Arbutus Lake

Forest County, Wisconsin

Comprehensive Management Plan

March 2013

Sponsored by:

Arbutus Lake Association, Inc.

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Onterra, LLC
Lake Management Planning

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

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1.0 INTRODUCTION

Arbutus Lake, Forest County, is a 161-acre seepage lake with a maximum depth of 28 feet. The only aquatic invasive species (AIS) known to exist in Arbutus Lake is the freshwater jellyfish. There are no non-native plant species known to be present in Arbutus Lake, but because of their presence in many nearby lakes (Pickerel Lake is within 1 mile and contains Eurasian water milfoil), the Arbutus Lake Association (ALA) has adopted a proactive strategy to protect their lake. The ALA elected to complete the planning program reported on their lake for two main reasons: to learn whether exotic plants occur in their lake and to understand their lake ecosystem more fully. The data collected from the studies outlined in this project will serve as a baseline set of data for which this planning project and those in the future may call upon.

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 May 24, 2008, a project kick-off meeting was held at lake residence's property in conjunction with the association's annual meeting. The presentation's purpose was to introduce the project to lake association members and the general public alike. The meeting was announced through a mailing and personal contact by Arbutus Lake Association board members. The approximately 35 attendees were welcomed by ALA President, Ryan Vanden Heuvel and were informed about the events that led to the initiation of the project. Vanden Heuvel's opening remarks were followed by a presentation given by Tim Hoyman that started with an educational component regarding general lake ecology and ending with a detailed description of the project including opportunities for stakeholders to be involved. Mr. Hoyman's presentation was followed by a question and answer session.

Stakeholder Survey
During June 2009, a six-page, 24-question survey was mailed to 98 riparian property owners in the Arbutus Lake watershed. Roughly 72 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Arbutus 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 September 30, 2009, Tim Hoyman of Onterra met with seven members of the Arbutus Lake Planning Committee for nearly 3 hours. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Several concerns were raised by the committee, including increased levels of aquatic plants in the lake.

Planning Committee Meeting II

On October 14, 2009, Tim Hoyman met with the members of the Planning Committee to discuss the stakeholder survey results and begin developing management goals and actions for the Arbutus Lake management plan.

Project Wrap-up Meeting

On May 15, 2010, the Arbutus Lake Association held a special meeting regarding the completion of the Arbutus Lake Management Planning Project. During the meeting, Tim Hoyman presented the results of the many studies that had been completed on the lake since 2008 along with a detailed description of the Implementation Plan the association's Planning Committee created. He also answered many questions about the lake and how it should be managed.

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, not all chemical attributes collected may have a direct bearing on the lake's ecology, but may be more useful as indicators of other problems. Finally, 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 analysis 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 ecology 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.

Comparisons with Other Datasets

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 similar lakes in the area. In this document, a portion of the water quality information collected in Arbutus Lake (data contained in Appendix C) are compared to other lakes in the region and state. 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 Arbutus Lake 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).

Lillie and Mason (1983) is an excellent source of data for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Forest County's lakes are included within the study's Northeast region (Figure 3.1-1) and are among 242 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data, along with data corresponding to statewide natural lake averages and historic data from Arbutus Lake are displayed in Figures 3.1-2 – 3.1-4. Please note that the data in these graphs represent values collected from the deepest location in Arbutus Lake (Map 1). 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 (see discussion under Internal Nutrient Loading on page 9). Surface samples in Arbutus Lake were collected at a depth of 3 feet.

Figure 3.1-1. Location of Arbutus Lake within the regions utilized by Lillie and Mason (1983).

The data presented in Figures 3.1-2 – 3.1-4 represents samples collected during the growing season (March 31-November 1) and during the summer (May 31-September 1). These values may differ due to seasonal fluctuations in nutrients or physical water events such as lake mixing and stratification (discussed further below); therefore, they are separated and analyzed differently.

Apparent Water Quality Index

Water quality, like beauty, is often in the eye of the beholder. A person from southern Wisconsin that has never seen a northern lake may consider the water quality of their lake to be good if the bottom is visible in four feet of water. On the other hand, a person accustomed to seeing the bottom in 18 feet of water may be alarmed at the clarity found in a southern Wisconsin lake.

Lillie and Mason (1983) used the extensive data they compiled to create the Apparent Water Quality Index (WQI). They divided the phosphorus, chlorophyll-*a*, and clarity data of the state's lakes into ranked categories and assigned each a "quality" label from "Excellent" to "Very Poor". The categories were created based upon natural divisions in the dataset and upon their experience. As a result, using the WQI as an assessment tool is very much like comparing a particular lake's values to values from many other lakes in the state. However, the use of terms like, "Poor", "Fair", and "Good" bring about a better understanding of the results than just comparing averages or other statistical values between lakes. The WQI values corresponding to the phosphorus, chlorophyll-*a*, and Secchi disk values for Arbutus Lake are displayed on Figures 3.1-2 – 3.1-4.

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. 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.

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.

Carlson (1977) presented a trophic state index that gained great acceptance among lake managers. Because Carlson developed his TSI equations on the basis of association among water clarity, chlorophyll-a, and total phosphorus values of a relatively small set of Minnesota Lakes, researchers from Wisconsin (Lillie et. al. 1993), developed a new set of relationships and equations based upon the data compiled in Lillie & Mason (1983). This resulted in the Wisconsin Trophic State Index (WTSI), which is essentially a TSI calibrated for Wisconsin lakes. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Citizen Lake Monitoring Network volunteers.

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.

*Lack of dissolved oxygen profiles and hypolimnetic phosphorus data prevents these analyses from being performed. The explanation provided under this heading is strictly for the information of the reader.

Arbutus Lake Water Quality Analysis

Arbutus Lake Long-term Trends

The available water quality data for Arbutus Lake spans the years of 1994 to 2009. However with several gaps in the dataset it is difficult to determine any realistic trends. This is unfortunate because having an understanding of how the lake has changed over the years is interesting and leads to sounder management decisions. According to the results of the stakeholder survey, roughly 86% of respondents consider the water quality of Arbutus Lake to be “Fair” to “Excellent” (Appendix B, Question 11) yet the majority of the stakeholders also believe that the lake’s water quality has either remained the same or degraded (82.3%) since they have owned their property (Appendix B, Question #12). Water quality degradation / pollution is the second highest concern amongst the responding stakeholders (Appendix B, Question #16). The historic data that does exist shows that while there are fluctuations in many parameters, the water quality appears to have remained relatively the same over the past 15 years.

As previously mentioned, the three most pertinent water quality parameters to examine are total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Summer 2009 total phosphorus concentrations are very similar to those measured in earlier years (Figure 3.1-2). These averages have remained within the WQI categories of “Good” and “Very Good” for all years since 1994. Furthermore, the averages are low when compared to other Wisconsin natural lakes and those lakes within the Northeast region. The range in this dataset is fairly small; that is averages have been very consistent during this time period. Environmental factors can drastically influence the water chemistry of a lake, and these variations can and do occur on an annual basis.

A similar historical dataset, in terms of size, exists for chlorophyll-*a* on Arbutus Lake. The summer average concentrations rank as "Very Good" in all years, and are exceptionally low when compared to state and regional lakes (Figure 3.1-3). Often, it is phosphorus that determines the amount of algal growth in lakes, and thus the concentration of chlorophyll-*a* as well. With low phosphorus concentrations, we would expect to see low chlorophyll-*a* values, and this is certainly the case in Arbutus Lake.

