Archibald Lake

Oconto County, Wisconsin

Comprehensive Management Plan

May 2018

Sponsored by:

Archibald Lake Association

WDNR Grant Program

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Onterra LLC
Lake Management Planning

Archibald Lake

Oconto County, Wisconsin

Comprehensive Management Plan

May 2018

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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:

Archibald Lake Planning Committee

Kevin Springob-Chair	Brian Michels
Tom Winn	Tim Counihan
Steve Fleming	

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1.0. INTRODUCTION

Archibald Lake, Oconto County, is a 392-acre two-basin seepage lake with a maximum depth of 58 feet and a mean depth of 17 feet. This oligotrophic lake has a relatively small watershed when compared to the size of the lake. Archibald Lake contains 42 native plant species, of which muskgrasses are the most common plant. Three exotic plant species are known to exist in Archibald Lake.

Field Survey Notes

Archibald Lake has excellent water clarity and beautiful stretches of natural shoreline. A variety of wildlife was seen during the surveys, including shorebirds and spotted musky.

Photograph 1.0-1. Archibald Lake, Oconto County

Lake at a Glance - Archibald Lake

Morphology	
Acreage	392
Maximum Depth (ft)	58
Mean Depth (ft)	17
Shoreline Complexity	9.4
Vegetation	
Early-Season AIS Survey Date	August 3-4, 2016 & August 10, 2016
Comprehensive Survey Date	August 4, 2016 & August 8, 2016
Number of Native Species	42
Threatened/Special Concern Species	-
Exotic Plant Species	Flowering rush, Giant reed, Eurasian watermilfoil
Simpson's Diversity	0.84
Average Conservatism	6.4
Water Quality	
Trophic State	Oligotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.5
Sensitivity to Acid Rain	Low Sensitivity
Watershed to Lake Area Ratio	7:1

The Archibald Lake Association (ALA), formed in 1958, has been among the most ambitious and diligent lake associations in the state of Wisconsin, initiating several grant-funded projects and overseeing a flowering rush monitoring and control program on their own. Volunteers participate in an Adopt-A-Shoreline invasive species monitoring program, Clean Boats Clean Waters (CBCW), and the Citizens Lake Monitoring Network (CLMN). With these efforts underway, the ALA wanted to work with professional lake managers to update their long-term management plan that would help guide them on EWM management and protect their lake ecosystem.

The studies included in this project document the present state of the native and exotic plant populations, compare them to previous historical occurrences, and use this information to develop a plan for future management of exotic populations. Information the ALA has been collecting on flowering rush would be integrated within the management plan. Additionally, the ALA sought to examine their lake in a holistic manner, understanding their lake ecosystem and better protecting it from future threats. Shoreland and fish habitat assessment results will be used to educate riparian property owners about healthy shorelines and how they may be able to improve their property through best management practices and/or habitat improvements. Finally, a stakeholder survey has been circulated as part of this project in order to assess the needs and concerns within the association. This information ultimately creates a comprehensive lake management plan that satisfies the requirements of 191.45(2), including long-term goals and associated actions needed to reach the goals.

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, the completion of a stakeholder survey, and updates within the lake group's newsletter.

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

Kick-off Meeting

On June 24, 2016, a project kick-off meeting was held at the Townsend Town Hall to introduce the project to the general public. The meeting was announced through a mailing and personal contact by ALA board members. The approximately 74 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.

Planning Committee Meeting

On June 26, 2017, Eddie Heath of Onterra met with members of the Archibald Lake Planning Committee for nearly four hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including, Eurasian watermilfoil treatment results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed.

Management Plan Review and Adaption Process

On February 5, 2018 a draft of the Comprehensive Lake Management Plan was provided to the Archibald Lake Association Planning Committee for review. On February 14, 2018, an official first draft of the ALA's Comprehensive Management Plan was supplied to Local WDNR Aquatic Specialists, Local WDNR Fisheries Manager, Great Lakes Indian Fish & Wildlife Service, Oconto County, Town of Townsent, and Oconto County Lakes and Waterways Association. The Planning Committee's comments were integrated within the first draft of the Comprehensive Lake Management Plan and the plan was finalized on May 25, 2018. Planning committee chair will present at the 2018 annual meeting for the board of directors to vote on adoption.

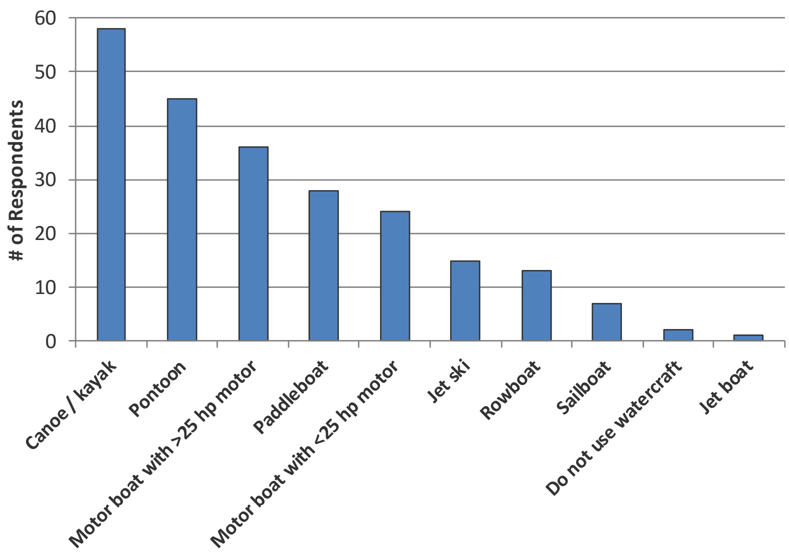
Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners around Archibald Lake. The survey was designed by Onterra staff and the ALA planning committee and reviewed by a WDNR social scientist. During October and November 2016, a seven-page, 31-question survey was posted online through Survey Monkey for 183 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. Approximately 40% 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 summarized and analyzed by Onterra for use at the planning meeting and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Archibald Lake. The majority of stakeholder respondents (52%) visit Archibald Lake on weekends throughout the year, while 32% are seasonal residents (summer only) and 7% are year-round residents. Sixty percent of stakeholder survey respondents have owned their property for over 25 years and 25% have owned their property for 10 to 25 years.

The following sections (Water Quality, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. Over 80% of survey respondents indicate that they use a canoe or kayak while over 50% answered they also use either a pontoon boat, larger motor boat or a combination of these vessels on Archibald Lake (Question 12). Paddleboats were also a popular option. On a lake, such as Archibald 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, several of the top recreational activities on the lake involve boat use. Boat traffic was, however, listed as a factor potentially impacting Archibald Lake in a negative manner (Question 21) and was ranked 2nd on a list of stakeholder's top concerns regarding the lake (Question 22).

Question 12: What types of watercraft do you currently use on the lake?



Question 15: Please rank up to three activities that are important reasons for owning your property on or near the lake.

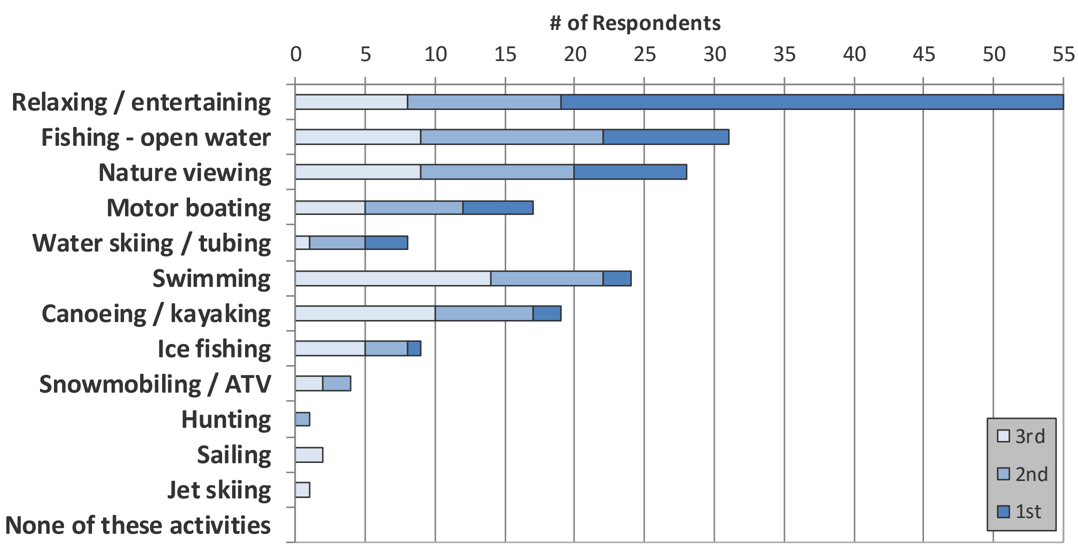
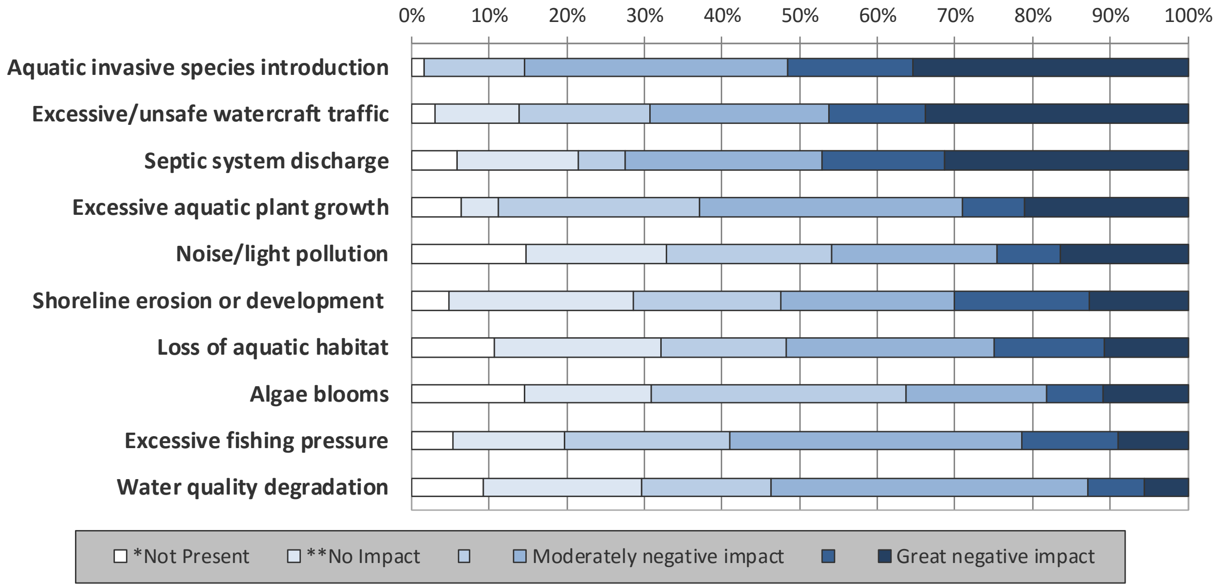


Figure 2.0-1. Select survey responses from the Archibald Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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



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

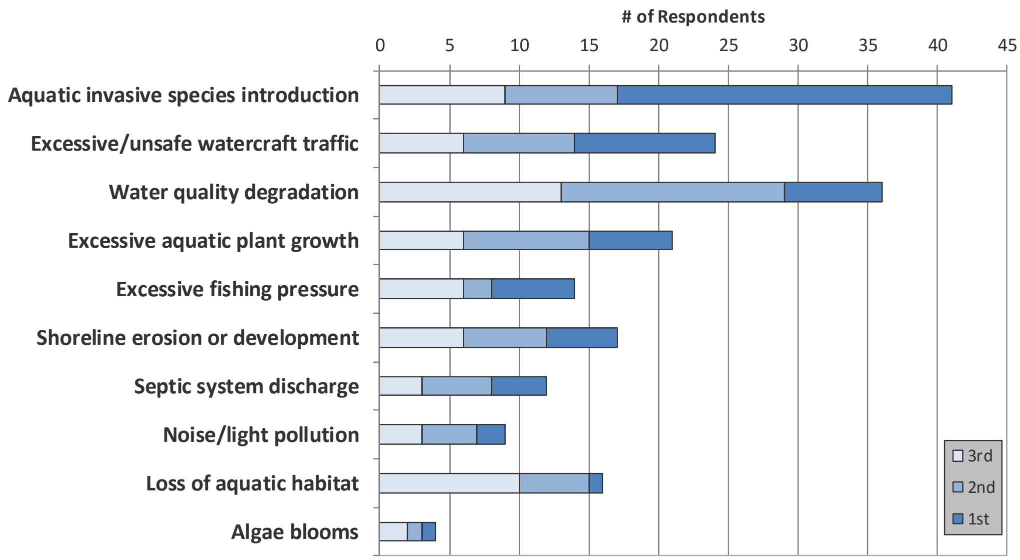


Figure 2.0-2. Select survey responses from the Archibald Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0. RESULTS & DISCUSSION

3.1. Lake Water Quality

Primer on 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 Archibald 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 Archibald Lake's water quality analysis:

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013) 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 Archibald Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
> > Headwater drainage lakes have a watershed of less than 4 square miles.
> >
> > Lowland drainage lakes have a watershed of greater than 4 square miles.

Because of its depth, small watershed and hydrology, Archibald Lake is classified as a deep seepage lake (category 7 on Figure 3.1-1).

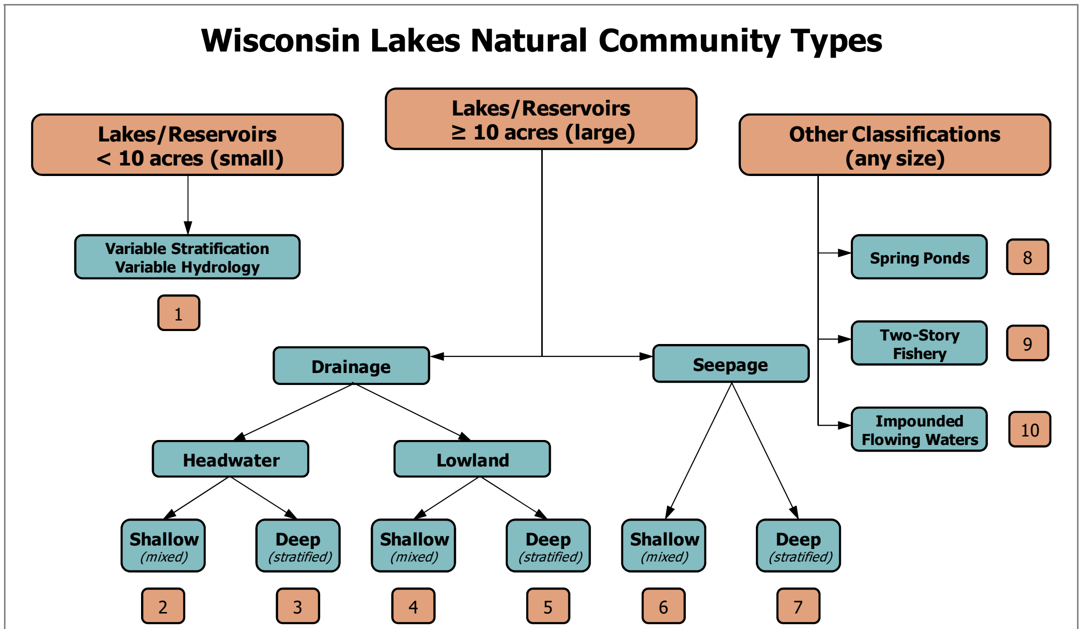


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013.

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

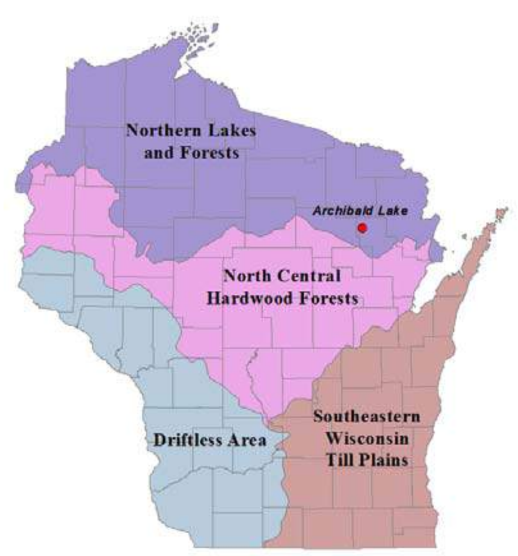


Figure 3.1-2. Location of Archibald Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2014 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

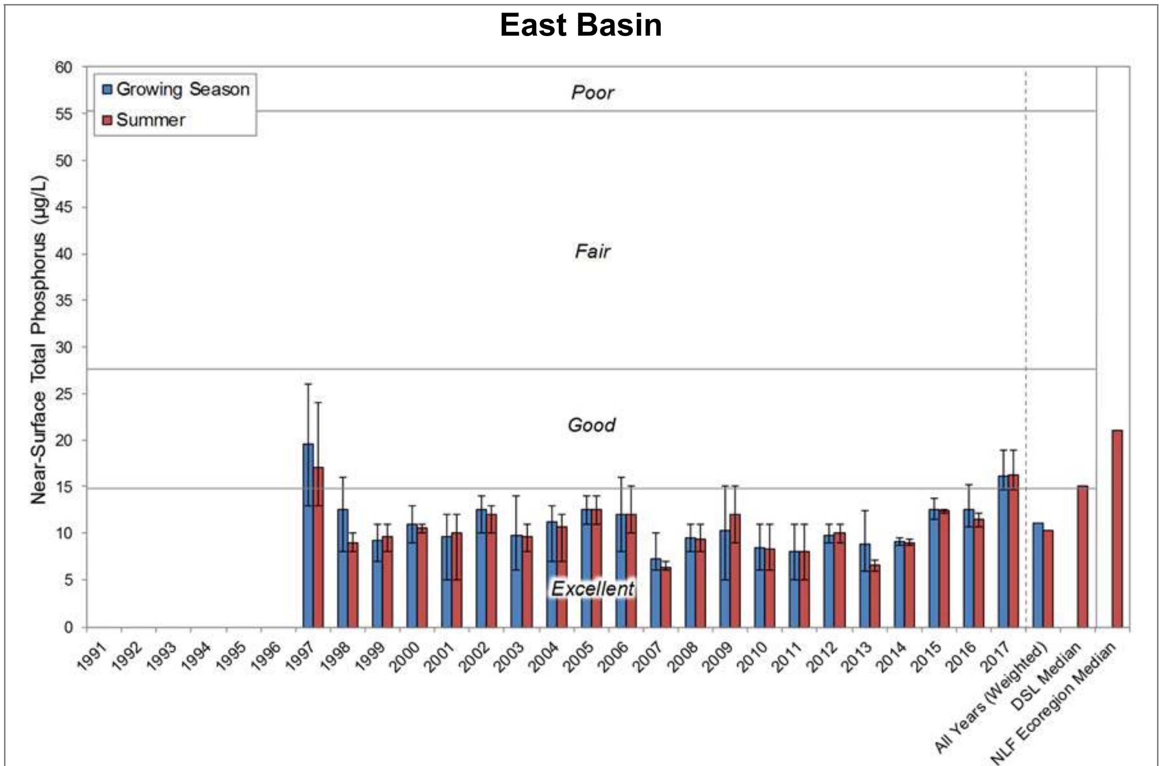
These data along with data corresponding to statewide natural lake means, historic, current, and average data from Archibald Lake are displayed in Figures 3.1-3 - 3.1-8. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) 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.

Archibald Lake Water Quality Analysis

Archibald Lake Long-term Trends

Near-surface total phosphorus data from Archibald Lake are available annually from 1997-2017 within the East Basin and from 1991-1996, 2001, and 2011-2017 in the West Basin (Figure 3.1-3). In the East Basin, average summer total phosphorus concentrations ranged from 6 µg/L in 2007 to 17 µg/L in 1997. In the West Basin, average summer total phosphorus concentrations ranged from 7 µg/L in 1993 to 18 µg/L in 2017. The long term weighted summer average total phosphorus concentration in both basins is about 10 µg/L. The average summer total phosphorus concentration from both basins falls within the *excellent* category for Wisconsin's deep seepage lakes and indicates Archibald Lake's phosphorus concentrations are lower than the majority of other deep seepage lakes in the state and all lake types within the NLF ecoregion. As is discussed below, when comparing phosphorus concentrations on similar days, concentrations tend to be slightly higher in the West Basin.

Initial analysis of the 1997-2016 phosphorus data from the East Basin using simple linear regression indicated that while phosphorus concentrations have been variable, a weak but statistically valid ($R^2 = 0.06$, p-value <0.05) decline in total phosphorus concentration had occurred over this period. However, once 2017 data were available and included in this analysis, the trend was no longer statistically valid. To gain a better understanding of the variability in phosphorus concentrations in the East Basin over time, Onterra ecologists contacted Dr. Matthew Diebel, a Water Resources Modeler with the WDNR. Given Archibald Lake is a seepage lake, Matthew believed that hydrologic variation was likely the primary driver of varying phosphorus concentrations. Matthew suggested exploring the relationship between phosphorus concentrations and precipitation.



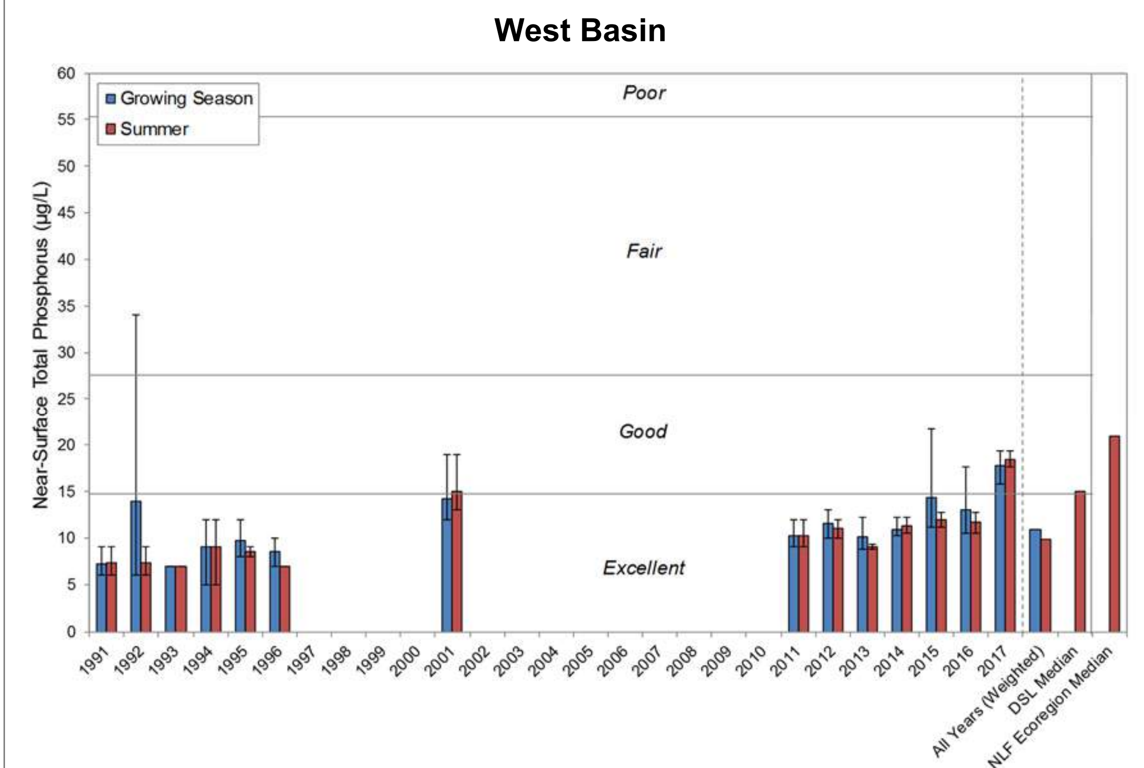


Figure 3.1-3. Archibald Lake East and West Basin annual average near-surface total phosphorus and state-wide deep seepage lakes (DSL) and Northern Lakes and Forests (NLF) lakes median summer total phosphorus. Error bars represent maximum and minimum values. Water Quality Index values adapted from WDNR PUB WT-913.

Precipitation data were obtained from a monitoring station in Antigo, WI, approximately 30 miles southwest of Archibald Lake. Analysis revealed that annual precipitation was not a good predictor of growing season phosphorus concentrations in the East Basin of Archibald Lake. However, when cumulative precipitation was compared against growing season phosphorus concentrations, specifically four years of cumulative precipitation (the sum of the year in question and three years previous), a strong, positive relationship was found (Figure 3.1-4).

