Squash Lake

Oneida County, Wisconsin

Comprehensive Management Plan

April 2014

Sponsored by:

Squash Lake Association, Inc.

WDNR Grant Program

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Onterra LLC
Lake Management Planning

Squash Lake
Oneida County, Wisconsin
Comprehensive Management Plan
April 2014

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1.0 INTRODUCTION

Squash Lake, Oneida County, is an approximate 396-acre seepage lake with a maximum depth of 74 feet and a mean depth of 22 feet (Map 1). This upper oligotrophic/lower mesotrophic lake has a surface watershed that encompasses approximately 1,110 acres, yielding a watershed to lake area ratio of 2:1. In 2012, 54 native aquatic plant species were located, of which stoneworts (*Nitella* spp.) were the most abundant. The non-native aquatic plant Eurasian water milfoil (*Myriophyllum spicatum*) was discovered in Squash Lake in 2009.

Field Survey Notes

Water is exceptionally clear with very little free-floating algae. The lake contains varying habitat types and supports a high number of native aquatic plant species. High-quality plant species were located including the state-listed special concern species Vasey's pondweed.

Photo 1.0-1 Squash Lake, Oneida County

Lake at a Glance - Squash Lake

Morphology	
Acreage	396 (WDNR Definition)
Maximum Depth (ft)	74
Mean Depth (ft)	22
Shoreline Complexity	7.6
Vegetation	
Curly-leaf Survey Date	June 6, 2012
Comprehensive Survey Date	July 10 & 11, 2012
Number of Native Species	54
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian water milfoil (*Myriophyllum spicatum*)
Simpson's Diversity	0.89
Average Conservatism	7.5
Water Quality	
Trophic State	Upper Oligotrophic/Lower Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.3
Sensitivity to Acid Rain	Low
Watershed to Lake Area Ratio	2:1

Squash Lake is located just southwest of the City of Rhinelander within the Wisconsin River drainage basin. In 2009, the non-native plant Eurasian water milfoil was confirmed to be present in Squash Lake by Wisconsin Department of Natural Resources (WDNR) biologists. Other non-native species present in Squash Lake include the invertebrates rusty crayfish, banded and Chinese mystery snails, and freshwater jellyfish. Following the discovery of Eurasian water milfoil, the Squash Lake Association, Inc. (SLA) contracted with Onterra, LLC to complete a Eurasian water milfoil survey in the summer of 2009 and assess possible control strategies.

Following that 2009 survey, the SLA was hesitant in using herbicides within Squash Lake and instead initiated an aggressive and well-organized hand-removal program. This program is facilitated through the efforts of volunteers and paid scuba divers, and the majority was initially funded through a WDNR Aquatic Invasive Species (AIS) Early Detection and Response Grant in 2010. The SLA has subsequently received WDNR funding in 2011 and 2013 to continue their hand-harvesting and monitoring efforts through 2013.

In addition to creating a hand-harvesting program for Eurasian water milfoil, the SLA, being proactive in nature, forged a partnership with nearby Crescent and Julia Lakes to fund and manage an AIS Education, Prevention, and Planning Grant aimed at educating area lake users about AIS. This AIS Grant also funds Clean Boats Clean Waters watercraft inspections on all three lakes.

Beyond the issue of controlling Eurasian water milfoil in Squash Lake, the SLA was interested in creating a lake management plan in order to ensure the preservation of Squash Lake for future generations. As described previously, the SLA is involved in numerous actions to preserve their lake; however, through the development of a lake management plan, they want to assure that they are working to preserve Squash Lake as an ecosystem, not just a recreational resource. For example, the SLA is interested in protecting the lake’s natural shoreline areas, particularly around the southeastern bay. Overall, the SLA recognized the value of gaining a better understanding of the Squash Lake ecosystem and its current condition. In the end, the information obtained from these studies will help guide future SLA plans and programs.

This report discusses the shoreline, watershed, water quality, aquatic plants, and Squash Lake stakeholder studies that were conducted in Squash Lake in 2012/2013. Also included is the Implementation Plan, which includes goals and actions specific to Squash Lake’s current and future management that were developed by both members of the Squash Lake Planning Committee and Onterra ecologists.

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, a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter. The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

Kick-off Meeting

On June 16, 2012, a project kick-off meeting was held at the Crescent Town Hall to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Squash Lake Association, Inc. board members. Twenty-nine attendees observed a presentation given by Brenton Butterfield and Tim Hoyman, aquatic ecologists with Onterra. Their presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I

On November 6, 2013, Onterra ecologists Brenton Butterfield met with members of the Squash Lake Planning Committee. In advance of this meeting, a draft copy of the Results and Discussion Sections (Section 3.0) was provided to attendees. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including the aquatic plant inventories, water quality analyses, and watershed modeling were presented and discussed. Information regarding moving forward with the Eurasian water milfoil hand-removal program was also discussed.

Planning Committee Meeting II

On December 2, 2013, Onterra ecologists Brenton Butterfield met with members of the Squash Lake Planning Committee to begin developing management goals and actions for the Squash Lake Association's Comprehensive Lake Management Plan. One of the major topics of discussion was related to Eurasian water milfoil management.

Project Wrap-up Meeting

Likely to occur in the summer of 2014.

Management Plan Review and Adoption Process

Prior to the first planning meeting, the Planning Committee received copies of the Results Section of this report (Section 3.0). Their comments were addressed at this meeting and the appropriate changes were incorporated within the management plan. Following the creation of the Implementation Plan following the second Planning Committee Meeting, the first draft of the management plan was provided to the Planning Committee and WDNR for their review in January 2014. The WDNR provided comments on the plan in April 2014, and Onterra staff discussed and addressed the WDNR comments. The plan was ultimately approved in April of 2014.

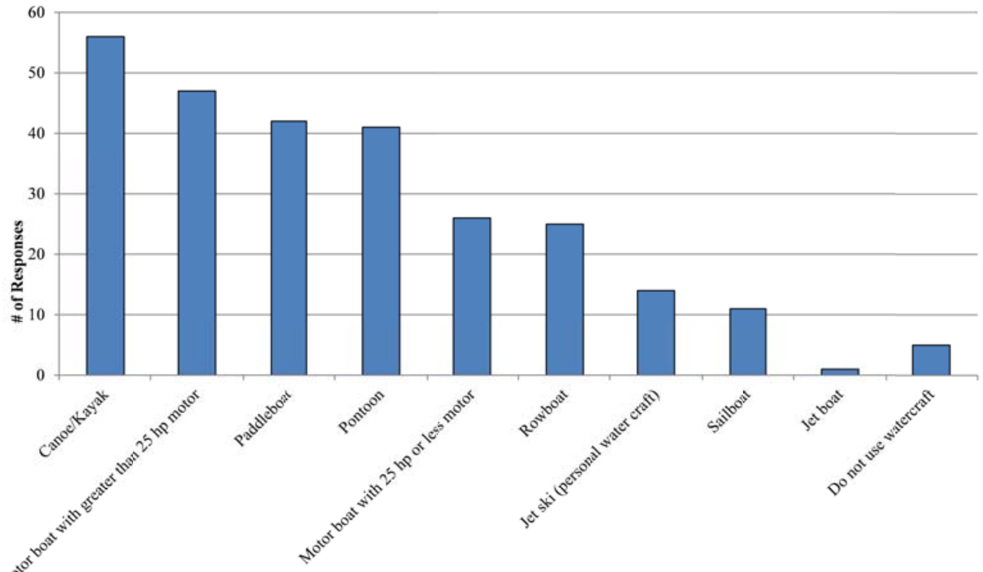
Stakeholder Survey

During September 2012, a seven-page, 30-question survey was mailed to 159 riparian property owners in the Squash Lake watershed. Over sixty percent of the surveys were returned and those results were entered into a spreadsheet by members of the Squash Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Squash Lake. The majority of stakeholders (43%) are year-round residents, 24% are summer residents only, and 21% visit on weekends throughout the year. Approximately 44% of respondents have owned their property on Squash Lake for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use a canoe/kayak, larger motor boat, paddleboat, pontoon boat, or combination of these four vessels on Squash Lake (Question 13). The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 14, the three top recreational activities on Squash Lake do not necessarily involve boat use, and boat traffic ranked 17th on a list of stakeholder’s top concerns regarding Squash Lake.

Question 13: What types of watercraft do you currently use on the lake?



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Question 14: Please rank up to three activities that are important reasons for owning your property on or near the lake.

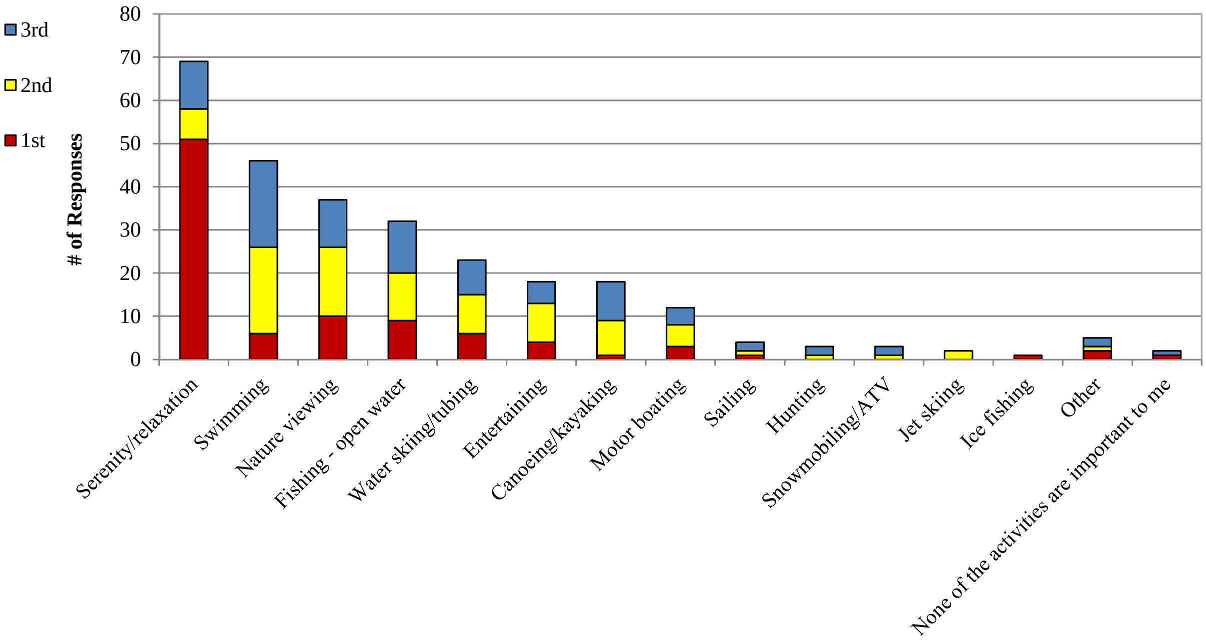

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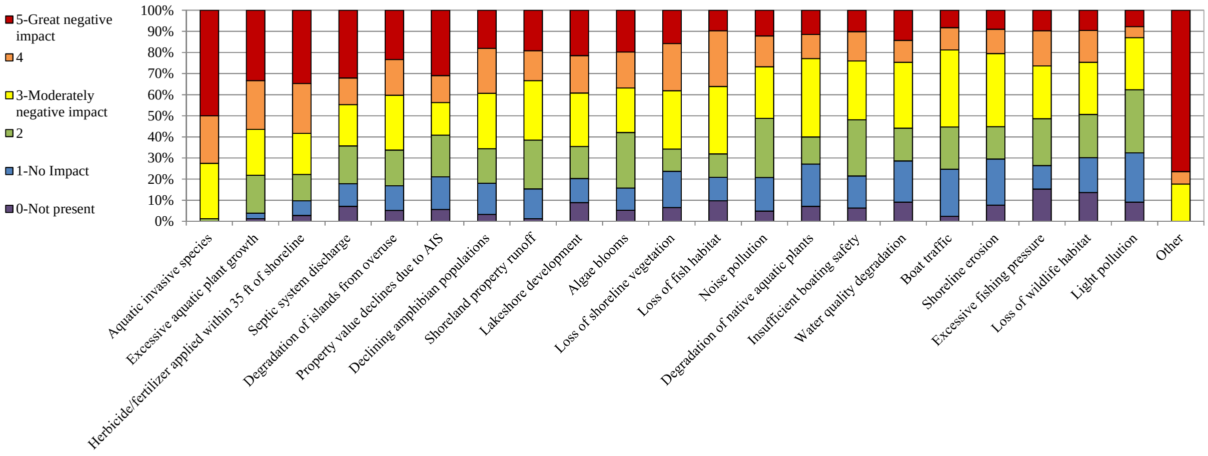
Figure 2.0-1. Select survey responses from the Squash Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 20: To what level do you believe these factors may be negatively impacting Squash Lake?



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Question 21: Please rank your top three concerns regarding Squash Lake.

