Bullhead Lake

Manitowoc County, Wisconsin

Comprehensive Management Plan

January 2019

Sponsored by:

Bullhead Lake Advancement Association, Inc.

WDNR Grant Program

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Onterra LLC
Lake Management Planning

Bullhead Lake

Manitowoc 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:

Bullhead Lake Planning Committee

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1.0 INTRODUCTION

Bullhead Lake is a drainage lake with a maximum depth of 38 feet and a mean depth of 14 feet. This eutrophic lake has a small watershed when compared to the size of the lake. Bullhead Lake contains 15 native plant species, of which coontail is the most common plant. Three exotic plant species are known to exist in Bullhead Lake. According to the 1972 recording sonar WDNR lake survey map, Bullhead Lake, Manitowoc County, is 67 acres. The WDNR website indicates the lake is 70 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program (NAIP)*, collected in the summer of 2015. Based on heads-up digitizing the water level from that aerial photograph, the lake was determined to be 73 acres.

Field Survey Notes

During the early season survey, Bullhead Lake was noted to have a wide variety of aquatic plants and relatively clear water. Upon return in July, a large algae bloom was occurring, creating unpleasant conditions for property owners.

Photograph 1.0-1 Bullhead Lake, Manitowoc County

Lake at a Glance - Bullhead Lake

Morphology	
Acreage	73
Maximum Depth (ft)	38
Mean Depth (ft)	14
Shoreline Complexity	1.2
Vegetation	
Curly-leaf Survey Date	May 26, 2017
Comprehensive Survey Date	July 13, 2017
Number of Native Species	15
Threatened/Special Concern Species	-
Exotic Plant Species	Eurasian watermilfoil, Curly-leaf pondweed, Giant hogweed
Simpson's Diversity	0.54
Average Conservatism	4.7
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	9.1
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	3:1

Bullhead Lake is located within the Town of Rockland in western Manitowoc County, WI. The lake is located in the Lower Manitowoc River watershed, which is dominated by agricultural land use. Surrounding row crop agriculture has degraded the lake's water quality and the WDNR lists the lake as impaired due to excessive algae growth and mercury. The lake is also on the 303(d) listing for phosphorus and mercury.

The algae blooms experienced in Bullhead Lake, particularly nuisance filamentous algae, is due to high levels of phosphorus. To help control the blooms an alum treatment was conducted on the lake in 1978 with a second treatment occurring in 1988. Bullhead Lake has also received a high ranking in the Nonpoint Source Program. The BLAA was awarded one large-scale LPL to fund a catch basin study in 1995 and two small-scale LPL grants to create an aquatic plant management plan in 2007.

Aquatic invasive species (AIS) have also been found to exist within Bullhead Lake. Curly-leaf pondweed was first found within the lake in 2003 and Eurasian watermilfoil was first found in 2005. Since their discovery, both AIS have been periodically monitored and have remained at low densities within the lake.

2.0 STAKEHOLDER PARTICIPATION

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

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

General Public Meetings

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

Kick-off Meeting

On June 24, 2017, a project kick-off meeting was held at a board member's home to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Bullhead Lake Advancement Association (BLAA) board members. The approximately 13 attendees observed a presentation given by Eddie Heath, an aquatic ecologist with Onterra. Mr. Heath's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Project Wrap-up Meeting

The Bullhead Lake Planning Committee will conduct a Wrap-up Meeting during the summer of 2019.

Committee Level Meetings

Planning committee meetings, similar to general public meetings, were used to gather comments, create management goals and actions and to deliver study results. These two meetings were open only to the planning committee and were held during the week. The first, following the completion of the draft report sections of the management plan. The planning committee members were supplied with the draft report sections prior to the meeting and much of the meeting time was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The objective of the first meeting was to fortify a solid understanding of their lake among the committee members. The second planning committee meeting was held a few weeks after the first and concentrated on the development of management goals and actions that make up the framework of the implementation plan.

Planning Committee Meeting I

Planning Meeting I was held on June 14, 2018 at Ron Gerrit's residence on the lake. Nine members of the BLAA Planning Committee attended the meeting that lasted approximately 3 hours. The primary objective of the meeting was to go over the results and conclusions of the studies completed by Onterra, LLC and the historical data that had been compiled. Tim Hoyman of Onterra delivered the results and conclusions during a presentation that covered Bullhead Lake's water quality, watershed, aquatic plants, shoreland condition, and fisheries. Much of the discussion revolved around the recent negative changes in Bullhead Lake's water quality, the reasons for the change, and possible solutions.

Planning Committee Meeting II

Planning Meeting II was held at Ron Gerrit's residence on July 23, 2018 and included 8 planning committee members. Tim Hoyman began the meeting by providing an overview of the results, conclusions, and discussions from the previous meeting. The Planning Committee was then led through an exercise that created a list of challenges that Bullhead Lake is facing and the BLAA is facing in managing the lake. Further discussion among the group converted those challenges to realistic management goals with associated management actions. Tim Hoyman utilized that list to create a rough draft of the Bullhead Lake Implementation Plan which was provided to the committee for comments in October 2018. The committee's comments were then integrated within the document.

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners and BLAA members around Bullhead Lake. The survey was designed by Onterra staff and the BLAA planning committee and reviewed by a WDNR social scientist. During September 2017, the eight-page, 31-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 BLAA volunteer for analysis. Thirty-nine percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Bullhead Lake. The majority of stakeholders (87%) are year-round residents while 13% visit on weekends throughout the years. 47% of stakeholders have owned their property for over 15 years, and 7% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1, 2.0-2, and

2.0-3 highlight several other questions found within this survey. Almost all survey respondents indicate that they use a pontoon boat (Question 12). Canoes and kayaks were also a popular option. On a small lake such as Bullhead Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 15, two of the top recreational activities on the lake involve boat use (pontoon riding and open water fishing). Although excessive watercraft traffic and unsafe watercraft practices were listed as factors potentially impacting Bullhead Lake in a negative manner (Question 21), they were not listed as one of the stakeholder's top concerns regarding the lake (Question 22).

A concern of stakeholders noted throughout the stakeholder survey (see Questions 21-22 and survey comments – Appendix B) was farm runoff within Bullhead Lake's watershed and algae blooms in the lake. This topic is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Question 12: What types of watercraft do you currently use on Bullhead Lake?

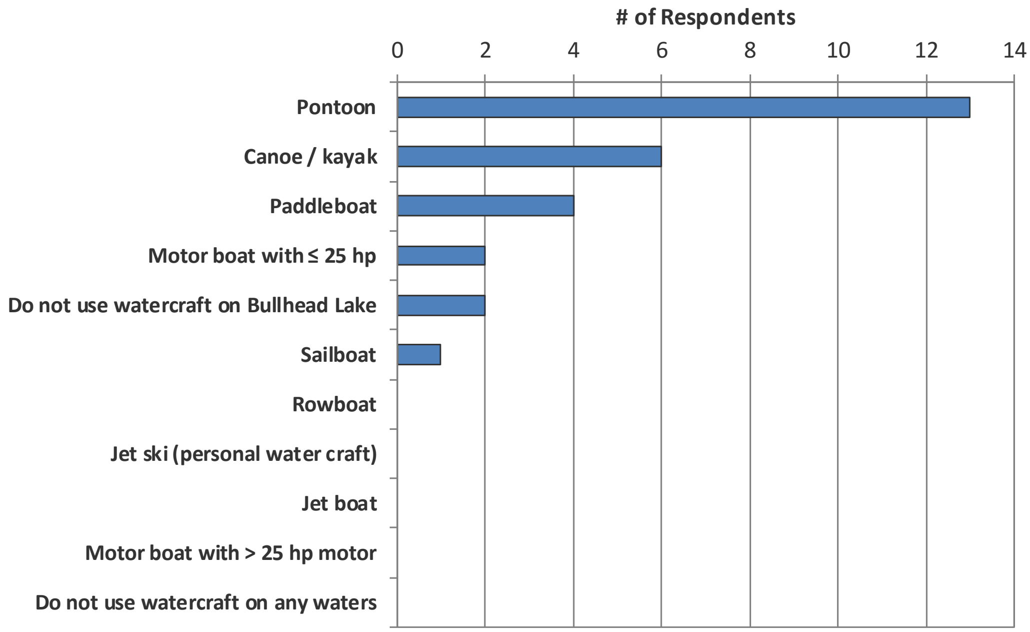
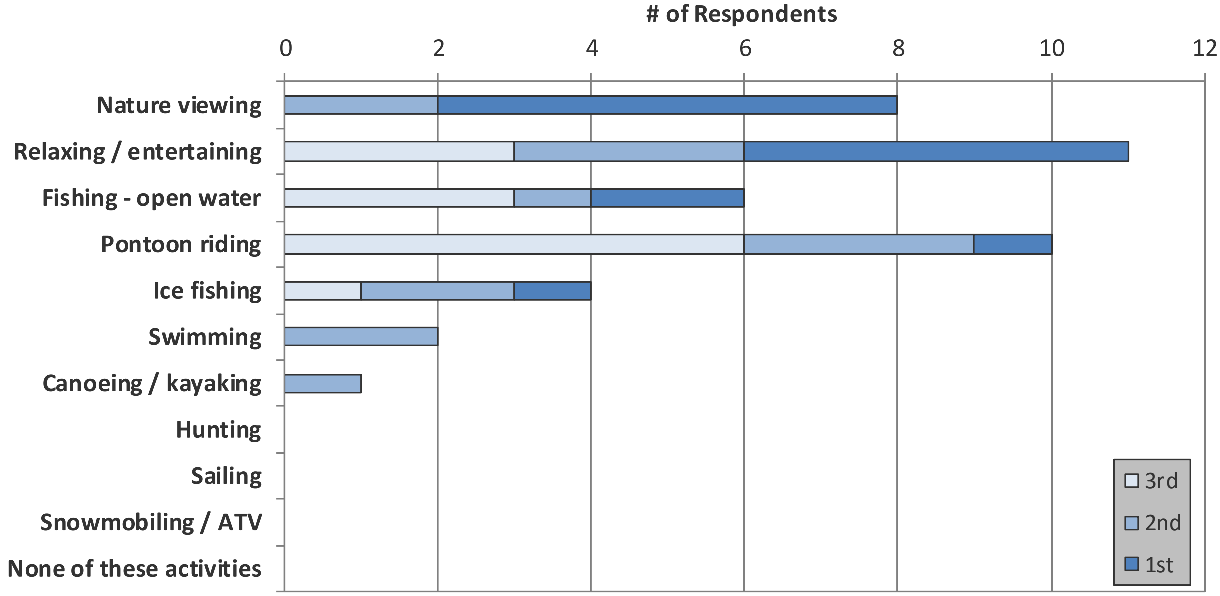


Figure 2.0-1. Select survey responses from the Bullhead Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 15: Please rank up to three activities that are important reasons for owning your property on Bullhead Lake.



Question 21: To what level do you believe these factors may be negatively impacting Bullhead Lake?

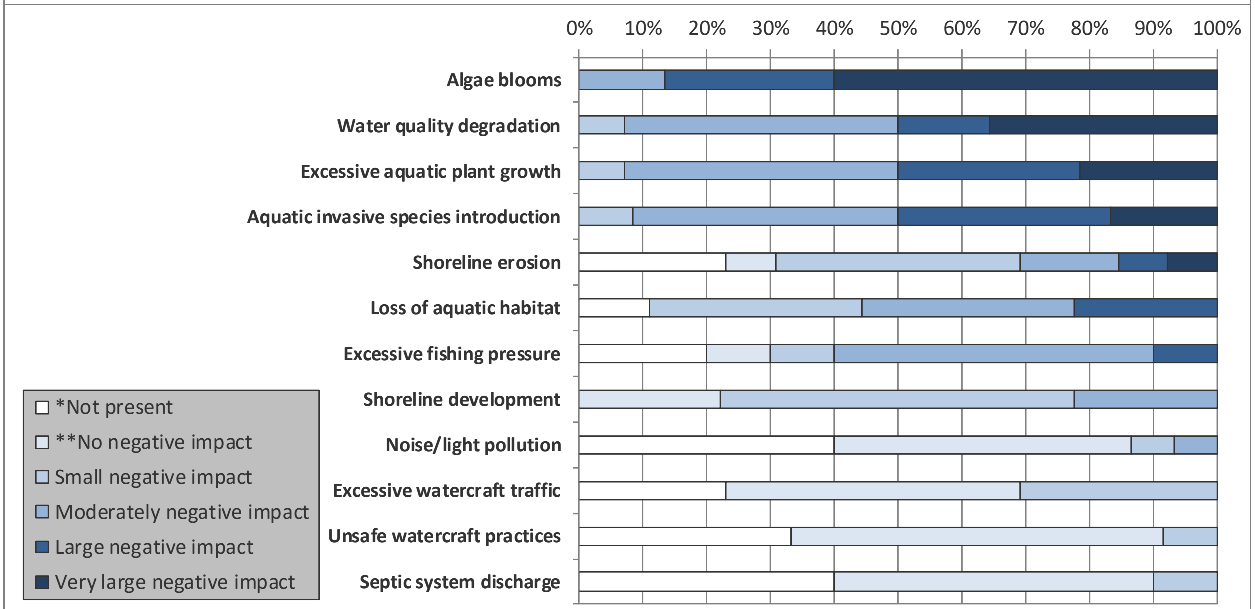


Figure 2.0-2. Select survey responses from the Bullhead Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Question 22: Please rank your top three concerns regarding Bullhead Lake.

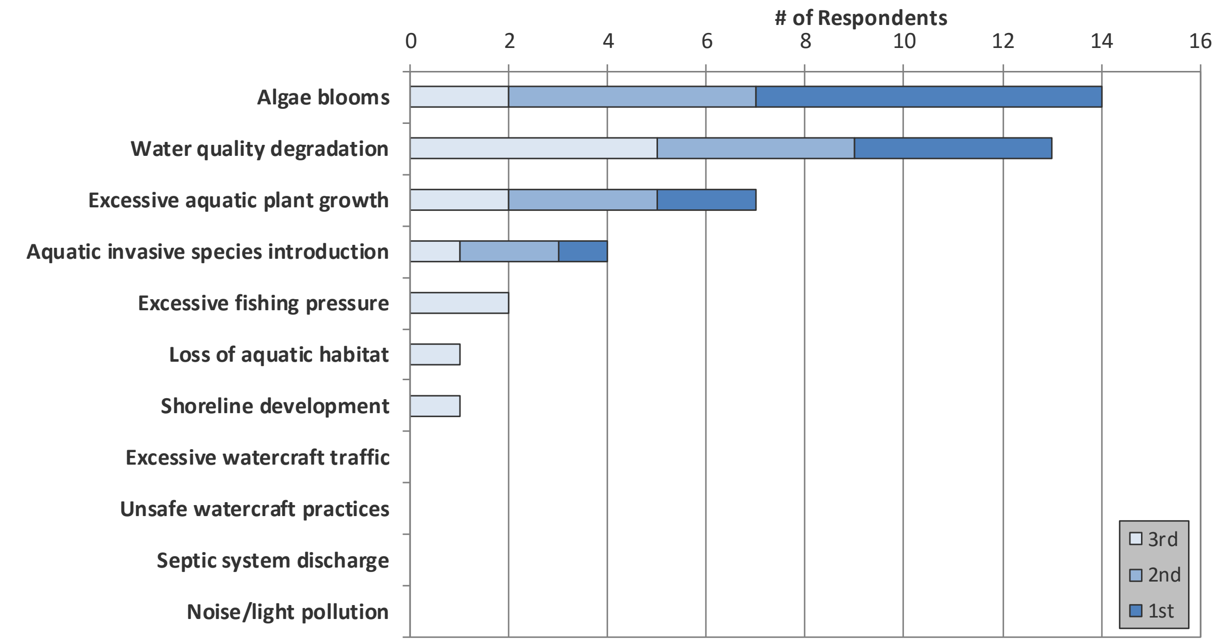


Figure 2.0-3. Select survey responses from the Bullhead Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

A primary objective of the Bullhead Lake management plan is to improve water quality. This is brought forth in Management Goal 1 and the actions listed to meet that goal. The final action in Goal 1 describes the completion of a diagnostic-feasibility study on Bullhead Lake to determine if an alum treatment would improve the lake's water quality for a reasonable period of time if the dosage was correct. A project design and estimated cost to complete the diagnostic-feasibility study was provided to the BLAA for use at the association annual meeting on June 24, 2018. The project was discussed and approved at the meeting.

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 Bullhead Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Bullhead 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 disc 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 disc 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 disc with alternating black and white quadrates (a Secchi disc) 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 disc 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

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.

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.

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

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

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

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

The WDNR lists Bullhead Lake as a deep seepage lake. However, a forested wetland borders the southeast lobe of the lake and during years of high lake levels it appears that Bullhead Lake likely drains to the wetland, which drains to a small stream to the east of the lake (Photograph 3.1-1). For this reason, following the review of Bullhead Lake's watershed and historical aerial photography, it was determined that Bullhead Lake is instead a deep headwater drainage lake (category 3 on Figure 3.1-1). In the following section, Bullhead Lake will be compared with deep headwater drainage lakes in Wisconsin instead of deep seepages lakes.

Photograph 3.1-1. Aerial View of Bullhead Lake. Aerial photograph: Google Earth, 2015.

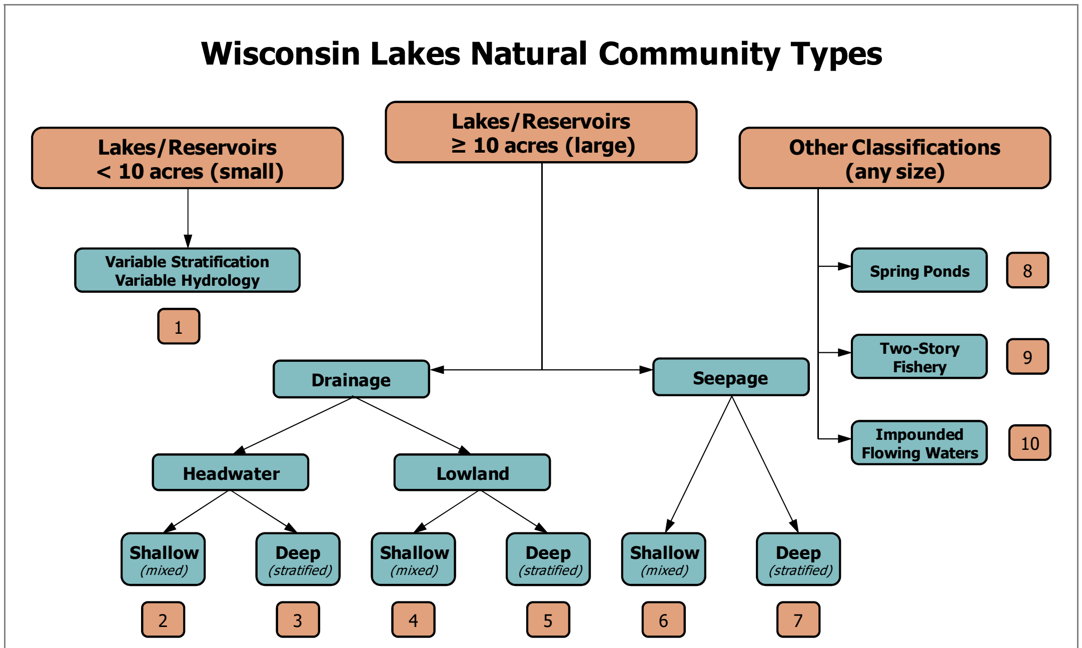


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

Garrison, et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disc 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. Bullhead Lake is within the Southeastern Wisconsin Till Plains (SWTP) ecoregion.

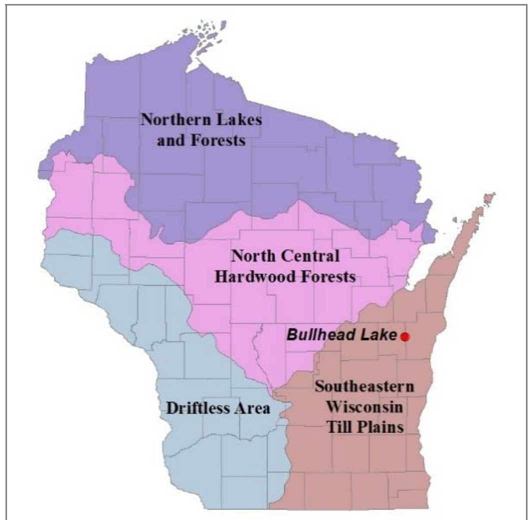


Figure 3.1-2. Location of Bullhead Lake within the ecoregions of Wisconsin. After Nichols 1999.

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 disc 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 Bullhead Lake is displayed in Figures 3.1-3 - 3.1-17. 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.

Bullhead Lake Water Quality Analysis

Bullhead Lake Long-term Trends

Near-surface total phosphorus data from Bullhead Lake is available intermittently from 1988 to 1991 and annually from 1993 to 2017 (Figure 3.1-3). Average summer total phosphorus concentrations ranged from 21 µg/L in 1997 to 62 µg/L in 2017. The weighted summer average total phosphorus concentration is 31 µg/L and falls into the *fair* category for Wisconsin's deep headwater drainage lakes. Bullhead Lake's phosphorus concentrations are approximately two times higher than the median values for deep headwater drainage lakes in the state and are higher than the median values of all lake types within the SWTP ecoregion.

Diatoms are an ecologically diverse algal group with silica-based cell walls called frustules. Diatom frustules are highly resistant to degradation and remain entombed in lake sediments after the algae die. This makes the diatom community useful in reconstructing a lake's ecological history. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels.

In 1991 a sediment core was collected from the deepest area in the lake by staff of the Wisconsin Department of Natural Resources. This core was used to reconstruct the water quality history of Bullhead Lake from 1840 through 1991 (Garrison 2008). The diatom community was used to reconstruct the phosphorus concentrations through time and found that the concentrations in the lake prior to the arrival of Euro-Americans was 15-20 µg/L (Figure 3.1-4). In the 1920s phosphorus concentrations greatly increased and peaked around 1940. This likely was the result of agricultural activity in the lake's watershed. An aerial photo taken in July 1938 shows farm fields at or near the lake edge on the east and west sides of the lake. Although the photograph is in black and white, the lake water appears opaque as if there was a severe algal bloom occurring. By 1960, the phosphorus levels were greatly reduced to around 30 µg/L and these concentrations remained until the early 1990s. The reduction in phosphorus likely was the result of some of the land in the watershed being converted from agricultural use to homes around the lakes. A similar trend was observed in Ashippun Lake in Waukesha County when agricultural land was converted to homes.

