Three Lakes Chain

Oneida County, Wisconsin

Comprehensive Management Plan

September 2013

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Funded by: Three Lakes Waterfront Association
Wisconsin Dept. of Natural Resources Lakes Grant Program

Acknowledgements

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

Three Lakes Chain of Lakes Planning Committee

The Planning Committee was comprised of 2-5 riparian property owners from the following lakes:

Virgin Lake	Whitefish Lake	The Thoroughfare
Big Lake	Dog Lake	Crystal (Mud) Lake
Deer Lake	Big Stone Lake	Laurel Lake

Organization

Town of Three Lakes

Wisconsin Dept. of Natural Resources

Carol Warden
Kevin Gauthier
John Kubisiak

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APPENDICES

1.0 INTRODUCTION

The Three Lakes Chain of Lakes is a 6,900+ acre flowage residing in north-eastern Oneida County, WI (Map 1). The Three Lakes Chain serves as the upper part of the Eagle River Chain of Lakes, draining north as the Eagle River and over the Burnt Rollways Dam.

Since its inception, the Three Lakes Waterfront Association (TLWA), along with its long-time partner, the Town of Three Lakes, has worked to prevent introduction and establishment of aquatic invasive species within the chain of lakes. The groups have approached this sometimes overwhelming task through diligent volunteer monitoring of the chain's littoral zone (Adopt-A-Shoreline) and an annual educational initiative that includes direct contact with lake stakeholders through multiple avenues, such as conducting annual meetings with educational speakers, staffing informational booths and manning the chain's many landings with Clean Boats / Clean Waters watercraft inspectors. The association also educates stakeholders through more passive activities, like direct mailings, newsletters and signage at boat landings.

Along with preventing aquatic invasive species establishment within the chain, it has been the long-term objective of the TLWA to create comprehensive management plans for the 21 lakes and two connecting waterways (the Thoroughfare and Townline Creek) within the Three Lakes Chain over a span of five to ten years. This project began with studies on Long Lake due to the discovery of Eurasian water milfoil and subsequent need for immediate attention. Beginning with discussions in 2009/2010, a phased approach was developed to address each lake within the chain, starting from the top of the chain (south) and working downstream towards Long Lake and the Eagle River above the Burnt Rollways Dam (Map 1). Developing management plans for small clusters of lakes within the chain allow for financial savings to be realized in overall project costs while creating a manageable process that allows for sufficient attention to be applied to each lake's needs. This is opposed to completing all plans simultaneously, which would facilitate great cost savings, but only produce generic plans for each lake and the chain as a whole. Financial assistance was obtained through the Wisconsin Department of Natural Resources' Lake Management Grant Program for each phase of the project.

Note: This chain-wide management plan and individual lake plans will serve as the deliverable for Phase I and Phase II of this Chain-wide project. As additional lakes are studied over the course of the remaining phases, their individual lake plans will be included to this report, and the Chain-wide section will be updated appropriately. Updates from previous phases (e.g. monitoring of Eurasian water milfoil in Virgin Lake) will be included in future reports.

The Three Lakes Chain is a highly sought after location amongst recreationists and anglers. In addition to the 14 public boat landings on the chain, there is access to the eight boat landings on the Lower Eagle River Chain by traveling over the Burnt Rollways Dam using the tracked boat-lift system. These intense public use opportunities most likely contributed to two small areas on the chain (Virgin Lake and Long Lake/Eagle River channel) becoming populated with Eurasian water milfoil. Throughout the project, Onterra staff continued to monitor these known infestations as well as sweeping new areas for signs of invasive species as well. During this time, the TLWA and Town of Three Lakes worked to educate stakeholders about Eurasian water milfoil and other aquatic invasive species; and along with the Clean Boats / Clean Waters program, help reduce new infestations to the chain and reduce the risk of Eurasian water milfoil from the chain infecting other area waterbodies.

2.0 STAKEHOLDER PARTICIPATION

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

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

Project Planning Process

Kick-off Meeting

On July 23, 2011, Tim Hoyman met with members of the TLWA for a dual -purpose meeting. First, an update was provided on activities associated with the Long Lake Management Plan and Eagle River Channel Eurasian water milfoil control and monitoring project. Then, the management planning project for the Phase I and Phase II lakes was discussed in detail. At that point in time, field studies had been completed for the Phase I lakes and activities regarding the Phase II lakes were underway. All project components were discussed and reported upon as available. Following the presentation, Mr. Hoyman answered many questions on general lake ecology as well as how the chain-wide management planning process would be conducted.

Planning Committee Meeting I

Planning meetings were conducted periodically through the chain-wide study, and focused upon the lakes involved with each current phase. On April 20, 2012, Tim Hoyman and Dan Cibulka met with a planning committee consisting of stakeholders from Phase I and Phase II lakes. During this 3.5 hour meeting, Mr. Hoyman and Mr. Cibulka went over the study results from these nine lakes. All project components, including water quality analyses, watershed studies, aquatic plant surveys and stakeholder survey information were discussed in detail. Many questions were answered by Mr. Hoyman and Mr. Cibulka pertaining to issues such as aquatic invasive species, nutrient concentrations within the lakes, and navigation and safety.

Planning Committee Meeting II

On August 23, 2012, Tim Hoyman and Dan Cibulka met again with the Planning Committee from the Phase I and Phase II lakes. During this meeting, the committee and Onterra staff discussed management goals the TLWA would implement for protecting and preserving the Three Lakes Chain of Lakes, and what steps would need to occur to reach these goals. The Implementation Plan (see Implementation Plan section) is largely the result of these conversations.

Management Plan Review and Adoption Process

Prior to the first Planning Committee Meeting, the Results Section of this document (Section 3.0) as well as the individual lake sections, were sent to all planning committee members for their review and preparation for the meeting. Following discussions at the second Planning Committee Meeting, Onterra staff drafted this report's Implementation Plan and sent it to TLWA board members for review. Their comments were integrated to the plan, and a first official draft was sent to the WDNR for a review in December of 2012. Following commentary from the WDNR in July/August of 2013, a final draft of the Phase I and II Three Lakes Chain of Lakes Comprehensive Management Plan was produced in September of 2013.

Stakeholder Survey

As a part of phase of Phase II of this project, a stakeholder survey was distributed to TLWA members and non-member riparian property owners. This survey was designed by Onterra staff and the TLWA planning committee in September of 2011. The draft survey was sent to a WDNR social scientist for review that same month. During October 2011, the eight-page, 32-question survey was mailed to 1,694 riparian property owners in the Three Lakes Chain of Lakes watershed. Thirty-six percent of the surveys were returned. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below. Following review of the survey data by Onterra and TLWA board members, Onterra staff assisted Jerry Schiedt of the TLWA in preparing a presentation of the survey results. Mr. Schiedt delivered this presentation to TLWA members at their July 2012 annual meeting.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Three Lakes Chain of Lakes. Thirty-seven percent of stakeholders are year-round residents, while 33% live on the chain seasonally and 23% visit on weekends throughout the year (Appendix B – Question #2). Fifty-nine percent of stakeholders have owned their property for over 15 years, and 35% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect to these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use a canoe or kayak on the chain (Question #9). Motorboats of various sizes, pontoon boats, and rowboats were also popular choices on this question. On an intense recreational system such as Three Lakes Chain of Lakes, the importance of responsible boating activities is increased. The need for boating responsibly increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question #10, several of the top recreational activities on the lake involve boat use. Three Lakes Chain stakeholders overwhelmingly indicated that watercraft use (jet skiing, water skiing/tubing and motor boating) has increased since they obtained their property (Question #11). Furthermore, boat traffic was ranked as the highest factor negatively impacting the Three Lakes Chain, and was ranked as the second top concern regarding the Chain of Lakes as well (Question #20 and #21). Comments were recorded regarding this issue on the Three Lakes Chain – both supporting the use of watercraft and criticizing the use of watercraft (Appendix B – Written Comments).

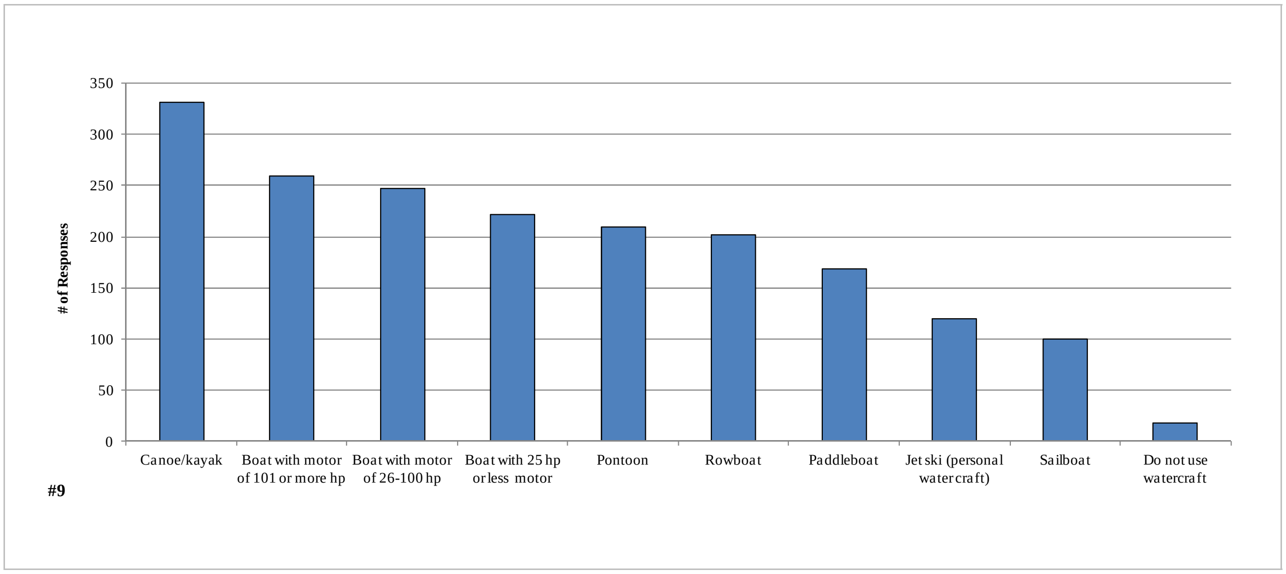
To gather information about opinions on watercraft speed and use on the chain, the TLWA, with assistance from Onterra staff and approval from social scientists at the WDNR, developed two questions on the stakeholder survey regarding the matter. The majority of survey respondents indicated that the number of slow-no-wake areas on the chain are "just right" (Question #11). 75% of all respondents indicated that they support the Wisconsin boating regulation prohibiting boaters from operating their boats at speeds greater than slow-no-wake 100 feet from shore and/or structures (Questions #12).

This regulation is known as Wisconsin Act 31, and was enacted in 2010. This act was set into place because of the disturbance to the lake that can result from boating at high speeds in this zone. Specifically, shoreline erosion, disruption of lake bottom sediments and nutrients, and destruction of aquatic organism habitats may occur. Safety for swimmers, slow-moving watercraft and other recreationalists was also considered into Act 31. Legislators writing this regulation realized there may be times when local authorities may wish to enact their own ordinances, either in addition to this regulation or in opposition to opt out of Act 31.

The Town of Three Lakes created a committee (Three Lakes Act 31 Advisory Committee) to examine this regulation and offer a recommendation to the Three Lakes Board of Supervisors on the applicability of Act 31 to the Three Lakes Chain of Lakes. The Committee offered a recommendation in favor of opting out of Act 31, and ultimately in 2010/2011 the Town of Three Lakes decided to opt out of the Act as well. Thus, the 100-foot rule does not apply to any waterbodies within the Town of Three Lakes (on the Three Lakes Chain or otherwise). The Committee's overall recommendation included suggestions for areas to be slow-no-wake zones, policing and enforcement options, and areas designated as quiet sport (canoe/kayak) zones, caution zones, or shallow water areas. A report detailing the Committee's consideration of Act 31 and their recommendations can be found in Appendix C.

Several concerns noted throughout the stakeholder survey include watercraft issues as described above and within the written comments portion of Appendix B, concern over aquatic invasive species detection and control, and Native American spear harvesting of walleye on the Three Lakes Chain. Spearing regulations and harvest data is summarized with the Fisheries Data Integration Section and aquatic invasive species information is detailed within the Aquatic Plants Section. Discussion regarding watercraft use on the Three Lakes Chain of Lakes is described completely within Appendix C, and is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Question #9: What types of watercraft do you currently use on the lake?



Question #10: Please rank up to three activities that are important reasons for owning your property on or near the lake.

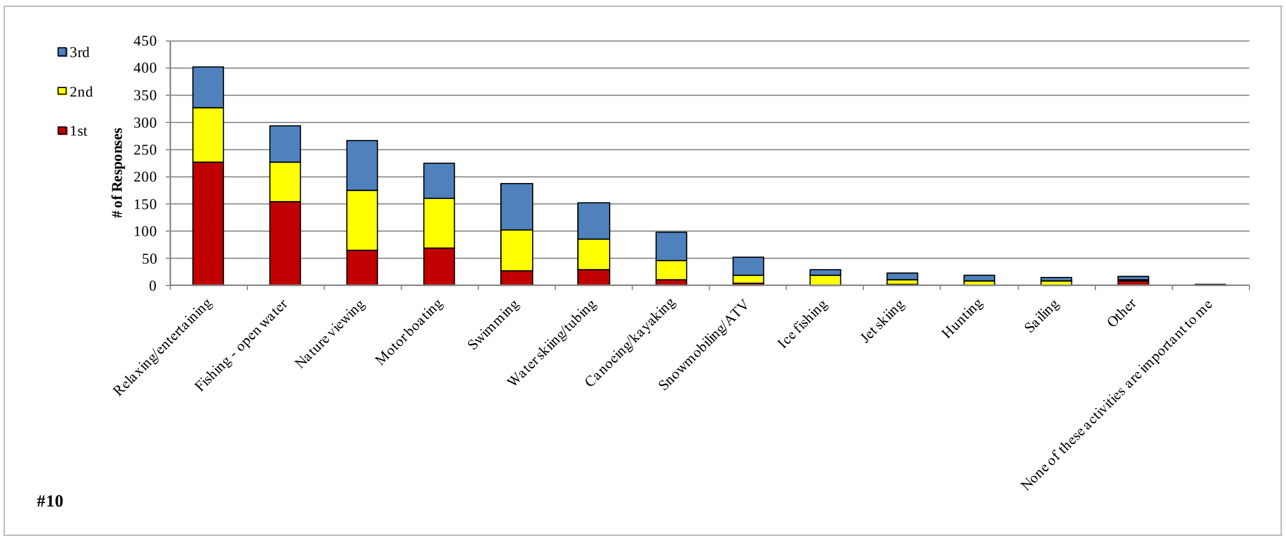
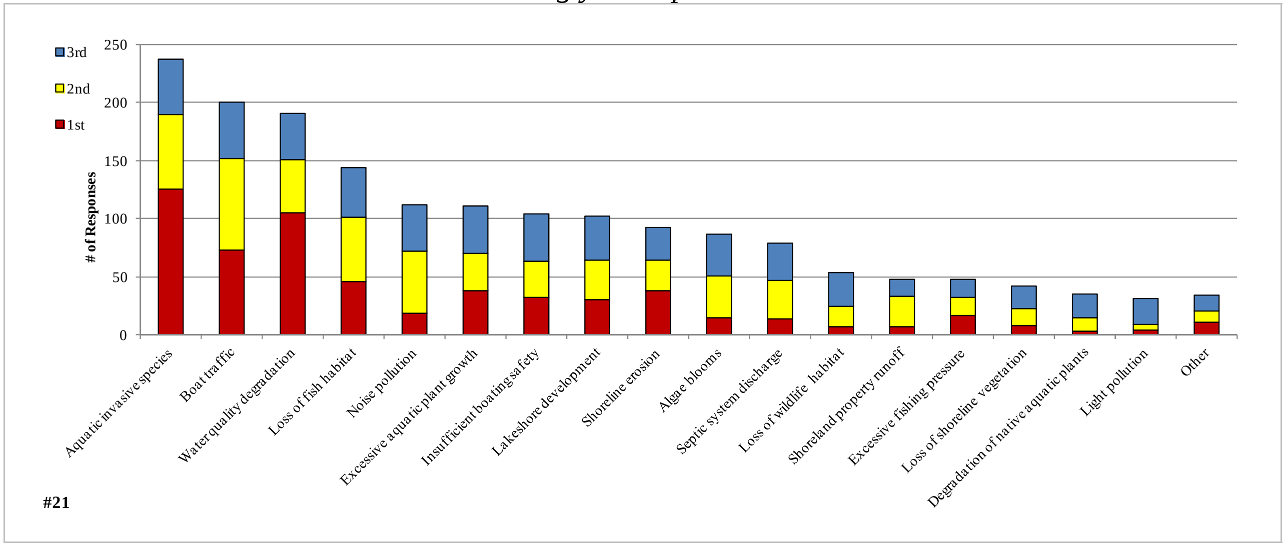


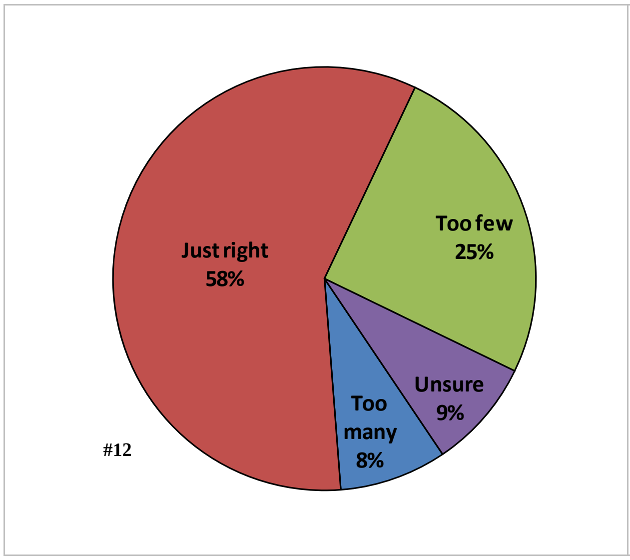
Figure 2.0-1. Select survey responses from the Three Lakes Chain of Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question #21: Please rank your top three concerns regarding Three Lakes Chain of Lakes, with 1 being your top concern.



Question #12: What is your opinion of the number of slow-no-wake areas on the entire Three Lakes Chain?

Question #13: Do you support or oppose the Wisconsin boating regulation prohibiting boaters from operating their boats at speeds greater than slow-no-wake 100 feet from shore and/or structures?



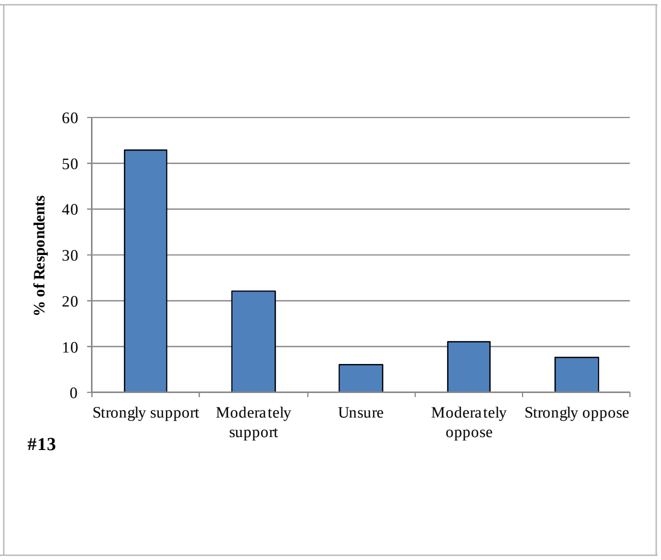


Figure 2.0-2. Select survey responses from the Three Lakes Chain of Lakes Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Three Lakes Chain of Lakes Stakeholder AIS Concerns

As with most Wisconsin lakes, there is great concern with Three Lakes Chain of Lakes stakeholders over the threat of aquatic invasive species. The Town of Three Lakes and TLWA have put forth much effort in educating area stakeholders and Three Lakes Chain visitors about the threat that invasive plants pose. Approximately 99% of stakeholder survey respondents indicated that they have heard of aquatic invasive species (Appendix B, Question #16). About 78% indicated they believe aquatic invasive species are present in their lake (Question #17). When asked what aquatic invasive species were present in their lake, survey respondents selected Eurasian water milfoil, rusty crayfish, Chinese mystery snail, *Heterosporosis*, and purple loosestrife as top choices. Table 2.0-1 lists the confirmed aquatic invasive species in each of the Three Lakes Chain lakes.

96% of survey respondents indicated that they are either somewhat or very concerned about the spread of invasive species to their lake (Question #19), and this topic was ranked first on a list of concerns stakeholders have regarding their lake (Question #21). Invasive species management can be a costly, time consuming and complicated task. Control strategies often become dependent on the stage of infestation, environmental factors of the ecosystem, and budget constraints of the managing entities. When it comes to managing plant species, Three Lakes Chain stakeholders favor an integrated control using several methodologies most (Question #24).

While no reasonable and efficient control strategy exists for several of the species on Table 2.0-1 (banded and Chinese mystery snails and rusty crayfish), several effective methods have been utilized for control of Eurasian water milfoil and purple loosestrife. For the Three Lakes Chain of Lakes in which aquatic invasive plants are present, the history and management strategy for each is discussed further within that lake’s Aquatic Plant Section and Implementation Plan.

Table 2.0-1. Aquatic Invasive Species located on the Three Lakes Chain lakes. Information obtained from WDNR internet databases (Invasive Species – How Wisconsin Is Doing - www.dnr.wi.gov/lakes/invasives/Default.aspx & Surface water data viewer - http://dnr.wi.gov/org/water/data_viewer.htm).

Lake	AIS and Year Confirmed
Big Lake	Chinese Mystery Snail (2011), Rusty Crayfish (2002), Purple Loosestrife (2010)
Big Fork Lake	Chinese Mystery Snail (2007)
Big Stone Lake	Banded Mystery Snail (2007), Chinese Mystery Snail (2007), Purple Loosestrife (2011), Rusty Crayfish (2002),
Crystal (Mud) Lake	Rusty Crayfish (2002)
Deer Lake	Chinese Mystery Snail (2007), Rusty Crayfish (2002)
Dog Lake	Rusty Crayfish (2002)
Fourmile Lake	Rusty Crayfish (2002)
Island Lake	Rusty Crayfish (Unknown)
Laurel Lake	Chinese Mystery Snail (2011), Purple Loosestrife (2011), Rusty Crayfish (2002)
Little Fork Lake	Chinese Mystery Snail (2007), Rusty Crayfish (2002)
Long Lake	Eurasian water milfoil (Eagle River channel - 2006), Hybrid cattail (2009), Purple Loosestrife (2009), Rusty Crayfish (1964)
Maple Lake	Banded Mystery Snail (2007), Chinese Mystery Snail (2007)
Medicine Lake	Chinese Mystery Snail (2007)
Planting Ground Lake	Chinese Mystery Snail (2007), Rusty Crayfish (Unknown)
Range Line Lake	Banded Mystery Snail (2007), Chinese Mystery Snail (2007), Rusty Crayfish (2002)
The Thoroughfare	Chinese Mystery Snail (2005)
Townline Lake	Chinese Mystery Snail (2005), Rusty Crayfish (2002)
Whitefish Lake	Rusty Crayfish (1957)
Virgin Lake	Eurasian water milfoil (2010)

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Three Lakes Chain of Lakes is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix D). 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 Three Lakes Chain of Lakes' water quality analysis:

Phosphorus is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.

Chlorophyll-*a* is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

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

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 μg/L.

- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

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

If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Comparisons with Other Datasets

The WDNR publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Three Lakes Chain of Lakes will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: **shallow (mixed)** or **deep (stratified)**. These lakes differ in many ways; for example, in their oxygen content and where aquatic plants may be found. Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or all of the lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

Seepage Lakes have no surface water inflow or outflow in the form of rivers and/or streams.

Drainage Lakes have surface water inflow and/or outflow in the form of rivers and/or streams.

Headwater drainage lakes have a watershed of less than 4 square miles.

Lowland drainage lakes have a watershed of greater than 4 square miles.

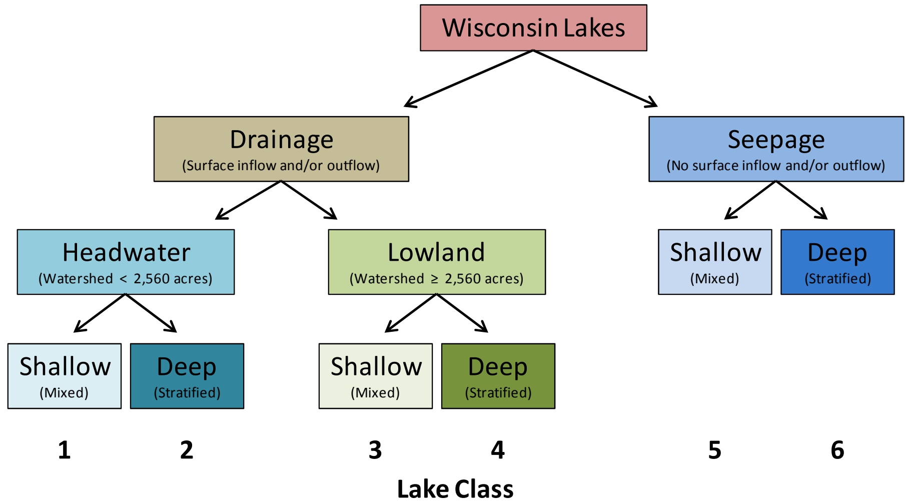


Figure 3.1-1. Wisconsin Lake Classifications. Adapted from WDNR PUB-SS-1044 2008.

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

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

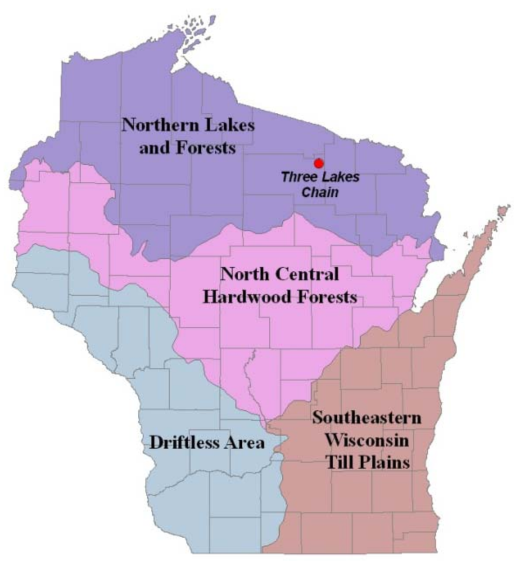


Figure 3.1-2. Location of Three Lakes Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Three Lakes Chain of Lakes is displayed in Figures 3.1-3 - 3.1-6. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Three Lakes Chain of Lakes Water Quality Analysis

Three Lakes Chain of Lakes Nutrient Content and Clarity

The amount of historical water quality data existing on the Three Lakes Chain varies by lake. Several lakes have volunteers that are actively monitoring their lake through the WDNR's Citizens Lake Monitoring Network (CLMN), collecting nutrient samples or Secchi disk clarity data several times each summer. Many lakes do not have active CLMN volunteers and because of this, there are no historic data to compare against the data that were collected as a part of this project. The importance of consistent, reliable data cannot be stressed enough; just as a person continuously monitors their weight or other health parameters, the water quality of a lake should be monitored in order to understand the system better and make sounder management decisions.

Onterra staff collected water quality samples and monitored Secchi disk clarity on each Three Lakes Chain lake during the course of this project. Monitoring occurred during the summer and following winter of each project phase (Phase I lakes sampled in 2010/2011, Phase II lakes sampled in 2011/2012, etc.). Long Lake completed a management plan in 2009, so data obtained through that process are displayed in the figures below. As a part of the current management project consisting of the entire Three Lakes Chain, Long Lake will be sampled again in 2016. Please note on the following figures that comparisons are best made across lakes of similar classification (shallow, lowland drainage lakes in light blue and deep, lowland drainage lakes in dark blue).

Total phosphorus values ranged largely between 14 and 32 µg/L (Figure 3.1-3). However, Crystal (Mud) Lake's average summer concentration averaged 72 µg/L in 2011. This value is exceptionally high, exceeding the value for other shallow, lowland drainage lakes across the state and region.

Average summer chlorophyll-*a* concentrations vary little within the Three Lakes Chain of Lakes. Some of the deeper lakes within the chain held lower concentrations (Long, Virgin and Whitefish) while other deep lakes, such as Laurel, were a bit higher (Figure 3.1-4). In the case of Laurel Lake, algae content may be affected from upstream shallow lakes like Big Lake. Average summer concentrations lie below values of similar lakes across the state and ecoregion, with the exception of Laurel Lake, which is only slightly above other deep, lowland drainage lakes across the state. As with aquatic macrophytes (aquatic plants), light penetration into the water column is necessary for algae to grow. As discussed further below, algae growth is likely limited to a certain extent in the Three Lakes Chain due to the naturally stained water.

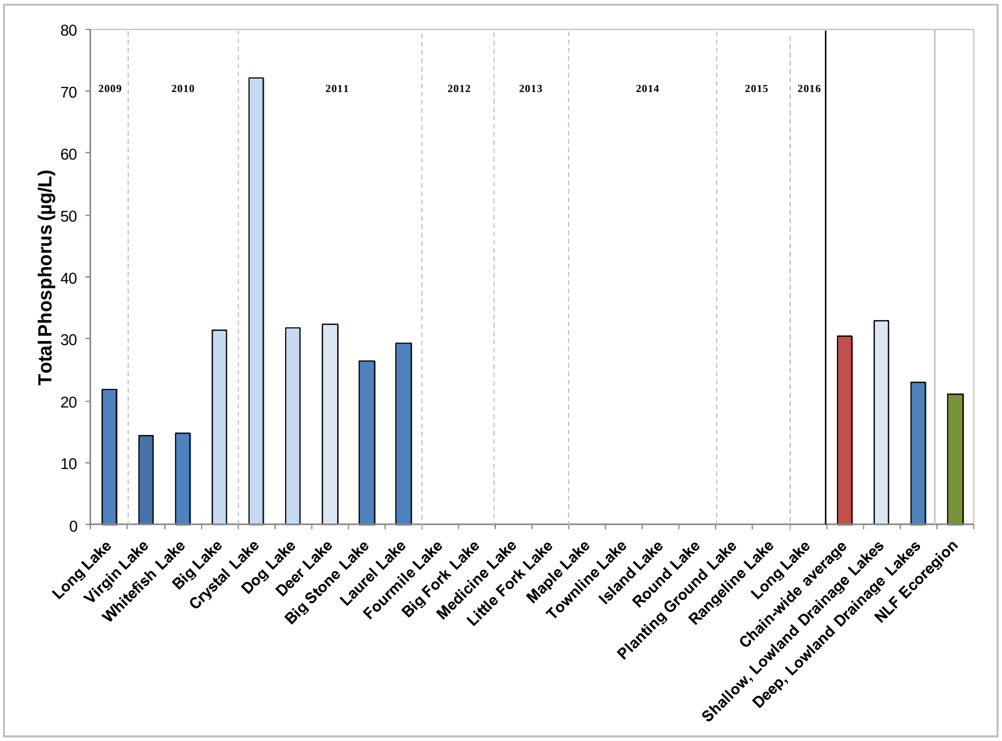


Figure 3.1-3. Three Lakes Chain of Lakes, state-wide class 3 and 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Similar lakes are compared (shallow in light blue and deep lakes in dark blue).

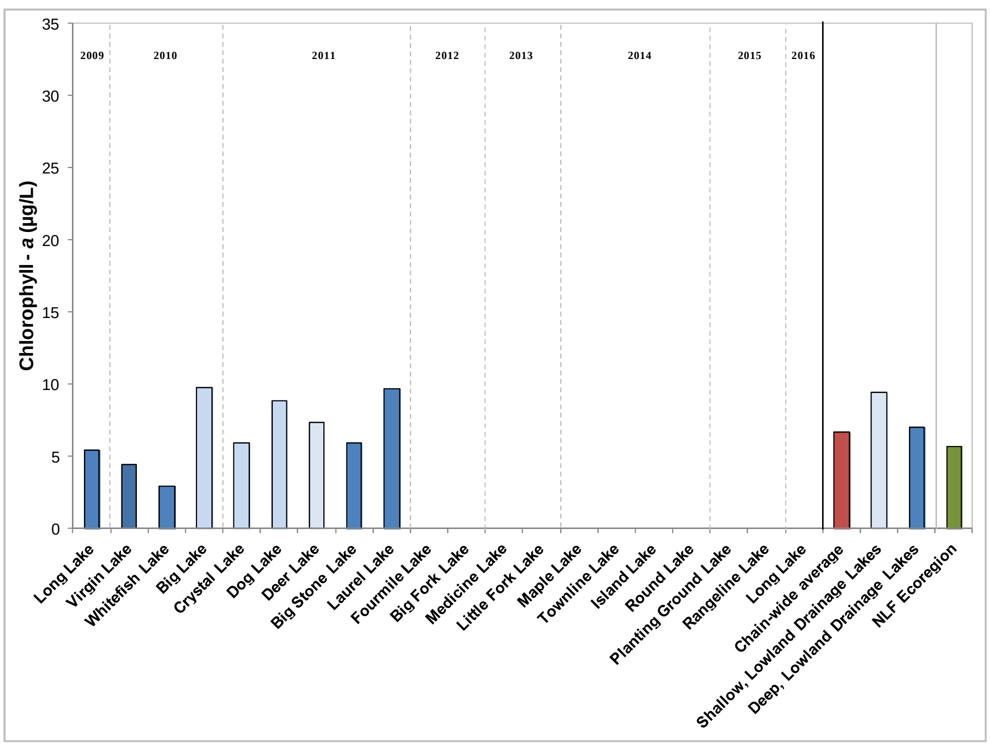


Figure 3.1-4. Three Lakes Chain of Lakes, state-wide class 3 and 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Similar lakes are compared (shallow lakes in light blue and deep lakes in dark blue).

Average summer Secchi disk clarity ranged from 1.5 feet deep to 10.6 feet deep in the Three Lakes Chain lakes (Figure 3.1-5). In the two lakes at the upper reaches of the chain (Virgin and Whitefish Lakes) Secchi disk depth was the greatest, falling above the value for similar deep, lowland drainage lakes statewide. Several lakes displayed average Secchi depths between one and four feet of depth. While the water in these lakes can be said to have very low clarity, the reason is not because of excessive algae, as established above. Systems with large watersheds (discussed further in the Watershed Section) drain many acres of forested lands and wetlands. When water drains these tracts of land into a lake, naturally occurring organic acids accumulate and stain the lake water a dark brown color. This is the cause of the Three Lakes Chain's "root beer" color. Furthermore, it is this factor that is limiting light penetration into the waters of the lakes which in turn limits algal production as well as the depth of aquatic plant growth (see the Aquatic Plant Section).

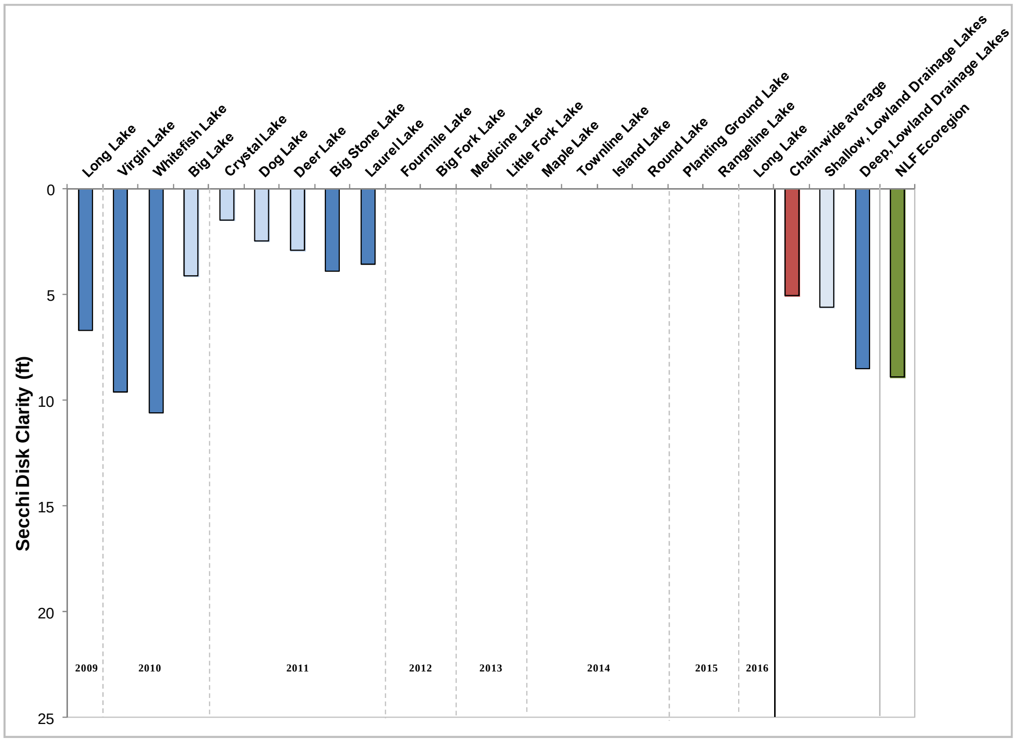


Figure 3.1-5. Three Lakes Chain of Lakes, state-wide class 3 and 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913. Similar lakes are compared (shallow lakes in light blue and deep lakes in dark blue).

Limiting Plant Nutrient of Three Lakes Chain of Lakes

Using average nitrogen and phosphorus concentrations from all lakes included in the Three Lakes Chain of Lakes study, a nitrogen:phosphorus ratio was calculated for each lake (Table 3.2-2). In all lakes, the ratio weighed heavily in favor of nitrogen, rather than phosphorus. This finding indicates that all of the lakes of the Three Lakes Chain of Lakes are 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 lakes.

Table 3.1-1. Three Lakes Chain of Lakes nitrogen and phosphorus values and N:P ratios. Ratios calculated from sub-surface samples taken in summer of 2009 from each lake.

Project Phase	Lake Name	Avg. Summer Nitrogen (μg/L)	Avg. Summer Phosphorus (μg/L)	N:P Ratio
Long Lake - 2009	Long Lake	665	21.8	31:1
Phase I - 2010	Virgin Lake	543	14.3	38:1
	Whitefish Lake	520	14.7	35:1
	Big Lake	953	31.4	30:1
Phase II - 2011	Crystal (Mud) Lake	1160	72.0	16:1
	Dog Lake	950	31.7	30:1
	Deer Lake	860	32.3	27:1
	Big Stone Lake	710	26.5	27:1
	Laurel Lake	1010	29.3	34:1
Phase III - 2012	Big Fork Lake			
	Fourmile Lake			
Phase IV - 2013	Moccasin Lake			
	Spirit Lake			
	Maple Lake			
Phase V - 2014	Little Fork Lake			
	Medicine Lake			
Phase VI - 2015	Island Lake			
	Round Lake			
	Townline Creek			
	Townline Lake			
Phase VII - 2016	Rangeline Lake			
	Planting Ground Lake			
Phase VIII - 2017	Long Lake			

Three Lakes Chain of Lakes Trophic State

Figure 3.1-6 contain the WTSI values for Three Lakes Chain of Lakes. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to lower eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters. Many of the lakes within the chain fall within the range of eutrophic – characterized by low water clarity and higher phosphorus and chlorophyll-*a* content. Several lakes, such as Virgin and Whitefish, rank within the mesotrophic category, this is not surprising, seeing that they are at the very top of the Three Lakes Chain and are not influenced by the other lakes (further discussion of this topic takes place in the Watershed Section).

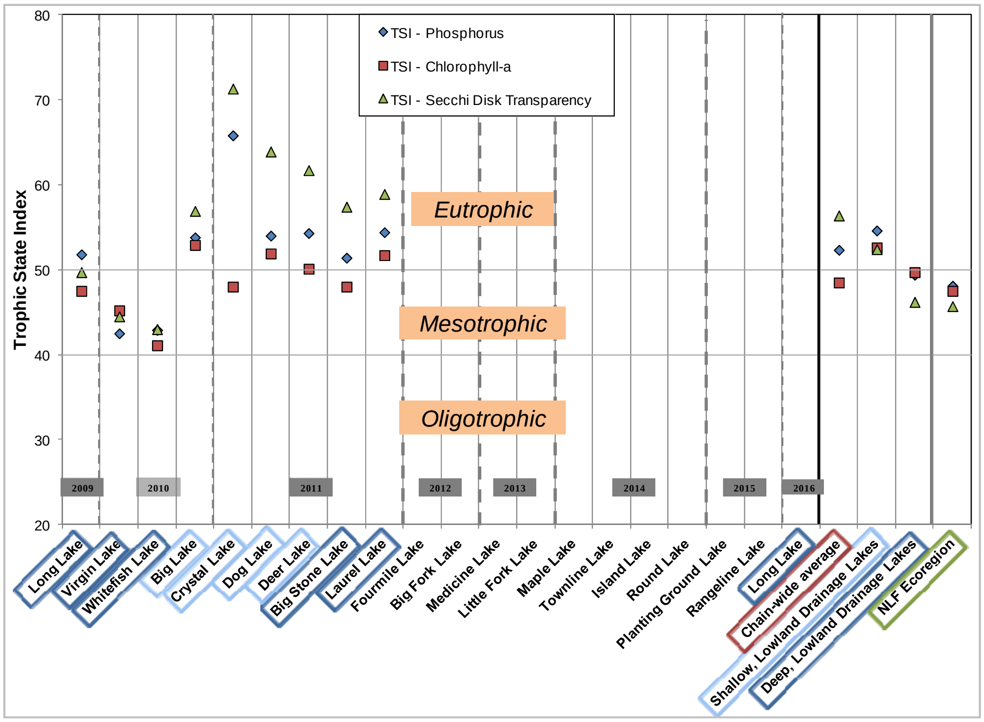


Figure 3.1-6. Three Lakes Chain of Lakes, state-wide class 3 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193. Similar lakes are compared (shallow lakes indicated with light blue and deep lakes indicated with dark blue).

Additional Water Quality Data Collected on the Three Lakes Chain of Lakes

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of the Three Lakes Chain of lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985). The variability in pH between lakes is most likely attributable to a number of environmental factors, with the chief determiner being geology near the lake and within its surface and underground watersheds. On a smaller scale within a lake or between similar lakes, photosynthesis by plants can impact pH because the process uses dissolved carbon dioxide, which acts as a carbonic acid in water. Carbon dioxide removal through photosynthesis reduces the acidity of lake water, and so pH increases. Within the Three Lakes Chain, there is little variability between lakes, as is to be expected on a string of connected waterbodies (Figure 3.1-7). The values seen within the chain lakes are near neutral and are normal for Wisconsin lakes.

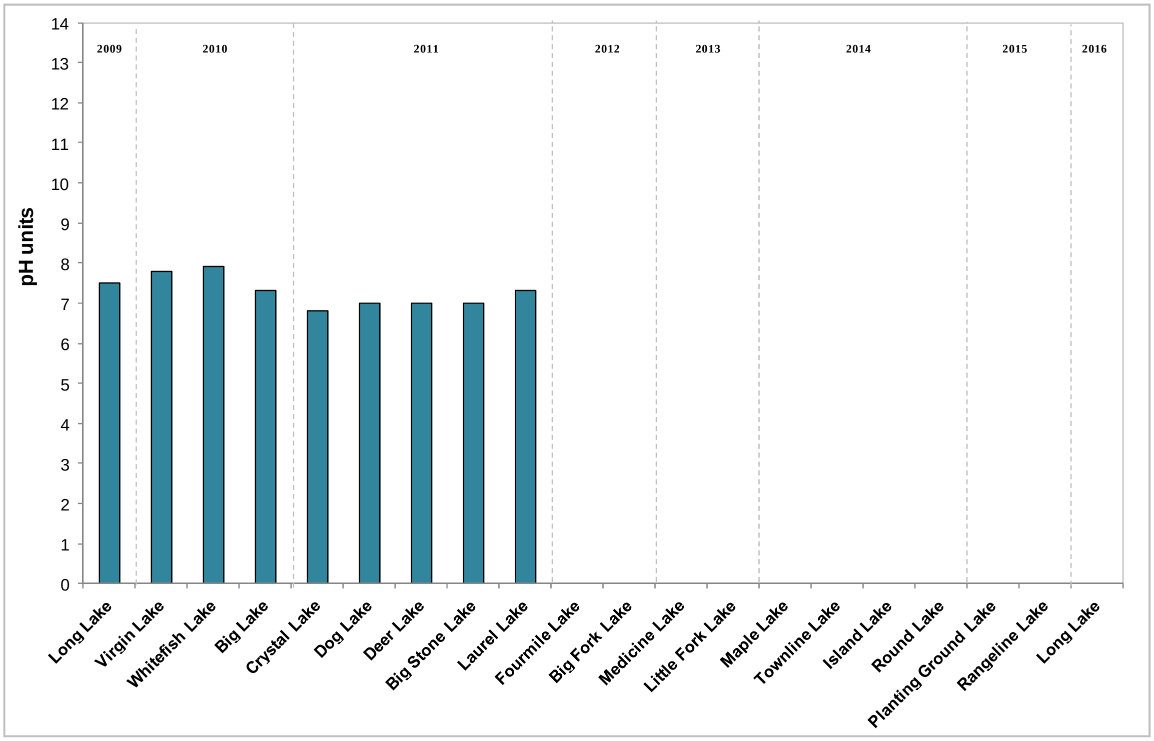


Figure 3.1-7. Three Lakes Chain of Lakes pH values. Data collected from summer month surface samples.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity it contains. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. Alkalinity is variable between the Three Lakes Chain of Lakes, but still within expected ranges for northern Wisconsin lakes (Figure 3.1-8). Alkalinity determines the sensitivity of a lake to acid rain. Values between 2 and 10 mg/L as $CaCO_3$ are considered to be moderately sensitive to acid rain, while lakes with values of 10 to 25 mg/L as $CaCO_3$ are considered to have low sensitivity, and lakes above 25 mg/L as $CaCO_3$ are non-sensitive.

