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Big Arbor Vitae Lake

Vilas County, Wisconsin

Comprehensive Management Plan

February 2013

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Acknowledgements

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

Big Arbor Vitae Lake Planning Committee

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1.0 INTRODUCTION

Big Arbor Vitae Lake, Vilas County, is a 1,090-acre drainage lake with a maximum depth of 41 feet and a mean depth of 18 feet (Map 1). This eutrophic lake has a relatively small to moderately sized watershed when compared to the size of the lake. Big Arbor Vitae Lake contains 31 native plant species, of which coontail is the most common plant.

Field Survey Notes

Aquatic plant density noticeably different between field visits in 2011 and 2012. Algae bloom noticed during late summer months. Much of the shoreline is in a natural state – great wildlife habitat.

Photograph 1.0-1 Big Arbor Vitae Lake, Vilas County

Lake at a Glance - Big Arbor Vitae Lake

Morphology	
Acreage	1,090
Maximum Depth (ft)	41
Mean Depth (ft)	18
Shoreline Complexity	3.4
Vegetation	
Curly-leaf Survey Date	June 28, 2011
Comprehensive Survey Date	July 22 and 27, 2011
Number of Native Species	31
Threatened/Special Concern Species	n/a
Exotic Plant Species	Curly-leaf pondweed (*Potamogeton crispus)* and Reed canary grass (*Phalaris arundinacea*)
Simpson's Diversity	0.89
Average Conservatism	6.2
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.5
Sensitivity to Acid Rain	Low
Watershed to Lake Area Ratio	6:1

Big Arbor Vitae Lake is located just northeast of the Town of Woodruff and is within the Wisconsin River drainage basin. Two inlet streams, Bog Creek and an unnamed tributary, feed the lake from the north. An outlet stream, Link Creek, flows from Big Arbor Vitae Lake south and then east into Little Arbor Vitae Lake. Eventually, this water enters the Minocqua Thoroughfare and drains into the Minocqua Chain of Lakes.

There is no shortage of lakes within this region, with the Minocqua Chain of Lakes located to the southwest, the Rainbow Flowage found to the southeast, the Lac Du Flambeau Chain nearby to the west, and the many Town of Boulder Junction and Town of St. Germain Lakes to the north and east, respectively. Recreational activity flourishes in this region, and is a considerable driving force behind the local economy. Big Arbor Vitae Lake itself has three boat landings with a combined total of 65 car-trailer parking spaces, in addition to having several resorts, a campground and picnic area. These access points considered, along with the fact that much of the lake's shoreline is within the Northern Highland State Forest, means that much public access is available for enjoyment of Big Arbor Vitae Lake.

Unfortunately, it is likely through these public access points that several aquatic invasive species have entered the lake. Big Arbor Vitae Lake now holds banded mystery snail, Chinese mystery snail, rusty crayfish as well as curly-leaf pondweed. Faced with issues such as aquatic invasive species and algae blooms, residents around the lake decided in 2009 to form a lake association. The Big Arbor Lake Association (BAVLA), formed in 2009, was "…established by local residents to help, inform, and organize the approximately 120 water front property owners and all lake users on the issues crucial to the continued quality of the shore, land and water quality of our lake, as well as the care and maintenance it requires."

In 2010/2011, the BAVLA became interested in creating a lake management plan to 1) understand the lake ecosystem better, 2) address the curly-leaf pondweed that resides within the lake, and 3) address growing concerns over a native plant population that was perceived to be growing at nuisance levels. The association understood the value in gaining a better understanding of the overall condition of the lake. Additionally, the association knew that the Wisconsin Department of Natural Resources (WDNR) can respond more quickly and accurately to address an invasive species establishment if the lake has management plan in place.

The BAVLA contacted Onterra, LLC during this time to discuss lake management planning options. Financial assistance was obtained through the WDNR's lake management grant program, with two grants obtained in April of 2011 and a third obtained in October 2011. Field studies began in 2011, with the planning process, management goal development, and goal implementation actions following in 2012/2013.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting
On June 4, 2011, a project kick-off meeting was held at the Arbor Vitae Town Hall to introduce the project to the general public. The meeting was announced through a mailing and personal contact by BAVLA board members. The attendees observed a presentation given by Tim Hoyman and Dan Cibulka, aquatic ecologists with Onterra. Their 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 I
On November 1, 2012, Tim Hoyman, Dan Cibulka and Brenton Butterfield met with the Big Arbor Vitae Lake Planning Committee and Vilas County Aquatic Invasive Species Coordinator Ted Ritter for 3.5 hours to discuss the results of the project study. All project components, including water quality studies, watershed analysis, aquatic plant inventories and fisheries data research were discussed at length. Many complicated subjects, such as native aquatic plant control, external and internal nutrient loading, and curly-leaf pondweed management were discussed during a question and answer session.

Planning Committee Meeting II
Later that same month, on November 30, 2012, Tim Hoyman, Dan Cibulka and Brenton Butterfield met with the Big Arbor Vitae Lake Planning Committee once again. WDNR Northern Region Lakes Management Coordinator, Kevin Gauthier, was present as well. Onterra ecologists summarized the discussions from the first planning meeting and then led the Planning Committee through exercises which would shape the management goals and actions found within the Implementation Plan of this report.

Board of Directors Meeting
In February of 2013, Tim Hoyman and Dan Cibulka met with the Big Arbor Vitae Lake Board of Directors to further discuss some of the issues brought up during the planning meetings. Specifics regarding the draft report’s Implementation Plan were discussed, and cost estimates

presented for potential future studies to be conducted on Big Arbor Vitae Lake. The components discussed included curly-leaf pondweed management and nutrient dynamic studies, in addition to other aspects outlined within the Implementation Plan.

Project Wrap-up Meeting
Yet to occur.

Management Plan Review and Adoption Process
Prior to the first planning meeting, the Planning Committee received copies of the Results Section of this report (Section 3.0). Their comments were addressed at this meeting and appropriate changes were incorporated within the management plan. Following creation of the Implementation Plan and the February 2013 Board of Directors meeting, the Big Arbor Vitae Lake Association Board of Directors approved of the draft management plan for Big Arbor Vitae Lake. Later that same month, a draft of the plan was sent to the WDNR for review.

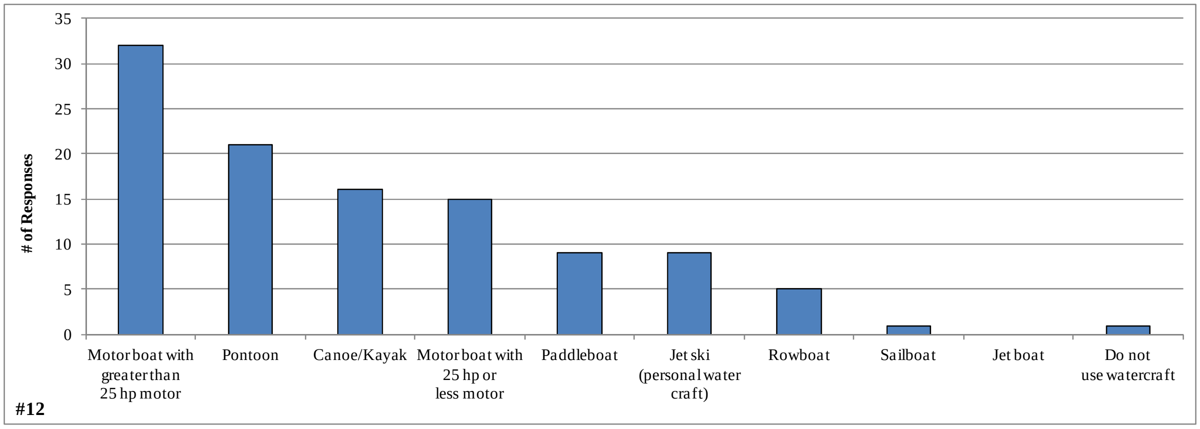
Stakeholder Survey
During June of 2011, members of the BAVLA planning committee and Onterra staff drafted a stakeholder survey that would be sent to BAVLA members and other riparian property owners. This survey was approved by a WDNR sociologist in July of 2011. During September of 2011, the seven-page, 29-question survey was mailed to 110 riparian property owners in the Big Arbor Vitae Lake watershed. 47 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Big Arbor Vitae Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Big Arbor Vitae Lake. The majority of stakeholders visit the lake on weekends throughout the year (35%) while 21% consider themselves seasonal (summer) residents and 18% live on the lake year-round (Question #1). 53% of stakeholders have owned their property for over 15 years, and 26% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use a larger motor boat on the lake, while pontoons, canoe/kayaks and smaller motor boats were popular options as well (Question #12). On a heavily visited lake such as Big Arbor Vitae 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 #13, several of the top recreational activities on the lake involve boat use. Boat traffic was listed relatively low on a list of factors potentially impacting Big Arbor Vitae Lake in a negative manner (Question #19), and was also ranked low by stakeholders on a list of potential concerns regarding the lake (Question #20).

A concern of stakeholders noted throughout the stakeholder survey (see Question #19, Question #20 and survey comments – Appendix B) was water quality degradation, algae blooms and excessive aquatic plant growth. These topics are discussed at length within the Water Quality and Aquatic Plant Sections, as well as within the Summary & Conclusions Section and Implementation Plan.

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



Question #13: Please rank up to three activities that are important reasons for owning your property on or near the lake.

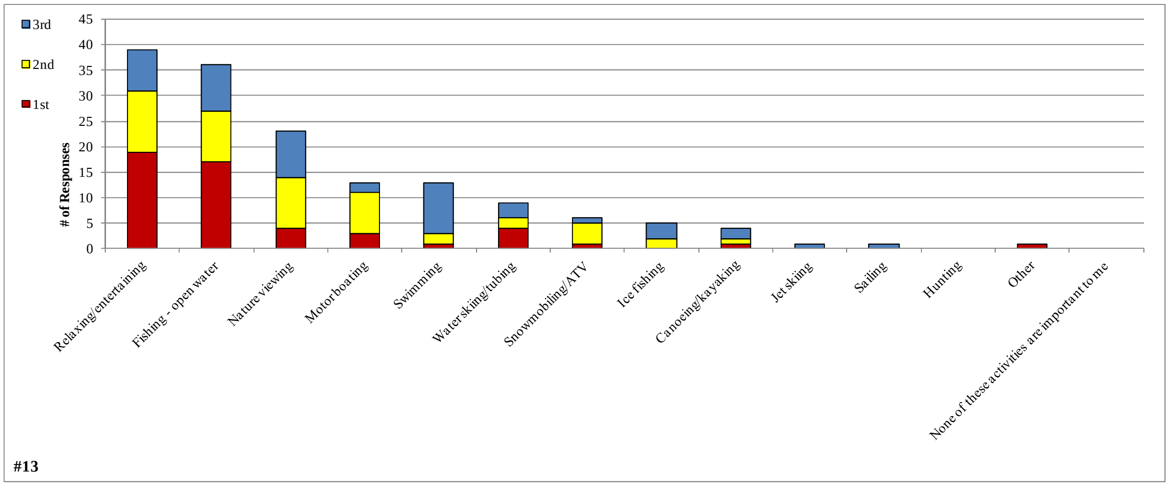
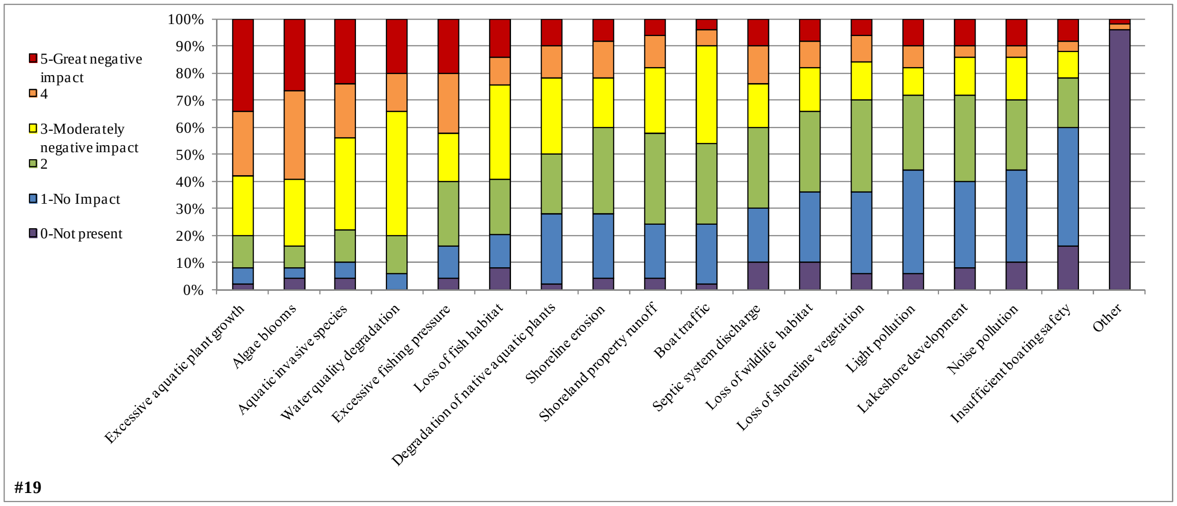


Figure 2.0-1. Select survey responses from the Big Arbor Vitae Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question #19: To what level do you believe these factors may be negatively impacting Big Arbor Vitae Lake?



Question #20: Please rank your top three concerns regarding Big Arbor Vitae Lake.

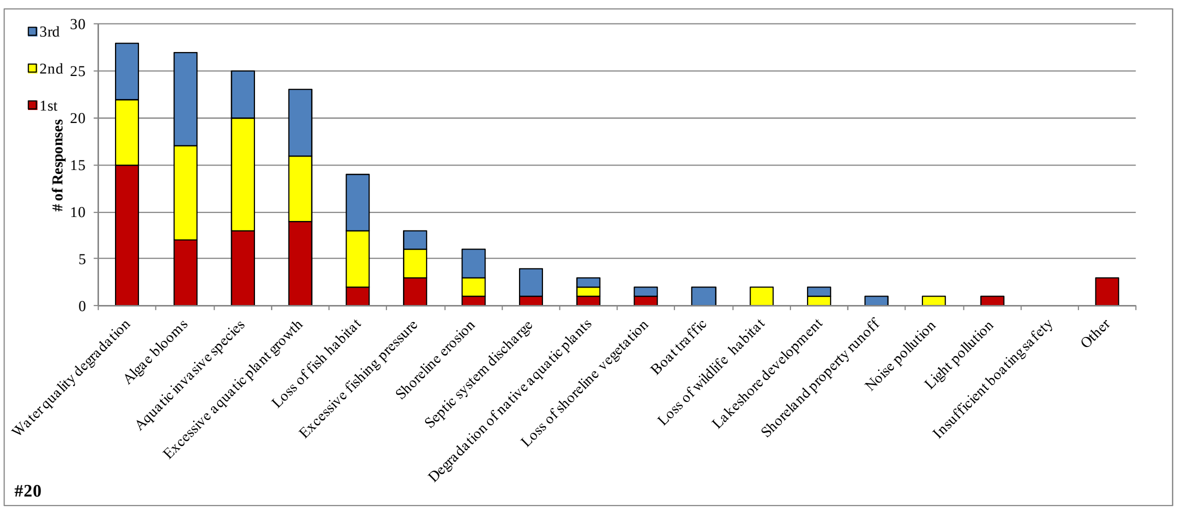


Figure 2.0-2. Select survey responses from the Big Arbor Vitae Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Big Arbor Vitae 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 Big Arbor Vitae 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

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, 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 process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading

In lakes that support strong stratification, 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 the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae 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 screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. months 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 publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) 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 Big Arbor Vitae Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: **shallow (mixed)** or **deep (stratified)**. Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or all of the lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). 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.

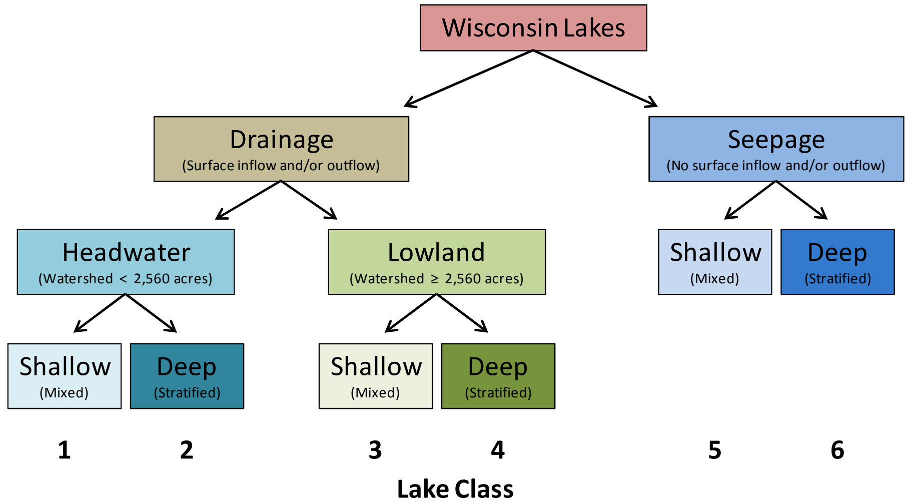


Figure 3.1-1. Wisconsin Lake Classifications. Big Arbor Vitae Lake is classified as a deep (stratified), lowland drainage lake (Class 4). Adapted from WDNR PUB-SS-1044 2008.

Lathrop and Lillie developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six 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. Big Arbor Vitae Lake is within the Northern Lakes and Forests ecoregion.

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM – WDNR 2009), is a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act (WDNR 2009). It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. In the report, they divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor". The categories were based on pre-settlement conditions of the lakes inferred from sediment cores and their experience.