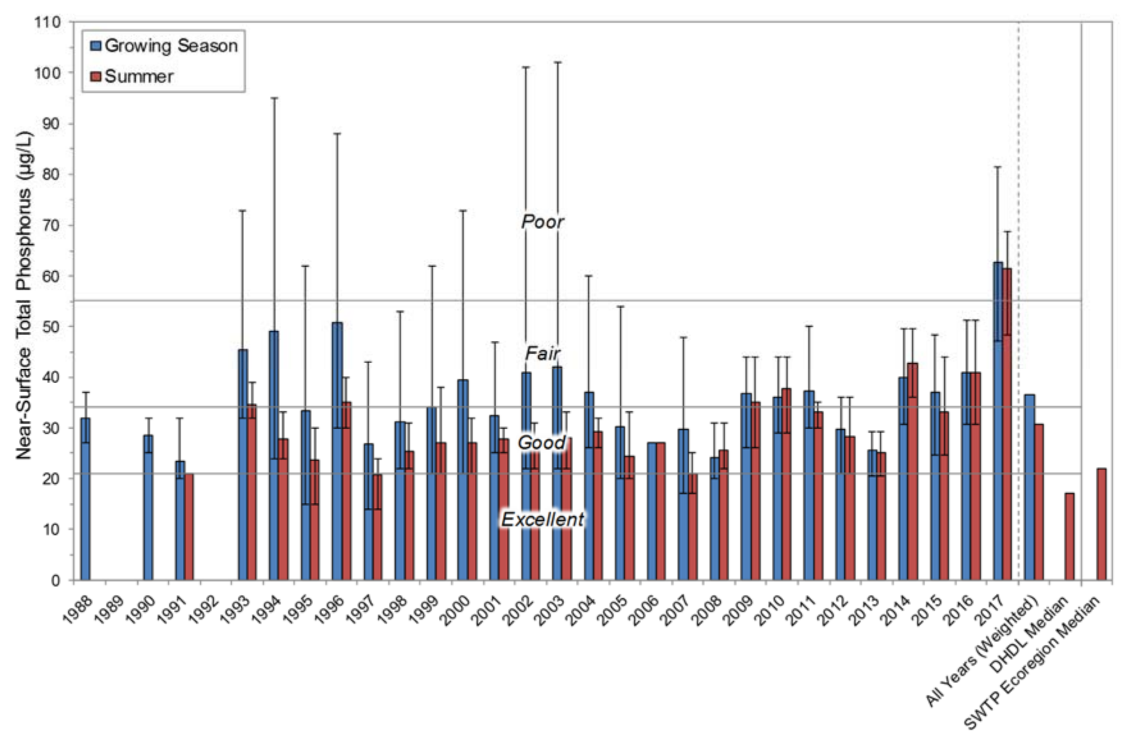


Figure 3.1-3. Bullhead Lake, deep headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

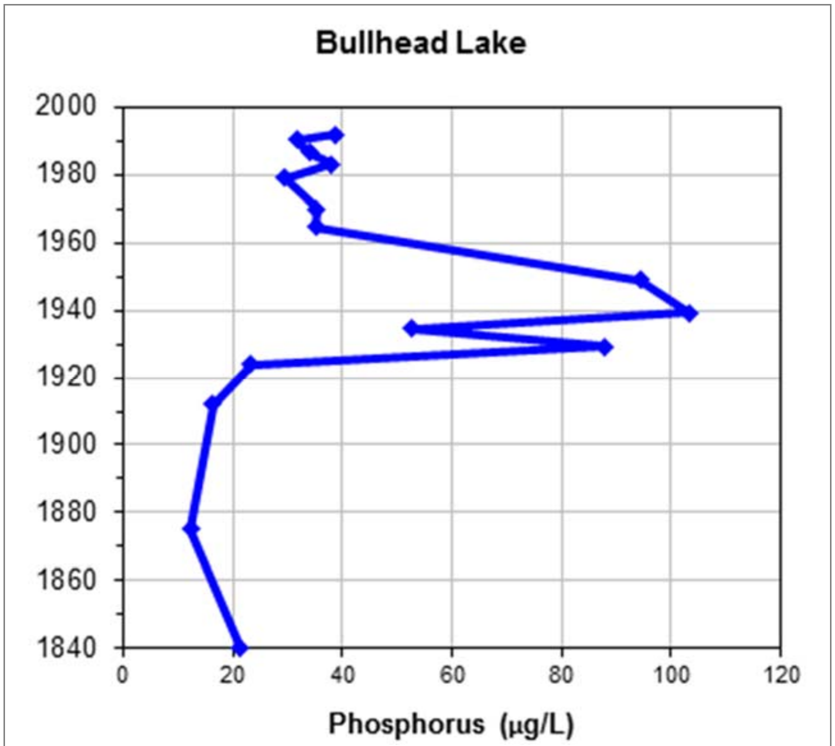


Figure 3.1-4. Historical phosphorus concentrations in Bullhead Lake estimated from the diatom community.

To determine if internal nutrient loading, previously discussed in the introductory sections, is a significant source of phosphorus in Bullhead Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom and near-surface total phosphorus concentrations are displayed in Figure 3.1-5 from 1988 to 2017. As illustrated, in April 2017 the near-bottom concentration is only slightly higher than the near-surface concentration, but July 2017 near-bottom concentrations are nearly nine times higher than near-surface concentrations. The higher concentrations of phosphorus near the bottom occurred when Bullhead Lake was stratified and the hypolimnion was anoxic. These higher concentrations near the bottom are an indication that phosphorus is being released from bottom sediments into the overlying water during periods of anoxia. Without an advanced water quality study, a measurement of the amount and extent of internal nutrient loading occurring in Bullhead Lake is impossible.

Aluminum sulfate (alum) treatments occurred on Bullhead Lake in 1978 and in 1988. Alum is applied to the near surface waters of the lake. It quickly settles to the bottom of the lake where it acts as a barrier to phosphorus being released from the sediments. While on the sediments the aluminum binds with sediment phosphorus to prevent it from entering the water column even when the bottom waters are anoxic. As mentioned above in the description of internal loading, iron bound phosphorus in the sediments dissolves when there is no oxygen and the iron and phosphorus move from the sediments into the over lying water. Alum is effective because it binds with the phosphorus and the aluminum-phosphorus bond is not sensitive to oxygen concentrations. In other words, the phosphorus bound with the aluminum remains in the sediments even in the absence of oxygen. Eventually all of the phosphorus binding sites are saturated and the alum layer no longer prevents internal loading. The longevity of the alum is dependent upon how much alum is added as well as how much sediment and phosphorus enters the lake from the watershed. The material from the watershed both buries the alum layer and provides phosphorus which help saturate the aluminum binding sites.

As seen in Figure 3.1-5, near-bottom phosphorus concentrations were similar to near-surface concentrations until 1990. If alum is applied in high enough doses, it is effective for a number of years. It appears that either not enough alum was added to the lake or enough phosphorus was delivered to Bullhead Lake for the alum treatment to only be effective for a few years. Internal nutrient loading began again in 1991 and continues at the present time with the highest measured phosphorus concentrations in the bottom waters occurring in 2017.

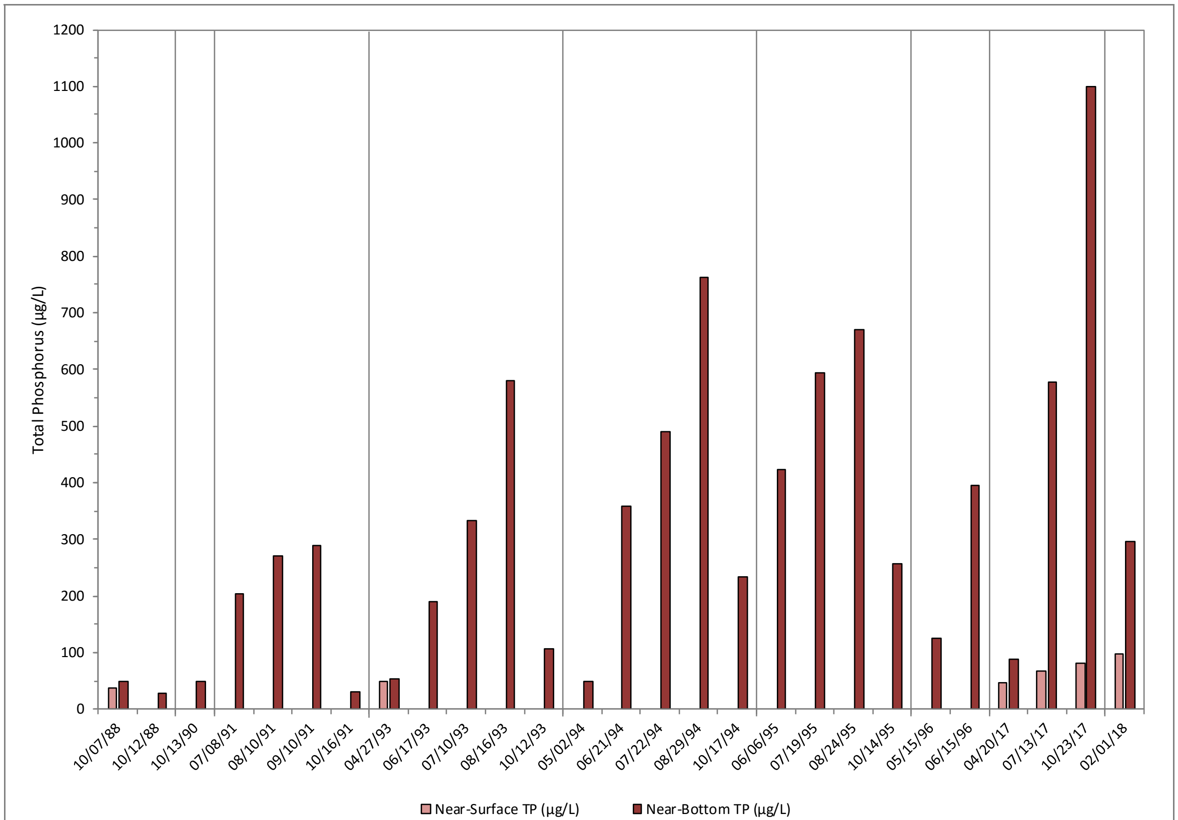


Figure 3.1-5. Bullhead Lake near-surface and near-bottom total phosphorus concentrations.

Chlorophyll-*a* concentration data are available annually from 1993 to 2017 (Figure 3.1-6). Average summer chlorophyll-*a* concentrations ranged from 2 µg/L in 2006 to 49 µg/L in 2017. It should be noted that only one summer chlorophyll-*a* sample was collected in 2006 and it may not be representative of the 2006 summer average chlorophyll-*a* concentration. The weighted summer chlorophyll-*a* concentration is 11 µg/L and falls into the *fair* category for chlorophyll-*a* concentrations in Wisconsin's deep headwater drainage lakes. Bullhead Lake's chlorophyll-*a* concentrations are approximately three times higher than the median values for deep headwater drainage lakes in the state and are approximately two times higher than the median values for all lake types within the SWTP ecoregion. Algal levels are considered to be a nuisance when the chlorophyll-*a* concentrations exceed 20 µg/L. Prior to 2010 this level was only exceeded 3 times out of 65 samples. Starting in 2010 this value has been exceeded at least 9 times with a chlorophyll-*a* concentration of 75 µg/L occurring on July 13, 2017. While no samples have been analyzed for blue green algal toxins, the World Health Organization considers chlorophyll-*a* levels exceeding 50 µg/L to pose a high risk for adverse health effects.

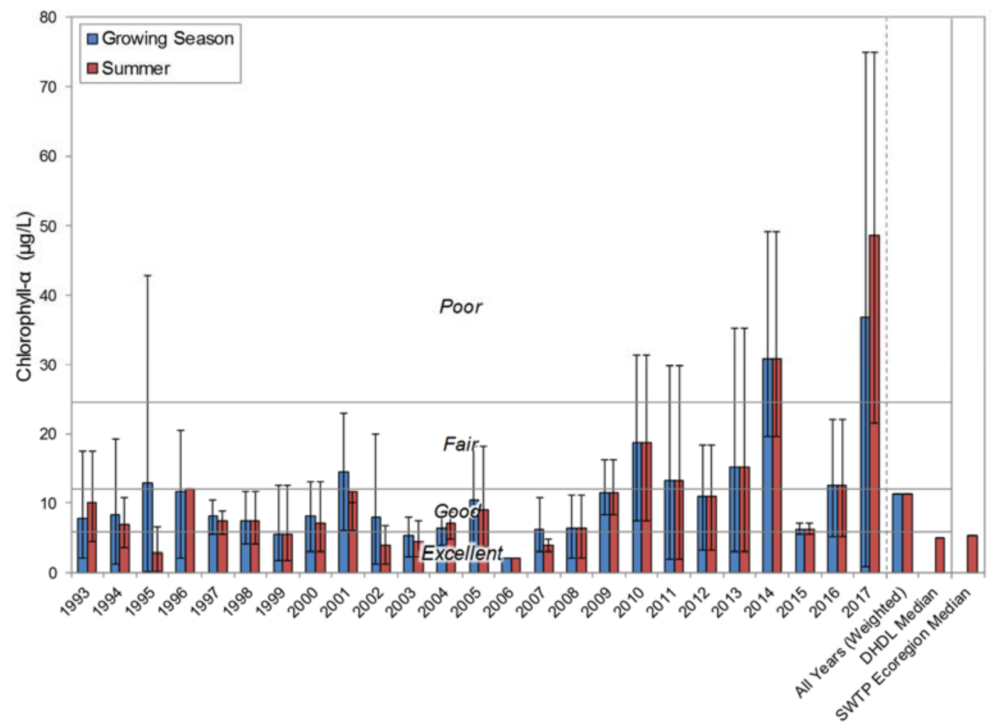


Figure 3.1-6. Bullhead Lake, deep headwater drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The 2017 average summer chlorophyll-*a* concentration was over four times higher than the lake's long-term weighted average, with an average concentration of 49 µg/L. Onterra crews noted an algal bloom and surface-matted *Cladophora* spp., filamentous algae or periphyton, in Bullhead Lake during the whole-lake aquatic vegetation surveys completed in July 2017 (Photograph 3.1-2). High nutrient conditions, as seen on Bullhead Lake in 2017, can result in extensive growth of *Cladophora* spp. (Bellinger and Sigee 2010). *Cladophora* spp. can grow in dense communities among vegetation in shallow water, which can break off and form floating mats. In July 2017, mats of filamentous algae were noted along the shoreline in Bullhead Lake, especially within floating-leaf vegetation, as seen in Photograph 3.1-2.

Photograph 3.1-2. Algal bloom (left) and surface-matting *Cladophora* spp. (right) in Bullhead Lake in 2017. Photo credit Onterra.

Annual Secchi disc transparency data are available from Bullhead Lake annually from 1986 to 2005 and from 2007 to 2017 (Figure 3.1-7). Average summer Secchi disc depth ranged from 3 feet in 2016 to 11.6 feet in 1990. The weighted summer average Secchi disc depth is 8.7 feet, which falls into the *good* category for Secchi disc depth in Wisconsin's deep headwater drainage lakes. The weighted average summer Secchi disc depth is less than the median values for deep headwater drainage lakes in Wisconsin but exceeds the median values for all lake types within the SWTP ecoregion.

The improvement in water clarity following the 1988 alum treatment is apparent in Figure 3.1-7. The summer Secchi disc transparency during the three years prior to the treatment were approximately 5 feet but it increased to 11 feet in the years following the treatment. The 2017 average summer Secchi disc depth was almost three times shallower than the lake's weighted average, with an average summer Secchi disc depth of 3 feet.

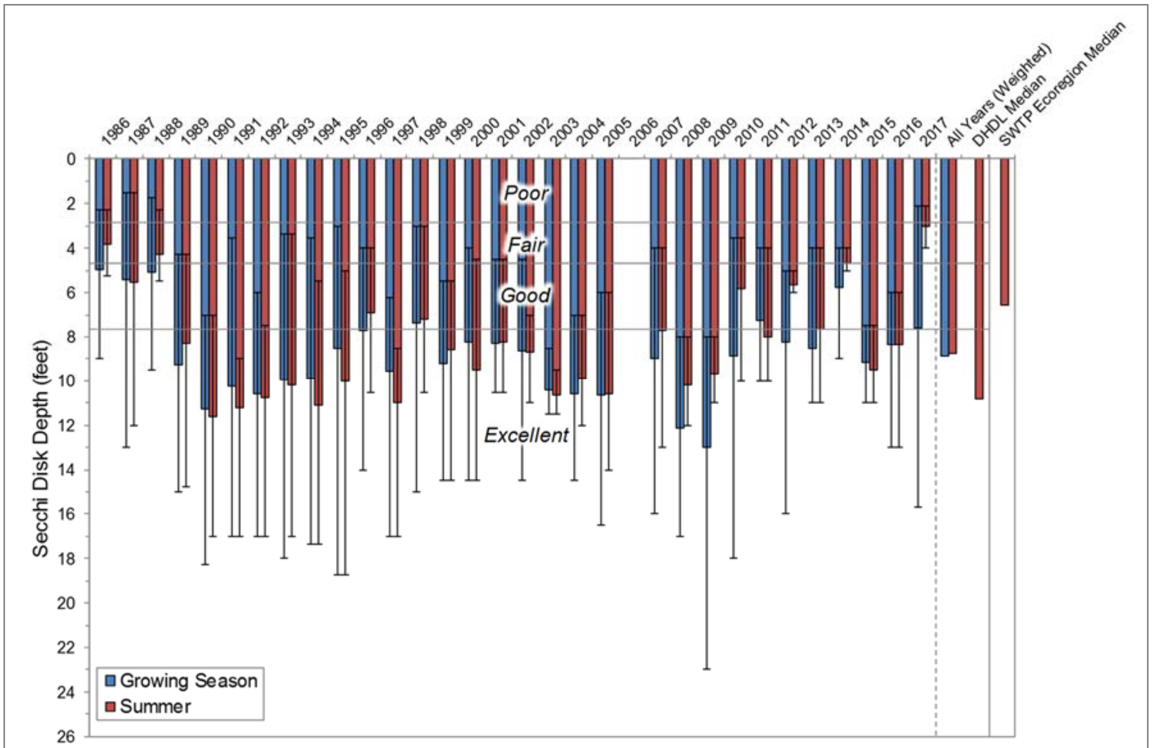


Figure 3.1-7. Bullhead Lake, deep headwater drainage lakes, and regional Secchi disc clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed in the previous section, water clarity in Wisconsin's lakes is primarily influenced by suspended particulates within the water, mainly phytoplankton. Abiotic suspended particulates, such as sediment, can also affect water clarity. *Total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were below the limit of detection in Bullhead Lake in April and October of 2017. Onterra crews noted an algal bloom during the summer of 2017 so it is unclear how the total suspended solids measurement would have changed if collected mid-summer.

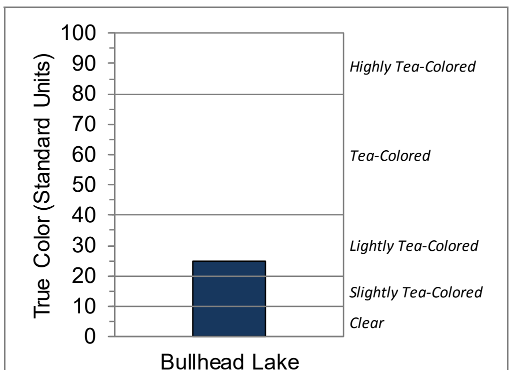


Figure 3.1-8. Bullhead Lake true color value.

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 decreasing water clarity. A measure of water clarity once all of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color* and indicates the level of dissolved material within the water. True color values measured from Bullhead Lake in 2017 averaged 25 SU (standard units) indicating the lake's water has a *light tea color* and that the lake's water clarity is slightly influenced by dissolved components in the water. This value indicates that the water clarity in Bullhead lake is mostly influenced by changes in chlorophyll-*a* from year to year.

Recent Changes in Bullhead Lake's Water Quality

All three trophic measures, phosphorus, chlorophyll-*a*, and Secchi disc transparency, show a significantly worsening trend in the past several years. Further, all three measures had the worst values in 2017 compared with any years since 1993. The chlorophyll-*a* concentration on July 13, 2017 exceeded the level at which the World Health Organization considers the probability of adverse health effects as being high. Although the trophic measures were highest in 2017, they began to show an increase in 2009 (Figure 3.1-9). A regression analysis for the period 1993 to 2008 showed no change in Secchi disc transparency, and a very slight decline in total phosphorus and chlorophyll-*a* concentrations. For the period 2008 to 2017, all three trophic measures increased with an average of 2 µg/L per year for total phosphorus and chlorophyll-*a* and a decline in Secchi disc transparency of 0.4 feet per year (Table 3.1-1). If data for 2017 are removed, the trend in all three measures is still a decline in the lake's trophic status. It is very likely that in recent years, phosphorus loading to the lake has increased which has resulted in greater algal blooms and worsening water clarity.

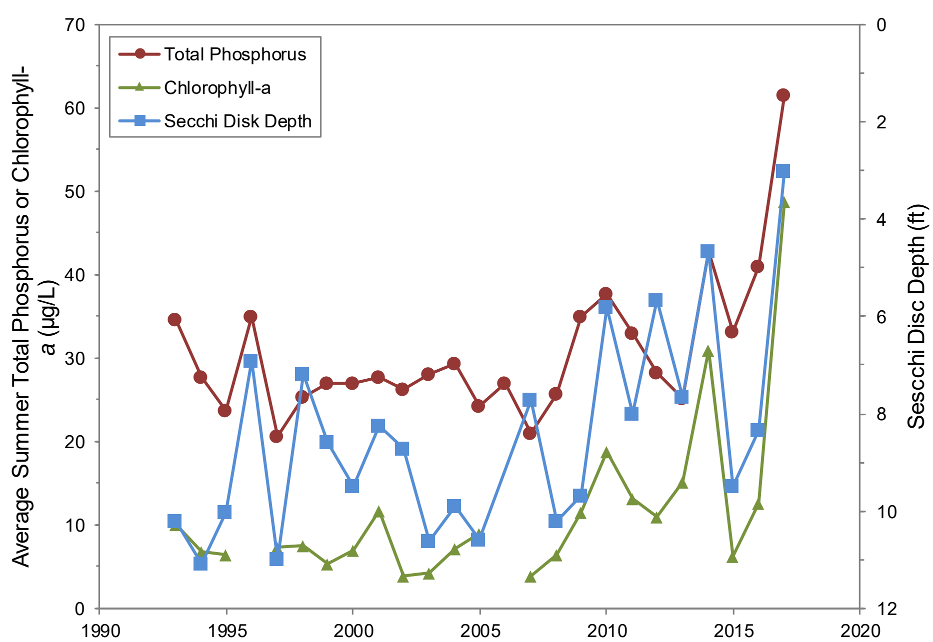


Figure 3.1-9. Trend in annual summer concentrations of total phosphorus, chlorophyll-*a*, and Secchi disc transparency. All three trophic measures have gotten worse since 2008.

Table 3.1-1. Linear regressions of trophic measures for 1993-2008 and 2008-2017. All three trophic measures are worse during the second time period compared with the first.

Trophic Measure	Time Period	Rate of Change
Total Phosphorus	1993-2008	-0.3 μg/L/years
	2008-2017	2.2 μg/L/years
Chlorophyll-*a*	1993-2008	-0.15 μg/L/years
	2008-2017	2.3 μg/L/years
Secchi Disc Transparency	1993-2008	0 feet
	2008-2017	-0.4 feet

While it is clear that the lake's trophic state has worsened over the last 9 years, with 2017 being the worst, it is not clear what are the causes. Three possible reasons exist: 1) there is an increase in precipitation or a higher frequency of intense storms, which results in higher runoff of phosphorus into the lake from the watershed, 2) an additional source of phosphorus has been added to the watershed, 3) there has been an increase in internal loading, primarily from the deep water sediments.

On Bullhead Lake, there is a weak positive trend between higher precipitation and higher summer phosphorus concentrations. However, comparing individual years with the highest phosphorus concentrations with the amount of precipitation shows that years with the higher phosphorus concentration did not always have the most precipitation (Figure 3.1-10). For example, 2017 had the highest average summer phosphorus levels, but summer rainfall was lower than 5 other years. Storm events over 1, 2, and 3 inches in intensity from March to September were also analyzed, and showed that the intensity of summer storms has not increased significantly in the last few years (Figure 3.1-11). There were no 3-inch storms in 2017 and only three 2-inch storms occurred. Similarly, six other years saw the same number or more of 2-inch storms.

Onterra staff had discussions with staff from the Manitowoc and Calumet County Land and Water Conservation Departments about possible recent landuse changes in the agricultural fields in the Bullhead Lake watershed. There does not appear to have been any significant changes in farming practices that would have resulted in increased delivery of phosphorus to the lake.

It appears that the most likely source of the increased phosphorus concentrations in the lake in the last several years are from within the lake itself. The trends of dissolved oxygen concentrations during the summer below the epilimnion are a good indicator of the lake's overall productivity. Algae and other organic matter is produced in the upper waters of the lake, and following death, the matter falls through the water column. Bacterial breakdown of this material consumes oxygen in the metalimnion and hypolimnion. An early indicator of eutrophication is the accelerated loss of oxygen in the hypolimnion. This can be quantified by determining the areal hypolimnetic oxygen demand. Because the hypolimnion in Bullhead Lake loses all of its oxygen very soon after stratification begins, it is not possible to determine this oxygen demand. However, by observing the loss of oxygen in the upper part of the hypolimnion and the metalimnion over time (years), we can determine if the lake's trophic status is worsening. Figure 3.1-12 shows selected July DO profiles from 1991 through 2017. For the period 1991 through 2013 the oxygen content was similar in the metalimnion and hypolimnion with the depth of anoxia moving shallower a small amount. Between 2013 and 2014, the depth of anoxia moved up in the water column by about 3 feet with the anoxic zone being depths greater than 12 feet. In 2017 the depth of anoxia moved further up in the water column so that little oxygen was present below 5 feet. As the depth of anoxia becomes shallower, more of the lake bottom is exposed to anoxic water meaning that there is a larger area of sediment that can release phosphorus. The lake's morphometry is such that there is a shelf between 15 and 20 feet which has been exposed to anoxic water in recent years. This has resulted in an increase in internal loading. This trend of increasing anoxia since 2013 indicates that the lake has become more productive in the last 4 years and supports the higher phosphorus and chlorophyll-*a* concentrations in 2017.