Because seepage lakes have longer water residence times than drainage lakes and their water levels are often influenced by the groundwater table, cumulative precipitation over longer periods of time can affect water levels and nutrient concentrations within the lake. It is believed that hydrologic variation – not human activity – is the primary driver of variations in annual phosphorus concentrations in the East Basin of Archibald Lake. The higher phosphorus concentrations measured in 2017 correspond to highest four-year cumulative precipitation over this period (128 inches). A similar relationship was found using the phosphorus data collected from the West Basin from 2011-2017 (Figure 3.1-4).

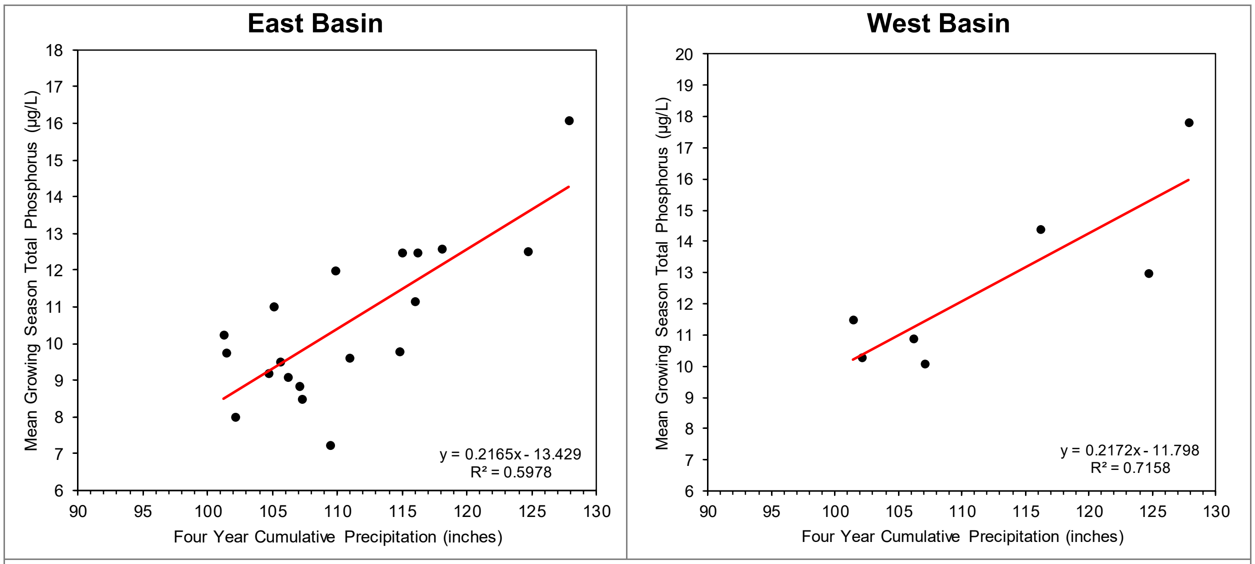


Figure 3.1-4. Archibald Lake annual growing season total phosphorus plotted against four-year cumulative precipitation. East Basin p-value <0.001; West Basin p-value: 0.016.

While the weighted summer average total phosphorus concentrations calculated from available data from the East and West basins were relatively similar, comparison of total phosphorus concentrations collected during the same time period (2001 & 2012-2017) within both basins showed that on average, total phosphorus concentrations are approximately 2.0 µg/L higher in the West Basin when compared to the East Basin (T-Test p-value = 0.008). The bathymetry data gathered from the 2016 acoustic survey indicates that the East Basin is approximately 36% more voluminous than the West Basin. The total mass of phosphorus within each basin was estimated using the water volume for each basin determined from the acoustic survey and the concentration of phosphorus measured during spring and fall turnover. These calculations indicate that both basins contain a similar mass of phosphorus during turnover, and that the differences in concentration between them may be due to differences in water volume. In other words, both basins receive a similar amount of phosphorus, but the East Basin, being more voluminous, is able to dilute phosphorus to a lower concentration. The West Basin may also be receiving more phosphorus inputs from its watershed from an adjacent wetland and/or a higher degree of shoreland development.

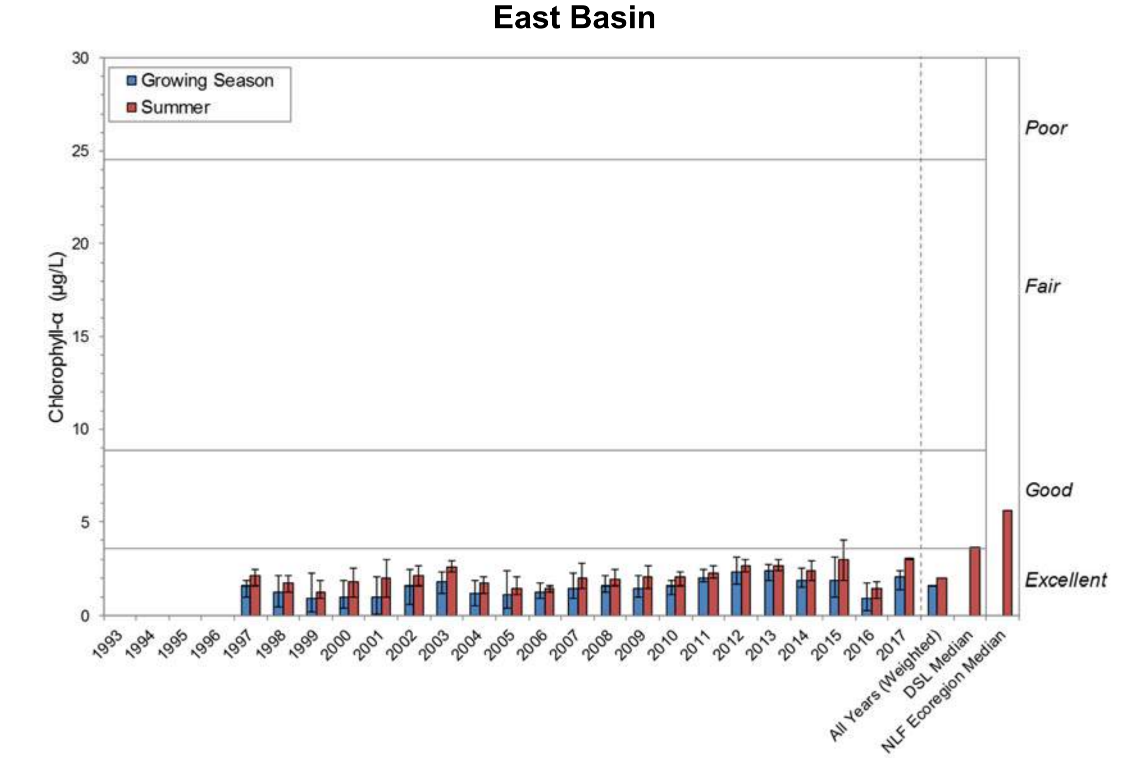
Chlorophyll-*a* concentration data are available from the East Basin annually from 1997-2017 and from the West Basin intermittently from 1993-2017 (Figure 3.1-5). In the East Basin, average summer chlorophyll-*a* concentrations ranged from 1.3 µg/L in 1999 to 3.0 µg/L in 2017. In the West Basin, chlorophyll-*a* concentrations ranged from 1.2 µg/L in 1995 to 3.5 µg/L in 2017. The weighted summer average chlorophyll-*a* concentration in the East and West Basin is 2.0 µg/L and 2.4 µg/L, respectively, falling within the *excellent* category for chlorophyll-*a* concentrations in Wisconsin's deep seepage lakes. The weighted summer average chlorophyll-*a* concentration in both basins falls below the median concentrations for deep seepage lakes in Wisconsin and all lake types within the NLF ecoregion.

Despite higher variability in phosphorus concentrations believed to be due to changes in precipitation, chlorophyll-*a* concentrations have remained stable and no significant trends over time are occurring in either basin. Like total phosphorus concentrations, analysis of chlorophyll-*a* data when data are available in both basins from the same time period (2001 & 2011-2016) indicates that chlorophyll-*a* concentrations in the West Basin are on average approximately 0.5 µg/L higher than the East Basin. The slightly higher chlorophyll-*a* concentrations in the West Basin are expected given the slightly higher total phosphorus concentrations. While the difference in chlorophyll-*a* concentrations between the two basins is small, this difference is sufficient to create detectable differences in algal levels between the two basins.

Annual Secchi disk transparency data are available from the East Basin from 1987-2017 and from the West Basin from 1973, 1974, and 1986-2017 (Figure 3.1-6). In the East Basin, average summer Secchi disk depth ranged from 11.4 feet in 1990 to 18.9 feet in 2005 and 2011. In the West Basin, average summer Secchi disk depth ranged from 9.9 feet in 1990 to 15.0 feet in 2013 (1973 was excluded as it only contained one summer measurement). The weighted summer average Secchi disk depth is 15.3 in the East Basin and 12.8 feet in the West Basin, both of which fall in the *excellent* category for Secchi disk depth in Wisconsin's deep seepage lakes. Archibald Lake has higher water clarity than the majority of other deep seepage lakes in Wisconsin and all lakes within the NLF ecoregion.

Secchi disc depth is influenced by many factors but one of the important ones is the amount of particulates in the water, for example algae. Other factors that can be important are water color and nonalgal particles. Since Archibald Lake is a marl lake, calcium carbonate particles in the water can affect water clarity. The 2.5-foot difference in mean Secchi disk depth between the East and West basins does not appear to be solely caused by differences in chlorophyll-*a* concentrations. There is not a significant relationship between chlorophyll-*a* and Secchi disk depth when they were collected on the same date.

Further, using the relationship between Secchi disk depth and chlorophyll in Archibald Lake, Oconto County, it was expected that based on measured Secchi disk depth in the late-1990s in Archibald Lake chlorophyll should have been higher. The relationship between these variables is more apparent in the last couple of years. It seems that in previous years Secchi disk depths were not significantly determined by algal levels but in recent years the water clarity is more dependent upon the amount of algae in the lake. At this time, it is not clear why non-algal particles were more common in the period around the turn of the century.



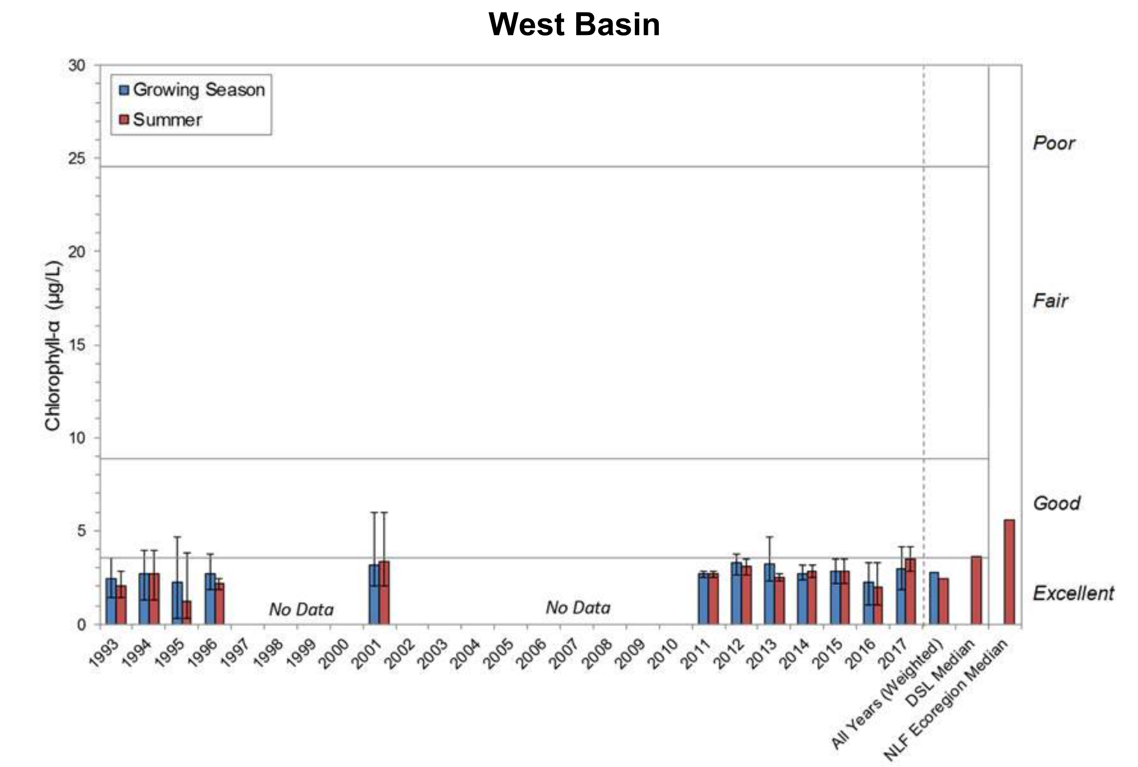


Figure 3.1-5. Archibald Lake East and West Basin annual average near-surface chlorophyll-α and state-wide deep seepage lakes (DSL) and Northern Lakes and Forests (NLF) lakes median summer chlorophyll-α. Error bars represent maximum and minimum values. Water Quality Index values adapted from WDNR PUB WT-913.

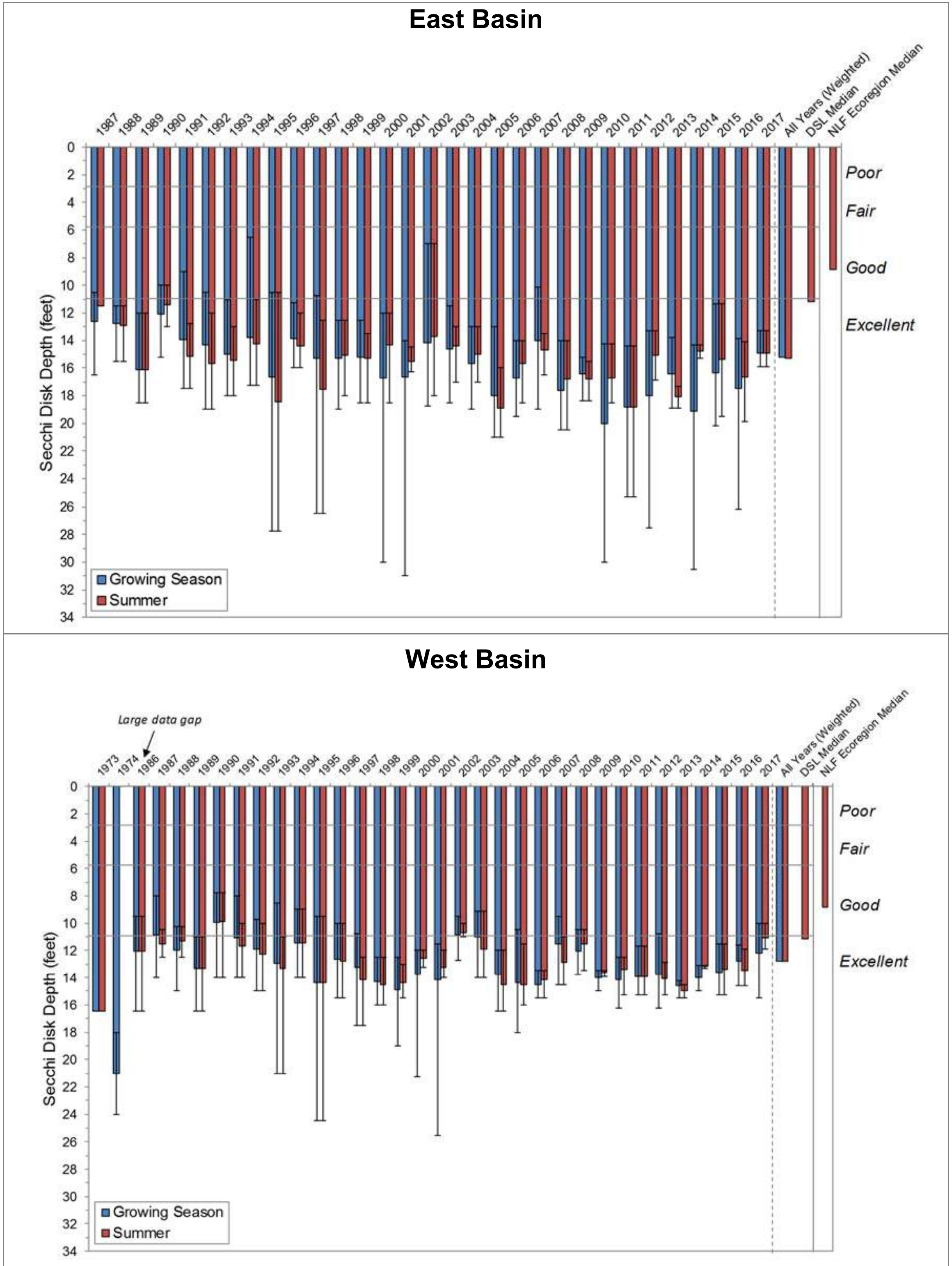


Figure 3.1-6. Archibald Lake East and West Basin annual average Secchi disk depth and state-wide deep seepage lakes (DSL) and Northern Lakes and Forests (NLF) lakes median Secchi disk depths. Error bars represent maximum and minimum values. Water Quality Index values adapted from WDNR PUB WT-913.

Simple linear regression of average growing season Secchi disk depth measured in the East Basin from 1987-2017 showed a statistically valid increasing trend in water clarity over this time period ($R^2 = 0.45$; p-value = <0.001; Figure 3.1-7). Secchi disk depth in the East Basin has increased by approximately 4.0 feet over from 1987-2017. While it is not clear what is the cause of the increased water clarity, it does not appear to be the result of less algae. This implies that likewise, phosphorus concentrations have not declined even though water clarity has improved.

Similarly, simple linear regression of average growing season Secchi disk depth within West Basin from 1986-2017 also showed a statistically valid improving trend in water clarity over this time period ($R^2 = 0.18$; p-value = <0.001) but to a lesser extent when compared to the East Basin (Figure 3.1-7). Secchi disk depth in the West Basin has increased be approximately 2.0 feet from 1986-2017. It is not clear why water clarity has increased at a higher rate within the East Basin when compared to the West Basin over this time period.

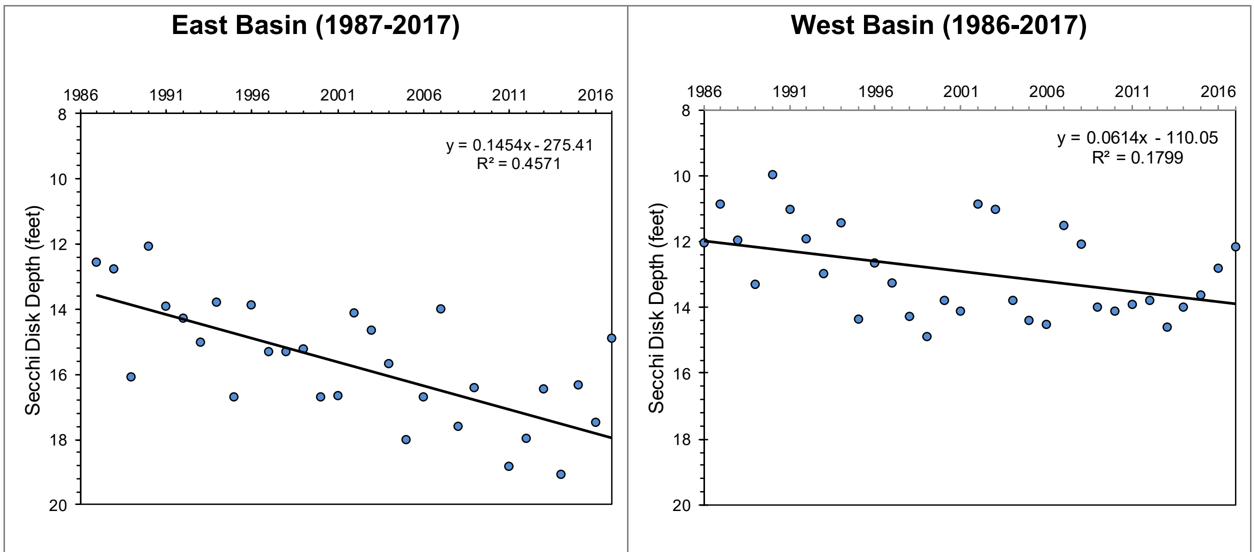


Figure 3.1-7. Simple linear regression of Secchi disk depth over time within the East and West basins of Archibald Lake. Trends in both basins are statistically significant (p-value <0.001).

Limiting Plant Nutrient of Archibald Lake

Using midsummer nitrogen and phosphorus concentrations from Archibald Lake, a nitrogen:phosphorus ratio of 45:1 and 38:1 were calculated within the East and West basins, respectively. This finding indicates that Archibald Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes and that phosphorus is the primary nutrient regulating phytoplankton production. If phosphorus inputs to Archibald Lake were to increase, phytoplankton production would likely also increase.

Archibald Lake Trophic State

Figure 3.1-8 contains the weighted average Trophic State Index (TSI) values for the East and West basins of Archibald Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project 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; for example dissolved compounds within the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation. The weighted average TSI values for total phosphorus and chlorophyll-*a* from both basins indicate Archibald Lake is currently in an oligotrophic state, or a state with low nutrients and productivity. It should be noted that in 2017 TSI for phosphorus and chlorophyll-*a* showed a worsening of trophic state going from oligotrophic to mesotrophic.

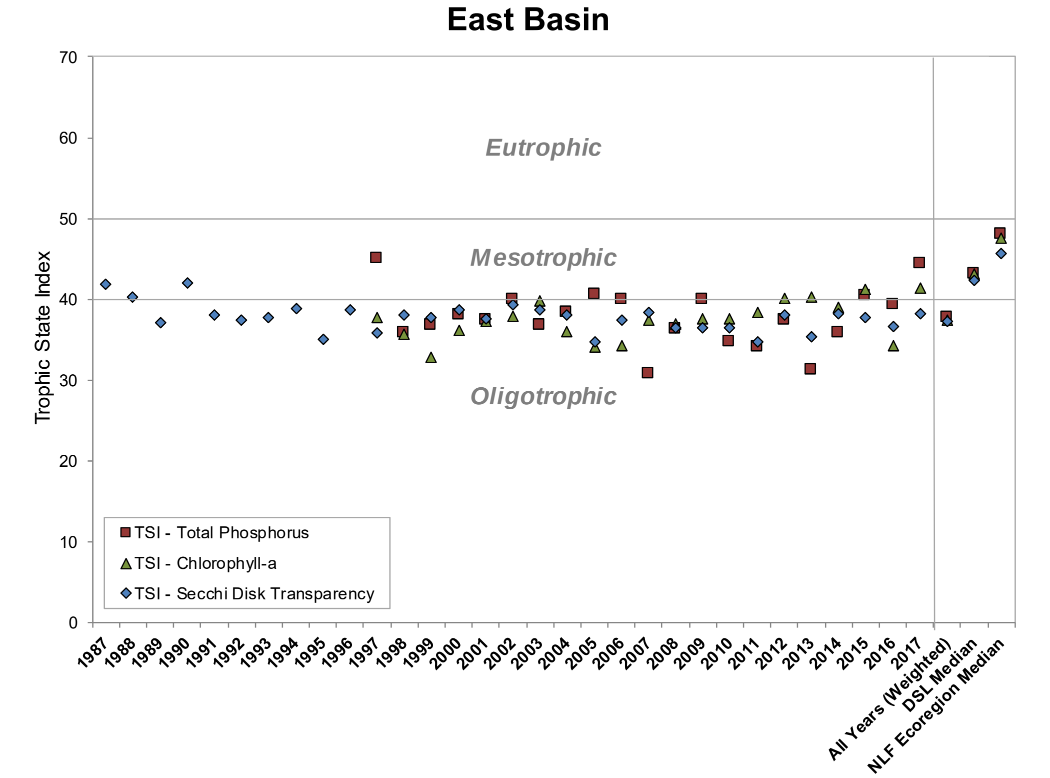
Dissolved Oxygen and Temperature in Archibald Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Archibald Lake by Onterra staff as well as the CLMN volunteer. Profiles depicting these data are displayed in Figures 3.1-9 and 3.1-10. These data indicate that both the East and the West basin remain thermally stratified during the summer, forming a distinct epilimnion and hypolimnion. The profiles collected during February 2017 also indicate that there is sufficient oxygen under the ice in winter to support aquatic life and that winter fishkills are not a concern on Archibald Lake.

