Upper Gresham Lake

Vilas County, Wisconsin

Comprehensive Management Plan

January 2020

Sponsored by:

Gresham L:akes Association

WDNR Surface Water Grant Program

LPL-1629-17

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Onterra, LLC
Lake Management Planning

Upper Gresham Lake

Vilas County, Wisconsin

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This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

Upper Gresham Lake Planning Committee

John Winkelman – Chair	Mike Winger	Charlie Spencer
Brad Subler	Jeff Frese	Cathy Snyder
Terry Boyle	Linda Frese	Gary Van Pelt

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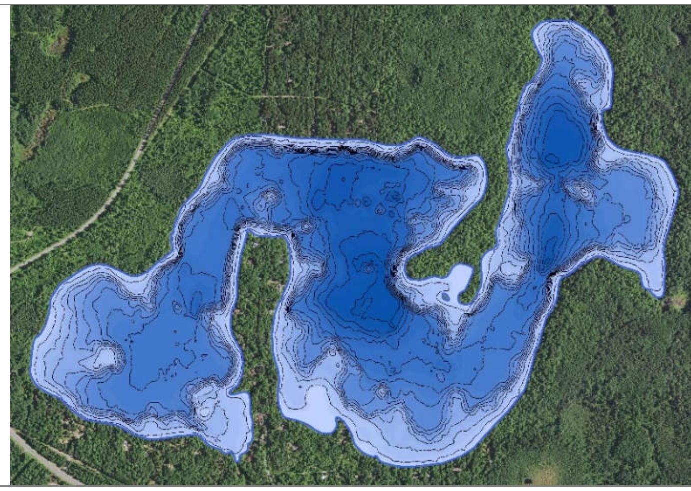
1.0 INTRODUCTION

At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in summer 2015. Based on heads-up digitizing of the water level from that Photograph, the lake was determined to be 376 acres. Upper Gresham Lake, Vilas County, is a deep headwater drainage lake with a maximum depth of 29 feet and a mean depth of 12 feet. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Upper Gresham Lake contains 56 native plant species, of which fern-leaf pondweed (*Potamogeton robbinsii*) is the most common plant. One exotic plant species, Eurasian watermilfoil, is currently known to exist in Upper Gresham Lake.

Field Survey Notes

Upper Gresham Lake has slightly stained water and beautiful stretches of natural shoreline. Aquatic plant surveys indicate the lake has a diverse aquatic plant population. Our crews enjoy the eagles that nest in dead-duck bay, except when they are chasing the baby loons.



Photograph 1.0-1 Upper Gresham Lake, Vilas County

Lake at a Glance - Upper Gresham Lake

Morphology	
Acreage	376
Maximum Depth (ft)	29
Mean Depth (ft)	12
Shoreline Complexity	4.8
Vegetation	
Number of Native Species	56
Threatened/Special Concern Species	Vasey's pondweed
Exotic Plant Species	Eurasian watermilfoil
Simpson's Diversity	0.93
Average Conservatism	7.0
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Transitional
Water Acidity (pH)	8.16
Sensitivity to Acid Rain	Low Sensitivity
Watershed to Lake Area Ratio	3:1

The Gresham Chain of Lakes, Vilas County, comprises three lakes (Upper, Middle, and Lower Gresham Lakes) with a surface area of nearly 570 acres. Water from this headwater drainage system ultimately leads to the Manitowish Waters Chain of Lakes.

The Gresham Lakes Association (GLA) and Town of Boulder Junction finalized *Comprehensive Management Plan* for all three lakes in May 2009. The GLA implemented the EWM control and monitoring components of this plan through a multi-year project from 2008-2013. The project largely consisted of herbicide spot treatments targeting EWM on Upper Gresham Lake, but also included periodic monitoring of Middle Gresham Lake which is known to contain a small population of EWM. From 2013-2017, non-herbicide management of EWM on Upper Gresham took place.

The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. As outlined in the 2009 Plan, the BMP for managing EWM was through granular 2,4-D (ester) spot treatments. At the time of this writing, that strategy is no longer a BMP. Emerging science demonstrated that liquid treatments provided more consistent results at a fraction of the cost of granular products, larger application areas appeared to retain herbicide concentrations and exposure times better, and attention needed to be paid to the addition of individual spot treatments that may cumulatively function as a whole-lake treatment. Additional toxicological studies have also been published since 2008 which are import considerations within the risk assessments.

When the GLA approached the Wisconsin Department of Natural Resources (WDNR) about resuming herbicide management of EWM in 2017, the WDNR recommended that an updated lake management planning project take place. This would allow the GLA to update its EWM management program to reflect that latest BMPs and risk assessment.

The GLA successfully received a WDNR Lake Planning Grant to construct an updated lake management plan. This report serves as the final deliverable for this grant-funded project (LPL-1629-17).

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.

EWM Management & Plan Revision Scoping Meeting

On December 15, 2015 a conference call took place with representatives from the GLA, WDNR, Vilas County, and folks involved with a cooperative research project between the University of Wisconsin Stevens Point (UWSP) and WDNR titled: *Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes*. After learning that Upper Gresham Lake was selected to be a control lake (i.e. receive no herbicide treatment) within that study, the GLA had concerns about being forced to not manage EWM. Information about the research project was shared during the teleconference and the GLA agreed to suspend herbicide management during this period. The GLA would be allowed to conduct hand-harvesting during this period. In order to be aligned for possible herbicides management of EWM following this three-year research project, the WDNR suggested that the GLA create an updated lake management plan.

Planning Committee Meeting

On December 18, 2017, Eddie Heath and Tim Hoyman of Onterra met with eight members of the GLA Planning Committee for three hours. The meeting focused on aquatic plant management, including a review of the GLA's historic control actions, discussion of current best management practices, emerging risk assessment of 2,4-D impacts on fish, and research on EWM trends in managed and unmanaged systems. The meeting also discussed the stakeholder survey results and began developing management goals and actions for the Upper Gresham Lake management plan. One result of this meeting was the development of an interim EWM management strategy to be initiated in 2018. The presentation materials from this meeting are included in Appendix A.

2018 EWM Management

In parallel to the lake management planning project, the GLA pursued herbicide management of EWM during the spring of 2018. Details relating to planning, implementation, and results of these efforts are included within this document. The GLA postponed the completion of the management planning project until after the results of these efforts were available, as they would be important to guide the EWM management strategy designed within the Plan.

Planning Committee Meeting II

On September 27, 2018, Eddie Heath of Onterra met with eight members of the GLA Planning Committee for three hours. The meeting focused on the results of the water quality, paleoecology, watershed, shoreland condition, and fisheries assessments. In addition, the results of the 2018 herbicide treatment program were discussed. The committee discussed management goals and management actions for the GLA to include within the updated Plan. The presentation materials from this meeting are included in Appendix A.

Management Plan Review and Adoption Process

On December 1, 2018, a draft outline of the Implementation Plan was provided to the Planning Committee for review. Comments were received from the Planning Committee approximately a month later and incorporated into a full-text version of the Implementation Plan Section. This section was provided to the Planning Committee in early April for further discussion. Following a month of review from the committee, the Implementation Plan Section (5.0) was married with the report sections (3.0) to create a mostly complete draft version of the Comprehensive Management Plan. This document was provided to the GLA's Planning Committee for final review before opening up comments to the document from a wider audience.

On July 12, 2019, an early draft of the Comprehensive Management Plan was provided to the WDNR with a subsequent teleconference (September 12, 2019) occurring with members of the GLA Planning Committee, Onterra (Eddie Heath), and WDNR (Carol Warden). This meeting focused on the Implementation Plan Section, allowing a multi-directional exchange of information and perspectives.

On September 18, 2019, an official first draft of the GLA's Comprehensive Management Plan for Upper Gresham Lake was supplied to the WDNR, Great Lakes Indian Fish and Wildlife Commission (GLIFWC), and Vilas County. Written review of the draft plan was received on September 19, 2019 from WDNR team leader Carol Warden (UW Trout Lake AIS Specialist). The WDNR comments and how they are addressed in the final plan are contained in Appendix G. An official second draft was created and shared with the WDNR on Dec 13, 2019. The WDNR indicated that all comments were adequately addressed and the plan was approved.

Riparian Stakeholder Survey

As a part of this project, a riparian stakeholder survey was distributed to riparian property owners around Upper, Middle, and Lower Gresham Lake. The survey was designed by Onterra staff and the GLA Planning Committee, and reviewed/approved by a WDNR social scientist.

During October 2017, the nine-page, 38-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 GLA volunteer for analysis. Of the 78 surveys sent to riparian property owners around Upper Gresham Lake, sixty-two percent of surveys were returned. With a response rate of 60% or higher, the responses to the following questions can be interpreted as being statistically representative of the population sampled. Therefore, when the following section discusses percent of stakeholders, it is reflective of the population that was provided surveys. It is not reflective of the percent of parcels, acreage, shoreline length, etc.

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. Please note that Appendix B contains both the pooled results from all three lakes as well as the stand-alone results for Upper Gresham Lake. The majority of the subsequent discussion of the Riparian Stakeholder Survey will focus on Upper Gresham Lake.

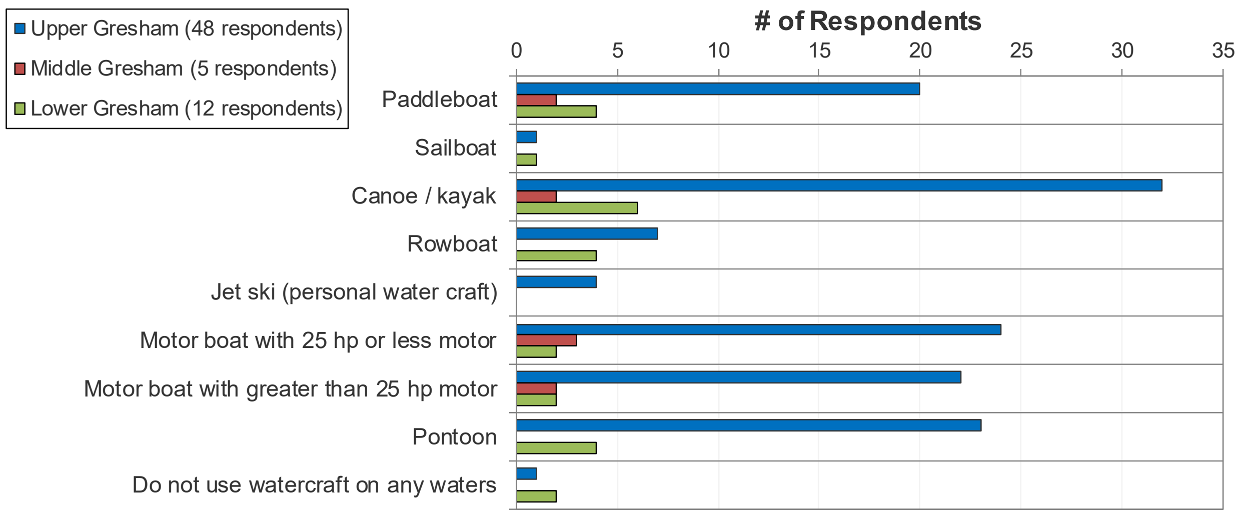
Based upon the results of the Stakeholder Survey, much was learned about the people that own property on the Gresham Lakes. Specific to Upper Gresham Lake, the majority of stakeholder respondents (36%) visit on weekends throughout the year, 29% live on the lake during the summer months only, 27% are year-round residents, and 2% are resort properties (Question 3). 75% of stakeholder respondents have owned their property for over 15 years, and 50% have owned their property for over 25 years (Question 5).

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. More than half (32 out of 48) of survey respondents indicate that they use either a canoe/kayak or a small motor boat on Upper Gresham Lake (Figure 2.0-1, Question 14). Pontoons, large motor boats, and paddleboats were also popular options. Stakeholder respondents indicated fishing, relaxing/entertaining, and nature viewing as the top reasons why they own property on the Gresham Lakes (Figure 2.0-1, Question 17).

When asked about the top three concerns regarding their lake, stakeholder respondents indicated aquatic invasive species, water quality degradation, and excessive aquatic plant growth were the largest concerns (Figure 2.0-1, Question 24). Interestingly, excessive aquatic plant growth was considered a greater concern by stakeholder respondents on Lower Gresham Lake than aquatic invasive species.

A concern of stakeholders noted throughout the stakeholder survey (see Questions 23-24 and survey comments – Appendix B) was Eurasian watermilfoil within Upper Gresham Lake and the campground on the lake. Eurasian watermilfoil is touched upon in the Aquatic Plants Section (3.5), Summary and Conclusions Section (4.0), as well as within the Implementation Plan (5.0).

Question 14: What types of watercraft do you currently use on your lake?



Question 17: Please rank up to three activities that are important reasons for owning your property on your lake. (data pooled from 1st, 2nd, & 3rd ranked activities).

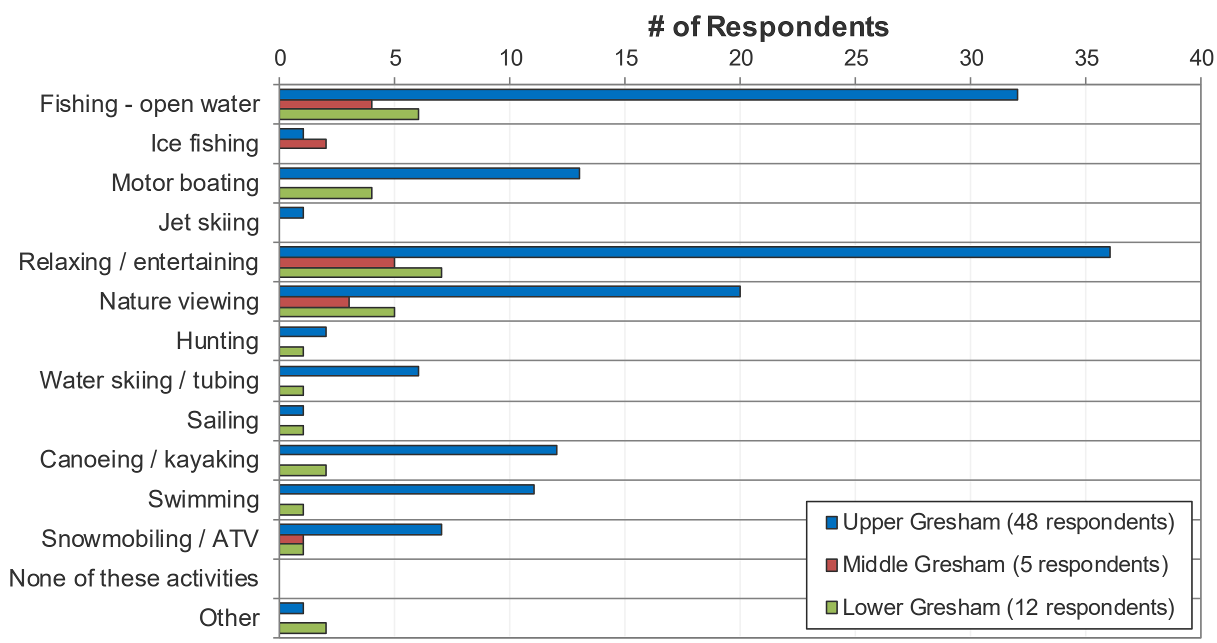


Figure 2.0-1. Select survey responses from the Upper Gresham Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 24: Please rank your top three concerns regarding your lake. (data pooled from 1st, 2nd, & 3rd ranked concerns).

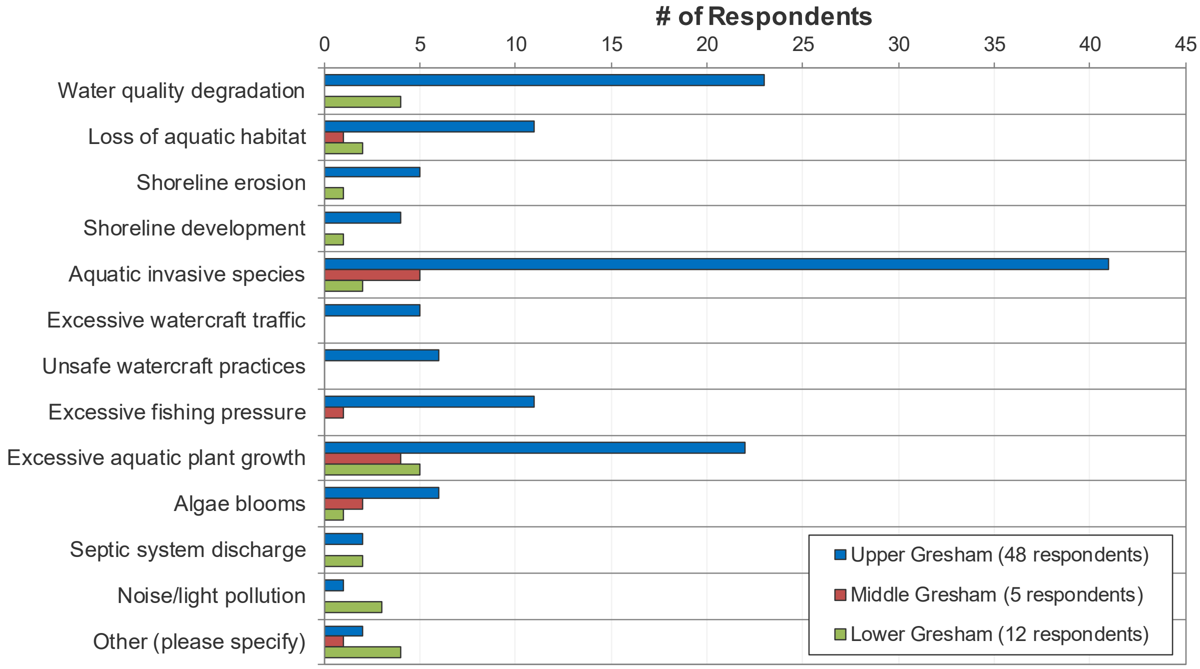


Figure 2.0-1 continued. Select survey responses from the Upper Gresham Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Upper Gresham Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region. 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 Upper Gresham 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 more clear 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

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.

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.

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 process 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 Upper Gresham 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, Upper Gresham Lake is classified as a deep headwater lake (category 3 on Figure 3.1-1).

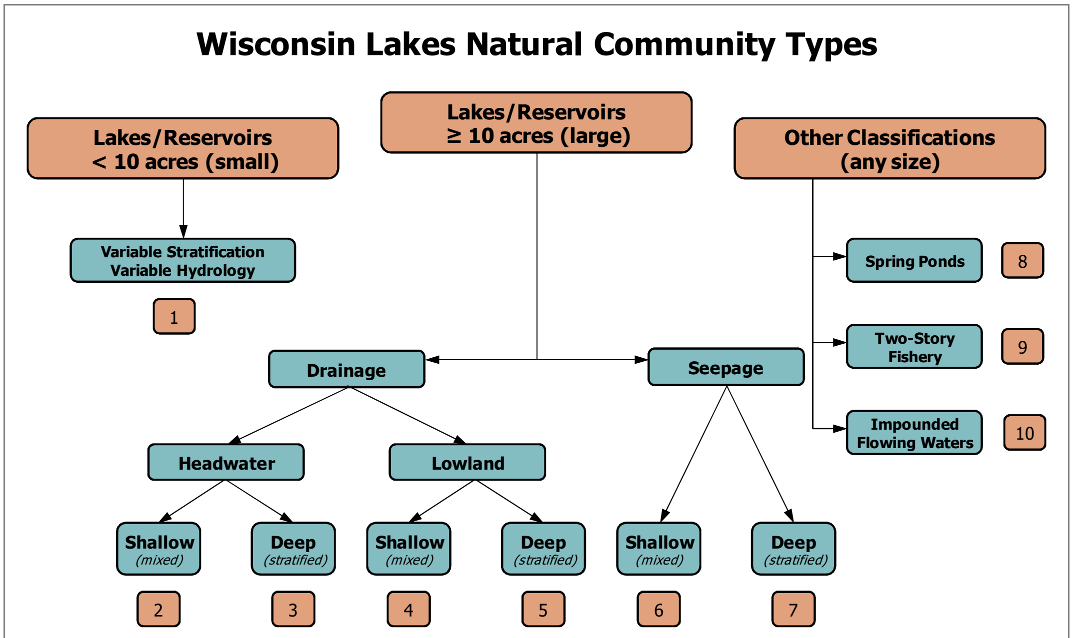


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Upper Gresham Lake is within the Northern Lakes and Forests (NLF) ecoregion.

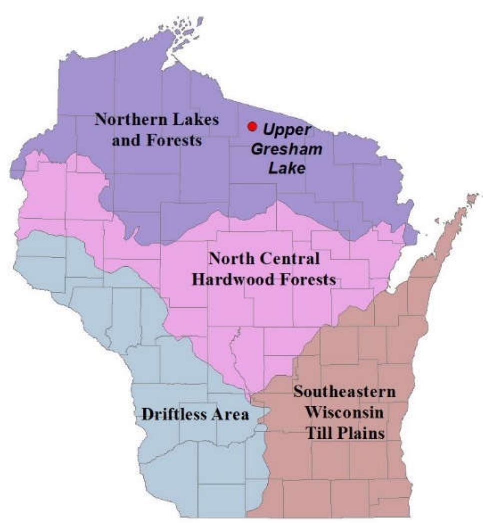


Figure 3.1-2. Location of Upper Gresham Lake within the ecoregions of Wisconsin. After Nichols 1999.

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 Upper Gresham 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.

Upper Gresham Lake Water Quality Analysis

Upper Gresham Lake Long-term Trends

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 Upper Gresham Lake participating in the Citizens Lake Monitoring Network (CLMN) have been collecting Secchi disk transparency intermittently from 1990 to 2000 and all three parameters annually since 2000; building a continual dataset that will yield valuable information on Upper Gresham Lake's water quality through time. Water quality data available through the WDNR's Surface Water Integrated Monitoring System (SWIMS) database is discussed wihtin and summarized in Appendix C.

Total Phosphorus

Near-surface total phosphorus data from Upper Gresham Lake are available from 1985 and annually from 2000 to 2017 (Figure 3.1-3). Average summer total phosphorus concentrations ranged from 14 µg/L in 2014 to 26 µg/L in 2006; however, only one near-surface total phosphorus sample was collected in 2014 and may not be representative of the 2014 summer average. The weighted summer average total phosphorus concentration is 18 µg/L and falls into the *excellent* category for Wisconsin's deep headwater drainage lakes and indicates Upper Gresham Lake's phosphorus concentrations are relatively similar to the majority of other deep headwater drainage lakes in the state and slightly better than the majority of lakes within the NLF ecoregion. While Upper Gresham Lake's weighted summer average total phosphorus concentration falls into the *excellent* category, total phosphorus concentrations have increased historically, as discussed further in the paleoecology section.

As discussed in the previous 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.

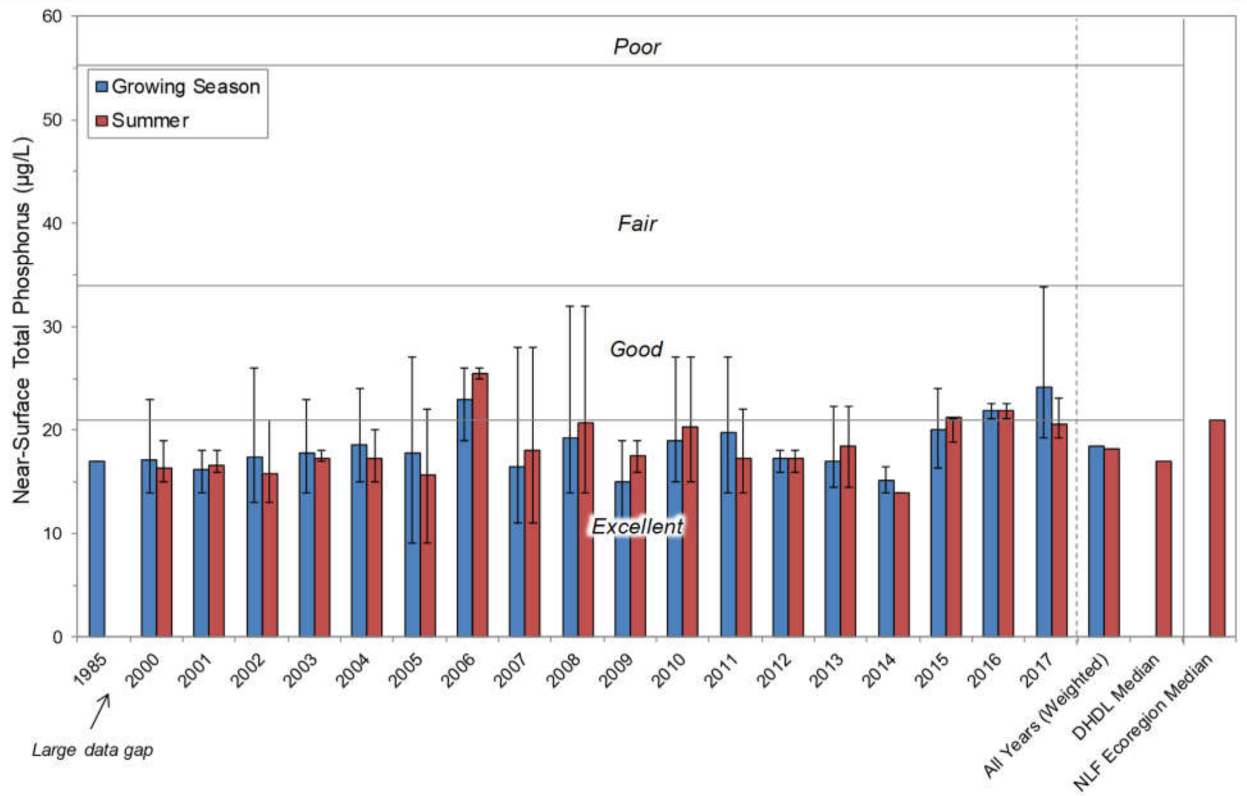


Figure 3.1-3. Upper Gresham Lake, state-wide deep headwater drainage lakes, and Northern Lakes and Forests (NLF) total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Figure 3.1-4 displays near-surface and near-bottom total phosphorus concentrations collected from Upper Gresham Lake in 2017 and the winter of 2018. As illustrated, in April of 2017 the near-bottom total phosphorus concentration is similar to the concentration measured near the surface, but near-bottom concentrations are higher than near-surface concentrations in both July and October 2017. Near-bottom phosphorus concentrations in late-July were almost 3.5 times the concentration measured near the surface. The higher concentrations of phosphorus measured near the bottom during these sampling events is an indication that phosphorus is being released from bottom sediments into the hypolimnion. During this sampling event 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 Upper Gresham Lake's water column, the impacts of internal loading are not significant. As previously mentioned, the lake' surface water total phosphorus values are similar to the median value for comparable lakes in Wisconsin.