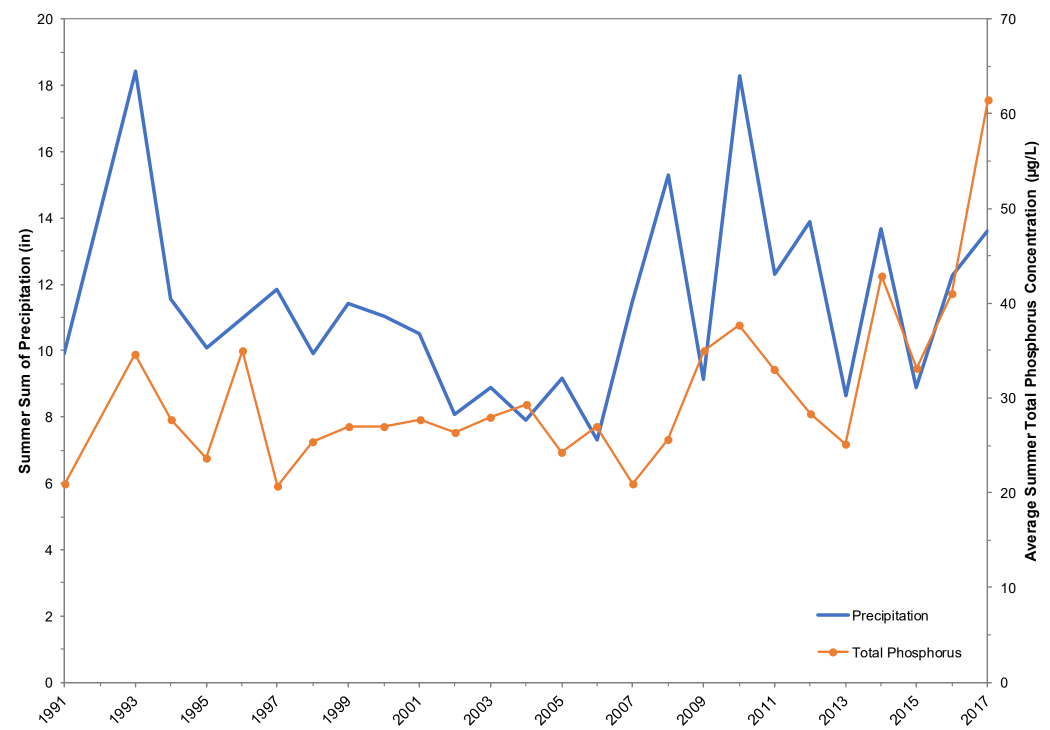


Figure 3.1-10. Comparison of summer average phosphorus concentrations with the sum of the amount of precipitation for the summer of the same year. Precipitation data from the Midwest Regional Climate Center (MRCC) from a Brillion, WI station (USC00471064).

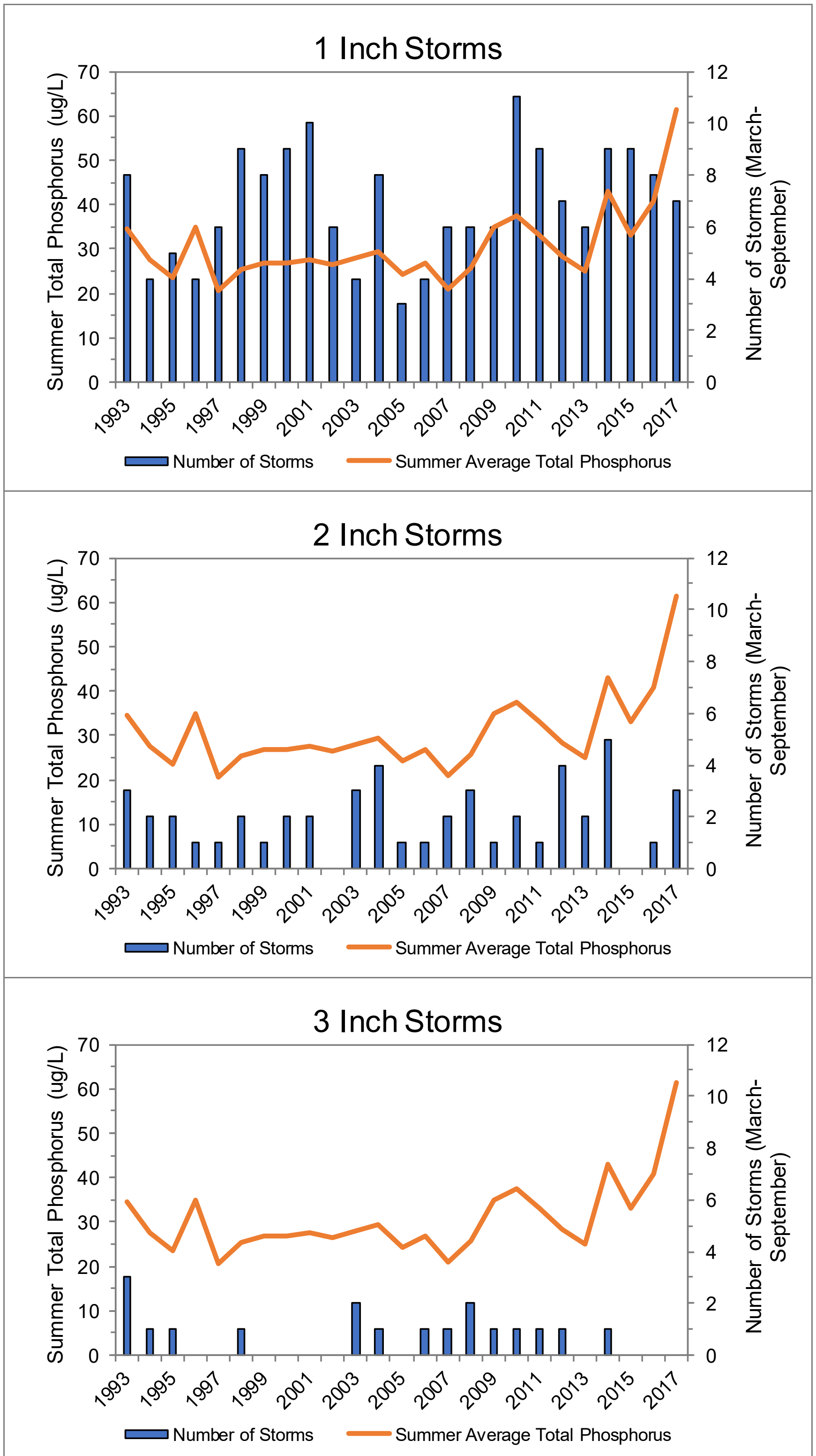


Figure 3.1-11. Comparison of summer average phosphorus concentrations with the number of storm events from March through September of the same year. Precipitation data from the Midwest Regional Climate Center (MRCC) from a Brillion, WI station (USC00471064).

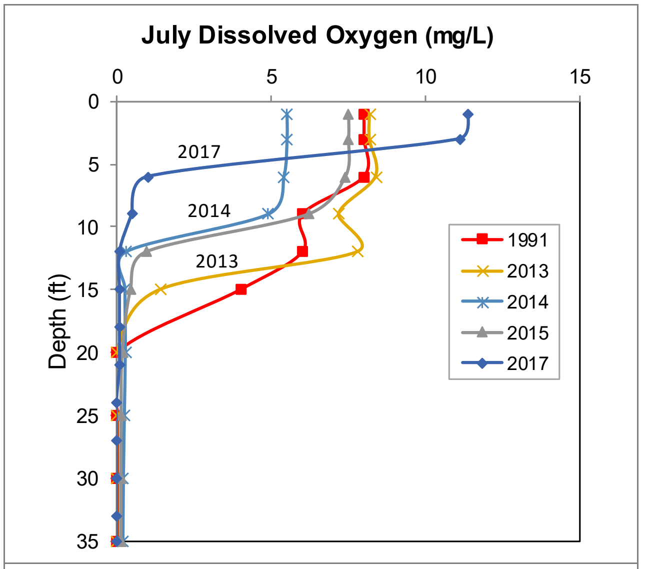


Figure 3.1-12. Selected DO profiles in Bullhead Lake from the period 1991-2017. The increasing amount of anoxia since 2013 is an indication of the worsening of the lake's trophic state.

Limiting Plant Nutrient of Bullhead Lake

Using midsummer nitrogen and phosphorus concentrations from Bullhead Lake, a nitrogen:phosphorus ratio of 29:1 was calculated. This finding indicates that Bullhead Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Bullhead Lake Trophic State

Figure 3.1-13 contains the weighted average Trophic State Index (TSI) values for Bullhead Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disc transparency data collected as part of this project along 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 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, a higher degree of correlation is indicated.

The TSI values for Secchi disc depth range from mesotrophic to eutrophic, TSI values for chlorophyll-*a* range from oligotrophic to borderline hypereutrophic, and the TSI values for total phosphorus range from mesotrophic to eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Bullhead Lake is in a eutrophic state (Figure 3.1-13). Bullhead Lake is more productive than other deep headwater drainage lakes in Wisconsin and more productive than the majority of lakes in the SWTP ecoregion.

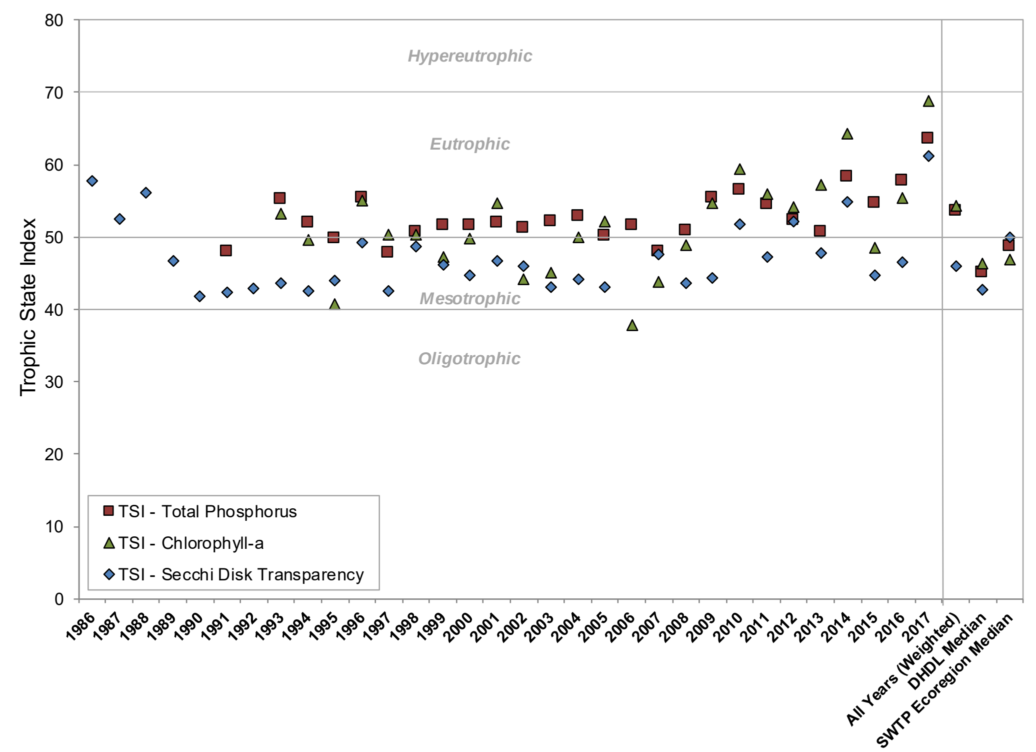


Figure 3.1-13. Bullhead Lake, deep headwater drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Bullhead Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Bullhead Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-14. Bullhead Lake is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over twice, 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 Bullhead 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 oxygen diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen.

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. The data also indicate that there was sufficient oxygen throughout most of the water column under the ice to support the fishery during late-winter sampling (Figure 3.1-14).

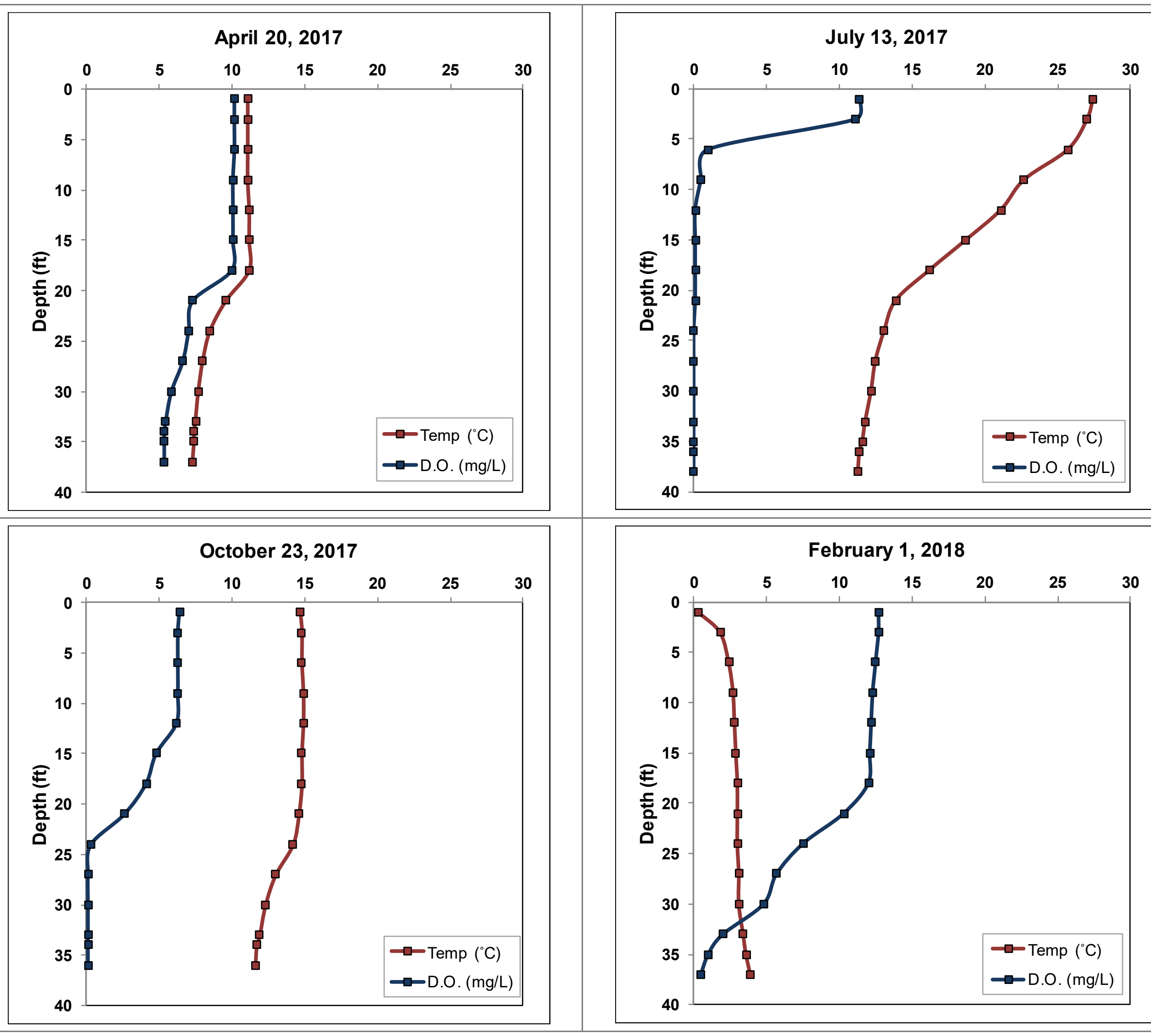


Figure 3.1-14. Bullhead Lake dissolved oxygen and temperature profiles.

Bullhead Lake 303(d) List Impairment Listing

The State of Wisconsin is required by law under the Clean Water Act to submit a list of lakes that do not meet specific water quality standards based upon lake type. The list of impaired waters, also known as the 303(d) list, is updated every two years. Each state is required to document the methodology used to assess the waterbodies. The WDNR developed and uses the Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) to set water quality standards and assess the state's waterbodies. The WDNR is currently using WisCALM 2018.

Bullhead Lake was first placed on the 303(d) list in 2012 because the lake's total phosphorus concentrations exceeded the WisCALM threshold for recreational use. In both 2014 and 2016, Bullhead Lake was kept on the 303(d) list because both total phosphorus and chlorophyll-*a* concentrations exceeded the WisCALM threshold for recreational use. In 2018, still on the 303(d) list, Bullhead Lake's total phosphorus concentrations exceeded the WisCALM thresholds for both recreational use and fish and aquatic life use and chlorophyll-*a* concentrations exceeded the WisCALM thresholds for recreational use.

Additional Water Quality Data Collected at Bullhead 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 Bullhead 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.

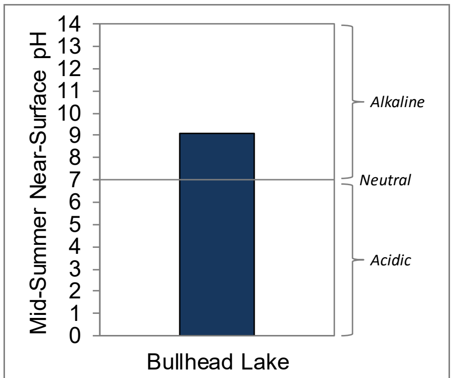


Figure 3.1-15. Bullhead Lake mid-summer near-surface pH value.

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 Bullhead Lake was found to be alkaline with a value of 9.1, and falls outside the normal range for Wisconsin lakes (Figure 3.1-15).

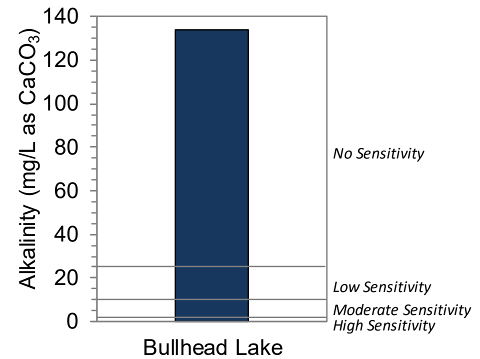


Figure 3.1-16. Bullhead Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 Bullhead Lake was measured at 134 (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 3.1-16).

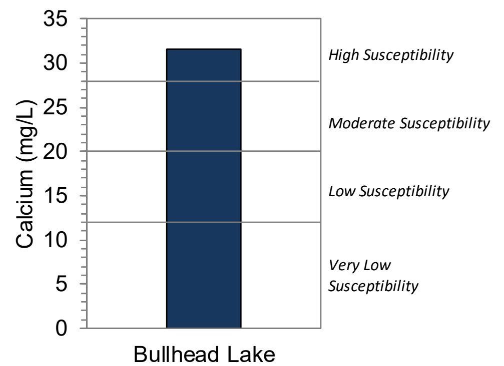


Figure 3.1-17. Bullhead Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Bullhead Lake's pH of 9.1 falls slightly outside 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 Bullhead Lake was found to be 31.5 mg/L, falling into the optimal range for zebra mussels (Figure 3.1-17).

Zebra mussels (*Dreissena polymorpha*) are small, bottom dwelling mussels native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. Zebra mussels can attach themselves to boats, boat lifts, and docks, and can live for up to five days after being taken out of the water. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring. Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Best practice methods for cleaning boats that have been in zebra mussel infested waters is inspecting and removing any attached mussels, spraying your boat down with diluted bleach, power-washing, and letting the watercraft dry for at least five days.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Bullhead Lake was considered suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in Bullhead Lake in 2017 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. The zebra mussel veliger samples were determined to be negative; zebra mussels are not currently present in Bullhead Lake.

Stakeholder Survey Responses to Bullhead Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Of the 38 surveys distributed, 15 (39%) were returned. Without a response rate of 60% or higher, the responses to the following questions regarding water quality cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of water quality in Bullhead Lake but cannot be stated with statistical confidence.

Figures 3.1-18 displays the responses of members of Bullhead Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Bullhead Lake. When asked how they would describe the current water quality of Bullhead Lake, 47% of respondents indicated *fair*, 33% indicated *poor*, 13% indicated *very poor*, and 7% indicated *good*.

When asked how they believe the current water quality has changed since they first visited the lake, the largest proportion of respondents, 53%, indicated it has *somewhat degraded*, 27% indicated it has *severely degraded*, 13% indicated it has *remained the same*, and 7% indicated it has *somewhat improved* (Figure 3.1-18). As discussed in the previous section, historical water quality data indicates total phosphorus and chlorophyll-*a* concentrations are increasing in Bullhead Lake.

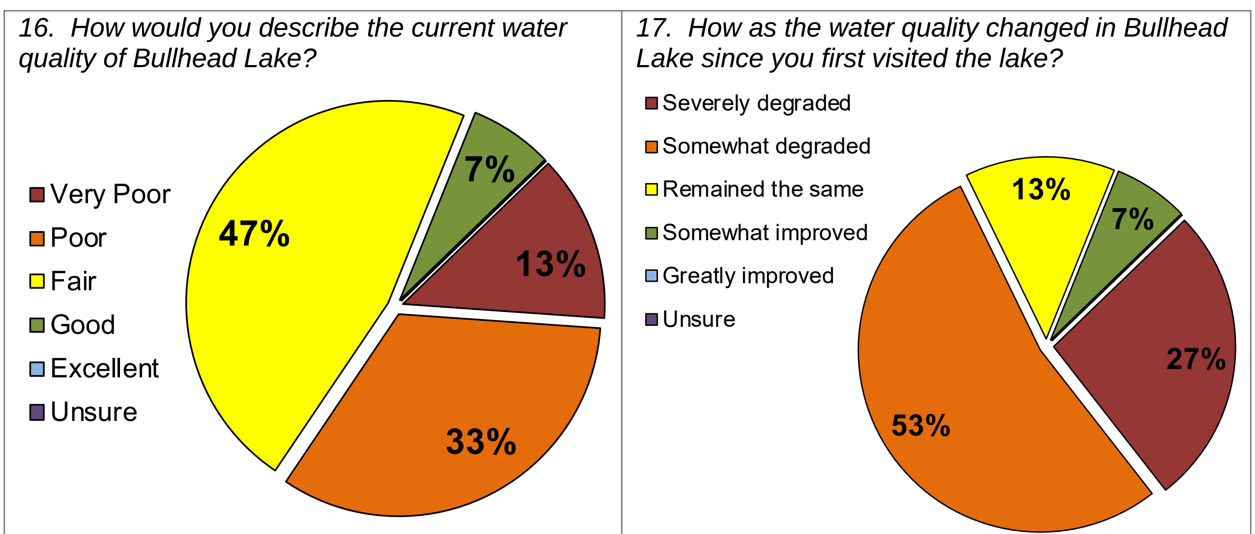


Figure 3.1-18. Bullhead Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Bullhead Lake Watershed Assessment

Bullhead Lake's watershed encompasses an area of approximately 301 acres, yielding a small watershed to lake area ratio of 3:1 (Map 2). In other words, approximately three acres of land drain to every one acre of Bullhead Lake. Approximately 33% of Bullhead Lake's watershed is composed of row crop agriculture, 26% of wetlands, 24% of Bullhead Lake's surface, 10% of rural residential areas, 5% pasture/grass, and 2% forest (Figure 3.2-1).