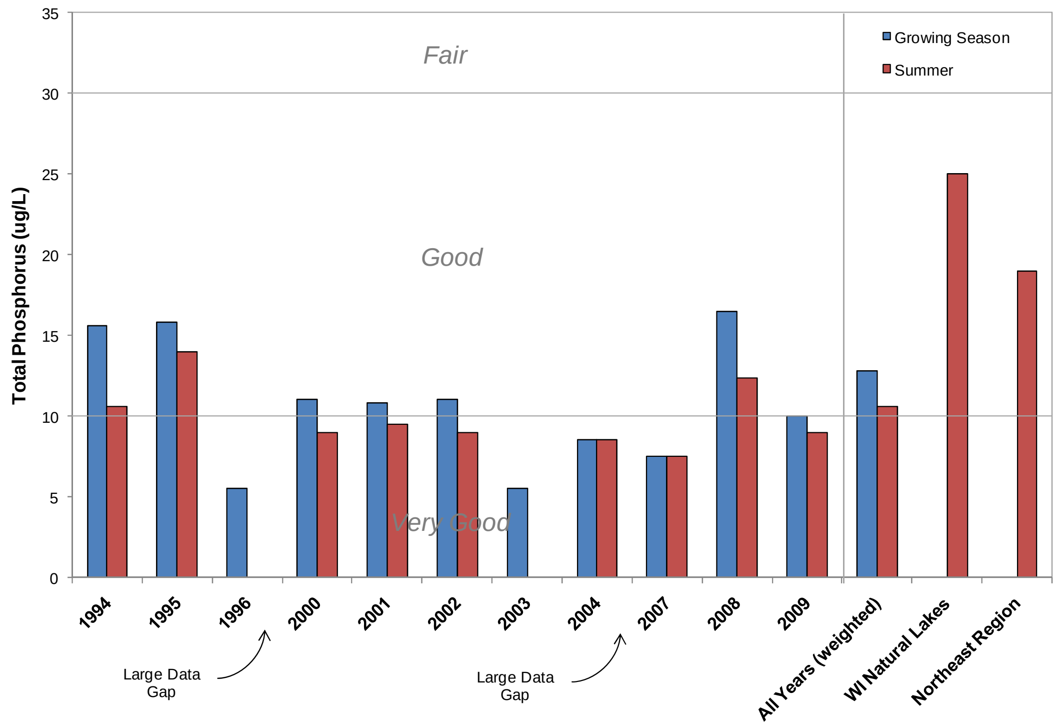

Figure 3.1-2. Arbutus Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

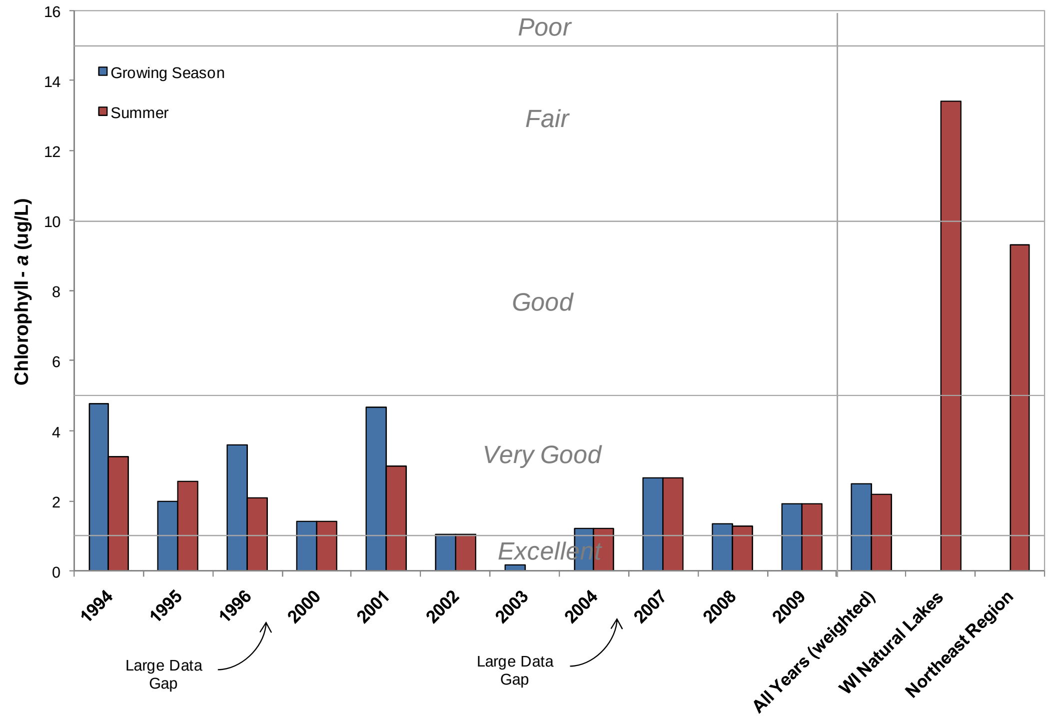

Figure 3.1-3. Arbutus Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

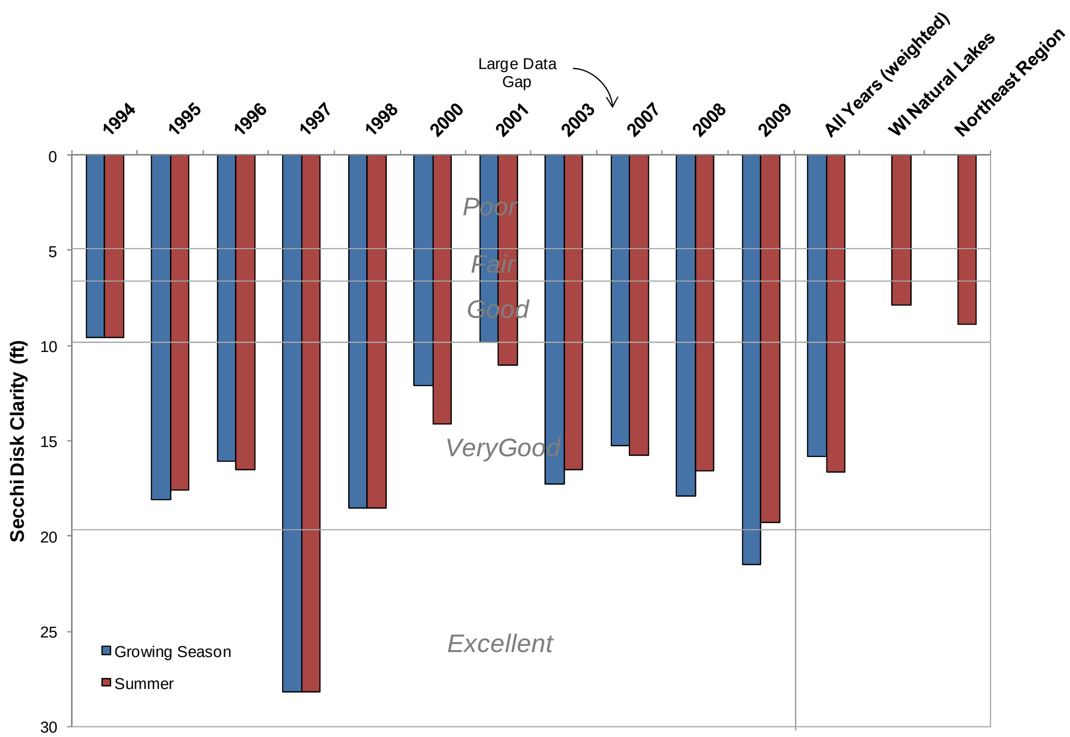

Figure 3.1-4. Arbutus Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

All of the Secchi disk transparency averages collected since 1994 exceed averages from Wisconsin natural lakes and those lakes found within the Northeast region (Figure 3.1-4, above). Please note the inverted graph on this chart, which is done so to represent depth into the water column. Although no apparent trend can be distinguished from the dataset, what is easily seen is that fluctuations in water clarity do occur on Arbutus Lake. These annual summer averages range from “Good” to “Excellent” though most years fall in a WQI category of “Very Good”. Many factors influence Secchi disk transparency, including algae abundance, siltation, or stained water color due to dissolved organic acids.