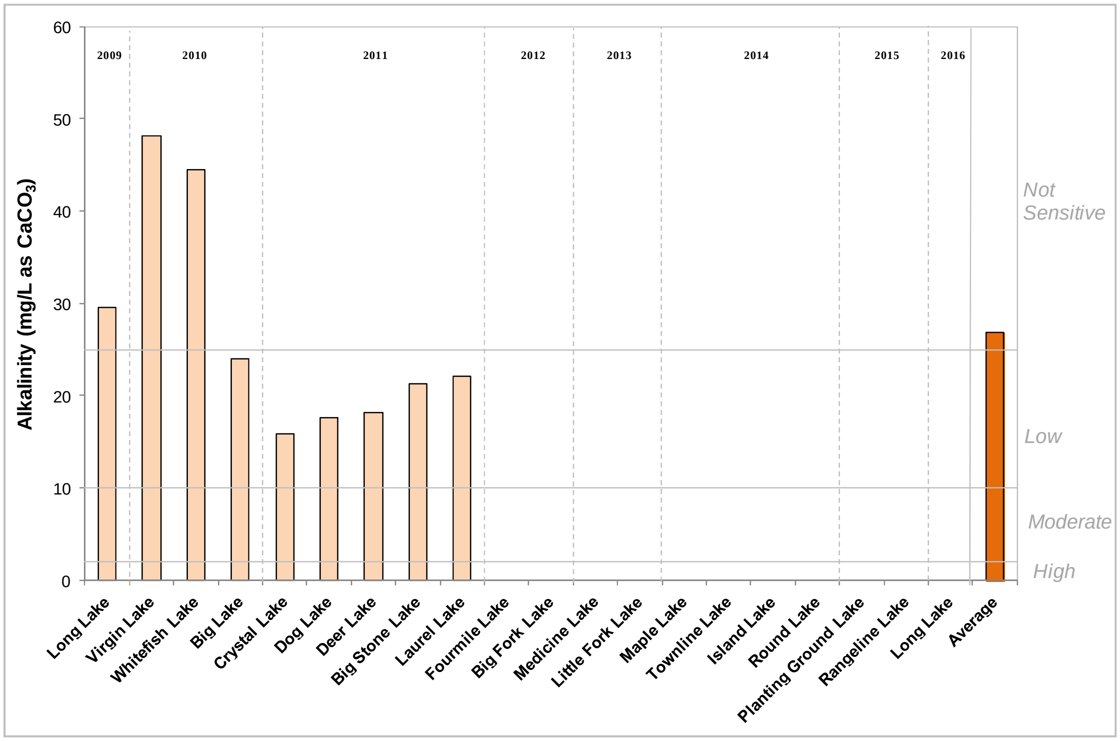


Figure 3.1-8. Three Lakes Chain of Lakes alkalinity values and acid rain sensitivity ranges. Data collected from summer surface samples.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, calcium concentration has been used to determine what lakes can support zebra mussel populations if they are introduced. These studies, conducted by researchers at the University of Wisconsin-Madison, have led to a suitability model called Smart Prevention (Vander Zanden and Olden 2008). This model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu).

Nearly all the lakes within the Three Lakes Chain are suitable for zebra mussel establishment based upon pH; Crystal (Mud) Lake (pH=6.8) falls slightly outside of this range. However, as indicated on Figure 3.1-9, the calcium concentrations within the chain lakes are at the very low end for zebra mussel suitability. This indicates calcium levels may be a limiting factor in allowing the lakes within the chain to support zebra mussels, should they be introduced.

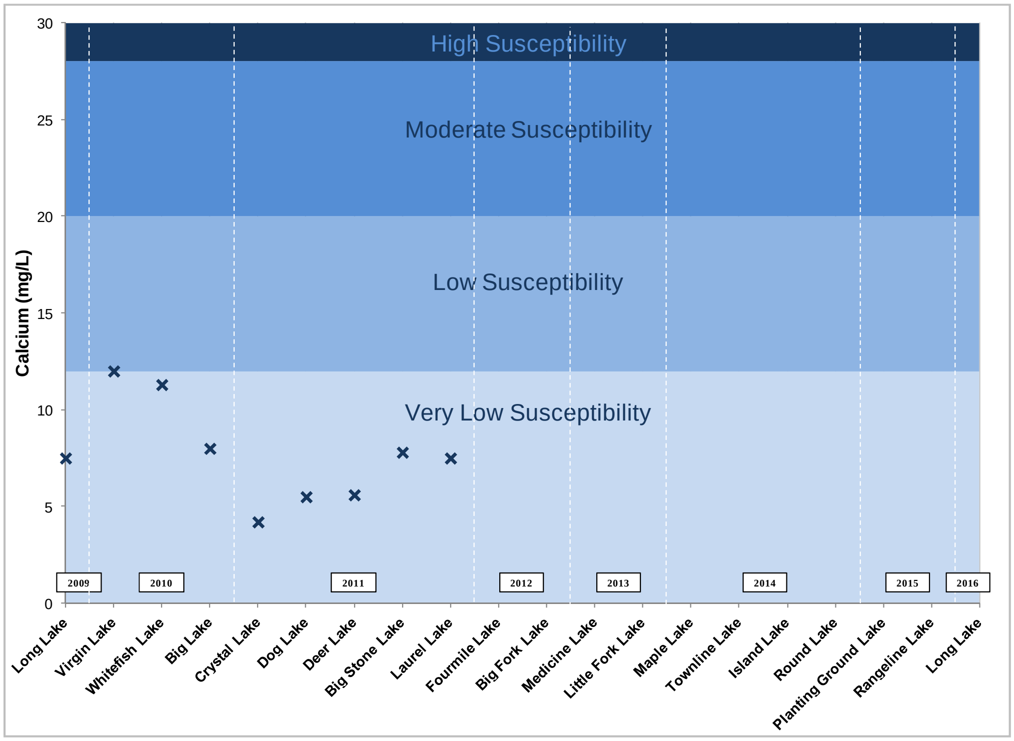


Figure 3.1-9. Three Lakes Chain of Lakes susceptibility to zebra mussel survivability and establishment based on calcium concentration. Created using surface calcium. Calcium susceptibility range adapted from Whittier et al. 2008.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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 (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A reliable and cost-efficient method of creating a general picture of a watershed's affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS – Panuska, 2003). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

As discussed above, the size of the watershed in relation to the size of the lake can have a considerable impact on the lake's water quality. There is an incredibly large amount of land draining to each of the Three Lakes Chain lakes (Figure 3.2-1 and Map 2). The watershed to lake area ratios of the lakes in the Three Lakes Chain lakes are all quite large with the smallest ratio being Big Lake at a ratio of 50:1. Approximately 72,196 acres of land drains to the Three Lakes Chain lakes, the majority (55% or 39,426 acres) of which is classified as wetland (Figure 3.2-2). Forested lands account for the second largest land cover type in the watershed (29% or 20,804 acres) while the surface of the Three Lakes Chain lakes is the third largest cover type at 10% (6,956 acres). Pasture/grass (4%) and row crops (2%) are found within the watershed to a lesser extent, while insignificant amounts of rural residential and urban areas exist as well.

Once completed near the end of this project, phosphorus modeling results will be discussed here. Watershed modeling data will be produced in Appendix E.

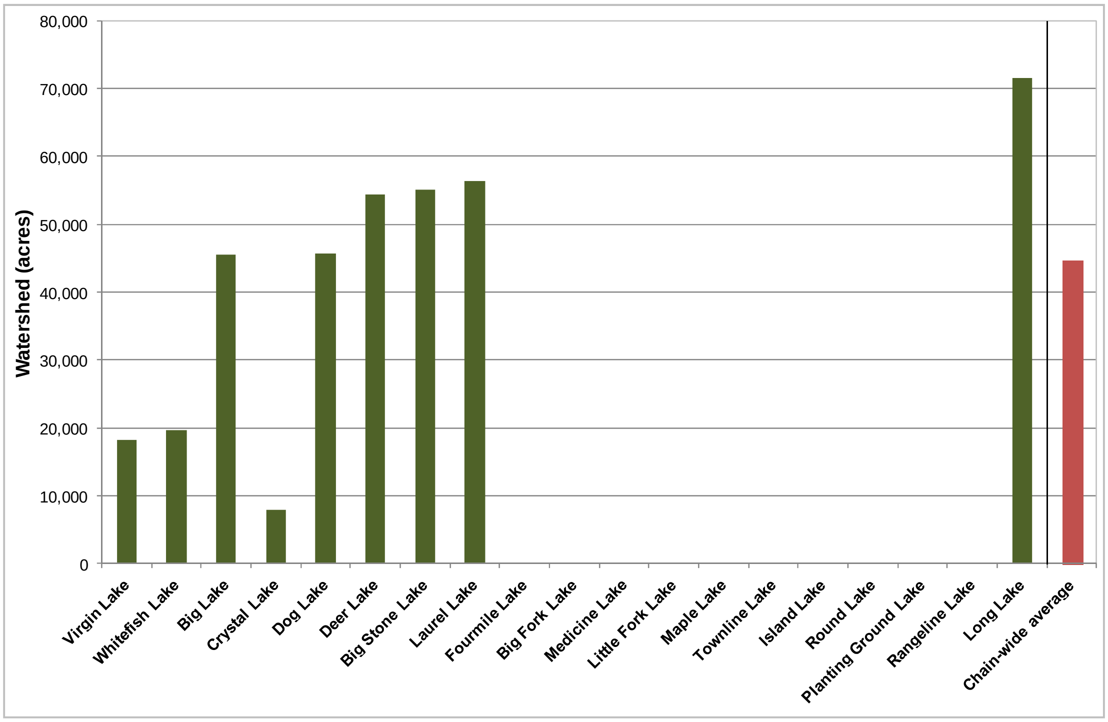


Figure 3.2-1. Three Lakes Chain of Lakes watershed size, in acres. Lakes are arranged in approximate order of furthest upstream to furthest downstream.

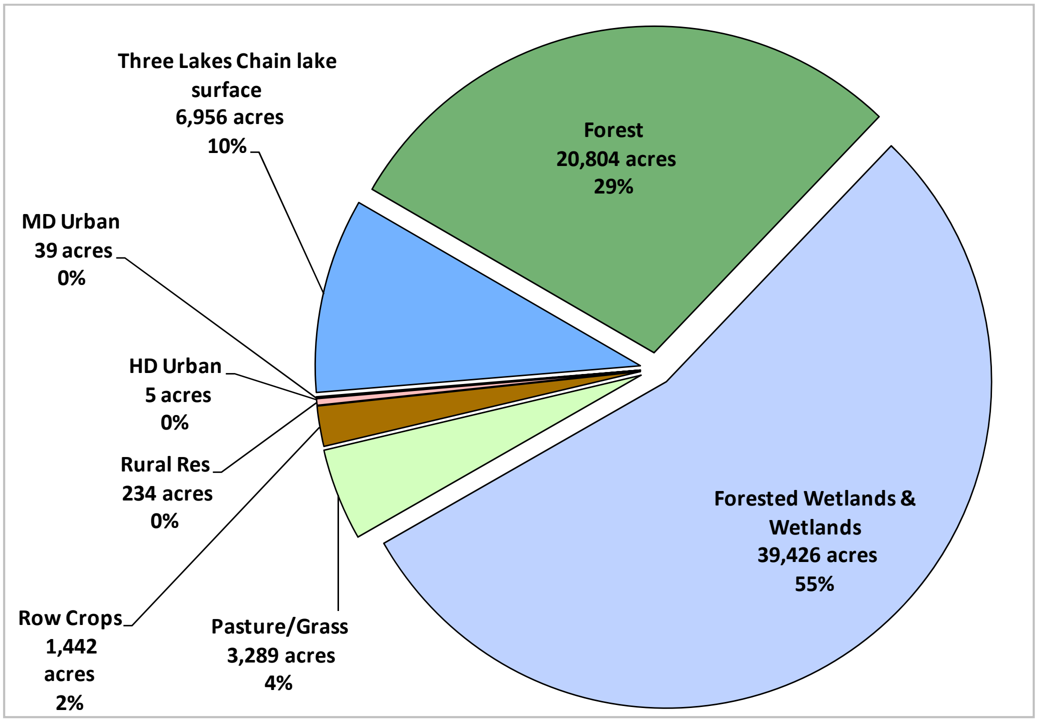


Figure 3.2-2. Three Lakes Chain of Lakes watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011)

Phosphorus loading chart will be included here once completed.

Figure 3.2-3. Three Lakes Chain of Lakes watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) affects on the lake is important in maintaining the quality of the lake's water and habitat. Along with this, the immediate shoreland area is often one of the easiest areas to restore.

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more strict shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances of their own. County ordinances may be more restrictive than NR 115, but not less so. These policy regulations require each county to amend ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows (Note: counties must adopt these standards by February 2014, counties may not have these standards in place at this time):

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface (but not more than 30%) on a lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
  - No expansion or complete reconstruction within 0-35 feet of shoreline
  - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
  - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
  - Vertical expansion cannot exceed 35 feet

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

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area as well as spawning habitat (Hanchin et al 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon in many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

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

National Lakes Assessment

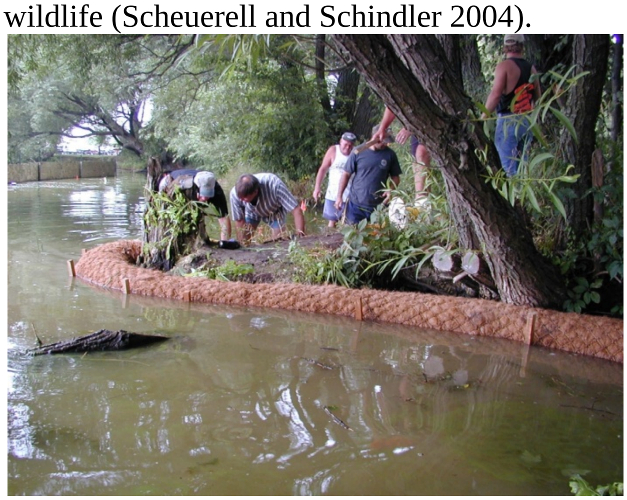
Unfortunately, along with Wisconsin's lakes, waterbodies within the entire United States have shown to have increasing amounts of developed shorelands. The National Lakes Assessment (NLA) is an Environmental Protection Agency sponsored assessment that has successfully pooled together resource managers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

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

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

Native Species Enhancement

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



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

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

Cost

The cost of native aquatic and shoreland plant restorations is highly variable and depends on the size of the restoration area, depth of buffer zone required to be restored, existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Some sites may require erosion control stabilization measures which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Protective measures may be used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting and using mulch to help retain moisture. Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

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

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

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

Three Lakes Chain of Lakes Shoreland Zone Condition

Shoreland Development

The lakes within the Three Lakes Chain were surveyed as a part of this project to determine the extent of their degree of development. Lakes were visited during each appropriate phase, generally during the late summer to conduct this survey.

A lake's shoreland zone can be classified based upon the amount of human disturbance (vegetation removal, construction of rip-rap or seawalls, etc.). In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-1 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.

Urbanized: This type of shoreline has essentially no natural habitat. Areas that are mowed or unnaturally landscaped to the water's edge and areas that are rip-rapped or include a seawall would be placed in this category.

Developed-Unnatural: This category includes shorelines that have been developed, but only have small remnants of natural habitat yet intact. A property with many trees, but no remaining understory or herbaceous layer would be included within this category. Also, a property that has left a small (less than 30 feet), natural buffer in place, but has urbanized the areas behind the buffer would be included in this category.

Developed-Semi-Natural: This is a developed shoreline that is mostly in a natural state. Developed properties that have left much of the natural habitat in state, but have added gathering areas, small beaches, etc within those natural areas would likely fall into this category. An urbanized shoreline that was restored would likely be included here, also.

Developed-Natural: This category includes shorelines that are developed property, but essentially no modifications to the natural habitat have been made. Developed properties that have maintained the natural habitat and only added a path leading to a single pier would fall into this category.

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

Figure 3.3-1. Shoreline assessment category descriptions.

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

The Three Lakes Chain of Lakes has stretches of shoreland that fit all of the five shoreland assessment categories. Some of the lakes surveyed had more areas of natural shoreline than others. In all, the Phase I and Phase II Three Lakes Chain lakes contain approximately about 22.4 miles of natural/undeveloped and developed-natural shoreline (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. A little over 8.5 miles of urbanized and developed–unnatural shoreline were recorded during field surveys. Figure 3.3-3 provides a breakdown of each Phase I and Phase II lake's shoreland condition, while each individual lake section discusses the shoreline condition further. Maps of each lake and the location of these categorized shorelands are included within each individual lake section as well.

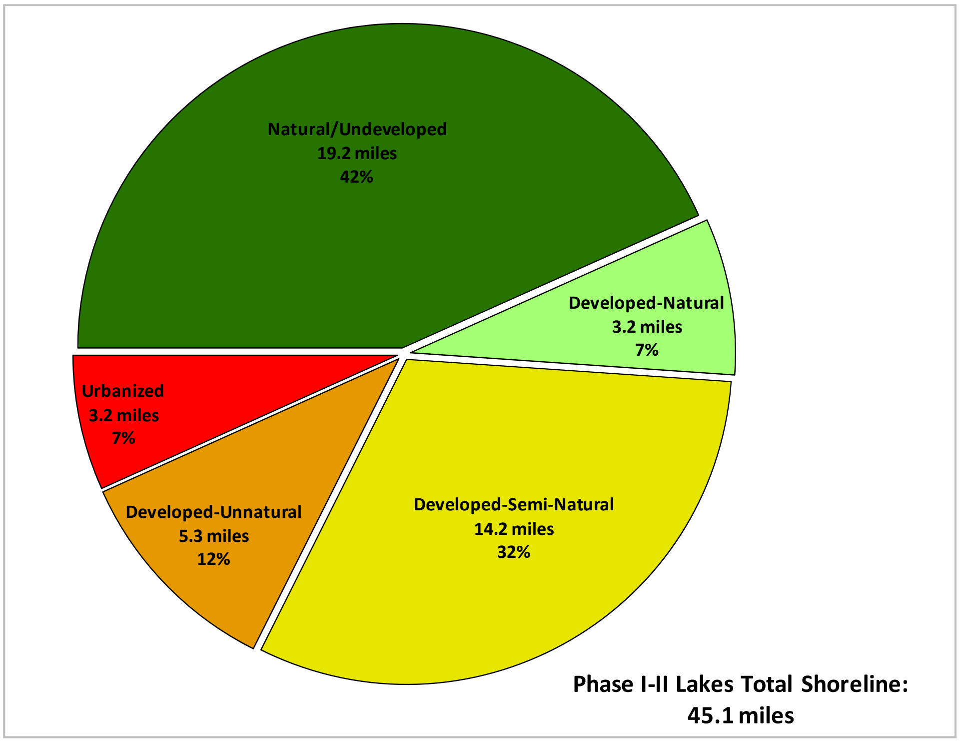


Figure 3.3-2. Phase I and II Three Lakes Chain of Lakes total shoreland classification. Based upon field surveys conducted in late summer 2010 and 2011.

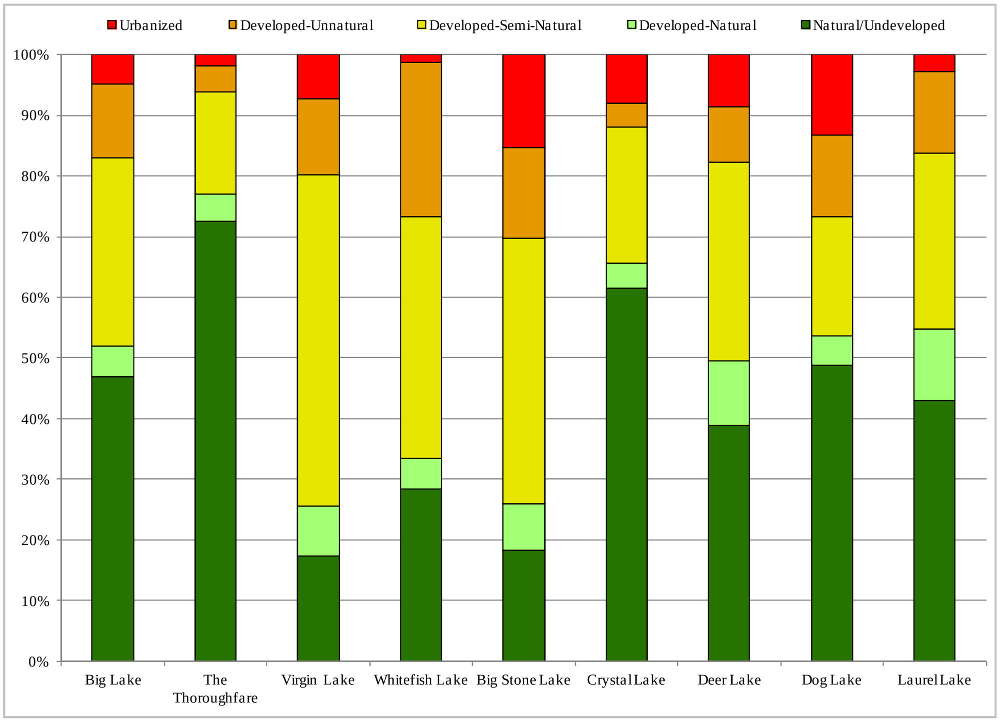


Figure 3.3-3. Phase I and Phase II Three Lakes Chain of Lakes shoreline condition breakdown. Based upon late summer 2010 and 2011 field surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

While producing a completely natural shoreline is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site.

3.4 Aquatic Plants

Introduction

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

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

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

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

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

Cost

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

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

Bottom Screens

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

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

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

Water Level Drawdown

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

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

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

Mechanical Harvesting

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

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.

Herbicide Treatment

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

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

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

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

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

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

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

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

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

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

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

Cost

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

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

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

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

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

Species Diversity and Richness

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

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Three Lakes Chain of Lakes. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Three Lakes Chain of Lakes will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1).

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. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species or those encountered during other aquatic plan surveys.

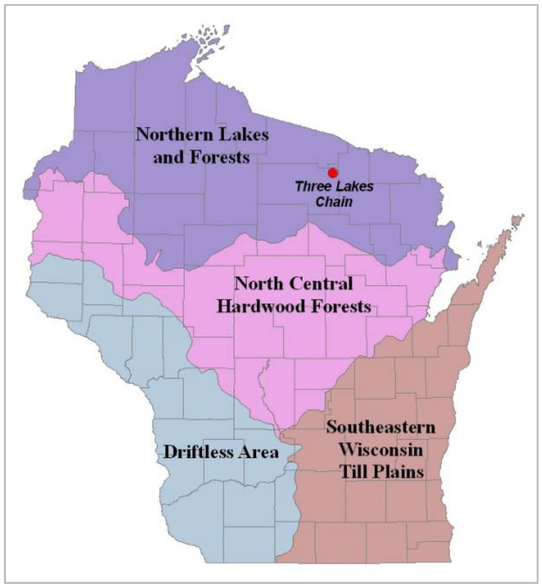


Figure 3.4-1. Location of Three Lakes Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

Community Mapping

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

Exotic Plants

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

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-2). 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.

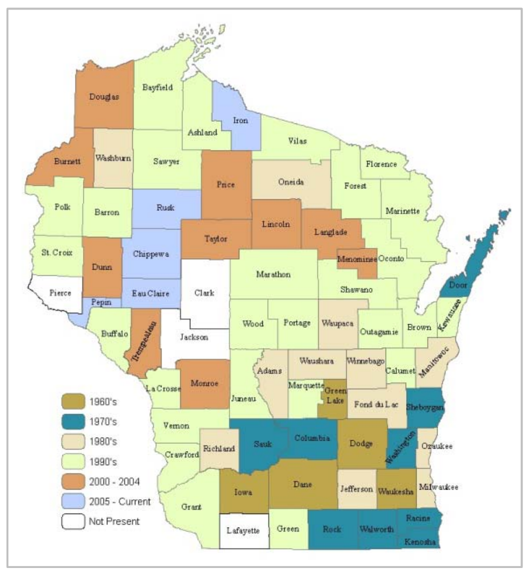


Figure 3.4-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.
Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian water milfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

Aquatic Plant Survey Results

Numerous plant surveys were completed as a part of this project. In June of each year, surveys were completed on all of the Three Lakes Chain of Lakes that focused upon curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed within any of the project lakes. It is believed that this aquatic invasive species either does not occur in Three Lakes Chain of Lakes or exists at an undetectable level. However, curly-leaf pondweed does exist in several nearby lakes, including Little Saint Germain, Kentuck and Pine Lakes.

The point intercept surveys were conducted on the Three Lakes Chain of Lakes in the months of July and August of each project year by Onterra. Additional surveys were completed during this time by Onterra to create the aquatic plant community maps (See "Aquatic Plant Community Map" after each individual lake section). Aquatic plant point-intercept survey data may be viewed in Appendix F.

A total of 88 different plant species were identified from the nine Phase I and II lakes involved with this project, as well as Long Lake, which completed a management planning project in 2009 (Figures 3.4-3, 3.4-4). The submergent pondweed species, clasping-leaf pondweed, was found within all 10 of these lakes. Six emergent or floating-leaf species were found within all 10 lakes as well. Many species were found only occasionally; 21 species were found within only one of these 10 lakes. This adds testament to the individuality of each of the lakes, even though essentially they are all part of the same ecosystem, or chain of lakes. One aquatic plant located within four of these lakes is considered to be particularly rare –Vasey's Pondweed (*Potamogeton vaseyi* – Photo 3.4-1). This species is listed as a species of special concern by the Natural Heritage Inventory Program. As the project continues on with Phase III, Phase IV, etc., this analysis will be expanded to encompass the lakes as they are studied.

Four of the species found during the plant surveys are considered non-native, invasive species: Eurasian water milfoil was the only submergent exotic plant found within the chain (Virgin Lake and the Long Lake Channel). Several emergent exotic plants were found, including purple loosestrife, located on the margins of Laurel, Long, Big Stone and Big Lake, hybrid cattail, located along Long Lake, and Amur silver grass, located on the shoreline of Big Lake. Another species, sweetflag, was once classified as exotic (not quite "invasive"), but now is thought to have become naturalized with the native flora found in the upper United States. Because of their importance, the exotic species will be discussed in depth within the individual lake vegetation sections.

Photo 3.4-1 Special concern species Vasey's pondweed (*Potamogeton vaseyi*).

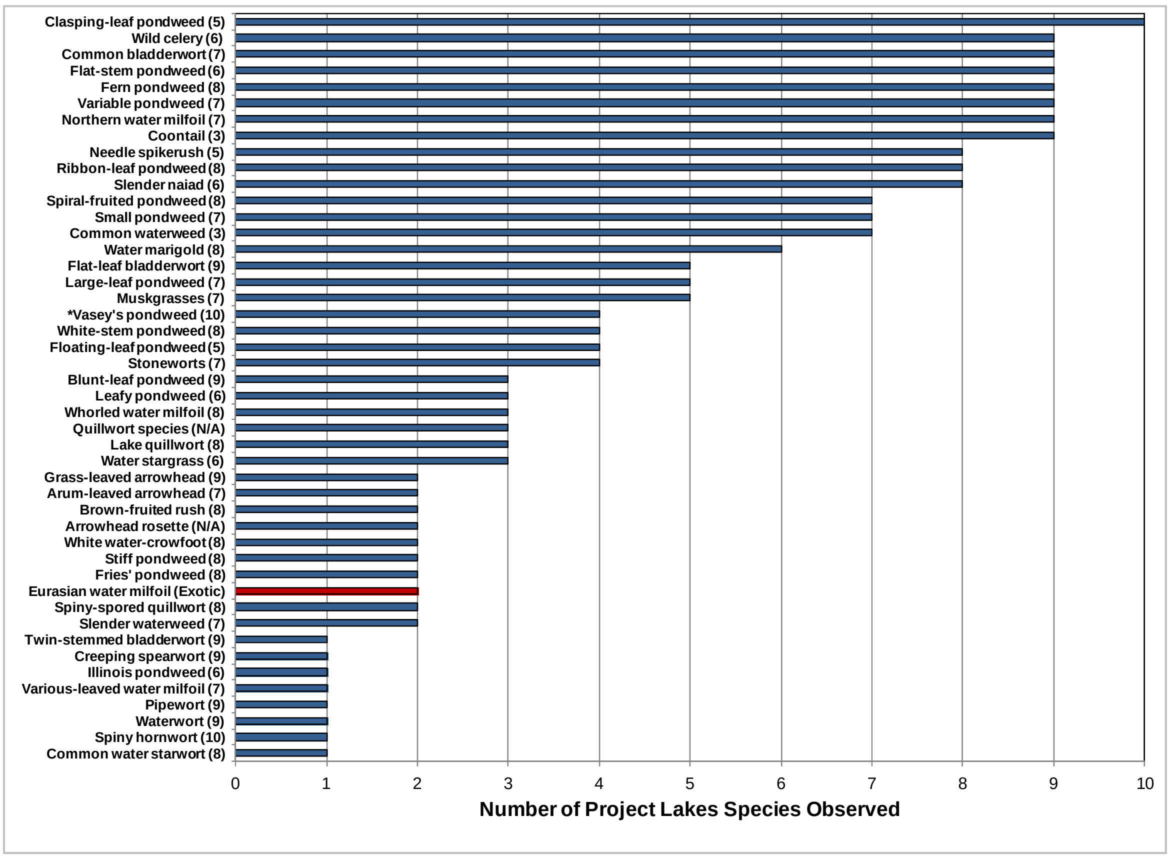


Figure 3.4-3 Three Lakes Chain of Lakes town-wide submergent aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.

* *State species of special concern*

The Three Lakes Chain of Lakes vary little in their watershed and water quality characteristics. For the most part, the lakes have similar substrate, nutrient concentrations, algae concentrations, pH, clarity and alkalinity; though, some exceptions do apply. The substrate and water chemical composition of a lake influences aquatic plant species composition and abundance, and has the ability to create completely different plant communities among lakes that may be located across the street from each other. Generally speaking, lakes can be divided into two main groups based upon their plant community composition: 1) lakes that are dominated by plants of the isoetid growth form, and 2) lakes dominated by plants of the elodeid growth form.

Plant species of the isoetid growth form are small, slow growing, inconspicuous submerged plants that have evergreen leaves located in a rosette and are usually found growing in sandy soils within the near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000). Some isoetid species found in the Three Lakes Chain of Lakes include pipewort, brown-fruited rush and needle spikerush. Conversely, submerged species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column. The elodeid growth form includes plants such as common waterweed, coontail and many varieties of pondweeds and milfoils.

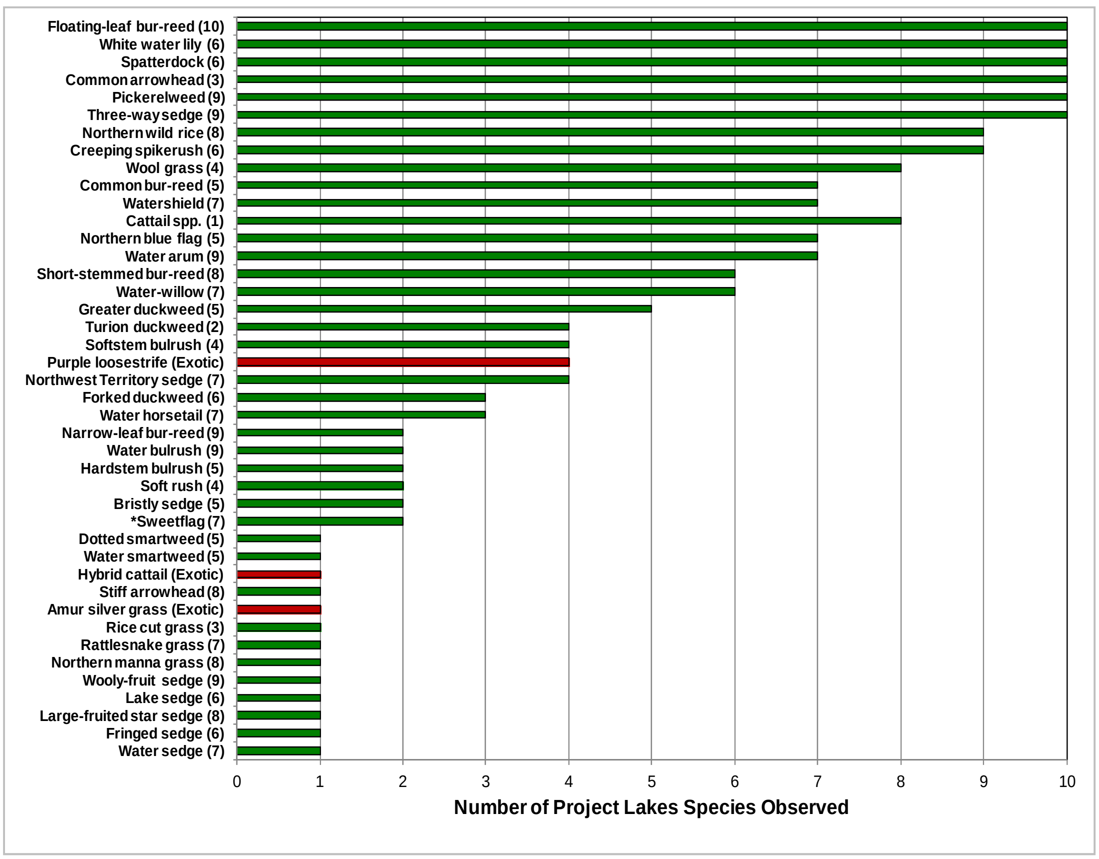


Figure 3.4-4 Three Lakes Chain of Lakes town-wide emergent, floating-leaf and free-floating aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.
**Sweetflag, an exotic plant, is now thought to be naturalized in Wisconsin.*

Alkalinity is the primary water chemistry factor determining whether a lake is dominated by plant species of the isoetid or elodeid growth form (Vestergaard and Sand-Jensen 2000). As mentioned in the Water Quality Section, alkalinity measures the concentration of calcium carbonate ($CaCO_3$) in the lake water and is a close descriptor of the amount of bicarbonate present. Isoetids, unable to use bicarbonate as source of carbon for photosynthesis, are typically found in lakes of lower alkalinity as they are adapted to grow in areas where carbon is limited. Through an extensive, permeable root system, isoetids are able to release oxygen into the sediment. This stimulates microbial decomposition while decreasing sediment pH (Urban et al. 2006). In turn, the decomposition process increases sediment carbon, which is not useable by plants of the elodeid growth form.

In lakes with higher alkalinity, elodeids grow in abundance as they are able to utilize the bicarbonate as a carbon source. In lakes with moderate alkalinity levels, both elodeids and isoetids may be found. While some of the project lakes displayed these alkalinity levels, most lakes were overwhelmingly dominated by elodeid plants, with instances of isoetid plants being found occasionally. While isoetid species are physically able to grow in lakes with higher alkalinity, their short stature makes them susceptible to shading from the much taller, leafy elodeid species which often restricts their growth to shallow, wave-exposed sites with course sediments (Vestergaard and Sand-Jensen 2000). Floating-leaf species, such as spatterdock and white water lily, obtain most of their carbon from the atmosphere, allowing them to be prevalent in most Wisconsin lakes.

Increases in alkalinity and sedimentation from residential development around a lake may result in creating a more suitable habitat for the taller elodeids, displacing isoetid species. As a result, many of the isoetid species have higher conservatism values as they are intolerant of disturbance and are indicators of high quality lake environments. Isoetid dominated lakes tend to be lower in species richness than elodeid dominated lakes. In general, the lakes within the Three Lakes Chain may be described as elodeid dominated lakes.

In the Three Lakes Chain of Lakes, the number of species observed per lake varied from 16 species in Crystal (Mud) Lake to 52 native species in Long Lake & the Eagle River Channel, with an average of 34 species per lake (Figure 3.4-5). Please note that Figure 3.4-5 displays the number of plants found within the point-intercept survey, as well as the additional species found incidentally. The total number of species is a combination of these two, however in comparing to ecoregion and state medians and computing conservatism values (see discussion below) only the plants located during the point-intercept survey are considered. Nine of the ten lakes met or exceeded the Northern Lakes Ecoregion median for species richness. Crystal (Mud) Lake, with 12 native species, fell just short of this standard comparison level. Plant growth may be limited in this lake due to its exceptionally discolored water and mucky substrate, which limits the depth and available littoral habitat for some plant species.

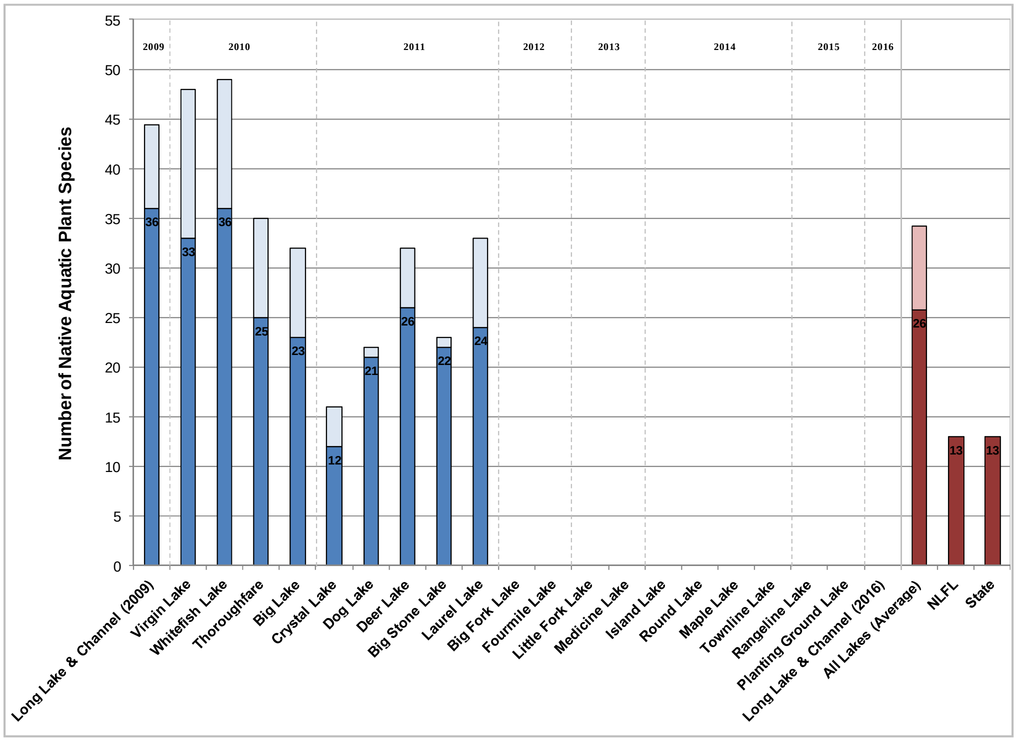


Figure 3.4-5 Three Lakes Chain of Lakes native species richness. Created using data from summer point-intercept and community mapping surveys. Chart includes incidental species (light colored bars). Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

Like species richness, the Three Lakes Chain of Lakes had a wide range of plant species diversity (Figure 3.4-6). As discussed earlier, how evenly the species are distributed throughout the system and species richness together influence species diversity. In other words, a lake with many species is not necessarily diverse, and a lake with few species is not necessarily lacking diversity. Simpson's diversity index (1-D) is used to make this distinction.

Species diversity ranged from 0.65 to 0.94 in the Three Lakes Chain of Lakes (Figure 3.4-6). Big Stone Lake, even with having moderate species richness, has a relatively low diversity value due to the distribution of plants within the lake. As discussed within the Big Stone Lake Aquatic Plant Section, wild celery dominates the plant community with a relative frequency of 58%. In comparison, Virgin Lake (Simpson's Diversity value of 0.94) has high distribution of the most commonly found plants; the most common plants in this lake have a relative frequency of 9%.
While a method of characterizing diversity values as "Fair" or "Poor", etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the Three Lakes Chain of lakes' scores rank. Using data obtained from WDNR Science Services, median values and upper/lower quartiles were calculated for 109 lakes within the Northern Lakes and Forests ecoregion (Figure 3.4-6). Six of the lakes rank above the median for the ecoregion, and seven of the lakes are either within the upper and lower quartile value range, or above it.

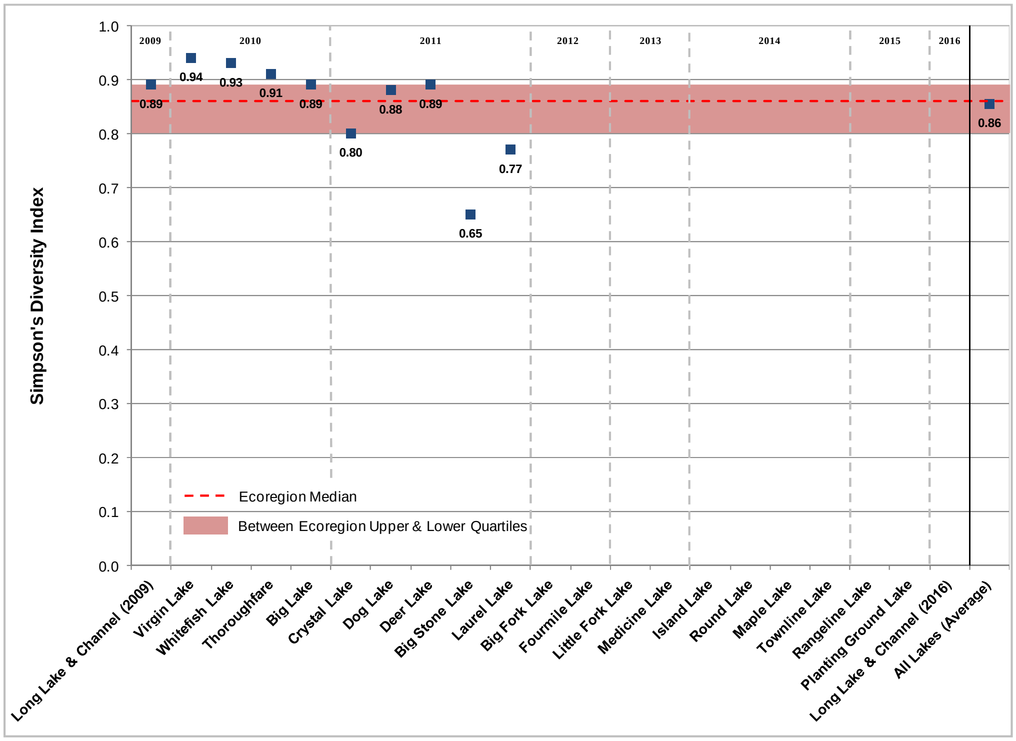


Figure 3.4-6 Three Lakes Chain of Lakes species diversity index. Created using data from summer point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Data collected from the aquatic plant surveys indicated that many of the lakes met or exceed the Northern Lakes Ecoregion median and all project lakes surveyed met or exceeded the state median for average plant species' conservatism values (Figure 3.4-7). This means the majority of the project lakes have plant communities that are more indicative of a pristine condition than those found in most lakes in the state and the ecoregion. The lakes that fell below the ecoregion median had higher nutrient levels and reduced light availability, supporting mainly disturbance-tolerant plant species (e.g., coontail, flat-stem pondweed) and fewer sensitive species.

Combining the species richness and average conservatism values for each project lake to produce the Floristic Quality Index (FQI) resulted in a range of values from 22.2 to 44.4, with an average of 34.6 (equation shown below) (Figure 3.4-8). All of the project lakes but Crystal (Mud) Lake exceed the state and ecoregion median FQI value. Again, this illustrates that the Three Lakes Chain of Lakes have high quality plant communities.

$$FQI = \text{Average Coefficient of Conservatism} * \sqrt{\text{Number of Native Species}}$$

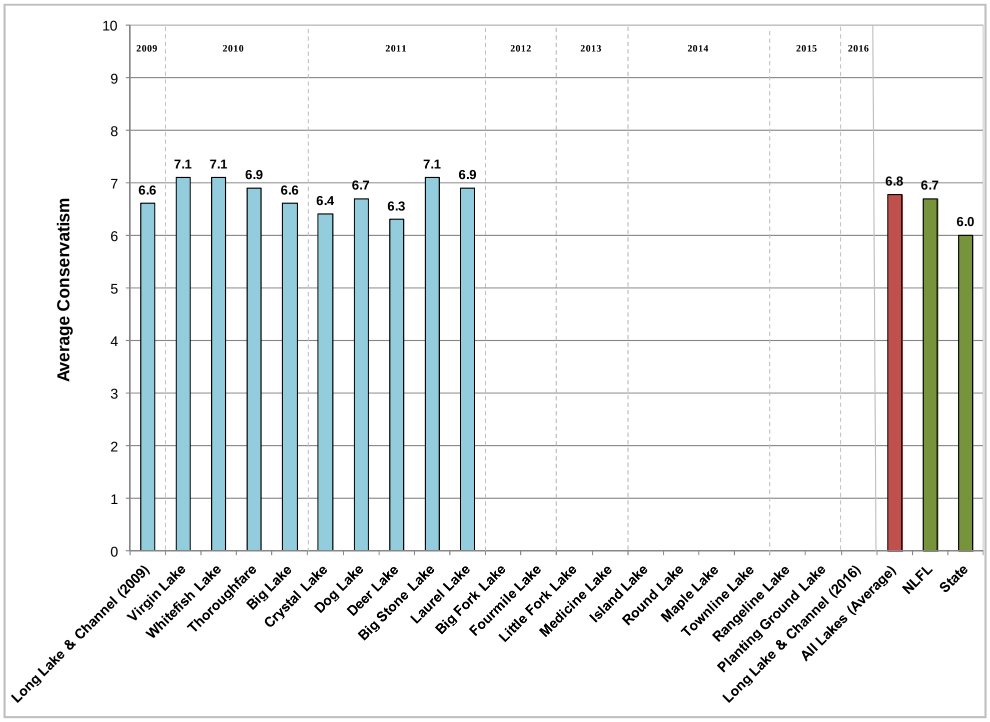


Figure 3.4-7 Three Lakes Chain of Lakes average native species' coefficients of conservatism. Created using data from summer point-intercept surveys. Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

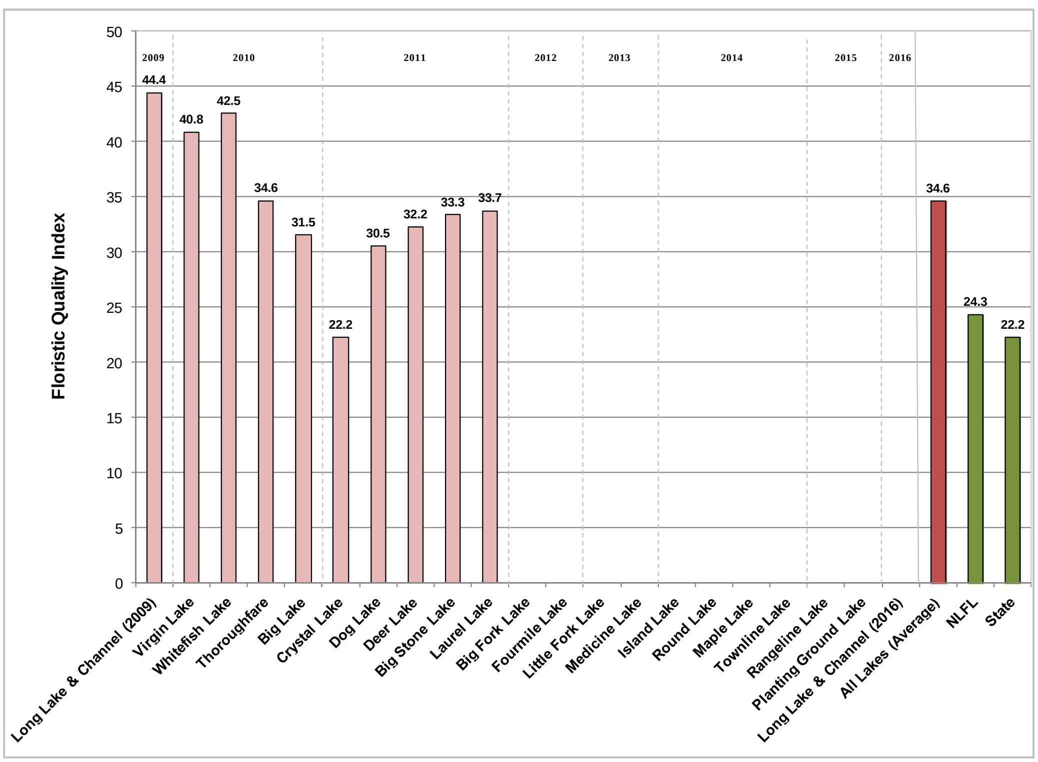


Figure 3.4-8. Three Lakes Chain of Lakes Floristic Quality Assessment. Created using data from summer point-intercept surveys. Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

As illustrated in the analyses above, the plant communities within the Three Lakes Chain are generally of high quality. One of the biggest advantages of having a healthy plant community in a lake is the habitat value it provides. Areas of emergent and floating-leaf plant communities provide valuable fish and wildlife habitat important to the ecosystem both inside and outside of the lake. These areas are utilized by adult fish for spawning, by juvenile fish as a nursery, and by forage fish for protection from predators. Wading birds can be found in these areas hunting fish and insects, and escaping dangerous predators. Finally, these communities protect shorelines from eroding, as they temper the energy on the waves approaching the shoreline from the interior of the lake.