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 estimated that approximately 129 pounds of phosphorus are delivered to the lake from its watershed on an annual basis (Figure 3.2-2). Phosphorus loading from septic systems was estimated using data obtained from the 2017 stakeholder survey of riparian property owners. Of the estimated 129 pounds of phosphorus being delivered annually to the lake, the majority, 69%, originates from row crop agriculture, 15% from direct atmospheric deposition into the lake, 6% from riparian septic systems, 5% from wetlands, 3% from pasture/grass, and 2% from rural residential areas,

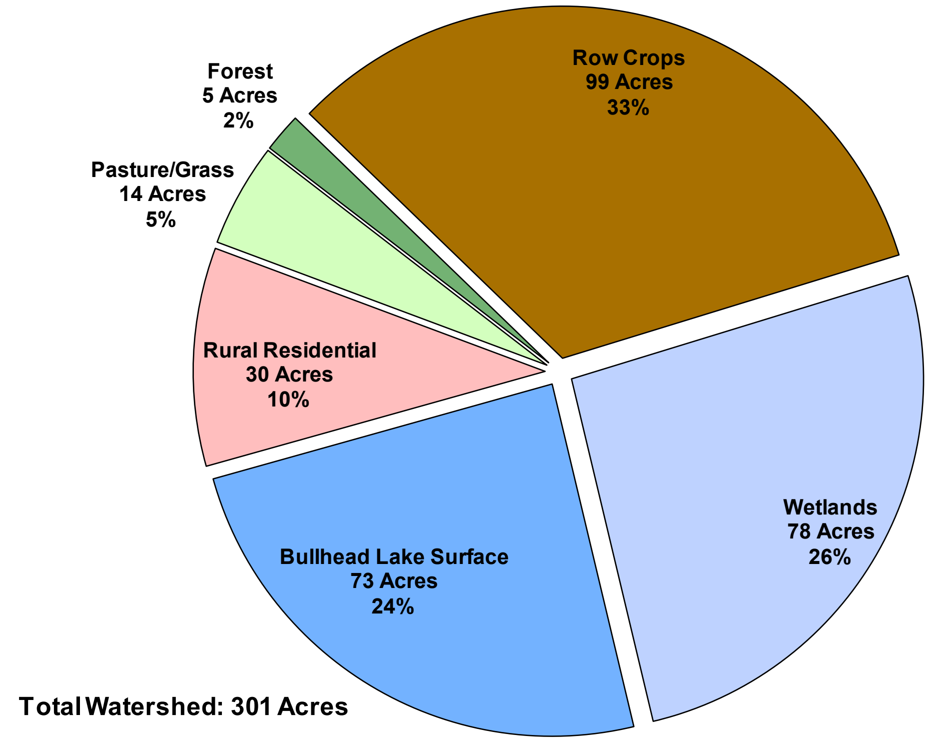


Figure 3.2-1. Bullhead Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

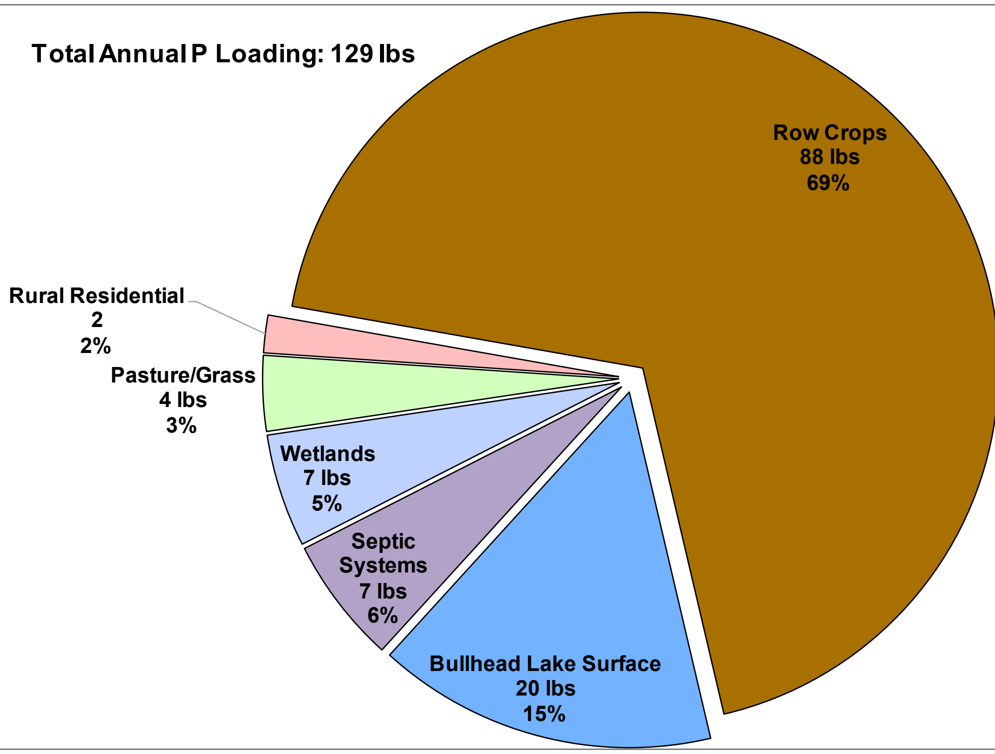


Figure 3.2-2. Bullhead Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using predictive equations and the potential annual phosphorus load generated by WiLMS, Bullhead Lake should have a growing season mean (GSM) total phosphorus concentration of approximately 42 µg/L. This predicted concentration is similar to the measured long-term GSM total phosphorus concentration of 37 µg/L; however, it is significantly lower than the 2017 GSM total phosphorus concentration of 63 µg/L. The WiLMS estimate only includes a small amount of internal phosphorus loading. Based upon the reasoning for past alum treatments and the high phosphorus concentrations measured in the near bottom waters in 2017, it is likely significant internal loading is occurring in Bullhead Lake. In order to accurately quantify the amount of internal loading is occurring, temperature, dissolved oxygen, and phosphorus profiles would need to be collected. The increase in phosphorus mass from the beginning of summer stratification to the end in late October would be the amount of internal loading. In nearby Round Lake it was found that internal loading was 55% of the annual phosphorus budget, but in Becker Lake which has a perennial stream, it was one third of the annual budget. As discussed in the Water Quality Section (Section 3.1), all three trophic measures, phosphorus, chlorophyll-*a*, and Secchi disc transparency, show a significantly worsening trend in the last few years and all three measures had the worst values in 2017 compared with any years since 1993, indicating that phosphorus loading to the lake has increased. Based upon the WiLMS modeling it is estimated that the amount of internal loading in 2017 could be about 107 pounds or 45% of the total annual phosphorus load.

3.3 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 groundwater 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 groundwater 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 3.3-1. 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 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 3.3-2. 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.

Cost

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

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

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

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

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

Bullhead Lake Shoreland Zone Condition

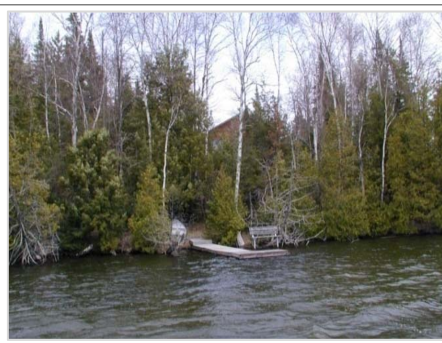
Shoreland Development

Bullhead 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 3.3-1 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.

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 3.3-1. Shoreland assessment category descriptions.

On Bullhead 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 3.3-2.

Bullhead Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.9 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-4). 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, 0.3 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Bullhead 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.

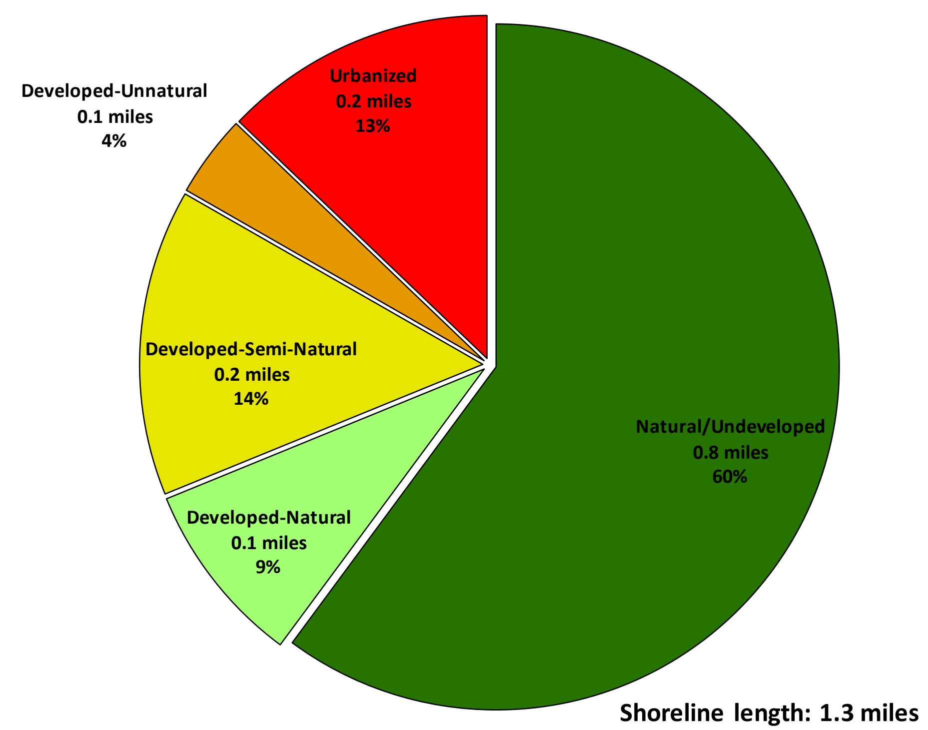


Figure 3.3-2. Bullhead Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Map 3.

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, Bullhead 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, 49 total pieces of coarse woody habitat were observed along 1.3 miles of shoreline (Map 4), which gives Bullhead Lake a coarse woody habitat to shoreline mile ratio of 37:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 49 total pieces of coarse woody habitat observed during the survey, 39 pieces were 2-8 inches in diameters, 10 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 Bullhead 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.

Onterra has completed coarse woody habitat surveys on 75 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 Bullhead Lake fell above the 75th percentile of these 75 lakes (Figure 3.3-3). However, it should be noted that while the *count* of coarse woody habitat is high in Bullhead Lake compared to other lakes sampled by Onterra, bulk of the wood occurrences were less then 8" in diameter and consisted of zero or minimal branching; therefore, little complex coarse woody habitat, which provides the greatest habitat benefit to the fishery, is available.

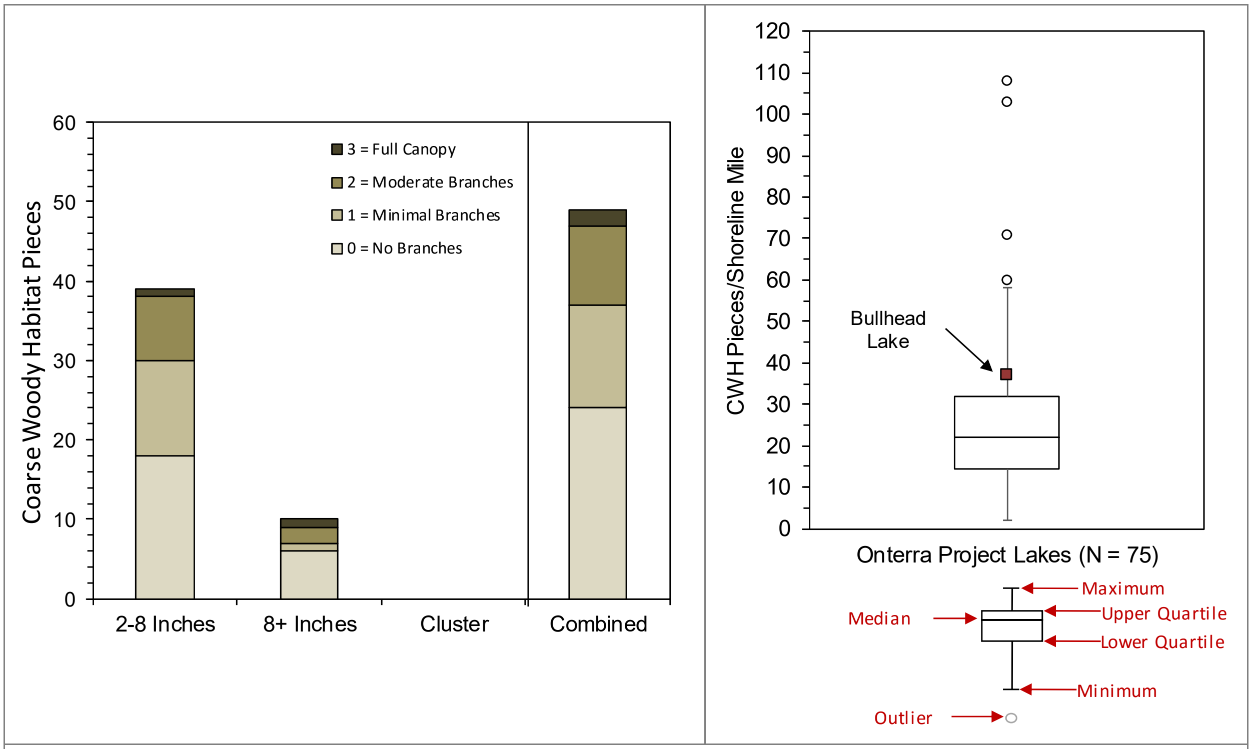


Figure 3.3-3. Bullhead Lake coarse woody habitat survey results. Based upon a Fall 2017 survey. Locations of Bullhead Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

Photograph 3.4-1. Example of emergent and floating-leaf communities.

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.

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 Bullhead 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 Bullhead 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


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

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

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

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

Cost

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

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

Photograph 3.4-3. 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

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.

Photograph 3.4-4. Granular herbicide application.

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

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

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

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

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

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

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

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

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Species Diversity

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from Bullhead Lake is compared to data collected by Onterra and the WDNR Science Services on 77 lakes within the Southeast Wisconsin Till Plain 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 Bullhead Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

Exotic Plants

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

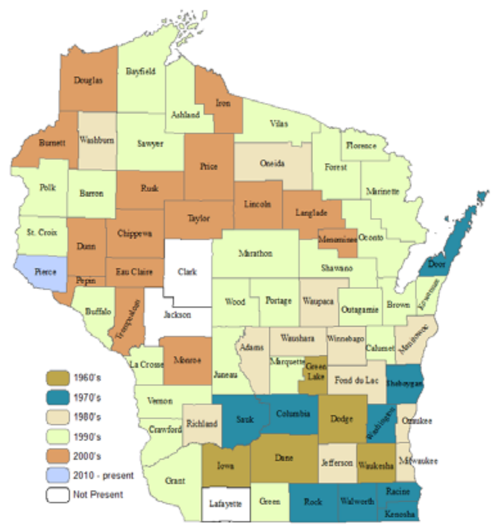


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

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

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

Bullhead Lake Aquatic Plant Survey Results

During the aquatic plant surveys completed on Bullhead Lake in 2017, a total of 17 species of plants were located, two of which are considered non-native, invasive species: Eurasian watermilfoil and curly-leaf pondweed (Table 3.4-1). The populations of these non-native plants in Bullhead Lake are discussed in detail in the subsequent Non-Native Aquatic Plant subsection. Table 3.4-1 also includes the list of aquatic plant species which were located during surveys completed in 2005, 2011, and 2012. A comparison of the 2017 aquatic plant survey data to these historical datasets is discussed later in this section.

Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants and generally leads to a higher number of aquatic plant species within the lake. In August 2017, Onterra completed an acoustic survey on Bullhead Lake. This sonar-based technology collects data pertaining to the substrate composition of the lake bottom. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

The substrate hardness data collected in 2017 showed that Bullhead Lake's substrate varies from very hard to very soft in different areas around the lake (Figure 3.4-2 and Map 5). The widest range in substrate hardness occurred in the shallowest areas of the lake, with depths from 1 to 5 feet supporting both the hardest and softest substrates in the lake. From 5 to approximately 15 feet, bottom substrates become more consistently hard. Beyond 15 feet, substrate hardness declines and is relatively consistent to the maximum depth of the 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.

The acoustic survey also recorded aquatic plant bio-volume, or the percentage of the water column occupied by aquatic plants, throughout the entire lake. The 2017 aquatic plant bio-volume data are displayed in Figure 3.4-2. 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 majority of aquatic plant growth in Bullhead Lake is located in shallower areas of the lake, with the highest aquatic plant bio-volume occurring between 1 and 3 feet of water. As is discussed in the Water Quality Section (Section 3.1), water clarity in Bullhead Lake was low in 2017 and aquatic plants were restricted to shallower areas where light availability is highest. During the 2017 whole-lake point-intercept survey, aquatic plants were recorded growing to a maximum depth of 12 feet. The 2017 acoustic survey found that approximately 29% (21 acres) of Bullhead Lake contained aquatic vegetation.

Table 3.4-1. Aquatic plant species located on Bullhead Lake during 2005, 2011, 2012 and 2017 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2005 (WDNR)	2011 (WDNR)	2012 (WNDR)	2017 (Onterra)
Emergent	*Carex pseudocyperus*	Cypress-like sedge	7				I
	Decodon verticillatus	Water-willow	7				I
	Iris sp.	Iris sp.	N/A				I
	Schoenoplectus acutus	Hardstem bulrush	5	X			
	Schoenoplectus tabernaemontani	Softstem bulrush	4		X	I	X
	Sparganium eurycarpum	Common bur-reed	5				I
	Sparganium sp.	Bur-reed sp.	N/A			I	
	Typha sp.	Cattail spp.	1	X			I
FL	*Brasenia schreberi*	Watershield	7			I	
	Nuphar variegata	Spatterdock	6	X	I	I	X
	Nymphaea odorata	White water lily	6	I	I	I	I
Submersed	*Ceratophyllum demersum*	Coontail	3	X	X	X	X
	Chara sp.	Muskgrasses	7	X		X	I
	Elodea canadensis	Common waterweed	3			X	
	Heteranthera dubia	Water stargrass	6	I			I
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X	X	
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X	X	X
	Najas flexilis	Slender naiad	6	I			
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X		X	I
	Potamogeton foliosus	Leafy pondweed	6			X	
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	I
	Ranunuculs aquatilis	White water crowfoot	8	X	X	X	
	Stuckenia pectinata	Sago pondweed	3		X	X	X
FF	*Lemna minor*	Lesser duckweed	5		X		
	Lemna trisulca	Forked duckweed	6	X	X	X	
	Spirodela polyrhiza	Greater duckweed	5				X

FL = Floating Leaf; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species comprise the aquatic plant community. Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 108 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2017, approximately 51% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2017 indicates that 42% of the 108 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 9% had a TRF rating of 2, and 0% had a TRF rating of 3 (Figure 3.4-3). The total rake fullness ratings indicate that where plants occurred Bullhead Lake in 2017 they were of relatively low biomass.

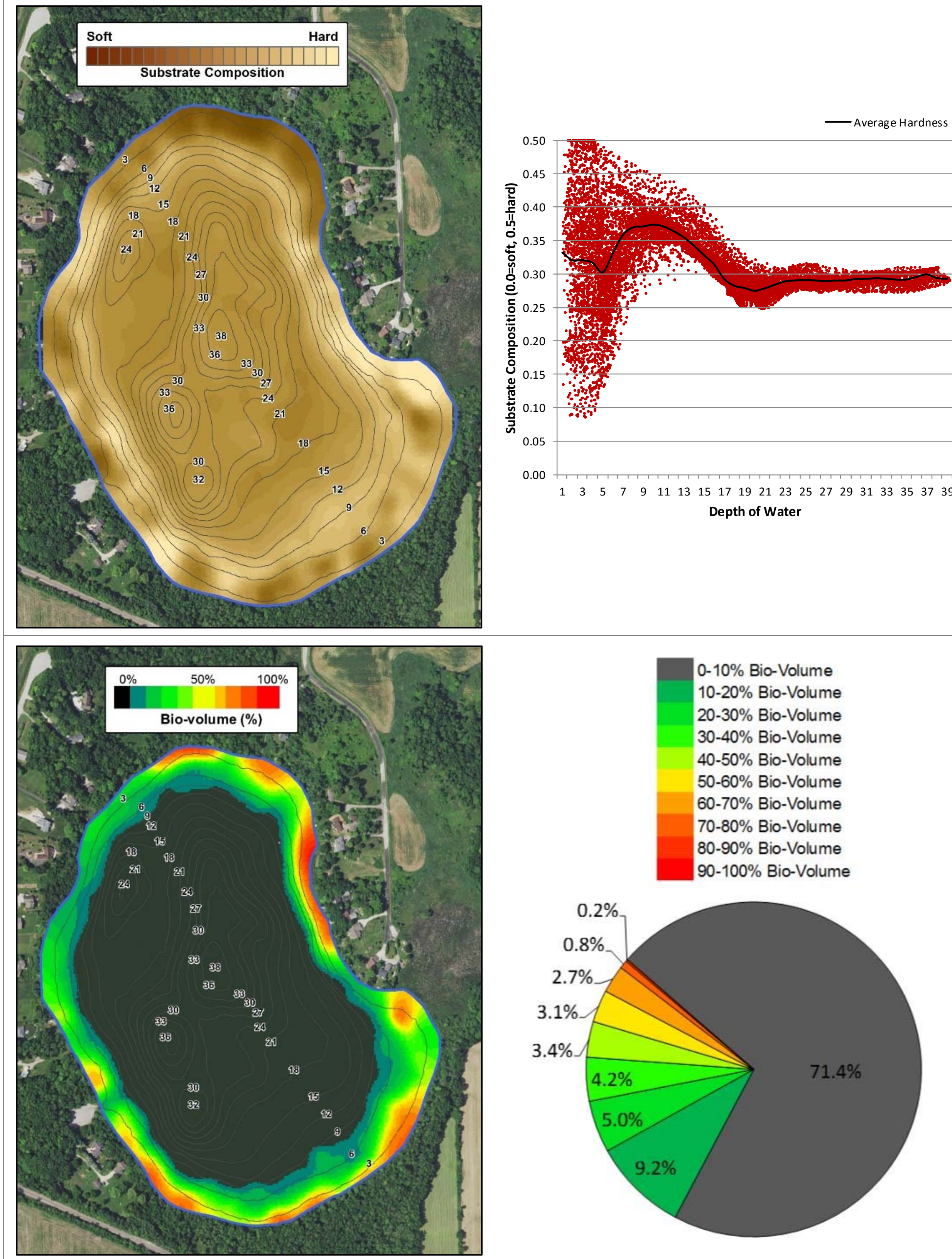


Figure 3.4-2. Bullhead Lake 2017 substrate hardness (top) and aquatic plant bio-volume (bottom). Created using data from August 2017 acoustic survey.

Aquatic plant point-intercept datasets are also available from 2005, 2011, and 2012 in Bullhead Lake, and the methodology and sampling locations were the same as the survey completed in 2017. The datasets from 2005, 2011, 2012, and 2017 can be statistically compared to determine if any significant changes in the overall occurrence of vegetation or in individual species' abundance have occurred over this time period. Figure 3.4-3 illustrates the littoral occurrence of vegetation from these four surveys and shows that the littoral occurrence of 51% recorded in 2017 was the lowest measured of the four surveys. The reduction in the occurrence of vegetation in Bullhead Lake in 2017 represents a statistically valid reduction of 39-45% from previous surveys.

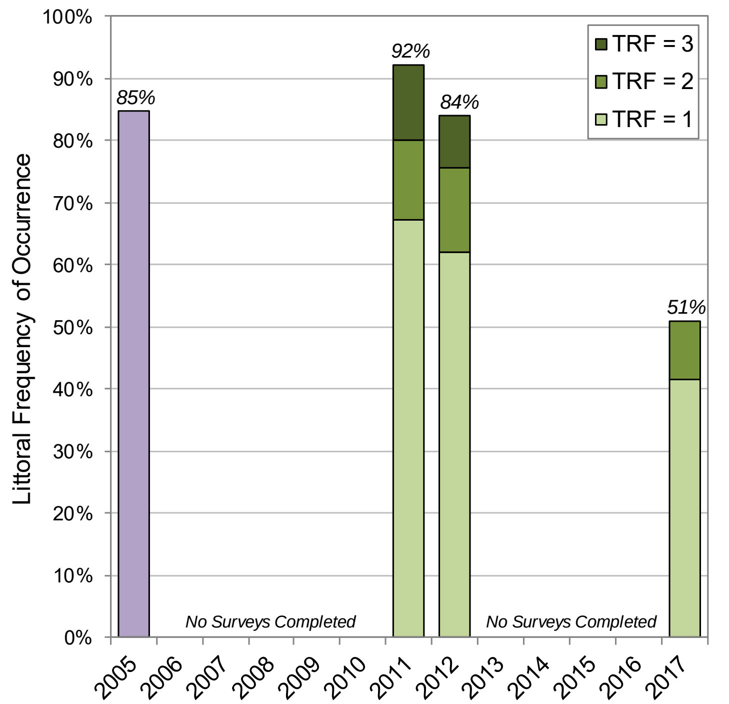


Figure 3.4-3. Aquatic plant frequency of occurrence and total rake fullness (TRF) ratings in Bullhead Lake from the 2005, 2011, 2012, and 2017 surveys. Total rake fullness ratings were not recorded in 2005. Littoral occurrence of vegetation in 2017 was statistically different from 2005, 2011, and 2012 (Chi-square α = 0.05).