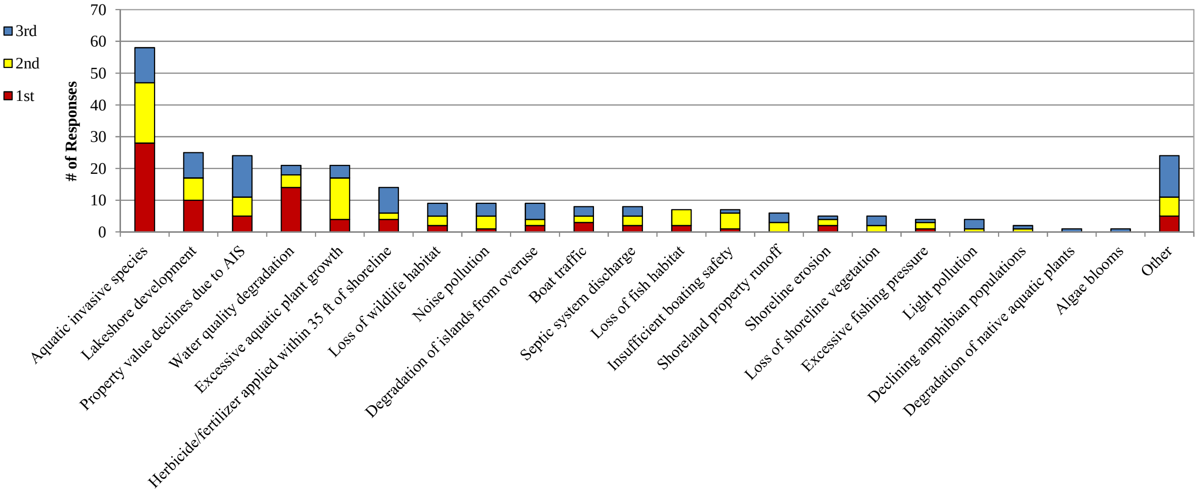

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Figure 2.0-2. Select survey responses from the Squash Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Squash Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Squash Lake's water quality analysis:

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The 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 Squash Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: **shallow (mixed)** or **deep (stratified)**. 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 the entire 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) that 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.

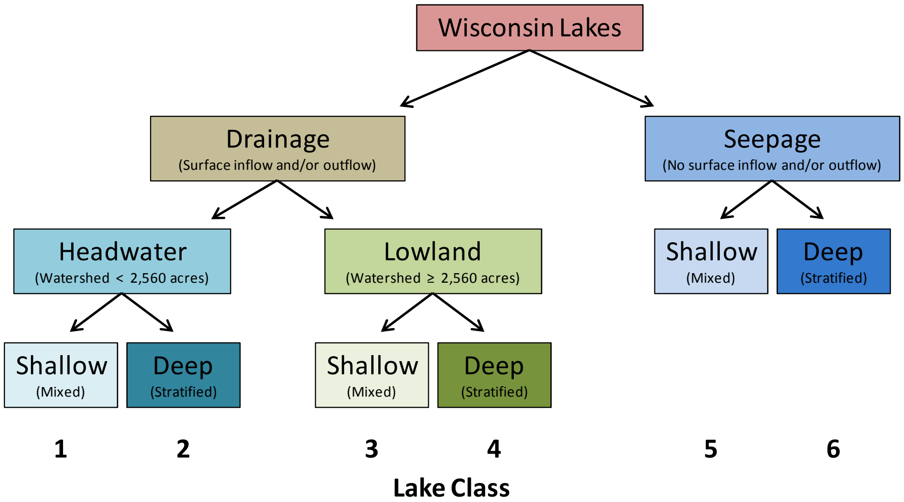

Figure 3.1-1. Wisconsin Lake Classifications. Squash Lake is classified as a deep (stratified) seepage lake (class 6). Adapted from WDNR PUB-SS-1044 2008.

Squash Lake is classified as deep (stratified) seepage lake. The WDNR 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. Squash Lake lies within the Northern Lakes and Forests ecoregion.

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, they were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

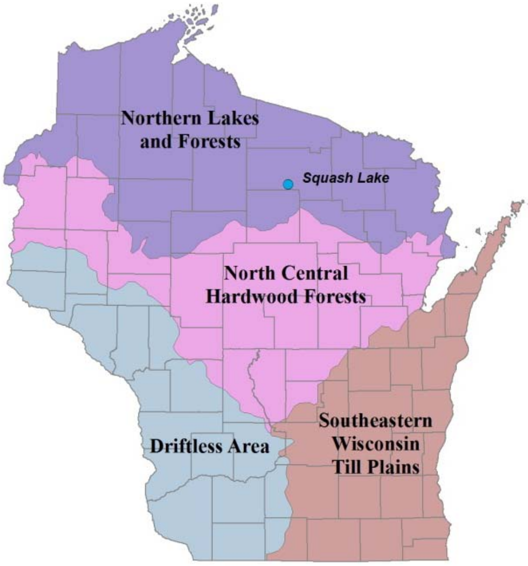

Figure 3.1-2. Location of Squash Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake medians, historical, current, and average data from Squash Lake are 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.

Squash Lake Water Quality Analysis

Squash Lake Long-term Trends

As a part of this study, Squash Lake stakeholders were asked about their perceptions of the lake's water quality. The majority (88.2%) of respondents rated the water quality of Squash Lake as *Good* or *Excellent*, 11.8% rated *Fair*, and 1.1% rated *Unsure* (Appendix B, Question #15). Approximately 46% of survey respondents indicated that the water quality of Squash Lake has *remained the same* since they first visited the lake, while approximately 43% believed the water quality has *somewhat degraded* (Question #16).

Volunteers have been and continue to be actively collecting water quality data from Squash Lake through the Citizens Lake Monitoring Network (CLMN) Program. Through this WDNR-sponsored program, volunteers are trained to collect water quality data on their lake. Samples are analyzed through the State Lab of Hygiene in Madison, WI and data are entered into the Surface Water Integrated Monitoring System (SWIMS), an online database which allows for quick access to all current and historical water quality data. This process allows stakeholders to become directly engaged in protecting their lake, while producing reliable and comparable data that managers may recall through a streamlined website.

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Volunteers from Squash Lake have been collecting these data on an annual basis since 1989, building a continual dataset that will yield valuable information on Squash Lake's water quality through time.

Near-surface total phosphorus data are available from Squash Lake annually from 1990-2012. As illustrated in Figure 3.1-3, average annual growing season and summer near-surface total phosphorus values have been relatively consistent, falling into the *Excellent* category for deep seepage lakes; with the exception of 1997, in which both the growing season and summer total phosphorus concentrations fell within the *Good* category and were approximately twice the level of any concentration measured before or since.

As discussed previously, total phosphorus, chlorophyll-*a*, and Secchi disk transparency are interrelated with one another. Given the level of total phosphorus concentrations measured in 1997, one would have expected higher chlorophyll-*a* concentrations and a measureable decline in Secchi disk transparency. However, chlorophyll-*a* concentrations and Secchi disk transparencies measured in 1997 were not significantly different from other years. While the total phosphorus concentrations measured in 1997 would normally indicate some type of phosphorus-loading event, the fact that there was no measureable response detected in chlorophyll-*a* and Secchi disk transparency indicates that error in reporting of the total phosphorus data is more probable; such as the data being from a different lake.

Trends analysis of near-surface total phosphorus concentrations from Squash Lake (excluding data from 1997) indicate that there are no trends (positive or negative) occurring at present over time. Overall, the weighted average for both the growing season and summer near-surface total phosphorus concentrations fall within the *Excellent* category for deep seepage lakes in Wisconsin, and is lower the median total phosphorus concentrations for state-wide deep seepage lakes and for lakes within the Northern Lakes and Forests Ecoregion (Figure 3.1-3).

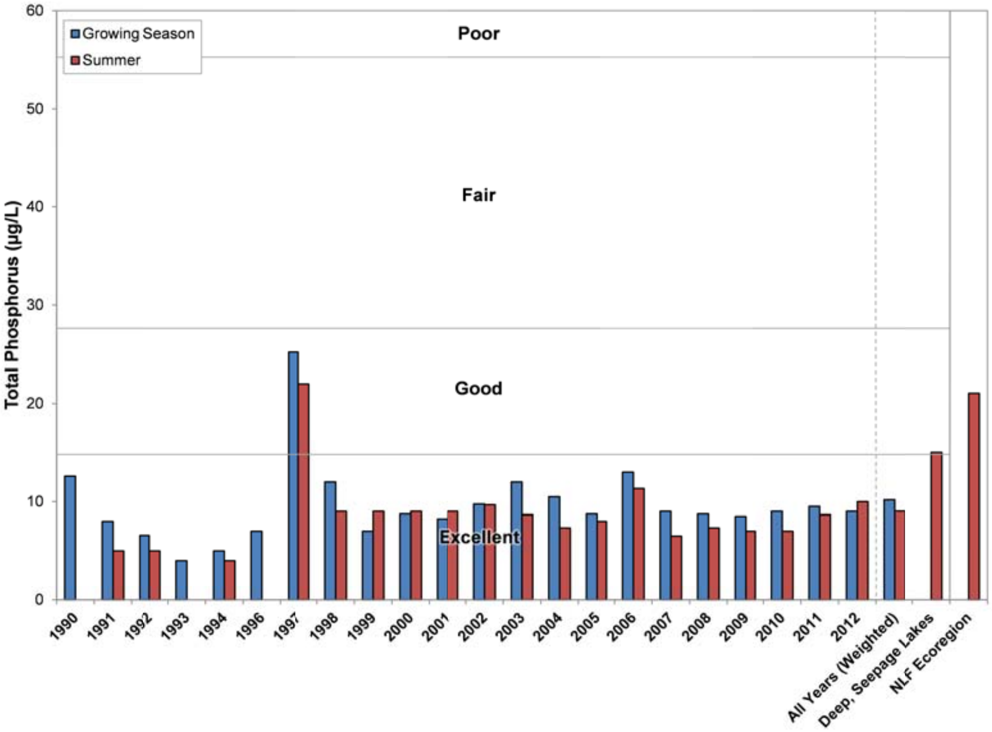

Figure 3.1-3. Squash Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep seepage lakes, and Northern Lakes and Forests Ecoregion lakes. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, is usually positively correlated with total phosphorus concentrations. While phosphorus limits the amount of algae growth in the majority of Wisconsin's lakes, other factors also affect the amount of algae produced within the lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton, which feed on algae, also influence algal abundance.

Chlorophyll-*a* data are available from Squash Lake from 1979 and annually from 1992-2012 (Figure 3.1-4). As illustrated, growing season and summer chlorophyll-*a* concentrations have remained relatively consistent over the time period for which data are available. Growing season chlorophyll-*a* concentrations in 1979 and 2003, and both growing season and summer chlorophyll-*a* concentrations in 2006, were slightly higher than the other years for which data are available. No total phosphorus data were collected in 1979, but total phosphorus concentrations measured in 2003 and 2006 were higher than average, and explain why chlorophyll-*a* concentrations were higher in those years. However, water clarity as measured via Secchi disk, did not appear to be affected by the increases in chlorophyll-*a* concentrations in 2003 and 2006

(Figure 3.1-5). Slight fluctuations in annual total phosphorus concentrations are to be expected, and are likely due to changes in the amount of phosphorus being delivered to the lake due to changes in annual precipitation.

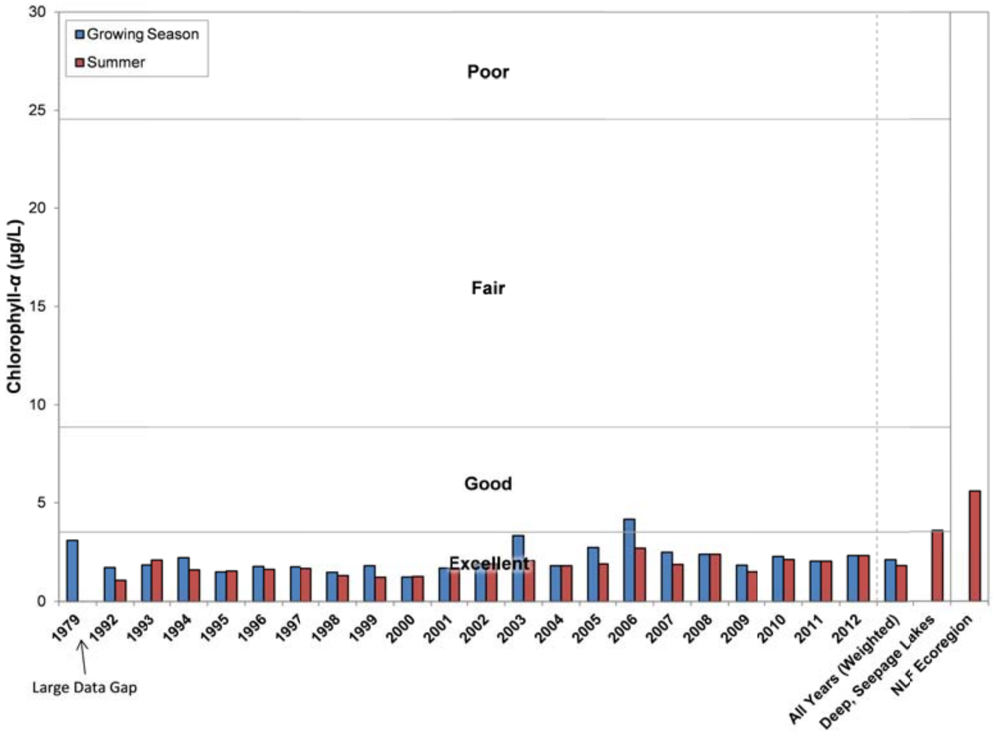

Figure 3.1-4. Squash Lake average annual near-surface chlorophyll-*α* concentrations and median near-surface chlorophyll-*α* concentrations for state-wide deep seepage lakes, and Northern Lakes and Forests Ecoregion lakes. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Trends analysis of the available chlorophyll-*a* concentrations from Squash Lake indicate free-floating algae within the water is not increasing nor decreasing over time. Overall, the weighted average for chlorophyll-*a* concentrations in Squash Lake falls in the *Excellent* category for Wisconsin's deep seepage lakes, and is lower than both the median chlorophyll-*a* concentrations for state-wide deep seepage lakes and for lakes within the Northern Lakes and Forests Ecoregion (Figure 3.1-4).