Additional Water Quality Data Collected at Archibald Lake

The previous section was focused on water quality parameters surrounding 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 Archibald Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The 2016 mid-summer near-surface pH in Archibald Lake was found to be alkaline at 8.6 and 8.3 within the East and West basins, respectively. As is discussed further, Archibald Lake is a marl lake with naturally higher concentrations of calcium as the result of groundwater passing through calcium-rich glacial till before entering the lake. These higher calcium concentrations, in part, result in the higher pH values.



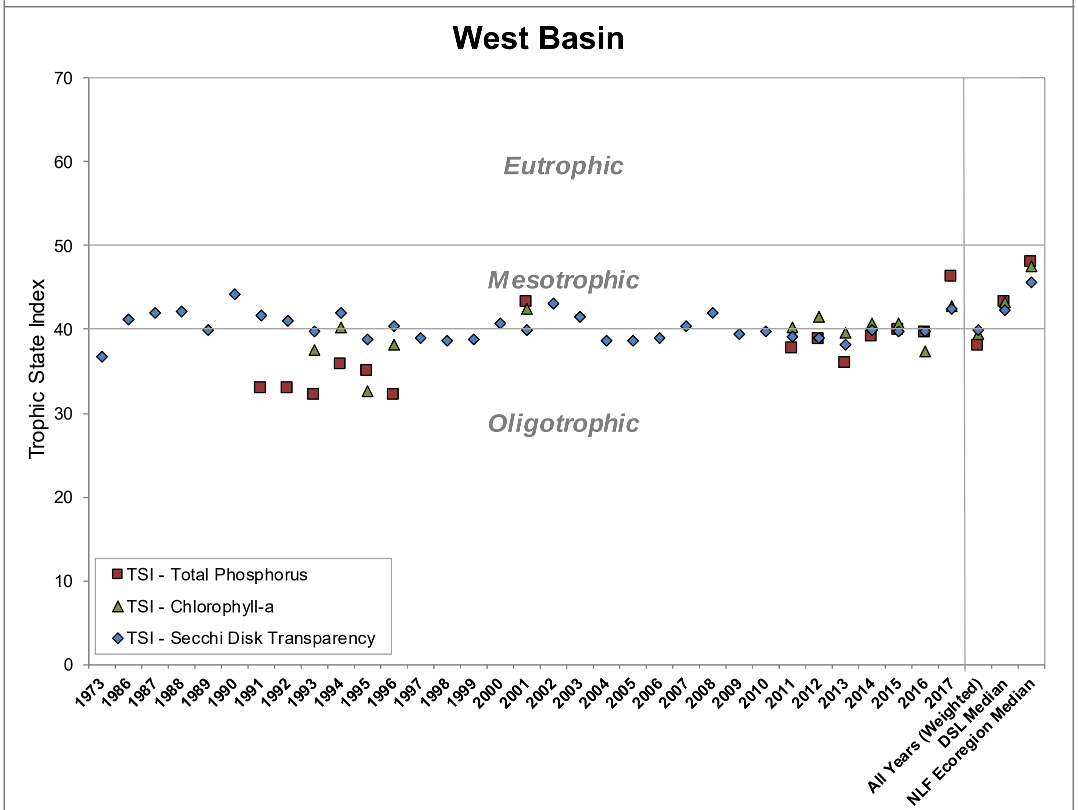


Figure 3.1-8. Archibald Lake Trophic State Index using data from East and West basins. Values calculated with summer month surface sample data using WDNR PUB-WT-193. DSL= Deep Seepage Lakes; NLF = Northern Lakes and Forests Ecoregion.

East Basin

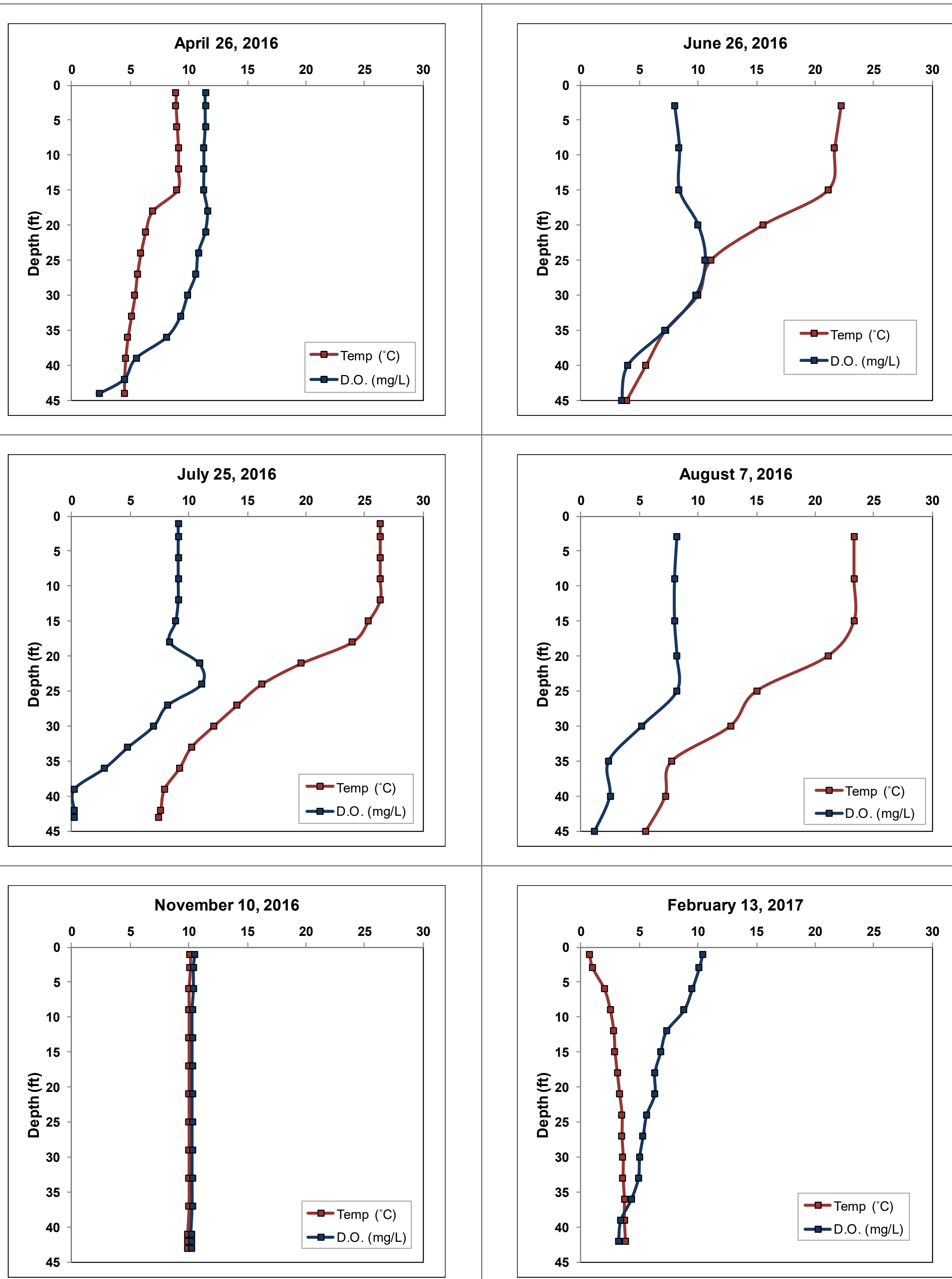


Figure 3.1-9. Archibald Lake East Basin 2016 Temperature and dissolved oxygen profiles.

West Basin

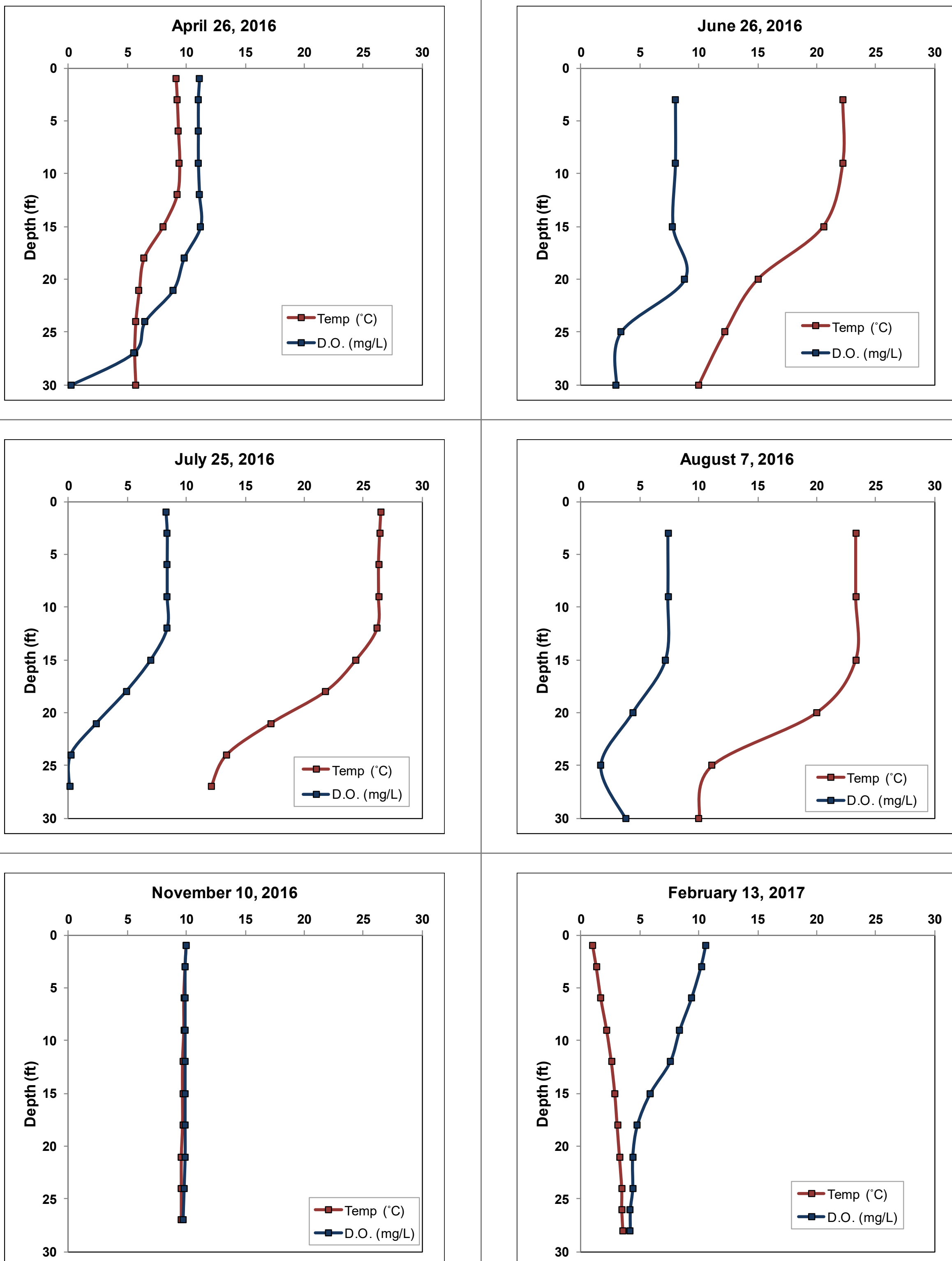


Figure 3.1-10. Archibald Lake West Basin 2016 temperature and dissolved oxygen profiles.

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 near-surface alkalinity measured in Archibald Lake in 2016 indicates high concentrations at 97 and 103 (mg/L as $CaCO_3$), in the East and West basins, respectively. The measured alkalinity in Archibald Lake indicates the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

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. 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. At present, there is no method for safely eradicating zebra mussels once that have become established within a waterbody.

The commonly accepted pH range for zebra mussels is 7.0 to 9.0, and Archibald Lake's pH falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. In 2016, near-surface calcium concentrations measured in Archibald Lake were at 23 and 25 mg/L within the East and West basins, respectively. Given Archibald Lake's pH and calcium concentrations, the lake is capable of supporting zebra mussels and has a moderate susceptibly to establishment if they were ever introduced to the lake. Onterra ecologists conducted plankton net tows at three locations in Archibald Lake in 2016 in an effort to detect potential occurrences of zebra mussel veligers, their free-floating larval stage. Analysis of these samples were negative for the presence of veligers and Onterra ecologists did not observe any adult zebra mussels during the 2016 surveys. Archibald Lake users should make sure their watercraft have been thoroughly cleaned, drained, and dried prior to launching into Archibald Lake.

Stakeholder Survey Responses to Archibald Lake Water Quality

As discussed in section 2.0, the stakeholder survey sent to Archibald Lake property owners asked many questions pertaining to perception of the lake and how it may have changed over the years. Of the 183 surveys distributed, only 73 (40%) were returned. Given the low response rate, 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 stakeholder perceptions of water quality in Archibald Lake but cannot be stated with statistical confidence.

Figure 3.1-11 displays stakeholder survey responses to questions regarding stakeholder perceptions of Archibald Lake's water quality. When asked how they would describe the current water quality of Archibald Lake, 97% of respondents indicated *good* or *excellent*, 2% indicated *fair*, and 1% indicated *unsure*. As discussed in the previous section, the water quality parameters used to asses Archibald Lake's current water quality all fall within the *excellent* category for Wisconsin's deep seepage lakes.

When asked how they believe the current water quality has changed since they first visited the lake, the largest proportion of 49% indicated it has *remained the same*, 29% indicated *somewhat degraded*, 11% indicated *somewhat improved*, 6% indicated *unsure*, 4% indicated *severely degraded*, and 1% indicated *greatly improved* (Figure 3.1-11). As discussed in the previous section, Secchi disk data indicate that both basins in Archibald Lake have seen increased water clarity over the period from 1986-2016. In addition, a declining trend in near-surface total phosphorus concentrations was also detected from 1997-2016 within the East Basin. The historical water quality data from Archibald Lake do not indicate degrading water quality conditions. The proportion of stakeholders who indicated Archibald Lake's water quality has somewhat or severely degraded may be taking into account the recent introduction of Eurasian watermilfoil or may have observed increases in aquatic plant abundance within the lake. Anecdotal reports indicate aquatic plant growth may have increased in certain areas of the lake, and these increases may be due to fluctuating water levels. But again, historical data indicate water quality has not been degrading over time in Archibald Lake.

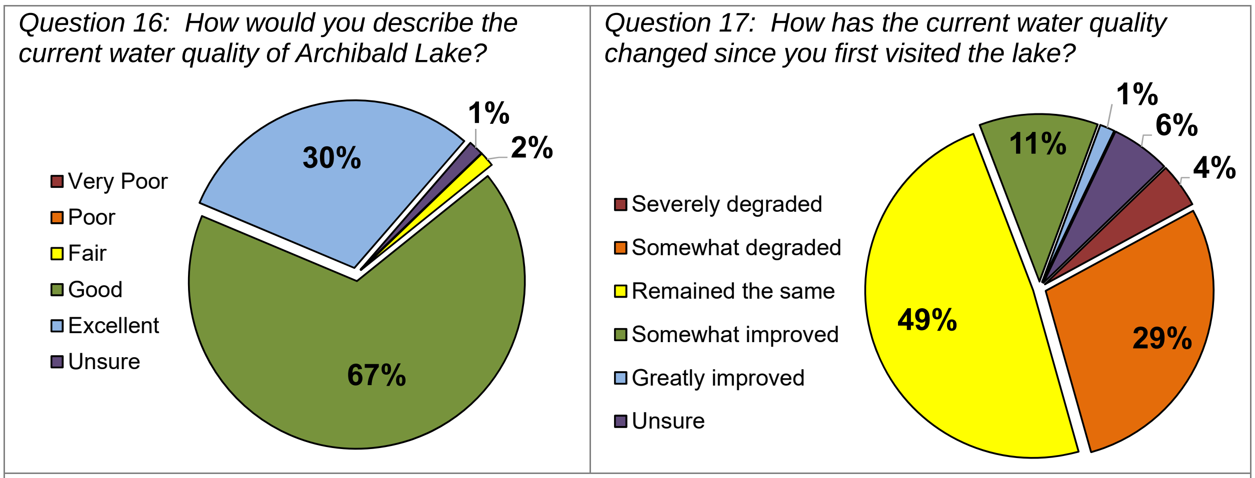


Figure 3.1-11. Archibald Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

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.

Archibald Lake Watershed Assessment

As discussed in the Water Quality Section (3.1), Archibald Lake is classified as a deep seepage lake. Archibald Lake's surficial watershed encompasses approximately 3,103 acres (5 square miles) in Oconto county (Figure 3.2-1 and Map 2) yielding a watershed to lake area ratio of 7:1. In other words, approximately 7 acres of land drains to every one acre of Archibald Lake. Approximately 59.3% of Archibald Lake's watershed is comprised of forests, 21.7% is comprised of wetlands, 12.6% is comprised of the lake's surface itself, 5.7% is comprised of areas of pasture/grass/rural open space, 0.5% is comprised of row crop agriculture, and 0.1% is comprised of rural residential areas (Figure 3.2-1).

Using the landcover within Archibald Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load from Archibald Lake's watershed. Using data collected from the stakeholder survey, an estimate of the amount of phosphorus loaded from riparian septic systems could also be made. It was estimated that approximately 385 pounds of phosphorus are delivered to the lake from its watershed on an annual basis. Of the 385 pounds, approximately 38% is estimated to originate from areas of forests, 28% from direct atmospheric deposition onto the lake's surface, 15% from wetlands, 12% from areas of pasture/grass/rural open space, 4% from row crop agriculture, and 3% from riparian septic systems.

Given the estimated 385 pounds of phosphorus delivered to Archibald Lake annually, WiLMS estimated that the lake should have a growing season mean total phosphorus concentration of approximately 20 μg/L, or approximately 61% higher than the measured average growing season concentration in Archibald Lake. The large discrepancy between measured and predicted total phosphorus concentrations in Archibald Lake indicates that the model is significantly overestimating the amount of phosphorus being loaded to the lake annually from its watershed.

Based on the measured growing season mean total phosphorus concentration of approximately 11 μg/L in Archibald Lake, it is estimated that a lesser amount of approximately 163 pounds of phosphorus are delivered to the lake on an annual basis (Figure 3.2-2). Of these 163 pounds, 106 pounds (65%) are estimated to originate from direct atmospheric deposition onto the lake surface, 26 pounds (16%) from forests, 11 pounds (6%) from wetlands, 8 pounds (5%) from pasture/grass/rural open space, 3 pounds (2%) from row crop agriculture, and 10 pounds (6%) from riparian septic systems (Figure 3.2-2).

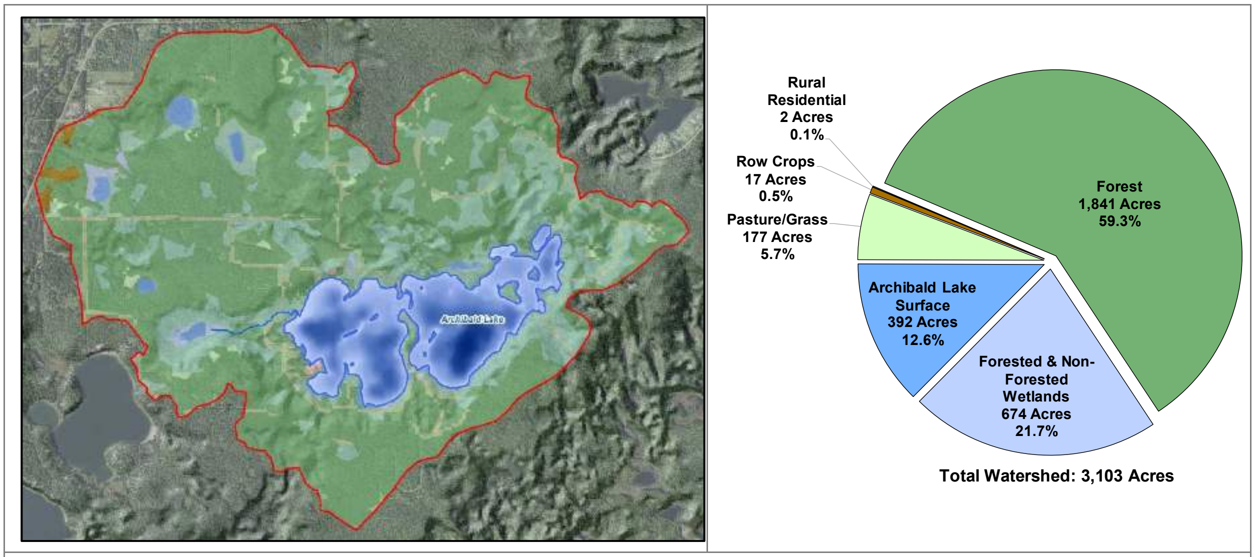


Figure 3.2-1. Archibald Lake watershed and land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

The lower than predicted phosphorus concentrations in Archibald Lake are due to the limitations of WiLMS when modeling phosphorus inputs to seepage lakes. Groundwater is the primary source of water for Archibald Lake, and the majority of the precipitation that falls within its watershed percolates into the ground rather than flowing into the lake.

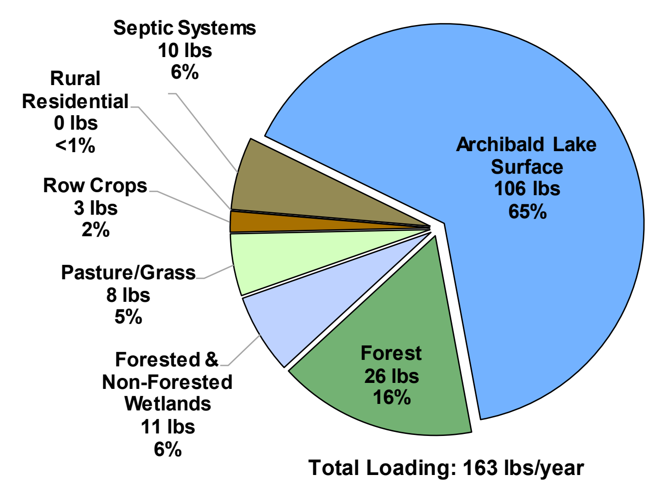


Figure 3.2-2. Archibald watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

In addition, Archibald Lake has higher concentrations of calcium and magnesium indicating that groundwater rich in these minerals is entering the lake. Groundwater passing through bedrock rich in these minerals dissolves and carries these minerals into the lake. Lakes with high concentrations of calcium, or *marl lakes*, tend to have lower phosphorus concentrations as phosphate binds to calcium carbonate where it precipitates to the lake bottom and is unavailable for biological use.

3.3. Shoreland Condition

The Importance of a Lake's Shoreland Zone

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 swimmer's 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 swimmer's 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 more strict shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

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

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
  - No expansion or complete reconstruction within 0-35 feet of shoreline
  - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
  - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
  - Vertical expansion cannot exceed 35 feet

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

Photograph 3.3-1. Example of coarse woody habitat in a lake.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area as well as spawning habitat (Hanchin et al 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon in 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*".

The results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect and restore lakes. This will become increasingly important as development pressured on lakes continue to steadily 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.

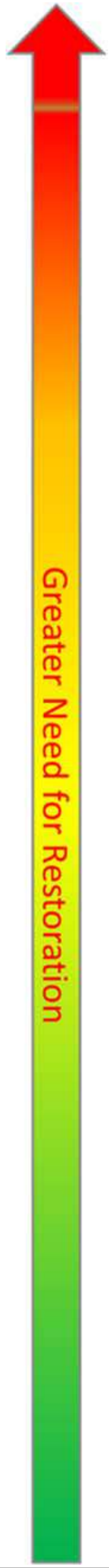
- Each site would need 70' of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property 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.

Archibald Lake Shoreland Zone Condition

Shoreland Development

Archibald 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 Archibald Lake, the development stage of the entire shoreland was surveyed during the fall of 2016, 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.

Archibald Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.7 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-2). 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, 2.2 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Archibald 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.