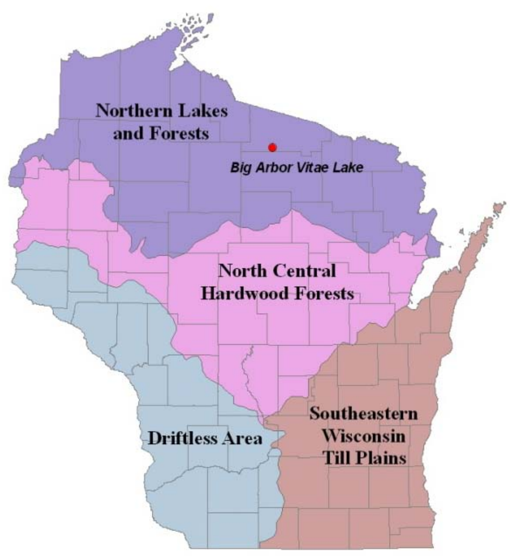


Figure 3.1-2. Location of Big Arbor Vitae Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Big Arbor Vitae Lake is displayed in the figures below. 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.

Big Arbor Vitae Lake Water Quality Analysis

Big Arbor Vitae Lake Long-term Trends

The historic water quality data that exists for Big Arbor Vitae Lake is minimal, so it is impossible to complete a long-term trend analysis. This is unfortunate because having an understanding of how the lake has changed over time is interesting and leads to sounder management decisions. It also provides a scientific basis behind anecdotal claims of a lake "getting worse" or "getting better". As part of this study, stakeholders in the Big Arbor Vitae Lake watershed were asked how they perceived the water quality of the lake. Responses were mixed, with 46% of respondents indicating they believe the water quality is "Poor" or "Fair", 38% responding "Good" or "Excellent", and 16% being "Unsure" (Appendix B, Question #14). About 61% of respondents stated that they believe the water clarity has degraded since they first visited Big Arbor Vitae Lake, while 37% believe the water has remained the same (Question #15).

As described above, three water quality parameters are of most interest in a planning project such as this; total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Total phosphorus data from Big Arbor Vitae Lake are contained in Figure 3.1-3. A weighted average across the three available years of data indicates that summer concentrations are comparable to the median concentrations in similar lakes across the state of Wisconsin and lakes within the Northern Lakes and Forests ecoregion (Figure 3.1-3). Overall, phosphorus levels in Big Arbor Vitae Lake can be described as ranking in the WQI category of 'Good'. It is important to note that a water sample collected on September 13, 1983 was measured to contain 80.0 μg/L of phosphorus. This single 1983 measurement is twice as high as the second highest surface phosphorus measurement, of 39.0 μg/L on September 6, 2011.

Chlorophyll-*a* data has been collected from Big Arbor Vitae Lake in three separate years; 1979, 1993 and 2011. A weighted mean across all years suggests that the concentration of algae in Big Arbor Vitae is slightly higher than the median concentration in similar lakes across the state and also higher than lakes within the Northern Lakes and Forests ecoregion (Figure 3.1-2). As a reminder, the methodology utilized to sample chlorophyll-*a* does not account for all algae in this system. When sampling for this water quality parameter, almost all protocols call for samples to be collected at the location of the deepest point on the lake. This provides a representative sample of the lake's water quality as a whole. Localized algae blooms, which Big Arbor Vitae Lake has experienced in years past and in 2012, may be sporadic and short lived and not captured within this monitoring regime.

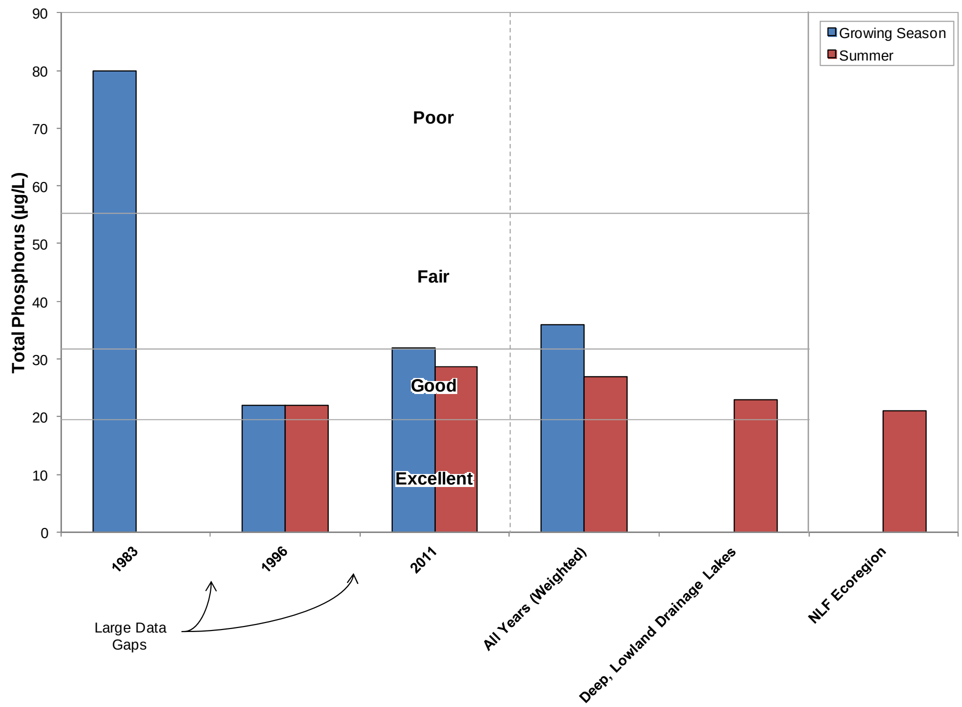


Figure 3.1-3. Big Arbor Vitae Lake, state-wide class 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index median values adapted from WDNR PUB WT-913.

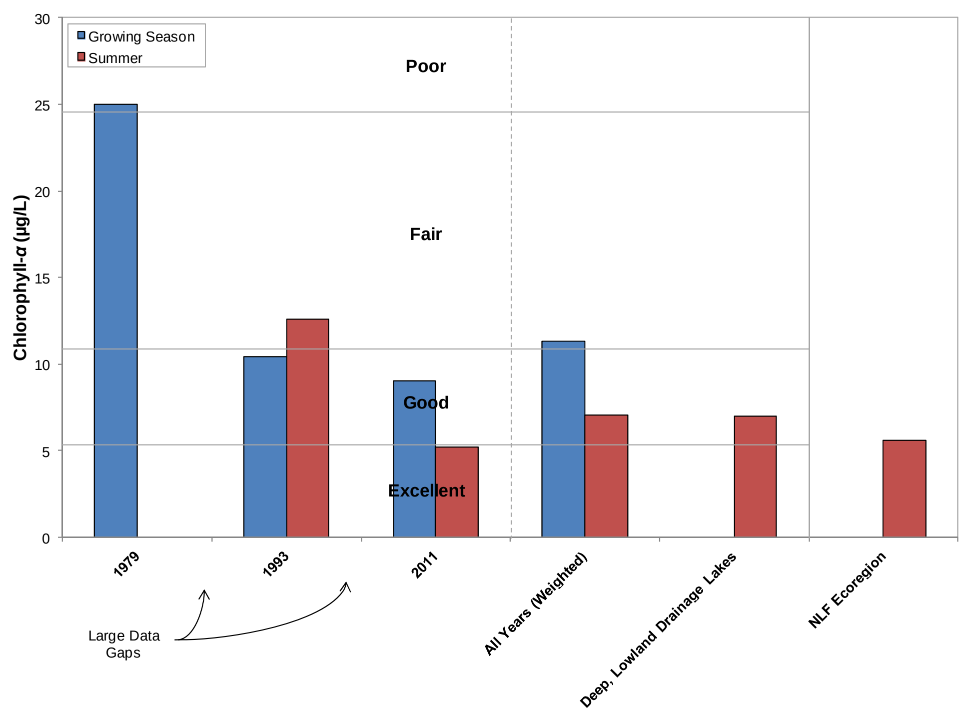


Figure 3.1-4. Big Arbor Vitae Lake, state-wide class 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index median values adapted from WDNR PUB WT-913.

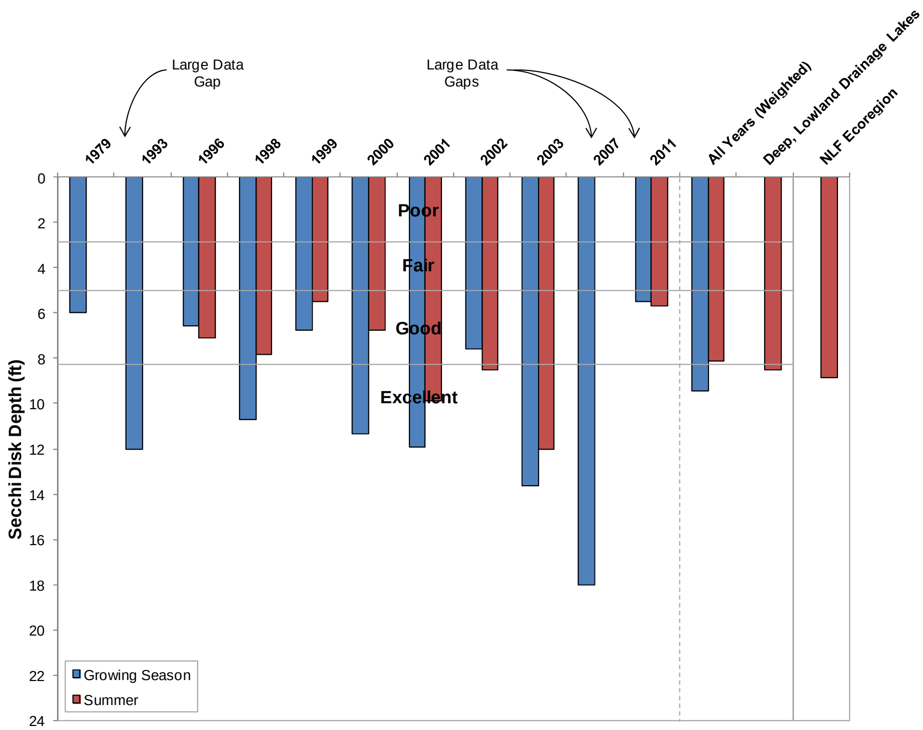


Figure 3.1-5. Big Arbor Vitae Lake, state-wide class 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index median values adapted from WDNR PUB WT-913.

Many types of algae (which contain chlorophyll pigment) are found free-floating and evenly distributed throughout a lake. However, anecdotal accounts as well as Onterra staff observations and correspondence with WDNR officials have confirmed that blue-green algae has, and continues to, produce "blooms" during the late summer months on Big Arbor Vitae Lake. Blue-green algae are a naturally occurring algal group that can produce bluish-green scums on the lake surface and thus are locally distributed, not found dispersed throughout the lake and water column like typical algae species. Therefore, blue-green blooms may not be fully accounted for within the deep-hole sample collections.

Considerably more historical data exists for the third primary water quality parameter – Secchi disk clarity. For a number of years, these data were collected by a volunteer on the lake through the Citizen Lake Monitoring Network, a state-sponsored, volunteer-based monitoring program. In general, these data show that the water clarity in Big Arbor Vitae Lake is 'Good' and comparable to similar lakes across the state and all lakes within the local ecoregion (Figure 3.1-5). Although water clarity is dependent upon a variety of environmental factors, one of the primary factors determining the clarity of a lake is algal abundance. Algae concentrations (not including floating, matted and condensed algae) were not considerably high in 2011, yet Secchi disk clarity was relatively low, yet still within the 'Good' category for deep, lowland drainage lakes. Algae concentration data from 1998 through 2003 would have been of interest for a better understanding of this factor's influence on water clarity, but unfortunately no data are available during this time period.

Seasonal variability exists in water clarity on most Wisconsin lakes. This variability is likely controlled by algal production in Big Arbor Vitae Lake. Figure 3.1-6 displays the seasonal variation that occurs in water clarity. It is important to note that the displayed data are derived from monthly averages over a large time span. However, a general trend is discernible in that water clarity is high during March, April and to a lesser extent May. When the water warms and algae growth begins, water clarity decreases as displayed during the months of August and September. As the water begins to cool and summer sunlight diminishes (October), algae die off and the clarity increases once again. While this is a normal occurrence in most lakes, it is exasperated in Big Arbor Vitae Lake by the frequent algal blooms it experiences.

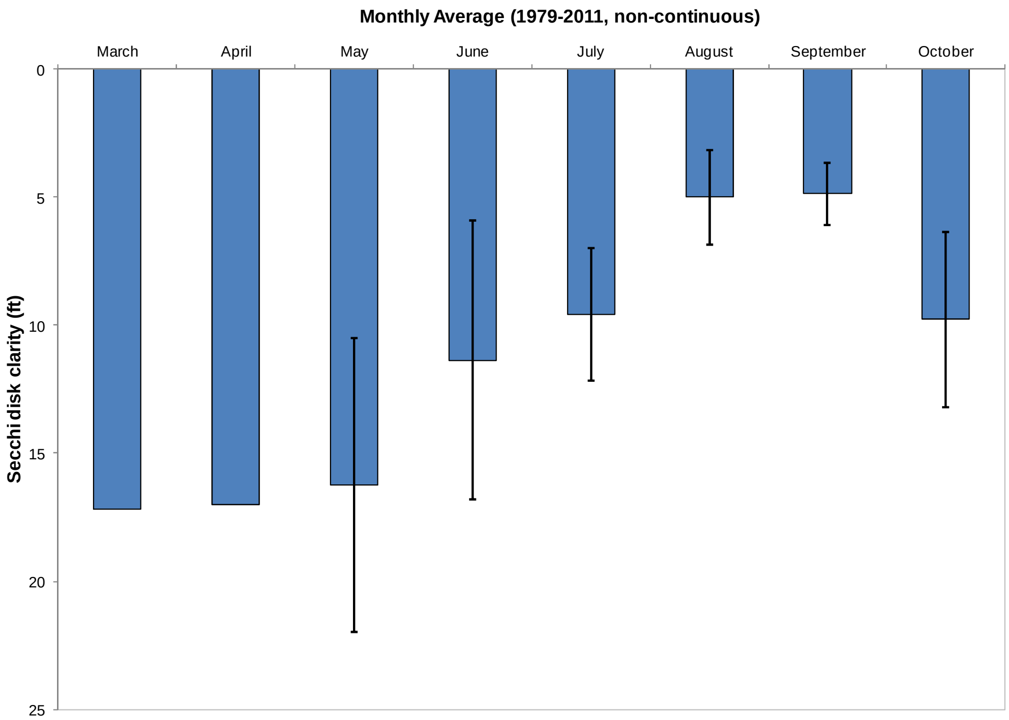


Figure 3.1-6. Big Arbor Vitae Lake monthly Secchi disk clarity averages. Includes all available data from years 1979 – 2011.

Paleolimnological Study of Big Arbor Vitae Lake

On September 19, 2012, a single sediment core was collected from the deep hole in Big Arbor Vitae Lake with a gravity corer by Tim Hoyman, Onterra and Paul Garrison, WDNR (Appendix D). Mr. Garrison analyzed the upper portion and lower portions for diatom assemblages. These are special algae types that are very representative of nutrient conditions within a lake. When examined in the upper layer, certain diatom types are known to represent current conditions. In the deeper layer of the sediment core, these diatoms represent conditions over 100 years earlier in the lake. A determination of nutrient concentrations can be derived from looking at what diatoms are present during those timeframes. In the case of the Big Arbor Vitae core sample, the differences in the diatom assemblages between the two layers indicate that historical phosphorus levels were significantly lower over 100 hundred years ago. This is important information because it confirms that the current high levels of phosphorus found in Big Arbor Vitae Lake are not natural and are likely the result of cumulating anthropogenic impacts. A core sample taken from Little Arbor Vitae Lake produced similar results. Additional study is required to diagnose those impacts and determine feasible actions to minimize them.

Limiting Plant Nutrient of Big Arbor Vitae Lake

Using midsummer nitrogen and phosphorus concentrations from Big Arbor Vitae Lake, a nitrogen:phosphorus ratio of 20:1 was calculated. This finding indicates that Big Arbor Vitae Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Big Arbor Vitae Lake Trophic State

Figure 3.1-7 contain the TSI values for Big Arbor Vitae Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from eutrophic to lower mesotrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters. Additionally, Big Arbor Vitae Lake's abundant plant growth and intermittent algae blooms must be considered; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Big Arbor Vitae Lake is in a eutrophic state.

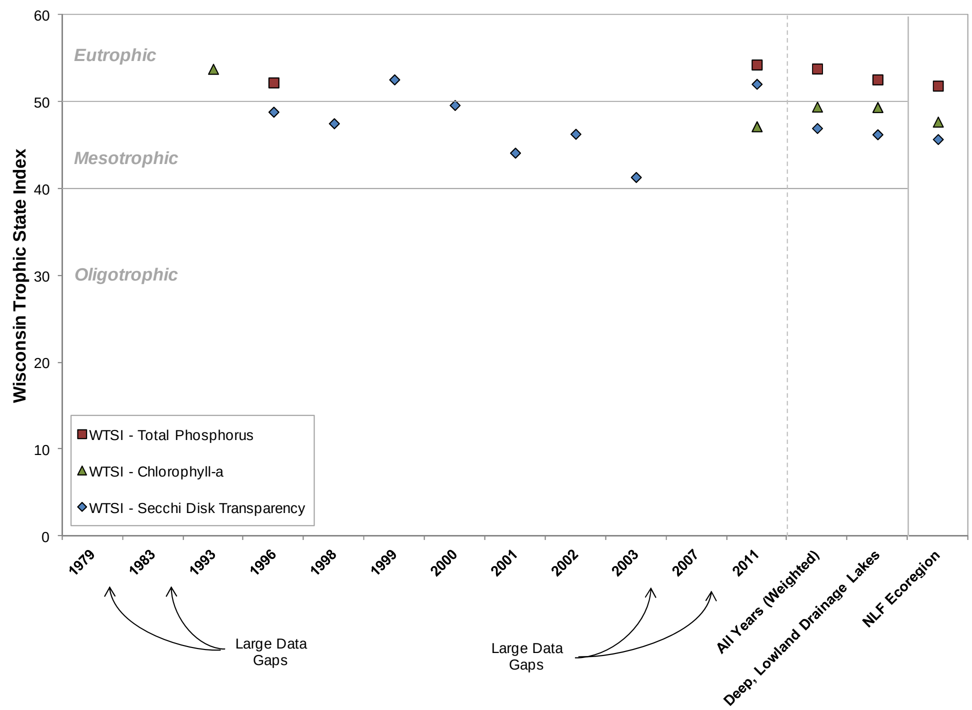


Figure 3.1-7. Big Arbor Vitae Lake, state-wide class 3 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Big Arbor Vitae Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Big Arbor Vitae Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-8.

