Stratton Lake

Waupaca County, Wisconsin

Comprehensive Management Plan

December 2019

Sponsored by:

Stratton Lake District

WDNR Grant Program

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Lake Management Planning

Stratton Lake

Waupaca County, Wisconsin

Comprehensive Management Plan

December 2019

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1.0 INTRODUCTION

According to the 1963 recording sonar WDNR Lake Survey Map, Stratton Lake is 87 acres. The WDNR website lists the lake as 63 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in summer of 2015. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 66 acres. Stratton Lake, Waupaca County, is a spring lake with a maximum depth of 38 feet and a mean depth of 10 feet. This mesotrophic lake has a small watershed when compared to the size of the lake. Stratton Lake contains 32 native plant species, of which muskgrasses are the most common plant. Four exotic plant species are known to exist in Stratton Lake.

Field Survey Notes

The clear water of Stratton Lake allows plants to grow quite deep in the lake.

Photograph 1.0-1. Stratton Lake, Waupaca County.

Lake at a Glance - Stratton Lake

Morphology	
Acreage	66
Maximum Depth (ft)	38
Mean Depth (ft)	10
Shoreline Complexity	2.9
Vegetation	
Curly-leaf Survey Date	May 30, 2017
Comprehensive Survey Date	July 13 & 17, 2017
Number of Native Species	32
Threatened/Special Concern Species	-
Exotic Plant Species	Eurasian watermilfoil, pale-yellow iris, purple loosestrife, reed canary grass
Simpson's Diversity	0.74
Average Conservatism	5.9
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.4
Sensitivity to Acid Rain	Low Sensitivity
Watershed to Lake Area Ratio	1:1

Stratton Lake is considered a two-story natural community due to its depth and available habitat for trout. The lake is known to contain NHI species including the pugnose shiner and Blanding's turtle. Stratton Lake is also labeled by the Wisconsin Department of Natural Resources (WDNR) as an ASNRI Endangered Threatened or Special Concern Area. At its outlet, the lake feeds into Radley Creek, an Outstanding and Exceptional Stream. Radley Creek has been listed as a Class I Trout stream and the Radley Creek Fishery Area offers much access to this premier trout stream. The lake receives heavy recreational use from ~65 seasonal and permanent riparian residences, the public access along the southwest corner of the lake, and a summer boys camp located on the northeastern shoreline.

In 1997, Waupaca County sponsored a two-phased study completed by UWSP, which was prompted by concerns over nitrate and triazine within the lake and groundwater. Eurasian watermilfoil (*Myriophyllum spicatum*; EWM), found in 2001, was addressed in 2007 with an AIS-EDR grant which the Stratton Lake Property Owners Association (SLPOA) sought to complete monitoring and control actions on the lake. Also, in 2007, the Town of Dayton sponsored an AIS-EPP project which developed an Aquatic Plant Management Plan focused on native plant protection as well as control of EWM.

The primary management unit for Stratton Lake is the Stratton Lake District (SLD), formed in January 2015. The district was formed with the intention of first creating a comprehensive management plan for the lake. To that end, the first order of duty for the lake district's board was to request proposals from qualified consultants. This process was started in February 2015, with interviews following during mid-summer, and a vote to proceed by the district membership at its first annual meeting later in the summer.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee and the completion of a stakeholder survey.

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

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

On June 10, 2017, a project kick-off meeting was held at the Dayton Town Hall to introduce the project to the general public. The approximately 20 attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Project Wrap-up Meeting

The Stratton Lake project wrap-up meeting was held on August 10, 2019 at the Dayton Town Hall. Tim Hoyman presented highlights of the study results, outlined the management goals and actions contained in the newly adopted management plan, and answered questions from the audience.

Committee Level Meetings

Planning committee meetings, similar to general public meetings, were used to gather comments, create management goals and actions and to deliver study results. These two meetings were open only to the planning committee and were held during the week. The first, 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 first meeting was to fortify a solid understanding of their lake among the committee members. The second planning committee meeting was held a few weeks after the first and concentrated on the development of management goals and actions that make up the framework of the implementation plan.

Planning Committee Meeting I

The first planning committee meeting was held on May 25, 2018 and included an in-depth discussion of the information that was compiled regarding Stratton Lake. This included the results of the aquatic plant surveys, water quality monitoring, watershed modeling, and the stakeholder survey. The primary objective of the meeting was to develop a solid understanding of Stratton Lake among the committee members so they were prepared to make good management decisions for the lake.

Planning Committee Meeting II

On August 31, 2018, the second planning committee meeting for the Stratton Lake Management Planning project. The goal of the meeting was to create a framework of management goals and actions for the Stratton Lake implementation plan. That goal was met by first creating a list of challenges facing the district and lake. The list of challenges was then refined and used to create a list of management goals. The committee then discussed and developed a list of actions that would allow the district to meet the management goals. Following the meeting, a full, written draft of the implementation plan was created and provided to the planning committee for comments.

Stakeholder Survey

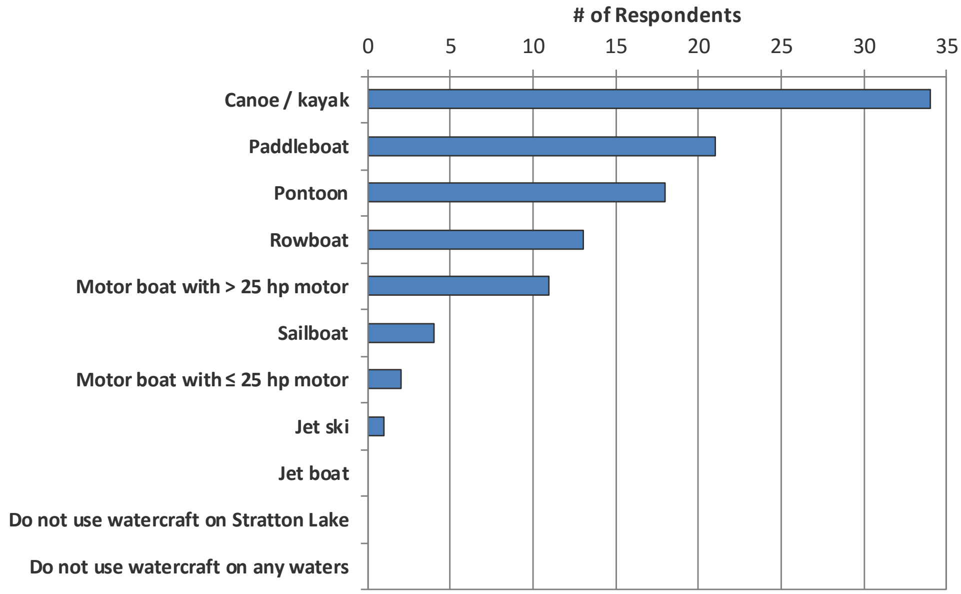
As a part of this project, a stakeholder survey was distributed to SLD members around Stratton Lake. The survey was designed by Onterra staff and the SLD planning committee and reviewed by a WDNR social scientist. During August 2017, the eight-page, 35-question survey was posted online through Survey 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 SLD volunteer for analysis. Fifty-nine percent of the surveys were returned. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Stratton Lake. The majority of stakeholders (36%) visit on weekends throughout the year, 28% are year-round residents, 26% live on the lake during the summer months only, 3% are resort properties, and 3% are rental properties. 61% of stakeholders have owned their property for over 15 years, and 45% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. Nearly all survey respondents indicate that they use a canoe or kayak, more than half of respondents indicate that they use a paddle boat, and nearly half of respondents indicate that they use a pontoon boat (Question 14). On a relatively small lake such as Stratton Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 17, one of the top recreational activities on the lake was canoeing or kayaking. Unsafe watercraft practices and excessive watercraft traffic were listed as factors potentially impacting Stratton Lake in a negative manner (Question 23) and they were ranked was ranked 4th and 7th, respectively, on a list of stakeholder's top concerns regarding the lake (Question 24).

Another concern of stakeholders noted in the stakeholder survey (see Question 24 and survey comments – Appendix B) was shoreland erosion and farm runoff within Stratton Lake's watershed.

Question 14: What types of watercraft do you currently use on Stratton Lake?



Question 17: Please rank up to three activities that are important reasons for owning your property on Stratton Lake.

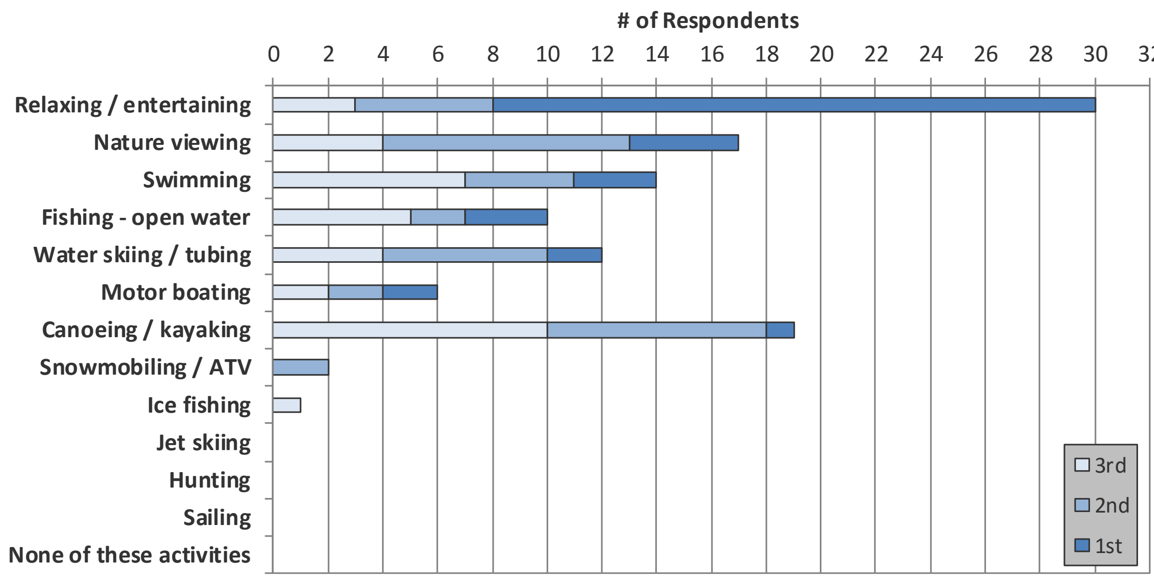
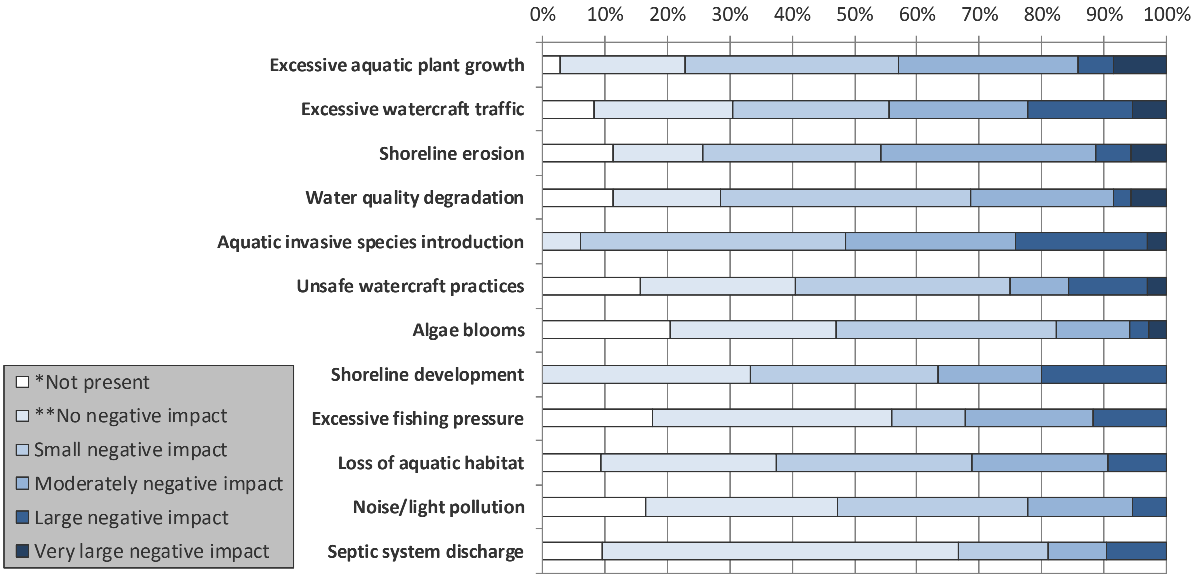


Figure 2.0-1. Select survey responses from the Stratton Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 23: To what level do you believe these factors may be negatively impacting Stratton Lake?



Question 24: Please rank your top three concerns regarding Stratton Lake.

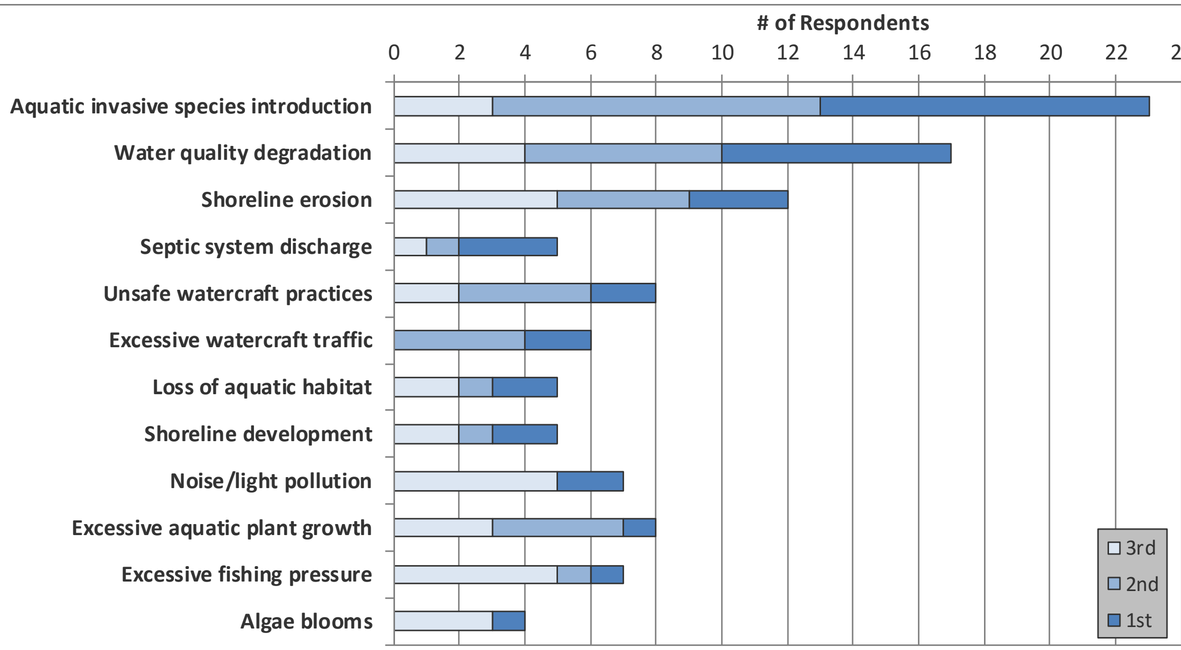


Figure 2.0-2. Select survey responses from the Stratton Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

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

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

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

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water (Canter et al. 1994, Dinius 2007, and Smith et al. 1991).

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epilimnion is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The hypolimnion is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The metalimnion, often called the thermocline, is the middle layer containing the steepest temperature gradient.

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR 2017) 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 Stratton Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (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, hydrology. An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

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

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

Because of its depth, small watershed and hydrology, Stratton Lake is classified as a deep headwater drainage lake (category 3 on Figure 3.1-1).

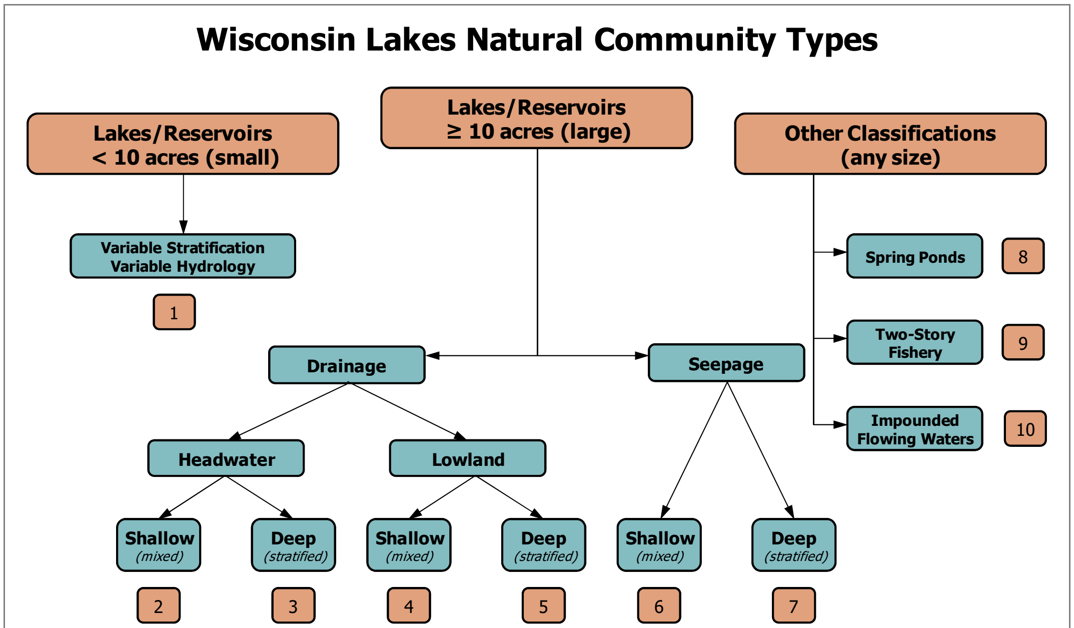


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Stratton Lake is within the North Central Hardwood Forests (NCHF) ecoregion.

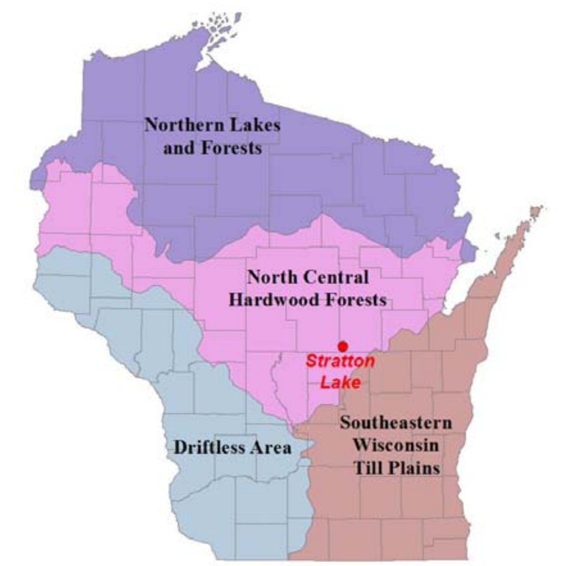


Figure 3.1-2. Location of Stratton Lake within the ecoregions of Wisconsin. After Nichols 1999.

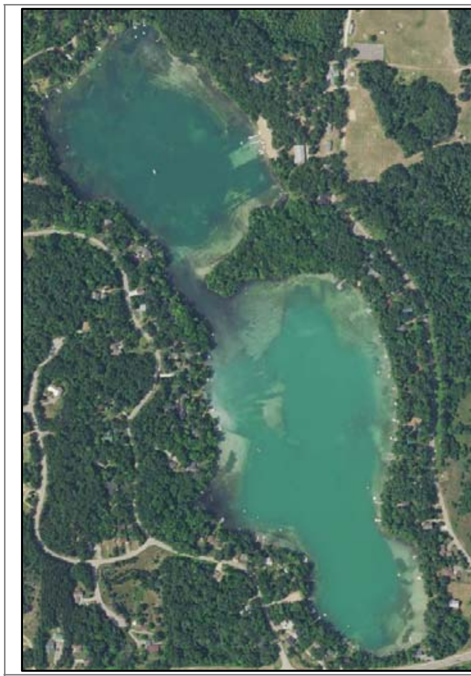
The Wisconsin 2018 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, 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.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Stratton Lake is displayed in Figures 3.1-3 - 3.1-13. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Stratton Lake Water Quality Analysis

Stratton Lake Long-term Trends

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



Photograph 3.1-1. Aerial view of Stratton Lake showing turquoise color of the marl lake. Aerial photography: NAIP, 2015.

Stratton Lake is a marl lake, which means it naturally possesses a high amount of calcium in its water. These types of lakes are generally only found in the glaciated region of the Laurentian Great Lakes. Marl lakes have naturally hard water, generally have lower nutrient concentrations with clear water, and appear turquoise in color due to the high concentrations of calcium carbonate (Photograph 3.1-1). The high amount of calcium in the water combines with phosphorus and coprecipitates to the lake bottom. This mechanism reduces phosphorus levels in the water and thus reduces algal growth. Submerged plants are usually covered with encrustations of this calcium carbonate and the nearshore sediments are often gray in color.

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Volunteers from Stratton Lake have been collecting some of these parameters on an annual basis since 1991, building a continual dataset that will yield valuable information on Stratton Lake's water quality through time.

Total Phosphorus

Near-surface total phosphorus data from Stratton Lake are available annually from 1994 to 1999 and from 2001 to 2017 (Figure 3.1-3). Some of the data reported from 1977, 1996-1999, and 2006 seem higher than what is normal for this lake. For this reason, these higher phosphorus concentrations were excluded from this analysis. Average summer total phosphorus concentrations ranged from 8 µg/L in 1994 to 18 µg/L in 2017. The weighted summer average total phosphorus concentration is 13 µg/L, which falls into the *excellent* category for Wisconsin's deep headwater drainage lakes. The lake's weighted summer average total phosphorus concentration is less than both the median value for other shallow headwater drainage lakes in the state and the median value for all lake types within the NCHF ecoregion.

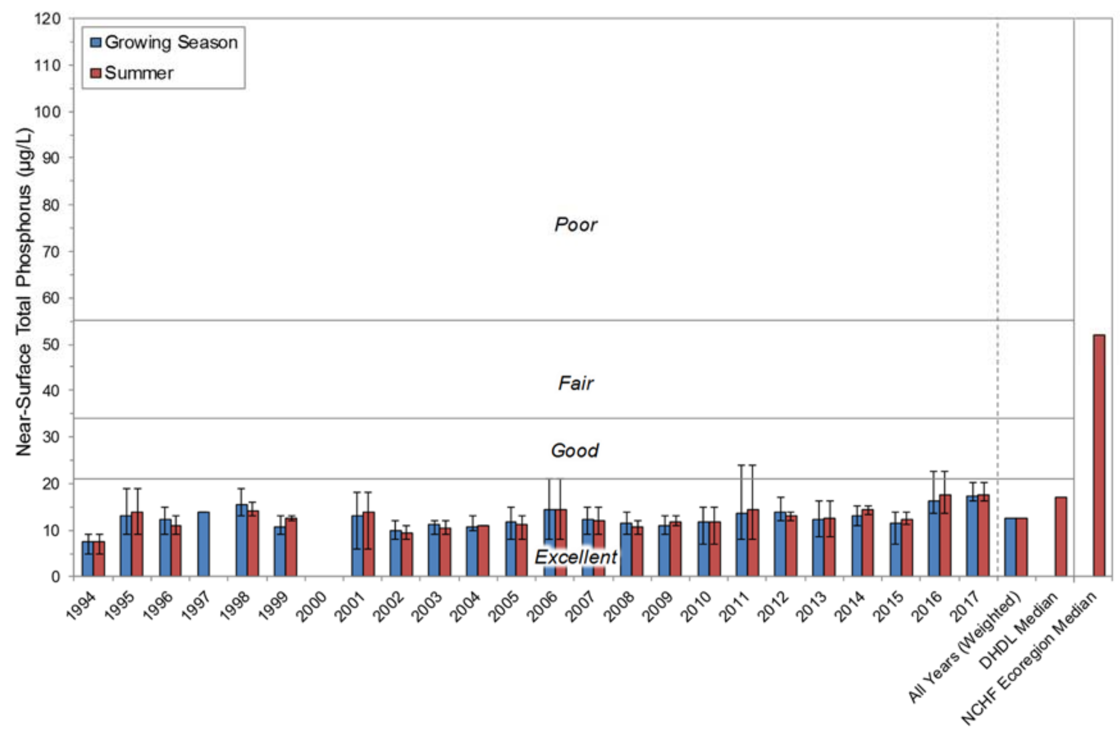


Figure 3.1-3. Stratton Lake, state-wide deep headwater drainage lakes, and regional lakes total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913. Selected suspect data from 1977, 1996-1999, and 2006 not included.