In 1997, when Secchi disk transparency was at its highest, phosphorus and chlorophyll-*a* data was not collected so it is impossible to correlate these parameters in this year. The data is somewhat suspect however, due to readings of 29 and 32 feet being collected in June of 1997. It was noted by the CLMN volunteer that the 32 ft. reading reached the bottom of the lake. The maximum depth of the lake is listed by the WDNR as 28 feet. Regardless, the lowest reading of 1997, 23.5 feet, is still an “Excellent” reading for water clarity.

Limiting Plant Nutrient of Arbutus Lake

Using midsummer nitrogen and phosphorus concentrations from Arbutus Lake, a nitrogen:phosphorus ratio of 37:1 was calculated. This finding indicates that Arbutus 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.

Arbutus Lake Trophic State

Figure 3.1-5 contains the WTSI values for Arbutus Lake. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from middle mesotrophic to upper oligotrophic. 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* WTSI values, it can be concluded that Arbutus Lake is in a middle mesotrophic state.

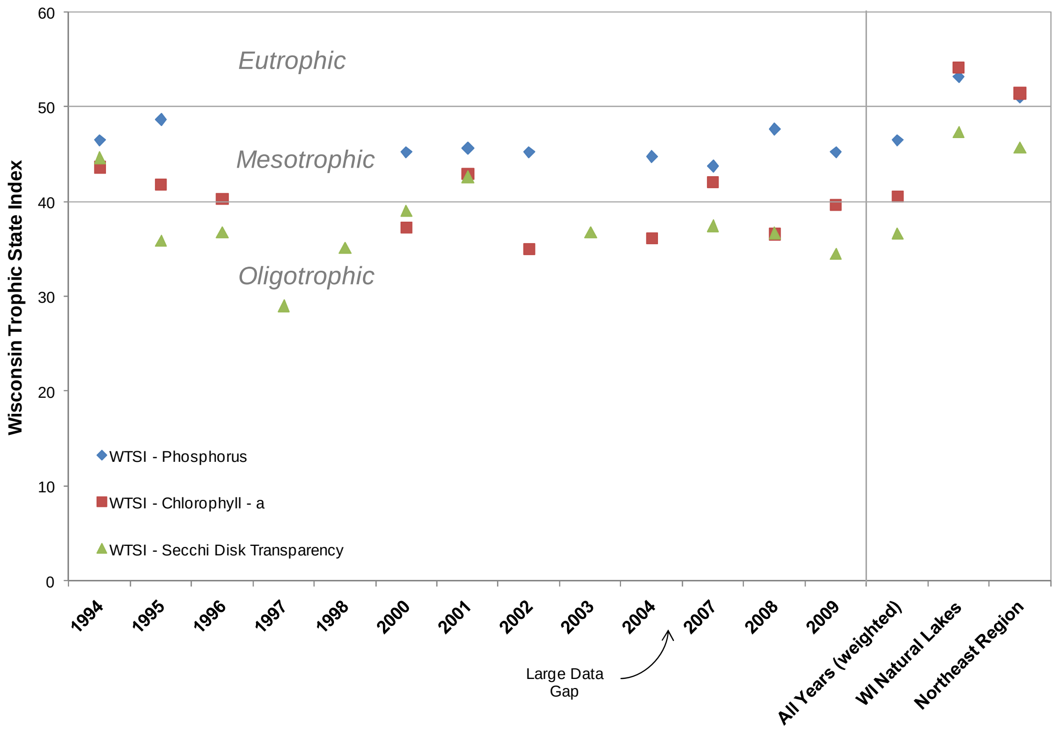

Figure 3.1-5. Arbutus Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Dissolved Oxygen and Temperature in Arbutus Lake

Dissolved oxygen and temperature were measured on several occasions in Arbutus Lake. Onterra staff measured both of these parameters during the 2008 spring and fall turnover, and also in the winter of 2009 (Figure 3.1-6). The data collected during May and October of 2008 shows considerably high dissolved oxygen levels throughout the entire water column. The February dissolved oxygen profile displays decreasing oxygen with depth. This is common in lakes with several months of ice cover. The water cannot exchange gases (carbon dioxide or oxygen) with the air due to the ice cover, and aquatic plants die off and decompose. This decomposition process occurs over the winter, and utilizes the available oxygen. The decrease in oxygen may appear drastic, however the vast majority of the lake still holds sufficient concentrations to support aquatic life (>5.0 mg/L) so consequences from low oxygen conditions (such as winter fish kills) should not be problematic for Arbutus Lake at this time.

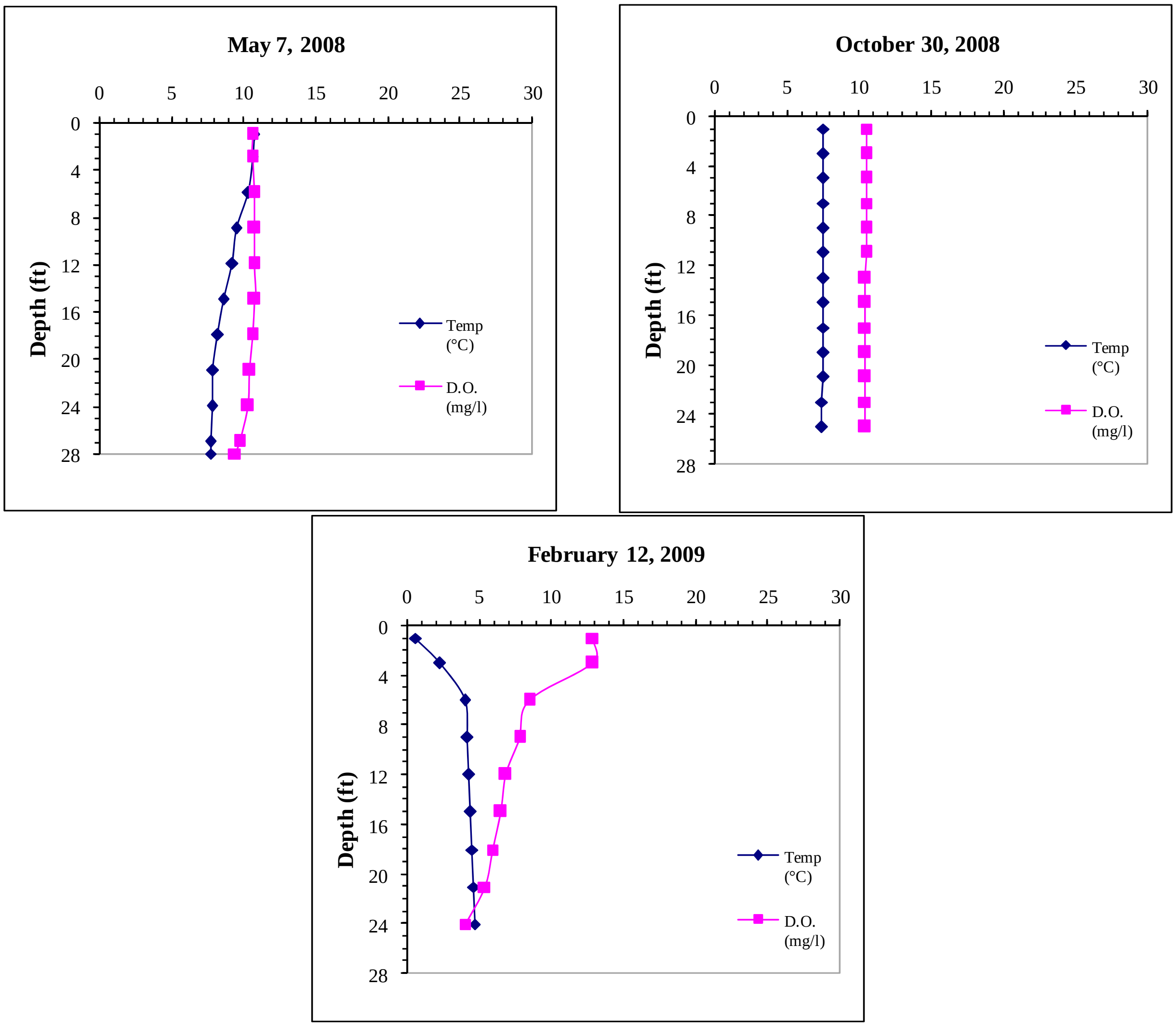

Figure 3.1-6. Arbutus Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Arbutus Lake

Alkalinity, pH, and calcium analysis were also performed on some of the water quality samples collected from Arbutus Lake. Alkalinity was measured at 24.0 mg/L as $CaCO_3$ during the month of May, 2008 indicating that the lake has a higher buffering capacity against acid rain. During the same time, the lake's pH was measured at 6.9 or slightly below neutral. The pH value is normal for a lake such as Arbutus Lake and is well within the optimal range for zebra mussels. However, calcium analysis from a sample collected during May 2008 returned a value of 5.8 mg/L, which is lower than the minimum concentration that is thought to be required for zebra mussels.