Many of the Three Lakes Chain lakes contain large areas of these plant communities. Figure 3.4-9 displays the percent of lake acreage occupied by either emergent, floating-leaf, or a combined emergent and floating-leaf plant communities. The Thoroughfare, a shallow passageway between Virgin and Whitefish Lakes, has an incredible 93% of its total acreage covered by both emergent and floating-leaf plant communities. Long Lake, a deep lake at the end of the Three Lakes Chain, has 5% of its lake acreage covered by these communities. The mapping of Long Lake communities was conducted in 2009; as a part of this comprehensive Chain-wide plan, the lake will be surveyed again in 2016 by Onterra ecologists. At that time, data may be compared to tell, qualitatively and quantitatively, if any changes in these plant communities had occurred.

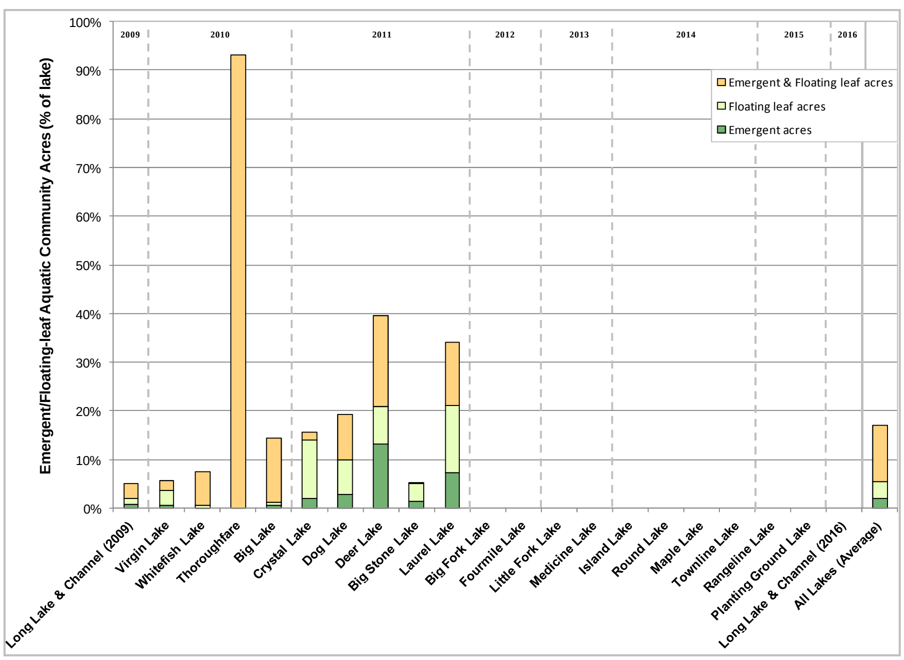


Figure 3.4-9. Three Lakes Chain of Lakes emergent and floating-leaf aquatic plant communities. Created using data from summer community mapping surveys.

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Three Lakes Chain of Lakes. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the TLWA stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2010 & GLIFWC 2012A and 2012B).

Three Lakes Chain of Lakes Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second highest ranked important or enjoyable activity on the Three Lakes Chain of Lakes (Question #10). Approximately 69% of these same respondents believed that the quality of fishing on the lake is fair or good (Question #7); however, approximately 87% believe that the quality of fishing has remained the same or gotten worse since they started fishing the lake (Question #8).

Table 3.5-1 is a list of popular game fish that are present in many northern Wisconsin lakes. The Three Lakes Chain of Lakes is host to many of these species. On some northern Wisconsin lakes, management actions aimed at controlling exotic plant species or excessive native aquatic plant species are utilized and include either herbicide applications or mechanical harvesting. While the Implementation Plan will discuss these specific management actions as they relate to any of the Three Lakes Chain of Lakes, it should be noted that these measures are planned in a manner that reduces their potential impact on the system's fishery. Herbicide applications usually occur in May when the water temperatures are below 65°F, while mechanical harvesting occurs in mid-June and later. The goal is to reduce the impact upon the spawning environment which would be to remove the submergent plants that are actively growing at these low water temperatures. Species that spawn in late spring or early summer may be impacted as water temperatures and spawning locations often overlap, and vital nursery areas for emerged fry could become vulnerable. Yellow perch and muskellunge are examples of species that could potentially be affected by early season herbicide applications, as the treatments could eliminate spawning substrate or nursery areas for the emerged fry.

When examining the fishery of a lake, it is important to remember what "drives" that fishery, or what is responsible for determining its mass and composition. The gamefish in Three Lakes Chain of Lakes are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscovores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

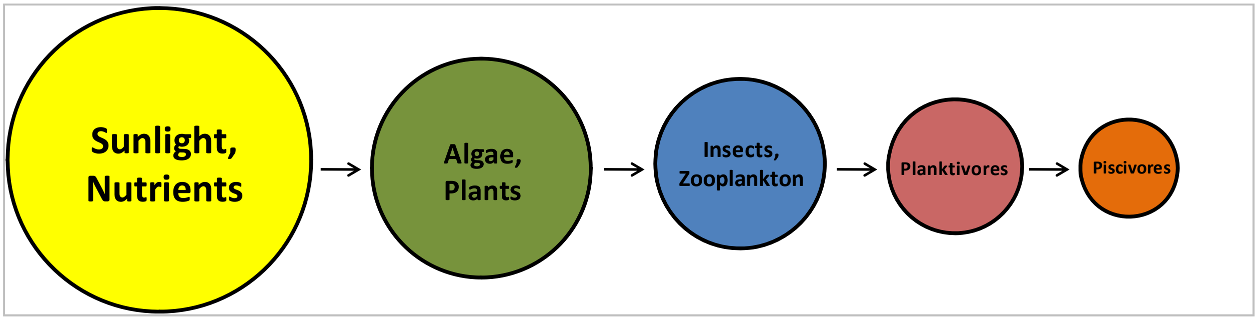


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

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

Table 3.5-1. Common gamefish present in Northern Wisconsin Lakes with biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	Lepomis gibbosus	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	Ambloplites rupestris	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass	Micropterus dolomieu	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye	Sander vitreus	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
White Crappie	Pomoxis annularis	13	May - June	Within 10 m from shore, over hard clay, gravel, or roots	Crustaceans, insects, small fish
Yellow Bullhead	Ameiurus natalis	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	Perca flavescens	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Native American Spearfishing

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-2). The Three Lakes Chain 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. This highly structured process begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then an "allowable catch" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% of a lake's fishing stock, but may vary on an individual lake basis. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The allowable catch number is then reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level". The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent, or declaration. This result is called the quota, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal 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). Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2012B). This regulation limits the harvest of the larger, spawning female walleye.

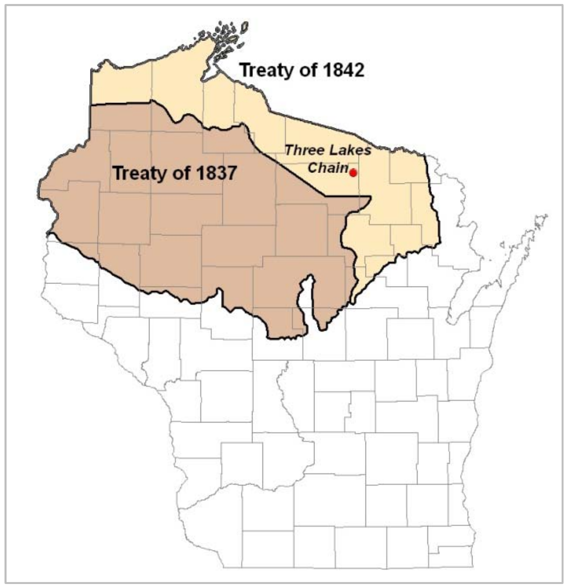


Figure 3.5-2. Location of Three Lakes Chain of Lakes within the Native American Ceded Territory (GLIFWC 2012A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2012B). 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. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

While a safe harvest level and quota have been established on all lakes at some time between 1989 and present time, not all lakes within the chain have experienced a spearfishing harvest. Lakes with no recorded walleye harvest over this time period include Deer, Dog, Maple, Moccasin, Crystal (Mud), Rangeline and Townline Lakes. Table 3.5-2 displays the walleye and muskellunge harvest frequency during the past 24 years in which data has been recorded. As seen on this table, the lakes that have historically seen a higher spear harvest include most of the larger bodied lakes in the chain – Big, Big Fork, Big Stone, Little Fork, Long, Medicine, and Planting Ground lakes.

Table 3.5-2. Native American spear harvest frequency on the Three Lakes Chain. The table summarizes the years in which each lake has experienced a walleye or muskellunge harvest. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

Lake	Years of walleye harvest, 1989-2012	Years of muskellunge harvest, 1989-2012
Planting Ground	23	5
Big Stone	21	
Big	20	2
Big Fork	20	2
Medicine	18	2
Long	13	2
Little Fork	11	
Island	7	2
Laurel	7	2
Whitefish	5	
Spirit	4	1
Fourmile	3	
Virgin	3	1
Round	1	
Deer		
Dog		
Maple		
Moccasin		
Crystal (Mud)		
Rangeline		
Townline		

Individual lake Native American spearing statistics are displayed in Appendix G. The relationship between the safe harvest number, declaration and actual harvest is displayed on a chain-wide basis for walleye (Figure 3.5-3) and muskellunge (Figure 3.5-4). Once a safe harvest number is set for a given lake, tribal leaders may declare a quota of fish they may spear in the upcoming season. From 1989 to 2012, tribal spearers have claimed a walleye quota that is between 53% and 82% of the safe harvest. On average, Native American spear fishermen have harvested 49% of the declared quota on the Three Lakes Chain of Lakes with respect to walleye.

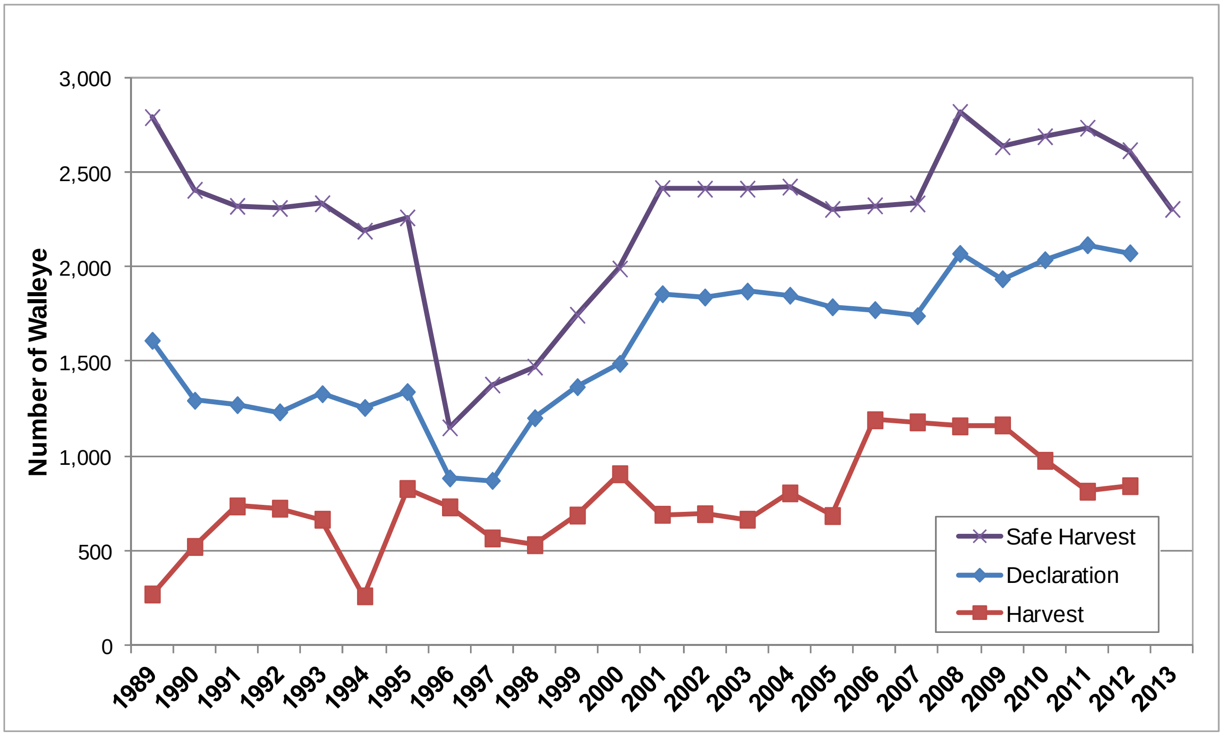


Figure 3.5-3. Total chain-wide walleye spear harvest statistics. Annual Native American walleye spear harvest statistics are summarized for 21 lakes in the Three Lakes Chain of Lakes. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

Figure 3.5-4 displays the Native American open water muskellunge spear harvest since 1989. Muskellunge spear harvests have been minimal on the Three Lakes Chain of Lakes; since 1989 an average of one muskellunge per year has been harvested on the entire chain during the open water spear fishery. This harvest has been as high as four fish (2004) and spear fishermen have rarely surpassed 4% of their allotted declaration (Figure 3.5-4).

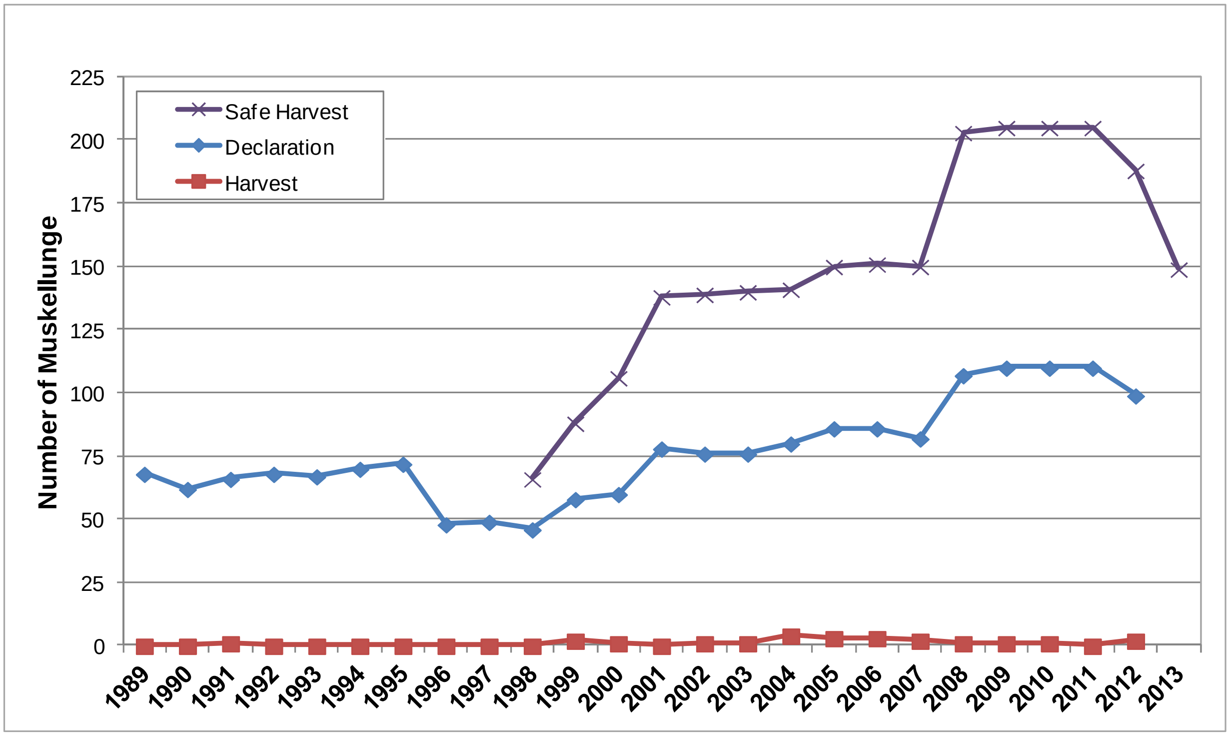


Figure 3.5-4. Total chain-wide muskellunge spear harvest statistics. Annual Native American muskellunge spear harvest statistics are summarized for 21 lakes in the Three Lakes Chain of Lakes. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

Three Lakes Chain of Lakes Fishing Regulations

Because Three Lakes Chain of Lakes is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may pertain to Three Lakes Chain of Lakes. In 2011, the daily bag limit remained at three walleyes for every lake on the chain, with the exception of Big Fork and Planting Ground Lakes in which a bag limit of two fish was set. On the Three Lakes Chain of Lakes, recent review of the fishery and its regulations resulted in changes of the minimum length limit for harvesting walleyes. Currently, there is no minimum length limit on walleye, but only one fish over 14" is allowed. WDNR fisheries biologist established this regulation in 2010 to maintain walleye size structure, provide increased opportunity for angler harvest and allow harvest of males over 14" in length (WDNR Correspondence/Memorandum, Appendix G).

For bass species, a catch-and-release season from early May to mid-June exists. Once the regular season begins in mid-June, the minimum length limit is 14" and a daily bag limit is limited to five fish. Three Lakes Chain of Lakes is in the northern half of the muskellunge and northern pike management zone. Muskellunge must be 34" to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and only five pike may be kept in a single day. Statewide regulations apply for all other fish species.

Three Lakes Chain of Lakes Fish Stocking

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

Currently, "maintenance" stocking of muskellunge is done on the Three Lakes Chain of Lakes to maintain this population. Stocking of this species occurs at a rate of 0.25 fish per acre, every other year. Nine of the 18 lakes within the chain have been stocked with muskellunge as recently as 2008 or 2010, and four other lakes within the chain have been stocked historically, but not in recent years. The WDNR does not stock walleye in the Three Lakes Chain of Lakes because the population has high recruitment which has resulted in a high-density fishery. Thus, there is little need to supplement the population with stocking. Stocking summaries for the Three Lakes Chain of Lakes can be viewed in Appendix G.

Three Lakes Chain of Lakes Creel Surveys

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

In 1994, a creel survey was conducted on six of the Three Lakes Chain of Lakes – Big, Big Stone, Laurel, Little Fork, Medicine and Planting Ground Lakes. Creel data shows that anglers targeted walleye and muskellunge the most during the survey period. On Little Fork Lake, anglers spent a combined 2,600 hours pursuing walleye, while a combined 9,800 hours was spent fishing for walleye on Planting Ground Lake. Table 3.5-3 displays data stemming from this 1994 survey for the two most sought after species in the Three Lakes Chain of Lakes – muskellunge and walleye.

Table 3.5-3. Three Lakes Chain of Lakes WDNR Creel Survey Summary, 1994. Table display effort for all species, effort directed at either muskellunge or walleye, and catch and harvest numbers as a unit per acre of each lake (WDNR 2012).

Species	Lake	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch / Acre	Harvest / Acre
Muskellunge	Big	20.4	4	0.2	0
	Big Stone	18	5.7	0.2	0
	Laurel	44.7	14.4	0.9	0
	Little Fork	15.4	5	0.2	0
	Medicine	20	9.9	0.4	0.1
	Planting Ground	19	8.1	0.8	0
Walleye	Big	20.4	10.9	3.1	1
	Big Stone	18	8.2	2.8	0.4
	Laurel	44.7	10.9	0.8	0.4
	Little Fork	15.4	7.9	4.6	0.9
	Medicine	20	6.8	2	0.7
	Planting Ground	19	9.7	1.4	0.5

Three Lakes Chain of Lakes Substrate Type

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

According to the point-intercept survey conducted by Onterra, the lakes within the Three Lakes Chain varied quite a bit in terms of their substrate type. Some of the lakes contained mostly a soft, mucky bottom, while others were dominated by sand (Table 3.5-4). Some of the lakes had a good mixture of both substrates, and incorporated some rocky areas as well.

Table 3.5-4. Substrate types for the Three Lakes Chain of Lakes. Data collected during point intercept surveys by Onterra (2009-2016).

Project Phase	Lake	% Muck	% Sand	% Rock
Long Lake (2009)	Long Lake	66	28	6
Phase I - 2010	Virgin Lake	34	51	15
	Whitefish Lake	24	74	3
	The Thoroughfare	95	5	0
	Big Lake	37	59	4
Phase II - 2011	Laurel Lake	63	36	1
	Big Stone Lake	4	92	5
	Dog Lake	24	75	0
	Crystal (Mud) Lake	91	9	0
	Deer Lake	60	39	1
Phase III - 2012	Fourmile Lake			
	Big Fork Lake			
Phase IV - 2013	Moccasin Lake			
	Spirit Lake			
	Maple Lake			
Phase V - 2014	Little Fork Lake			
	Medicine Lake			
Phase VI - 2015	Round Lake			
	Island Lake			
	Townline Creek			
	Townline Lake			
Phase VII - 2016	Planting Ground Lake			
	Range Line Lake			

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Three Lakes Chain of Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within each lake, if any were found.
3) Collect sociological information from Three Lakes Chain of Lakes stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

Completing a comprehensive management plan for a large and diverse ecosystem such as the Three Lakes Chain of Lakes is a tremendous undertaking. By splitting this project into numerous phases, the TLWA, Town of Three Lakes, WDNR, and Onterra ecologists were able to give individualized attention to several lakes of the chain at a time and address specific issues that came about during this planning project. This is important, as during the studies it was learned that each lake has its own unique ecology as well as both positive facets and known challenges. In addressing each lake in a phased manner, a greater understanding was achieved about this ecosystem as a whole also. Though the chain has seen some human disturbance, the lakes are largely in good condition and need protection to ensure that they remain this way.

The large quantity of water the Three Lakes Chain of Lakes holds is the result of a large area of land that drains to these lakes. Over 72,000 acres of land drains towards these lakes. The large watershed consists of primarily natural land cover types, such as forest, forested wetlands, wetlands, etc. These land cover types are the most ecologically beneficial within a lakes watershed, as they allow water to permeate the ground as opposed to allowing more surface water runoff. This creates a naturally occurring filtering process and reduces the amount of nutrients and pollutants entering the lakes. In other watersheds, large amounts of urban and agricultural land reduce this filtration process and increase the amount of surface water pollution a lake receives.

Immediately surrounding each of the Three Lakes Chain of Lakes is the shoreland zone, which serves as an important buffer area for surface water runoff as well as habitat for many terrestrial and aquatic organisms. As the Three Lakes Chain of Lakes is a heavily visited and utilized system, it is not surprising that the shoreland zone shows a large amount of human disturbance. Restoring these disturbed shoreland areas, and protecting the natural shoreland areas that currently exist, may benefit each lake ecosystem and help in creating a natural, picturesque “up north” feel to the Three Lakes Chain of Lakes.

While the watershed is largely responsible for determining the general water quality in a lake or chain of lakes ecosystem, the biological, chemical and physical parameters of the water in a lake may in turn be the largest single factor in determining the health of a lake, including its aquatic plant community, fishery, etc. These components, contributing to the lake’s overall water quality, are an important aspect for recreational activities as well. The water within the Three Lakes Chain of Lakes is moderate to low in terms of its water clarity; however, this is primarily determined by the natural staining color that is derived from the decomposition of plant material in the watershed. So, considering this interesting aspect, the clarity measured on the Three Lakes

Chain of Lakes is not unexpected. Nutrient levels were assessed on the project lakes also, and turned up some interesting results – particularly with phosphorus. Phosphorus concentrations were found to vary amongst the project lakes, and this is partially due to differences in the morphology (deep drainage lakes vs. shallow drainage lakes) and placement of the lakes (higher or lower) in the chain. As eluded to within the Water Quality Section and discussed within the Implementation Plan, there is an unaccounted for nutrient in some of the project lakes that requires additional research if a source of this nutrient input is to be discovered.

A major component of this project's studies included assessments of the native and if applicable, non-native aquatic species in each project lake. It is interesting to note that although these lakes are interconnected, and very close in proximity to each other, each project lake contains some similar species yet has its own unique aquatic plant community as well. Along with water quality differences, factors such as shoreline condition, substrate type, and lake morphology can determine the amount and type of habitat for aquatic plant species. As described in the Aquatic Plant Section, there is a great diversity of these habitat conditions so it is not surprising that a species rich aquatic plant community exists. Altogether, a total of 88 different plant species were identified from Long Lake as well as the nine Phase I and Phase II lakes associated with this project. The plant communities showed some variance between lakes in terms of their diversity index value and coefficient of conservatism as well. These values are typically used to assess the level of human disturbance.

Another indication of human disturbance is the presence of non-native species. Currently, aquatic invasive species, primarily Eurasian water milfoil, is the largest ecological threat facing the integrity of the Three Lakes Chain of Lakes. An aggressive, ongoing battle has been fought on the Long Lake Burnt Rollways channel targeting this invasive plant. While the plant has largely been kept under control, resurgence has been documented each year since the plant was first discovered (2006). In Virgin Lake, a lake in which native milfoils grow quite prolifically, the Eurasian water milfoil colony that was first discovered in 2010 has become largely unmanageable by passive (hand-harvesting) techniques and in 2012 required an herbicide treatment to reduce fragmentation and spreading of this plant. Moving into the future, these infestations must be monitored diligently to ensure that management efforts are successful in containing the spread to other locations. Additionally, as outlined within the Implementation Plan, continued efforts must be conducted to monitor these lakes for new infestations, as an early infestation is always easier to manage than a previously undetected, advanced-stage infestation.

The Three Lakes Chain of Lakes is a unique resource that many individuals with many different interests utilize. It provides for an outstanding recreational facility that anglers, boaters, swimmers, connoisseurs of nature and others can enjoy. Billed as part of "the largest freshwater chain of lakes in the world", it is a large and complex ecosystem that inspires one with its picturesque beauty and serene, "up north" feeling. With the knowledge that has been gained through this series of studies, the TLWA and their lake management partner, the Town of Three Lakes, now have a strategic plan in place to maximize the positive attributes of each lake, address the negative attributes, and effectively and efficiently manage the entire ecosystem as a whole. The Chain Wide Implementation Plan that follows is a result of the hard work of many Three Lakes Chain of Lakes stakeholders, and can be applied to each and every lake within the chain. Lakes with added attention or specific issues that were brought forth during this study will have their own Lake Specific Implementation Plan which is located at the end of each individual lake section.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the TLWA and ecologist/planners from Onterra. It represents the path the TLWA 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 Three Lakes Chain of Lakes 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 continuous review and adjustment depending on the condition of the chain lakes, the availability of funds, level of volunteer involvement, and the needs of the stakeholders. While the TLWA is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee of the TLWA (e.g. Education & Communication Committee, Water Quality Committee, and Invasive Species Committee). The TLWA will be responsible for deciding whether the formation of sub-committees is needed to achieve the various management goals.

Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

Timeframe: In progress.

Facilitator: Board of Directors.

Grant: Lake Management Protection Grant in Diagnostic/Feasibility Studies category.

Description: The Three Lakes Waterfront Association and Town of Three Lakes have been diligent about protecting the Three Lakes Chain of Lakes and preserving it as a recreational yet natural resource. They realize that the best way to protect the waterbodies in the chain is to fully understand their current level of health so that proper planning and management may occur.

The Three Lakes Waterfront Association, with assistance from their partner the Town of Three Lakes, will continue to develop comprehensive management plans for each lake in the chain. This phased project will continue within the timeframe projected in Map 1. These studies may be completed with the assistance of state funds through the WDNR's Lake Management Protection Grant program.

Action Steps:

1. Apply for WDNR grants annually to continue state financial assistance in management planning projects.
2. Retain qualified consultant to conduct science-based studies and facilitate management planning.

Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Timeframe: In progress.

Facilitator: Board of Directors along with TLWA Clean Boats/Clean Waters coordinators.

Description: With over 6,100 acres of water, 14 public boat landings (eight more on the Lower Eagle River Chain) one tracked boat-lift system, numerous resorts and several fishing tournaments, the Three Lakes Chain of Lakes provide recreational opportunity for many people. With so many public access opportunities, the threat of the introduction of non-native species is greatly heightened. As outlined in the Table 2.0-1, most of the lakes within the chain hold at least one or two invasive species, such as rusty crayfish, Chinese mystery snail or banded mystery snail. Currently, two waterbodies, the Eagle River below Long Lake and Virgin Lake, are known to hold small populations of Eurasian water milfoil.

The Clean Boats/Clean Waters (CBCW) program of the TLWA supplies both paid and volunteer boat inspectors at 10 public landings on the chain, including focused monitoring at the Burnt Rollways boat lift to assure removal of vegetation from boats coming over the dam from the Lower Eagle River Chain to the Three Lakes Chain of Lakes. The TLWA's efforts include inspecting nearly 10,000 boats and contacting over 26,000 people in over 8,000 hours of work during a timespan from 2005 – 2012 (WDNR CBCW website, data accessed October 2012). This is a tremendous effort to coordinate, staff, and carry out but the Town of Three Lakes, TLWA and its dedicated members have proven that monitoring efforts of this scale can be completed efficiently and effectively.

The CBCW boat inspections at these public access points have undoubtedly played a great role in reducing the introduction of invasive species to the Three Lakes Chain of Lakes. Furthermore, opportunities of species from the Three Lakes Chain elsewhere have certainly been diminished. CBCW inspectors cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of its spread.

Action Steps:

1. Members of the TLWA periodically attend CBCW training session through CBCW coordinator to update their skills to current standards.
2. Begin inspections during high-risk weekends

3. Report results to WDNR and TLWA
4. Report results to the WDNR and TLWA
5. Promote enlistment and training of Three Lakes Chain volunteers to broaden volunteer base and ensure program survival.

<u>Management Action:</u> Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Timeframe: In progress.

Facilitator: TLWA in coordination with Lake Captains and lake residents.

Description: In lakes with Eurasian water milfoil or other invasive species, early detection of pioneer colonies commonly leads to successful control. While efforts to control Eurasian water milfoil within Virgin Lake and the Eagle River channel of Long Lake have been successful, eradication of this hearty and resilient invasive plant is very difficult. Therefore, it is crucial for locations of new plants to be promptly identified before they reproduce.

The TLWA has initiated a strategy in which lake residents are coordinated to search the lakeshore area for invasive plant species. These efforts take place on many lakes within the Three Lakes Chain of Lakes. In fact, TLWA volunteers have logged over 1,700 hours in this program since 2005. A Lake Captain (a member of the planning committee) is responsible for recruiting riparian property owners to participate in these shoreline patrols. Although most shorelines have been patrolled on an annual basis over the last several years, more volunteers are needed to assure future coverage. Volunteers also intensively cover the area near the Burnt Rollways Dam in the Long Lake channel, as this is a point of special interest due to Eurasian water milfoil being located here.

Action Steps:

1. Volunteers from TLWA update their skills by attending a training session conducted by WDNR/UW-Extension through the AIS Coordinator for Oneida County (Michele Sadauskas – 715.365.2750).
2. Trained volunteers recruit and train additional association members.
3. Complete lake surveys following protocols.
4. Report results to WDNR and TLWA.

Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety, and quality of life on the Three Lakes Chain of Lakes.

Timeframe: Begin Summer 2013.

Facilitator: Board of Directors to form Education Committee.

Description: Education represents an effective tool to address issues that impact water quality such as lake shore development, lawn fertilization, and other issues such as air quality, noise pollution, and boating safety. An Education Committee will be created to promote lake protection through a variety of educational efforts.

The TLWA regularly distributes newsletters to association members and has launched a website (http://www.threelakeswaterfrontassociation.com) which allows for exceptional communication within the lake group. This level of communication is important within a management group because it builds a sense of community while facilitating the spread of important association news, educational topics, and social happenings. It also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well-written newsletter can be used as a tool to increase awareness of many aspects of lake ecology and management among association members. By doing this, meetings can be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the association newsletter may contain monitoring results, association management history, as well as other educational topics listed below.

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

Example Educational Topics:

- Specific topics brought forth in other management actions
- Aquatic invasive species identification & monitoring
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreland restoration and protection
- Septic system maintenance
- Fishing Regulations

Action Steps:

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR Small-scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. The TLWA Board will identify a base level of annual financial support for educational activities to be undertaken by the Education Committee.

Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Timeframe: Continuation of current effort.

Facilitator: Board of Directors to appoint TLWA representatives.

Description: As stated on the association website, the purpose of the TLWA is *to preserve and protect our waterways and shorelines…today and for generations to come*. The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while other organizations are similar to the TLWA in that they rely on voluntary participation.

It is important that the TLWA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. The primary management units regarding the Three Lakes Chain of Lakes include governmental units such as the WDNR, or Town of Three Lakes, but also include entities similar to the TLWA such as the Unified Lower Eagle River Chain of Lakes Commission. Each entity is specifically addressed on the next page.

Action Steps:

1. See table guidelines on the next page.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Wisconsin Department of Natural Resources	Fisheries Biologist (John Kubisiak – 715.365.8919)	Manages the fishery of the Three Lakes Chain.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.5211)	Oversees management plans, grants, all lake activities.	Once a year, or more as necessary.	Information on updating a lake management plans, submitting grants or to seek advice on other lake issues.
	Warden (Patrick Novesky – 715.365.8948) WDNR Tip Line (1.800.847.9367)	Oversees regulations handed down by the state.	As needed.	Suspected violations pertaining to recreational activity on Three Lakes Chain of Lakes, including fishing, boating safety, ordinance violations, etc.
	Program Director (Sandra Wickman – 715.365.8951)	Training and assistance on CLMN monitoring, and data entry.	Twice a year or more as needed.	Winter: contact to arrange for training as needed, in addition to planning out monitoring for the open water season. Fall: report monitoring activities.
Oneida County	Oneida County AIS Coordinator (Michele Saduaskas – 715.365.2750)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: Report activities to Ms. Saduaskas.
Town of Three Lakes	Town Chair (Don Sidlowski - 715.546.331)	Supports TLWA endeavors, assists in management of lakes.	As needed. Visit website (http://www.townofthreelakes.com/home) often.	Contact regarding grant applications, projects such as CBCW, town events, etc.
Three Lakes Chamber of Commerce	Executive Chamber Director (Skip Brunswick - (715.546.3344)	Coordinates recreational and town-wide events, partner in managing lakes	As needed.	AIS project results may be shared, or displayed at public events, etc. Informative packets available at chamber of commerce.
Oneida County Lakes & Rivers Association	Secretary (Connie Anderson – 715.282.5798)	Protects Oneida Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oneida Co. waterways.
UW-Extension	Program Coordinator Erin McFarlane (715.346.4978)	Clean Boats Clean Waters Program	As needed.	May be contacted to set up CBCW training sessions, report data, etc.
Unified Lower Eagle River Chain of Lakes Commission	Commission Chair (Jim Spring – 715.891.1095)	Oversees AIS management of the Lower Eagle River Chain of Lakes	Once a year or as needed. May visit website (http://eagleriverchaincommission.org/index.htm) as needed.	May contact to coordinate Burnt Rollways Dam monitoring. A TLWA representative should attend annual meeting to keep communication flow between organizations.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	TLWA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

***Management Goal 5*: Maintain Current Water Quality Conditions**

<u>Management Action:</u> Monitor water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation and expansion of current effort.

Facilitator: Planning Committee.

Description: Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to discovering the reason as to why the trend is developing.

The Citizens Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers trained as a part of the CLMN program begin by collecting Secchi disk transparency data for at least one year, then if the WDNR has availability in the program, the volunteer may enter into the *advanced program* and collect water chemistry data including chlorophyll-a, and total phosphorus. The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. Note: as a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

Currently, some of the lakes within the Three Lakes Chain have active volunteers collecting data each year – either within the confines of the initial or advanced program. Ideally, all lakes within the chain would have advanced monitoring occurring each year; however, it is a more realistic goal to push for all lakes monitoring Secchi disk transparency for now. It is important to get volunteers on board with the base Secchi disk data CLMN program so that when additional spots open in the advanced monitoring program, volunteers from interested lakes will be ready to make the transition into more advanced monitoring.

It is the responsibility of the Planning Committee to coordinate new volunteers. When a change in the collection volunteer occurs, it will be the responsibility of the Planning Committee to contact Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. See description above.

<u>Management Action:</u> Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Timeframe: Continuation of current effort.

Facilitator: Board of Directors to appoint Shoreland Representative(s).

Description: As the watershed section discusses, the Three Lakes Chain of Lakes 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 faulty septic systems, shoreland areas that are maintained in an unnatural manner, and impervious surfaces.

On April 14th, 2009, Governor Doyle signed the "Clean Lakes" bill (enacted as 2009 Wisconsin Act 9) which prohibits the use of lawn fertilizers containing phosphorus. Phosphorus containing fertilizers were identified as a major contributor to decreasing water quality conditions in lakes, fueling plant growth. This law went into effect in April 2010. While this law also bans the display and sale of phosphorus containing fertilizers, educating lake stakeholders about the regulations and their purpose is important to ensure compliance.

To reduce these negative impacts, the TLWA 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. The Association website is (and has been) a good venue for broadcasting awareness. A good initial educational topic may be a discussion of the Oneida County Private Onsite Wastewater Treatment System Ordinance, which requires septic tanks to be enrolled in the County's Maintenance Program no later than October 1st of 2013. Phase II of this initiative requires visual inspections, and, if necessary, pumping of septic tanks every 3 years.

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

Action Steps:

1. Recruit a member of the Board of Directors or other interested person to be an advocate and facilitator for shoreline conservation and education.
2. Facilitator gathers appropriate information from WDNR, UW-Extension, Oneida County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for association meetings (development of conservation and restoration education model).
4. Facilitator takes results of Shoreland Assessment and identifies feasible areas for conservation. May visit with new home owners to discuss conservation efforts or restoration possibilities.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Timeframe: Begin 2013.

Facilitator: Board of Directors to appoint Shoreland Representative(s).

Description: Currently, roughly half of the Phase I and II project lakes' shorelines are considered to be in a natural/undeveloped or developed-natural state. 19% of shoreline may be classified as urbanized or developed-unnatural, while the remaining 32% of the shoreline is categorized as developed-semi-natural. A priority for the TLWA should be to ensure that the amount of natural and undeveloped land be kept as natural as possible. As the Three Lakes Chain of Lakes is a popular destination for tourists and for individuals seeking that quaint "place on a lake up north", this is no easy task. However, if resources and interest exist, would be worthwhile for the TLWA to investigate restoration of some of the developed areas of the chain. In particular, Big Stone, Whitefish, Virgin, Deer and Dog Lakes had the highest percentage of developed shoreline (Figure 3.3-3).

The Shoreland Condition map for each lake indicates the locations of disturbed shorelands. These areas should be considered a priority should restoration efforts be enacted. An appointed representative(s) from the TLWA will work with the education initiative volunteer (this may also be the same person) to research grant programs, shoreland restoration techniques, and other pertinent information that will aid the TLWA in making enhancements to applicable shoreline areas. Several valuable resources for this type of conservation work include the WDNR, UW-Extension, etc. Several resources include:

- Wisconsin Lakes website: *(www.wisconsinlakes.org/shorelands)*
- Langlade County Land Records and Regulations Department – Shoreland Restoration: *(http://lrrd.co.langlade.wi.us/shoreland/index.asp)*
- UW-Extention Shoreland Restoration: *http://www.uwex.edu/ces/shoreland/Why1/whyres.htm)*
- WDNR Shoreland Zoning website: *(http://dnr.wi.gov/topic/ShorelandZoning/)*

Action Steps:

1. Recruit facilitator.
2. Facilitator gathers appropriate information from sources described above. This includes biological research as well as grant/funding opportunities.
3. Facilitator assists residents that are interested in shoreland restoration with process of contacting shoreland restoration specialists (public or private) and carrying out restoration plan.
4. Retain potential of having completed projects serve as a "model" for other residents who may be interested in restoration work.

Management Action: Investigate sources of phosphorus Big, Crystal (Mud), Rangeline and Townline Lakes.

Timeframe: Begin 2013.

Facilitator: Planning Committee.

Description: During the first Planning Meeting associated with this project, Onterra staff presented water quality results to the planning committee, including higher than expected phosphorus value results which had been obtained from sampling efforts conducted on Crystal (Mud) Lake. Discussions were then held about potential phosphorus sources within the Three Lakes Chain of Lakes watershed. The current level of baseline monitoring that has been conducted on Crystal (Mud) Lake, as well as within other Three Lakes Chain lakes, cannot pinpoint the exact cause of the elevated phosphorus. It is believed by lake stakeholders that elevated nutrients may be present within Big Lake and Townline Lake also, potentially stemming from upstream watershed practices. Though elevated nutrient levels were not captured on Big Lake during these studies, stakeholders presented Onterra staff with photographic evidence of large blue-green algal blooms which had occurred on the lake in the past.

The studies conducted on the Three Lakes Chain thus far are designed to give managers an indication of ecosystem health, and to provide a clue of potential issues that may be occurring. This was achieved during monitoring of Crystal (Mud) Lake. In order to gain an understanding of the source of nutrients to Crystal (Mud) Lake, further studies must be conducted which would consist of higher interval sampling of the lake and tributary stream. These studies are recommended for Big Lake, Rangeline and Townline Lake as well, and will help to determine the source of nutrient contribution to these lakes. Within further grants that will be written as a part of the Three Lakes Chain Management Planning Project, time will be included for Onterra staff to research watershed activities and determine quantitative impacts, if any, to these receiving lakes.

Action Steps:

1. See above description.

Management Goal 6: **Improve Fishery Resource and Fishing**

<u>Management Action:</u> Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Timeframe: Ongoing.

Facilitator: Board of Directors.

Description: With over 6,900 acres of water, many residences and visitors and several fishing tournaments, it is safe to say the Three Lakes Chain of Lakes draws much attention from anglers both local and non-local. The ecosystem of the chain is in great shape currently, which is beneficial for producing a quality fishery for anglers to enjoy. However, with the amount of visitors the Three Lakes Chain of Lakes receives it remains important to continuously monitor the fish populations on the chain to ensure that exploitation is not occurring.

During discussions with the planning committees and others involved with the TLWA, it became clear that those who were anglers had concerns over walleye populations in the Three Lakes Chain of Lakes. WDNR biologists proposed a rule change, effective 2011 for the entire Three Lakes Chain of Lakes, which would initiate a no minimum length limit on walleye with a five fish daily bag limit, however only one fish longer than 14" could be kept. This adjustment would allow the fishery, which experiences high recruitment but slow growth, to produce a higher fishable and spawning stock.

Though walleye are at the forefront of anglers concerns, Three Lakes Chain stakeholders must keep in mind that other species as well as other components of the fishery impact walleye population dynamics; therefore, a holistic approach must be considered when looking at the chain's fishery. In other words, education of issues and enhancement of all fish populations must be enacted in order to sustain a quality walleye fishery. In order to keep informed of survey studies and stocking of the Three Lakes Chain of Lakes, a TLWA representative should be selected to contact WDNR fisheries biologist John Kubisiak (715.365.8919) at least once a year for an update, which can be published on the association's website and in periodic newsletter. During this conversation, the TLWA representative may discuss options for improving the fishery, such as collaborating with WDNR staff on habitat enhancement projects.

Action Steps:

1. See above description.

6.0 METHODS

Lake Water Quality

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

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

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on the Three Lakes Chain of Lakes during mid to late June in order to correspond with the anticipated peak growth of the plant. Please refer to each individual lake section for the exact date in which each survey was conducted. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on the system to characterize the existing communities within each lake and included inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete the studies. Based upon advice from the WDNR, the following point spacing and resulting number of points comprised the surveys:

Phase & Field Work Year	Lake	Point-intercept Resolution (meters)	Number of Points	Survey Dates
Phase I - 2010	Virgin Lake	54	361	Aug. 5 & 9, 2010
	Whitefish Lake	42	449	August 10, 2010
	The Thoroughfare	40	439	Aug. 8 & 9, 2010
	Big Lake	68	738	Aug. 5 & 9, 2010
Phase II - 2011	Laurel Lake	48	436	August 10, 2011
	Big Stone Lake	50	981	August 10, 2011
	Dog Lake	45	404	August 9, 2011
	Deer Lake	40	477	August 4 & 9, 2011
	Crystal (Mud) Lake	38	324	August 4 & 5, 2011

Community Mapping

During the species inventory work, the aquatic vegetation community types within each 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 each of the lakes.