A linear regression analysis of average summer total phosphorus concentrations from 1994 to 2017 indicated that summer phosphorus concentrations show a statistically significant increasing trend (p-value = 0.014, R^2 = 0.27) of nearly 0.2 µg/L over this time period (Figure 3.1-4). More important, the years with the highest concentrations occurred in 2016 and 2017 at 18 µg/L, an increase of over 4 µg/L compared with the highest concentrations in 2011 and 2014. Although the weighted summer average total phosphorus concentration falls into the *excellent* category for Wisconsin's deep headwater drainage lakes, sediment core analyses indicate phosphorus concentrations were lower prior to Euro-American settlement in the mid-1800's when compared to current concentrations.

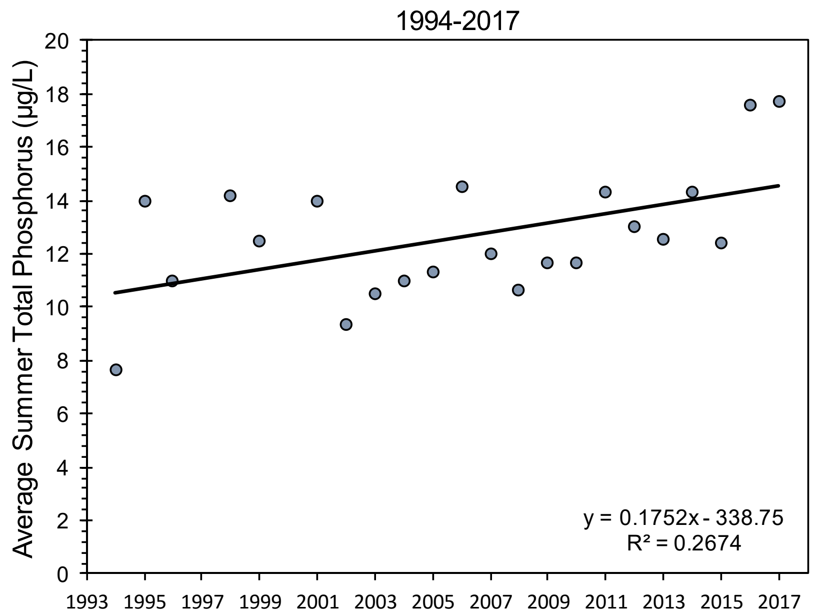


Figure 3.1-4. Simple linear regression of summer average total phosphorus concentrations over time within Stratton Lake. Trend is statistically significant (p-value = 0.014).

As is discussed in the Paleoecology Section (Section 3.2), nutrients have increased as a result of shoreland development, agricultural activities in the watershed, and other human-sources. The lake's current water quality is still high largely as a result of the high concentration of calcium carbonate in Stratton Lake which mitigates against the effects of increasing nutrient concentrations, mainly by binding with phosphorus and making it unavailable for use by algae. As is discussed further in this section, this is why despite a trend in increasing phosphorus and chlorophyll-*a* in Stratton Lake, no statistically valid trends in Secchi disk depth (water clarity) were detected. However, with sustained increases in nutrient loading, marl lakes like Stratton Lake can eventually become eutrophic with higher levels of algae and reduced water clarity. This is likely what occurred in Lake Mendota in Dane County, a marl lake that received phosphorus inputs which eventually overwhelmed the buffering capacity the lake's calcium carbonate and the lake transitioned to a eutrophic state.

As discussed in the primer section, internal nutrient loading is a process by which phosphorus (and other nutrients) are released from bottom sediments when bottom waters become devoid of oxygen (anoxic). Internal nutrient loading is more prevalent in deeper lakes which experience summer stratification or in shallow lakes that are highly productive where high rates of decomposition deplete oxygen near the sediment-water interface. To determine if internal nutrient loading of phosphorus is occurring in a stratified lake, phosphorus concentrations are measured near the bottom in the deepest part of the lake. In lakes which experience high levels of internal nutrient loading, the near bottom phosphorus concentrations are usually significantly higher than those measured near the surface.

Figure 3.1-5 displays near-surface and near-bottom total phosphorus concentrations collected from Stratton Lake in 1994, 1995, 1996, and 2017. As illustrated, in every year except 1995, the near-bottom total phosphorus concentration is similar to the concentration measured near the surface in spring. Near-bottom concentrations exceed near-surface concentrations by June or July in every year except 1995, indicating that phosphorus is being released from bottom sediments into the hypolimnion during anoxia. During the sampling events in 2017 where near-bottom concentrations exceed near-surface concentration, the lake was found to be stratified with little or no oxygen measured within the hypolimnion. Overall, while this process may be contributing some phosphorus to Stratton Lake's water column, the impacts of internal loading are not significant. This is because the hypolimnion of the lake is small compared to the rest of the lake volume so when the lake mixes in the fall the higher phosphorus concentrations in the bottom waters are diluted. In the few years when there is phosphorus data during fall turnover there is no increase in the surface phosphorus concentration, which would be expected if there was significant internal loading.

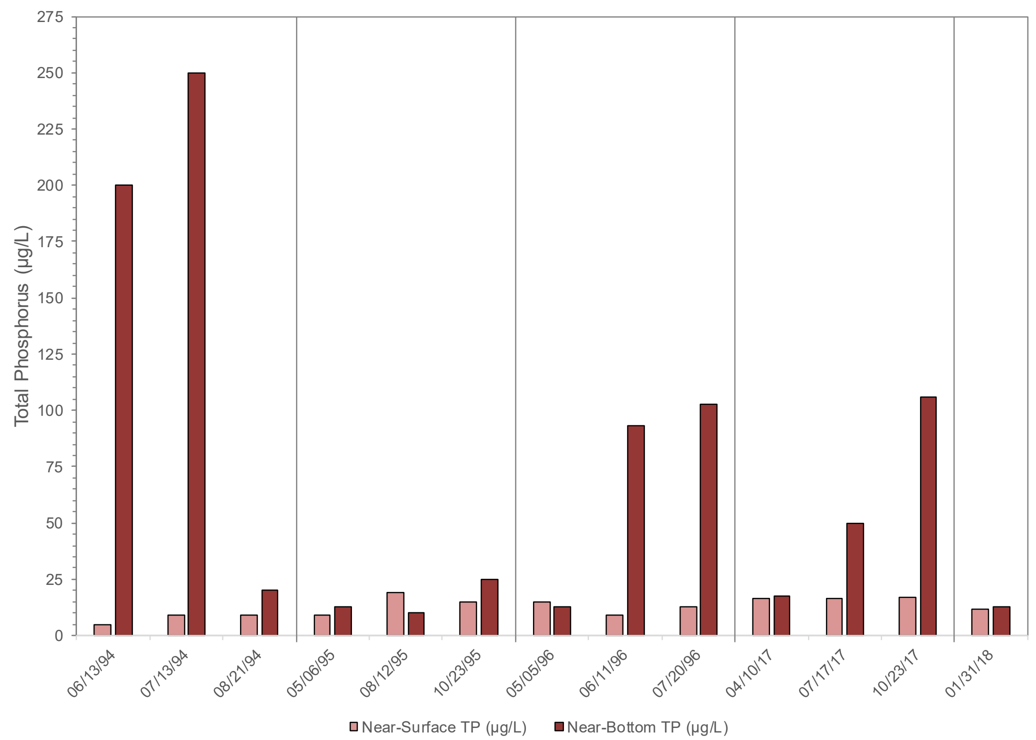


Figure 3.1-5. Stratton Lake near-surface and near-bottom total phosphorus concentrations. All concentrations are actual values, not averages.

Chlorophyll-α

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, is usually positively correlated with total phosphorus concentrations. While phosphorus limits the amount of algal growth in the majority of Wisconsin's lakes, other factors also affect the amount of algae produced within a lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton, which feed on algae, also influence algal abundance.

Chlorophyll-*a* data are available annually from Stratton Lake from 1994 to 1999 and from 2001 to 2017 (Figure 3.1-6). Average summer chlorophyll-*a* concentrations ranged from 2 µg/L in 2008 to 6 µg/L in 2016. The weighted summer average total chlorophyll-*a* concentration is 3 µg/L and falls into the *excellent* category for Wisconsin's deep headwater drainage lakes and indicates that Stratton Lake's chlorophyll-*a* concentrations are slightly lower than the median value for deep headwater drainage lakes in the state and the median value for all lake types within the NCHF ecoregion.

A linear regression analysis on the summer average chlorophyll-*a* concentrations from 1994 to 2017 indicated that summer chlorophyll-*a* concentrations show a statistically significant increasing trend (p-value = 0.007, $R^2 = 0.31$, Figure 3.1-7). Although chlorophyll-*a* concentrations were not higher than other years in 2017 the summer average in 2016 was the highest recorded. This elevated phosphorus and chlorophyll-*a* concentrations in the last 2 years indicate that there may be increased input of nutrients to the lake.

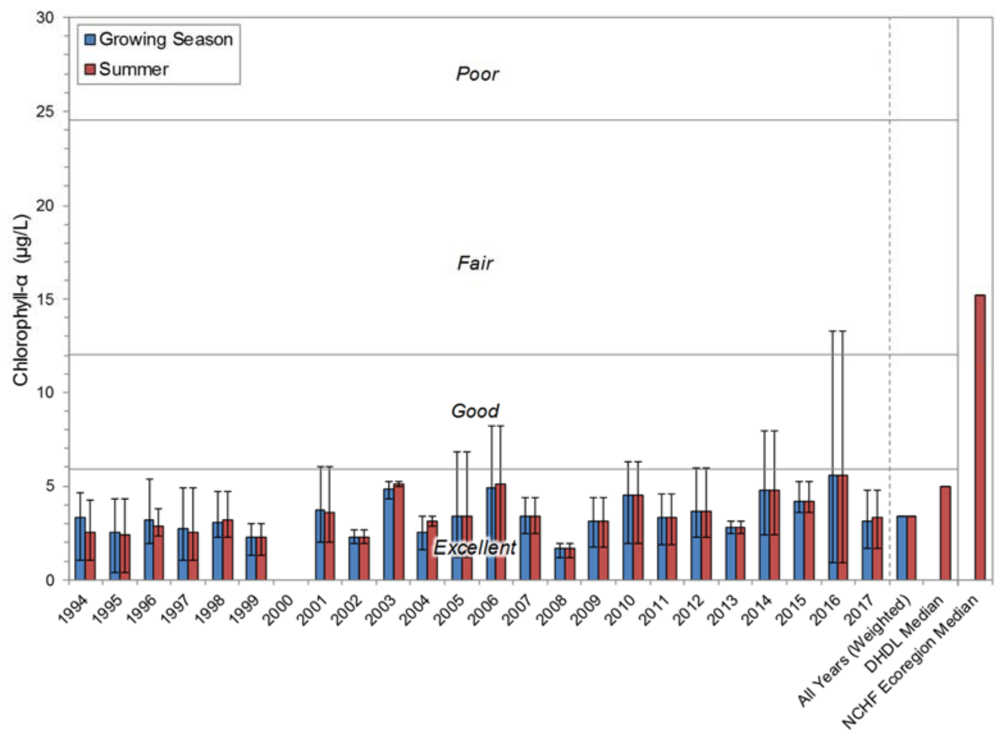


Figure 3.1-6. Stratton Lake, state-wide deep headwater drainage lakes, and regional lakes chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913. Selected suspect data from 2003 not included.

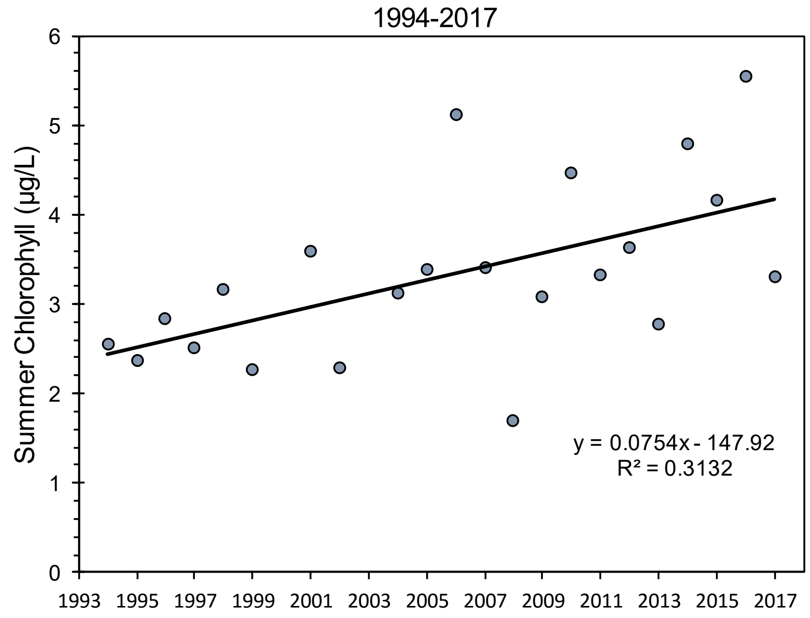


Figure 3.1-7. Simple linear regression of summer average chlorophyll-*a* concentrations over time within Stratton Lake. Trend is statistically significant (p-value = 0.018).

Water Clarity

Secchi disk transparency data are available from Stratton Lake from 1977 and annually from 1991 to 2017 (Figure 3.1-8). Average summer Secchi disk depths ranged from 10.5 feet in 2017 to 20.7 feet in 1993; however, only one summer Secchi disk measurement was taken in 2017 and may not be an accurate representative of the summer average. The weighted summer average Secchi disk depth is 14.4 feet and falls into the *excellent* category for Wisconsin's deep headwater drainage lakes. The lake's weighted summer average Secchi disk depth exceeds the median values for deep headwater drainage lakes in the state and for all lake types within the NCHF ecoregion.

Although phosphorus and chlorophyll-*a* show increased concentrations in the last two years, this is not the case with Secchi disc transparency. In many lakes the amount of algae can significantly affect water clarity; however, in Stratton Lake the relationship between chlorophyll-*a* and Secchi disc transparency is not strong. This likely is because the lake is a marl lake. The presence of elevated levels of calcium carbonate (marl) often results in the formation of clouds of calcium carbonate (referred to as whiting events) during the summer which reduces water clarity.

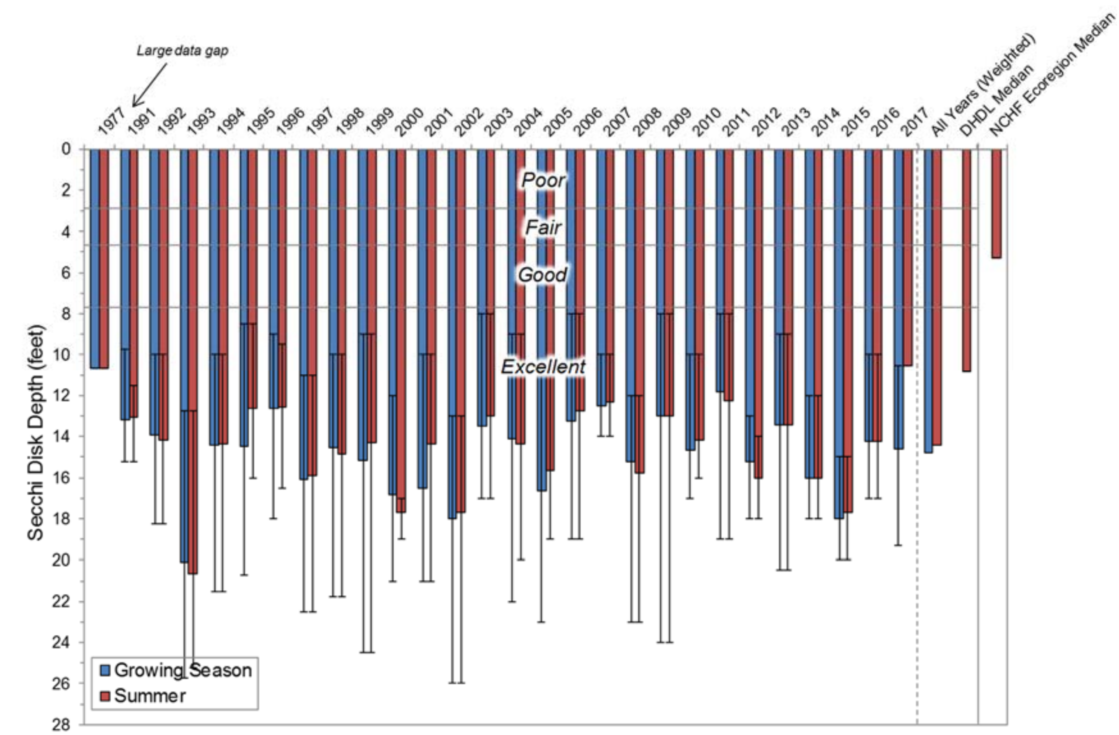


Figure 3.1-8. Stratton Lake, deep headwater drainage lakes, and regional lakes Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Stratton Lake

Using midsummer nitrogen and phosphorus concentrations from Stratton Lake, a nitrogen:phosphorus ratio of 284:1 was calculated. This finding indicates that Stratton Lake is phosphorus limited as are the vast majority of Wisconsin lakes. This is unsurprising as Stratton Lake is a marl lake and the high amount of calcium in the water combines with phosphorus and coprecipitates to the lake bottom. Stratton Lake also has high levels of nitrogen and a study completed by the University of Wisconsin – Stevens Point found that the summer total nitrogen concentrations in Stratton Lake were well above the mean total nitrogen concentration for natural lakes in Wisconsin, likely due to agricultural practices within the lake's watershed (Hudson et al. 2000).

Stratton Lake Trophic State

Figure 3.1-9 contains the weighted average Trophic State Index (TSI) values for Stratton Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-a, and Secchi disk transparency data collected as part of this project with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved compounds in the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton. The TSI values for Secchi disk transparency, chlorophyll-*a*, and total phosphorus concentrations range from oligotrophic to mesotrophic; however, TSI values since 2011 have been primarily in the mesotrophic category (Figure 3.1-9). It appears Stratton Lake was historically in an oligo-mesotrophic state, based on available historical data, and has recently transitioned to a mesotrophic state. Stratton Lake is slightly less productive than other deep headwater drainage lakes in Wisconsin and is much less productive than the majority of lakes in the NCHF ecoregion.

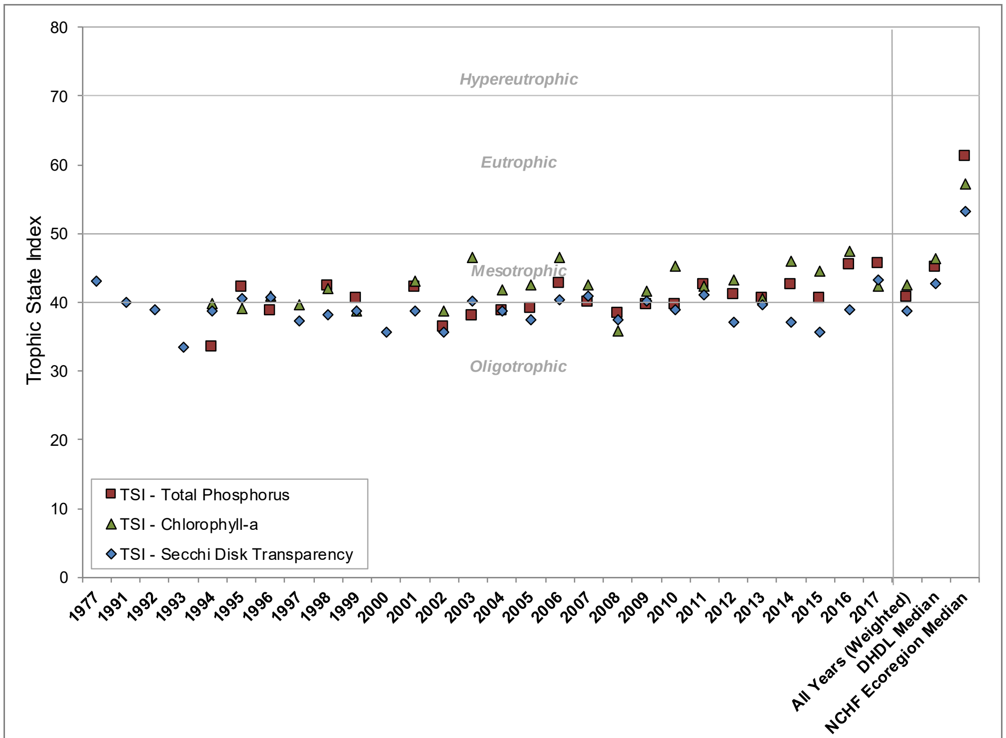


Figure 3.1-9. Stratton Lake, state-wide class 3 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Stratton Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Stratton Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-10. Stratton Lake is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, during the spring and fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Stratton Lake's deeper nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen.

In July of 2017, a slight bump is seen in dissolved oxygen concentrations at approximately 15 and 21 feet (Figure 3.1-10). This is likely due to the warmer temperature of the epilimnion during the summer. When Stratton Lake stratifies, following spring turnover, dissolved oxygen concentrations are higher in the water column because the colder water can maintain a higher saturation of dissolved oxygen. As the epilimnion warms in the summer, the warmer surface waters cannot maintain the same levels of dissolved oxygen as the cooler metalimnion.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39 °F, while oxygen gradually declines once again towards the bottom of the lake. The data also indicate that there was sufficient oxygen throughout the water column under the ice to support the fishery during late-winter sampling (Figure 3.1-10).

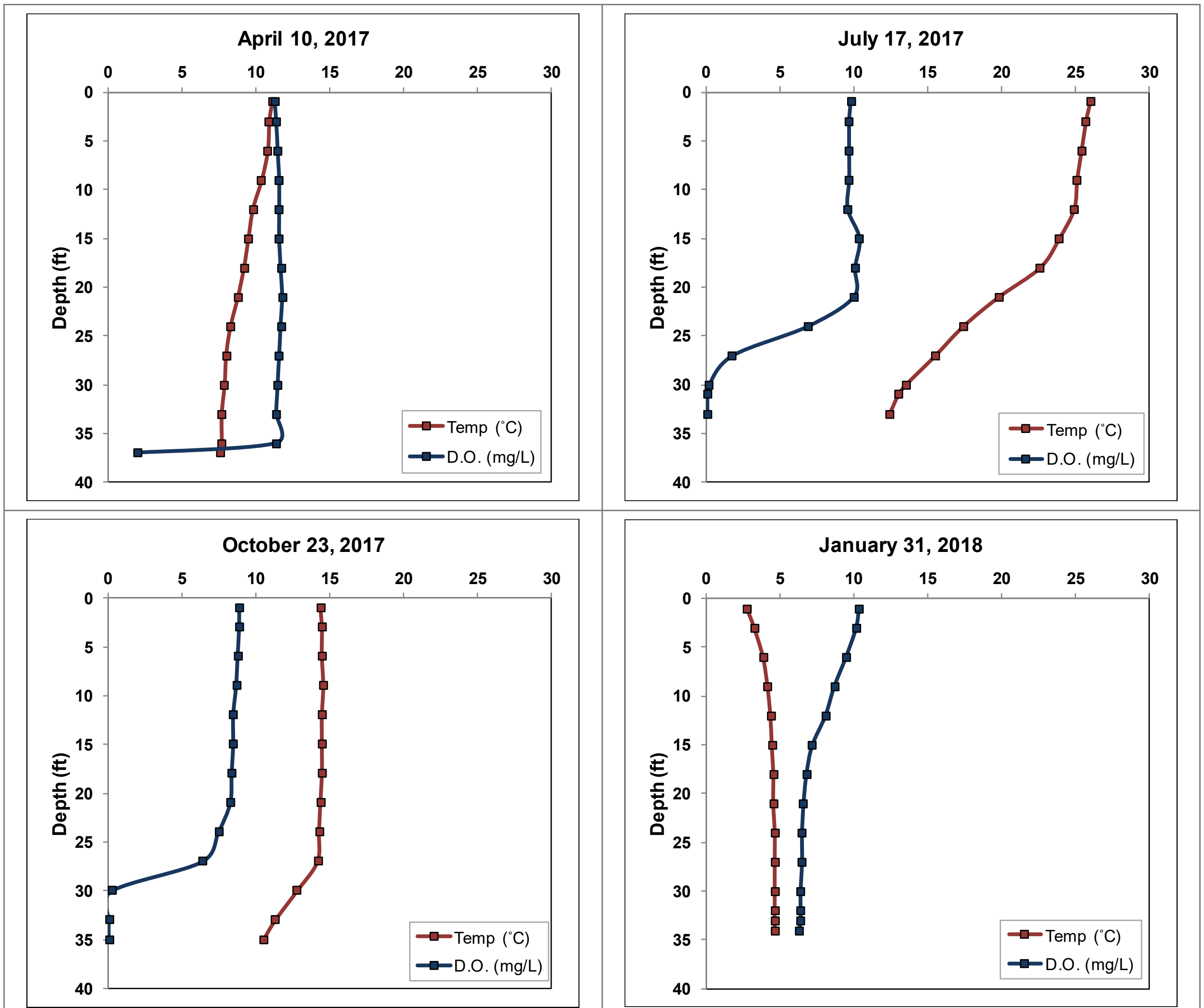


Figure 3.1-10. Stratton Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Stratton 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 Stratton 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.