As is discussed within the Water Quality Section (Section 3.1), 2017 saw the lowest summer water clarity on record for Bullhead Lake with a mean summer Secchi disc depth of only 3.0 feet. Onterra ecologists noted that there was more submersed vegetation present during the late-May ESAIS survey in 2017 when the Secchi disk depth was higher at 12.5 feet. By June, Secchi disc depth had declined to 4.0 feet and declined further to 2.0 – 3.0 feet through at least late August. The large reduction in the littoral occurrence of aquatic plant growth measured in 2017 is likely due to the rapid decline in water clarity caused by excessive phytoplankton production. With reduced light availability, aquatic plant abundance declined dramatically. Onterra ecologists noted many of the plants observed during the 2017 point-intercept survey appeared to be unhealthy – brown in color and covered in filamentous algae. Even in the shallowest areas of Bullhead Lake between 1 and 6 feet of water where light availability is highest, aquatic plant occurrence declined by 66% in 2017 when compared to 2005.

In addition to a reduction in the occurrence of vegetation, the 2017 point-intercept data also indicated aquatic plant biomass declined when compared to past surveys. In 2011 and 2012, approximately one quarter of the sampling locations that contained aquatic vegetation had TRF ratings of 2 or 3 (Figure 3.4-3). In 2017, no sampling locations had a TRF rating of 3 and less than 20% had a TRF rating of 2. The point-intercept methodology was in its infancy in 2005, and TRF ratings were not yet being recorded.

While the littoral occurrence of vegetation in Bullhead Lake declined significantly in 2017, the recorded maximum depth of plant growth of 12 feet was relatively similar to the maximum depth recorded in 2005 (15 feet), 2011 (10 feet), and 2012 (12 feet). Water clarity and the resulting light availability limits the depth to which aquatic plants can grow. Declining water clarity due to increased phytoplankton production or other factors typically results in a reduction or loss of aquatic plants from deeper waters. The changes in the maximum depth of aquatic plant growth correspond with changes in average growing season Secchi disc depth. While the average summer Secchi disc depth in 2017 was low at 3.0 feet, the plants recorded in deeper waters were likely established earlier in the year when water clarity was higher. The reduction in the maximum depth of plant growth from 15 feet in 2005 to 12 feet in 2017 represents a reduction in littoral area of approximately 7.0 acres or 18%.

Of the 17 aquatic plant species located in Bullhead Lake in 2017, 7 were encountered directly on the rake during the whole-lake point intercept survey. The remaining 10 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 7 species encountered on the rake, coontail was the most frequently encountered, followed by sago pondweed and greater duckweed (Figure 3.4-4).

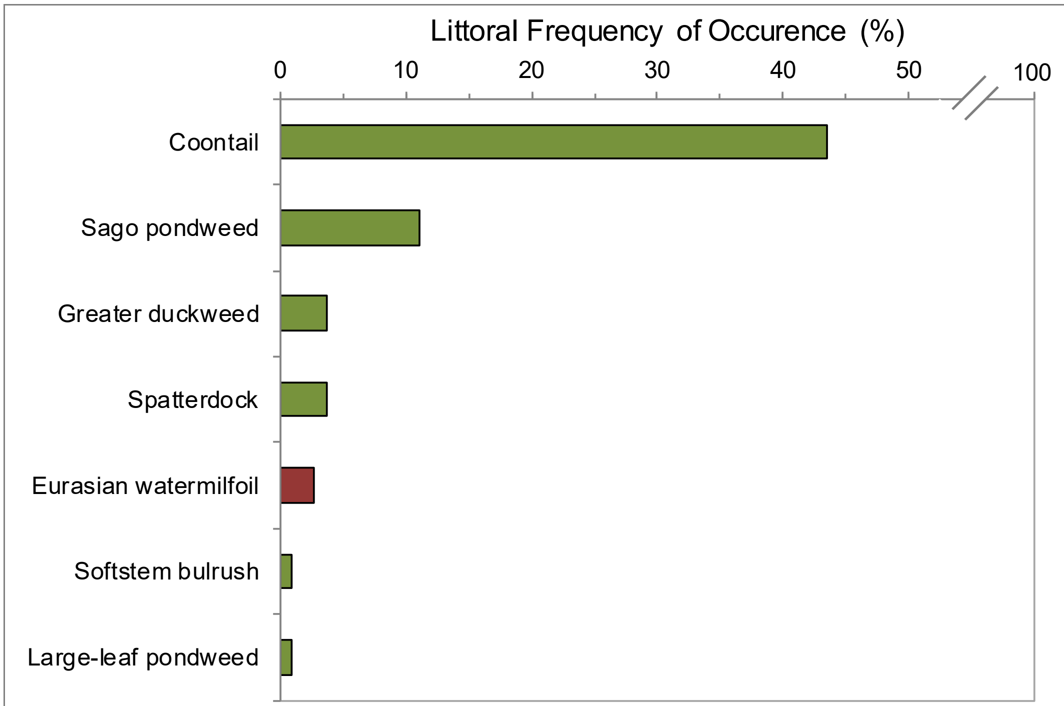


Figure 3.4-4. Bullhead Lake aquatic plant littoral frequency of occurrence. Exotic species indicated with red. Created using data from the 2017 whole-lake aquatic plant point-intercept survey. While curly-leaf pondweed is present within the lake, it went undetected during the 2017 whole-lake point-intercept survey.

Coontail, arguably the most common aquatic plant in Wisconsin, was the most frequently encountered aquatic plant in Bullhead Lake in 2017 with a littoral frequency of occurrence of 44% (Figure 3.4-4). It was most abundant between 1 and 10 feet of water. 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. Because it lacks true 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 and low water clarity.

Sago pondweed was the second-most frequently encountered aquatic plant in Bullhead Lake in 2017 with a littoral frequency of occurrence of 11% (Figure 3.4-4). Like coontail, sago pondweed is tolerant of low-light conditions, and is often more abundant in high-nutrient, eutrophic lakes. However, unlike coontail, sago pondweed is rooted in the lake bottom and spreads via rhizomes. These networks of rhizomes help to stabilize bottom sediments, and the numerous seeds and tubers produced by sago pondweed make it a very valuable food source for waterfowl and other wildlife (Borman et al. 1997). Sago pondweed was most abundant in shallower areas between 2 and 6 feet of water in 2017.

The third-most frequently encountered aquatic plant in 2017 was greater duckweed with a littoral frequency of occurrence of 4% (Figure 3.4-4). Unlike most other aquatic plants, greater duckweed is free-floating, unattached from the sediment and floating on the surface where it obtains nutrients directly from the water and carbon from the atmosphere (Huebert and Shay 1991). While these plants are flowering plants, they mainly reproduce vegetatively via budding. Under optimal conditions, they can double their population every 16 hours (Hasan and Chakrabarti 2009), allowing them to completely cover areas of waterbodies in a very short time. These plants cannot grow and reproduce in fast-moving water and they require areas of still or slow-moving water. In Bullhead Lake, greater duckweed was primarily observed growing in quiet water near shore amongst water lilies and surface-matted filamentous algae (*Cladophora* sp.). Large populations of surface-dwelling duckweeds are an indicator of high nutrient levels in the water, particularly ammonia nitrogen. Sources of ammonia nitrogen to lakes include fertilizers and animal wastes and/or release from anoxic bottom sediments.

Figure 3.4-5 displays changes in littoral frequency of occurrence for individual species from the 2005, 2011, 2012, and 2017 surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one of the four surveys are displayed. In total, six aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence between 2005 and 2017 (Figure 3.4-5). Five of these six species saw statistically valid reductions in their occurrence from 2005 to 2017 and include: coontail (36% decline), northern watermilfoil (100% decline), forked duckweed (100% decline), flat-stem pondweed (100% decline), and large-leaf pondweed (100% decline). One species, sago pondweed, increased in its occurrence from 0% in 2007 to 11% in 2017. The littoral occurrence of four species was not statistically different between 2005 and 2017 and include: Eurasian watermilfoil, spatterdock, curly-leaf pondweed, and leafy-pondweed. Eurasian watermilfoil and curly-leaf pondweed will be discussed in the subsequent Non-Native Aquatic Plants section.

As illustrated in Figure 3.4-5, the declines observed in a number of aquatic plant species occurred between 2005 and 2011 before declining further between 2012 and 2017. Forked duckweed was the most frequently encountered aquatic plant species in Bullhead Lake in 2005 with a littoral occurrence of 72%. Between 2005 and 2012, forked duckweed declined in occurrence by 90% and was not detected in Bullhead Lake in 2017. Like the other duckweed species found in Bullhead Lake, forked duckweed is a free-floating aquatic plant and is found growing in lakes with higher nutrient content. However, unlike the other duckweed species which float on the water's surface, forked duckweed is usually found growing along the bottom or entangled amongst other plants below the surface.

While forked duckweed requires water with higher nutrient content, it also requires moderate water clarity to obtain sufficient light near the bottom where it grows. Studies have shown that decreases in water clarity due to increased phytoplankton production have caused declines in forked duckweed populations (Toivonen 1985). The decline and possible extirpation of forked duckweed from 2005 to 2017 Bullhead Lake corresponds with a decline in average summer water clarity of approximately 4.0 feet over this time period.

Similarly, the native northern watermilfoil and large-leaf pondweed also saw large declines in their occurrence in Bullhead Lake between 2005 and 2017. Both northern watermilfoil and large-leaf pondweed are found in lakes with higher water clarity and are intolerant of eutrophication and low-light availability (Hansel-Welch et al. 2003, Mikulyuk et al. 2011). Flat-stem pondweed, which is thought to be more tolerant of low-light conditions, declined from an occurrence of 29% in 2012 to 0% in 2017. In contrast, sago pondweed, a native species that has been found to be tolerant of eutrophication and is associated with lakes of low water clarity (Mikulyuk et al. 2011), increased in its occurrence in Bullhead Lake from 0% in 2005 to 11% in 2017.

The decline of environmentally-sensitive species and increase in disturbance-tolerant species in Bullhead Lake between 2005 and 2017 is an indication of degrading conditions, likely the result of increasing nutrient concentrations and declining water clarity measured over this period. In addition to these changes in species' occurrences, the Floristic Quality Assessment also indicates degrading environmental quality in Bullhead Lake. 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 15 native aquatic plant species were located in Bullhead Lake during the 2017 surveys, 6 were directly encountered on the rake during the point-intercept survey. The conservatism values of these 6 native plant species encountered during the point-intercept survey are used to calculate Bullhead Lake's FQI.

Figure 3.4-6 displays the native species richness, average conservatism, and FQI values for Bullhead Lake calculated using the data from the 2005, 2011, 2012, and 2017 point-intercept surveys. Bullhead Lake's native species richness declined from 9-10 species in 2005, 2011, and 2012 to 6 species in 2017. The 2017 species richness value falls below the 25th percentile for lakes within the Southeast Wisconsin Till Plains (SWTP) ecoregion and for lakes throughout Wisconsin.

Bullhead Lake's average conservatism values in 2005, 2011, and 2012 were similar to the median conservatism value (5.4) for lakes in the SWTP ecoregion (Figure 3.4-6). In 2017, average conservatism declined to 4.7, falling below the 25th percentile for lakes in the SWTP ecoregion. Likewise, Bullhead Lake's FQI values calculated using native species richness and average conservatism show a large decline in 2017 compared to previous surveys. Bullhead Lake's average FQI value from the 2005, 2011, and 2012 surveys was 17.2, falling slightly below the median value (21.1) for lakes in the SWTP ecoregion. In 2017, Bullhead Lake's FQI value was 11.4, falling well below the 25th percentile for lakes in the SWTP and for lakes in Wisconsin. The decline in Bullhead Lake's floristic quality is another indicator of the environmental degradation that has occurred over this period.

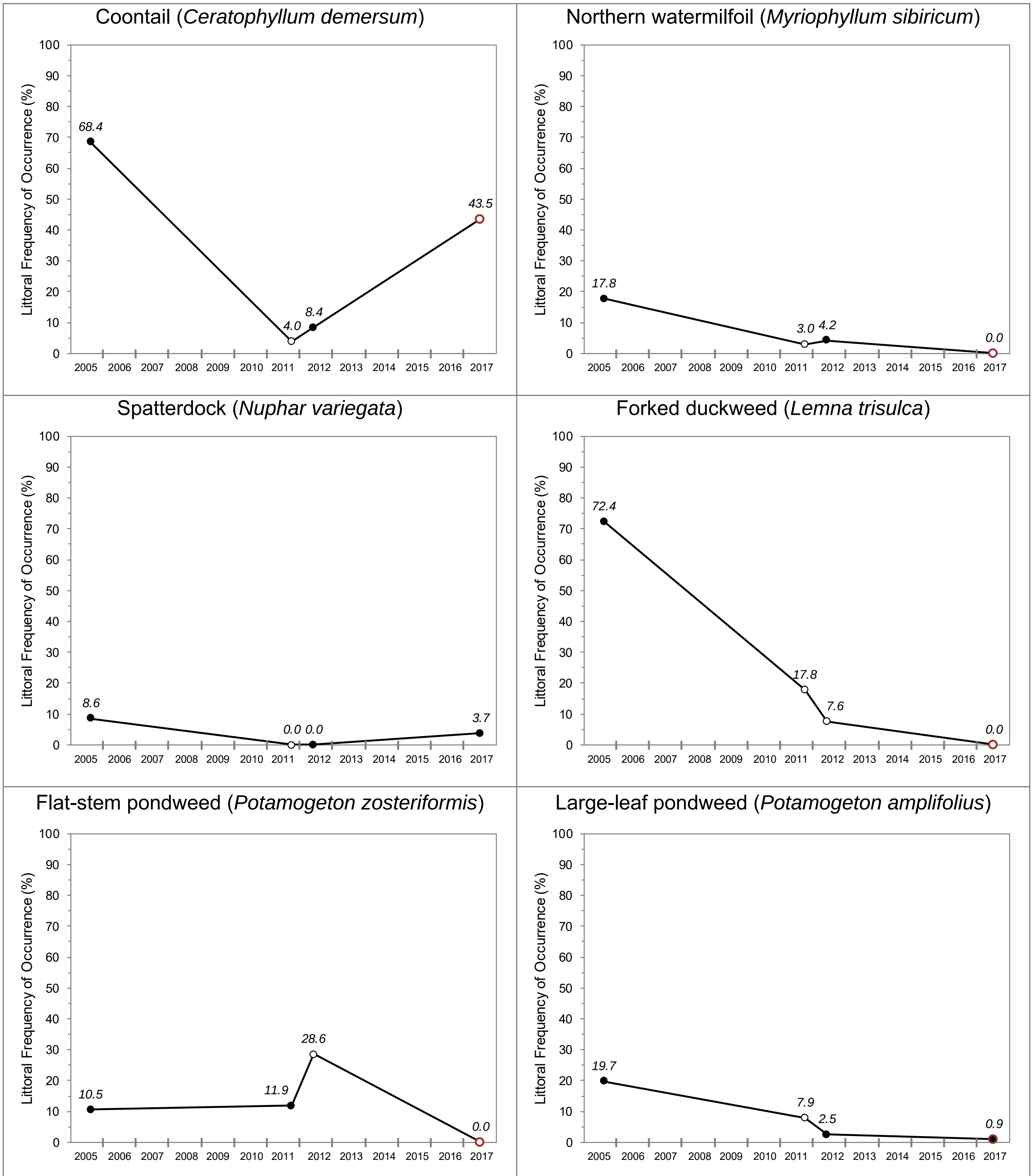


Figure 3.4-5. Littoral frequency of occurrence of select native aquatic plant species in Bullhead Lake from 2005-2017. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2017 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the four surveys. Created using data from WDNR 2005 (N = 152), WDNR 2011 (N = 101), WDNR 2012 (N = 119), and Onterra 2017 (N = 108) whole-lake point-intercept surveys.

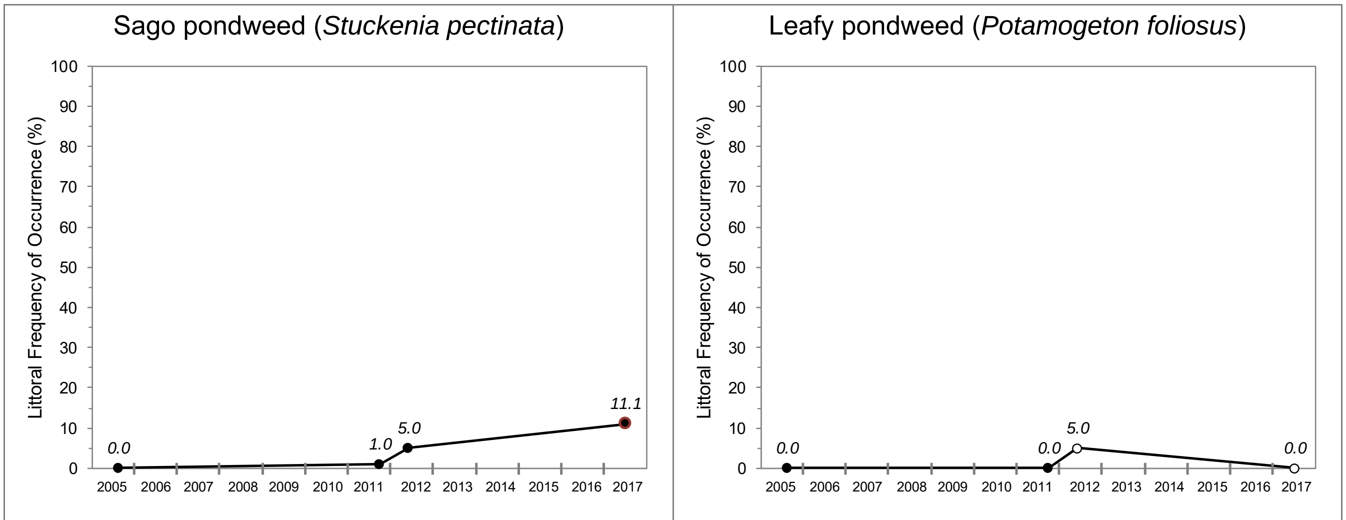


Figure 3.4-5 continued. Littoral frequency of occurrence of select native aquatic plant species in Bullhead Lake from 2005-2017. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2017 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the four surveys. Created using data from WDNR 2005 (N = 152), WDNR 2011 (N = 101), WDNR 2012 (N = 119), and Onterra 2017 (N = 108) whole-lake point-intercept surveys.

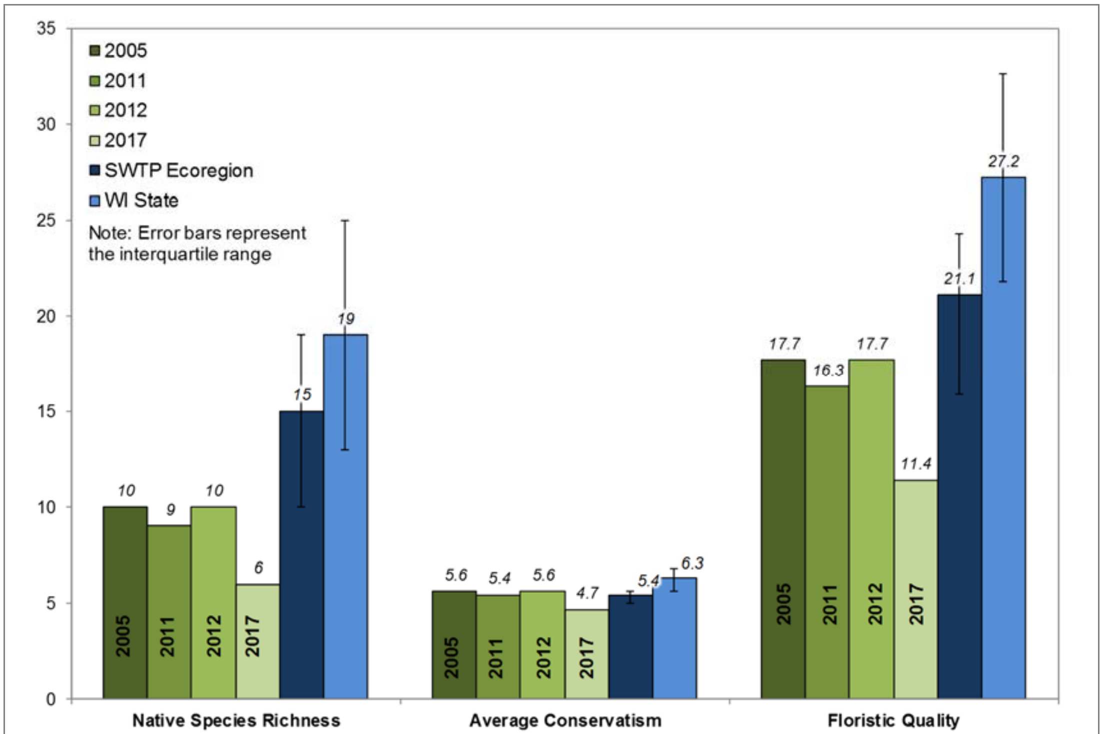


Figure 3.4-6. Bullhead Lake Floristic Quality Assessment. Created using data from WDNR 2005, 2011, and 2012, and Onterra 2017 whole-lake point-intercept surveys. Analysis follows Nichols (1999).

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Bullhead Lake contains a lower number of native aquatic plant species, one may assume the aquatic plant community also has lower 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 Bullhead Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the SWTP ecoregion (Figure 3.4-7). Data collected from the 2005, 2011, 2012, and 2017 point-intercept surveys in Bullhead Lake was used to calculate the aquatic plant community's Simpson's Diversity Index for each year. As illustrated, Bullhead Lake's Simpson's Diversity value of 0.80 in 2005, 2011, and 2012 was similar to the median value for lakes in the SWTP ecoregion. However, in 2017, Simpson's Diversity declined significantly to 0.54, falling below the 25th percentile for lakes in the SWTP ecoregion. In other words, prior to 2017 there was an 80% probability that aquatic plants sampled from two different locations in Bullhead Lake would be of different species. In 2017, this probability declined to 54%. The decline in species diversity in Bullhead Lake is another indicator of declining environmental quality.

One way to visualize Bullhead Lake's reduction in species diversity is to look at the relative frequency of occurrence of aquatic plant species (Figure 3.4-8). In 2005, approximately 80% of Bullhead Lake's plant community was comprised of four species: forked duckweed, coontail, spatterdock, and greater duckweed. In 2017, the four-most abundant plants in Bullhead Lake accounted for 94% of the plant community. The loss of aquatic plant species in 2017 and increase in dominance of disturbance-tolerant species resulted in lower species diversity.

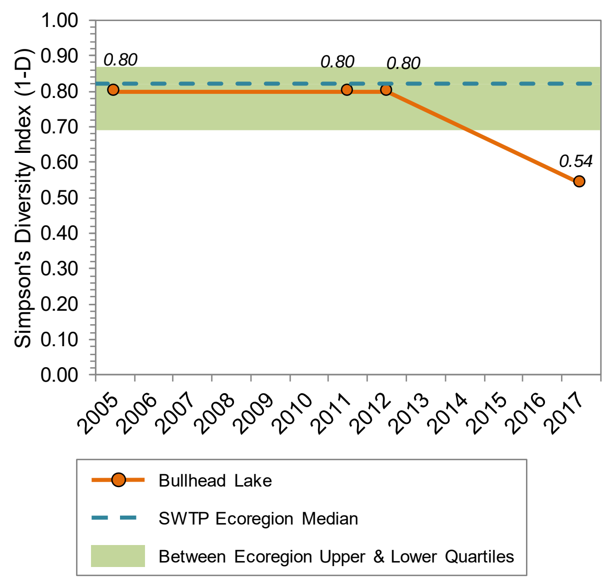


Figure 3.4-7. Bullhead Lake species diversity index. Created using data from 2005, 2011, 2012, and 2017 aquatic plant surveys. Ecoregion data from 77 SWTP lakes collected by WDNR Science Services and Onterra.