Secchi disk transparency data from Squash Lake are available from 1973 and 1974, and annually from 1989-2012 (Figure 3.1-5). Of the three water quality parameters, average growing season and summer Secchi disk transparency values have displayed the most inter-annual variation. Average growing season transparency values range from 12.8 feet recorded in 1998 to 22.0 feet in 1993. Although 2008 saw the lowest water transparency values recorded, chlorophyll-*a* concentrations were not above normal, indicating water clarity was being influenced by something other than algae.

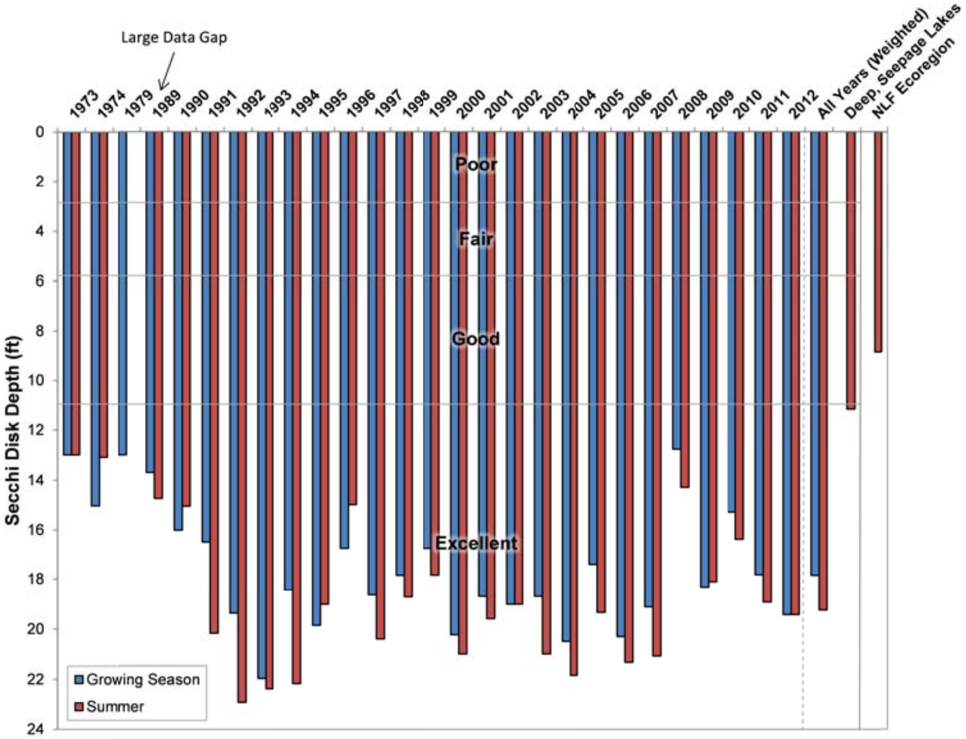

Figure 3.1-5. Squash Lake average annual Secchi disk transparency and median Secchi disk transparency for state-wide deep seepage lakes, and Northern Lakes and Forests Ecoregion lakes. Median values calculated with summer month transparency data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Squash Lake

Using midsummer nitrogen and phosphorus concentrations from Squash Lake, a nitrogen:phosphorus ratio of 32:1 was calculated. This finding indicates that Squash Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that phosphorus is primary nutrient controlling aquatic macrophyte and algae abundance within Squash Lake.

Squash Lake Trophic State

Figure 3.1-6 contains the Trophic State Index (TSI) values for Squash Lake. In general, the best values to use in judging a lake's trophic state are total phosphorus and chlorophyll-*a*, as other factors other than algal abundance can affect a lake's water clarity. The weighted average TSI values for total phosphorus and chlorophyll-*a* indicate that Squash is currently in an oligotrophic state. However, much of Squash Lake's productivity exists within its aquatic macrophyte community, which is not taken into account in the TSI analysis. Given Squash Lake's abundant aquatic macrophyte growth, it's more likely that Squash Lake is an upper oligotrophic/lower mesotrophic state.

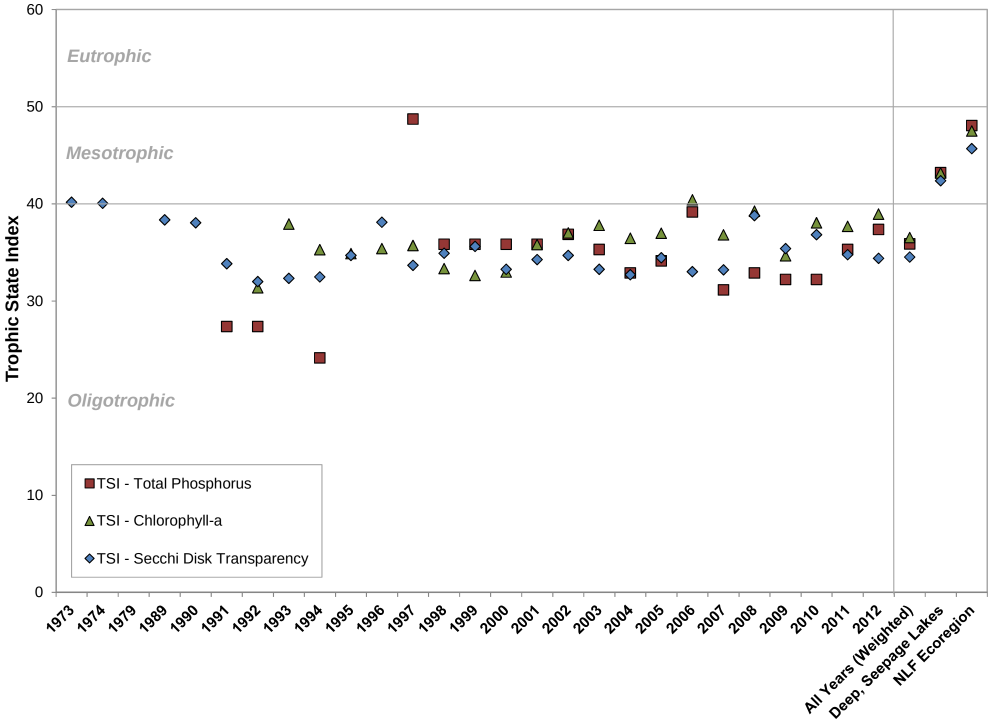

Figure 3.1-6. Squash Lake average Trophic State Index values and median Trophic State Index values for deep seepage lakes in Wisconsin and lakes within the Northern Forests and Lakes Ecoregion. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Squash Lake

Dissolved oxygen and temperature were measured at regular depth intervals during water quality sampling visits to Squash Lake by Onterra staff and the Squash Lake CLMN volunteer. Profiles depicting these data are displayed in Figure 3.1-7. These data indicate that Squash Lake was already stratified in late March, and remained stratified through the summer months. The lake was not stratified in early November, indicating fall turnover, and was stratified during the winter sampling in February through the ice.

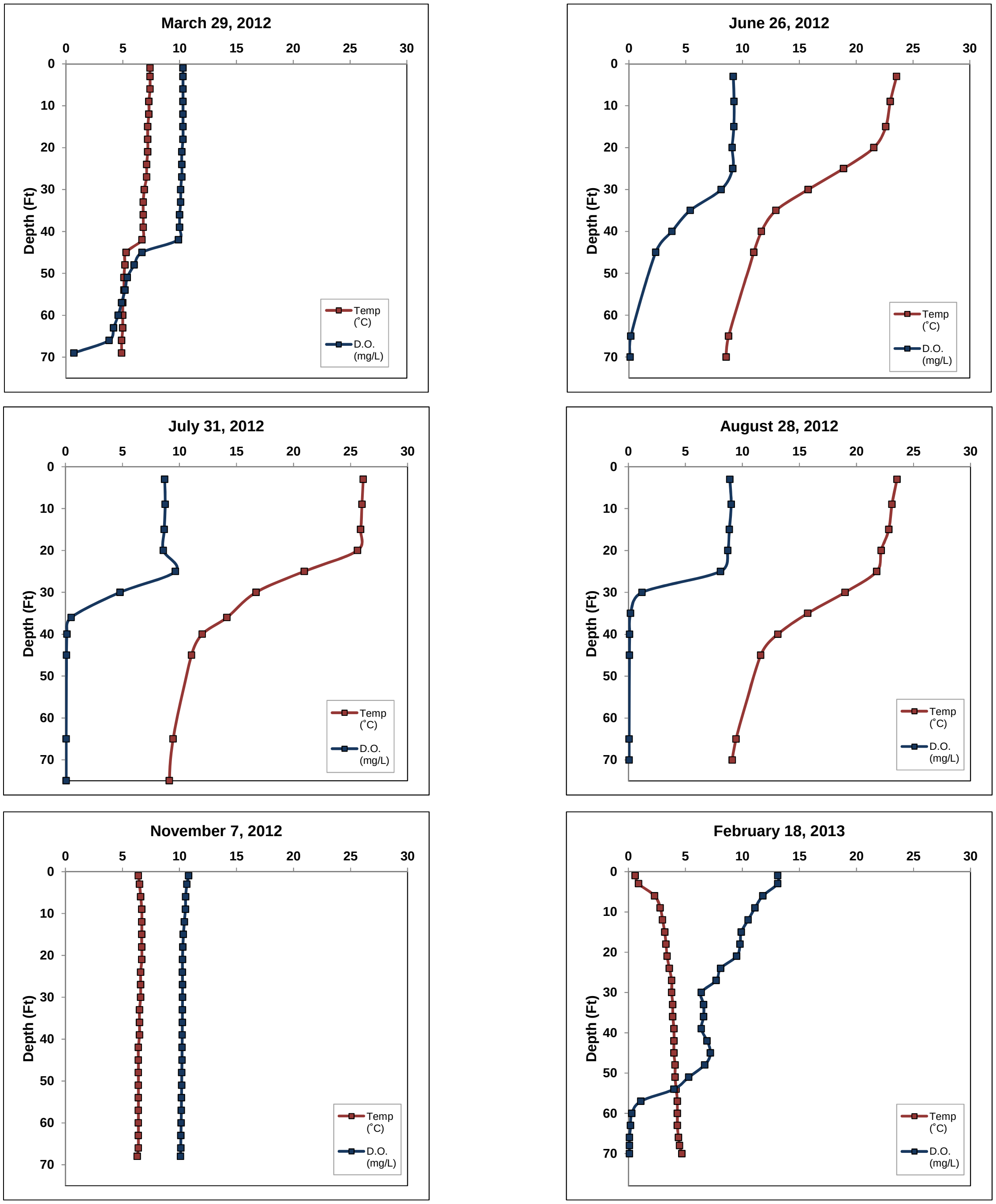

Figure 3.1-7. Dissolved oxygen and temperature profiles from Squash Lake.

Additional Water Quality Data Collected at Squash Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985). The pH of the water in Squash Lake in 2012 was found to be near neutral with surface values of approximately 7.2, falling within the normal range for Wisconsin's lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with little to no alkalinity have lower pH due to their inability to buffer against acid inputs. In 2012, the alkalinity in Squash Lake was approximately 22.6 (mg/L as $CaCO_3$) indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can sustain zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, and Squash Lake's pH of 7.2 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 Squash Lake was found to be 6.9 mg/L in 2012, falling in the *low susceptibility* category for zebra mussel establishment.

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

Based upon this analysis, Squash Lake was considered unsuitable for zebra mussel establishment.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grass or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g. reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

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

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

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

Squash Lake Watershed Assessment

Squash Lake's surface watershed (including the lake's surface) encompasses approximately 1,110 acres (Map 2). The majority of Squash Lake's watershed (534 acres or 48%) is comprised of forests, 398 acres (36%) is comprised of the lake surface itself, 70 acres (6%) is comprise of rural residential areas, 48 acres (4%) is comprised of forested and non-forested wetlands, 33 acres (3%) is comprised of row crop agriculture, and 28 acres (3%) is comprised of areas of pasture/grass (Figure 3.2-1).