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 and Nimphius 1985). The pH of the water in Stratton Lake was found to be alkaline with a value of 8.4, and falls just within the normal range for Wisconsin Lakes (Figure 3.1-11).

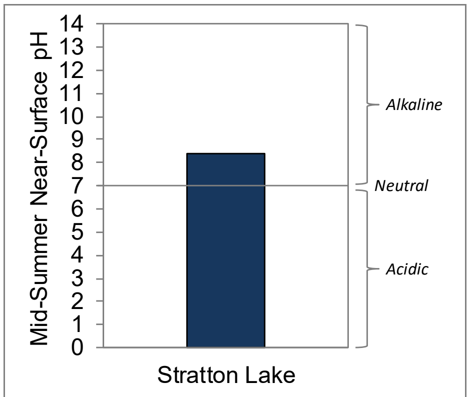


Figure 3.1-11. Stratton Lake mid-summer near-surface pH value.

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 Stratton Lake was measured at 120 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain (Figure 3.1-12).

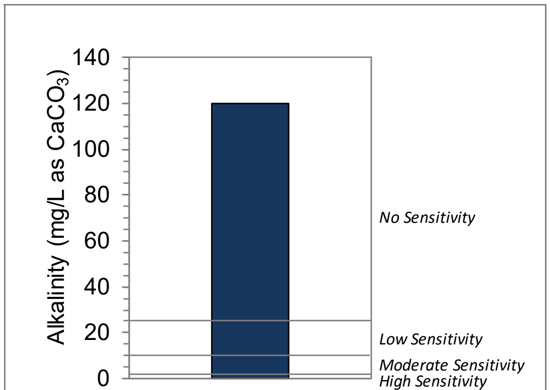


Figure 3.1-12. Stratton Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

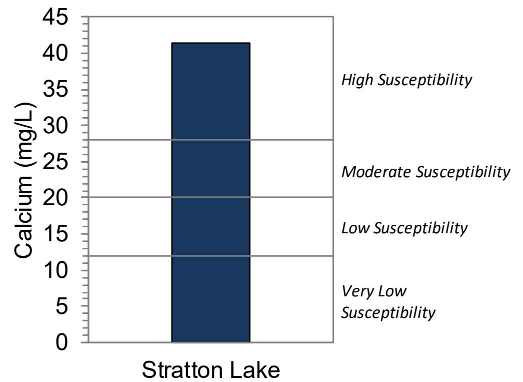


Figure 3.1-13. Stratton Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

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 Stratton Lake's pH of 8.4 falls inside of 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 Stratton Lake was found to be 41.3 mg/L, falling well into the optimal range for zebra mussels (Figure 3.1-13).

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.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Stratton Lake was considered to be suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in Stratton Lake in 2017 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 2017 surveys. However, in 2018, a Stratton Lake property owner located suspicious mussels in the lake and provided pictures to members of the district board. The mussels in the picture were thought to be zebra mussels. Confirmation of zebra mussels in Stratton Lake occurred within a few weeks. By the end of the 2018 growing season, many riparians were reporting infestations of zebra mussels on items left in the lake for extended periods, like piers and swim rafts. It is unknown at this time if the zebra mussels will become a serious issue in Stratton Lake. As mentioned above, the lake's chemistry is suitable for this exotic, but other factors not fully understood about zebra mussels may limit their growth in the lake.

The non-native Asiatic clams (*Corbicula fluminea*) were discovered in Stratton Lake in 2017 by Golden Sands Resource Conservation & Development Council (RC & D). Asiatic clams are native to Asia, Africa, and Australia, and were thought to be first introduced to the Great Lakes through the food items of Chinese immigrants (Counts 1981) or through the importation of oysters. Since their introduction to the Great Lakes, they can be found in all 50 states within the United States. Since their introduction to Wisconsin in 1977, they have been discovered in waterbodies within twelve counties (WDNR 2017). Throughout Wisconsin, Asiatic clams are mostly found in rivers but are more recently being found within lakes. Like other invasive species, Asiatic clams can alter aquatic ecosystems and may be a vector for parasites and pathogens (Sousa et. al 2008). Similar to zebra mussels in their ability to invade and rapidly reproduce, Asiatic clams seem to be more ubiquitous in the environments which they are able to invade. Belanger et. al (1985) found that Asiatic clams are able to utilize a variety of substrates, from finer sands to gravel, but the most important factor for optimal establishment is a well oxygenated substrate. Asiatic clams have been found to quickly bury themselves and in laboratory studies were found to completely bury themselves in the sediment within three days of introduction (Belanger et al. 1985). Their ability to burrow makes it more difficult to detect initial introductions of Asiatic clams into a system. Asiatic clams are also tolerant of cooler temperatures, allowing them to be biologically active later in the growing season when most native invertebrates have gone dormant (Sousa et. al 2008).

Asiatic clams, unlike zebra mussels and native mussels, do not have a free-floating larval stage within their life cycle. Instead, these invasive clams are hermaphroditic or self-reproducing. After a brief period of maturation within the parent clam, small juvenile clams (250 μm) are released into the environment with an already developed shell, digestive system, gills, etc. (McMahon 2002). Asiatic clams reach adulthood after 3 to 9 months and have a life span of only 1 to 5 years; however, the majority of Asiatic clams do not make it to adulthood (McMahon 2002). Asiatic clams reproduce, generally twice within a growing season, once in late-spring and again in late-summer. This ability to reproduce rapidly and produce numerous self-sufficient offspring gives Asiatic clams a great advantage over native mollusks.

Similar to zebra mussels, Asiatic clams are impressive filter feeders. They have been found to impact native mussel juvenile recruitment due to their suspension, deposit feeding, and ingestion of large numbers of native mussel reproductive material (Yeager et al. 1994, Hakenkamp & Palmer 1999, Strayer 1999). They also compete with organisms throughout the aquatic ecosystem for food resources, especially other, native, filter feeders (McMahon 1991). Like zebra mussels, when Asiatic clams are in high abundance, they have been found to affect water clarity, nutrient cycling, and sedimentation rates (Yamamuro & Koike 1993, 1994, Gerritsen et al. 1994, Phelps 1994, Dame 1996, Ricciardi et al. 1997, Strayer et al. 1999, Nakamura & Kerciku 2000, Gangnery et al. 2001, Kohata et al. 2003, Ruesink et al. 2005).

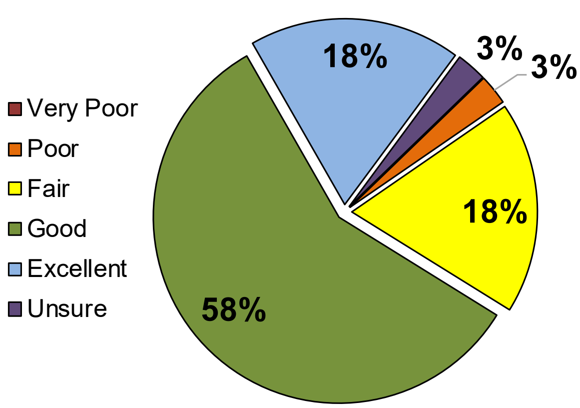
Stakeholder Survey Responses to Stratton Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Of the 66 surveys distributed to Stratton Lake stakeholders, 39 (59%) were returned.

Figure 3.1-14 displays the responses of Stratton Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Stratton Lake. When asked how they would describe the current water quality of Stratton Lake the majority of respondents, 58%, indicated *good*, 18% indicated *excellent*, 18% indicated *fair*, 3% indicated they were *unsure*, and 3% indicated *poor*.

When asked how they believe the current water quality has changed since they first visited the lake the majority of respondents, 58%, indicated it has *remained the same*, 29% indicated it has *somewhat degraded*, 8% indicated they were *unsure*, and 5% indicated it has *somewhat improved* (Figure 3.1-14). As discussed in the previous section, Stratton Lake has good water quality. The proportion of stakeholder respondents who indicated the lake's water quality has somewhat degraded may be taking into account the Eurasian watermilfoil growth in the lake as the top concern for stakeholder respondents was aquatic invasive species introduction (Question 24, Appendix B). However, the second top concern for stakeholders was water quality degradation followed by shoreline erosion.

18. How would you describe the current water quality of Stratton Lake?



19. How as the water quality changed in Stratton Lake since you first visited the lake?

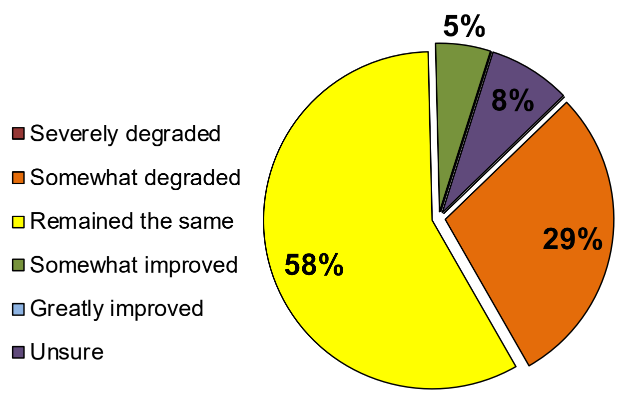


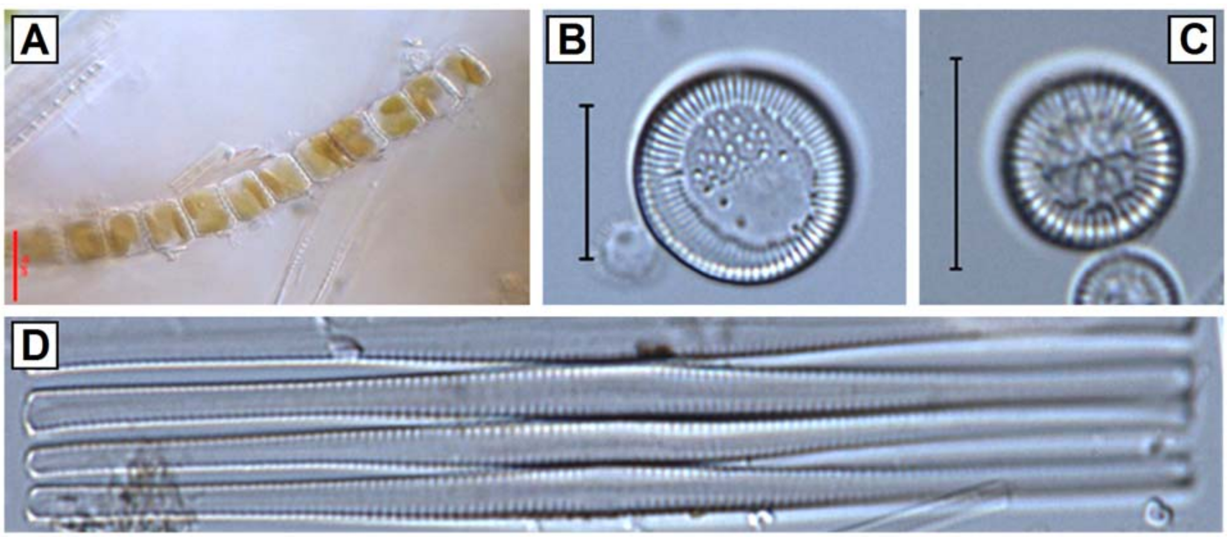
Figure 3.1-14. Stratton Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

3.2 Paleoecology

Primer on Paleoecology and Interpretation

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

These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants. The diatom community are especially useful in reconstructing a lake's ecological history as they are highly resistant to degradation and are ecologically diverse. Diatom species have unique features as shown in Photograph 3.2-1, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to objects such as aquatic plants or the lake bottom.



Photograph 3.2-1. Photomicrographs of the diatoms commonly found in the sediment core from Stratton Lake. The top diatom (A) *Staurosirella pinnata* comprised over 70% of the diatom community in the bottom sample. This diatom grows on the lake sediments in Stratton Lake. *Cyclotella michiganiana* (B) grows in the metalimnion of the lake and was found in the top sample. *Cyclotella comensis* (C) is an invasive that was imported from the northern Europe. It was found in low numbers in the top sample. *Fragilaria crotonensis* (D) is more common with moderate phosphorus levels but indicates higher nitrogen concentrations. It was found in the top sample.

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

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

Stratton Lake Paleoecological Results

A sediment core was collected from the deep area in Stratton Lake by Onterra staff on October 23, 2017. The total length of the core was 54 cm. The top 28 cm of the core was medium gray in color. Below 28 cm there were color changes in the core (Photograph 3.2-2). From 28 to 42 cm the core was gray intermixed with black sediment. From 42 to 50 cm the sediment color was medium and light brown. The bottom 4 cm of the core were very dark brown in color. While it is not clear why these color changes have occurred, it does indicate that Stratton Lake has experienced ecological changes during the time period encompassed by the core, likely 200+ years. The top 1 cm was kept for analysis and it is assumed this represents present day water quality conditions in the lake. A bottom sample, 52-53 cm, was analyzed and this is assumed to represent conditions before the arrival Euroamerican settlers in the middle of the nineteenth century.

Photograph 3.2-2. Photo of sediment core collected from Stratton Lake. There were several color changes below 42 cm.

Multivariate Statistical Analysis

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

The results revealed two clear axes of variation in the diatom data, with 31% and 21% of the variance explained by axis 1 and axis 2, respectively (Figure 3.2-1). 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.

Stratton Lake is at the top of Figure 3.2-1 because even though the lake stratifies during the summer, most of the diatom community is composed of benthic taxa. This is because the lake has relatively low phosphorus concentrations and very good water clarity. There is only a moderate change in the diatom community compared with some other lakes, e.g. Horsehead, Upper Gresham lakes.

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 et al. (1989) on 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 Stratton Lake indicates higher alkalinity at the present time compared to historical times.

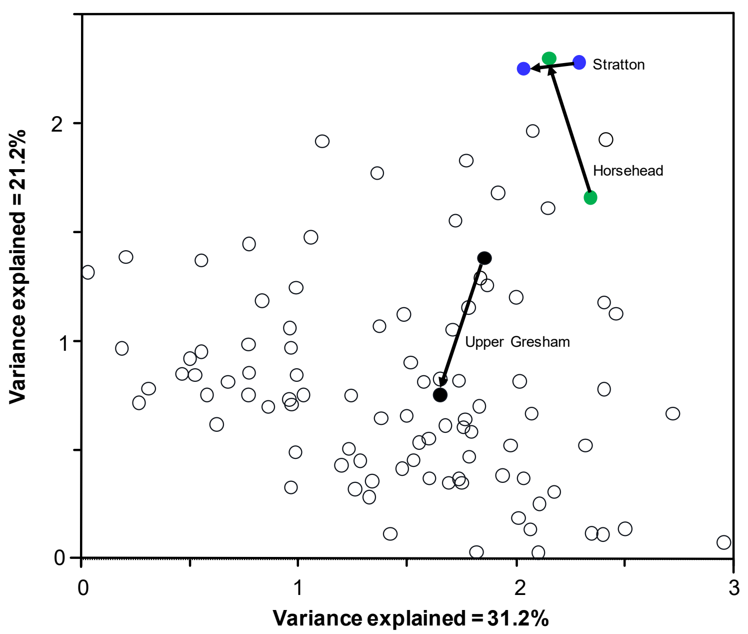


Figure 3.2-1. DCA plot of top/bottom samples from Stratton Lake. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. Stratton Lake has changed only a moderate amount since the arrival of Euroamerican settlers over 150 years ago.

Diatom Community Changes

The diatom community in the bottom sample of the Stratton Lake core was dominated by diatoms that grow on the lake sediments (Figure 3.2-2). The dominant diatom was *Staurosirella pinnata* (Photograph 3.2-1A). This has been found in other marl lakes in Wisconsin (Garrison and Wakeman 2000, Garrison 2012) and indicates excellent water clarity and low phosphorus concentrations. In the top sample, *S. pinnata* numbers are greatly reduced but benthic diatoms are still dominant even though Stratton Lake is relatively deep. This demonstrates that the lake still possesses good water clarity and relatively low phosphorus concentrations. Even though the diatom community is still dominated by the benthic community at the present time, there are more planktonic diatoms present. This typically happens as nutrient levels increase. Water clarity becomes reduced so light is not able to reach as much of the lake bottom so there is less area for the diatoms to grow. The dominant planktonic diatom is *Cyclotella michiganiana* (Photograph 3.2-1B) which usually grows in the metalimnion of the lake. This diatom is one of the first planktonic diatoms to increase with increased nutrients. Water clarity is still good as sufficient light must reach the metalimnion for this diatom to flourish.

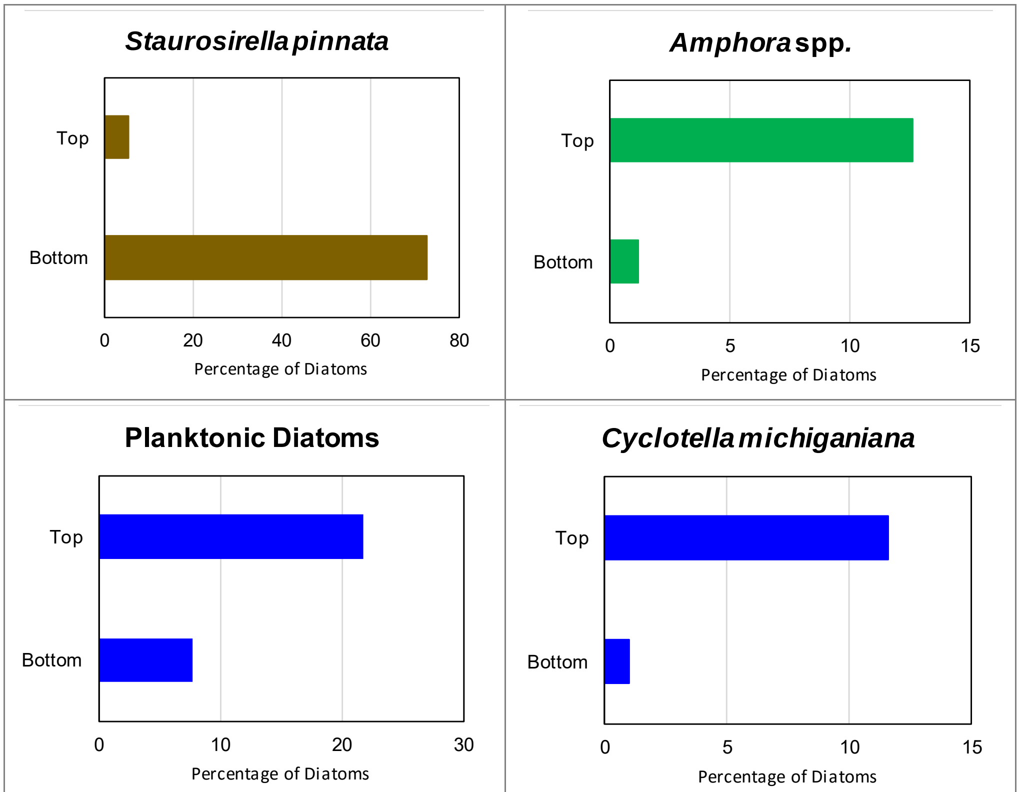


Figure 3.2-2. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Stratton Lake. The bottom sample is dominated by *S. pinnata* which grows on the lake sediments indicating this moderately deep lake historically had excellent water clarity and low phosphorus concentrations.

One of the benthic diatoms that is more common in the top sample is *Amphora*. This diatom grows attached to macrophytes and its increased frequency signals that there are more macrophytes at the present time compared to historical times. Borman (2007) found that in northwestern Wisconsin, the macrophyte community often changed in seepage lakes, from one dominated by low growing plants to a community dominated by larger macrophytes, as a result of shoreline development. The structure of the macrophyte community changes because the increased runoff of sediment during construction on the shoreline enables the establishment of the larger plants. With the larger plants there is much more surface area available on which diatoms and the other periphytic algae are able to grow.

In the top sample the diatom *Cyclotella comensis* (Photo 3.2-1C) was present. It is believed this diatom is an introduced species from northern Europe (Stoermer 1993, 1998). This diatom has been found in sediments deposited since 1950 in the Great Lakes (Stoermer et al. 1985, 1990; 1993) as well as inland lakes in northern lower Michigan (Fritz et al. 1993; Wolin and Stoermer 2005) and over 20 lakes in Wisconsin. In lakes from New Jersey and New York, this diatom was only found in the top samples of the 26 lakes examined (Enache et al. 2012). The diatom *C. comensis* typically is found growing in the open water in the middle part of the water column. This means that this taxa is found in lakes with good water clarity but elevated nutrient levels in the deeper waters. Studies indicate that this diatom responds to increased phosphorus and nitrogen levels (Schelske et al. 1972; Wolin and Stoermer 2005). In Stratton Lake *C. comensis* was found at a concentration of 3.4% which is relatively low.

Lake Diatom Condition Index

The Lake Diatom Condition Index (LDCI) was developed by Dr. Jan Stevenson, Michigan State University (Stevenson et al. 2013). The LDCI uses diatoms to assess the ecological condition of lakes. The LDCI ranges from 0 to 100 with a higher score representing better ecological integrity. The index is weighted towards nutrients, but also incorporates ecological integrity by examining species diversity where higher diversity indicates better ecological condition. The index also incorporates taxa that are commonly found in undisturbed and disturbed conditions. The breakpoints (poor, fair, good) were determined by the 25th and 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 sample places Stratton Lake in the good category (Figure 3.2-3). The bottom sample places the lake in the fair category. The apparent worse condition in the bottom sample reflects the historical oligotrophic condition of the lake. The bottom sample had very low species richness (22 vs 55) and poor diversity. It is not unusual for oligotrophic lakes to have better biotic integrity with a small increase in productivity as the macrophyte community becomes more diverse which provides more habitat for the algae, insects, and fish.

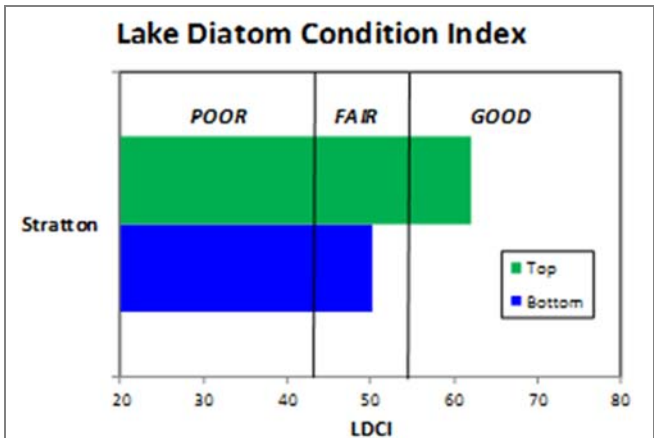


Figure 3.2-3. The Lake Diatom Condition Index (LDCI) for Stratton Lake. The biotic integrity is better in the top sample compared with the bottom sample because historically the lake was oligotrophic with very few macrophytes.