The 2017 emergent and floating-leaf aquatic plant community mapping survey found that Bullhead Lake contains approximately 3.9 acres of these communities (Table 3.4-2 and Map 6). Eight floating-leaf and emergent species were located on Bullhead Lake in 2017, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

Because the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Bullhead Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

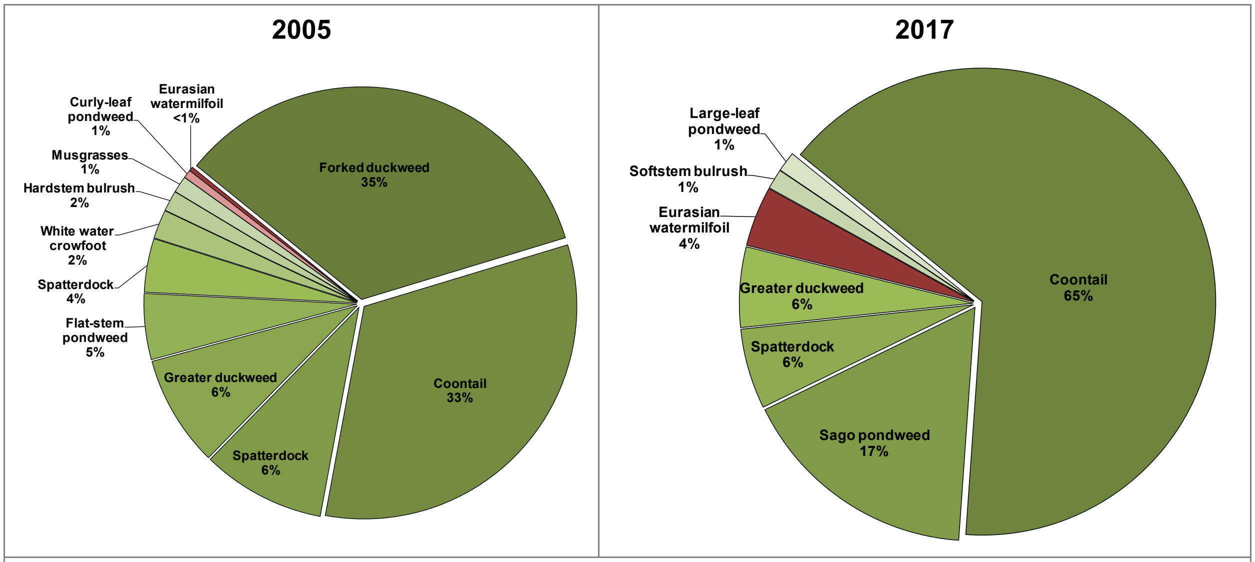


Figure 3.4-8. Bullhead Lake 2005 and 2017 relative plant littoral frequency of occurrence. Created using data from the 2005 and 2017 point-intercept surveys.

Table 3.4-2. Bullhead Lake acres of plant community types. Created from 2017 community mapping survey.

Plant Community	Acres
Emergent	1.5
Floating-leaf	2.4
Mixed Emergent & Floating-leaf	0.0
Total	**3.9**

Non-native Plants in Bullhead Lake

Curly-leaf pondweed & Eurasian watermilfoil

Curly-leaf pondweed (CLP; Photograph 3.4-5) was first recorded in Bullhead Lake in 2003 by the WDNR. During the 2017 late-May Early-Season AIS Survey in Bullhead Lake, Onterra ecologists mapped approximately 7.2 acres of curly-leaf pondweed (Map 7). Of these 7.2 acres, 2.0 acres were made up of *dominant* or *highly dominant* colonies of curly-leaf pondweed. The other 5.2 acres were less dense and were made up of colonies of *highly scattered* and *scattered* plants. Conditions were excellent for the survey, with a Secchi disc reading of 12.5 feet.

Because CLP is at peak growth early in the summer before naturally senescing by July, the summer point-intercept surveys do not accurately represent the full extent of the CLP population in Bullhead Lake. While approximately 7.2 acres of CLP were mapped in Bullhead Lake in late-May of 2017, it was not detected during the July point-intercept survey. Figure 3.4-9 illustrates the littoral occurrence of CLP as determined from the 2005, 2011, 2012, and 2017 point-intercept surveys. In 2012, the survey was completed in early June corresponding with the peak growth of

CLP and captured a relatively high littoral occurrence of 31%. The 2012 point-intercept survey data and the 2017 mapping data indicate Bullhead Lake supports a larger CLP population, but the majority of this population senesces by July.

Photograph 3.4-5. Curly-leaf pondweed and Eurasian watermilfoil, two non-native, invasive aquatic plants in Bullhead Lake.

Eurasian watermilfoil (EWM; Photograph 3.4-5) was first documented in Bullhead in 2005 by the WDNR. During the 2017 Early-Season AIS Survey, Onterra ecologist mapped 0.6 acres of colonized Eurasian watermilfoil (Map 8). Eurasian watermilfoil was also mapped during September 2017. Due to the large algae bloom seen on Bullhead during July, only three *single plants* of Eurasian watermilfoil were found in September (Map 9). Due to this, the colonies of Eurasian watermilfoil from the Early-Season AIS Survey likely better represent the population within Bullhead Lake. Figure 3.4-9 displays the littoral frequency of occurrence of Eurasian watermilfoil in Bullhead Lake from 2005 to 2017. Over the course of this time period, the occurrence of EWM in Bullhead Lake has remained low, and its occurrence in 2017 was not statistically different from any of the previous surveys.

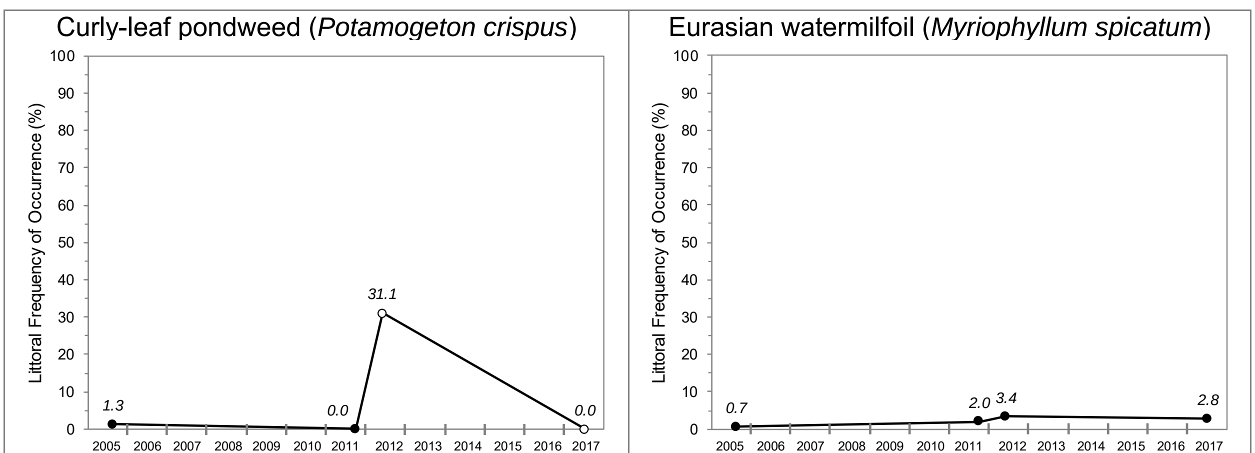


Figure 3.4-9. Littoral frequency of occurrence of curly-leaf pondweed and Eurasian watermilfoil in Bullhead Lake from 2005-2017. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2017 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the four surveys. Created using data from WDNR 2005 (N = 152), WDNR 2011 (N = 101), WDNR 2012 (N = 119), and Onterra 2017 (N = 108) whole-lake point-intercept surveys.

Stakeholder Survey Responses to Aquatic Vegetation within Bullhead Lake

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.4-10 and 3.4-11 display the responses of members of Bullhead Lake stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, including, algae, during the open water season, negatively impacts the enjoyment of Bullhead Lake, the majority of stakeholder survey respondents (50%) indicated *often*, 36% indicated *always*, and 14% indicated *sometimes* (Figure 3.4-10).

As the discussed previously, there was a lack of submergent native aquatic plants present in Bullhead Lake in 2017 but Eurasian watermilfoil and curly-leaf pondweed are present. These plants can create dense, undrivable, colonies, as discussed in the Non-Native Aquatic Plant subsection, which may have lead the respondents to answer the way they did. Question 23 also includes the option of algae being a factor that negatively impacts the enjoyment of Bullhead Lake. There was, as mentioned, a significant algae bloom in 2017, which also may have led respondents to answer the way they did.

When asked if they believe aquatic plant control is needed on Bullhead Lake, 60% of respondents indicated *definitely yes* and 40% indicated *probably yes.* The presence of AIS within Bullhead Lake is well-known knowledge for the respondents so while aquatic plants may impact user's enjoyment of the lake, stakeholder survey respondents believe that control of AIS is needed. As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating aquatic invasive species. The management strategy that will be taken to manage AIS in Bullhead Lake is discussed within the Implementation Plan Section (Section 5.0).

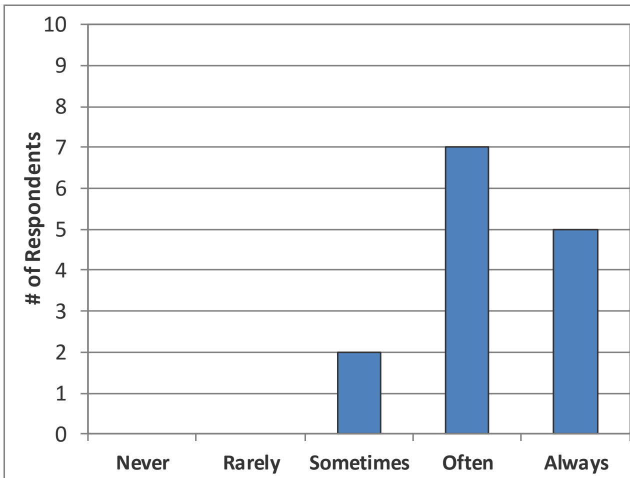


Figure 3.4-10. Stakeholder survey response Question #23. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Bullhead Lake?

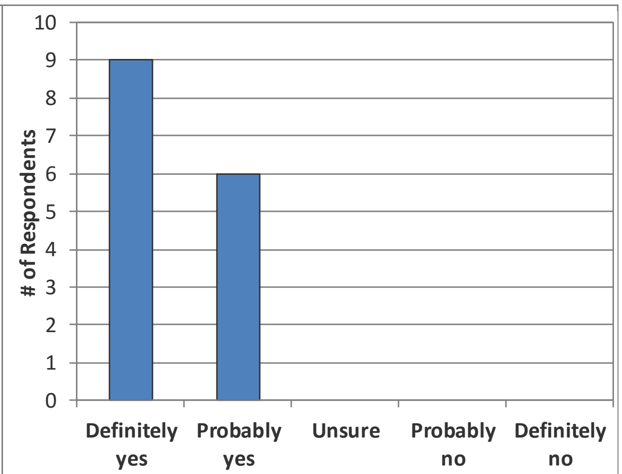


Figure 3.4-11. Stakeholder survey response Question #24. Do you believe aquatic plant control is needed on Bullhead Lake?

3.5 Aquatic Invasive Species in Bullhead Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Bullhead Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are four AIS present (Table 3.5-1).

Table 3.5-1. AIS present within Bullhead Lake

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.4 – Aquatic Plants
	Giant hogweed	*Heracleum mantegazzianum*	Section 3.5 - Aquatic Invasive Species
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 3.5 - Aquatic Invasive Species

Figure 3.5-1 displays the five aquatic invasive species that Bullhead Lake stakeholders believe are in Bullhead Lake. Only the species present in Bullhead Lake are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

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

Aquatic Animals

Mystery snails

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

Aquatic Plants

Giant hogweed

Giant hogweed (*Heracleum mantegazzianum*), also known as giant cow parsley and cartwheel-flower, is an invasive plant that generally inhabits roadsides, empty lots and woodland edges. The sap from giant hogweed is capable of causing severe burns and blisters on the skin if exposed to sun after contact with the sap. It is easily recognizable by its height, 8-20 feet, and the large, white, umbrella-like flowers it produces. It is possible to control giant hogweed, if proper measures are taken. Giant hogweed can be hand-dug out of the ground and then the flower heads burned or placed in the landfill. Foliar sprays can also be used or placed on cut stems.

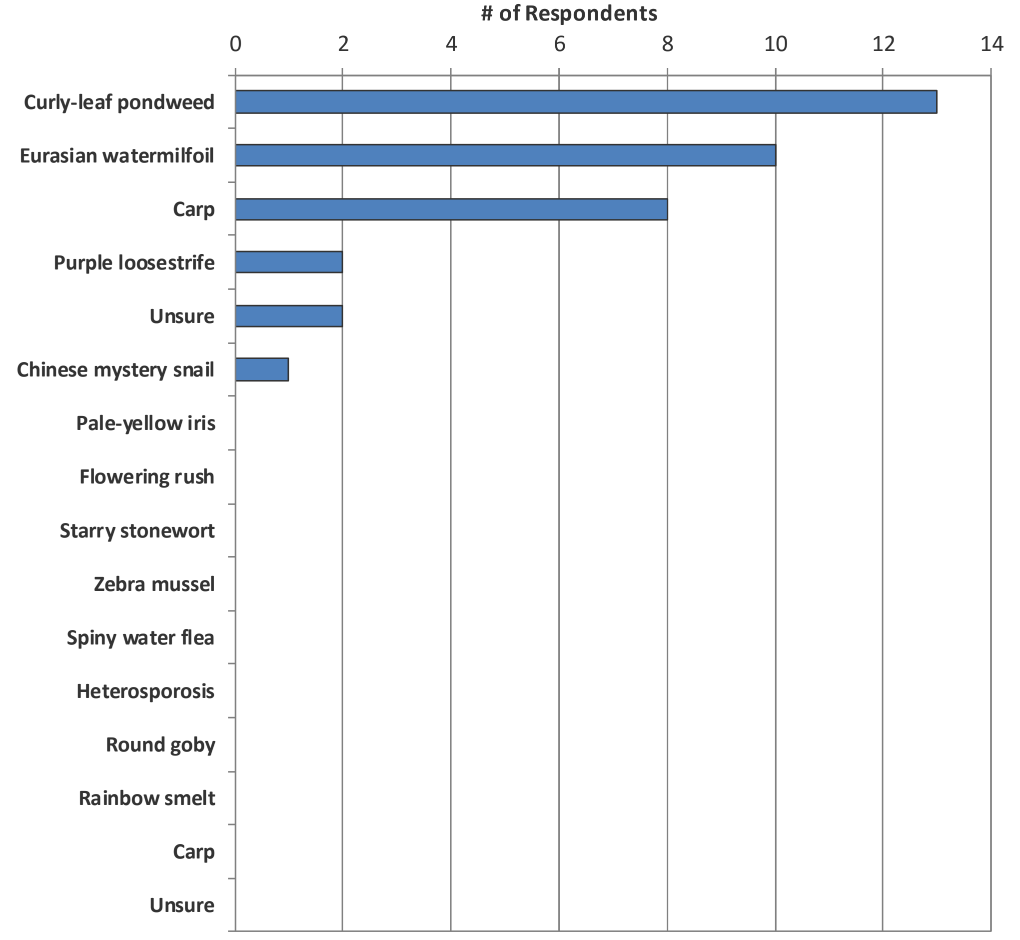


Figure 3.5-1. Stakeholder survey response Question #20. Which aquatic invasive species do you believe are in Bullhead Lake?

3.6 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 Bullhead 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).

Bullhead 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 Bullhead 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 3.6-1.

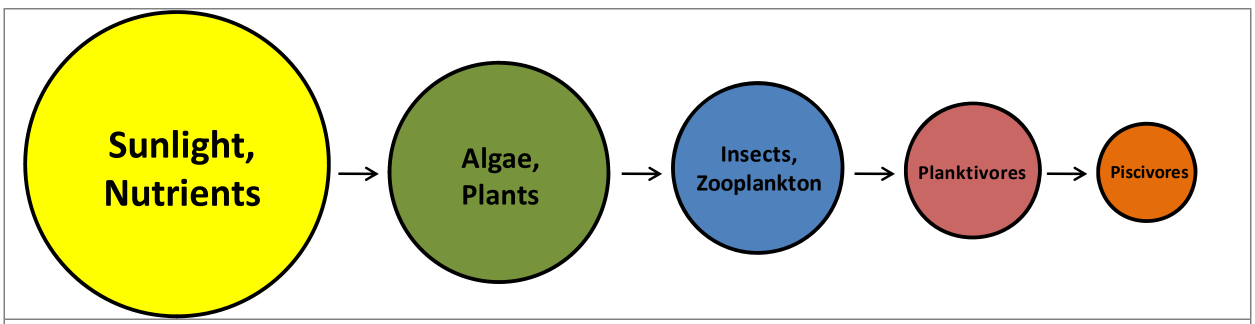


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Bullhead Lake is a eutrophic system, meaning it has a high nutrient content and thus relatively high primary productivity. Simply put, this means Bullhead Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.6-1 shows the popular game fish present in the lake. Although not an exhaustive list of fish species in the lake, additional fish species found in past surveys of Bullhead Lake include common carp (*Cyprinus carpio*), white sucker

(*Catostomus commersonii*), Iowa darter (*Etheostoma exile*) and the central mudminnow (*Umbra limi*).

Table 3.6-1. Gamefish present in Bullhead Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead (*Ameiurus melas*)	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Brown Bullhead (*Ameiurus nebulosus*)	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Green Sunfish (*Lepomis cyanellus*)	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead (*Ameiurus natalis*)	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.6-1). 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) then release the captured fish.

The other commonly used sampling method is electroshocking (Photograph 3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell, fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

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

Photograph 3.6-1. Fyke net positioned in the littoral zone of a Wisconsin lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). 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. Bullhead Lake has been stocked from 1973 to 2017 with walleye and northern pike/muskellunge hybrid otherwise known as tiger muskellunge. Stocking efforts from 1973 to 2017 are displayed in Table 3.6-2 and Table 3.6-3.

Photograph 3.6-2. Fingerling Walleye. (Photo by UW-Stevens Point)

Table 3.6-2. Stocking data available for walleye in Bullhead Lake (1983 to 2017).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1983	Unspecified	Fingerling	3350	5
1985	Unspecified	Fingerling	3500	4
1989	Unspecified	Fry	3094	3
1992	Unspecified	Fingerling	1774	2.5
1994	Unspecified	Fingerling	1776	2.5
1995	Unspecified	Fingerling	1677	2.8
1997	Unspecified	Small Fingerling	1675	2.7
1999	Unspecified	Small Fingerling	6700	1.5
2001	Unspecified	Small Fingerling	6700	1.6
2003	Lake Michigan	Small Fingerling	6695	1.5
2005	Lake Michigan	Small Fingerling	3335	1.4
2009	Lake Michigan	Small Fingerling	2245	1.8
2011	Lake Michigan	Small Fingerling	2570	1.9
2013	Mississippi Headwaters	Small Fingerling	2340	2
2015	Lake Michigan	Small Fingerling	1504	1.7
2017	Mississippi Headwaters	Small Fingerling	2,432	1.7

Table 3.6-3. Stocking data available for northern pike X muskellunge in Bullhead Lake (1973 to 1980).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1973	Unspecified	Fingerling	300	15
1974	Unspecified	Fingerling	240	9
1976	Unspecified	Fingerling	300	8
1977	Unspecified	Fingerling	300	10
1978	Unspecified	Fingerling	300	9
1979	Unspecified	Fingerling	300	8.5
1980	Unspecified	Fingerling	300	11

Fishing Activity

As is discussed in the Stakeholder Participation Section (2.0), the results of the stakeholder survey should not be interpreted as being statistically representative of all Bullhead Lake stakeholders as a statistical benchmark of 60% response rate was not received. Based on data collected from the stakeholder survey (Appendix B), fishing was the third-most important reason for owning property on or near Bullhead Lake (Question #15). Figure 3.6-2 displays the fish that Bullhead Lake stakeholders enjoy catching the most, with bluegill/sunfish and crappie being the most popular. Of these respondents, 30% believed that fishing on the lake is poor, 30% believed that the fishing is fair, and 30% believed fishing is good (Question 10, Figure 3.6-3). While Bullhead Lake survey respondents did not agree on the current quality of fishing, 50% believe that the fishing has remained the same, while another 40% believe the fishing has become somewhat worse (Figure 3.6-4).

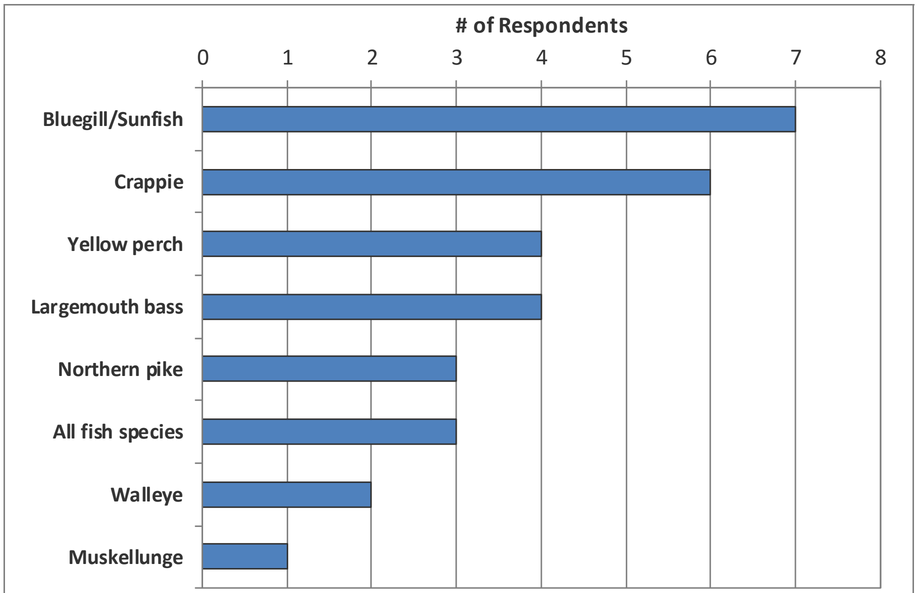


Figure 3.6-2. Stakeholder survey response Question #9. What species of fish do you like to catch on Bullhead Lake?

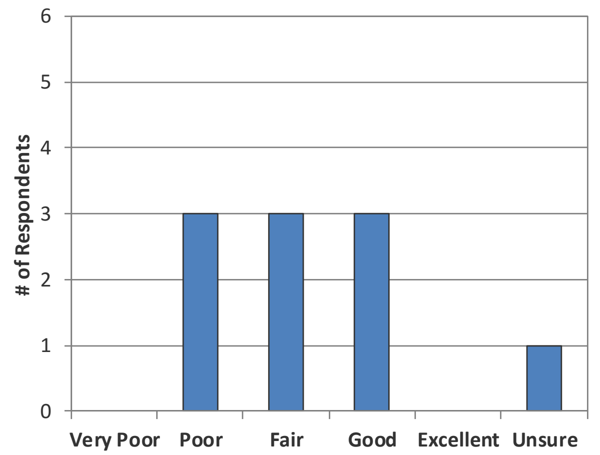


Figure 3.6-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on Bullhead Lake?

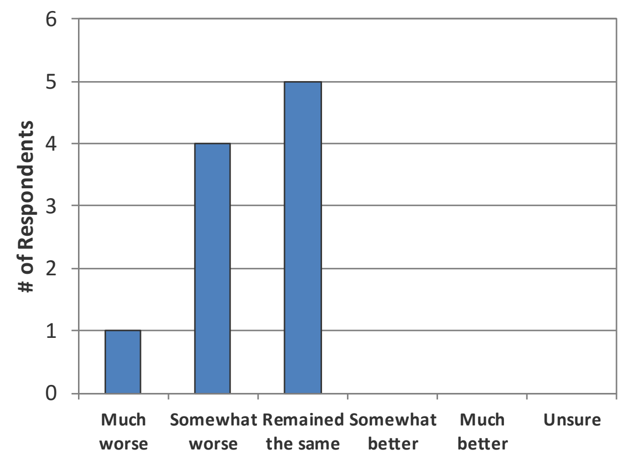


Figure 3.6-4. Stakeholder survey response Question #11. How has the quality of fishing changed on Bullhead Lake since you started fishing the lake?

Fish Populations and Trends

Utilizing the fish sampling techniques mentioned above and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing).

Bullhead Lake has been traditionally managed as a bass and panfish fishery with a stocked component of walleye and northern pike X muskellunge hybrid for angling opportunities. The WDNR 2011 survey found similar results to previous surveys with largemouth bass size and abundance near statewide averages. Bluegill abundance, however, decreased in 2011 following a trend since the 1999 WDNR fisheries survey. Other panfish that were sampled, including yellow perch and black crappie, also decreased in abundance (WDNR 2011).

Bullhead 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 upright or overhanging vegetation along with 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 do 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, 86% of the substrate sampled in the littoral zone of Bullhead Lake were soft sediments, 12% was composed of sand and 2% was composed of rock sediments.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006).

A fall 2017 survey documented 49 pieces of coarse woody along the shores of Bullhead Lake, resulting in a ratio of approximately 37 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 3.6-3. 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 3.6-3). 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 BLAA 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 Bullhead Lake.

Regulations and Management

Regulations for Bullhead Lake gamefish species as of April 2018 are displayed in Table 3.6-4. Bullhead Lake is one of 93 lakes chosen to participate in an experimental daily bag limit on panfish. Below are the three different daily bag limits selected to determine which is best at improving panfish size.