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Note: Methodology, explanation of analysis and biological background on Virgin Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.1 Virgin Lake

An Introduction to Virgin Lake

Virgin Lake, Oneida County, is a drainage lake with a maximum depth of 31 feet and a surface area of 276 acres. This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Virgin Lake contains 48 native plant species, of which flat-stem pondweed was the most common plant. One exotic plant, Eurasian water milfoil, was observed in 2010.

Field Survey Notes

Many species observed during aquatic plant surveys. Several bryozoans (aquatic invertebrates consisting of colonies of microscopic organisms called "zooids" – pictured to the right), *some relatively large in size, spotted as well.*

Small colony of Eurasian water milfoil discovered during point-intercept survey, roughly 20 ft. in diameter. Area marked with GPS.

Photo 8.1 Bryozoan from Virgin Lake, Oneida County

Lake at a Glance* – Virgin Lake

Morphology	
Acreage	276
Maximum Depth (ft)	31
Mean Depth (ft)	13
Volume (acre-feet)	3,638
Shoreline Complexity	2.0
Vegetation	
Curly-leaf Survey Date	June 17, 2010
Comprehensive Survey Date	August 4 & 5, 2010
Number of Native Species	48
Threatened/Special Concern Species	*Potamogeton vaseyi* (Vasey's pondweed)
Exotic Plant Species	Eurasian water milfoil
Simpson's Diversity	0.94
Average Conservatism	7.1
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	65:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.1.1 Virgin Lake Water Quality

Water quality data was collected from Virgin Lake on six occasions in 2010/2011. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity for almost two decades (1994-2011). These efforts provide a considerable amount of historical data, which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Virgin Lake.

Unfortunately, very limited data exists for the other two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2010, average summer phosphorus concentrations (14.3 µg/L) were less than the median value (23.0 µg/L) for other deep, lowland drainage lakes in the state. Similarly, summer average chlorophyll-*a* concentrations (4.4 µg/L) were slightly less than the median value (7.0 µg/L) for other lakes of this type. Both of these values rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2010 visits to the lake, Onterra ecologists recorded field notes describing good water conditions, though slightly stained water. As explained below, the stained water is not due to nutrients or another form of pollution.

From the examination of two decades worth of Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Virgin Lake's water can be described as *Excellent* in most years (Figure 8.1.1-1). A weighted average over this timeframe is above the median value for other deep, headwater lowland lakes in the state. Secondly, with exception to 2011, there is very little variation seen in this data set. In 2011, Onterra ecologists noted exceptionally stained water during visits to monitor a small Eurasian water milfoil infestation (see the Aquatic Plant Section for more details on this). Similar stained water was observed on the other lakes in the Three Lakes Chain of lakes, as well as other lakes within the Northwoods of Wisconsin.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Virgin Lake as well as the other lakes in the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Virgin Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

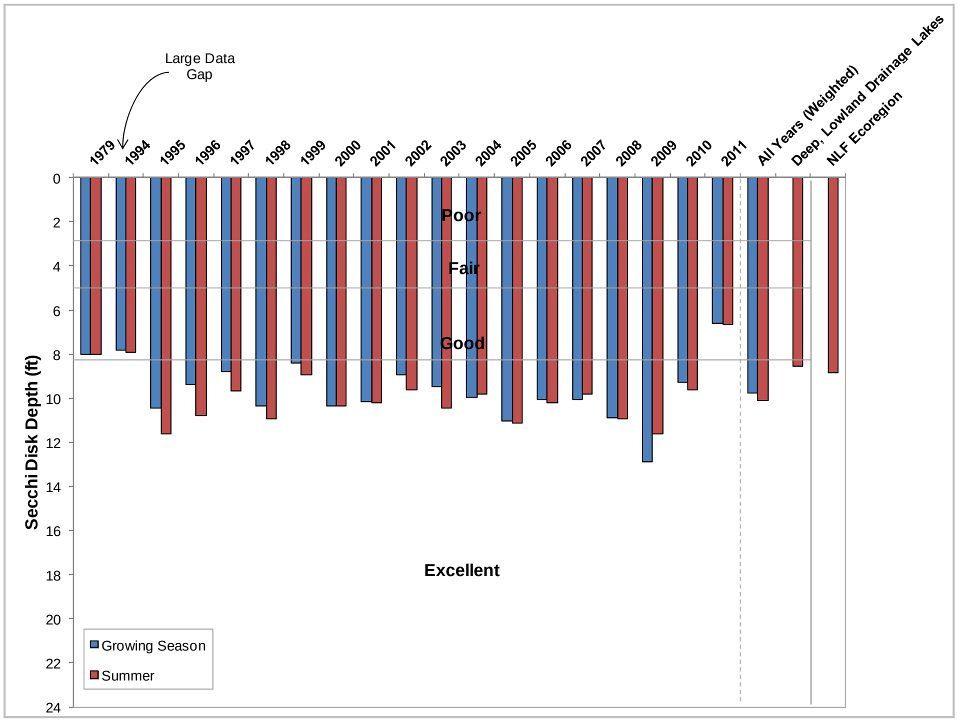

Figure 8.1.1-1. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Virgin Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.1.1-2). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Virgin Lake is in a mesotrophic state.

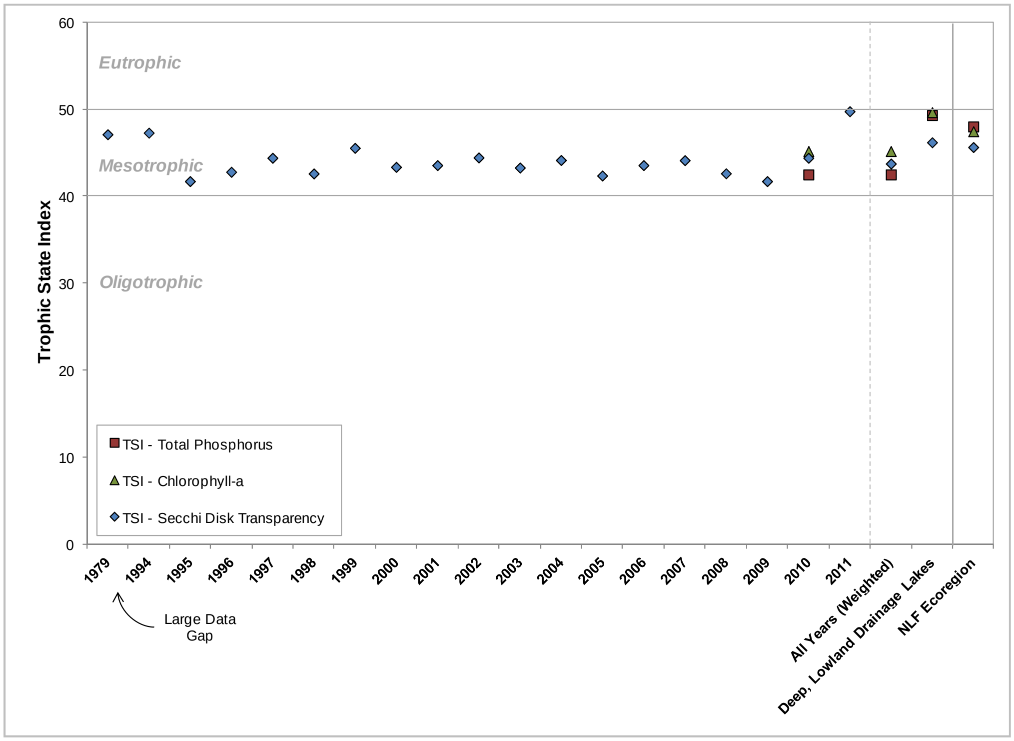

Figure 8.1.1-2. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Virgin Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Virgin Lake by Onterra staff. Graphs of those data are displayed in Figure 8.1.1-3 for all sampling events.

Virgin Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in fairly deep Wisconsin lakes, where wind energy is not sufficient during the summer to mix the entire water column – only the upper portion. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2011, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

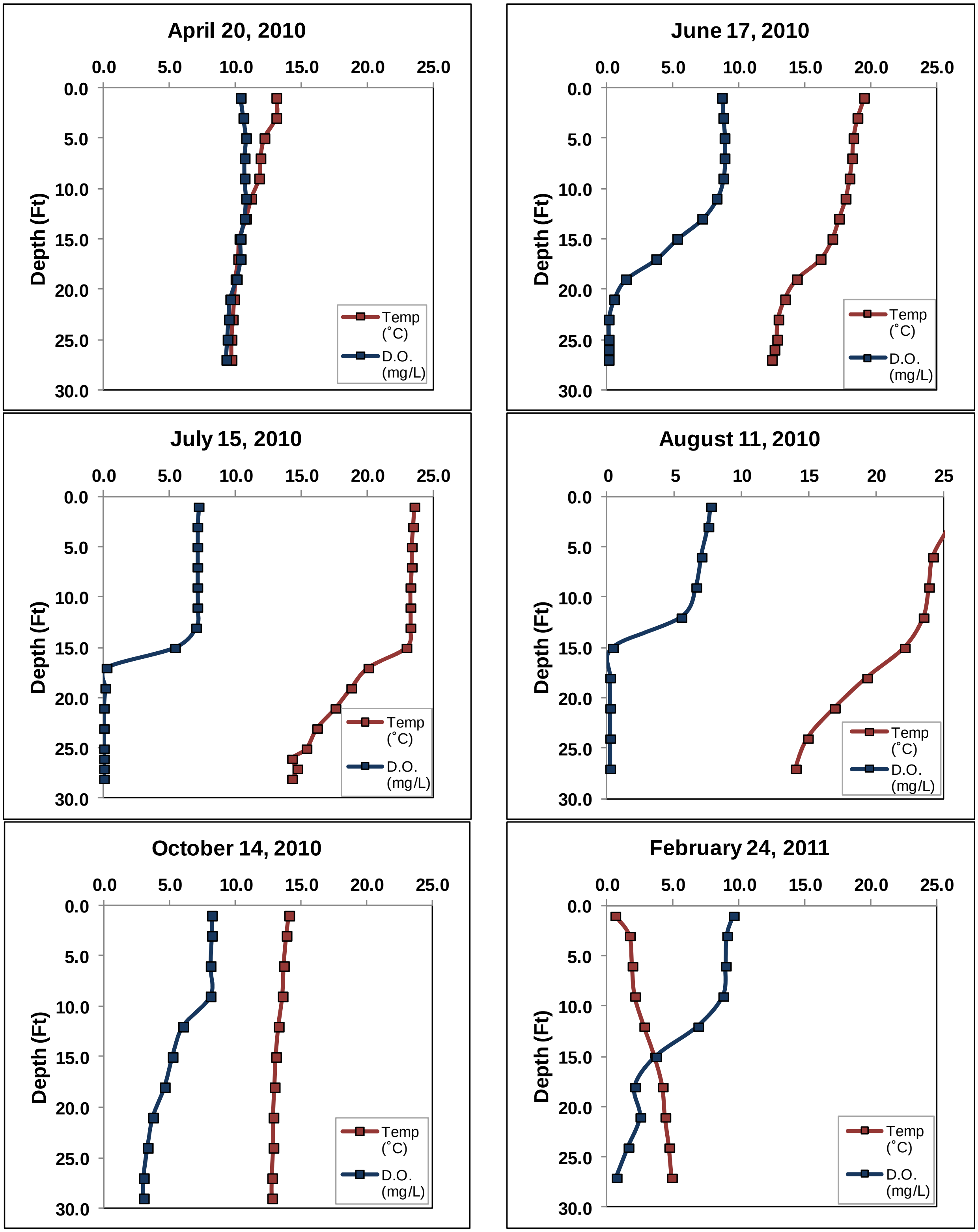

Figure 8.1.1-3. Virgin Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Virgin Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Virgin Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Virgin Lake's surface water pH was measured at roughly 7.8 during summer 2010. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Virgin Lake was measured at 48.2 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Virgin Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Virgin Lake's pH of 7.8 - 7.9 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Virgin Lake was found to be 12.0 mg/L, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (zebra mussels in the larval form) were found within these samples.

8.1.2 Virgin Lake Watershed Assessment

Virgin Lake's watershed is 18,268 acres in size. Compared to Virgin Lake's size of 205 acres, this makes for an incredibly large watershed to lake area ratio of 65:1.

Exact land cover calculation and modeling of nutrient input to Virgin Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.1.3 Virgin Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, Virgin Lake's immediate shoreline was assessed in terms of its development. Virgin Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.9 miles (25% of the total shoreline) of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.6 miles of urbanized and developed–unnatural shoreline (20% of the total shoreline) was observed. If restoration of the Virgin Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Virgin Lake Map 1 displays the location of these shoreline lengths around the entire lake.

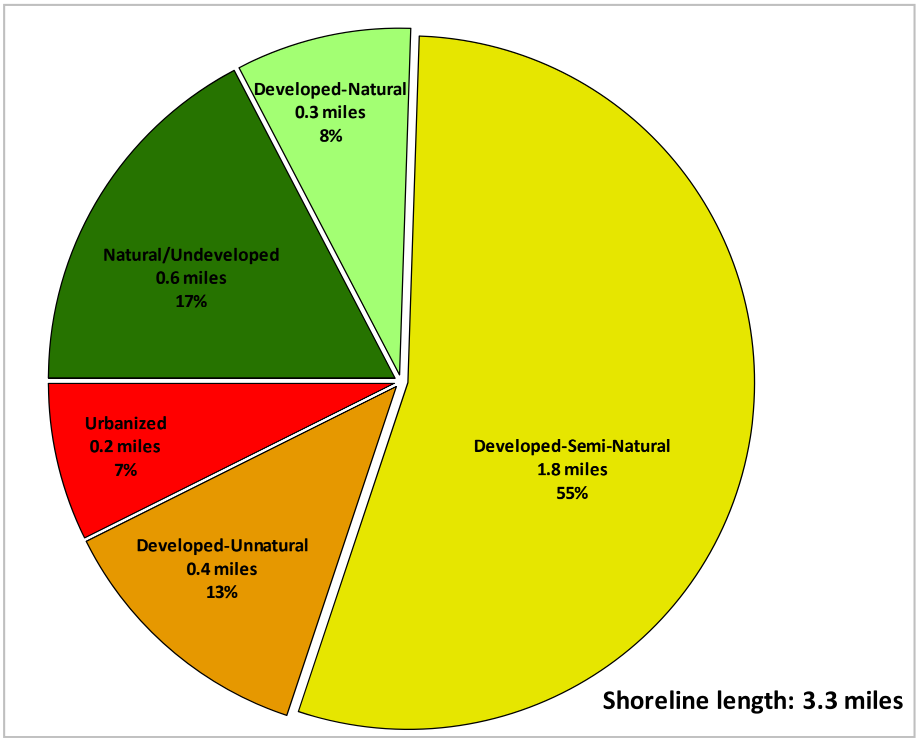

Figure 8.1.3-1. Virgin Lake shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Virgin Lake Map 1.

8.1.4 Virgin Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Virgin Lake on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Virgin Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Virgin Lake on August 4 & 5, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Virgin Lake Map 2) during this time. During all surveys, 48 species of native aquatic plants were located in Virgin Lake (Table 8.1.4-1). 33 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 15 feet, which is deep relative to the other lakes within the Three Lakes Chain of lakes, where plants may be found growing to only six feet of water. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. One aquatic plant that was found during the 2010 surveys, Vasey's pondweed (*Potamogeton vaseyi*) is listed by the Natural Heritage Inventory (NHI) Program as a species of special concern in Wisconsin.

Of the 181 point-intercept locations sampled within the littoral zone, approximately 62% contained aquatic vegetation. Approximately 51% of the point-intercept sampling locations where sediment data was collected at were sand, 34% consisted of a fine, organic substrate (muck) and 15% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.1.4-1. Aquatic plant species located in the Virgin Lake during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2010 (Onterra)
Emergent	*Carex lacustris*	Lake sedge	6	I
	Carex lasiocarpa	Wooly-fruit sedge	9	I
	Carex utriculata	Northwest Territory sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus subterminalis	Water bulrush	9	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Zizania palustris	Northern wild rice	8	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
	Polygonum punctatum	Dotted smartweed	5	I
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	I
Submergent	*Chara spp.*	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Eriocaulon aquaticum	Pipewort	9	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes echinospora	Spiny-spored quilwort	8	I
	Isoetes lacustris	Lake quillwort	8	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	I
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Nitella sp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	I
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Ranunculus flammula	Creeping spearwort	9	X
	Ranunculus aquatilis	White water-crowfoot	8	X
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	X
	Sagittaria cuneata	Arum-leaved arrowhead	7	I

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

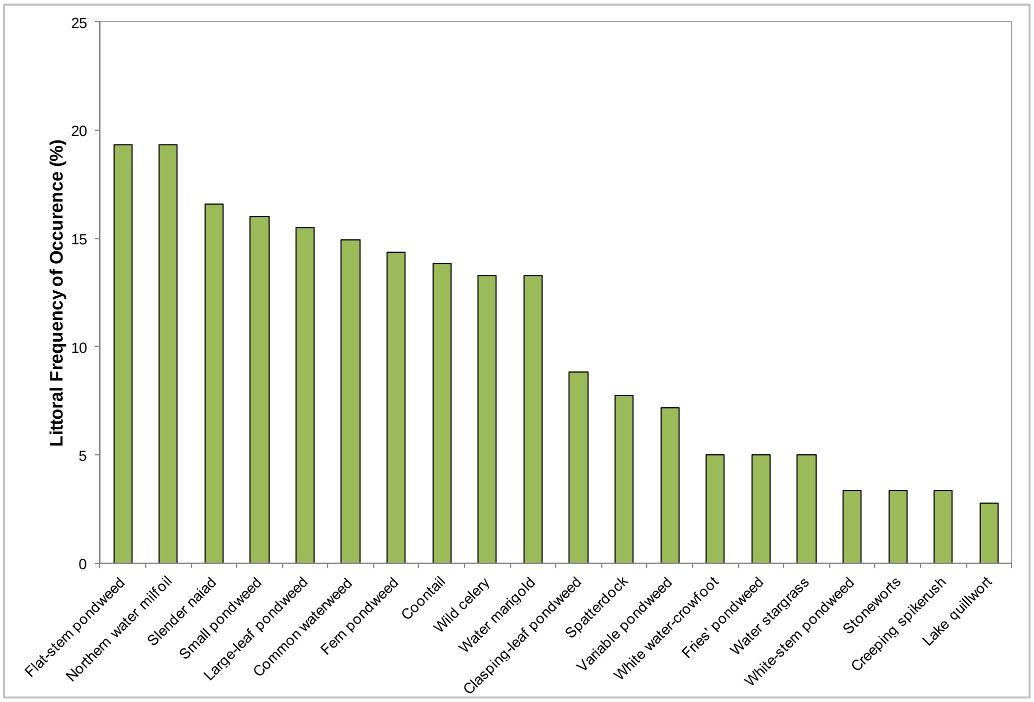

Figure 8.1.4-1 Virgin Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 2.5% only. Created using data from a 2010 point-intercept survey.

Figure 8.1.4-1 (above) shows that flat-stem pondweed, northern water milfoil, and slender naiad were the most frequently encountered plants within Virgin Lake. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, two (northern water milfoil and Eurasian water milfoil) were located from Virgin Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic. Eurasian water milfoil, an exotic relative of northern water milfoil, was found within Virgin Lake as well. Because of its significance, details of Eurasian water milfoil's presence in Virgin Lake will be discussed towards the end of this section and within the Implementation Plan.

An incredible 48 species of native aquatic plants (including incidentals) were found in Virgin Lake, along with one non-native plant. 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 influence the diversity. The diversity index for Virgin Lake's plant community (0.94) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while northern water milfoil was found at 19% of the sampling locations, its relative frequency of occurrence is 9%. Explained another way, if 100 plants were randomly sampled from Virgin Lake, 9 of them would be northern water milfoil. This distribution can be observed in Figure 8.1.4-2, where together 10 species account for 71% of the population of plants within Virgin Lake, while the other 23 species account for the remaining 29%. Fifteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.1.4-1 as incidentals.

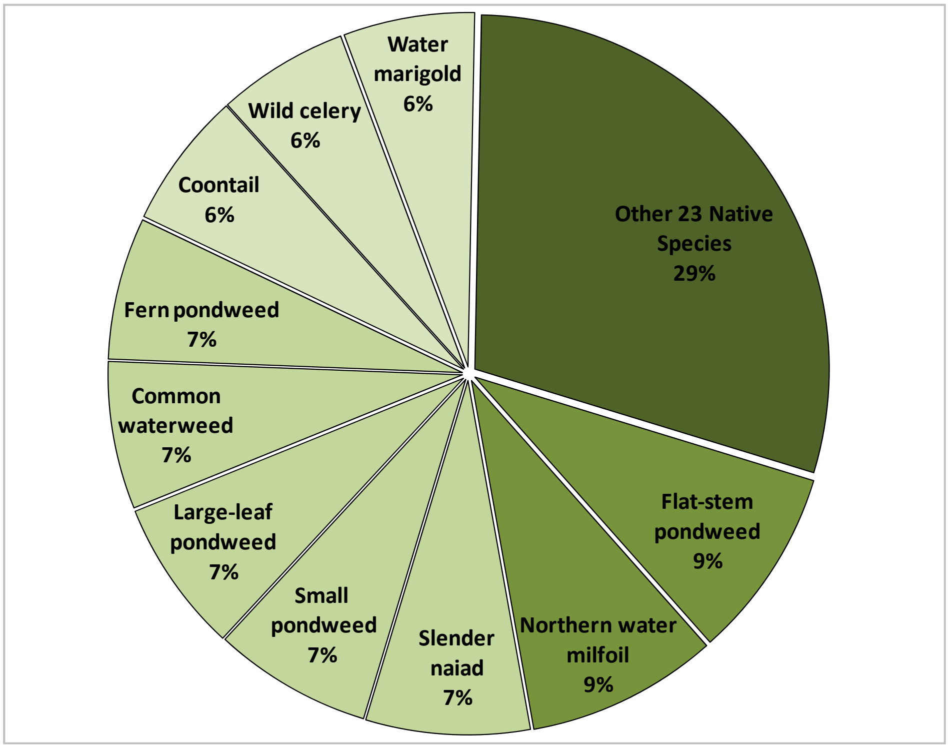

Figure 8.1.4-2 Virgin Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

Virgin Lake's average conservatism value (7.1) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Virgin Lake is indicative of an undisturbed system. This is not surprising considering Virgin Lake's plant community has great diversity and high species richness. Combining Virgin Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 40.8 which is well above the median values of the ecoregion and state.

The quality of Virgin Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.6 acres of the lake contains these types of plant communities (Virgin Lake

Map 2, Table 8.1.4-2). Fifteen floating-leaf and emergent species were located on Virgin Lake (Table 8.1.4-1), all of which provide valuable wildlife habitat.

Table 8.1.4-2. Virgin Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	1.6
Floating-leaf	8.4
Mixed Floating-leaf and Emergent	5.6
Total	15.6

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Virgin Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to 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.

Aquatic Invasive Species in Virgin Lake

Virgin Lake is currently monitoring a small Eurasian water milfoil population (Virgin Lake Map 3). During the point-intercept survey in August of 2010, Onterra staff located a small plant colony just south-west of the Virgin Lake island. The colony measured approximately 15-feet in diameter, and was located within a depth of about 8 to 9 feet. Although the colony was too large to remove from a boat using a rake, several plants located outside of the main colony were removed. Onterra staff marked the colony with GPS coordinates as well as temporary buoys, and the proper communications ensued with TWLA planning committee members and WDNR personnel. Shortly after that time, TWLA volunteers placed more permanent buoys around the colony to alert boaters to its presence, in hopes of reducing fragmentation of the plants.

On July 8, 2011, Onterra staff visited Virgin Lake to hand harvest Eurasian water milfoil plants located within the colony. Because of the relatively shallow depth, snorkeling gear was utilized. Two staff members repeatedly swam to the lake bottom and removed Eurasian water milfoil by the roots of the plant. Plants were carefully placed into mesh bags following extraction from the sediment. A third staff member remained in the boat, unloading the mesh bags periodically from the snorkelers and grabbing plant fragments from the water with a pool skimmer on an extendable pole. Weather conditions were good, however visibility into the water column and under the water was impaired by the naturally stained water of the lake. One laundry basket (approximately 50-70 plants) was filled following the removal efforts, which lasted a little over an hour, and no plants were observed on post-removal inspection of the area.

Photo 8.1.4-1 a) Virgin Lake Eurasian water milfoil hand harvesting, and **b) Hand harvesting results.** Hand harvesting occurred in July and September of 2011.

Following reports from TLWA members that more Eurasian water milfoil existed within the previously marked colony, Onterra staff members revisited the lake on September 8th to conduct plant removal again. This time, three staff slipped on donned snorkeling gear while a fourth staff member emptied mesh bags and scooped plant fragments from the surface with a pool skimmer on an extendable pole. About 35 plants were pulled during this time, though stained water was again an issue the snorkelers faced and some single plants were likely left behind.

On July 3, 2012, Onterra staff once again visited Virgin Lake to hand remove Eurasian water milfoil plants. Donning SCUBA gear this time, three staff members entered the water hoping to spend more time near the substrate and get a better grasp on the extent of milfoil growth. A fourth staff member stayed aboard a nearby boat, coordinating the three SCUBA divers, emptying mesh harvesting bags and planning to catch stray fragments with a pool skimmer. Soon after the divers entered the water, they observed that the colony had expanded only slightly in size, but increased very much in density. In addition to many "tall" plants, a good number of plants were very short in stature and not visible from the surface. The biomass was too much to hand remove, so their attention turned towards determining the outer extents of the colony and identifying outlier plants by swimming transect lines from the center of the population.

Following this survey, discussions were held between Onterra staff, TLWA board members and WDNR staff. It was decided that an aggressive approach – a mid-summer 2,4-D herbicide application, was necessary in order to bring the rapidly expanding colony under control and reduce plant auto fragmentation. A treatment of 0.9 acres at 4.0 ppm 2,4-D herbicide, which is the maximum label rate, was conducted in mid-July of 2012.

The infestation of Eurasian water milfoil in Virgin Lake is still in its infancy, and has been aggressively attacked and monitored since its discovery. At this point in time, continued monitoring of the entire lake is necessary to identify expansion of the known colony and also identify any additional areas where Eurasian water milfoil may be located. Onterra staff will continue to visit the known Eurasian water milfoil colony and determine the appropriate course of action, be it herbicide application or hand-removal methods. .

8.1.5 Virgin Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Virgin Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Virgin Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Virgin Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Virgin Lake's implementation plan is compiled by describing how Virgin Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Virgin Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Virgin Lake does not contain a public access and because of this, the threat of introduction of aquatic invasive species is reduced from transient boaters. However, in lakes without a single public access, often lake residents (and friends and family) access the lake on their individual properties. This essentially creates the potential to have numerous points on a lake where different boats with different owners may be entering occasionally.

Virgin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Virgin Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Virgin Lake or from Virgin Lake elsewhere. If a Virgin Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

<u>Management Action:</u> Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Virgin Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Because of the current population of Eurasian water milfoil on the lake, professional surveys are encouraged (see next management action), however having more "eyes on the water" increases the odds of spotting early pioneer colonies of Eurasian water milfoil should they develop.

<u>Management Action:</u> Continue aggressive control strategy for early-stage Eurasian water milfoil population

Description: As a part of Phase I of this project (2010), a small colony of Eurasian water milfoil was discovered within Virgin Lake. Because of its size, it is believed this is a very recent introduction. As outlined within the Aquatic Plant Section, the small colony was first addressed with hand-removal efforts, with several visits by Onterra ecologists in summer of 2011 and again in 2012. In 2012, four Onterra SCUBA certified ecologists visited the lake to hand harvest once again. Unfortunately, underwater observations indicated the biomass of the colony was more substantial than that which was observed the previous summer. The amount of plant encountered was in fact too much for hand removal, and an aggressive strategy was enacted to conduct an herbicide treatment upon the colony. This treatment occurred in July, which is somewhat atypical, but warranted given the rapidly growing/expanding nature of the colony.

The TLWA will continue to have professional monitoring conducted on the Eurasian water milfoil colony, as well as the rest of Virgin Lake. Continuing with an aggressive strategy on this early, relatively small population, the TLWA and Virgin Lake riparian property owners should be prepared to continue herbicide applications on the Eurasian water milfoil colony. Monitoring costs can be supported through a WDNR Aquatic Invasive Species Early Detection and Response grant, which would fund three years (2012, 2013 and 2014) of treatments and professional monitoring. Eurasian water milfoil management in Virgin Lake (monitoring and control) will combine an integrated approach of manual removal by certified SCUBA divers and volunteers as well as herbicide applications, and will be conducted in the following format:

<u>*Spring Pretreatment Confirmation & Refinement Surveys (April/May)*</u>
In April/May of each year during this project, Onterra ecologists would visit areas marked through the summer 2012 mapping survey to

verify the growth of Eurasian water milfoil. A qualitative assessment would be completed at this time (prior to herbicide applications) to verify treatment area extents. This survey would determine if colonial expansion had occurred from the previous year and would be utilized to determine the final treatment areas. An herbicide treatment would occur in late spring/early summer of 2013 upon the colonies observed during this survey. Subsequent spring pretreatment surveys would deliver information about the Eurasian water milfoil colonies and from there, the appropriate strategy (herbicide treatment, hand-removal efforts, etc.) would be determined.

Early-Season Aquatic Invasive Species Surveys (June)
A survey would be conducted in June of each project year to search the entire littoral zone of Virgin Lake for aquatic invasive species. Water clarity is greater at this time of year, and native plants have just begun their growth and thus are lower in the water column than Eurasian water milfoil, which grows rapidly in the spring. Thus, this is an excellent time of year for spotting aquatic invasive species colonies. Locations of Eurasian water milfoil colonies identified during this survey would be marked with GPS technology. If only single plants or small clumps were encountered, hand-removal efforts by Onterra staff would be deployed to remove these plants from the lake. All occurrences would be refined by Onterra staff during the peak-biomass surveys discussed below.

Summer Peak-biomass Mapping Surveys (August-September)
As the name implies, the Eurasian water milfoil peak-biomass survey is completed when the plant is at its peak growth, allowing for a true assessment of the amount of the exotic within the lake. As with the early-season AIS survey, this survey would include a complete meander survey of the lake's littoral zone by professional ecologists. Past findings from professional and volunteer surveys would be used as focus areas.

The re-treatment of previously treated areas is not uncommon in Eurasian water milfoil management as dense areas often require multiple years of treatment to significantly reduce a site's density and/or size. The TLWA and Virgin Lake residents understand that multiple years of herbicide treatment and hand-removal will likely be needed on Virgin Lake. The results of the summer peak-biomass survey will help to shape management strategy for the next spring.

It is the responsibility of the TLWA to contract with a licensed commercial aquatic pesticide to conduct early season treatments of Eurasian water milfoil. The treatments would occur roughly each year before June 1 when water temperatures are between 55-65°F. Onterra would create the treatment areas in the form of polygons within their Geographic Information System (GIS) and then transmit them to the applicator in native shapefile format or similar format recognized by the applicator's GPS technology. The association's applicator would be responsible for completing the necessary permit applications.

Letter Report (Winter)
During the winter following each herbicide treatment, a brief letter report would be provided that would include an assessment of the prior spring's treatment and guidance for the next year's control strategy. A map depicting the peak-biomass survey results and recommended treatment areas would be included within the report. Those remedial actions may include further monitoring, manual harvesting (hand removal), herbicide treatments, or a combination of all three.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Virgin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Virgin Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Virgin Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: Currently, Virgin Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Virgin Lake is protected. Volunteers from Virgin Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Virgin Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Virgin Lake shoreline was categorized in terms of its development. According to the results from this survey, only 25% of the shoreline is in a natural or developed-natural state, while over half (55%) of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Virgin Lake.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Virgin Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Virgin Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on Whitefish Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.2 Whitefish Lake

An Introduction to Whitefish Lake

Whitefish Lake, Oneida County, is a drainage lake with a maximum depth of 33 feet and a surface area of 205 acres. This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Whitefish Lake contains 49 native plant species, of which wild celery is the most common plant. No exotic plants were observed during the 2010 lake surveys.

Field Survey Notes

Difficulty accessing lake via Throoughfare in mid-April, due to lower water levels. Access was possible later in the month.

Many (49) aquatic plant species encountered during poin-intercept survey. Very large muskellunge spotted in shallow waters of isolated eastern bay.

Photo 8.2.1 Whitefish Lake, Oneida County

Lake at a Glance* – Whitefish Lake

Morphology	
Acreage	205
Maximum Depth (ft)	33
Mean Depth (ft)	16
Volume (acre-feet)	3,252
Shoreline Complexity	3.1
Vegetation	
Curly-leaf Survey Date	June 17, 2010
Comprehensive Survey Date	August 10, 2010
Number of Native Species	49
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.93
Average Conservatism	7.1
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	95:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.2.1 Whitefish Lake Water Quality

During 2011/2012, water quality data was collected from Whitefish Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity since 2006, with advanced monitoring (total phosphorus and chlorophyll-*a*) beginning in 2007. These efforts provide consistent, reliable data on which a comparable database may be built. Monitoring should be continued in order to understand trends in the water quality of Whitefish Lake for years to come.

During this time, summer average total phosphorus concentrations have ranged consistently between 14.5 and 19.7 µg/L (Figure 8.2.1-1). Some of these average annual concentrations rank within the TSI category of *Good*, with most ranking as *Excellent*. A weighted value across all years is lower than the median for deep, lowland drainage lakes in the state of Wisconsin. As with the total phosphorus values, average summer chlorophyll-*a* concentrations also rank within categories of *Good* and mostly *Excellent*, and a weighted average is less than the median concentration for similar lakes across the state (Figure 8.2.1-2).

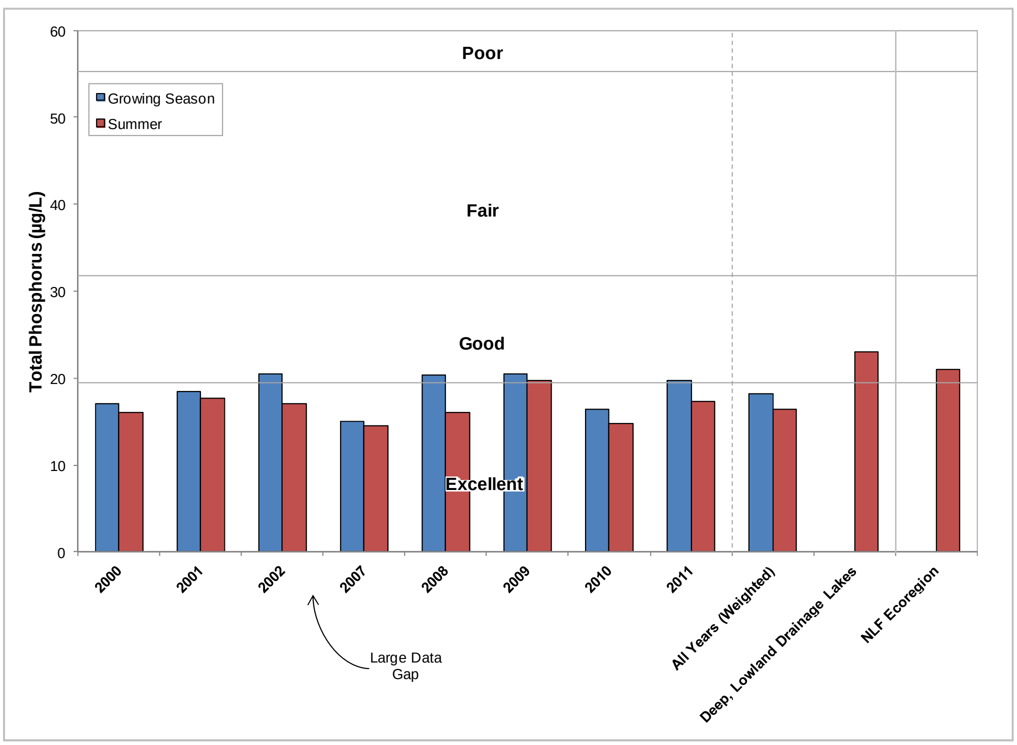

Figure 8.2.1-1. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

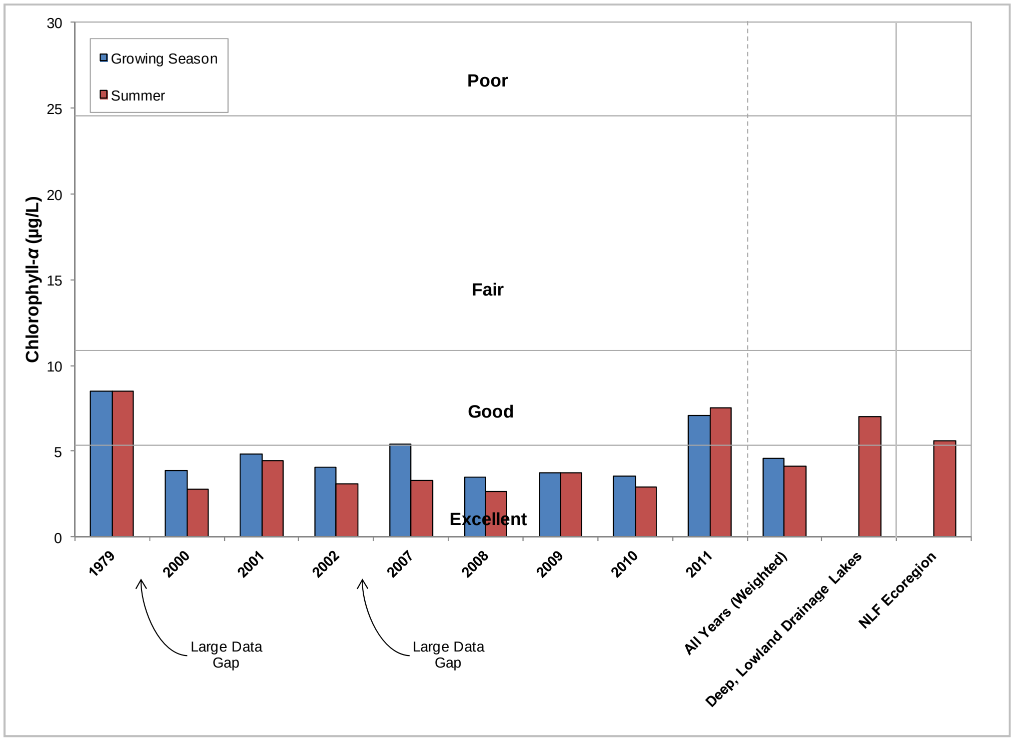

Figure 8.2.1-2. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters (Figure 8.2.1-3). Summer averages lie mostly within the *Excellent* category. A weighted average across all years is slightly greater than the average for deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. Comparing the chlorophyll-*a* dataset with the Secchi disk clarity dataset, it is apparent that during most years the two parameters do indeed have an inverse relationship. For example, in 2010 chlorophyll-*a* concentrations were relatively low in the lake, and in that same year Secchi disk depth averages are fairly high. On the other hand, in 2011 average chlorophyll-*a* concentrations were particularly high for Whitefish Lake and, as a result, the average Secchi disk depth was fairly low during that time.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water also plays a role in light penetration, and thus water clarity, as well. The darker waters of Whitefish Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

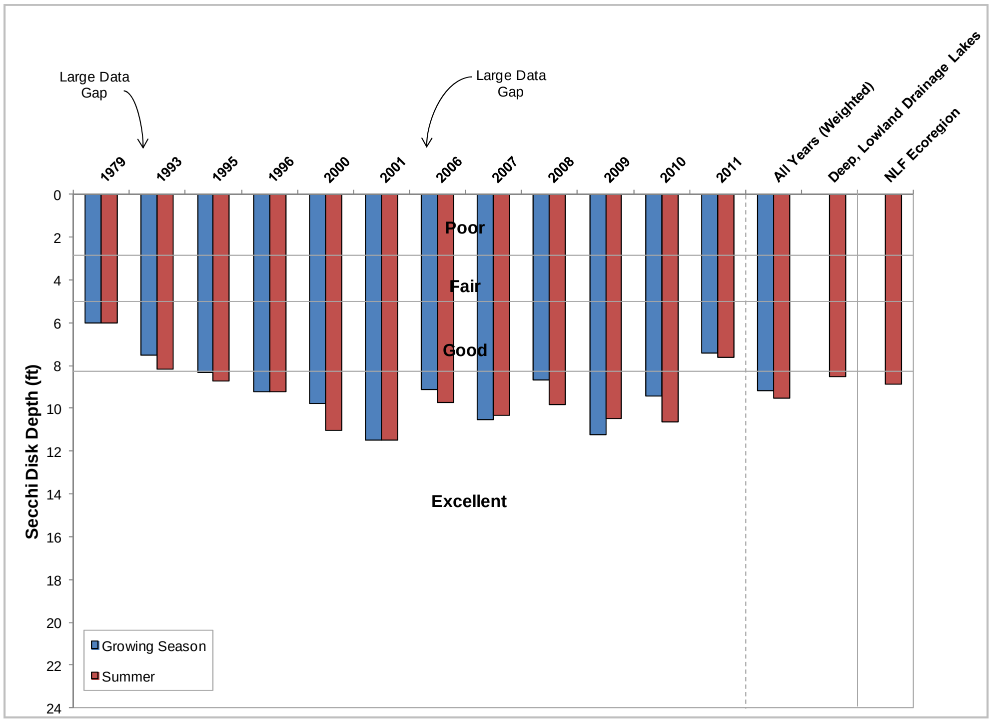

Figure 8.2.1-3. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Whitefish Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.2.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Whitefish Lake is in a mesotrophic state.

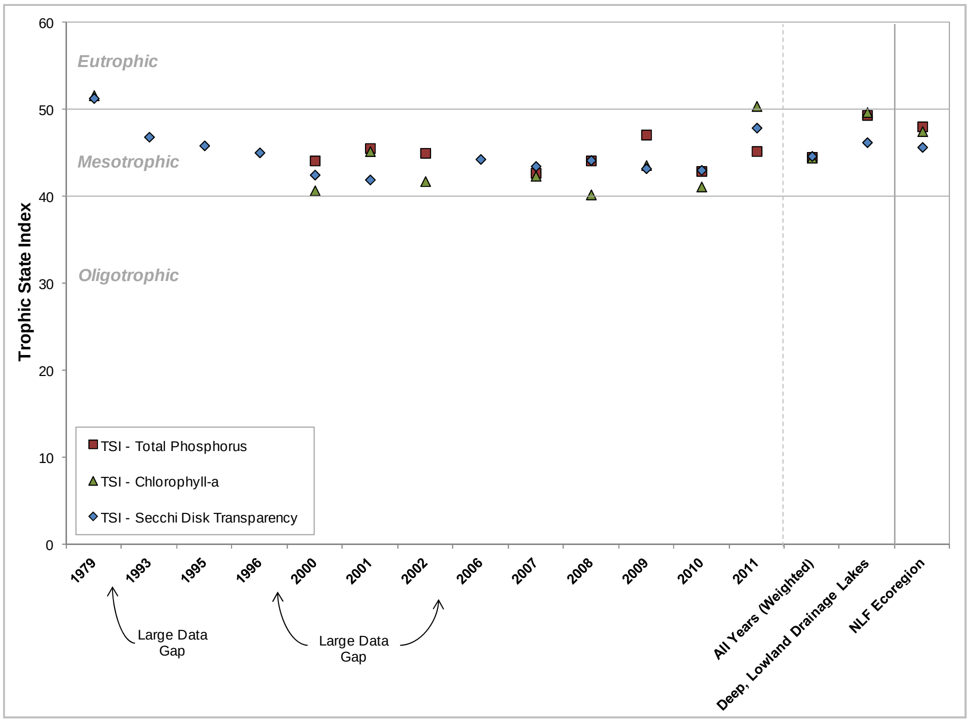

Figure 8.2.1-4. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Whitefish Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Whitefish Lake by Onterra staff. Graphs of those data are displayed in Figure 8.2.1-5 for all sampling events.

Whitefish Lake was found to be thoroughly mixed during the spring, but quickly stratified once the weather warmed the uppermost layers of water in June. Throughout the summer months, the lake remained thermally stratified at about 15 feet. This is not uncommon in lakes that are moderate in size and fairly deep. Energy from the wind is sufficient to mix only the upper layer of water, allowing the cooler, denser water to remain below. Decomposition of organic matter along the lake bottom is the cause of the decrease in dissolved oxygen observed in the summer months. In October, the lake is mixed once again by fall winds and oxygen is restored throughout the water column. During the winter months, dissolved oxygen depletes within the lake because the water is not able to exchange oxygen with the air through the ice. Dissolved oxygen levels remained sufficient in the upper 15 feet of the water column year-round to support most aquatic life found in northern Wisconsin lakes.