Inference models

Diatom assemblages have been used as indicators of trophic changes in a qualitative way (Bradbury 1975, Carney 1982, Anderson et al. 1990) but quantitative analytical methods exist. Ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration (Birks et al. 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 et al., 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 estimated phosphorus concentrations in the top and bottom samples of Stratton Lake are very similar at 13 and 12 µg/L, respectively (Table 3.2-1). The diatom inferred phosphorus concentration in the top sample is very close to the average summer phosphorus concentrations measured in the lake over the last decade.

Table 3.2-1. Diatom inferred phosphorus concentrations in core samples (µg/L).

Sample	Phosphorus (µg/L)
Stratton Top	13
Stratton Bottom	12

Summary

Stratton Lake historically was an oligotrophic lake with very few macrophytes. Water clarity was excellent and phosphorus concentrations were low. Phosphorus levels in the lake were low enough that there were very few planktonic diatoms. Most diatoms, and likely other algae, grew on the lake sediments. Although at the present time the benthic diatoms dominate the community, there are more planktonic diatoms now compared to 100 years ago. This likely reflects a small increase in nutrients.

A greater change that has occurred in the lake is the increase in macrophyte cover. Studies have found that the littoral area of a lake often responds earliest to increased nutrient input from the watershed. This is because the littoral zone is the interface between the surrounding watershed and the main body of the lake. The increase in macrophytes experienced in Stratton Lake has been observed in many other Wisconsin lakes as a result of shoreland development. The few lakes that have been cored that do not have cottages or homes do not generally show an increase in diatoms that are indicative of increased macrophyte growth. This trend of increased macrophyte cover with shore land development has also been seen in lakes in northeastern US (Vermaire and Gregory-Eaves 2008).

3.3 Watershed Assessment

Watershed Modeling

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

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

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

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

In systems with high WS:LA ratios, like those 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 plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see a change in plant production. Both of these situations occur frequently in impoundments.

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

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

Stratton Lake Watershed Assessment

The Stratton Lake total watershed encompasses an area of approximately 583 acres; however, part of the watershed likely does not contribute water or nutrients due to isolated small lakes and wetlands (Map 2). In these parts of the watershed, runoff from the landscape remains in these isolated waterbodies and does not enter Stratton Lake. After examining topographical maps and aerial photographs, the watershed used for the modeling was reduced to approximately 141 acres, yielding a watershed to lake area ratio of 1:1. Approximately 47% of Stratton Lake's watershed is composed of Stratton Lake's surface, 23% forest, 16% wetlands, 8% pasture/grass, 4% row crop agriculture, and 2% rural residential areas (Figure 3.3-1). WiLMS modeling indicates that Stratton Lake's water is completely replaced approximately once every 8 years (residence time) or 0.13 times a year (flushing rate); however, WiLMS does not take groundwater inflow into account, which is likely the largest source of water to the lake. While WiLMS is likely overestimating the residence time in the lake, without flow data from the lake's outlet it is impossible to calculate the residence time in Stratton Lake.

Using the landcover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Stratton Lake's watershed. It was estimated that approximately 35 pounds of phosphorus are delivered to the lake from its watershed on an annual basis (Figure 3.3-1). Phosphorus loading from septic systems was also estimated using data obtained from the 2017 stakeholder survey of riparian property owners. Of the estimated 35 pounds being delivered to Stratton Lake 50% is estimated to originate from direct atmospheric deposition into the lake, 19% from septic systems, 13% from row crop agriculture, 6% from forest, 6% from wetlands, and 2% from pasture/grass.

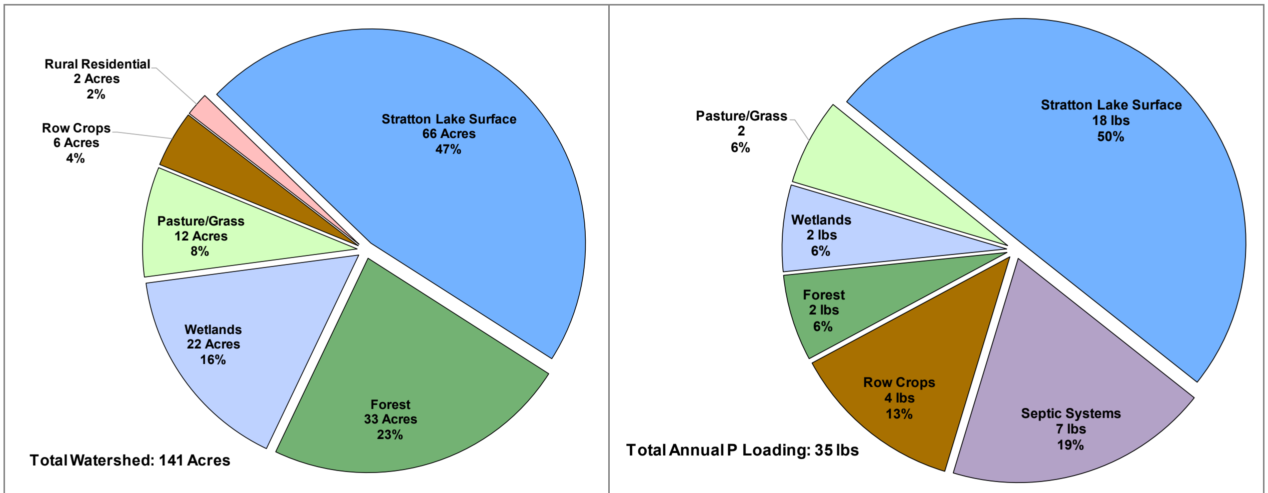


Figure 3.3-1. Stratton Lake watershed land cover types in acres and phosphorus loading in pounds. Based upon National Land Cover Database (NLCD – Fry et. al 2011) and Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using predictive equations, WiLMS estimates that based on the potential annual phosphorus load, Stratton Lake should have a growing season mean total phosphorus concentration of approximately 14 µg/L to 26 µg/L. The lower phosphorus concentration estimate of 14 µg/L is likely more realistic due to the lake's calcium-rich water, and is much closer to the measured growing season mean total phosphorus concentration of 13 µg/L. The high amount of calcium in the water combines with phosphorus and coprecipitates to the lake bottom. This mechanism reduces phosphorus levels in the water.

As discussed previously, in systems with lower WS:LA ratios like Stratton Lake, small changes in the watershed can lead to significant changes in water quality. To illustrate this, a scenario was modeled converting 25% of the forest in Stratton Lake's watershed to row crop agriculture. WiLMS estimates that the GSM total phosphorus concentration would increase to be approximately 16 µg/L. Using predictive equations by Carlson (1977), average chlorophyll-*a* and Secchi disk transparency values can be estimated using the average growing season surface phosphorus value. If 25% of forested land were converted to row crop agriculture, the estimated growing season mean concentration for chlorophyll-*a* would increase to approximately 5 µg/L, which is approximately 1.5 µg/L higher than the average measured growing season mean chlorophyll-*a* concentration. The estimated growing season mean Secchi disk depth is estimated to decline to approximately 10 feet, which is about a 5-foot reduction in the average measured growing season mean Secchi depth of 14.8 feet.

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. Passed in February of 2010, the final 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. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

- 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: 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.

- 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 with the following caveats:
  - No expansion or complete reconstruction within 0-35 feet of shoreline
  - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
  - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
  - Vertical expansion cannot exceed 35 feet

- 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.

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.

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, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photograph 3.4-1. Example of a biolog restoration site.

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

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

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

- Spring planting timeframe.
- 100’ of shoreline.
- An upland buffer zone depth of 35’.
- An access and viewing corridor 30’ x 35’ free of planting (recreation area).
- Planting area of upland buffer zone 2- 35’ x 35’ areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5’ x 35’ areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

Advantages	***Disadvantages***
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreland erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Once native plants are established, they require less water, maintenance, no fertilizer; provide wildlife food and habitat, and natural aesthetics compared to ornamental (non-native) varieties. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Stratton Lake Shoreland Zone Condition

Shoreland Development

The development stage of Stratton Lake's entire shoreland was surveyed in 2014 by the Waupaca County Land and Water Conservation Department (LWCD). The shorelands were surveyed using a WDNR Lake Shoreland Habitat Monitoring Field Protocol on a parcel-by-parcel basis. Some protocol modifications were made, such as considering the area of shoreland 50 feet inland from the water's edge instead of 35 feet, in accordance with a local zoning ordinance. Shoreland areas were defined by natural vegetation (trees, shrubs, and grasses) and human disturbances (mowed lawn, structures, impervious surfaces, rip-rap, and erosion). In general, developed shorelands impact a lake ecosystem in a negative manner, while definite benefits occur from shorelands that are left in their natural state.

Stratton Lake has stretches of shoreland that range from nearly completely developed to completely natural. Of the 2 miles of shoreland surveyed, approximately 16% is in a completely natural state (Figure 3.4-1). This shoreland type provides the most benefit to the lake and should be left in its natural state if at all possible. No stretches of the lake's shoreland were in a completely developed state and only 24% of the lake's shoreland contains stretches where 80-99% of the shoreland is developed. If restoration of the Stratton Lake's shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. On Stratton Lake, approximately 0.3 miles of the shoreland surveyed was composed of hard armor, such as rip-rap or seawall, which correlates to approximately 15% of the shoreland length. Map 3 displays the location of these shoreland categories around Stratton Lake.

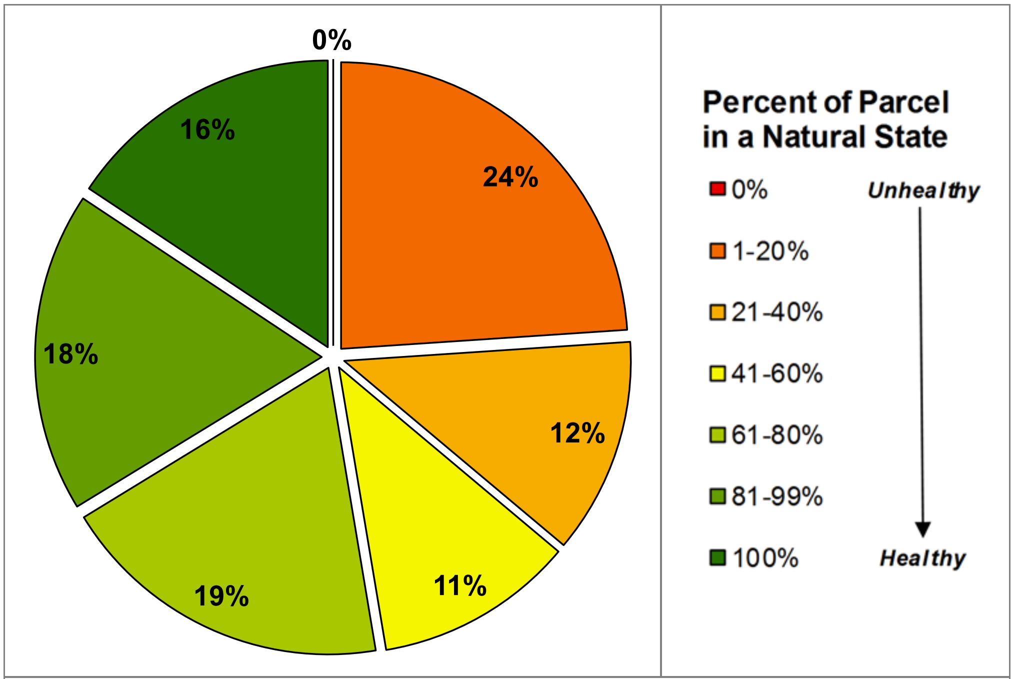


Figure 3.4-1. Stratton Lake shoreland categories. Based upon a Waupaca County LWCD 2014 survey.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. Allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

3.5 Aquatic Plants

Introduction

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

Photograph 3.5-1. Example of emergent and floating-leaf communities.

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

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

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

Aquatic Plant Management and Protection

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

Important Note:
Even though most of these techniques are not applicable to Stratton Lake, 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 Stratton Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Permits

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

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

Manual Removal

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

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. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width. Please note that the use of powered cutters may require a mechanical harvesting permit to be issued by the WDNR.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1,200 to $11,000.

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.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive. If a hydro-electric facility is operating on the system, the costs associated with loss of production during the drawdown also need to be considered, as they are likely cost prohibitive to conducting the management action.

Advantages	***Disadvantages***
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian watermilfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant effects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed and reed canary grass. • Permitting process may require an environmental assessment that may take months to prepare. • Non-selective.

Mechanical Harvesting

Photograph 3.5-3. Mechanical harvester.

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

Cost

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

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

Herbicide Treatment

Photograph 3.5-4. Granular herbicide application.

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 et al. (2009).

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

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

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

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

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; Eurasian water milfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, 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

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.

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

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

Cost

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

Advantages	*Disadvantages*
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause 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 emergents 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 Stratton Lake; 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 Stratton Lake in 2016. 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 Stratton Lake, 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 Stratton Lake to be compared to other lakes within the region and state.

FQI = Average Coefficient of Conservatism * √ 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 Stratton Lake is compared to data collected by Onterra and the WDNR Science Services on 85 lakes within the Northcentral Hardwood 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 Stratton Lake 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.

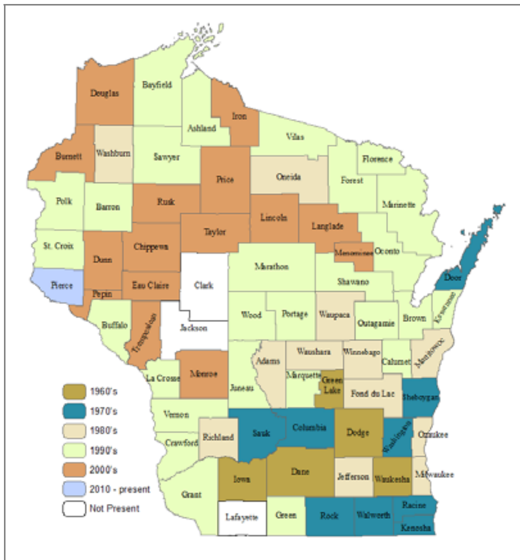


Figure 3.5-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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.

Stratton Lake Aquatic Plant Survey Results

As mentioned previously, numerous plant surveys were completed as a part of this project. An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Stratton Lake on May 30, 2017. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of the non-native curly-leaf pondweed which should be at or near its peak growth at this time. Fortunately, no curly-leaf pondweed was located in Stratton Lake in 2017, and it is believed that curly-leaf pondweed is not present within the lake or exists at an undetectable level. However, pale-yellow iris, a non-native wetland plant, was located in numerous locations along Stratton Lake's shoreline. Because of its ecological significance, pale-yellow iris is discussed further in the subsequent Non-Native Aquatic Plants in Stratton Lake subsection.

Onterra ecologists completed the whole-lake aquatic plant point-intercept survey on Stratton Lake on July 13, 2017, while the emergent and floating-leaf aquatic plant community mapping survey was completed on July 17, 2017. During these surveys, a total of 36 species of plants were located in Stratton Lake, four of which are considered non-native, invasive species: Eurasian watermilfoil, pale yellow iris, purple loosestrife, and reed canary grass (Table 3.5-1). Because non-native plants in Stratton Lake have the ability to negatively impact lake ecology, recreation, and aesthetics, the populations of these plants are discussed in detail within the Non-Native Aquatic Plants in Stratton Lake subsection. The aquatic plant species list also contains species recorded during a whole-lake point-intercept survey completed in 2007 by the WDNR. Changes in species' abundance between these two surveys are discussed later in this section.

Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition. On August 3, 2017, Onterra ecologists completed an acoustic survey on Stratton Lake. The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2017 acoustic survey revealed that the widest range of substrate hardness occurs in the shallowest areas of Stratton Lake (Figure 3.5-2 and Map 4). On average, the hardest substrates (sand/rock/gravel) are found within 1 to 7 feet of water. The sediment within Stratton Lake gradually declines to softer sediments as water depth increases but remains moderately hard throughout the entirety of the lake. Figure 3.5-2 illustrates the spatial distribution of substrate hardness in Stratton Lake. 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 areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 3.5-1. Aquatic plant species located on Stratton Lake during 2007 and 2017 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2007 WDNR	2017 Onterra
Emergent	*Carex diandra*	Bog panicled sedge	9	I	
	Carex lasiocarpa	Narrow-leaved woolly sedge	9		I
	Carex pellita	Broad-leaved woolly sedge	4	I	I
	Carex stricta	Common tussock sedge	7	I	
	Cladium mariscoides	Smooth saw-grass	10	I	I
	Eleocharis erythropoda	Bald spikerush	3	I	
	Eleocharis palustris	Creeping spikerush	6		I
	*Eleocharis quinqueflora**	Few-flowered spikerush	8	I	
	Iris pseudacorus	Pale yellow iris	Exotic		I
	Lythrum salicaria	Purple loosestrife	Exotic	I	I
	Phalaris arundinacea	Reed canary grass	Exotic		I
	Sagittaria latifolia	Common arrowhead	3	I	I
	Schoenoplectus acutus	Hardstem bulrush	5	I	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
	Typha latifolia	Broad-leaved cattail	1	I	I
FL	*Nuphar variegata*	Spatterdock	6	I	I
	Nymphaea odorata	White water lily	6	I	I
	Persicaria amphibia	Water smartweed	5		I
Submergent	*Chara* spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6		I
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6		X
	Najas guadalupensis	Southern naiad	7		X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7		I
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X
	Potamogeton illinoensis	Illinois pondweed	6	X	X
	Potamogeton natans	Floating-leaf pondweed	5	I	I
	Potamogeton praelongus	White-stem pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	7	X	
	Potamogeton strictifolius	Stiff pondweed	8	X	X
	Potamogeton X haynesii	Haynes' pondweed	N/A		I
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	I
	Ranunculus aquatilis	White water crowfoot	8		I
	Stuckenia pectinata	Sago pondweed	3	X	X
	Vallisneria americana	Wild celery	6	X	X
	Zannichellia palustris	Horned pondweed	7		X
FF	*Lemna minor*	Lesser duckweed	5	I	X

FL = Floating-leaf; FF = Free-floating
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as 'special concern' in Wisconsin*

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2017 aquatic plant bio-volume data are displayed in Figure 3.5-3 and Map 5. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no plant growth are displayed in blue. The 2017 whole-lake point-intercept survey and acoustic survey found aquatic plants growing to a maximum depth of 30 feet, a testament to the high-water clarity found in Stratton Lake. Aquatic vegetation is abundant from 1 to 24 feet in Stratton Lake, with 88% of the sampling locations containing aquatic plants within this depth range in 2017. Beyond 24 feet, the occurrence of vegetation declines rapidly with only 25% of the sampling locations between 25 and 30 feet containing aquatic plants. The 2017 acoustic survey indicates that approximately 49% (32 acres) of Stratton Lake's area contains aquatic vegetation (Figure 3.5-3).

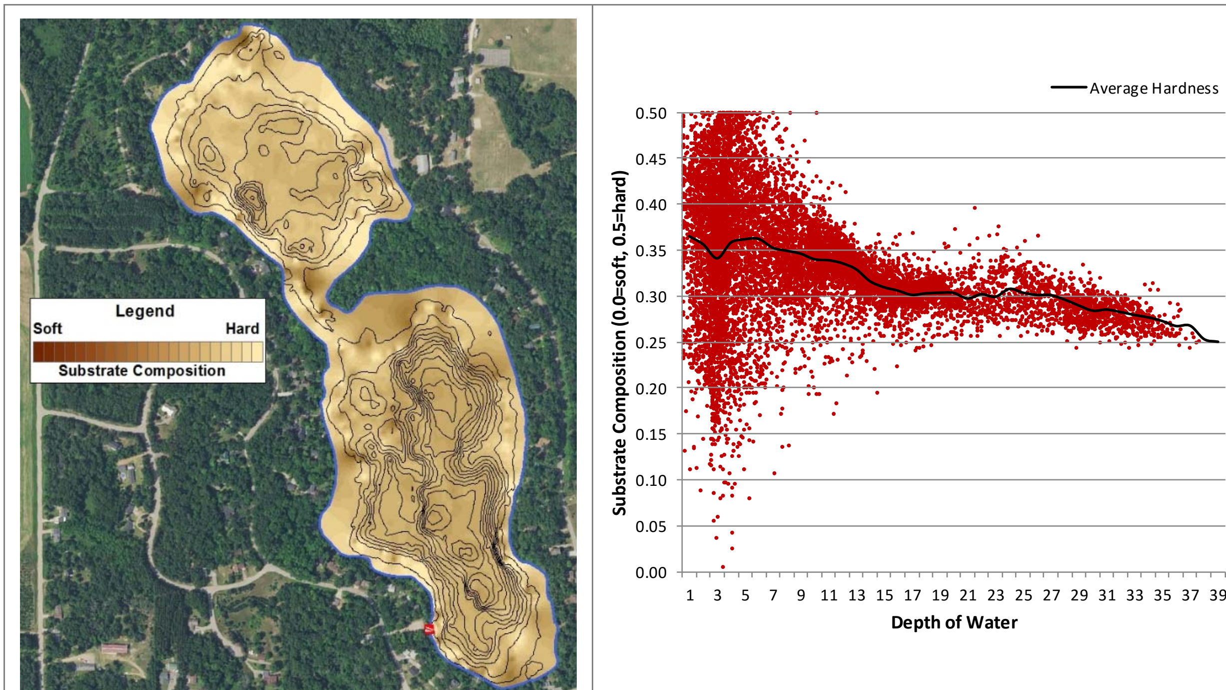


Figure 3.5-2. Stratton Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Individual data points are displayed in red. Created using data from August 2017 acoustic survey.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species comprise the aquatic plant community. Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 262 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2017, approximately 84% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2017 indicates that 71% of the 262 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 11% had a TRF rating of 2, and 2% had a TRF rating of 3 (Figure 3.5-4). The TRF data indicates that overall biomass of aquatic plants in Stratton Lake is low.

In 2007, aquatic plants were recorded growing to a shallower maximum depth of 22 feet. Of the 229 sampling locations that were at or shallower than 22 feet, 98% contained aquatic vegetation (Figure 3.4-4). While the 2007 data appear to indicate that the littoral occurrence of vegetation within Stratton Lake has declined, this is largely due to the differences in maximum depth recorded between the two surveys (22 feet in 2007 versus 30 feet in 2017) resulting in a different number of sampling locations within the littoral zone (229 in 2007 versus 278 in 2017). The number of sampling locations that contained aquatic vegetation in 2007 and 2017 were relatively similar at

224 and 221, respectively. Looking solely at the littoral frequency of occurrence likely exaggerates the change in aquatic plant abundance between 2007 and 2017.

In 2007, the proportion of TRF ratings of 2 and 3 were higher when compared to 2017 indicating higher aquatic plant biomass. While this difference could be to the result of different surveyors, it is also possible that biomass of aquatic plants was higher in 2007 when compared to 2017. The 8-foot difference in maximum depth of aquatic plant growth recorded in 2007 and 2017 may be due to differences in water clarity between these two years. In 2007, spring Secchi disk depth was 13 feet compared to 19 feet in 2017. The higher water clarity in the spring of 2017 may have allowed aquatic plants to establish in deeper waters than in 2007.