3.2 Watershed Assessment

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

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

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

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 can be 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 watershed of Arbutus Lake encompasses approximately 753 acres. This watershed is largely dominated by forest (496 acres or 66%), with smaller portions of the lake surface (22%), wetlands (11%) and pasture / grass (1%) comprising the rest (Figure 3.2-1). The watershed covers three times as much surface as the lake, creating a watershed to lake area ratio of 3:1. As previously mentioned, the land cover becomes increasingly influential in lake water quality with a smaller watershed to lake area ratio.

The land cover type surrounding Arbutus Lake is that which is very efficient at absorbing nutrients and water, which should result in little runoff to the lake. Modeling of phosphorus runoff to Arbutus Lake using WiLMS confirms this. The annual phosphorus load for the lake is estimated to be 92.6 lbs, a relatively small amount for a lake of this size. Of the land cover types situated within the watershed, the largest contributing source to Arbutus Lake is the actual lake surface. An estimated 48% (44.1 lbs.) of phosphorus enters the lake annually through atmospheric deposition. Forested land (66% of the watershed) contributes 43% of this phosphorus load, with wetlands (7%) and pasture / grass (2%) rounding out the rest of the load (Figure 3.2-2).

Although the watershed is ideal for protecting the lake's water quality (small watershed to lake area ratio, highly vegetated land cover, etc.), concern should still be expressed regarding phosphorus inputs to the lake. Arbutus Lake flushes 37% of its entire volume of water in one year, which results in a water residence time of 2.7 years – meaning that the lake refills with new water every 2.7 years. This is a fairly low flushing rate, which means that the sediments and nutrients that are added to the lake tend to remain in the lake. Over time, these elements will build up in the system as this is a natural course for lakes to follow. This process (called eutrophication) can become accelerated by anthropogenic (human) impacts or disturbances (cultural eutrophication). On a lake such as Arbutus, the most significant source for pollutants to the lake will be from the lake's immediate watershed – its shoreland area. When a lake's shoreline becomes developed, these human disturbances (impervious surface, removal of natural vegetation, installation of septic systems, etc.) can increase the pollutant load to the lake while at the same time degrading important habitat. Keeping these anthropogenic effects to a minimum is vital to maintain the current high quality of the lake's water and habitat.

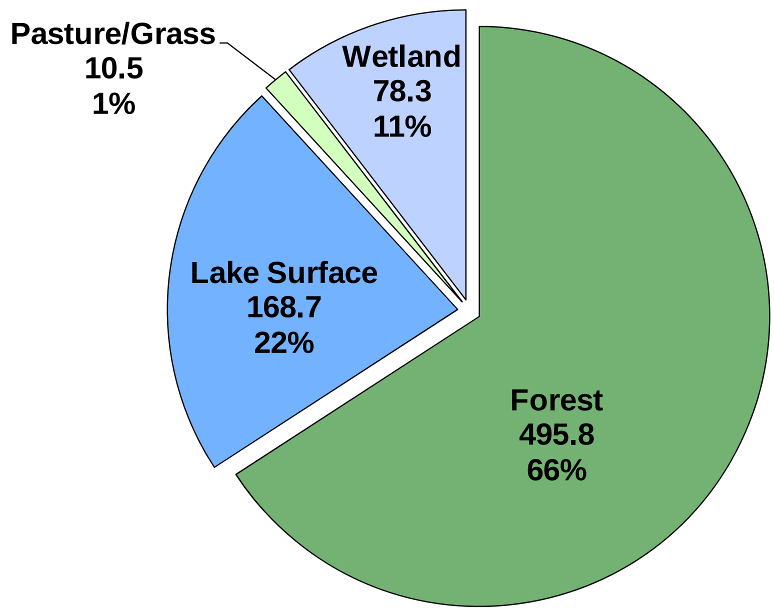

Figure 3.2-1. Arbutus Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

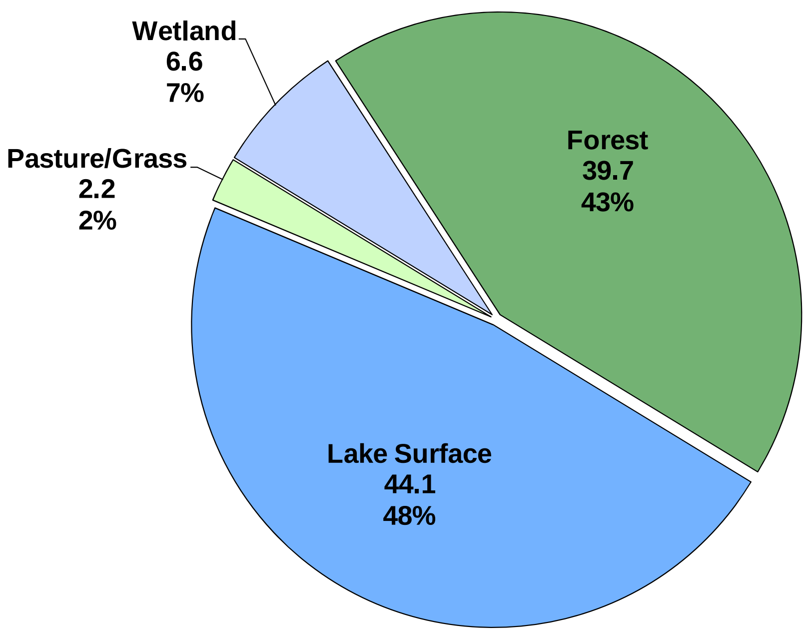

Figure 3.2-2. Arbutus Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Aquatic Plants

Introduction

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

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

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced numbers of predator fish and a stunted pan-fish population. Exotic plant species, such as Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

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

Important Note:
Even though most of these techniques are not applicable to Arbutus Lake, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake**.** The techniques applicable to Arbutus Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Permits

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

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

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 shoreline. 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 shoreline sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photograph 3.3-1. Example of a biolog restoration site.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic and shoreland plant restorations is highly variable and depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:
  - An upland buffer zone measuring 35’ x 100’.
  - An aquatic zone with shallow-water and deep-water areas of 10’ x 100’ each.
  - Site is assumed to need little invasive species removal prior to restoration.
  - Site has a moderate slope.
  - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
  - Plant spacing for the aquatic zone would be 3 feet.
  - Each site would need 100’ of biolog to protect the bank toe and each site would need 100’ of wavebreak and goose netting to protect aquatic plantings.
  - Each site would need 100’ of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
  - 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 shoreline erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • 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.

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.

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 affects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

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

Costs
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.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

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 does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

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.

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.

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 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. Some herbicides are applied at a high dose with the anticipation that the exposure time will be short. Granular herbicides are usually applied at a lower dose, but the release of the herbicide from the clay carrier is slower and increases the exposure time.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters where dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothall (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothall (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions may apply.