During the summer, when phosphorus is being released from the sediments, the phosphorus is not being utilized by algae because it is trapped in the hypolimnion, well below the depths the algae populate. In Figure 3.1-5, on average, as phosphorus concentrations increase from the addition of the hypolimnetic phosphorus during fall turnover, the lake experiences an increase in algal biomass as indicated by the increase in chlorophyll-*a*. In the same chart, average spring phosphorus concentrations are higher than the fall, which is likely due to increased runoff resulting from snow melt and spring rains. Figure 3.1-5 depicts chlorophyll-a concentrations increasing in the late summer. In dimictic lakes with relatively good water clarity, as found in Upper Gresham Lake, an algal layer develops in the metalimnion where the algae are exposed to higher nutrients. In the late summer and fall, as the surface waters cool, the epilimnion deepens and the deep algal layer becomes distributed in the surface waters.

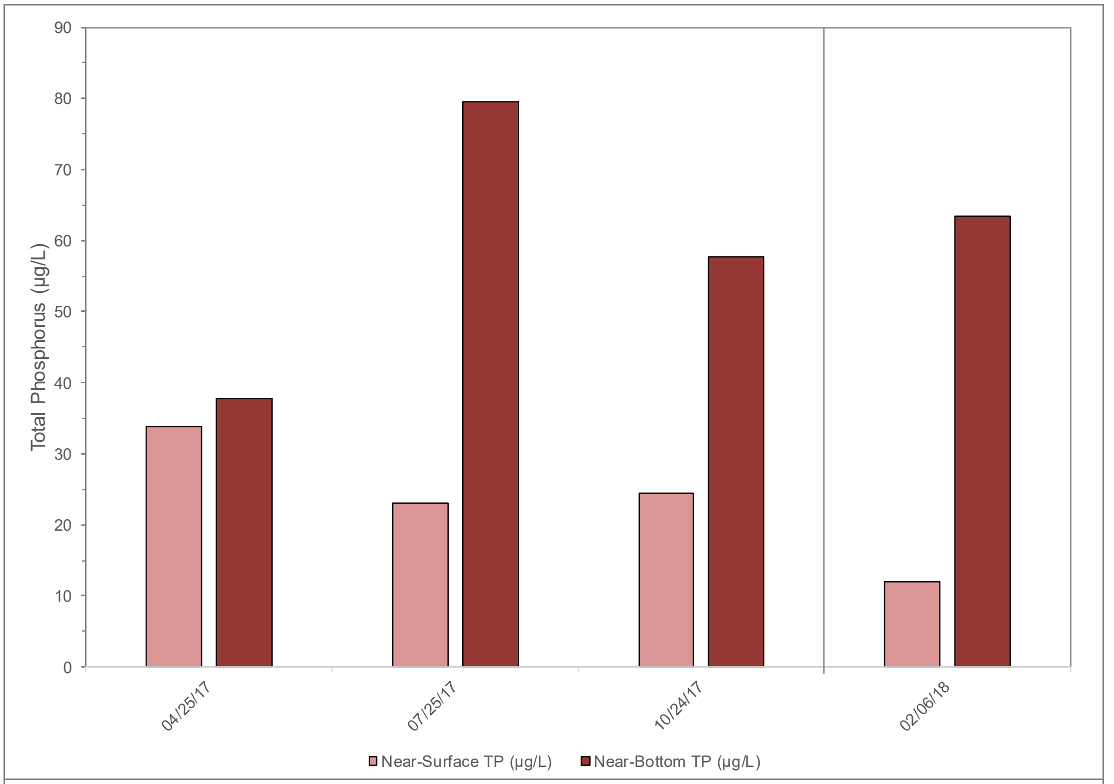


Figure 3.1-4. Upper Gresham Lake near-surface and near-bottom total phosphorus concentrations. Data collected during Onterra 2017 and 2018 sampling. All concentrations are actual values, not averages.

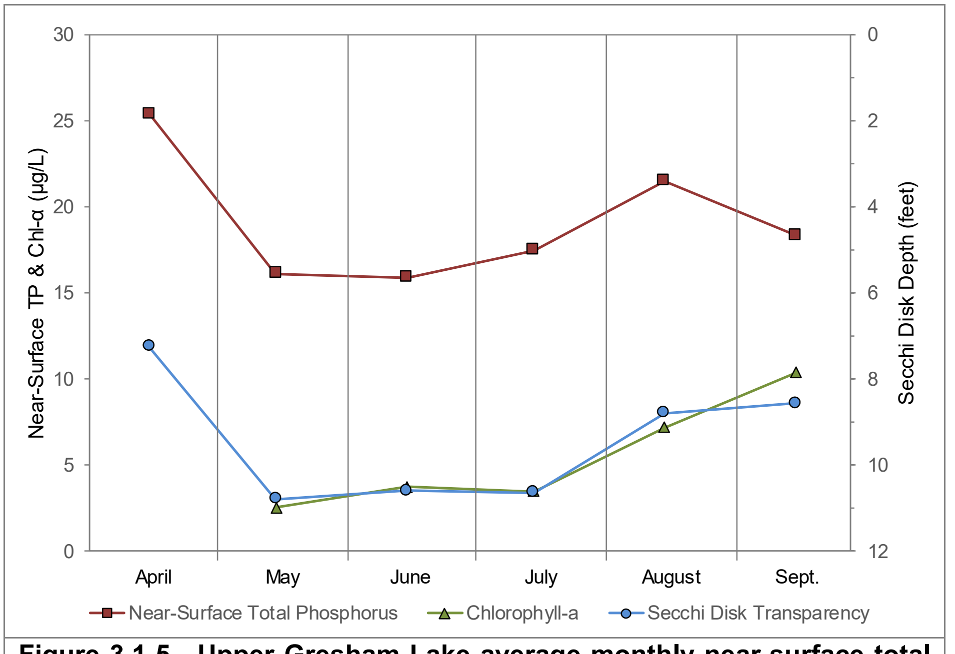


Figure 3.1-5. Upper Gresham Lake average monthly near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency using all available data.

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 from Upper Gresham Lake from 1984 and annually from 2000 to 2017 (Figure 3.1-6). Average summer chlorophyll-*a* concentrations ranged from 3 µg/L in 2016 to 10 µg/L in 2006. The weighted summer average chlorophyll-*a* concentration is 5 µg/L and falls into the *excellent* category for Wisconsin's deep headwater drainage lakes and indicates Upper Gresham Lake's chlorophyll-*a* concentration are relatively similar to the majority of other deep headwater drainage lakes in the state and slightly lower than the majority of lakes within the NLF ecoregion.

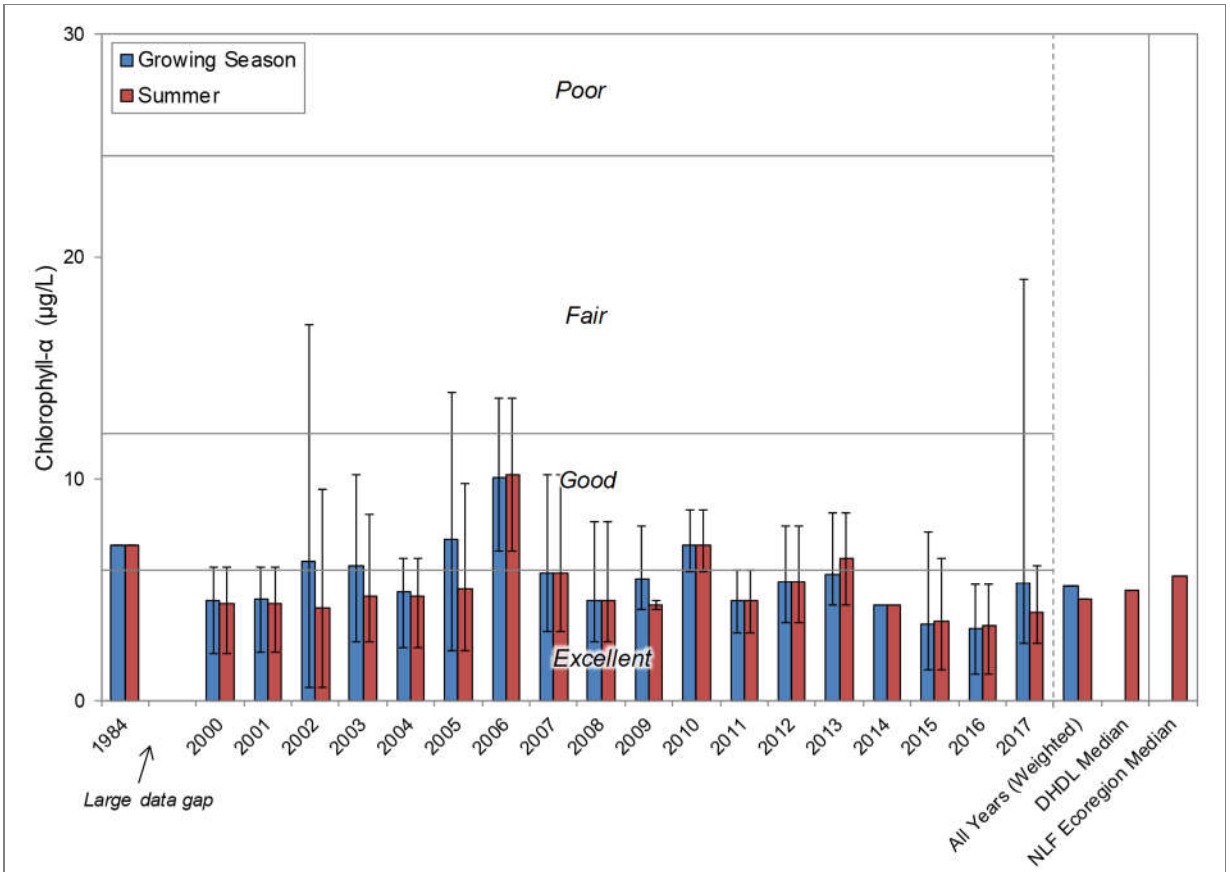


Figure 3.1-6. Upper Gresham Lake, state-wide deep headwater drainage lakes, and Northern Lakes and Forests (NLF) chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water Clarity

Secchi disk transparency data are available from Upper Gresham Lake intermittently from 1984 to 1994, and annually from 1997 to 2017 (Figure 3.1-7). Average summer Secchi disk depths ranged from 6.8 feet in 2010 to 12.4 feet in 1992. The weighted summer average Secchi disk depth is 10 feet and falls into the *excellent* category for Wisconsin's deep headwater drainage lakes. The lake's weighted summer average Secchi disk depth is slightly worse than the median value for deep headwater drainage lakes in the state and exceeds the median value for lakes within the NLF ecoregion.

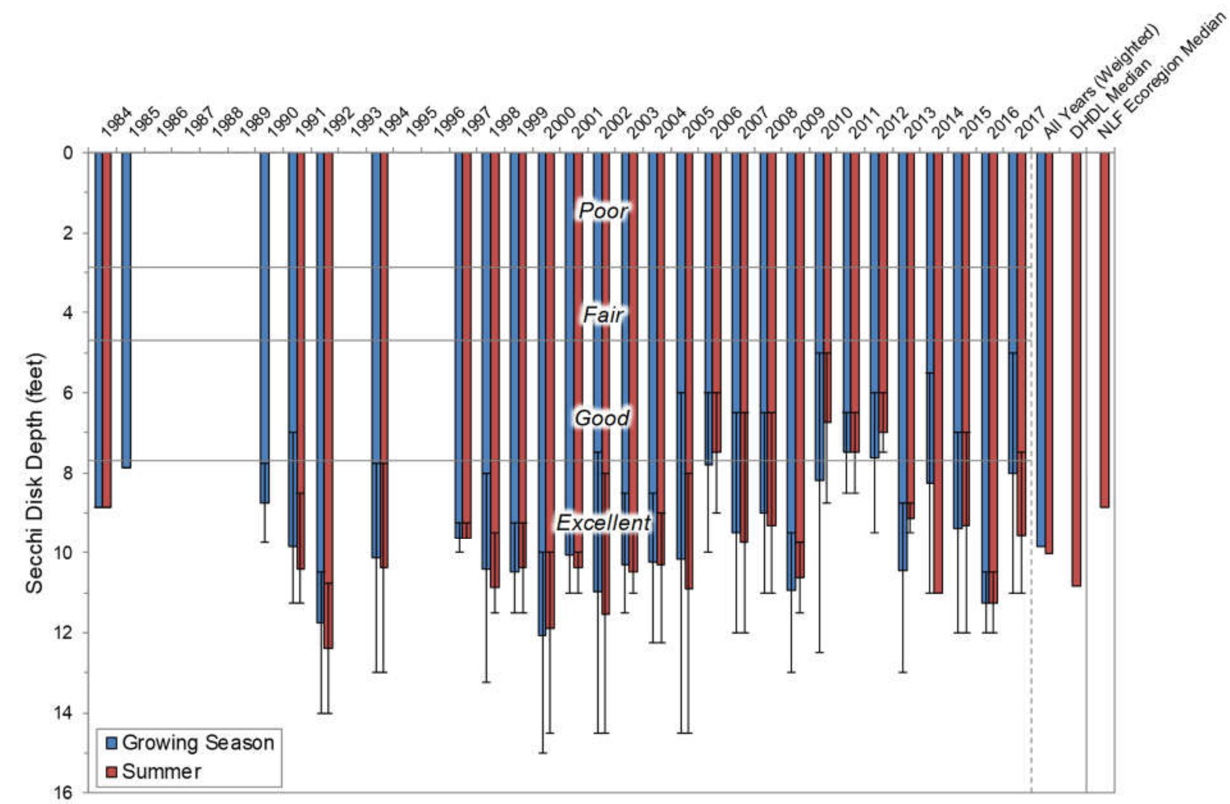


Figure 3.1-7. Upper Gresham Lake, state-wide deep headwater drainage lakes, and Northern Lakes and Forests (NLF) Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

A linear regression analysis on the data collected from 2000 through 2017 indicated that the summer phosphorus concentrations are increasing and Secchi disk depths show a statistically significant decreasing trend. There was not a statistically significant trend with chlorophyll-*a* data. Although two of the three trophic parameters indicate conditions may be getting worse over the last 18 years, the change is not great. The sediment core study also indicated a decline in the trophic status of the lake over a much longer time period.

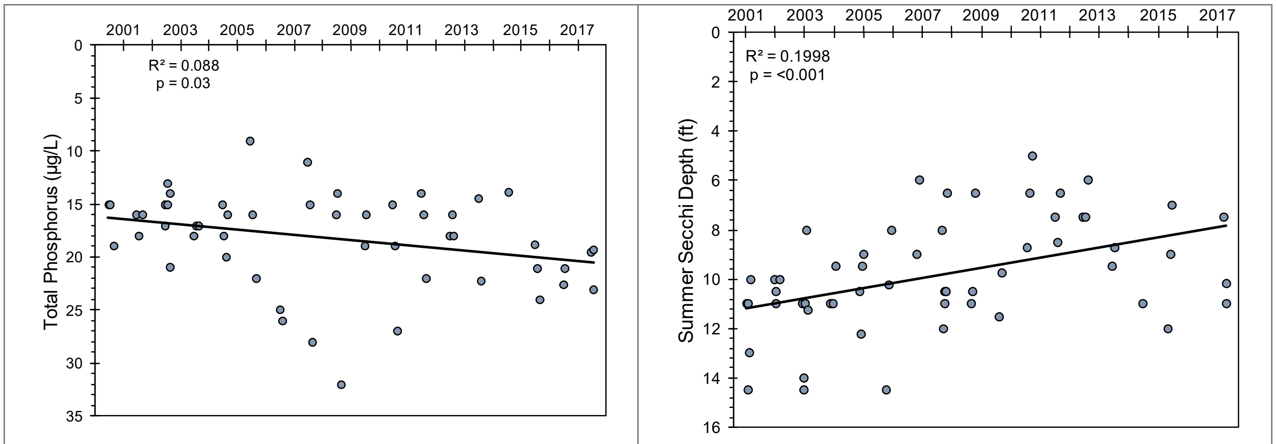


Figure 3.1-8. Upper Gresham Lake linear regressions for average summer total phosphorus(left) and chlorophyll-α(right) from 2000-2017. Solid line indicates regression line, dashed lines indicated upper and lower confidence limits (95%).

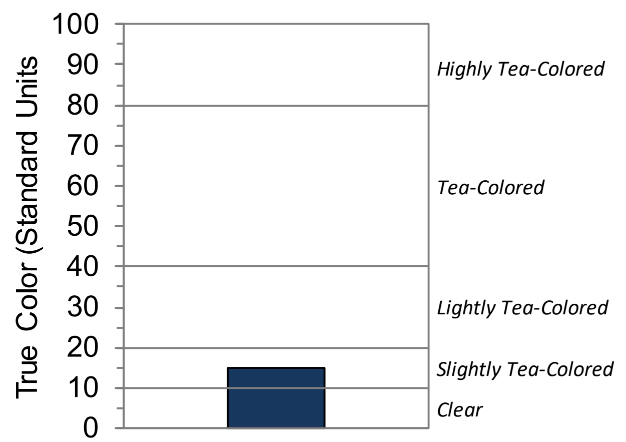


Figure 3.1-9. Upper Gresham Lake true color value.

Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Upper Gresham Lake in 2017 averaged 15 SU (standard units) indicating the lake's water is *slightly colored* and that the lake's water clarity is not influenced by dissolved components in the water (Figure 3.1-9).

Limiting Plant Nutrient of Upper Gresham Lake

Using historic mid-summer nitrogen and phosphorus concentrations from Upper Gresham Lake, a nitrogen:phosphorus ratio of 20:1 was calculated. In 2017, this ratio was closer to 11:1. This finding indicates that Upper Gresham Lake is phosphorus limited as are the vast majority of Wisconsin lakes; however, with large phosphorus inputs the lake could transition to being nitrogen limited. In general, this means that cutting both phosphorus and nitrogen inputs may limit plant growth within the lake.

Upper Gresham Lake Trophic State

Figure 3.1-9 contains the weighted average Trophic State Index (TSI) values for Upper Gresham 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.

The TSI values for all three parameters place the lake in a mesotrophic state (Figure 3.1-10). Upper Gresham Lake has similar levels of productivity as other deep headwater drainage lakes in Wisconsin and is slightly less productive than the majority of lakes in the NLF ecoregion.

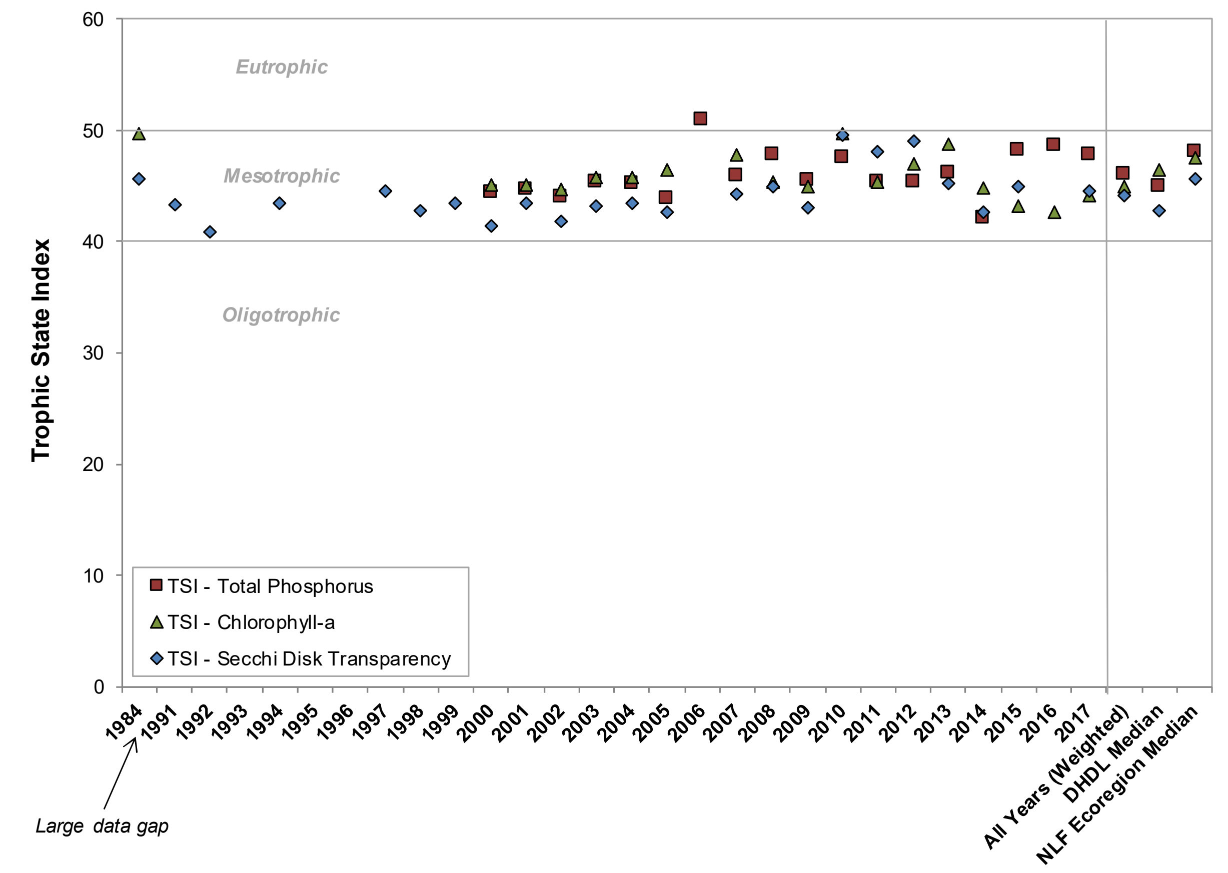


Figure 3.1-10. Upper Gresham Lake, state-wide deep headwater drainage lakes, and Northern Lakes and Forests (NLF) Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Upper Gresham Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Upper Gresham Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-11. Upper Gresham Lake is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, once in spring and once in 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 Upper Gresham 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.

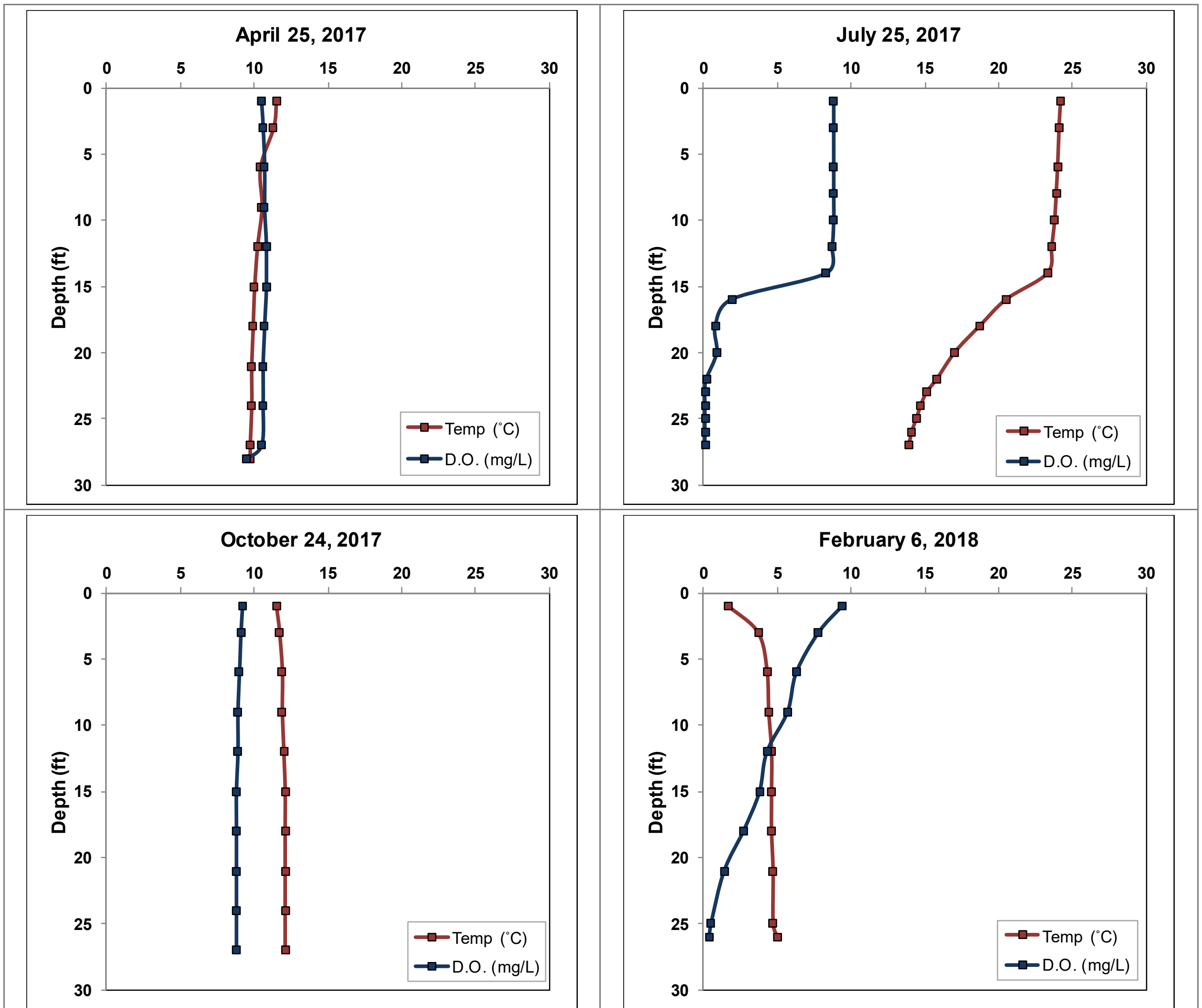


Figure 3.1-11. Upper Gresham Lake dissolved oxygen and temperature profiles.

