Little Arbor Vitae Lake

Vilas County, Wisconsin

Comprehensive Management Plan

September 2013

DRAFT

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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:

Little Arbor Vitae Lake Planning Committee

Nancy Grapentine
Gary Grapentine
Scott Popelka
Paul Wroblewski
Jerry Brzeski
Bob Johnson
Glenn SPeich
Dick Zagrzebski
Fritz Brandenburg
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Wisconsin Dept. of Natural Resources
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1.0 INTRODUCTION

Little Arbor Vitae Lake, Vilas County, Wisconsin, is a 534-acre drainage lake with a maximum and mean depth of 32 and 11 feet, respectively. This productive, eutrophic lake has a relatively large watershed encompassing nearly 22 square miles, and in 2010, was found to contain 34 native plant species, of which coontail (*Ceratophyllum demersum*) is the most common plant. A few plants of the non-native purple loosestrife (*Lythrum salicaria*) were observed growing along the shoreline of the lake.

Field Survey Notes

Large amount of natural shoreline noted surrounding lake. A variety of wildlife seen during survey: eagles, loons, white-tail deer, and several northern water snakes.

Very green water noted during several summer field surveys.

Photograph 1.0-1. Little Arbor Vitae Lake, Vilas County, Wisconsin.

Lake at a Glance - Little Arbor Vitae Lake

Morphology	
Acreage	534
Maximum Depth (ft)	32
Mean Depth (ft)	11
Shoreline Complexity	3.9
Vegetation	
Curly-leaf Survey Date	June 24, 2010
Comprehensive Survey Date	August 2 & 3, 2010
Number of Native Species	34
Wisconsin Natural Heritage Listed Species	0
Exotic Plant Species	Purple loosestrife (*Lythrum salicaria*)
Simpson's Diversity	0.79
Average Conservatism	6.3
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.8 - 8.9
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	21:1

The Little Arbor Vitae Protection and Rehabilitation District (LAVLPRD) was formed in the 1970's to meet the requirements for the creation of a dam at the lake's outlet. Since its inception, its members have expanded their responsibilities to include the protection and enhancement of the Little Arbor Vitae Lake ecosystem. With hard work they have monitored the lake for invasive species through the Shoreline Sentinels and Clean Boats Clean Waters Programs, and kept their membership informed on lake-related topics.

The LAVLPRD was interested in creating a lake management plan for two primary reasons. First, they want to be in a position which will allow them to react quickly to invasive species if they ever become established within the lake. The district understands 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. And second, they understand the value in gaining a better understanding of the overall condition of the lake. In the end, the information obtained would help guide future LAVLPRD plans and programs.

Little Arbor Vitae Lake is a highly sought after location amongst recreationists and anglers. Annual tournaments, such as the Greater Wisconsin Muskie Tournament occur on the lake and it is home to a single resort (Blue Island Resort). These intense public use opportunities expose the lake to potential AIS introductions, especially considering Little Saint Germain Lake, which is used in the Greater Wisconsin Muskie Tournament, holds both curly-leaf pondweed and Eurasian water milfoil. Furthermore, Big Arbor Vitae Lake, which drains to Little Arbor Vitae Lake via Link Creek, contains an established population of curly-leaf pondweed. All of these lakes provide sources of invasive species that would add to the Little Arbor Vitae Lake's existing rusty crayfish and Chinese mystery snail occurrences.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting

On June 10, 2010, a project kick-off meeting was held at the Arbor Vitae Community Center to introduce the project to the general public. The meeting was announced through a mailing and personal contact by LAVLPRD board members. The approximately 25 attendees observed a presentation given by Eddie Heath, an aquatic ecologist with Onterra. Mr. Heaths's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Stakeholder Survey

During September of 2010, a seven-page, 26-question survey was mailed to 106 riparian property owners in the Little Arbor Vitae Lake watershed. Fifty-six percent of the surveys were returned and those results were entered into a spreadsheet by members of the Little 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.

Planning Committee Meeting I

On October 25th, 2011, Tim Hoyman and Brenton Butterfield of Onterra met with several members of the Little Arbor Vitae Lake Planning Committee for over 3 hours. In advance of the meeting, attendees were provided an early draft of the study reports sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including water quality and watershed analyses and modeling, aquatic plant inventories, and stakeholder survey results were presented and discussed. Concerns regarding the lake's water quality, introduction of AIS by visiting lake users, and lack of community and district member involvement were raised by the committee members.

Planning Committee Meeting II

On November 16, 2011, Tim Hoyman and Brenton Butterfield met with the members of the Planning Committee to begin developing management goals and actions for the Little Arbor Vitae Lake management plan. The group constructed a Mission Statement, located in the beginning of the Implementation Plan Section, that will serve to guide to committee and the LAVLPRD as they manage and monitor the lake ecosystem.

Planning Committee Meeting III

On June 17, 2013, Tim Hoyman met with the members of the Planning Committee and the LAVLRPD Board of Directors at the Arbor Vitae Town Hall to go through the details of the draft Implementation Plan that the Planning Committee and Onterra staff had created during Planning Meeting II.

Project Wrap-up Meeting

Has not yet occurred.

Management Plan Review and Adoption Process

Following Planning Meeting III, Glenn Speich provided a summary of the Implementation Plan to district members at the district's annual meeting on June 22, 2013, and the district members voted to move forward with the goals and actions outlined within the Implementation Plan.

Stakeholder Survey

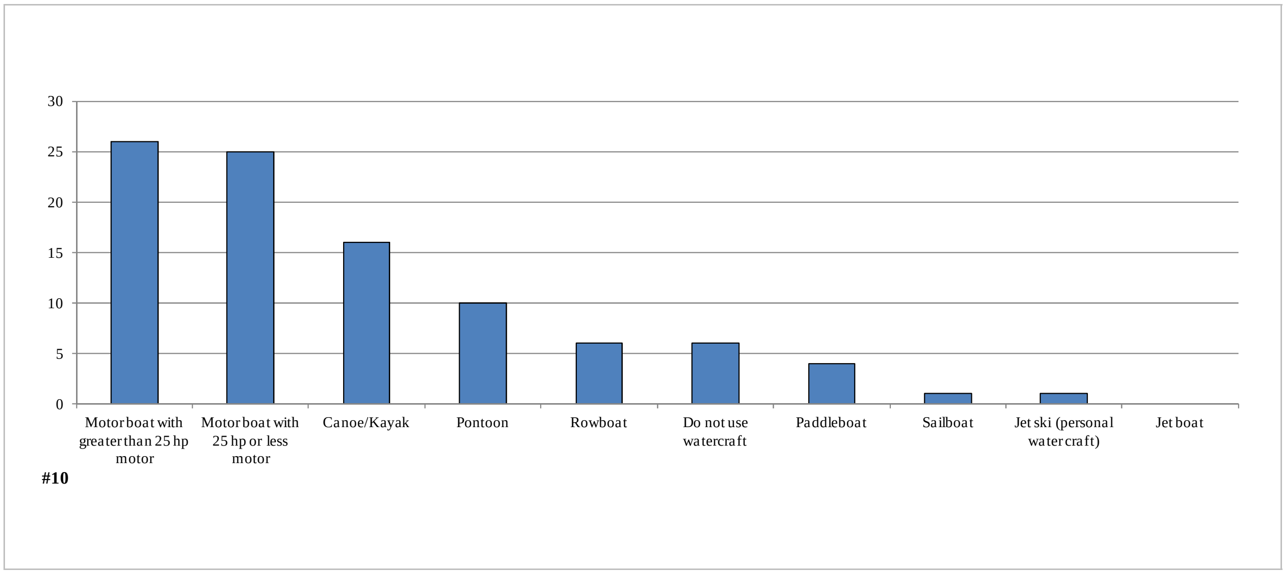
During September of 2010, a seven-page, 26-question survey was mailed to 106 riparian property owners in the Little Arbor Vitae Lake watershed. 56 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Little Arbor Lake Planning Committee. The data were 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 Little Arbor Vitae Lake. The majority of stakeholders (40%) are year-round residents, while 26% visit seasonally and 19% visit on weekends through the year (Question #1, Appendix B). 50% of stakeholders have owned their property for over 15 years, and 28% 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. A little under half of survey respondents indicate that they use a motor boat on the lake, while canoes/kayaks and pontoon boats were also popular options (Question #10). On any size lake, the importance of responsible boating activities is important. 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 #11, several of the top recreational activities on the lake involve boat use. Boat traffic was ranked fairly low on a list of stakeholder's top concerns regarding the lake (Question #18).

A concern of stakeholders noted throughout the stakeholder survey (see Question 18 and survey comments – Appendix B) was algae blooms and excessive aquatic plant growth. These topics are touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Question #10: What types of watercraft do you currently use on the lake?



Question #11: Please rank up to three activities that are important reasons for owning your property on or near the lake.

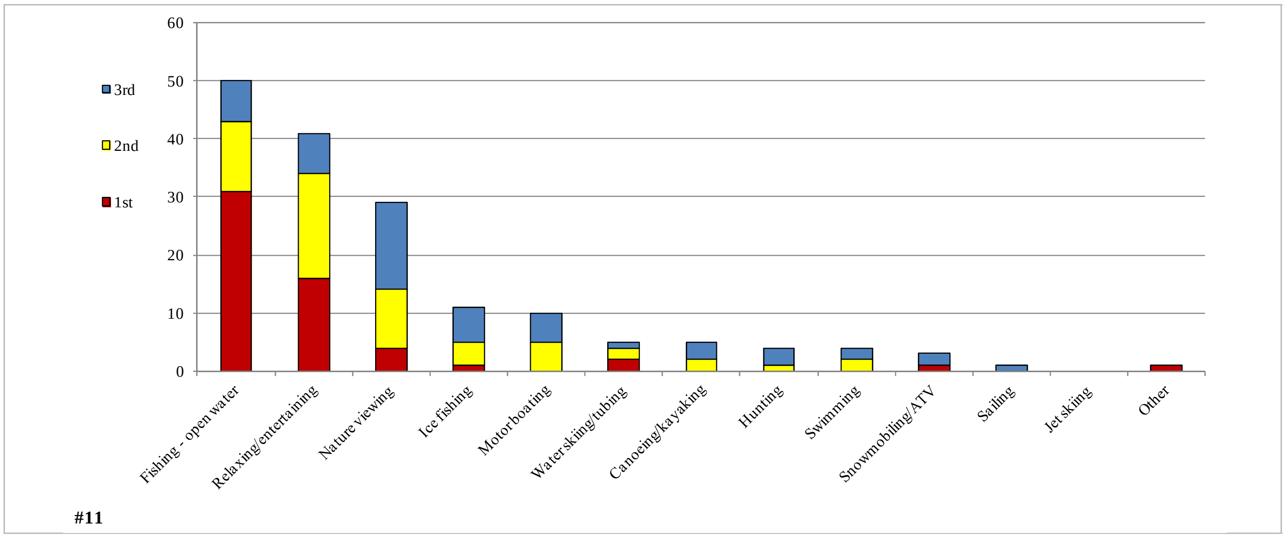
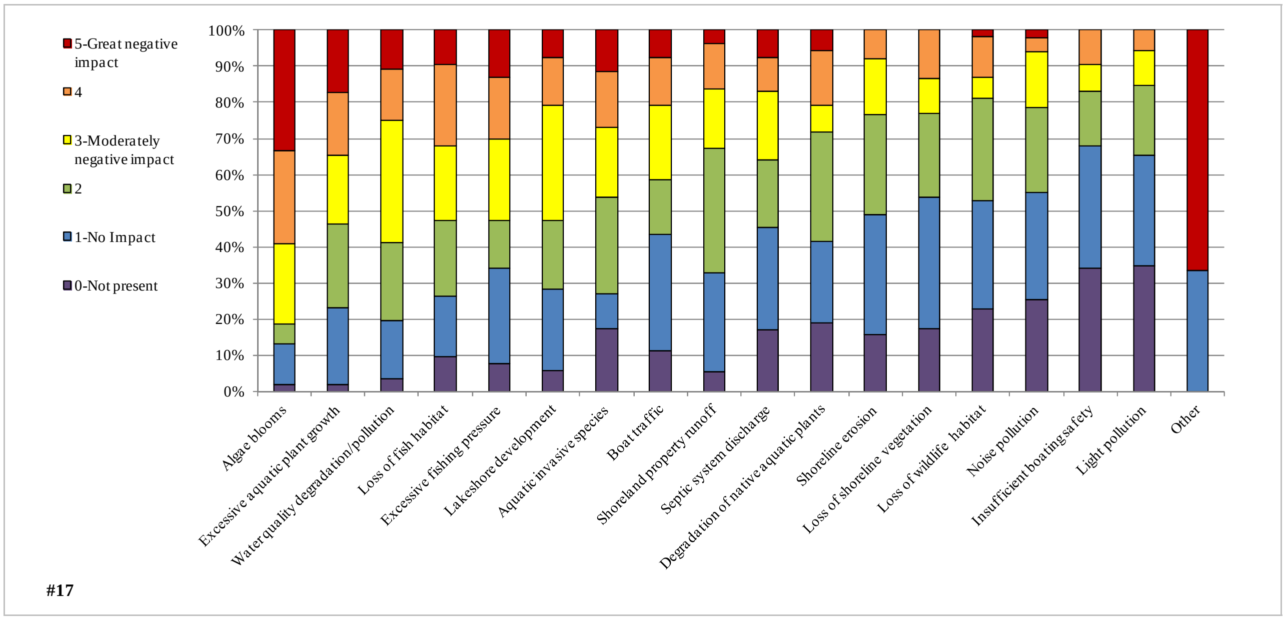


Figure 2.0-1. Select survey responses from the Little Arbor Vitae Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question #17: To what level do you believe these factors may be negatively impacting Little Arbor Vitae Lake?



Question #18: Please rank your top three concerns regarding Little Arbor Vitae Lake.