During the spring months of May and early June, the water column within Big Arbor Vitae Lake is thoroughly mixed, with similar temperatures and dissolved oxygen being present from the surface to the bottom of the lake. In July of 2011, anoxic (no oxygen) conditions were observed in the lake beginning at roughly 17 feet of depth. Temperatures decreased at this depth as well.

This occurs when a temperature gradient occurs between the cool hypolimnion and the cooler epiliminion, which is warmed by the summer sun. Without replenishment from the epilimnion, the water near the bottom of the lake (hypolimnion) becomes depleted of oxygen as naturally occurring bacteria decompose organic matter. Once the epilimnion temperatures cool and fall winds begin to pick up, the lake mixes thoroughly again (seen in September and October profiles).

During the winter months, Big Arbor Lake becomes inversely stratified when temperatures near the ice at the surface are the coldest and the denser, warmer water sinks to the bottom. Oxygen may become depleted during this time as well. In March of 2012, some anoxic conditions were seen near the lower seven feet of the water column, but the remaining water held plenty of oxygen to support warm water aquatic species, including fish. Because of this, winter fish kill is not thought to be an issue on Big Arbor Vitae Lake at this time.

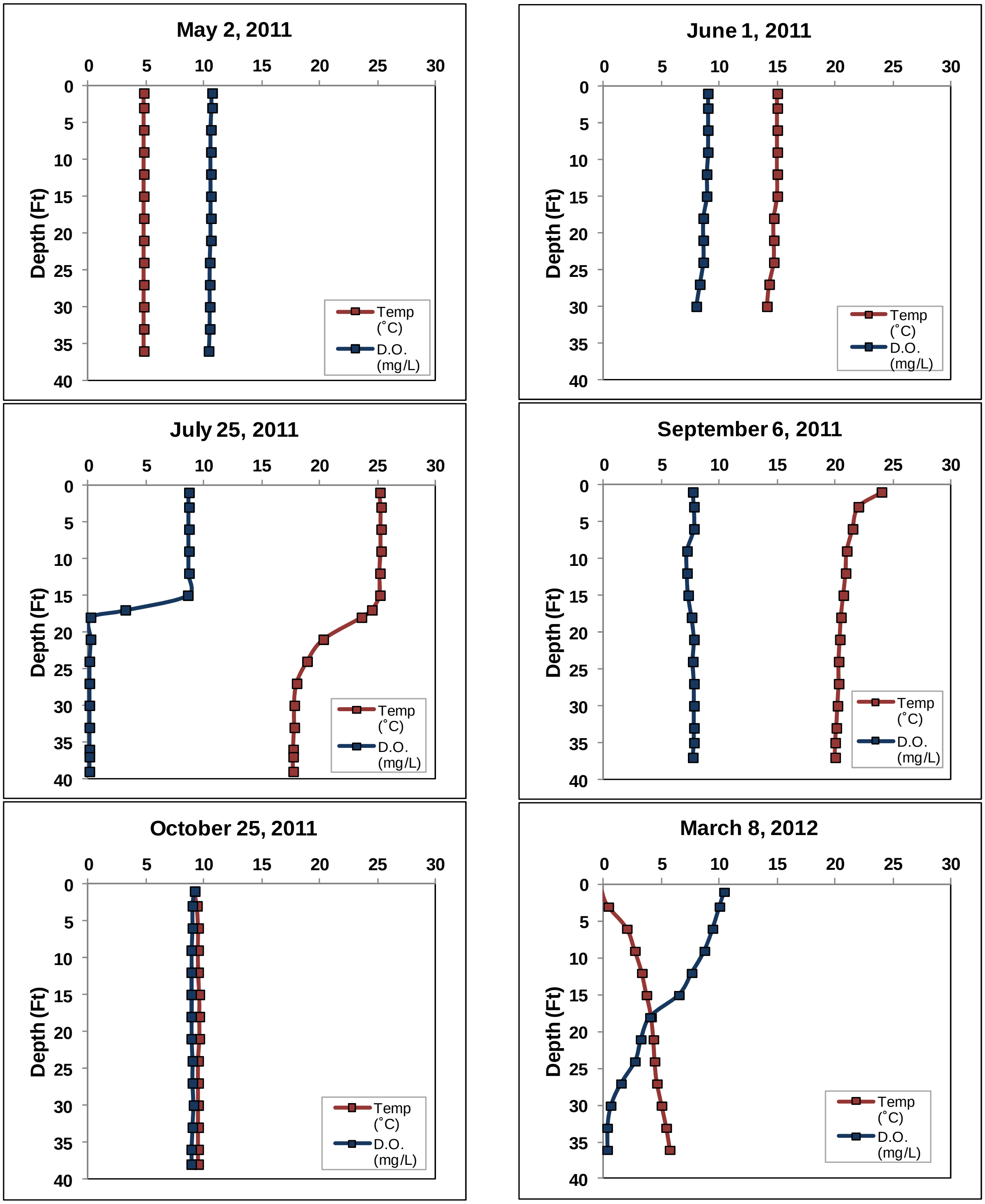


Figure 3.1-8. Big Arbor Vitae Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Big Arbor Vitae Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Big Arbor Vitae 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 et al. 2004). The pH of the water in Big Arbor Vitae Lake was found to be above neutral with a value of 8.5 during mixing of the water column, and falls within the normal range for Wisconsin Lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Big Arbor Vitae Lake was measured at 53.6 (mg/L as $CaCO_3$), indicating that 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. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Arbor Vitae Lake's pH of 8.5 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Big Arbor Vitae Lake was found to be 14.8 mg/L, lying within the optimal range for zebra mussels.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu).

Based upon this analysis, Big Arbor Vitae Lake was considered borderline suitable for mussel establishment. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

Evidence for Internal Nutrient Loading in Big Arbor Vitae Lake

During water quality sampling events, water samples were collected from the near bottom portion of the water column on Big Arbor Vitae Lake. Comparisons of surface and bottom sample phosphorus concentrations are displayed in Figure 3.1-9. During the early sampling occurrences, phosphorus was equally distributed in the water column. However, during periods of anoxia (July 25 and March 8 – see oxygen profiles in Figure 3.1-8), phosphorus concentrations were found to be quite high within the lower water column. When the lake had mixed (September 6), surface and bottom samples matched equally in phosphorus concentration once again. As discussed in the primer portion of this section, high bottom phosphorus values are an indication of internal nutrient loading in a lake. Further exercises, discussed in the Watershed Assessment Section, point towards an indication of internal nutrient loading as well.

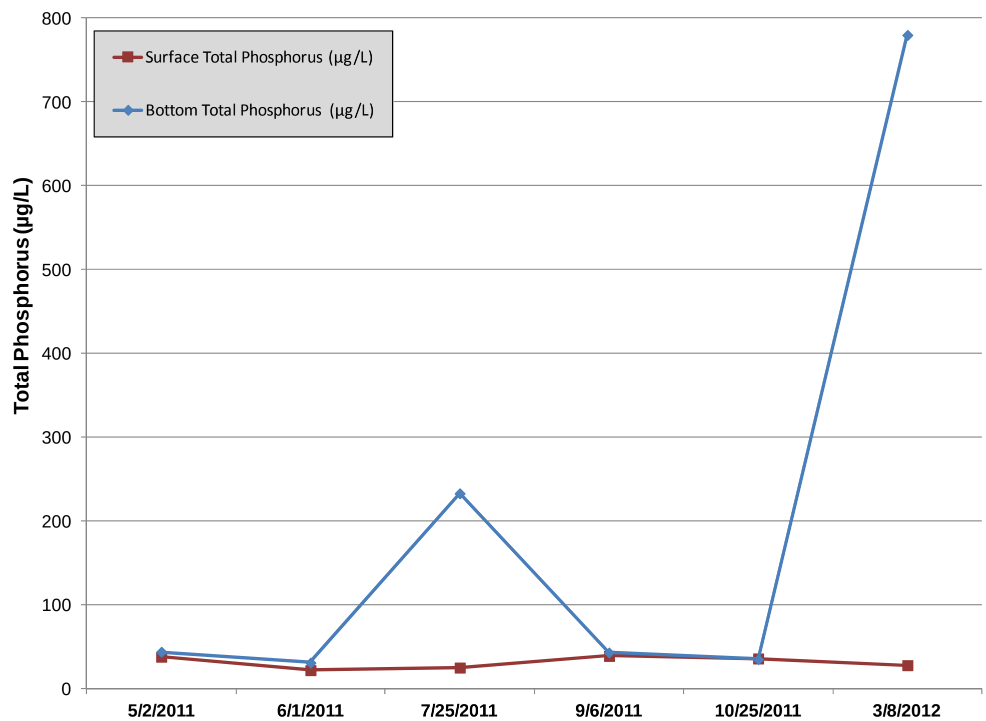


Figure 3.1-9. Big Arbor Vitae Lake phosphorus concentrations, 2011 - 2012. Includes both surface and bottom concentrations collected during water quality visits in 2011 and 2012.

3.2 Watershed Assessment

Watershed Modeling

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.

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.

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 exceeding 10-15:1, 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 (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. 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 affect 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.

Big Arbor Vitae Lake's watershed is 7,656 acres in size and is largely dominated by forests (4,803 acres, or 63% of the total acreage) and forested wetlands and wetlands (1,438 acres or 19%) while the actual surface of the lake (1,090 acres or 14%) makes up a considerable portion of the watershed as well (Figure 3.2-1 and Map 2). Pasture/grass land, row crops and rural residential land make up minor portions of this watershed. Overall, the watershed is six times larger than the sizable Big Arbor Vitae Lake itself, making for a watershed to lake area ratio of 6:1. As discussed above, in watersheds with relatively small ratios, the land cover type often influences the quality of the water in the lake substantially. The land cover in Big Arbor Vitae Lake's watershed is quite favorable with respect to a lake's ecology and chemistry, with an abundance of forest, forested wetlands, and wetlands being found within it. However, as discussed further below, the total phosphorus load to the lake is substantial; in fact, it is more than expected for a watershed displaying the characteristics described above.

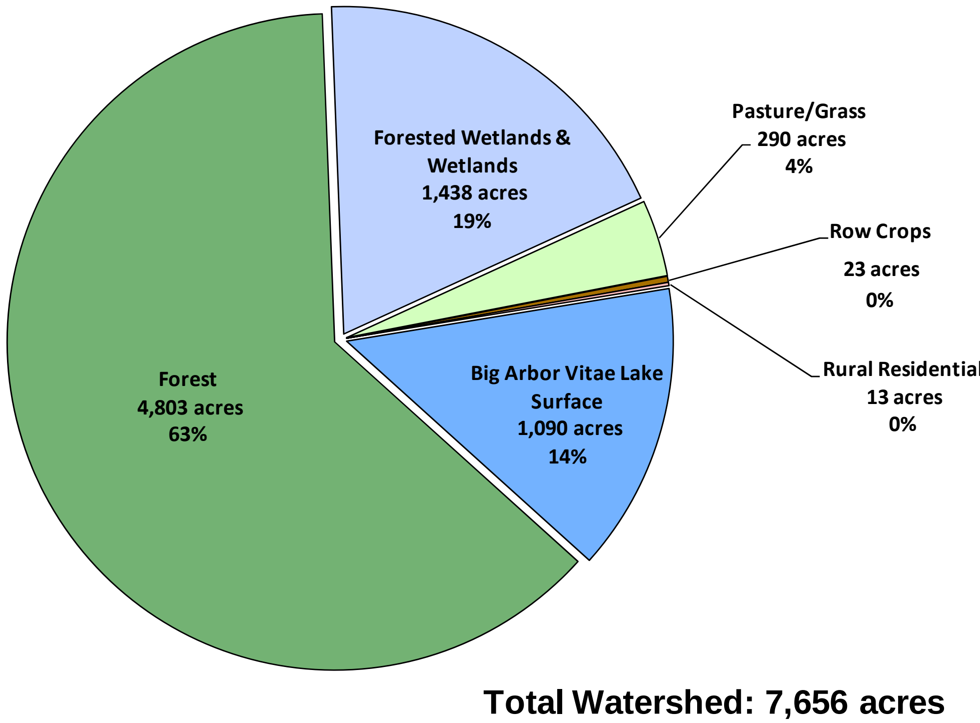


Figure 3.2-1. Big Arbor Vitae Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Modeling of Big Arbor Vitae Lake's watershed was conducted utilizing WiLMS and the land cover acreages displayed in Figure 3.2-1. Modeling results are available within Appendix E. WiLMS estimated that the watershed alone contributes 904 lbs of phosphorus to the lake on an annual basis. During modeling procedures, observed phosphorus values that were collected during 2011 water quality sampling were compared with phosphorus values that the model predicted for Big Arbor Vitae Lake, based upon the land cover within the watershed and lake morphology. A predictive equation within WiLMS estimated that the growing season mean phosphorus should be around 17 µg/L. However, through water samples collected during 2011 it was found that a weighted growing season mean phosphorus concentration is nearly double this value at 29.6 µg/L. This is an indication of an unaccounted source of phosphorus impacting the lake.

Generally speaking, there are several possible sources that may be impacting the nutrient content of Big Arbor Vitae Lake. One of these potential sources is the population of curly-leaf pondweed that is found in the lake. As discussed further in the Aquatic Plant Section, there is roughly five acres of colonized curly-leaf pondweed that are located in Big Arbor Vitae Lake. Curly-leaf pondweed is an interesting species in that it grows vigorously in the early spring following ice-out and reaches its peak growth in mid to late June. This is unlike the native plants found in Wisconsin lakes, which typically reach their peak growth in July or August. Curly-leaf pondweed naturally dies back in early summer releasing phosphorus into the lake as it decays. However, because of the small amount of curly-leaf pondweed present in Big Arbor Vitae Lake relative to the lake's size and volume, it is not believed that curly-leaf pondweed is a significant source of phosphorus loading.

Septic systems within the lake's watershed can leach phosphorus which can make its way into a lake. Using the septic output estimator in WiLMS, an estimate of phosphorus loading attributed to septic leakage was calculated based on the results received from the Big Arbor Vitae Lake stakeholder survey. Using the number of riparians per type of residence (year-round, seasonal, etc.) and assuming each residence has two people and that the septic system is functioning properly, the model indicated that Big Arbor Vitae Lake receives approximately 9 pounds of phosphorus annually from septic tank outputs. While this is only an estimate, this amount of phosphorus does not account for the levels observed lake-wide in 2011.

Even if faulty septic tanks were found along Big Arbor Vitae's shorelands, this source would be shy of the unaccounted phosphorus load to the lake. The stakeholder survey was distributed to 110 residences around Big Arbor Vitae Lake in 2011. For demonstrative purposes, perhaps 25% (28 residences) of these residences have faulty septic systems. Again, there is no reason to believe there are any faulty septic systems along Big Arbor Vitae Lake; this discussion is purely for the sake of demonstration. If the 28 residences with faulty septic systems drained nutrients into the lake, each residence would have to produce 39 lbs of phosphorus from their waste in an average year to reach the 1,000+ lbs of unaccounted phosphorus that WiLMS is predicting (discussed at length below). To clarify, this is 39 lbs of phosphorus, not 39 lbs of total waste. Furthermore, the phosphorus would all have to be soluble (in a dissolved form) to make its way through the soil and reach the lake. If this were happening, the result would likely be localized blooms of algae or aquatic plants that are dissimilar from what is occurring lake-wide.

Another factor to consider with septic system inputs to a lake is the hydrology of the lake, both in terms of its groundwater and surface flow. Groundwater follows water table gradients much like surface water does. The groundwater flow typically, though not always, follows the general pattern of surface water flow. On Big Arbor Vitae Lake, the surface water flow is predominantly from the north, where two inlets exist, to the south, where the lake's outlet exists. It is very likely that the groundwater pattern is similar. Because the vast majority of development occurs on the south-south west region of the lake (refer to the shoreline condition map – Map 3), any septic leakage into the lake would be in very close proximity to the outlet stream. Additionally, on Big Arbor Vitae Lake there are many areas where groundwater flows towards the lake, and many areas where groundwater flows from the lake elsewhere. Portions of the lake may contribute groundwater towards land; this essentially means that groundwater (and septic leachate if it exists) may flow from residences away from the lake and not into it.

As discussed earlier in the Water Quality Section, hypolimnetic phosphorus values were found to be in excess of 200 μg/L during two water quality visits in 2011 – 2012; in fact, one of these concentrations measured close to 800 μg/L. These concentrations diminished once the lake mixed, allowing for phosphorus to mix with the entire lake volume. These high hypolimnetic values, as discussed in the Water Quality Section, are an indication that internal nutrient loading is likely occurring to some extent in Big Arbor Vitae Lake, and further, it is a portion of the unaccounted for phosphorus source that is impacting the lake. Additional modeling indicates that although the watershed surrounding Big Arbor Vitae Lake accounts for 904 lbs, this unaccounted for source is responsible for roughly 55% of the phosphorus load at 1,091 lbs. The annual potential phosphorus load then is a little less than 2,000 lbs per year (Figure 3.2-2). It is known that internal nutrient loading is likely occurring, however the available data cannot tell us how much of the unaccounted for load is from internal loading, and how much is from other sources such as groundwater inputs, or an atypical tributary load, etc.