In 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, while oxygen gradually declines once again towards the bottom of the lake. During the winter, oxygen was depleted below 5.0 mg/L at depths of 12 feet and deeper (Figure 3.1-11). When low oxygen levels are present under the ice, the potential for fish kills exist. However, WDNR biologists believe that the sport fish found in warm-water Wisconsin lakes can survive under fairly low oxygen conditions. It is believed that fish may tolerate dissolved oxygen levels of 1 mg/L under the ice for up to 3 weeks at a time. Additionally, it is most often the smaller fish that are more susceptible to winter kill because they have smaller home ranges, and lack the experience to find more suitable (higher oxygenated) waters. It may become important to monitor winter oxygen levels in future years, as well as observe the lake closely for signs of fish winter kill.

Additional Water Quality Data Collected at Upper Gresham 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 Upper Gresham Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

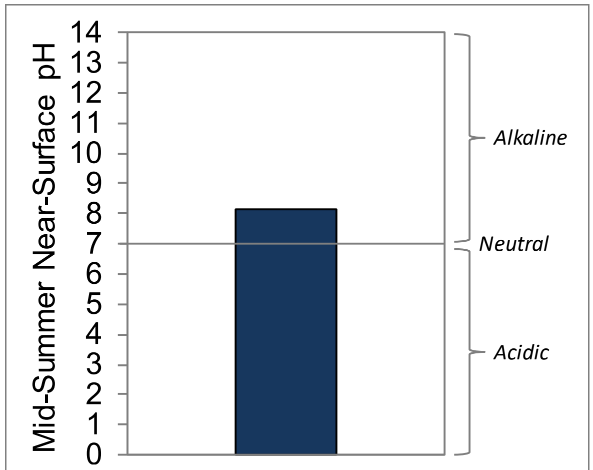


Figure 3.1-12. Upper Gresham Lake mid-summer near-surface pH value.

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 Upper Gresham Lake was found to be alkaline with a value of 8.2, and falls within the normal range for Wisconsin Lakes (Figure 3.1-12).

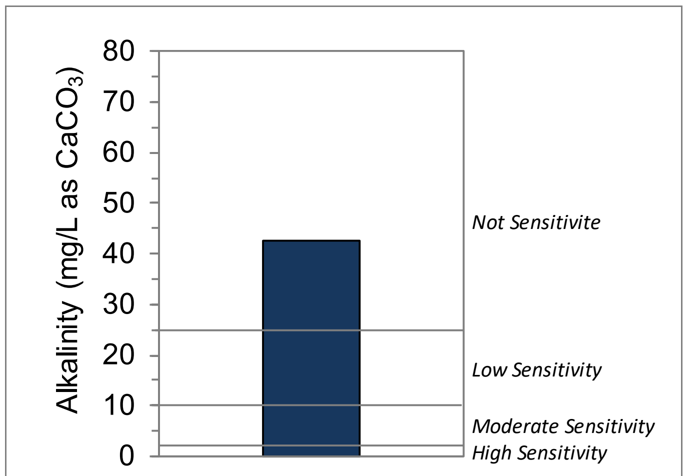


Figure 3.1-13. Upper Gresham Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 Upper Gresham Lake was measured at 42.6 (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 3.1-13).

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 Upper Gresham Lake's pH of 8.4 falls inside 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 Upper Gresham Lake was found to be 14.1 mg/L, falling into the optimal range for zebra mussels (Figure 3.1-14).

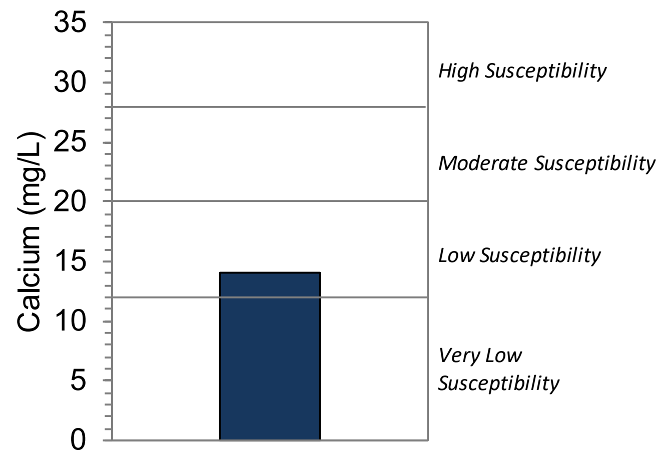


Figure 3.1-14. Upper Gresham Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

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). Although the pH values in Upper Gresham Lake make it susceptible to zebra mussel growth, the relatively low calcium concentrations (14 mg/L) means the lake has a low susceptibility to mussel establishment. Onterra ecologists did not observe any adult zebra mussels during the 2017 surveys.

Stakeholder Survey Responses to Upper Gresham 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. 118 surveys were distributed to Gresham Lakes stakeholders on Upper, Middle, and Lower Gresham Lakes. Of the 118 surveys, 78 were sent to stakeholders on Upper Gresham Lake, 15 to Middle Gresham Lake, and 25 to Lower Gresham Lake. It should be noted that while all stakeholder survey responses are displayed in Appendix B, the results displayed below are only representative of stakeholders on

Upper Gresham Lake. Of the 78 surveys sent to Upper Gresham Lake stakeholders, 48 (62%) were returned.

Figure 3.1-15 displays the responses of members of Upper Gresham Lake stakeholder respondents to questions regarding water quality and how it has changed over their years visiting Upper Gresham Lake. When asked how they would describe the current water quality of Upper Gresham Lake the majority of respondents, 52%, indicated *good*, 31% indicated *fair*, 9% indicated *excellent*, 6% indicated *poor*, and 2% indicated they were *unsure*.

When asked how they believe the current water quality has changed since they first visited the lake the majority of respondents, 51%, indicated it has *somewhat degraded*, 38% indicated it has *remained the same*, 7% indicated it has *severely degraded*, 2% indicated it has *somewhat improved*, and 2% indicated that they were *unsure* (Figure 3.1-15). As discussed in the previous section, a decreasing trend in Secchi disk transparency was observed. The proportion of stakeholder respondents who indicated the lake's water quality has somewhat or severely degraded may be taking into account the decreased water clarity or the Eurasian watermilfoil growth in the lake.

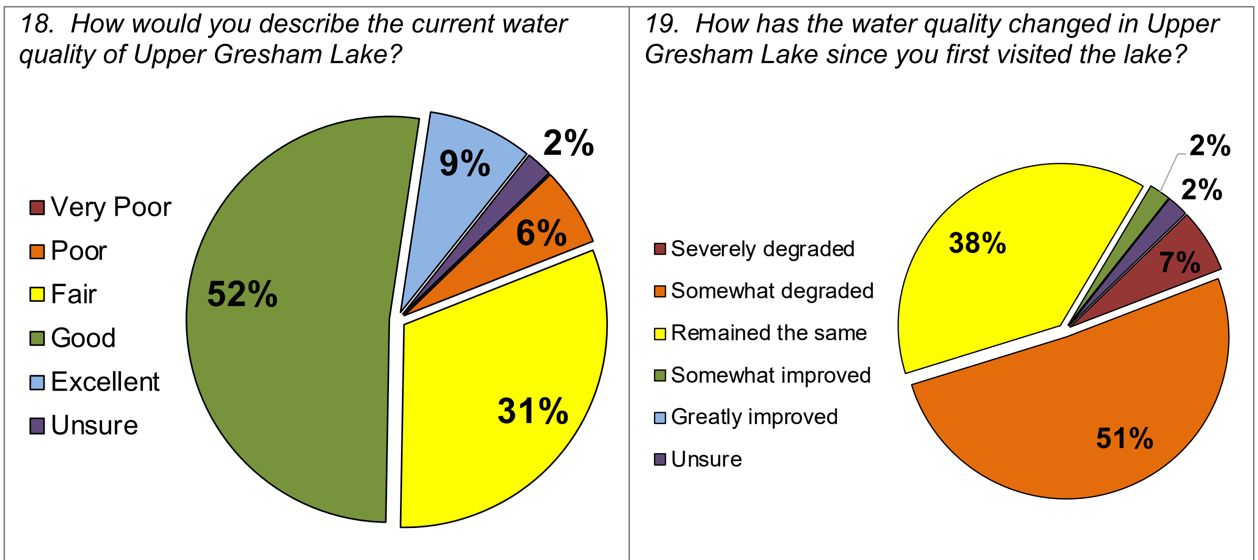


Figure 3.1-15. Upper Gresham Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

3.2 Paleoecology

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.

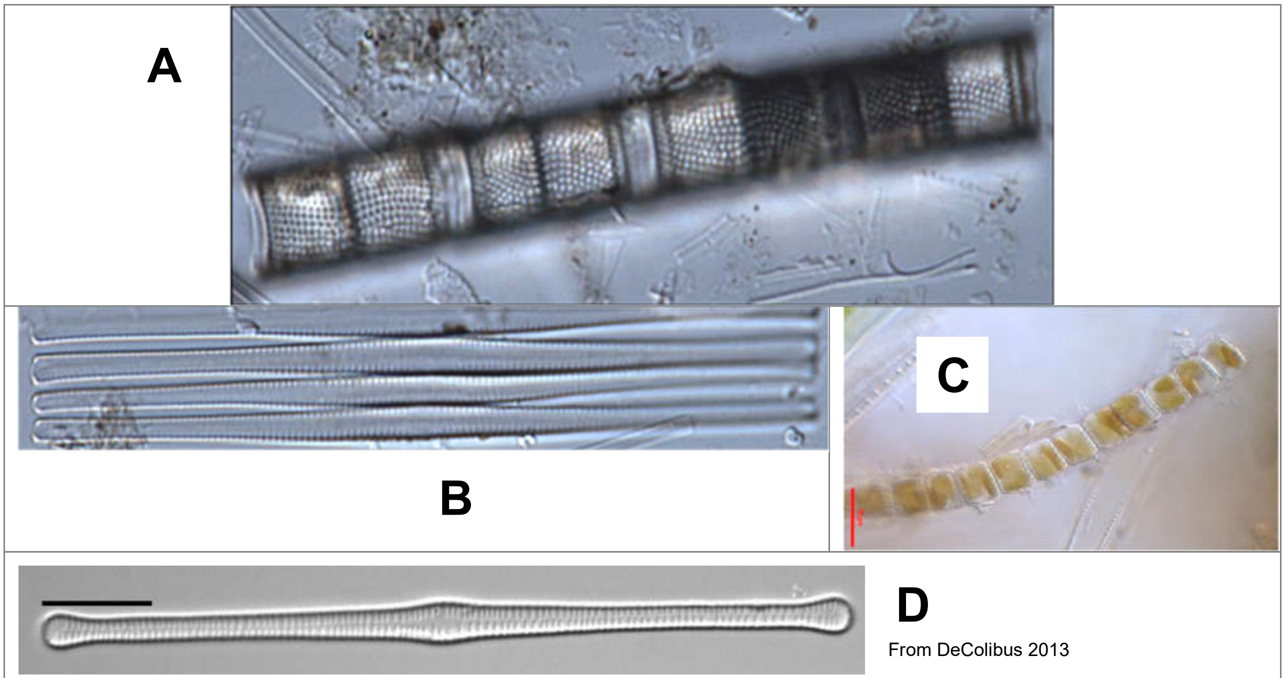
The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. By collecting an intact sediment core, sectioning it off into layers, and utilizing all of the information described above, paleoecologists 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 (Photograph 3.2-1). 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.

Photograph 3.2-1. Example sediment core. Photo credit Onterra.

Upper Gresham Lake Paleoecological Results

A sediment core was collected from the deep area of the central basin in Upper Gresham Lake by Onterra staff on October 24, 2017. The total length of the core was 64 cm. The top 41 cm of the core was black in color while the color of the remaining core was mostly black mixed with brown colored sediment. The depth of the water at the coring site was 27 feet. 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, 58-60 cm, was analyzed and this is assumed to represent conditions before the arrival Euro-American settlers in the middle of the nineteenth century.



Photograph 3.2-1. Photomicrographs of the diatoms commonly found in the sediment core from Upper Gresham Lake. The diatom *Aulacoseira ambigua* (A) is found floating in the open water and was common in the bottom sample. *Fragilaria crotonensis (B)* and *Tabellaria flocculosa* (D) are more common with moderate phosphorus levels. *F. crotonensis* and *T. flocculosa* were found in the top sample. *Staurosirella pinnata* (C) grows on lake sediments and can be associated with macrophytes. *S. pinnata* is a component of the group benthic *Fragilaria* which was more common in the bottom sample than the top sample.

Multivariate Statistical Analysis

In order to make a comparison of environmental conditions between the bottom and top samples of the core from Upper Gresham Lake, an exploratory detrended correspondence analysis (DCA) was performed (CANOCO 5 software, 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.

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.

There is considerable distance between the bottom and top samples in the Upper Gresham Lake sediment core. This indicates that the diatom community at the present time is different from historical times. This implies there has been a change in the lake's ecology during the last 150 years.

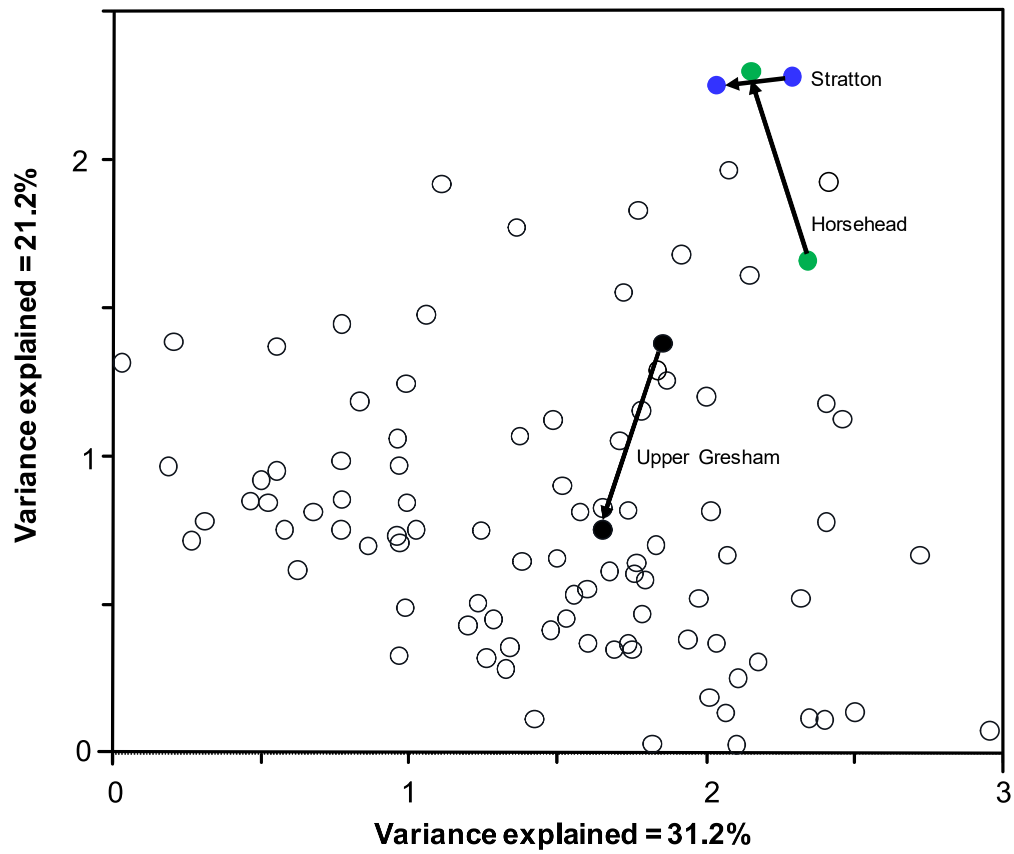


Figure 3.2-1. DCA plot of top/bottom samples from Upper Gresham Lake. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. Upper Gresham Lake has changed a significant amount since the arrival of Euro-American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

Diatom Community Changes

The diatom community in the bottom and top samples of the Upper Gresham Lake core was dominated by planktonic diatoms, those that float in the open water (Figure 3.2-2). In the bottom sample, the dominant planktonic diatom was *Aulacoseira ambigua* which is often found in lakes in northern Wisconsin, Michigan, and Minnesota that have low phosphorus levels (Camburn and Kingston 1986, Kingston et al. 1990, Garrison and Fitzgerald 2005). Benthic *Fragilaria*, which often grow on lake sediments, were more common in the bottom sample. This likely signals the lake had better water clarity historically compared with the present time.

In the top sample, planktonic diatoms are nearly as common as they were in the bottom sample but the composition has changed. The percentage of *A. ambigua* which typically is found in low nutrient waters in northern Wisconsin has been replaced by *Fragilaria crotonensis* and *Tabellaria flocculosa* (Figure 3.2-2) (Photograph 3.2-1). The increase of the latter diatoms are indicative of higher nutrient concentrations, especially nitrogen (Wolfe et al. 2001).

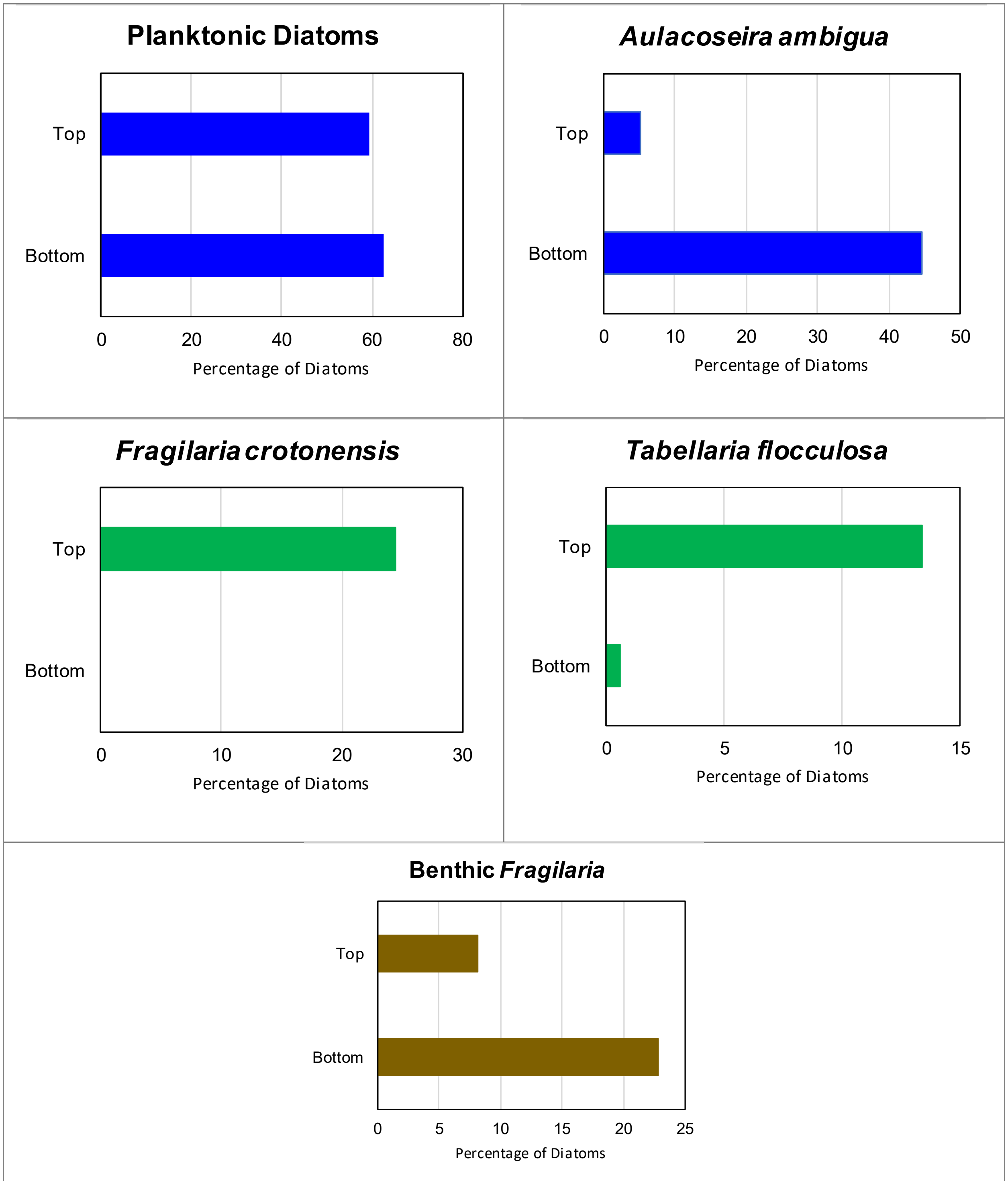


Figure 3.2-2. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Upper Gresham Lake. Although planktonic diatoms were equally common in the top and bottom samples, the composition of this diatom group has changed with taxa that indicate higher nutrients are more common at the present time. There are less benthic *Fragilaria* at the present time which likely signals poorer water clarity as these taxa often grow on the lake sediments.

Lake Diatom Condition Index

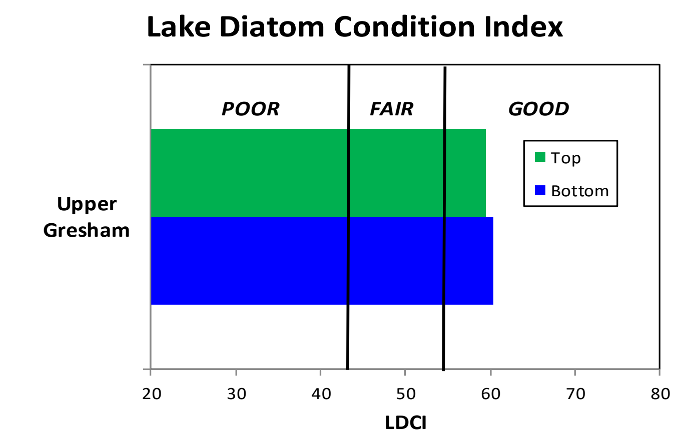


Figure 3.2-3. The Lake Diatom Condition Index (LDCI) for Upper Gresham Lake. The biotic integrity is similar at the present time compared with historical times.

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 bottom and top samples place Upper Gresham Lake in the good category (Figure 3.2-3). This indicates that during the last 150 years the lake's biotic integrity has not been degraded even though nutrient levels are higher now than they were historically. As mentioned above, nutrients are an important part of the LDCI. As shown in Figure 3.2-4, the percentage of diatoms typically found at higher phosphorus and nitrogen concentrations are more common in the top sample of the core.

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.

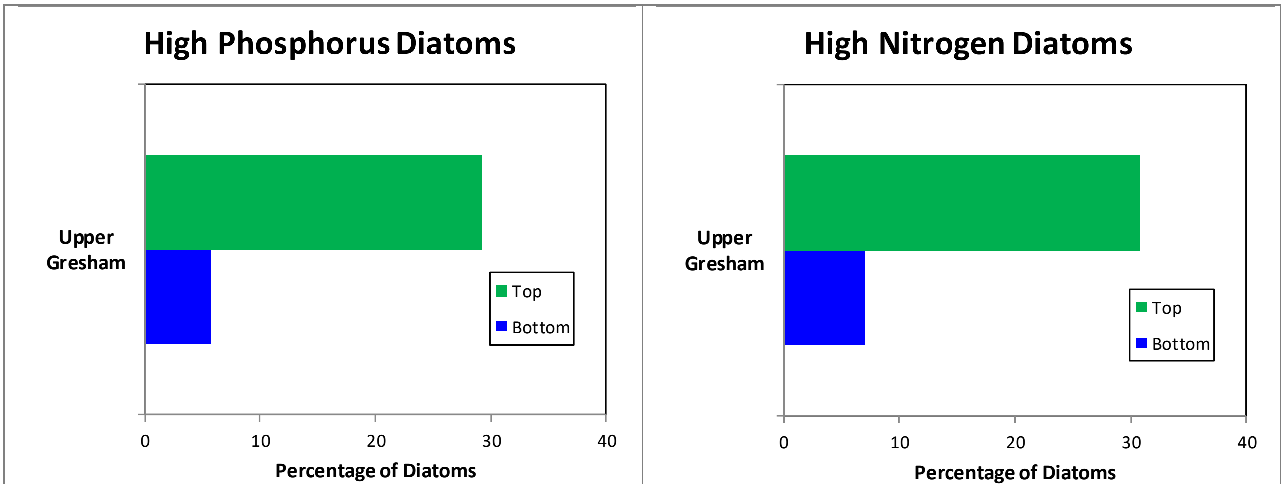


Figure 3.2-4. The amount of diatoms that prefer high phosphorus and nitrogen concentrations that were present in the top and bottom samples from Upper Gresham Lake. This increase in nutrients in the top sample is consistent with the loss of *A. ambigua* and the increase of *F. crotonensis* and *T. flocculosa*.

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 sample of Upper Gresham Lake is higher than the bottom sample, 22 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 indicating that the model results are likely accurate.

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

Lakes	Phosphorus
Upper Gresham Top	22
Upper Gresham Bottom	12

Paleoecology Summary

Upper Gresham Lake has seen a significant change in water quality during the last 150 years. The biotic integrity of the lake historically was good and this is true today. However, nutrient levels are higher now. The diatom community was historically dominated by planktonic diatoms and this remains true today. However, the dominant species have changed from those that indicate low phosphorus concentrations to a community indicative of higher phosphorus concentrations.

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. 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 shoreland development has also been seen in lakes in northeastern US (Vermaire and Gregory-Eaves 2008).

In Upper Gresham Lake, overall the diatom community indicates that the extent of the macrophyte community, either biomass or area of coverage has not changed a great deal over the last 150 years. This is mostly true for the central basin as that is where the sediment core was collected. It is possible there have been changes in some areas of the other basins, especially in the western basin where there is more shoreland development. It is likely that historically this lake had a diverse macrophyte community. The macrophyte community in some lakes in northern Wisconsin prior to arrival of Euro-American settlers, consisted of low growing, small leaved macrophytes such as isoetids. In contrast, the community in Upper Gresham Lake had a larger percentage of more robust growing macrophytes. Although there are less benthic *Fragilaria* in the top sample compared with the bottom, this likely signals a reduction in water clarity and not a loss of macrophytes.

The sediment core clearly indicates that at the present time nutrient levels are higher in the lake than they were 150 years ago with historical phosphorus concentrations being about 13 µg/L while they currently are around 23 µg/L. Because of the diverse macrophyte community and the moderate nutrient levels, the lake has maintained its good biotic integrity.