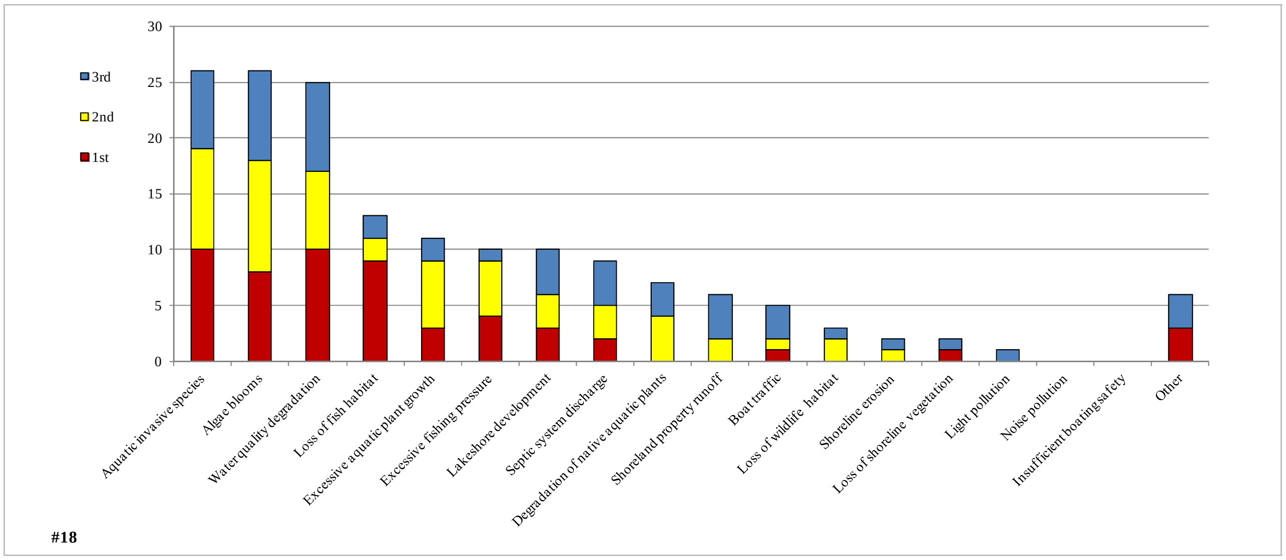


Figure 2.0-2. Select survey responses from the Little Arbor Vitae Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Little Arbor Vitae is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region. Little Arbor Vitae water quality values are included within 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 Little Arbor Vitae's water quality analysis:

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

> Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epiliminion 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 Little Arbor Vitae 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). These lakes differ in many ways; for example, in their oxygen content and where aquatic plants may be found. 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.

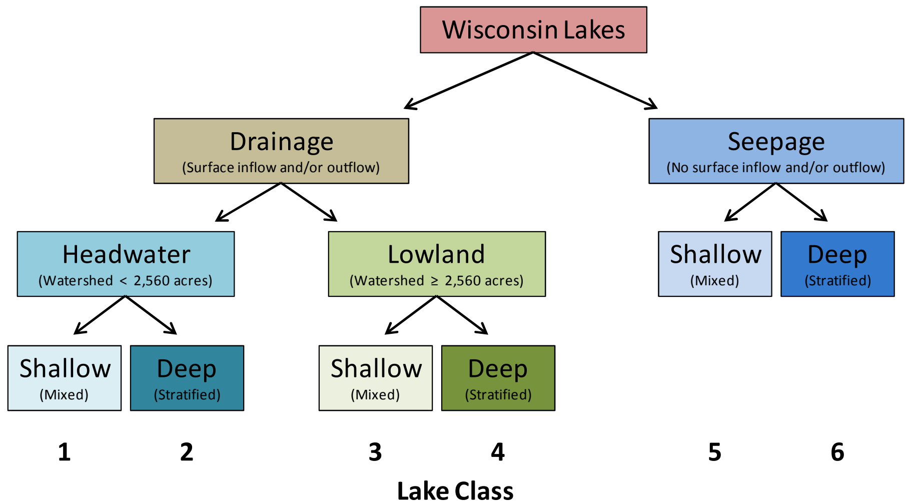


Figure 3.1-1. Wisconsin Lake Classifications. Little Arbor Vitae Lake is classified as a deep (stratified), lowland drainage lake (Class 4). Adapted from WDNR PUB-SS-1044 2008.

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. Little Arbor Vitae Lake is within the Northern Lakes and Forests ecoregion.

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, 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.

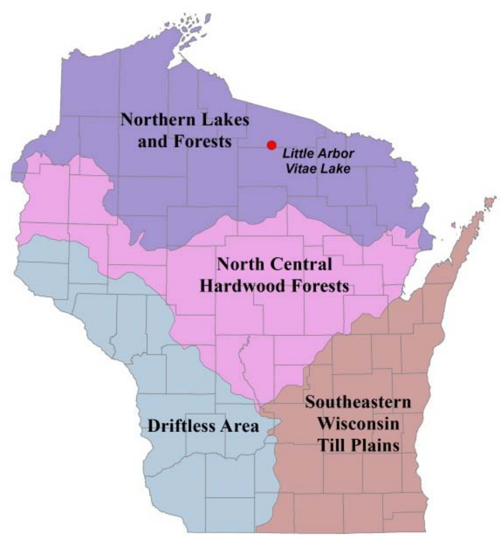


Figure 3.1-2. Location of Little Arbor Vitae Lake within the ecoregions of Wisconsin. After Nichols 1999.

Little Arbor Vitae historic and current data are graphed alongside data corresponding to statewide and regional natural lakes in Figures 3.1-3 - 3.1-7. 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.

Little Arbor Vitae Lake Water Quality Analysis

Little Arbor Vitae Lake Long-term Trends

As described above, the long-term trend analysis focuses upon three parameters, total phosphorus, chlorophyll-*a*, and Secchi disk clarity. For Little Arbor Vitae Lake, a moderate amount of historical data exists in the WDNR and USGS databases. Total phosphorus data was collected during 1979, a period from 1991-1996 by the USGS, and by Onterra in 2010. Large gaps exist between years within the dataset, but the data available indicate that surface total phosphorus values have remained relatively constant over this time period, with the exception of some lower values in 1993 and 1996 (Figure 3.1-3). Calculating a weighted average total phosphorus value for all years shows that Little Arbor Vitae Lake's phosphorus falls into the 'Fair' category for deep, lowland drainage lakes, exceeding both the Wisconsin State and Northern Lakes and Forests Ecoregion medians (Figure 3.1-3).

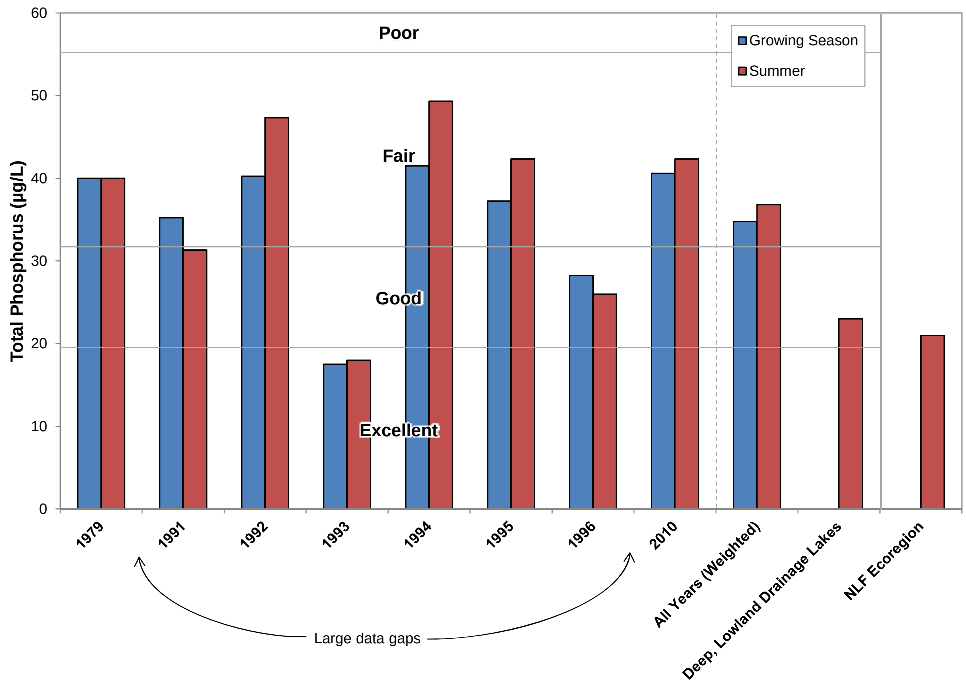


Figure 3.1-3. Little Arbor Vitae Lake, state-wide class 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913. Note that NLF stands for Northern Lakes and Forests ecoregion.

Chlorophyll-*a* values are available for the same years as those of total phosphorus. The highest annual mean value of chlorophyll-*a* was recorded in 1979. Aside from lower chlorophyll-*a* levels in 1991 and 1993, these values have remained relatively constant during the time periods for which data is available. The weighted average chlorophyll-*a* value calculated with all available data, falls into the 'Fair' category, like phosphorus exceeding both the median values for deep, lowland drainage lakes and lakes in the Northern Lakes Ecoregion (Figure 3.1-4).

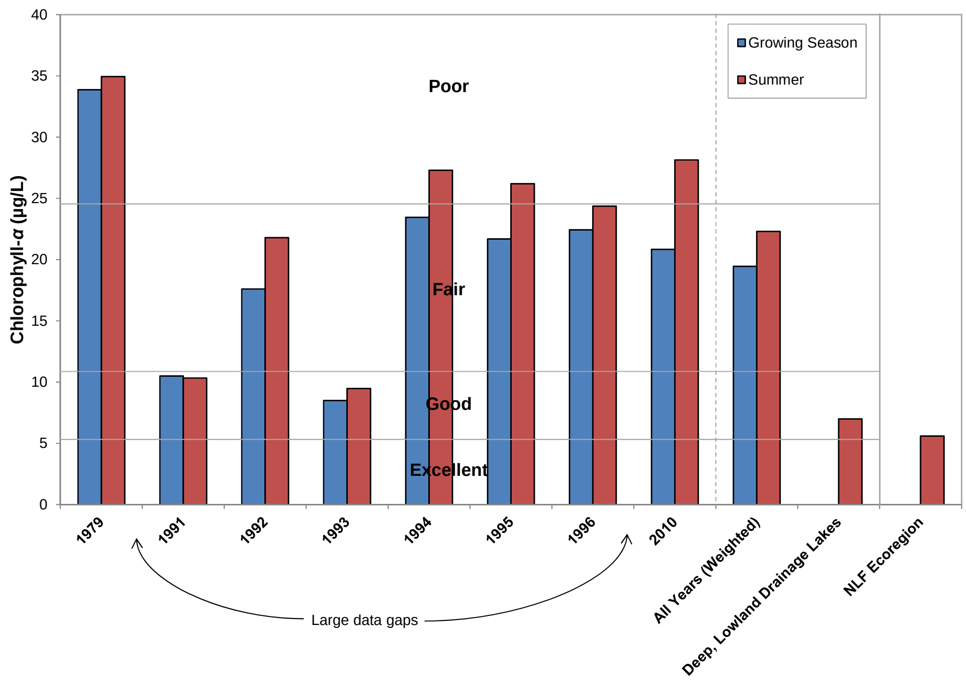


Figure 3.1-4. Little Arbor Vitae Lake, state-wide class 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913. Note that NLF stands for Northern Lakes and Forests ecoregion.

The largest amount of historic water quality data from Little Arbor Vitae Lake exists for Secchi disk transparency. Data is available from 1979, 1990 through 1996 by CLMN volunteers and the USGS, from 2007 to 2009 by CLMN volunteers, and 2010 by CLMN volunteers and Onterra. These data exhibit slightly more variability than those of phosphorus and chlorophyll-*a*. Secchi disk values recorded during the period between 1990 and 1996 show that water clarity increased annually from 1990 to 1993, then fluctuated annually from 1994 to 1996 (Figure 3.1-5). A Secchi disk depth of 19 feet was recorded in early May of 2007. From 2008 to 2010, water clarity appears to have increased slightly (Figure 3.1-5). Overall, the Secchi disk weighted average for all years falls into the 'Good' category for the growing season and 'Fair' category for the summer, falling below both the deep, lowland drainage lakes and Wisconsin State medians (Figure 3.1-5).

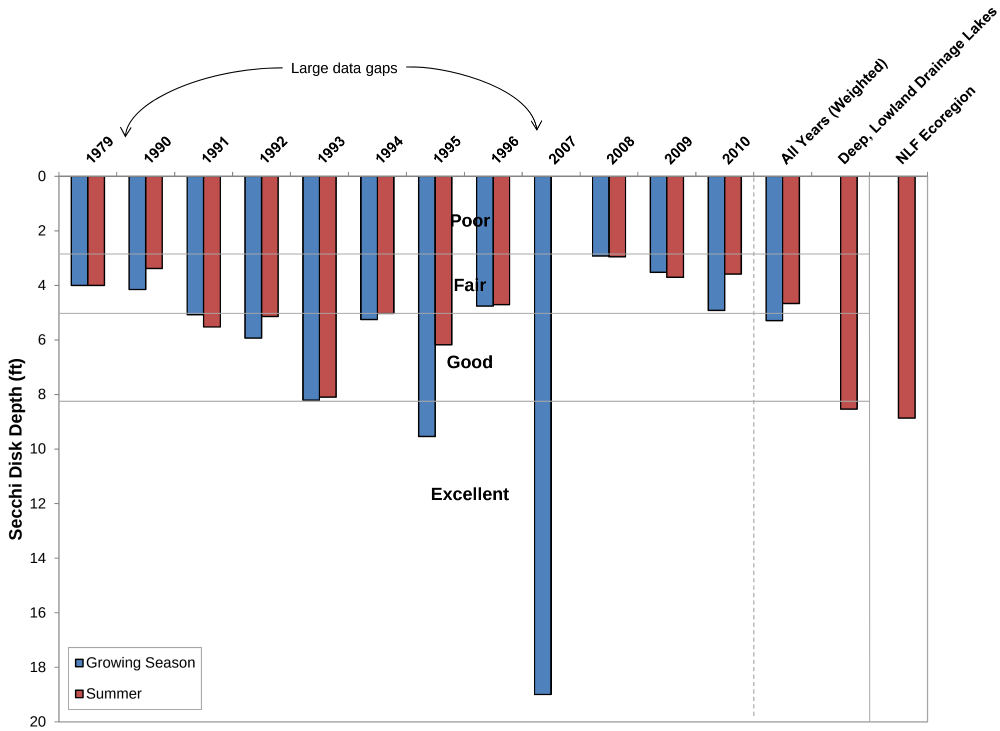


Figure 3.1-5. Little Arbor Vitae Lake, state-wide class 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913. Note that NLF stands for Northern Lakes and Forests ecoregion.