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

Bullhead Lake was chosen to be under the spawning season 15/5 experimental regulation. The efficacy of the regulations as well as anglers support of the changes will be evaluated in 2021 and 2026 (WDNR 2017). For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-4. WDNR fishing regulations for Bullhead Lake (As of April 2018).

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

General Waterbody Restrictions: Motor Trolling is allowed with 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 3.6-5. 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 3.6-5. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline and historical data to increase the general understanding of the Bullhead Lake ecosystem.
2) Collect detailed information regarding lake water quality, with the primary emphasis being on sources of nutrients that drive algal blooms.
3) Collect sociological information from Bullhead 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 Bullhead Lake ecosystem, the people that care about the lake, and what needs to be completed to protect and enhance it.

Bullhead Lake has long been considered a productive system based upon earlier planning projects and voluntary water quality monitoring. The monitoring completed as a part of this project indicated that 2017 was the worst year for total phosphorus and chlorophyll-*a* concentration in the Bullhead Lake dataset. The spring and summer of 2017 were one of the wettest on record, so high nutrient and algae concentrations are not surprising in a drainage lake situated in an agricultural setting. However, trend analysis also indicated that 2017, while unusually high, was also just a part of a worsening trend since 2009 regarding the lake's total phosphorus, chlorophyll-*a*, and water clarity. All three of these trophic parameters showed a significantly valid trend towards worsening water quality during those 8 years compared to previous years. Unknown changes in land use within the Bullhead Lake watershed were first investigated as the primary cause of this trend as that has been the case in other Manitowoc and Calumet county lakes in recent years. However, discussions with land conservation department staff from both counties yielded no significant changes in land use or cover within the Bullhead Lake watershed. In fact, discussions with the family that farms most of the land within the Bullhead Lake watershed indicate that best management practices (BMPs) are being utilized to a high degree with the intention of protecting the lake.

Further investigation, including the analysis of past temperature and dissolved oxygen profiles from Bullhead Lake, show a substantial increase in anoxic water volume within the lake over the past decade. This means that there is much more non-oxygenated water with in the lake. Furthermore, the area of sediment exposed to that water has also increased. This has led to a much greater degree of internal phosphorus loading within the lake over this same time period. With the increased phosphorus, there is a subsequent increase in algal growth and a loss of water clarity. In 2017, the increased internal loading coupled with higher external loads brought on by a wet growing season, led to the worst water quality recorded in the lake, including chlorophyll-*a* concentrations surpassing levels the World Health Organization considers to be safe for human contact.

While the recent water quality trend has worsened, the overall water quality in Bullhead Lake has been fair to poor for decades. This has led to subdued overall ecological health within the lake as evidenced by low diversity and floristic quality within the lake's aquatic plant community. Further, point-incept survey results indicated that the abundance of aquatic plants has diminished in the lake as well. Much of the issues within the lake's plant community are driven by poor water clarity and dominance by one or two species especially suited to thrive in the turbid and nutrient rich system.

The exotic plant species, Eurasian watermilfoil and curly-leaf pondweed, occur within Bullhead Lake, but neither appear to bring on clear issues with the ecology of the lake or recreational use. Curly-leaf pondweed grows in most areas of the lake and was documented to dominate in some of those areas during 2017; however, as part of its normal lifecycle, this exotic typically dies back by early July and does not present an issue over the bulk of the growing season. Eurasian watermilfoil has been documented during each of the four point-intercept surveys completed since 2005, but always at very low frequencies. While neither of these species are causing issues at present, improvements in the lake's water quality, especially water clarity, may allow these exotic populations to increase and impact recreation and possibly the ecological health of Bullhead Lake. Improved water quality and the general ecological health are primary objectives within the Implementation Plan that follow. If that goal is met, the BLAA must be prepared to battle increasing populations of these exotics.

As mentioned above, improved water quality is a primary goal of this management plan. One possible solution that will be investigated fully is the use of an alum treatment to reduce internal phosphorus loading. Alum treatments were completed on Bullhead Lake during 1978 and 1988 with short-term success. In both cases, the treatment benefits only lasted a few years, likely due to insufficient alum dose rates and high rates of external loading. If a third alum treatment is to be completed on Bullhead Lake, documentation of efforts to minimize external sources of phosphorus will be developed and studies will be completed to determine the correct alum dose to assure a long-lasting (15 or more years) improvement in the lake's water quality.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Bullhead Lake Advancement Association Planning Committee and ecologist/planners from Onterra. It represents the path the BLAA 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 Bullhead Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Improve Overall Ecological Health of Bullhead Lake

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

Management Action:	Conduct periodic quantitative vegetation monitoring on Bullhead Lake.
Timeframe:	Point-Intercept Survey every 3-5 years, Community Mapping every 7-10 years
Possible Grant:	Small-Scale Lake Planning Grant or AIS-Education, Prevention, and Planning in <$10,000 category.
Facilitator:	BLAA Board of Directors
Description:	As part of the ongoing aquatic plant management program, a whole-lake point-intercept survey will be conducted at a minimum once every 3-5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Bullhead Lake. A point-intercept survey was conducted on Bullhead Lake in 2017; therefore, the next point-intercept survey will be completed between 2020 and 2022, depending on the level of plant management being completed. In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Bullhead Lake, a community mapping survey would be conducted every 7-10 years. A community mapping survey was conducted on Bullhead Lake in 2017 as a part of this management planning effort. The next community mapping survey will be completed between 2024 and 2027.
Action Steps:	
1.	Contract with qualified aquatic plant survey consultant.
2.	Apply for funding through WDNR grant program.
3.	Complete surveys and alter management plan as appropriate.

Management Action:	Document positive changes to agricultural practices utilized in Bullhead Lake watershed.
Timeframe:	Begin spring 2019
Facilitator:	Nick Dallmann
Prospective Grant:	See action below
Description:	The Dallmann family has been farming in the Bullhead Lake area for decades and operate much of the land north and east of the lake. Over the past 8 years, the Dallmanns have altered the way they farm the land in the Bullhead Lake watershed to minimize impacts to the lake. As described in the Water Quality Section 3.1, water quality in Bullhead Lake has worsened in the last nine years. Often, this type of change is brought on by changes in the watershed, like increased row cropping or manure spreading. This is not the case in Bullhead Lake, in fact, the change was brought on by increased anoxic water volume in the lake leading to a greater amount of internal loading. The management action below calls for the completion of an alum treatment diagnostic-feasibility study on Bullhead Lake. As a part of that project, the consultants completing the study would work with the

	Dallmann family to document the positive changes they have made in the Bullhead Lake watershed. A summary of those changes would be included in the diagnostic-feasibility study report.
Action Steps:	
1.	See description above.

<u>Management Action:</u>	Complete a diagnostic-feasibility study on Bullhead Lake to discover if an alum treatment would improve the lake's water quality.
Timeframe:	Initiate spring 2019
Facilitator:	BLAA Board of Directors
Prospective Grant:	Lake Protection Grant – Diagnostic-Feasibility Category
Description:	Long-term trends analysis documented within the Water Quality Section 3.1 discovered a decrease in Bullhead Lake's water quality. Further analysis found that the worsening water quality was brought on by increasing volume of anoxic water in the hypolimnion. With the increase volume of anoxic water, there has been an appreciable increase in internal phosphorus loading as well. Alum treatments were completed on Bullhead Lake during 1978 and 1988. Both resulted in positive, but short-lived results. It appears that either not enough alum was added to the lake or enough phosphorus was delivered to Bullhead Lake from its watershed for the alum treatment to only be effective for a few years. It was not uncommon for under dosing to occur in early alum treatments in Wisconsin. The diagnostic-feasibility study would include three primary components: 1) detailed water quality monitoring to document and quantify internal nutrient loading to the lake, 2) sediment core collection and analysis to determine an appropriate alum dose should that action be pursued, and 3) document the positive changes made in the Bullhead Lake watershed as described in the preceding management action.
Action Steps:	
1.	Finalize diagnostic-feasibility study design.
2.	Create Lake Protection Grant application for Feb. 1, 2019 deadline.
3.	Complete studies and determine if alum treatment is appropriate and if the BLAA can reasonably afford to complete it with grant funding.

Management Action:	Remove excessive floating mats of filamentous algae.
Timeframe:	Continuation of current effort
Facilitator:	BLAA Board of Directors
Description:	For the past several years, large floating mats of filamentous algae have been forming on the lake surface during the summer months. These mats sometimes cover greater than 10 acres and greatly limit recreational activities and aesthetic value. Since 2015 the association has been utilizing a mechanical harvester to skim mats that are away from the near-shore areas, unloading them at the boat launch and depositing the algae into the digester at the Dallmann farm. Each load is approximately 1500 lbs (wet weight) of algae and contains about one pound of total phosphorous. Algae removal improves lake navigation, aesthetic pleasure and contributes to phosphorous reduction. From 2015-2018 approximately 100 loads of filamentous algae have been removed. Continuing this practice requires volunteer efforts to operate and maintain the mechanical harvester as well as the funds to support ongoing operation and maintenance. If an alum treatment is approved and is effective in reducing algae formation, mechanical harvesting could cease. Until that time, the riparian owners and fishermen value the improvements the mechanical removal of algal surface mats makes to the lake. The following procedures will be adhered to as a part of the Bullhead Lake floating algae removal program: 1. As illustrated in Figure 5.0-1, the collection area is 50 feet wide beginning 75 feet from shore. 2. A harvesting schedule will be supplied to the WDNR Water Resources Manager at least four working days prior to the start of harvesting activities. 3. Vegetation will not be cut as a part of the operation. 4. Harvesting will not disturb bottom sediments. 5. Harvesting will not begin until after June 15th to limit disturbance of spawning and/or nesting panfish in shallow areas. If significant numbers of fish are being captured during harvesting, operations will be stopped and not restarted until after July 1st. All species caught during harvesting will be returned to the lake. 6. A copy of the harvesting permit will be maintained aboard the harvester at all times during operation. The operators will read and understand the harvesting conditions of the permit prior to operation of the equipment. 7. All harvested material will be removed from the lake and disposed of in Dallmann manure digester.

	8. Mechanical harvesting records will be kept and a report meeting the specifications outlined in the permit will be furnished to the WDNR by November 1 of each year in which harvesting occurs.
Action Steps:	See description above

Figure 5.0-1. Floating algae removal areas.

Management Goal 2: Increase the Bullhead Lake Advancement Association's Capacity to Effectively Manage Bullhead Lake into the Future

Management Action:	Develop and implement improved communication strategy
Timeframe:	Initiate 2019
Facilitator:	BLAA Board of Directors
Prospective Grant:	Small-scale Lake Planning Grant for some start-up costs
Description:	Two-way communication between the lake association and its members is important in keeping members informed, enlisting sufficient volunteers, and assuring funding for association projects. Two types of communication will be enhanced by the BLAA as a part of this strategy: **Periodic/Planned Communications** This would include development of a consistent newsletter and an association website. These media types will be used to pass along educational materials, meeting agendas and minutes, and results of BLAA management action results. Use of the kiosk at the public landing would also be used in this manner as well. **Quick/Responsive Communications** This would include the development of a complete email address list of association members that utilize email and the development of an association FaceBook group. These media types would be used to direct members to the website for additional information and possibly deliver electronic versions of the newsletter. They can also be used develop the social aspects of having property on a lake and allow for communication among association members.
Action Steps:	
1.	See description above.

Management Action:	Investigate and promote funding opportunities above annual association membership dues.
Timeframe:	Initiate 2019
Facilitator:	BLAA Board of Directors
Description:	Bullhead Lake has approximately 40 properties around it. Even if the association had 100% property owner membership, the annual dues would not supply sufficient funds to allow the association to effectively manage the lake, especially if an alum treatment is to be completed and additional aquatic plant management is required. To increase membership above association dues income, the BLAA

	Board of Directors will investigate the following potential funding sources: **GoFundMe Drive (or similar)** GoFundMe is a web-based crowd funding platform that many individuals and non-profit groups utilize to raise funds for specific projects or needs. One advantage of this platform is that a link to a specific GoFundMe campaign can be sent via social media, email, or even text; therefore, it can be shared easily and quickly and generate funding outside of the group setting up the fund. **Approach local outdoor sporting clubs** Local sporting clubs benefit from the fishing and hunting opportunities that Bullhead Lake provides to the area. It is reasonable to approach these groups and request donations to help fund specific projects or actions aimed at improving the natural resource those clubs rely upon for recreation. **Formation of a Lake Management District** A lake management district is a taxation entity with no ordinance or enforcement powers. The district is set up to generate funding from those properties within the district, which is typically the properties that abut the lake. A lake district is the only taxation entity in which the members vote annually on what the tax levy will be; therefore, the levy amount is completely controlled by the members. This is a fair way to spread the cost of managing the lake among all of the lake property owners. Lake districts are automatically eligible to receive state funding through grant programs.
Action Steps:	
1.	See description above.
2.	
3.	

<u>Management Action:</u>	Establish BLAA's involvement with other entities that have responsibilities in managing (management units) Bullhead Lake
Timeframe:	2019
Facilitator:	BLAA 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 that rely on voluntary participation. It is important that the BLAA 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 below.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Rockland	Linda Gilbertson, Clerk (rocklandcollins@tds.net) (https://townofrockland-wi.com/)	Bullhead Lake falls within the Town of Rockland.	Once a year, or more as needed. May check website for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Reedsville Sportsmen's Club	920.754.4884	Supports the conservation of wildlife and its habitat in the Bullhead Lake area	As needed	Can aid in funding for projects around the lake.
Rockea Hunting Club, Inc.	Alvin Rabe, Jr	Supports the conservation of wildlife and its habitat in the Bullhead Lake area	As needed	Can aid in funding for projects around the lake.
Manitowoc County Lakes Association	Tom Ward, President (wardswaters@gmail.com)	Protects Manitowoc County waters through facilitating discussion and education.	As needed. May check website (www.manitowoc county lakesassociation.org) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Manitowoc Co. waterways.
Manitowoc County Soil and Water Conservation Dept.	Jerry Halverson, Dept. Head (920.920.683.4183)	Oversees conservation efforts for land and water projects.	As needed	Can aid with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Steve Hogler, Fisheries Biologist (920.662.5480)	Manages the fishery of Bullhead Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Mary Gansberg, Water Resource Specialist (920.662.5489)	Oversees management plans, grants, and all lake activities.	Once a year, or more as issues arise.	Keep updated on lake management activities.

Management Goal 3: Improve Bullhead Lake Fishery

Management Action:	Work with WDNR fisheries staff to increase proper fish habitat and determine appropriate stocking routine.
Timeframe:	2020
Facilitator:	BLAA Board of Directors
Description:	Fishing is an important activity cited by respondents to the stakeholder survey distributed as a part of this project. It is the fourth most important activity after relaxing/entertaining, pontoon riding, and nature viewing. Over 65% of respondents had fished the lake in the past three years and of those people, half believe that the quality of fishing has gotten somewhat worse or much worse. The BLAA will work with local fisheries biologists to determine what type of fish structure improvements could be made to the lake to improve its fishery. Further, once those improvements are made, determine a stocking routine that will provide quality fishing opportunities on the lake.
Action Steps:	
1.	See description above.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Bullhead Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred twice during the summer. In addition to the samples collected by BLAA members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, summer, fall and winter. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disc transparency was also included during each visit.

All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (SLOH). The parameters measured, sample collection timing, and designated collector are contained in the table below.

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

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Bullhead Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – Fry et. al 2011) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Bullhead Lake during a May 26, 2017 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Bullhead Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on July 13, 2017. A point spacing of 30 meters was used resulting in approximately 306 points.

Community Mapping

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

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

7.0 LITERATURE CITED

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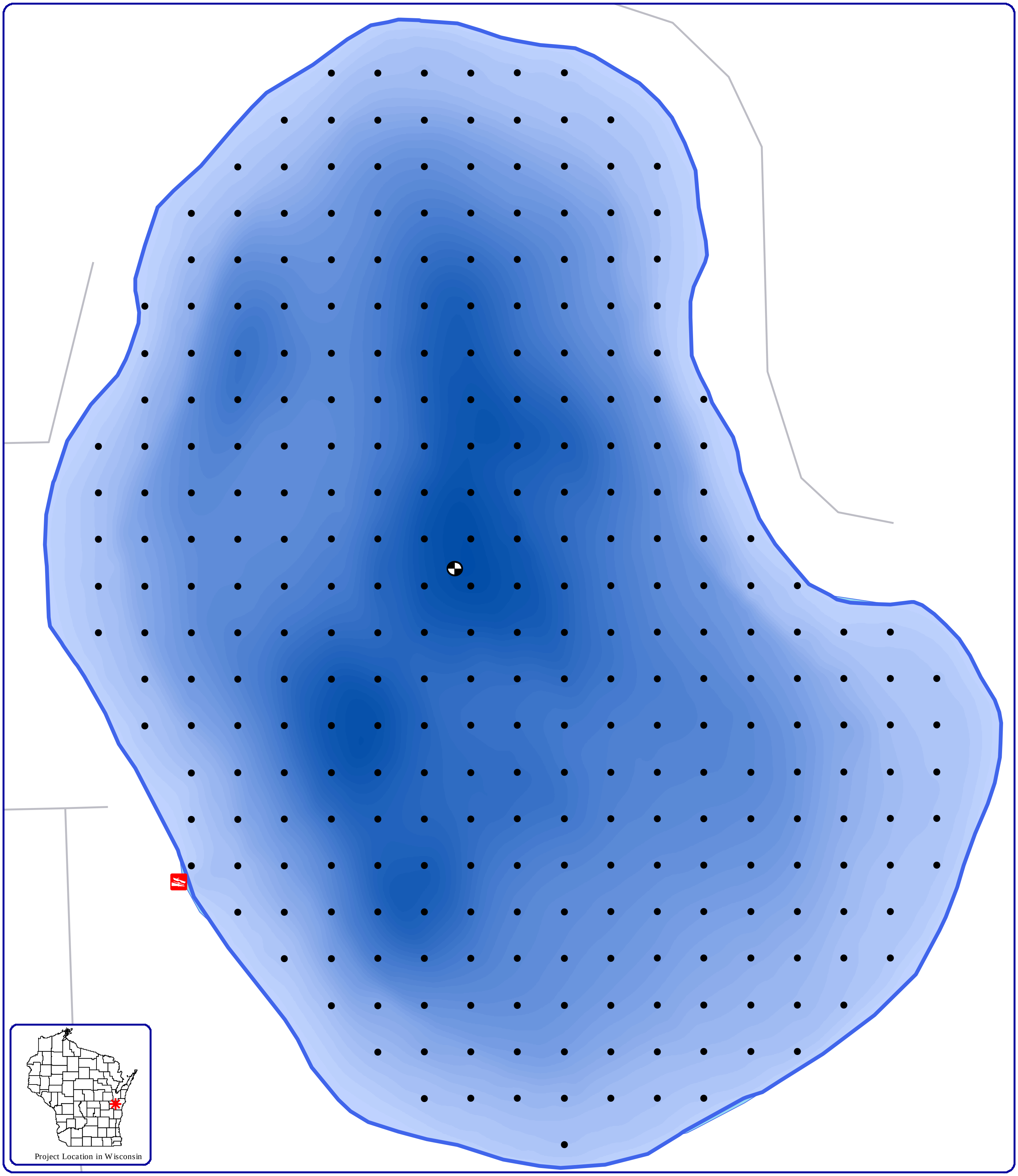

N
W E
S

260

Feet

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Lake Management Planning
135 South Broadway Suite C
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads & Hydro: WDNR
Map Date: April 13, 2018
Filename: Map1_Bullhead_Location.mxd

Legend

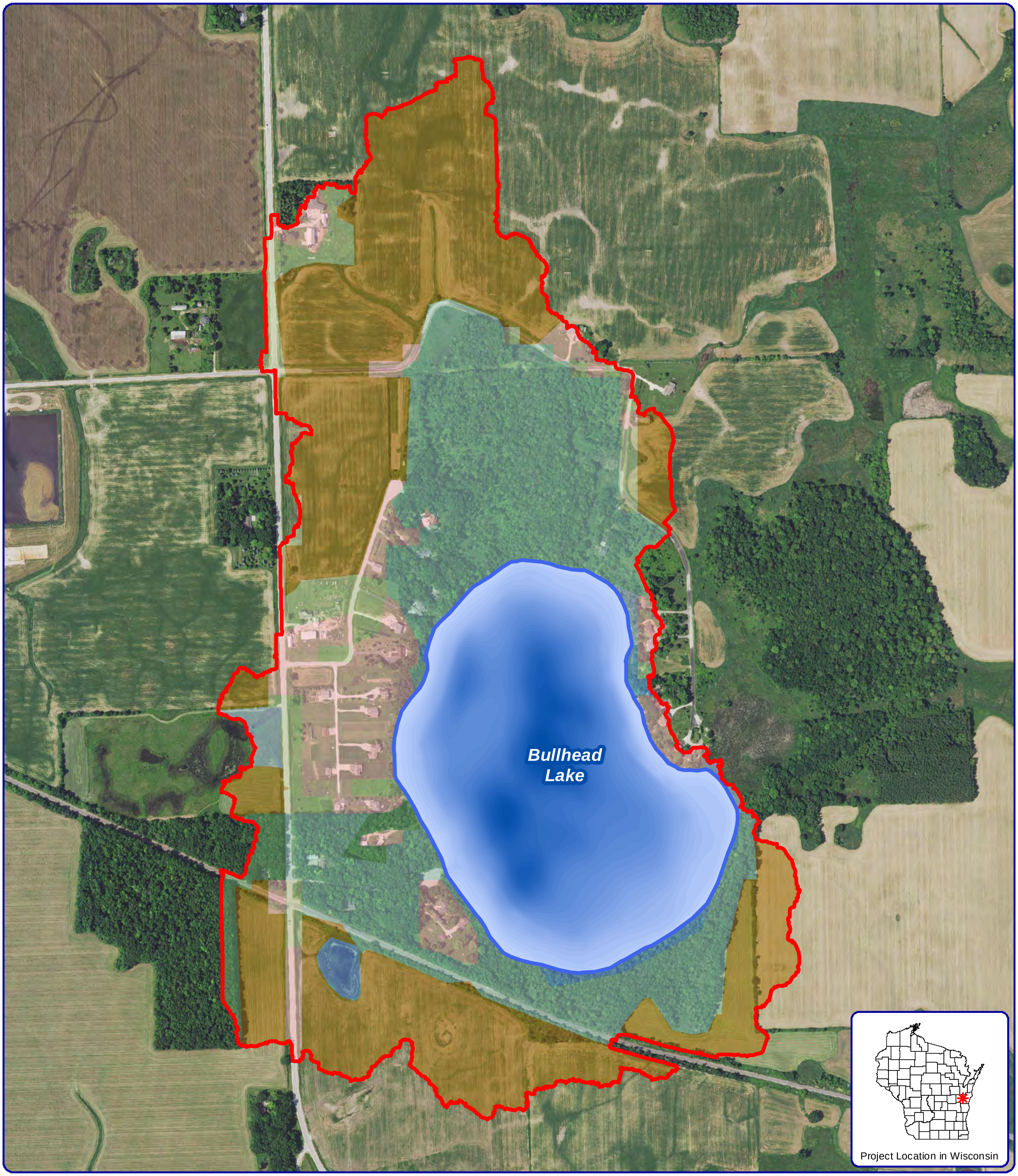
- Bullhead Lake
  WDNR Definition
- Point-intercept Sample Location
  30 meter points
- Public Access
- WDNR Managed Lands
  (None)
- USDA Forest Service Land
  (None)
- Water Quality Sampling Location

Map 1

Bullhead Lake

Manitowoc County, Wisconsin

Project Location
& Lake Boundaries



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740
Feet

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Sources:
Hydro: WDNR
Bathymetry: Onterra 2017
Orthophotography: NAIP 2015
Land Cover: NLCD 2011
Watershed Boundaries: Onterra 2017
Map Date: October 30, 2017
Filename: Map2_Bullhead_WS.mxd