Triclopyr (Renovate®) Selective, systemic herbicide that is effective on broad leaf plants and, similar to 2,4 D, will not harm native monocots. Triclopyr is available in liquid or granular form, and can be combined with Endothal in small concentrations (<1.0 ppm) to effectively treat Eurasian water-milfoil. Triclopyr has been used in this way in Minnesota and Washington with some success.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a surfactant to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*). Glyphosate is also marketed under the name Roundup®; this formulation is not permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.

Imazapyr (Habitat®) Broad spectrum, systemic herbicide, slow-acting liquid herbicide used to control emergent species. This relatively new herbicide is largely used for controlling common reed (giant reed, *Phragmites*) where plant stalks are cut and the herbicide is directly applied to the exposed vascular tissue.

Cost

Herbicide application charges vary greatly between $400 and $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • 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.	• 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 herbicides are nonselective. • Most herbicides have a combination of use restrictions that must be followed after their application. • Many herbicides are slow-acting and may require multiple treatments throughout the growing season. • Overuse may lead to plant resistance to herbicides

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 waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. 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 Arbutus Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Arbutus Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, relative frequency of occurrence is used to describe how often each species occurred in the plots that contained vegetation. 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

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.

Figure 3.3-1. Location of Arbutus Lake within the ecoregions of Wisconsin. After Nichols 1999.

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 Arbutus Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.3-1).

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.

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 3.3-2). 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

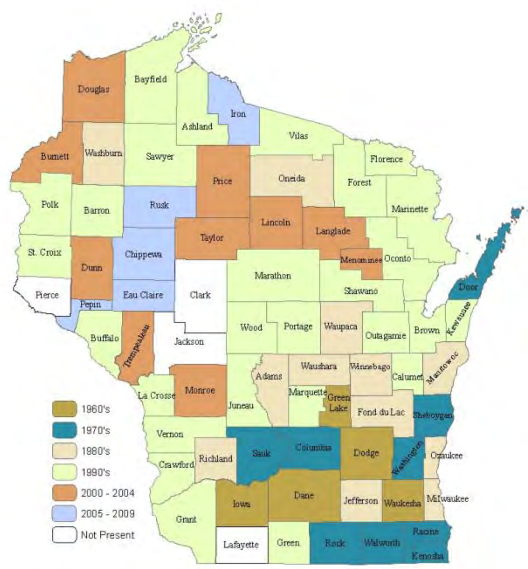

Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2009 mapped by Onterra.

vegetation. Like Eurasian water-milfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

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

Aquatic Plant Survey Results

As mentioned above, numerous plant surveys were completed as a part of this project. On June 17, 2008, a survey was completed on Arbutus Lake that focused upon curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed. It is believed that this aquatic invasive species either does not occur in Arbutus Lake or exists at an undetectable level.

Median Value This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

The point intercept survey was conducted on Arbutus Lake on August 4, 2008 by Onterra. Additional surveys were completed by Onterra on Arbutus Lake to create the aquatic plant community maps (Map 3) on this same day. No Eurasian water milfoil (EWM) or any other exotic invasive species were located within the system during the aquatic plant surveys. However, Pickerel and Crane Lakes, which are in very close proximity to Arbutus Lake, do have established populations of "hybrid" water milfoil, an invasive cross between EWM and one of our native milfoils, northern water milfoil (*Myriophyllum sibiricum*). Only one milfoil species, dwarf-water milfoil (*Myriophyllum tenellum*), was located in Arbutus Lake and is morphologically much different from the other 6 milfoil species known to occur in Wisconsin. Northern water milfoil, often falsely identified as Eurasian water milfoil, was not found growing in Arbutus Lake, so any other milfoil species observed other than dwarf-water milfoil should be suspect of being Eurasian or hybrid water milfoil.

During the point-intercept and aquatic plant mapping surveys, 36 species of plants were located in Arbutus Lake (Table 3.3-1), all of which are considered native. The plant community in Arbutus Lake is comprised of both isoetids and elodeids; terms used to described two morphological growth forms of aquatic plants.

Isoetids are small, slow-growing, turf-forming species, while elodeids are the much taller, leafy plants that most people have in their minds when it comes to aquatic plants. Most elodeids are restricted to lakes of relatively higher alkalinity, as their carbon demand for photosynthesis cannot be met solely by the dissolved carbon dioxide (CO_2) present in the water, and they must acquire additional carbon through bicarbonate (HCO_3^-). While isoetids are able to grow in lakes of higher alkalinity, their short stature makes them poor competitors for light, and they are usually outcompeted and displaced by the taller elodeids. Thus, isoetids are most prevalent in lakes of low alkalinity where they can avoid competition from elodeids. However, in lakes with intermediate alkalinity levels, like Arbutus Lake, we see a mixed community of both, with isoetids inhabiting the shallow, sandy/rocky areas and elodeids thriving in the deeper areas of soft sediment.

Table 3.3-1. Aquatic plant species located in Arbutus Lake during August 2008 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)
E	*Carex utriculata**	Common yellow lake sedge	7
	Dulichium arundinaceum	Three-way sedge	9
	*Eleocharis erythropoda**	Creeping spikerush	3
	*Sagittaria latifolia**	Common arrowhead	3
	Schoenoplectus subterminalis	Water bulrush	9
	*Typha latifolia**	Broad-leaved cattail	1
FL	*Brasenia schreberi*	Watershield	7
	Nuphar variegata	Spatterdock	6
	Nymphaea odorata	White water lily	6
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9
	*Sparganium emersum**	Short-stemmed bur-reed	8
Submergent	*Chara sp.*	Muskgrasses	7
	Elatine minima	Waterwort	9
	Elodea canadensis	Common waterweed	3
	Eriocaulon aquaticum	Pipewort	9
	Heteranthera dubia	Water stargrass	6
	Isoetes lacustris	Lake quillwort	8
	Lobelia dortmanna	Water lobelia	10
	Myriophyllum tenellum	Dwarf water milfoil	10
	Najas flexilis	Slender naiad	6
	Nitella sp.	Stoneworts	7
	Potamogeton amplifolius	Large-leaf pondweed	7
	Potamogeton epihydrus	Ribbon-leaf pondweed	8
	Potamogeton foliosus	Leafy pondweed	6
	Potamogeton gramineus	Variable pondweed	7
	Potamogeton natans	Floating-leaf pondweed	5
	Potamogeton pusillus	Small pondweed	7
	Potamogeton richardsonii	Clasping-leaf pondweed	5
	Potamogeton robbinsii	Fern pondweed	8
	Potamogeton zosteriformis	Flat-stem pondweed	6
	Ranunculus flammula	Creeping spearwort	9
	Utricularia intermedia	Flat-leaf bladderwort	9
	Utricularia vulgaris	Common bladderwort	7
	Vallisneria americana	Wild celery	6
SE	*Eleocharis acicularis*	Needle spikerush	5
	Juncus pelocarpus	Brown-fruited rush	8

E = Emergent
FL = Floating Leaf
FL/E = Floating Leaf and Emergent
S/E = Submergent and Emergent
* = Incidental

The southwestern bay of Arbutus Lake had a unique plant community of its own, with floating mats of vegetation along the shoreline indicative of a bog-like habitat. These habitat types, often nutrient poor, are home to many fascinating plant species, most notably carnivorous plants that prey on animals for supplementary nutrients. Three carnivorous species were observed in this area, including two bladderwort (*Utricularia*) species and the state's only pitcher plant species, the purple pitcher plant (*Sarracenia pupurea*).

Both bladderwort species observed in Arbutus Lake are submersed species, and are so named for their small, sac-like 'bladders' they produce to trap and digest small zooplankton prey. The pitcher plants were observed growing on the floating mats of vegetation, and at the time of the survey were producing their signature, large maroon flowers (Photograph 3.3-2). Like their name suggests, they produce pitcher-like leaves which fill with rain water to capture and digest insects.

Photograph 3.3-2 Pitcher Plants (*Sarracenia purpurea*) Flowers (left) and leaves (right) of pitcher plants on floating vegetation mats in the southwestern bay of Arbutus Lake.