Using the land cover types and their acreages within Squash Lake's watershed, WiLMS was utilized to estimate the annual phosphorus load to Squash Lake. It is difficult to accurately model lakes with no tributary input (spring lakes and seepage lakes), as WiLMS is better-suited to model drainage systems with an inlet and an outlet most accurately. However, this modeling program may be used to give managers a general idea of the phosphorus load to a spring or seepage lake. Additionally, in-field samples of the lake's total phosphorus are used to calibrate the model and ensure accuracy. Because total phosphorus data are readily available through the efforts of Squash Lake volunteers and also through this project, these calibrations were able to be made.

WiLMS predicted that the annual phosphorus load to Squash Lake is approximately 212 pounds (Figure 3.2-2). The model indicates that the greatest contributor of phosphorus to Squash Lake is through atmospheric deposition to the lake's surface itself, which accounts for 50% (106 lbs) of the total annual phosphorus load. Areas of forests were estimated to contribute 42 lbs (20%), 29 lbs (13%) from areas of row crop agriculture, 7 lbs (3%) from both pasture/grass and rural residential, and 4 lbs (2%) from forested and non-forested wetlands. Using data from the Squash Lake stakeholder survey regarding how many people and how much time they typically spend at their properties in a given year on the lake, an estimate of phosphorus loading from septic sources was calculated. This calculation estimated that approximately 18 lbs or 9% of the total annual phosphorus load to Squash Lake may come from septic sources around the lake. However, this estimate does not include the flow of groundwater into and out of Squash Lake. Those septic sources located in areas where groundwater flow was moving out of Squash Lake would have to be removed as phosphorus from those sources would have to move 'up stream' to reach the lake, and thus, this estimate from septic sources is likely overestimated.

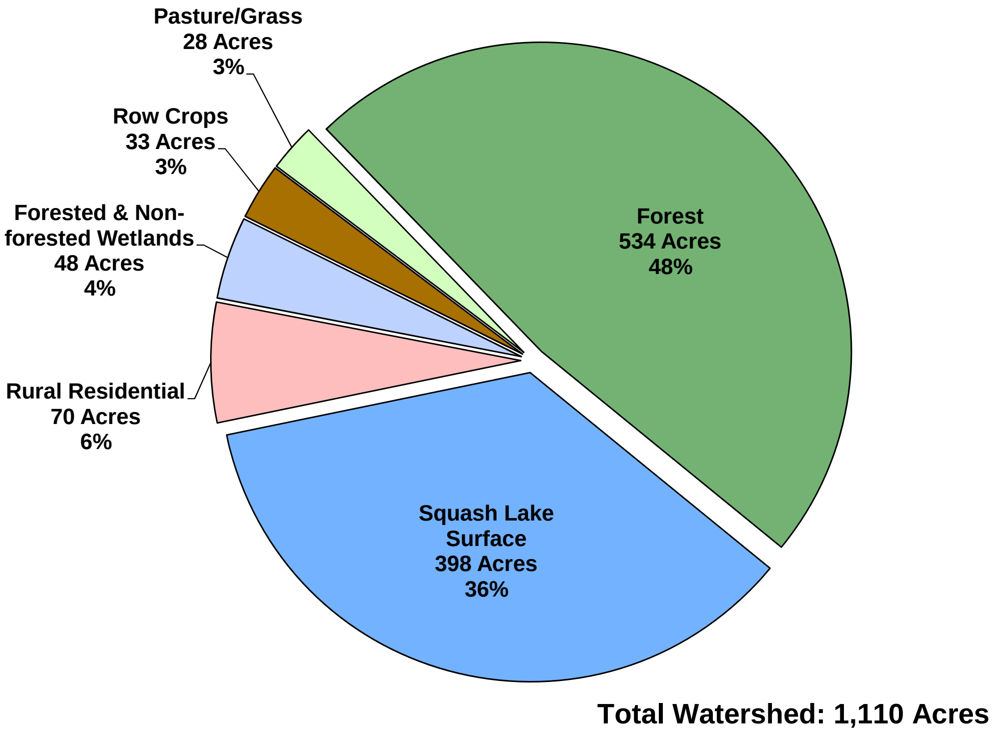

Figure 3.2-1. Squash Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Based upon the predicted phosphorus load to Squash Lake, WiLMS predicted a within-lake growing season total phosphorus concentration of 16 µg/L, which just slightly higher than the measured near-surface total phosphorus concentration of 10.8 µg/L. This indicates that the WiLMS watershed model is relatively accurate, and that there are no significant, unaccounted sources of phosphorus being loaded to Squash Lake at this time.

As previously mentioned, lakes that have a small watershed to lake area ratios like Squash Lake are particularly vulnerable to changes that may occur within the watershed. A relatively small conversion of one land cover type to another may have significant impacts upon the lake. WiLMS was utilized to model a scenario in which 25% (133.5 acres) of the forested land present in the watershed was converted to row crop agriculture. This relatively small change in land management resulted in a 100% increase in the lake's growing season total phosphorus concentration. Using predictive equations from Lillie et al. (1993), this would result in an increase of chlorophyll-*a* from the observed growing season of average of approximately 2.1 µg/L to 6.7 µg/L, and Secchi disk transparency would decline from the observed growing season average of approximately 18 feet to 8 feet. This scenario illustrates the importance of maintaining natural land cover within a lake's watershed, particularly those lakes with small watershed to lake area ratios.

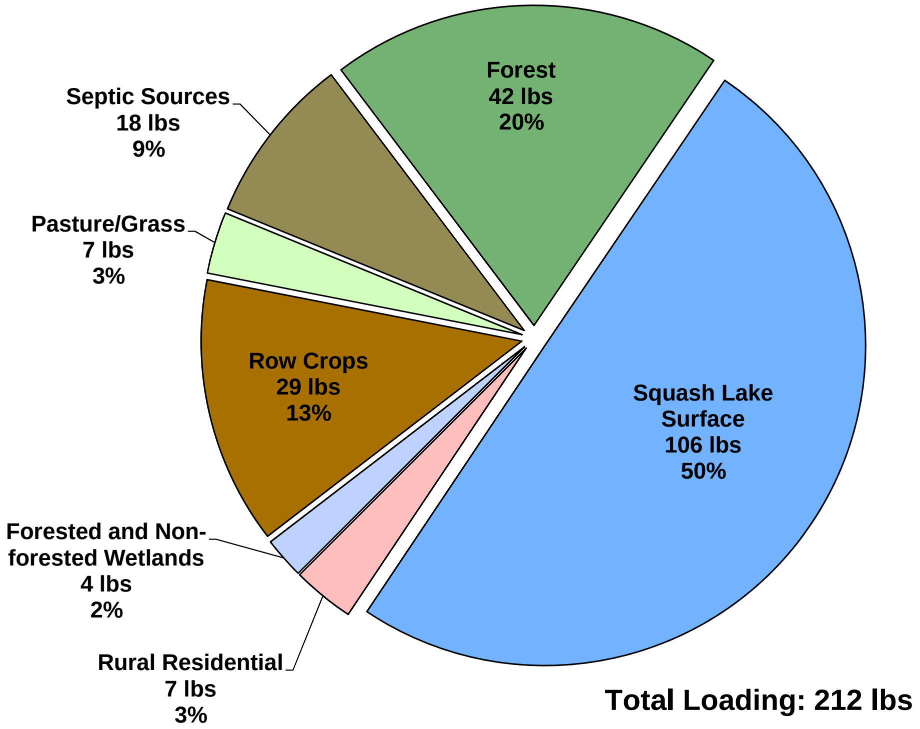

Figure 3.2-2. Squash Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

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 habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

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

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

National Lakes Assessment

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

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

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

Native Species Enhancement

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

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

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

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

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do nott allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

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

- Spring planting timeframe.
- 100’ of shoreline.
- An upland buffer zone depth of 35’.
- An access and viewing corridor 30’ x 35’ free of planting (recreation area).
- Planting area of upland buffer zone 2- 35’ x 35’ areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.

  - An aquatic zone with shallow-water 2 - 5’ x 35’ areas.
  - Plant spacing for the aquatic zone would be 3 feet.
  - Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
  - Soil amendment (peat, compost) would be needed during planting.
  - There is no hard-armor (rip-rap or seawall) that would need to be removed.
  - The property owner would maintain the site for weed control and watering.

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

Squash Lake Shoreland Zone Condition

Shoreland Development

Squash Lake’s shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-1 displays a diagram of shoreland categories, from “Urbanized”, meaning the shoreland zone is completely disturbed by human influence, to “Natural/Undeveloped”, meaning the shoreland has been left in its original state.

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

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

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

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

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

Figure 3.3-1. Shoreland assessment category descriptions.

On Squash Lake, the development stage of the entire shoreland was surveyed during the fall of 2012, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Squash Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.6 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.3 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Squash Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

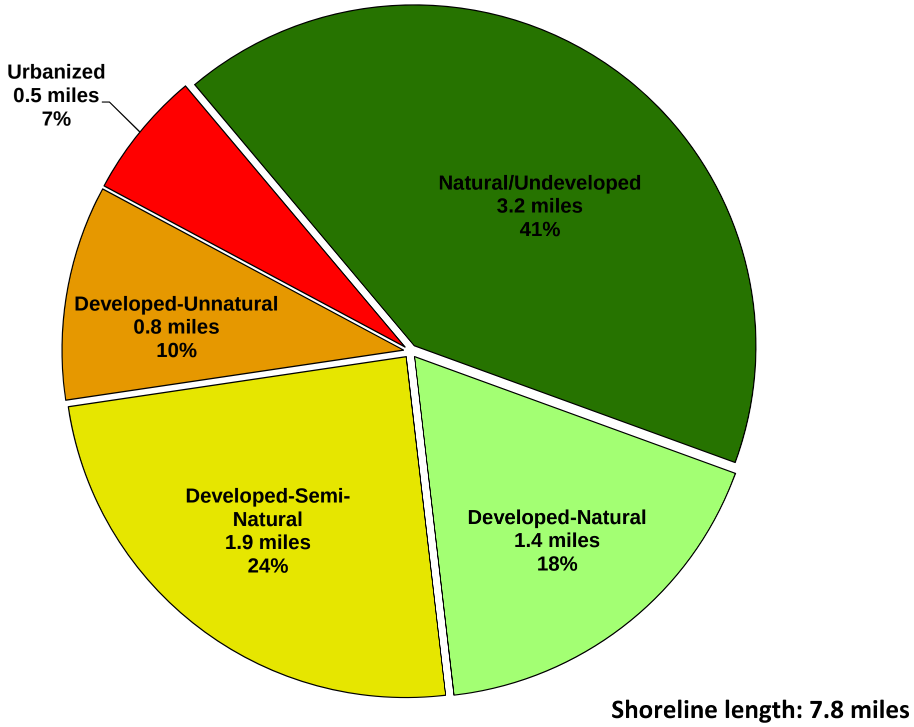

Figure 3.3-2. Squash Lake shoreland categories and total lengths. Based upon a fall 2012 survey. Locations of these categorized shorelands can be found on Map 3.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

Squash Lake was also surveyed in the fall of 2012 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 53 total pieces of coarse woody habitat were observed along 7.8 miles of shoreline, which gives Squash Lake a coarse woody habitat to shoreline mile ratio of 7:1. Locations of coarse woody habitat are displayed on map 4.

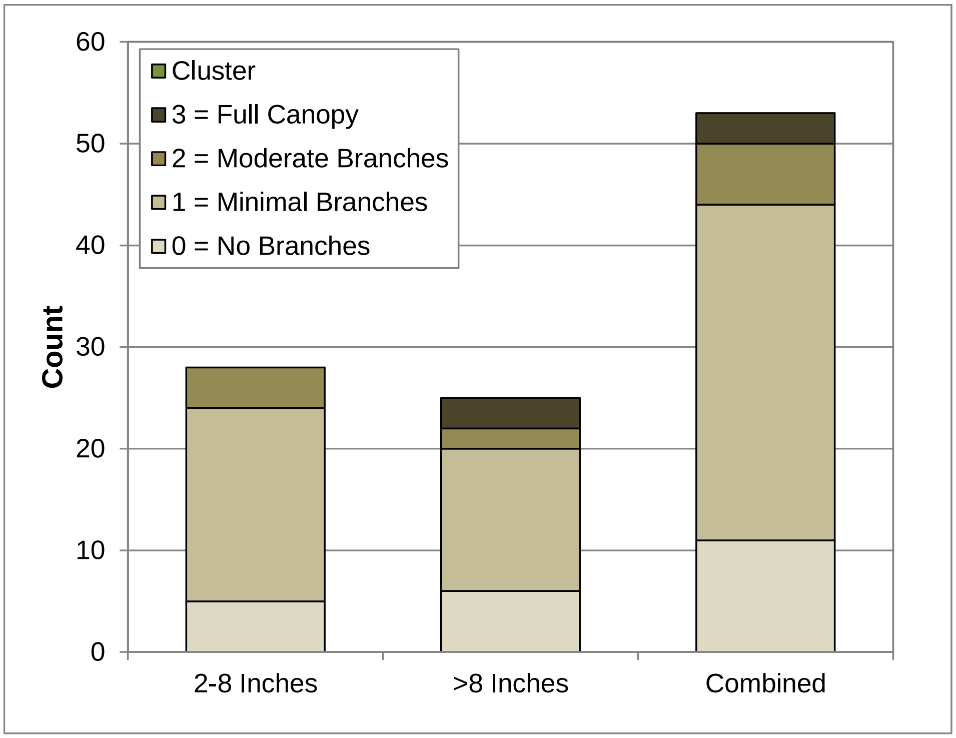

Figure 3.3-3. Squash Lake coarse woody habitat survey results. Based upon a fall 2012 survey. Locations of Squash Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

General Manual Removal Techniques

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.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and piling of fragments on shore. 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.