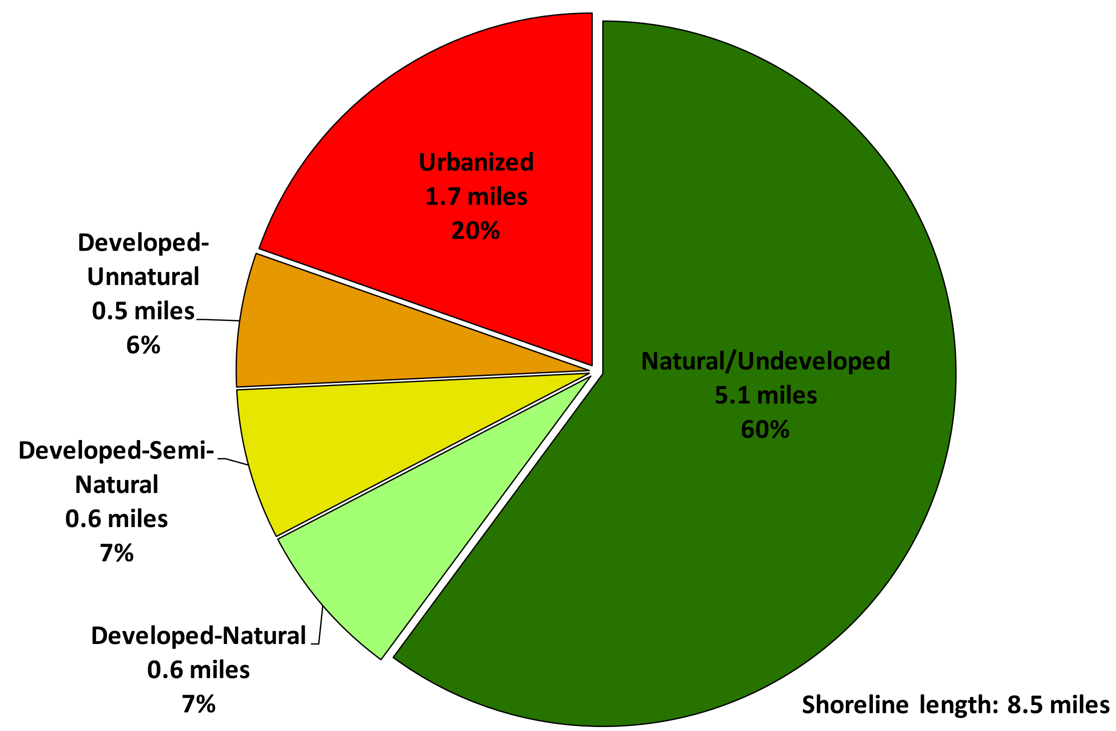


Figure 3.3-2. Archibald Lake shoreland categories and total lengths. Based upon a Fall 2016 survey. Locations of these categorized shorelands can be found on Map 3.

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, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. 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

Archibald Lake was surveyed in the fall of 2016 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) 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.

During this survey, 166 total pieces of coarse woody habitat were observed along 8.5 miles of shoreline, which gives Archibald Lake a coarse woody habitat to shoreline mile ratio of 20:1. Locations of coarse woody habitat are displayed on Map 4. 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 Archibald Lake and those citied in the 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 98 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Archibald Lake fell just below the median for these 98 lakes.

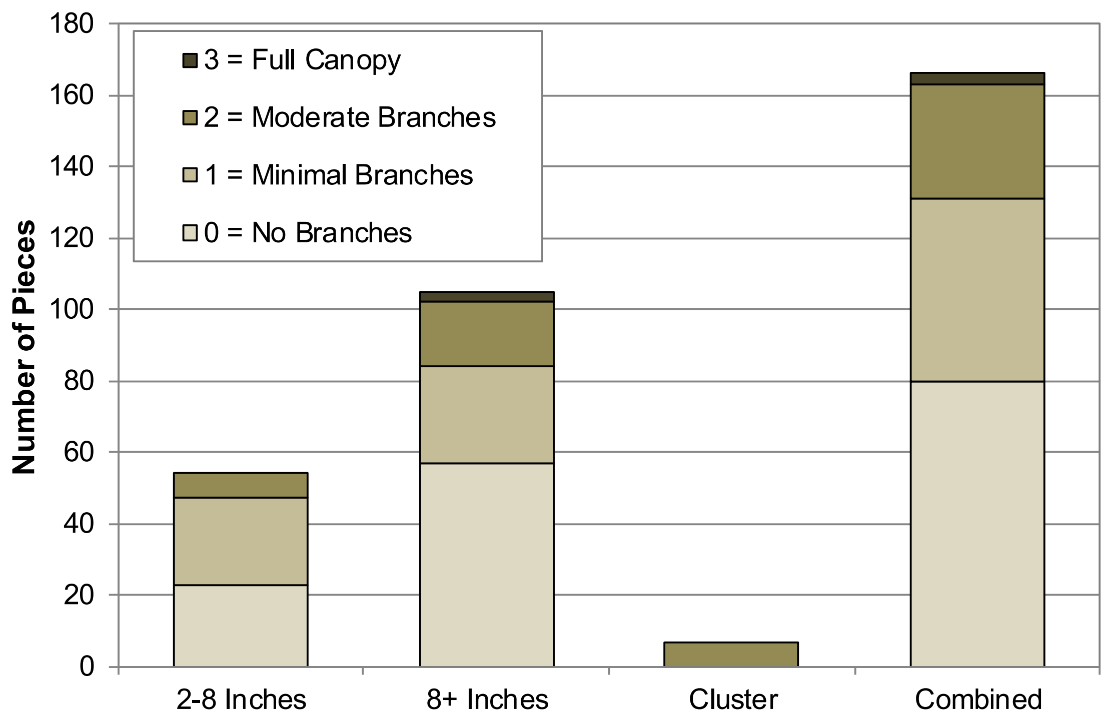


Figure 3.3-3. Archibald Lake coarse woody habitat survey results. Based upon a Fall 2016 survey. Locations of Archibald Lake coarse woody habitat can be found on Map 4.

3.4. Aquatic Plants

Introduction

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

Photograph 3.4-1. Emergent and floating-leaf aquatic plant communities.

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

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These species are discussed further in depth in the Aquatic Invasive Species Section (Section 3.5). 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 Archibald 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 Archibald Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Often, 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

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.

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

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 15^{th}.

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 15^{th}. • 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

Photograph 3.4-4. Granular herbicide application.

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

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

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

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

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

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

<table>
<tr><th colspan="2">General Mode of Action</th><th>Compound</th><th>Specific Mode of Action</th><th>Most Common Target Species in Wisconsin</th></tr>
<tr><td rowspan="3">Contact</td><td rowspan="3"></td><td>Copper</td><td>plant cell toxicant</td><td>Algae, including macro-algae (i.e. muskgrasses & stoneworts)</td></tr>
<tr><td>Endothall</td><td>Inhibits respiration & protein synthesis</td><td>Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides</td></tr>
<tr><td>Diquat</td><td>Inhibits photosynthesis & destroys cell membranes</td><td>Nusiance natives species including duckweeds, targeted AIS control when exposure times are low</td></tr>
<tr><td rowspan="7">Systemic</td><td rowspan="2">Auxin Mimics</td><td>2,4-D</td><td>auxin mimic, plant growth regulator</td><td>Submersed species, largely for Eurasian water milfoil</td></tr>
<tr><td>Triclopyr</td><td>auxin mimic, plant growth regulator</td><td>Submersed species, largely for Eurasian water milfoil</td></tr>
<tr><td>In Water Use Only</td><td>Fluridone</td><td>Inhibits plant specific enzyme, new growth bleached</td><td>Submersed species, largely for Eurasian water milfoil</td></tr>
<tr><td rowspan="2">Enzyme Specific (ALS)</td><td>Penoxsulam</td><td>Inhibits plant-specific enzyme (ALS), new growth stunted</td><td>New to WI, potential for submergent and floating-leaf species</td></tr>
<tr><td>Imazamox</td><td>Inhibits plant-specific enzyme (ALS), new growth stunted</td><td>New to WI, potential for submergent and floating-leaf species</td></tr>
<tr><td rowspan="2">Enzyme Specific (foliar use only)</td><td>Glyphosate</td><td>Inhibits plant-specific enzyme (ALS)</td><td>Emergent species, including purple loosestrife</td></tr>
<tr><td>Imazapyr</td><td>Inhibits plant-specific enzyme (EPSP)</td><td>Hardy emergent species, including common reed</td></tr>
</table>

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 fishkills 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 Archibald 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 Archibald Lake in 2016. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Archibald 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 Archibald 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 Archibald Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forest Lakes 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 Archibald 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.

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.

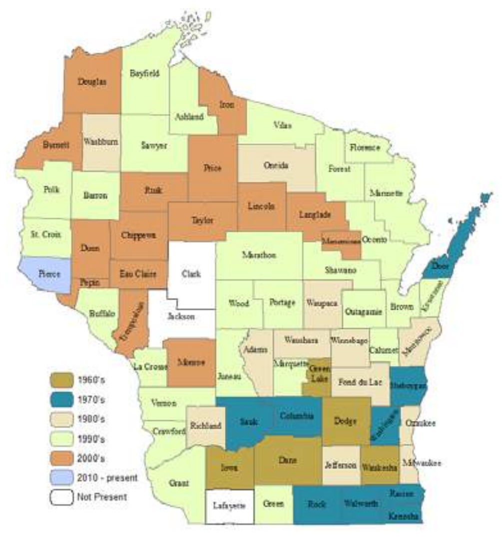


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

During the aquatic plant surveys completed on Archibald Lake in 2016, a total of 46 species of plants were located in Archibald Lake, three of which are considered non-native, invasive species: Eurasian watermilfoil, flowering rush, and giant reed (aka *Phragmites*) (Table 3.4-1). The aquatic plant species list also contains species recorded during whole-lake point-intercept surveys completed in 2010 and 2013. Changes in species' abundance between these three surveys are discussed later in this section. On June 9, 2016, an Early-Season AIS Survey was completed on Archibald Lake that focused on locating and mapping potential occurrences of curly-leaf pondweed. This meander-based, visual survey did not locate any occurrences of this non-native plant. At present, curly-leaf pondweed either does not occur in Archibald Lake or exists at an undetectable level. Because the non-native plants found in Archibald Lake have the ability to negatively impact lake ecology, recreation, and aesthetics, the populations of these plants are discussed in detail within the Non-Native Aquatic Plants in Archibald Lake Section.

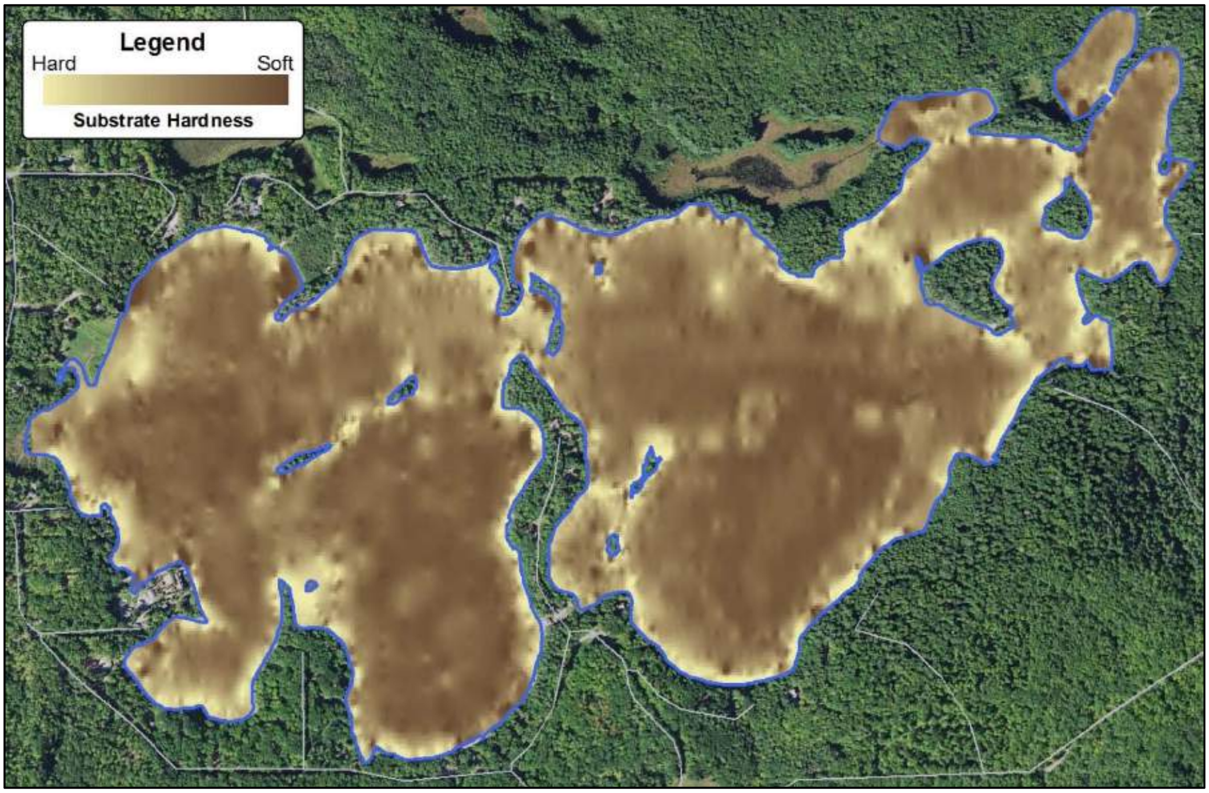
The whole-lake aquatic plant point-intercept survey was conducted on Archibald Lake on August 3, 4, and 10, 2016 by Onterra. The emergent and floating-leaf aquatic plant community mapping survey was completed by Onterra on August 4 and 8, 2016. Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition. On August 4 and 5, 2016, Onterra ecologists completed an acoustic survey on Archibald Lake. The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Archibald Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2016 acoustic survey revealed that Archibald Lake's average substrate hardness ranges from hard to moderately hard with deeper areas containing softer, more flocculent sediments (Figure 3.4-2 and Map 5). On average, the hardest substrates (sand/rock/gravel) are found within 1 to 8 feet of water. The greatest transition between hard and softer substrates is found between 9 and 16 feet of water, with hardness declining rapidly with depth. In 16 feet of water and deeper, substrate hardness remains relatively constant. Figure 3.4-2 illustrates the spatial distribution of substrate hardness in Archibald Lake. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 3.4-1. Aquatic plant species located on Archibald Lake during point-intercept surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2010 (ALA)	2013 (WDNR)	2016 (Onterra)
Emergent	*Butomus umbellatus*	Flowering-rush	Exotic	I	X	I
	Carex comosa	Bristly sedge	5			I
	Carex vesicaria	Blister sedge	7			I
	Cladium mariscoides	Smooth sawgrass	10			I
	Dulichium arundinaceum	Three-way sedge	9			I
	Eleocharis palustris	Creeping spikerush	6			I
	Iris versicolor	Northern blue flag	5			I
	Phragmites australis subsp. *australis*	Giant reed	Exotic			I
	Sagittaria latifolia	Common arrowhead	3	I		I
	Schoenoplectus acutus	Hardstem bulrush	5		X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I		I
	Sparganium emersum var. *acaule*	Short-stemmed bur-reed	8			I
	Typha latifolia	Broad-leaved cattail	1	I		I
FL	*Brasenia schreberi*	Watershield	7	X	X	X
	Nuphar variegata	Spatterdock	6	I	X	X
	Nymphaea odorata	White water lily	6	X	X	X
	Persicaria amphibia	Water smartweed	5	I	I	X
	Sparganium fluctuans	Floating-leaf bur-reed	10		X	
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	X
	Heteranthera dubia	Water stargrass	6	X	X	X
	Myriophyllum heterophyllum	Various-leaved watermilfoil	7		X	
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	I	X	I
	Najas flexilis	Slender naiad	6	X	X	X
	Najas guadalupensis	Southern naiad	7	X	X	X
	Nitella spp.	Stoneworts	7		X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X
	Potamogeton berchtoldii	Slender pondweed	7	X	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8			I
	Potamogeton friesii	Fries' pondweed	8			X
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X	X
	Potamogeton illinoensis	Illinois pondweed	6	X	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X	X
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	X		
	Potamogeton praelongus	White-stem pondweed	8	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8		X	X
	Potamogeton strictifolius	Stiff pondweed	8		X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X
	Ranunculus aquatilis	White water crowfoot	8			X
	Stuckenia pectinata	Sago pondweed	3	I		
	Utricularia intermedia	Flat-leaf bladderwort	9			X
	Utricularia vulgaris	Common bladderwort	7			X
	Vallisneria americana	Wild celery	6	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	I	X	X
	Sagittaria cristata	Crested arrowhead	9			X
	Schoenoplectus subterminalis	Water bulrush	9			X
FF	*Lemna minor*	Lesser duckweed	5			X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species



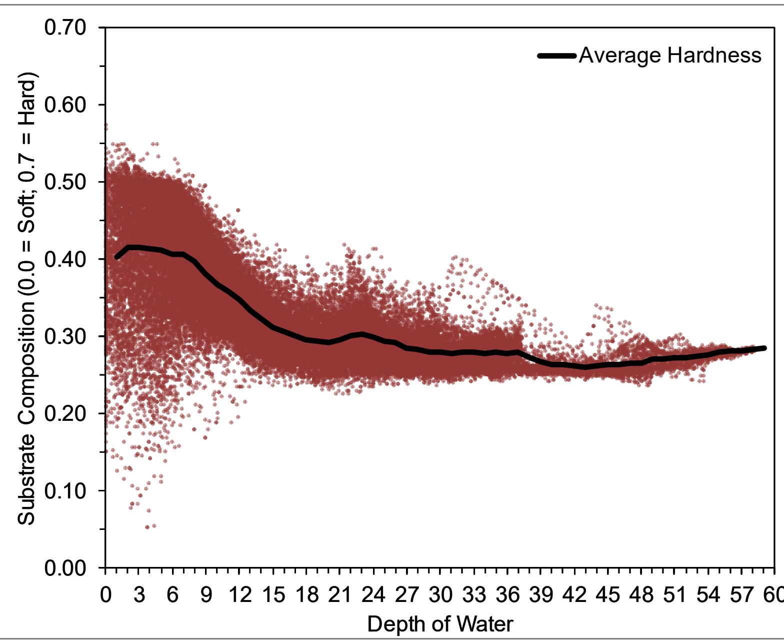


Figure 3.4-2. Archibald Lake spatial distribution of substrate hardness (top) and substrate hardness across water depth (bottom). Individual data points are displayed in red. Created using data from August 2016 acoustic survey.

The water quality data from Archibald Lake indicate the lake is classified as hardwater lake, a lake with a high concentration of dissolved minerals – particularly calcium. Lakes rich in calcium are often termed *marl lakes*. When dissolved calcium reaches a concentration at which the water can no longer dissolve additional calcium (saturation point), the calcium combines with carbonate forming calcium carbonate, or marl, and it precipitates out of the water. The soft sediments found in Archibald Lake are likely largely comprised of marl.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2016 aquatic plant bio-volume data are displayed in Figure 3.4-3 and Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2016 whole-lake point-intercept survey and acoustic survey found aquatic plants growing to a maximum depth of 22 feet, a testament to the high-water clarity found in Archibald Lake. However, the majority of aquatic plant growth occurs within the first 11 feet of water, and the presence of aquatic plants quickly diminished beyond 16 feet. Overall, the 2016 acoustic survey indicates that approximately 40% of Archibald Lake contains aquatic vegetation (Figure 3.4-3). The remaining area of the lake is too deep and does not receive adequate light to support aquatic plant growth.

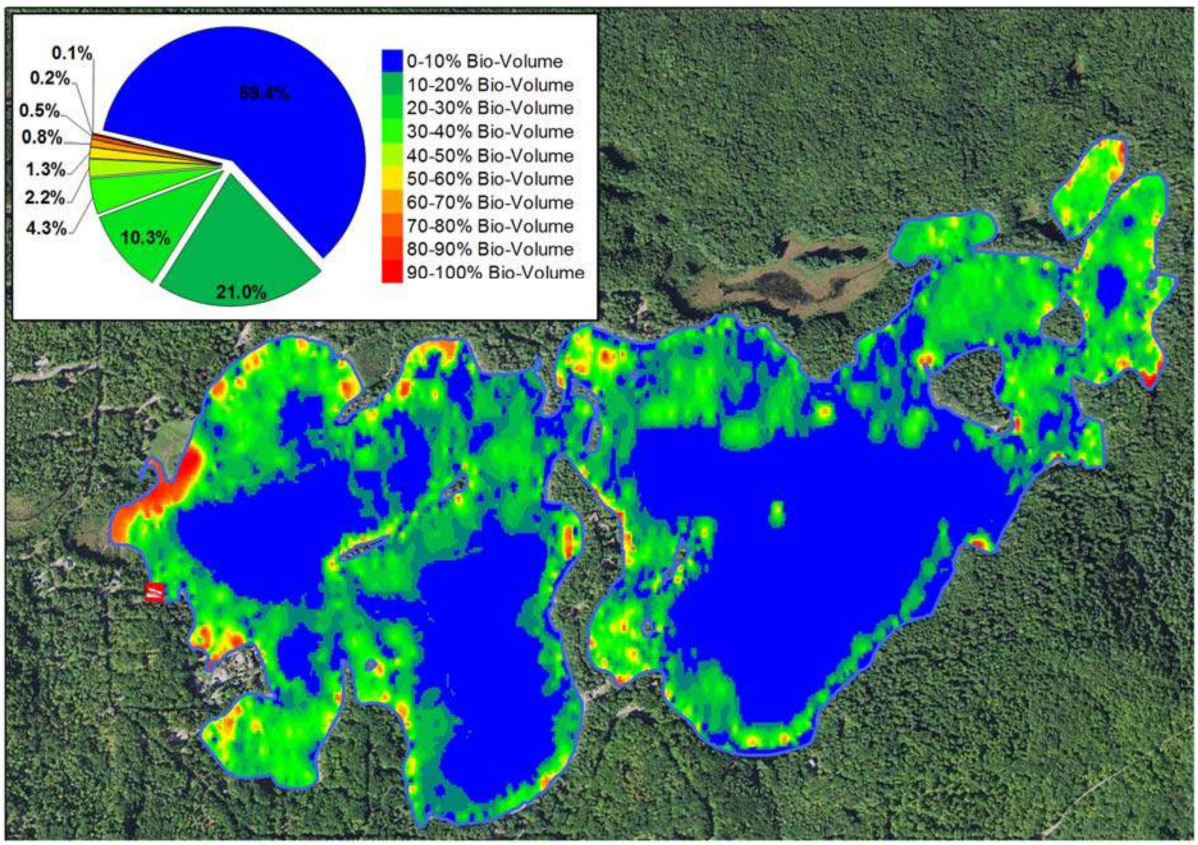


Figure 3.4-3. Archibald Lake 2016 aquatic plant bio-volume. Created using data from August 2016 acoustic survey.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species comprise the aquatic plant community. Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 610 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2016, approximately 78% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 23% of the 610 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 25% had a TRF rating of 2, and 30% had a TRF rating of 3 (Figure 3.4-4). The TRF data indicates that where aquatic plants are present in Archibald Lake, they are moderately dense.

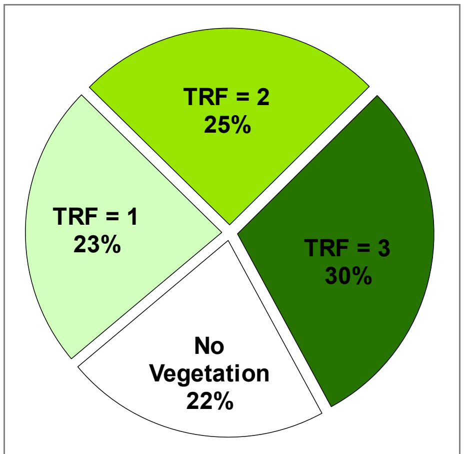


Figure 3.4-4. Archibald Lake 2016 aquatic vegetation total rake fullness (TRF) ratings within littoral areas. Created from data collected during the 2016 whole-lake aquatic plant point-intercept survey.

Of the 46 aquatic plant species located in Archibald Lake in 2016, 32 were encountered directly on the rake during the whole-lake point intercept survey. The remaining 14 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of these 32 species, muskgrasses were the most frequently encountered, followed by slender naiad, wild celery, and southern naiad (Figure 3.4-5).