When looking at the annual averages of total phosphorus, chlorophyll-*a*, and Secchi disk values from Little Arbor Vitae Lake, for the most part they have remained relatively constant during the time periods for which data is available. However, looking at these values within their respective year, a large amount of variability throughout the growing season can be seen. For example, Figure 3.1-6 displays total phosphorus, chlorophyll-*a*, and Secchi disk values recorded by Onterra during the growing season of 2010. Over the course of the growing season, chlorophyll-*a* levels increase in magnitude by over 5 times from April to August, and thus Secchi disk values decrease by nearly 4 feet during this same period.

Increases in chlorophyll-*a* levels over the course of the growing season are to be expected as water temperatures rise and algae growth escalates. However, the magnitude of increase of chlorophyll-*a* levels observed in Little Arbor Vitae Lake suggest that nutrient levels, specifically phosphorus, may be increasing over the course of the growing season as well; and during the summer of 2010, this is what was observed. Surface total phosphorus values nearly doubled from April to August, indicating large amounts of phosphorus loading to the lake during that time period (Figure 3.1-6). Watershed modeling based on the area and type of land cover within Little Arbor Vitae Lake's watershed predicted a within-lake annual growing season total phosphorus average of 23.0 µg/L; much lower than the weighted average growing season value of approximately 35 µg/L. While this modeling is limited, its purpose is to detect abnormalities such as these. This large discrepancy between observed and predicted values indicates that there is an unaccounted phosphorus source(s) entering Little Arbor Vitae Lake. This phenomenon will be discussed further within the Watershed Section.

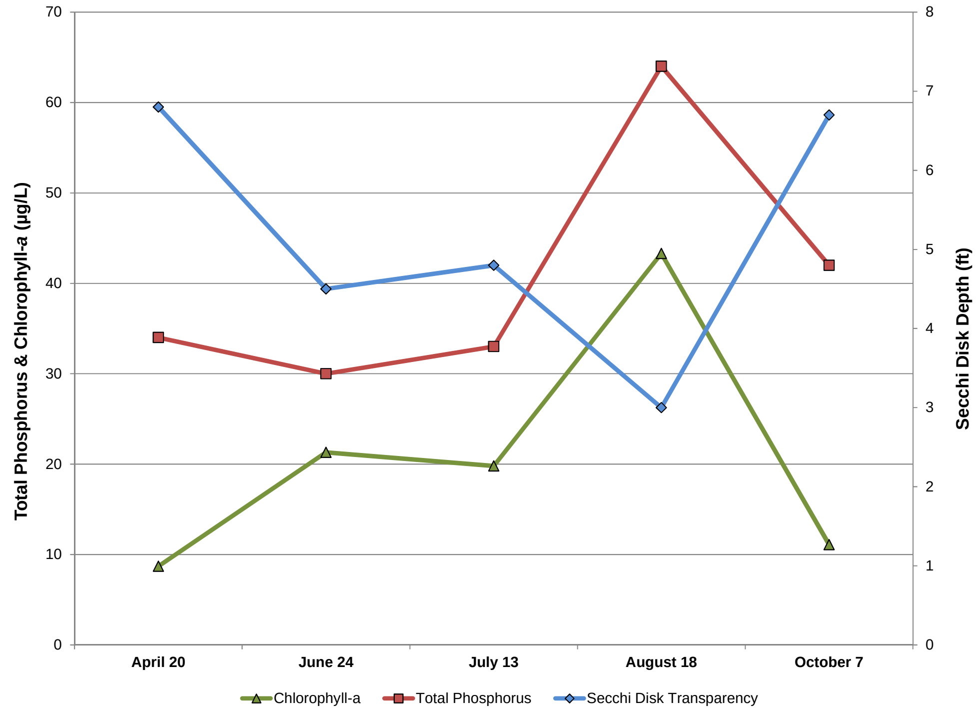


Figure 3.1-6. Little Arbor Vitae Lake 2010 growing season water quality parameters.

Paleolimnological Study of Little Arbor Vitae Lake

On September 19, 2012, a single sediment core was collected from the deep hole in Little Arbor Vitae Lake with a gravity corer by Tim Hoyman, Onterra, and Paul Garrison, WDNR (Appendix F). 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 Little 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 Little Arbor Vitae Lake are not natural and are likely the result of cumulating anthropogenic impacts. A core sample taken from Big 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 Little Arbor Vitae Lake

Using midsummer nitrogen and phosphorus concentrations from Little Arbor Vitae Lake, a nitrogen:phosphorus ratio of 16:1 was calculated. This finding indicates that Little 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.

Little Arbor Vitae Lake Trophic State

Figure 3.1-7 contains the TSI values for Little Arbor Vitae Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to upper eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Little Arbor Vitae Lake is in a eutrophic state.

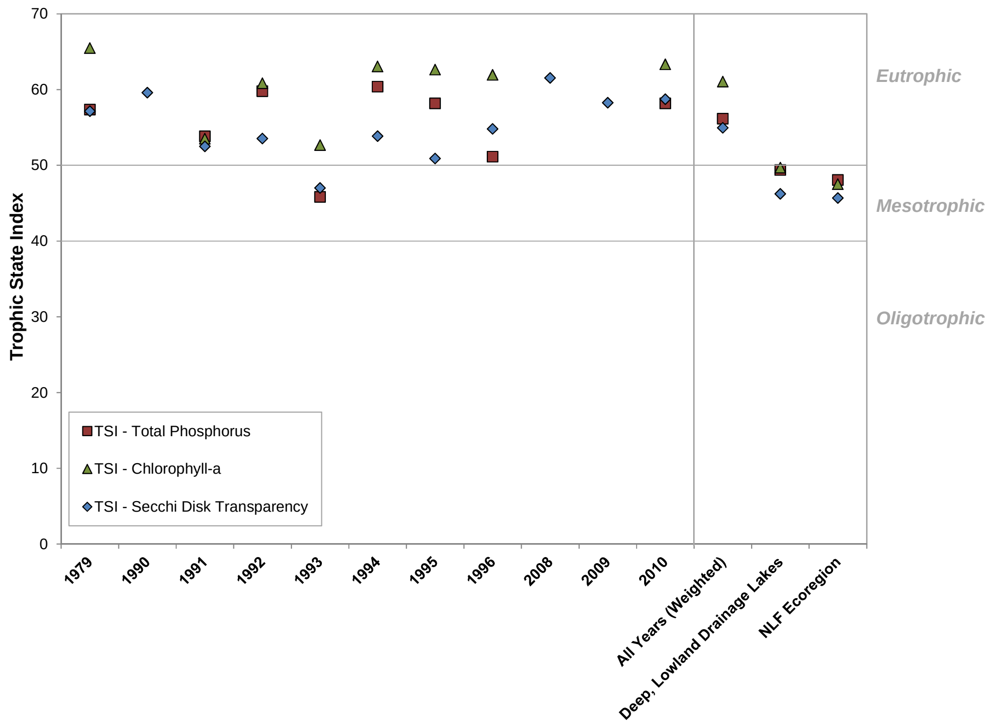


Figure 3.1-7. Little Arbor Vitae Lake, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193. Note that NLF stands for Northern Lakes and Forests ecoregion.

Dissolved Oxygen and Temperature in Little Arbor Vitae Lake

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

In April of 2010, Little Arbor Vitae Lake was mixed (often called turning over), with temperatures and dissolved oxygen remaining constant from the surface towards the bottom of the lake. In a moderately deep, smaller lake such as Little Arbor Vitae Lake, the spring winds are sufficient to mix the cold water. When the epilimnion warms in June, the hypolimnion remains cold as the winds are no longer strong enough to mix the water column. During this time, bacteria breakdown organic materials near the bottom of the lake. In doing so, they utilize the available oxygen and create an anoxic zone within the epilimnion. This occurred in both June and July, while periods of mixing likely occurred in between. August and October saw the lake mixed once again.

In the winter months, the lake becomes stratified but in an opposite manner. Water is at its densest when it reaches 4°C, so in the winter the warmer water is found near the bottom of the lake and the colder water is near the surface, just under the ice. Once again, bacterial decomposition is occurring which reduces the oxygen content in the epilimnion of the lake.

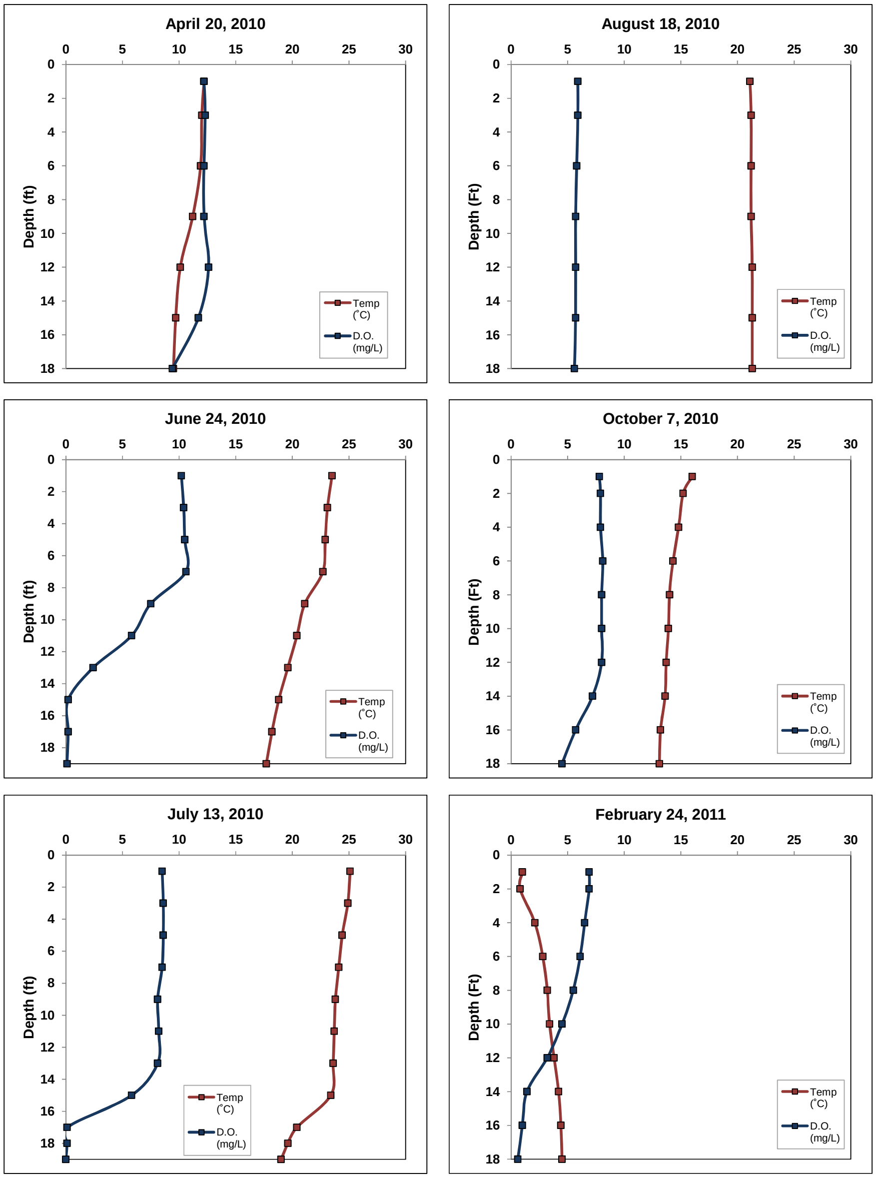


Figure 3.1-8. Little Arbor Vitae Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Little 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 Little 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 and Nimphius, 1985). The pH of surface water in Little Arbor Vitae Lake was found to be alkaline with an average growing season value of 8.9, falling above the normal range for Wisconsin lakes. The high pH value observed in Little Arbor Vitae Lake in 2010 is likely due to the high concentration of algae.

Algae, like other plants, take in carbon dioxide from the water during the day for photosynthesis. This dissolved carbon dioxide makes the water slightly acidic (pH < 7). In lakes with high levels of algae, large amounts of dissolved carbon dioxide are removed during the day which consequently raises the pH to alkaline levels (pH > 7) during the day. At night when algae are producing carbon dioxide, the pH level drops. These daily fluctuations in pH are natural, but larger swings due to an overabundance of algae may become stressful for some fish and other wildlife.

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. Alkalinity also determines the sensitivity of a lake to acid rain. Values between 2.0 and 10.0 mg/L as $CaCO_3$ are considered to be moderately sensitive to acid rain, while lakes with values of 10.0 to 25.0 mg/L as $CaCO_3$ are considered to have low sensitivity, and lakes above 25.0 mg/L as $CaCO_3$ are non-sensitive. The alkalinity in Little Arbor Vitae Lake was measured at 59.0 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a little 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 Little Arbor Vitae Lake's pH of 8.9 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, while concentrations of 12 to 20 mg/L are considered to provide low susceptibility, 20 to 28 mg/L moderate susceptibility and above 28 mg/L high susceptibility. The calcium concentration of Little Arbor Vitae Lake was found to be 16.4 mg/L, indicating that the lake has a low susceptibility to zebra mussel establishment if they were introduced. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. They did not find larval zebra mussels in any of the samples.

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

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

A reliable and cost-efficient method of creating a general picture of a watershed's 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.