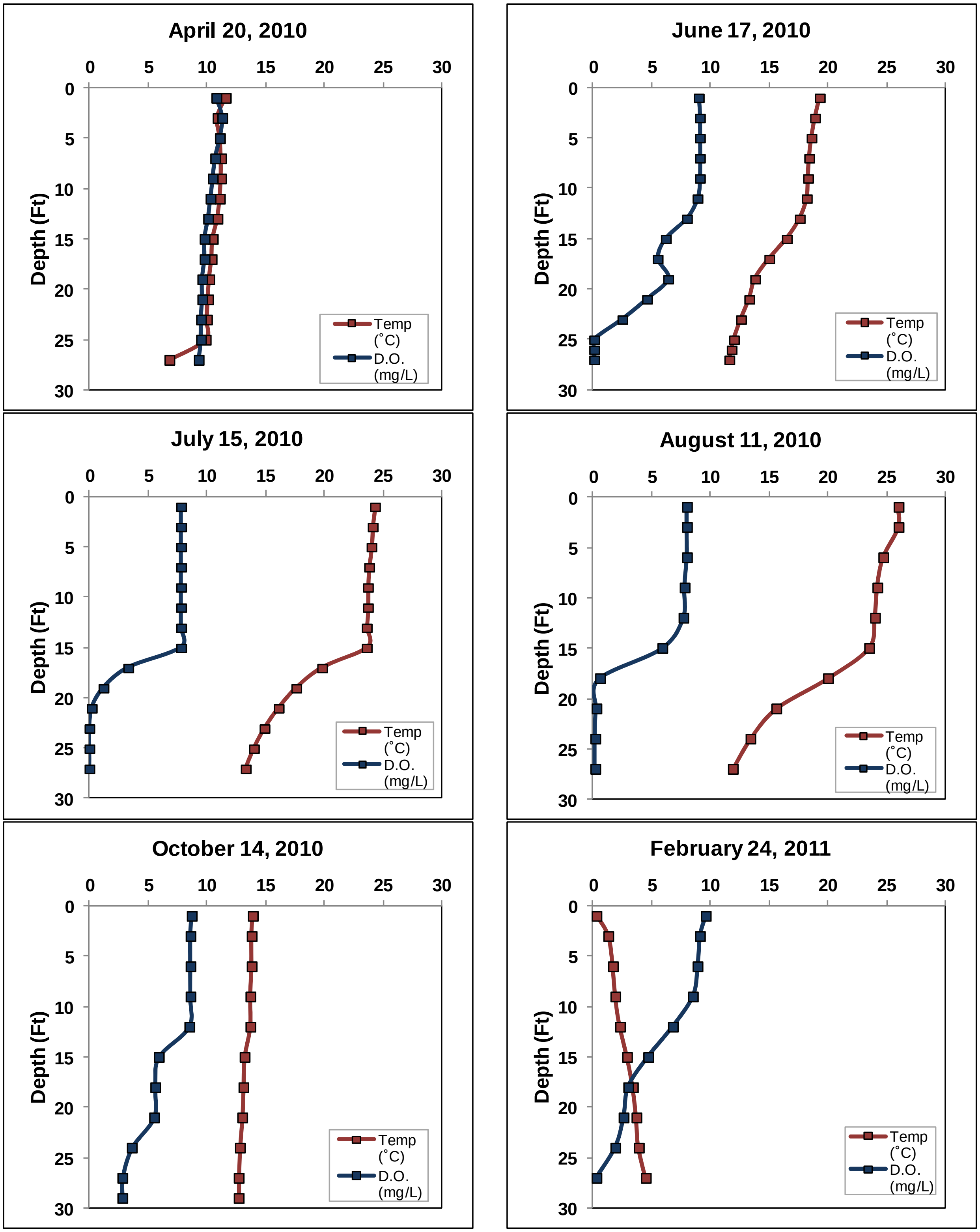

Figure 8.2.1-5. Whitefish Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Whitefish Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Whitefish Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Whitefish Lake's pH was measured at roughly 7.9 in the summer months of 2010. This value is above neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Whitefish Lake was measured at 44.5 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Samples of calcium were also collected from Whitefish Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Whitefish Lake's pH of 7.9 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Whitefish Lake was found to be 11.3 mg/L, falling just below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval mussels. No veligers (larval mussels) were found within these samples.

8.2.2 Whitefish Lake Watershed Assessment

Whitefish Lake's watershed is 19,630 acres in size. Compared to Whitefish Lake's size of 205 acres, this makes for an incredibly large watershed to lake area ratio of 95:1.

Exact land cover calculation and modeling of nutrient input to Whitefish Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.2.3 Whitefish Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, Whitefish Lake's immediate shoreline was assessed in terms of its development. Whitefish Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.1 miles of natural/undeveloped and developed-natural shoreline (33% of the entire shoreline) were observed during the survey (Figure 8.2.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, about 0.9 miles of urbanized and developed–unnatural shoreline (27% of the total shoreline) was observed. If restoration of the Whitefish Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Whitefish Lake Map 1 displays the location of these shoreline lengths around the entire lake.

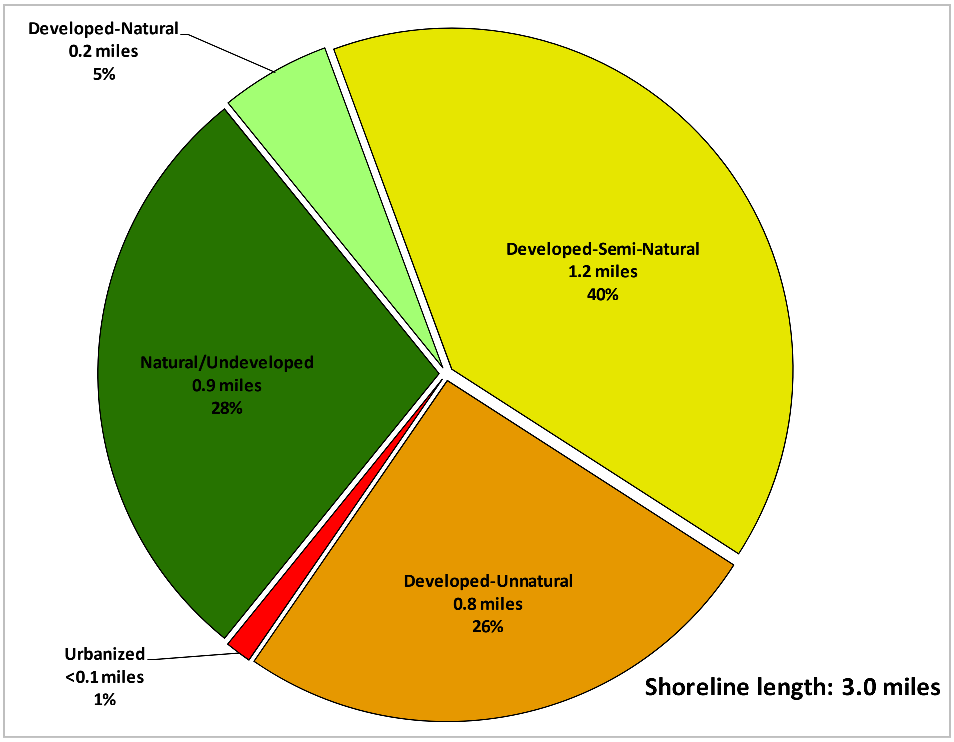

Figure 8.2.3-1. Whitefish Lake shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Whitefish Lake Map 1.

8.2.4 Whitefish Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Whitefish Lake on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Whitefish Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Whitefish Lake on August 10, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Whitefish Lake Community Map). During all surveys, 49 species of native aquatic plants were located in Whitefish Lake (Table 8.2.4-1). 36 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 14 feet, which is deep relative to the other lakes within the Three Lakes Chain of lakes, where plants may be found growing to only six feet of water. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 174 point-intercept locations sampled within the littoral zone, approximately 86% contained aquatic vegetation. Approximately 74% of the point-intercept sampling locations where sediment data was collected at were sand, 24% consisted of a fine, organic substrate (muck) and 3% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.2.4-1. Aquatic plant species located in the Whitefish Lake during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2010 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	5	I
	Carex utriculata	Northwest Territory sedge	7	I
	Calla palustris	Water arum	9	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Iris versicolor	Northern blue flag	5	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	I
	Scirpus cyperinus	Wool grass	4	I
	Schoenoplectus subterminalis	Water bulrush	9	X
	Typha spp.	Cattail spp.	1	X
	Zizania palustris	Northern wild rice	8	X
FL	*Brasenia schreberi*	Watershield	7	I
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	X
	Sparganium emersum	Short-stemmed bur-reed	8	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Chara spp.*	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes lacustris	Lake quillwort	8	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Nitella sp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton strictifolius	Stiff pondweed	8	I
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton pusillus	Small pondweed	7	X
	Ranunculus aquatilis	White water-crowfoot	8	X
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X

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

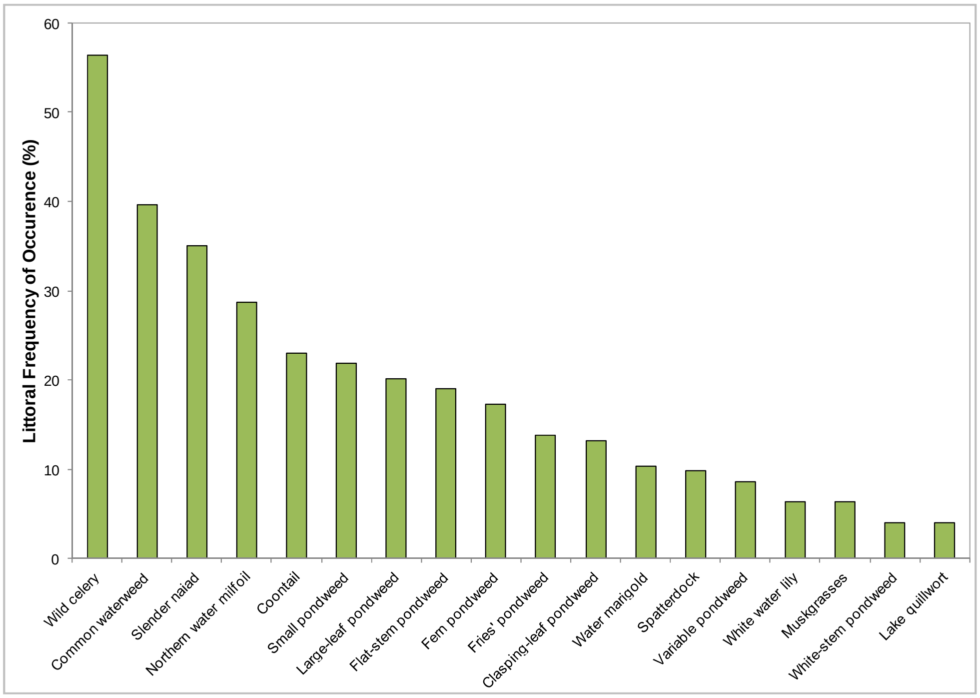

Figure 8.2.4-1 Whitefish Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 3.0% only. Created using data from a 2010 point-intercept survey.

Figure 8.2.4-1 (above) shows that wild celery, common waterweed, and slender naiad were the most frequently encountered plants within Whitefish Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. Common waterweed is able to obtain most of its nutrients through the water and thus does not produce extensive root systems. Sometimes, this plant may produce structures similar to roots (rhizoids) or become partially buried in the sediment. Because of this, the plant is susceptible to being easily uprooted and migrated by water-action and movement. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was located from Whitefish Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

An incredible 49 species of aquatic plants (including incidentals) were found in Whitefish Lake 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 influence the diversity. The diversity index for Whitefish Lake's plant community (0.93) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at 56% of the sampling locations, its relative frequency of occurrence is 15%. Explained another way, if 100 plants were randomly sampled from Whitefish Lake, 15 of them would be wild celery. This distribution can be observed in Figure 8.2.4-2, where together nine species account for 72% of the population of plants within Whitefish Lake, and the other 27 species account for the remaining 28%. Thirteen additional species were found incidentally within the lake (not from of the point-intercept survey), and are indicated in Table 8.2.4-1 as incidentals.

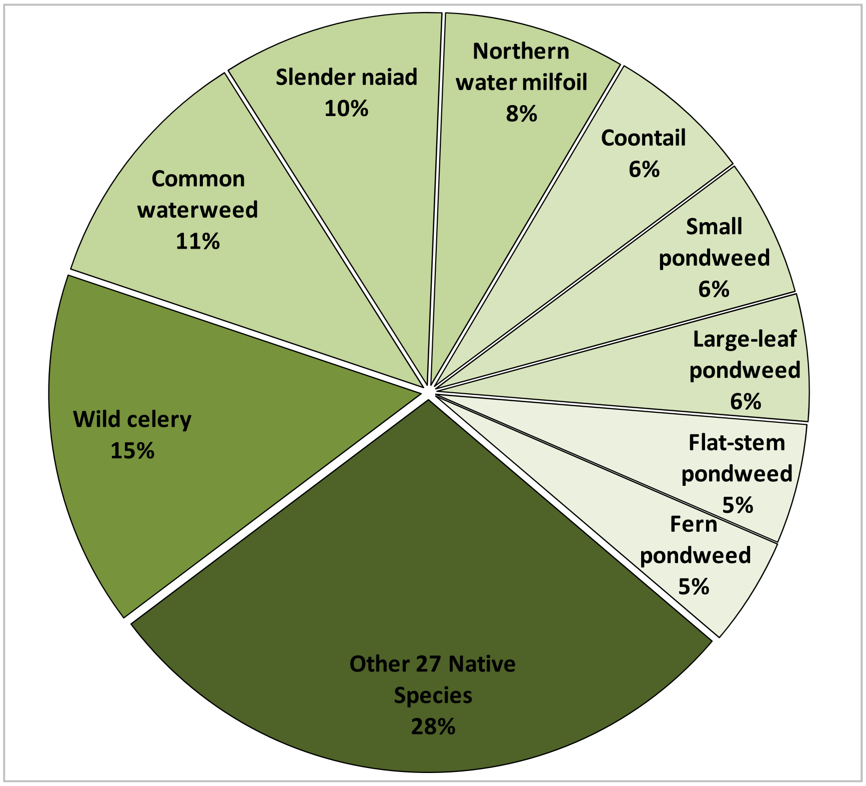

Figure 8.2.4-2 Whitefish Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

Whitefish Lake's average conservatism value (7.1) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Whitefish Lake is indicative of an undisturbed system. This is not surprising considering Whitefish Lake's plant community has great diversity and high species richness. Combining Whitefish Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 42.5 which is well above the median values of the ecoregion and state.

The quality of Whitefish Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.4 acres of the lake contains these types of plant communities (Whitefish Lake Map 2, Table 8.2.4-2). 18 floating-leaf and emergent species were located on Whitefish Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.2.4-2. Whitefish Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	0.1
Floating-leaf	1.2
Mixed Floating-leaf and Emergent	14.1
Total	15.4

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Whitefish Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to 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.

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8.2.5 Whitefish Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Whitefish Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Whitefish Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Whitefish Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Whitefish Lake's implementation plan is compiled by describing how Whitefish Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Whitefish Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Whitefish Lake contains a public carry-in access, and is accessible through the Thoroughfare which contains several public access points. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters. Therefore, both parties must be educated on the threat of aquatic invasive species.

Whitefish Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Whitefish Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Whitefish Lake or from Whitefish Lake elsewhere. If a Whitefish Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Whitefish Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Whitefish Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Whitefish Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Whitefish Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Whitefish Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: Currently, Whitefish Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Whitefish Lake is protected. Volunteers from Whitefish Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Whitefish Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Whitefish Lake shoreline was categorized in terms of its development. According to the results from this survey, 27% of the shoreline is in an urbanized or developed-unnatural state, while 40% is of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Whitefish Lake.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Whitefish Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Whitefish Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on The Thoroughfare studies are contained within the Three Lakes Chain-wide Management Plan document.

8.3 The Thoroughfare

An Introduction to the Thoroughfare

The Thoroughfare, Oneida County, is a narrow passage-way that connects Big Lake to Whitefish Lake. It has a maximum depth of 12 feet and a surface area of 175 acres. The Thoroughfare contains 35 native plant species, of which coontail was the most common plant as determined through the point-intercept survey. Wild rice, an emergent species, was found in great abundance as well but was not accounted for as often using the point-intercept methodology. No exotic plants were observed during the 2010 lake surveys.

Field Survey Notes

Much undeveloped shoreline observed along the Thoroughfare. Fluctuating water levels made access to Whitefish Lake difficult in mid-April.

Numerous emergent and floating-leaf aquatic plants observed during point-intercept survey, including wild rice, sedge species, cattails, white water lilies, spatterdock and watershield.

Photo 8.3.1 The Thoroughfare, Oneida County

Lake at a Glance* – The Thoroughfare

Morphology	
Acreage	175
Maximum Depth (ft)	12
Shoreline Complexity	13.5
Vegetation	
Curly-leaf Survey Date	June 17, 2010
Comprehensive Survey Date	August 8 & 9 2010
Number of Native Species	35
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.91
Average Conservatism	6.9

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.3.1 The Thoroughfare Water Quality

Water quality studies were not completed on the Thoroughfare as a part of this project.

8.3.2 The Thoroughfare Watershed Assessment

Because the Thoroughfare is more of a passage between lakes than a lake per se, watershed modeling was not conducted as a part of this project. A shoreline assessment, however, was completed as described in the next section.

8.3.3 The Thoroughfare Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, the Thoroughfare's immediate shoreline was assessed in terms of its development. The Thoroughfare has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.2 miles of natural/undeveloped and developed-natural shoreline (77% of the entire shoreline) were observed during the survey (Figure 8.3.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.4 miles of urbanized and developed–unnatural shoreline (6% of the total shoreline) was observed. If restoration of the Thoroughfare shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. The Thoroughfare Map 1 displays the location of these shoreline lengths around the entire lake.

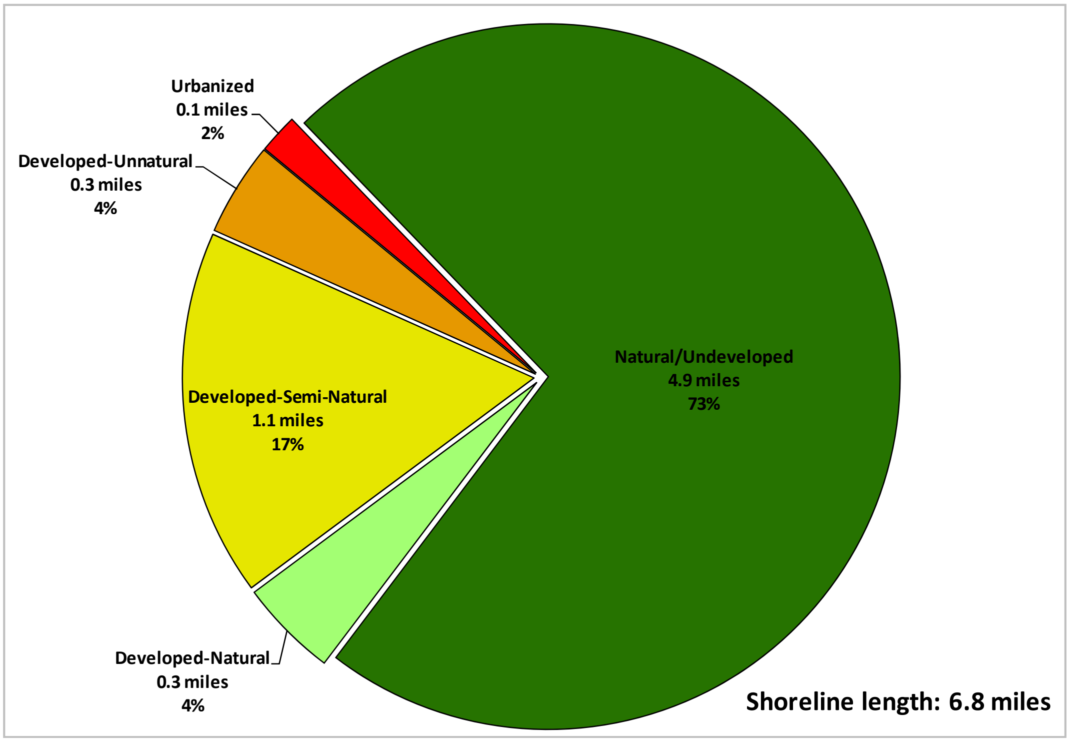

Figure 8.3.3-1. The Thoroughfare shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on the Thoroughfare Shoreline Condition Map.

8.3.4 The Thoroughfare Aquatic Vegetation

The curly-leaf pondweed survey was conducted on the Thoroughfare on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in the Thoroughfare or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on the Thoroughfare on August 8 & 9 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 10 to create the aquatic plant community map (The Thoroughfare Map 2) during this time. During all surveys, 35 species of native aquatic plants were identified in the Thoroughfare (Table 8.3.4-1). 25 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of nine feet. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 139 point-intercept locations sampled within the littoral zone, approximately 61% contained aquatic vegetation. Approximately 5% of the point-intercept sampling locations where sediment data was collected at were sand and 95% consisted of a fine, organic substrate (muck). No rocky areas where encountered (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.3.4-1. Aquatic plant species located in the Thoroughfare during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	Onterra 2010
Emergent	*Calla palustris*	Water arum	9	I
	Carex aquatilis	Water sedge	7	I
	Carex utriculata	Northwest Territory sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria rigida	Stiff arrowhead	8	I
	Scirpus cyperinus	Wool grass	4	I
	Sagittaria latifolia	Common arrowhead	3	X
	Typha spp.	Cattail spp.	1	I
	Zizania palustris	Northern wild rice	8	X
FL	*Brasenia schreberi*	Watershield	7	I
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Elodea canadensis	Common waterweed	3	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum verticillatum	Whorled water milfoil	8	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	*Sagittaria cuneata*	Arum-leaved arrowhead	7	X
	Sagittaria graminea	Grass-leaved arrowhead	9	X
FF	*Lemna trisulca*	Forked duckweed	6	X
	Lemna turionifera	Turion duckweed	2	X
	Spirodela polyrhiza	Greater duckweed	5	X

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

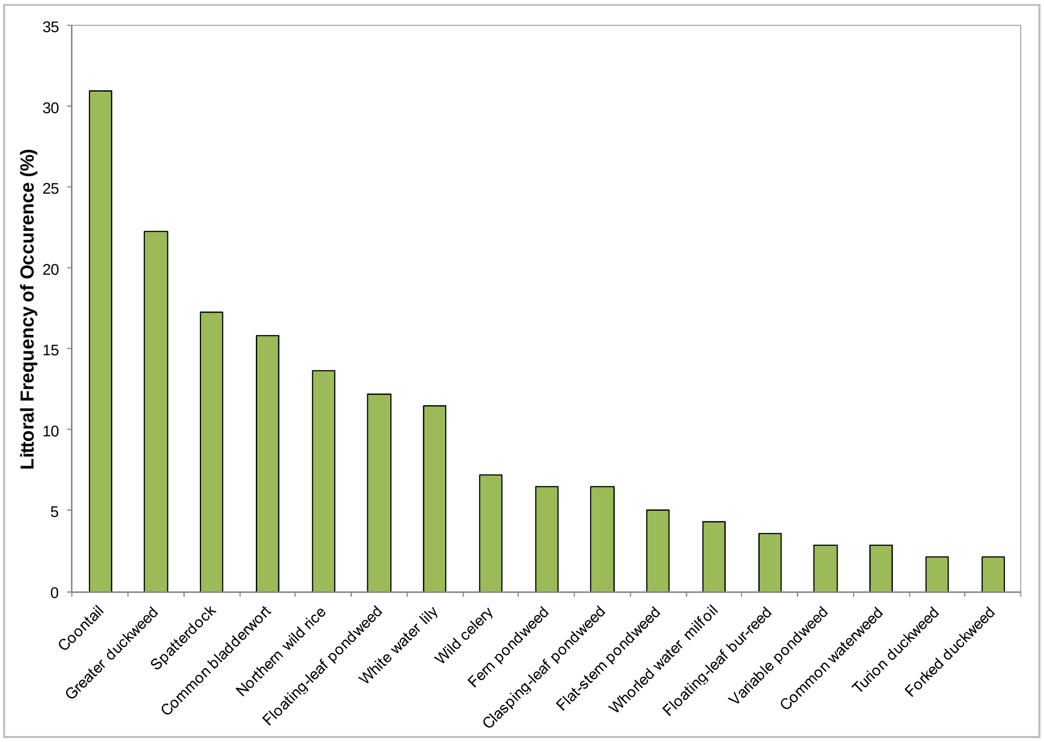

Figure 8.3.4-1 The Thoroughfare aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.5% only. Created using data from a 2010 point-intercept survey.

Figure 8.3.4-1 (above) shows that coontail, greater duckweed, and spatterdock were the most frequently encountered plants within the Thoroughfare. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making them susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form mats. Greater duckweed has round to oval-shaped leaf bodies called fronds that float individually or in groups on the water surface. This plant can be found worldwide in freshwater habitats that are protected from the wind where wave action in minimal. Interestingly, duckweed is largely made up of metabolically active cells with very little fiber; the tissue contains twice the protein, fat, nitrogen and phosphorus as other vascular plants. This makes the plant very high in nutritional value, and is a preferred food choice by waterfowl. Spatterdock is a rooted, floating-leaved plant with heart-shaped leaves and a bright yellow roundish flower in the summer months. This plant provides shade, cover from predators, and a source of food for several species of mammals such as waterfowl, muskrat, beaver, and deer.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one was located within the Thoroughfare. Whorled water milfoil is a submerged milfoil plant with leaves in whorls of 4 to 5. The leaves have somewhat of a feathery appearance. It is often mistaken for other species of milfoil, such as northern water milfoil or the invasive Eurasian water milfoil. This plant is most readily distinguished from other milfoils by its overall size (whorled water milfoil is typically larger and more robust) and the length between leaf nodes, which is less than other species of milfoil (about 1 cm apart). Additionally, leaflet counts are helpful in identification – whorled water milfoil typically has 9-13 leaflet segments on each side of the midrib of the leaflet, while northern water milfoil has 5-10 and Eurasian water milfoil 12-24 leaflets.

35 species of aquatic plants (including incidentals) were found in the Thoroughfare 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 influence the diversity. The diversity index for the Thoroughfare's plant community (0.91) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at 31% of the sampling locations, its relative frequency of occurrence is 18%. Explained another way, if 100 plants were randomly sampled from the Thoroughfare, 18 of them would be coontail. This distribution can be observed in Figure 8.3.4-2, where together 7 species account for 71% of the population of plants within the Thoroughfare and the other 18 species account for the remaining 29%. Ten additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.3.4-1 as incidentals.

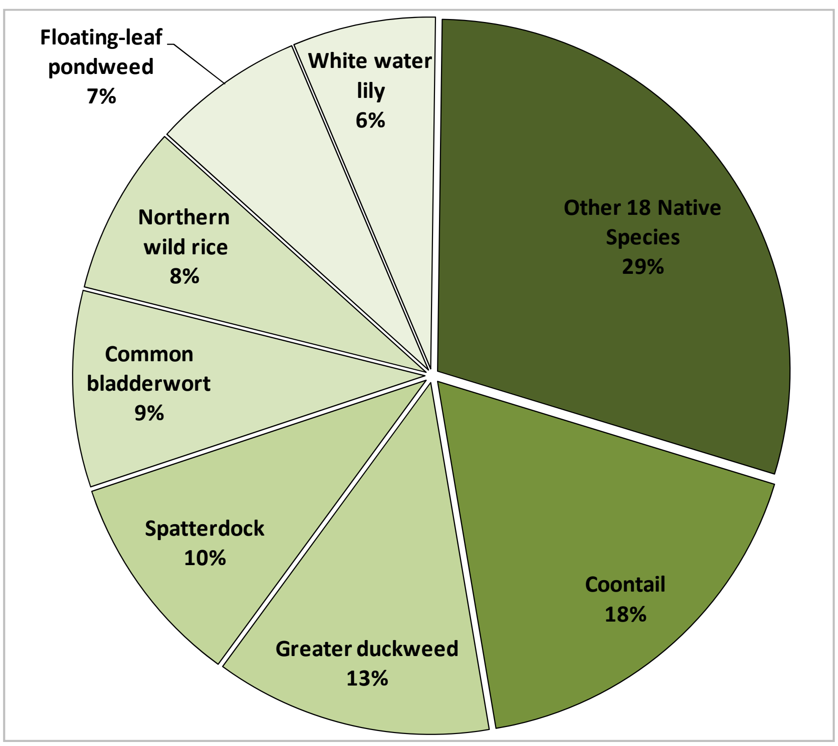

Figure 8.3.4-2 The Thoroughfare aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

The Thoroughfare's average conservatism value (6.9) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of the Thoroughfare is indicative of an undisturbed system. This is not surprising considering the Thoroughfare's plant community has great diversity and high species richness. Combining the Thoroughfare's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 34.6 which is well above the median values of the ecoregion and state.

The quality of the Thoroughfare is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 162.9 acres of the lake contains these types of plant communities (The Thoroughfare Map 2, Table 8.3.4-2). Ten floating-leaf and emergent species were located on the Thoroughfare (Table 8.3.4-1), all of which provide valuable wildlife habitat.

Table 8.3.4-2. The Thoroughfare acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	0
Floating-leaf	0
Mixed Floating-leaf and Emergent	162.9
Total	162.9

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within the Thoroughfare. 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.

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8.3.5 The Thoroughfare Implementation Plan

The Implementation Plan below is a result of collaborative efforts between the Thoroughfare stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of the Thoroughfare and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including the Thoroughfare's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, the Thoroughfare's implementation plan is compiled by describing how the Thoroughfare stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to the Thoroughfare

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: The Thoroughfare contains several public access points and is accessible from many other Three lakes Chain lakes by only a short boat ride. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters. Therefore, both parties must be educated on the threat of aquatic invasive species.

The Thoroughfare stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On the Thoroughfare, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to the Thoroughfare or from the Thoroughfare elsewhere. If a Thoroughfare property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: The Thoroughfare stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Thoroughfare riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: The Thoroughfare stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving the Thoroughfare and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, the Thoroughfare property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: This management action is not applicable to the Thoroughfare

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. The Thoroughfare stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Thoroughfare shoreline was categorized in terms of its development. According to the results from this survey, 73% of the Thoroughfare's nearly 7 miles of shoreline is in a natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

Restoring areas of the Thoroughfare shoreline is not imperative due to its already largely natural state, so educating riparian property owners on the benefits of conserving this natural land may be of more importance. However, if property owners are interested in restoring their property's shoreline a plan has been put into place to do so. The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to the Thoroughfare.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Thoroughfare stakeholders have specific questions/concerns about the walleye population or the overall fishery of the Thoroughfare, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on Big Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.4 Big Lake

An Introduction to Big Lake

Big Lake, Oneida County, is a drainage lake with a maximum depth of 27 feet and a surface area of 865 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Big Lake contains 32 native plant species, of which wild celery was the most common plant. Two wetland exotic plants were observed during the 2010 lake surveys.

Field Survey Notes

Rough water conditions experienced during survey on August 5th. Several otters spotted near island – very playful critters!

Purple loosestrife plant located along shoreline. Plant was hand-pulled entirely, location marked with GPS coordinates.

Photo 8.4.1 Big Lake, Oneida County

Lake at a Glance* – Big Lake

Morphology	
Acreage	865
Maximum Depth (ft)	27
Mean Depth (ft)	12
Volume (acre-feet)	10,810
Shoreline Complexity	2.6
Vegetation	
Curly-leaf Survey Date	June 18, 2010
Comprehensive Survey Date	August 5 & 9, 2010
Number of Native Species	32
Threatened/Special Concern Species	-
Exotic Plant Species	Amur silver grass & Purple loosestrife
Simpson's Diversity	0.89
Average Conservatism	6.6
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage lake
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus

Watershed to Lake Area Ratio	52:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.4.1 Big Lake Water Quality

Water quality data was collected from Big Lake on three occasions in summer of 2010. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water quality through an advanced monitoring program since 2006. These efforts provide a considerable amount of data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Big Lake.

During this time, summer average total phosphorus concentrations have fluctuated slightly, ranging between 25.0 and 37.0 µg/L (Figure 8.4.1-1). These average values rank within the TSI categories of *Good* and *Excellent*, and a weighted value across all years is slightly lower than the median value for shallow, lowland drainage lakes in the state of Wisconsin. Average chlorophyll-*a* concentrations have shown some variation within the dataset (Figure 8.4.1-2). Most values fall within the TSI *Excellent* category, though some rank as *Good*. The weighted average across all years is similar to the median for other shallow, lowland drainage lakes statewide.

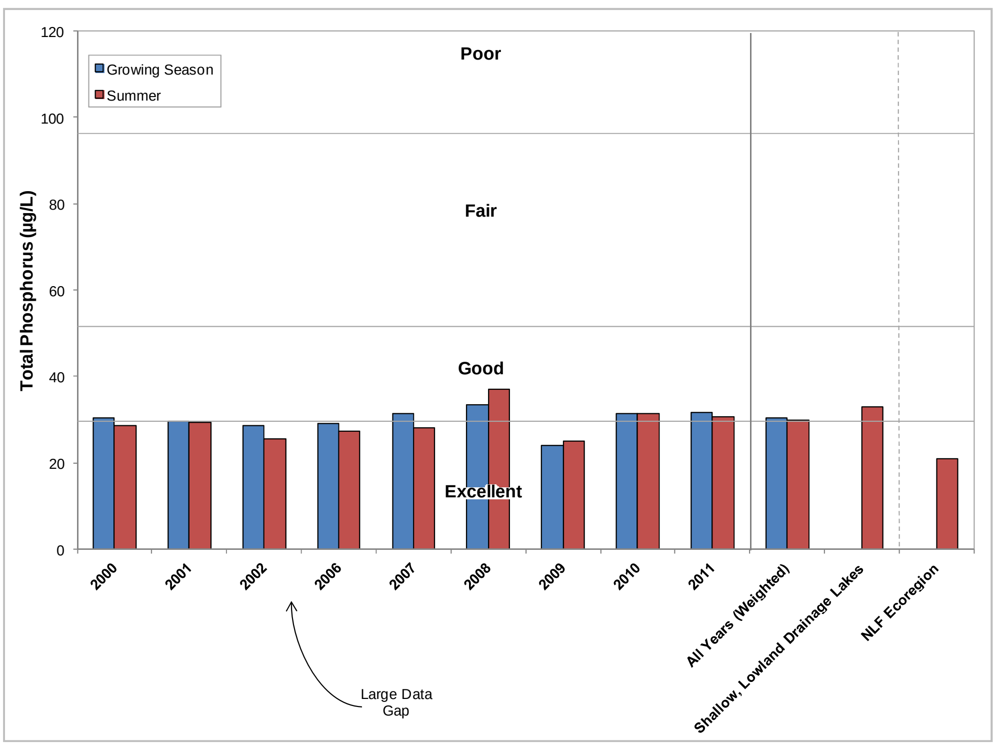

Figure 8.4.1-1. Big Lake, state-wide shallow, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

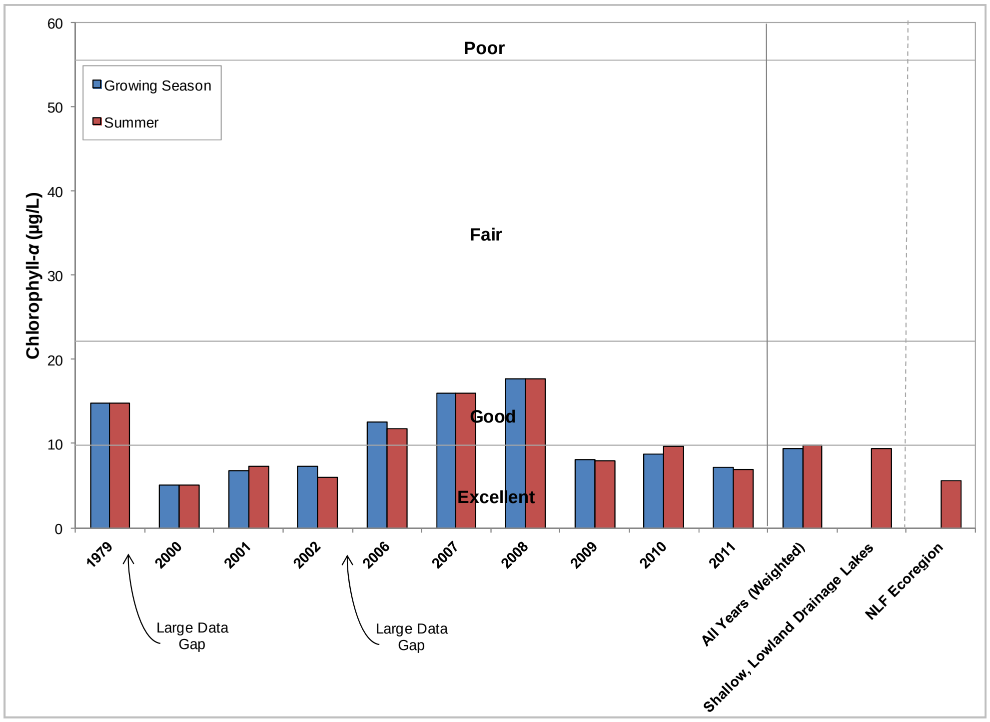

Figure 8.4.1-2. Big Lake, state-wide shallow, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters, and show little annual variance (Figure 8.4.1-3). All summer averages range between categories of *Fair* and *Good*, and a weighted average across all years is less than the median for shallow, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. It is likely, however, that another factor is limiting the water clarity in Big Lake.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. Indeed, during the point-intercept aquatic vegetation survey that took place on Big Lake in 2010, aquatic plants were found growing to a maximum depth of seven feet.

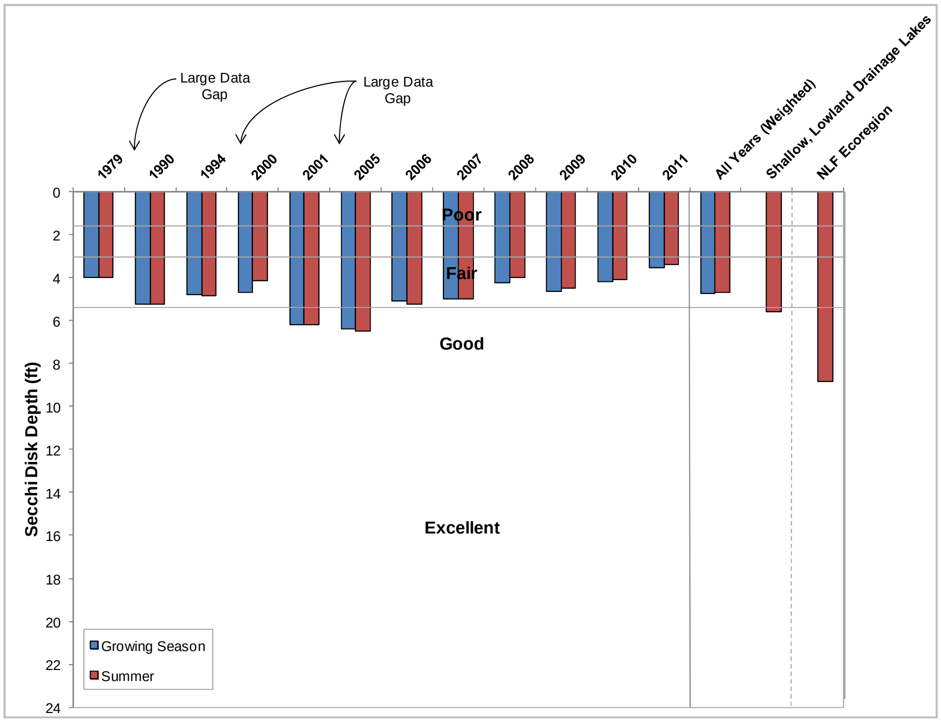

Figure 8.4.1-3. Big Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Big Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.4.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Big Lake is in a eutrophic state.

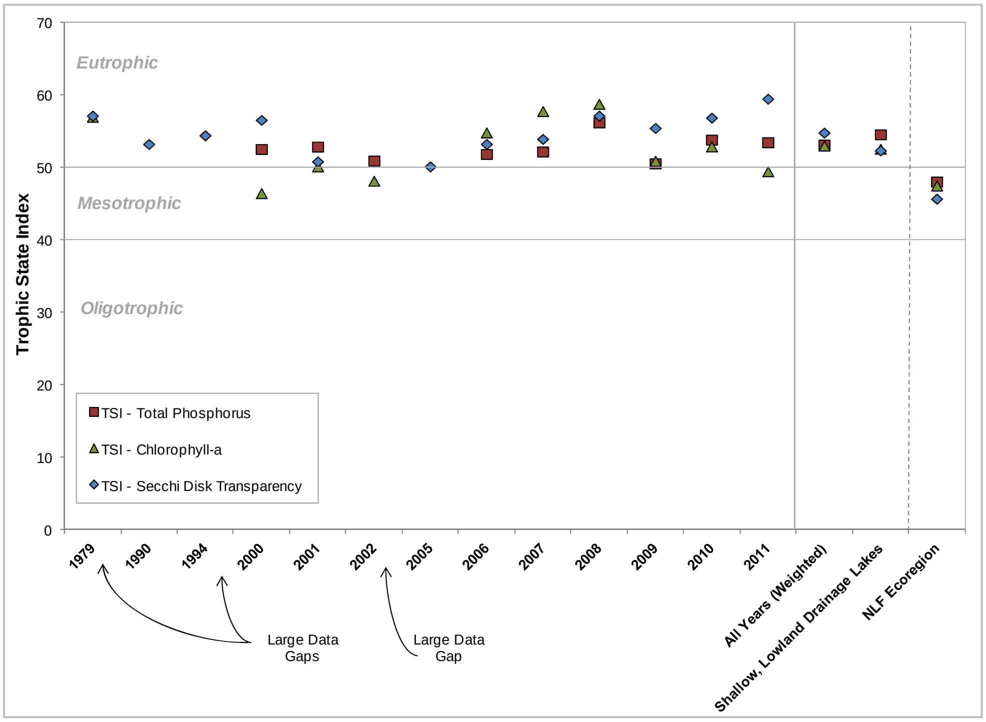

Figure 8.4.1-4. Big Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Big Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Lake by Onterra staff. Graphs of those data are displayed in Figure 8.4.1-5 for all sampling events.

Big Lake remained thoroughly mixed throughout most of the summer months in 2010, though a small amount of stratification likely occurs periodically in the deeper portions of the lake as seen in the August profile. This is not uncommon in lakes that are large in size and moderately deep. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in the summer and winter months. Despite this decrease in oxygen near the bottom of the lake, levels remained sufficient to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen was also ample during the winter months of 2011, when oxygen may decrease due to ice cover on the lake and lack of oxygen production from plants and algae.

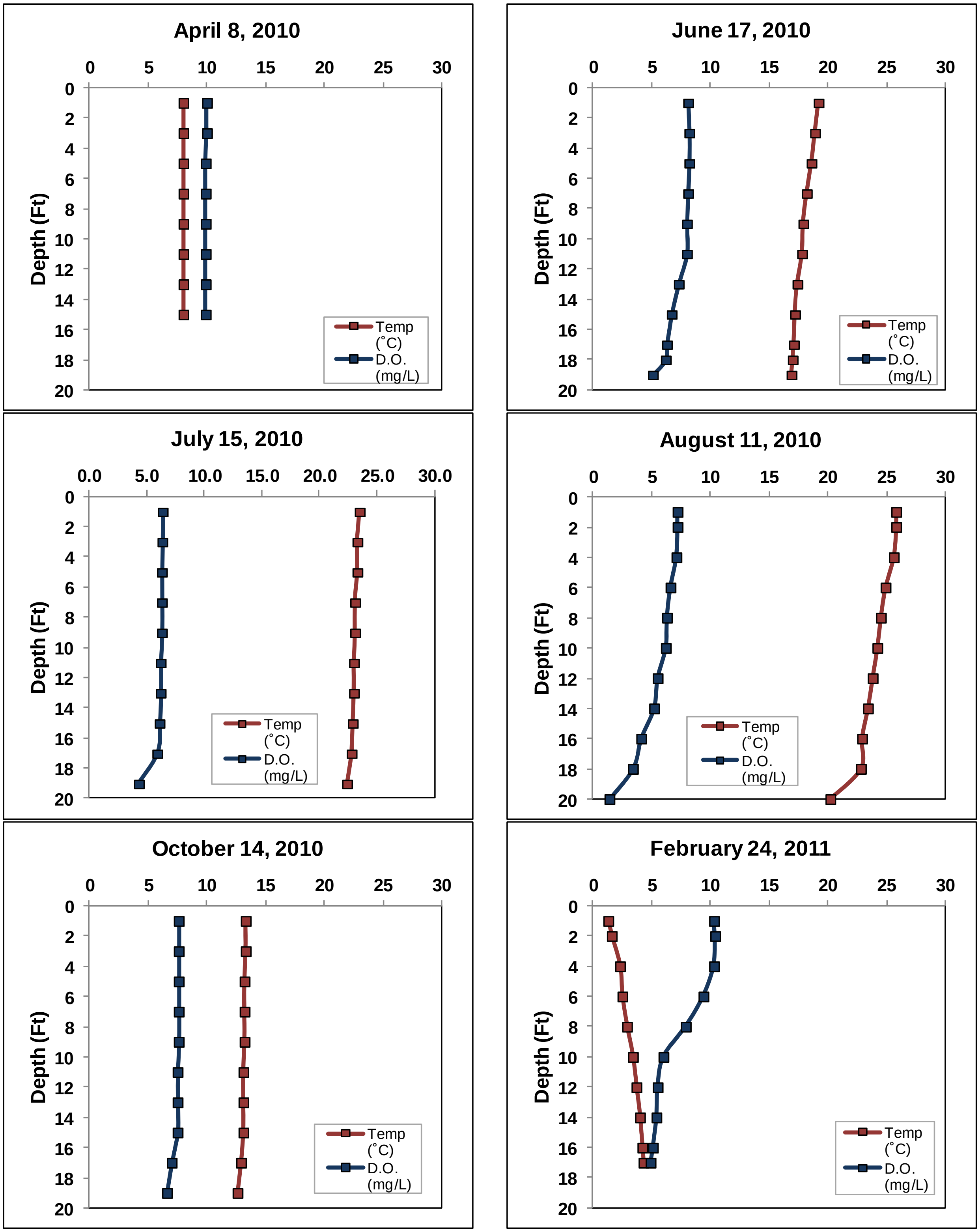

Figure 8.4.1-5. Big Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Big Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Big Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Big Lake's pH was measured at roughly 7.3 in the summer months of 2010. This value is near neutral and fall within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Big Lake was measured at 24.0 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Big Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Lake's pH of 7.3 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Big Lake was found to be 8.0 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval mussels) were found within these samples.

8.4.2 Big Lake Watershed Assessment

Big Lake's watershed is 45,504 acres in size. Compared to Big Lake's size of 865 acres, this makes for a large watershed to lake area ratio of 52:1.

Exact land cover calculation and modeling of nutrient input to Big Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.4.3 Big Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, Big Lake's immediate shoreline was assessed in terms of its development. Big Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.7 miles of natural/undeveloped and developed-natural shoreline (52% of the shoreline) were observed during the survey (Figure 8.4.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.2 miles of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Big Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Big Lake Map 1 displays the location of these shoreline lengths around the entire lake.