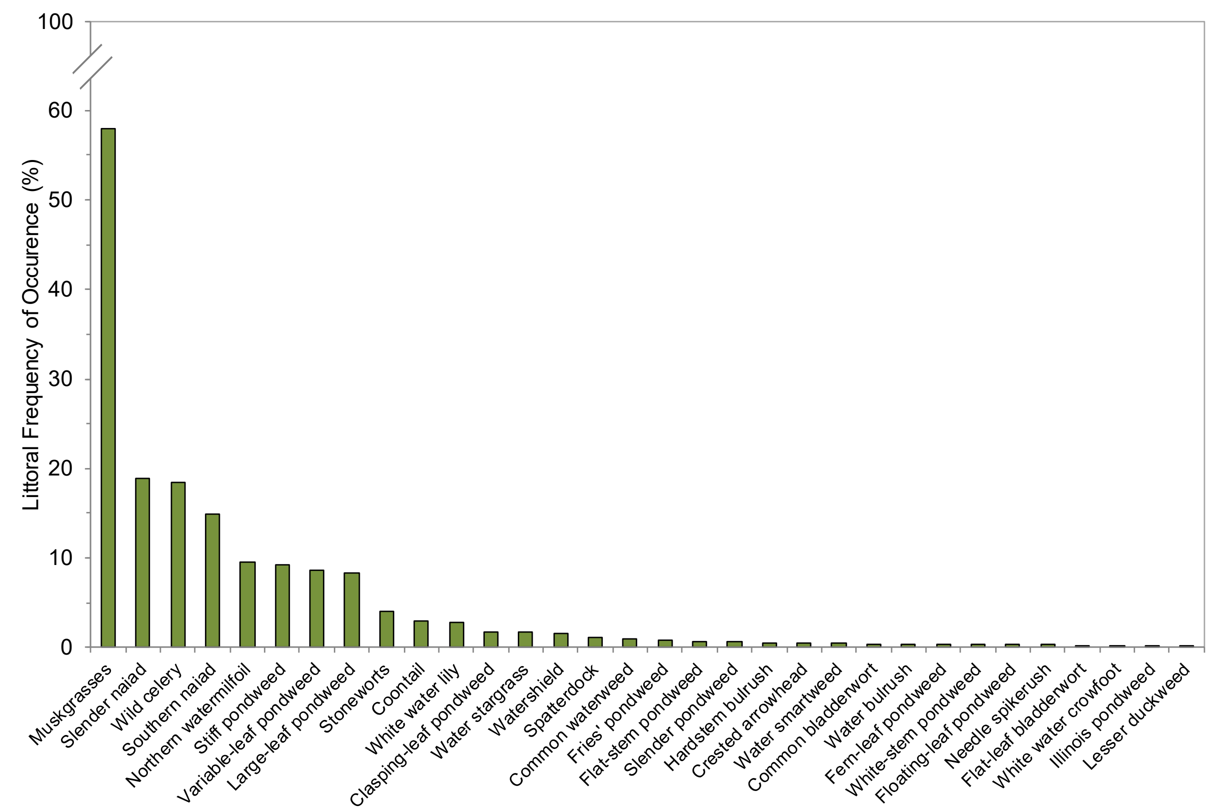


Figure 3.4-5. 2016 Littoral frequency of occurrence of aquatic plant species in Archibald Lake. Created using data 2016 whole-lake aquatic plant point-intercept survey. While Eurasian watermilfoil is present within the lake, it went undetected during the 2016 whole-lake point-intercept survey.

Photograph 3.4-5. The aquatic macroalgae muskgrasses (*Chara* spp.). Photo credit Onterra.

Muskgrasses are a genus of macroalgae of which there are seven species in Wisconsin (Photograph 3.4-5). In 2016, muskgrasses had a littoral frequency of occurrence of approximately 58% (Figure 3.4-5). Dominance of the aquatic plant community by muskgrasses is common in hardwater lakes like Archibald Lake, and these macroalgae have been found to more competitive against vascular plants (e.g. pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002; Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002). In Archibald Lake, muskgrasses were abundant across littoral depths in 2016.

Slender naiad, the second-most frequently encountered aquatic plant in 2016 with a littoral frequency of occurrence of 19% (Figure 3.4-5), is a submersed, annual plant that produces numerous seeds. Slender naiad is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 2014). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. In Archibald Lake, slender naiad was most prevalent between 3 and 8 feet of water.

Photograph 3.4-6. Slender naiad (Najas flexilis; left) and southern naiad (N. guadalupensis; right). Photo credit Onterra.

Southern naiad was the fourth-most frequently encountered aquatic plant in Archibald Lake in 2016 with a littoral frequency of occurrence of approximately 15% (Figure 3.4-5). Southern naiad is similar to slender naiad, and they are often difficult to separate (Photograph 3.4-6). While southern naiad is native to North America, observations have been indicating that populations of this plant have been expanding and behaving invasively, particularly in northern Wisconsin lakes. It is not known if this behavior represents recent introductions of these plants to waterbodies where it was not found naturally, or if certain environmental conditions are favoring the expansion of southern naiad. As is discussed further in this section, southern naiad was recorded during the 2010 the 2013 point-intercept surveys complete on Archibald Lake, and these data indicate southern naiad occurrence has not increased over this time period.

Wild celery, also known as tape or eel grass, was the third-most frequently encountered aquatic plant species with a littoral frequency of occurrence of 18% during the 2016 point-intercept survey (Figure 3.4-5). Wild celery is relatively tolerant of low-light conditions and is able to grow in deeper water. Its long leaves provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. Additionally, the leaves, fruit, tubers, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife. In Archibald Lake, wild celery was most abundant between 4 and 12 feet of water.

The recorded maximum depth of aquatic plant growth was 18 in 2010, 20 in 2013, and 22 feet in 2016. Despite an increase in the recorded maximum depth of plant growth from 2010-2016, an increasing trend in Secchi disk transparency was not apparent. Aquatic plant occurrence is low in these deeper depths, and the changes in the recorded maximum depth of aquatic plant growth may simply be the result of the low occurrence of plants in deeper areas of Archibald Lake's littoral zone.

Using the total number of point-intercept sampling locations (858) divided by the number of sampling locations that contained vegetation in each survey yields the frequency of occurrence within the entire lake, not solely the littoral zone. The frequency of occurrence of aquatic vegetation was 50% in 2010, 54% in 2013, and 56% in 2016 (Figure 3.4-6). The change in the frequency of occurrence of aquatic vegetation from 2010 to 2013 and from 2013 from 2016 was not statistically valid; however, comparison of the frequency of occurrence from 2010 and 2016 indicates they are statistically different (Chi-square α = 0.05). This analysis shows that aquatic plant occurrence has increased in Archibald Lake over the time period from 2010-2016. In addition, 2010 and 2016 had a higher proportion of TRF ratings of 3, possibly signifying that aquatic plant growth has also become denser over this period (Figure 3.4-6).

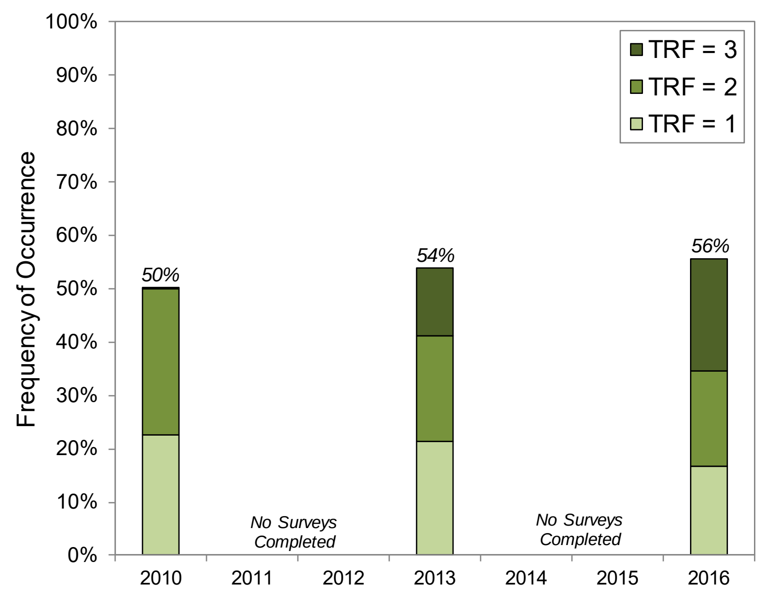


Figure 3.4-6. Aquatic plant frequency of occurrence and total rake fullness (TRF) ratings in Archibald Lake from the 2010, 2013, and 2016 surveys.

Figure 3.4-7 displays the littoral frequency of occurrence of aquatic plant species from the 2010, 2013, and 2016 point-intercept surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one of the three surveys are displayed. In total, seven aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence between 2010 and 2016 (Figure 3.4-7).

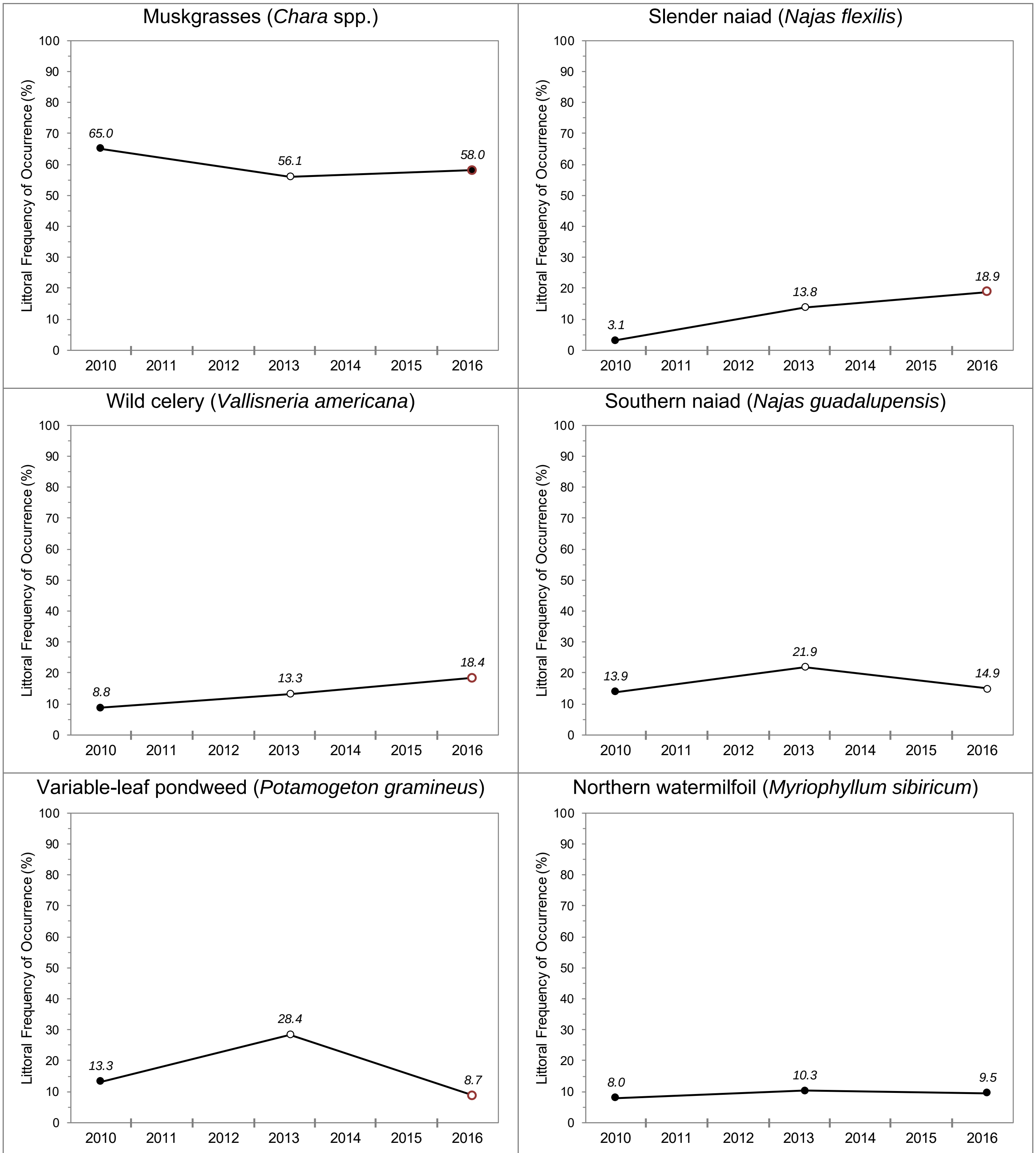


Figure 3.4-7. Littoral frequency of occurrence of select native aquatic plant species in Archibald Lake from 2010-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2010 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys.

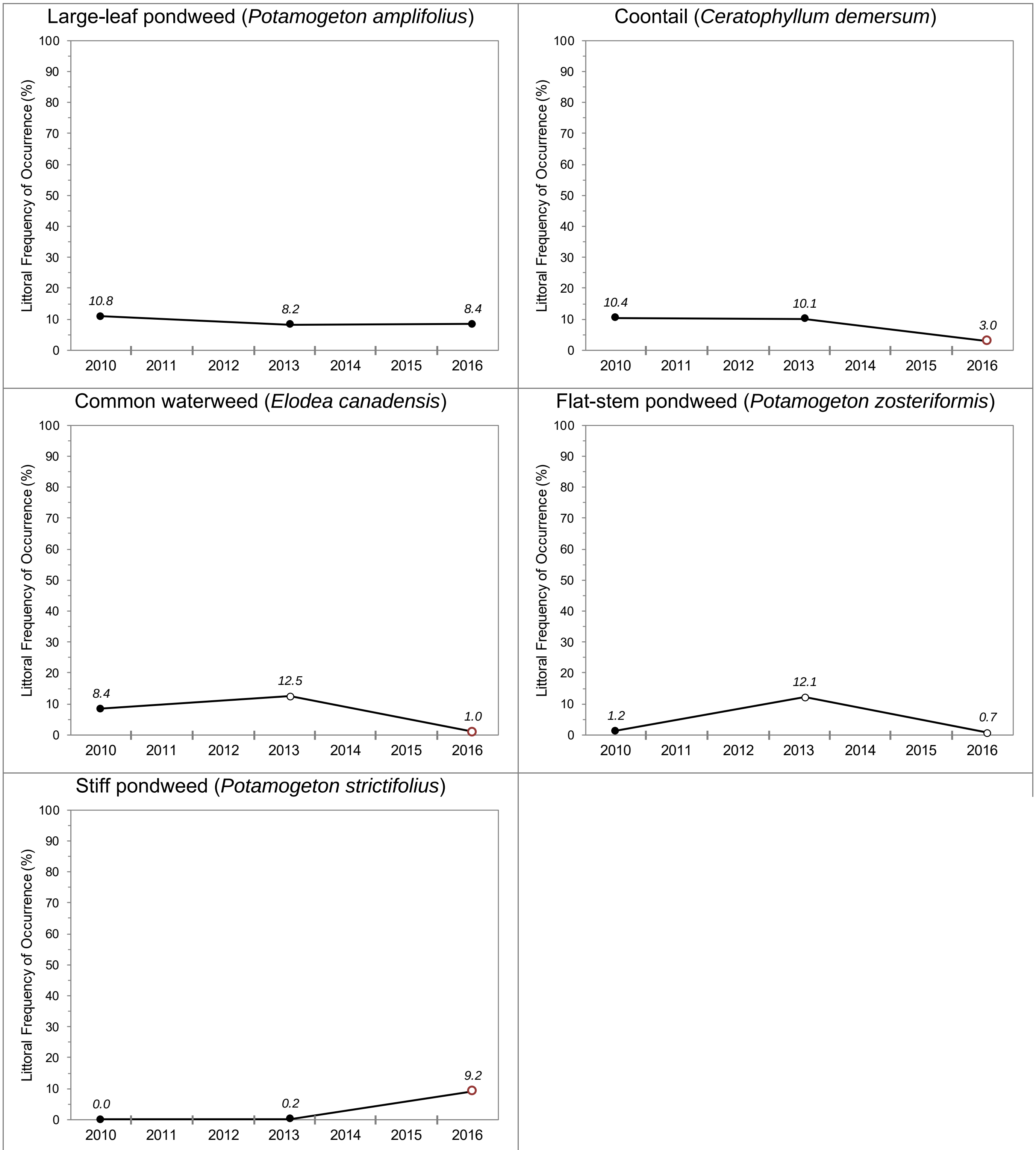


Figure 3.4-7 continued. Littoral frequency of occurrence of select native aquatic plant species in Archibald Lake from 2010-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2010 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys.

Muskgrasses, variable-leaf pondweed, coontail, and common waterweed all decreased in their littoral occurrence from 2010-2016, while slender naiad, wild celery, and stiff pondweed all increased in occurrence over this time period. The occurrences of southern naiad, northern watermilfoil, large-leaf pondweed, were not statistically different over this time period.

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

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 46 native aquatic plant species were located in Archibald Lake during the 2016 surveys, 32 were directly encountered on the rake during the point-intercept survey. Archibald Lake's native aquatic plant species richness in 2016 exceeded the 75th percentile value for lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and for lakes throughout Wisconsin (Figure 3.4-8). The species richness recorded in 2016 (32) was also higher than that recorded during the 2010 (19) and 2013 (28) point-intercept surveys. Given Archibald Lake has not seen significant changes in water quality or seen major disturbances over this period, the large differences in species richness between these surveys are likely due to differences in the surveyors' aquatic plant identification abilities. The differences in the aquatic plant species list between these surveys can be viewed in Table 3.4-1.

The average conservatism of the 32 native aquatic plants recorded on the rake in 2016 was 6.5, falling just below the median value (6.7) for lakes within the NLFL ecoregion and just above the median value (6.3) for lakes throughout Wisconsin (Figure 3.4-8). This indicates that Archibald Lake has a slightly lower number of native aquatic plant species with high conservatism values when compared to the majority of lakes within the NLFL ecoregion. Average conservatism in 2016 was higher when compared to the average conservatism values recorded in 2010 and 2013 of 6.2 and 6.4, respectively.

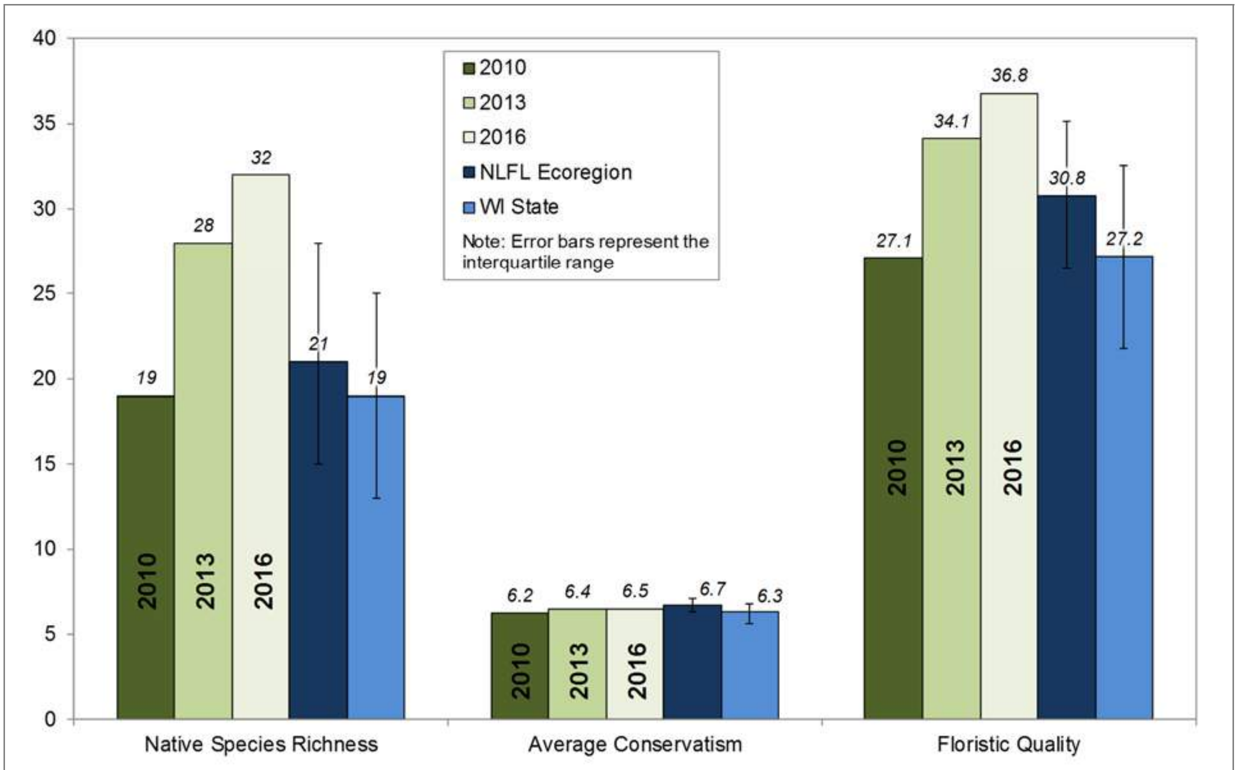


Figure 3.4-8. Archibald Lake Floristic Quality Analysis. Created using data from ALA 2010, WDNR 2013, and Onterra 2016 whole-lake point-intercept surveys. Analysis follows Nichols (1999).

Using Archibald Lake's 2016 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 36.8, exceeding the 75th percentile values for lakes within the NLFL ecoregion and the state. This indicates that Archibald Lake's aquatic plant community is of higher quality in terms of species richness and community composition than the majority of lakes within the ecoregion and the state. Given that native species richness and average conservatism were higher in 2016 when compared to 2010 and 2013, the 2016 Floristic Quality Index value was also higher than those calculated for 2010 and 2013.

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 Archibald Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Archibald Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 3.4-9). Using the data collected from the 2010, 2013, and 2016 point-intercept surveys, Archibald Lake's aquatic plant community is shown to have relatively low species diversity. Simpson's Diversity Index values were 0.78 in 2010, 0.87

in 2013, and 0.84 in 2016. These diversity value fall below the median value of 0.88 for lakes in the NLFL ecoregion.

While Archibald Lake contains a high number of aquatic plant species, the majority of the plant community is comprised of just three species. One way to visualize Archibald Lake's lower species diversity is to look at the relative occurrence of aquatic plant species. Figure 3.4-10 displays the relative frequency of occurrence of aquatic plant species created from the 2016 whole-lake point-intercept survey and illustrates the relatively uneven distribution of aquatic plant species within the community. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population).

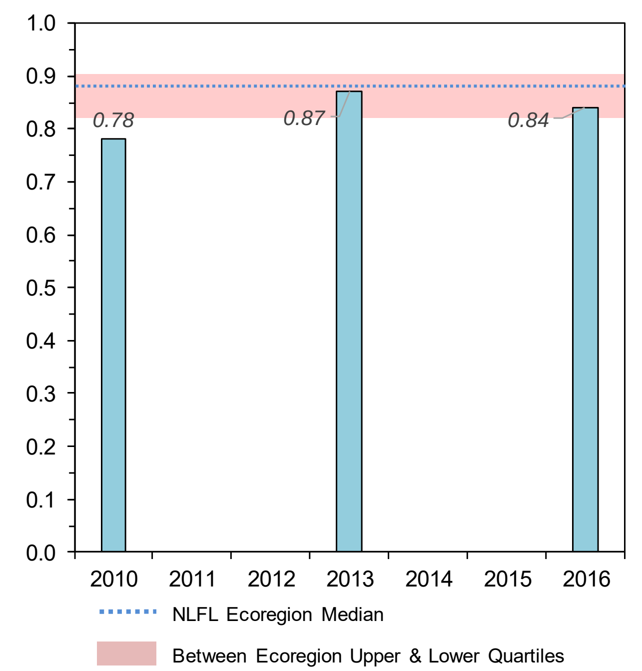


Figure 3.4-9. Archibald Lake species diversity index. Created using data from 2010, 2013, and 2016 aquatic plant surveys. Ecoregion data from 212 NLFL lakes collected by WDNR Science Services and Onterra.

For instance, while muskgrasses had a littoral frequency of occurrence of 58%, their relatively frequency of occurrence was 34%. Explained another way, if 100 plants were sampled from Archibald Lake, 34 would be muskgrasses. Figure 3.4-10 illustrates that 56% of Archibald Lake's aquatic plant community was comprised of just three species in 2016: muskgrasses, slender naiad, and wild celery. Despite having a higher number of aquatic plant species (species richness), the dominance of the plant community by a few number of species results in lower species diversity. As discussed previously, hardwater lakes rich in calcium like Archibald Lake are often dominated by muskgrasses which are able to outcompete other plants in these conditions. The lower species diversity in Archibald Lake is not an indication of degraded conditions, but rather the result of calcium-rich conditions as a result of the underlying geology around Archibald Lake.