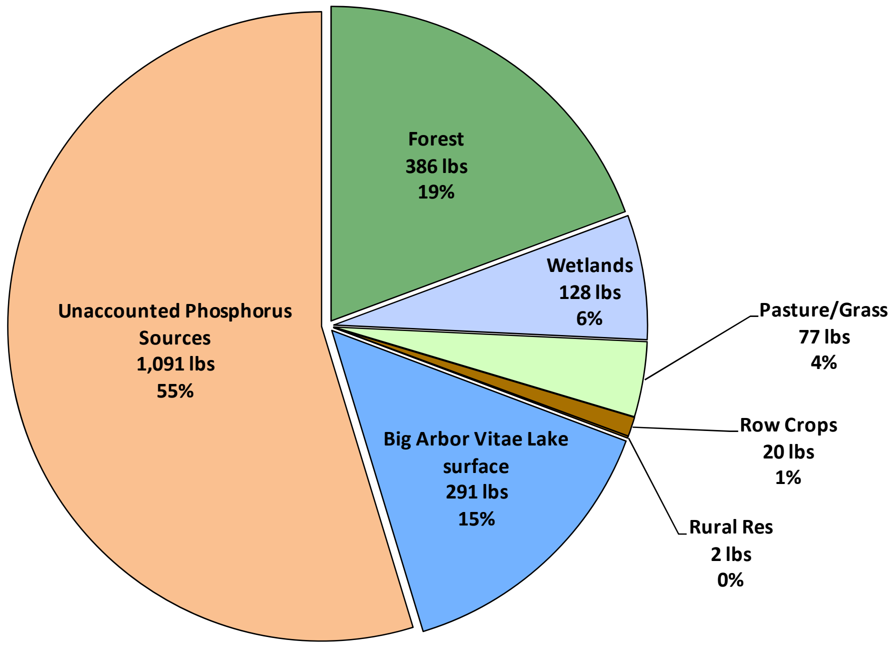


Figure 3.2-2. Big Arbor Vitae Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

The Osgood Index is a measure relating a lake's volume to its surface area and is used to determine whether a lake is dimictic or polymictic. Dimictic lakes completely mix or turnover two times per year, once in spring and again in fall; while polymictic lakes have the potential to turn over multiple times per year depending upon wind events. The Osgood Index uses a ratio of mean depth to square root of lake surface area (mean depth (meters) divided by the square root of lake surface area (square kilometers)). Lakes with ratios exceeding 6:1 are considered strongly stratified and have little chance of destratification during summer months (dimictic). Lakes with lower ratios (less than 6:1) may stratify and turn over multiple times (polymictic). Big Arbor Vitae Lake has a calculated Osgood Index value of 2.6, indicating that it is polymictic. The lake's large surface area makes it susceptible to mixing during periods of high winds. From the dissolved oxygen/temperature profiles taken during water quality sampling, it is known that during calmer weather periods Big Arbor Vitae Lake stratifies and forms an anoxic hypolimnion to which phosphorus is released from the bottom sediments. During high winds stratification is broken and the phosphorus from the hypolimnion is mixed throughout the entire water column, making it available to algae growing near the surface and fueling undesired blooms.

Internal nutrient loading in polymictic lakes may be more problematic than internal nutrient loading in dimictic lakes. Although phosphorus concentrations within the hypolimnion may reach higher levels in dimictic lakes because they remain stratified during the entire summer, these lakes turn over at times of the year (spring and fall) when water temperatures are cooler and algae growth is reduced. Though the amount of phosphorus delivered from the hypolimnion to the rest of the water column may be lower in polymictic lakes, the pulse-based loading of phosphorus during the summer when algae is actively growing can cause and sustain unwanted blooms.

The data collected in 2011 provides an indication that internal nutrient loading is occurring in Big Arbor Vitae Lake. Studies in Little Arbor Vitae Lake, downstream of Big Arbor Vitae Lake, have indicated internal nutrient loading is occurring there as well. Additionally, Little Arbor Vitae Lake receives a significant portion of its phosphorus budget (794 lbs or 40% of the total annual load) from its inlet stream which flows from Big Arbor Vitae Lake. While this study was able to identify this occurrence and determine its potential contribution of phosphorus to both Big and Little Arbor Vitae Lakes, a reliable and completely accurate assessment of this phenomenon is not achievable through the studies conducted as a part of this management planning project. Before control actions to combat internal nutrient loading are considered, a more in-depth diagnostic/feasibility study should be conducted to quantify the amount of phosphorus being delivered via internal nutrient loading in Big Arbor Vitae Lake. This would include a more rigorous sampling regime of epilimnetic and hypolimnetic phosphorus values throughout the year and the collection and analysis of sediment cores to determine phosphorus-release rates. Also, sampling near the mouth of tributary streams would also be required to determine a more accurate amount of phosphorus being delivered from the watershed. Details surrounding this potential future study and the pros and cons of addressing internal nutrient loading are further discussed in the Summary and Conclusions and Implementation Plan Sections

Although it is known that internal nutrient loading is probably constitutes a large portion of the unaccounted phosphorus source in both Big and Little Arbor Vitae Lakes, the exact portion cannot be derived until data is collected in the manner described above. However, at this point scenario modeling can be developed to determine what kind of response these lakes might show should internal nutrient loading be brought under control. Table 3.2-1 displays the results of modeling procedures using equations derived from lake modeling research. Essentially, Big Arbor Vitae Lake was modeled under several scenarios – 1) the unaccounted phosphorus source is 100% derived from internal nutrient loading, 2) 90% of the source is from internal nutrient loading with 10% from other unknown sources, 3) 75% of the source is from internal nutrient loading, and 4) the unaccounted source is 50% generated from internal nutrient loading. In-lake treatments, applied to Big Arbor Lake to reduce internal loading, were assumed to reduce the internal load by 90%. In the best case scenario, which would be if 100% of the unaccounted load was from internal nutrient loading, in-lake treatments could potentially cut the overall annual phosphorus load by 49%. If the unaccounted source consisted of a smaller portion of internal nutrient loading, smaller reductions in the overall phosphorus load would be the result.

Table 3.2-1 Big Arbor Vitae Lake Internal Nutrient Loading Scenarios. The total unaccounted phosphorus load is modeled with 100%, 90%, 75% and 50% of the load assumed to be derived from internal nutrient loading.

Scenario	100% Unaccounted Load is Internal Loading	90% Unaccounted Load is Internal Loading	75% Unaccounted Load is Internal Loading	50% Unaccounted Load is Internal Loading
Total internal load (lbs)	1,091	982	818	546
Remaining unaccounted load (lbs)	0	109	273	546
Internal load 90% reduction (lbs)	109	98	82	55
* New total phosphorus load (lbs)	1,013	1,111	1,259	1,505
Percent reduction from current total load (lbs)	49%	44%	37%	25%

** Includes an assumed external load from watershed of 904 lbs*

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) affects on the lake is important in maintaining the quality of the lake's water and habitat. Along with this, the immediate shoreland area is often one of the easiest areas to restore.

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted 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 of their own. County ordinances may be more restrictive than NR 115, but not less so. These policy regulations require each county to amend ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows (Note: counties must adopt these standards by February 2014, counties may not have these standards in place at this time):

- <u>Vegetation Removal</u>: 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 the lesser of 30 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).

- <u>Impervious surface standards</u>: 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. A county may allow more than 15% impervious surface (but not more than 30%) on a lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner.

- <u>Nonconforming structures</u>: 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. New 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 no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- <u>Mitigation requirements</u>: New 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, dependent on the county.

- Contact the county's regulations/zoning department for all minimum requirements.

Wisconsin Act 31

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

Shoreland Research

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

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 debris 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).

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).

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 nott 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.

Big Arbor Vitae Lake Shoreland Zone Condition

Shoreland Development

Big Arbor Vitae 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 shoreland 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 shorelands 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 shoreland 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 shoreland that was restored would likely be included here, also.

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

Figure 3.3-1. Shoreline assessment category descriptions.

On Big Arbor Vitae Lake, the development stage of the entire shoreline was surveyed during fall of 2011, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

Big Arbor Vitae Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.9 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 3.3-2). 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, 1.5 miles of urbanized and developed–unnatural shoreline were observed. If restoration of the Big Arbor Vitae Lake shoreline 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 shoreline lengths around the entire lake.

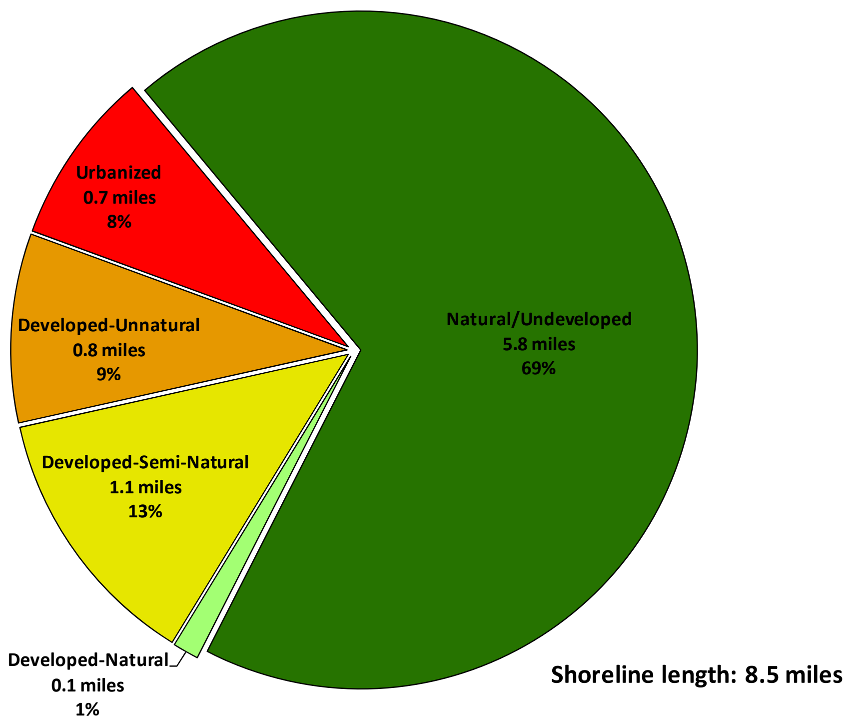


Figure 3.3-2. Big Arbor Vitae Lake shoreland categories and total lengths. Based upon a fall 2011 survey. Locations of these categorized shorelands can be found on Map 3.

While producing a completely natural shoreline 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. Locating 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.

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.

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 shoreline 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 water-milfoil (*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 invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

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

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

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

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

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

Bottom Screens

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

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

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

Water Level Drawdown

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

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

Advantages	***Disadvantages***
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian water-milfoil 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 (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

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

Cost

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

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

Herbicide Treatment

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

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

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

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

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

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

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

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

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

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

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

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • 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 water-milfoil 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 water-milfoil 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 water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

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 water-milfoil 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 Big Arbor Vitae 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 species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific 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 life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain 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 Big Arbor Vitae Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Species Diversity and Richness

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to a diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

Simpson's diversity index is used to determine this diversity in a lake ecosystem. Simpson's diversity (1-D) is calculated as:

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

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. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Big Arbor Vitae Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

> **Box Plot** or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreline. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreline complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreline complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Big Arbor Vitae Lake will be compared to lakes in the same ecoregion and in the state.

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.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. 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 survey and does not include incidental species or those encountered during other aquatic plan surveys.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

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 water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian water-milfoil 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 water-milfoil 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 water-milfoil 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.

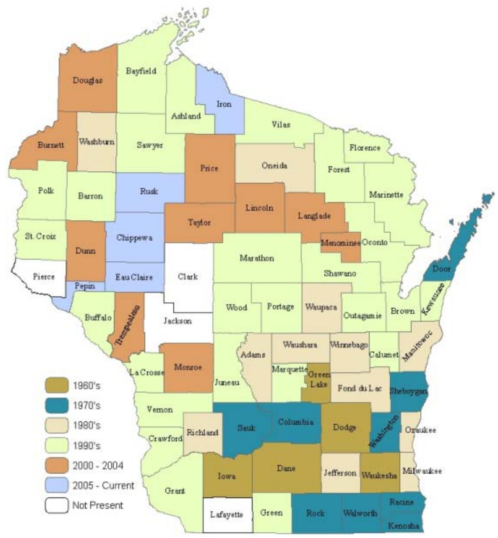


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 water-milfoil, 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 water milfoil 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

Littoral Zone is the area of a lake where sunlight is able to penetrate down to the sediment and support aquatic plant growth.

As mentioned earlier, numerous aquatic plant surveys were completed as a part of this project. On June 28, 2011, an early-season aquatic invasive species (AIS) survey was completed on Big Arbor Vitae Lake. While the intent of this survey is to locate any potential non-native species within the lake, it's primarily focused on locating any occurrences of curly-leaf pondweed. During this meander-based survey of the *littoral zone*, Onterra ecologists located a number of curly-leaf pondweed occurrences in the southern and southeast portions of the lake. Because of this plant's importance, the occurrence of curly-leaf pondweed in Big Arbor Vitae Lake and recommended actions to control this invasive plant will be discussed in the following Non-native Plants Section.

The comprehensive aquatic plant point-intercept and aquatic plant community mapping surveys were conducted on Big Arbor Vitae Lake on July 22 and 27, 2011, by Onterra. Data from this survey is available within Appendix F. During these surveys, 33 species of aquatic plants were located in Big Arbor Vitae Lake (Table 3.4-1), two of which are considered to be non-native, invasive species: curly-leaf pondweed and reed canary grass. These non-native plants will be discussed in detail in the Non-native Plants Section.

As determined from the point-intercept survey, 50% of the point-intercept locations that fell at or below 14 feet contained organic sediments or muck, while 43% contained sand and 7% contained rock (Figure 3.4-2). Map 4 illustrates that these substrate types are distributed throughout littoral areas of Big Arbor Vitae Lake. The substrate types in deeper areas of the littoral zone (>14 feet) were not able to be determined due to the sampling methodology.

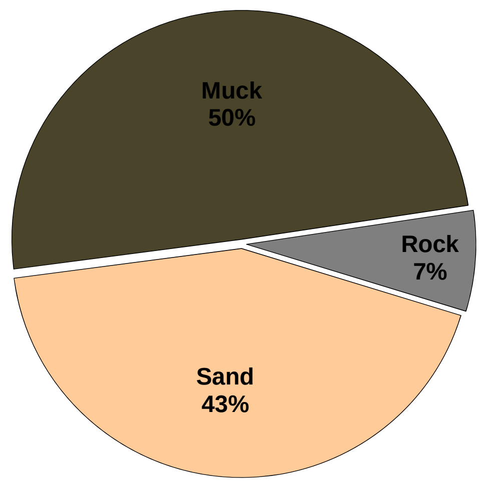


Figure 3.4-2. Big Arbor Vitae Lake proportion of substrate types within littoral areas. Created using data from 2011 aquatic plant point-intercept survey.

Approximately 50% of the 512 point-intercept sampled within the maximum depth of plant growth (22 feet), or the littoral zone, contained aquatic vegetation. It was surprising to locate aquatic vegetation growing in over 20 feet of water given the average Secchi disk clarity for 2011 was 5.5 feet. Map 5 shows that shallower, southeast portion of the lake contains the majority of the lake's aquatic vegetation, while the western portion of the lake is sparsely vegetated due to deeper depths.

While some aquatic plants were located growing past 20 feet, the majority of vegetation was encountered between 1 and 11 feet (Figure 3.4-3). Figure 3.4-3 also illustrates that shallower areas of Big Arbor Vitae Lake (< 4 feet) are dominated by wild celery, while deeper areas are dominated by coontail, northern water milfoil, flat-stem pondweed, and common waterweed.