The drainage basin for Little Arbor Vitae Lake covers approximately 11,488 acres in Vilas County (Map 2). Little Arbor Vitae Lake's direct watershed covers 3,832 acres while Big Arbor Vitae Lake's watershed comprises the remaining 7,656 acres. The land cover types within this watershed include forests, wetlands, pasture/grass, rural residential, and the surface water of the lakes. Forested land, Little Arbor Vitae Lake's surface, and wetlands cover roughly 95% of the lake's direct watershed, while pasture/grass and rural residential land cover types comprise less than 5% (Figure 3.2-1). Of course, the majority of land within Little Arbor Vitae's watershed drains through Big Arbor Vitae, and is part of this watershed as well. Approximately 99% of Big Arbor Vitae Lake's watershed is comprised of forest, wetlands, and the lake's surface. As discussed previously, forests and wetlands typically deliver minimal amounts of pollutants (nutrients and sediment) to lakes.

Little Arbor Vitae Lake's watershed is significantly larger than the lake itself, yielding a watershed to lake area ratio of 21:1. With a ratio this large, the size of the watershed begins to become more influential over the water quality than just the land cover types in the watershed alone. Although Little Arbor Vitae Lake's watershed is comprised of land cover types that are very efficient at retaining nutrients and allowing precipitation to be absorbed into the ground, the sheer size of the watershed delivers sufficient amounts of nutrients to create a productive, eutrophic system.

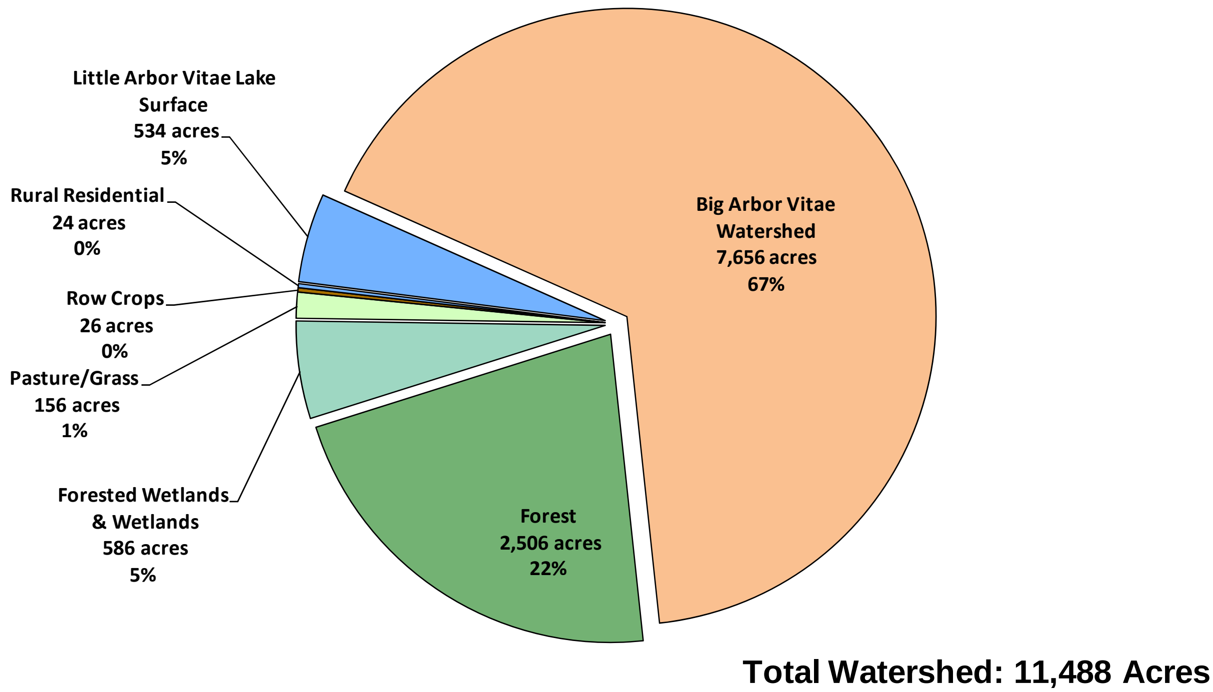


Figure 3.2-1. Little Arbor Vitae Lake watershed land cover types in acres. Based upon National Land Cover Database for the Conterminous United States (NLCD) (Fry et. al 2006).

Evidence for Internal Nutrient Loading in Little Arbor Vitae Lake

As previously discussed, during modeling procedures, WiLMS produced a different estimated growing season mean phosphorus value than what was observed through water quality sampling on Little Arbor Vitae Lake. This is an early indication that there is an unaccounted phosphorus source impacting Little Arbor Vitae Lake. In a watershed that contains no agricultural land cover, four likely sources of phosphorus exist that would be unaccounted for in the watershed modeling procedure: natural sources via groundwater inputs, early summer die-off of curly-leaf pondweed, septic system discharge, and/or internal nutrient loading from lake sediments.

The scope of this project did not include the study of groundwater nutrient content or inflow into Little Arbor Vitae Lake. Groundwater usually does not carry high amounts of phosphorus as phosphorus does not dissolve easily in water; therefore, it is not likely that groundwater is a significant source of phosphorus on Little Arbor Vitae Lake. Still, in lakes near Little Arbor Vitae, like Muskellunge and Little Saint Germain Lakes to the east, natural, phosphorus-rich groundwater does significantly impact the nutrient budgets of these lakes. The paleolimnological analysis presented in the watershed section does not support groundwater impacts to Little Arbor Vitae Lake because the analysis indicated significantly lower phosphorus concentrations in Little Arbor Vitae historically, than currently. If groundwater inputs were adding significant levels of phosphorus to the lake, the historical phosphorus levels and current levels would have been similar.

Another possible source of phosphorus to Little Arbor Vitae Lake is a form of internal nutrient loading from the early summer die-off of curly-leaf pondweed. While no curly-leaf pondweed was located in Little Arbor Vitae Lake, an established population of approximately 5 acres exists in upstream Big Arbor Vitae Lake. This aquatic invasive plant naturally decays in early summer releasing phosphorus into the lake. While all of the phosphorus within these plants does not likely get released into the water column, other Wisconsin lakes have seen significant increases in total phosphorus following curly-leaf pondweed die-off. However, because of the amount present in Big Arbor Vitae Lake relative to the lake's size, it is not believed that curly-leaf pondweed is a significant source of phosphorus loading.

Faulty septic systems within the lake's watershed can leach phosphorus which eventually can flow into the lake. Using the septic tank output estimator in Wisconsin Lake Modeling Suit, an estimate of how much phosphorus loading can be attributed to septic leakage was calculated based on the results received from the Little 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, the model indicated that Little Arbor Vitae Lake receives approximately 15 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 on Little Arbor Vitae Lake in 2010.

In lakes that stratify in the summer and develop a hypolimnion (bottom layer) devoid of oxygen, accumulated sediment phosphorus can be released into this layer and become mixed throughout the entire water column during turnover events fueling algae blooms. Dissolved oxygen/temperature profiles taken on Little Arbor Vitae Lake during the growing season indicate that in June and July the lake was stratified with a developed anoxic hypolimnion at around 15 feet. The average total phosphorus concentration within the hypolimnion in 2010 was 47.6 µg/L, well below the 200 µg/L internal nutrient loading threshold for candidate lakes. However, looking at historic hypolimnetic phosphorus data from 1991 to 1996 shows that in some of the July and August sampling periods, total phosphorus values ranged from 100 µg/L to 486 µg/L indicating potential for internal nutrient loading.

The buildup of sediment phosphorus in Little Arbor Vitae Lake is likely due to both natural and anthropogenic factors. Though the runoff from Little Arbor Vitae Lake's watershed carries relatively little sediment (see Watershed Assessment Section), the cumulative amounts from natural delivery from a large watershed over the 10,000-year period of the lake's existence have built up a significant sediment layer. Lakes with large watersheds fill in, or age, more rapidly than lakes with smaller watersheds. On top of this, human settlement within Little Arbor Vitae Lake's watershed likely hastened this process with the advent of historic clear-cutting logging practices and damming of both Little and Big Arbor Vitae Lakes. Removal of forests and construction of impervious surfaces increases the amount and velocity of runoff entering the lake. While damming lakes increases their volume, it reduces their flow and flushing rate which increases the rate of sediment accumulation.

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. Little Arbor Vitae Lake has a calculated Osgood Index value of 2.3, indicating that it is polymictic. Its large surface area and relatively shallow depth make it susceptible to mixing during periods of high winds. From the dissolved oxygen/temperature profiles, it is known that during calmer weather periods Little

Arbor Vitae Lake stratifies and forms an anoxic hypolimnion to which phosphorus is released from the bottom sediments. During high wind events stratification is broken and the phosphorus from the hypolimnion is mixed throughout the entire water column, making the phosphorus available to algae growing near the surface and fueling undesired algae blooms. Observed hypolimnetic phosphorus concentrations do not always exceed 200 µg/L because Little Arbor Vitae Lake is likely mixing multiple times throughout the summer, preventing stratification for a long enough period to accumulate higher phosphorus concentrations. However, the years 1993 and 1996 have the lowest summer surface phosphorus values recorded from Little Arbor Vitae Lake and some of the highest recorded hypolimnetic values. This indicates the lake may have remained stratified for a longer period of time allowing hypolimnetic phosphorus to reach higher levels. The polymictic nature of the lake makes surface phosphorus concentrations highly variable and dependent on meteorological events.

Internal nutrient loading in polymictic lakes such as Little Arbor Vitae can be more problematic than internal nutrient loading in dimictic lakes. Although phosphorus concentrations within the hypolimnion reach higher levels in dimictic lakes because they remain stratified during the summer, these lakes turn over at times of the year (spring and fall) when 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 periodic loading of phosphorus during the summer when algae is actively growing can cause unwanted blooms.

WiLMS was utilized to model the land cover types within the Little Arbor Vitae Lake watershed and quantify nutrient runoff. The model was also used to produce an estimate of the unaccounted source of phosphorus. Modeling using the land cover types and acreages in Figure 3.2-1 as well as the known phosphorus concentrations measured from Big Arbor Vitae Lake in 2011, the model estimated that 1,978 pounds of phosphorus is delivered to Little Arbor Vitae Lake on an annual basis (Figure 3.2-2). The unaccounted phosphorus source (of which a large portion is likely internal nutrient loading) accounts for 40% of the annual load, while Big Arbor Vitae Lake's watershed produces a substantial 37% of the load. The remaining 23% is attributed to land cover types within the lake's direct watershed, the majority of which comes from forested land and Little Arbor Vitae's Lake surface. This accumulation occurs through atmospheric deposition of dust and other particles, which hold small amounts of phosphorus, onto the lake's surface.

The majority of Little Arbor Vitae Lake's watershed is currently in excellent shape, with intact forests and wetlands dominating the land cover. While some small areas exist within the direct watershed of the lake (discussed in Shoreline Assessment below) that could qualify as candidates for restoration, the restoration of these areas, while beneficial, would likely not have a noticeable impact on improving the water quality of the lake. However, restoration of these areas would improve wildlife habitat, most notably fish, which have been shown to decline in abundance when associated with developed shorelines (Radomski and Goeman 2001). Restoration of these areas would also enhance the aesthetic beauty of the lake.

While the data collected in 2010 provides evidence that internal nutrient loading is a significant source of phosphorus for Little Arbor Vitae Lake, we cannot, with the data available at this time, accurately estimate the amount. However, the amount is likely higher than what the model predicted. There are actions that can be taken to reduce this internal source, but their costs can often be substantial. And before control efforts could be initiated, a more in-depth diagnostic/feasibility study specifically attempting to quantify the amount of phosphorus being delivered via internal nutrient loading on Little Arbor Vitae Lake would have to be conducted. 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 at the mouth of Link Creek would also be required to determine a more accurate amount of phosphorus being delivered from Big Arbor Vitae Lake. 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.

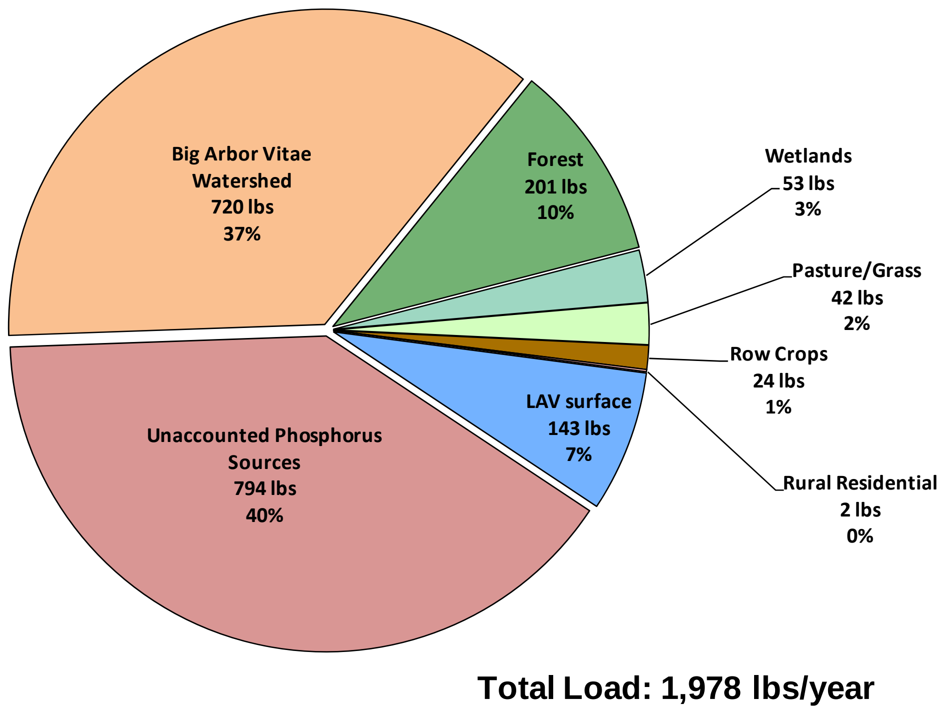


Figure 3.2-2. Little Arbor Vitae Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Little Arbor Vitae Lake and its upstream counterpart, Big Arbor Vitae Lake, are suffering from man-made disturbances that are now impacting the ecology and recreational opportunity on these lakes. According to the paleolimnological analysis, some man-made process has occurred within the past 100 years to cause these lakes to go from moderately productive systems to systems which are highly productive. But what exactly occurred during this time? Further studies may or may not produce the answer to this question, however they will determine and better quantify the sources of current phosphorus production to the lakes, and assist in steps that may be carried out to mediate this excessive phosphorus load.