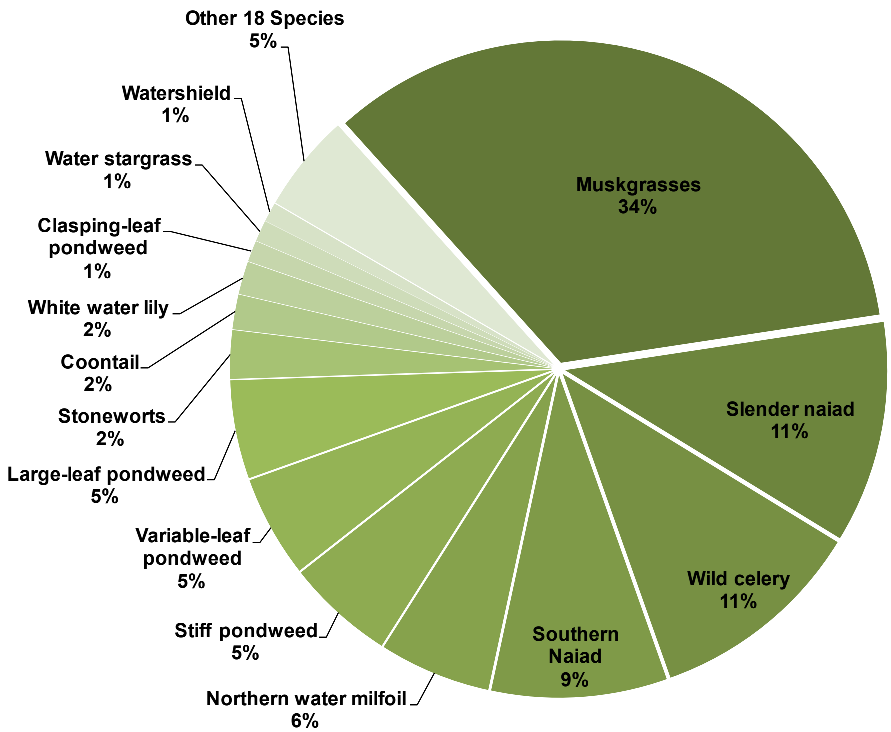


Figure 3.4-10. 2016 relative frequency of occurrence of aquatic plants in Archibald Lake. Created using data from 2016 point-intercept survey.

The quality of Archibald Lake's plant community is also indicated by the high number of native emergent and floating-leaf aquatic plant species located in 2016 (Table 3.4-1). The 2016 community mapping survey found that approximately 29.4 acres (7.5%) of the 392 acre-lake contain these types of plant communities (Table 3.4-2 and Map 7 & 8). Fifteen floating-leaf and emergent species were located on Archibald Lake, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

Table 3.4-2. Archibald Lake acres of plant community types. Created from August 2016 community mapping survey.

Plant Community	Acres
Emergent	7.1
Floating-leaf	22.2
Mixed Emergent & Floating-leaf	0.2
Total	29.4

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 Archibald 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.

Non-native Plants in Archibald Lake

Eurasian watermilfoil

Photograph 3.4-7. Eurasian watermilfoil, a non-native, invasive aquatic plant. Photo credit Onterra.

Eurasian watermilfoil (Photograph 3.4-7) was first documented in Archibald Lake in 2009. Since its discovery, the ALA has been very proactive in managing this invasive plant through a combination of localized herbicide spot treatments and manual hand-removal. It is generally believed that this proactive management has kept the EWM population at low levels. In 2009, the ALA successfully applied for a WDNR Early-Detection and Response (EDR) Grant and contracted with Cason and Associates to conduct herbicide treatments targeting EWM in the fall of 2009. Monitoring continued in 2010 with the formation of an adopt-a-shoreline program within the lake association. This helped identify EWM areas for herbicide control in the fall of 2010 and again in spring of 2011 and 2012.

Beginning in 2011, smaller occurrences of EWM identified were targeted with manual removal by volunteers within the ALA. Surveys conducted in late 2012 and early 2013 showed the EWM population had expanded to many locations in the western lobe of the lake and led to an aggressive control approach using a combination of herbicide and manual removal control tactics. Post-treatment surveys conducted in the late summer of 2013 showed that the control efforts were successful with a significant reduction of EWM. In 2014, the ALA was awarded a second AIS-EDR grant and contracted with Onterra, LLC to monitor the EWM population in Archibald Lake.

Monitoring since 2014 has shown the EWM population remains small, and that hand-harvesting activities by ALA volunteers have been successful at maintaining the low level of EWM. Onterra ecologists completed a Late-Summer EWM Peak-Biomass Survey on Archibald Lake on September 12, 2016. During this survey, only two *clumps of plants* were located – one each within the east and west basins (Figure 3.4-11 and Map 9). An additional *single or few plants* were located during the June 2017 Early Season AIS Survey. At present, EWM it as at a level at which it is not having adverse impacts to lake ecology, recreation, or aesthetics. However, continued monitoring and active management will ensure that EWM population in Archibald Lake remains at low levels.

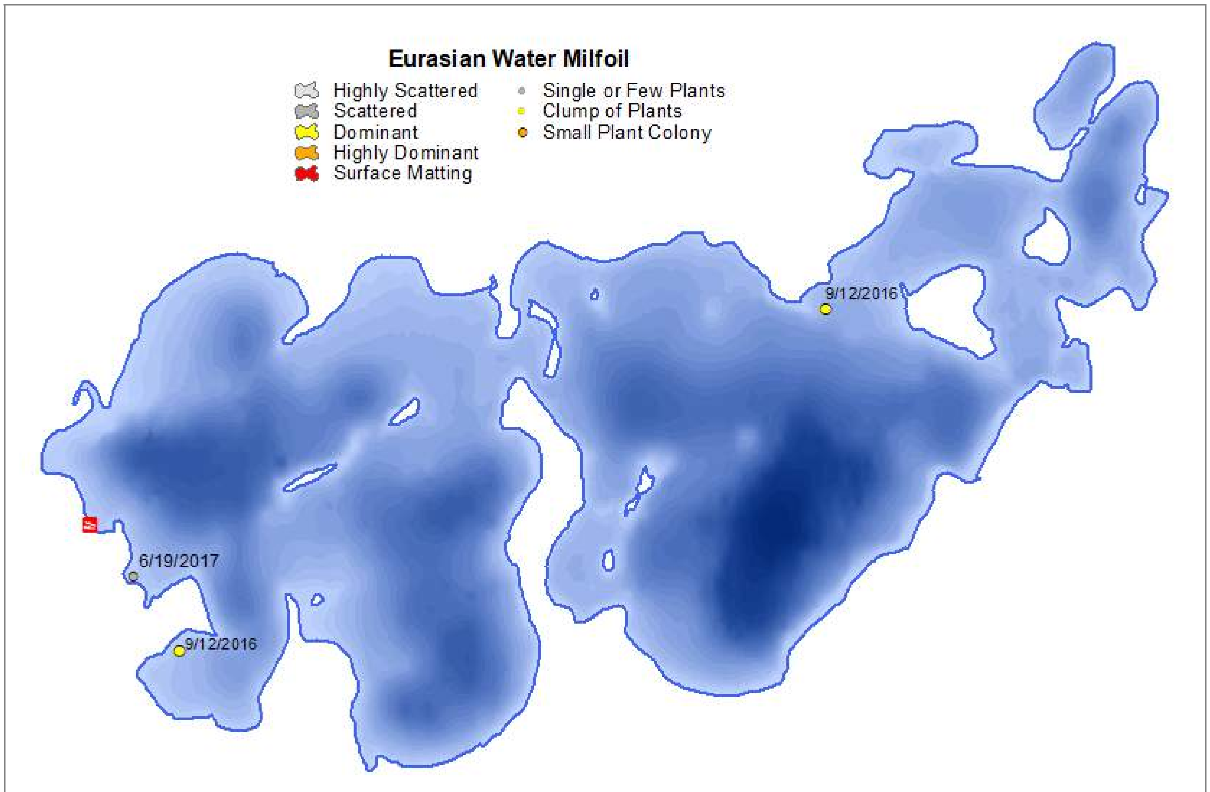


Figure 3.4-11. Archibald Lake 2016-2017 Eurasian watermilfoil locations.

Giant Reed (aka *Phragmites*)

Giant reed (*Phragmites australis* subsp. *australis*) is a tall, perennial grass that was introduced to the North America from Europe (Photograph 3.4-8). While a native strain (*P. australis* subsp. *americanus*) of this species exists in Wisconsin, the plants located along the shorelines and in shallow water in Archibald Lake were identified to be the non-native, invasive strain. The identification between the non-native and native strain is often difficult, and the plants found in Archibald Lake had characteristics that were more indicative of the non-native strain. Phragmites forms towering, dense colonies that overtake native vegetation and replace it with a monoculture that provides inadequate sources of food and habitat for wildlife.

Photograph 3.4-8. Colony of giant reed, a non-native invasive wetland grass growing on the shoreline of Archibald Lake. Photo credit Onterra.

Six areas of phragmites were found around the shoreline of Archibald Lake in 2016 (Photograph 3.4-7 and Maps 7 and 8). These colonies have been monitored over the last few years. Previously, phragmites was only found in one area on the eastern shore in the west basin (and was controlled with herbicide applications) and it seems to have become more widespread If continual monitoring indicates expansion, an effort should be made to remove these plants. Because this species has the capacity to displace the valuable wetland plants along the exposed shorelines, it is recommended that these plants be removed by cutting and bagging the seed heads and applying herbicide to the cut ends. This management strategy is most effective when completed in late summer or early fall when the plant is actively storing sugars and carbohydrates in its root system in preparation for over-wintering. A permit issued by the WDNR will likely be needed to place herbicide on plants that are located within the water.

Flowering rush

Flowering rush (*Butomus umbellatus*) is an invasive aquatic plant that is native to Europe (Photograph 3.4-9). This perennial plant flowers in late summer to early fall. It ranges in size from 1-5 feet, generally growing it shallow water, though it can be found growing submersed in up to 10 feet. Like other non-native invasive plants, flowering rush displaces native aquatic and wetland plants and can alter ecosystem functions.

Photograph 3.4-9. Flowers, stem, and colony of flowering rush in Archibald Lake, a non-native invasive wetland plant growing on the shoreline of Archibald Lake. Photo credit Onterra.

Flowering rush was first discovered in Archibald in 1989. In 2010, the ALA received a grant to research and control the flowering rush populations in Archibald Lake. In 2011, two trial areas were treated with granular endothall (Aquathol® SuperK) and a granular combination triclopyr and 2,4-D product (Renovate Max G®). A statistically valid decrease was seen with the combination auxin treatment (2,4-D and triclopyr); and while there was a decrease in the granular endothall site, it was not statistically significant. In 2013, the granular combination auxin herbicide as well as liquid diquat (Reward ®) were tested to treat the flowering rush and in 2014 and 2015. The principal investigators of the study determined that diquat was the best for controlling and the regrowth of flowering rush tubers. Diquat was shown to be effective in treating emergent as well as submergent flowering rush populations. Fleming and Fleming (2016) found there to be an 86% reduction in flowering rush populations from 2011 to spring 2015 and a 98% reduction from 2011 to fall of 2015.

Maps 7 and 8 displays the locations that flowering rush was found in 2016. A total of 0.05 acres were mapped as well as *single or few plants, clumps of plants* and one *small plant colony*. Flowering rush was found mainly within the western basin but a *clump of plants* and *single or few* plants were found on the western shore of the eastern basin. A submergent colony of flowering rush was noted by the ALA in the far eastern part of the lake that went undetected during the 2016 community mapping surveys.

Stakeholder Survey Responses to Aquatic Vegetation within Archibald 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 3.4-12 and 3.4-13 display the responses of members of Archibald Lake stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, during the open water season, negatively impacts the enjoyment of Archibald Lake, the majority of stakeholder survey respondents (56%) indicated *rarely* or *never*, 38% indicated *sometimes*, 4% indicated *often*, and 2% indicated *always* (Figure 3.4-12).

When asked if they believe aquatic plant control is needed on Archibald Lake, 65% of respondents indicated *definitely yes* and *probably yes*, 24% indicated that they were *unsure*, and 11% indicated *probably no* or *definitely no.* The presence of AIS within Archibald Lake is well-known knowledge for the stakeholders so while aquatic plants do not generally impact user's enjoyment of the lake, stakeholders 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 Archibald Lake is discussed within the Implementation Plan Section (Section 5.0).

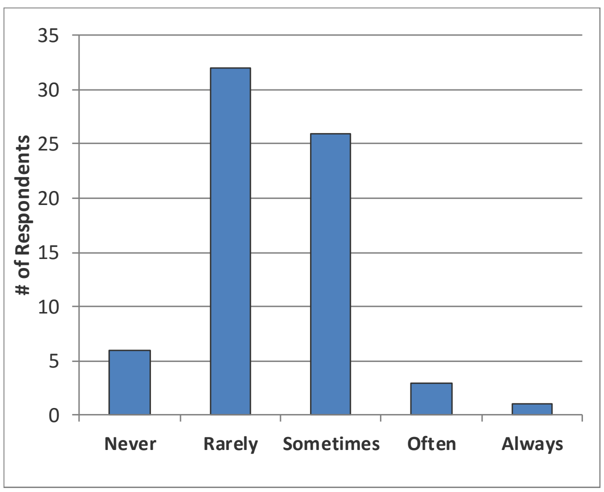


Figure 3.4-12. Stakeholder survey response Question #23. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Archibald Lake?

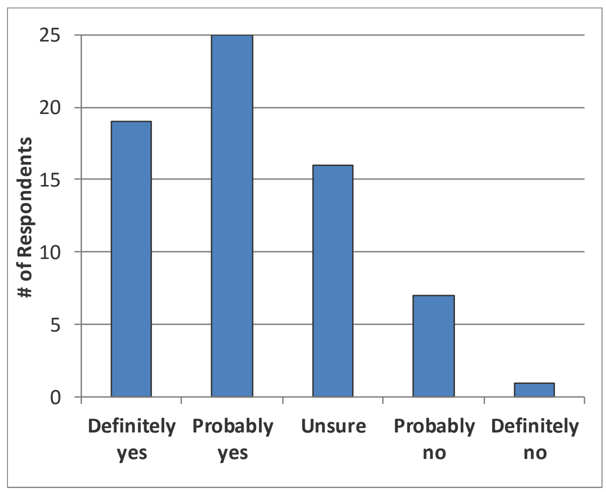


Figure 3.4-13. Stakeholder survey response Question #24. Do you believe aquatic plant control is needed on Archibald Lake?

3.5 Aquatic Invasive Species in Archibald Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Archibald 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 Archibald Lake.

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Giant reed	*Phragmites australis* subsp. *australis*	Section 3.4 – Aquatic Plants
	Flowering rush	*Butomus umbellatus*	Section 3.4 – Aquatic Plants
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 3.5 – Aquatic Invasive Species

Figure 3.5-1 displays the 12 aquatic invasive species that Archibald Lake stakeholders believe are in Archibald Lake. Only the species present in Archibald 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). Rusty crayfish are not believed to be present with Archibald Lake.

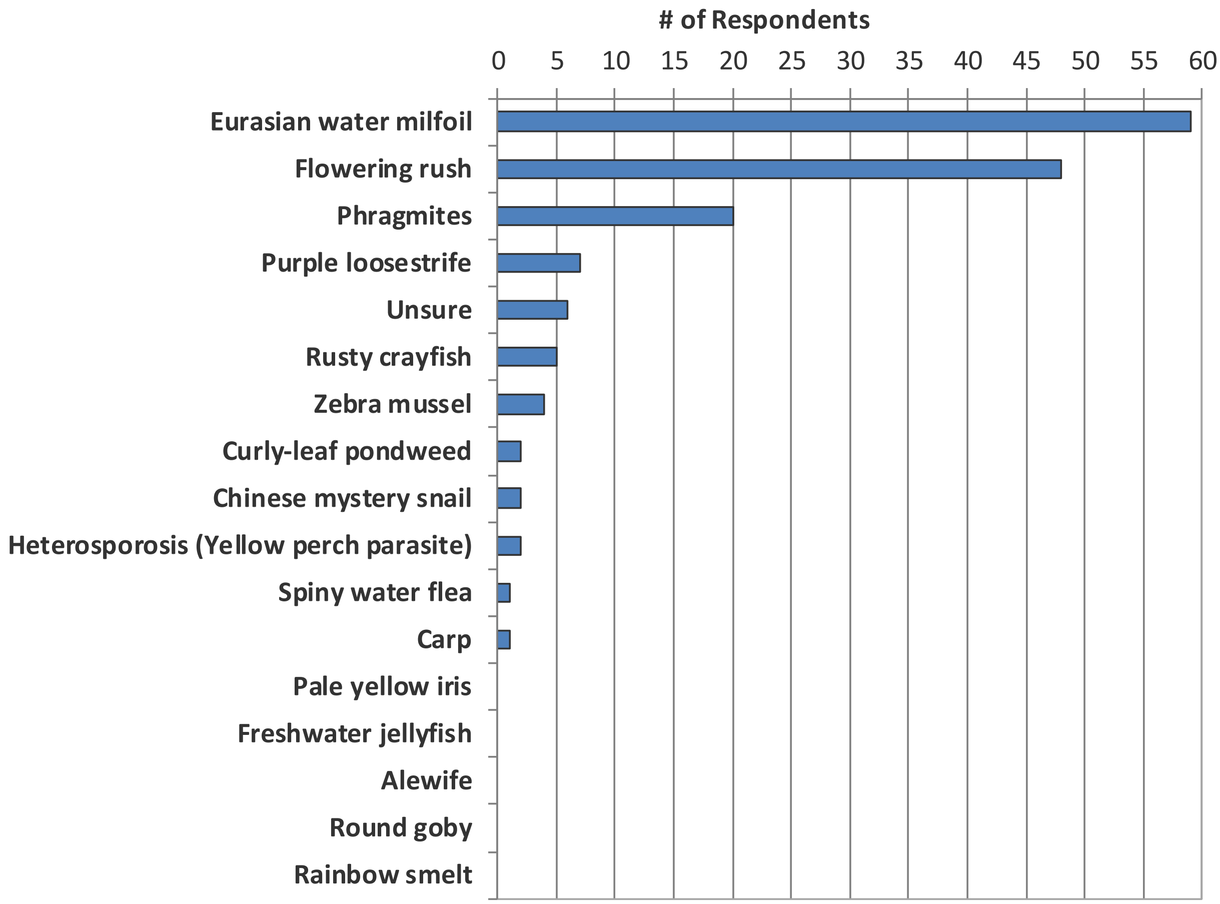


Figure 3.5-1. Stakeholder survey response Question #20. Which aquatic invasive species do you believe are in Archibald Lake?

3.6. Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a 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 Archibald Lake. The goal of this section is to provide an overview of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR), the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Chip Long (WDNR 2017 & GLIFWC 2016A & GLIFWC 2016B).

Herbicide Use and Fisheries Impacts

As is discussed in the Aquatic Plant Section (3.4), several aquatic herbicides have been historically applied on Archibald Lake to target aquatic invasive species. It is likely that future in-lake herbicide treatments would use 2,4-D (Eurasian watermilfoil) or diquat (flowering rush or Eurasian watermilfoil. It is important to note that US EPA registration of aquatic herbicides requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with spot-treatment use patterns (high concentrations, short exposure times). These toxicity studies are briefly discussed below as they apply to potential future herbicide use on Archibald Lake. The use of aquatic herbicides includes regulatory oversight and must comply with the following list. Additional information from the WDNR on aquatic herbicide regulation is included within Appendix E.

- Labeled and registered with U.S. EPA's office of Pesticide Programs;
- Registered for sale and use by the Department of Agriculture, Trade, and Consumer Protection (DATCP);
- Permitted by the Wisconsin Department of Natural Resources (WDNR); and
- Applied by a DATCP-certified and licensed applicator,

Diquat is a fact-acting contact herbicide that does not breakdown (degrade), rather binds with organic matter indefinitely. At approved label rates, diquat does not have any short-term effects on most aquatic organisms that were tested, except for certain zooplankton (*Daphnia* spp.) and benthic insects (*Amphipoda* spp.) (Appendix E). Also, walleye have been shown to be sensitive to diquat treatments at labeled rates.

2,4-D is an auxin mimic herbicide that gets translocated throughout the plant (acts systemically) and suppresses growth regulation hormones. While the ester formulations of 2,4-D have been shown to be toxic to some fish and important invertebrates, the amine formulations of 2,4-D are considered "non-toxic" and spot treatment use rates (Appendix E). The historic granular 2,4-D treatments on Archibald Lake utilized the ester 2,4-D formulation (Navigate ®).

While herbicides have not been applied in this use-pattern on Archibald Lake, it is important to note that only limited organismal toxicity data is available for concentrations and exposure times consistent with large-scale (aka whole-lake treatment) use patterns (low concentrations, long exposure times). While spot treatments of 2,4-D ester and 2,4-D amine are common throughout Wisconsin, the use of 2,4-D amine has been more common in recent years due to having a lower toxicological profile. This herbicide is also more commonly being used in large-scale use patterns. With the assistance of a WDNR AIS-Research Grant, DeQuattro and Karasov (2015) investigated the impacts on fathead minnow of 2,4-D amine concentrations more relevant to what would be observed in large-scale treatments. Because of their durability as a laboratory species, fathead minnows are often the subject of organismal toxicity studies. The LC50 (lethal concentration when half die) for fathead minnow exposure to 2,4-D (amine salt) has been determined to be 263 ppm ae sustained for 96 hours, a thousand times higher than fish would be exposed to in a large-scale treatment (target of approximately 0.3 ppm ae); however, a large-scale treatment would expose the fish to the herbicide for much longer than 96 hours.

Since the mode of action of 2,4-D involves growth regulating hormone mimicry, the focus of DeQuattro and Karasov was on reproductive toxicity and/or possible endocrine disruption potential from the herbicide. The study revealed morphological changes in reproducing male fathead minnows, such that they had lower facial tubercle scores (analogous to smaller antlers on a male white-tail deer) with some 2,4-D products/use-rates and not with others. This may suggest that the "inert" carrier may be the cause, not the 2,4-D itself. At a static exposure for 58 days (fish exposed for 28 days then eggs they laid were continued to be exposed for 30 more days post fertilization) uncovered a reduction in larval fathead survival from 97% to 83% at the lowest dose (0.05 ppm ae) of one commercially available 2,4-D amine product that was tested (no reduction at higher doses).

While the study above discusses an herbicide use-pattern not used to date within Archibald Lake, it underscores acknowledgement that herbicide use comes with a risk of environmental toxicity.

Archibald 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 Archibald 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.

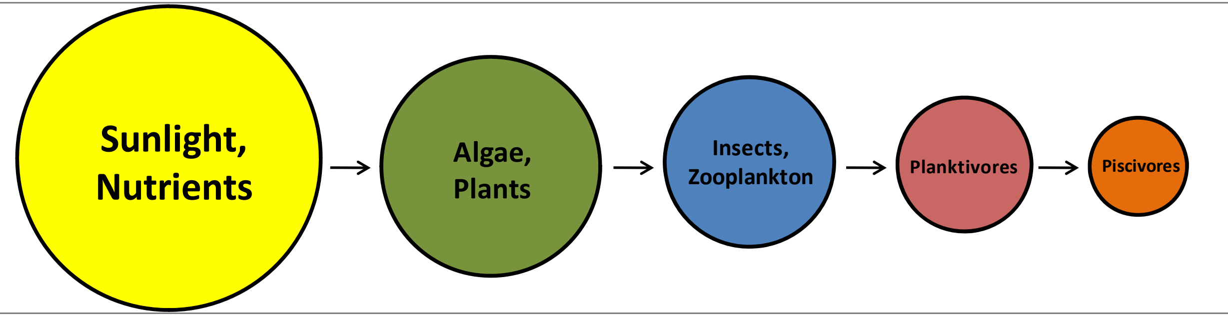


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Archibald Lake is oligotrophic, meaning it has high water clarity, but a low amount of nutrients and thus low primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscivores) because the supporting food chain is relatively small. Table 3.6-1 shows the popular game fish present in the system. An additional fish species found in surveys was the white sucker (*Catostomus commersonii*).

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

Common Name (*Scientific name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
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
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead (*Ameiurus natalis*)	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch (*Percu 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 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 common passive trap used 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 and sort the fish that were captured. All fish species were targeted with fyke nets during the 2011 WDNR fisheries survey (Long 2011).

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 target species for the WDNR electroshocking on Archibald Lake in 2011 were gamefish, panfish and YOY (young of year) walleye (Long 2011).