Table 3.4-1. Aquatic plant species located on Big Arbor Vitae Lake during July 2010 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	*I*
	Carex comosa	Bristly sedge	5	*I*
	Carex crinita	Fringed sedge	6	*I*
	Iris versicolor	Northern blue flag	5	*I*
	Phalaris arundinacea	Reed canary grass	Exotic	*I*
FL	*Nuphar variegata*	Spatterdock	6	*I*
	Nymphaea odorata	White water lily	6	*X*
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	*I*
Submergent	*Chara spp.*	Muskgrasses	7	*X*
	Ceratophyllum demersum	Coontail	3	*X*
	Elodea canadensis	Common waterweed	3	*X*
	Heteranthera dubia	Water stargrass	6	*X*
	Myriophyllum sibiricum	Northern water milfoil	7	*X*
	Najas flexilis	Slender naiad	6	*X*
	Nitella sp.	Stoneworts	7	*X*
	Potamogeton amplifolius	Large-leaf pondweed	7	*X*
	Potamogeton crispus	Curly-leaf pondweed	Exotic	*X*
	Potamogeton friesii	Fries' pondweed	8	*X*
	Potamogeton praelongus	White-stem pondweed	8	*X*
	Potamogeton pusillus	Small pondweed	7	*X*
	Potamogeton richardsonii	Clasping-leaf pondweed	5	*X*
	Potamogeton robbinsii	Fern pondweed	8	*X*
	Potamogeton spirillus	Spiral-fruited pondweed	8	*X*
	Potamogeton strictifolius	Stiff pondweed	8	*X*
	Potamogeton zosteriformis	Flat-stem pondweed	6	*X*
	Ranunculus aquatilis	White water-crowfoot	8	*X*
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	*X*
	Stuckenia pectinata	Sago pondweed	3	*I*
	Vallisneria americana	Wild celery	6	*X*
SE	*Sagittaria cuneata*	Arum-leaved arrowhead	7	*I*
FF	*Lemna turionifera*	Turion duckweed	2	*X*
	Lemna trisulca	Forked duckweed	6	*X*
	Spirodela polyrhiza	Greater 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

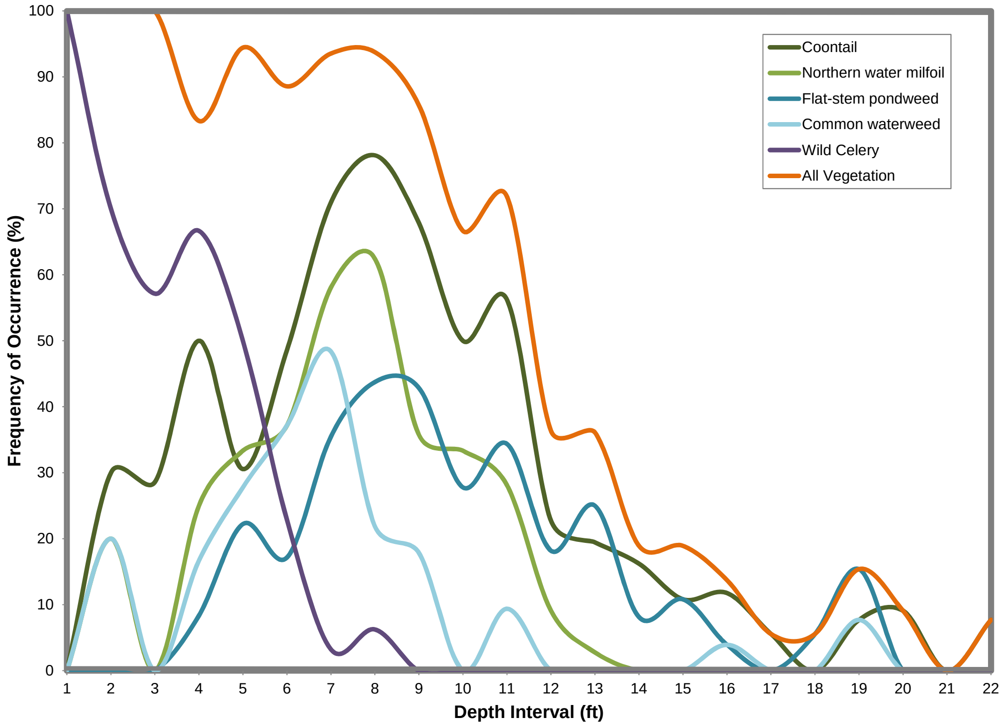


Figure 3.4-3. Frequency of occurrence of select aquatic plant species across littoral depths of Big Arbor Vitae Lake. Created using data from 2011 aquatic plant point-intercept survey. Lines are smoothed to ease visualization.

Of the 24 aquatic plant species recorded on the rake during the point-intercept survey, coontail, northern water milfoil, flat-stem pondweed, and common waterweed the four-most frequently encountered (Figure 3.4-4). Coontail, as its name suggests, with its densely whorled branches resembles a raccoon's tail. This species is widespread and common in Wisconsin, and does very well in lakes with higher nutrient levels. Able to tolerate lower light levels and obtain the majority of its nutrients directly from the water, coontail is often one of the most abundant plant species in eutrophic systems. Lacking true roots, coontail is often found growing entangled amongst rooted aquatic vegetation. Because of its ability to tolerate eutrophic conditions, coontail is an important species in these systems as it provides sources of food and habitat to a number of aquatic organisms. However, under certain conditions, coontail can often grow to excessive levels which can interfere with recreational activities on the lake. In Big Arbor Vitae Lake, coontail was located at approximately 32% of the point-intercept locations that fell within the littoral zone (Figure 3.4-4), and was most abundant between 4 and 11 feet of water (Figure 3.4-3).

Northern water milfoil was the second-most frequently encountered aquatic plant species during the 2011 point-intercept survey with a littoral occurrence of approximately 19% (Figure 3.4-4). Northern water milfoil is one of seven native milfoils present in Wisconsin, and is likely the most common. It is often falsely identified as its close relative, the non-native Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as it reacts to sun exposure as the growing season progresses. Northern water milfoil is different from Eurasian water milfoil in having less leaflets (usually less than 10) per side on the leaved and whorls of leaves that are spaced closer together on the stem. The feathery foliage of northern water milfoil traps detritus and provides habitat for filamentous algae, in turn creating valuable habitat for aquatic invertebrates. Because northern water milfoil prefers higher water clarity, its populations are declining state-wide as lakes are becoming more eutrophic. In Big Arbor Vitae Lake, northern water milfoil was most abundant between 4 and 11 feet of water (Figure 3.4-3).

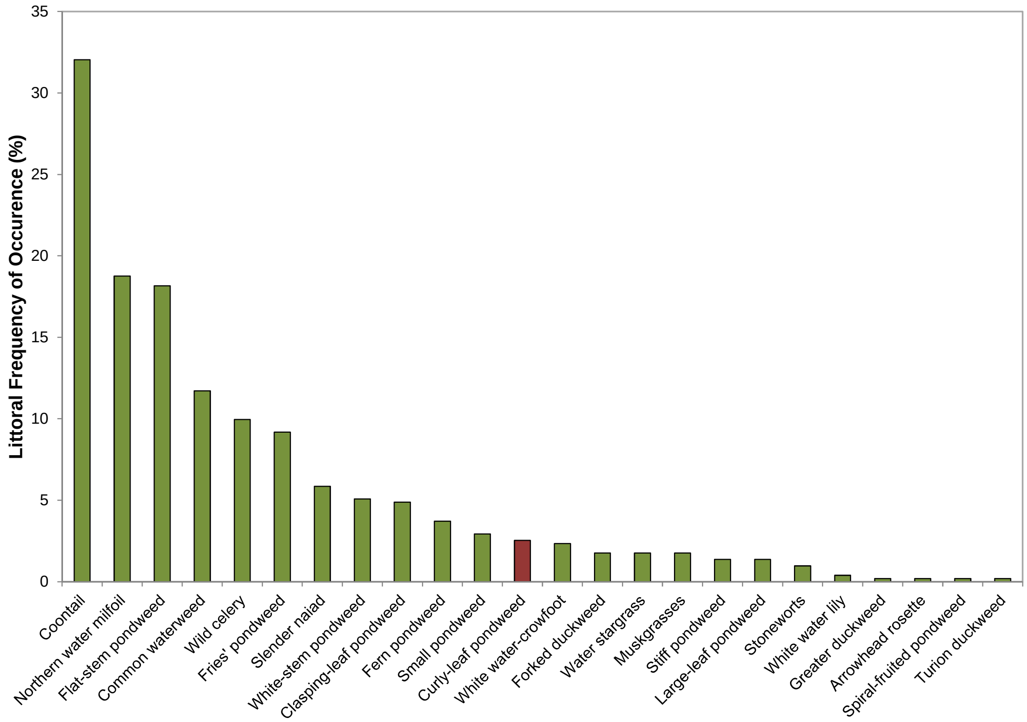


Figure 3.4-4. Big Arbor Vitae Lake aquatic plant littoral occurrence analysis. Created using data from 2011 aquatic plant point-intercept survey.

Flat-stem pondweed was the third-most frequently encountered aquatic plant species during the 2011 point-intercept survey (Figure 3.4-4). Flat-stem pondweed is a rooted aquatic plant that possesses long, slender leaves as well as a flattened or compressed stem. Like coontail, flat-stem pondweed is usually found in lakes of higher nutrient content and productivity and can tolerate lower light levels. Its tall stature provides aquatic organisms with excellent structural habitat and its fruit is likely a good food source for water fowl. Flat-stem pondweed was most abundant between 7 and 11 feet of water in 2011 (Figure 3.4-3).

The fourth-most frequently encountered aquatic plant species during the 2011 point-intercept survey was common waterweed. Like coontail, common waterweed lacks true roots and can obtain the majority of its essential nutrients directly from the water. Dense beds of common waterweed provide habitat and sources of food for aquatic organisms. However, this species is known to grow to excessive levels and hinder recreational activities when conditions allow.

While only the four-most frequently encountered aquatic plant species were discussed, all the of the native aquatic plant species encountered on the rake in 2011 are used in calculating Big Arbor Vitae Lake's Floristic Quality Index (FQI). These calculations do not include species that were located 'incidentally' during the 2011 surveys. For example, while a total of 31 native aquatic plant species were located in Big Arbor Vitae Lake during the 2011 surveys, 23 were encountered on the rake during the point-intercept survey. The native species encountered on the rake and their conservatism values were used to calculate the FQI of Big Arbor Vitae Lake's aquatic plant community (equation shown below).

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

Figure 3.4-5 compares the FQI components from Big Arbor Vitae Lake calculated from the 2011 point-intercept survey to median values of lakes within the Northern Lakes and Forests Ecoregion in Wisconsin. As displayed in Figure 3.4-5, the native species richness (23) is higher than both the ecoregional and state medians. The lake's average conservatism value (6.2) is lower than the ecoregional median and slightly higher than the median for lakes state-wide (Figure 3.4-5). Combining Big Arbor Vitae Lake's native species richness and average conservatism values yields am FQI value of 29.9, higher than both the ecoregional and state medians (Figure 3.4-5). While Big Arbor Vitae Lake contains a relatively high number of native aquatic plant species, the conservatism value suggests the aquatic plant community in terms of species composition is comprised of species that are more tolerant of eutrophic conditions. This indicates that the aquatic plant community in Big Arbor Vitae Lake is of slightly lower quality than other lakes within the ecoregion but comparable to lakes state-wide.

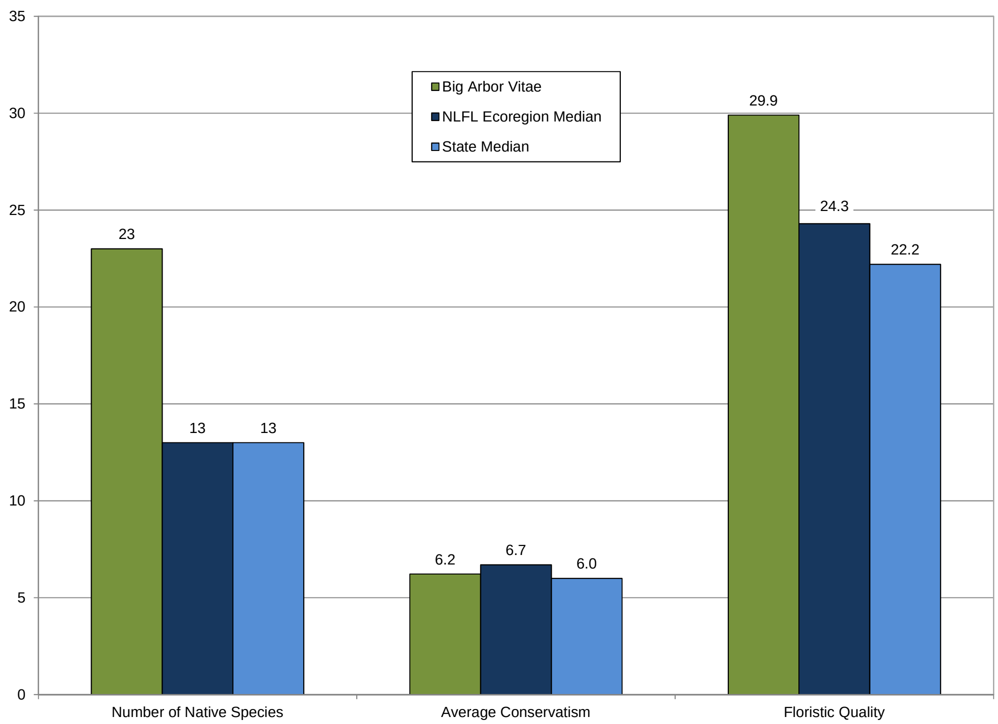


Figure 3.4-5. Big Arbor Vitae Lake Floristic Quality Assessment. Created using data from 2011 aquatic plant point-intercept survey.

As explained earlier, 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 Big Arbor Vitae Lake contains a relatively high number of native aquatic plant species, one may assume the aquatic plant community 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 Big Arbor Vitae Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLFL Ecoregion (Figure 3.4-6). Using the data collected from the 2011 point-intercept survey, Big Arbor Vitae Lake's aquatic plant community was shown to have very high species diversity with a Simpson's diversity value of 0.89. This diversity value falls on the upper quartile for the lakes within the northern region and above the upper quartile for lakes state-wide (Figure 3.4-6). This value indicates that if two individual aquatic plants were randomly sampled from Big Arbor Vitae Lake, there would be an 89% probability that they would be different species.

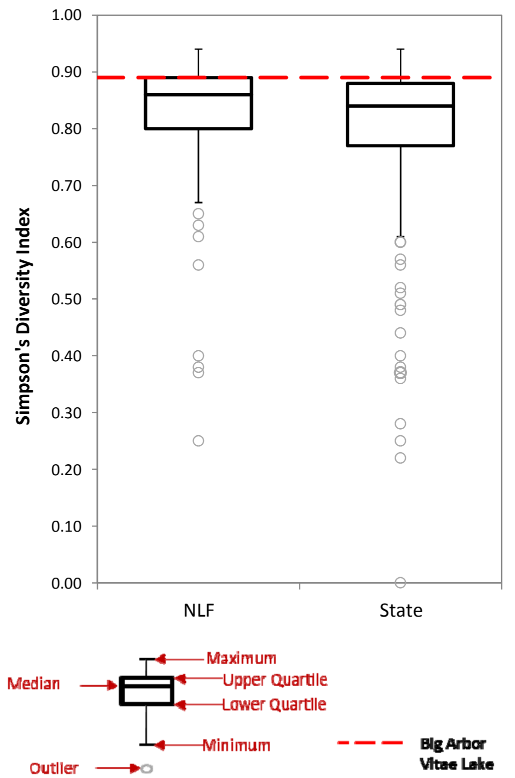


Figure 3.4-6. Big Arbor Vitae Lake species diversity index. Created using data from 2011 aquatic plant point-intercept survey.

Figure 3.4-7 displays the relative frequency of occurrence of aquatic plant species in Big Arbor Vitae Lake from the 2011 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species which creates a diverse community.

The emergent and floating-leaf aquatic plant communities were also assessed in Big Arbor Vitae Lake in 2011. The 2011 community map (Map 6) indicates that approximately 5.2 acres (0.5%) of the 1,090-acre lake contain these types of plant communities (Table 3.4-2). Eight floating-leaf and emergent species were located in Big Arbor Vitae Lake (Table 3.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody debris can become quite sparse along the shores of receding water lines.

Continuing the analogy that the community map represents a 'snapshot' of the important plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Big Arbor Vitae Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

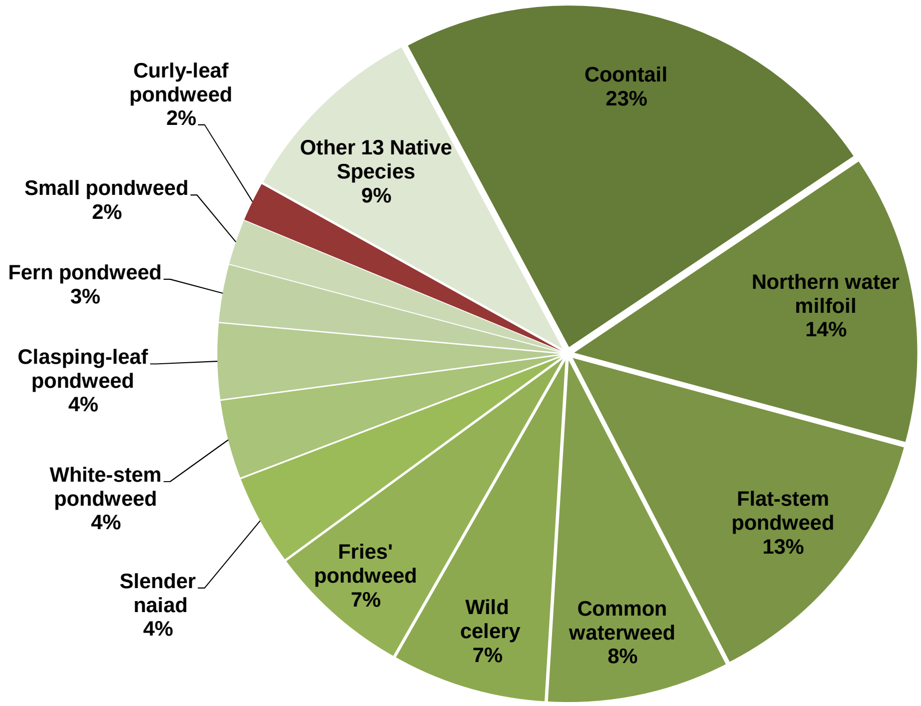


Figure 3.4-7. Big Arbor Vitae Lake aquatic plant relative occurrence analysis. Created using data from 2011 aquatic plant point-intercept survey.

Table 3.4-2. Big Arbor Vitae Lake acres of floating-leaf and emergent plant communities. Created from the 2011 community mapping survey.

Plant Community	Acres
Emergent	0.07
Floating-leaf	1.28
Mixed Emergent & Floating-leaf	3.87
Total	**5.22**

Nuisance-Native Aquatic Plant Growth in Big Arbor Vitae Lake

In 2011, during this project's surveys of Big Arbor Vitae Lake, the combination of a relatively late ice-out and normal summer temperatures kept aquatic plant growth within the lake to a lower or moderate level. Realizing that the aquatic plant growth in 2011 was not representative of an average year on Big Arbor Vitae Lake, Onterra volunteered to conduct an additional survey in August of 2012. In contrast to 2011, 2012 saw a very early ice-out and higher-than-normal temperatures, exacerbating aquatic plant growth in all of the lakes that Onterra works on as well as other lakes in Wisconsin.

In some lakes when conditions are favorable, native aquatic plants can grow to levels which impede recreational activities such as boating, fishing, and swimming. In these cases, the WDNR may provide a permit to control these plants and allow access from developed properties to open water areas of the lake. Our goal in completing the survey in 2012 was to document areas where nuisance growth of aquatic plants is occurring and where control may be desired.