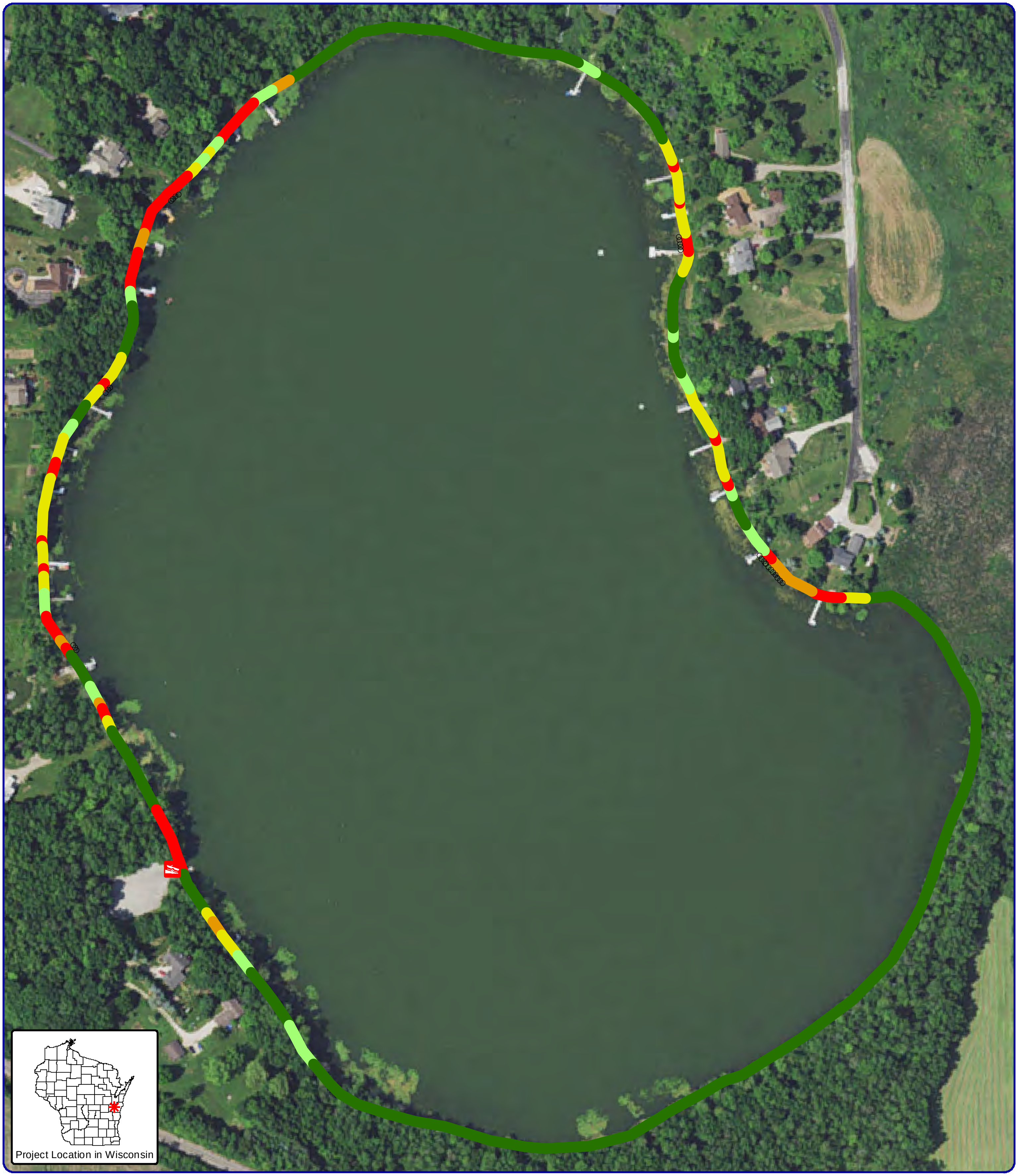
Legend

- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Rural Open Space
- Pasture/Grass
- Row Crops
- Rural Residential
- Bullhead Lake Watershed Boundary

Map 2

Bullhead Lake
Manitowoc County, Wisconsin

Watershed Boundaries & Land Cover Types



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Legend

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

Seawall
Masonry/Wood/Metal
Rip-Rap

Map 3
Bullhead Lake
Manitowoc County, Wisconsin

2017 Shoreline Condition Assessment

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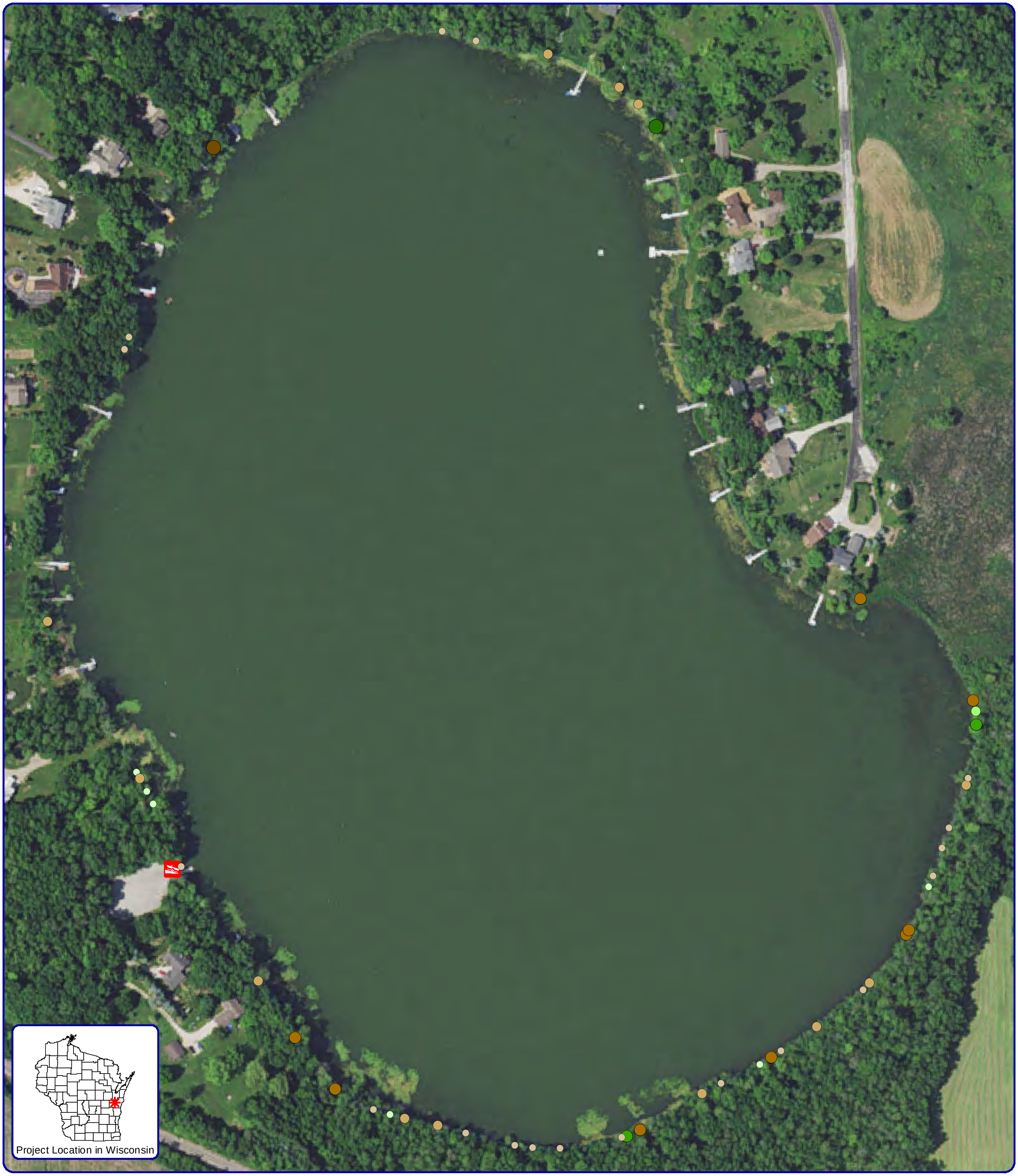
Sources:
Roads and Hyrdo: WDNR
Shoreline Assessment: Onterra, 2017
Map Date: October 16, 2017
Filename: Map3_Bullhead_ShorelandCondition_2017.mxd



N
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275
Feet

Legend

2-8 Inch Pieces
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy

8+ Inch Pieces
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy

Cluster of Pieces
- No Branches *(None)*
- Minimal Branches *(None)*
- Moderate Branches *(None)*
- Full Canopy *(None)*

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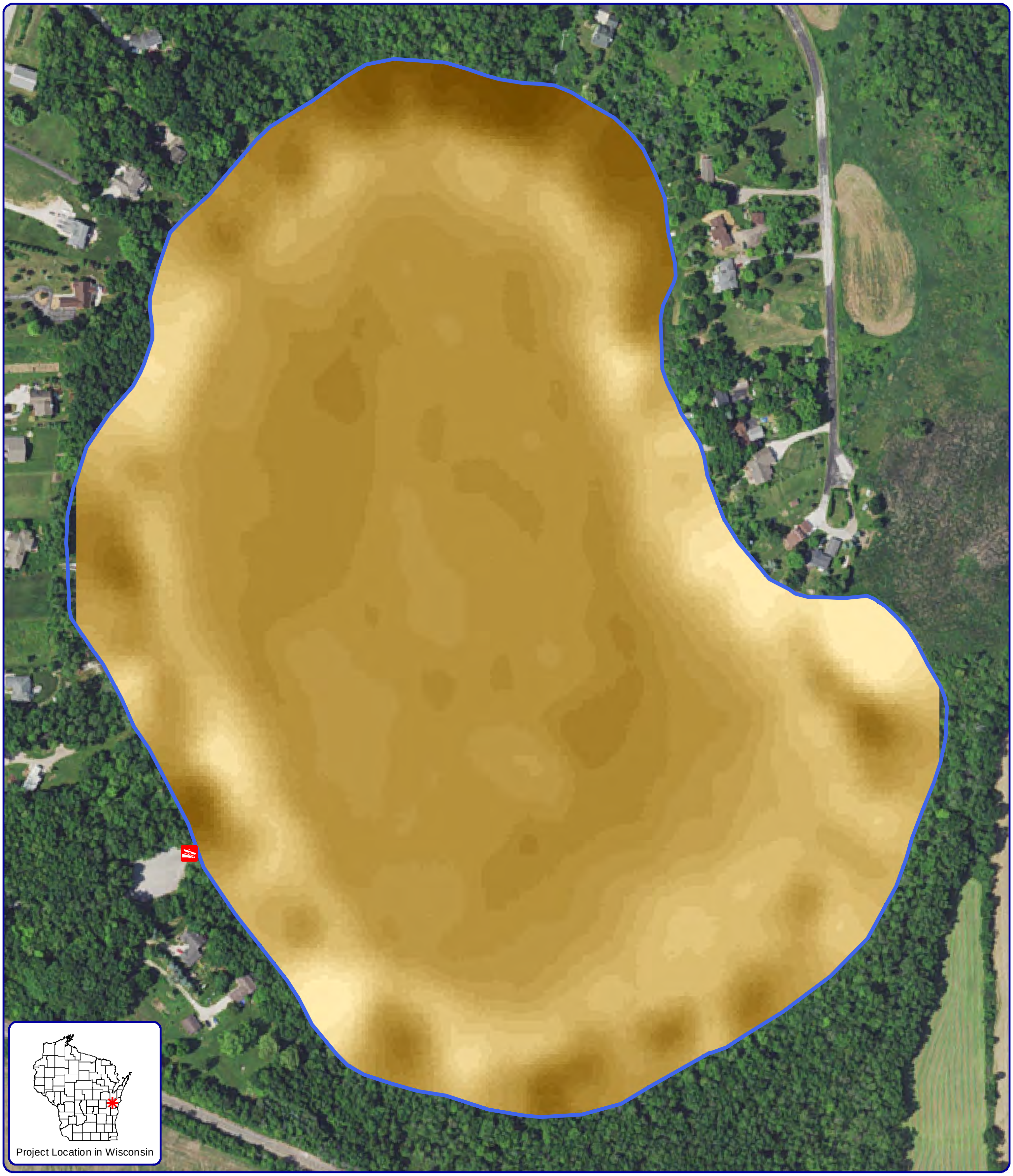
Sources:
Roads and Hyrdo: WDNR
CWH Survey: Onterra, 2017
Map Date: October 16, 2017
Filename: Map4_Bullhead_CWH_2017.mxd

Map 4

Bullhead Lake
Manitowoc County, Wisconsin

2017 Coarse Woody Habitat Survey Results



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Feet

Legend

Soft ... Hard

Substrate Composition

Map 5
Bullhead Lake
Manitowoc County, Wisconsin

2017 Bio-Acoustic Survey Results - Substrate Hardness

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Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Substrate Hardness: Onterra, 2017; procesed by C-Map USA
Map Date: September 28, 2017
Filename: Map5_Bullhead_Acoustic_Sediment.mxd

325
Feet

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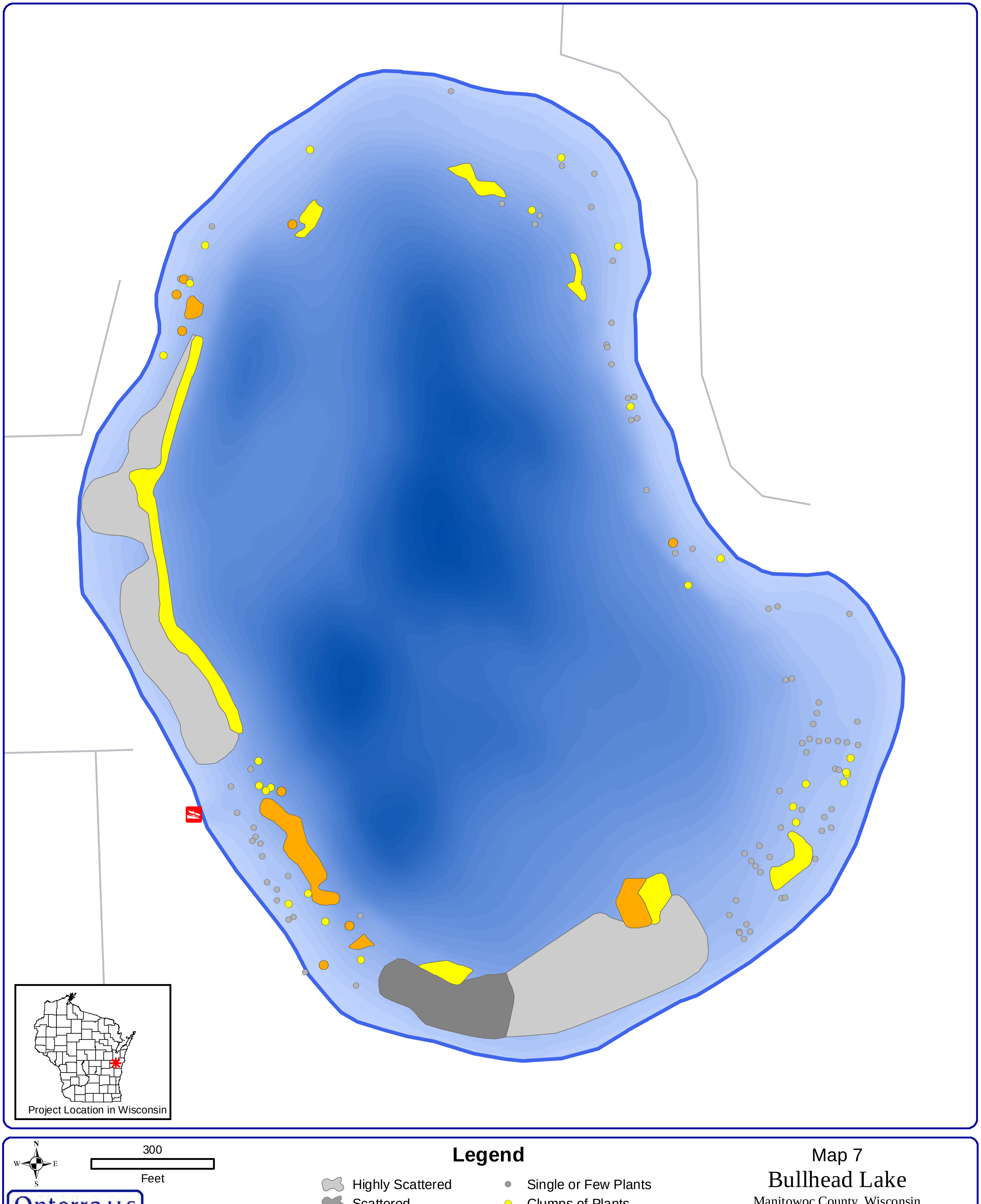
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plant Survey: Onterra, 2017
Map Date: July 17, 2017
Filename: *Map6_Bullhead_Comm_July17.mxd*

Legend

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

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

Map 6
Bullhead Lake
Manitowoc County, Wisconsin
2017 Plant Survey: Community Mapping



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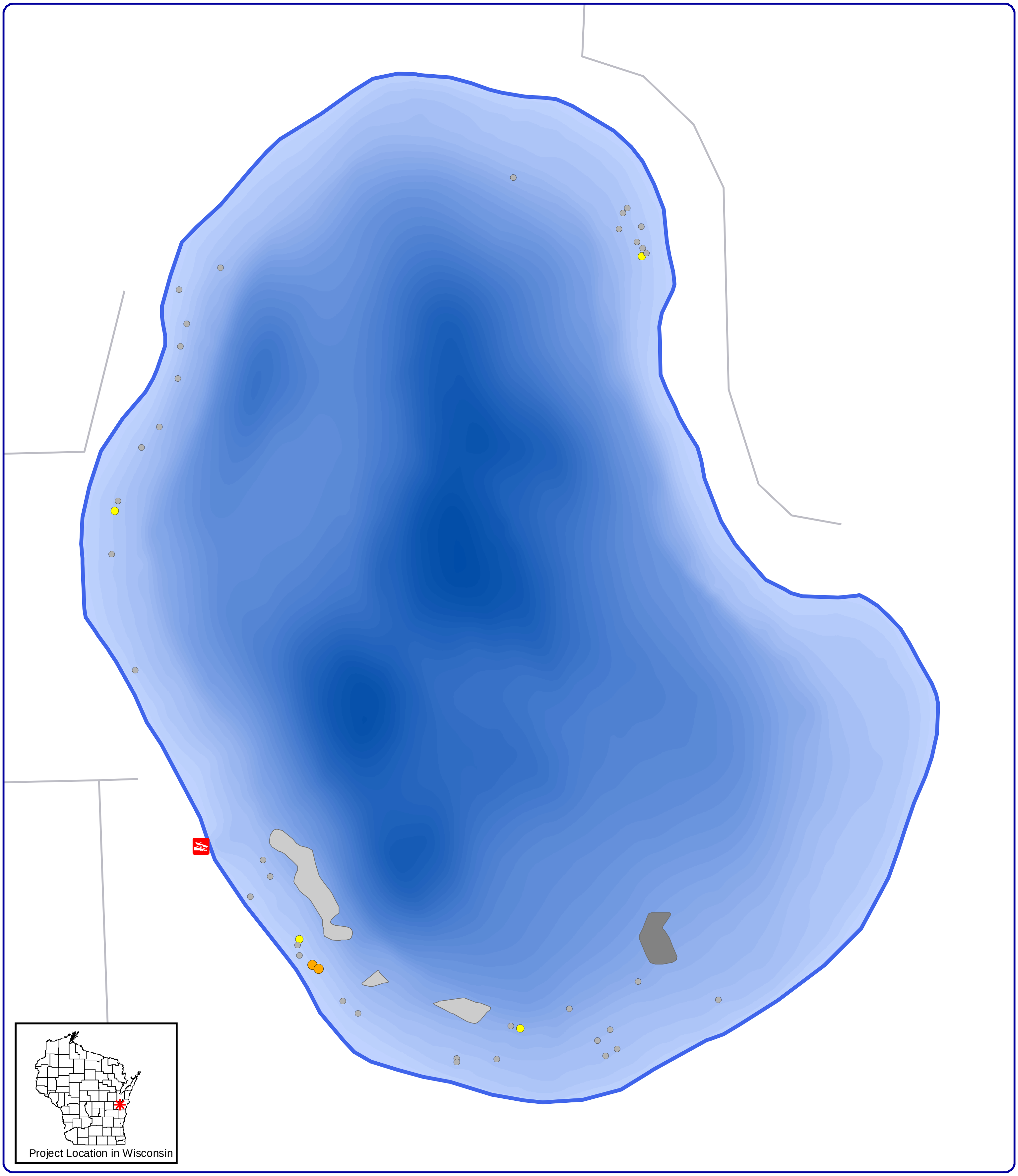
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plant Survey: Onterra, 2017
Map Date: May 26, 2017
Filename: *Map7_Bullhead_CLP_May17.mxd*

Map 7
Bullhead Lake
Manitowoc County, Wisconsin
May 2017 CLP Survey Locations



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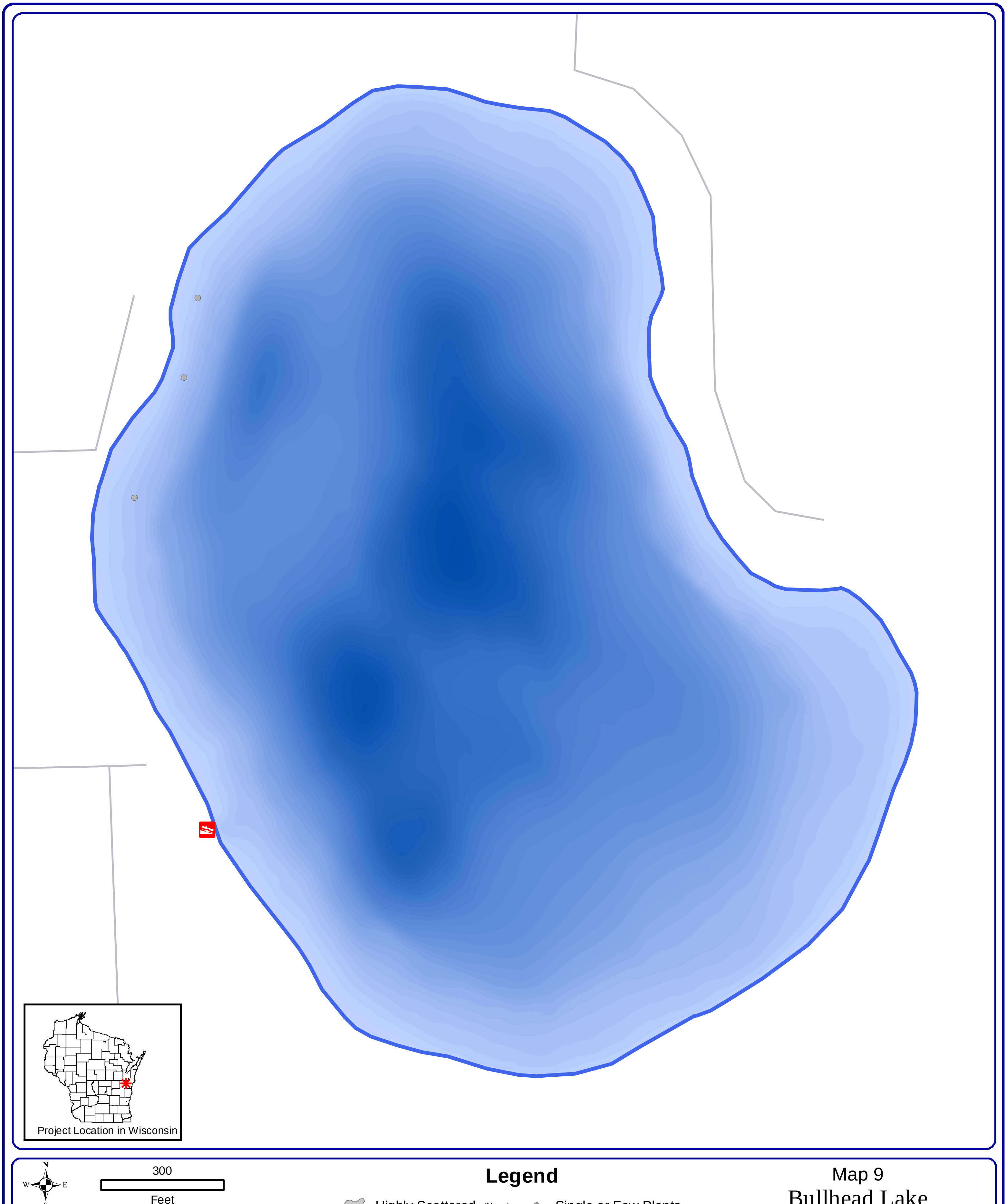
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plant Survey: Onterra, 2017
Map Date: May 26, 2017
Filename: *Map8_Bullhead_EWM_May17.mxd*

Legend

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

Map 8
Bullhead Lake
Manitowoc County, Wisconsin
May 2017 EWM Survey Locations



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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2017
Map Date: September 11, 2017
Filename: *Map9_Bullhead_EWMPB_Sept17.mxd*

Legend

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

Map 9
Bullhead Lake
Manitowoc County, Wisconsin
September 2017 EWM Survey Locations