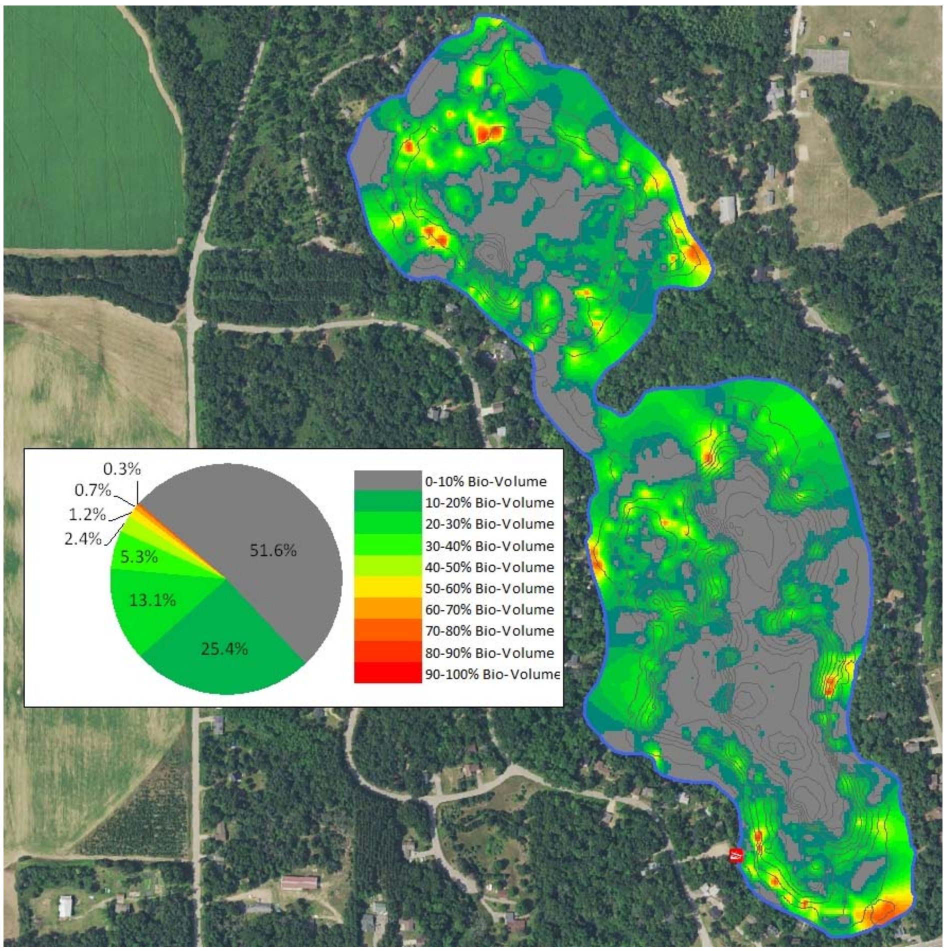


Figure 3.5-3. Stratton Lake 2017 aquatic plant bio-volume. Created using data from August 2017 acoustic survey.

Of the 36 aquatic plant species located in Stratton Lake in 2017, 18 were encountered directly on the rake during the whole-lake point intercept survey. The remaining 18 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of these 18 species, muskgrasses were the most frequently encountered, followed by slender naiad, wild celery, and variable-leaf pondweed (Figure 3.5-5).

Muskgrasses are a genus of macroalgae with seven species represented in Wisconsin (Photograph 3.5-5). In 2017, muskgrasses were the most frequently-encountered aquatic plant in Stratton Lake with a littoral frequency of occurrence of approximately 65% (Figure 3.5-5). Dominance of the aquatic plant community by muskgrasses is common in hardwater lakes like Stratton Lake, and these macroalgae have been found to more competitive against vascular plants (e.g. pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002; Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002). In Stratton Lake, muskgrasses were abundant across littoral depths in 2017.

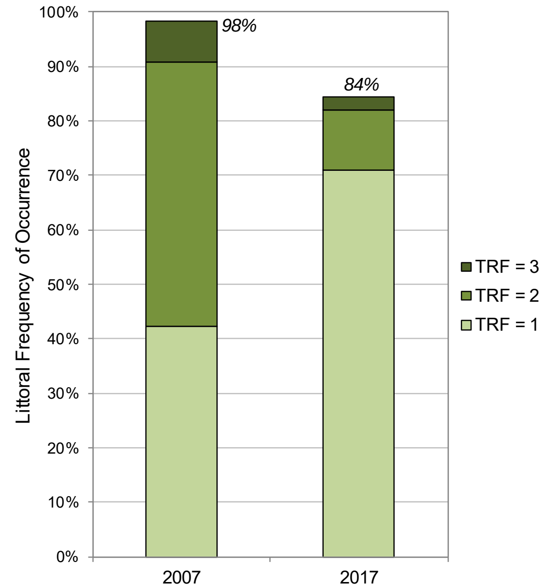


Figure 3.5-4. Stratton Lake 2007 and 2017 aquatic vegetation total rake fullness (TRF) ratings within littoral areas. Created from data collected during the 2007 and 2017 whole-lake aquatic plant point-intercept survey.

Slender naiad, the second-most frequently encountered aquatic plant in 2017 with a littoral frequency of occurrence of 17% (Figure 3.5-5), is a submersed, annual plant that produces numerous seeds. Slender naiad is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 2014). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. In Stratton Lake, slender naiad was most prevalent between 2.0 and 8.0 feet of water.

Wild celery, also known as tape or eel grass, was the third-most frequently encountered aquatic plant species with a littoral frequency of occurrence of 16% during the 2017 point-intercept survey (Figure 3.5-5). Wild celery is relatively tolerant of low-light conditions and is able to grow in deeper water. Its long leaves provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. Additionally, the leaves, fruit, tubers, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife. In Stratton Lake, wild celery was most abundant between 6.0 and 12.0 feet of water.

Photograph 3.5-5. The aquatic macroalgae muskgrasses (Chara spp.). Photo credit Onterra.

Variable-leaf pondweed, the fourth-most encountered species with a littoral frequency of 10%, is a submersed plant that produces a thin, cylindrical stem that has numerous branches (Figure

3.5-5). These branches produce linear leaves that grow anywhere from four to eleven centimeters long, and may produce three to seven veins per leaf. This plant also hybridizes easily with other pondweed (*Potamogeton*) species; thus, this plant can appear quite variable in size and shape and is named appropriately.

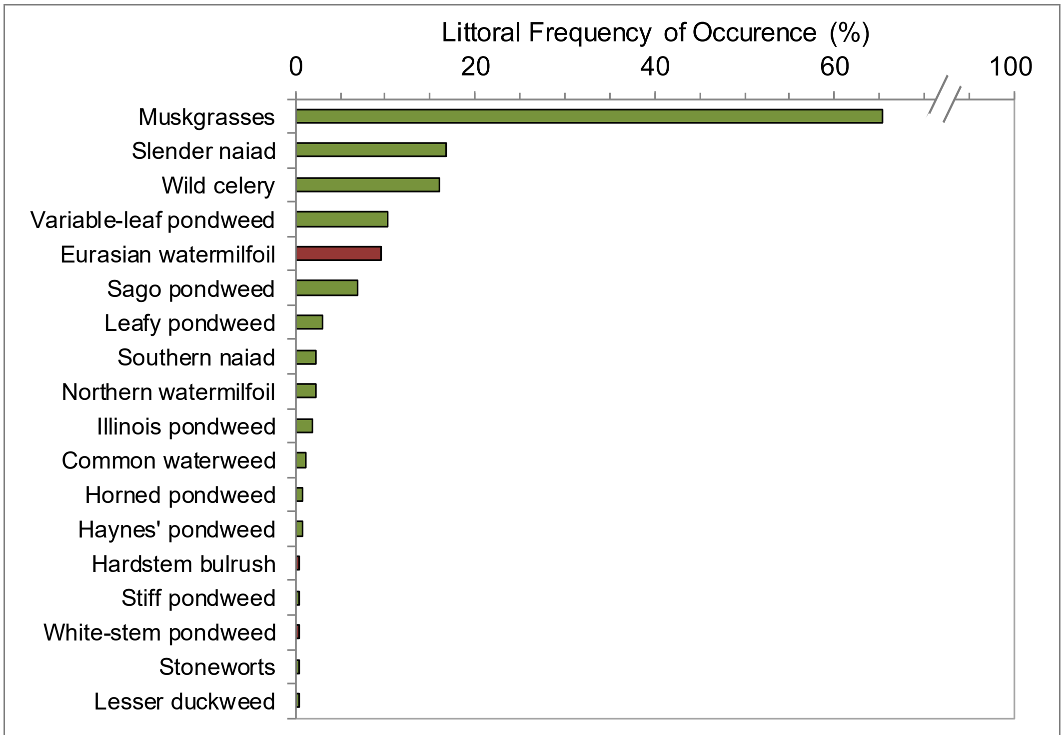


Figure 3.5-5. Stratton Lake 2017 littoral frequency of occurrence of aquatic plant species. Created using data the 2017 point-intercept survey.

In the summer of 2007, the WDNR conducted a whole-lake point-intercept survey on Stratton Lake using the same methodology and sampling locations that were used in 2017.Therefore, the data collected from these two surveys can be statistically compared to determine if any significant changes in Stratton Lake's aquatic plant community have occurred between these two surveys. Figure 3.5-6 displays the littoral frequency of occurrence of aquatic plant species from the 2007 and 2017 point-intercept surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one of the two surveys are applicable for analysis.

Of the seven aquatic plant species which had a littoral occurrence of at least 5% in one of the two surveys, four exhibited statistically valid changes in their occurrence in Stratton Lake between the 2007 and 2017 surveys (Figure 3.5-6). Due to their morphological similarities, slender naiad and southern naiad were combined to be naiad spp. for this analysis. The littoral occurrence of muskgrasses declined from 93% in 2007 to 65% in 2017, naiad spp. declined from 25% in 2007 to 19% in 2017, and Illinois pondweed declined from a littoral occurrence of 6% in 2007 to 2% in 2017. Eurasian watermilfoil increased in littoral occurrence from 4% in 2007 to 10% in 2017.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, water levels, changes in clarity, herbivory, competition, and disease among other factors. Certain native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants. These observed reductions and increases in occurrence of certain species are believed to be due to varying interannual environmental conditions. Ongoing collection of aquatic plant data from Wisconsin's lakes shows that aquatic plant populations have the capacity to fluctuate widely on an interannual basis under natural conditions. It is not known what has driven the changes observed in Stratton Lake, but it is likely the result of a combination of primarily natural factors. Having a relatively species-rich plant community like that found in Stratton Lake is important as when conditions are unfavorable for some species, other species can fill in to fulfill their ecological role.

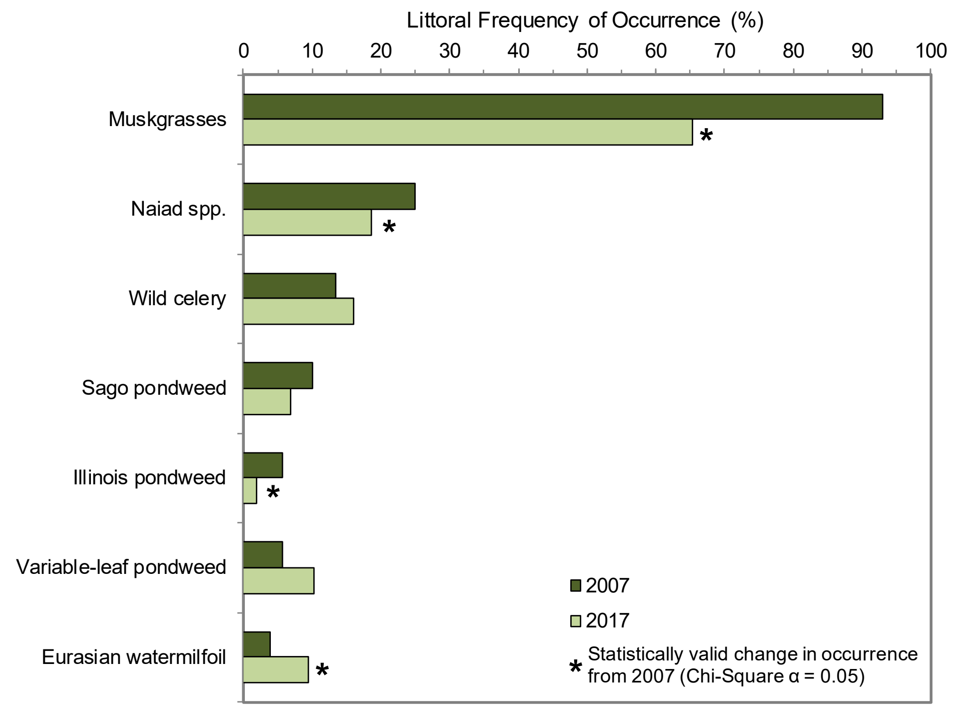


Figure 3.5-6. Stratton Lake aquatic plant littoral frequency of occurrence for select species. Created using data from 2007 and 2017 surveys. Only species with a littoral frequency of occurrence of 5% or more were included.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the native aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total of 32 native aquatic plant species were located in Stratton Lake during the 2017 surveys, 17 were directly encountered on the rake during the point-intercept survey. Stratton Lake's native aquatic plant species richness in 2017 exceeded the median value for lakes within the North Central Hardwood Forests (NCHF) ecoregion but is below the median for lakes throughout Wisconsin (Figure 3.5-7). The species richness recorded in 2017 (17) was also higher than that recorded during the 2007 (13) point-intercept survey. The differences in the aquatic plant species list between these surveys can be viewed in Table 3.5-1.

The average conservatism of the 17 native aquatic plants recorded on the rake in 2017 was 6.1, falling above the median value (5.8) for lakes within the NCHF ecoregion and just below the median value (6.3) for lakes throughout Wisconsin (Figure 3.5-7). This indicates that Stratton Lake has a larger number of native aquatic plant species with higher conservatism values when compared to the majority of lakes within the NCHF ecoregion. Average conservatism in 2017 was slightly lower when compared to the average conservatism values recorded in 2007 of 6.2.

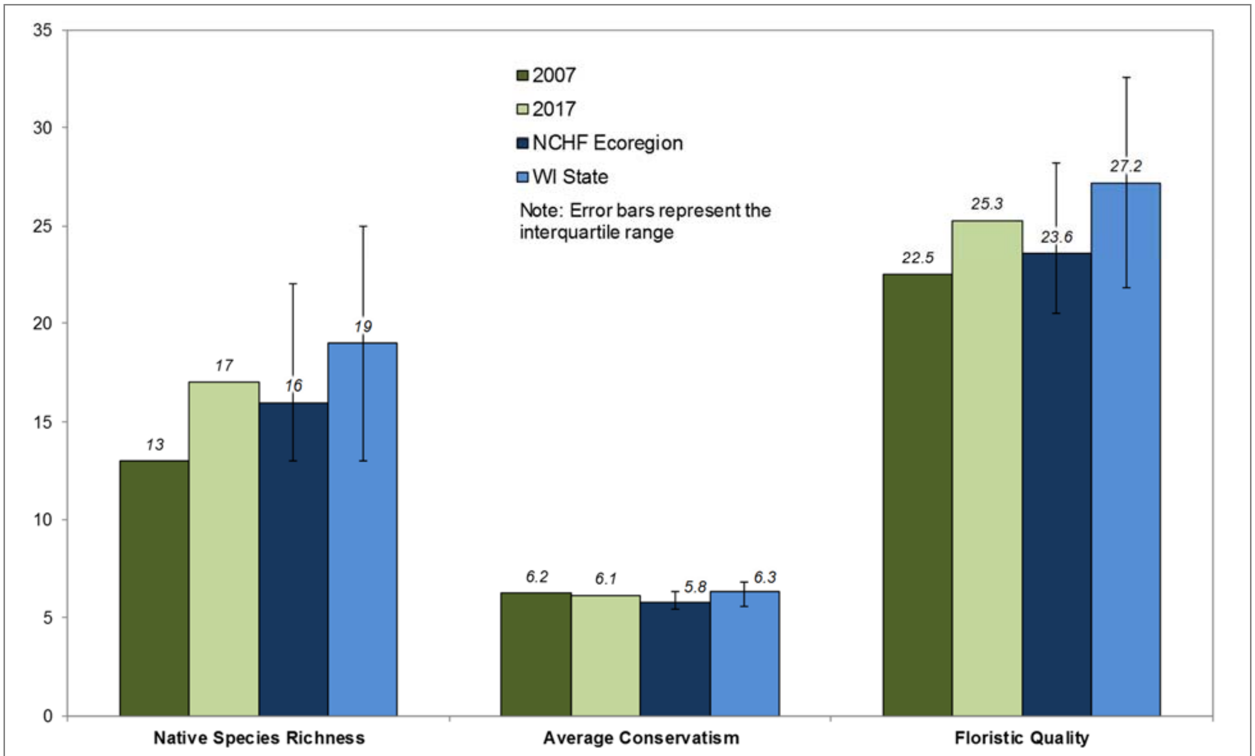


Figure 3.5-7. Stratton Lake Floristic Quality Assessment. Created using data from 2007 and 2017 surveys. Analysis following Nichols (1999) where NCHF= North Central Hardwood Forests Ecoregion.

Using Stratton Lake's 2017 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 25.3, exceeding the median value for lakes within the NCHF ecoregion but falling below the median for the state. This indicates that Stratton Lake's aquatic plant community is of higher quality in terms of species richness and community composition than the majority of lakes within the ecoregion. The 2017 Floristic Quality Index value was also higher than the value of 22.5 from 2007.

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Stratton Lake contains a moderate number of native aquatic plant species, one may assume the aquatic plant community also has moderate to high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within 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 Stratton Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 85 lakes within the NCHF ecoregion (Figure 3.5-8). Using the data collected from the 2007 and 2017 point-intercept surveys, Stratton Lake's aquatic plant community is shown to have low species diversity. Simpson's Diversity Index values were 0.65 in 2007 and 0.74 in 2017. These diversity value fall below the median value of 0.84 for lakes in the NCHF ecoregion.

While Stratton Lake contains a moderate number of aquatic plant species, the majority of the plant community is comprised of just one species: muskgrasses. One way to visualize Stratton Lake's lower species diversity is to look at the relative occurrence of aquatic plant species. Figure 3.5-9 displays the relative frequency of occurrence of aquatic plant species created from the 2017 whole-lake point-intercept survey and illustrates the relatively uneven distribution of aquatic plant species within the community. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population).

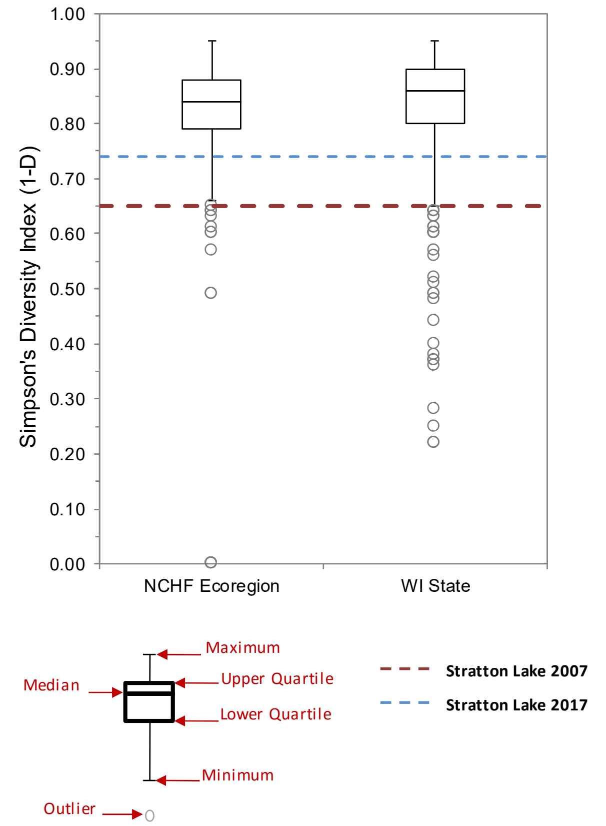


Figure 3.5-8. Stratton Lake species diversity index. Created using data from 2007 and 2017 aquatic plant surveys. Ecoregion data from 85 NCHF lakes collected by WDNR Science Services and Onterra.

For instance, while muskgrasses had a littoral frequency of occurrence of 65%, their relatively frequency of occurrence was 47%. Explained another way, if 100 plants were sampled from Stratton Lake, 47 would be muskgrasses. Despite having a higher number of aquatic plant species (species richness), the dominance of the plant community by one species results in lower species diversity. As discussed previously, hardwater lakes rich in calcium like Stratton Lake are often dominated by muskgrasses which are able to outcompete other plants in these conditions. The lower species diversity in Stratton Lake is not an indication of degraded conditions, but rather the result of calcium-rich conditions present in Stratton Lake.

The quality of Stratton Lake's plant community is also indicated by the high number of native emergent and floating-leaf aquatic plant species located in 2017 (Table 3.5-1). The 2017 community mapping survey found that approximately 0.4 acres (0.6%) of the 66 acre-lake contain these types of plant communities (Table 3.5-2 and Map 6). Eleven floating-leaf and emergent species were located on Stratton Lake, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

Because the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Stratton Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and 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.

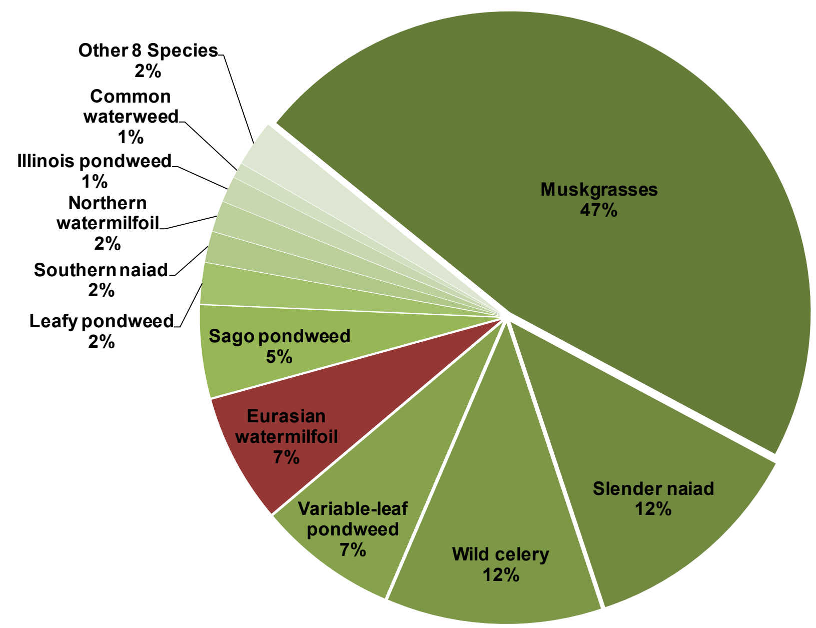


Figure 3.5-9. 2017 relative frequency of occurrence of aquatic plants in Stratton Lake. Created using data from 2017 point-intercept survey.

Table 3.5-2. Stratton Lake acres of plant community types. Created from July 2017 community mapping survey.

Plant Community	Acres
Emergent	0.1
Floating-leaf	0.1
Mixed Emergent & Floating-leaf	0.1
Total	**0.4**

Non-Native Plants in Stratton Lake

Eurasian watermilfoil

Eurasian watermilfoil (EWM; Photograph 3.5-6) was first documented in Stratton Lake in 2001. Herbicide treatments were conducted in 2006, 2008, and 2009 to help control the spread of Eurasian watermilfoil around Stratton Lake. Onterra ecologist visited Stratton Lake in September 2016 to map locations of Eurasian watermilfoil. During that survey, approximately 1.0 acre of colonized EWM was mapped, with the majority being denoted with a density rating of *highly dominant* (Map 7).

Photograph 3.5-6. Eurasian watermilfoil, a non-native, invasive aquatic plant. Photo credit Onterra.

The EWM was mapped again by Onterra in September of 2017. During this survey, approximately 1.1 acres of colonized EWM were found (Map 8), similar to what was mapped in 2016. In August 2018, Onterra ecologists visited the lake again and found that the EWM population had crashed and there was little to be found (Map 9). Despite being present in Stratton Lake for nearly 20 years, the Eurasian watermilfoil population is relatively small and largely isolated to a handful of small areas. In 2017, EWM was the fifth-most frequently encountered aquatic plant during the point-intercept survey with a littoral frequency of occurrence of 10%, a statistically valid increase in occurrence from a littoral occurrence of 4% in 2007. A point-intercept survey was not completed in 2018. Ongoing research indicates that EWM populations have the capacity to fluctuate widely in abundance from year to year and over longer periods of time. This is obviously the case in Stratton Lake based upon the three mapping surveys completed as a part of this project. Future surveys will provide more insight into the EWM population dynamics in Stratton Lake.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous 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 has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. Populations of purple loosestrife were observed along the shoreline of Stratton Lake (Map 6)

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Control of purple loosestrife on Stratton Lake will be discussed in the Implementation Plan Section.