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

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.

Upper Gresham Lake Watershed Assessment

In the Gresham Lakes Chain 2009 Management Plan, Upper Gresham Lake is described as having a watershed of approximately 1,858 acres. Following the review of topographic maps and utilizing watershed delineation tools, Upper Gresham Lake's watershed was reduced to an area of approximately 1,348 acres, yielding a watershed to lake area ratio of 3:1 (Map 2). In other words, approximately three acres of land drain to every one acre of Upper Gresham Lake. According to WiLMS modeling, the lake's water is completely replaced approximately once every 3.57 years (residence time) or 0.28 times per year (flushing rate).

Approximately 45% of Upper Gresham Lake's watershed is composed of forest, 28% of the lake's surface, 20% of wetlands, and 7% of pasture/grass (Figure 3.3-1). The remaining portions of Upper Gresham Lake's watershed are composed of rural residential areas.

As discussed earlier, the land cover within watersheds of lakes with watershed to lake area ratios of 10-15:1 or less has a greater influence on the water quality of the lake. Utilizing the land cover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Upper Gresham Lake's watershed. It was estimated that approximately 208 pounds of phosphorus are delivered to the lake from its watershed on an annual basis (Figure 3.3-2). Phosphorus loading from septic systems was also estimated using data obtained from the 2017 stakeholder survey of riparian property owners. Of the estimated 208 pounds of phosphorus being delivered annually to the lake, 49% is estimated to originate from direct atmospheric deposition into the lake, 23% from forest, 13% from pasture/grass, 12% from wetlands, and 3% from riparian septic systems.

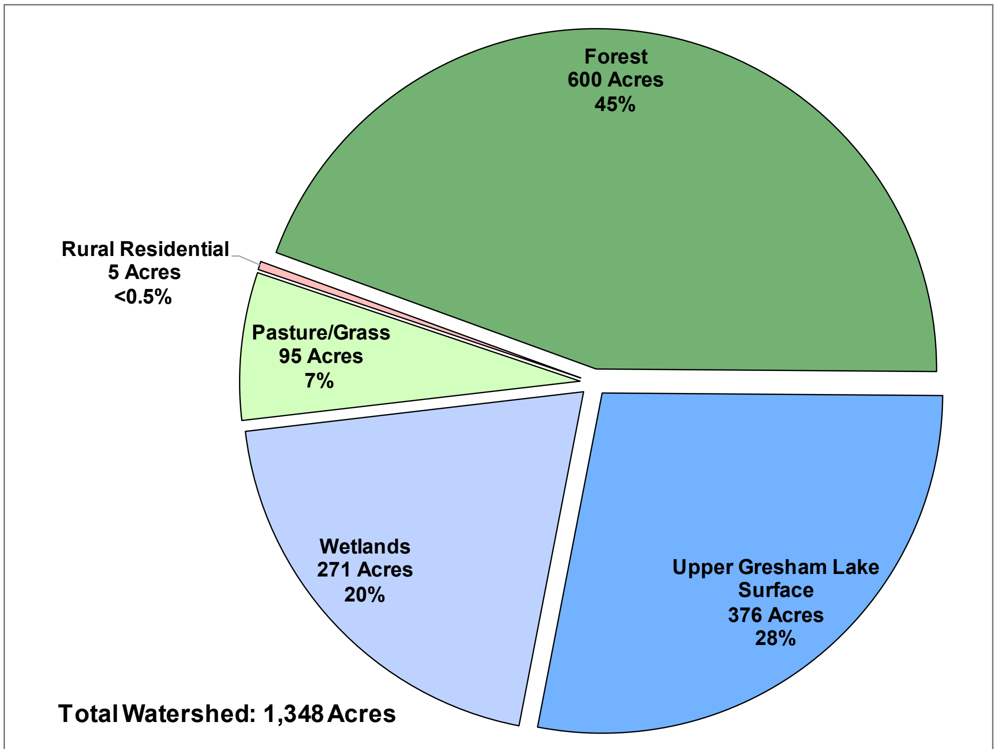


Figure 3.3-1. Upper Gresham Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

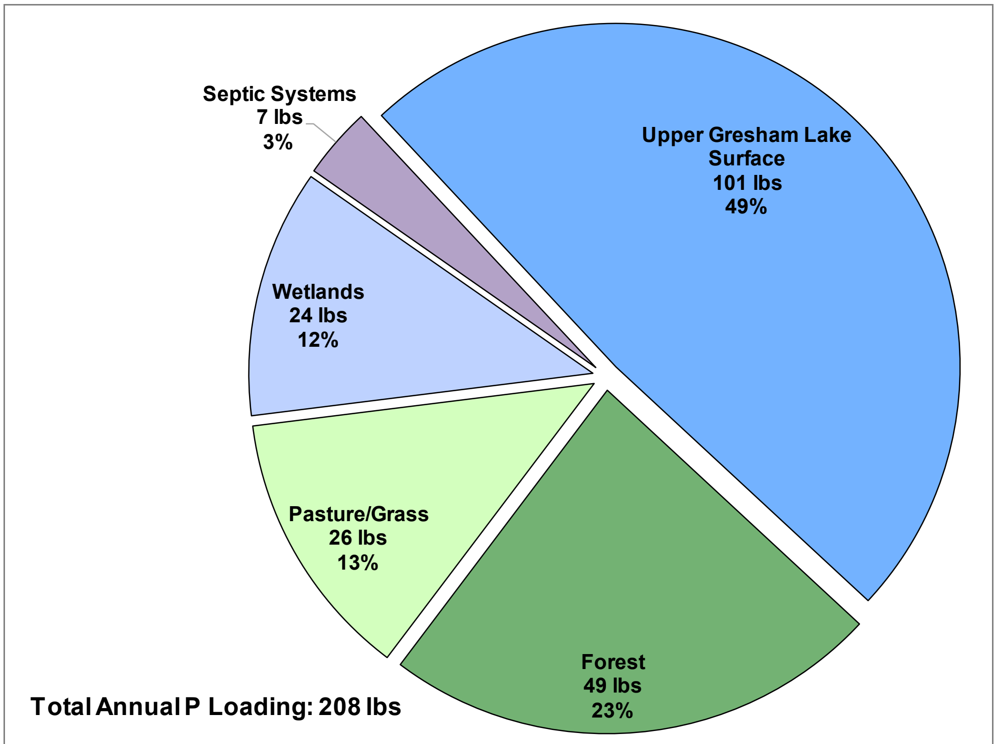


Figure 3.3-2. Upper Gresham Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using predictive equations, WiLMS estimates that based on potential annual phosphorus load, Upper Gresham Lake should have a growing season mean (GSM) total phosphorus concentration of approximately 19 µg/L. This predicted concentration is the same as the measured GSM total phosphorus concentration of 18.5 µg/L. This indicates the lake's watershed and phosphorus inputs were modeled fairly accurately and the measured phosphorus concentrations in Upper Gresham Lake are near expected levels based on the lake's watershed size and land cover composition. There are no indications that significant sources of unaccounted phosphorus are being loaded to the lake.

As discussed previously, in systems with lower WS:LA ratios like Upper Gresham 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 the lake's watershed to row crop agriculture. WiLMS estimates that the GSM total phosphorus concentration would increase to be approximately 26 µg/L. Currently, Upper Gresham Lake's average GSM total phosphorus concentration correlates to a TSI value of 46, falling into the mesotrophic category.

Should 25% of the lake's forested land in the watershed be converted to row crop agriculture, it is estimated that the lake would have a TSI value of 51, falling just into the eutrophic category. Using predictive equations developed 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 GSM concentration for chlorophyll-a would increase to almost 10 µg/L, which is almost double the average measured GSM chlorophyll-a concentration of 5.1 µg/L. The estimated GSM Secchi disk depth is estimated to decline to approximately 6.5 feet, which is just over a 3-foot reduction in the average measured GSM Secchi depth of 9.8 feet.

County Highway H Cranberry Farm

As shown on Map 2, Broken Arrow Holdings own and operates a cranberry farming operation adjacent to, but just outside of, the Upper Gresham Lake watershed drainage basin. Water is extracted from Upper Gresham via a pipe to flood the cranberry fields during harvest. The water is not pumped back into the lake, but allowed to seep into the groundwater. The watershed modeling was accurate for Upper Gresham Lake, indicating no significant sources of unaccounted nutrients. The GLA will continue to understand the cranberry farming operation for potential changes in the operation that could possibly impact the Gresham Lakes.

The watershed model discussed above (WiLMS) does not have a runoff coefficient for cranberry bog land use. A TMDL study in Massachusetts found that phosphorus export coefficient for their cranberry bogs was over three times greater than the export coefficient for row crop agriculture (Mattson 2015). So generically, watershed land use changes from forest to cranberry bog can be much more impactful to a lake than forest to row crop agriculture. A study in Lac Courte Oreilles in Sawyer County, WI found that cranberry farms increased the phosphorus load to the bays adjacent to the farms (Garrison and Fitzgerald 2005).

But unlike the entirely gravity-influenced runoff patterns of row crop agriculture, cranberry bogs use pumps and can alter how, when, and where they release the runoff. The impact of a cranberry bog operation can be extremely variable due to the complexity of their operations.

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.

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

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

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

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

National Lakes Assessment

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

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nations lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA

2009). Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, 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 3.4-2. 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.

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forwards shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program is divided based upon the location of the enhancement activity: 1) in-lake, 2) transition zone, and 3) upland. A sub-category of the WDNR Surface Water Grant Program was created to assist landowners with funding, with applications due on February 1st of each year. More information on this program can be found here: https://healthylakeswi.com/

Upper Gresham Lake Shoreland Zone Condition

Shoreland Development

Upper Gresham Lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.4-1 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.

On Upper Gresham Lake, the development stage of the entire shoreland was surveyed during fall of 2017, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.4-2.

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

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

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

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

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

Figure 3.4-1. Shoreland assessment category descriptions.

Upper Gresham Lake has stretches of shoreland that fit all of the five shoreland assessment categories. The left pie chart of Figure 3.2-4 shows the percent shoreland composition of the entire lake and the right pie chart shows the percent shoreline composition of the privately owned shorelines (i.e. excludes the state-owned land). In all, 5 miles of natural/undeveloped and developed-natural shoreland were observed during the survey, of which approximately 3.7 miles are state owned land. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.6 miles of urbanized and developed–unnatural shoreland were observed. While these two shoreland types comprise just under 10% of the overall shoreline of Upper Gresham Lakes, they make up almost a quarter of the shoreland types of the privately owned lands. If restoration of the Upper Gresham Lake 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. Map 3 displays the location of these shoreland lengths around the entire lake.

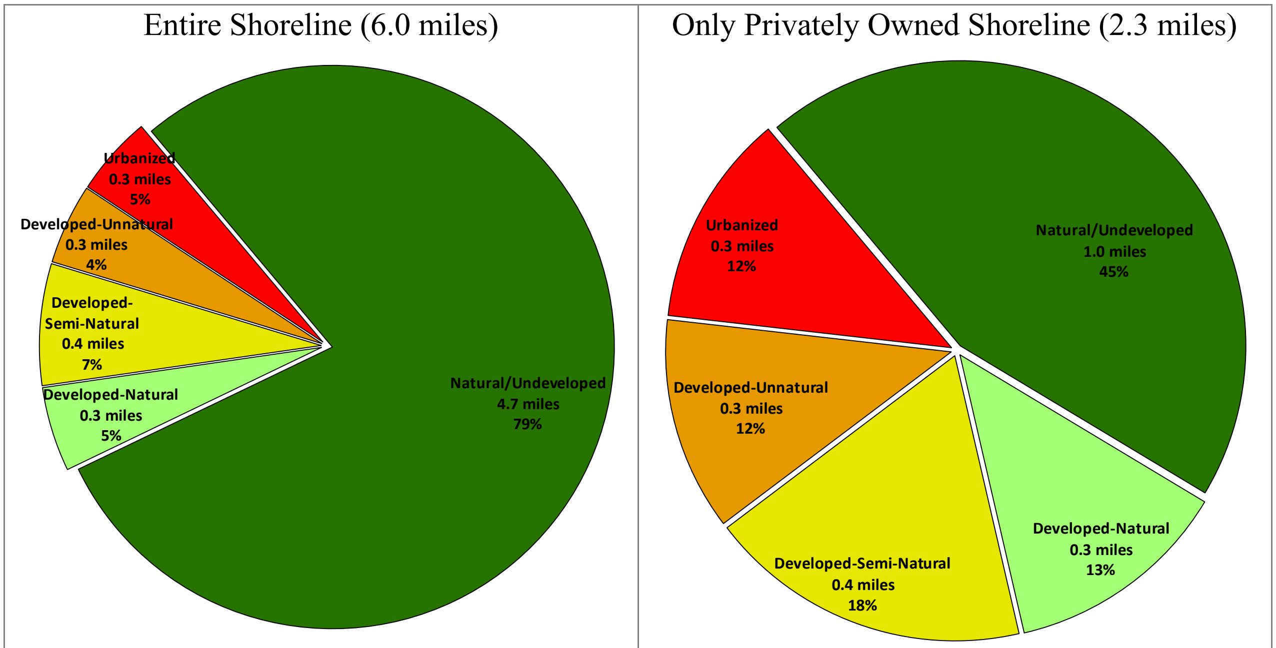


Figure 3.4-2. Upper Gresham Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Map 3.

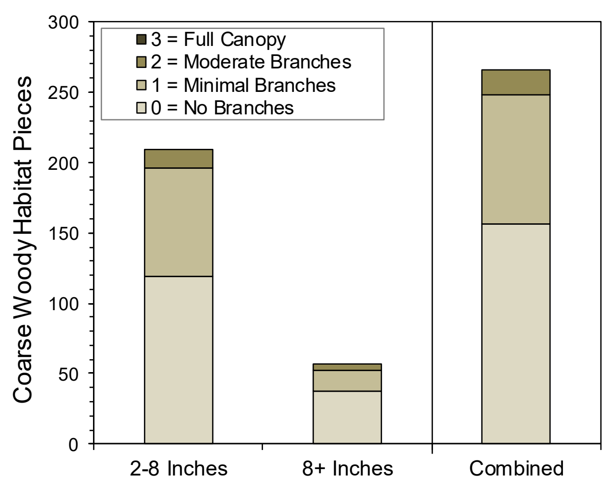
While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, un-sloped 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. And, 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.

Coarse Woody Habitat

As part of the shoreland condition assessment, Upper Gresham Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, >8 inches in diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

During this survey, 266 total pieces of coarse woody habitat were observed along 6 miles of shoreline (Map 4), which gives Upper Gresham Lake a coarse woody habitat to shoreline mile ratio of 45:1 (Figure 3.4-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 266 total pieces of coarse woody habitat observed during the survey, 209 pieces were 2-8 inches in diameters, 57 were 8 inches in diameter or greater, and no clusters of pieces of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Upper Gresham Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.



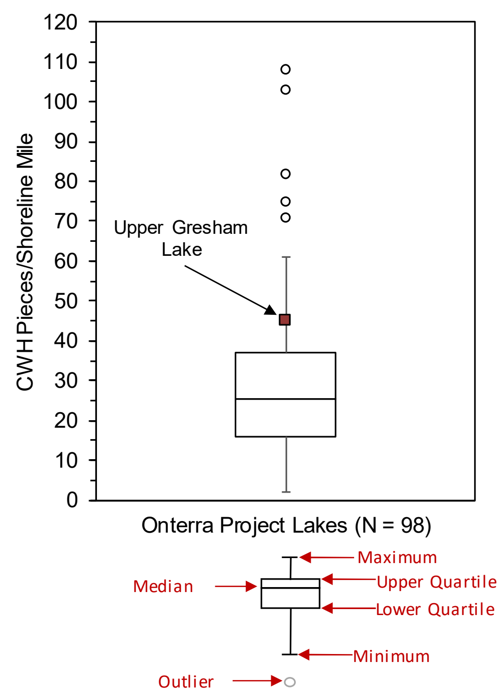


Figure 3.4-3. Upper Gresham Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Upper Gresham Lake coarse woody habitat can be found on Map 4.

Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Upper Gresham Lake fell into the 83rd percentile of these 98 lakes (Figure 3.4-3).

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

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

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.

Permits

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

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

Manual Removal (Hand-Harvesting & DASH)

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

Photograph 3.4-2. Example of aquatic plants that have been removed manually.

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

Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,000 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,000 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

Advantages	***Disadvantages***
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if large-scale efforts are conducted after June 15th.to correspond with fish spawning • 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.

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 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. Figure 3.5-1 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.

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.

Table 3.5-1. Common herbicides used for aquatic plant management.

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

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

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Upper Gresham 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 Upper Gresham Lake in 2017. 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 Upper Gresham 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 Upper Gresham Lake to be compared to other lakes within the region and state.

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

Species Diversity

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

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

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

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

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

Community Mapping

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

Upper Gresham Lake Aquatic Plant Survey Results

Numerous aquatic plant surveys have been conducted on Upper Gresham Lake since 2005. During this time period, a total of 56 species of plants have been located within or along the margins of Upper Gresham Lake since 2005 (Table 3.5-2). Please note that some of these species are only sparsely located and/or marginal wetland species. Two species located are considered non-native, invasive species: Eurasian watermilfoil and *Nymphaea odorata var. rosea*, or what is commonly called a pink water lily.

Pink water lily is a subspecies of white water lily that is commonly found planted within small ornamental ponds or aquariums. It is popular in this arena due to the bright pink/rose-colored flower it produces. Identification of this sub-species requires the plant to be in flower. Pink water lily was found to exist in only a single location in 2013. A replicate survey in 2017 did not locate pink or white water lily in the vicinity of the 2013 finding, likely indicating that the plant did not overwinter or was removed.

While common reed (*Phragmites australis*) was found in 2005, 2013, and 2017, it was not until 2017 that it was confirmed as the native variety (*Phragmites australis* subsp. *americanus*). It was previously thought that the common reed around Upper Gresham Lake was exotic but after having a specimen collected and verified by Dr. Freckmann at the UW – Stevens Point Herbarium confirmed that the specimen was indeed, native.

The population of Eurasian watermilfoil (EWM) is discussed in detail in the subsequent Eurasian Watermilfoil in Upper Gresham Lake Subsection. Appendix D contains the full matrix of aquatic plant frequencies from the available point-intercept surveys.

Table 3.5-2. Aquatic plant species located on Upper Gresham Lake during 2005, 2013, 2015, 2016, and 2017 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2005	2013	2015	2016	2017
Emergent	*Carex aquatilis*	Long-bracted tussock sedge	7					I
	Carex lacustris	Lake sedge	6	I				
	Carex pseudocyperus	Cypress-like sedge	8		I			
	Carex sp. (sterile)	Carex sp. (sterile)	N/A					I
	Carex stricta	Tussock sedge	7		I			
	Carex utriculata	Common yellow lake sedge	7		I			I
	Dulichium arundinaceum	Three-way sedge	9	I	I			I
	Eleocharis palustris	Creeping spikerush	6	I	I			X
	Equisetum fluviatile	Water horsetail	7		X			
	Myrica gale	Sweet gale	9			X		
	Phragmites australis subsp. *americanus*	Common reed	5	I	I			I
	Pontederia cordata	Pickerelweed	9	I	X		I	X
	Sagittaria latifolia	Common arrowhead	3	I				
	Sagittaria sp.	Arrowhead sp.	N/A	X			X	X
	Schoenoplectus acutus	Hardstem bulrush	5	I	X	X	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I				
	Sparganium americanum	American bur-reed	8		I			I
	Typha spp.	Cattail spp.	1	I	I			I
FL	*Brasenia schreberi*	Watershield	7	X	X	X	X	X
	Nuphar variegata	Spatterdock	6	X	X	X	I	X
	Nymphaea odorata	White water lily	6	X	X	X	X	X
	Nymphaea odorata f. *rosea*	Pink water lily	Exotic		I			
	Persicaria amphibia	Water smartweed	5	I	X			I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	X	I			X
	Sparganium fluctuans	Floating-leaf bur-reed	10					I
FL/E	*Sparganium emersum* var. *acaule*	Short-stemmed bur-reed	8	I	X			I
	Sparganium sp.	Bur-reed sp.	N/A					X
Submergent	*Bidens beckii*	Water marigold	8	X	X	X	X	X
	Ceratophyllum demersum	Coontail	3	X	X	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	X	X	X
	Eriocaulon aquaticum	Pipewort	9	X	X			X
	Heteranthera dubia	Water stargrass	6	X	X	X		X
	Isoetes spp.	Quillwort spp.	8	X	X	X	X	X
	Lobelia dortmanna	Water lobelia	10	X	X			X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X	X	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	10	X	X	X	X	X
	Najas flexilis	Slender naiad	6	X	X	X	X	X
	Nitella spp.	Stoneworts	7	X	X	X	X	X
	Potamogeton alpinus	Alpine pondweed	9				X	I
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X		X
	Potamogeton berchtoldii	Slender pondweed	7		X	X		
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X	X	X	
	Potamogeton foliosus	Leafy pondweed	6			X		X
	Potamogeton friesii	Fries' pondweed	8	X	X	X		X
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X	X	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X			X
	Potamogeton praelongus	White-stem pondweed	8	X	X	X	X	X
	Potamogeton pusillus	Small pondweed	7	X	X	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8					I
	Potamogeton strictifolius	Stiff pondweed	8	X	X			
	*Potamogeton vaseyi**	Vasey's pondweed	10		X		X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	X	X
	Ranunculus aquatilis	White water crowfoot	8					X
	Ranunculus flammula	Creeping spearwort	9	X				
	Stuckenia pectinata	Sago pondweed	3	X	I	X		X
	Utricularia geminiscapa	Twin-stemmed bladderwort	9					X
	Utricularia minor	Small bladderwort	10					X
	Utricularia vulgaris	Common bladderwort	7	X				X
	Vallisneria americana	Wild celery	6	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X	X	X	X
	Juncus pelocarpus	Brown-fruited rush	8	X	X	X	X	X
	Sagittaria cristata	Crested arrowhead	9		X			
	Sagittaria graminea	Grass-leaved arrowhead	9	I				
	Schoenoplectus subterminalis	Water bulrush	9		X			X
	Sparganium natans	Little bur-reed	9					I
FF	*Lemna minor*	Lesser duckweed	5					X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern by WI Natural Heritage Inventory*

Data regarding substrate hardness collected during the 2017 acoustic survey revealed that Upper Gresham Lake's average substrate hardness ranges from moderately soft to moderately hard with deeper areas containing the hardest sediments (Figure 3.5-2 and Map 5). On average, the softest substrates (organic, mucky) are found within 1 to 5 feet of water. The sediment within Upper Gresham Lake gradually increases to harder sediments as water depth increases with the largest change in sediment between 5 and 13 feet. Figure 3.5-2 illustrates the spatial distribution of substrate hardness in Upper Gresham 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.

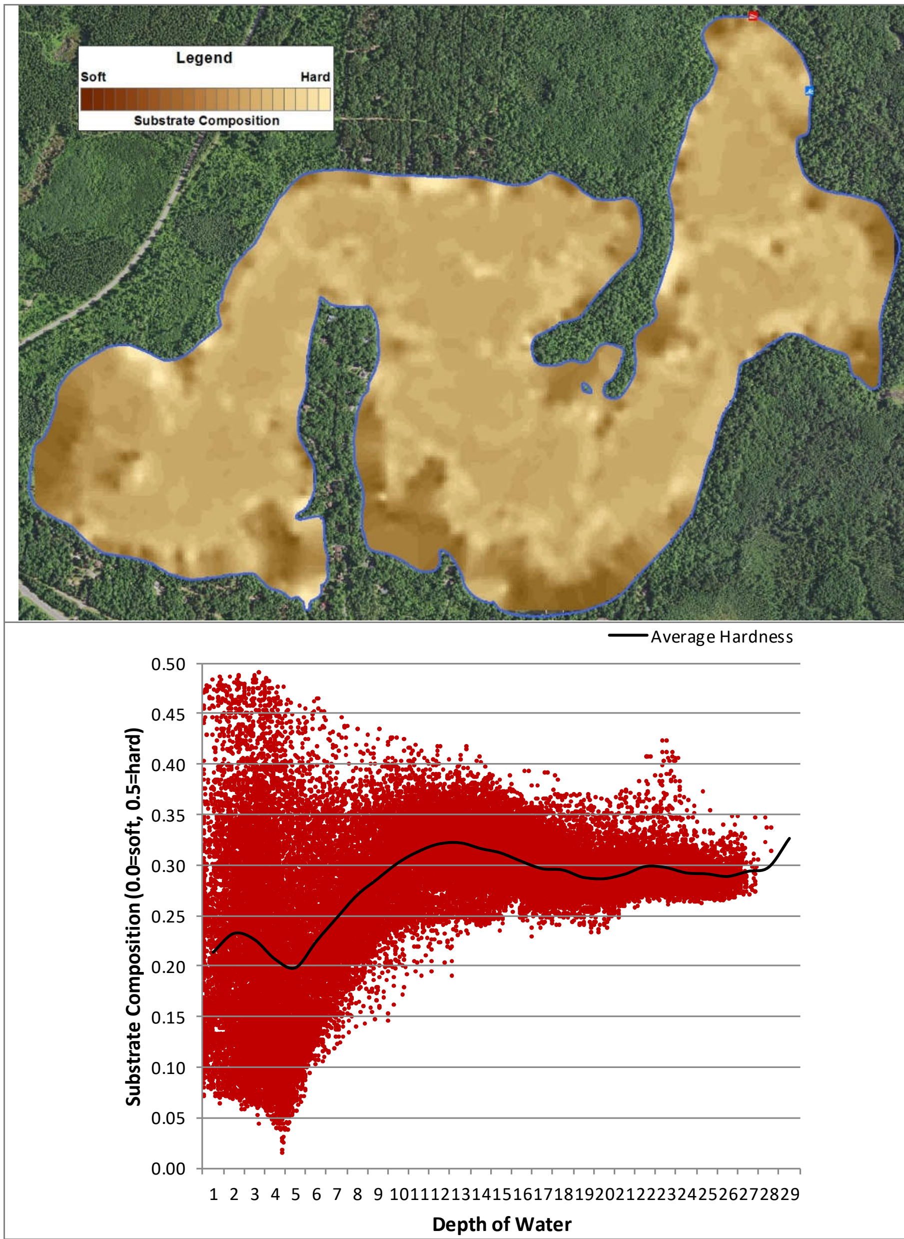


Figure 3.5-2. Upper Gresham Lake spatial distribution of substrate hardness (top) and substrate hardness across water depth (bottom). Individual data points are displayed in red. Created using data from September 2017 acoustic survey.