Important Note:
Squash Lake does not contain nuisance levels of native aquatic plants that require manual removal, and as will be discussed in the Aquatic Plant Survey Results Section, the lake contains a very high-quality native aquatic plant community. Efforts should be taken to enhance and protect the lake's native aquatic plant community, and any manual removal efforts discussed in this section should focus upon non-native aquatic plants like Eurasian water milfoil.

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.

Application to Squash Lake

As will be discussed in the Aquatic Plant Survey Results Section, Squash Lake has a very high-quality native aquatic plant community. There are no areas within the lake that contain nuisance levels of native aquatic plants that would require manual removal for navigation purposes. However, a small population of the non-native, invasive plant species Eurasian water milfoil was discovered in Squash Lake in 2009. While herbicide applications are used in Wisconsin lakes to control Eurasian water milfoil, for reasons discussed on page 42 the SLA elected not to conduct herbicide treatments in Squash Lake. Instead, the SLA chose to initiate an aggressive hand-removal program utilizing SCUBA divers (Photo 3.4-1). With this manual removal technique, SCUBA divers are able to selectively remove Eurasian water milfoil and minimize impacts to valuable native aquatic plants. As will be discussed later in this section, the annual hand-removal efforts of the SLA have maintained a low-density population of Eurasian water milfoil within the lake and have greatly minimized its ecological impact.

Photo 3.4-1. Diver hand-removing EWM in Squash Lake. Photo credit Stephanie Boismenue (SLA) 2013.

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 mainly 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.

Application to Squash Lake

Squash Lake is a natural seepage lake lacking both a defined inlet and outlet, and water levels are primarily dictated by groundwater levels and not via a control structure such as a dam. Therefore, a water level drawdown to control Eurasian water milfoil would not be an applicable management strategy for Squash Lake.

Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants in areas where navigation may be hindered, 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.

In addition to larger mechanical harvesting 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.

Cost

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

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

Application to Squash Lake

As discussed previously, Squash Lake does not contain any areas where native and/or non-native aquatic plants inhibit navigation within the lake. Because of this, mechanical harvesting of aquatic plants is not an applicable management strategy for Squash Lake.

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. For more information on the use of herbicides in Wisconsin's lakes, please visit:

http://dnr.wi.gov/lakes/plants/factsheets/GeneralherbicideFAQ.pdf.

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.

Application to Squash Lake

As mentioned, herbicides are used to control non-native aquatic plants like Eurasian water milfoil in Wisconsin's lakes. However, while Eurasian water milfoil can be controlled, there has never been a documented case in Wisconsin where it was completely eliminated from a lake following its introduction. Therefore, ongoing annual herbicide treatments are generally required to maintain a small Eurasian water milfoil population. Because these herbicides can also impact native aquatic plants and can have adverse effects to fish and other wildlife, the use of herbicides to control Eurasian water milfoil in Squash Lake was deemed unacceptable by the SLA. Current research is also indicating that herbicides applied to seepage lakes tend to take longer to degrade due to the lower rate of water exchange and lower rates of biological activity. Additionally, herbicide treatment of Eurasian water milfoil is most effective when applied to larger colonized areas. Because the Eurasian water milfoil in Squash Lake is mainly comprised of small clumps and individual plants, herbicide treatment was deemed a less viable option for control than hand-harvesting.

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.

Application to Squash Lake

Milfoil weevils have generally been used in lakes with Eurasian water milfoil populations that are larger and denser than that found in Squash Lake. The goal of milfoil weevil application is to supplement the lake's native weevil population to reduce Eurasian water milfoil. Lakes that have seen good control utilizing weevils have seen a reduction in Eurasian water milfoil density while most of the plants are prevented from reaching the surface where they create nuisance conditions. Weevils are generally used to control larger areas of colonized Eurasian water milfoil, and the Eurasian water milfoil population in Squash Lake is mainly comprised of widely scattered plants and clumps of plants. There is likely not enough Eurasian water milfoil in Squash Lake to sustain an introduced weevil population. In addition, as mentioned, research is still being conducted on weevil use in Wisconsin and they are currently not a WDNR grant-eligible method for Eurasian water milfoil control.

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 Squash Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Squash Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity and Richness

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes

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.

within the WDNR Science Services dataset will be compared to Squash Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-1) 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 shoreland. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreland complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreland complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

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

Community Mapping

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

Exotic Plants

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

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

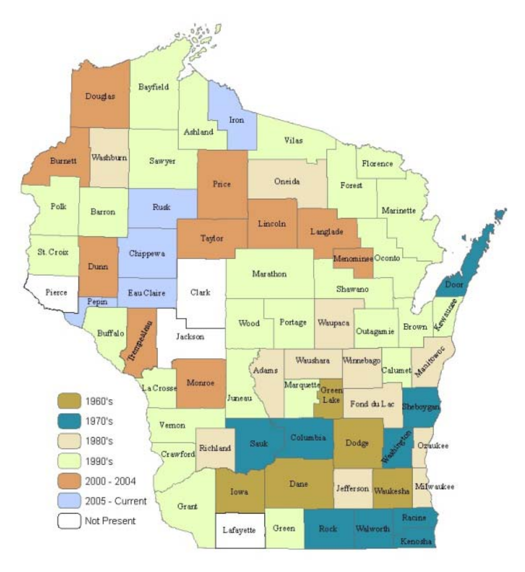

Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

As mentioned above, numerous plant surveys were completed as a part of this project. On June 6, 2012, a survey was completed on Squash Lake that focused upon locating any potential occurrences of the non-native curly-leaf pondweed. During this meander-based survey of the *littoral zone*, no occurrences of this invasive plant were located. It is believed that curly-leaf pondweed is currently not present in Squash Lake or it exists at an undetectable level.

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

The whole-lake aquatic plant point-intercept and community mapping surveys were conducted on Squash Lake on July 10 and 11, 2011 by Onterra (Appendix F). During these surveys, a total of 55 aquatic plant species were located, of which one is considered to be a non-native, invasive species: Eurasian water milfoil. Because of its ecological significance, the Eurasian water milfoil population in Squash Lake will be discussed in the following section. Most of the aquatic plant species located in 2012 were located in 2009 during a whole-lake point-intercept survey conducted by the WDNR. Table 3.4-1 contains a list of the aquatic plant species located in 2012 and a list of the aquatic plant species located during the WDNR's whole-lake point-intercept survey in 2009.

During the 2012 whole-lake point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 13 feet). These data indicate that the majority (71.2%) of point-intercept locations less than 13 feet contained sand, 14.6% contained soft/organic sediments, 13.9% contained rock, and 0.2% contained woody debris (Figure 3.4-2).

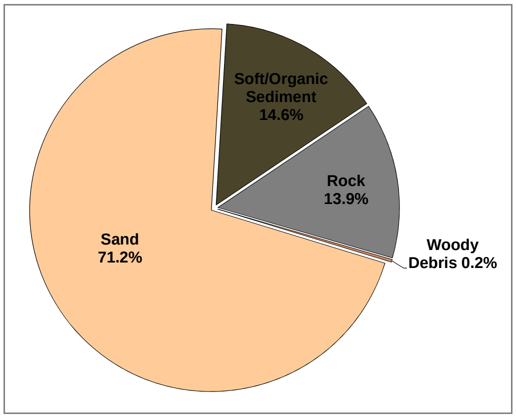

Figure 3.4-2. Squash Lake proportion of substrate types within littoral areas. Created using data from 2012 point-intercept survey.

Map 5 displays the distribution of substrates in Squash Lake as determined from the 2012 point-intercept survey. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 3.4-1. Aquatic plant species located in Squash Lake during Onterra 2012 and WDNR 2009 surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2009 (WDNR)	2012 (Onterra)
Emergent	*Carex gynandra*	Nodding sedge	6		I
	Carex hystericina	Porcupine sedge	3		I
	Drosera intermedia	Narrow-leaved sundew	8		I
	Dulichium arundinaceum	Three-way sedge	9		X
	Eleocharis palustris	Creeping spikerush	6		X
	Equisetum fluviatile	Water horsetail	7		I
	Iris versicolor	Northern blue flag	5		I
	Juncus effusus	Soft rush	4		X
	Pontederia cordata	Pickerelweed	9		X
	Schoenoplectus acutus	Hardstem bulrush	5		I
	Schoenoplectus pungens	Three-square rush	5		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		X
	Scirpus cyperinus	Wool grass	4		I
	Typha spp.	Cattail spp.	1		I
FL	*Brasenia schreberi*	Watershield	7	X	X
	Nuphar variegata	Spatterdock	6		X
	Nymphaea odorata	White water lily	6		X
FL/E	*Sparganium americanum*	Eastern bur-reed	8		I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	X	X
	Sparganium fluctuans	Floating-leaf bur-reed	10		X
	Sparganium sp.	Bur-reed species	N/A	X	
Submergent	*Bidens beckii*	Water marigold	8		X
	Ceratophyllum echinatum	Spiny hornwort	10		X
	Chara spp.	Muskgrasses	7	X	X
	Elatine minima	Waterwort	9	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Elodea nuttallii	Slender waterweed	7	X	X
	Eriocaulon aquaticum	Pipewort	9	X	X
	Isoetes spp.	Quillwort species	8	X	X
	Lobelia dortmanna	Water lobelia	10	X	X
	Myriophyllum alterniflorum	Alternate-flowered water milfoil	10	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	I	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton berchtoldii	Slender pondweed	7		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X
	Potamogeton foliosus	Leafy pondweed	6	X	X
	Potamogeton gramineus	Variable pondweed	7	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	Potamogeton strictifolius	Stiff pondweed	8		X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6		X
	Ranunculus flammula	Creeping spearwort	9	X	X
	Utricularia cornuta	Horned bladderwort	10		I
	Utricularia intermedia	Flat-leaf bladderwort	9	X	X
	Utricularia vulgaris	Common bladderwort	7	X	
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X
	Juncus pelocarpus	Brown-fruited rush	8	X	X
	Sagittaria cristata	Crested arrowhead	9	X	X
	Sagittaria graminea	Grass-leaved arrowhead	9		I
	Schoenoplectus subterminalis	Water bulrush	9		X

FL = Floating Leaf; FL/E = Floating-leaf/Emergent; S/E = Submergent/Emergent
X = Located on rake during point-intercept survey; I = Incidental species
** = Species listed as 'special concern' in Wisconsin*

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 30 feet. As discussed in the Water Quality Section, Squash Lake has very high water clarity which allows sunlight to penetrate further into the water column and support plant photosynthesis at greater depths. Of the 1,071 point-intercept locations that fell at or below 30 feet, 75% contained aquatic vegetation, indicating Squash Lake's littoral zone is highly vegetated. Map 6 illustrates that the majority of the lake supports aquatic plant growth, with only the deepest areas in the western basin lacking vegetation.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 3.4-1). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 3.4-1). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum sibiricum*) are classified as elodeids.

Photo 3.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and fern pondweed (*Potamogeton robbinsii*) of the elodeid growth form (right).

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in some lakes, like Squash Lake, with moderate alkalinity levels, the aquatic plant community is comprised of both isoetids and elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

Figure 3.4-3 illustrates the 2012 frequency of occurrence of isoetids, elodeids, characeans (macroalgae - *Chara* spp. and *Nitella* spp.), and floating-leaf and emergent aquatic plants across littoral depths of Squash Lake as determined from the 2012 whole-lake point-intercept survey. As illustrated, both isoetids and elodeids inhabit depths from 1 to 11 feet, but isoetids are dominant in shallow water between 1 and 2 feet, while elodeids are dominant at deeper depths from 3 to 16 feet. Able to tolerate lower light conditions, characeans (primarily *Nitella* spp.) dominate water depths beyond 16 feet out to 30 feet. Emergent and floating-leaf aquatic plants are restricted to shallower water, mainly less than 6 feet.