Photo 3.4-1. Excessive growth of coontail and northern water milfoil in Big Arbor Vitae Lake. Photo taken during August 2012 survey.

On August 29, 2012, Onterra ecologists completed a survey of Big Arbor Vitae that focused on areas that were indicated on a map to contain excessive aquatic plant growth by Don Wallace and other members of the Planning Committee. During this survey, a number of areas containing dense, surface-matted native aquatic vegetation were observed and documented (Map 7). The majority of these areas were composed of rooted northern water milfoil (*Myriophyllum sibiricum*) growing at or near the surface with entangled free-floating mats of coontail (*Ceratophyllum demersum*).

While these areas of excessive plant growth are extensive, some of the most impactful areas were observed in front of undeveloped areas of the lake where navigation out from riparian properties is not an issue. Areas of excessive plant growth were observed in front of many riparian properties, but in most cases did not extend all the way to shore and the majority of the surface-matted growth was recorded in approximately four to seven feet of water. While some of these areas may see excessive growth on an annual basis, as described above, the early ice-out in combination with higher-than-normal temperatures this year created much higher levels of plant growth.

Blue-Green Algae in Big Arbor Vitae Lake

During the 2012 aquatic plant survey, a widespread algal bloom, potentially of blue-green algae, was observed around the lake during this survey, likely spurred by this summer's hot temperatures. Big Arbor Vitae Lake is not alone, blue-green algae blooms have been observed on numerous area lakes this year. Many species of blue-green algae can naturally be found in Wisconsin waters, some of which (but not all) can produce toxins potentially dangerous to people and animals. Because dogs and other domestic animals actively drink water from lakes, they have an increased risk of health issues associated with these toxins.

Photo 3.4-2. Blue-green algae bloom on Big Arbor Vitae Lake. Photo taken during August 2012 survey.

Non-Native Plants in Big Arbor Vitae Lake

Curly-Leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) was first documented in Big Arbor Vitae Lake in 2008. In that year, GLIFWC (Great Lakes Indian Fish and Wildlife Commission) staff visited the lake and found curly-leaf pondweed in the southeast bay of the lake. They documented "a few hundred plants covering about 0.5 to 1.0 acres" (Dara Olson, personal communication). Curly-leaf pondweed waypoints from this survey may be viewed on Map 8. A 2009 mapping survey conducted by Barb Gajewski as part of a Vilas County project turned up curly-leaf pondweed in several areas of the lake (Map 8). During the 2011 early-season AIS survey, approximately five acres of colonized curly-leaf pondweed were mapped in the south-central portion of the lake while clumps of plants and single plant occurrences were located in the southwestern bay (Map 8). While areas of single plants or clumps of plants are designated with point-based data, large colonized communities were mapped with polygon-based mapping. Density categories were assigned to the large colonies based upon the visual appearance of the colony; 4.2 of the 5 acres were categorized as scattered (several plants blending in within the native community), 0.4 acres as dominant (curly-leaf pondweed dominates the plant community in this area, with 50% aerial coverage) and 0.4 acres as highly dominant (curly-leaf pondweed is highly dominant within the local plant community, occupying greater than 50% of the area).

While the current level of curly-leaf pondweed is beyond control using passive techniques (e.g. hand removal by divers or snorkelers), the infestation in Big Arbor Vitae Lake may not require more intensive control strategies such as herbicide application at this time. In many Northwoods Wisconsin lakes, curly-leaf pondweed does not cause the nuisance like conditions observed in southern Wisconsin lakes. In some cases, the plant has rarely spread through these lakes as well. Though the text below discusses herbicide applications for the purposes of managing curly-leaf pondweed, this may not be warranted for use on Big Arbor Vitae Lake with the current level of growth seen. Many Northwoods Wisconsin lake groups choose instead to monitor this invasive plant, and determine if its colony extents are showing signs of growth or density increase from one year to the next.

Curly-Leaf Pondweed Herbicide Applications – A Background

In some Wisconsin lakes, herbicides rated for aquatic use are utilized to control this invasive species. Because curly-leaf pondweed, an annual plant, produces reproductive structures (turions) that may sprout years after the initial parent plant is gone, a control strategy must be devised that includes treating this sample plant colony (or its geographical acreage, rather). The goal for curly-leaf pondweed control is to reduce the plant's ability to reproduce through turion production. This is typically approached by attempting to reduce the turion base within the infected areas of the lake. To accomplish this, the same areas and roughly same acreage are treated annually several times over with a contact herbicide (endothall).

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 dilute herbicide concentration within aquatic systems. Understanding concentration-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 a joint research project between the WDNR and the US Army Corps of Engineers (USACE). Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) spot treatments, and 2) whole-lake treatments.

Spot treatments are a type of treatment 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. For curly-leaf pondweed, endothall is typically applied between 1.5 and 3.0 ppm a.i. in spot treatment scenarios. A newly adopted term, micro-treatments are small spot treatments (working definition is less than 5 acres) and because of their small size, rarely are effective because of the rapid dilution of the herbicide. Larger treatment areas tend to be able to hold effective concentrations for a longer time. Emerging information suggests that in order for an application of 1.5 ppm a.i. endothall to be effective at controlling curly-leaf pondweed, the concentration needs to be maintained for at least 12-24 hours. That length of exposure time is very difficult to achieve, especially in micro-treatment situations.

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 (of the lake or a lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire lake or basin. Endothall application rates are typically applied based upon active ingredient (a.i.) while herbicide residual analysis, which is a measure of the herbicide within the water column, is based upon acid equivalent (a.e.). The application rate of whole-lake treatments is dictated by the volume of water which the herbicide will reach equilibrium within. The target herbicide concentration is typically between 0.225 and 0.300 ppm a.e. when exposed to the target plants for 7-14 days or longer.

The infestation of curly-leaf pondweed in Big Arbor Vitae Lake is still minimal, at roughly five acres. Herbicide applications would target these colonies in a spot treatment scenario as described above. Treatments would be required for a number of years in order to deplete the turion base, and continued monitoring of this AIS necessary for years to follow as well.

Reed Canary Grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines.

Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic. At this time, populations on the shorelines of Big Arbor Vitae Lake are not excessive, though it is recommended that continued monitoring of reed canary grass takes place. During the community mapping survey in 2011, Onterra ecologists mapped an occurrence of reed canary grass along the northwest shoreline of the lake with sub-meter GPS technology (Map 6).

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as 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 numerous fisheries biologists overseeing Big Arbor Vitae Lake. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the BAVLA stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2012 & GLIFWC 2012A and 2012B).

Big Arbor Vitae Lake Fishery

Big Arbor Vitae Lake Species and Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second highest ranked important or enjoyable activity on Big Arbor Vitae Lake (Question #13). Most anglers prefer to catch walleye, and crappie, bluegill/sunfish, yellow perch and muskellunge are popular species targeted as well (Question #10). 70% of anglers have been fishing the lake for a period of time greater than 15 years (Question #8). When asked how they would describe the current quality of fishing on Big Arbor Vitae Lake, responses were somewhat mixed; 44% responded either "Poor" or "Fair" while 37% responded "Good" or "Excellent" and 9% responded as being "Unsure" (Question #9). The majority (63%) of survey respondents, however, indicated that the fishing has gotten "Much worse" or "Somewhat worse" since they began fishing the lake (Question #11).

Table 3.5-1 shows the popular game fish that are present in the system, while Table 3.5-2 displays some of the non-game fish species. 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 Big Arbor Vitae 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 piscovorous 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 3.5-1.

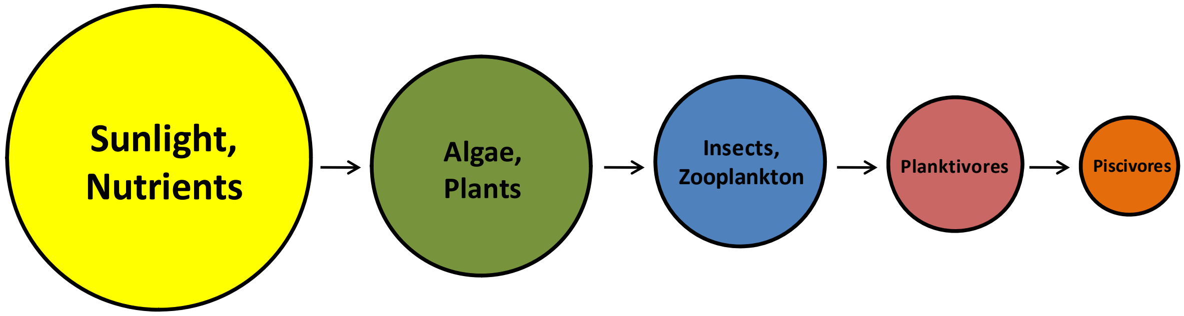


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Big Arbor Vitae Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Big Arbor Vitae Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust.

Because Big Arbor Vitae Lake is located within ceded territory (discussed further below), special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may pertain to Big Arbor Vitae Lake. In 2012-2013, the daily bag limit was adjusted to two walleye per day. There is currently no minimum length limit for walleye, but only one fish over 14” is allowed.

For bass species, a catch and release season exists from the first Saturday in May through the third Friday in June. After the third Saturday in June the minimum length limit is 14” and a daily bag limit is limited to five fish. Big Arbor Vitae Lake is in the northern half of the muskellunge and northern pike management zone. Muskellunge must be 40” to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and five pike may be kept in a single day. Statewide regulations apply for all other fish species.

Table 3.5-1. Gamefish present in the Big Arbor Vitae 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
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, wave-washed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent vegetation	Small fish, aquatic invertebrates

Table 3.5-2 Non-gamefish present in Big Arbor Vitae. Information provided by WDNR Surveys (WDNR 2012).

Common Name	Scientific Name	Common Name	Scientific Name
Blacknose shiner	*Notropis heterolepis*	Iowa darter	*Etheostoma exile*
Bluntnose minnow	*Pimephales notatus*	Johnny darter	*Ethostoma nigrum*
Bowfin	*Amia calva*	Logperch	*Percina caprodes*
Brook Stickleback	*Culaea inconstans*	Mimic shiner	*Notropis volucellus*
Burbut	*Lota lota*	Mottled sculpin	*Cottus bairdi*
Creek chub	*Semotilus atromaculatus*	White sucker	*Catostomus commersoni*
Golden shiner	*Notemigonus crysoleucas*		

Big Arbor Vitae 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 3.5-2). Big Arbor Vitae 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" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that

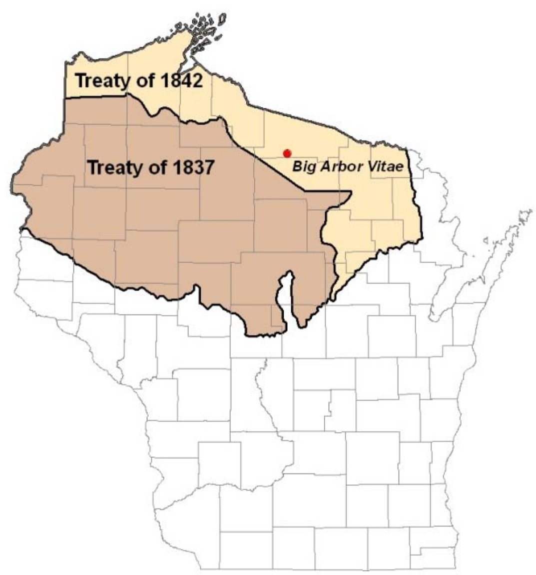


Figure 3.5-2. Location of Big Arbor Vitae Lake within the Native American Ceded Territory (GLIFWC 2012). This map was digitized by Onterra; therefore it is a representation and not legally binding.

reflects the confidence they have in their population estimates for the particular lake. This number is called the “safe harvest level”. Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. 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 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). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

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 2010B). 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. 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 3.5-3. One common misconception is that the spear harvest targets the large spawning females. Figure 3.5-3 shows that 6.4% of the total walleye harvest (213 fish) since 1998 was comprised of female fish. 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 2010B). This regulation limits the harvest of the larger, spawning female walleye.

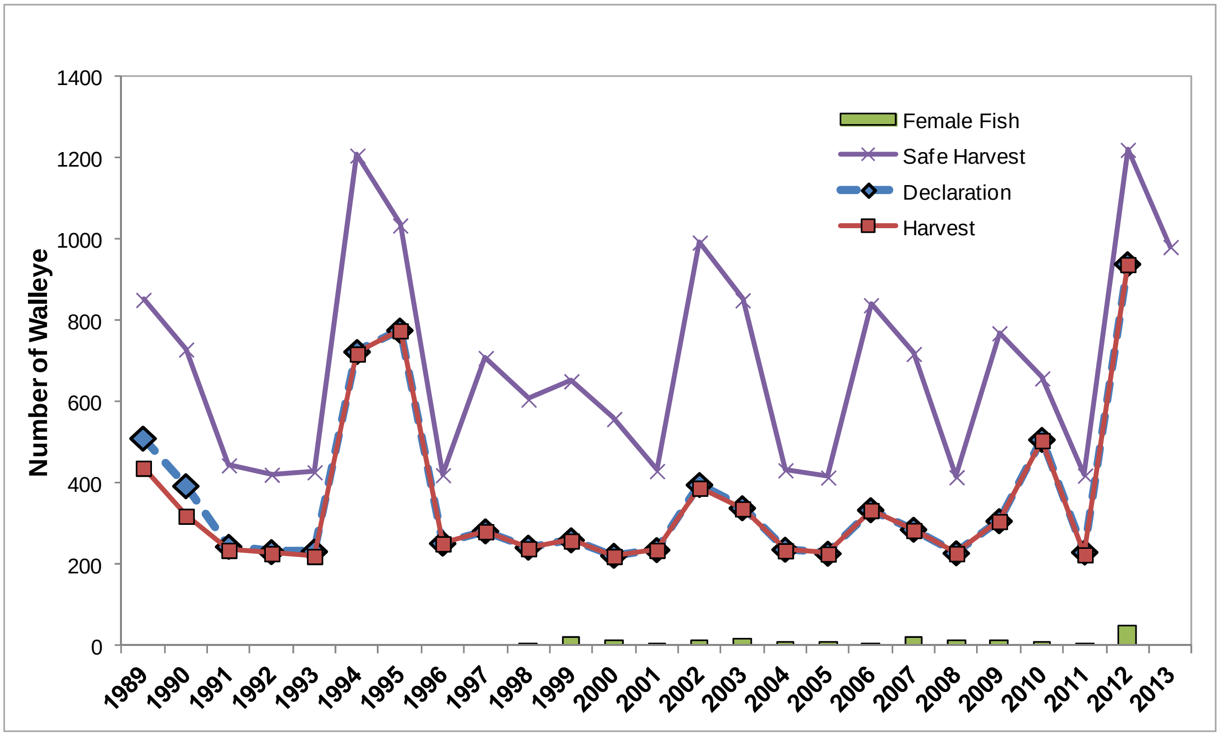


Figure 3.5-3. Open water spear harvest data of walleye for Big Arbor Vitae Lake. Annual walleye spear harvest statistics are displayed since 1989 (T. Cichosz, personal communication).

Figure 3.5-4 displays the Native American open water muskellunge spear harvest since 1998. Since 1998, approximately 11 muskellunge have been harvested per year during the open water spear fishery. Tribal spearers have harvested their full quota on six occasions, and on the average harvest 86% of the declared number of muskellunge per year.

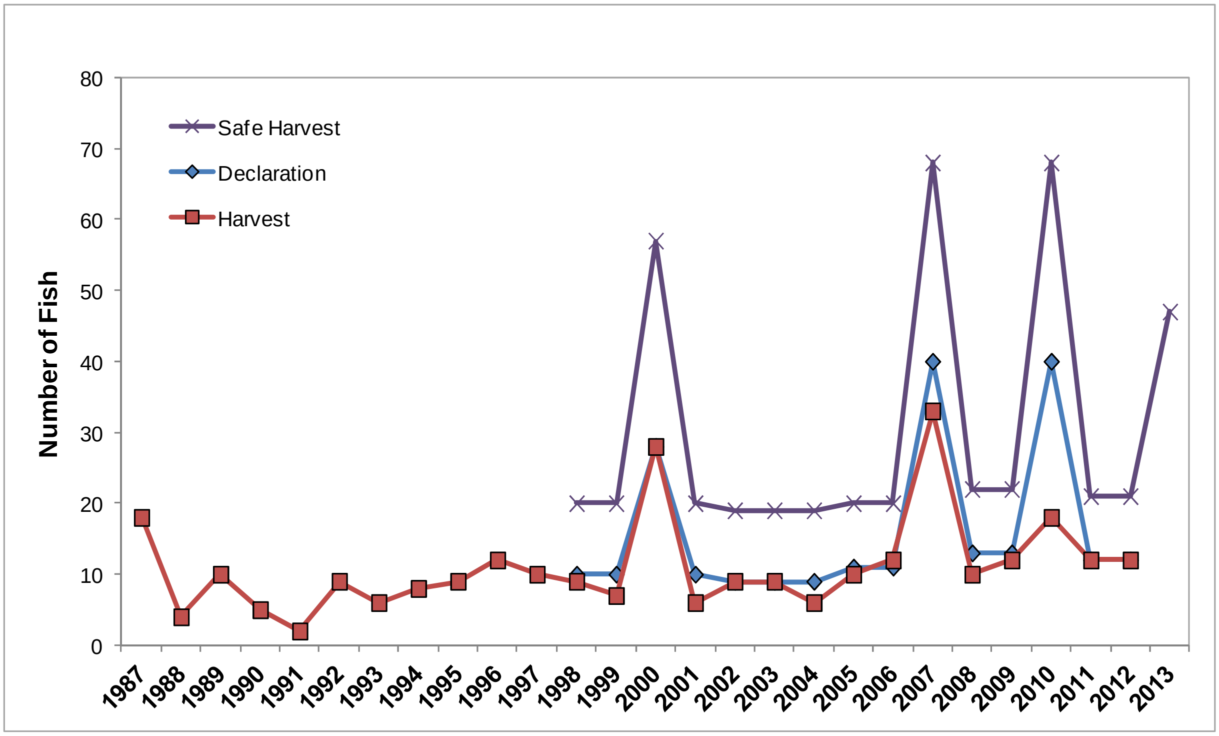


Figure 3.5-4. Big Arbor Vitae Lake muskellunge spear harvest data. Annual total muskellunge harvest and female muskellunge harvest are displayed since 1998 from GLIFWC annual reports for Big Arbor Vitae Lake (Krueger 1998-2010).