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 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic 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 20 feet, a testament to the high-water clarity found in Upper Gresham Lake. However, the majority of aquatic plant growth occurs within the first 14 feet of water, and the presence of aquatic plants quickly diminished beyond 14 feet. Overall, the 2017 acoustic survey indicates that approximately 66% of Upper Gresham Lake contains aquatic vegetation (Figure 3.5-3). The remaining area of the lake is too deep and does not receive adequate light to support aquatic plant growth.

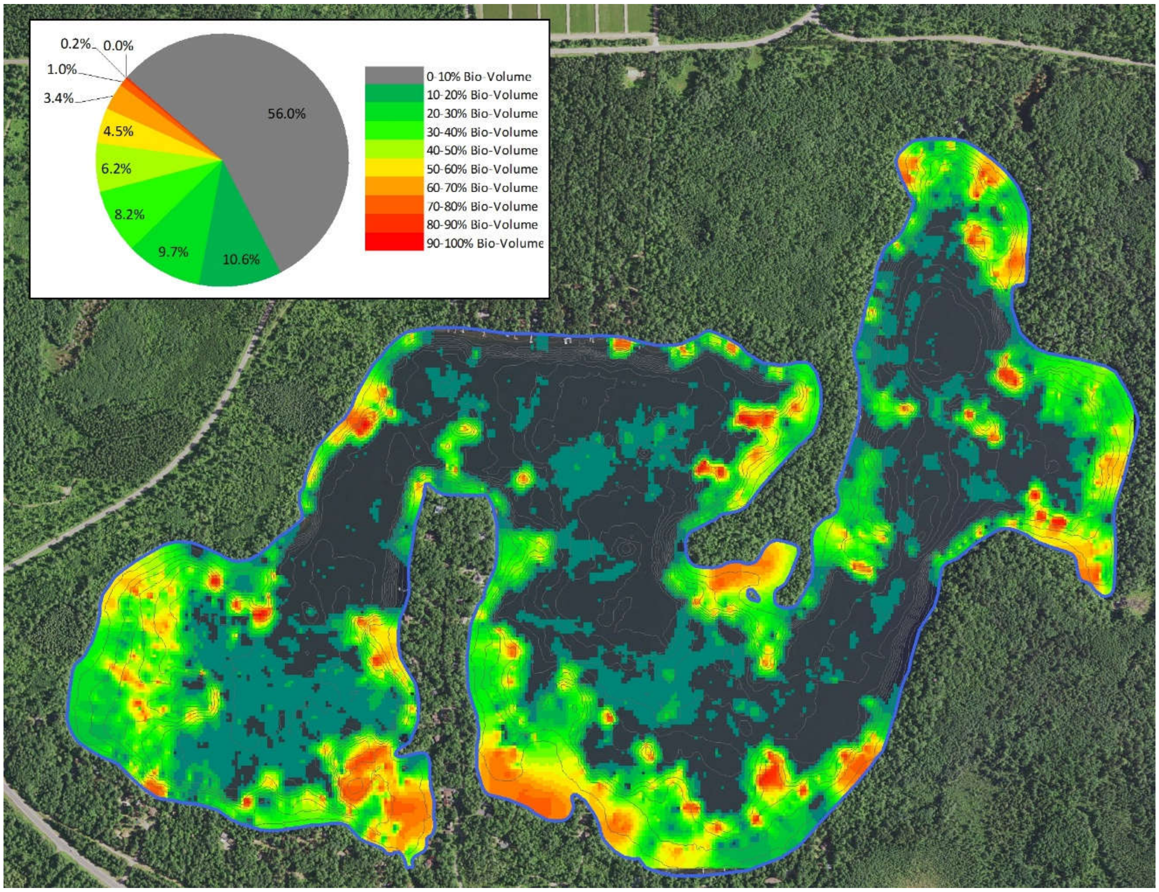


Figure 3.5-3. Upper Gresham Lake 2017 aquatic plant bio-volume. Created using data from September 2017 acoustic survey.

Of the 428 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2017, approximately 66% contained aquatic vegetation compared with 58% in 2005. Figure 3.5-4 shows a semi-quantitative analysis of the abundance of aquatic plants through looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). Please note that this type of data was not differentiated during the 2005 survey. Aquatic plant rake fullness data collected in 2017 indicates that 39% of the 428 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 26% had a TRF rating of 2, and 1% had a TRF rating of 3 (Figure 3.5-4). The TRF data indicates that where aquatic plants are present in Upper Gresham Lake, they are moderately sparse. Total rake fullness ratings were also collected in 2013, 2015, and 2016 and were variable from those found in 2017. The 2016 survey was almost identical to the 2017 survey while the 2013 and 2015 surveys were almost identical but displayed larger percentages of total rake fullness ratings of 3 than found in 2016 and 2017 (Figure 3.5-4). This difference may be showing a shift in plants becoming less dense throughout Upper Gresham Lake, further studies would need to be completed to determine the cause of the variability.

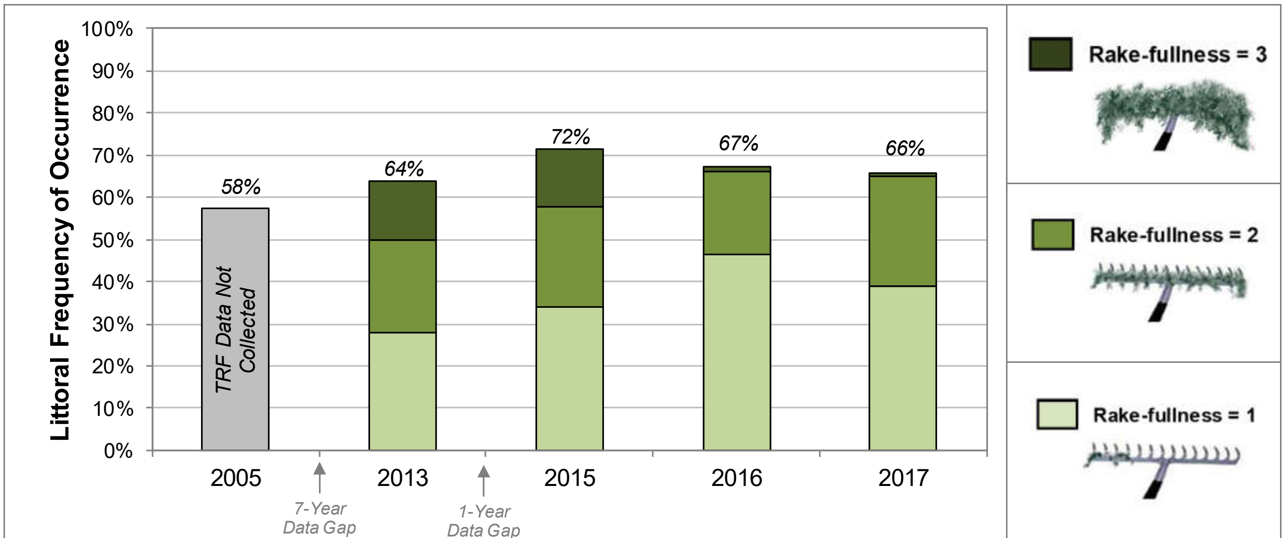


Figure 3.5-4. Upper Gresham Lake aquatic vegetation total rake fullness (TRF) ratings within littoral areas. Created from data collected during whole-lake aquatic plant point-intercept survey.

Of the 56 aquatic plant species located in Upper Gresham Lake in 2017, 44 were encountered directly on the rake during the whole-lake point intercept survey. The remaining 12 species were located incidentally, meaning they were observed by Onterra ecologists while completing the emergent and floating-leaf community mapping survey. 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 44 species, fern-leaf pondweed was the most frequently encountered, followed by coontail, wild celery, and small pondweed (Figure 3.5-5).

Fern-leaf pondweed was the most abundant aquatic plant in Upper Gresham Lake in 2017 with a littoral frequency of occurrence of approximately 30% (Figure 3.5-5). As its name indicates, this plant resembles a terrestrial fern frond in appearance, and is often a dominant species in plant communities of northern Wisconsin lakes. Fern-leaf pondweed is generally found growing in thick beds over soft substrates, where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. In Upper Gresham Lake, fern-leaf pondweed was most abundant between 6.0 and 10.0 feet of water.

Coontail, arguably the most common aquatic plant in Wisconsin, was the second-most frequently encountered aquatic plant in Upper Gresham Lake in 2017 with a littoral frequency of occurrence of 19% (Figure 3.5-5). Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Lacking roots, coontail derives most of its nutrients directly from the water (Gross et al. 2013). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in eutrophic waterbodies with higher nutrients. In Upper Gresham Lake, coontail was most abundant between 7.0 and 12.0 feet of water.

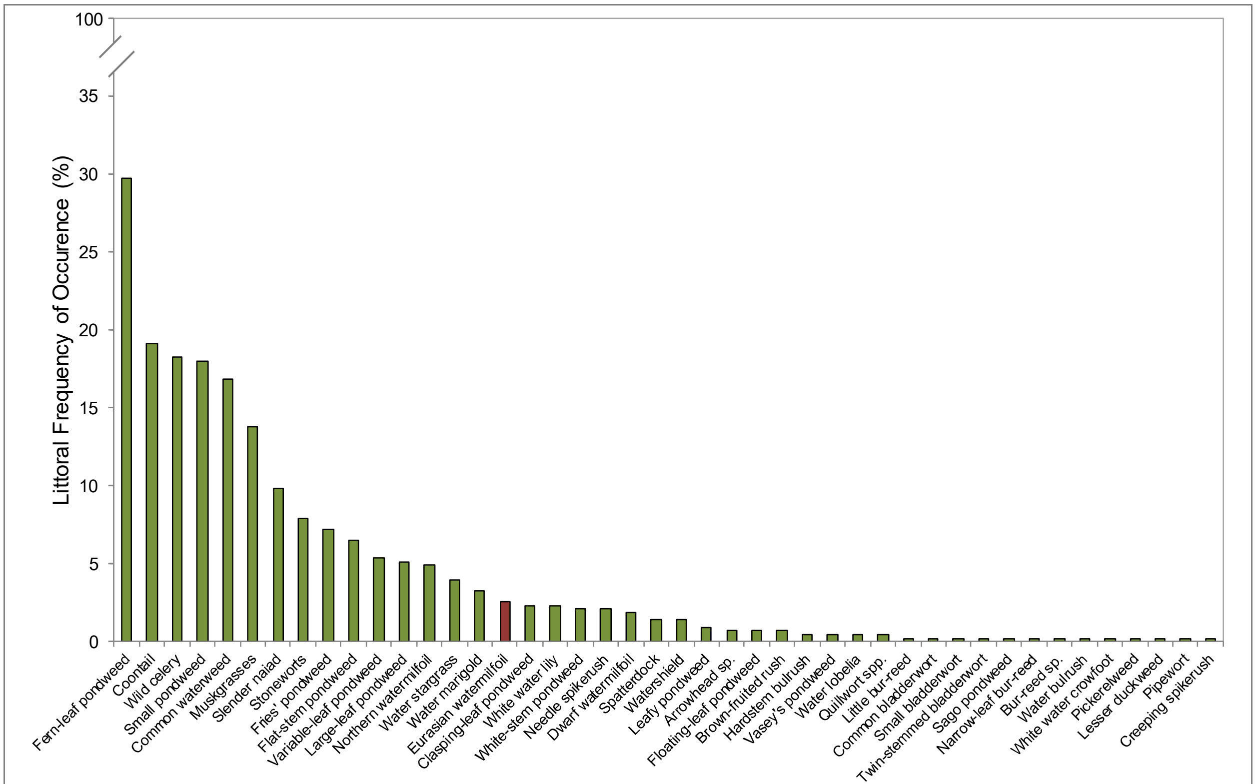


Figure 3.5-5. Upper Gresham Lake aquatic plant littoral frequency of occurrence. Created using data from 2017 whole-lake point-intercept survey.

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 18% 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 Upper Gresham Lake, wild celery was most abundant between 7.0 and 12.0 feet of water.

Small pondweed was the fourth-most abundant aquatic plant encountered in Upper Gresham Lake in 2017 with a littoral frequency of occurrence of 18% (Figure 3.5-5). Small pondweed is a common thin-leaved pondweed found throughout the state of Wisconsin. It can be identified from the other thin-leaved pondweeds by its lack of floating leaves and its winter buds with tight cigar shaped leaves in the middle. In Upper Gresham Lake, small pondweed was most abundant between 3.0 and 6.0 feet of water.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, disease, and management among other factors. Ongoing research on Wisconsin's lakes shows that native aquatic plant populations can fluctuate over short- and long-term periods which are believed to be driven be natural variations in climate, growing season, water levels, etc. Aquatic plant communities can also respond to management activities such as mechanical harvesting or herbicide treatments of aquatic invasive species. On Upper Gresham Lake, herbicide treatments targeting EWM occurred from 2007 to 2013. Therefore, changes from 2005 (pretreatment) to

2013 (post treatment) may be a result of the management activities. More discussion of the active management program on Upper Gresham Lake are discussed in the subsequent sub-section on Eurasian Watermilfoil in Upper Gresham Lake. Figure 3.5-6 displays the littoral frequency of occurrence of aquatic plant species from the available whole-lake point-intercept surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one of the five surveys are displayed. Because of their morphological similarity and often difficulty in differentiating between them, the occurrences of muskgrasses (*Chara* spp.) and stoneworts (*Nitella* spp.) were combined as were small pondweed (*Potamogeton pusillus*) and slender pondweed (*Potamogeton berchtoldii*), for this analysis.

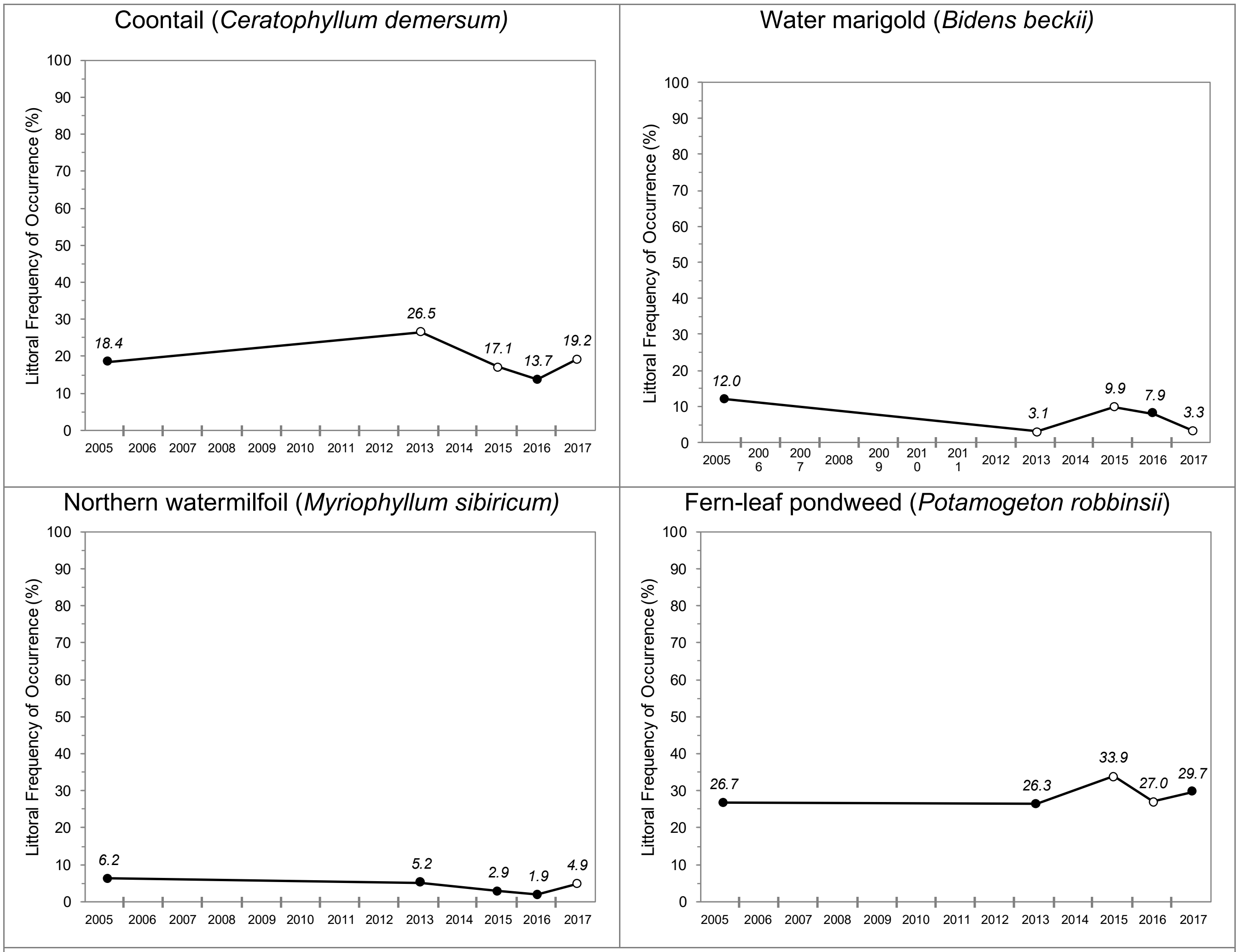


Figure 3.5-6. Upper Gresham Lake littoral frequency of occurrence of aquatic plant species from 2005, 2013, 2015, 2016, and 2017. Open circle indicates statistically valid change in occurrence from previous survey (Chi-square α = 0.05).

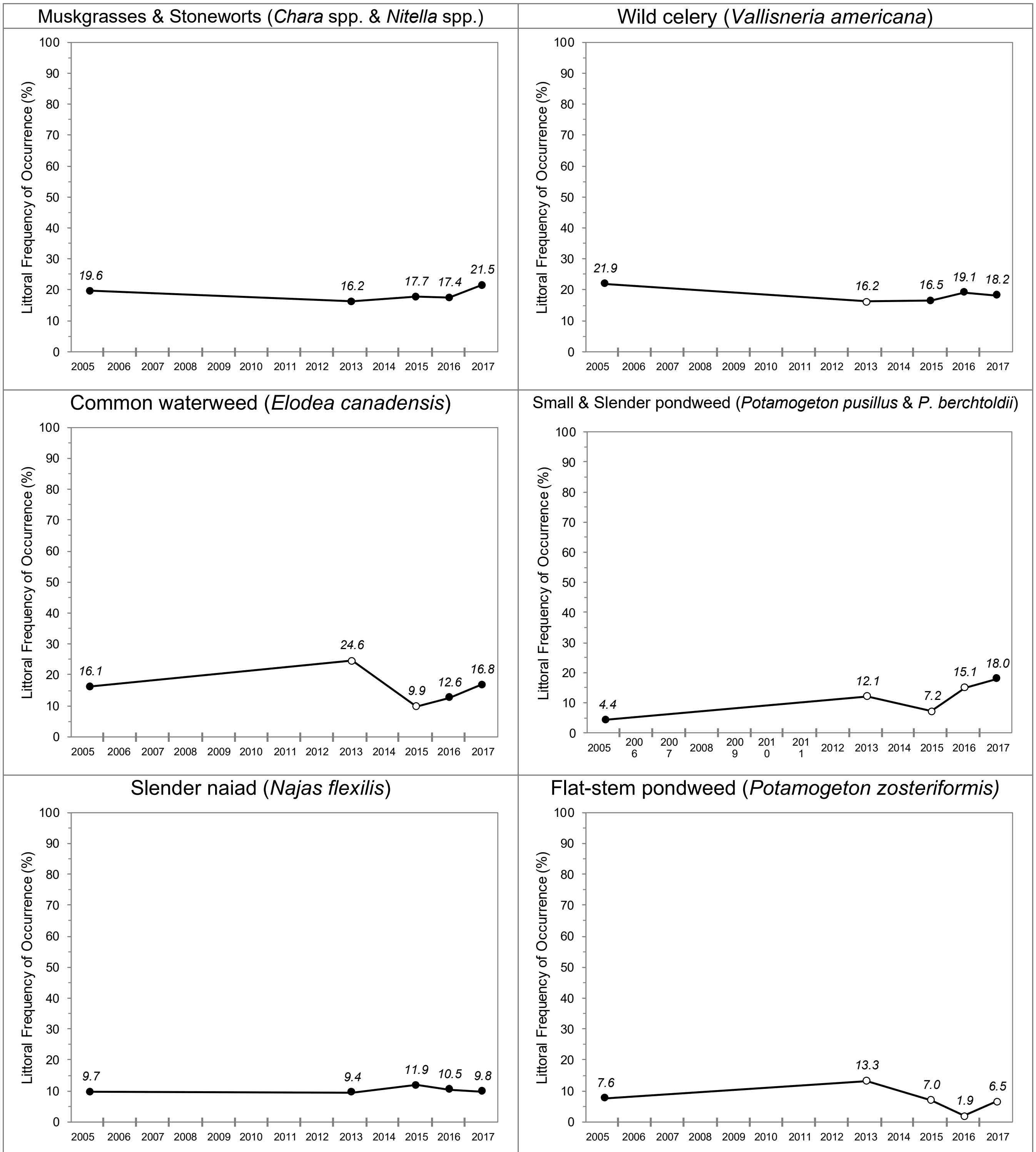


Figure 3.5-6, continued. Upper Gresham Lake littoral frequency of occurrence of aquatic plant species from 2005, 2013, 2015, 2016, and 2017. Open circle indicates statistically valid change in occurrence from previous survey (Chi-square α = 0.05).

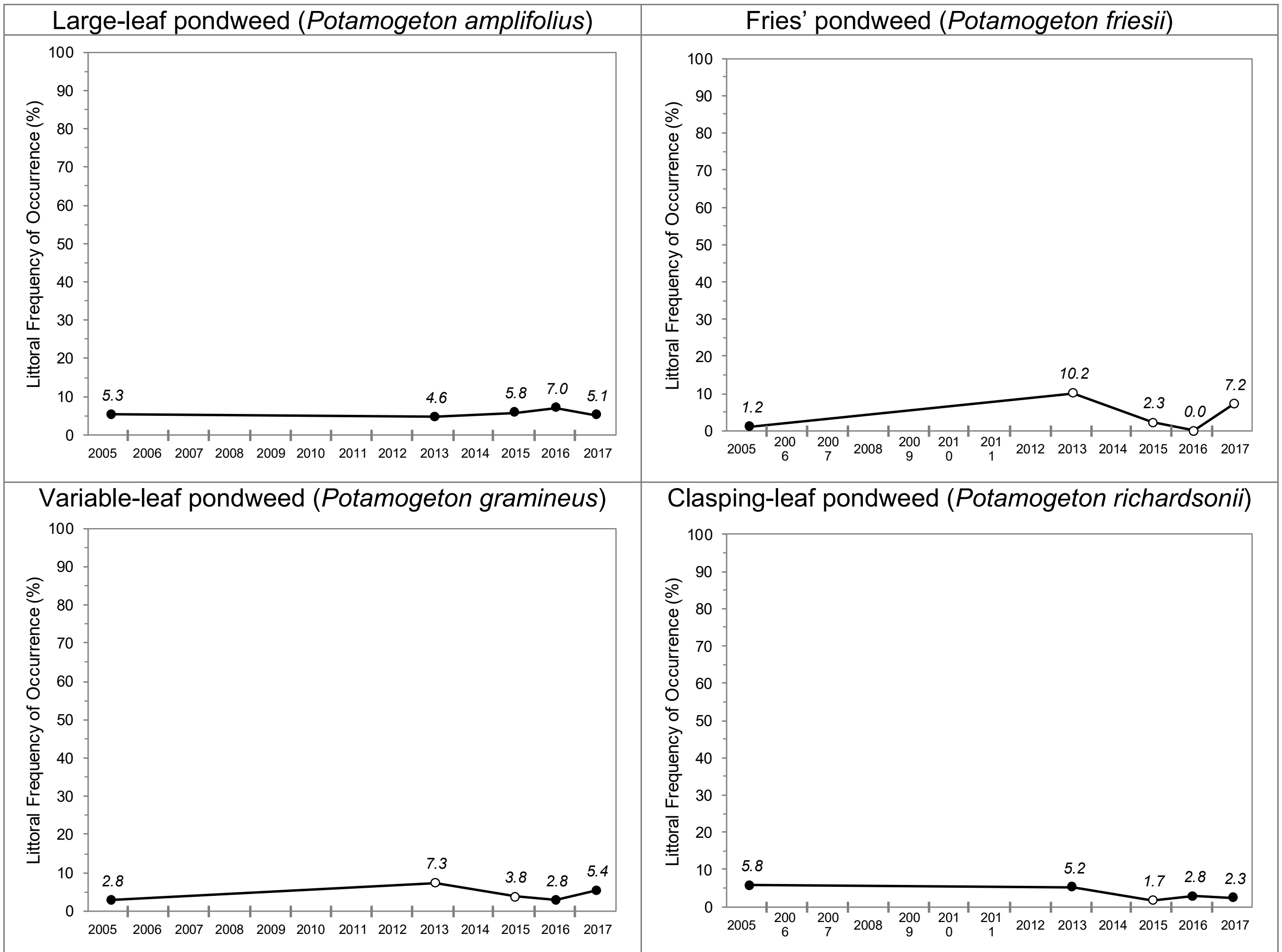


Figure 3.5-6, continued. Upper Gresham Lake littoral frequency of occurrence of aquatic plant species from 2005, 2013, 2015, 2016, and 2017. Open circle indicates statistically valid change in occurrence from previous survey (Chi-square α = 0.05).

In total, four aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence between 2005 and 2017 (Figure 3.5-6). Water marigold (73% decline) and clasping-leaf pondweed (59% decline) saw a significant decrease from 2005 to 2017 while small and slender pondweed (311% increase) and Fries' pondweed (529% increase) saw a significant increase over the same time period. Coontail, northern watermilfoil, fern-leaf pondweed, muskgrasses and stoneworts, wild celery, common waterweed, slender naiad, flat-stem pondweed, large-leaf pondweed, and variable-leaf pondweed saw no significant changes from 2005 to 2017.