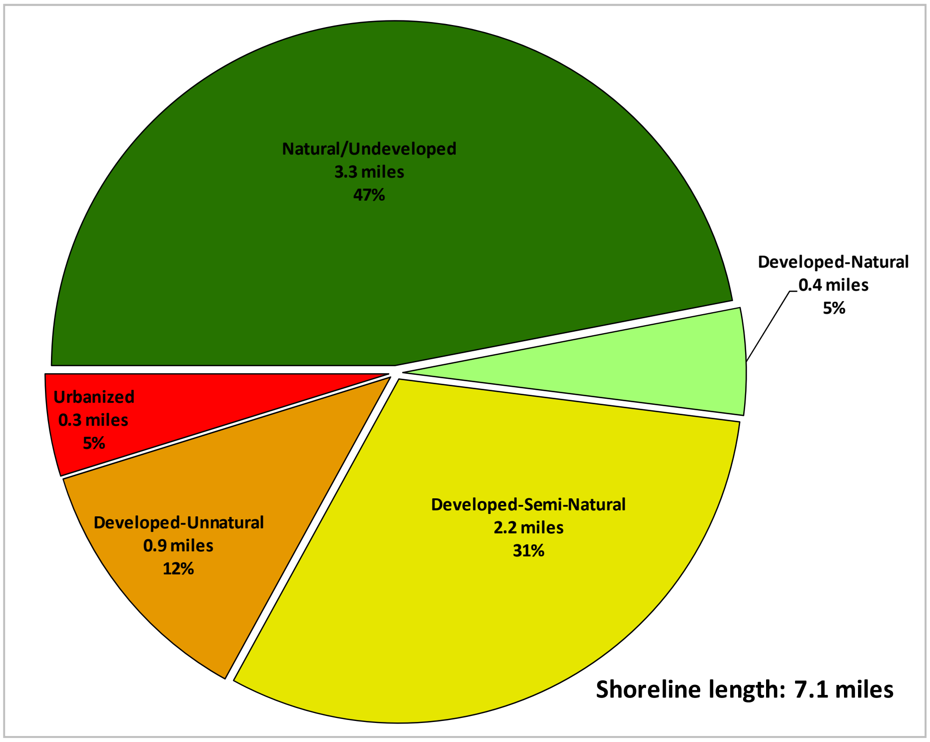

Figure 8.4.3-1. Big Lake shoreland categories and total lengths. Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Big Lake Map 1.

8.4.4 Big Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Big Lake on June 18, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Big Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Big Lake on August 5 & 9, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Big Lake Map 2). During all surveys, 32 species of native aquatic plants were located in Big Lake (Table 8.4.4-1). 23 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Additionally, two species of emergent exotic plants were found on the Big Lake shoreline – amur silver grass and purple loosestrife. Submergent aquatic plants were found growing to a depth of seven feet, which is not uncommon for lakes as heavily stained as Big Lake (see the Big Lake Water Quality Section for discussion on Big Lake's water clarity). As discussed later on within this section, many of the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 236 point-intercept locations sampled within the littoral zone, approximately 56% contained aquatic vegetation. Approximately 59% of the point-intercept sampling locations where sediment data was collected at were sand, 37% consisted of a fine, organic substrate (muck) and 4% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.4.4-1. Aquatic plant species located in the Big Lake during the 2010 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2010 (Onterra)
Emergent	*Carex crinita*	Fringed sedge	6	I
	Carex utriculata	Common yellow lake sedge	7	I
	Calla palustris	Water arum	9	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Equisetum fluviatile	Water horsetail	7	X
	Eleocharis palustris	Creeping spikerush	6	X
	Glyceria canadensis	Rattlesnake grass	7	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Miscanthus sacchariflorus	Amur silver grass	Exotic	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Scirpus cyperinus	Wool-grass	4	I
	Zizania palustris	Northern wild rice	8	X
FL	*Nymphaea odorata*	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Elodea canadensis	Common waterweed	3	X
	Isoetes echinospora	Spiny-spored quilwort	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Megalodonta beckii	Water marigold	8	X
	Nitella sp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Utricularia intermedia	Flat-leaf bladderwort	9	I
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
FF	*Lemna trisulca*	Forked duckweed	6	X

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

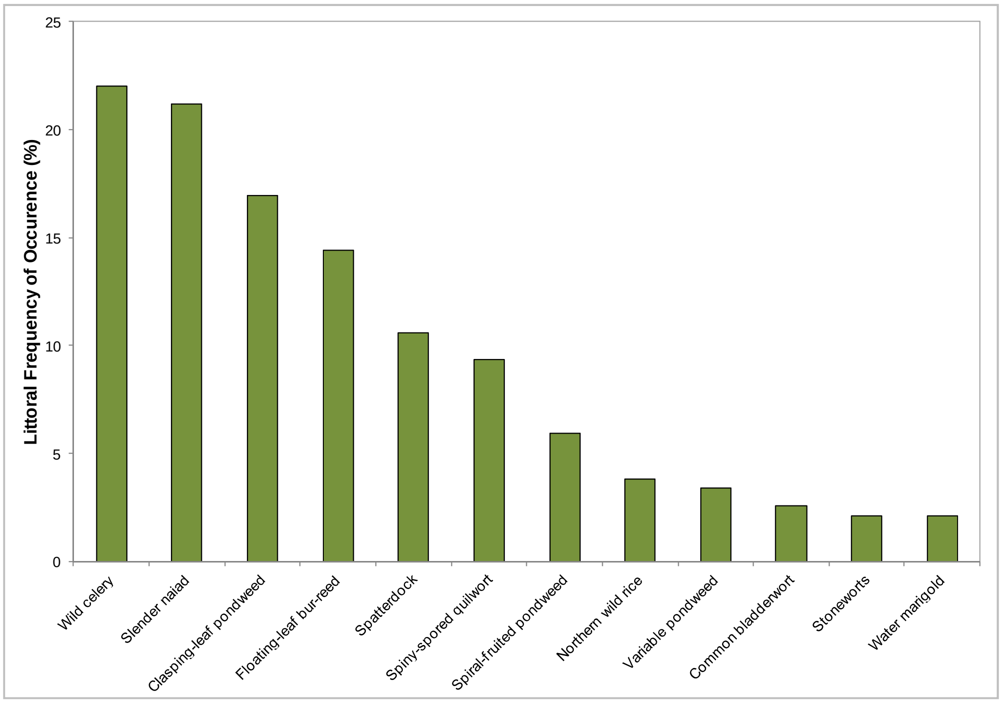

Figure 8.4.4-1 Big Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2010 point-intercept survey.

Figure 8.4.4-1 (above) shows that wild celery, slender naiad and clasping-leaf pondweed were the most frequently encountered plants within Big Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is also a food source of waterfowl. Clasping-leaf pondweed is a submergent plant that has oval to somewhat lance-shaped leaves that "clasp" around one-half to three-quarters of the stem circumference. Unlike many other pondweeds, this plant does not produce floating leaves.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, one was located within Big Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

32 species of native aquatic plants (including incidentals) were found in Big Lake 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 influence the diversity. The

diversity index for Big Lake's plant community (0.89) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds good diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at 22% of the sampling locations, its relative frequency of occurrence is 18%. Explained another way, if 100 plants were randomly sampled from Big Lake, 18 of them would be wild celery. This distribution can be observed in Figure 8.4.4-2, where together 10 species account for 88% of the population of plants within Big Lake, while the other 13 species account for the remaining 12%. Eleven additional species (native and non-native) were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.4.4-1 as incidentals.

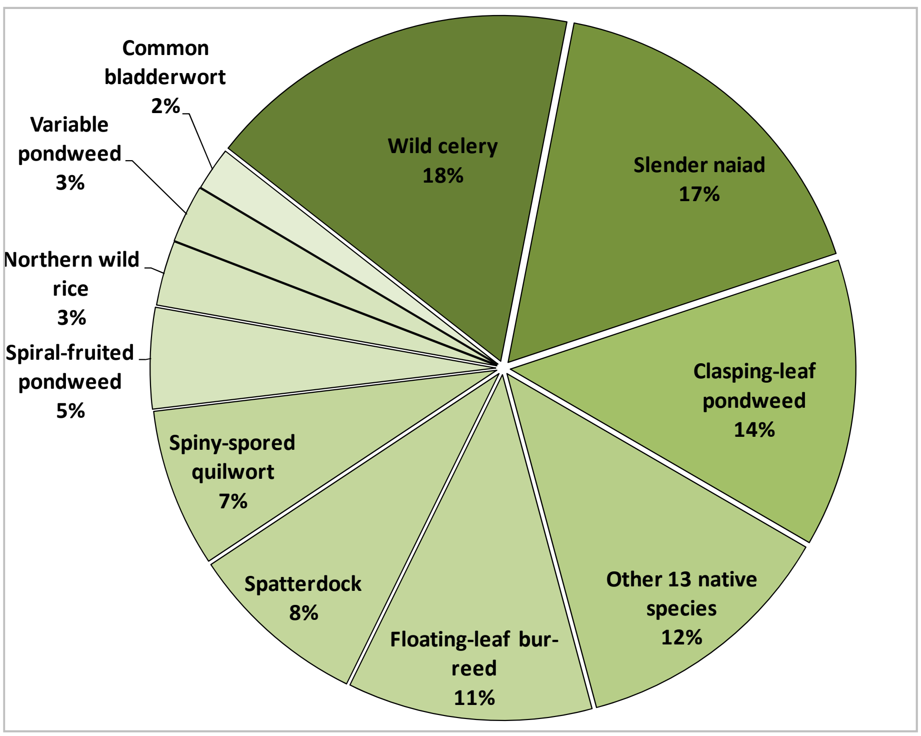

Figure 8.4.4-2 Big Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2010 point-intercept survey.

Big Lake's average conservatism value (6.6) is higher than the state median (6.0) but slightly under the ecoregion median (6.7). This indicates that the plant community of Big Lake is indicative of a moderately disturbed system. This is not surprising considering Big Lake's plant community has good diversity and fairly high species richness. Combining Big Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 31.5 which is above the median values of the ecoregion and state.

The quality of Big Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 125.1 acres of the lake contains these types of plant communities (Big Lake Map 2, Table 8.4.4-2). Fifteen floating-leaf and emergent species were located on Big Lake (Table 8.4.4-1), all of which provide valuable wildlife habitat.

Table 8.4.4-2. Big Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	4.7
Floating-leaf	5.5
Mixed Floating-leaf and Emergent	114.9
Total	125.1

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Big Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to 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.

Aquatic Invasive Species in Big Lake

During the 2011 community mapping survey, a single purple loosestrife plant was located on the shoreline of Big Lake (Big Lake Map 2). Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

The single plant that was found on Big Lake was carefully pulled by Onterra staff. Volunteer monitoring of this location and the Big Lake shoreline in general is recommended to spot any other occurrences of purple loosestrife. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Detailed discussion regarding this control effort will be discussed in the Implementation Plan.

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8.4.5 Big Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Lake's implementation plan is compiled by describing how Big Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Big Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Big Lake contains multiple public access points and is directly connected to the rest of the Three Lakes Chain of Lakes via Dog Lake and is also accessible by Whitefish Lake through the Thoroughfare. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Lake or from Big Lake elsewhere. If a Big Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Big Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Big Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

<u>Management Action:</u> Monitor water quality through WDNR Citizens Lake Monitoring Network.

Description: Currently, Big Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Big Lake is protected. Volunteers from Big Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

<u>Management Action:</u> Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

<u>Management Action:</u> Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Big Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while 33% is of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: As mentioned within the Chain-wide Implementation Plan, photographic evidence of sporadic blue-green algae blooms in Big Lake was discussed during planning meetings associated with this project. To begin understanding dynamics that may play a role in production of these algal blooms, further studies are needed to quantify nutrient inputs to the lake.

The TLWA, in coordination with Big Lake stakeholders, will retain a professional consultant to investigate nutrient contributions to the lake through tributary streams.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on Dog Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.5 Dog Lake

An Introduction to Dog Lake

Dog Lake, Oneida County, is a lowland drainage lake with a maximum depth of 22 feet and a surface area of 216 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Dog Lake contains 32 native plant species, of which wild celery was the most common plant. No exotic plants were observed during the 2011 lake surveys.

Field Survey Notes

Unusually large community of water horsetail (Equisetum fluviatile) encountered during aquatic plant surveys (pictured at right).

Photo 8.5.1 Dog Lake, Oneida County

Lake at a Glance* – Dog Lake

Morphology	
Acreage	216
Maximum Depth (ft)	22
Mean Depth (ft)	8
Volume (acre-feet)	1,710
Shoreline Complexity	3.2
Vegetation	
Curly-leaf Survey Date	June 21, 2011
Comprehensive Survey Date	August 9, 2011
Number of Native Species	32
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.88
Average Conservatism	6.7
Water Quality	
Wisconsin Lake Classification	Shallow, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	210:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.5.1 Dog Lake Water Quality

During 2011/2012, water quality data was collected from Dog Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Additionally, historical databases were searched for any prior data that may have been collected on Dog Lake. Unfortunately, Secchi disk clarity data had been collected only sporadically on Dog Lake in the past, making a long term trend analysis difficult. However, it is possible to make some comparisons from recent data to that which was collected years ago.

Dog Lake total phosphorus and chlorophyll-*a* values can be found in Table 8.5.1-1. In 2011, summer total phosphorus concentrations averaged 31.7 µg/L, which is slightly lower than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 µg/L). The 2011 average summer chlorophyll-*a* concentration (8.8 µg/L) is somewhat lower than the average for other shallow, lowland drainage lakes statewide (median = 9.4 µg/L). The total phosphorus average ranks as *Good* in the Trophic State Index, while the chlorophyll-*a* average value ranks as *Excellent*.

Table 8.5.1-1. Dog Lake, state-wide shallow, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

	Secchi (feet)				Chlorophyll-*a* (µg/L)				Total Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1979	1	4.0	1	4.0	1	3.6	1	3.6	1	43.0	1.0	43.0
1990	5	5.2	5	5.2								
1991	6	3.0	6	3.0								
1994	6	4.2	4	4.2								
1995	8	4.6	8	4.6								
1996	11	4.3	8	4.4								
2011	5	2.5	3	2.5	5	8.0	3	8.8	5	34.6	3.0	31.7
All Years (Weighted)		4.0		4.1		7.3		7.5		36.0		34.5
Shallow, Lowland Drainage Lakes				5.6				9.4				33.0
NLF Ecoregion				8.9				5.6				21.0

In addition to data collected during 1979 and the 1990's, measurements of Secchi disk clarity were taken in Dog Lake during 2011 field visits as well. A weighted average across all summers ranks as *Good*, however is slightly below the median value for other shallow, lowland drainage lakes in Wisconsin. During the aquatic plant surveys that took place on Dog Lake in 2011, plants were found growing to a maximum depth of six feet; however, the vast majority of plants grew to only five feet of depth. This is an added testament to the low water clarity in Dog Lake.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Dog Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

Dog Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.5.1-1). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Dog Lake is in a eutrophic state.

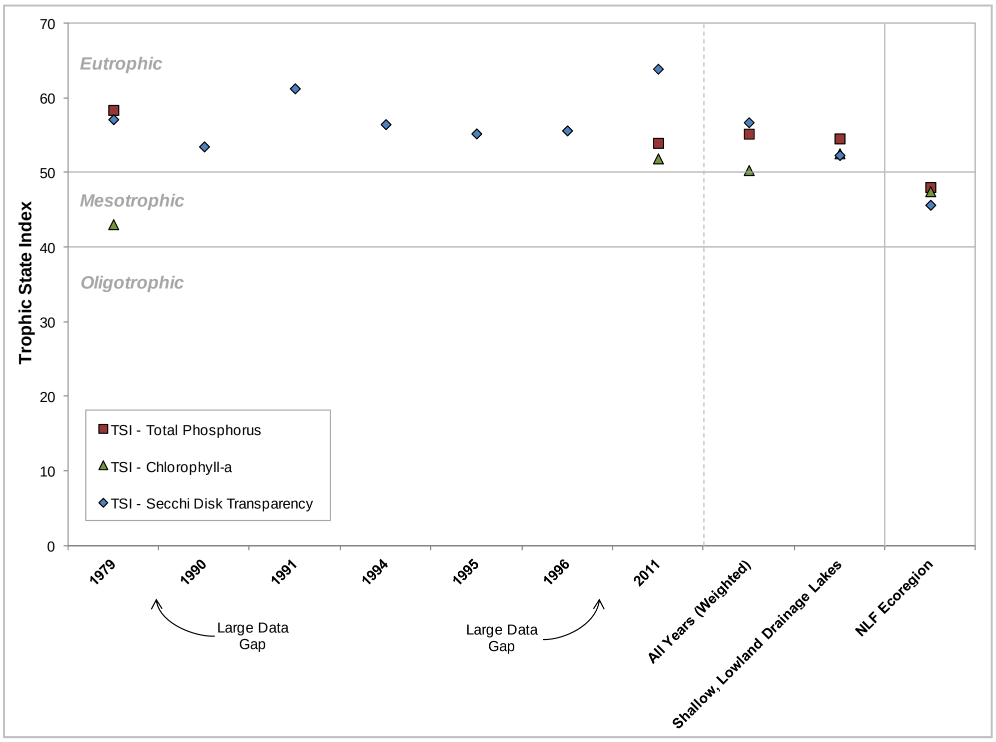

Figure 8.5.1-1. Dog Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Dog Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Dog Lake by Onterra staff. Graphs of those data are displayed in Figure 8.5.1-2 for all sampling events.

Dog Lake remained thoroughly mixed throughout most of the summer months in 2011, though a small amount of stratification likely occurs periodically in the deeper portions of the lake. This is not uncommon in lakes that are moderate in size and depth. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column. Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in July. Despite this late summer dip, dissolved oxygen levels remained sufficient in the upper ~12 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen was also ample during the winter months of 2012, when oxygen may decrease due to ice cover on the lake and lack of oxygen production from plants and algae.

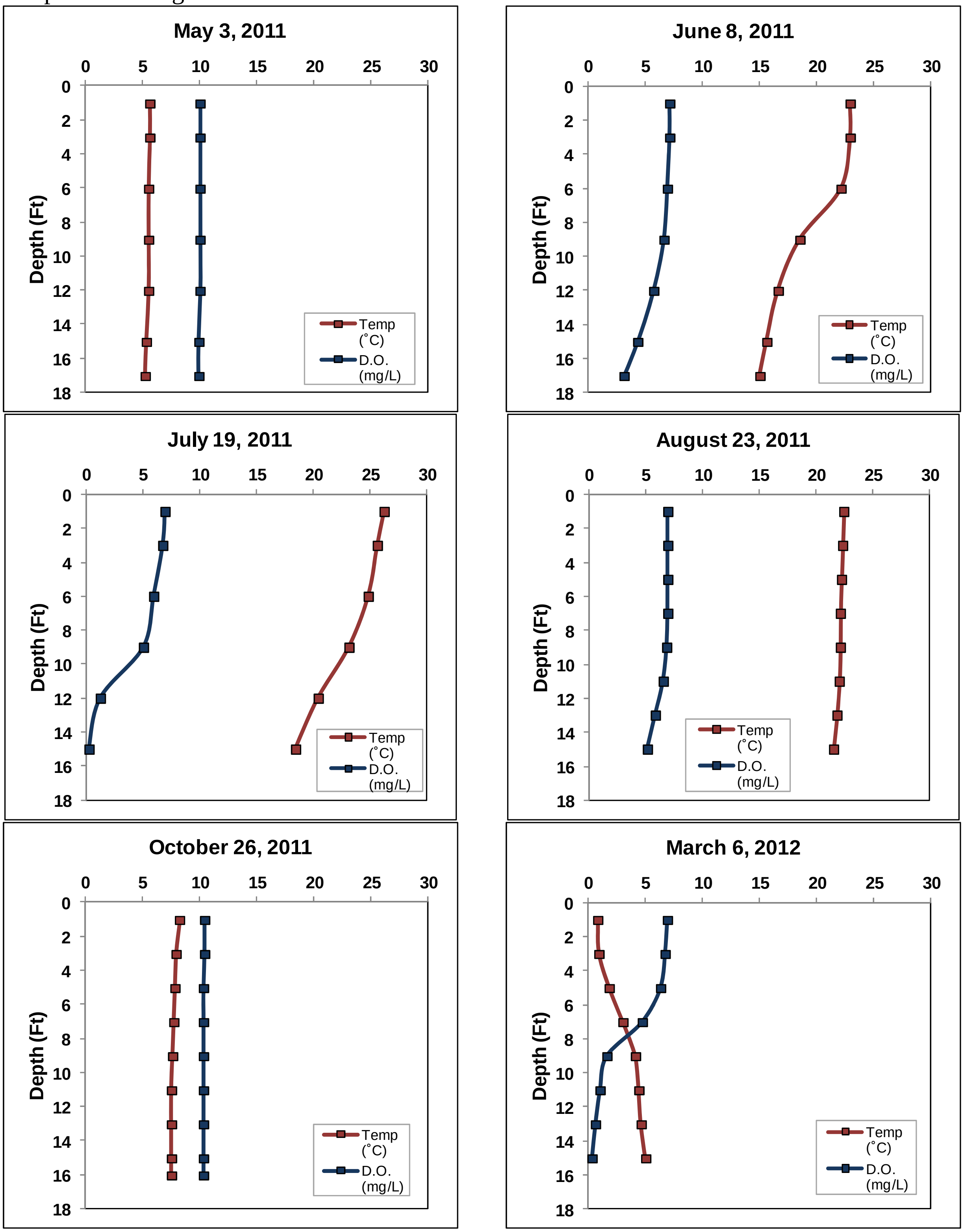

Figure 8.5.1-2. Dog Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Dog Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Dog Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Dog Lake's pH was measured at 7.0 during the summer months in 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Dog Lake was measured at 17.6 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Dog Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Dog Lake's pH of 7.0 is at the bottom end of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Dog Lake was found to be 5.5 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.5.2 Dog Lake Watershed Assessment

Dog Lake's watershed is 45,631 acres in size. Compared to Dog Lake's size of 216 acres, this makes for an incredibly large watershed to lake area ratio of 210:1.

Exact land cover calculation and modeling of nutrient input to Dog Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.5.3 Dog Lake Shoreline Condition

As mentioned previously in the Chain-wide Shoreline Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Dog Lake's immediate shoreline was assessed in terms of its development. Dog Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.0 miles of natural/undeveloped and developed-natural shoreline (54% of the entire shoreline) were observed during the survey (Figure 8.5.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.0 miles of urbanized and developed–unnatural shoreline (26% of the total shoreline) was observed. If restoration of the Dog Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. The Dog Lake Map 1 displays the location of these shoreline lengths around the entire lake.

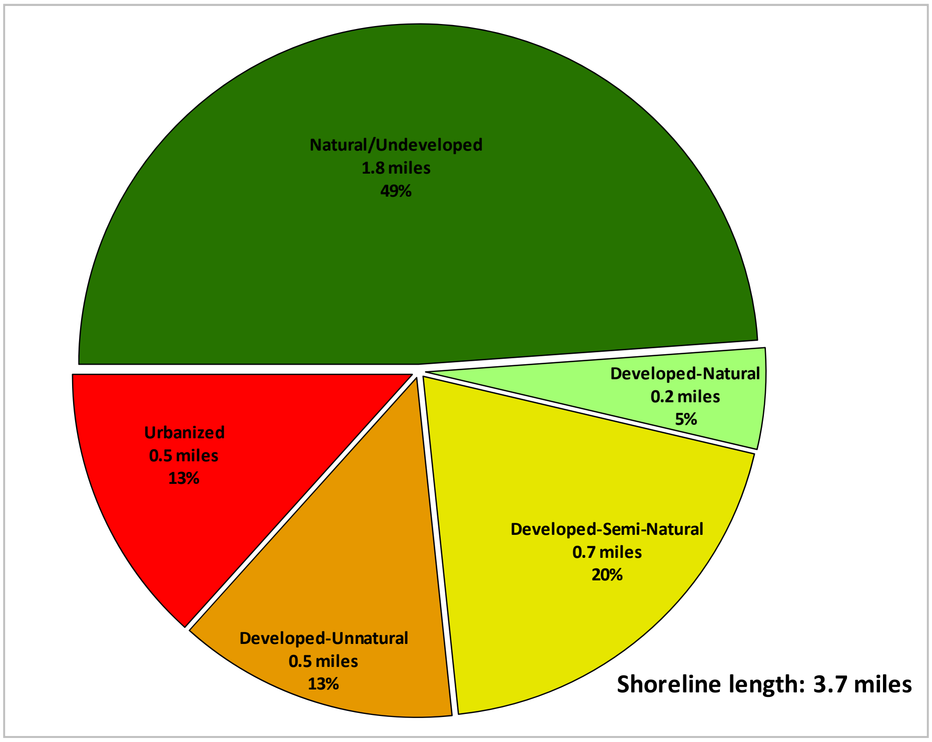

Figure 8.5.3-1. Dog Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Dog Lake Map 1.

8.5.4 Dog Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Dog Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Dog Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Dog Lake on August 9, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 9 & 10 to create the aquatic plant community map (Dog Lake Map 2). During all surveys, 32 species of native aquatic plants were located in Dog Lake (Table 8.5.4-1). 21 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of six feet, which is common within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 116 point-intercept locations sampled within the littoral zone, approximately 56% contained aquatic vegetation. Approximately 75% of the point-intercept sampling locations where sediment data was collected at were sand, 24% consisted of a fine, organic substrate (muck) and no areas of rocky substrate were encountered (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.5.4-1. Aquatic plant species located in the Dog Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	Acorus calamus	Sweetflag	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Equisetum fluviatile	Water horsetail	7	X
	Eleocharis palustris	Creeping spikerush	6	X
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
	Zizania palustris	Northern wild rice	8	X
FL	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
FL/E	Sparganium emersum	Short-stemmed bur-reed	8	I
	Sparganium eurycarpum	Common bur-reed	5	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	Elodea canadensis	Common waterweed	3	X
	Isoetes sp.	Quilwort species	N/A	X
	Myriophyllum sibiricum	Northern water milfoil	7	I
	Najas flexilis	Slender naiad	6	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	Eleocharis acicularis	Needle spikerush	5	X

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

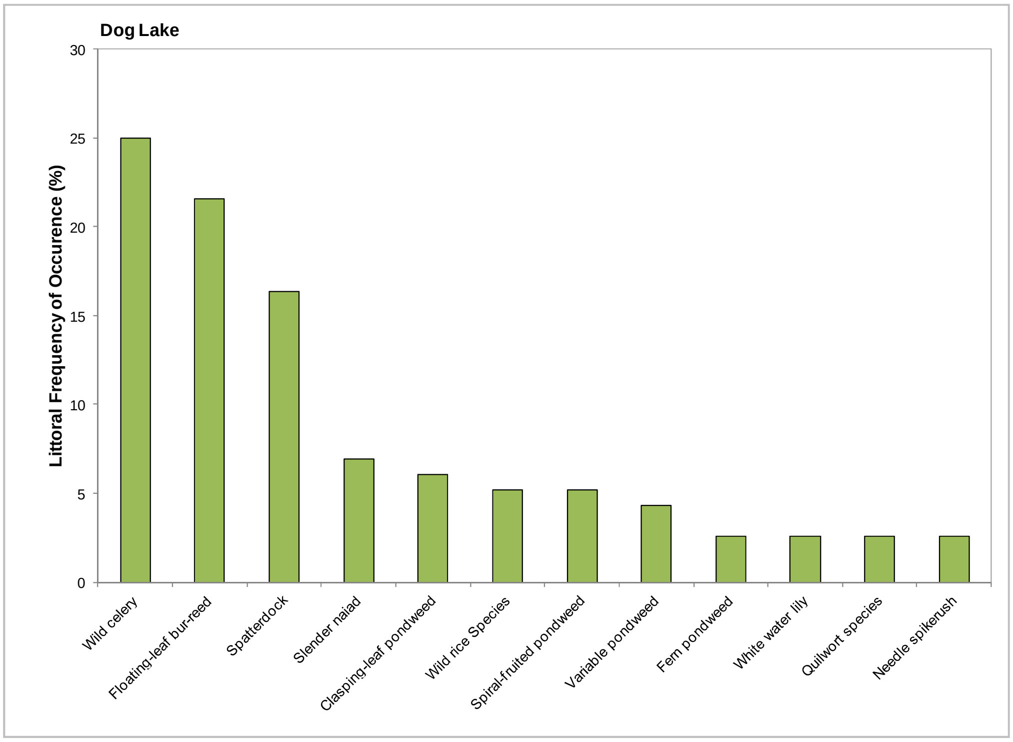

Figure 8.5.4-1 Dog Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 2.5% only. Created using data from a 2011 point-intercept survey.

Figure 8.5.4-1 (above) shows that wild celery, floating-leaf bur-reed and spatterdock were the most commonly encountered species during the point-intercept survey. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Floating-leaf bur-reed is an aquatic plant which includes long (2.5 to 5 ft) stems and long (2 to 3.25 ft) linear, ribbon-like leaves. Several species of bur-reed exist in Wisconsin, and while some differences exist in the leaves of these plants, the best way to differentiate between them is by the characteristics of their fruits. Spatterdock is a rooted, floating-leaved plant with heart-shaped leaves and a bright yellow roundish flower in the summer months. This plant provides shade, cover from predators, and a source of food for several species of mammals such as waterfowl, muskrat, beaver, and deer.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was found within Dog Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

32 species of aquatic plants (including incidentals) were found in Dog Lake 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 influence the diversity. The diversity index for Dog Lake's plant community (0.88) lies slightly above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake has good diversity in its plant community.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at 25% of the sampling locations, its relative frequency of occurrence is 23%. Explained another way, if 100 plants were randomly sampled from Dog Lake, 23 of them would be wild celery. This distribution can be observed in Figure 8.5.4-2, where together 10 species account for 71% of the population of plants within Dog Lake, while the other 23 species account for the remaining 29%. Fifteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.5.4-1 as incidentals.

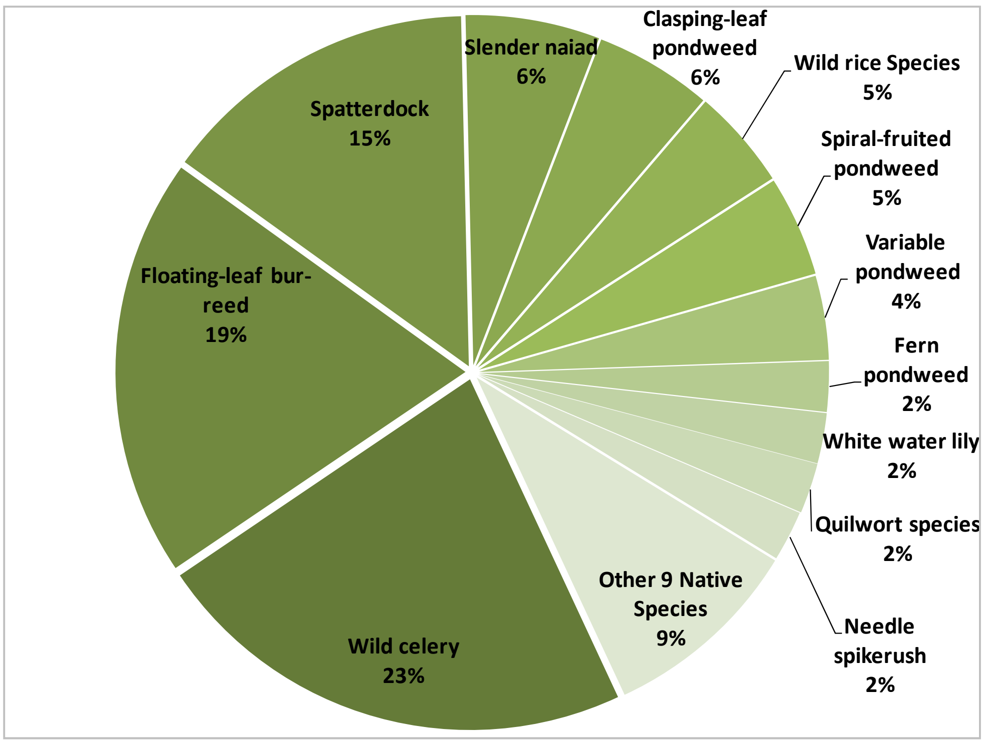

Figure 8.5.4-2 Dog Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Dog Lake's average conservatism value (6.7) is equal to the ecoregion but larger than the state-wide median. This indicates that the plant community of Dog Lake is indicative of a moderately undisturbed system. This is not surprising considering Dog Lake's plant community has good diversity and high species richness. Combining Dog Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 30.5 which is above the median values of the ecoregion and state.

The quality of Dog Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 41.6 acres of the lake contains these types of plant communities (Dog Lake Map 2, Table 8.5.4-2). Seventeen floating-leaf and emergent species were located on Dog Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.5.4-2. Dog Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	6.3
Floating-leaf	15.0
Mixed Floating-leaf and Emergent	20.3
Total	41.6

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Dog Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to 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.

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8.5.5 Dog Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Dog Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Dog Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Dog Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Dog Lake's implementation plan is compiled by describing how Dog Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Dog Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: While Dog Lake does not have a public access point, it is directly connected to the rest of the Three Lakes Chain of Lakes via Big Lake and Deer Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Dog Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Dog Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Dog Lake or from Dog Lake elsewhere. If a Dog Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

<u>Management Action:</u> Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Dog Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Dog Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

<u>Management Action:</u> Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Dog Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Dog Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

<u>Management Action:</u> Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Dog Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: Currently, no volunteer water quality collection is occurring on Dog Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Dog Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Dog Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Dog Lake shoreline was categorized in terms of its development. According to the results from this survey, 49% of the shoreline is currently in a natural state, while 26% is in an urban or developed-unnatural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Dog Lake.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Dog Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Dog Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on Crystal (Mud) Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.6 Crystal (Mud) Lake

An Introduction to Crystal (Mud) Lake

Crystal (Mud) Lake, Oneida County, is a drainage lake with a maximum depth of nine feet and a surface area of 124 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Crystal (Mud) Lake contains 26 native plant species, of which floating-leaf bur-reed was the most common plant. No exotic plants were observed during the 2011 lake surveys.

Field Survey Notes

A shallow, dark lake consisting primarily of mucky substrate. Few sampling locations held aquatic plants. No exotic aquatic plant species observed during 2011 field work.

Photo 8.6.1 Crystal (Mud) Lake, Oneida County

Lake at a Glance* – Crystal (Mud) Lake

Morphology	
Acreage	124
Maximum Depth (ft)	9
Mean Depth (ft)	5
Volume (acre-feet)	648
Shoreline Complexity	3.0
Vegetation	
Curly-leaf Survey Date	June 22, 2011
Comprehensive Survey Date	August 4 & 5, 2011
Number of Native Species	26
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.80
Average Conservatism	6.4
Water Quality	
Wisconsin Lake Classification	Shallow, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	63:1

These parameters/surveys are discussed within the Chain-wide portion of the management plan.

8.6.1 Crystal (Mud) Lake Water Quality

During 2011/2012, water quality data was collected from Crystal (Mud) Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Additionally, historical databases were searched for any prior data that may have been collected on Crystal (Mud) Lake. Only a single historical record was turned up for each of the three water quality parameters – in 1979. No additional data was discovered, leaving only the 2011/2012 data available for analysis.

Crystal (Mud) Lake total phosphorus and chlorophyll-*a* values can be found in Table 8.6.1-1. In 2011, summer total phosphorus concentrations averaged 72.0 µg/L, which is considerably higher than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 µg/L). The 2011 average summer chlorophyll-*a* concentration (5.9 µg/L) is somewhat lower than the average for other shallow, lowland drainage lakes statewide (median = 9.4 µg/L). The total phosphorus average ranks as *Fair* within the WiSCALM narrative, while the chlorophyll-*a* average value ranks as *Excellent*.

Measurements of Secchi disk clarity were taken in Crystal (Mud) Lake during 2011 field visits as well. The summer average was 1.5 feet, ranking as *Poor* within the Trophic State Index and falling below the median for other Wisconsin shallow, lowland drainage lakes (5.6 feet). It is interesting to note that while total phosphorus values are exceptionally high, an elevated abundance of algae was not picked up through chlorophyll-*a* sampling. It is possible that the water clarity of the lake is limiting the algal and plant growth, more so than the abundance of nutrients, which are sufficient for algae and plant growth. During the aquatic plant surveys that took place on Crystal (Mud) Lake in 2011, plants were found growing to a maximum depth of seven feet; however, the vast majority of plants grew to only 4 feet of depth. This is an added testament to the *Poor* water clarity in Crystal (Mud) Lake.

Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Crystal (Mud) Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Crystal (Mud) Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

Table 8.6.1-1. Crystal (Mud) Lake, state-wide shallow, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

	Secchi (feet)				Chlorophyll-a (µg/L)				Total Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1979	1	1.5	1	1.5	1	5.2	1	5.2	1	13.0	1.0	13.0
2011	5	1.6	3	1.5	5	7.8	3	5.9	5	70.8	3.0	72.0
All Years (Weighted)		1.6		1.5		7.3		5.7		61.2		57.3
Shallow, Lowland Drainage Lakes				5.6				9.4				33.0
NLF Ecoregion				8.9				5.6				21.0

Crystal Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values fall into categories of mesotrophic (chlorophyll-*a*) and eutrophic (phosphorus and Secchi disk clarity). Values above 50 are generally classified as being within the eutrophic category; two of Crystal (Mud) Lake's water quality parameters fall above this benchmark (Table 8.6.1-2). Therefore, it can be concluded that Crystal (Mud) Lake is in a eutrophic state.

Table 8.6.1-2. Crystal (Mud) Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Year	TP	Chl-a	Secchi
1979	41.1	46.8	71.3
2011	65.8	48.0	71.3
All Years (Weighted)	62.5	47.7	71.3
Shallow, Lowland Drainage Lakes	54.6	52.6	52.4
NLF Ecoregion	48.1	47.5	45.7

Dissolved Oxygen and Temperature in Crystal (Mud) Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Crystal (Mud) Lake by Onterra staff. Graphs of those data are displayed in Figure 8.6.1-1 for all sampling events.

Crystal (Mud) Lake remained thoroughly mixed throughout the spring, summer and fall months in 2011. This is not uncommon in lakes that are moderate in size and fairly shallow. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

Dissolved oxygen concentrations remained sufficient throughout the open water months for warm water fish species. In the winter months, when ice cover and limited oxygen production from plants reduces oxygen content of the water, there is often concern that the levels of oxygen may dip below what is necessary for fish in the lake. Although oxygen concentrations decreased near the bottom of Crystal (Mud) Lake, levels remained high enough in the upper half of the water column.

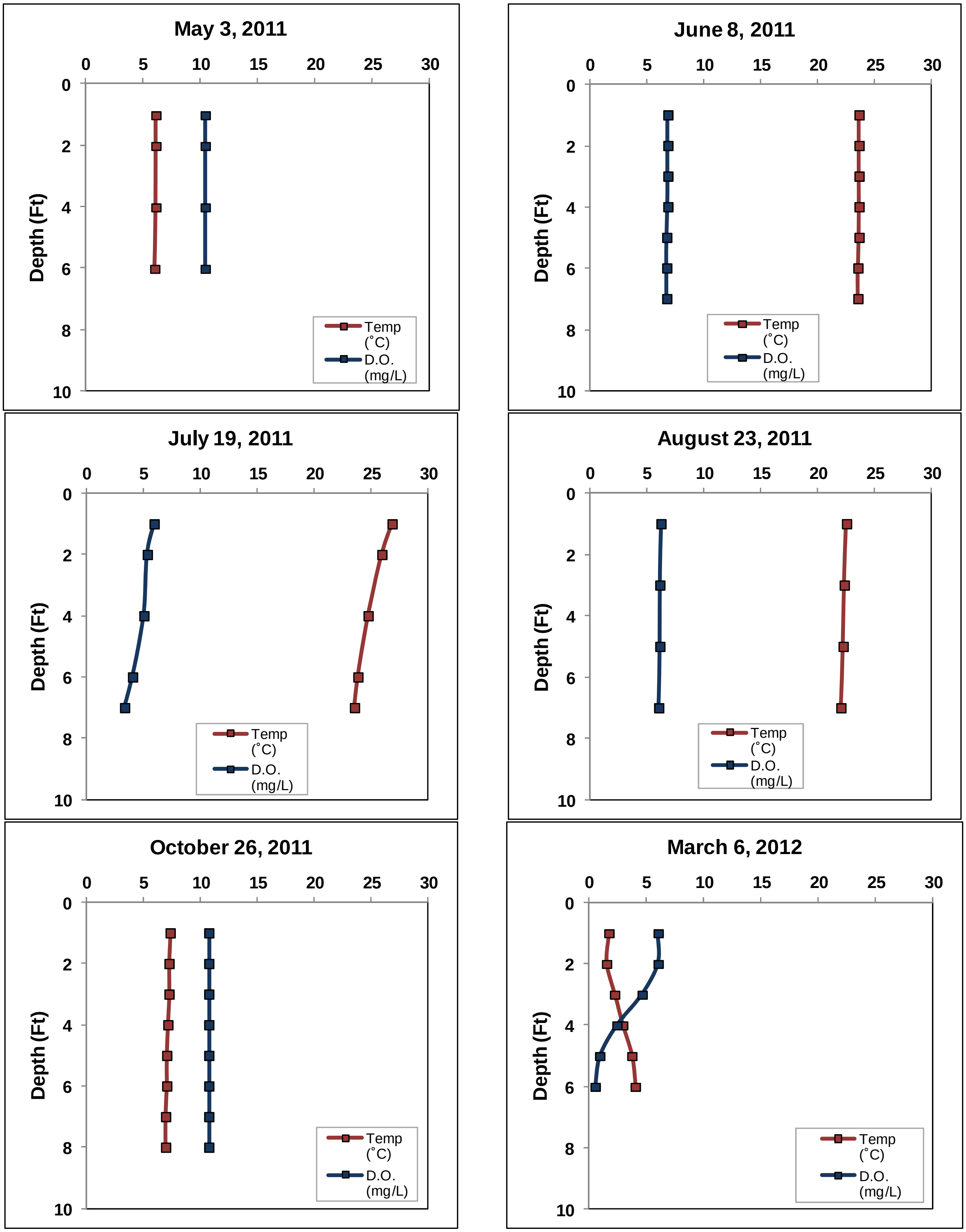

Figure 8.6.1-1. Crystal (Mud) Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Crystal (Mud) Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Crystal (Mud) Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Crystal (Mud) Lake's pH was measured at 6.8 in the summer months of 2011. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Crystal (Mud) Lake was measured at 15.9 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Crystal (Mud) Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Crystal (Mud) Lake's pH of 6.8 falls slightly outside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Crystal (Mud) Lake was found to be 4.2 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.6.2 Crystal (Mud) Lake Watershed Assessment

Crystal (Mud) Lake's watershed is 7,964 acres in size. Compared to Crystal (Mud) Lake's size of 124 acres, this makes for an incredibly large watershed to lake area ratio of 63:1.

Exact land cover calculation and modeling of nutrient input to Crystal (Mud) Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.6.3 Crystal (Mud) Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Crystal (Mud) Lake's immediate shoreline was assessed in terms of its development. Crystal (Mud) Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.8 miles of natural/undeveloped and developed-natural shoreline (66% of the entire shoreline) were observed during the survey (Figure 8.6.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.3 miles of urbanized and developed–unnatural shoreline (12% of the total shoreline) was observed. If restoration of the Crystal (Mud) Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. The Crystal (Mud) Lake Map 1 displays the location of these shoreline lengths around the entire lake.

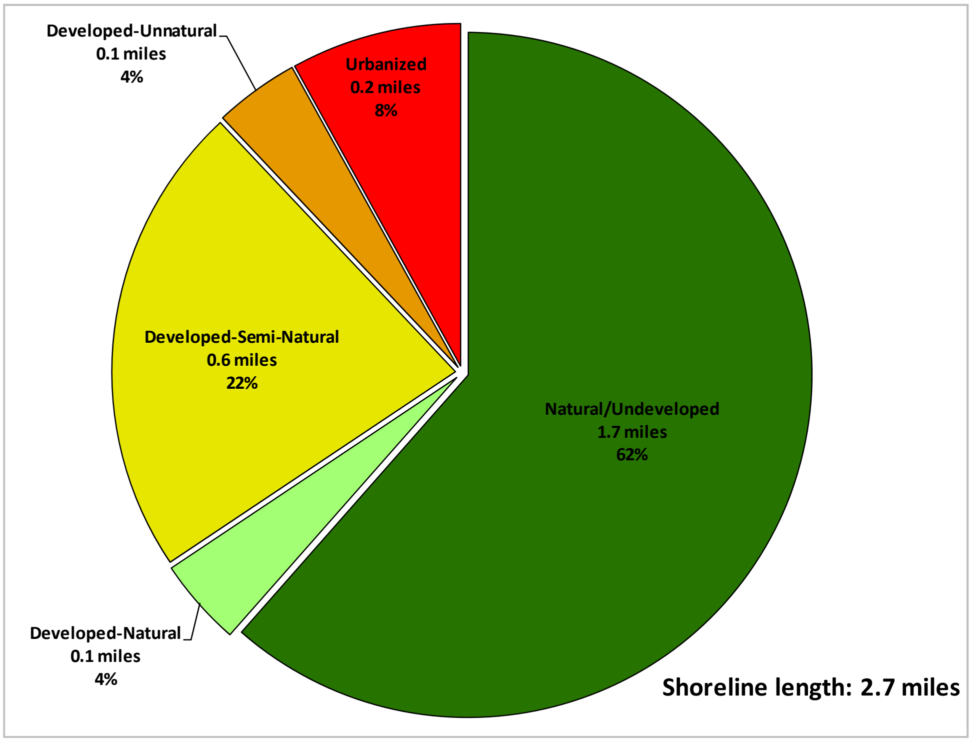

Figure 8.6.3-1. Crystal (Mud) Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Crystal (Mud) Lake Map 1.

8.6.4 Crystal (Mud) Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Crystal (Mud) Lake on June 22, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Crystal (Mud) Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Crystal (Mud) Lake on August 4 & 5, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 8th to create the aquatic plant community map (Crystal (Mud) Lake Map 2). During all surveys, 26 species of native aquatic plants were located in Crystal (Mud) Lake (Table 8.6.4-1). 12 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of seven feet, which is comparable to the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and moderately diverse.