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 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 stock fry, fingerling or adult fish in a waterbody that were raised in nearby 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. Archibald Lake has special stocking actions in terms of great lakes spotted muskellunge (GLSM). Spotted muskellunge disappeared from Green Bay and Lake Michigan waters by the 1930s due to water pollution, overfishing and other ecological factors (Rowe 2010). Efforts made in

Photograph 3.6-2. Fingerling Muskellunge.

1989, by the WDNR and various Musky Clubs, reintroduced spotted muskellunge to Green Bay waters and developed a plan to maintain a stable population (Rowe 2010). Archibald Lake plays a critical role in this plan by serving as a brood stock lake for adult GLSM. Disease free yearling GLSM are stocked in Archibald Lake to help develop an established population. Future adult GLSM caught on Archibald Lake by the WDNR will be used for egg collection to ultimately bring new spotted muskellunge genetics to the Bay of Green Bay and its surrounding tributaries.

Future stocking efforts of walleye will also be consistent following Archibald Lakes' inclusion in the Wisconsin Walleye Initiative. The Initiative was made possible by the governor's office, Department of Natural Resources and statewide partners to maintain the walleye population in Wisconsin's lakes and improve walleye fisheries in lakes capable of sustaining the sportfish (WDNR 2014). Lakes chosen to be included were selected based upon anticipated fingerling survival, natural reproduction opportunities, public access, tribal interest (for ceded territory lakes) and potential impacts to tourism (WDNR 2014). Stocking rates are randomly assigned and Archibald Lake was selected to receive the second top stocking rate (15 large fingerling walleye/acre) (WDNR 2013). Beginning in 2014 and in even years thereafter, Archibald Lake will receive the assigned stocking rate of walleye as funding allows (WDNR 2014).

Table 3.6-2 displays 1994-2017 stocking efforts of muskellunge and walleye in Archibald Lake.

Table 3.6-2. Stocking data available for Archibald Lake (1994-2017).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1999	Muskellunge	Unspecified	Yearling	500	16
2005	Muskellunge	Unspecified	Large Fingerling	100	13
2009	Muskellunge	Great Lakes Spotted	Yearling	566	9
2010	Muskellunge	Great Lakes Spotted	Yearling	107	10.8
2013	Muskellunge	Great Lakes Spotted	Fall Yearling	272	13.3
2015	Muskellunge	Great Lakes Spotted	Fall Yearling	1,176	13.6
2016	Muskellunge	Great Lakes Spotted	Fall Yearling	400	13.9
2017	Muskellunge	Great Lakes Spotted	Yearling	599	17
1994	Walleye	Unspecified	Fingerling	11,267	3.4
1998	Walleye	Unspecified	Small Fingerling	15,000	1.7
2000	Walleye	Unspecified	Small Fingerling	15,000	1.7
2003	Walleye	Mississippi Headwaters	Small Fingerling	15,000	2.1
2004	Walleye	Lake Michigan	Small Fingerling	14,988	1.3
2006	Walleye	Lake Michigan	Small Fingerling	14,983	1.4
2008	Walleye	Mississippi Headwaters	Small Fingerling	13,799	1.4
2008	Walleye	Unspecified	Large Fingerling	312	10
2010	Walleye	Lake Michigan	Small Fingerling	13,800	1.4
2012	Walleye	Lake Michigan	Small Fingerling	14,996	1.6
2014	Walleye	Unspecified	Large Fingerling	5,880	7.6
2016	Walleye	Upper Mississippi River	Large Fingerling	5,980	7.4

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second-most important reason for owning property on or near Archibald Lake (Question #15), relaxing/entertaining was the first most important reason. Figure 3.6-2 displays the types of fish Archibald Lake stakeholders enjoy catching the most, with bluegill/sunfish, yellow perch and walleye being the most popular among stakeholder respondents. Approximately 53% of respondents who fish Archibald Lake believe the current quality of fishing is fair or poor, compared to 40% that described the quality of fishing as good or excellent (Figure 3.6-3). Approximately 85% of these same respondents believed the quality of fishing on the lake either remained the same or had gotten worse since they first started fishing the lake (Figure 3.6-4).

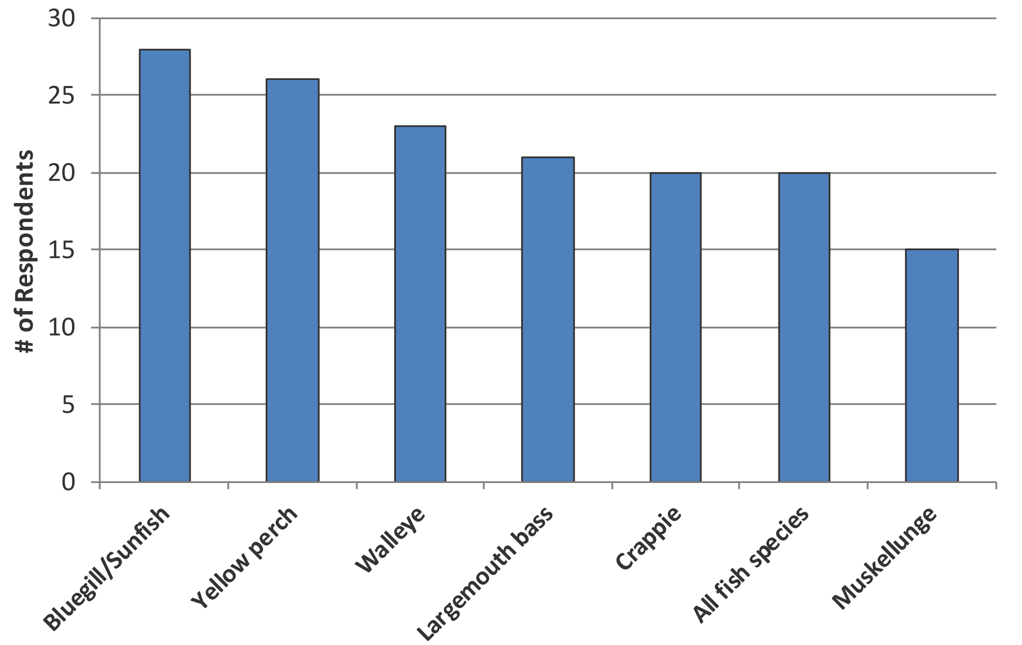


Figure 3.6-2. Stakeholder survey response Question #9. What species of fish do you like to catch on Archibald Lake?

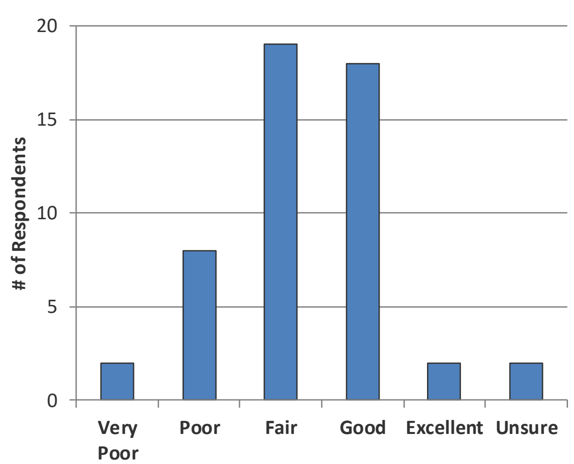


Figure 3.6-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on Archibald Lake?

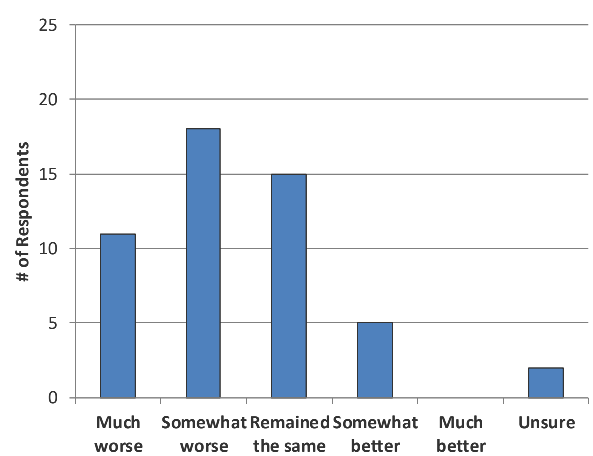


Figure 3.6-4. Stakeholder survey response Question #11. How has the quality of fishing changed on Archibald Lake since you started fishing the lake?

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. This helps biologists assign proper management strategies or goals to the fishery. The number of fish caught and calculated densities reported in the 2011 WDNR Fisheries Report are listed below (Long 2011).

Gamefish

The gamefish present on Archibald Lake represent different population dynamics depending on the species. Overall, healthy populations of gamefish are present. Brief summaries of popular gamefish in Archibald Lake are provided based off of the fisheries survey completed in 2011.

Walleye are an important sportfish for Archibald Lake. From 2000 to 2016 102,566 small fingerlings and 12,172 large fingerling walleyes have been stocked (Table 3.6-2). During 2011, no walleye were stocked and 17 YOY walleye were captured. The spawning reef addition, constructed in 2008, is the likely contributor to the successful walleye natural reproduction observed in 2011. Good walleye natural reproduction was also observed in 2016 and 2017 (Long 2018). The walleye population estimates also increased from 1.5 fish/acre in 2007 to 1.9 fish/acre in 2011. This increase may also be due to a the change of stocking strategy between 2013 and 2014 with Archibald Lake's inclusion into the WI Walleye Initiative and large fingerling stocking events began (Long 2018).

Largemouth bass, in terms of abundance, are the most dominant predator in Archibald Lake. However, when comparing the 2007 to 2011 surveys of largemouth bass, the density (fish/acre) decreased from 5.0 fish/acre to 3.5 fish/acre, respectively. In 2007 a large year class of bass between 6 and 7 inches was collected. This year class was collected again in 2011 and was recorded between 10 and 12 inches. Improved bass fishing opportunities should be available currently as this year class should be surpassing the minimum length limit of 14-inches.

Northern Pike have maintained their density of 0.8 in 2007 to 1.1 fish per acre in 2011. The abundance of shallow, vegetated water will continue to provide habitat for northern pike to flourish in Archibald Lake.

Muskellunge numbers decreased from 2007 to 2011 with 100 and 23 fish collected, respectively. No explanation could be determined for this decrease in numbers. Additionally, no Great Lakes Spotted Muskellunge (GLSM) were collected during the 2011 fyke net survey. The WDNR does not find this unusual as in order to be susceptible for capture in a fyke net the GLSM must be sexually mature and establish a population. The WDNR first began stocking GLSM in 2009 and muskellunge take 6-7 years to mature plus additional years to establish a population (Long 2018). Stocking and assessment of spotted muskellunge is a long-term commitment and will continue depending on the availability of funds and staff.

Panfish

The panfish present on Archibald Lake represent different population dynamics depending on the species however, overall good populations of panfish are present. The results for the stakeholder survey show landowners prefer to catch bluegill/sunfish and yellow perch on Archibald Lake (Figure 3.6-2).

Bluegill and Yellow perch comprised the majority of the panfish population in 2007 and 2011. Bluegill was the most targeted and harvested fish species in the 2011-2012 fishing season according to the creel survey results. However, bluegill abundance did decrease from 2007 to 2011, 37% to 11% respectively. This may be due to the increase in abundance of yellow perch which rose from 18% in 2007 to 50% in 2011. The increased yellow perch population may be due to the addition of 100 tree drops in 2009.

Archibald Lake Fish Parasite: Black Spot

The black spot is relatively common in most lakes and in particular for Archibald Lake bluegill were found to have prevalent black spot markings. A summary of the black spot is provided based off of information from WDNR and MNDNR 2017.

The black spot is caused by a parasitic flatworm called trematodes. The parasites have a very complex life cycle involving organisms such at fish eating birds, snails, and various fish species as the host animal. The parasite also does not affect the fish they infect or any humans who have consumed them. Proper cleaning and cooking of fish will ensure any remaining parasites are killed and filets are safe to consume.

Archibald Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.6-5). Archibald Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a “total allowable catch” (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A “safe harvest” value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest limits are set through

Figure 3.6-5. Location of Archibald Lake within the Native American Ceded Territory (GLIFWC 2016B). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through tribal or recreational harvesting means. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009).

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

Walleye open water spear harvest records are provided in Figure 3.6-6 from 2000 to 2017, however, records extend to 1991. As many as 57 walleye have been harvested from the lake in the past (1991), however the average harvest is roughly 9 fish in a given year with many years not meeting that average. Spear harvesters on average have taken 16% of the declared quota. No spearing effort has occurred on the lake since 2010. Muskellunge open water spear harvest records are provided in Figure 3.6-7 from 1999 to 2017. Records show only two harvesting years (2007 and 2008) in which 2 muskellunge each year were taken (Figure 3.6-7).

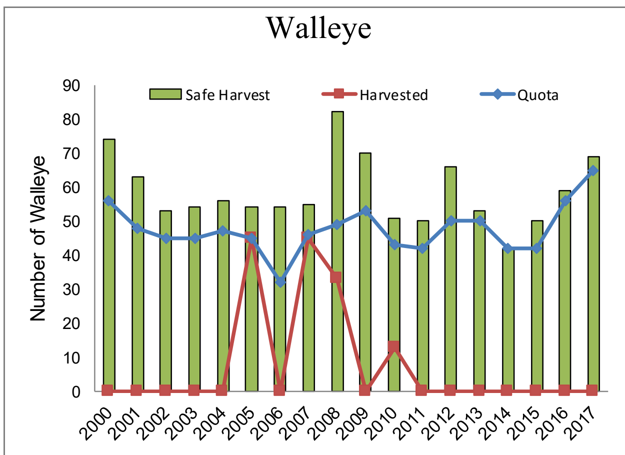


Figure 3.6-6. Archibald Lake walleye spear harvest data. (GLIFWC 1998-2017).

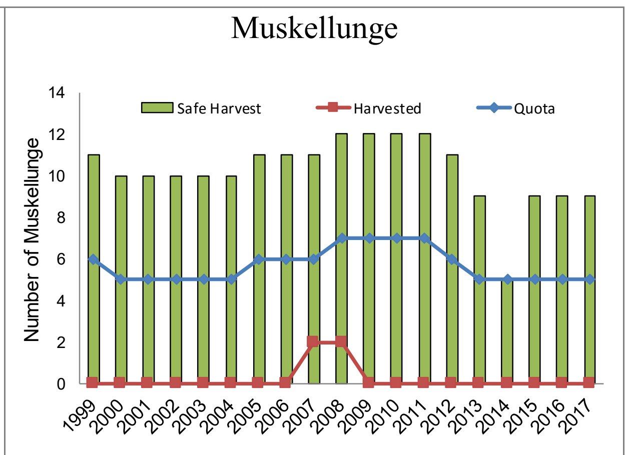


Figure 3.6-7. Archibald Lake muskellunge spear harvest data. (GLIFWC 1998-2017).

Archibald 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, and contain few aquatic plant species or coarse woody habitat.

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

According to the point-intercept survey conducted by Onterra in 2016, 87% of the substrate sampled in the littoral zone of Archibald Lake was soft sediments, 9% was sand with the remaining 4% composed of rock substrate.

Coarse Woody Habitat and Fish Sticks Program

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).

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 (WDNR 2014). Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or

Photograph 3.6-3. Fish Stick Example (Photo courtesy of WDNR 2013)

partner contributions. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. During Onterra's 2016 coarse woody habitat survey, Archibald Lake had 20 coarse woody pieces/mile of shoreline. Archibald Lake is an excellent candidate to install coarse woody habitat and tree drops have previously taken place on Archibald Lake. During 2009, 100 trees were placed at 46 locations for a fish sticks project (Long 2011).

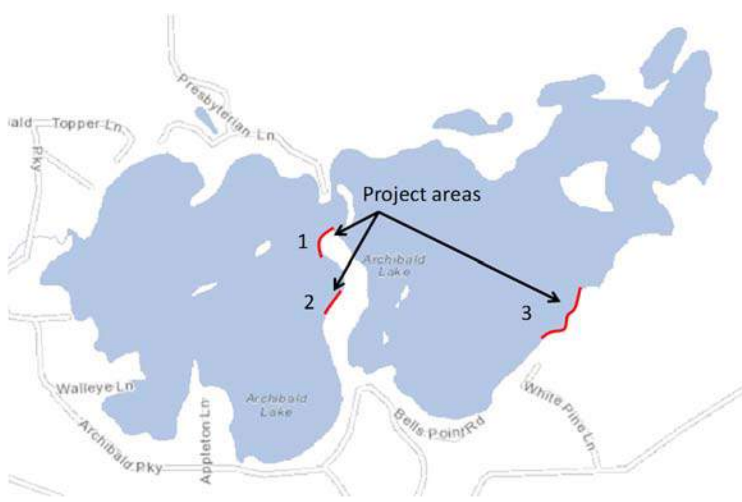


Figure 3.6-8. Map of Archibald Lake and rock reef project areas (Chip Long 2016)

Additional fish habitat built for Archibald Lake includes a rock bed constructed in 2009 to increase spawning habitat for walleye. This reef proved to be beneficial in the 2011 WDNR fisheries survey when 17 YOY walleye were captured indicating natural reproduction was occurring. While this is an improvement, this is not a sustainable number to support a desirable walleye fishery. Hence the Archibald Lake Ecology Improvement Effort, a five-year project led by the Archibald Lake Ecology Improvement Committee, was presented and approved in 2015 which would provide a plan to build additional segments of rock reefs in Archibald Lake (Figure 3.6-8). The segments included one - 600' stretch on the south shore of the East lobe (Project area 3) and two - 300' segments on the west shore of the main peninsula in the West lobe (Project area 1 and 2). In February of 2017 sufficient ice depth allowed for project area 3 to be completed. Construction of project areas 1 and 2 are expected to take place during the winter of 2018.

Regulations and Management

Archibald Lake has a boating regulation of slow no wake from 5:00PM to 10:00PM and within 100' of shore. Additionally, special fisheries regulations occur, specifically in terms of muskellunge and walleye. A 50-inch minimum size limit for muskellunge was proposed and approved during the 2011 Annual Spring Fish and Wildlife Rule Hearings (Long 2011). The purpose of this regulation is to ensure the WDNR has adequate opportunities to harvest eggs from the great lakes spotted muskellunge population. Also following the 2011 WDNR comprehensive fisheries survey, the walleye length limit was changed from 15" to 18". The regulation change will likely improve adult walleye population density and also natural reproduction over time (Long 2018). The next comprehensive fisheries survey by the WDNR is scheduled for 2019.

Table 3.6-3 displays the 2017-2018 regulations for Archibald Lake gamefish species. For specific fishing regulations, 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 3.6-3. WDNR fishing regulations for Archibald Lake (2017-2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	June 17, 2017 to March 4, 2018
Smallmouth bass	Catch and release only	None	May 6, 2017 to June 16, 2017
Largemouth bass	5	14"	May 6, 2017 to June 16, 2017
Muskellunge and hybrids	1	50"	May 27, 2017 to November 30, 2017
Northern pike	5	None	May 6, 2017 to March 4, 2018
Walleye, sauger, and hybrids	3	18"	May 6, 2017 to March 4, 2018

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 3.6-9. 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 3.6-9. Wisconsin statewide safe fish consumption guidelines. 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 main objectives:

1) Collect detailed information on Archibald Lake's water quality, watershed, shoreland habitat, and aquatic plant community.
2) Collect sociological information from Archibald Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.
3) Using the ecological and sociological data, work with the ALA to develop an updated management plan to protect and enhance Archibald Lake into the future.

These three objectives were fulfilled during this project and have led to an updated and detailed picture of the Archibald Lake ecosystem, the people who care for it, and the management actions that need to be taken to continue to protect and enhance the Archibald Lake ecosystem. The studies completed on Archibald Lake indicate that the lake is overall very healthy. All of the water quality parameters that were assessed fell within the excellent category for deep seepage lakes in Wisconsin, and the lake harbors a native aquatic plant community which is of higher quality than the majority of the lakes within the region.

The favorable water quality conditions observed in Archibald Lake is a result of the overall watershed and the condition of near-shore properties. Over 93% of the Archibald Lake watershed contains land cover types that contribute the least amount of phosphorus to the lake (i.e. forest, wetlands, and lake surface). Approximately 67% of Archibald Lake's shoreland is in a *natural/undeveloped*, or *developed-natural* condition. These are the shoreland types that provide the largest nutrient buffering capabilities, as well as providing the greatest habitat for aquatic and terrestrial wildlife. The system's shoreline is approximately 26% composed of *urbanized* and *developed-natura*l conditions, the shoreland types that have the least habitat value and nutrient buffering capacity.

While Archibald Lake likely contains less coarse woody habitat than pre-European settlement, they contained approximately 20 coarse woody habitat pieces per shoreland mile. Based on other surveys Onterra has conducted, these values fall slightly below the average. This may in part be due to the large water level fluctuations that have occurred on Archibald Lake. As water levels fall and dead wood becomes exposed, it dries out and decays. When water levels go back up, these pieces of wood either float against shore and/or decay further. Increasing coarse-woody habitat above current levels would have great habitat value to Archibald Lake, and continues to be a priority of the ALA and local fisheries managers.

The aquatic plant community within the lake and along the shorelines of Archibald Lake was found to be of good quality. Archibald Lake contains a high number of native plant species, although 56% of Archibald Lake's aquatic plant community was comprised of just three species in 2016: muskgrasses, slender naiad, and wild celery. As discussed previously, naturally hardwater lakes rich in calcium like Archibald Lake are often dominated by muskgrasses. This dense carpet of muskgrasses makes it difficult for some aquatic plant species to become established, including Eurasian watermilfoil. Eurasian watermilfoil populations are present, but currently extremely low in Archibald Lake. Continued monitoring and potential small-scale management will be a priority of the ALA.

5.0. IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the ALA Planning Committee and ecologist/planners from Onterra. It represents the path the ALA 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 Archibald 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.

The ALA will be responsible for deciding whether the formation of sub-committees and or directors is needed to achieve the various management goals.

Management Goal 1: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Archibald Lake

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at public access location
Timeframe:	Continuation of current effort
Facilitator:	Clean Boats Clean Waters Committee, Volunteer Coordinator
Description:	Currently the ALA monitors the Town-owned public boat landing using training provided by the Clean Boats Clean Waters program. Archibald Lake is a popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasive species that originated in Archibald Lake. The goal is to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. The ALA has set a goal of 200 hours of annual volunteer-based watercraft inspections with focus on high-use periods such as weekends and holidays. In 2016, the ALA conducted 517 hours of volunteer hours at the landing, inspecting over 600 boats. With permission, the ALA volunteers place CBCW stickers on the boat trailers of frequently inspected lake users to streamline their efforts during busy periods. The watercraft inspectors also convey areas of Archibald Lake known to contain AIS to transient boaters, of which maps are displayed at the ALA-maintained kiosk. The ALA continues to brainstorm ways to keep the program fresh and volunteerism from falling.

Action Steps:	
	See description above as this is an established program.

Management Action:	Coordinate volunteer monitoring of AIS
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee or Lake Management Committee, Adopt-a-Shoreline Coordinator, Volunteer Coordinator
Description:	ALA members have received past training on AIS identification from WDNR and UW-Extension staff. The ALA also has a dedicated GPS to transfer information to and from professional surveyors. These surveys would be conducted to augment professional surveys, not replace them. Volunteers would look for known AIS that exist in Archibald (EWM, phragmites, flowering rush) as well as those species that are currently found in the lake. The Adopt-a-Shoreline Coordinator would coordinate the volunteers at the beginning of the growing season to ensure complete coverage of the Archibald Lake littoral zone. The Coordinator would also be responsible for collecting all reporting forms (available on the ALA website) and compiling the information into a useable format. Although most shorelines have been patrolled on an annual basis over the last several years, more volunteers are needed to assure future coverage.
Action Steps:	
1.	Volunteers from ALA update their skills by attending a training session conducted by WDNR/UW-Extension (Paul Skawinski – 715.346.4853).
2.	Trained volunteers recruit and train additional association members.
3.	Complete lake surveys following protocols.
4.	Report results to consultant and ALA, entering hours spent into SWIMS.

Management Action:	Initiate Rapid Response Plan Following Detection of New AIS
Timeframe:	If/When Necessary
Facilitator:	AIS Committee or Lake Management Committee
Description:	If volunteer or professional surveys locate a suspected new AIS within Archibald Lake, the location would be marked (e.g. GPS, maker buoy) and a specimen would be taken to the WDNR Lake Coordinator (Brenda Nordin) for verification. If the suspected specimen is indeed a non-native species, the WDNR will fill out an incident form and develop a strategy to understand the population level within the lake. The lake would be professionally surveyed, either by agency personnel or a private consulting firm during that plant species' peak growth phase.