Arbutus Lake contains a high number of aquatic plant species, and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influences the diversity. The diversity index for Arbutus Lake's plant community (0.87) indicates that the lake has a relatively even distribution (relative frequency) of plant species throughout the lake. Figure 3.3-3 shows that common waterweed, fern pondweed, and stoneworts were the most abundant species in Arbutus Lake. These dominant plants provide valuable structural habitat for invertebrates and foraging opportunities for fish species. Stoneworts, a type of macro-algae, were found consistently growing to a depth of 24 feet, a testament to the excellent water clarity in Arbutus Lake.

Data collected from the aquatic plant surveys indicate that the average conservatism value (6.8) is higher than the state median and the Northern Lakes Ecoregion median (Figure 3.3-4). This shows that the aquatic plants within Arbutus Lake are more indicative of a pristine condition than those found in most lakes in the state and the ecoregion.

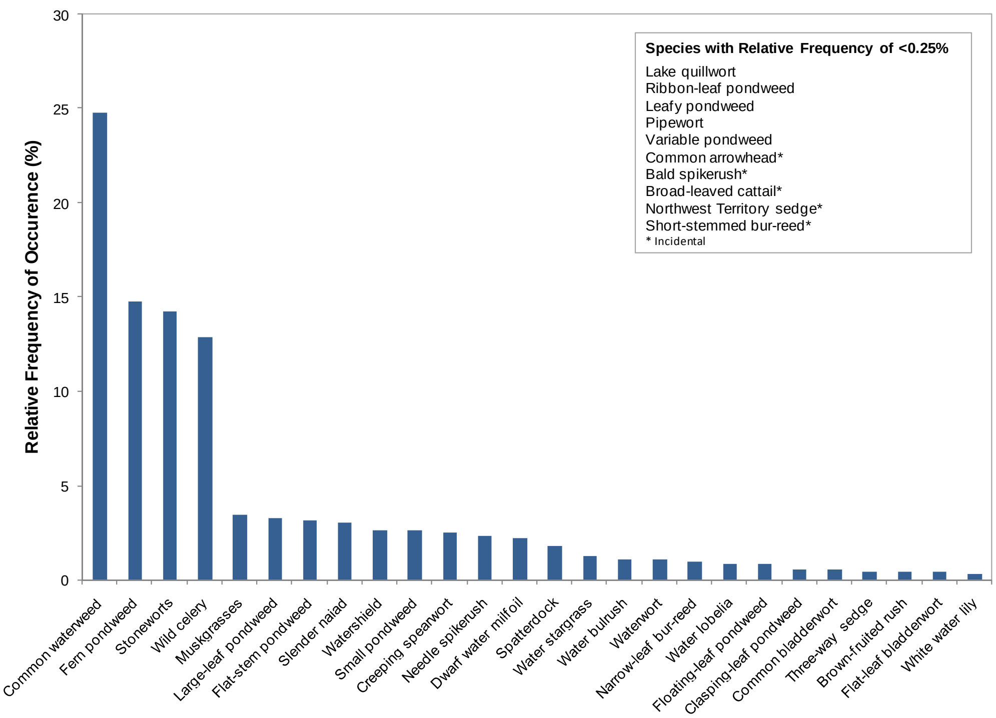

Figure 3.3-3 Arbutus Lake aquatic plant occurrence analysis. Created using data from August 2008 surveys.

In a stakeholder survey sent to association members, there were many comments and concerns regarding increases in aquatic plant growth and sedimentation, specifically within the shallower bays. With no historic vegetation data available, it is not possible to quantify increasing plant growth over time, but with the number of concerns raised this is likely the case. As stated previously, increased nutrient loading can lead to enhanced and sometimes excessive aquatic plant growth. However, as indicated in the water quality section, Arbutus Lake is currently in a lower-mesotrophic state with excellent water quality and no apparent immediate trend of decline. Excessive nutrient loading does not appear to be an issue on Arbutus Lake. A lake management plan conducted on Arbutus Lake in the mid 1990s did not find any evidence of faulty septic systems.

The increased aquatic plant growth may be a result of falling water levels. As the water level drops, plants that were once in deeper areas are now able to grow closer to the surface as well as colonize areas that were once too deep with light becoming more available. As mentioned before, the tall, leafy elodeids inhabit the deeper areas in Arbutus Lake and likely have expanded their range lakeward as water levels dropped. The lower water levels will also allow floating-leaf plants, like lily pads, to expand lakeward. More plant biomass in the growing season would mean more decay material in the fall, likely resulting in the increased sedimentation described by many stakeholders.

Traditional forms of disturbance that often affect lakes include human development of the lake's shoreline and motorboat traffic. The stakeholder survey of Arbutus Lake Association members indicates that motorboats with a 25 horsepower or greater motor are the second most prevalent watercraft on the lake after pontoon boats. Many studies have documented the adverse effects of motorboat traffic on aquatic plants (e.g. Murphy and Eaton 1983, Vermaat and de Bruyne 1993, Mumma et al. 1996, Asplund and Cook 1997). In all of these studies, lower plant biomasses and/or declines and higher turbidity were associated with motorboat traffic.

Combining the lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in an exceptionally high value of 41.0 (equation shown below); again, well above the median values of the state and ecoregion (Figure 3.3-4).

FQI = Average Coefficient of Conservatism (6.8) * √ Number of Native Species (36)
FQI = 41.0

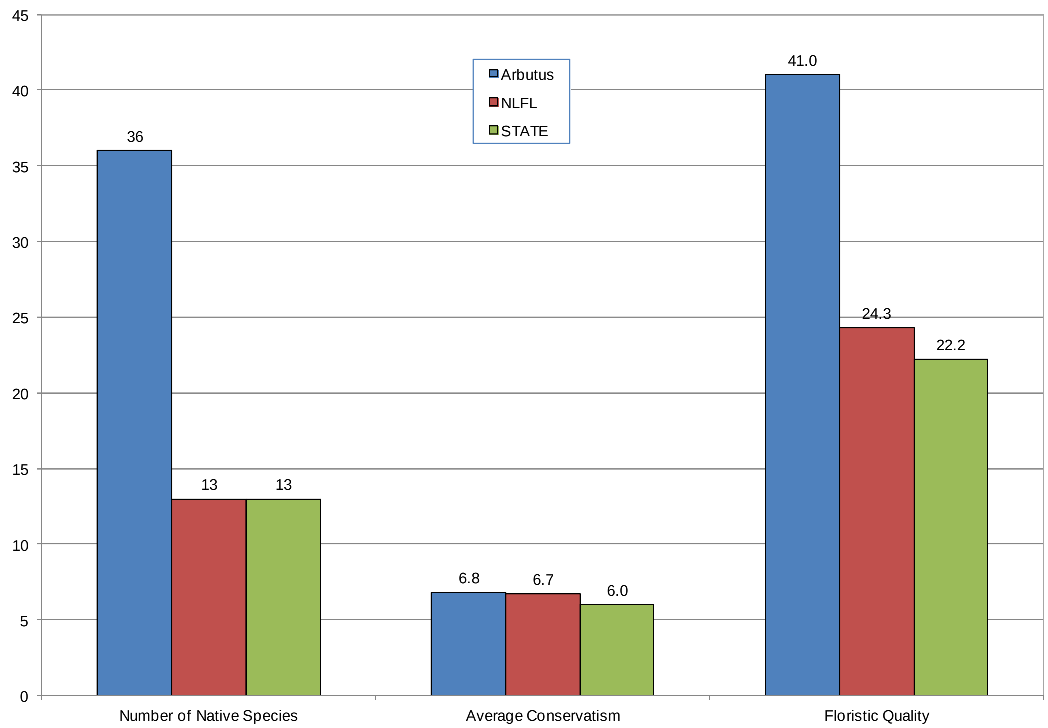

Figure 3.3-4. Arbutus Lake Floristic Quality Assessment. Created using data from August 2008 surveys. Analysis following Nichols (1999). Note that NLFL indicates Northern Lakes and Flowages Ecoregion. State and regional values are given as medians for their respective data ranges.