Pale yellow iris

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers (Photograph 3.5-7). Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. Pale yellow iris was observed growing around the shoreline of Stratton Lake in 2017 (Map 6). Control of pale-yellow iris on Stratton Lake will be discussed in the Implementation Plan Section.

Reed Canary Grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height (Photograph 3.5-7). Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. Reed canary grass was observed along the western shore of Stratton Lake (Map 6). Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

Purple loosestrife	Pale-yellow iris	Reed canary grass
		

Photograph 3.5-7. Non-native, invasive wetland plants located in shoreland areas of Stratton Lake.

Stakeholder Survey Responses to Aquatic Vegetation within Stratton Lake

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.5-10 and 3.5-11 display the responses of members of Stratton Lake stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, during the open water season, negatively impacts their enjoyment of Stratton Lake, the majority of stakeholder survey respondents (49%) indicated *rarely*, 35% indicated *sometimes*, 11% indicated *often* or *always*, and5% indicated *never*.

When asked if they believe aquatic plant control is needed on Stratton Lake, 54% indicated *definitely yes* or *probably yes*, 27% indicated *unsure*, and 19% indicated *probably no* or *definitely no*. The presence of AIS within Stratton Lake is well-known knowledge for the stakeholders so while aquatic plants do not generally impact user's enjoyment of the lake, stakeholders may believe that control of AIS is needed. As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating aquatic invasive species. The management strategy that will be taken to manage AIS in Stratton Lake is discussed within the Implementation Plan Section (Section 5.0).

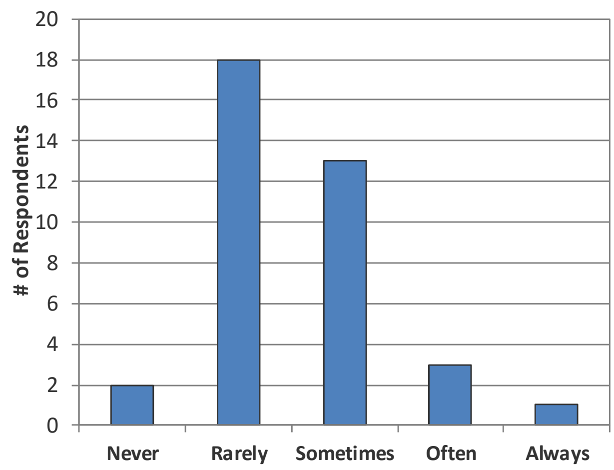


Figure 3.5-10. Stakeholder survey response Question #25. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Stratton Lake?

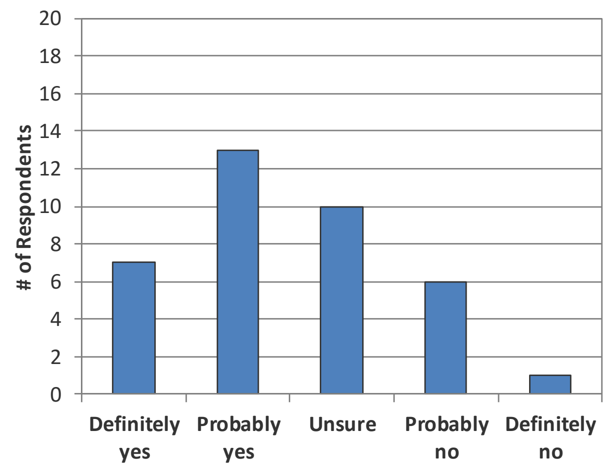


Figure 3.5-11. Stakeholder survey response Question #26. Do you believe aquatic plant control is needed on Stratton Lake?

3.6 Aquatic Invasive Species in Stratton Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Stratton Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are six AIS present (Table 3.6-1).

Table 3.6-1. AIS present within Stratton Lake

Type	Common Name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
	Pale yellow iris	*Iris pseudacorus*	Section 3.4 – Aquatic Plants
	Reed canary grass	*Phalaris arundinacea*	Section 3.4 – Aquatic Plants
Invertebrates	Asiatic clam	*Corbicula fluminea*	3.1 – Water quality
	Zebra mussel	*Dreissena polymorpha*	3.1 – Water quality
	Banded mystery snail	*Viviparus georgianus*	Section 3.5 – Aquatic Invasive Species

Figure 3.6-1 displays the 10 aquatic invasive species that Stratton Lake stakeholders believe are in Stratton Lake. Only the species present in Stratton Lake are discussed below or within their respective locations listed in Table 3.6-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

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

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 et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009).

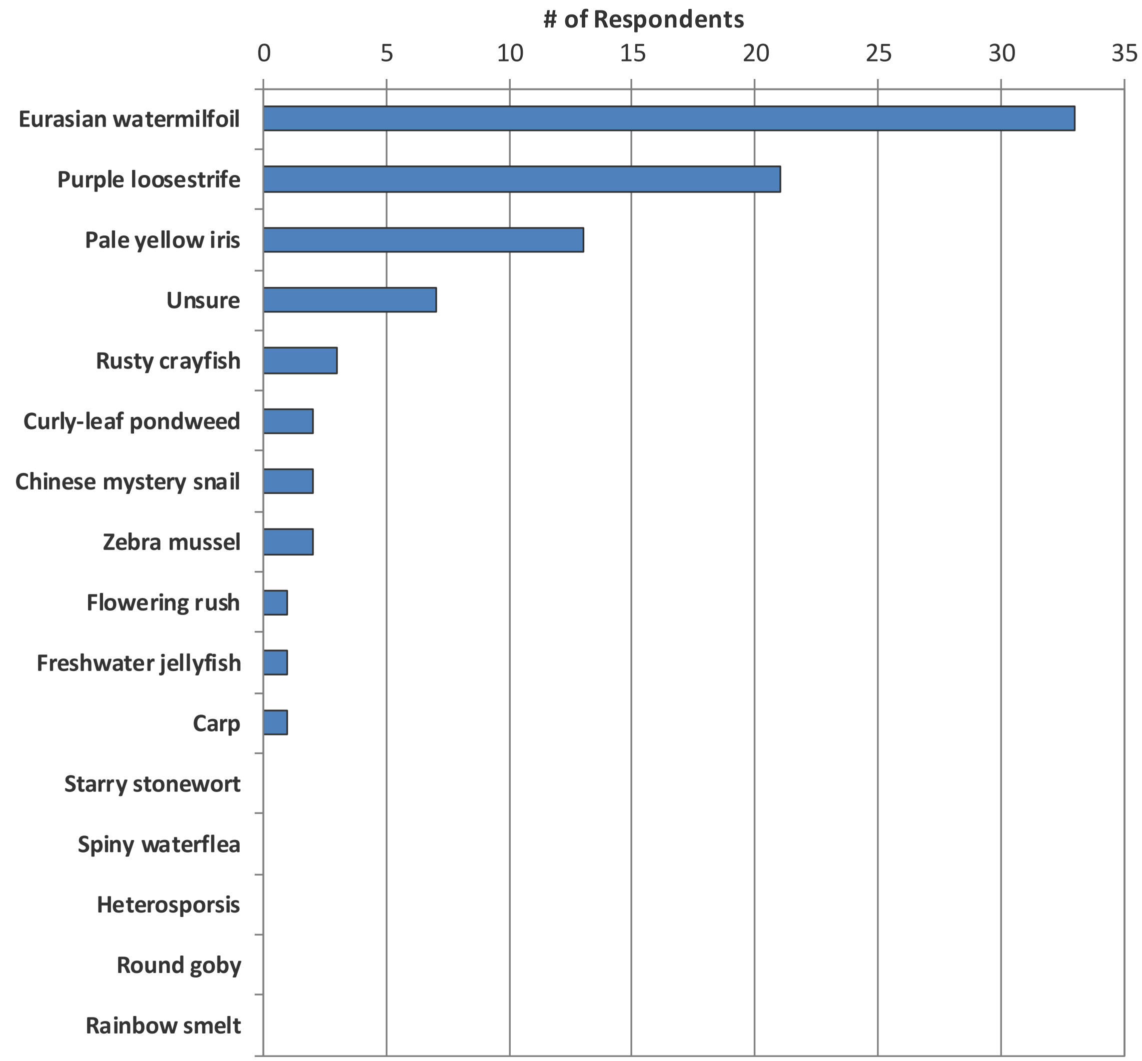


Figure 3.6-1. Stakeholder survey response Question #22. Which aquatic invasive species do you believe are in Stratton Lake?

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 Stratton Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) and personal communications with DNR Fisheries Biologist Jason Breeggemann (WDNR 2018).

Stratton Lake 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 Stratton Lake 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.

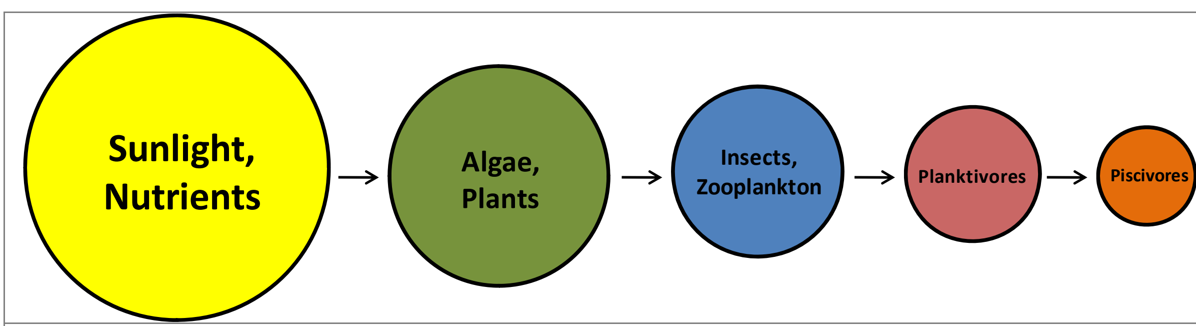


Figure 3.7-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Stratton Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Stratton Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. 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 species documented in past surveys of Stratton Lake include white sucker (*Catostomus commersonii*), brook silverside (*Labidesthes sicculus*) and the bluntnose minnow (*Pimephales notatus*).

Table 3.7-1. Gamefish present in Stratton 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*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Brown Trout (*Salmo trutta*)	18	October - December	Large streams to small spring-fed tributaries with gravel bottom	Aquatic invertebrates, terrestrial insects, worms, fish, and crayfish
Green Sunfish (*Lepomis cyanellus*)	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
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
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Yellow Bullhead (*Ameiurus natalis*)	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
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 electroshocking (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 easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking 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 fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries. Stocking of 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. Stratton Lake was stocked from 1984 to 1988 with brown trout (Table 3.7-2).

Table 3.7-2. Stocking data available for brown trout in Stratton Lake (1984-1988).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1984	Brown Trout	Yearling	400	9
1986	Brown Trout	Yearling	400	8
1988	Brown Trout	Yearling	260	9

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the third most important reason for owning property on or near Stratton Lake (Question #17). Figure 3.7-2 displays the fish that Stratton Lake survey respondents enjoy catching the most, with bluegill/sunfish, largemouth bass and northern pike being the most popular. Approximately 91% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.7-3). Approximately 82% of the survey respondents who fish Stratton Lake believe the quality of fishing has remained the same or gotten worse since they started fishing the lake (Figure 3.7-4).

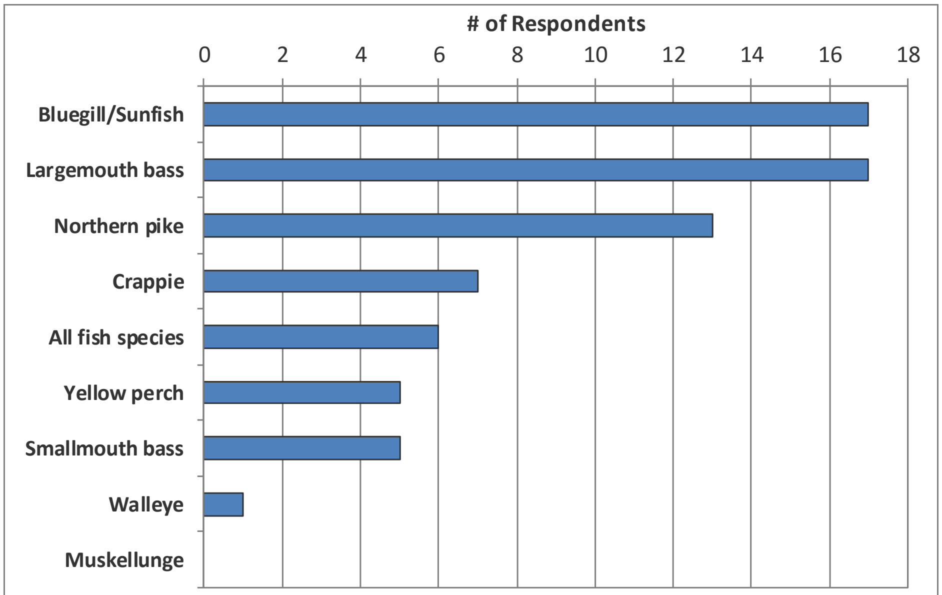


Figure 3.7-2. Stakeholder survey response Question #9. What species of fish do you like to catch on Stratton Lake?

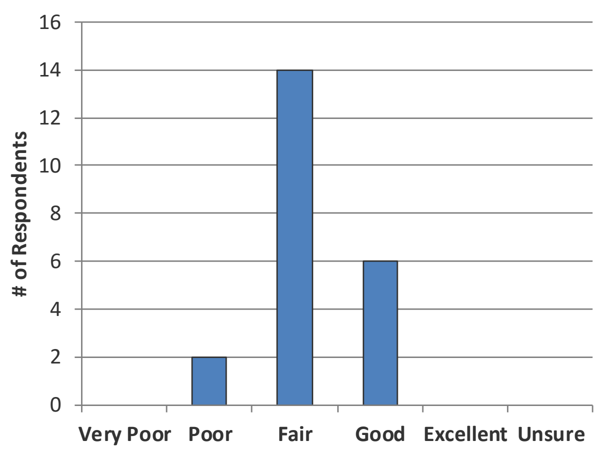


Figure 3.7-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on Stratton Lake?

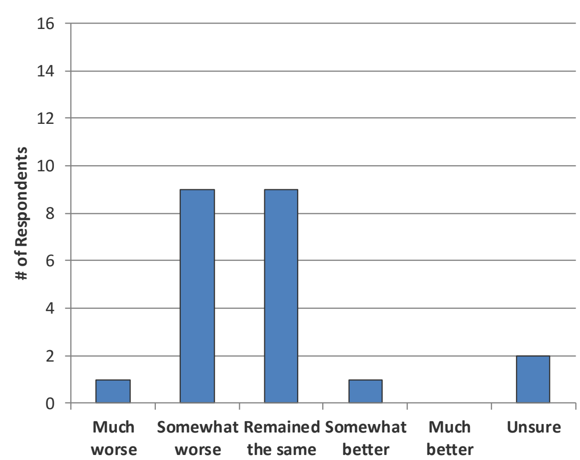


Figure 3.7-4. Stakeholder survey response Question #11. How has the quality of fishing changed on Stratton Lake since you started fishing the lake?

Fish Populations and Trends

Utilizing the fish sampling techniques mentioned above and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). In the past 10 years Stratton lake has been sampled in 2011 and 2016. The 2016 WDNR fisheries survey was specifically targeting panfish species in Stratton Lake. Overall, the 2016 survey showed panfish size structure and relative abundance at moderate levels (Appendix F).

Stratton Lake Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2017, 98% of the substrate sampled in the littoral zone of Stratton Lake was sand sediment and 2% was composed of soft sediment.

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 barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006).

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. 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. 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 3.7-2. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

Fish cribs are a fish habitat structure that is placed on the lakebed. Installing fish cribs may 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.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.7-2). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 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 does not require 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.

The SLD should 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 Stratton Lake.

Regulations and Management

Regulations for Stratton Lake gamefish species as of April 2018 are displayed in Table 3.7-4. Stratton Lake is one of 93 lakes chosen 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.

- 25/10 – A total of 25 panfish may be kept but only 10 of any one species.
- Spawning season 15/5 – A total of 25 panfish may be kept except during May and June when a total of 15 panfish may be kept but no more than five of any one species.
- 15/5 – A total of 15 panfish may be kept but only five of any one species.

Stratton Lake was chosen to be under the 25/10 experimental regulation. The efficacy of the regulations as well as anglers support of the changes will be evaluated in 2021. 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 3.7-3. WDNR fishing regulations for Stratton Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25 panfish may be kept but only 10 of any one species	None	Open All Year
Smallmouth bass and largemouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 5, 2018 to December 31, 2018
Northern pike	2	26"	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	5	15"	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with up to 3 hooks, baits, or lures per angler.

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 3.7-5. 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/)

4.0 SUMMARY AND CONCLUSIONS

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

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

The three objectives were fulfilled during the project and have led to a good understanding of the Stratton Lake ecosystem, the folks that care about the lake, and what needs to be completed to protect and enhance it.

Stratton Lake is a moderately deep marl lake fed greatly by groundwater. Like many lakes in Central Wisconsin, it has seen a fair amount of development pressure and is utilized by riparian and transient boaters. Although these factors have brought on changes in the lake, including the introduction of several aquatic invasive species, Stratton Lake would be considered a healthy lake ecosystem.

Compared to other lakes in the ecoregion and state, Stratton Lake's water quality is considered excellent as evidenced by low phosphorus and chlorophyll-*a* concentrations and high water clarity values. Paleoecological studies completed on Stratton Lake sediment cores indicated that while phosphorus levels are considered low at present, they were even lower prior to human development in the area. This is by no means uncommon. Natural lakes respond quickly and distinctly to human activity in the lake's watershed and on its immediate shoreline. The most notable is typically increased nutrient levels and aquatic plants, which were both documented to have occurred in Stratton Lake. While the input of phosphorus has increased, Stratton Lake's high marl content works to bind with phosphorus, settling it to the bottom and rendering it unusable by algae and most vascular plants. The marl precipitation also slowly reduces water depth and volume. Some lake residents have voiced issues brought on by this natural and uncontrollable phenomenon; therefore, the district may complete studies to discover the sediment accumulation rate and determine if actions are necessary to remove some precipitated marl from the lake.

The paleoecological studies also determined that the minimally dense macrophyte (vascular) plant population in Stratton Lake was first started by development on the lake's shorelands and within its watershed. As mentioned above, this is a common occurrence brought on by anthropogenic activities around a lake. During the 2017 aquatic plant surveys, 32 native species were discovered in Stratton Lake. Four non-native species were also recorded, including both emergent and submergent varieties. The native species population is very highly dominated by the macroalgae, *Chara* (muskgrasses), which do well in marl lakes with clear water. Stratton Lake's plant community quality is slightly lower than most lakes in the state and slightly higher than most lakes in the ecoregion. The plant community's diversity is much lower than lakes in both the ecoregion and state. This is not surprising nor of concern because of Stratton Lake's low phosphorus levels. Algae and macrophyte production are control by phosphorus levels in Stratton Lake. Phosphorus levels in the lake are considered low; therefore, plant production is also be expected to be low.

As mentioned above, four exotic plant species were found in Stratton Lake, Eurasian watermilfoil, purple loosestrife, pale yellow iris, and reed canary grass. Eurasian watermilfoil raises the greatest concern among district members; however, in the 20 years the exotic has existed in the lake, it has not reached levels that impact the lake's recreational use or its ecology. The Stratton Lake management plan includes periodic professional monitoring to track the population and determine if control is appropriate. The other exotic plant species are found in many parts of the lake and can likely be controlled through volunteer efforts as discussed in the plan.

Two exotic animal species have recently been discovered in Stratton Lake, Asiatic clams in 2017 and zebra mussels in 2018. The Asiatic clam population is thought to be very small and will likely remain at that level. The zebra mussel population expanded greatly over the summer of 2018; however, that is not an indication that the high growth rate will continue. Many exotic infestations begin with a rapid population expansion followed by a massive crash as resources are utilized. It is unknown how these two exotic populations will behave in Stratton Lake. Both are filter feeders and rely on algae for nutrients. As discussed above, algae levels are low in the lake which may minimize populations. The management plan contains an action to monitor zebra mussel population in Stratton Lake because they are of the most concern at present.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Stratton Lake District Planning Committee and ecologist/planners from Onterra. It represents the path the SLD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Stratton Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain Water Quality in and around Stratton Lake

Management Action:	Monitor water quality through the WDNR Citizen Lake Monitoring Network
Timeframe:	Continuation of current effort
Facilitator:	SLD Board of Commissioners
Prospective Grant:	Funded by WDNR at no cost to district
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Volunteer water quality monitoring is currently being completed annually by Stratton Lake riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The SLD currently monitors the deep hole site in the south basin as a part of the advanced CLMN program, including collecting Secchi disc transparency and sending in water chemistry samples (chlorophyll-a, and total phosphorus) to the Wisconsin State Laboratory of Hygiene for analysis. The volunteers also collect Secchi disc transparency in the deepest area of the north basin. The samples are collected once during the spring and three times during the summer. It is important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS). It will be the Board of Commissioners responsibility to ensure that a volunteer is prepared to communicate with WDNR representatives and collect water quality samples each year. The WDNR maintains a waiting list of lake groups that would like to participate in the CLMN

	program. Groups that do not consistently participate are often dropped from the program to allow other groups to participate.
Action Steps:	
	See description above.

Management Action:	Conduct periodic groundwater drinking well testing of Stratton Lake riparian properties, nitrate testing in Stratton Lake, and water quality testing in Stratton Lake outlet.
Timeframe:	2019
Facilitator:	SLD Board of Commissioners
Prospective Grant:	Small-scale Lake Management Planning
Description:	In 2011 and 2015, the Center for Watershed Science and Education, in partnership with the Waupaca County UW-Extension Office and the Stratton Lake Association, completed testing on several Stratton Lake riparian wells for nitrates, chloride, and an indicator of triazine type pesticides. These studies were intended to update studies reported on in 2000. In 2015, a portion of the well testing was repeated and those results, along with additional spring and fall overturn water quality data from the lake's two basins, were reported on. While drinking well levels of all of these chemicals have lessened, there are still concerns among riparians. A committee formed by the Stratton Lake District will work with the Center for Watershed Science at UW-Stevens Point to repeat the well testing, analyze water quality data collected since 2015, and further carry out the recommendations contained in the 2011 and 2015 summary reports. Upon completion, an updated list of recommended activities will be created. Further, the committee will report the results to the district along with acceptable levels of nitrates in drinking water.
Action Steps:	
1.	Create SLD committee to implement project, communicate with partners, and report results to district members.
2.	Contact Center for Watershed Science to develop project design and timeline.
3.	Discuss possible WDNR Small-scale Planning Grant applicability with WDNR Lakes Coordinator (see contact table on page 92)
4.	Complete project and report results to SLD and WDNR.

Management Action:	Inform Stratton Lake riparian property owners regarding the importance of natural shorelines and septic system maintenance.
Timeframe:	2019
Facilitator:	SLD Board of Commissioners
Description:	As discussed in the Water Quality Section 3.1 and Watershed Section 3.3, Stratton Lake has a small watershed; therefore, the immediate

	watershed around the lake, which includes all shoreland properties, is very important in determining the lake's water quality. Further, water quality data trend analysis and paleocore analysis indicate that the water quality of Stratton Lake has worsened slightly over the decades and these changes were likely brought on in part by shoreland development. Maintaining septic systems so they operate efficiently and effectively is important in keeping nutrients and other pollutants out of the lake. Natural and near-natural shorelands buffer the lake from shoreland runoff while providing important habitat at the water-land interface. The SLD will work to inform district members about the importance of maintaining septic systems and naturalizing their shoreline. An important part of this action will be getting information out to district members regarding the WDNR Healthy Lakes Initiatives program that provides easily accessible funding for shoreland restoration. This action may be best implemented by the Education, Communication, and Volunteer Committee described below.
Action Steps:	
1.	Review information available from Waupaca County, WDNR, and UW-Extension Lakes Program regarding these topics.
2.	Create newsletter articles utilizing information from above.
3.	Recruit speakers from these agencies and others to present this information at district annual meeting.