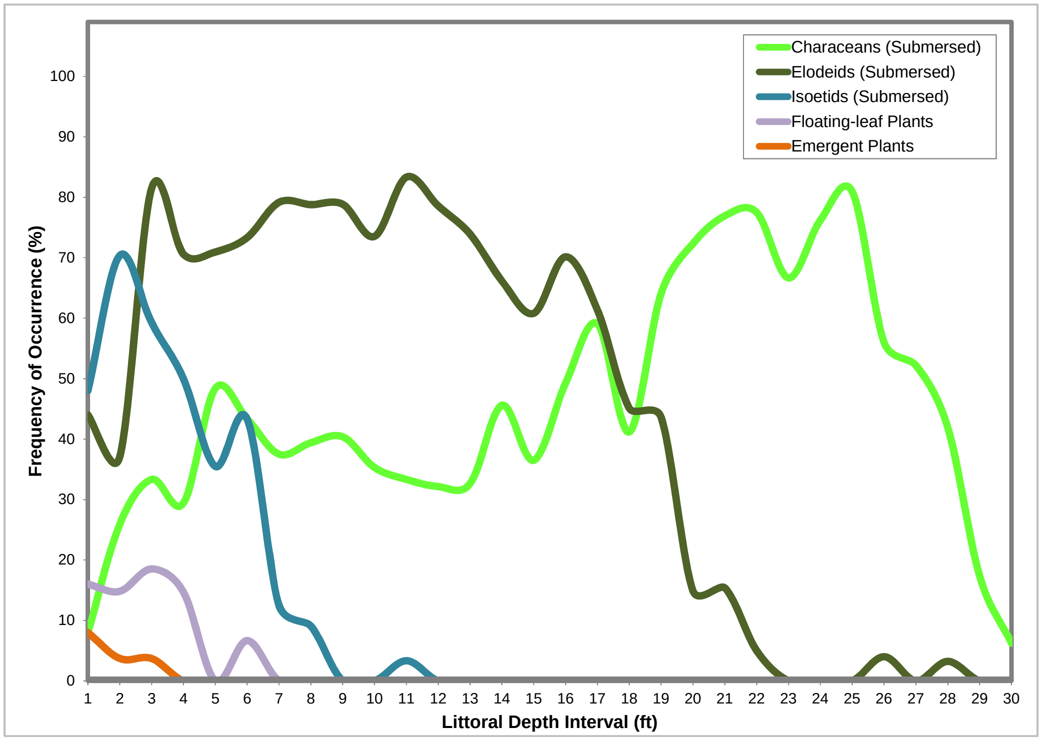

Figure 3.4-3. Frequency of occurrence of isoetids, elodeids, characeans, floating-leaf, and emergent aquatic plant species on Squash Lake. Created using data from July 2012 aquatic plant point-intercept survey. Lines smoothed to ease visualization.

Of the 53 native aquatic plant species located during 2012 surveys on Squash Lake, 42 were physically encountered on the rake during the whole-lake point-intercept survey. The remaining 12 species were located incidentally or during the community mapping survey. Of the 42 species encountered on the rake, stoneworts, fern pondweed, muskgrasses, and slender naiad were the four-most frequently encountered (Figure 3.4-4). Stoneworts (*Nitella* spp.), a genus of macroalgae, were located at approximately 32% of the point-intercept locations within Squash

Lake's littoral zone, and were the dominant plants between 14 and 30 feet of water. Despite not being a vascular plant, the stoneworts can grow relatively large and form dense beds along the lake bottom, supplying oxygen to deeper waters and providing structural habitat for micro- and macroinvertebrates and fish.

Fern pondweed (Photo 3.4-1) was the second-most frequently encountered aquatic plant in Squash Lake with a littoral frequency of approximately 20% (Figure 3.4-4), and was most abundant between 4 and 17 feet of water. As its name suggests, fern pondweed resembles the appearance of a terrestrial fern, and is a common plant of lakes in northern Wisconsin. It is generally found growing in thick beds over soft sediments, where it stabilizes bottom sediments and provides a dense network off structural habitat for aquatic wildlife.

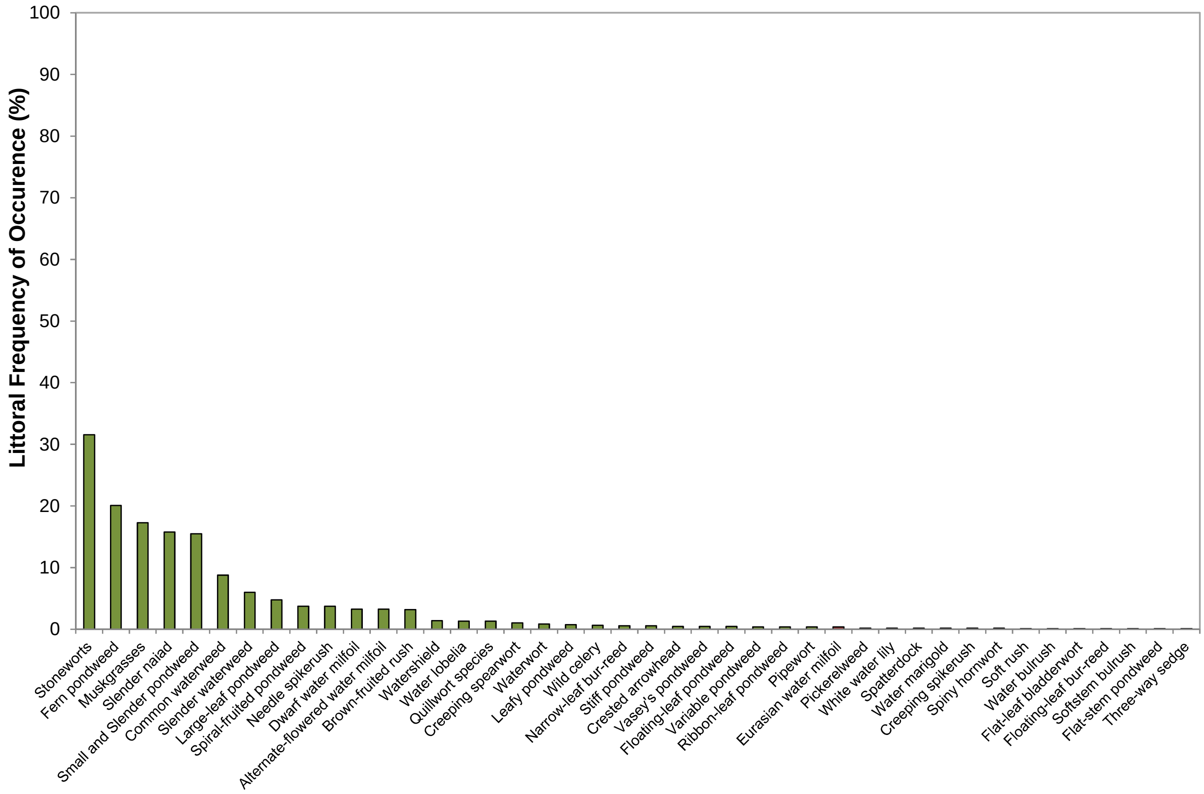

Figure 3.4-4. 2012 littoral frequency of occurrence of aquatic plant species in Squash Lake. Created using data from July 2012 aquatic plant point-intercept survey. Exotic species indicated in red.

The third-most frequently encountered aquatic plant during the 2012 point-intercept survey were the muskgrasses (*Chara* spp.), with a littoral frequency of occurrence of approximately 17% (Figure 3.4-4). Like the stoneworts, muskgrasses are a genus of macroalgae and are similar in their appearance. In Squash Lake, muskgrasses occupy shallower water than stoneworts, being most abundant between 3 and 14 feet of water. Like stoneworts, muskgrasses have long stems with multiple whorls of branches, which provide valuable structural habitat.

Slender naiad, the fourth-most frequently encountered plant species in Squash Lake, is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 1997). Being an annual, slender naiad produces numerous seeds every year, and its small, condensed network of leaves provide excellent habitat for aquatic organisms. In Squash Lake, slender naiad was most abundant between 3 and 12 feet of water.

Small pondweed (*Potamogeton pusillus*) and slender pondweed (*Potamogeton berchtoldii*) were both located in Squash Lake in 2012. However, at the time of the survey, slender pondweed was considered to be a subspecies of small pondweed, and the occurrence of slender pondweed was not recorded separately. Since the 2012 survey, slender pondweed is now considered to be a distinct species (Les 2009). As illustrated on Figure 3.4-4, the occurrences of small and slender pondweed were pooled, and together they were the fifth-most frequently encountered plants in Squash Lake in 2012.

One aquatic plant species located in both 2009 and 2012, Vasey's pondweed (*Potamogeton vaseyi* – Photo 3.4-2), is listed as special concern in Wisconsin by the Natural Heritage Inventory due to uncertainty regarding its population and rarity in the state (WDNR PUBL-ER-001 2011). It is one of a number of narrow-leaf pondweeds in Wisconsin, and possesses long, narrow submersed leaves and small round floating leaves. Its presence in Squash Lake is an indicator of the high-quality conditions.

Photo 3.4-3. State-listed special concern species Vasey's pondweed (*Potamogeton vaseyi*) located in Squash Lake.

In the summer of 2009, members of the WDNR conducted a whole-lake point-intercept survey on Squash Lake. Since the sampling methodology and sampling locations were the same as the survey conducted in 2012, the data that were collected during these surveys can be compared to determine if any changes in plant community composition occurred over this time period. Figure 3.4-5 displays the littoral frequency of occurrence of aquatic plant species from the 2009 and 2012 point-intercept surveys; only those species that had at least an occurrence of 5% were included in the analyses. Two native aquatic plant species, small/slender pondweed and large-leaf pondweed, were the only aquatic plants to exhibit a statistically valid change in their occurrence from 2009 to 2012 (Chi-square $\alpha = 0.05$). The occurrences of all the other aquatic plant species were not statistically different over this time period.

Aquatic plant communities are dynamic, and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, and disease among other factors. It is not known which factor(s) caused the detected changes in occurrence of small/slender pondweed and large-leaf pondweed from 2009 to 2012, and these small fluctuations in occurrence of certain species over time are to be expected. However, if large reductions in occurrence or a complete loss of a species were observed, it may indicate an environmental disturbance such as pollution or displacement from invasive species.

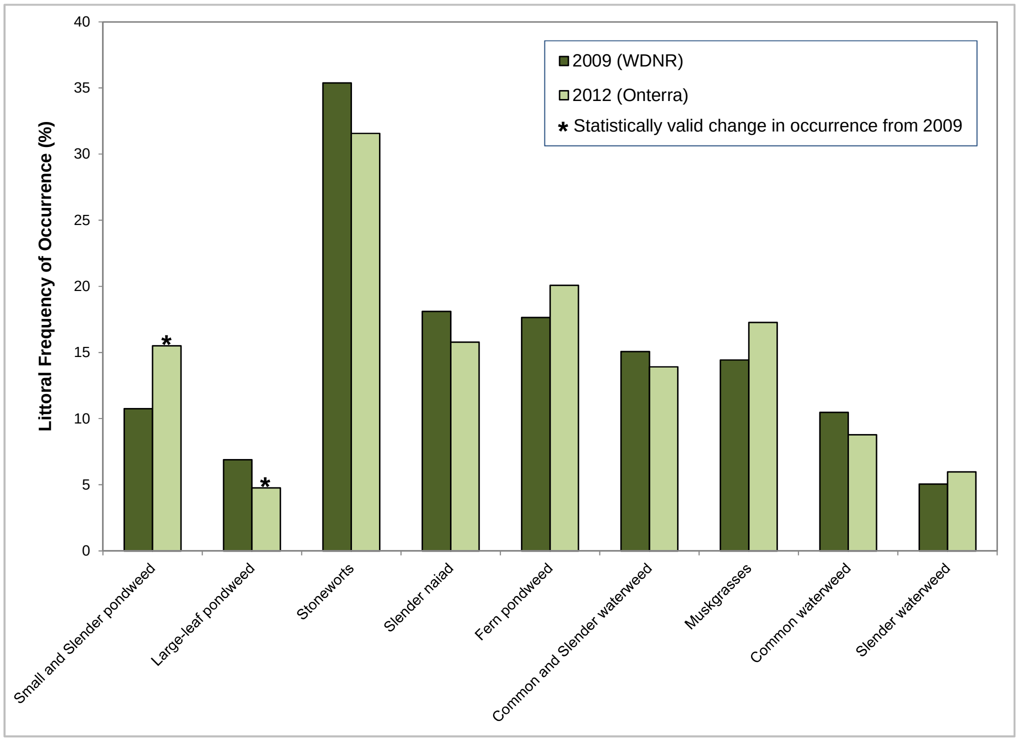

Figure 3.4-5. Littoral frequency of occurrence of select aquatic plant species from WDNR 2009 and Onterra 2012 point-intercept surveys. Note: only those species with an occurrence of at least 5% in either survey are displayed. Created using data from WDNR 2009 and Onterra 2012 point-intercept surveys.

As discussed in the primer section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The native species encountered on the rake during the 2009 and 2012 point-intercept surveys and their conservatism values were used to calculate the FQI of Squash Lake's aquatic plant community (equation shown below).

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

Figure 3.4-6 compares the 2009 and 2012 FQI components of Squash Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion and lakes throughout Wisconsin. Squash Lake is species-rich, as indicated by the native aquatic plant species richness values of 32 and 42 from the 2009 and 2012 point-intercept surveys, respectively. These values greatly exceed the upper quartile values for lakes in the NLFL Ecoregion and lakes in Wisconsin.