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 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 55 native aquatic plant species were located in Upper Gresham Lake during the 2017 surveys, 43 were directly encountered on the rake during the point-intercept survey. Upper Gresham Lake's native aquatic plant species richness in 2017 exceeded the 75th percentile value for lakes within the Northern Lakes and Forest (NLF) ecoregion and throughout Wisconsin (Figure 3.5-7). The species richness recorded in 2017 (42) was also higher than that recorded during the 2005 (33), 2013 (38), and 2015 (30), and 2016 (25) point-intercept surveys. The difference in species richness are mostly due to changes in a species being found on the rake versus incidentally, most species have been found every year but they are not always found on the rake. The differences in the aquatic plant species list between these surveys can be viewed in Table 3.5-1.

The average conservatism of the 42 native aquatic plants recorded on the rake in 2017 was 7.0, falling above the median value (6.7) for lakes within the NLF ecoregion and above the 75th percentile value (6.3) for lakes throughout Wisconsin (Figure 3.5-7). This indicates that Upper Gresham Lake has a high number of native aquatic plant species with high conservatism values when compared to the majority of lakes within the NLF ecoregion. Average conservatism in 2017 was higher when compared to the average conservatism values recorded in 2005 (6.8), 2015 (6.5), and 2016 (6.8) but lower than that recorded in 2013 (7.1).

Using Upper Gresham Lake's 2017 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 45.5, exceeding the 75th percentile value for lakes within the NLF ecoregion and for the state. This indicates that Upper Gresham 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 and the state. Given that native species richness and average conservatism were overall higher in 2017, the 2017 Floristic Quality Index value was also higher than 2005, 2013, 2015, and 2016

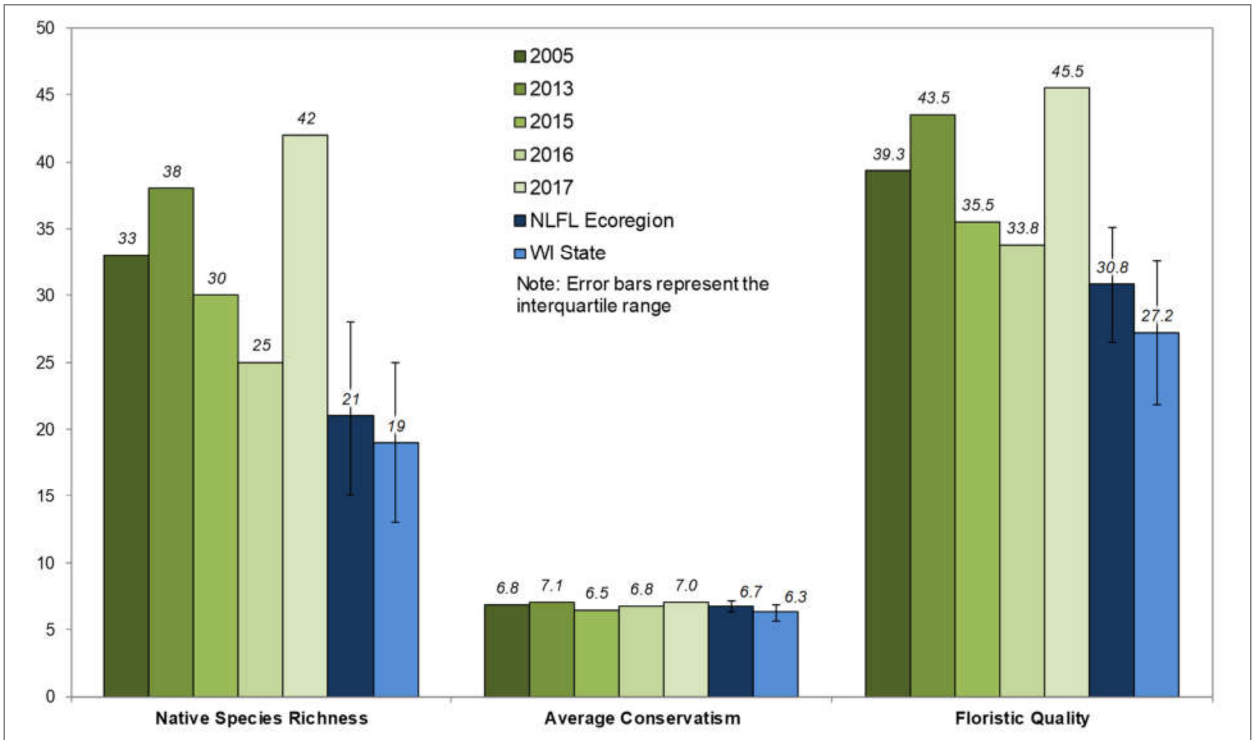


Figure 3.5-7. Upper Gresham Lake 2005, 2013, 2015, 2016 and 2017 Floristic Quality Assessment. Analysis follows Nichols (1999).

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and some believe a 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 Upper Gresham Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has 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 Upper Gresham Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF ecoregion (Figure 3.5-8). Using the data collected from the 2005, 2013, 2015, 2016, and 2017 point-intercept surveys, Upper Gresham Lake's aquatic plant community is shown to have high species diversity. These diversity value fall above the upper quartile of 0.90 for lakes in the NLF ecoregion, indicating that the diversity of Upper Gresham Lake is in the top 25% of lakes in the ecoregion.

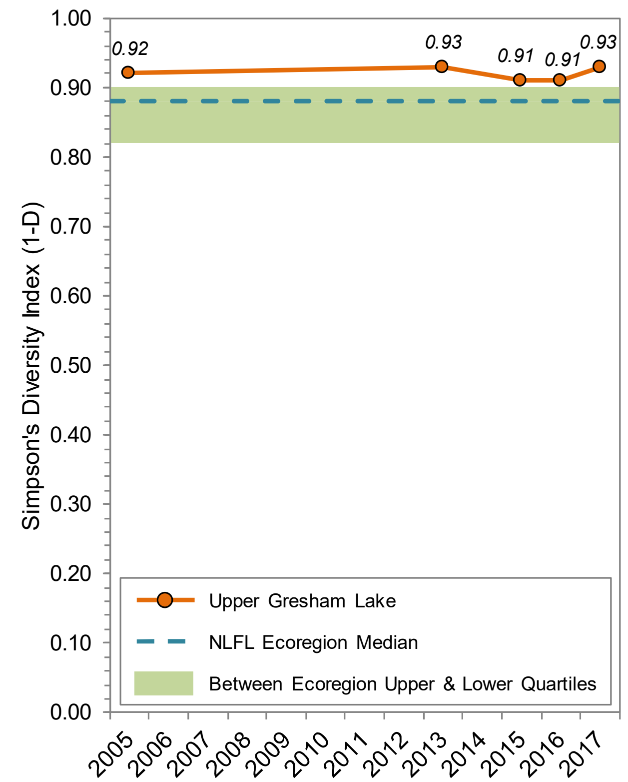


Figure 3.5-8. Upper Gresham Lake species diversity index. Created using data from 2005, 2013, 2015, 2016, and 2017 aquatic plant surveys. Ecoregion data from 212 NLF lakes collected by WDNR Science Services and Onterra.

While Upper Gresham Lake contains a high number of aquatic plant species, approximately half (53%) of the plant community is comprised of five species while another 14% is made up of 30 species. One way to visualize Upper Gresham Lake's high 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 even 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).

For instance, while fern-leaf pondweed had a littoral frequency of occurrence of 30%, their relatively frequency of occurrence was 15%. Explained another way, if 100 plants were sampled from Upper Gresham Lake, 15 would be fern-leaf pondweed. By having a higher number of aquatic plant species (species richness), the dominance of the plant community by many species results in higher species diversity.

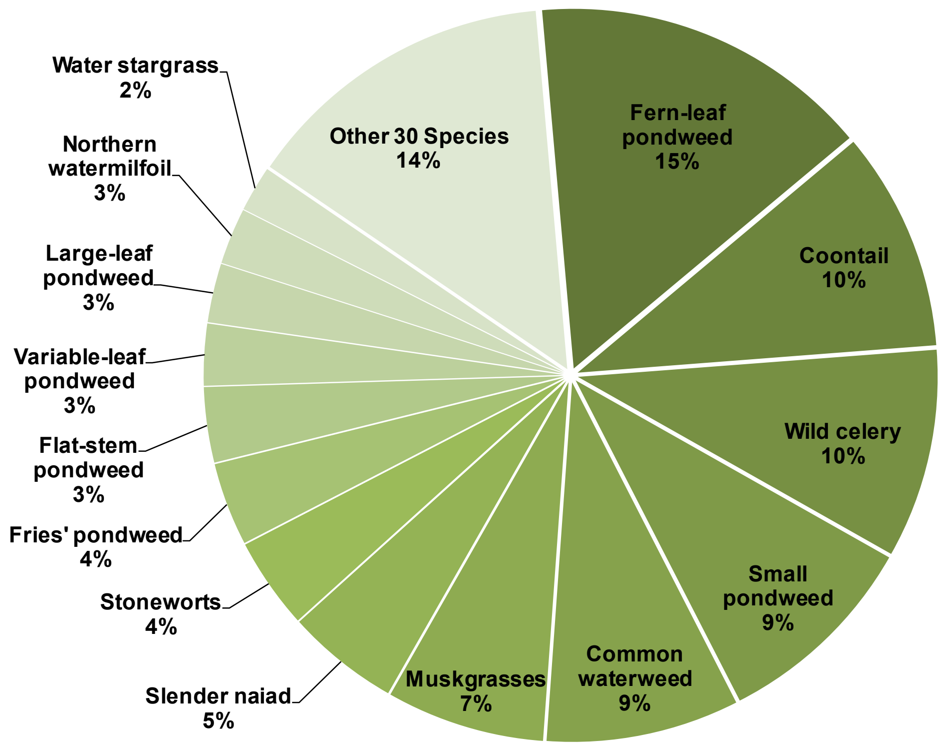


Figure 3.5-9. 2017 relative frequency of occurrence of aquatic plants in Upper Gresham Lake. Created using data from 2017 point-intercept survey.

The quality of Upper Gresham 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 29.2 acres (7.8%) of the 376 acre-lake contain these types of plant communities (Table 3.5-3 and Map 7). Twenty floating-leaf and emergent species were located on Upper Gresham 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.

Emergent and floating-leaf aquatic plant community mapping surveys were also completed on Upper Gresham Lake in 2007 and 2013. There was a total of 23.6 acres found in 2007 and 27.8 acres in 2013. Both of these surveys were found to delineate less acres than were found in 2017. Overlaying the three community mapping surveys, Onterra investigated differences in these surveys. The differences between the surveys is most likely due to improving technology used in each survey as well as the slow expansion of floating-leaf aquatic plant communities around the lake.

Table 3.5-3. Upper Gresham Lake acres of plant community types. Created from 2007, 2013, and 2017 community mapping surveys.

	Acres		
Plant Community	**2007**	**2013**	**2017**
Emergent	1.4	4.2	4.6
Floating-leaf	0.5	9.2	6.9
Mixed Emergent & Floating-leaf	21.7	14.4	17.8
Total	**23.6**	**27.8**	**29.2**

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 Upper Gresham 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.

Eurasian Watermilfoil in Upper Gresham Lake

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.5-10). 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, EWM 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 sometimes 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. However, in some lakes, EWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

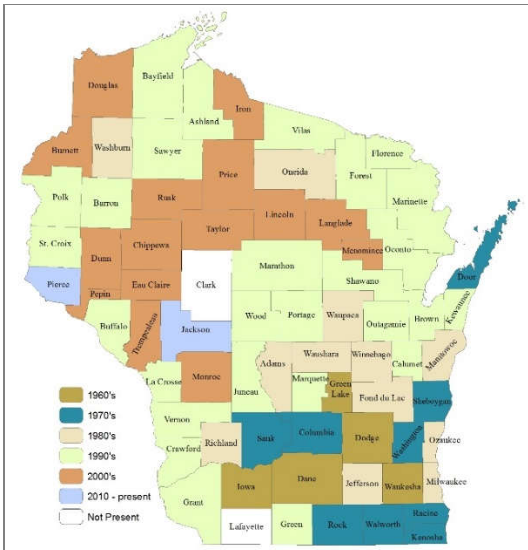


Figure 3.5-10. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes are not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 3.5-11). The upper frame of Figure 3.5-11 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected "unmanaged lakes" were moved into the "managed" category as the EWM populations were targeted for control by the local lake organization as populations increased.

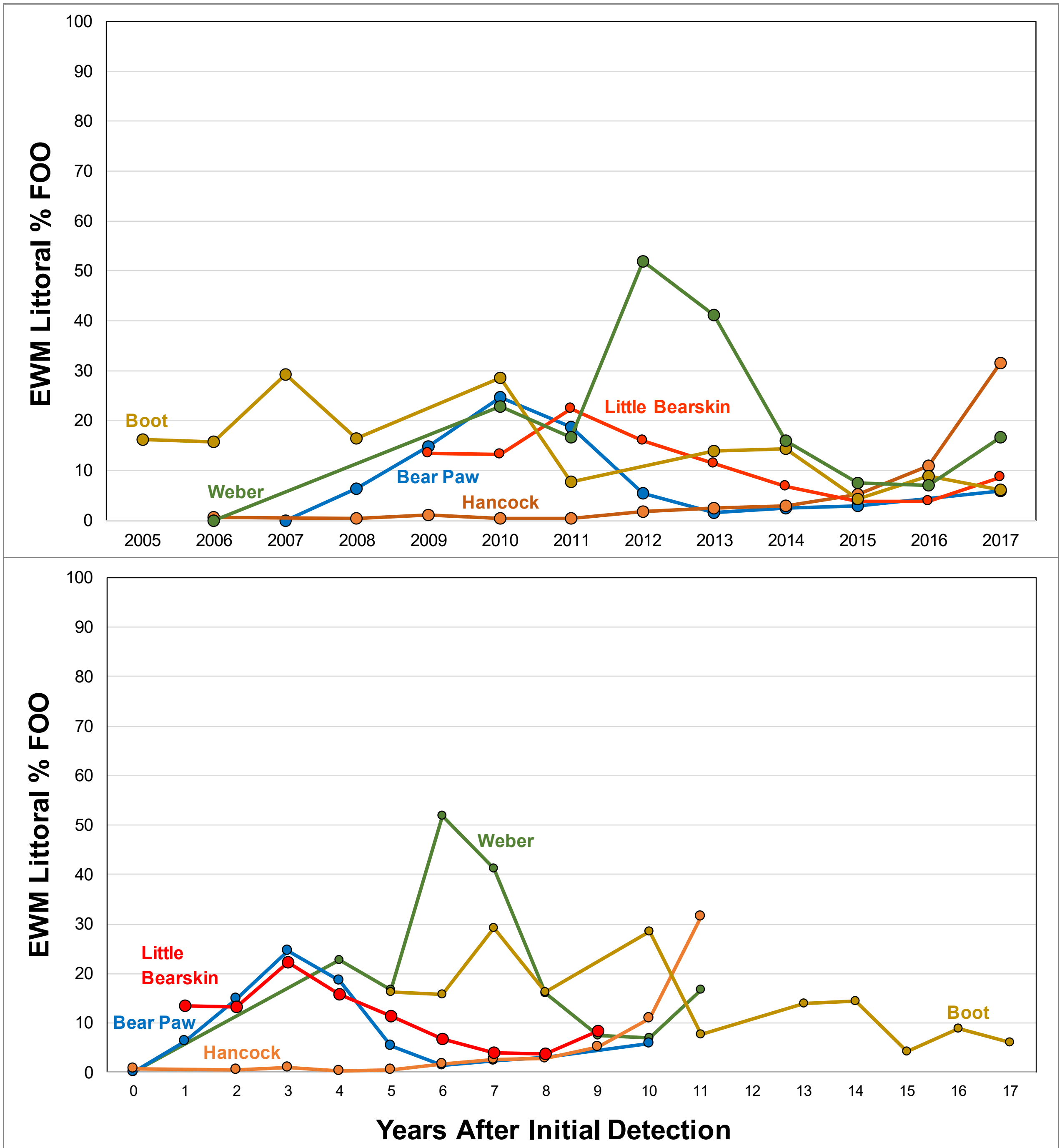


Figure 3.5-11. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Regional climatic factors also seem to be a driver in EWM populations, as many EWM populations declined in 2015 even though the lakes were at vastly different points in time following initial detection within the lake.

Upper Gresham Lake Historic EWM Management

It is important to note that two types of surveys are discussed in the subsequent materials: 1) point-intercept surveys and 2) AIS mapping surveys. As discussed above, the point-intercept survey provides a standardized way to gain quantitative information about a lake's aquatic plant population. The survey methodology allows comparisons to be made over time, as shown on Figure 3.5-10. The EWM population of Upper Gresham Lake was below 2% until 2017 when the population increased to 2.6%. Onterra's experience on waterbodies across the state confirms that Upper Gresham Lake contains an extremely low population of EWM.

The point-intercept survey also allows comparison to be made between lakes, as discussed in Figure 3.5-11. EWM was first officially documented from Upper Gresham Lake in 2001. This means that in 2017, EWM has been present for 16 years. For perspective, consider this population in the context of the unmanaged EWM populations shown on the bottom frame of Figure 3.5-11.

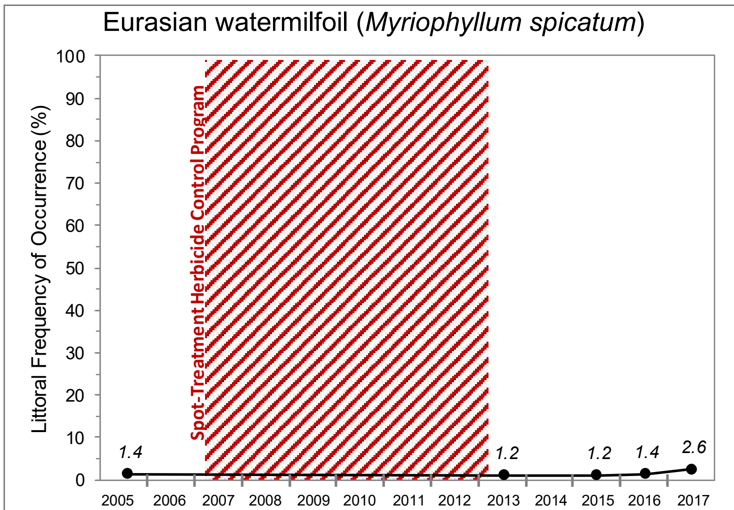


Figure 3.5-12. Littoral frequency of occurrence of EWM from 2006-2017. Open circle represents statistically valid change from previous survey.

Photograph 3.5-5. EWM fragment with adventitious roots. Photograph credit Onterra.

Photograph 3.5-6. EWM mapping survey on Cloverleaf Lakes, Shawano County. Photograph credit Onterra.

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake. During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat (Photograph 3.5-6). Field crews supplemented the visual survey by deploying a submersible camera along with periodically doing rake tows. The EWM population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to EWM locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.

For reference, both the point-intercept survey and EWM mapping surveys occurred in 2017 and are shown on Map 8. EWM was located at 2.6% of the littoral point-intercept sampling locations, which are displayed on the bottom frame. No point-intercept locations contained EWM near the boat landing and campground area. However, the meander-based 2017 EWM mapping survey documented numerous and dense accounts of EWM within this part of the lake. Overall, each survey has its strengths and weaknesses, which is why both are utilized in different ways as part of this project.

Late-season EWM mapping surveys have occurred since 2018 using a consistent density rating system as described above (Figure 3.5-13). Please note that this figure only represents only the acreage of mapped EWM polygons, not EWM mapped within point-based methodologies (*Single or Few Plants, Clumps of Plants,* or *Small Plant Colonies*). Said another way, EWM marked with point-based mapping methods do not contribute to colonized acreage as shown on Figure 3.5-13.

In 2008, the GLA successfully applied for a WDNR AIS-Established Population Control (EPC) Grant to aid in funding a multi-year EWM control project from 2008-2013. Spatially-targeted herbicide spot treatments targeting EWM occurred from 2007-2013 (Figure 3.5-14). Figure 3.5-14 shows the application acreage (primary vertical axis) and the quantity of active ingredient of herbicide applied (secondary vertical axis) and the of the GLA's EWM control program on Upper Gresham Lake. It is important to note that application areas typically extend around a mapped EWM colony by a predefined buffer distance (e.g. 40-feet). The application areas may also encompass noncontiguous EWM colonies or EWM marked with point-based methods which result in an application area much greater than the EWM colonies they target. Specifications regarding the design of each years' application areas is contained within the respective annual *AIS Control & Monitoring Reports* and can be found on the GLA's website (http://greshamlakes.website).

From 2007 to 2013, the acreage of colonized EWM was reduced from 3.3 acres to 0.8 acres (Figure 3.5-13). Although a small decrease in acreage was documented during this time period, each annual *AIS Control & Monitoring Report* indicated that the results were shorter than expectations and the herbicide dose was increased each year in efforts to provide better and longer-term results. The *Upper Gresham Lake EWM Control & Prevention Project Final Report* (Onterra 2014) recommended that herbicide spot treatments cease on Upper Gresham Lake until a more efficacious strategy could be identified.

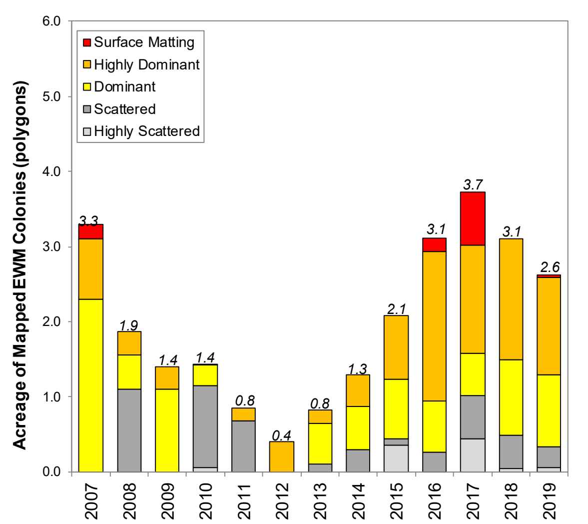


Figure 3.5-13. Acreage of mapped EWM colonies on Upper Gresham Lake from 2007-2019.

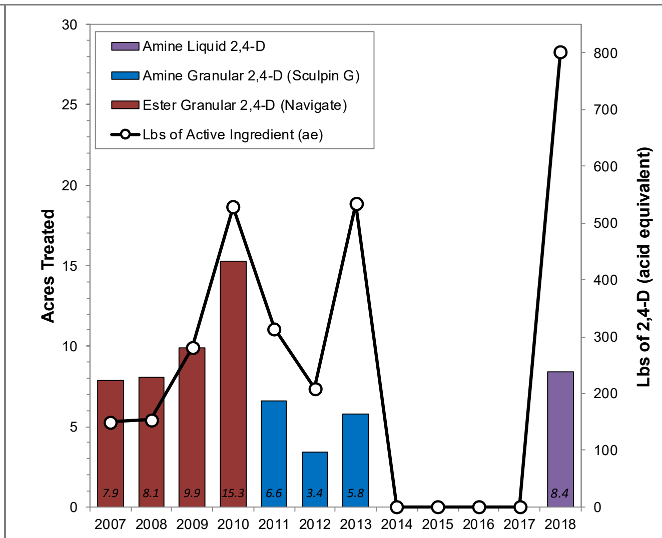


Figure 3.5-14. Upper Gresham Lake Herbicide Treatment History. No herbicide treatment in 2019

During the interim, the use of hand-harvesting was proposed to target small areas of EWM. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process.

Hand-harvesting operations in 2014 (Many Waters, LLC conducted 3 days of DASH) and 2015 (APM, LLC conducted 5 days of traditional hand-harvesting) were moderately effective in reducing the density of EWM within the targeted areas, however, the lake-wide rate of EWM population increase in Upper Gresham Lake exceeded the rate at which hand-removal can keep the population suppressed. Hand-harvesting was not recommended as a population suppression mechanism after 2015. However, localized hand-removal of EWM by residents was discussed as an important tool to lessen the nuisance and recreational conditions in high-use areas.

Upper Gresham Lake was chosen to be a control lake (not receive an herbicide treatment) within a 2015-2017 cooperative research project between the UWSP and WDNR titled: *Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in*

Northern Wisconsin Lakes. The GLA reservedly agreed to suspend herbicide treatment until at least 2018 to align with the research interests of the project. This came with the understanding that if EWM populations justified herbicide management after the research project concluded, the WDNR would allow these efforts to take place.

A 2017 mid-summer survey conveyed numerous locations around Upper Gresham Lake that EWM was exhibiting *highly dominant* and *surface matting* conditions. What was most concerning to the GLA was not the overall population, but select areas that harbor dense and surface-matted colonies of EWM (Photograph 3.5-7). The GLA identified approximately 15 areas in 2017 that they believe the density of EWM impacted riparian's ability to navigate and recreate in these areas. The GLA again attempted to target these areas by contracting 3 days of hand-removal using DASH. In three days, the contractor was only able to visit part of one site. Some EWM density reduction was observed in this area following these activities, but well below the expectations of the GLA. Based upon these efforts, the GLA considers the costs of hand-harvesting very expensive and not commensurate with quantity of impact these activities provide.

Photograph 3.5-7. Surface-matted EWM colony on Upper Gresham Lake. Photograph credit Onterra.

Following subsequent conversations with Onterra and WDNR, the GLA considered a few locations on the lake to implement herbicide spot treatments aimed at reducing the prevalence of nuisance-causing conditions within the lake. Onterra's experience is that herbicide spot treatments using weak-acid auxin hormone mimics (e.g. 2,4-D, triclopyr) are rarely effective when below the somewhat arbitrary size threshold of five acres. Even in some cases where larger treatment areas can be constructed, their narrow shape or exposed location within a lake may result in insufficient herbicide concentrations and exposure times for long-term control. Preliminary potential spot treatment sites on Upper Gresham Lake were constructed with large buffers around the targeted EWM occurrences in attempt to produce longer herbicide concentration and exposure times (CETs). The location of these sites within semi-protected "basins" was also speculated to result in a few hours of additional exposure time to result in EWM control.