Of the 174 point-intercept locations sampled within the littoral zone, approximately 24% contained aquatic vegetation. Approximately 9% of the point-intercept sampling locations where sediment data was collected at were sand, 91% consisted of a fine, organic substrate (muck) while no rocky substrate was encountered (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.6.4-1. Aquatic plant species located in the Crystal (Mud) Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	*I*
	Dulichium arundinaceum	Three-way sedge	9	*I*
	Decodon verticillatus	Water-willow	7	*I*
	Eleocharis palustris	Creeping spikerush	6	*I*
	Iris versicolor	Northern blue flag	5	*I*
	Pontederia cordata	Pickerelweed	9	*X*
	Sagittaria latifolia	Common arrowhead	3	*I*
	Schoenoplectus tabernaemontani	Softstem bulrush	4	*I*
	Scirpus cyperinus	Wool grass	4	*I*
	Typha spp.	Cattail spp.	1	*I*
	Zizania palustris	Northern wild rice	8	*I*
FL	*Brasenia schreberi*	Watershield	7	*I*
	Nuphar variegata	Spatterdock	6	*X*
	Nymphaea odorata	White water lily	6	*X*
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	*I*
	Sparganium emersum	Short-stemmed bur-reed	8	*I*
	Sparganium fluctuans	Floating-leaf bur-reed	10	*X*
Submergent	*Ceratophyllum demersum*	Coontail	3	*X*
	Myriophyllum sibiricum	Northern water milfoil	7	*X*
	Potamogeton robbinsii	Fern pondweed	8	*X*
	Potamogeton zosteriformis	Flat-stem pondweed	6	*X*
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	*X*
	Potamogeton richardsonii	Clasping-leaf pondweed	5	*X*
	Utricularia vulgaris	Common bladderwort	7	*X*
FF	*Lemna turionifera*	Turion duckweed	2	*X*
	Spirodela polyrhiza	Greater duckweed	5	*I*

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

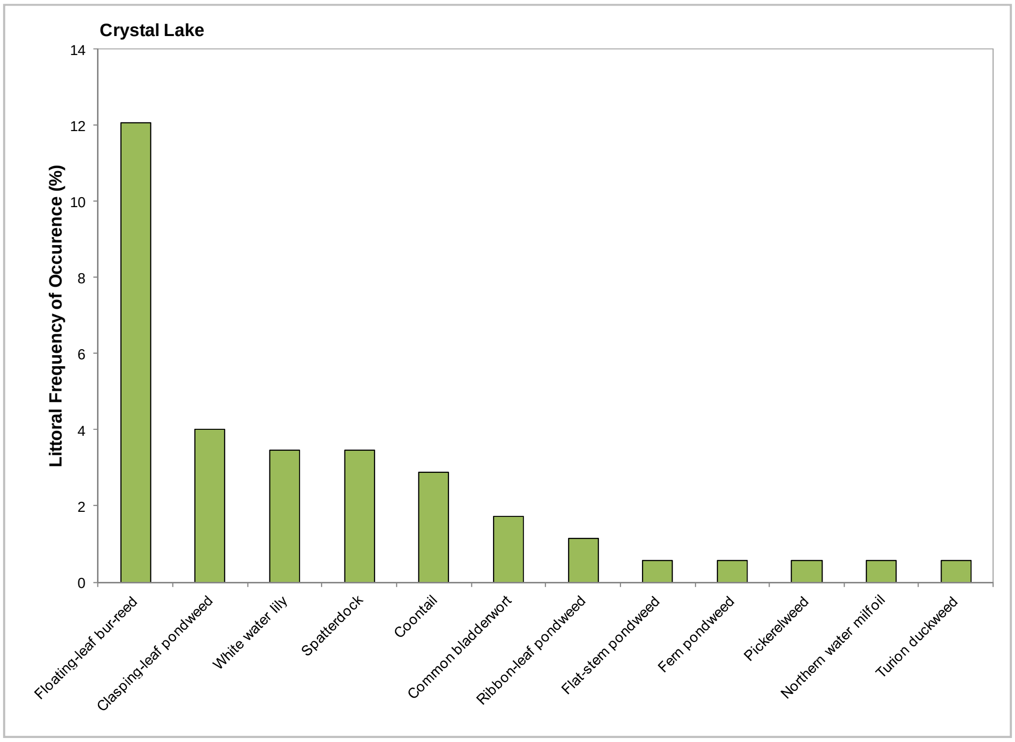

Figure 8.6.4-1 Crystal (Mud) Lake aquatic plant littoral frequency of occurrence analysis. Chart includes all species encountered during the 2011 point-intercept survey.

Figure 8.6.4-1 (above) shows that floating-leaf bur-reed, clasping-leaf pondweed were the two species encountered most within the point-intercept survey. White water lily and spatterdock were encountered often as well. Floating-leaf bur-reed is an aquatic plant which includes long (2.5 to 5 ft) stems and long (2 to 3.25 ft) linear, ribbon-like leaves. Several species of bur-reed exist in Wisconsin, and while some differences exist in the leaves of these plants, the best way to differentiate between them is by the characteristics of their fruits. Clasping-leaf pondweed has oval to somewhat lance-shaped leaves that "clasp" around one-half to three-quarters of the stem circumference. Leaves have 13-21 veins, which is a good characteristic to use in distinguishing this plant from other similar looking plants in the genus *Potamogeton*. White water lily and spatterdock are floating-leaf plants that are commonly found near the shoreline on Wisconsin lakes. White water lilies, as the name implies, are round in shape and produce a white flower. Spatterdock leaves resemble a heart shape and produce yellow roundish flowers in the summer months.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was found within Crystal (Mud) Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

26 species of aquatic plants (including incidentals) were found in Crystal (Mud) Lake 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 influence the diversity. The diversity index for Crystal (Mud) Lake's plant community (0.80) lies below the Northern Lakes and Forests Lakes ecoregion median value (0.86).

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while floating-leaf bur-reed was found at 12% of the sampling locations, its relative frequency of occurrence is 38%. Explained another way, if 100 plants were randomly sampled from Crystal (Mud) Lake, 38 of them would be floating-leaf bur-reed. Floating-leaf bur-reed is therefore relatively dominant compared to other species within the lake. This distribution can be observed in Figure 8.6.4-2, where together seven species account for 91% of the population of plants within Crystal (Mud) Lake, while the other five species account for the remaining 9%. Fourteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.6.4-1 as incidentals.

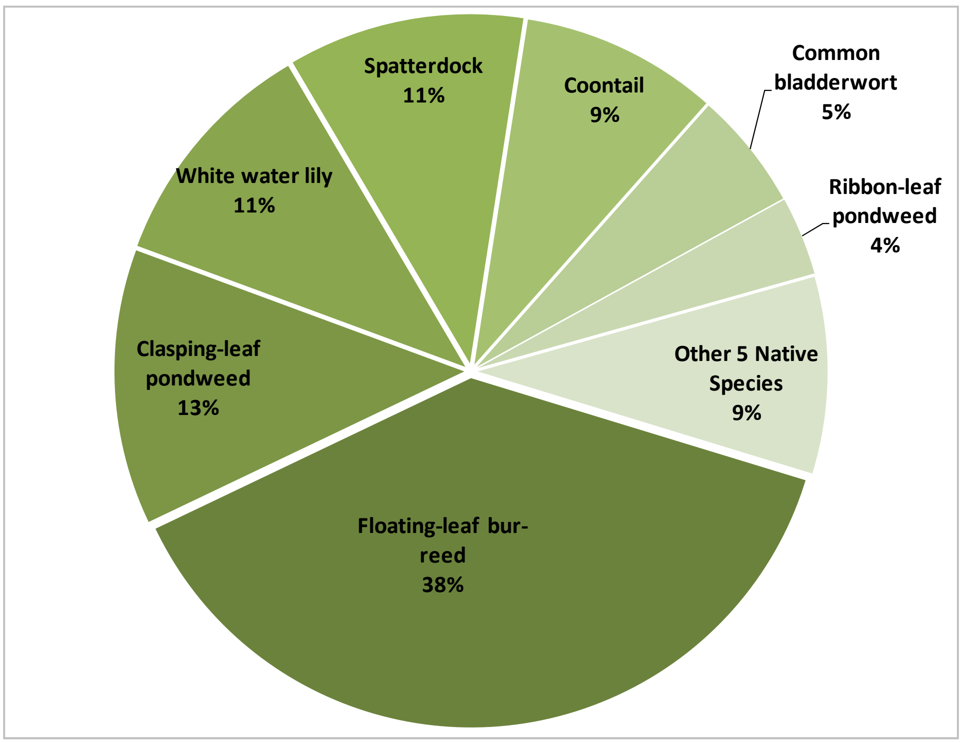

Figure 8.6.4-2 Crystal (Mud) Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Crystal (Mud) Lake's average conservatism value (6.4) is lower than the ecoregion median, but higher than the state median. This indicates that the plant community of Crystal (Mud) Lake is indicative of moderately disturbed system. This is not surprising considering Crystal (Mud) Lake's plant community has moderate diversity and low species richness. Combining Crystal (Mud) Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 22.2 which is below the median value of the ecoregion and equal to the state median value.

Crystal (Mud) Lake holds numerous areas of emergent and floating-leaf plant communities. The 2011 community map indicates that approximately 19.3 acres of the lake contains these types of plant communities (Crystal (Mud) Lake Map 2, Table 8.6.4-2). Fifteen floating-leaf and emergent species were located on Crystal (Mud) Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.6.4-2. Crystal (Mud) Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	2.6
Floating-leaf	14.7
Mixed Floating-leaf and Emergent	2.0
Total	19.3

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Crystal (Mud) Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to 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.

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8.6.5 Crystal (Mud) Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Crystal (Mud) Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Crystal (Mud) Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Crystal (Mud) Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Crystal (Mud) Lake's implementation plan is compiled by describing how Crystal (Mud) Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Crystal (Mud) Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Crystal (Mud) Lake contains a single public access and is directly connected to the rest of the Three Lakes Chain of Lakes via Deer Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Crystal (Mud) Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Crystal (Mud) Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Crystal (Mud) Lake or from Crystal (Mud) Lake elsewhere. If a Crystal (Mud) Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Crystal (Mud) Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Crystal (Mud) Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Crystal (Mud) Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Crystal (Mud) Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Crystal (Mud) Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: Currently, no volunteer water quality collection is occurring on Crystal (Mud) Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Crystal (Mud) Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Crystal (Mud) Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Crystal (Mud) Lake shoreline was categorized in terms of its development. According to the results from this survey, 62% of the shoreline is currently in a natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

Restoring areas of the Crystal (Mud) Lake shoreline is not imperative due to its already largely natural state, so educating riparian property owners on the benefits of conserving this natural land may be of more importance. However, if property owners are interested in restoring their property's shoreline a plan has been put into place to do so. The

TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: As mentioned within the Chain-wide Implementation Plan, evidence of elevated nutrient levels in Crystal (Mud) Lake was discussed during planning meetings associated with this project. To begin understanding dynamics that may play a role in producing these high nutrient levels, further studies are needed to quantify nutrient inputs to the lake.

The TLWA, in coordination with Crystal (Mud) Lake stakeholders, will retain a professional consultant to investigate nutrient contributions to the lake through its tributary stream.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Crystal (Mud) Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Crystal (Mud) Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on Deer Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.7 Deer Lake

An Introduction to Deer Lake

Deer Lake, Oneida County, is a drainage lake with a maximum depth of 20 feet and a surface area of 177 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Deer Lake contains 38 native plant species, of which white water lily was the most common plant. No exotic plants were observed during the 2011 lake surveys.

Field Survey Notes

Navigation tricky on west side of lake, where shallow water and thick floating-leaf aquatic plants were commonly encountered. Dark, stained water observed during surveys.

Photo 8.7.1 Deer Lake, Oneida County

Lake at a Glance* – Deer Lake

Morphology	
Acreage	177
Maximum Depth (ft)	20
Mean Depth (ft)	10
Volume (acre-feet)	1,794
Shoreline Complexity	9.7
Vegetation	
Curly-leaf Survey Date	June 21, 2011
Comprehensive Survey Date	August 4 & 9, 2011
Number of Native Species	38
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.89
Average Conservatism	6.3
Water Quality	
Wisconsin Lake Classification	Shallow, lowland drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	306:1

These parameters/surveys are discussed within the Chain-wide portion of the management plan.

8.7.1 Deer Lake Water Quality

During 2011/2012, water quality data was collected from Deer Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water clarity since 2006, and various volunteers and agencies have taken Secchi readings on Deer Lake in the late 1980's and mid 1990's also (Figure 8.7.1-1). These efforts provide a database of historical clarity data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Deer Lake. Unfortunately, only Secchi disk clarity has been monitored in the past, as monitoring for total phosphorus and chlorophyll-*a* requires additional sampling and funding and has not been sampled besides dates in 1979 and 2011.

In 2011, summer total phosphorus concentrations averaged 32.3 μg/L, which is slightly lower than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 μg/L). 2011 average summer chlorophyll-*a* concentrations (11.0 μg/L) are somewhat higher than the median for other shallow, lowland drainage lakes statewide (9.4 μg/L). Both the total phosphorus and chlorophyll-*a* average concentrations rank as *Good* in the Trophic State Index.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters, and show some variance between years (Figure 8.7.1-1). Summer averages fall mostly within categories of *Fair* and *Good*, and a weighted average across all years is less than the average for shallow, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Deer Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Deer Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. In 2011, aquatic plants were found growing to a depth of only six feet within the lake.

Deer Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.7.1-2). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Deer Lake is in a eutrophic state.

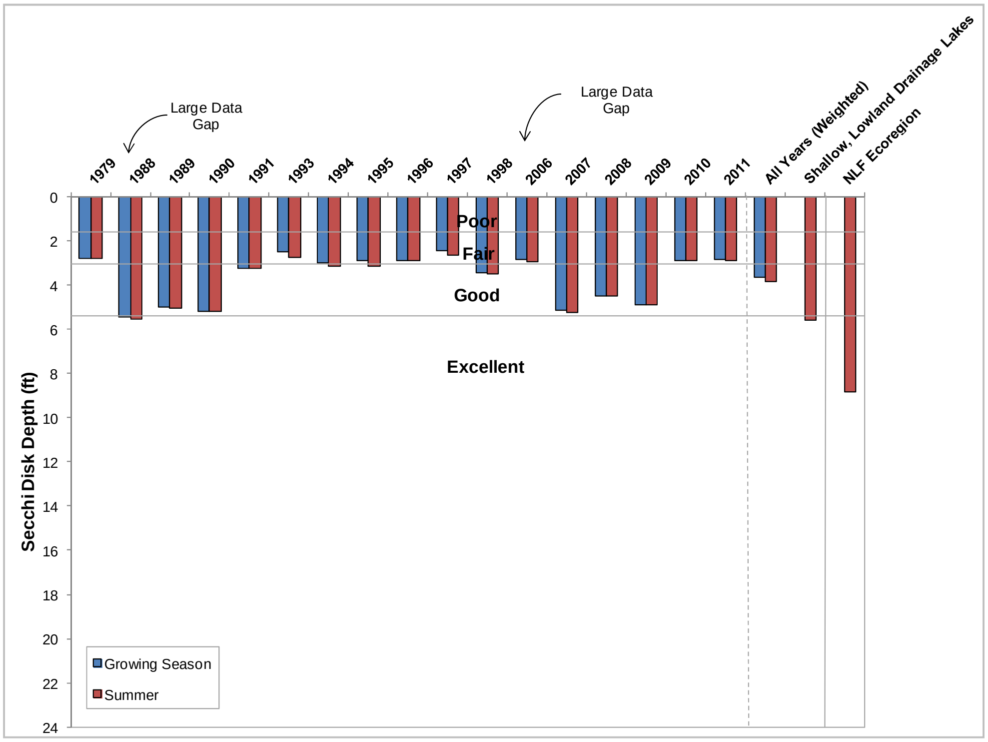

Figure 8.7.1-1. Deer Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

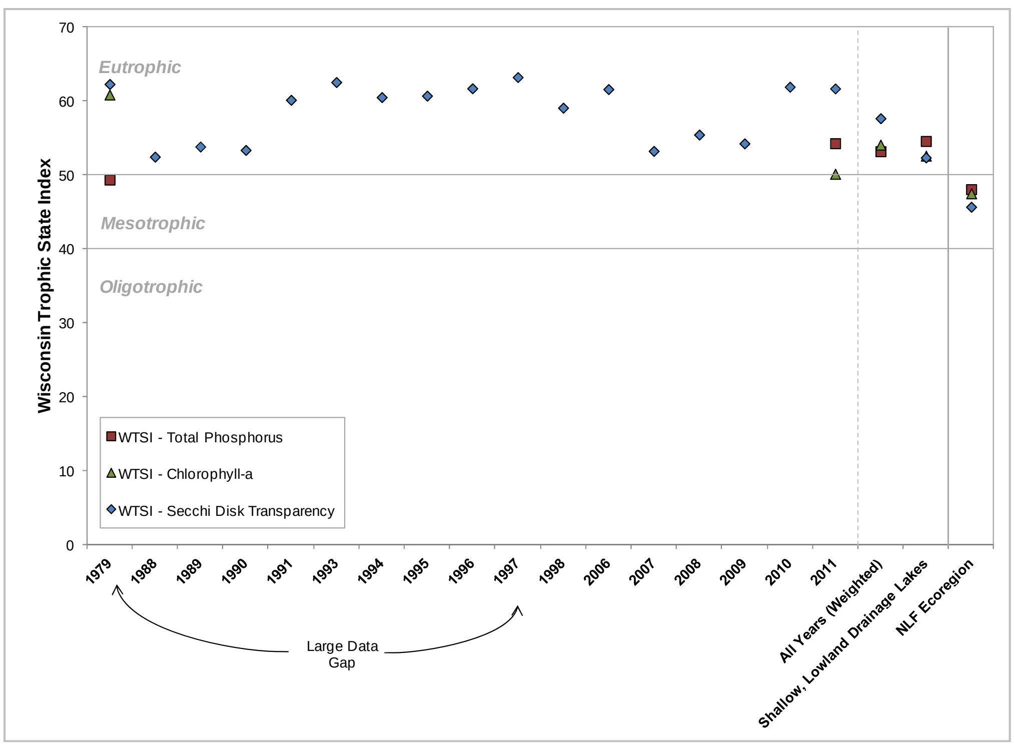

Figure 8.7.1-2. Deer Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Deer Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Deer Lake by Onterra staff. Graphs of those data are displayed in Figure 8.7.1-3 for all sampling events.

Deer Lake remained thoroughly mixed throughout most of the summer months in 2011, though a small amount of stratification likely occurs periodically in the deeper portions of the lake. This is not uncommon in lakes that are moderate in size and depth. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in the summer months. Despite this late summer dip, dissolved oxygen levels remained sufficient in the upper ~13 feet of the water column to support most aquatic life found in northern Wisconsin lakes. In the winter months, when ice cover and limited oxygen production from plants reduces oxygen content of the water, there is often concern that the levels of oxygen may dip below what is necessary for fish in the lake. Although oxygen concentrations decreased near the bottom of Deer Lake, levels remained high enough in the upper half of the water column.

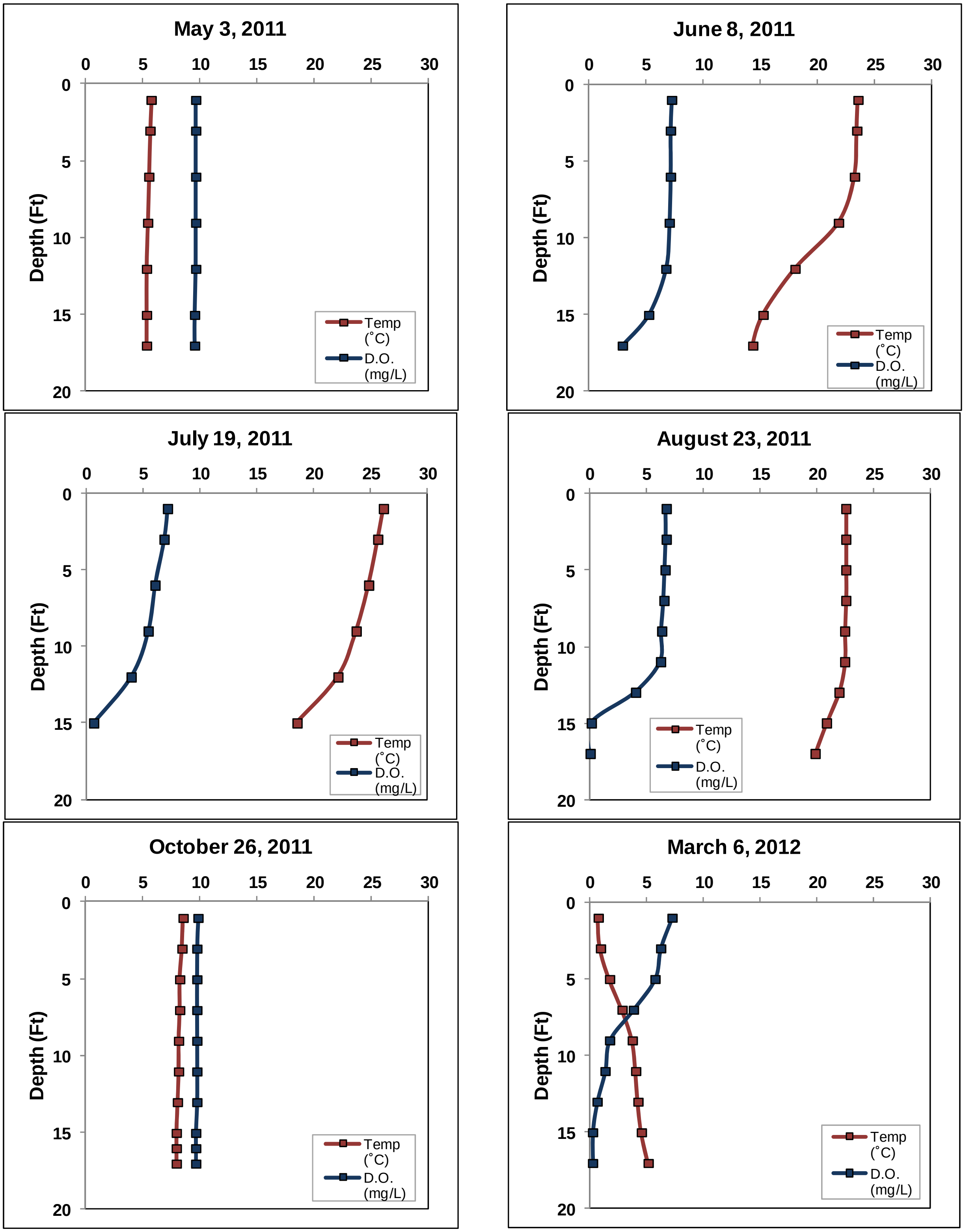

Figure 8.7.1-3. Deer Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Deer Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Deer Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Deer Lake's pH was measured at 7.0 during the summer months in 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Deer Lake was measured at 18.1 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Deer Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Deer Lake's pH of 7.0 is at the bottom end of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Deer Lake was found to be 5.6 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

8.7.2 Deer Lake Watershed Assessment

Deer Lake's watershed is 54,378 acres in size. Compared to Deer Lake's size of 177 acres, this makes for an incredibly large watershed to lake area ratio of 306:1.

Exact land cover calculation and modeling of nutrient input to Deer Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.7.3 Deer Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Deer Lake's immediate shoreline was assessed in terms of its development. Deer Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.9 miles of natural/undeveloped and developed-natural shoreline (50% of the entire shoreline) were observed during the survey (Figure 8.7.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.0 mile of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Deer Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Deer Lake Map 1 displays the location of these shoreline lengths around the entire lake.

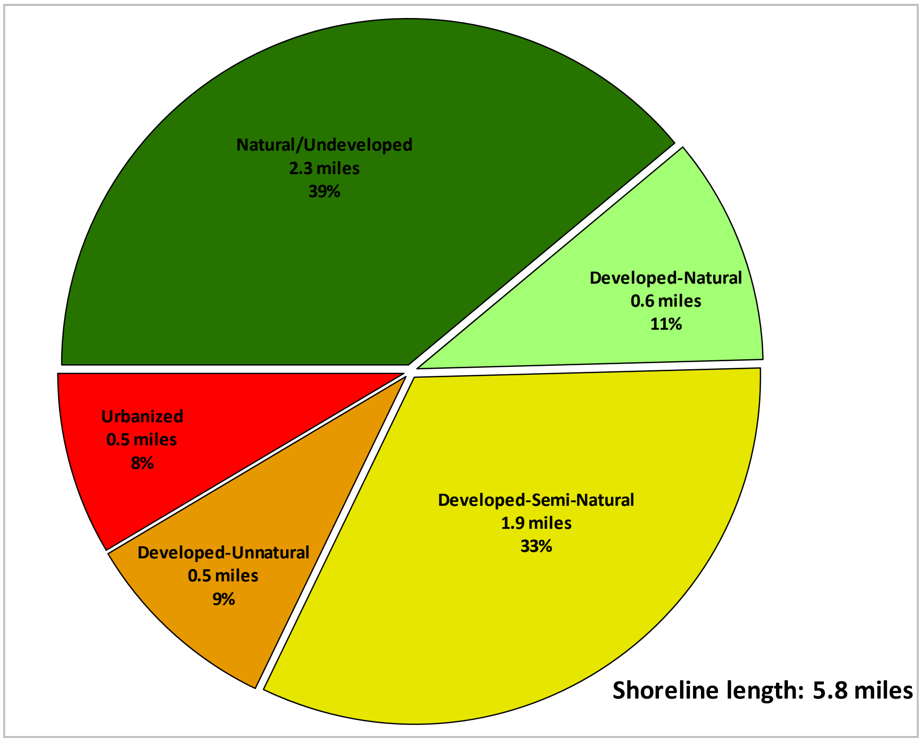

Figure 8.7.3-1. Deer Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Deer Lake Map 1.

8.7.4 Deer Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Deer Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Deer Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Deer Lake on August 4 & 9, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 8 & 9 to create the aquatic plant community map (Deer Lake Map 2). During all surveys, 38 species of native aquatic plants were located in Deer Lake (Table 8.7.4-1). 26 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of six feet, which is comparable to the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 149 point-intercept locations sampled within the littoral zone, approximately 64% contained aquatic vegetation. Approximately 39% of the point-intercept sampling locations where sediment data was collected at were sand, 60% consisted of a fine, organic substrate (muck) and only 1% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.7.4-1. Aquatic plant species located in the Deer Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Eleocharis palustris	Creeping spikerush	6	X
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	X
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	X
	Zizania palustris	Northern wild rice	8	X
FL	*Nuphar variegata*	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Chara spp.*	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elodea canadensis	Common waterweed	3	I
	Elodea nuttallii	Slender waterweed	7	X
	Isoetes sp.	Quilwort species	N/A	X
	Myriophyllum sibiricum	Northern water milfoil	7	I
	Myriophyllum verticillatum	Whorled water milfoil	8	I
	Najas flexilis	Slender naiad	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
FF	*Lemna turionifera*	Turion duckweed	2	I
	Lemna trisulca	Forked duckweed	6	X
	Spirodela polyrhiza	Greater duckweed	5	I

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

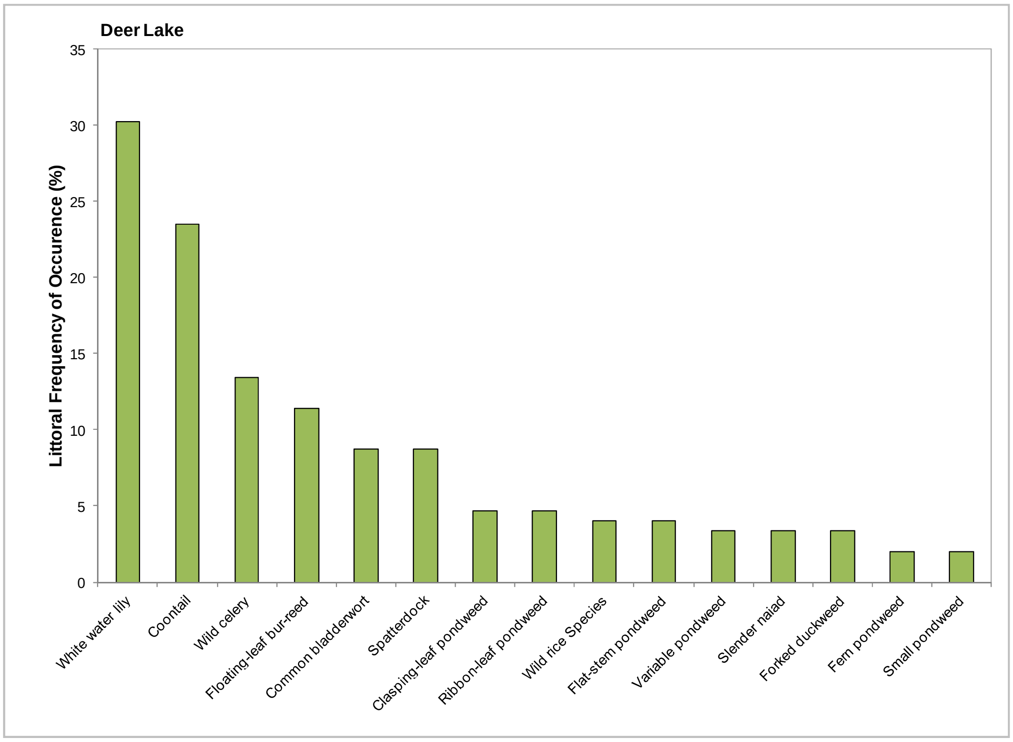

Figure 8.7.4-1 Deer Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.7.4-1 (above) shows that white water lily, coontail and wild celery were the most frequently encountered plants within Deer Lake. White water lily is a floating-leaf species that produces broad, round leaves and a white flower. This plant is common in Wisconsin lakes around the shoreline, and in addition to creating shade for aquatic organisms it also serves as a food source. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making it susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats. Coontail is tolerant to low-light conditions. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, two (northern water milfoil and whorled water milfoil) were located from Deer Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Whorled water milfoil is a submerged milfoil plant with leaves in whorls of 4 to 5. As with northern water milfoil, the leaves of this plant have somewhat of a feathery appearance. It is often mistaken for northern water milfoil or the invasive Eurasian water milfoil. This plant is most readily distinguished from other milfoils by its overall size (whorled water milfoil is typically larger and more robust) and the length between leaf nodes, which is less than other species of milfoil (about 1 cm apart). Additionally, leaflet counts are helpful in identification – whorled water milfoil typically has 9-13 leaflet segments on each side of the midrib of the leaflet, while northern water milfoil has 5-10 and Eurasian water milfoil 12-24 leaflets.

38 species of aquatic plants (including incidentals) were found in Deer Lake 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 influence the diversity. The diversity index for Deer Lake's plant community (0.89) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds great diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at 23% of the sampling locations, its relative frequency of occurrence is 17%. Explained another way, if 100 plants were randomly sampled from Deer Lake, 17 of them would be coontail. This distribution can be observed in Figure 8.7.4-2, where together 10 species account for 83% of the population of plants within Deer Lake, while the other 16 species account for the remaining 17%. Twelve additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.7.4-1 as incidentals.

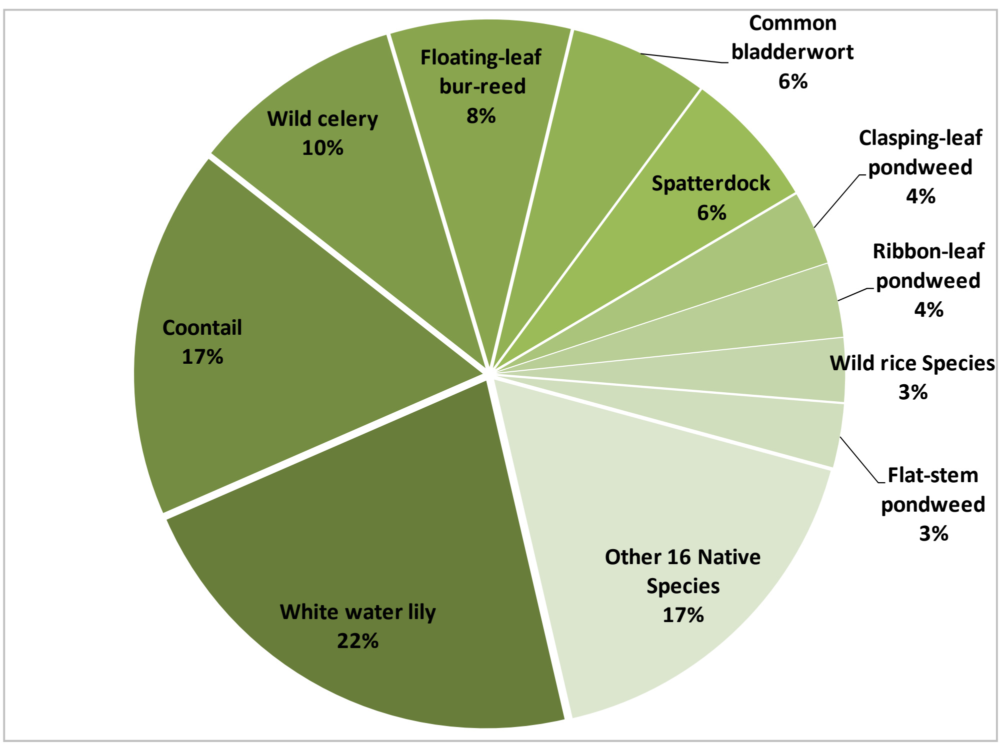

Figure 8.7.4-2 Deer Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Deer Lake's average conservatism value (6.3) is slightly higher than the state median value, but lower than the ecoregion median. This indicates that the plant community of Deer Lake is indicative of a moderately disturbed system. This is not surprising considering Deer Lake's plant community has moderate diversity and species richness. Combining Deer Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 32.2 which is above the median values of the ecoregion and state.

The quality of Deer Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 70.2 acres of the lake contains these types of plant communities (Deer Lake Map 2, Table 8.7.4-2). Fifteen floating-leaf and emergent species were located on Deer Lake (Table 8.7.4-1), all of which provide valuable wildlife habitat.

Table 8.7.4-2. Deer Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	23.2
Floating-leaf	13.9
Mixed Floating-leaf and Emergent	33.1
Total	70.2

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Deer Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to 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.

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8.7.5 Deer Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Deer Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Deer Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Deer Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Deer Lake's implementation plan is compiled by describing how Deer Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Deer Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Deer Lake does not have a public access location, but is directly connected to the rest of the Three Lakes Chain of Lakes via Crystal (Mud), Dog and Big Stone Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Deer Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Deer Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Deer Lake or from Deer Lake elsewhere. If a Deer Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Deer Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Deer Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Deer Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Deer Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Deer Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: Currently, Deer Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Deer Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Deer Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Deer Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Deer Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Deer Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while 33% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Deer Lake.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Deer Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Deer Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on Big Stone Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.8 Big Stone Lake

An Introduction to Big Stone Lake

Big Stone Lake, Oneida County, is a drainage lake with a maximum depth of 57 feet and a surface area of 548 acres. This lake has a relatively large watershed when compared to the size of the lake. Big Stone Lake contains 33 native plant species, of which wild celery was the most common plant. Purple loosestrife, an invasive wetland plant, was observed during the 2011 lake surveys.

Field Survey Notes

Much purple loosestrife observed in the southeastern wetland area of lake. Another colony spotted near Hwy 32.

Lake is quite deep. The littoral region is dominated by a sandy substrate. Primary plant species appears to be wild celery. Much unnatural shoreline observed during surveys.

Photo 8.8.1 Big Stone Lake, Oneida County

Lake at a Glance* – Big Stone Lake

Morphology	
Acreage	548
Maximum Depth (ft)	57
Mean Depth (ft)	21
Volume (acre-feet)	11,701
Shoreline Complexity	4.4
Vegetation	
Curly-leaf Survey Date	June 21, 2011
Comprehensive Survey Date	August 10, 2011
Number of Native Species	33
Threatened/Special Concern Species	-
Exotic Plant Species	Purple loosestrife
Simpson's Diversity	0.65
Average Conservatism	7.1
Water Quality	
Wisconsin Lake Classification	Deep, lowland drainage
Trophic State	Eutrophic / mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	99:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.8.1 Big Stone Lake Water Quality

During 2011/2012, water quality data was collected from Big Stone Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity since 2006, with advanced monitoring (total phosphorus and chlorophyll-*a*) beginning in 2007. These efforts provide consistent, reliable data on which a comparable database may be built. Monitoring should be continued in order to understand trends in the water quality of Big Stone Lake for years to come.

During this time, summer average total phosphorus concentrations have fluctuated little, ranging between 18.8 and 26.7 µg/L (Figure 8.8.1-1). These average values rank within the TSI category of *Good*. A weighted value across all years is nearly equal to the median for deep, lowland drainage lakes in the state of Wisconsin. As with the total phosphorus values, average chlorophyll-*a* concentrations also rank in the *Good* category, and a weighted average is nearly equal to the median concentration for similar lakes across the state (Figure 8.8.1-2). Very little fluctuation is seen in this small dataset.

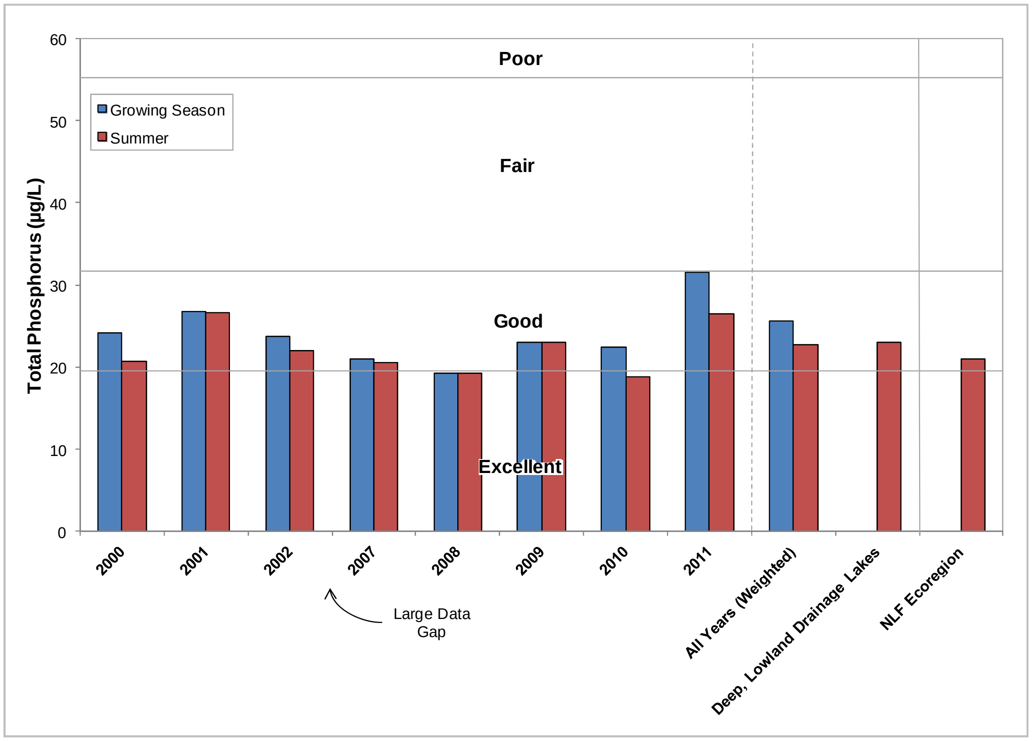


Figure 8.8.1-1. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

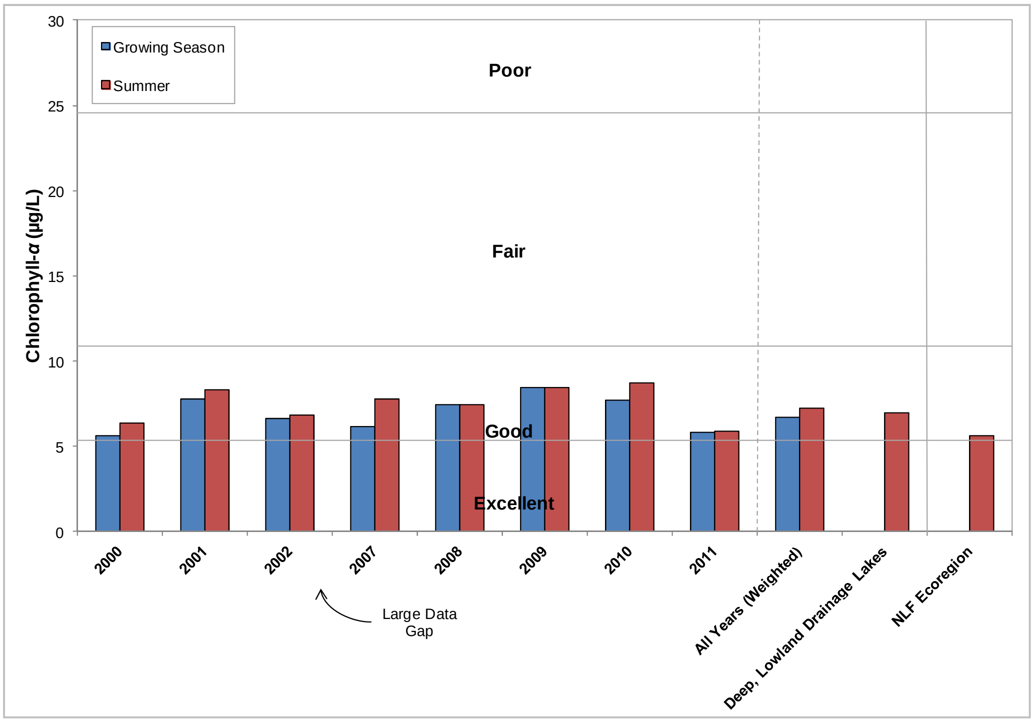


Figure 8.8.1-2. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Measurements of Secchi disk clarity span a similar timeframe as the other two primary water quality parameters, and show a little annual variance as well (Figure 8.8.1-3). All summer averages range between categories of *Fair* and *Good*, though a weighted average across all years is less than the median for deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However, other factors may influence the clarity of a lake's water as well. For example, in 2011 Onterra ecologists noted exceptionally dark water – more so than in previous years when studies had been completed on the Three Lakes Chain of lakes. As seen in Figure 8.8.3-1, nutrient levels were slightly higher in 2011, but chlorophyll-*a* concentrations were not elevated; in fact, they were slightly lower than in previous years (Figure 8.8.1-2). In that same year, the Secchi disk depth summer average was roughly 2.5 feet lower than in previous years (Figure 8.8.1-3). Clearly, presence or absence of algae is not the cause of the reduced water clarity in 2011.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Stone Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. It is possible that wetlands flushed the Three Lakes Chain with these organic acids in 2011. Even with higher-than-normal nutrients in the water column, the natural staining of the water reduced visibility as well as light penetration, which is likely the cause for relatively limited algal production in that year.

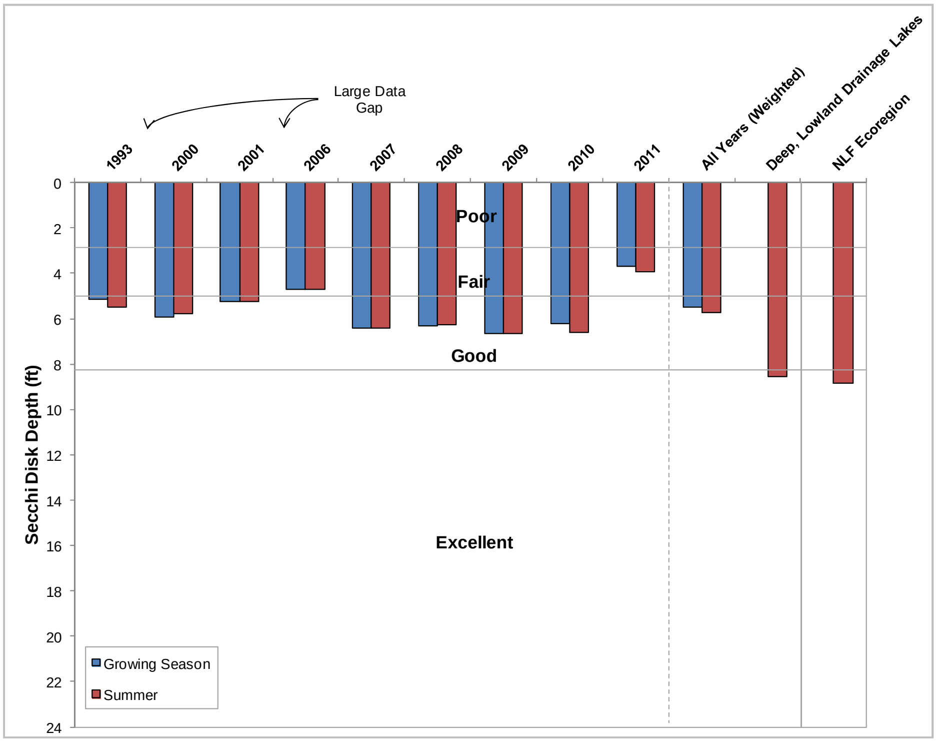


Figure 8.8.1-3. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Big Stone Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.8.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Big Stone Lake is in a borderline eutrophic/mesotrophic state.

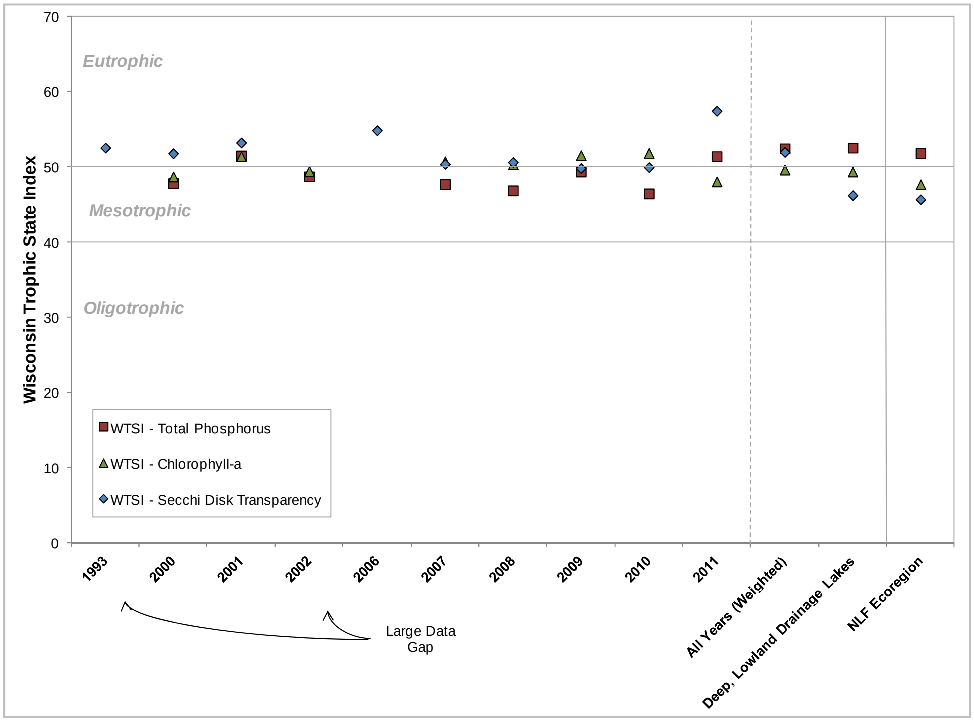


Figure 8.8.1-4. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Big Stone Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Stone Lake by Onterra staff. Graphs of those data are displayed in Figure 8.8.1-5 for all sampling events.