Littoral area, water clarity, depth and sediment variation, shoreline complexity, and water chemistry are all factors that influence aquatic plant species richness. Squash Lake, having high water clarity, has a relatively large proportion of its lake that can support aquatic plant growth (littoral area). As discussed earlier, Squash Lake contains a variety of sediment types; soft sediments, sand, and rock. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft sediments, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

Squash Lake also has high *shoreline complexity*. Shoreline complexity is an index that relates the area of the lake to the perimeter of its shoreline. If a lake were a perfect circle, its shoreline complexity value would be 1. The farther a lake deviates from a perfect circle, the higher its shoreline complexity value is. Lakes with higher shoreline complexity have more backwater areas that are sheltered from wind and wave action creating different habitats for aquatic plants. Squash Lake's high shoreline complexity (7.6) adds to the diversity of habitat types found within the lake. In addition, mesotrophic lakes like Squash Lake with moderate alkalinity tend to have the highest species richness, supporting a diverse assemblage of isoetids and characeans that can cohabitate below a scattered canopy of the larger elodeids (Vestergaard and Sand-Jensen 2000).

The average conservatism value for Squash Lake's aquatic plant community was 7.5 in both 2009 and 2012, indicating that Squash Lake contains a high number of aquatic plant species that are sensitive to environmental degradation and require high-quality conditions to persist. Squash Lake's average conservatism value falls near the upper quartile value for lakes in the NLFL Ecoregion and above the upper quartile value for lakes throughout Wisconsin (Figure 3.4-6). Combining the native species richness and average conservatism values for both 2009 and 2012 yields exceptionally high FQI values of 42.5 and 48.8, respectively, with both greatly exceeding the upper quartile values for lakes in the NLFL Ecoregion and lakes throughout the state. This analysis indicates that the aquatic plant community of Squash Lake is of higher quality than the majority of the lakes within the NLFL Ecoregion and the entire state of Wisconsin.

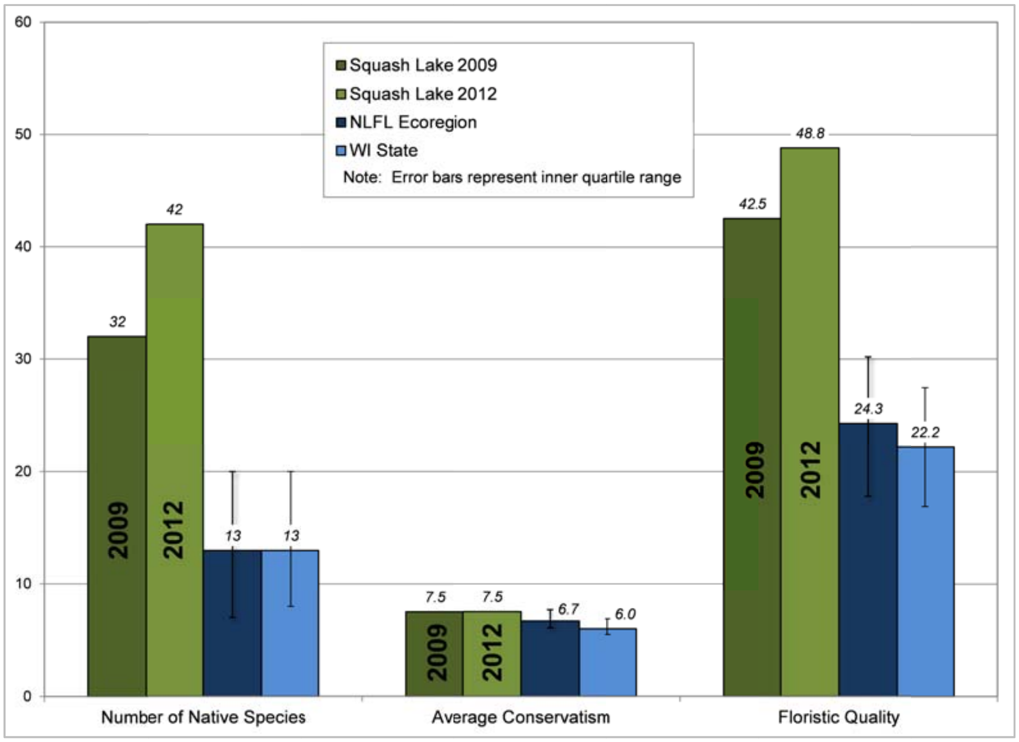

Figure 3.4-6. Squash Lake Floristic Quality Assessment. Created using data from WDNR 2009 and Onterra 2012 point-intercept surveys. Analysis follows Nichols (1999).

As explained earlier, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Squash Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

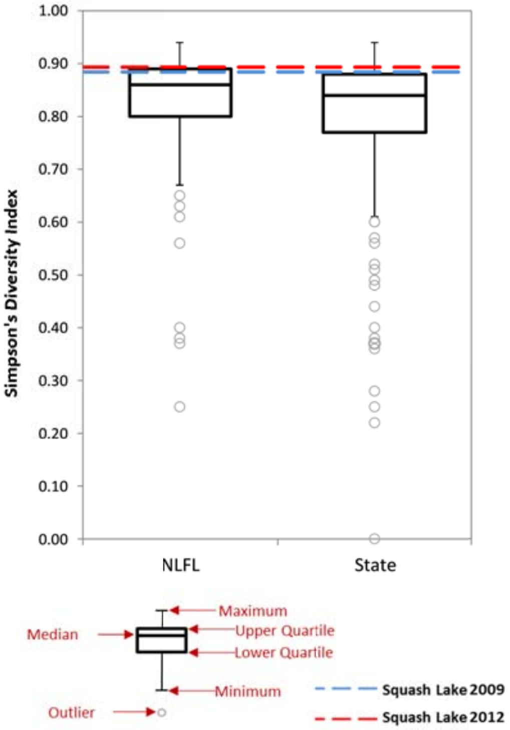

Figure 3.4-7. Squash Lake species diversity index. Created using data from WDNR 2009 and Onterra 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Squash Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLFL Ecoregion (Figure 3.4-7). Using the data collected from the 2009 and 2012 point-intercept surveys, Squash Lake's aquatic plant community was shown to have high species diversity with a Simpson's diversity values of 0.88 and 0.89, respectively. These diversity values fall right on the upper quartile values for lakes in the NLFL Ecoregion and slightly above the upper quartile value for lakes throughout Wisconsin (Figure 3.4-6). In other words, if two individual aquatic plants were randomly sampled from Squash Lake in 2012, there would be an 89% probability that they would be different species.

As explained earlier, 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 stoneworts were found at 32% of the littoral sampling locations in Squash Lake in 2012, its relative frequency of occurrence is 21%. Explained another way, if 100 plants were randomly sampled from Squash Lake, 21 of them would be stoneworts. Figure 3.4-8 displays the relative occurrence of aquatic plant species from Squash Lake in 2012, and illustrates that the aquatic plant community is not overly-dominated by one or few species, leading to higher species diversity.

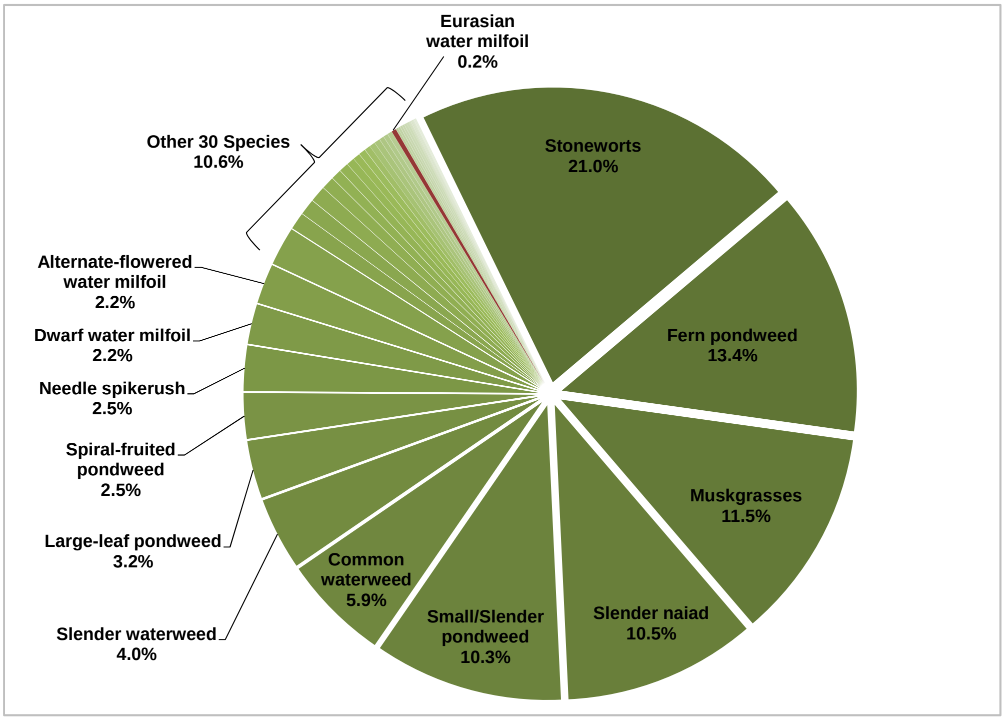

Figure 3.4-8. Squash Lake 2012 relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

The 2012 aquatic plant community mapping survey revealed that Squash Lake contains approximately 13.5 acres of emergent and floating-leaf aquatic plant communities (Table 3.4-2, Maps 7 & 8). Twenty emergent and floating-leaf aquatic plant species were located in the lake in 2012 (Table 3.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines. These communities in the southwest bay of Squash Lake were found to harbor some high-quality plant species, including the carnivorous species horned bladderwort (*Utricularia cornuta*) and narrow-leaved sundew (*Drosera intermedia*) (Photo 3.4-3).

Table 3.4-2. Acres of emergent and floating-leaf aquatic plant communities on Squash Lake. Created using data from 2012 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	0.8
Floating-leaf	0.9
Mixed Emergent & Floating-leaf	11.8
Total	**13.5**

Photo 3.4-4. Horned bladderwort (*Utricularia cornuta*) and narrow-leaved sundew (*Drosera intermedia*) located on the shores of Squash Lake.

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Squash Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. A stakeholder survey of SLA members indicates that motorboats with a 25 horsepower or greater motor are the second-most prevalent watercraft on the lake (Appendix B, Question #13). Additionally, stakeholders indicated throughout the survey that lakeshore development is one of their top concerns regarding Squash Lake (Questions #21).

Non-native Aquatic Plants in Squash Lake

Eurasian water milfoil

Eurasian water milfoil (*Myriophyllum spicatum*) was first discovered in Squash Lake in 2009. In September of that year, Onterra ecologists completed a full-lake meander-based survey to locate and map its locations. That survey revealed that Eurasian water milfoil was spread within near-shore areas around the lake, but at very low abundance, mainly in the northern, northwestern, and western portions of the lake (Map 9). The results of this survey along with potential management options were presented to members of the SLA. After reviewing these options, the association decided to move forward with an aggressive hand-harvesting effort to reduce the Eurasian water milfoil population in Squash Lake.

Hand-harvesting using paid scuba divers began during the 2010 growing season, and have since been carried out through the growing seasons of 2011, 2012, and 2013. Seventy-five percent of the cost of these hand-harvesting efforts, training, and associated monitoring has been funded through WDNR AIS Early Detection and Response Grants awarded to the SLA in 2009 and 2011. The SLA recently received a third WDNR AIS Early Detection and Response Grant in February of 2013 to continue their hand-harvesting and monitoring efforts through 2013. A summary of the Eurasian water milfoil peak-biomass surveys from September 2009-2013 within each region of Squash Lake follows. Lake-wide maps displaying Eurasian water milfoil locations from 2009-2013 can be found in Maps 9-15, while Figures 3.4-9, 3.4-10, and 3.4-11 offer a more detailed, regional view of the Eurasian water milfoil locations.

Squash Lake – North

The north region of Squash Lake includes Saw Mill and Dog Ear Bays, as well as the northwest shore of the lake (Figure 3.4-9). The first Eurasian water milfoil survey in September of 2009 revealed that the Eurasian water milfoil within this area was mainly located near shore, and comprised of *single or few plants*, a few *clumps of plants*, and one *small plant colony*. The 2010 survey revealed that overall Eurasian water milfoil occurrence within this area had declined, particularly in Dog Ear Bay and along the northwest shore of the lake. However, two small colonized areas of Eurasian water milfoil were located, one *dominant* colony in the bay west of the island, and another *scattered/highly scattered* colony along the northwest shore. The occurrence of Eurasian water milfoil in 2011 was similar to what was located in 2010, though there was a slight increase in the number of plants observed in Dog Ear Bay and Saw Mill Bay. Both of the colonized areas of Eurasian water milfoil mapped in 2010 had been reduced to point-based mapping (*single or few plants* and *clumps of plants*) in 2011.