The benefit to Little Arbor Vitae Lake is that actions carried out on Big Arbor Vitae Lake will directly benefit this downstream ecosystem. Currently, Big Arbor Vitae Lake experiences an annual potential phosphorus load of nearly 1,995 lbs, 1,091 of which is unaccounted for and likely derived from internal nutrient loading. Calculations of several scenarios were conducted on Big Arbor Vitae Lake to determine what kind of reduction may occur in this lake's phosphorus load if 100%, 90%, 75% or 50% of the unaccounted source was derived from internal nutrient loading, and an in-lake treatment was conducted to remove 90% of the phosphorus from this source. The calculations indicate that anywhere from 25-49% reduction of the total annual potential phosphorus load (1,995 lbs) could be achieved.

Naturally, a reduction in internal nutrient loading within Big Arbor Vitae Lake would equate to a smaller phosphorus load being delivered to Little Arbor Vitae Lake. Because the Big Arbor Vitae Lake contribution to Little Arbor Vitae Lake through Link Creek is only a portion of the overall phosphorus load, a similar reduction would not necessarily occur (i.e. a 49% reduction in Big Arbor Vitae Lake's internal nutrient load does not mean a 49% reduction in the phosphorus load from Big to Little Arbor Vitae Lake). Calculations indicate that Little Arbor Vitae Lake's total phosphorus load of 1,978 lbs could be reduced anywhere from 10-17% if actions were taken to reduce internal nutrient loading in Big Arbor Vitae Lake. The best case scenario, a 17% reduction, assumes that 100% of Big Arbor Vitae Lake's unaccounted source load is derived from internal nutrient loading, and that in-lake treatments could inactivate 90% of this phosphorus source. It is important to remember that, as described above and within the Summary & Conclusions and Implementation Plan, further diagnostic/feasibility studies would need to be conducted to determine exact responses of Little Arbor Vitae Lake to management actions on Big Arbor Vitae Lake.

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):

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed 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).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. 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.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. 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

- Mitigation requirements: 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 many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

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

National Lakes Assessment

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

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nations lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009). Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat*".

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

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

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.

Little Arbor Vitae Lake Shoreland Zone Condition

Shoreland Development

Little 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 Little Arbor Vitae Lake, the development stage of the entire shoreline was surveyed during the fall of 2010 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 3.3-2.

Little Arbor Vitae Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.8 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, 1.1 miles of urbanized and developed–unnatural shoreline were observed. If restoration of the Little 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.

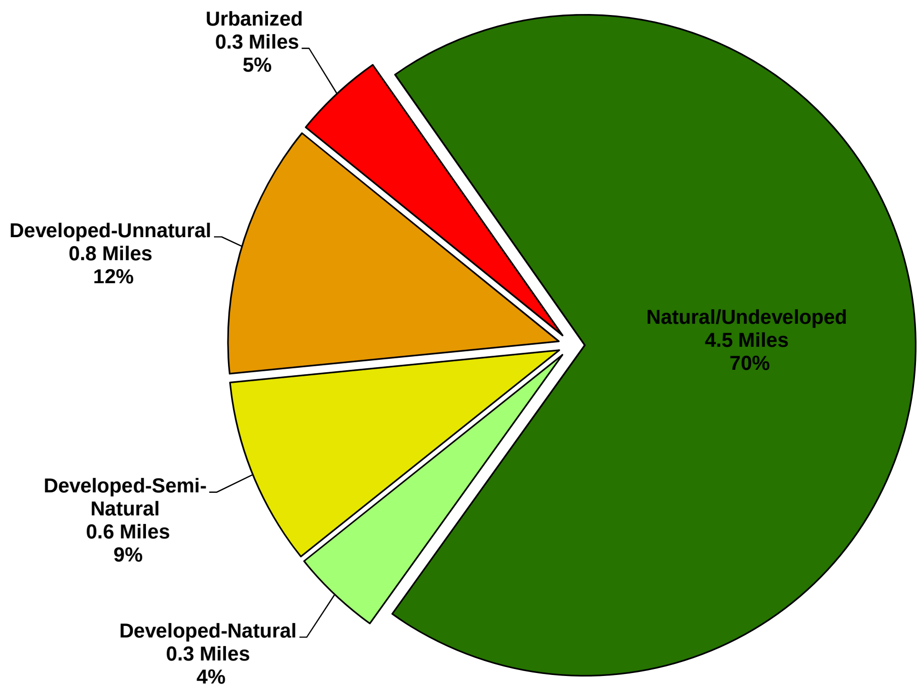


Figure 3.3-2. Little Arbor Vitae Lake shoreland categories and total lengths. Based upon a fall 2010 survey. Locations of these categorized shorelands can be found on Map 3.

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 shoreland erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian 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

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

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

Permits

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

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

Manual Removal

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 and reed canary grass. • Permitting process may require an environmental assessment that may take months to prepare. • Non-selective.

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, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian 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 Little Arbor Vitae; 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 Little Arbor Vitae, 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 of 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 Little Arbor Vitae. Comparisons will be displayed using boxplots that show 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.

A boxplot 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 shoreland. 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 shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland 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 shoreland 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 shoreland 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 Little Arbor Vitae will be compared to lakes in the same ecoregion and in the state (Refer to the Water Quality Section, 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.

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.

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.

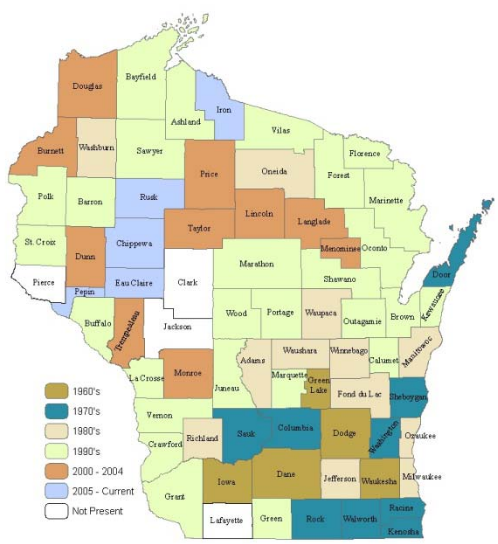


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

Aquatic Plant Survey Results

As mentioned above, numerous plant surveys were completed as a part of this project. On June 24, 2010, a survey was completed on Little Arbor Vitae Lake that focused upon curly-leaf pondweed. This meander-based survey did not locate any occurrences of if this aquatic invasive plant. It is believed that curly-leaf pondweed presently does not occur in Little Arbor Vitae Lake or exists at an undetectable level. However, an established population of curly-leaf pondweed does exist in Big Arbor Vitae Lake which is located only a quarter mile from Little Arbor Vitae Lake and connected via Link Creek. It is recommended that lake residents familiarize themselves with the identification of this plant and report any potential occurrences to Onterra or the WDNR.

The whole-lake aquatic plant point-intercept and aquatic plant community mapping surveys were conducted on Little Arbor Vitae Lake on August 2-3, 2010 by Onterra. During these surveys, 35 species of aquatic plants were located in Little Arbor Vitae Lake (Table 3.4-1), only one of which is considered to be a non-native, invasive species: purple loosestrife. A single plant of purple loosestrife was found growing on the northwest shoreline near the mouth of Link Creek. This invasive plant is discussed in more detail at the end of this section. No other invasive plant species, including Eurasian water milfoil, were located during the 2010 surveys.

Table 3.4-1. Aquatic plant species located in Little Arbor Vitae Lake during August 2010 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)
Emergent	*Carex comosa*	Bristly sedge	5
	Carex lacustris	Lake sedge	6
	Calla palustris	Water arum	9
	Decodon verticillatus	Water-willow	7
	Iris versicolor	Northern blue flag	5
	Lythrum salicaria	Purple loosestrife	Exotic
	Sagittaria latifolia	Common arrowhead	3
	Schoenoplectus acutus	Hardstem bulrush	5
	Schoenoplectus tabernaemontani	Softstem bulrush	4
	Typha latifolia	Broad-leaved cattail	1
FL	*Nuphar variegata*	Spatterdock	6
	Nymphaea odorata	White water lily	6
FL/E	*Sparganium americanum*	Eastern bur-reed	8
	Sparganium eurycarpum	Common bur-reed	5
Submergent	*Chara sp.*	Muskgrasses	7
	Ceratophyllum demersum	Coontail	3
	Elodea canadensis	Common waterweed	3
	Myriophyllum sibiricum	Northern water milfoil	7
	Najas flexilis	Slender naiad	6
	Nitella sp.	Stoneworts	7
	Potamogeton epihydrus	Ribbon-leaf pondweed	8
	Potamogeton strictifolius	Stiff pondweed	8
	Potamogeton foliosus	Leafy pondweed	6
	Potamogeton friesii	Fries' pondweed	8
	Potamogeton pusillus	Small pondweed	7
	Potamogeton amplifolius	Large-leaf pondweed	7
	Potamogeton richardsonii	Clasping-leaf pondweed	5
	Potamogeton praelongus	White-stem pondweed	8
	Potamogeton zosteriformis	Flat-stem pondweed	6
	Ranunculus aquatilis	White water-crowfoot	8
	Utricularia vulgaris	Common bladderwort	7
	Vallisneria americana	Wild celery	6
FF	*Lemna trisulca*	Forked duckweed	6
	Lemna turionifera	Turion duckweed	2
	Spirodela polyrhiza	Greater duckweed	5

FL = Floating Leaf
FL/E = Floating Leaf and Emergent
FF = Free Floating

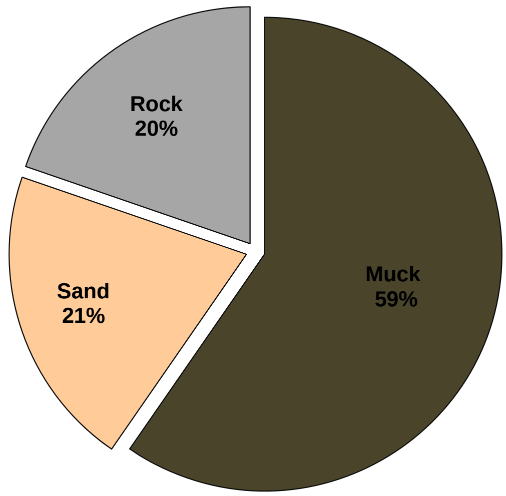


Figure 3.4-2. Little Arbor Vitae Lake proportion of substrate types within littoral areas. Created using data from 2010 aquatic plant point-intercept survey.

The sediment within littoral areas of Little Arbor Vitae Lake is very conducive for supporting lush aquatic plant growth. Data from the point-intercept survey indicate that approximately 59% of the sampling locations located within the littoral zone contained fine organic sediment (muck), 21% contained sand, and 20% contained rock (Figure 3.4-2).

Approximately 53% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth (13 feet), or the littoral zone, contained aquatic vegetation. Map 5 shows that the majority of the aquatic vegetation in Little Arbor Vitae Lake is located within the shallow bays and near-shore areas. As discussed in the water quality section, the water clarity in Little Arbor Vitae Lake is relatively low which limits sunlight penetration and restricts aquatic plants from inhabiting deeper areas of the lake. Figure 3.4-3 shows that the majority of the aquatic vegetation in Little Arbor Vitae Lake grows between 1 and 7 feet.

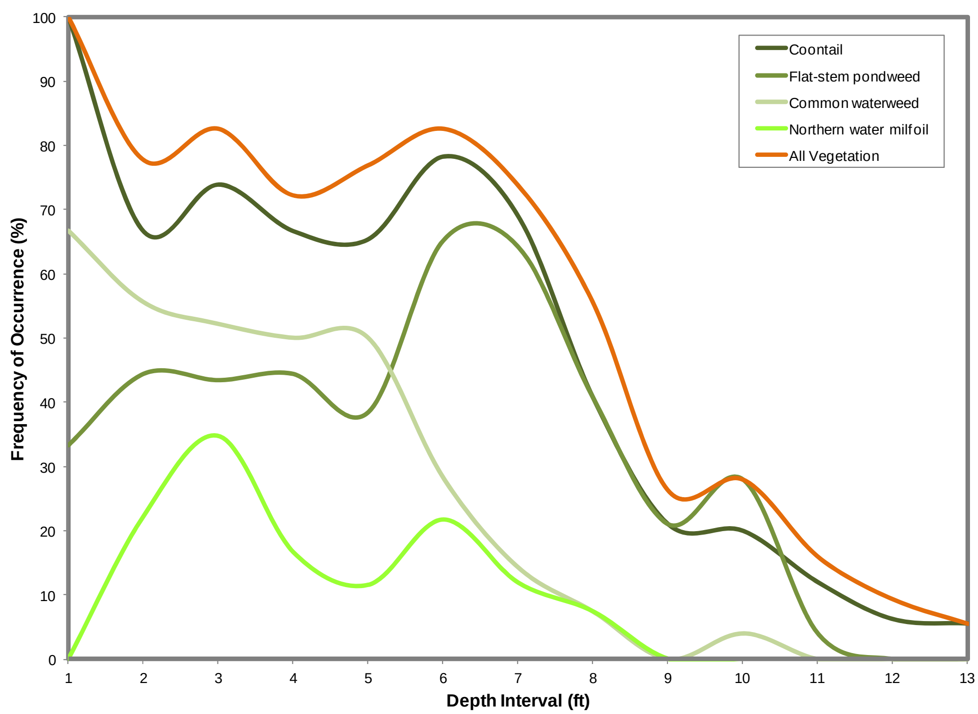


Figure 3.4-3. Frequency of occurrence over water depth for several aquatic plant species. Created using data from 2010 aquatic plant point-intercept survey. Lines are smoothed to ease visualization.