The quality is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in the bays. The 2008 community map indicates that approximately 16 acres (9.5%) of the 168-acre lake contains these types of plant communities (Table 3.3-2). Eleven floating-leaf and emergent species were located on Arbutus Lake, providing valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important since structural habitat of fallen trees and other forms of course-woody debris are quite sparse along the shoreline of Arbutus Lake, and most of the debris present is located above the receding water line.

Table 3.3-2. Arbutus Lake acres of plant community types from the 2008 community mapping survey.

Plant Community	Acres
Emergent	2.3
Mixed Floating-leaf and Emergent	13.7
Total	16.0

Continuing the analogy that the community map represents a 'snapshot' of the important plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Arbutus Lake, especially regarding their change with fluctuating water levels. 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 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.

Overall, Arbutus Lake has a high quality, diverse aquatic plant community which not only provides essential habitat for wildlife, but will help protect against any possible introductions of invasive plant species. These invasive plants are opportunistic, taking hold in openings where native vegetation has been disturbed or removed. While hand-removal of native aquatic plants is permitted, the WDNR in the Northern Region takes a protective approach towards native aquatic plants, and attempts to avoid any large-scale losses of them due to harvesting or chemical herbicides.

3.4 Arbutus Lake Fishery

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 2010 & GLIFWC 2010).

Table 3.4-1. Gamefish present in the Arbutus 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
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)
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
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
Walleye	*Sander vitreus*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Based on data collected from the stakeholder survey (Appendix B), fishing was the second highest ranked important or enjoyable activity on Arbutus Lake (Question #10). Approximately 95% of these same respondents believed that the quality of fishing on the lake was either fair or poor (Question #7); and approximately 97% believe that the quality of fishing has remained the same or gotten worse since they have obtained their property (Question #8).

Table 3.4-1 (above) shows the popular game fish that are present in the system. Although non-native plant species have not been found on Arbutus Lake, should an infestation occur it will be important to understand how management of AIS may impact fish species. Furthermore, any control of native plant communities must be done with minimal impact on fish. Any herbicide applications or mechanical harvesting should occur in May when the water temperatures are below 60°F. Yellow perch is a species that could potentially be affected by early season herbicide applications, as the treatments could eliminate nursery areas for the emerged fry of these species.

Figure 3.4-1. Location of Arbutus Lake within the Native American Ceded Territory (GLIFWC 2009). This map was digitized by Onterra; therefore it is a representation and not legally binding.

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 3.4-1). Arbutus 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. Studies suggest that up to 35% of a lake's walleye population and 20% of a muskellunge population can be removed annually without adverse affects. Each year, a "Safe Harvest" level is set at 35% of the walleye population and 20% of the muskellunge population. 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. In late winter, the six Wisconsin Chippewa Bands declare their intent to harvest a tribal quota. The tribal quota is a portion of the safe harvest. Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal quota and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2004). 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 quota 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 quota is met or the season ends.

Walleye quotas have been published every year since 1999 for Arbutus Lake; however a harvest has not occurred on the lake. Quotas have ranged from 10 to 20 fish for a given year, which is a relatively small number. A combination of a low estimated safe harvest for walleye and the availability to spear other lakes in the region with a higher estimated safe harvest have likely contributed to Arbutus Lake not holding a spear harvest.

Walleye have been stocked in Arbutus Lake by the WDNR (Table 3.4-2) in an effort to influence the populations of these species. The last recorded stocking was in 2005.

Table 3.4-2. Walleye stocking data available from the WDNR from 1972 to present. (WDNR 2010).

Year	Age Class	# Stocked	Avg. Length (inches)
1974	Fingerling	5,000	1.5
1976	Fingerling	8,000	2.0
1978	Fingerling	8,000	3.3
1984	Fingerling	8,000	1.5
1988	Fingerling	9,240	1.5
1989	Fingerling	10,360	4.5
1990	Fingerling	2,000	3.0
1993	Fingerling	2,888	3.0
1994	Fingerling	2,304	4.5
1995	Fingerling	327	3.0
2001	Small Fingerling	2,800	3.0
2001	Small Fingerling	2,800	3.0
2002	Small Fingerling	2,500	2.0
2004	Small Fingerling	4,885	5.0
2005	Small Fingerling	2,500	5.0

According to the point-intercept survey conducted by Onterra, 91% of the substrate sampled in the littoral zone on Arbutus Lake was muck, with the remaining 9% classified as a sandy substrate (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 they do not get buried in sediment and suffocate. 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 two primary objectives;

1) Collect baseline data to increase the general understanding of the Arbutus Lake ecosystem.
2) Collect sociological information from Arbutus 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 two objectives were fulfilled during the project and have led to a good understanding of the Arbutus Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

Overall, the studies that were completed on Arbutus Lake's water quality, watershed, and aquatic plants, indicate that the lake is in very good health. The water quality of the lake, as discussed above was found to be good to very good and at all times better than that found in most other lakes within the region and the state. Unfortunately, not a great deal of historic water quality exists prior to the past two decades, but the data that does exist was shown to fluctuate over the years and not show a definite trend towards improving or degrading water quality within Arbutus Lake. Continued water quality monitoring on Arbutus Lake will be an important aspect of maintaining the lake's water quality.

The Arbutus Lake's good water quality can be directly attributed to the lake's watershed (drainage basin), which encompasses approximately 753 acres. Roughly 66% of that watershed is in forested land cover with the bulk of the remainder being the lake's surface itself. Combining the watershed's small size (about 3 acres of land drain to each acre of lake) with land cover types that export very little phosphorus, leads to minimal nutrient loading to the lake. In the end, the most controllable area of the watershed is the immediate watershed adjacent to the lake. These areas are comprised of the shoreland properties that occur around the lake and likely have the greatest negative impact on the lake's health.

The aquatic vegetation surveys completed on Arbutus Lake found a total of 36 native species and no exotic species within the lake. The analysis associated with the surveys concluded that the lake's plant population is healthy and an indicator of the lake's good, general health.

As mentioned in the Aquatic Plan Section, some lake shore property owners indicated that they were not pleased with the expansion and increased density of some of the aquatic plants within the lake. Some believe that floating-leaf species are expanding and as a result have hampered navigation to and from their properties. It is common of native floating-leaf and emergent species to expand with time along a lake's shore. Once these species inhabit an area, they tend to expand as the incomplete decomposition of the previous year's growth make additional substrate for the current year. This cycle continues year-after-year and as a result, the plants are able to expand over the substrate they are helping to create. This is a natural occurrence in lakes and the thoughts expressed by some riparians about dredging these areas, while understandable, are not practical due to the incredible cost of dredging and the ecological damage it could cause. The ecological damage would be the opening up of sediment for easy infestation by exotic plant species, like Eurasian water milfoil or curly-leaf pondweed.

Other riparians expressed concerns over increased levels of submergent species, likely large-leaf pondweed. While there may have been an increase in this species over the past few years, it is likely that the residents are also noticing more due to the lower water levels within the lake. Regardless, large-leaf pondweed and other submergent species are very beneficial to the lake by providing competition to any exotic introductions and by providing valuable habitat to fish and other aquatic wildlife.

With the exception of stocking data that spans from 1974-2005, there is not a great deal of fish information available for Arbutus Lake. This lack of data prompted the Planning Committee to include a management action aimed at the development of a fisheries management plan for Arbutus Lake by the WDNR.

5.0 IMPLEMENTATION PLAN

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

Management Goal 1: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation of current effort.

Facilitator: Board of Directors

Description: Monitoring water quality is an import 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. The lack of this type of historical information hampered the water quality analysis during this project. Early discovery of negative trends may lead to the reason as of why the trend is developing. Volunteers from the Arbutus Lake Association have collected Secchi disk clarities and water chemistry samples during this project and in the past through the WDNR Citizen Lake Monitoring Program. At this time, a volunteer from the lake has been trained to collect the samples and enter the data into the WDNR database. Stability will be added to the program by recruiting additional volunteers to keep the program fresh.