Big Arbor Vitae Lake Fisheries Management

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults.

WDNR records indicate that muskellunge have been stocked since 1972, and have been continuously stocked every other year on even years within the last decade at a rate of 1 large fingerling or 0.65 large fingerling per acre (Appendix G). Walleye were stocked most recently in 1995. The walleye in Big Arbor Vitae are naturally reproducing and their populations have consistently been healthy, with the WDNR estimating numbers at between 4.9 and 9 fish per acre in surveys conducted between 1993 and 2011 (WDNR 2012). Typically, stocking of a waterbody is not conducted when natural reproduction of a species is occurring and population numbers are adequate to meet management goals.

Periodically, the WDNR will conduct creel surveys on Wisconsin lakes to gather information on the fishery. Creel surveys are a series of short, informal interviews with fisherman and are conducted right on the lake of interest. They provide valuable information on sport angler activities and their impacts on the fish populations of a waterbody. From this data, fisheries managers can determine trends in total catch and harvest for the lake, and also estimate the number of hours anglers spend pursuing a particular species of fish. Table 3.5-3 summarizes creel survey data from 1993, 2005, 2008 and 2011.

Table 3.5-3. Big Arbor Vitae Lake WDNR Creel Survey Summary (WDNR 2012)

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch / Acre	Harvest / Acre
Largemouth Bass	1993	67.5	1.8	0.2	0.1
	2005	67.4	2.1	1	0
	2008	53	2.4	4.7	0
	2011	54.3	8	9.2	0.2
Muskellunge	1993	67.5	21.5	0.7	0
	2005	67.4	19.7	0.9	0
	2008	53	16.4	0.7	0
	2011	54.3	12.3	0.4	0
Northern Pike	1993	67.5	0.4	0	0
	2005	67.4	1.4	0	0
	2008	53	0.7	0.1	0
	2011	54.3	0.6	0	0
Smallmouth Bass	1993	67.5	0.5	0	0
	2005	67.4	0.8	1	
	2008	53	0.8	0.6	0
	2011	54.3	7.4	2.7	0.1
Walleye	1993	67.5	38.5	21.5	0.5
	2005	67.4	28.9	7.2	4.9
	2008	53	19.9	2.7	1.8
	2011	54.3	22.6	2.8	1.9

Big Arbor Vitae is a popular fishing destination; in 2008 anglers spent 57,790 hours (53 per acre) fishing the lake. In 1993 and 2005, the fishing effort was even greater at 73,466 hours (67.5 and 67.4 hours per acre. Walleye received the most fishing pressure in 2008, with anglers spending 21,665 hours targeting this species. Interestingly, in 2008 there was a substantial decrease in walleye catch and harvest compared to the 2005 census.

In two of the years that creel surveys have been conducted (2005 and 2008) the WDNR has also surveyed Big Arbor Vitae to estimate the populations of gamefish. Additionally, data has been collected on tribal spearing activities for muskellunge and walleye during these years (Figures 3.5-3 and 3.5-4). This provides an opportunity to look at populations of muskellunge and walleye in the lake and where harvests have occurred. Table 3.5-4 displays muskellunge and walleye harvest data compiled through WDNR and GLIFWC reports for years 2005 and 2008, for anglers and tribal spearers. These data suggest that although both anglers and tribal members harvest muskellunge and walleye from the lake, the angler harvest is likely more significant on an annual basis.

Table 3.5-4. Big Arbor Vitae Lake Fish Harvest Summary. Data compiled through WDNR population assessments and creel surveys (WDNR 2012) and WDNR tribal harvest datasets (T. Cichosz, personal communication).

Muskellunge	2005	2008	2011
Population Estimate	647	642	449
Angler Harvest	10	11	7
Angler Harvest %	2%	2%	2%
Tribal Harvest	10	10	12
Tribal Harvest %	2%	2%	3%

Walleye	2005	2008	2011
Population Estimate	6,860	6,290	8,515
Angler Harvest	5,342	2,002	2,117
Angler Harvest %	78%	32%	25%
Tribal Harvest	228	229	226
Tribal Harvest %	3%	4%	3%

Big Arbor Vitae Substrate and Near Shore Habitat

Just as forest wildlife require proper trees and understory growth to flourish, fish prefer certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Indeed, lakes with primarily a silty/soft substrate and much 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.

According to the point-intercept survey conducted by Onterra, 50% of the substrate sampled in the littoral zone on Big Arbor Vitae Lake was muck, with 43% being categorized as sand and the remaining 7% being classified as rock (Map 4). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge 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 is 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 in muck as well.

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.

Heterosporis **sp. – Yellow Perch Parasite**

First found in the Eagle River Chain of Lakes in 2000, yellow perch parasite has since been found in several other northern Wisconsin lakes as well as in Minnesota and Lake Ontario. This parasite is actually closely related to fungi and less similar to other common fish parasites. Although first found in yellow perch, the parasite has also been detected in walleye, northern pike, burbot, pumpkinseed and rock bass as well. The parasite infects muscle tissue of these species, producing millions of spores which eventually destroy the muscle tissue. Affected muscle tissue appears as it is cooked or possibly freezer-burned; it is generally a light, whitish opaque color.

Little is known about the parasite's life cycle, though it is known that a fish may contract the disease when spores are picked up from the water or infected prey fish or carcasses are eaten. Based on studies conducted by the Center for Disease Control in Atlanta, there is currently no evidence that the parasite can infect humans. It is believed, though not proven, that thoroughly cooking infected fish will destroy any parasitic spores. Placing fish fillets in a home freezer for a period greater than 24 hours will also kill the spores. Appendix H contains a informative *Heterosporis* bulletin produced by the Great Lakes Fishery Commission. The WDNR recommends the following to help control the spread of this parasite:

- Do not throw infected fish back into a lake or other natural water body. Instead, place the fish in the garbage or bury them.
- Thoroughly dry all equipment (outside of boats and trailers, nets, boots, etc.) when moving from one water body to another. *Heterosporis* can survive under moist conditions, but are vulnerable to dry conditions (dessication).
- Drain all live wells and bilges away from lakes and rivers, on soil if possible so the water does not run into a natural water body. Because it is difficult to dry live wells and bilges completely, these areas can be disinfected with a bleach solution (one cup bleach in five gallons of water).

4.0 SUMMARY AND CONCLUSIONS

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

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

The three objectives were fulfilled during the project and have led to a good understanding of the Big Arbor Vitae Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

The studies conducted on Big Arbor Vitae Lake indicate that the lake is a fairly healthy ecosystem, albeit with several pressing issues that are of concern to lake residents. Concerns over the lake's water quality, native aquatic plant abundance and now the presence of non-native species have been voiced, rightfully so, by lake residents and other stakeholders. With baseline studies conducted and an initial understanding achieved regarding some of these issues, the BAVLA can begin moving towards management strategies. However, as many questions have been answered as to what is occurring ecologically within the lake, many answers have surfaced as well which will require further investigation.

Water quality analyses indicate that the lake is unexpectedly productive. Annual surface total phosphorus averages fall within 20 to 30 μg/L, which is slightly high for a deep, lowland drainage lake in Wisconsin. During the course of this study, hypolimnetic phosphorus values were observed to be quite high – reaching 220 μg/L during a stratified period in July of 2011 and then reaching nearly 800 μg/L in March of 2012, also during a time of stratification. Phosphorus concentrations were evenly distributed within the water column when oxygen was present in the hypolimnion. This is an indication that a phenomenon seen in some lakes, internal nutrient loading, may be occurring.

Watershed modeling was conducted upon the Big Arbor Vitae Lake to determine what the annual potential phosphorus load is to the lake, based upon the land cover acreages. With a watershed in great condition such as Big Arbor Vitae Lake's, it would be expected that the phosphorus load would be at its minimum. Indeed, this is what the model predicted – a minimal annual total load of 904 lbs. The model was also used to estimate in-lake phosphorus average concentration for the summer months as well as the entire growing season. This estimated average was much lower than what was observed through phosphorus analysis of the water column in 2011. Back-calculating through the model, it was estimated that roughly 1,091 lbs of phosphorus is loaded to the lake on an annual basis, however the model could not account for this additional source. This is a second indication that internal nutrient loading may be occurring in Big Arbor Vitae Lake.

Internal loading, as discussed in the Watershed Section, is a complicated process. Furthermore, many factors have to align in order for internal nutrient loading to impact a lake. A fair amount of lakes experience some amount of internal loading during which nutrients are released from the bottom sediments into the lower water column. In dimictic lakes, which stratify during the summer and winter and turnover only in spring and fall, the impacts of a nutrient-enriched water column may not be observed as algae are not actively growing during the spring and fall. Big Arbor Vitae Lake may turn over several times in a year, depending upon temperature and wind conditions. When this occurs in the mid to late summer, the impacts of nutrient rich water may be observed. The likely result is a dramatic increase in the algal content of the lake.

The algae content of the lake is similar to the median value for all Wisconsin lakes statewide; however, infrequent, intense algae blooms do occur. One such bloom occurred in late summer of 2012, and caused reason for health concern due to the type of algae that was observed – blue-green algae. Blue-green algae are a naturally occurring algal group that is found in Wisconsin lakes. Their numbers may flourish in times of nutrient enrichment, particularly with excessive phosphorus inputs. Phosphorus is the nutrient limiting plant growth in most Wisconsin lakes, but when excessive inputs of phosphorus occur, there are times when algal growth may require more nitrogen, as phosphorus concentrations are ample. Blue-green algae, which are able to utilize nitrogen from the atmosphere, obtain a competitive advantage during this time because they have ample phosphorus and now have a nitrogen source in the atmosphere that other algal forms cannot access. When phosphorus is released to the near-surface water layer via internal nutrient loading, this provides a perfect opportunity for blue-green algae to do well. Some, not all, blue-green algae species release toxins into the water. When their numbers are vast, these toxins may reach concentrations that are harmful to humans as well as dogs and other wildlife.

In addition to algae, native aquatic plants thrive under varying conditions as well. Onterra ecologists observed two very different situations during visits to Big Arbor Vitae Lake in 2011 and 2012. The climatic conditions during the summer of 2011 were relatively cold and fairly overcast. Ice persisted on the Northwoods Wisconsin lakes until late April that year. In contrast, during 2012, ice cover disappeared from many Wisconsin lakes in mid-March and aquatic plant growth started much sooner than normal. Furthermore, temperatures rose quickly and remained quite warm throughout much of the early and late summer. In short, conditions were less than ideal for aquatic plant growth in 2011, but were prime for growth of both plants and algae in 2012.

Big Arbor Vitae Lake stakeholders became very concerned over the levels of aquatic plant growth observed in 2012. During a late summer survey, Onterra ecologists noted several species (primarily coontail and northern water milfoil) had grown to the point of becoming matted on the surface of the lake. In some areas, navigation with watercraft was nearly impossible. The matter was discussed during planning meetings between Onterra staff, the BAVLA Planning Committee and the WDNR (Kevin Gauthier). It was discussed that these plants are growing in a nutrient rich lake, so a certain amount of aquatic plant growth needs to be expected. Exceptional conditions were experienced in 2012 climactically, and this translated into what was likely the worse-case scenario for aquatic plant growth on the lake. Excessive inputs of phosphorus due to internal nutrient loading, while clearly impacting algae growth in the lake, are not expected to play a considerable role in excessive aquatic plant growth because these rooted plants have access to nutrient rich soils at all times. Management actions such as mechanical removal were debated upon during planning meeting discussions, but were deemed very expensive for a minimal payoff. The BAVLA Planning Committee agreed that manual removal of the plants was likely the best option for now, while monitoring of aquatic plant growth in the future was important. The Implementation Plan goes on to discuss means to address worsening conditions of aquatic plant growth, should it be observed in the future.

The growth of an invasive aquatic plant, curly-leaf pondweed, poses a different set of problems. Curly-leaf pondweed was first discovered and mapped by GLIFWC in 2008, and remapped in 2009 by Vilas County. During Vilas County's survey, curly-leaf pondweed was noted as being located at several point-intercept locations, and then mapped along the shoreline of the lake in several other areas of the lake's southeastern bay. In 2011, an Onterra curly-leaf pondweed survey identified five acres of colonized curly-leaf pondweed in the central part of the lake, with other scattered occurrences being found in the southeastern-most bay. While it is unknown to what extent colonization had been present in 2009, as this was not documented, it is safe to assume that according to the differences in density noticed between 2009 and 2011, the curly-leaf pondweed population has spread in both aerial coverage and density. The BAVLA Planning Committee discussed the matter during the course of this project, and has decided to follow a monitoring and control strategy as outlined in the Implementation Plan. This strategy will first accomplish further documentation of any changes that are occurring in the plant community and follow with an appropriate course of action.

As elaborated upon throughout this report, Big Arbor Vitae Lake stakeholders are facing several complicated management issues in the form of invasive species control, water quality issues and to a minor degree native aquatic plant growth. These issues, while identified and initially researched through the course of this study, require additional investigation to fully understand what management activities are appropriate and what kind of ecological impact is possible. Within the next section, the Implementation Plan, specific tasks are outlined which enacted will guide the BAVLA towards further understanding, and beginning the process of remediating, the Big Arbor Vitae Lake ecosystem.

5.0 IMPLEMENTATION PLAN

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

Management Goal 1. Control and Contain the Current Curly-Leaf Pondweed Infestation and Prevent Future Aquatic Invasive Species Introductions to Big Arbor Vitae Lake.

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Big Arbor Vitae Lake public access.

Timeframe: Continuation of current efforts.

Facilitator: Planning Committee.

Description: At this time, the only aquatic invasive plant known to exist within Big Arbor Vitae Lake is curly-leaf pondweed. This infestation is thought to be fairly recent, with the species first observed in 2008. Though the lake now holds approximately five acres of this invasive plant, further actions (described below) are being undertaken to control and monitor the population. Right now, an important aspect of managing Big Arbor Vitae Lake's ecosystem lies in prevention of the introduction of further aquatic invasive species. Additionally, it is of great importance that any invasive species (Big Arbor Vitae also holds rusty crayfish, banded mystery snail and Chinese mystery snail) are not transported from this lake to others nearby.

Members of the BAVLA have been trained on Clean Boats Clean Waters (CBCW) protocols and complete boat inspections at the public landings on a regular basis. Because this system is currently free of exotic species, the intent of the boat inspections is to prevent additional invasives from entering the lake through its public access point. The goal would be to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of aquatic invasive species on our lakes and educating people about how they are the primary vector of its spread. In 2012, 40 boats were inspected during 17 hours of watercraft inspections at two boat landing locations.

Action Steps:

1. Members of association periodically attend Clean Boats Clean Waters training session through the volunteer AIS Coordinator (Erin McFarlane – 715.346.4978) to update their skills to current standards.
2. Training of additional volunteers completed by those trained in previous summers.
3. Continue inspections during high-use weekends.
4. Report results to the WDNR and BAVLA
5. Promote enlistment and training of new volunteers to keep program fresh.

<u>Management Action:</u> Initiate assessment of shoreline and littoral areas of the lake for aquatic invasive species.

Timeframe: Begin Summer 2013

Facilitator: Planning Committee

Description: In lakes without Eurasian water milfoil and curly-leaf pondweed, early detection of these species commonly leads to successful control and in cases of small infestations, possible even eradication. Additionally, monitoring of current populations of curly-leaf pondweed is important as documentation of the spread of this plant is necessary.

One way in which lake residents can spot early infestations of aquatic invasive plants is through conducting "Lake Sweeps" on their lake. During a lake sweep, volunteers monitor the entire area of the system in which plants grow (littoral zone) annually in search of non-native plant species. This program uses an "adopt-a-shoreline" approach where volunteers are responsible for surveying specified areas of the lake.

In order for accurate data to be collected during these surveys, volunteers must be able to identify non-native species such as Eurasian water milfoil and curly-leaf pondweed. Distinguishing these plants from native look-a-likes is very important. Additionally, the collection of suspected invasive plant would need to be collected for verification, and, if possible, GPS coordinates should be collected.

Action Steps:

1. Volunteers from BAVLA update their skills by attending a training session conducted by WDNR/UW-Extension through the AIS Coordinator for Vilas County (Ted Ritter – 715.479.3738).
2. Trained volunteers recruit and train additional association members.
3. Complete surveys following protocols.
4. Report results to the WDNR, BAVLA and consultant if necessary.

Management Action: Contact Water Guard John Preuss regarding watercraft usage at Big Arbor Vitae public access.

Timeframe: Begin Summer 2013

Facilitator: Planning Committee

Description: During the planning process associated with this project, members of the Planning Committee expressed concern over a local watercraft sales business and their use of Big Arbor Vitae Lake to test-run watercraft. With bringing multiple watercraft to a lake and running them to ensure adequate motor function, it is important that the business be aware of and also adhere to standards and regulations set forth by the state of Wisconsin for watercraft use. Currently, it is the uncertainty of lake residents of how this business reduces transport of organisms and water from one lake to the next that is of chief concern.

A member of the Big Arbor Vitae Lake Planning Committee will contact local water guard John Preuss regarding this matter, to ascertain if Mr. Preuss has had prior discussions with this business owner about techniques to reduce transport of aquatic invasive species. This BAVLA member will then make friendly contact with the business owner to hold a discussion on the dangers and impacts of aquatic invasive species, and what might be done to limit spread of these species by the watercraft the business operates. If an amicable relationship is established, no further action may be needed. If difficulty is reached in coming to an agreement on the issue, further contact by Mr. Preuss or other regulatory entities may be necessary.