Operationally, a lake-wide (or basin-wide) 2,4-D concentration above 0.1 ppm acid equivalent (ae) is considered by Onterra to represent a large-scale treatment, assuming 'typical' exposure time from herbicide degradation. Onterra has observed lake-wide impacts to some sensitive native plants when lake-wide concentrations were above 0.1 ppm ae; but being more durable, EWM mortality does not typically occur when lake-wide concentrations are below 0.275 ppm ae. It was determined that only two 5-acre sites could be treated in Upper Gresham Lake to be below the lake-wide large-scale threshold discussed above (0.1 ppm ae).

The GLA selected two sites on the lake to conduct herbicide spot treatments in 2018 (Figure 3.5-15). Both areas contain high boat traffic, with A-18 being in front of the public landing, fishing pier, campground, and beach. The lake was also divided into three somewhat arbitrary basins to better understand potential basin-wide herbicide concentrations. These calculations indicate potential basin-wide concentrations of around 0.2 ppm ae. But because these "basins" are not completely contained, sustained concentrations are not anticipated as herbicide dilution progresses towards a lake-wide equilibrium of less than 0.1 ppm ae. Except for particularly sensitive native plant species, Onterra's experience is that native plant impacts are likely to be limited to the application area and relatively close surrounding.

Figure 3.5-10 displays a comparison of the EWM population from late-summer 2017 to late-summer 2018 (Map 9) and 2019 (Map 10) following the spring 2018 herbicide treatment in sites A-18 and B-18. The EWM population was found to have been reduced in site A-18 with minimal plants located during the late-summer 2018 and 2019 surveys (Figure 3.5-15, top frame). Site B-18 exhibited a lesser degree of control in 2018 with the two main colonies of EWM decreasing by one density level (ex: from *surface matting* to *highly dominant*) but rebounding by the year after treatment (Figure 3.5-15, bottom frame).

It is believed that the herbicide spot treatment in spring 2018 attained sufficient concentration exposure time (CET) in site A-18 to achieve control, whereas CET's in site B-18 were not sufficient to control EWM. The morphology of the lake may have been more favorable in the area near site A-18 to allow the herbicide to remain in the targeted area long enough to result in EWM mortality.

During these discussions, conversation regarding risk assessment of the various management actions were prominent. Onterra provided extracted relevant supplemental chapters from the WDNR's *Strategic Analysis of Aquatic Plant Management in Wisconsin (June 2019)* regarding herbicide treatment (3.3), Physical removal (3.4), and biological control (3.5) to serve as an objective baseline for the GLA to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Upper Gresham Lake Ecosystem. These chapters are included as Appendix E.

As discussed above, Upper Gresham Lake served as a control lake within a cooperative UW-Steven's Point and WDNR research project entitled *Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes.* This research endeavor was conducted in response to this laboratory work documenting impacts of 2,4-D on larval fish survivability when exposed at specific times in their lifecycle. Three lakes were given large-scale 2,4-D amine treatments and a paired set of three lakes served as untreated reference lakes. The limnological, zooplankton, fisheries, and aquatic plant communities of these lakes were thoroughly sampled during the year prior to treatment, the year of treatment, and the year after treatment. A plethora of important data came from the study; however, measurable impacts from the herbicide treatments on the zooplankton and fisheries were not documented. A one-page summary report from the UWSP/WDNR study is included as part of Appendix F to this report.

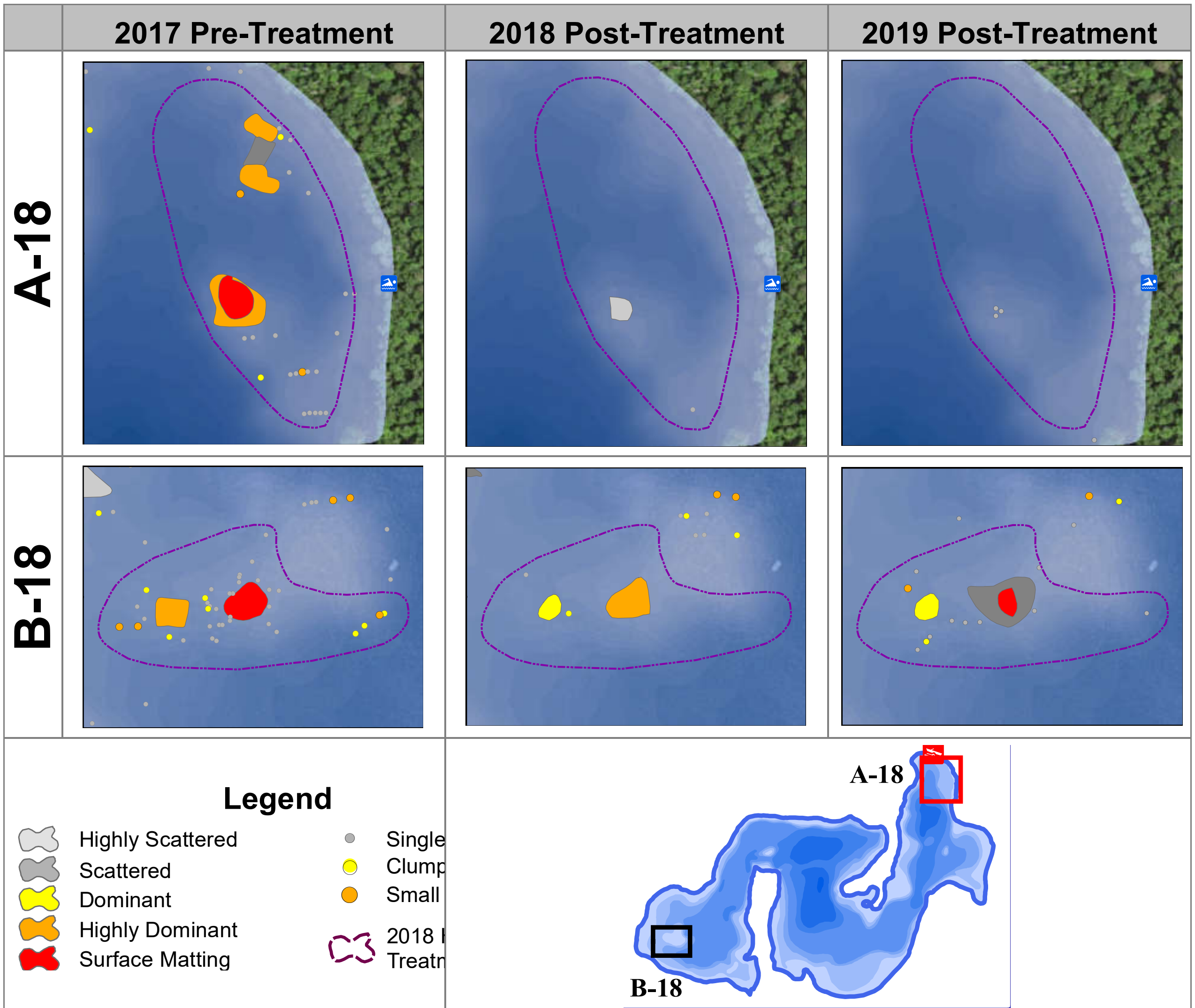


Figure 3.5-15. Late-Summer 2017 Pre- and Late-Summer 2018 and 2019 Post Herbicide Treatment EWM survey results for sites A-18 (top frame) and B-18 (bottom frame).

Eurasian Watermilfoil in Middle & Lower Gresham Lakes

As a part of this project, Late-Summer EWM Peak-Biomass Surveys were also completed on Middle Gresham Lake and Lower Gresham Lake in 2017. Mapping surveys that was completed on Middle Gresham Lake in 2007, 2012, and 2013 showed a very low EWM population composed of *single or few plants* or *clumps of plants*. A September 19, 2017 survey on Middle Gresham Lake found the EWM population remains very low with a small number of single plants and a small clump (Figure 3.5-16). The majority of EWM occurrences were located out from the Gresham Creek inlet that connects the upstream Upper Gresham Lake to Middle Gresham Lake.

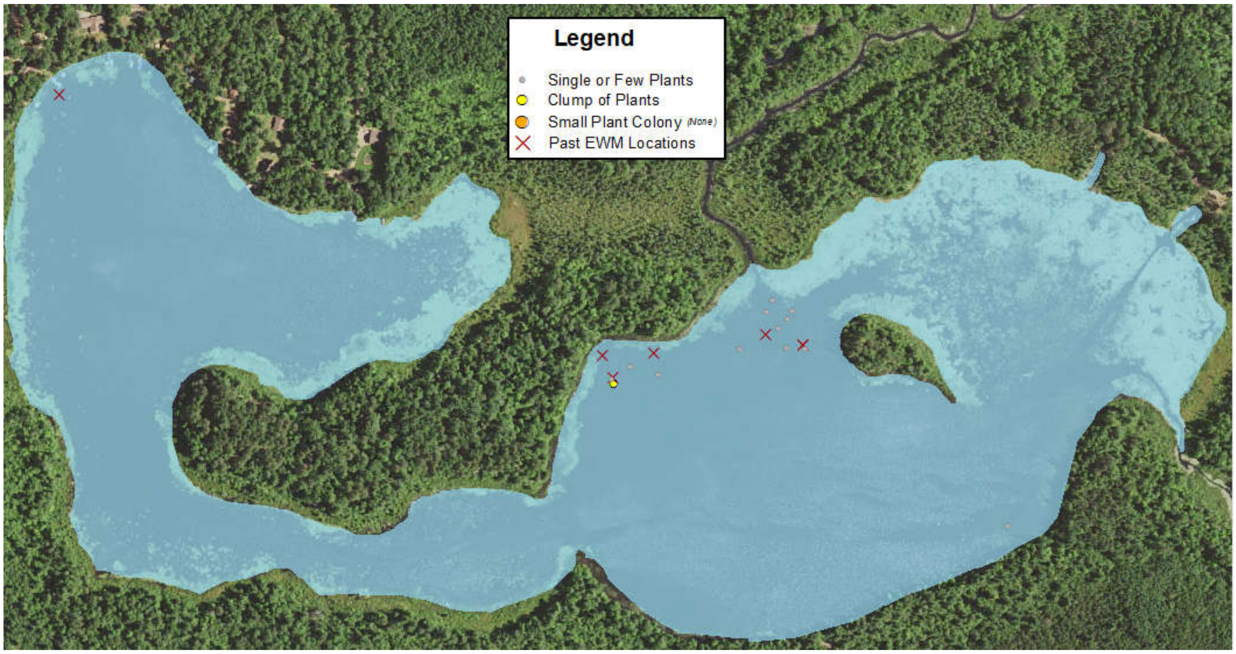


Figure 3.5-16. Late-Summer 2017 EWM survey results from Middle Gresham Lake. Additional data displayed from past surveys completed in 2007, 2012, & 2013.

Lower Gresham Lake is listed by the WDNR as having an *observed* status of EWM within the lake. This status means that EWM populations have not been verified from the Lake. Onterra conducted systematic lake-wide meander survey in search of EWM in 2007 on Lower Gresham Lake and did not locate and EWM.

As part of this project, Onterra ecologists again surveyed Lower Gresham Lake on September 19, 2017 to search for any possible occurrences of EWM. During the survey, the entire littoral area of the lake was searched and no EWM was located anywhere in the lake. A volunteer from the lake provided GPS coordinates of some suspicious watermilfoil occurrences on the east end of the lake. The Onterra survey crew thoroughly inspected the area of interest and noted the presence of native aquatic plant species that may have been the plants in question. The native aquatic species of northern watermilfoil as well as water marigold were observed in the vicinity of the volunteer point.

3.6 Aquatic Invasive Species

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

Table 3.6-1. AIS present within Upper Gresham Lake

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Pink water lily	*Nymphaea odorata var. rosea,*	Section 3.4 – Aquatic Plants
Invertebrates	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 - Aquatic Invasive Species
	Rusty crayfish	*Orconectes rusticus*	Section 3.5 - Aquatic Invasive Species

Figure 3.6-1 displays the eight aquatic invasive species that Upper Gresham Lake stakeholders believe are in Upper Gresham Lake. Only the species present in Upper Gresham 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

Rusty Crayfish

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell. They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake.

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).

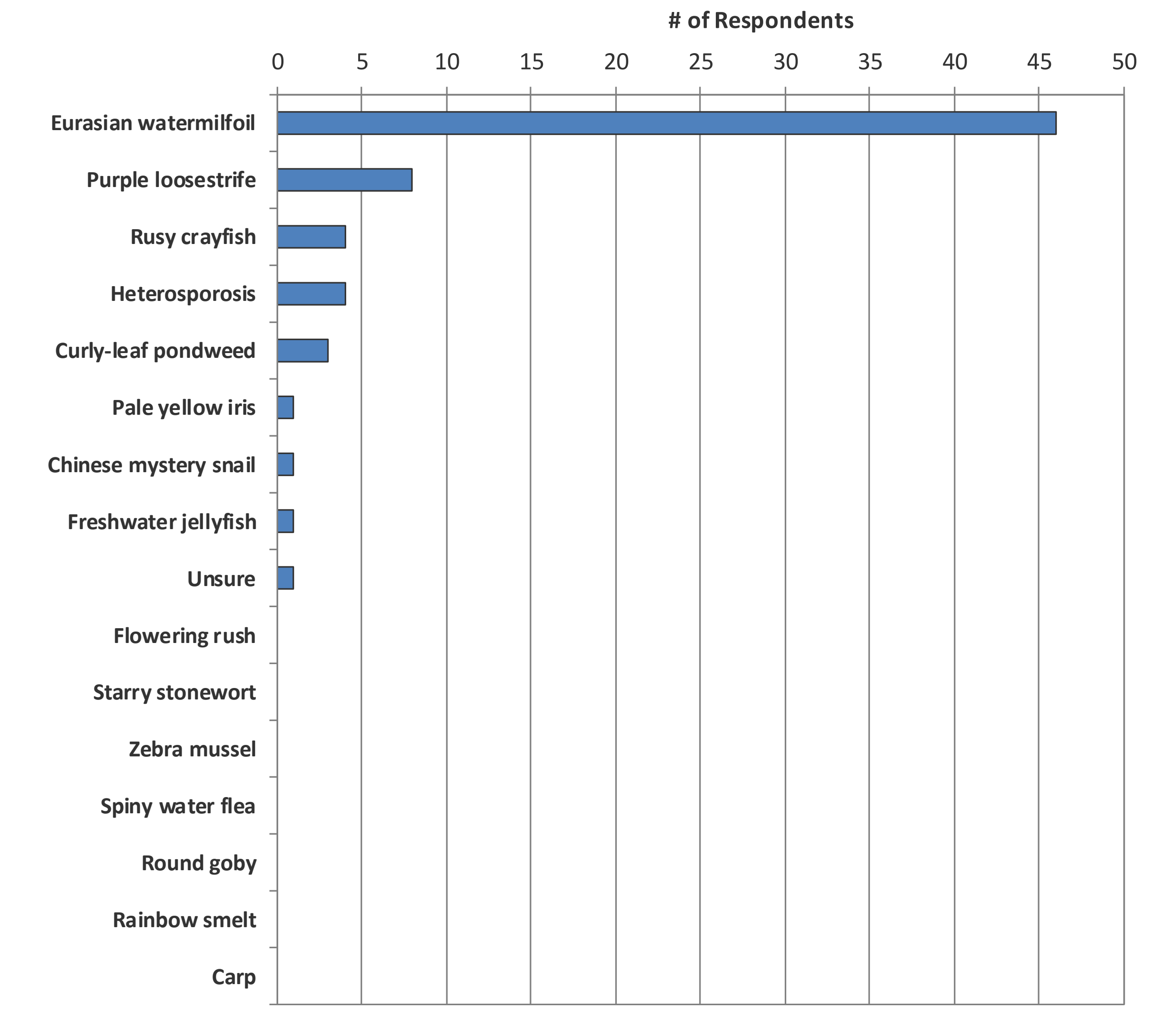


Figure 3.6-1. Stakeholder survey response Question #22. Which aquatic invasive species do you believe are in your lake?

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 Upper Gresham 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) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2018 & GLIFWC 2017).

Upper Gresham 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 Upper Gresham 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.

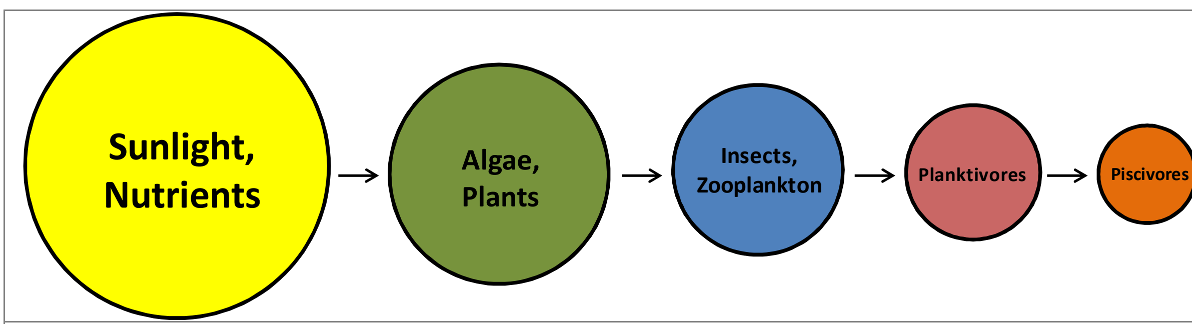


Figure 3.7-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Upper Gresham 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 Upper Gresham Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 3.6-1 shows the popular game fish present in the system.

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

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

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.

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

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.

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 (Photograph 3.7-2). 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. Upper Gresham Lake has been stocked from 1972 to 2017 with muskellunge and walleye (Tables 3.6-2 and 3.6-3).

Photograph 3.7-2. Fingerling Muskellunge.

Table 3.7-2. Stocking data available for muskellunge in Upper Gresham Lake (1975-2017).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1975	Unspecified	Fingerling	400	9
1977	Unspecified	Fingerling	700	7
1979	Unspecified	Fingerling	350	11
1981	Unspecified	Fingerling	400	12
1985	Unspecified	Fingerling	700	11
1987	Unspecified	Fingerling	2,100	12
1989	Unspecified	Fingerling	338	5
1991	Unspecified	Fingerling	100	11
1992	Unspecified	Fingerling	100	11
1993	Unspecified	Fingerling	300	11
1995	Unspecified	Fingerling	300	11.3
1997	Unspecified	Large Fingerling	150	9.9
1999	Unspecified	Large Fingerling	152	10.5
2001	Unspecified	Large Fingerling	366	10.2
2003	Unspecified	Large Fingerling	366	9.9
2005	Unspecified	Large Fingerling	382	10.6
2007	Upper Wisconsin River	Large Fingerling	244	13
2009	Upper Wisconsin River	Large Fingerling	365	10.5
2011	Upper Wisconsin River	Large Fingerling	363	9.2
2013	Upper Wisconsin River	Large Fingerling	366	11.35
2015	Upper Wisconsin River	Large Fingerling	372	11.8
2016	Upper Wisconsin River	Large Fingerling	363	10.3
2017	Upper Wisconsin River	Large Fingerling	227	10.9

Table 3.7-3. Stocking data available for walleye in Upper Gresham Lake (1972-2016).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Unspecified	Fingerling	9,000	3
1974	Unspecified	Fingerling	15,000	3
1975	Unspecified	Fingerling	15,000	3
1976	Unspecified	Fingerling	15,000	3
1977	Unspecified	Fingerling	17,000	3
1980	Unspecified	Fingerling	10,000	2.5
1984	Unspecified	Fingerling	19,080	2
1986	Unspecified	Fingerling	19,000	3
1988	Unspecified	Fingerling	19,000	5
1990	Unspecified	Fingerling	18,900	3
1991	Unspecified	Fingerling	9,072	3
1992	Unspecified	Fingerling	9,312	2
1994	Unspecified	Fingerling	17,919	2.3
1996	Unspecified	Fingerling	18,054	1.8
1998	Unspecified	Small Fingerling	36,000	1.5
2000	Unspecified	Small Fingerling	18,203	3.1
2002	Mississippi Headwaters	Small Fingerling	18,300	1.7
2004	Mississippi Headwaters	Small Fingerling	18,290	1.3
2006	Mississippi Headwaters	Small Fingerling	13,062	1.8
2008	Mississippi Headwaters	Small Fingerling	12,790	1.7
2010	Mississippi Headwaters	Small Fingerling	12,796	1.75
2012	Mississippi Headwaters	Small Fingerling	12,810	1.7
2014	Mississippi Headwaters	Large Fingerling	5,432	7.4
2016	Mississippi Headwaters	Large Fingerling	5,302	7.8

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), open water fishing was the most important reason for owning property on or near Upper Gresham Lake (Question #17). Figure 3.6-2 displays the fish that Upper Gresham Lake stakeholders enjoy catching the most, with crappie and largemouth bass being the most popular. Approximately 82% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.7-3). Approximately 84% of respondents who fish Upper Gresham Lake believe the quality of fishing has remained the same or gotten worse since they started fishing the lake (Figure 3.7-4).

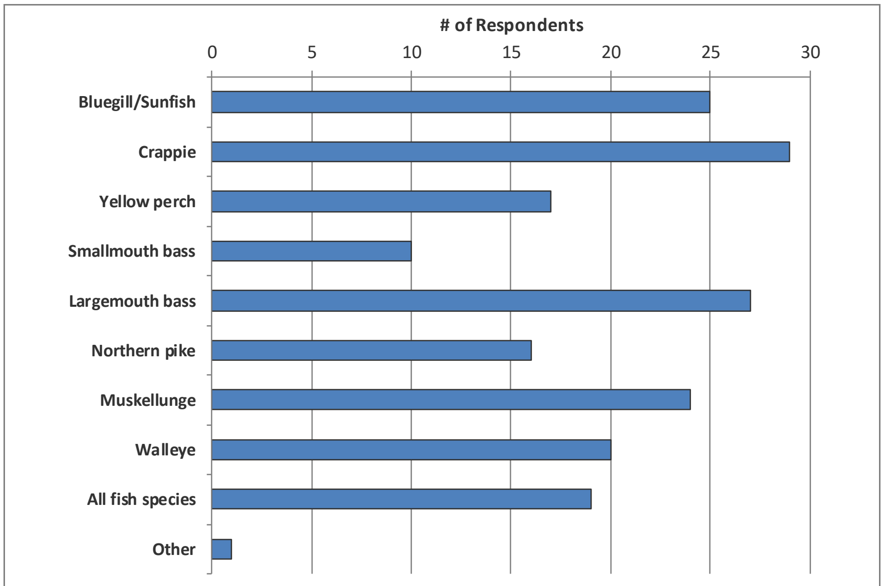


Figure 3.7-2. Stakeholder survey response Question #11. What species of fish do you like to catch on Upper Gresham Lake?

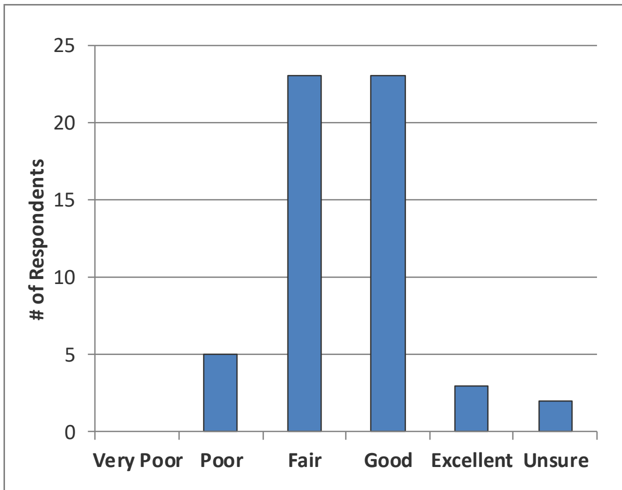


Figure 3.7-3. Stakeholder survey response Question #12. How would you describe the current quality of fishing on Upper Gresham Lake?

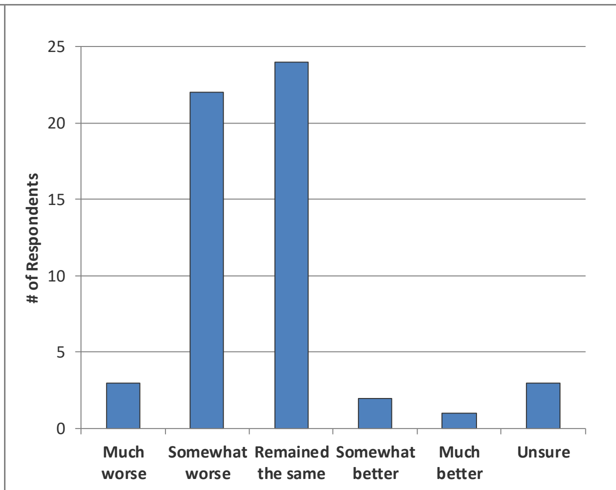


Figure 3.7-4. Stakeholder survey response Question #13. How has the quality of fishing changed on Upper Gresham Lake since you started fishing the lake?

Upper Gresham Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.7-5). Upper Gresham Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through tribal or recreational harvesting means. By March 15th of each year the relevant Indian communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal spearers or netters annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

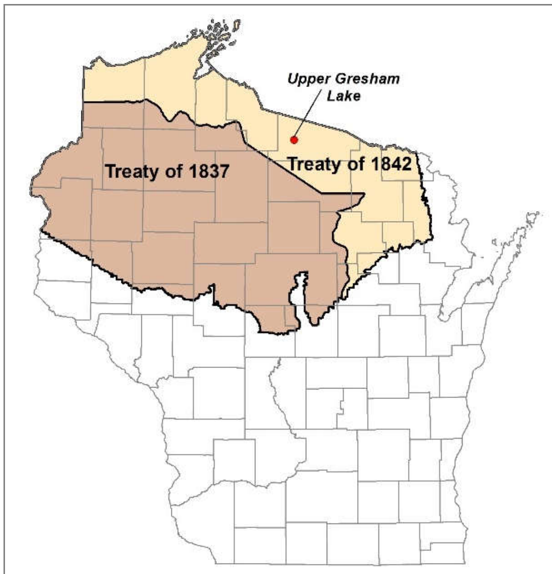


Figure 3.7-5. Location of Upper Gresham Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2016). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 3.7-6 from 2010 to 2017. As many as 49 walleye have been harvested from the lake in the past (2017), but the average harvest is roughly 22 fish in a given year. Spear harvesters on average have taken 59% of the declared quota. On average, 1% of harvested walleye have been female.