Action Steps:

1. Board of Directors recruits one or two additional volunteers to be involved in the water quality collection.
2. New volunteers receive training from WDNR and existing volunteer.
3. Volunteers coordinate efforts to assure that all volunteers utilize their new skills by collecting water quality samples.
4. Volunteers collect data and report results to WDNR and to association members during annual meeting.

Management Action: Minimize phosphorus and sediment loads from shoreland watershed to Arbutus Lake.

Timeframe: Begin 2010

Facilitator: Planning Committee to recruit volunteers or Board of Directors forms Education Committee

Description: As the watershed section discusses, the Arbutus Lake watershed is in good condition; however, watershed inputs still need to be focused upon, especially in terms of the lake's shoreland properties. These sources include the use of phosphorus-containing fertilizers, shoreland areas that are maintained in an unnatural manner, faulty septic systems, and impervious surfaces. To reduce these impacts, the ALA will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include newsletter articles and guest speakers at association meetings.

Topics of educational items may include benefits of good septic system maintenance, methods and benefits of shoreland restoration, including reduction in impervious surfaces, and the options available regarding conservation easements and land trusts.

Action Steps:

1. Recruit volunteers to facilitate initiative or form Education Committee.
2. Facilitator gathers appropriate information from WDNR, UW-Extension, Forest County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for association meetings.

Management Goal 2: Strengthen Communication Capacity and Content of Arbutus Lake Association

Management Action: Create and support an Arbutus Lake Association Education & Communication Committee

Timeframe: Begin 2010

Facilitator: Board of Directors to create committee.

Description: Currently, the Arbutus Lake Association communicates with its membership via a periodic (about twice/year) newsletter, at its annual meeting and summer picnic, and on a posting board near the lake. While these methods have sufficed for general communications, the association would like to improve its capacity to communicate with its members and to enhance the content of the communication in order to promote greater association membership, facilitate two-way communication between the association and its members, and to solidify the association’s function among its members and outside entities, such as local municipalities.

To facilitate this goal, the Board of Directors will create an Arbutus Lake Association Education and Communication Committee and provide annual funding to the committee within the association budget. Once formed, the committee would be responsible for managing the communication efforts of the association, including posting of meeting notices, disbursement of meeting minutes and other general communications. The committee would also work to enhance the association’s communication capacity by developing an association website and email list. Further, the association will work to move forward the education initiatives described within this plan along with other topics as ideas arise. For instance, the committee may be charged with facilitating small group meetings among lake association members and/or facilitating listening sessions with larger groups in the hope of maintaining communication levels between the lake association members and leaders within the association itself.

Action Steps:

1. See description above.

Management Action: Bring about a better understanding of shoreland and watershed zoning regulations among lake association and its members.

Timeframe: Begin 2010

Facilitator: Planning Committee to recruit volunteers or Board of Directors forms Education Committee

Description: During the Planning Committee meetings, discussion ensued regarding development of shoreland properties and those within the Arbutus Lake watershed. During these discussions, it was discovered that there is not a full understanding of town, county, and state laws regarding development of land on Arbutus Lake's shore and within its watershed. A better understanding of these laws and regulations will better facilitate protection of these areas from harmful and/or unlawful development practices.

To complete this task, the facilitator will research town, county, and state shoreland and non-shoreland zoning laws. Good sources of information include county and state websites, the Wisconsin Association of Lakes, WDNR, and UW-Extension Lakes Program. Results of the research could be presented as a series of articles in the association newsletter or through a pamphlet summarizing the information.

Management Goal 3: Prevent Aquatic Invasive Species Establishment in Arbutus Lake

Management Action: Begin *Modified* Clean Boats Clean Waters watercraft inspections at Arbutus Lake public access.

Timeframe: Begin 2010

Facilitator: Planning Committee

Description: Arbutus Lake is believed to be free of aquatic invasive species. Initiating a modified program of watercraft inspections based upon the WDNR Clean Boats Clean Waters program will help to reduce the chance that exotic species, such as Eurasian water milfoil, zebra mussels, and curly-leaf pondweed would be introduced to the lake. Arbutus Lake is not considered a primary fishing-destination in Forest County, however; numerous lakes in the area, such as Pickerel and Crane Lakes contain AIS; therefore, a modified inspection program aimed at the most busy weekends of the year would be targeted for watercraft inspections by volunteers from Arbutus Lake. The program would also be aimed at raising awareness among shoreland property owners who have private landings that their family and friends are also allowed to utilize. While inspections would not be completed at these private landings, getting the word out to the owners that they should notify all users to inspect their watercraft before using their property to launch their boat would be important in reducing Arbutus Lake's exposure to AIS.

Action Steps:

1. Members of association attend Clean Boats Clean Waters training session (completed spring 2010)
2. Training of additional volunteers completed by those trained during the spring of 2010.
3. Begin inspections during high-risk weekends
4. Report results to WDNR and ALA.
5. Promote enlistment and training of new of volunteers to keep program fresh.

Management Action: Coordinate annual volunteer monitoring of Aquatic Invasive Species
Timeframe: Start 2010
Facilitator: Planning Committee
Description: Early detection of invasive plant species within a lake increases the chances of control and possible eradication of the species as opposed to discovering an exotic once it becomes well established. Using trained volunteers is a feasible method to monitor for the occurrence of these unwanted species. The keys to success are proper training and persistence by the lake group.

Action Steps:

1. Volunteers from ALA attend training session conducted by WDNR/UW-Extension (completed spring 2010).
2. Trained volunteers recruit and train additional association members.
3. Complete lake surveys following protocols.
4. Report results to WDNR and ALA.

Management Goal 4: Increase Understanding and Effective Management of Arbutus Lake Fishery

Management Action: Create Resolution of Arbutus Lake Association urging WDNR to complete comprehensive studies of Arbutus Lake fishery and form a fishery management plan.
Timeframe: Begin 2010
Facilitator: Board of Directors
Description: The completion of fisheries studies and development of a fisheries management plan was beyond the scope of this project; however, the project did include the compilation of existing fisheries data. The result of Onterra's research found that very little information exists regarding the fishery of Arbutus Lake. This was somewhat expected as Arbutus Lake is not a priority fishery in the State of Wisconsin or Forest County. Still, fishing is an important aspect of why Arbutus Lake stakeholders own property on the lake. In fact, stakeholder survey results indicate that 90% of respondents have fished on Arbutus Lake in the last three

years (App. B, Q6) and of those anglers, 47.5% believe the fishing is less than fair on the lake (App. B, Q7), and 75% believe fishing has gotten worse on the lake in recent years (App. B, Q8).

The Arbutus Lake Association will work to urge the Forest County Fisheries Biologist (Mike Vogelsang - Michael.Vogelsang@wisconsin.gov) with the WDNR to complete a comprehensive fishery survey of Arbutus Lake and with those results create a realistic fisheries management plan for the lake. To communicate this need, the Arbutus Lake Association will create a resolution to be voted upon by their members during the 2010 annual meeting. The resolution will be sent directly to Mr. Vogelsang with a copy to his supervisor, Mr. Steven Avelallemant (steven.avelallemant@wisconsin.gov). If a response to the resolution is not heard within 30 days, the ALA will follow-up with a call to Mr. Vogelsang.

Action Steps:

See description above.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Arbutus 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:

	Spring		June		July		August		Fall		Winter	
Parameter	**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.

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Arbutus Lake during a June 17, 2008 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. No curly-leaf pondweed plants were observed during this survey.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Arbutus Lake during an August 4th, 2008 survey 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 C" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin - Draft, (April 20, 2006) was used to complete the studies. A point spacing of 43 meters was used resulting in approximately 358 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Arbutus 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.

Watershed Analysis

The watershed analysis began with an accurate delineation of the Arbutus Lake 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 Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND), 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).

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