Coontail, flat-stem pondweed, common waterweed, and northern water milfoil were the four-most frequently encountered aquatic plant species during the 2010 aquatic plant point-intercept survey (Figure 3.4-4). All four of these species are common throughout Wisconsin, and under the proper conditions can grow to densities which hamper navigation and recreational activities. Able to obtain the majority of their essential nutrients directly from the water, coontail and common waterweed do not produce extensive root systems, making them susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats.

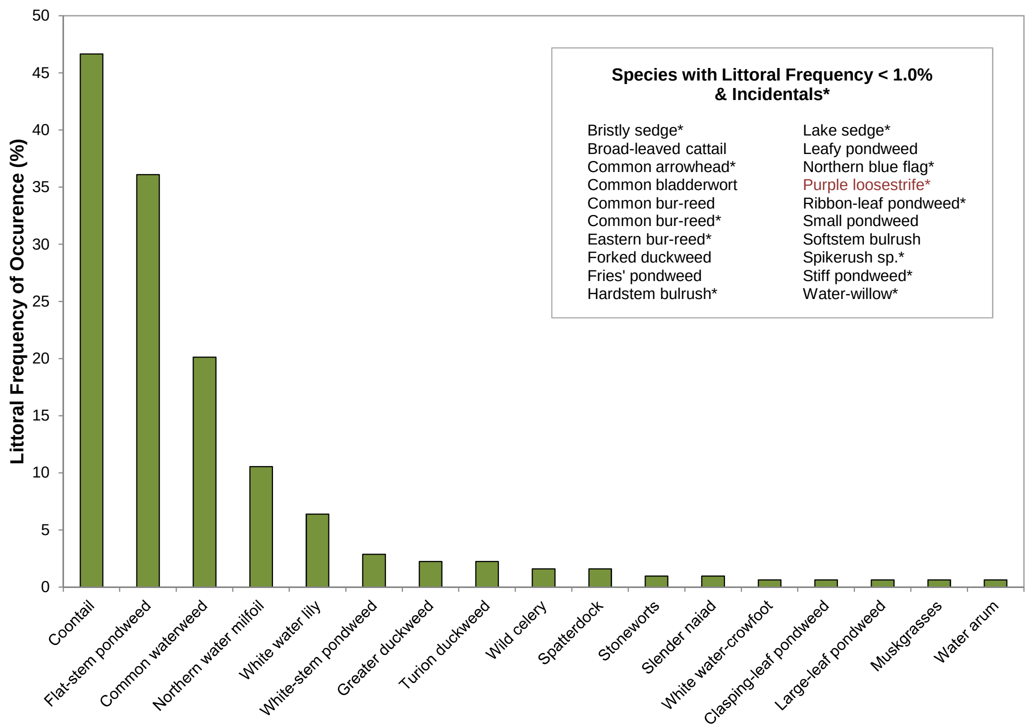


Figure 3.4-4. Little Arbor Vitae Lake aquatic plant littoral occurrence analysis. Created using data from 2010 aquatic plant point-intercept survey. Exotic species indicated with red.

Flat-stem pondweed, one of many pondweed species found in Wisconsin, is very common and as its name suggests has a conspicuously flattened stem. Northern water milfoil, arguably Wisconsin's most common native milfoil species, is often falsely identified as Eurasian water milfoil with its feather-like leaves and 'reddish' appearance observed in late summer as it reacts to sun exposure. The feathery foliage of northern water milfoil traps detritus and provides habitat for filamentous algae, in turn creating valuable habitat for aquatic invertebrates. While these four species have the potential to reach nuisance levels, these plants provide numerous ecological benefits to the Little Arbor Vitae Lake ecosystem including food and habitat sources for many different species of wildlife. These plants become even more important in lakes like Little Arbor Vitae Lake where vegetation is rather sparse and confined to shallow bays.

Little Arbor Vitae Lake contains a high number of aquatic plant species. The native species richness (34) is well above the Northern Lakes Ecoregion and Wisconsin State medians (Figure 3.4-5). Given the high number of native aquatic species, one may assume that the lake also has high species diversity. However, as discussed earlier, species diversity also is influenced by how evenly the plant species are distributed within the community. Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. 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.

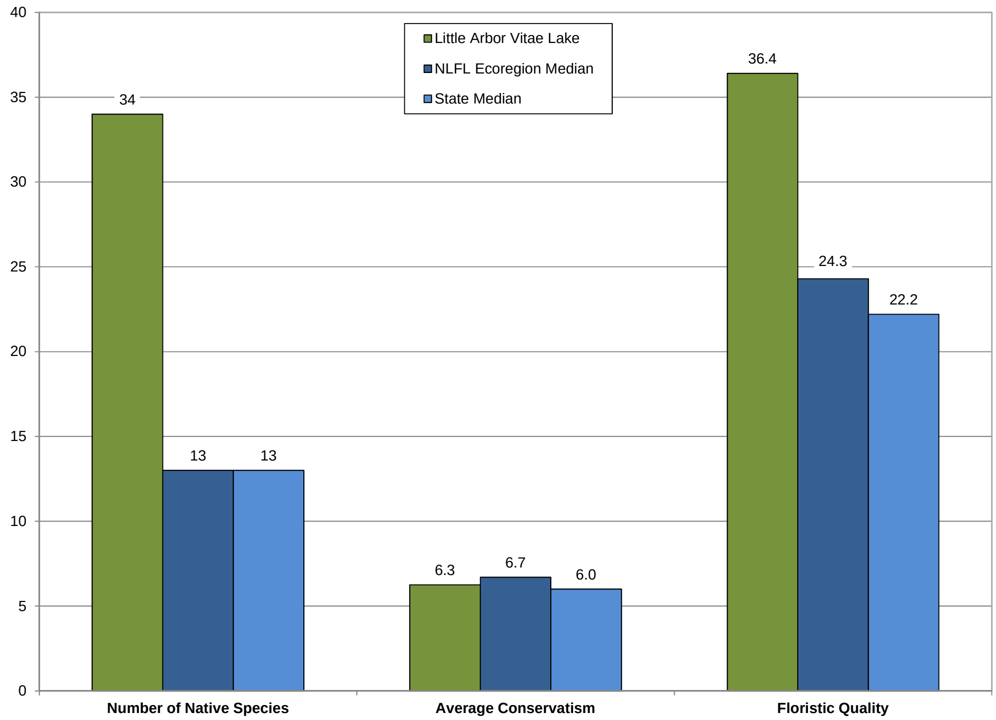


Figure 3.4-5 Little Arbor Vitae Lake Floristic Quality Assessment. Created using data from 2010 aquatic plant point-intercept survey. Analysis following Nichols (1999) where NLFL = Northern Lakes and Forest Lakes Ecoregion.

Using the data collected from the 2010 aquatic plant point-intercept survey, the diversity of the aquatic plant community of Little Arbor Vitae Lake was found to be relatively low, with a Simpson's diversity value of 0.79. In other words, if two individual plants were randomly sampled from Little Arbor Vitae Lake's plant community, there would be a 79% probability that the two individuals would be of different species. The lower species diversity in Little Arbor Vitae Lake can be attributed to a plant community that is dominated by a few number of species, mainly coontail, flat-stem pondweed, and common waterweed.

As explained above in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at almost 47% of the sampling locations, its relative frequency of occurrence is approximately 34%. Explained another way, if 100 plants were randomly sampled from Little Arbor Vitae Lake 34 of them would be coontail.

Figure 3.4-6 indicates that these three species make up 74% of the lake's plant community. These species, able to obtain essential nutrients directly from the water and tolerate low-light conditions, have competitive advantages over other aquatic plant species and thrive in high-nutrient, low water clarity lakes like Little Arbor Vitae. Thus, lakes with these characteristics tend to have a less diverse aquatic plant community.

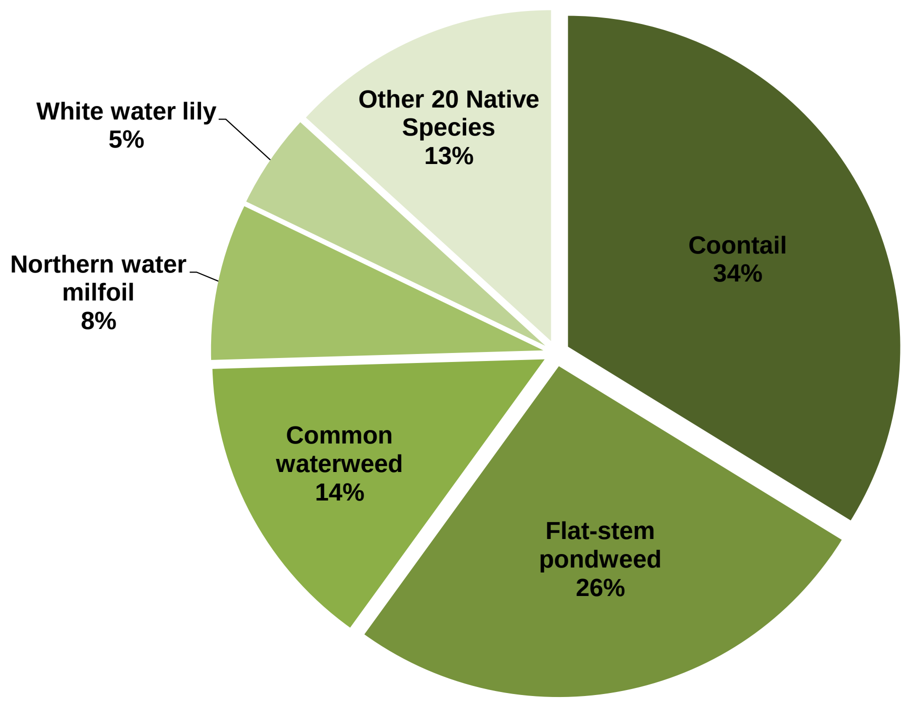


Figure 3.4-6. Little Arbor Vitae Lake aquatic plant relative occurrence analysis. Created using data from 2010 aquatic plant point-intercept survey.

The conservatism value (6.3) of Little Arbor Vitae Lake's aquatic plant community falls slightly below the Northern Lakes Ecoregion median and slightly above the Wisconsin State median (Figure 3.4-5). This indicates that the aquatic plant community of Little Arbor Lake is of comparable quality to most of the lakes in the ecoregion and state. Combining Little Arbor Vitae Lake's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in an exceptionally high value of 36.4 (equation shown below); well above the median values for both the ecoregion and state (Figure 3.4-5).

$$\text{FQI} = \text{Average Coefficient of Conservatism } (6.3) * \sqrt{\text{Number of Native Species } (34)}$$
$$\text{FQI} = 36.4$$

The quality of Little Arbor Vitae Lake's aquatic plant community is also indicated by the high number of emergent and floating-leaf plant species (14) that occur in near-shore areas around the lake. The 2010 community map indicates that approximately 16 acres (3%) of the 534 acre-lake contain these types of plant communities. These communities were comprised of both floating-leaf and emergent aquatic plant species, all of which provide valuable habitat to wildlife and stabilize lake substrate and shoreline areas by dampening wave action from wind and watercraft.

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

Exotic Plants in Little Arbor Vitae Lake

As previously indicated, Big Arbor Vitae Lake contains an established population of curly-leaf pondweed and due to the proximity of Little Arbor Lake to Big Arbor Vitae Lake and the fact that the two lakes are connected by a relatively short creek, additional concern existed about whether this exotic plant species was also located in Little Arbor Vitae Lake. However, curly-leaf pondweed was not located in Little Arbor Lake during any of the surveys conducted in 2010, including one survey specifically targeting this species during the late spring of the year which corresponds with its peak growth (biomass) phase.

As described above, only one invasive plant species, purple loosestrife, was located within Little Arbor Vitae Lake during this project's studies. This species was located during the aquatic plant community mapping survey in one location on the shoreline near the mouth of Link Creek (Map 6). Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

The infestation of purple loosestrife on Little Arbor Vitae Lake seems to be in its early stages. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines of Little Arbor Vitae Lake. Detailed discussion regarding this control effort will be discussed in the Implementation Plan.

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. 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 2013 & GLIFWC 2013A and 2013B).

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

Little Arbor Vitae Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the highest ranked important or enjoyable activity on Little Arbor Vitae Lake (Question #11). When asked their thoughts as to how the current quality of fishing was on the lake, 41% responded Very Poor or Poor, while 59% responded Good or Fair (Question #8). Approximately 80% believe that the quality of fishing has remained the same or gotten worse since they have obtained their property (Question #9). Many respondents expressed concerns over the presence of northern pike in the lake (Appendix B, Comments).

Table 3.5-1 (above) shows the popular game fish that are present in the system. 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 Little 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 piscovores, 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 piscovores 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.

As discussed in the Water Quality section, Little Arbor Vitae Lake is eutrophic, meaning it has relatively high amounts of nutrients and thus high primary productivity. Simply put, this means that the lake is able to support a large population of predatory fish (piscovores) because the supporting food chain is relatively large.

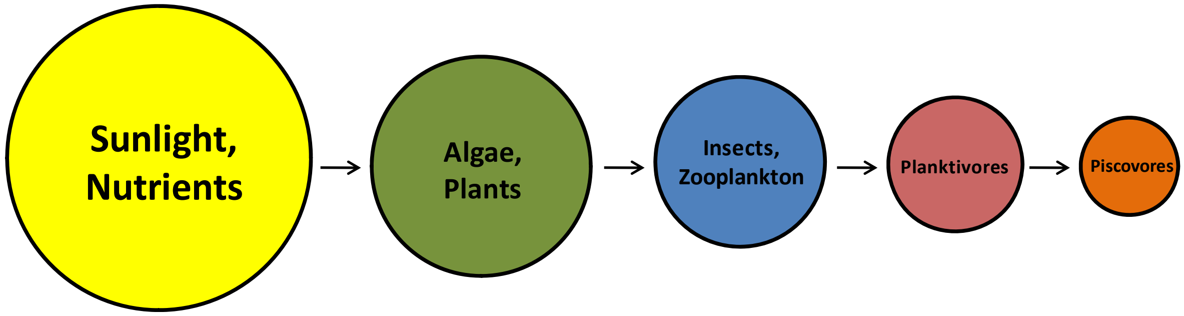


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

Little 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). Little 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 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).