Muskellunge open water spear harvest records are provided in Figure 3.7-7 from 2010 to 2017. As many as five muskellunge have been harvested from the lake in the past (2013), however the average harvest is two fish in a given year.

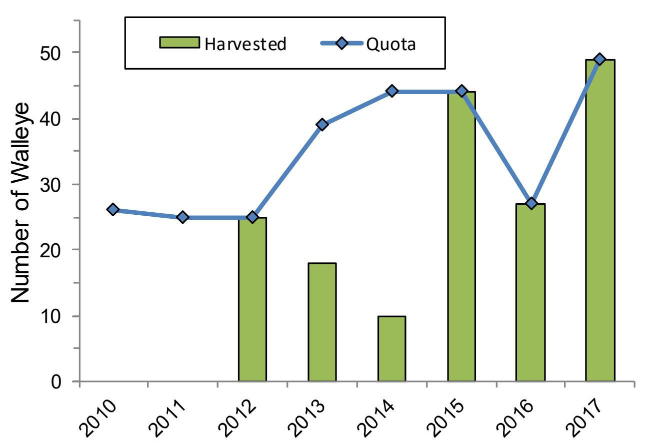


Figure 3.7-6. Upper Gresham Lake walleye spear harvest data. (GLIFWC 2010-2017).

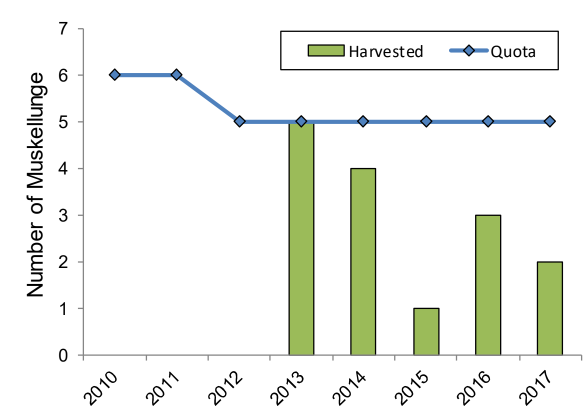


Figure 3.7-7. Upper Gresham Lake muskellunge spear harvest data. (GLIFWC 2010-2017).

Upper Gresham 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, 57% of the substrate sampled in the littoral zone of Upper Gresham Lake were soft sediments, 40% was composed of sand and 3% was composed of rock.

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). A fall 2017 survey documented 266 pieces of coarse woody along the shores of Upper Gresham Lake, resulting in a ratio of approximately 45 pieces per mile of shoreline.

Fish Habitat Structures

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

Photograph 3.7-3. Examples of fish sticks (left) and half-log habitat structures. (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 3.7-3). 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 GLA 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 Upper Gresham Lake.

Fishing Regulations

Regulations for Upper Gresham Lake gamefish species as of April 2018 are displayed in Table 3.7-4. 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. Upper Gresham Lake was one of five chosen lakes in Vilas County to experiment with a 28" minimum muskellunge size. Also included in the program is stocking of walleye and muskellunge (WDNR 2017).

Table 3.7-4. WDNR fishing regulations for Upper Gresham Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass	Catch and release only	None	May 5, 2018 to June 15, 2018
	5	14"	June 16, 2018 to March 3, 2019
Largemouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	28"	May 26, 2018 to November 30, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

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

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

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

Fish Consumption Guidelines for Most Wisconsin Inland Waterways

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

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

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

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 Upper Gresham 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 Upper Gresham 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 Upper Gresham Lake ecosystem, the folks that care about the lakes, and what steps can be taken by the GLA to protect and enhance the system.

Upper Gresham Lake contains *Good* to *Excellent* water quality compared to other deep headwater drainage lakes. Water clarity, total phosphorus, and chlorophyll-a parameters are all similar to mean values of other deep headwater drainage lakes and slightly lower than the mean values of lakes in the Northern Lakes and Forests ecoregion. There is some evidence that total phosphorus concentrations may be slightly increasing over the time of available data. Looking at sediment cores and inferring phosphorus concentrations from diatom fossils, Upper Gresham Lake currently has much higher phosphorus concentrations compared to before European settlers colonized the area.

Upper Gresham Lake contains a small watershed compared to the size of the lake, with most of the land within the watershed consisting of those types that deliver the least amount of phosphorus to the lake. Having a small watershed, the land use around the immediate shoreline areas are going to have a large influence over the lake's water quality. Only 9% of Upper Gresham Lake's shoreline consisted of the two most impactful categories (*urbanize*d and *developed–unnatural* shoreland, whereas 84% consisted of shorelines in the two most ecologically beneficial categories (*developed–natural* and *undeveloped*). It is fundamental to the health of Upper Gresham Lake to preserve natural shorelands and take steps towards shifting the proportion of developed shorelines into less impactful categories.

Upper Gresham Lake is a popular destination for anglers that primary target panfish, bass, muskellunge, and walleye. While riparian stakeholders believe the fishery is currently fair to good, they also believe that the fishery has remained the same or gotten worse since they first started fishing the lake. Upper Gresham Lake was found to have a relatively high amount of emergent coarse woody habitat, which is important for sustaining the lake's fishery.

By all standard metrics, the vegetation surveys revealed that the aquatic plant community of Upper Gresham Lake is of high quality and relatively stable over time. The paleocore studies indicate that Upper Gresham Lake likely had a similar distribution of short-statured turf-like aquatic plants (i.e. isoetids) and tall leafy aquatic plants (i.e. elodeids) prior to European settlement compared to present.

Exotic species, particularly EWM has been a focus of management for the GLA. The GLA used spatially targeted herbicide spot treatments from 2008 to 2013 in an effort to maintain a lowered EWM population within Upper Gresham Lake. This form of management was considered the best management practice (BMP) of the time, with the goal to target as small of an acreage as possible to minimize non-target impacts.

During this timeframe, the GLA participated in important collaborative research with the WDNR, US Army Corps of Engineers Research and Development Center (USACE), and private consultants. The GLA add layers of data collection to these spot treatments, such as rigorous sub-sample point-intercept surveys to evaluate the level of control and native plant collateral impacts from each treatment. These data were indicating the results of these treatments were mixed, with many only achieving seasonal EWM population suppression. This means that the EWM was largely undetectable for multiple months after the treatment took place, but rebound was occurring by the end of the growing season during the year of treatment and EW was found to be approximately at pretreatment levels by the end of the year after treatment.

Using a concept called adaptive management, each subsequent treatment strategy implemented by the GLA adopted advancements in BMPs that were emerging as part of the collaborative research project. This included changing herbicide formulations, increasing application dose, and increasing the size of the treatments with larger buffers. Ultimately it was determined that even by implementing the new BMPs, EWM control was largely limited to a single season.

The GLA pivoted towards hand-harvesting in 2014 and 2015, investing close to $7,500 per year for divers to remove EWM. These efforts fell short of the GLA's expectations. While engaged with the 2015-2017 cooperative research project between the UWSP and WDNR, the GLA was not permitted to conduct herbicide management. The EWM population during 2017, the final year of the project consisted of approximately 15 large, dense, and surface matting EWM colonies. Again, the GLA attempted to use manual removal of EWM with DASH but it became strikingly obvious that the size and densities of these colonies was beyond the scale at which hand-harvesting could be impactful. The hand harvesting strategy was only able to target a fraction of the acreage compared to herbicide treatment of the same monetary value.

In 2018, the GLA conducted additional trial herbicide treatments in two locations. The EWM in these areas was almost undetectable for most of the 2018 open water season. The late-season EWM mapping survey indicated that the larger and more protected site near the boat landing appeared to be quite effective, with only a small and low-density EWM colony being detected with submersible camera technology. This survey indicated that the other treatment site had significantly rebounded by the end of the summer and was almost at pretreatment levels. The results of these trial treatments were important considerations in developing an EWM management strategy as part of this management planning project.

Through the process of this lake management planning effort, the GLA has learned much about their system, both in terms of its positive and negative attributes. The GLA continues to be tasked with properly maintaining and caring for this resource. It is particularly important to protect high quality aspects of the Gresham Lakes ecosystem.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the GLA Planning Committee and ecologist/planners from Onterra. It represents the path the GLA 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 Gresham Lake stakeholders as portrayed by the members of the Planning Committee, the returned riparian 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 Lowered EWM Population Through Active Management

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at Upper Gresham public access location
Timeframe:	Starting 2020
Facilitator:	Board of Directors
Description:	Currently the GLA monitors the public boat landing at Upper Gresham Lake using training provided by the Clean Boats Clean Waters program. Upper Gresham Lake is a 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 Upper Gresham Lake. The goal would be 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 WDNR grant program favors projects that conduct a minimum of 200 annual hours of Clean Boats Clean Waters (CBCW) is an important. While the GLA has been able to meet past watercraft inspections commitments, this program has resulted in volunteer fatigue. Inspections at the Upper Gresham Lake landing peaked at approximately 150 hours in 2010. However, no hours have been recorded in 2014-2018. The GLA has committed to being a part of a town-wide CBCW program starting in 2020. This would consist of paid inspectors being present at the Upper Gresham public landing with partial funding through the WDNR's streamlined CBCW grant program.

Action Steps:	
	See description above.

<u>Management Action:</u>	Conduct three-tiered EWM population management on Upper Gresham Lake
Timeframe:	Continuation of current effort
Facilitator:	Invasive Species Committee w/ Board of Directors oversight
Description:	The goal of this action will be to minimize the periodic nuisance conditions that EWM causes on Upper Gresham Lake. The following management options are not listed in order of preference, but are in order of decreasing scale. The WDNR has indicated their preference for hand-harvesting during this project, and will continue to support the least secondarily impactful method that is feasible to alleviate an aquatic plant issue. The Lac du Flambeau Tribal Natural Resource Department maintains opposition to herbicide treatment on any lake within ceded territory for concerns of impacts to sensitive wild rice populations as well as potential impacts to larval fish. 1. **<u>Herbicide Spot Treatment</u>** When a Late Season AIS Survey documents colonized EWM populations that are *dominant* or greater in density, an herbicide spot treatment would be considered for the following early-spring. Herbicide spot treatment techniques would only be considered if the colonies have a size/shape/location where management is anticipated to be effective. In general, this would be areas confined to bays (not exposed), broad in shape (not narrow bands), and of sufficient size to hold core concentrations and exposure times (likely at least 5 acres or larger). The GLA understand that future herbicide use on Upper Gresham Lake is likely to have only limited applicability as most areas contain a narrow littoral footprint of EWM. Also, by targeting an area big enough to be effective, attention to basin-wide and lake-wide impacts also needs to occur. Future spot herbicide treatments may need to consider herbicides (diquat, florpyrauxifen-benzyl, etc) or herbicide combinations (2,4-D/endothall, diquat/endothall, etc) thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides (e.g. 2,4-D, triclopyr). However, these claims continue to be investigated in the field. Advancements in research into new herbicides and use patterns will need to be integrated into future management strategies, including effectiveness, native plant selectivity, and environmental risk profile. If the GLA decides to pursue future

herbicide management towards EWM, the following set of bullet points would occur:

- Early consultation with WDNR would occur.
- The proceeding annual AIS monitoring report would outline the precise control and monitoring strategy.
    - Monitoring EWM efficacy by comparing annual late-summer EWM mapping surveys.
    - If grant funds are being used or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with Appendix D of the WDNR Guidance Document, Aquatic Plant Management in Wisconsin (WDNR 2010). This generally consist of collecting quantitative point-intercept sub-sampling on sites approximately 10-acres or greater during the summer before the treatment (pre) and summer following the treatment (post). Herbicide concentration monitoring may also occur surrounding the treatment in these instances.
- An herbicide applicator firm would be selected in late-winter and a conditional permit application would be applied to the WDNR.
- A focused pretreatment survey would take place approximately a week or so prior to treatment (approx. 2-3 weeks after ice-out). This site visit would evaluate the growth stage of the EWM (and native plants) as well as to confirm the proposed treatment area extents and water depths. This information would be used to finalize the permit, potentially with adjustments and dictate approximate ideal treatment timing.
- Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would occur. This would consist of the herbicide treatment occurring when mid-depth water temperatures are roughly below 60°F and active growth tissue is confirmed on the target plants. Considerations would also be given to completing the herbicide application after the Lac du Flambeau Band of Lake Superior Chippewa Indians has finished their spring open-water spear harvest.

2. **Mechanical Harvesting** When the Late Season AIS Survey documents colonized EWM populations that are *highly dominant* or *surface matting* and are impacting navigation and recreation, contracting with a mechanical harvesting program (i.e. weed cutter) would be considered for the following summer. The mechanical harvester would remove the dense biomass that is near

the surface. It is likely that a predetermined minimum acreage of mechanical harvesting would be required in a given year to be commensurate with the costs of mobilization. Current estimates of contracting mechanical harvesting at the time of this writing is potentially $3,000 a day plus a mobilization fee ($1,500). Many mechanical harvesting contract firms have a minimum project size (e.g. 3 days' worth of harvesting) that needs to be considered. At this time, the EWM population in Upper Gresham Lake is below thresholds that would justify the GLA purchasing their own equipment, but the concept could be revisited at a later date.

- Early consultation with WDNR would occur.
- The annual AIS monitoring report would outline the control strategy.
- A mechanical harvester firm would be selected in late-winter and a conditional permit application would be applied to the WDNR.
- A focused pre-harvesting survey (likely in mid-June) may be requested by WDNR to finalize the permit, potentially with adjustments, and dictate approximate ideal implementation timing. Conditions the WDNR includes on the permit will drive the scope of the pre-harvesting survey, if one is necessary. Some research has indicated more selectivity towards EWM and longer lasting results if implemented earlier in the season (potentially mid-June) before the EWM gains significant biomass and expresses the conditions that trigger implementation.
- Mechanical harvesting operations would have the following guidelines:
    - The harvester would not be permitted in waters less than 3-feet to minimize sediment disturbance.
    - Cut no more than half the water depth.
    - An attempt would be made to return all gamefish, panfish, amphibians, and turtles to the water immediately.
    - The goal would be to have maximum vegetation reduction during July-August, corresponding with peak summer use of the lake. Harvesting may be warranted to start in late-June to early-July. A second cutting may be required.
    - The WDNR has indicated that they would not allow for the harvest of areas below the thresholds outlined above in order to give a harvester sufficient work to satisfy a minimum contract size.

3. **<u>Hand-Harvesting (includes DASH)</u>** The GLA feels that hand-harvesting for EWM population control is "costly and ineffectual," but may be applicable to minimize nuisance

	conditions if targeted towards small areas. If large and contiguous EWM colonies exist, removing EWM in navigation lanes through hand-harvesting, likely with Diver-Assisted Suction Harvest (DASH), may be appropriate. ▪ The GLA may choose to defer the costs of conducting the hand-harvesting to the benefitting riparians even though the GLA would be the entity applying for and funding the permit. • In high-use areas that benefit more than adjacent riparians, the GLA would give considerations to incurring the hand-harvesting costs. • A hand-harvesting firm would be selected and a conditional permit application would be applied to the WDNR. The strategy outlined above does not specifically address the EWM population of Upper Gresham Lake, rather the nuisance conditions that future EWM populations may cause on Upper Gresham Lake. The 2017 point-intercept survey yielded EWM present at 2.7% of the littoral sampling points within Upper Gresham Lake. If the EWM population quadruples (4x), the population would be just over 10%. If the EWM populations exceeds 10% as measured by the point-intercept survey, the nuisance strategy outlined here would be revisited, potentially for considering the development of more aggressive forms of management including, but not limited to, a whole-lake herbicide treatment strategy. The WDNR will be notified when the trigger is reached and consulted when a strategy is being considered.
Action Steps:	
	See description steps above.

Management Goal 2: Monitor Aquatic Vegetation on the Gresham Lakes

Management Action:	Coordinate professional monitoring of EWM
Timeframe:	Continuation of current effort
Facilitator:	Invasive Species Committee w/ Board of Directors oversight
Description:	As the name implies, the Late-Season EWM Mapping Survey is completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For the Gresham Lakes, this survey would likely take place in mid-August to late-September. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). This survey would serve three main roles: 1) document the EWM population at the peak of its growth stage in a given year, 2) assess the management efforts that took place over the growing season, and 3) be used to formulate a management strategy. If a lake is conducting or considering active EWM management, this survey would occur during the year prior to management and the year of management. On Upper Gresham Lake, it is anticipated that this survey would take place annually or semi-annually, prompted by perceived conditions of the lake by the GLA Board. On Middle Gresham Lake, EWM exists but the population has remained extremely low since detection. The GLA will consider conducting a Late-Season EWM Mapping Survey on Middle Gresham Lake approximately every 3-5 years. EWM has not been detected from Lower Gresham Lake. Conducting a Late-Season EWM Mapping Survey on Lower Gresham Lake approximately every 5 years would assist in locating AIS populations early and before they become established. If EWM is suspected from Lower Gresham Lake, this may also trigger a mapping survey to take place.
Action Steps:	
	See description above as this is an established program.

Management Action:	Coordinate Periodic Point-Intercept Surveys
Timeframe:	Every 3-5 years depending on management strategies being employed
Facilitator:	Invasive Species Committee w/ Board of Directors oversight

Description:	The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) have been conducted on the Gresham Lakes in the past. At each point-intercept location within the *littoral zone,* information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR generally recommends that a whole-lake point-intercept survey be conducted once every 5 years if a lake group wants to understand the aquatic plant community dynamics of a lake. This will also allow an understanding of changes in the EWM population for determination if active management should be considered, particularly if EWM populations exceed 10% of the littoral zone as measured by the point-intercept survey. For lakes conducting active management, a whole-lake point-intercept surveys should be conducted at a minimum once every 3 years (potentially on Upper Gresham Lake). In some instances of particularly aggressive active management, the WDNR may require annual point-intercept surveys. The GLA will plan to complete point-intercept surveys on Middle Gresham Lake and Lower Gresham Lake at approximately 5-year intervals.
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
Timeframe:	Every 10 years unless prompted
Facilitator:	Invasive Species Committee w/ Board of Directors oversight
Description:	In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in the Gresham Lakes, a community mapping survey would be conducted approximately every 10 years unless a specific rationale prompts a shorter interval. This survey would delineate the margins of floating-leaf (e.g. water lilies) and emergent (e.g. cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system.
Action Steps:	
	See description above as this is an established program.

Management Goal 3: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality of Gresham Lakes through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors
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 should be completed annually by Gresham Lakes 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 GLA currently monitor a single site in Upper Gresham Lake under the advanced CLMN program. This includes collecting Secchi disk transparency, as well as sending in water chemistry samples (chlorophyll-*a*, and total phosphorus) to the Wisconsin State Laboratory of Hygiene (WSLH) for analysis. The samples are collected three times during the summer and once during the spring. 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). Historically, water quality information has been completed only semi-periodically on Middle Gresham Lake and Lower Gresham Lake. The GLA will strive to at least collect Secchi disk transparency data on these lakes in conjunction with the sampling that is currently being conducted on Crooked Lake. At an interval of approximately every 5 years, the GLA would have water chemistry data collected on Middle Gresham and Lower Gresham Lake consistent with the advanced CLMN program. Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to enroll in this program, ensure the proper training occurs, and the necessary sampling materials are received. As a part of the program the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer. It also must be noted that the CLMN program may be changing in the near future.
Action Steps:	

1.	Contact Sandra Wickman (715.365.8951) to enroll in the CLMN program.
2.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and report results to association members during annual meeting.
3.	CLMN volunteer and/or GLA would facilitate new volunteer(s) as needed

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

Management Action:	Use education to promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The GLA maintains an updated website (greshamlakesassociation.com), periodic newsletter, and a Facebook Page (www.facebook.com/greshamlakes) for social announcements and communication These mediums allow for exceptional communication with association members. This level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings. The GLA 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. *Example Educational Topics* • Aquatic invasive species identification • Basic lake ecology • Noise, air, and light pollution • Shoreline habitat restoration and protection • Fireworks • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Boating safety (promote existing guidelines, Vilas County Courtesy Code)
Action Steps:	
	See description above as this is an established program.

Management Action:	Continue GLA's involvement with other entities that have responsibilities in managing (management units) The Gresham Lakes
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
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 GLA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page:
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Boulder Junction	Daniel Driscoll (Clerk/Treasurer) clerk@townofboulderjunction.org	The Gresham Lakes falls within the Town of Boulder Junction and has representation on this committee	GLA representative attend committee meetings	Aspects of the Gresham Lakes that involve the township government such as ordinances, building and zoning, and funding opportunities
Vilas County Lakes & Rivers Association	President (Tom Ewing. tomewingjr@aol.com)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	Invasive Species Coordinator (Cathy Higley – 715.479.3738)	Oversees AIS monitoring and prevention activities locally.	As issues arise.	AIS training and ID, AIS monitoring techniques
Vilas County Land & Water Conservation Department.	Conservation specialist (Mariquita Sheehan – 715.479.3721)	Oversees conservation efforts for land and water projects.	As opportunities arise.	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Eric Wegleitner – 715-356-5211 ext. 246)	Manages the fishery of The Gresham Lakes	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.8937 or Carol Warden - 715.356.9494)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	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.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
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.	GLA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years
Facilitator:	Board of Directors
Description:	Approximately once every 5-7 years, an updated stakeholder survey would be distributed to the Gresham Lakes riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during fall 2017, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

Management Goal 5: Improve Lake and Fishery Resource

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Ongoing effort
Facilitator:	Board of Directors
Description:	As discussed in the Shoreland Condition Section (3.3), the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. Approximately a quarter of Upper Gresham Lakes' privately-owned shoreline is either *urbanized* or *developed-unnatural* and could be the focus of potential future restoration efforts. The GLA believes its constituents are concerned about perceived overreach of property rights and policing of shorelines when the topic of shoreland restoration is discussed. The GLA will continue to provide information to association members on shoreland restoration and the

	WDNR's Healthy Lakes Implementation Plan. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through Vilas County. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap) • Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances • Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available Approximately 45% of Upper Gresham Lakes' privately-owned shoreline is *natural/undeveloped* and could be the focus of preservation efforts. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Vilas County Land & Water Conservation Department. Several websites of interest include: • Conservation easements or land trusts: (www.northwoodslandtrust.org) • UW-Extension Shoreland Restoration: (https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/ecology/shoreland/default.aspx) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)
Action Steps:	
	See description above

Management Action:	Educate Stakeholders on the Importance of course woody habitat in the Gresham Lakes
Timeframe:	Ongoing effort
Facilitator:	Board of Directors

Description:	GLA stakeholders realize the complexities and capabilities of the Gresham Lakes ecosystem with respect to the fishery it can produce, particularly on Upper Gresham Lakes. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.4) and Fisheries Data Integration Section (3.7) discuss the benefits of coarse woody habitat in detail. The GLA will continue to provide information to association members on coarse woody habitat and the WDNR's Healthy Lakes Implementation Plan.
	
	The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for fish stick projects. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
	    o The landowner would need to commit to leaving the area un-mowed
	    o The landowner would need to implement a native planting (also cost share thought this grant program available)
	• Coarse woody habitat improvement projects require a general permit from the WDNR
	• Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:	
	See description above

Management Action:	Conduct beaver population control
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors
Description:	As a natural part of the ecosystem, beavers are able to influence water levels and potentially create user conflicts. However, the influence of beavers on the water levels of a lake is often over-estimated. WDNR regulations (NR12) indicate that aside from legal harvest of beavers by a licensed trapper, beaver control will be permitted only when property damage is documented. The natural connections between and flowing from the Gresham Lakes are ideal habitat for beavers. It is a common belief among Gresham Lakes riparians that beaver activity has a large influence on the water levels of all three lakes. It is further believed that if beaver populations are left unchecked, damage and destruction of riparian shorelines can occur from high-water. The GLA would periodically hire a professional trapper to harvest beavers during the permitted season. They would also periodically remove beaver dams (between Middle Gresham Lake and Lower Gresham Lake and on the outlet of Lower Gresham Lake) when properties are being impacted. This action would be on an as-needed basis.
Action Steps:	
	See description above as this is an established program.

Management Action:	Initiate the Loon Watch program
Timeframe:	Spring 2019
Facilitator:	Board of Directors
Description:	The GLA has passively monitored Loon activity, particularly on Upper Gresham Lake, and has interest in participating in a more formal program. The Loon Watch Program is operated through the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide a picture of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. The GLA will make an effort to keep a volunteer(s) enrolled in this program, with that volunteer providing information and education to its membership at the association's annual meetings.
Action Steps:	
	See description above

6.0 METHODS

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Upper Gresham 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 once in spring and three times during the summer. In addition to the samples collected by Gresham Lake Association, members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, winter, and fall. Although GLA members collected a spring total phosphorus sample, professionals also collected a near bottom sample to coincide with the bottom total phosphorus sample. 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**	**S**	**S**	**B**	**S**	**B**
Total Phosphorus	■♦	■	♦	♦	♦	■	■	■	■
Dissolved Phosphorus	■	■						■	■
Chlorophyll-*a*	■		♦	♦	♦	■			
Total Kjeldahl Nitrogen	■	■	●	●	●	■		■	■
Nitrate-Nitrite Nitrogen	■	■	●	●	●	■		■	■
Ammonia Nitrogen	■	■	●	●	●	■		■	■
Laboratory Conductivity	■	■							
Laboratory pH	■	■							
Total Alkalinity	■	■							
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 Upper Gresham 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)

Paleocore Collection & Analysis

A sediment core was collected in the deep area of the lake. The top 1 cm of sediment was collected and represents present day conditions. A sample of sediment near the bottom of the core was also collected and represents pre-European settlement conditions. To assure that the bottom sample represents pre-settlement conditions, a portion of it is analyzed at the WSLH for the isotope, lead 210. This isotope remains at detectable levels for about 130 years, so if concentrations are negligible, we know that the sediment was deposited over 130 years ago. The diatom community is examined in the top and bottom samples.

Acoustic Modeling Survey

During the mid- to late-summer 2017, Onterra systematically collected continuous, advanced sonar data across the Upper Gresham Lake. The resulting data was electronically sent to a Minnesota-based firm (Navico) for initial processing. The acoustic data collected during the lake management planning project was analyzed for bathymetry, submersed aquatic vegetation bio-volumes, and substrate analysis models.

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on Upper Gresham 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.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types within Upper Gresham Lake (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) receiver 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.

AIS Mapping Surveys

During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat. Field crews may supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to EWM locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.

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