Big Stone Lake mixed thoroughly during the spring (May) and fall (October) of 2011. This is the case in many Wisconsin lakes, as high winds and changing air temperatures during this time mix the water column up and distribute temperatures and oxygen throughout the lake. In the early summer months, the lake begins to stratify as temperatures increase in the top of the water column and remain constant towards the bottom. Dissolved oxygen is used by bacteria near the bottom of the lake to breakdown organic matter. As the decomposition occurs, oxygen is depleted and not replenished from the overlying water, which becomes stratified by June and continues through August. Once the fall winds begin, the lake mixes completely and oxygen is restored to the bottom of Big Stone Lake. Despite the late summer dip, dissolved oxygen levels remained sufficient in the upper 20 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Ample oxygen concentrations were also present within the winter months of 2012 as well, when dissolved oxygen is of most concern.

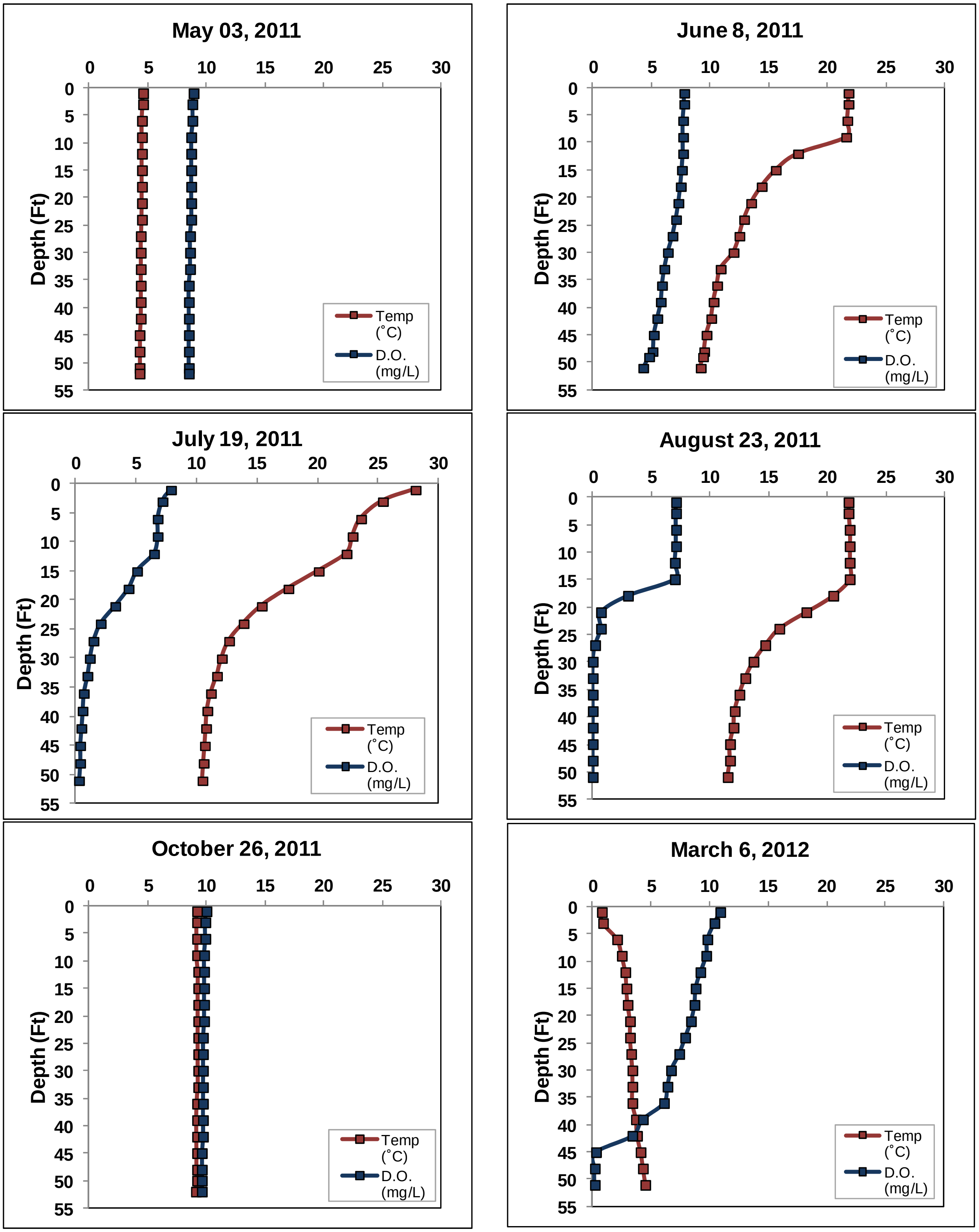


Figure 8.8.1-5. Big Stone Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Big Stone Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Big Stone Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Big Stone Lake's pH was measured at 7.0 during the summer months of 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Big Stone Lake was measured at 21.3 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Big Stone Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Stone Lake's pH of 7.0 falls at the lower end of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Big Stone Lake was found to be 7.8 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. Results to be included in next draft.

8.8.2 Big Stone Lake Watershed Assessment

Big Stone Lake's watershed is 55,027 acres in size. Compared to Big Stone Lake's size of 548 acres, this makes for an incredibly large watershed to lake area ratio of 99:1.

Exact land cover calculation and modeling of nutrient input to Big Stone Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.8.3 Big Stone Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Big Stone Lake's immediate shoreline was assessed in terms of its development. Big Stone Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.8 miles of natural/undeveloped and developed-natural shoreline (26% of the entire shoreline) were observed during the survey (Figure 8.8.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 2.1 miles of urbanized and developed–unnatural shoreline (30% of the total shoreline) was observed. If restoration of the Big Stone Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Big Stone Lake Map 1 displays the location of these shoreline lengths around the entire lake.

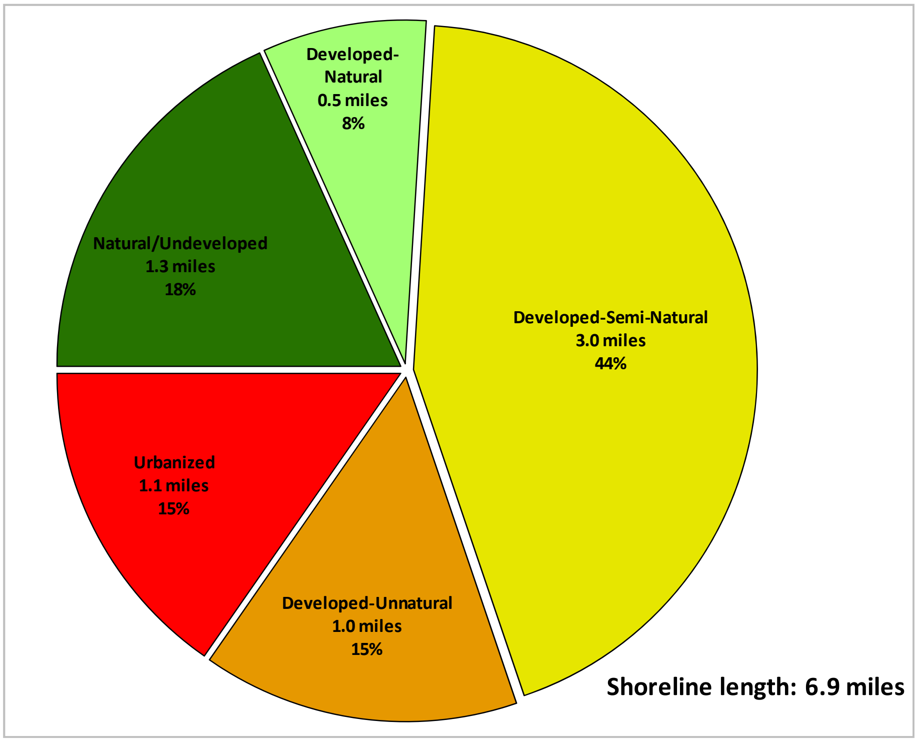


Figure 8.8.3-1. Big Stone Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Big Stone Lake Map 1.

8.8.4 Big Stone Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Big Stone Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not exist in Big Stone Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Big Stone Lake on August 10, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to create the aquatic plant community map (Big Stone Lake Map 2). During all surveys, 33 species of native aquatic plants were located in Big Stone Lake (Table 8.8.4-1). 22 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of seven feet, which is comparable to the maximum depth of plant growth within the other Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in these surveys indicate that the overall aquatic plant community is healthy and fairly diverse.

Of the 170 point-intercept locations sampled within the littoral zone, approximately 66% contained aquatic vegetation. Approximately 92% of the point-intercept sampling locations where sediment data was collected at were sand, 4% consisted of a fine, organic substrate (muck) and 5% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.8.4-1. Aquatic plant species located in the Big Stone Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	*Calla palustris*	Water arum	9	*I*
	Dulichium arundinaceum	Three-way sedge	9	*I*
	Decodon verticillatus	Water-willow	7	*I*
	Eleocharis palustris	Creeping spikerush	6	*I*
	Iris versicolor	Northern blue flag	5	*I*
	Lythrum salicaria	Purple loosestrife	Exotic	*I*
	Pontederia cordata	Pickerelweed	9	*X*
	Sagittaria latifolia	Common arrowhead	3	*I*
	Scirpus cyperinus	Wool grass	4	*I*
	Typha spp.	Cattail spp.	1	*I*
	Zizania palustris	Northern wild rice	8	*X*
FL	*Brasenia schreberi*	Watershield	7	*X*
	Nymphaea odorata	White water lily	6	*X*
	Nuphar variegata	Spatterdock	6	*X*
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	*I*
	Sparganium eurycarpum	Common bur-reed	5	*I*
	Sparganium fluctuans	Floating-leaf bur-reed	10	*X*
Submergent	*Callitriche palustris*	Common water starwort	8	*X*
	Ceratophyllum demersum	Coontail	3	*X*
	Myriophyllum sibiricum	Northern water milfoil	7	*I*
	Najas flexilis	Slender naiad	6	*X*
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	*X*
	Potamogeton obtusifolius	Blunt-leaf pondweed	9	*X*
	Potamogeton amplifolius	Large-leaf pondweed	7	*X*
	Potamogeton pusillus	Small pondweed	7	*X*
	Potamogeton robbinsii	Fern pondweed	8	*X*
	Potamogeton zosteriformis	Flat-stem pondweed	6	*X*
	Potamogeton vaseyi	Vasey's pondweed	10	*X*
	Potamogeton spirillus	Spiral-fruited pondweed	8	*X*
	Potamogeton richardsonii	Clasping-leaf pondweed	5	*X*
	Potamogeton gramineus	Variable pondweed	7	*X*
	Utricularia vulgaris	Common bladderwort	7	*X*
	Vallisneria americana	Wild celery	6	*X*
SE	*Eleocharis acicularis*	Needle spikerush	5	*X*

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

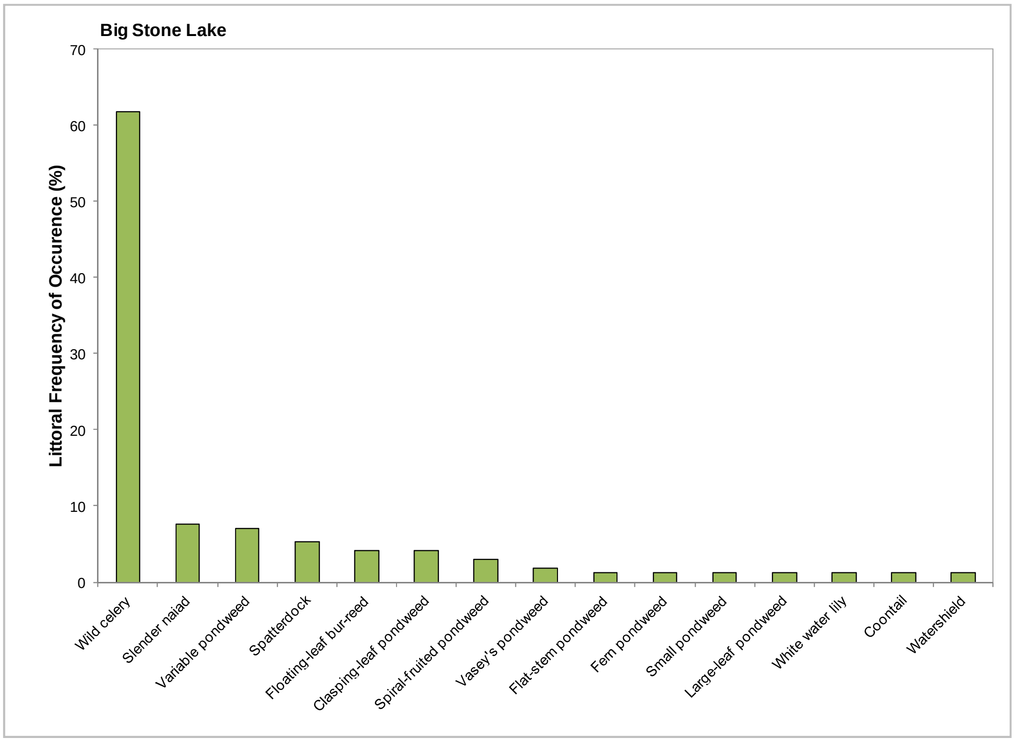


Figure 8.8.4-1 Big Stone Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.8.4-1 (above) shows that wild celery, slender naiad and variable pondweed were the most frequently encountered plants within Big Stone Lake. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Variable pondweed, is a submersed plant that produces a thin, cylindrical stem that has numerous branches. These branches produce linear leaves that grow anywhere from four to eleven centimeters long, and may produce three to seven veins per leaf. The floating leaves this plant produces are much more oval in shape, and may have 11 to 19 veins per leaf. This plant also hybridizes easily with other pondweed (*Potamogeton*) species; thus, this plant can appear quite variable in size and shape and is named appropriately.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only northern water milfoil were located from Big Stone Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. It was found only incidentally on Big Stone Lake; the presence of much hard substrate may be keeping this plant from establishing itself to a larger level. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

33 species of aquatic plants (including incidentals) were found in Big Stone Lake, which is more than the regional and state median value. 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 influence the diversity. The diversity index for Big Stone Lake's plant community (0.65) lies below the Northern Lakes and Forests Lakes ecoregion median value (0.86), indicating the lake's plant community holds low diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at 62% of the sampling locations, its relative frequency of occurrence is 58%. Explained another way, if 100 plants were randomly sampled from Big Stone Lake, 58 of them would be wild celery. This distribution can be observed in Figure 8.8.4-2, where together seven species account for 87% of the population of plants within Big Stone Lake, while the other 15 species account for the remaining 13%. Wild celery dominates the plan community, with a relative frequency of 58%. Eleven additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.8.4-1 as incidentals.

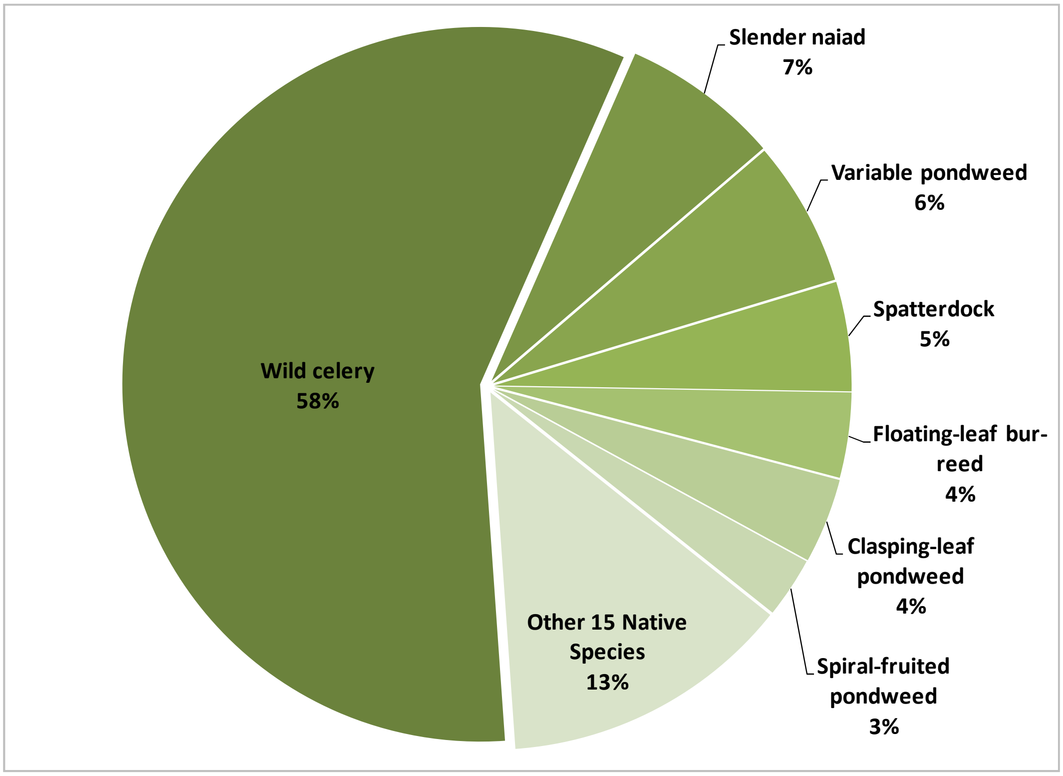


Figure 8.8.4-2 Big Stone Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Big Stone Lake's average conservatism value (7.1) is higher than both the state and ecoregion median. This indicates that the plant community of Big Stone Lake is indicative of an undisturbed system. This is not surprising considering Big Stone Lake's plant community has moderate diversity but high species richness. Combining Big Stone Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.3 which is above the median values of the ecoregion and state.

The quality of Big Stone Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 27.5 acres of the lake contains these types of plant communities (Big Stone Lake Map 2, Table 8.8.4-2). Eleven floating-leaf and emergent species were located on Big Stone Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.8.4-2. Big Stone Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	8.2
Floating-leaf	19.3
Mixed Floating-leaf and Emergent	0.1
Total	27.5

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities. Replications of this survey will provide a valuable understanding of the dynamics of these communities within Big Stone Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to 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 developed shorelines.

Aquatic Invasive Species in Big Stone Lake

During the 2011 community mapping survey, numerous occurrences of purple loosestrife were located along the shorelines of Big Stone Lake and within shallow emergent plant communities (Big Stone Lake Map 2, Table 8.8.4-2). Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

Purple loosestrife has likely been present in Big Stone Lake for some time. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Additional purple loosestrife monitoring during periods of control efforts would be required to ensure the eradication of the plant from the shorelines of Big Stone Lake. .

8.8.5 Big Stone Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Stone Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Stone Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Stone Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Stone Lake's implementation plan is compiled by describing how Big Stone Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Big Stone Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: Big Stone Lake contains a public access and is directly connected to the rest of the Three Lakes Chain of Lakes via Deer and Laurel Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Stone Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Stone Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Stone Lake or from Big Stone Lake elsewhere. If a Big Stone Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Big Stone Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Stone Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Big Stone Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Stone Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Stone Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: Currently, Big Stone Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Big Stone Lake is protected. Volunteers from Big Stone Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Stone Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Big Stone Lake shoreline was categorized in terms of its development. According to the results from this survey, 30% of the shoreline is in an urbanized or developed-unnatural state, while 44% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Big Stone Lake.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Stone Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Stone Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

Note: Methodology, explanation of analysis and biological background on Laurel Lake studies are contained within the Three Lakes Chain-wide Management Plan document.

8.9 Laurel Lake

An Introduction to Laurel Lake

Laurel Lake, Oneida County, is a drainage lake with a maximum depth of 27 feet and a surface area of 232 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Laurel Lake contains 33 native plant species, of which wild celery was the most common. Purple loosestrife, an exotic emergent wetland plant, was found along Laurel Lake.

Field Survey Notes

Many emergent and floating-leaf plants as well as islands located in north-eastern section of lake – very diverse habitat, great for wildlife!

Photo 8.9.1 Laurel Lake, Oneida County

Lake at a Glance* – Laurel Lake

Morphology	
Acreage	232
Maximum Depth (ft)	27
Mean Depth (ft)	*Not available*
Volume (acre-feet)	*Not available*
Shoreline Complexity	7.4
Vegetation	
Curly-leaf Survey Date	June 22, 2011
Comprehensive Survey Date	August 10, 2011
Number of Native Species	33
Threatened/Special Concern Species	-
Exotic Plant Species	Purple loosestrife
Simpson's Diversity	0.77
Average Conservatism	6.9
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage Lake
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	242:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.9.1 Laurel Lake Water Quality

During 2011/2012, water quality data was collected from Laurel Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water clarity since 2006. These efforts provide a database of historical clarity data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Laurel Lake. Unfortunately, only Secchi disk clarity has been monitored in the past, as monitoring for total phosphorus and chlorophyll-*a* requires additional sampling and funding.

In 2011, summer total phosphorus concentrations averaged 29.3 µg/L, which is higher than the median value for other deep, lowland drainage lakes in the state of Wisconsin (23.0 µg/L). As with the total phosphorus values, 2011 average summer chlorophyll-*a* concentrations are also somewhat higher than the median for other deep, lowland drainage lakes statewide (Table 8.9.1-1). Both the total phosphorus and chlorophyll-*a* values rank as *Good* in the Trophic State Index.

Table 8.9.1-1. Laurel Lake, state-wide deep, lowland drainage lakes, and regional values for water quality parameters. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

	Secchi (feet)				Chlorophyll-*a* (µg/L)				Total Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1979	1	4.6	1	4.6								
1993	4	3.5	4	3.5								
1994	7	4.4	4	4.6								
2006	6	4.4	4	4.5								
2007	8	6.5	7	6.6								
2008	9	5.4	8	5.3								
2009	7	7.0	7	7.0								
2010	4	6.3	4	6.3								
2011	10	3.4	7	3.6	5	8.6	3	9.6	5	31.0	3.0	29.3
All Years (Weighted)		5.1		5.3		8.6		9.6		31.0		29.3
Deep, Lowland Drainage Lakes				8.5				7.0				23.0
NLF Ecoregion				8.9				5.6				21.0

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters (Figure 8.9.1-1). All summer averages range between categories of *Fair* and *Good*; but a weighted average across all years is less than the median for other deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Laurel Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Laurel Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

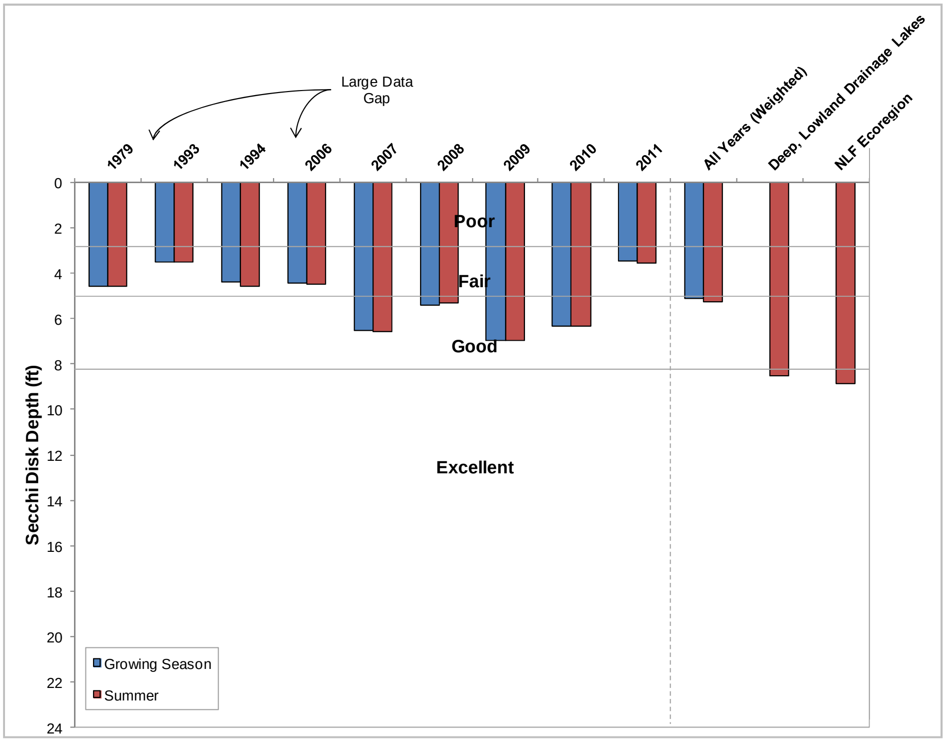


Figure 8.9.1-1. Laurel Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Laurel Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.9.1-2). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Laurel Lake is in a eutrophic state.

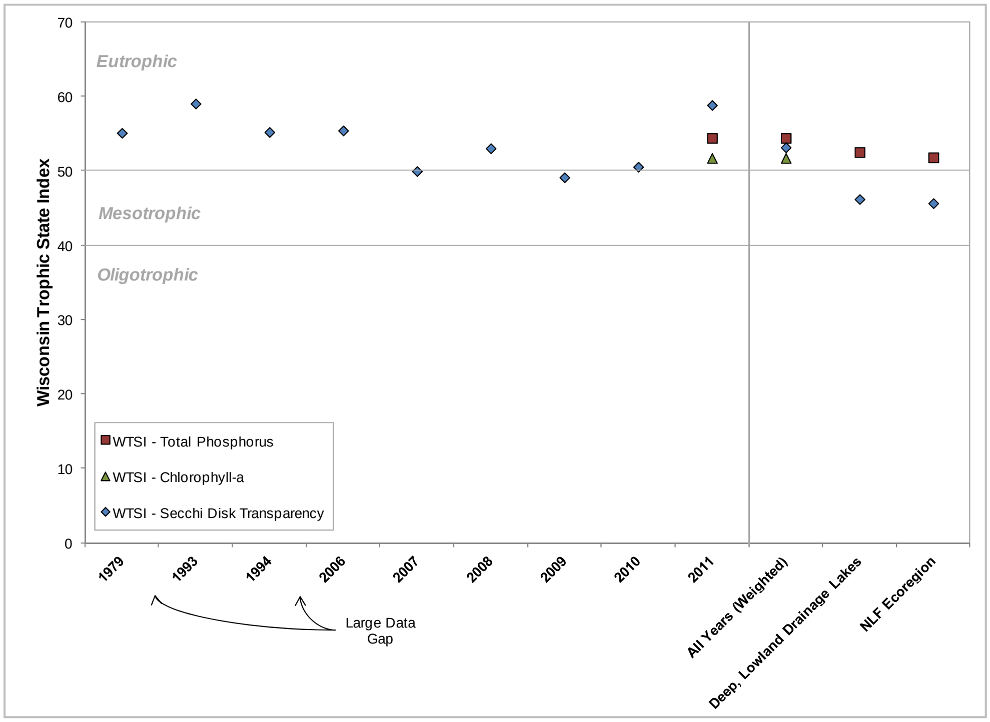


Figure 8.9.1-2. Laurel Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Laurel Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Laurel Lake by Onterra staff. Graphs of those data are displayed in Figure 8.9.1-3 for all sampling events.

Laurel Lake mixed thoroughly during the spring (May) and fall (October) of 2011. This is the case in many Wisconsin lakes, as high winds and changing air temperatures during this time mix the water column up and distribute temperatures and oxygen throughout the lake. In the early summer months, the lake begins to stratify as temperatures increase in the top of the water column and remain constant towards the bottom. Dissolved oxygen is used by bacteria near the bottom of the lake to breakdown organic matter. As the decomposition occurs, oxygen is depleted and not replenished from the overlying water, which has been fully stratified by August. Once the October winds begin, the lake mixes completely and oxygen is restored to the bottom of Laurel Lake.

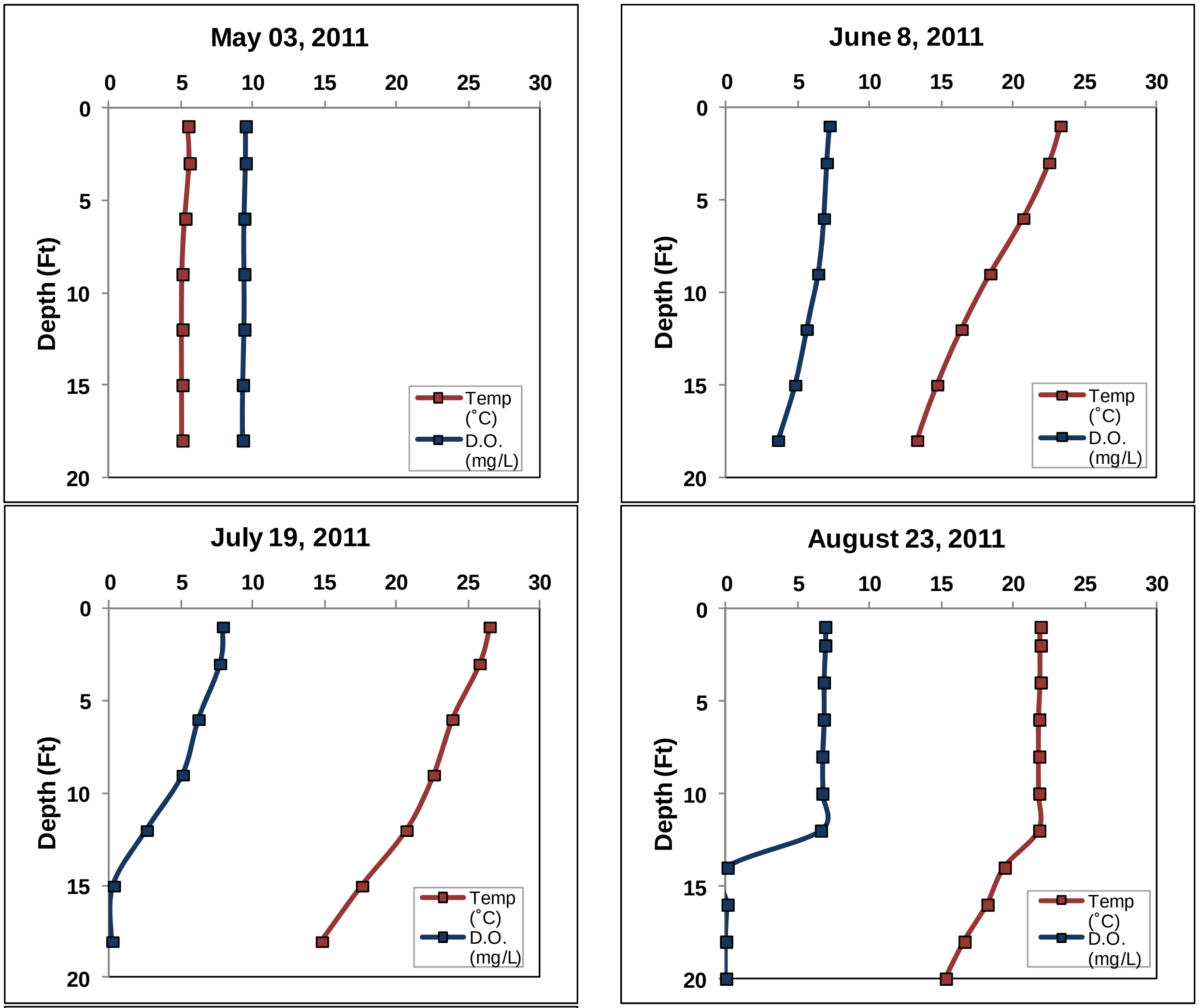
Additional Water Quality Data Collected at Laurel Lake

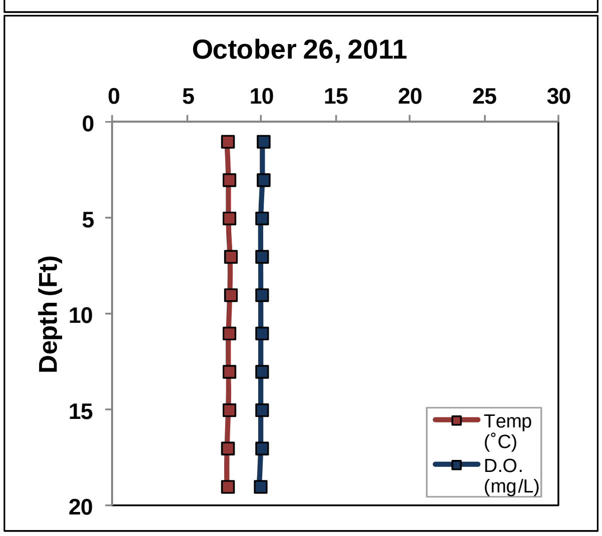
The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Laurel Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Laurel Lake's pH was measured at about 7.3 during summer 2011 surveys. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Laurel Lake was measured at 22.1 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Laurel Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Laurel Lake's pH of 7.3 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Laurel Lake was found to be 7.5 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.





No profile was taken during the winter WQ sampling due to equipment failure.

Figure 8.9.1-3. Laurel Lake dissolved oxygen and temperature profiles.

8.9.2 Laurel Lake Watershed Assessment

Laurel Lake's watershed is 56,382 acres in size. Compared to Laurel Lake's size of 232 acres, this makes for an incredibly large watershed to lake area ratio of 242:1.

Exact land cover calculation and modeling of nutrient input to Laurel Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.9.3 Laurel Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Laurel Lake's immediate shoreline was assessed in terms of its development. Laurel Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.2 miles of natural/undeveloped and developed-natural shoreline (55% of the entire shoreline) were observed during the survey (Figure 8.9.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.0 mile of urbanized and developed–unnatural shoreline (16% of the total shoreline) was observed. If restoration of the Laurel Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. The Laurel Lake Map 1 displays the location of these shoreline lengths around the entire lake.

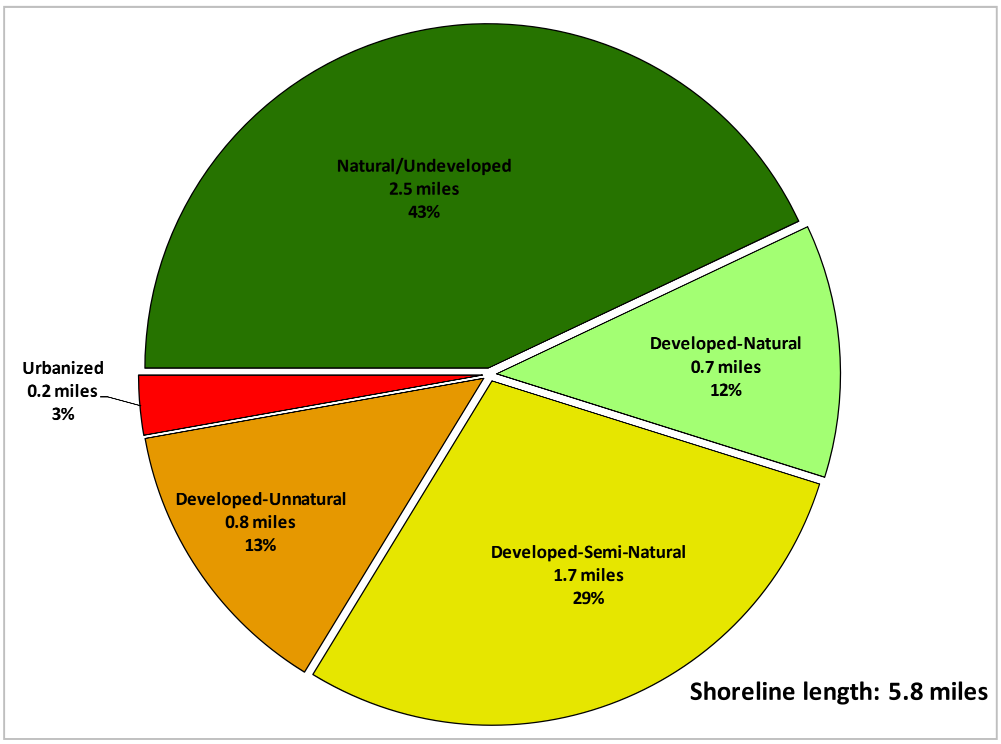


Figure 8.9.3-1. Laurel Lake shoreland categories and total lengths. Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Laurel Lake Map 1.

8.9.4 Laurel Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Laurel Lake on June 22, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Laurel Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Laurel Lake on August 10, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 10 & 11 to create the aquatic plant community map (Laurel Lake Map 2). During all surveys, 33 species of native aquatic plants were located in Laurel Lake (Table 8.9.4-1). 24 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. An additional exotic plant, purple loosestrife, was found along the shoreline of Laurel Lake. Submergent aquatic plants were found growing to a depth of eight feet, which is comparable to the maximum depth of plants in the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 158 point-intercept locations sampled within the littoral zone, approximately 71% contained aquatic vegetation. Approximately 36% of the point-intercept sampling locations where sediment data was collected at were sand, 63% consisted of a fine, organic substrate (muck) and 1% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-3).

Table 8.9.4-1. Aquatic plant species located in the Laurel Lake during the 2011 aquatic plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (Onterra)
Emergent	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Eleocharis palustris	Creeping spikerush	6	I
	Iris versicolor	Northern blue flag	5	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
	Zizania palustris	Northern wild rice	8	I
FL	Brasenia schreberi	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	Sparganium eurycarpum	Common bur-reed	5	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	Chara spp.	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elodea nuttallii	Slender waterweed	7	X
	Isoetes sp.	Quillwort species	N/A	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton gramineus	Variable pondweed	7	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	Eleocharis acicularis	Needle spikerush	5	X
FF	Spirodela polyrhiza	Greater duckweed	5	X

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

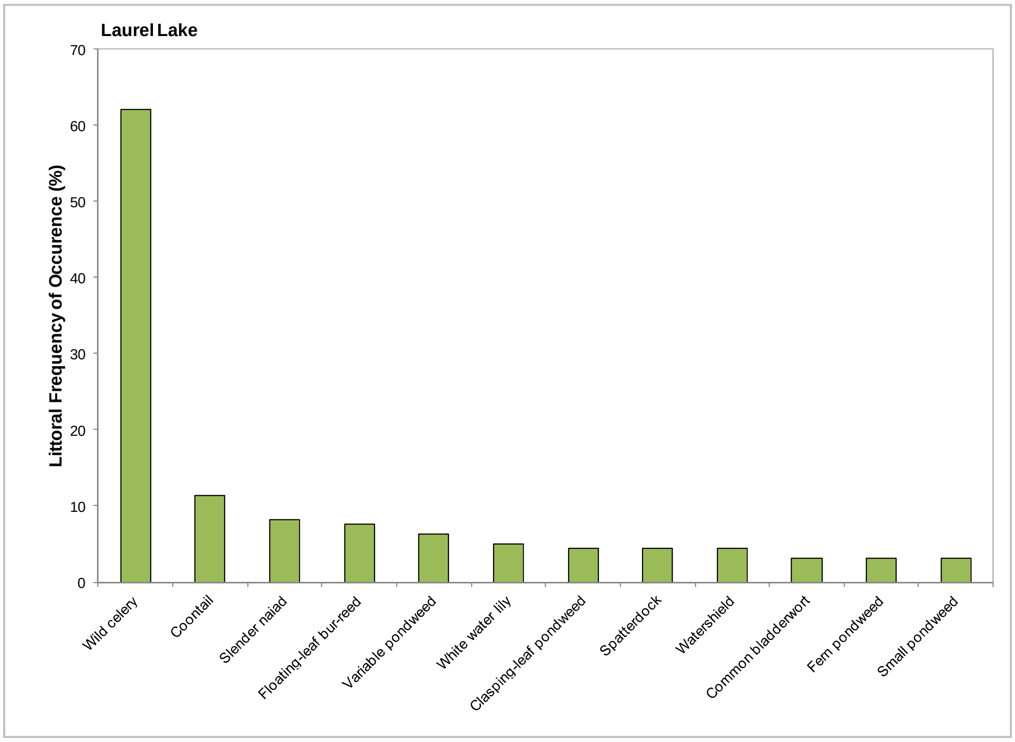


Figure 8.9.4-1 Laurel Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 2.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.9.4-1 (above) shows that wild celery, coontail and slender naiad were the most frequently encountered plants within Laurel Lake. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making the plant susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats. Further, coontail is able to tolerate low-light conditions; this in addition to its ability to obtain nutrients directly from the water allow this species to thrive in productive systems. Slender naiad, as its name implies, is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only northern water milfoil was located within Laurel Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

33 species of aquatic plants (including incidentals) were found in Laurel Lake 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 influence the diversity. The diversity index for Laurel Lake's plant community (0.77) lies below the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake only moderate diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at 62% of the sampling locations, its relative frequency of occurrence is 46%. Explained another way, if 100 plants were randomly sampled from Laurel Lake, 46 of them would be wild celery. This distribution can be observed in Figure 8.9.4-2, where together 12 species account for 90% of the population of plants within Laurel Lake, while the other 12 species account for the remaining 20%. However, wild celery clearly dominates the plan community. Nine additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.9.4-1 as incidentals.

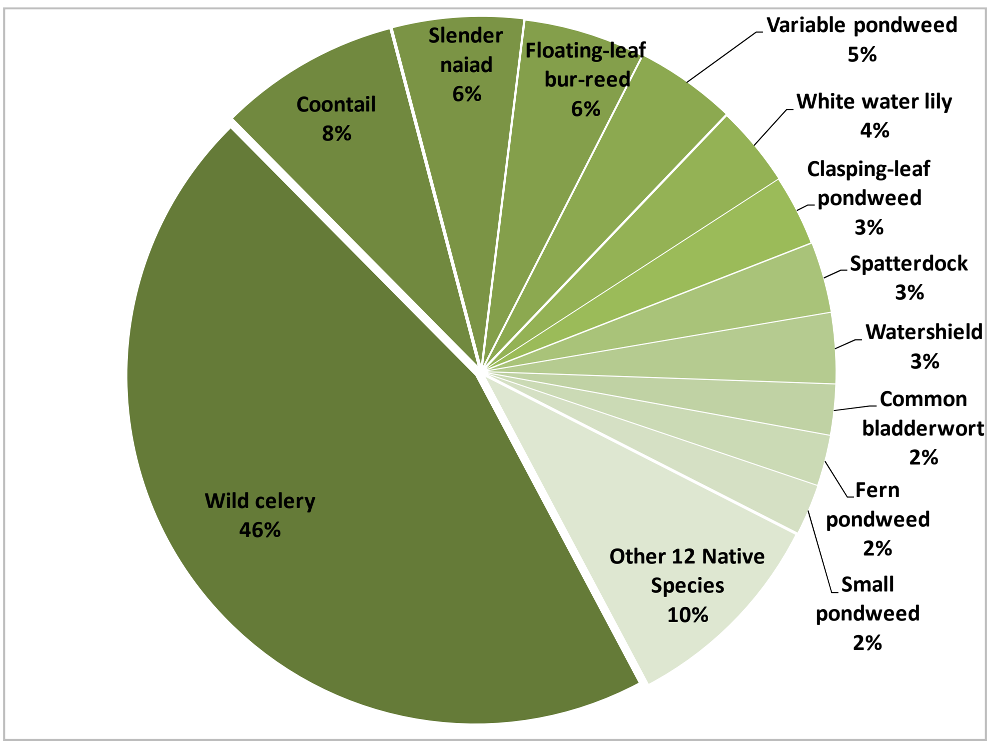


Figure 8.9.4-2 Laurel Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2011 point-intercept survey.

Laurel Lake's average conservatism value (6.9) is higher than both the state and ecoregion median. This indicates that the plant community of Laurel Lake is indicative of a moderately undisturbed system. This is not surprising considering Laurel Lake's plant community has great diversity and high species richness. Combining Laurel Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.7 which is above the median values of the ecoregion and state.

The quality of Laurel Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 79.1 acres of the lake contains these types of plant communities (Laurel Lake Map 2, Table 8.9.4-2). Fourteen floating-leaf and emergent species were located on Laurel Lake (Table 8.9.4-1), all of which provide valuable wildlife habitat.

Table 8.9.4-2. Laurel Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.

Plant Community	Acres
Emergent	17.1
Floating-leaf	31.7
Mixed Floating-leaf and Emergent	30.3
Total	79.1

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

Aquatic Invasive Species in Laurel Lake

During the 2011 community mapping survey, a single occurrence of purple loosestrife was located along the shorelines of Laurel Lake (Laurel Lake Map 2). Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930’s, it has now spread to 70 of the state’s 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Additional purple loosestrife monitoring during periods of control efforts would be required to ensure the eradication of the plant from the shorelines of Laurel Lake. Detailed discussion regarding this control effort will be discussed in the Implementation Plan.

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8.9.5 Laurel Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Laurel Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Laurel Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Laurel Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Laurel Lake's implementation plan is compiled by describing how Laurel Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

Chain-wide Implementation Plan – Specific to Laurel Lake

Chain-wide Management Goal 1: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

Description: In addition to having a public access location, Laurel Lake is directly connected to the rest of the Three Lakes Chain of Lakes via Laurel and Medicine Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Laurel Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Laurel Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Laurel Lake or from Laurel Lake elsewhere. If a Laurel Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

Management Action: Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

Description: Laurel Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Laurel Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

Chain-wide Management Goal 2: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

Description: Laurel Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Laurel Lake and its stakeholders.

Chain-wide Management Goal 3: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

Description: While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Laurel Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

Chain-wide Management Goal 4: Maintain Current Water Quality Conditions

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

Description: Currently, Laurel Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Laurel Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Laurel Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Laurel Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to the Three Lakes Chain of Lakes.

Description: This management action ties in very much with the action under Management Goal 2, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Laurel Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

Management Action: Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

Description: As a part of this project, the entire Laurel Lake shoreline was categorized in terms of its development. According to the results from this survey, 16% of the shoreline is in an urbanized or developed-unnatural state, while 29% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

Description: This management action is not applicable to Laurel Lake.

Chain-wide Management Goal 5: Improve Fishery Resource and Fishing

Management Action: Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

Description: A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Laurel Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Laurel Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.