	If the AIS is a NR40 prohibited species (i.e. red swamp crayfish, starry stonewort, hydrilla, etc.), the WDNR may take an active role in the response. If the AIS is a NR40 restricted species (i.e. purple loosestrife, curly-leaf pondweed, etc.), the ALA would need to reach out to a consultant to develop a formal monitoring and/or control strategy. The WDNR would be able to help financially through the AIS Grant Program's Early Detection and Response program. This grant program is non-competitive and doesn't have a specific application deadline, but is offered on a first-come basis to the sponsor of project waters that contain new infestations (found within less than 5% of the lake and officially documented less than 5 years from grant application date). Currently this program will fund up to 75% percent of monitoring and control costs, up to $20,000.
Action Steps:	
	See description above

<u>Management Action:</u>	Coordinate annual professional monitoring of EWM monitoring
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee or Lake Management Committee, Adopt-a-Shoreline Coordinator
Description:	An Early Season AIS (ESAIS) Survey would be conducted annually during June to setup that years' program. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using GPS technology. This survey would serve three main roles: 1) document the EWM population at the beginning of each growing season, 2) be used to propose hand-harvesting management for that summer, and 3) serve as a comparable dataset to compare to future surveys to understand EWM population changes over time. If the management strategy for a given year contains a professional hand-harvesting component and is paid for with WDNR grant funds, a late-season EWM mapping survey would be conducted to access the control strategy that took place.
Action Steps:	
	See description above as.

<u>Management Action:</u>	Conduct EWM Population Control Using Hand-Harvesting and/or Herbicide Spot Treatments
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee or Lake Management Committee

Description:	The proactive EWM management strategy that has occurred in Archibald Lake since its detection has kept the EWM population at low levels. At these low levels, the EWM population is not likely causing measurable negative ecological impacts to the system nor diminishing the navigability, recreation, or aesthetics of the lake. The ALA would like to continue on a proactive management approach to EWM to keep the population low within the lake, preferably with non-herbicide control options. _Hand-Harvesting_ If the ESAIS Survey reveal areas of EWM that are comprised of *single plants* or *clumps of plants* and are not 'colonized', the ALA will organize efforts to hand-remove the plants. Depending on the level of volunteerism and size of the EWM occurrences, the ALA will determine if volunteer- or professional-based methods would be solicited. As discussed above, the hand-harvesting would occur following the June ESAIS Survey in roughly mid-June to mid-September. Conducting hand-harvesting earlier or later in the year can reduce the effectiveness of the strategy, as plants are more brittle and extraction of the roots more difficult. If a professional-based hand-harvesting method is chosen and WDNR funds are being used to offset the costs, a Late-Summer EWM Peak-Biomass Mapping Survey would take place following the hand-harvesting. The Late-Summer Survey may be limited to just the areas where hand-harvesting occurs for assessment purposes. If a Diver Assisted Suction Harvest (DASH) component is utilized, the ALA and contracted firm would be responsible for the WDNR permit procedures. The contracted firm would be guided with GPS data from the consultant following the ESAIS Survey and would track their efforts (when, where, time spent, quantity removed) for post assessments. _Herbicide Spot Treatment_ If the following trigger is met, the ALA would consider conducting herbicide spot treatments: "colonized (polygons) areas where a sufficiently large treatment area can be constructed to hold concentration and exposure times." It is believed that these areas are too large to be controlled using hand-harvesting techniques. It is likely that these areas may be small (3-5 acres) and would need to be conducted with herbicides that require short exposure times, such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.). If large areas (>5 acres) or sites in protected parts of the lake are to be targeted with an herbicide spot treatment, more traditional systemic herbicides like 2,4-D may be appropriate. In late-winter, an herbicide applicator firm would be selected and a conditional permit application would be applied to the WDNR. The

	herbicide treatment would occur when surface water temperatures are roughly below 60°F and active growth tissue is confirmed on the target plants. A pretreatment survey a week or so prior to treatment would be used to finalize the permit, potentially with adjustments, and dictate approximate ideal treatment timing. If individual treatment sizes exceed 10 acres, a quantitative (sub-sample point-intercept) monitoring component may be required by the WDNR. Overall, the ALA will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen.
Action Steps:	
	See description above

<u>Management Action:</u>	Control Flowering Rush Populations
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee or Lake Management Committee
Description:	Flowering rush has likely existed in Archibald Lake since the early 1980s. The ALA investigated a number of non-herbicide control options such as hand-digging, repeated cutting, and cutting flowerheads before they go to seed. These efforts had little to no success. In 2011, the ALA received a WDNR Research and Control Grant to test a few herbicide control options for their applicability in Archibald Lake. The results indicate that diquat had the best control for both emergent and submergent growth forms of flowering rush. When an active management strategy is enacted, a series of two herbicide treatments would occur at maximum label rates (2 gallons per surface acre) in June and roughly 2 months later in August. Due to the hardiness of this species, the first treatment may result in incomplete control and exposing the plant to an additional dose of herbicide during its recovery period can results in more complete control. The 2016 survey of Archibald Lake revealed only minimal flowering rush, all in the emergent form (Maps 7-8), likely as a result of favorable management in the past and the increasing water levels of the system. A submergent colony of flowering rush was noted by the ALA in the far eastern part of the lake that went undetected during the 2016 community mapping surveys. The ALA supports action by individual riparians to control flowering rush on their property. The WDNR is moving away from allowing individual riparians from getting separate permits to conduct control options, preferring that the local unit of government (i.e. the lake association) procure the permit. Riparians interested in conducting

	flowering rush treatments should contact the ALA in early spring of each year. The ALA would cover the costs of the permit fees and conduct the applicator selection, but would defer the costs of conducting the treatment to the benefitting riparians. Combining treatments of this nature together will save costs through economies of scale, ensure proper best management practices are being completed, and allow an easier mechanism for tracking the herbicide use history in and around Archibald Lake.
Action Steps:	
	See description above

Management Action:	Control Phragmites Population Control
Timeframe:	Continuation of current effort
Facilitator:	AIS Committee or Lake Management Committee
Description:	During the July 2014 ESAIS Survey, Onterra ecologists documented the presence of giant reed (aka *Phragmites*). Suspected to be the non-native strain, Onterra sent voucher specimens of the plant to the UWSP herbarium where it was later confirmed to be of the non-native variety. The ALA partnered with the WDNR through a program conducted under a Great Lake Research Initiative (GLRI) grant to help control common reed populations along the Lake Michigan shoreline, which includes Oconto County. Following the appropriate notifications and obtaining landowner permissions, common reed control actions, coordinated by the WDNR (Jason Granberg), were implemented at the three sites on Archibald Lake in 2015. A licensed herbicide applicator (Nature Care Ecological Consulting and Services) treated approximately 145 square feet of common reed populations on September 3, 2015. The 2016 survey of Archibald Lake revealed that these populations were successfully controlled, but additional phragmites occurrences were noted around the lake, particularly in the eastern lobe (Maps 7-8). Phragmites populations continue to spread across the state from east to west, with many occurrences in the vicinity of Archibald Lake. The ALA will continue to informally monitor the invasive phragmites populations on the lake's shorelands. Similar to the strategy for flowering rush, the ALA would support landowner efforts to control populations on their shorelines. The ALA would also consider initiating management on sensitive public lands if phragmites populations appear to be forming large dense monocultures that threaten the integrity of these valuable ecosystems.
Action Steps:	
	See description above

Management Action:	Investigate and Study Alternative Management Methodologies
Timeframe:	As appropriate
Facilitator:	AIS Committee or Lake Management Committee with assistance from Consultant
Description:	The ALA understands that management of EWM will be a long-term part of the management of Archibald Lake. The ALA would like to be on the front edge of Best Management Practices for controlling EWM. What constitutes a Best Management Practice (BMP) changes in time as science and adaptive management progresses through science. For instance, small spot-treatments using 2,4-D was once the BMP for controlling EWM in Wisconsin waters. Science and monitoring has determined that these treatments rarely meet their target concentrations and are unpredictable on their effectiveness. National and regional aquatic plant management industries and trade associations have partnered with scientists (academia and government) to better understand control actions, their benefits and risks, and applicability. The ALA would continue to be updated on the management efforts being conducted in surrounding states as well as the nation when it pertains to AIS management (EWM, flowering rush, phragmites). This would include, but not be limited to new herbicide use-patterns and their potential environmental and human toxicological profile. Other emerging technologies may include non-herbicide options.
Action Steps:	
	See description above

Management Action:	Coordinate Periodic Quantitative Vegetation Monitoring
Timeframe:	Point-Intercept Survey every 3-4 years, Community Mapping every 7-8 years
Facilitator:	Lake Management Committee
Description:	Lake-wide point-intercept surveys should be conducted at a minimum once every 5 years. This will allow an understanding of the submergent aquatic plant community dynamics within Archibald Lake. Point-intercept surveys have been conducted on Archibald Lake in 2010, 2013, and 2016. Building this dataset over time will assist in understanding natural and unnatural population dynamics. In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Archibald Lake, a community mapping survey would be conducted every 7-8 years. The community mapping survey has been conducted on Archibald Lake in 2016 and will serve as a comparative for future replicated surveys. This effort is typically

	conducted as part of each future lake management planning project update.
Action Steps:	
	See description above as.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Lake Management Committee
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 Archibald 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 ALA currently monitors two sites within the lake (one in each lobe) under the advanced CLMN program. This includes collecting Secchi disk transparency and dissolved oxygen readings, as well as sending in water chemistry samples (chlorophyll-*a*, and total phosphorus) to the Wisconsin State Laboratory of Hygiene for analysis. The samples are collected three times during the summer and once during the spring. It is important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS). 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 within each basin during each year.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
2.	CLMN volunteer and/or ALA Board of Directors would facilitate new volunteer(s) as needed
3.	Coordinator contacts Sandra Wickman (715.365.8951) to acquire necessary materials and training for new volunteer (s)

Management Goal 3: Increase ALA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Use education to promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	Education Committee
Description:	Education represents an effective tool to address many lake issues. The ALA regularly distributes newsletters (The Archi Times spring and fall editions) and maintains a website (http://www.archibaldlake.com/). These mediums allow for exceptional communication with association members. This level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings. The ALA will continue to make the education of lake-related issues a priority. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. The ALA will work with UW-Extension Lakes staff (Patrick Goggin: Patrick.Goggin@wisconsin.gov) to use stock articles as appropriate to lessen the workload and ensure the messaging is accurate. UW-Extension Lake staff is also a great resource for providing examples of education and outreach strategies that may be adopted by the ALA *www.uwsp.edu/cnr-ap/UWEXLakes* *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology • Impacts of drought and low water levels • Sedimentation • Boating safety (promote existing guidelines, Lake Use Information handout) • Swimmers itch • Shoreline habitat restoration and protection • Fireworks use and impacts to the lake • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Recreational use of the lakes
Action Steps:	

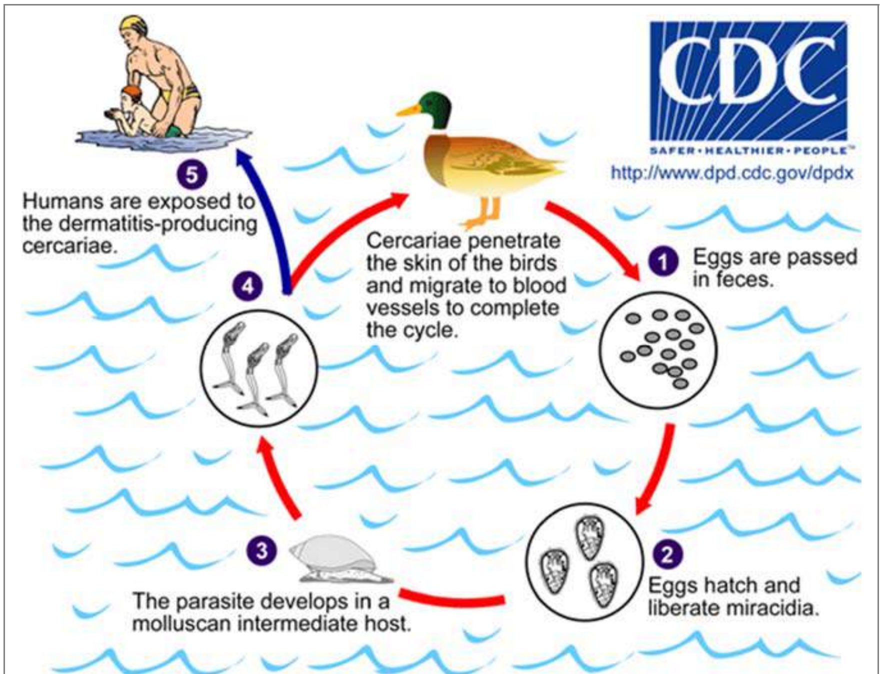
	See description above as this is an established program.

Management Action:	Continue ALA's involvement with other entities that have responsibilities in managing (management units) Archibald Lake
Timeframe:	Continuation of current efforts
Facilitator:	Education Committee
Description:	As outlined within the ALA's Constitution: "The purpose of the Archibald Lake Association is to preserve and protect Archibald Lake and its surrounding area and to enhance the aquatic quality, recreational use and aesthetic values of Archibald Lake as a public recreational facility for today and for future generations." The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the ALA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page:
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Townsend	Chairperson (Carla Van Camp – 715.276.7480)	Archibald Lake falls within this township.	Once a year, or more as needed. May check website (http://townoftownsend.com) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Oconto County Lakes & Waterways Association	President (Mike Winius– 920.740.2110)	Protects Oconto Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.oclawa.org) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oconto Co. waterways.
Oconto County Land Conservation Department.	County Conservationist (Ken Dolta – 920.834.7152)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	May have County-level funding opportunities available. Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Christopher [Chip] Long– 715-582-5017)	Manages the fishery of Archibald Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery and fish structure
	Lakes Coordinator (Brenda Nordin – 920.360.3167)	Oversees management plans, grants, all lake activities.	Once a year, or more as issues arise	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues including AIS management.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	ALA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years
Facilitator:	Education Committee
Description:	Approximately once every 5-6 years, an updated stakeholder survey would be distributed to the Archibald Lake riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2016, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

Management Action:	Educate Stakeholders on Boating Regulation and Boating Safety
Timeframe:	Continuation of current efforts
Facilitator:	Education Committee
Description:	Archibald Lake is a popular destination by multiple types of users including recreationists and anglers. In an effort to promote boating safety and minimize the negative impacts watercraft can have on a lake, the ALA uses education its primary tool. Archibald Lake has a slow-no-wake curfew between 5:00 pm and 10:00 am, per a Town of Townsend Ordinance. There are also slow-no-wake buoys that need to be abided by within the channel between the two islands. The State of Wisconsin laws demand that boats observe slow-no-wake rules within 100 feet of the shore and all lake users and objects. This law is more restrict for personal watercrafts, as they need to operate at slow-no-wake speeds within 200 feet of the shore (Map 10). The ALA also requests that recreational watercraft use, such as waterskiing, occur in a counter-clockwise direction.
Action Steps:	
	See description above as this is an established program.

Management Action:	Educate Stakeholders on Swimmers Itch
Timeframe:	Ongoing
Facilitator:	Ecology Improvement Committee or Education Committee
Description:	Cercarial dermatitis or swimmer's itch is a type of skin reaction that is caused when the larval stage of a schistosome flatworm accidentally burrows into a human's skin when that person is spending time in the water (Figure 5.0-1). The skin reaction varies from one individual to another, but is usually accompanied by intense itching and a rash of small red bumps that look similar to insect bites. Each of the red bumps is caused by localized, inflammatory immune response to an individual parasite which will die within hours of entering into the skin. While perfectly harmless, it can greatly compromise the recreational value for those who enjoy spending time in the water. Young children seem to be more affected by this condition; as they typically spend more time in the water, have more sensitive skin, and have a tendency to spend more time in near-shore areas of the lake where the flatworms may be more concentrated.  **Figure 5.0-1. Swimmer's itch life cycle.** Obtained directly from the Centers for Disease Control & Prevention website (CDC 2012). The larval stage (cercariae) of this group of flatworms needs to burrow into the skin of certain bird species to complete its lifecycle ❹. While the primary hosts are ducks, gulls, geese, swans, and red-winged blackbirds, other non-bird species (e.g. muskrats, mice) have also been shown to complete this parasite's life cycle. Mergansers have been known to have some of the highest infection rates of this group of parasites. After the flatworm matures in the bird host, it

produces eggs that are released into the water through the bird's feces ❶. The eggs hatch ❷ and the immature life stage (miracidia) of the parasite seeks out a snail host to continue maturation ❸. While not all snail species will suffice as intermediate hosts for the flatworms, nine or more species have been known to host flatworm species associated with swimmer's itch. Once the flatworm matures the larval cercaria emerges and seeks out a definitive host to complete the lifecycle. However, sometimes the cercariae accidently encounter a human and attempt to burrow into the skin ❺, causing the skin reaction discussed above.

Historically, molluscicides have been used to combat swimmer's itch by targeting the intermediate host, snails. The pesticides are non-selective towards snails, mussels, and other mollusks that play an integral part of the aquatic ecosystem. For that reason, along with the high expense and uncertain long-term consequences of applying these metal-based pesticides, this management technique has gone out of favor and typically is not permitted in Wisconsin.

The ALA would like to use education to help riparian understand the steps that can be taken to prevent or reduce the discomfort caused by swimmer's itch. The following summary list is based off information available on the WDNR's website:

- Avoid spending time in shallow water, especially if swimmer's itch has been known to be a problem in the area.
- Avoid spending time in the water between noon and 2 p.m., during which cercariae are most prevalent.
- Towel off immediately after getting out of the water. Cercariae will not penetrate the skin until after the person leaves the water. There may be an opportunity to remove the parasite before this occurs.
- Discourage ducks and other waterfowl from congregating in or near swimming areas by keeping near-shore areas vegetated, and by avoiding feeding the birds.
- Avoid using riprap or seawalls along the shoreline, as this provides an excellent substrate for many snail species. Host snails are known to live on all types of substrate (sand, rock, mulch, vegetation) with an increased preference for sandy beaches.

Action Steps:

See description above

Management Goal 4: Improve Lake and Fishery Resource of Archibald Lake

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Initiate 2018
Facilitator:	Ecology Improvement Committee
Description:	As discussed in the Shoreland Condition Section (3.3), the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. Approximately 26% of Archibald Lake's shoreline is either urbanized or developed-unnatural and could be the focus of early restoration efforts. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, the ALA has decided to take the following steps to increase shoreland restoration on Archibald Lake: 1. Educate riparians about the importance of healthy and natural shorelands. 2. Solicit 1-3 riparians to allow shoreland restoration and storm water runoff designs for their property. 3. The ALA work with Oconto County (Ken Dolta) or private entity to create design work. Small-scale WDNR grants may be sought to offset design costs. 4. Designs can be shared with ALA members to provide further education of shoreland restoration projects. 5. Move forward with implementing shoreland restoration per the designs that were developed for those riparians that wish to. Project funding would be available through the WDNR's Healthy Lakes Implementation Plan (see below). 6. The ALA's goal would be to have at least 2 shoreland restoration sites to serve as demonstrations sites to encourage other riparians to follow same path of shoreland restoration. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through Oconto County. Oconto County

	has been a proponent of shoreland restoration activities and has been seeking participation from landowners and lake groups. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap) • Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances • Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available
Action Steps:	
1.	Recruit facilitator from Planning Committee
2.	Facilitator contacts the Oconto County Land Conservation department to gather information on initiating and conducting shoreland restoration projects. If able, the County Conservationist would be asked to speak to ALA members about shoreland restoration at their annual meeting.
3.	The ALA would encourage property owners that have restored their shorelines to serve as demonstration sites.

<u>Management Action:</u>	Protect natural shoreland zones around Archibald Lake
Timeframe:	Initiate 2018
Facilitator:	Ecology Improvement Committee
Description:	Approximately 5.7 miles (67%) of the Archibald Lake's shoreline was found to be in either a *natural* or *developed-natural* state. The Chequamegon-Nicolet National Forest (CNNF) borders much of the lake's east basin, in the form of the Cathedral Pines State Natural Area, which makes up a large percentage of the natural shorelines. However, large stretches of privately owned lands also contain shorelines of these designations. It is therefore very important that owners of these properties become educated on the benefits their shoreland is providing to the Archibald, and that these shorelands remain in a natural state. Map 3 indicates the locations of *natural* and *developed-natural shorelands* on Archibald Lake. Private shorelands that are in either a *natural* or *developed-natural state* should be prioritized for education initiatives and physical preservation. The Holt Family currently has over 900 acres around the northeastern part of the lake

	in a 90-year trust to ensure no building occurs in that portion of the lake. A Planning Committee appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the ALA in preserving Archibald Lake shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Oconto County Land Conservation Department. Several websites of interest include: • Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands) • Conservation easements or land trusts: (http://www.northwoodslandtrusts.org/) • UW-Extension Shoreland Restoration: (www.uwex.edu/ces/shoreland/Why1/whyres.htm) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)
Action Steps:	
1.	Recruit facilitator (potentially same facilitator as previous management action).
2.	Facilitator gathers appropriate information from sources described above.

<u>Management Action:</u>	Coordinate with WDNR and private landowners to expand coarse woody habitat in Archibald Lake
Timeframe:	Initiate 2018
Facilitator:	Ecology Improvement Committee
Description:	ALA stakeholders must realize the complexities and capabilities of Archibald Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.5) discuss the benefits of coarse woody habitat in detail.

	The ALA has been active in installing woody structures in the past. Fish shelters (1950) and fish cribs (1990s) were added with the intention to create more fish habitat. In the past decades, the addition of fish cribs has gone out of favor with fisheries managers, now emphasizing the need for near-shore woody material. The ALA will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with WDNR fisheries biologist.
	
	The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
	    o The landowner would need to commit to leaving the area un-mowed
	    o The landowner would need to implement a native planting (also cost share thought this grant program available)
	• Coarse woody habitat improvement projects require a general permit from the WDNR
	• Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:	
1.	Recruit facilitator from Planning Committee (potentially same facilitator as previous management actions).
2.	Facilitator contacts Brenda Nordin (WDNR Lakes Coordinator) and Chip Long (WDNR Fisheries Biologist) to gather information on initiating and conducting coarse woody habitat projects.
3.	The ALA would encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

Management Action:	Coordinate with WDNR to Increase Walleye Population
Timeframe:	Initiate 2018
Facilitator:	Ecology Improvement Committee
Description:	Ongoing
Action Steps:	Natural reproduction of walleye in Archibald Lake is occurring however, it is insufficient to support a fishable population. Improving walleye spawning habitat is thought to provide the necessary substrate to promote additional natural reproduction. A series of rock reefs have been strategically added to Archibald Lake to increase natural reproduction of walleye. The ALA continues to support the WDNR in this endeavor and may give consideration to future fisheries habitat improvements in the future if the efforts prove successful. Fingerling walleyes have been stocked into Archibald Lake by the WDNR since 1994, with an every-other year rotation occurring in recent years. The ALA supports the stocking activities.
	See description above

Management Action:	Continue the Loon Watch Program
Timeframe:	Ongoing
Facilitator:	Loon Watch Committee
Description:	The ALA has formed a Loon Watch Committee to monitor Archibald Lake for loon activity. The Loon Watch Program is operated through the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide a picture of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. The ALA will continue this program, providing information and education to its membership at the association's annual meetings.
Action Steps:	
	See description above

6.0 METHODS

Lake Water Quality

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

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

	Spring		June	July	August	Fall		Winter	
Parameter	**S**	**B**	**S**	**S**	**S**	**S**	**B**	**S**	**B**
Total Phosphorus	■♦	■	♦	♦	♦	■	■	■	■
Dissolved Phosphorus	■	■						■	■
Chlorophyll-*a*	■		♦	♦	♦	■			
Total Kjeldahl Nitrogen	■	■	●	●	●	■		■	■
Nitrate-Nitrite Nitrogen	■	■	●	●	●	■		■	■
Ammonia Nitrogen	■	■	●	●	●	■		■	■
Laboratory Conductivity	■	■							
Laboratory pH	■	■							
Total Alkalinity	■	■							
Total Suspended Solids	■	■				■	■	■	■
Calcium	■								

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Archibald 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 Archibald Lake during a June 9, 2016 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 Archibald 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 August 3-4, 2016 and August 10, 2016. A point spacing of 43 meters was used resulting in approximately 858 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Archibald Lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT 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 by the University of Wisconsin – Steven's Point Herbarium.

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