Figure 3.5-2. Location of Little Arbor Vitae Lake within the Native American Ceded Territory (GLIFWC 2013A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2013B). 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 the opposite is true with only 7% of the total walleye harvest (115 fish) since 1998 comprising of female fish on Little Arbor Vitae Lake. 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 2013B). This regulation limits the harvest of the larger, spawning female walleye.

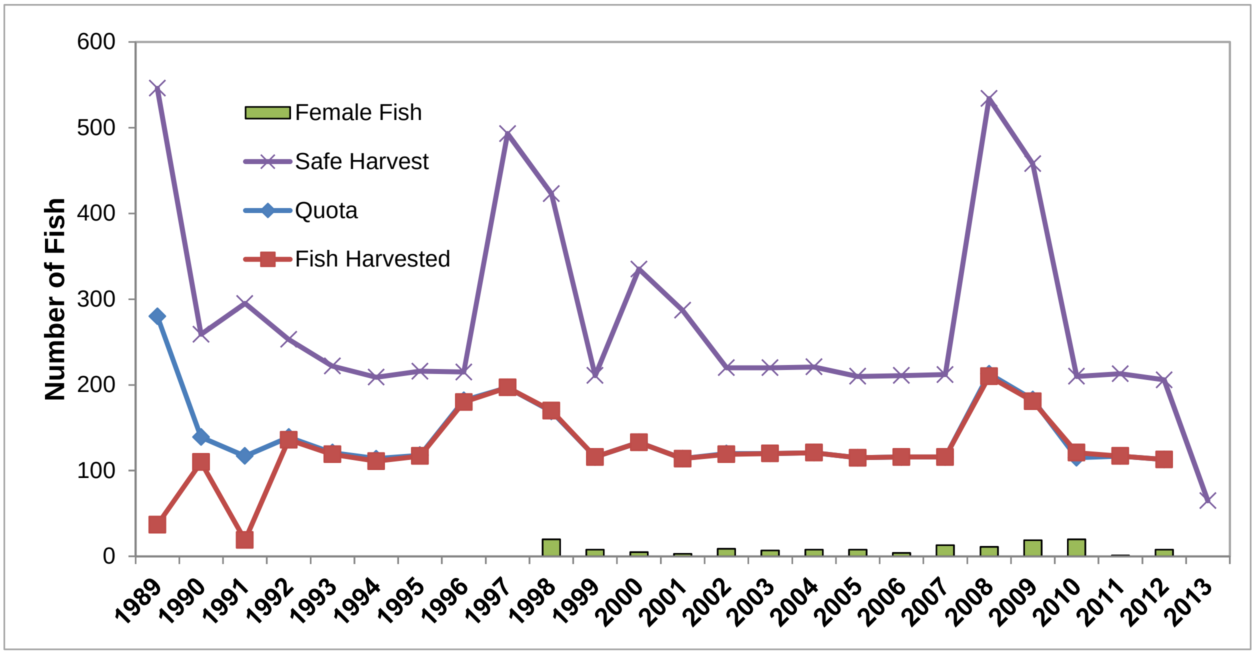


Figure 3.5-3. Open water spear harvest data of walleye for Little Arbor Vitae Lake. Annual walleye spear harvest statistics are displayed since 1989 (T. Cichosz, personal communication).

Figure 3.5-4 displays the Native American open water muskellunge spear harvest since 1998. Since 1998, an average of four muskellunge per year have been harvested during the open water spear fishery. During three of these years, no harvest occurred and in two of these years the quota set for that season was met. In 2009 the quota was adjusted from eight to 19 fish, which allowed for a greater harvest in this year.

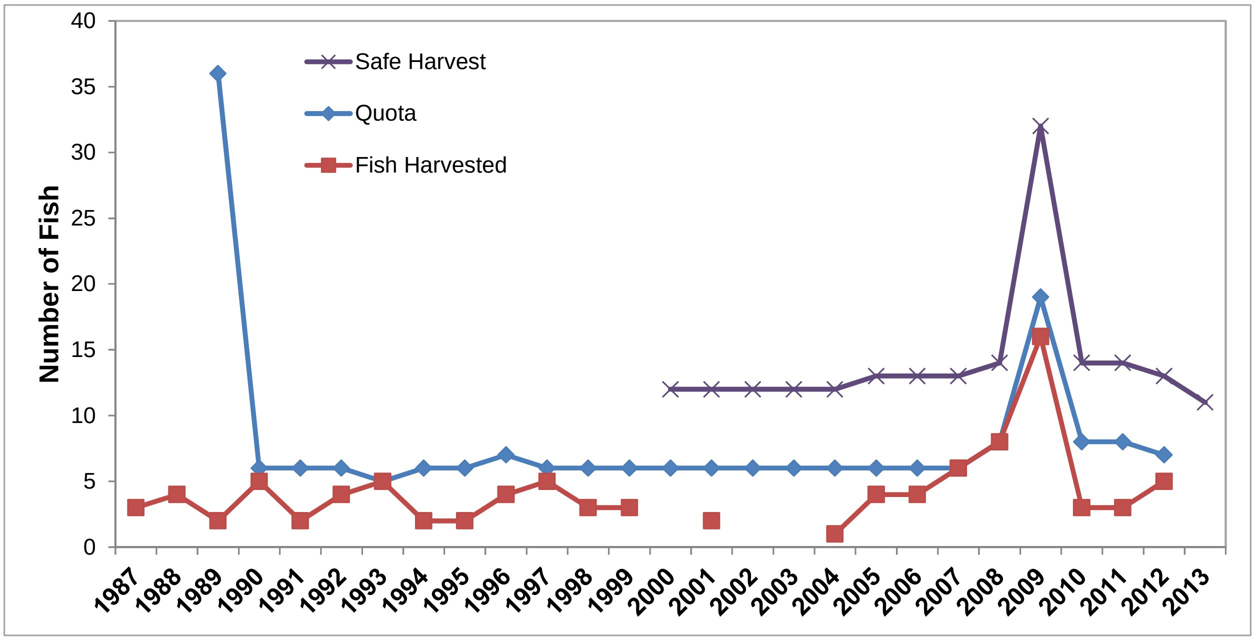


Figure 3.5-4. Open water spear harvest data of muskellunge for Little Arbor Vitae Lake. Annual walleye spear harvest statistics are displayed since 1989 (T. Cichosz, personal communication).

Little Arbor Vitae Lake Fish Stocking

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.

Muskellunge have been actively stocked in the lake from 1972 to present, while walleye stocking occurred to a lesser degree from 1972 to 1990, and ended in 1997. Data regarding WDNR stocking efforts can be found in Appendix G.

Little Arbor Vitae Lake Creel Surveys

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 it takes anglers to catch a particular species of fish. Creel surveys have been taken on Little Arbor Vitae Lake in 1990, 1996 and 2007. Directed effort at walleye has changed little between these years, while effort towards catching bass has increased and effort towards muskellunge has decreased (Table 3.5-2).

Table 3.5-2. Little Arbor Vitae Lake WDNR Creel Survey Summary (WDNR 2013)

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch / Acre	Harvest / Acre
Largemouth Bass	1990	64.7	0.8	0.4	0
	1996	60	0.9	0.1	0
	2007	47.3	1.9	1.5	0
Muskellunge	1990	64.7	29.8	2	0.2
	1996	60	24.3	2.1	0.1
	2007	47.3	10	0.4	0
Northern Pike	1990	64.7	0.1	0	0
	2007	47.3	1.4	0.9	0.4
Smallmouth Bass	1990	64.7	0.6	0.1	0
	1996	60	0.1	0	0
	2007	47.3	3.1	3.5	0.1
Walleye	1990	64.7	27.2	32.6	0.6
	1996	60	31.2	24.3	2
	2007	47.3	29.8	6.4	4.4

WDNR surveys have produced a wealth of information regarding fish harvest, both for tribal spearing and for anglers. Fisheries biologists use the term exploitation rate to describe the harvest that occurs with the adult population of a species. Tribal exploitation rates are determined by dividing the total tribal walleye harvest (all adult fish) by the estimated adult walleye population. Angler exploitation rates of adult fish are a little more complicated to assess. During years in which WDNR population estimates are made, creel survey studies are also typically conducted. Fish captured during population estimate surveys are given a mark, usually in the form of a fin clip, and are then released. When creel survey clerks interview anglers on the lake, they are able to estimate the number of marked fish that are recaptured. This allows biologists to calculate the angler exploitation rate of adult fish; this is done by dividing the estimated number of marked fish harvested by the total number of marked fish present in the lake. Essentially, this allows for a comparable exploitation rate to be made for tribal and angler harvest.

Figure 3.5-5 summarizes adult walleye exploitation rate data that have been calculated by the WDNR for Little Arbor Vitae Lake. These data suggest that although both anglers and tribal members harvest walleye from the lake, the angler harvest is usually more significant on an annual basis. This comparison analysis is typically not conducted for muskellunge because of the difficulties in achieving accurate population estimates and accurately measuring angler harvest.

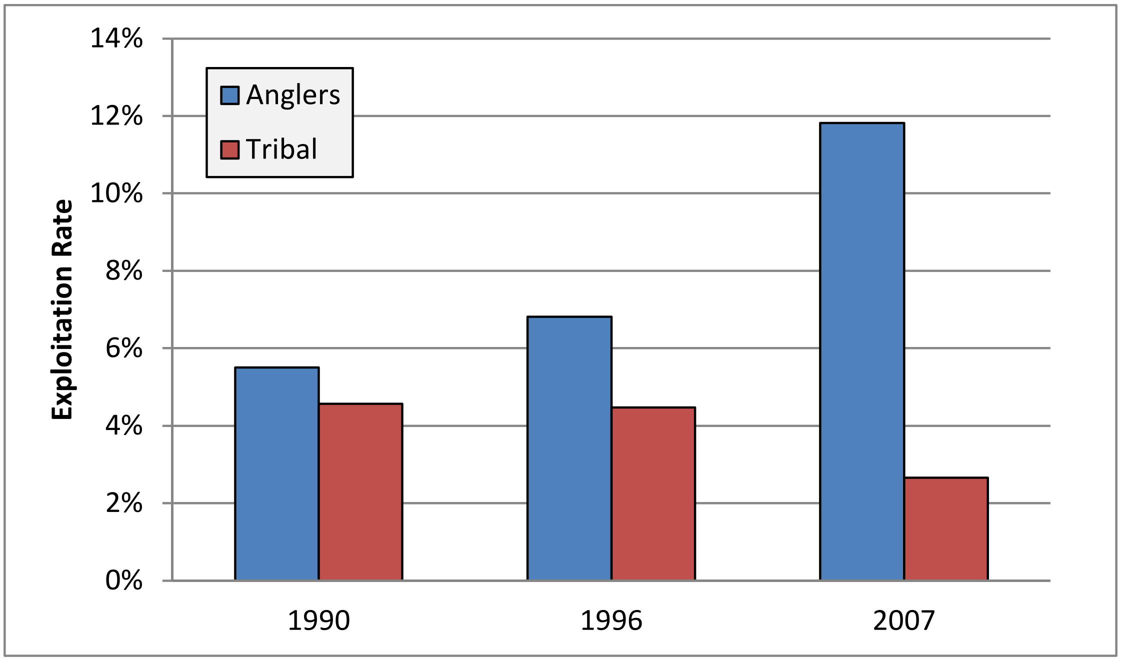


Figure 3.5-5. Little Arbor Vitae Lake walleye exploitation rates. Rates are calculated by WDNR personnel through tribal spear harvest monitoring, population estimate surveys and creel survey counts. Data was provided by the WDNR (T. Cichosz, personal communication).

Little Arbor Vitae Lake Substrate Type

According to the point-intercept survey conducted by Onterra, 59% of the substrate sampled in the littoral zone on Little Arbor Vitae Lake was muck, with 21% being classified as sand and 20% 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.

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 Little Arbor Vitae Lake ecosystem.
2) Determine if any non-native, invasive aquatic plant species exist within the lake, with a primary emphasis on curly-leaf pondweed and Eurasian water milfoil.
3) Collect sociological information from Little 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 an understanding of the Little Arbor Vitae Lake ecosystem, the people who have an active interest in the lake, and the actions needed to continue to protect and enhance it.

While there is limited and temporally sporadic historic water quality data, the data that are available along with the data collected in 2010 indicate that overall the water quality of Little Arbor Vitae Lake is *fair* for deep, lowland drainage lakes in Wisconsin. Phosphorus concentrations in Little Arbor Vitae Lake are relatively high when compared to other lakes within the region, and these high levels of nutrients produce high abundances of free-floating algae which reduces water clarity. Analysis of available water quality data shows that there are no apparent trends (positive or negative) occurring over the short timeframe in which we have data. However, analysis of core samples extracted from the lake bottom during the fall of 2012 indicate that nutrient conditions within the lake have changed significantly with higher concentrations occurring in present times compared to 100 or more years in the past.

The water quality of Little Arbor Vitae Lake is a reflection of the landscape in which the lake resides. While the lake's watershed is mainly comprised of intact forests and wetlands which export minimal amounts of phosphorus, the watershed is very large relative to the area of the lake and one would expect Little Arbor Vitae have higher levels of nutrients. However, watershed modeling revealed that the phosphorus levels within Little Arbor Vitae Lake are much higher than what is to be expected given the size and landscape of its watershed, and indicate an unaccounted source(s) of phosphorus is being delivered to the lake. As discussed within the Water Quality and Watershed Sections, it is believed that some of this phosphorus is coming from periodic phosphorus loading from bottom sediments. Studies conducted on upstream Big Arbor Vitae Lake indicate that this same phenomenon is also occurring, which is likely delivering even more phosphorus to Little Arbor Vitae Lake through Link Creek. Both lakes share the same watershed, and what happens on Big Arbor Vitae Lake is going to have an impact on Little Arbor Vitae Lake. While the data collected on these lakes in 2010 and 2011 suggests that internal nutrient loading is occurring on both systems, a more rigorous and detailed study needs to be conducted to gain a better understanding of how much phosphorus is being delivered via internal loading and its impacts to these lakes' ecology. Details pertaining to this study can be found in the Implementation Plan Section.