Management Action:	Work with Waupaca County Highway Department to keep culverts under Highway 22 free of debris and reduce shoreline erosion brought on by high water levels.
Timeframe:	2019
Facilitator:	SLD Board of Commissioners
Description:	Stratton Lake's outlet flows under State Highway 22 and occasionally, the culverts under they highway are partially blocked by debris. This constricts water flow and can increase water levels in Stratton Lake, which can cause shoreland erosion to occur. The SLD will work with the Waupaca County Highway Department (see contact table on page 92) to discover how the district and department can partner to reduce the occurrence of debris buildup and minimize the occurrence of unnaturally high water levels and the erosion it causes.
Action Steps:	
1.	See description above.

Management Goal 2: Manage Current Aquatic Invasive Species Populations and Prevent Further Introductions to Stratton Lake

Management Action:	Control existing purple loosestrife and pale-yellow iris populations in Stratton Lake.
Timeframe:	2019
Facilitator:	SLD Board of Commissioners
Description:	Surveys completed in 2017 located several occurrences of the emergent, exotic species, purple loosestrife and pale-yellow iris along the shoreline of Stratton Lake. In some situations, these species can outcompete native species and occupy large areas of shoreline. The SLD will work with local agencies to learn how to identify and manage these species with the objective of keeping populations very low along the shores of Stratton Lake. The volunteers will track their activities so they are able to inform district members on progress of controlling these AIS.
Action Steps:	
1.	Board of Commissioners recruit volunteers to facilitate action.
2.	Contact Golden Sands Resource Conservation & Development Council (see contact table on page 92) to schedule training session.
3.	Volunteers locate and perform control actions.
4.	Volunteers report activities to district members in newsletter and/or at annual meeting.

Management Action:	Monitor zebra mussel populations in Stratton Lake and gauge perceived impact of zebra mussels on riparian property owners.
Timeframe:	Initiate 2019
Facilitator:	SLD Board of Commissioners
Description:	During the summer of 2018, adult zebra mussels were discovered by a Stratton Lake property owner. Over the course of the summer, many property owners reported finding zebra mussels on items left in the lake for extended periods. The rapid expansion of zebra mussels in Stratton Lake is not atypical for the initial infestation of a lake with a new invasive species. Often, species such as this produce a quick spread within the system followed by a decrease to some dynamic level of occurrence. As discussed in the Water Quality Section 3.1, there is no way of predicting how this AIS will impact Stratton Lake. In some systems, even those with the correct lake chemistry to support zebra mussels, the population remains low and does not impact the lake's ecology or recreational opportunities. There are limited control options for zebra mussel populations at this time and within the State of Wisconsin, all are considered experimental. If the population of zebra mussels within Stratton Lake expands to the point that it is impacting recreational activities and

	potentially the lake's ecological function, the SLD may consider approaching the WDNR about initiating a control action on Stratton Lake. Documenting the zebra mussel population and its potential impact on riparians is essential in determining if the district should consider control. To document the zebra mussel population, the SLD will contact Paul Skawinski, UW-Extension Lakes Program (see contact table on page 92) to receive information and training on zebra mussel monitoring techniques. To understand how zebra mussels are impacting the riparian property owners on Stratton Lake, the district will seek comments and discussions at annual meetings. The SLD will document the findings for at least three years. At the end of the three years, the district will convene with the WDNR Lakes Coordinator and discuss whether a control action is needed and appropriate on Stratton Lake.
Action Steps:	
	See description above.

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at public access location.
Timeframe:	Continuation of current effort
Facilitator:	SLD Board of Commissioners
Potential Grant:	WDNR AIS-Clean Boats Clean Waters Grant (https://dnr.wi.gov/lakes/cbcw/)
Description:	Currently the SLD monitors the Stratton Lake public boat landing using training provided by the Clean Boats Clean Waters program. Stratton Lake is a somewhat popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasive species that originated in Stratton Lake. 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 its spread. The SLD has set a goal of 200 hours of annual watercraft inspections utilizing a combination of volunteer and paid inspectors. Volunteers would focus upon high-use periods such as weekends and holidays. The SLD may approach the Waupaca Chain O' Lakes District to discuss a partnership in providing part-time paid inspectors for both systems.

	To achieve maximum efficiency in educating boaters and for the convenience of those boaters, SLD volunteers, with permission, will place CBCW stickers on the boat trailers of frequently inspected lake users.
Action Steps:	
	See description above as this is an established program.

Management Action:	Conduct periodic quantitative vegetation monitoring on Stratton Lake.
Timeframe:	Point-Intercept Survey every 3-5 years, Community Mapping every 7-10 years
Possible Grant:	Small-Scale Lake Planning Grant or AIS-Education, Prevention, and Planning in <$10,000 category.
Facilitator:	SLD Board of Commissioners
Description:	As part of the ongoing AIS management program, a whole-lake point-intercept survey will be conducted at a minimum once every 3-5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Stratton Lake. A point-intercept survey was conducted on Stratton Lake in 2017; therefore, the next point-intercept survey will be completed between 2020 and 2022, depending on the perceived level of Eurasian watermilfoil in the lake by the SLD. In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Stratton Lake, a community mapping survey would be conducted every 7-10 years. A community mapping survey was conducted on Stratton Lake in 2017 as a part of this management planning effort. The next community mapping survey will be completed between 2024 and 2027.
Action Steps:	
	See description above.

Management Goal 3: Enhance Fishing Opportunities on Stratton Lake

Management Action:	Work with WDNR fisheries staff to increase proper fish habitat and determine appropriate stocking routine.
Timeframe:	2020
Possible Grant:	WDNR Healthy Lakes Initiative Grant (Fishsticks)
Facilitator:	SLD Board of Commissioners
Description:	Fishing is an important activity sited by respondents to the stakeholder survey distributed as a part of this project. Nearly 58% of respondents had fished the lake in the past three years and of those people, almost half believe that the quality of fishing has gotten somewhat worse or much worse since the began fishing on the lake.

	The SLD will work with local fisheries biologists to determine what type of fish structure improvements could be made to the lake to improve its fishery. Further, once those improvements are made, determine a stocking routine that will provide quality fishing opportunities on the lake.
Action Steps:	
1.	See description above.

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

Management Action:	Use education and communication to promote lake protection and enjoyment.
Timeframe:	2019
Facilitator:	SLD Board of Commissioners
Description:	Education and communication represent an effective tool to address many lake issues. To facilitate this, the SLD will develop a periodic newsletter, create a FaceBook Group, and develop a website. These mediums allow for communication with district members. Maximizing the level of communication is important within a lake management group because it facilitates the spread of important district news, educational topics, and even social happenings. The SLD will continue to make the education of lake-related issues a priority. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. As a part of this action, the SLD Board of Commissioners will consider creating a standing committee, with an annual budget, that will be tasked with producing educational materials, maintaining media such as the FaceBook Group, website, and newsletter, and developing a diverse group of volunteers. The chair of the new *Stratton Lake Education, Communication, and Volunteer Committee* would be an officer and that task would be part of the officer's position description. This committee will also strive to contact weekend residents, new residents, and long-time residents that are not active in district activities. *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology

	• Impacts of drought and low water levels • Sedimentation • Boating safety (promote existing guidelines, Lake Use Information handout) • Shoreline habitat restoration and protection • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Recreational use of the lake
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Participate in annual Wisconsin Lakes Partnership Convention.
Timeframe:	Annually
Facilitator:	SLD Board of Commissioners
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events within the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the state and is specifically suited to the needs of lake associations and districts. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/district. The SLD will sponsor the attendance of 3-5 district members annually at the convention. Following the attendance of the convention, the members will report specifics to the board of commissioners regarding topics that may be applicable to the management of Stratton Lake and operations of the SLD. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the district membership at the annual meeting. Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/convention/default.aspx.
Action Steps:	
	See description above.

Management Action:	Continue SLD's involvement with other entities that have responsibilities in managing (management units) Stratton Lake
Timeframe:	Continuation of current efforts
Facilitator:	SLD Board of Commissioners
Description:	The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the SLD actively engage with all management entities to enhance the district'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 below:
Action Steps:	
	See guidelines in Table 5.0-1.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Dayton	Dayton Town Clerk (715.258.0930)	Stratton Lake falls within this township.	Once a year, or more as issues arise.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Golden Sands Resource Conservation & Development Council	Staff (715.343.6215)	Nonprofit organization that covers central WI	Once a year, or more as issues arise.	Provide information on conservation and natural resource preservation
Waupaca County Highway Department	Commissioner (Casey Beyersdorf, casey.beyersdorf@co.waupaca.wi.us)	Maintains STH 22.	As needed	Contact to discuss debris management in Hwy 22 culverts
Waupaca County Land Conservation Department/Committee	County Conservationist (Brian Haase - Brian.Haase@co.waupaca.wi.us)	Oversees conservation efforts for land and water projects.	Continuous as it relates to lake and watershed activities	Can aid with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Jason Breeggemann – 715.526.4227)	Manages the fishery of Stratton Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery and fish structure
	Lakes Coordinator (Ted Johnson – 920.424.2104)	Oversees management plans, grants, all lake activities.	Continuous as it relates to lake management activities	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues including AIS management.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Early spring: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
University of Wisconsin – Extension Lakes Program	Eric Olson, Director and Lakes Specialist (715.346.2192) Paul Skawinski, Citizens Lake Monitoring Network Educator (715.346.4853)	Provide general information regarding lakes and lake districts. Assist in CLMN training and education.	As needed.	The UW-Ext Lakes Program is a resource for educational materials and guidance regarding lakes, lake monitoring, and the operations of lake management districts.
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.	Members may attend WL's annual conference to keep up-to-date on lake issues.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Stratton Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred twice during the summer. In addition to the samples collected by SLD 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.

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

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Stratton Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – 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 and Kreider 2003)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Stratton Lake during a May 30, 2017field 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 Stratton Lake 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 July 13 and 17, 2017. A point spacing of 30 meters was used resulting in approximately 282 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Stratton Lake (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 and vouchered for the University of Wisconsin – Steven's Point Herbarium.

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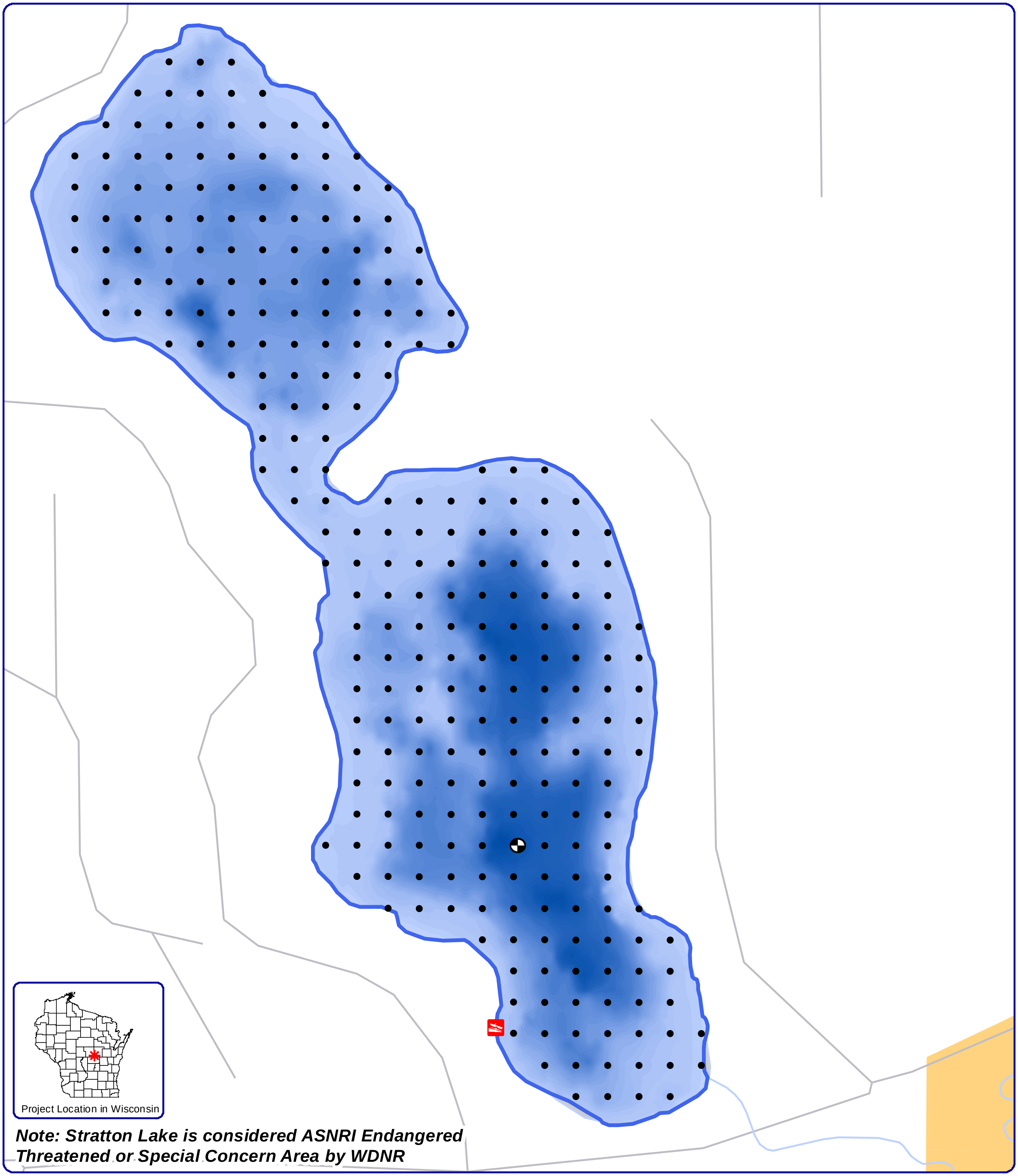

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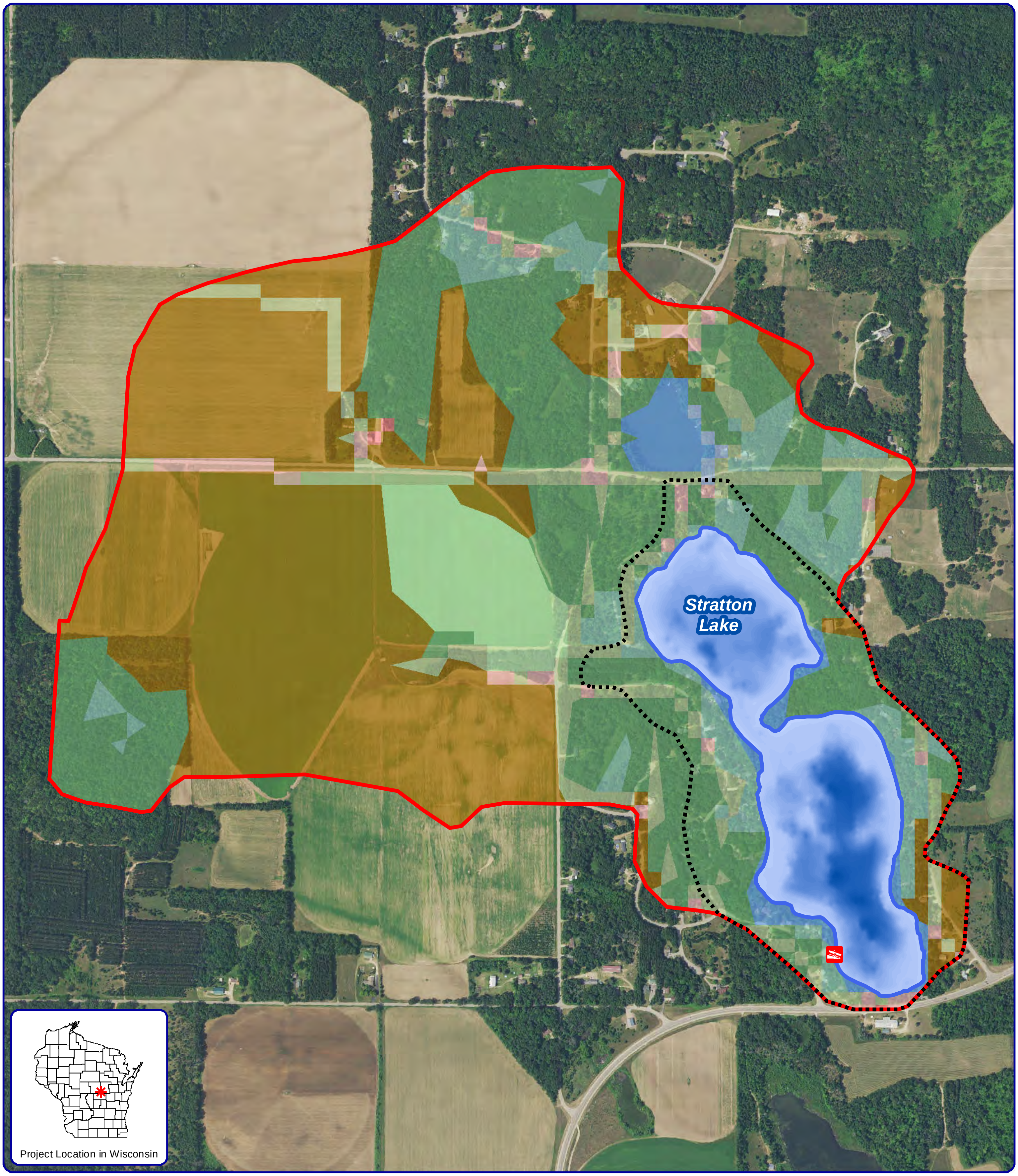
Sources:
Roads and Hydro: WDNR
Map Date: April 16, 2018
Filename: Map1_Stratton_Waupaca_Location.mxd

Legend

- Stratton Lake ~ 63 acres
  WDNR Definition
- Public Access
- Radley Creek State Fishery Area
- Point-intercept Sample Location
  30 meter points
- Water Quality Sampling Location

Map 1
Stratton Lake
Waupaca County, Wisconsin
Project Location & Lake Boundary



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Sources:
Hydro: WDNR
Bathymetry: Onterra 2017
Orthophotography: NAIP 2015
Land Cover: NLCD 2011
Watershed Boundaries: Onterra 2017

Map Date: October 30, 2017

Filename: Map2_Stratton_WS.mxd

Legend

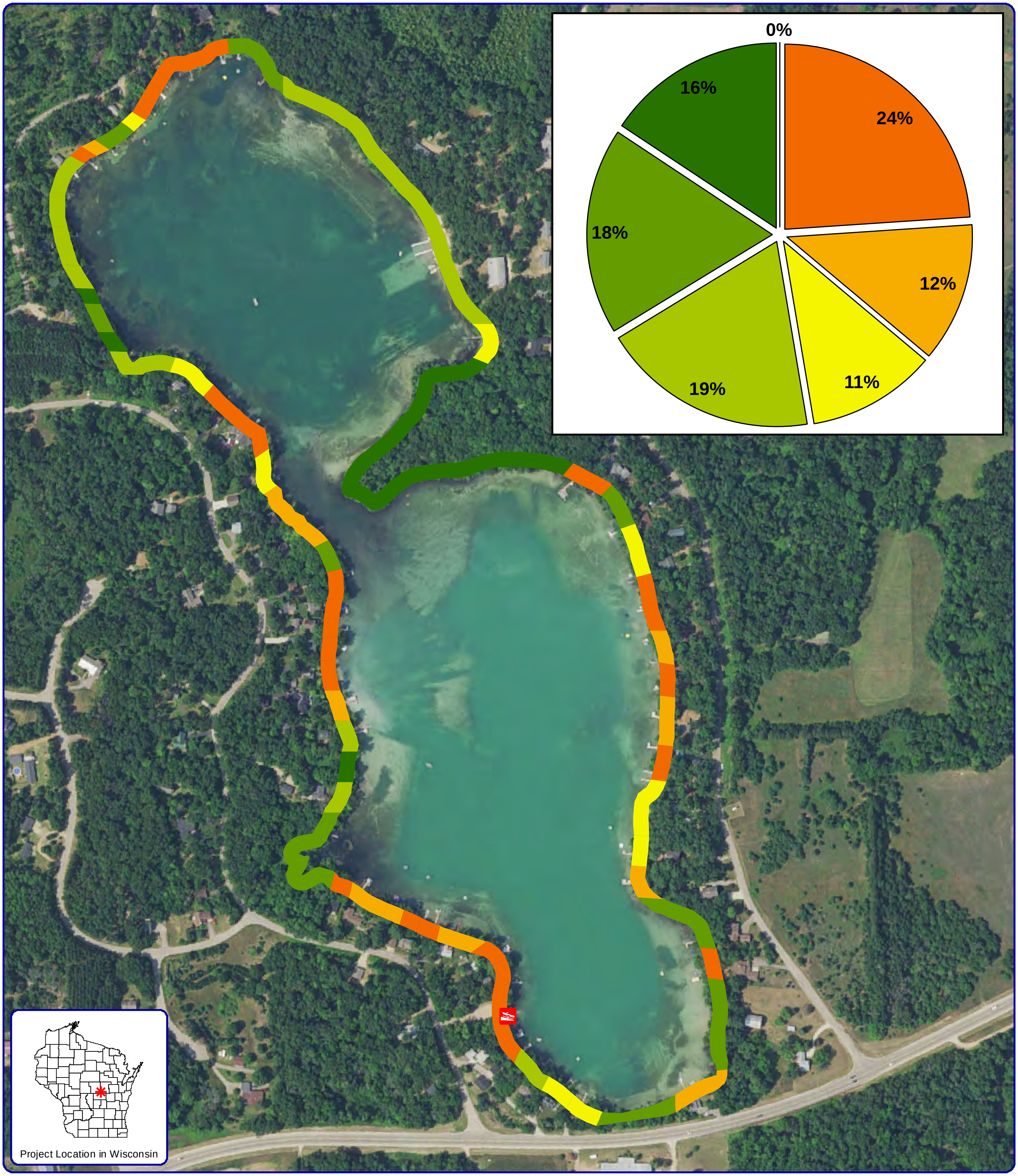
- Stratton Lake Watershed Boundary
- Stratton Lake Modeled Watershed Boundary
- Forest
- Forested Wetlands
- Pasture/Grass
- Rural Open Space
- Rural Residential
- Non-Forested Wetlands
- Open Water