Action Steps:

1. See above description.

Management Action: Develop monitoring and control strategy for curly-leaf pondweed infestation in Big Arbor Vitae Lake.

Timeframe: Begin Summer 2013

Facilitator: Planning Committee

Description: Curly-leaf pondweed was first located in Big Arbor Vitae Lake in 2008, and has grown to a 2011 population of roughly five acres of colonized growth. Additional areas of single/few plants, clumps and small plant colonies exist. While still a recent introduction, the level of growth in Big Arbor Vitae Lake is beyond manual removal; eventually, if control efforts are to be initiated, an herbicide application will be the only reasonable means of combating this invasive plant.

In summer of 2013, a survey will be conducted to map the densities and locations of curly-leaf pondweed growth in Big Arbor Vitae Lake. This survey will occur in mid-June, or at a time when the plant has reached its peak growth but has not yet senesced (died off). This will give the WDNR, BAVLA and Onterra ecologists a good idea of how the population has changed between 2011 and this time period. From these survey results, one of two decisions will be made regarding further actions on the plant colonies. 1) If the colonies have expanded little or have changed in density very little, the BAVLA may elect to continue monitoring and forgo an herbicide treatment until the dynamics of the species in this lake are understood. In some northern Wisconsin lakes, curly-leaf pondweed expands very little and does not cause tremendous issues on the lake. 2) If colonial expansion or density increases are observed, the BAVLA may elect to proceed with herbicide treatments on areas delineated within the 2013 survey. These herbicide treatments would occur in 2014 using the methodology outlined below. The results of the 2013 survey would be used to approximate acreage for treatment.

2014 Curly-leaf Pondweed Pre-treatment Survey

In May 2014, Onterra ecologists would visit areas marked through the summer 2013 mapping survey to verify the growth of curly-leaf pondweed. This survey would determine if colonial expansion had occurred from the previous year and would be utilized to determine the final treatment areas.

Herbicide Concentration Monitoring

Following the application of the herbicide, trained BAVLA volunteers will collect water samples from both within the treatment area and outside of the treatment area at set intervals to understand the herbicide concentration in these areas. Samples would be collected following a study design determined by the United States Army Corps of Engineers (USACE). Following collection, properly preserved samples will then be sent to the USACE laboratory for analysis. The information obtained from this monitoring will tell the BAVLA if target concentrations were reached, how long the herbicide resided in the water column, how long it took to diffuse, etc. In short, this information would be useful for further herbicide decision making.

2014 Curly-leaf Pondweed Post-treatment Survey

In June 2014, when curly-leaf pondweed is at or near its peak growth, Onterra ecologists would again survey known areas of curly-leaf pondweed to qualitatively assess the effectiveness of the treatment. Because of curly-leaf pondweed's unique lifecycle, quantitative assessments following the treatment would not be able to differentiate mortality caused by the herbicide and the natural senescence of the plant at that time of year.

A Note on Curly-leaf Pondweed Herbicide Applications

Applying herbicide within the aquatic environment is much different than on a terrestrial environment. 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. Spot treatments (such as what is proposed for Big Arbor Vitae Lake) that target a specific colony of that target plant have extremely short exposure times (hours) due to dilution of the herbicide within the lake. In spot treatments, a high herbicide dose is required to offset the short exposure time. Not surprisingly, a larger treatment area holds concentrations at a higher level for a longer time than smaller treatment areas.

In controlling curly-leaf pondweed, a contact herbicide is applied to the target plant colonies. This herbicide works through contact with the tissue of the plant's structure, as opposed to a systemic herbicide which incorporates the herbicide into the plant. Contact herbicides are non-selective, meaning they may impact native species. For this reason, herbicide use is reserved for late spring, or until water temperatures have reached 60°F and native aquatic plants have begun actively growing. This reduces the impacts the native aquatic plant community may see as a result of the herbicide application.

Curly-leaf pondweed has been present in Big Arbor Vitae Lake for several years. As discussed in the Aquatic Plants Section, this plant has an unusual life cycle that is unlike Wisconsin's native plants. In mid-summer, the plant senesces and leaves behind small reproductive structures called turions. These turions fall to the sediment and produce next year's plants. After only several years, turions will build in the sediments of the lake. In subsequent years, these turions may sprout and produce plants long after their original host plant had perished. As a result, it takes several years to achieve success in curly-leaf pondweed control, because the goal is to deplete the turion base that has built up from previous years of deposition.

Control Project Applicable Funding

Costs for 2013 monitoring would be able to be collected should the BAVLA be successful in obtaining funds through the WDNR Aquatic Invasive Species Grant Program. Specifically, an Early Detection and Response Grant would be applicable to assist with partially funding this control program. This grant would provide funding for monitoring and treatment costs in a multi-year project, and would be written following 2013 surveys.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the cyclic series of steps discussed above.
2. Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3. Initiate control plan.
4. Revisit control plan in 3-6 years.
5. Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Goal 2. Enhance Current Water Quality Conditions

Management Action: Monitoring of Big Arbor Vitae Lake's water quality through the WDNR Citizen Lake Monitoring Network.

Timeframe: Begin 2013.

Facilitator: Planning 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 will likely aid in an earlier definition of what may be causing the trend.

The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. At this time, there are no BAVLA members currently collecting data as a part of the CLMN. Volunteers trained by the WDNR as a part of the CLMN program begin by collecting Secchi disk transparency data for at least one year, then if the WDNR has availability in the program, the volunteer may enter into the *advanced program* and collect water chemistry data including chlorophyll-a, and total phosphorus. The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. Note: as a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

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

Action Steps:

1. Contact Sandra Wickman (715.365.8951) to determine if space is available in the CLMN program.
2. Board of Directors recruits volunteer coordinator from the BAVLA.
3. Coordinator directs water quality monitoring program efforts and volunteers.
4. Volunteers collect data and coordinator/volunteers report results to WDNR and to association members during annual meeting.

Management Action: Discover/Investigate unaccounted sources of phosphorus impacting Big and Little Arbor Vitae Lakes.

Timeframe: Begin 2014

Facilitator: Big Arbor Vitae Lake and Little Arbor Vitae Lake Boards of Directors

Description: As discussed in the Water Quality and Watershed sections, total phosphorus concentrations in Big Arbor Vitae Lake are unexpectedly high based upon watershed characteristics indicating an unaccounted source(s) of phosphorus is being delivered to the lake. Data collected in 2011 suggests that at least a portion of this phosphorus is originating from bottom sediments. Big Arbor Vitae Lake is polymictic, meaning it has the potential to break stratification and turnover multiple times throughout the growing season provided there is sufficient wind energy. When Big Arbor Vitae Lake becomes stratified, the lower layer of water (the hypolimnion) becomes anoxic and high levels of phosphorus are released from bottom sediments. Periodically throughout the growing season, likely during high-wind events, the lake breaks stratification and the high concentrations of phosphorus within the hypolimnion are mixed throughout the water column where it can fuel algae blooms. Little Arbor Vitae Lake is also polymictic and studies conducted in 2010 indicate higher than expected levels of phosphorus within the lake and that this same phenomenon of periodic phosphorus delivery from bottom sediments is also occurring.

Big Arbor Vitae and Little Arbor Vitae Lakes share much of the same watershed, and the high concentrations of phosphorus in Big Arbor Vitae Lake are likely being delivered to Little Arbor Vitae Lake through Link Creek. For these reasons, Onterra proposes that a project involving both lakes be conducted simultaneously, with the BAVLA and Little Arbor Vitae Lake Protection and Rehabilitation District (LAVLPRD) dividing the costs. This study would include an intense sampling regime over the course of two growing seasons to determine from where the majority of the unaccounted phosphorus is originating. The BAVLA and LAVLPRD would apply for a Wisconsin Department of Natural Resources Lake Protection Grant under the Diagnostic/Feasibility Category as early as May of 2014. Instrumentation used for the project would be calibrated and tested during the summer of 2013, and the project would deploy during the growing seasons of 2014 and 2015 yielding two years of data. The study would include the following components:

Internal Phosphorus Load Modeling

As part of the internal load modeling component, total phosphorus samples would be collected from near-surface and near-bottom depths from both lakes every two weeks from mid-April through October by BAVLA and LAVLPRD volunteers. A dissolved oxygen and temperature profile would also be created during each of the sampling events.

Big Arbor Vitae and Little Arbor Vitae Lakes Tributaries Monitoring

Flow meters will be deployed at the mouths of the inlets flowing into both Big Arbor Vitae and Little Arbor Vitae Lakes to obtain continuous flow measurements. In addition, total phosphorus samples would be collected at these locations every two weeks and following storm events by BAVLA and LAVLPRD volunteers. These data will be processed using the United States Army Corps of Engineers FLUX model to estimate the loads of phosphorus entering through the inlets. It must be noted that this portion of the study will only be applicable if there is a suitable area where the equipment can be deployed.

Groundwater Flow and Nutrient Monitoring

In order to understand the contribution of groundwater to both Big Arbor Vitae Lake and Little Arbor Vitae Lake, monitoring would be conducted to determine groundwater flow direction, flow quantity and nutrient contribution to these systems. Piezometers would be deployed around both lakes and utilized to determine inflow, outflow and static areas of groundwater movement. These monitoring locations would provide access to flow quantity and quality measurements as well.

Sediment Core Analysis

Bottom sediment cores would be collected from 5-10 locations throughout the lake for phosphorus partitioning. This type of analysis determines the phosphorus constituents within the sediment based upon sediment depth. The analysis would be used to determine the amount of phosphorus that is available for release during internal loading. It is also important in understanding how an alum treatment would be dosed if completed.

Action Steps:

1. Participate in Scoping Meeting between BAVLA, LAVPRD and consultant. Meeting would be held to further answer any questions regarding the studies that have previously been conducted and begin discussion on further monitoring activities, including parameters to be tested, study timeframe, grant assistance, etc.
2. Consultant solidifies study design with assistance from WDNR and other agencies as applicable.
3. Create preliminary project cost estimate.
4. Study design is proposed to WDNR technical review team.
5. Apply for Lake Protection Grant in May 2014.

Management Goal 3. Gain Further Understanding of the Big Arbor Vitae Lake Fishery.

Management Action: Work with fisheries managers to understand and enhance fishery while communicating aspects of fishery studies to BAVLA members.

Timeframe: Ongoing.

Facilitator: Planning Committee.

Description: Fishing, a hobby that is no stranger to Wisconsin residents, was ranked as the second most important activity by Big Arbor Vitae Lake stakeholders in a 2011 survey (Appendix B, Question #13). The vast majority (70%) of survey respondents indicated that they have fished the lake for a period longer than 15 years (Question #8), and indicated that walleye, crappie and other panfish species were their favorite to fish for (Question #10). Muskellunge was also a popular species.

BAVLA members wish for fishing conditions in the lake to remain the same or improve. To keep realistic expectations about the Big Arbor Vitae Lake fishery, an understanding of the habitat and population dynamics must be obtained. Fortunately, Big Arbor Vitae Lake is studied often by WDNR and GLIFWC biologists. Big Arbor Vitae Lake is considered a “trend” lake, meaning that a comprehensive survey takes place every three years to identify changes in the fish community. Because there are so many lakes in Wisconsin, many lakes do not receive this much attention from fishery managers with the WDNR. With so much attention being received from WDNR and GLIFWC biologists, the BAVLA has several knowledgeable biologists at hand to answer questions on the fishery, who themselves have data from numerous years to draw conclusions from.

The BAVLA would like to continue to strengthen its relationship with the WDNR and GLIFWC fisheries biologists, and learn of the monitoring studies each entity is conducting. A representative of the Planning Committee will be appointed to contact WDNR biologists (Steve Gilbert, WDNR Inland Fisheries Biologist Vilas County: 715-356-5211 ext. 229 and Dennis Scholl, WDNR Treaty Fisheries Supervisor: 715-356-5211 ext. 210) on an annual basis. The purpose of the contact would be to go over any surveys that are occurring that particular year, obtaining results from previous surveys, etc. The BAVLA volunteer will ask for a WDNR representative to come to a BAVLA meeting and deliver a short presentation on the fishery status of Big Arbor Vitae Lake, perhaps on an annual or bi-annual basis. Additionally, the BAVLA may discuss options for improving the fishery in Big Arbor Vitae Lake, which may include changes in angling regulations, habitat enhancements, or private stocking.

Action Steps:

1. See above description.

Management Goal 4. Solidify and Strengthen Big Arbor Vitae Lake Association Functionality.

Management Action: Finalize 501(c)3 status, formalize by-laws.

Timeframe: Complete in 2013.

Facilitator: Board of Directors.

Description: At the second planning meeting, members of the BAVLA Board of Directors discussed the need to finalize several association formalities, including their 501(c)3 status and by-laws. Completing these tasks will improve functionality of the group. Board members will discuss these tasks during the winter of 2012/2013, with the goal of having these complete by summer 2013.

Action Steps:

1. See above description.

Management Action: Increase membership and participation.

Timeframe: Complete in 2013.

Facilitator: Board of Directors.

Description: The effectiveness of a lake association is often a reflection of the time and talents of the individuals the association draws from. While it is true that several dedicated people can conduct a vast amount of association-related work, it is helpful to have a large pool of volunteers and talent to draw upon for various lake association and lake management related tasks.

The BAVLA is a fairly new organization, but has grown strong in its initial years, undertaking many large projects and drawing a good foundation of support from riparian property owners. The board of directors has discussed improving membership still, and also improving participation within the group. At the second planning meeting, these topics were discussed at length.

To increase membership within the BAVLA, volunteers from the association will meet with their neighbors face-to-face for friendly conversations about the benefits of membership, what a BAVLA membership entails, etc. This type of membership drive is not only more effective than a limited form of contact, but helps to build a sense of community and friendship amongst neighbors. These face-to-face drives may be utilized to ask for assistance in volunteer-heavy tasks, such as the CBCW program.

Also discussed at the second meeting was the possibility of having a two-tier membership. Some "lake residents" live off of the lake and therefore do not see the need to become a member of the BAVLA.

Current members discussed having an Associate Membership option, in addition to the full membership. The Associate Member would pay less in annual dues, but would be eligible for some (but not all) of the association benefits. The BAVLA Board of Directors will discuss the viability of a two-tier membership system, and determine payments, benefits included, etc. for each membership option.

Action Steps:

1. See above description.

<u>Management Action:</u> Formalize Standing Committees.

Timeframe: Complete in 2013.

Facilitator: Board of Directors.

Description: With the BAVLA taking on many different lake related tasks (management plan, further nutrient studies, curly-leaf pondweed management, various social events, CBCW inventories, etc.), the distribution of these tasks amongst several people has become vital. Already, the group has moved towards forming committees to distribute this work load. Discussion at the second planning meeting resulted in four current, non-formal committees:

- Education and Communication Committee
- Membership Committee
- Social Committee
- Fundraising Committee

In 2013, the BAVLA Board of Directors will finalize their standing committees, including the committee descriptions which will include committee officers, tasks to work on, and goals to develop. The distribution of work will make the BAVLA more efficient in conducting lake-related business.

Action Steps:

1. See above description.

Management Goal 5. Assure Reasonable Access to Open Water Portions of Big Arbor Vitae Lake.

<u>Management Action:</u> Annually Assess Need for Mechanical Harvesting Plan

Timeframe: Initiate July of 2013.

Facilitator: Planning Committee.

Description: As discussed within the Aquatic Plant Section and the Summary and Conclusions Section, the potential for aquatic plant problems exists on Big Arbor Vitae Lake. This was observed in 2012 when conditions were very conducive for plant production. Members of the BAVLA believe that over the years, aquatic plant nuisance conditions have been worsening. The word “nuisance” is difficult to define, because each person’s tolerance is different in terms of aquatic plant growth. The WDNR’s Northern Region Aquatic Plant Management Strategy document (Appendix I) states that “severe impairment or nuisance will generally mean vegetation grows thickly and forms mats on the water’s surface”. In general, nuisance conditions are such that navigation of watercraft through aquatic plant beds is severely impeded. This would not be applicable to areas in which no homes are present; thus there is no reason to access shorelines in these areas.

Harvesting was discussed thoroughly at the BAVLA Planning Meetings for its applicability to Big Arbor Vitae Lake. Some of the limitations, including logistics and cost, were discussed at length. Some of these limitations include the permitting process and availability of harvesting contractors. Also discussed were the benefits. The BAVLA sees the potential and applicability of harvesting in the future, if nuisance conditions worsen, and will follow the step-wise procedure listed below on an annual basis to determine feasibility.

Action Steps:

1. Annually, the BAVLA Board of Directors will discuss the need for harvesting by the end of July. If it is determined by the board that nuisance conditions exist, contact will be made with the WDNR Northern Region Lake Coordinator (Kevin Gauthier – 715-365-8937) to schedule a time for a lake visit.
2. If the WDNR believes that nuisance conditions exist and that harvesting is a feasible option, the lake association will contact a firm that is capable of mapping the presence of nuisance aquatic plants and constructing a harvesting plan. Permits will need to be filed with the WDNR.
3. Because of the timing of lake surveys and time associated with permitting and logistics planning, the harvesting plan that is created will be applicable for the following summer. Note that if nuisance conditions do not exist the following summer, as determined by the WDNR and the BAVLA, harvesting will not occur. This would require another lake survey by WDNR personnel.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Big Arbor Vitae Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

Parameter	Spring		June		July		August		Fall		Winter	
	S	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**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	●											

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 5.

Watershed Analysis

The watershed analysis began with an accurate delineation of Big Arbor Vitae 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 Big Arbor Vitae Lake during a June 28, 2011 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 Big Arbor Vitae Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on July 22 and 27, 2011. A point spacing of 63 meters was used resulting in approximately 1,090 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Big Arbor Vitae 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 – Stevens Point Herbarium. A set of samples was also provided to the BAVLA.

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