The 2010 shoreline assessment survey revealed that the majority of Little Arbor Vitae Lake's shoreline is currently in a completely natural or undeveloped state. These areas are important for maintaining the integrity of Little Arbor Vitae Lake's environment as they buffer runoff from the immediate watershed and provide essential habitat for aquatic and terrestrial wildlife. While it may be of interest for Little Arbor Vitae Lake stakeholders to restore some of the more developed shorelines around the lake, it is even more important and feasible to preserve the shoreline areas that are currently undeveloped.

The 2010 aquatic plant studies show that Little Arbor Vitae Lake contains a high number of native aquatic plant species, though species diversity is low as the community is highly dominated by just a few species. The high abundance of coontail and common waterweed are indicative of a highly productive system as these species are able to obtain most of their nutrients directly from the water and are tolerant of low light conditions. Most of the vegetation in Little Arbor Vitae Lake is located in the shallow bays, making these areas very important in terms of structural habitat and food for wildlife. Neither Eurasian water milfoil nor curly-leaf pondweed were located during the 2010 surveys.

5.0 IMPLEMENTATION PLAN

During the second Planning Meeting, the Little Arbor Vitae Lake Planning Committee discussed the results of the management plan study with ecologists/planners from Onterra and closely examined Little Arbor Vitae Lake as well as the people who live around it. The committee developed a mission statement to set a focus point for the next step in the lake management process, which would be to develop goals and strategies to deal with challenges raised during the study.

Mission Statement

To preserve and enhance the Little Arbor Vitae Lake Ecosystem and its recreational value through continued monitoring of the lake environment and education and involvement of all lake users.

Following the development of this mission statement, the Planning Committee examined the strengths and weaknesses of Little Arbor Vitae Lake and its stakeholders, as well as the opportunities and threats they face. These issues were discussed in terms of 1) feasibility of addressing the issue, and 2) level of the issue's importance. As of result of the discussion, the LAVLPRD was able to identify goals for protection and enhancing Little Arbor Vitae Lake, as well as communicating and educating individuals who use the lake.

The implementation plan presented below represents the path the LAVLPRD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and achievable, as are the action steps required to reach these goals. The implementation plan is a living document that 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 lake's stakeholders.

Management Goal 1: Increase Little Arbor Vitae Lake Protection & Rehabilitation District's Capacity to Communicate with Lake Stakeholders

Management Action: Support an Education and Communication Committee to promote stakeholder involvement, inform stakeholders on lake issues such as water quality and invasive species, as well as the quality of life on Little Arbor Vitae Lake.

Timeframe: Begin 2013

Facilitator: Board of Directors to form Education and Communication Committee.

Description: Education represents an effective tool to address lake issues like water quality, invasive species, shoreline development, lawn fertilization, as well as other concerns such as community involvement, noise or light pollution, and boating safety. An Education and Communication Committee will be created to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the LAVLPRD regularly publishes and distributes a printed district newsletter to members. While this is an excellent source of communication to district members, the LAVLPRD would like to reach out beyond those in the district and encompass additional individuals who take an interest in or recreate on Little Arbor Vitae Lake. To increase the district's level of communication to district and non-district members alike, the LAVLRPD will launch a district website and publish an electronic form of their newsletter.

This level of communication is important within a management group because it builds a sense of community while facilitating the spread of important district news, educational topics, and even social happenings. It also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well-written newsletter can be used as a tool to increase awareness of many aspects of lake ecology and management among district members. By doing this, meetings can often be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the district newsletter may contain monitoring results, district management history, as well as other educational topics listed below.

In addition to creating a regularly published district newsletter, a variety of educational efforts will be initiated by the Education and Communication Committee. These may include educational materials, awareness events and demonstrations for lake users, as well as activities which solicit local and state government support.

Example Educational Topics:

- Aquatic invasive species monitoring updates
- Water quality monitoring updates
- Catch-and-release fishing
- Fishing rules and regulations
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreline restoration and protection
- Septic system maintenance
- Specific topics brought forth in other management actions

Action Steps:

1. Recruit volunteers to form Education and Communication Committee.
2. Investigate if WDNR Small-scale Lake Planning or AIS Education, Planning, and Prevention Grants would be appropriate to cover initial setup costs.
3. The LAVLPRD Board will identify a base level of financial support for educational activities to be undertaken by the Education and Communication Committee on an annual basis.

Management Goal 2: Enhance Current Water Quality Conditions

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

Timeframe: Continuation of current effort.

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.

Through the WDNR Citizen Lake Monitoring Network (CLMN) program, volunteers from Little Arbor Vitae Lake (Nancy and Gary Grapentine) have collected Secchi disk transparency data since 2008. In 2013, the LAVLPRD entered into the CLMN's advanced water quality monitoring program, where in addition to Secchi disk transparency, near-surface total phosphorus and chlorophyll-*a* concentrations are collected four times per year.

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. Board of Directors recruits volunteer coordinator from district.
2. Coordinator directs water quality monitoring program efforts and volunteers.
3. 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: Little Arbor Vitae and Big Arbor Vitae Lakes Boards of Directors

Description: As discussed in the Water Quality and Watershed sections, total phosphorus concentrations in Little 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 2010 suggests that this phosphorus is originating from bottom sediments. Little Arbor Vitae Lake is a polymictic lake, meaning it has the potential to break stratification and turnover multiple times throughout the growing season provided there is sufficient wind energy. When Little 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. Big Arbor Vitae Lake is also polymictic and studies conducted in 2011 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.

Little Arbor Vitae and Big 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 Little Arbor Vitae Lake Protection and Rehabilitation District (LAVLPRD) and Big Arbor Vitae Lake Association (BAVLA) 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 LAVLPRD and BAVLA would apply for a Wisconsin Department of Natural Resources Lake Protection Grant under the Diagnostic/Feasibility Category as early as May of 2013. 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 LAVLPRD and BAVLA volunteers. A dissolved oxygen and temperature profile would also be created during each of the sampling events.

Little Arbor Vitae and Big Arbor Vitae Lakes Tributaries Monitoring

Flow meters will be deployed at the mouths of the inlets flowing into both Little Arbor Vitae and Big 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 LAVLPRD and BAVLA 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 Little Arbor Vitae and Big Arbor Vitae Lakes, 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 partioning. 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 LAVPRD, BAVLA and consultant if available. 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.

<u>Management Action:</u> Initiate restoration of Blue Island Resort and Condos shoreland zone.

Timeframe: Initiate 2014

Facilitator: LAVLPRD Board of Directors

Description: As discussed within the Shoreland Condition Section, the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects.

Many misconceptions are held regarding a natural shoreland. The costs involved, the level of work required for restoration, the visual aspects of the end product; these elements are largely unknown to most lake residents. Fortunately, restoration of the shoreland zone can be less expensive, less time-consuming and much easier to accomplish than restoration efforts in other parts of the watershed. Cost-sharing grants and Vilas County staff devoted to these types of projects give private property owners the funds and information resources to restore quality shoreland habitat to their lakeside residence. Vilas County conservation specialists have much experience with this matter, and while their ability to answer questions and describe what a restored shoreland site might feature is useful, few things are as effective as a physical demonstration site. It could be used as a demonstration tool to inform other riparian property owners about the costs.

In 2013, property owners of the Blue Island Resort and Condos worked with Quita Sheehan, a Lake Conservations Specialist with Vilas County Land and Water Conservation Department, to initiate a shoreland restoration project on their property to reduce shoreline erosion and to act as a demonstration site for other Little Arbor Vitae Lake riparian property owners. Currently, Quita and the LAVLPRD are actively seeking a WDNR Lake Protection Grant, of which the deadline was extended to the end of 2013, to aid in funding the shoreland restoration. During and following the shoreland restoration, pictures, educational material and site field trips, with property owner permission (if applicable), would be promoted by the district to inform other property owners of the shoreland restoration process. This in turn would hopefully spur further shoreland restoration actions on Little Arbor Vitae Lake.

Action Steps:

1. Work with Vilas County Lake Conservation Specialist (Quite Sheehan) to obtain WDNR Lake Protection Grant to fund the shoreland restoration on the Blue Island Resort and Condos' property.
2. Upon completion of the project, highlight efforts of the process in the district's newsletter, website, or other means as determine appropriate by the LAVLPRD board of directors.

Management Goal 4: Prevent Aquatic Invasive Species Introductions to Little Arbor Vitae Lake

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

Timeframe: Continuation of current effort.

Facilitator: Planning Committee

Description: At this time, Little Arbor Vitae Lake is believed to be free of the non-native species Eurasian water milfoil and curly-leaf pondweed. At present, the non-native purple loosestrife, rusty crayfish, and the Chinese and banded mystery snails are known to occur in Little Arbor Vitae Lake.

Members of the LAVLPRD have been trained on Clean Boats Clean Waters (CBCW) protocols and completing boat inspections at public landings on a regular basis. The intent of these boat inspections is prevent the introduction additional invasive species to the lake as well as preventing invasive species from being transported from the lake. The goal would be to cover the landing during periods of highest use to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of spread.

While the LAVLPRD has utilized paid inspectors in the past and will continue to use them in the future, they would like to increase their number of inspection hours by using unpaid volunteers. An education initiative (see Education Goal) will attempt to reach out to other district members and inform them on the importance of these inspections, and in turn the district will hopefully gain more volunteers for inspections.

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 during the summer of 2013.
3. Continue inspections during high-use weekends.
4. Report results to WDNR and SGLA.
5. Promote enlistment and training of new volunteers to keep the program fresh.

Management Action: Continue assessment of shoreline and littoral areas of the lake for aquatic invasive species via the Shoreline Sentinels.

Timeframe: In progress

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. Currently, the LAVLPRD performs a considerable amount of aquatic invasive species (AIS) monitoring through their "Shoreline Sentinels," in which the LAVLPRD volunteers monitor the entire area of the system in which plants can grow (littoral zone) annually in search of Eurasian water milfoil and curly-leaf pondweed. This program uses an "adopt-a-shoreline" approach where volunteers are responsible for surveying specified areas of the system.

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 LAVLPRD 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.

Management Action: Initiate aquatic invasive species rapid response plan upon discovery of infestation.

Timeframe: Initiate upon exotic infestation

Facilitator: Planning Committee with professional help as needed

Description: In the event that an aquatic invasive species is located by the trained volunteers, the areas would be marked using GPS and would serve as focus areas for professional ecologists. Those focus areas would be surveyed by professionals during that plant species peak growth phase (late summer for Eurasian water milfoil, early summer for curly-leaf pondweed) and the results would be used to create a prospective treatment strategy for the following spring. Eurasian water milfoil is the primary aquatic invasive species being managed in this region of the state and the following paragraphs will contain specific information pertaining to this species.

Small isolated infestations of Eurasian water milfoil can most appropriately be controlled using manual removal methods, likely through scuba or snorkeling efforts. The responsible use of this technique is well supported by LAVPRD stakeholders as indicated by approximately 86% of stakeholder survey respondents indicating that they are at least moderately supportive of a manual removal program (Appendix B, Question #27). In order for this technique to be successful, the entire plant (including the root) needs to be removed from the lake. During manual extraction, careful attention would need to be paid to all plant fragments that may detach during the control effort.

At this time, the most feasible method to control larger infestations is through herbicide applications, specifically, early-spring treatments with 2,4-D. Likely as a condition of the WDNR herbicide application permit, a spring refinement and verification survey by professionals would precede the treatment as well as post treatment surveys to evaluate the control action. Approximately 47% of LAVLPRD stakeholders were not supportive of an herbicide control program (Appendix B, Question #21). Depending on the level of support for an herbicide control program at the time of a Eurasian water milfoil or curly-leaf pondweed population discovery, if the population is too large to be controlled using manual removal techniques, the LAVLPRD needs to be educated on potential alternative strategies and/or not doing anything.

If large populations of Eurasian water milfoil or curly-leaf pondweed are located, a formal monitoring strategy consistent with the WDNR document, Aquatic Plant Community Evaluation with Chemical Manipulation (Draft), would need to accompany the herbicide application. This form of monitoring is required by the WDNR for all large scale herbicide applications (exceeding 10 acres in size or 10% of the area of the water body that is 10 feet or less in depth and treatment areas that are more than 150 feet from shore) and grant-funded projects where scientific and financial accountability are required.

Action Steps:

1. See description above.

<u>Management Action:</u> Reduce occurrence of purple loosestrife on Little Arbor Vitae Lake shorelines.

Timeframe: Begin 2013

Facilitator: Planning Committee

Description: In 2010, one occurrence of purple loosestrife was documented on the lake's shoreline near the mouth of Link Creek (Map 6). As with any invasive species, early control strategies are essential to gain control of the population. In regards to purple loosestrife, this hardy perennial is more resilient the longer it is allowed to grow in one location as its root system becomes more robust and extensive. It also produces a large number of seeds which can germinate years after the parent plant has been removed, which makes continued monitoring essential for control.

Manually removing isolated purple loosestrife plants is likely the best control strategy at this time. Once the property owner grants permission to remove the plant, it should be dug out of the ground, roots and all. If flowers or seeds are present at the time of the extraction, the flower heads should be carefully cut off and bagged to make sure seeds don't inadvertently get spread around during removal. Plants and seed heads should either be burned or bagged and put into the garbage.

Action Steps:

1. Monitor shoreline areas during Shoreline Sentinel surveys for purple loosestrife plants.
2. If plants are located, initiate manual removal control methods.
3. Monitor results and reapply control as necessary.
4. Keep stakeholders and managers informed regarding program results.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Little 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 Little 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 Little Arbor Vitae Lake during a June 2010 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 Little 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 "Appendix D" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2007) was used to complete this study on August 2 and 3, 2010. A point spacing of 56 meters was used resulting in approximately 692 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Little 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 – Steven's Point Herbarium. A set of samples was also provided to the LAVLPRD.

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