Map 2

Stratton Lake

Waupaca County, Wisconsin

Watershed Boundaries & Land Cover Types



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Legend

Healthy

Unhealthy

- 0%
- 1-20%
- 21-40%
- 41-60%
- 61-80%
- 81-99%
- 100%

Percent of Parcel in a Natural State

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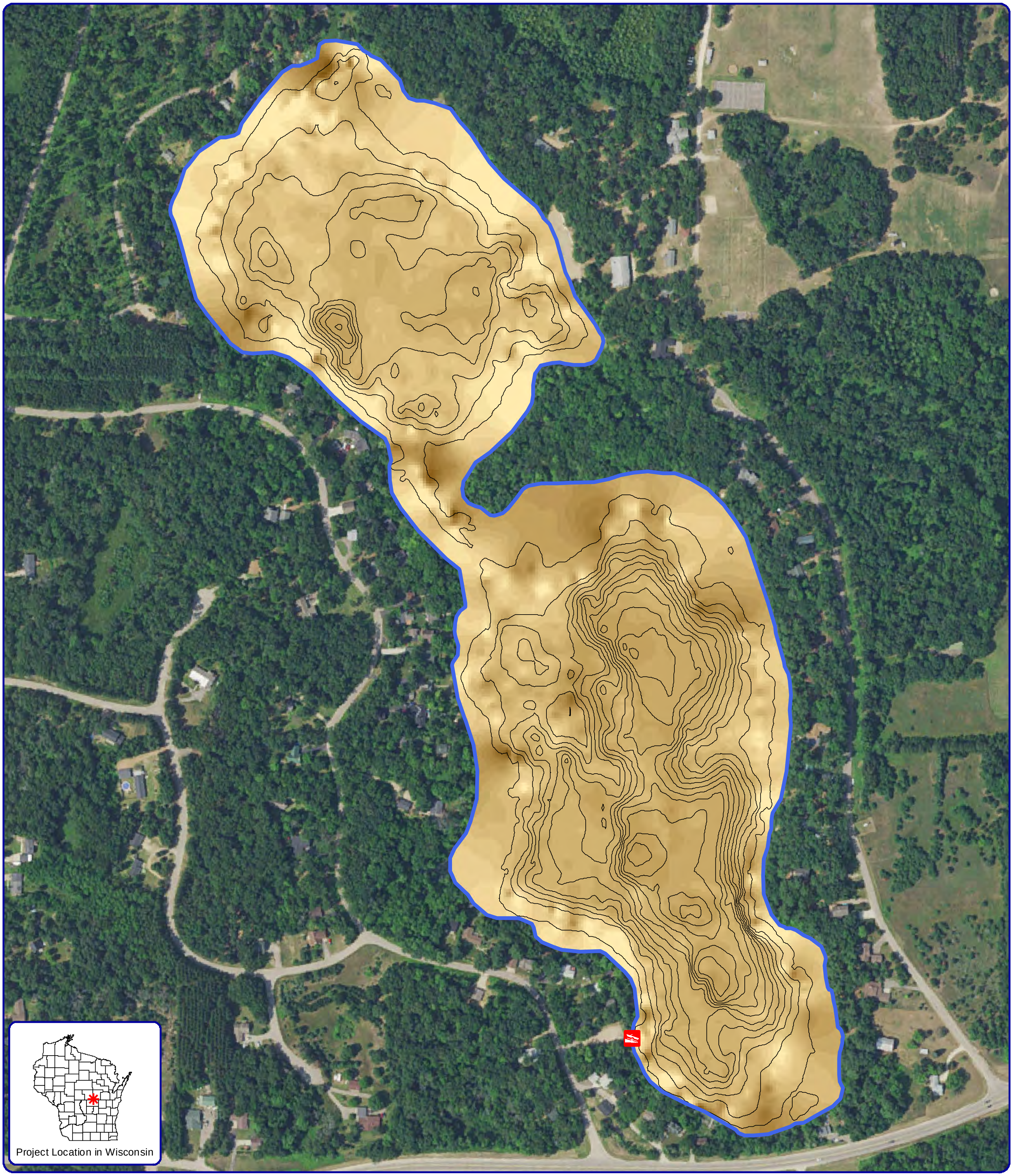
Sources:
Hydro: WDNR
Orthophotography: NAIP 2015
Shoreland Survey: Waupaca County LWCD, 2014
Map Date: January 26, 2018
Filename: *Map3_Stratton_ShorelandCondition_2014.mxd*

Map 3
Stratton Lake
Waupaca County, Wisconsin

2014 Waupaca County LWCD Shoreland Condition Survey Results



Legend

Soft — Hard

Substrate Composition

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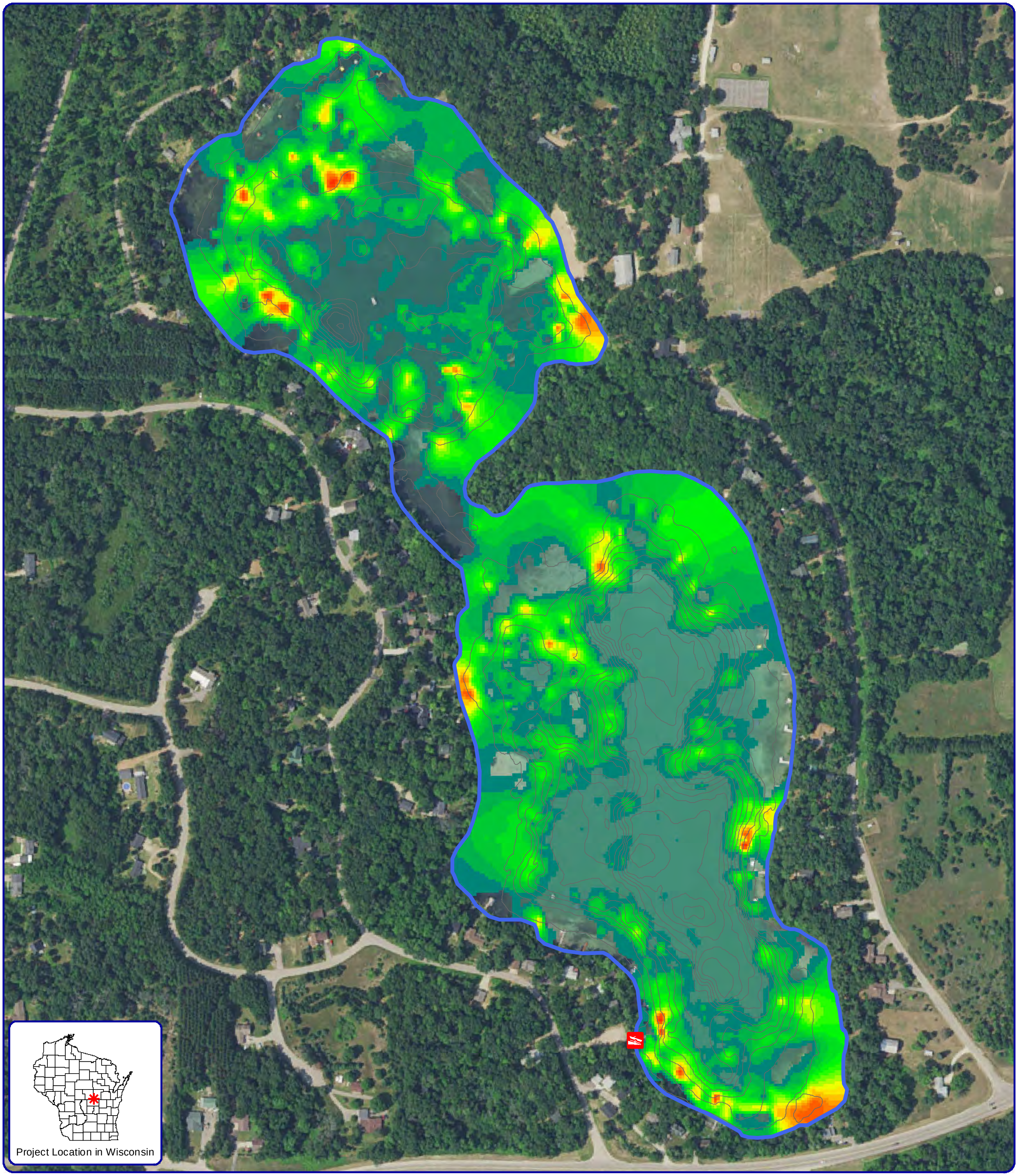
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Substrate Hardness: Onterra, 2017; procesed by C-Map USA
Map Date: February 19, 2018
Filename: Map4_Stratton_Acoustic_Sediment.mxd

Map 4
Stratton Lake
Waupaca County, Wisconsin

2017 Bio-Acoustic Survey Results - Substrate Hardness



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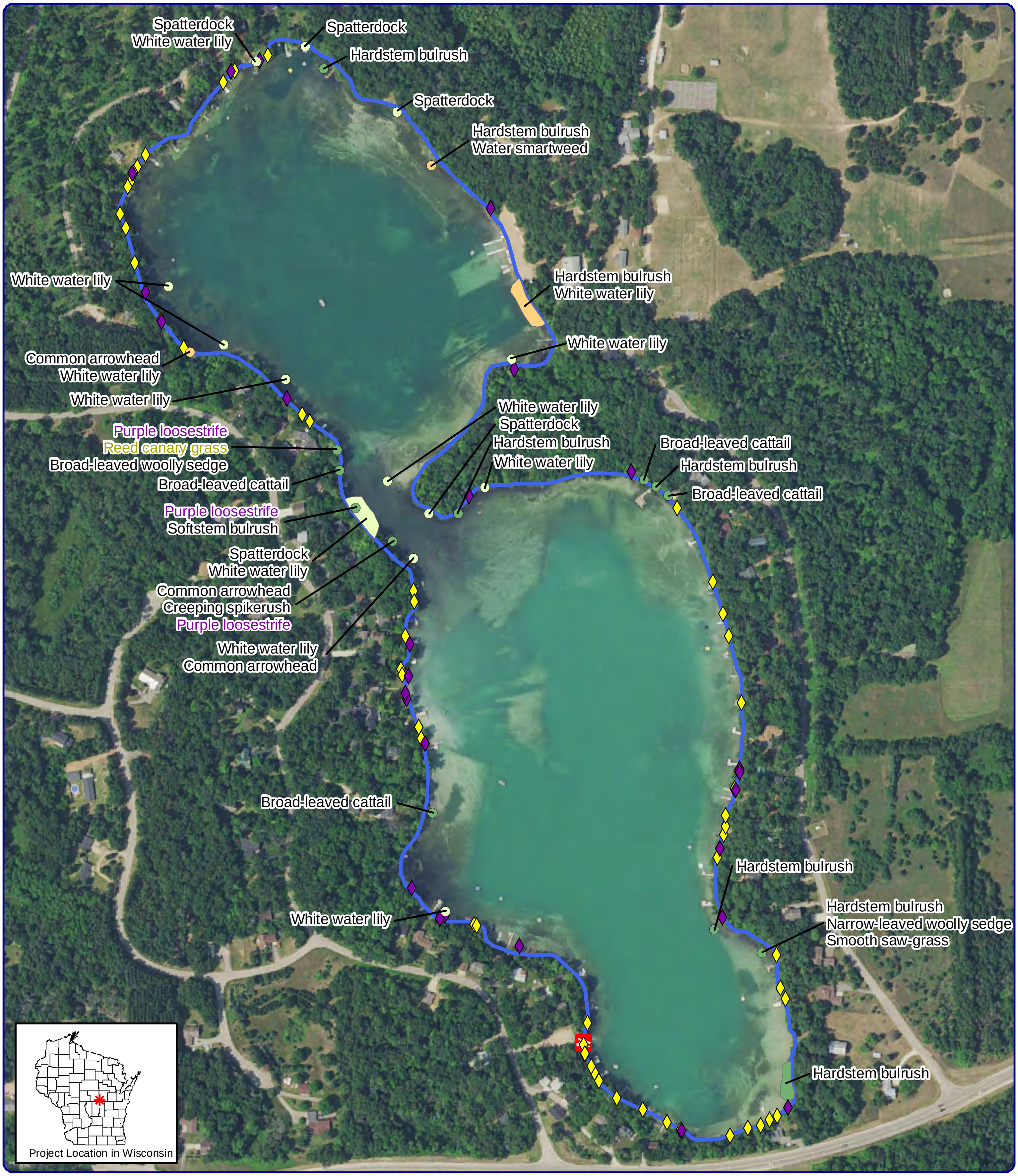
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Bio-Volume: Onterra, 2017;
processed by C-Map USA
Map Date: October 25, 2017
Filename: Map5_Stratton_Acoustic_Veg.mxd

Legend

0% 50% 100%

Bio-volume (%)

Map 5
Stratton Lake
Waupaca County, Wisconsin
2017 Bio-Acoustic Survey Results - Aquatic Plant Bio-Volume



Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Pale-yellow iris
- Purple loosestrife

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

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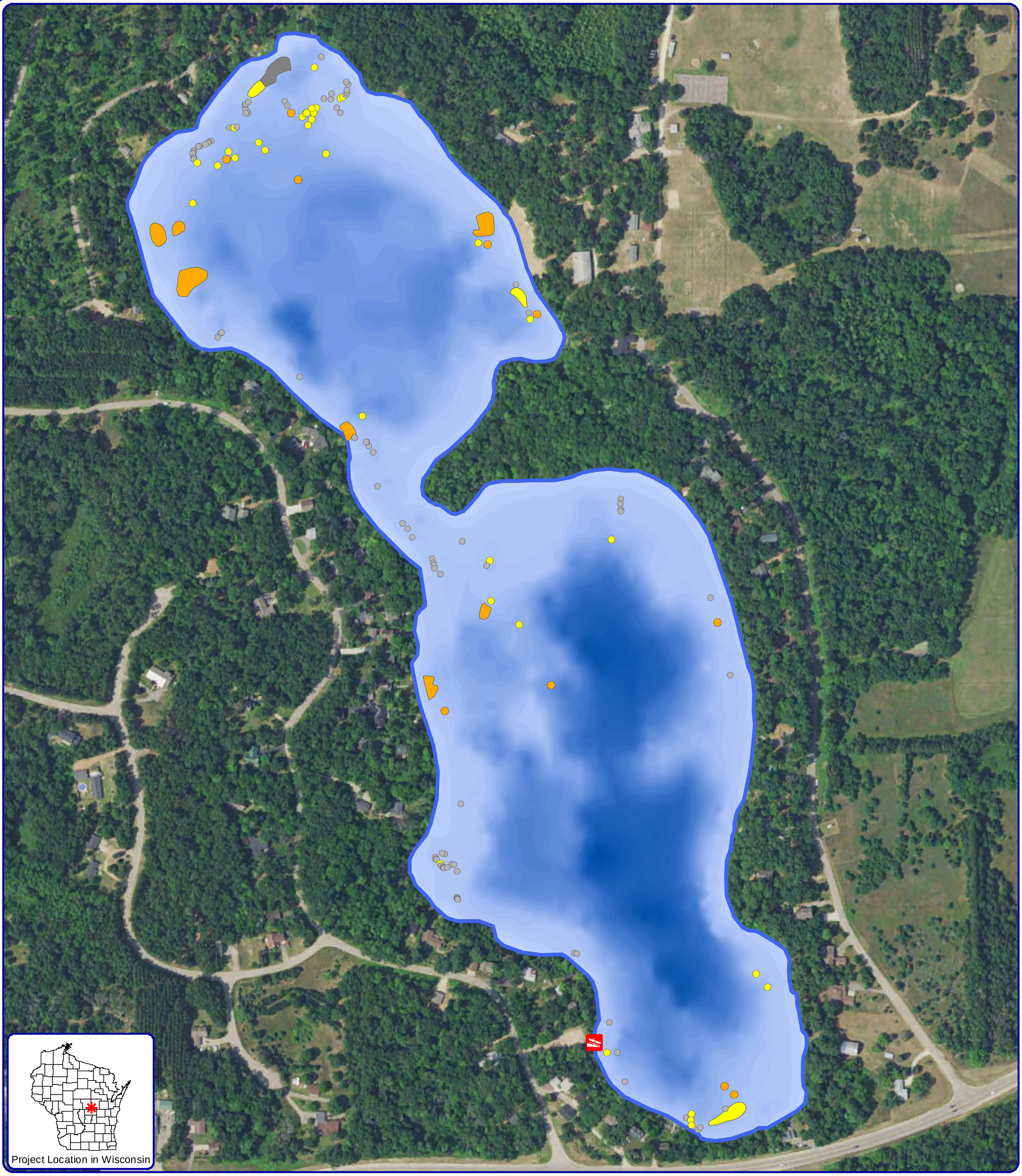
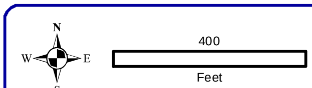
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plant Survey: Onterra, 2017
Map Date: July 18, 2017
Filename: *Map6_Stratton_Comm_July17.mxd*

Map 6
Stratton Lake
Waupaca County, Wisconsin

2017 Plant Survey: Community Mapping





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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, September 2016
Map Date: September 2, 2016
Filename: Map7_Stratton_EWM_PB_Sept16.mxd

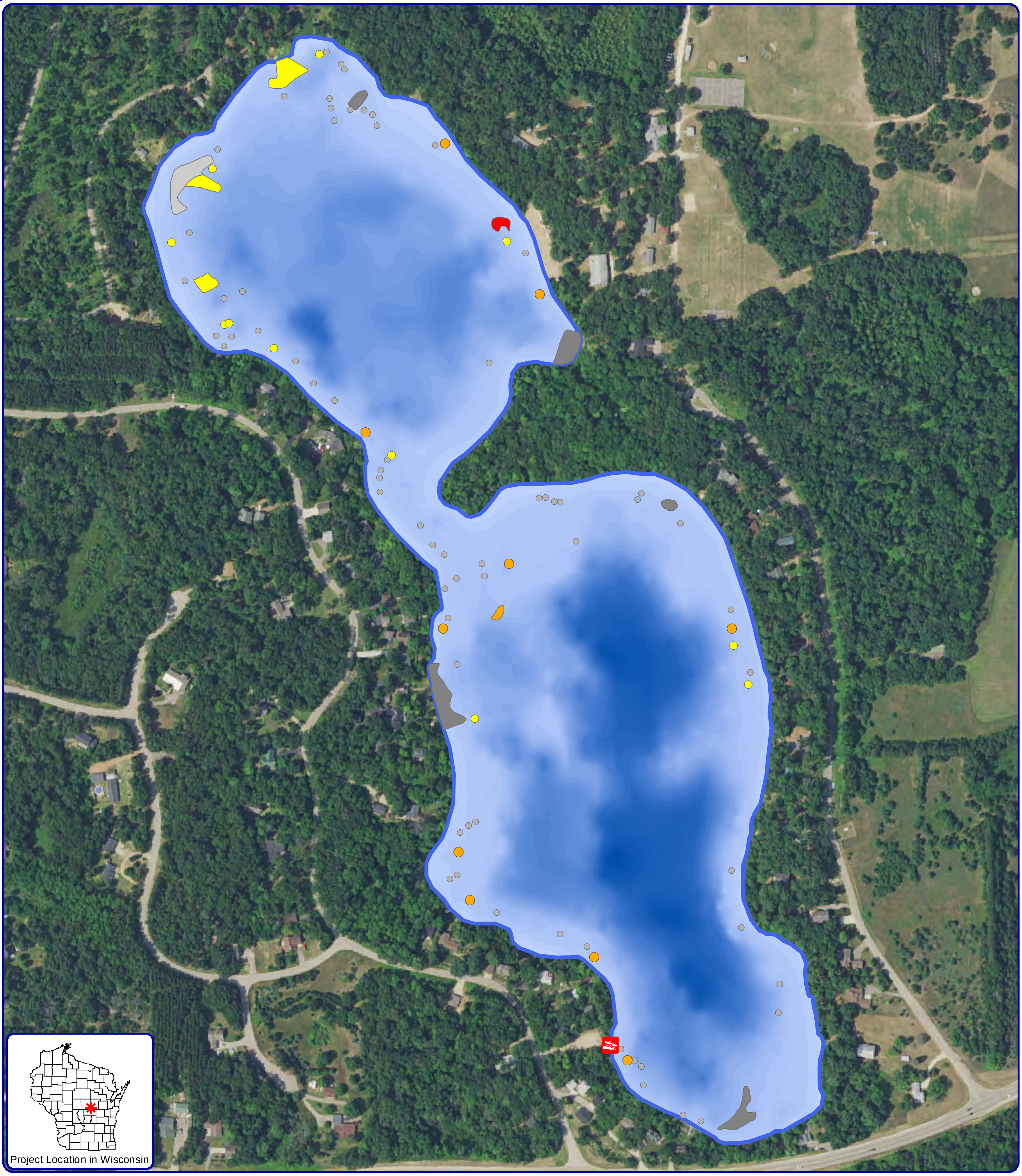
Legend

Eurasian Water Milfoil (September 2016)

- Highly Scattered *(None)*
- Scattered *0.10 acres*
- Dominant *0.17 acres*
- Highly Dominant *0.44 acres*
- Surface Matting *(None)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

Map 7
Stratton Lake
Waupaca County, Wisconsin

September 2016
EWM Survey Results



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Sources:
Roads and Hyrdo: WDNR
Orthophotograph: NAIP, 2015
Aquatic Plants: Onterra, September 2017
Map Date: October 3, 2017
Filename: Map8_Stratton_EWM_PB_Sept17.mxd

Legend

Eurasian Water Milfoil (September 2017)

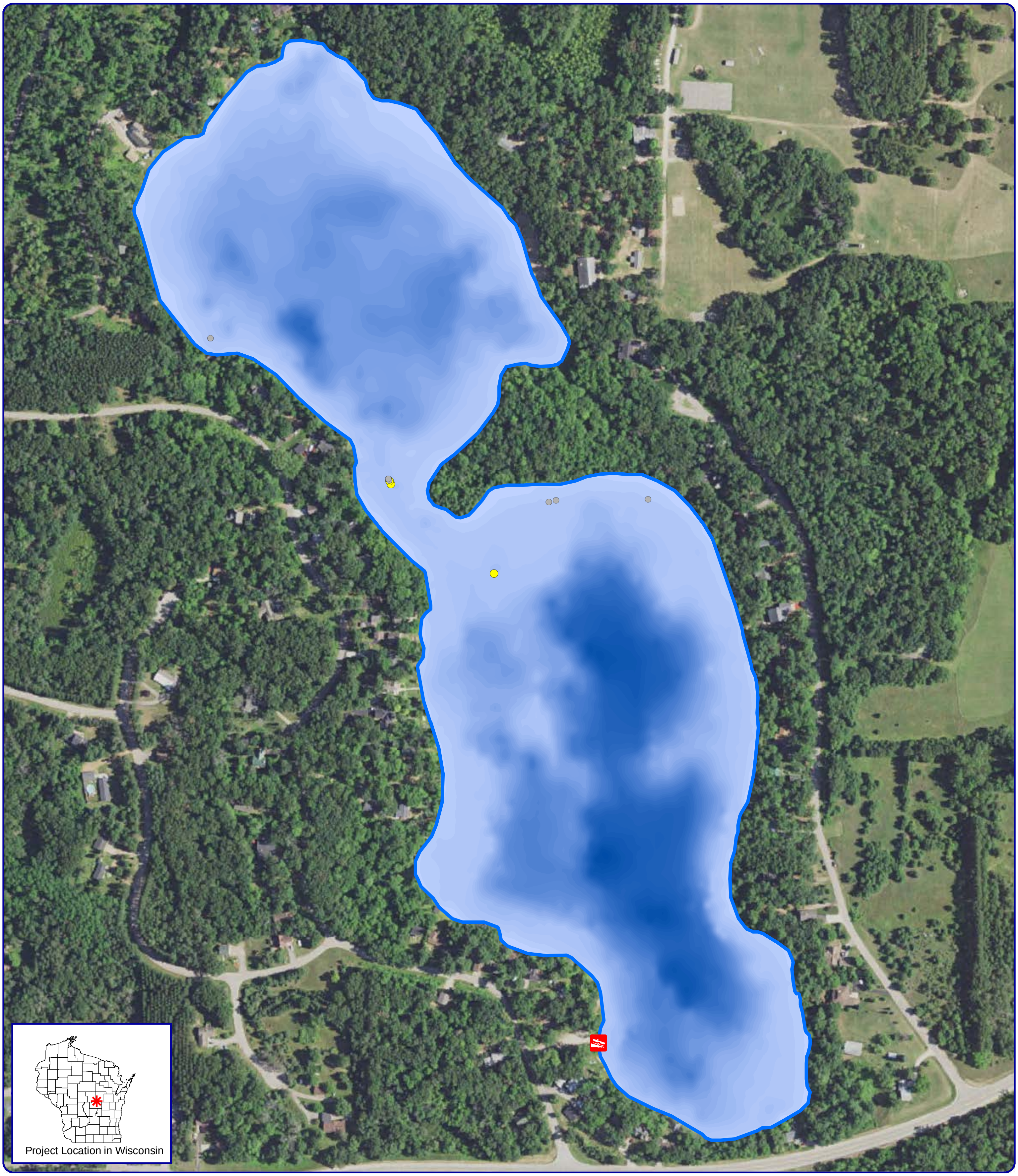
- Highly Scattered *0.22 acres*
- Scattered *0.56 acres*
- Dominant *0.29 acres*
- Highly Dominant *0.02 acres*
- Surface Matting *0.04 acres*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

Map 8

Stratton Lake

Waupaca County, Wisconsin

September 2017
EWM Survey Results



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Feet

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Sources
Hydro: WDNR
Bathymetry: Onterra, 2017; processed by C-Map USA
Orthophotograph: NAIP, 2017
Aquatic Plants: Onterra, 2018
Map Date: August 22, 2018 JLW
Filename: *Stratton_EWM_Aug18.mxd*

Legend

- Highly Scattered *(none found)*
- Scattered *(none found)*
- Dominant *(none found)*
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(none found)*

Map 9

Stratton Lake

Waupaca, Wisconsin

August 2018 EWM Survey Results