The September 2012 survey revealed that there was a slight reduction in Eurasian water milfoil occurrence from 2011 in Dog Ear Bay and within the bay west of the island. However, Eurasian water milfoil was found to have increased in Saw Mill Bay, with a number of *single or few plants* located, a couple of *clumps of plants*, and a small *scattered* colony of Eurasian water milfoil located. The number of *single or few plants* and *clumps of plants* also increased slightly along the northwest shore from 2011 to 2012. The most recent Eurasian water milfoil survey conducted in September of 2013 showed that Eurasian water milfoil had declined within Dog Ear Bay and along the western-most portion of the northwest shore. Unfortunately, Eurasian water milfoil increased in Saw Mill Bay, comprised of two colonized areas delineated as *scattered* and one delineated as *dominant*.

When comparing the level of Eurasian water milfoil from 2009-2013 within the northern region of Squash Lake, the results are mixed. The number of *single or few plants* and *clumps of plants* located within Dog Ear Bay was lower than what was located in 2009. While not displayed in Figure 3.4-9, a June 2012 survey located a small *highly dominant* colony of Eurasian water milfoil within Dog Ear Bay, and following hand-harvesting, this colony has not been re-observed. The number of Eurasian water milfoil occurrences also is lower along the northwest shoreline of the lake in 2013 than what was mapped in 2009. However, when comparing the level of Eurasian water milfoil within Saw Mill Bay from 2009 to 2013 shows that it has increased markedly in this area, from single *clumps of plants* in 2009 to larger, colonized areas of *scattered* and *dominant* Eurasian water milfoil.

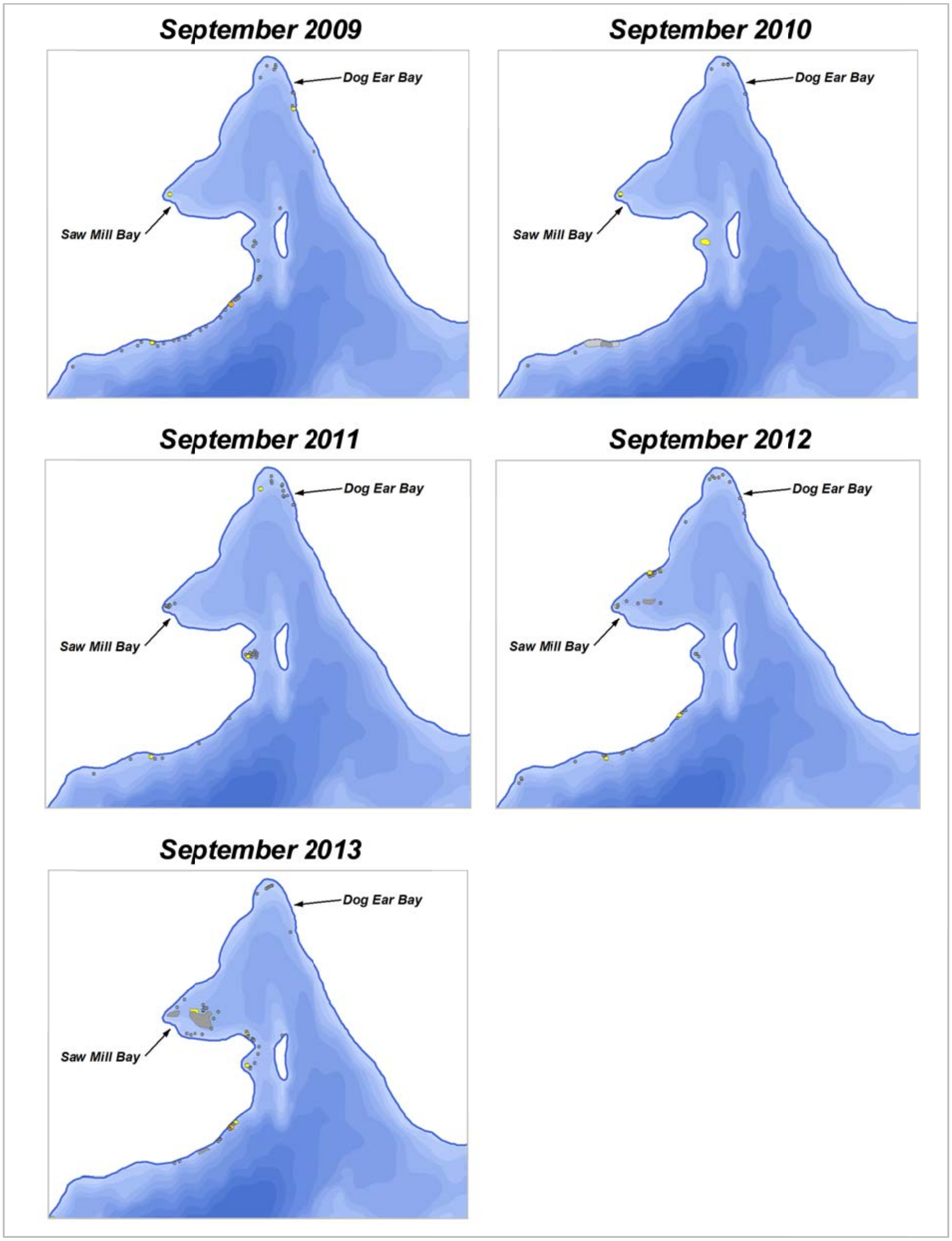

Figure 3.4-9. Squash Lake-North EWM locations from September 2009 – September 2013 Peak-Biomass Surveys. *Gray Point = Single Plant; Yellow Point = Clumps of Plants; Orange Point = Small Plant Colony; Gray Polygon = Scattered; Yellow Polygon = Dominant; Orange Polygon = Highly Dominant.*

Squash Lake – West

The western region of Squash Lake includes Pickerel Bay, Water Lily Bay, Finger Bay, Serenity Bay, Resort Bay, and shoreline areas between these bays (Figure 3.4-10). The first Eurasian water milfoil survey conducted in September 2009 indicated that Eurasian water milfoil was very sparse within this region of the lake, comprised of widely-scattered *single or few* plants. The majority were located in Pickerel and in and around Water Lily Bay. In 2010, Eurasian water milfoil was found to have increased within this area, with *scattered* and *highly scattered* colonies being mapped in Pickerel Bay, Water Lily Bay, between Water Lily Bay and Finger Bay, and on the far eastern side of Serenity Bay.

In 2011, all of the colonized areas of Eurasian water milfoil mapped were reduced to *single or few plants* and clumps of plants, although the occurrence of these increased along the shoreline between Water Lily Bay and Finger Bay, and within Finger Bay and Serenity Bay. A couple *single or few plants* were also located along the shoreline of Resort Bay in 2011. The 2012 Eurasian water milfoil survey revealed that the Eurasian water milfoil had declined in Pickerel Bay from 2011, but had increased along the shoreline between Water Lily Bay and Finger Bay. The occurrence of Eurasian water milfoil was relatively similar in Finger Bay from 2011 to 2012, but had increased in Serenity Bay with a higher number of *single or few plants* and *clumps of plants* being located than in 2011, as well as a colonized area of *dominant* Eurasian water milfoil on the eastern end. The two *single or few* plants observed in Resort Bay in 2011 had increased to four *single or few plants* in 2012.

The amount of Eurasian water milfoil located in 2013 from within Pickerel Bay and along the shoreline to just outside Finger Bay was similar to what was located in 2012. However, a large increase in the number of *single or few plants* and *clumps of plants* were observed within Finger Bay from 2012 to 2013, and a small colonized area of *scattered* Eurasian water milfoil was located along the northwest shoreline of Finger Bay in 2013. In addition, the number of *single or few plants* and *clumps of plants* increased along the shorelines of Serenity Bay and Resort Bay from 2012 to 2013, and colonized areas of Eurasian water milfoil delineated as *scattered* and *highly scattered* were located in Serenity Bay in 2013.

When comparing the level of Eurasian water milfoil in the western portion of Squash Lake from 2009 to 2013, overall it has increased in its occurrence. However, this increase is not evenly distributed throughout the western area of the lake. The number of Eurasian water milfoil plants encountered from Pickerel Bay and south along the shoreline but not including Finger Bay has only increased slightly from 2009 to 2013. The most notable increase in Eurasian water milfoil within this area has been within Finger Bay, Serenity Bay, and Resort Bay. While Eurasian water milfoil has increased within the western portion of Squash Lake from 2009 to 2013, it still remains at very low densities, comprised mainly of *single or few plants* and *clumps of plants*.

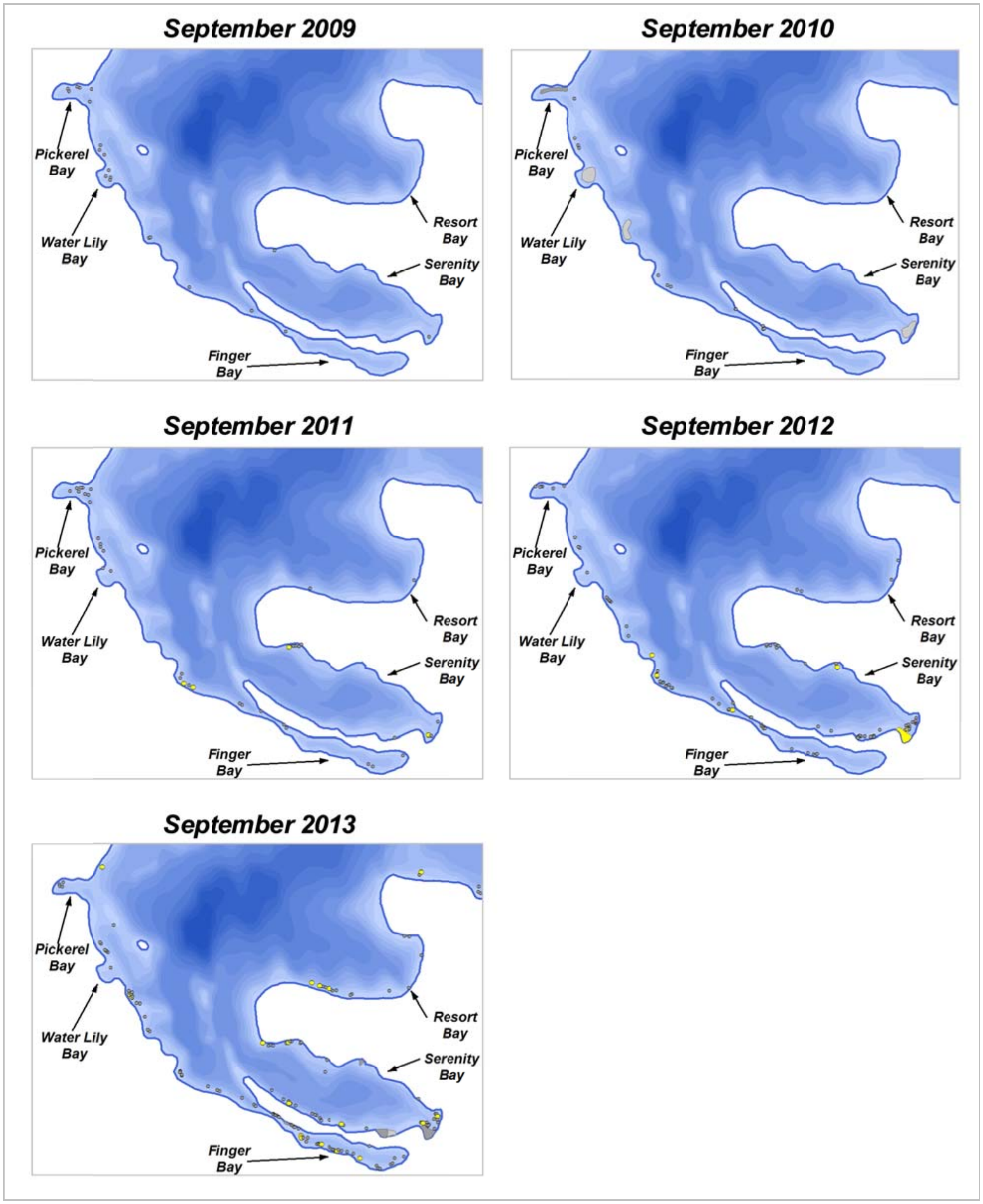

Figure 3.4-10. Squash Lake-West EWM locations from September 2009 – September 2013 Peak-Biomass Surveys. *Gray Point = Single Plant; Yellow Point = Clumps of Plants; Orange Point = Small Plant Colony; Gray Polygon = Scattered; Yellow Polygon = Dominant; Orange Polygon = Highly Dominant.*

Squash Lake – East

The eastern portion of Squash Lake includes Heron Bay, Singing Frog Bay, Loon Bay, Sleeping Turtle Bay, and the areas between (Figure 3.4-11). This area of Squash Lake has seen little Eurasian water milfoil over the course of the five surveys, with a one *single or few plants* being located along the western shore of this area in 2009, none that could be located in 2010 or 2011, one *single or few plants* in Singing Frog Bay in 2012, and approximately six *single or few plants* located again along the western shore in 2013. This area of Squash Lake is one of the most densely vegetated as determined from the 2012 point-intercept survey, and Eurasian water milfoil fragments may have a more difficult time establishing in this area of the lake due to competition from native plants.

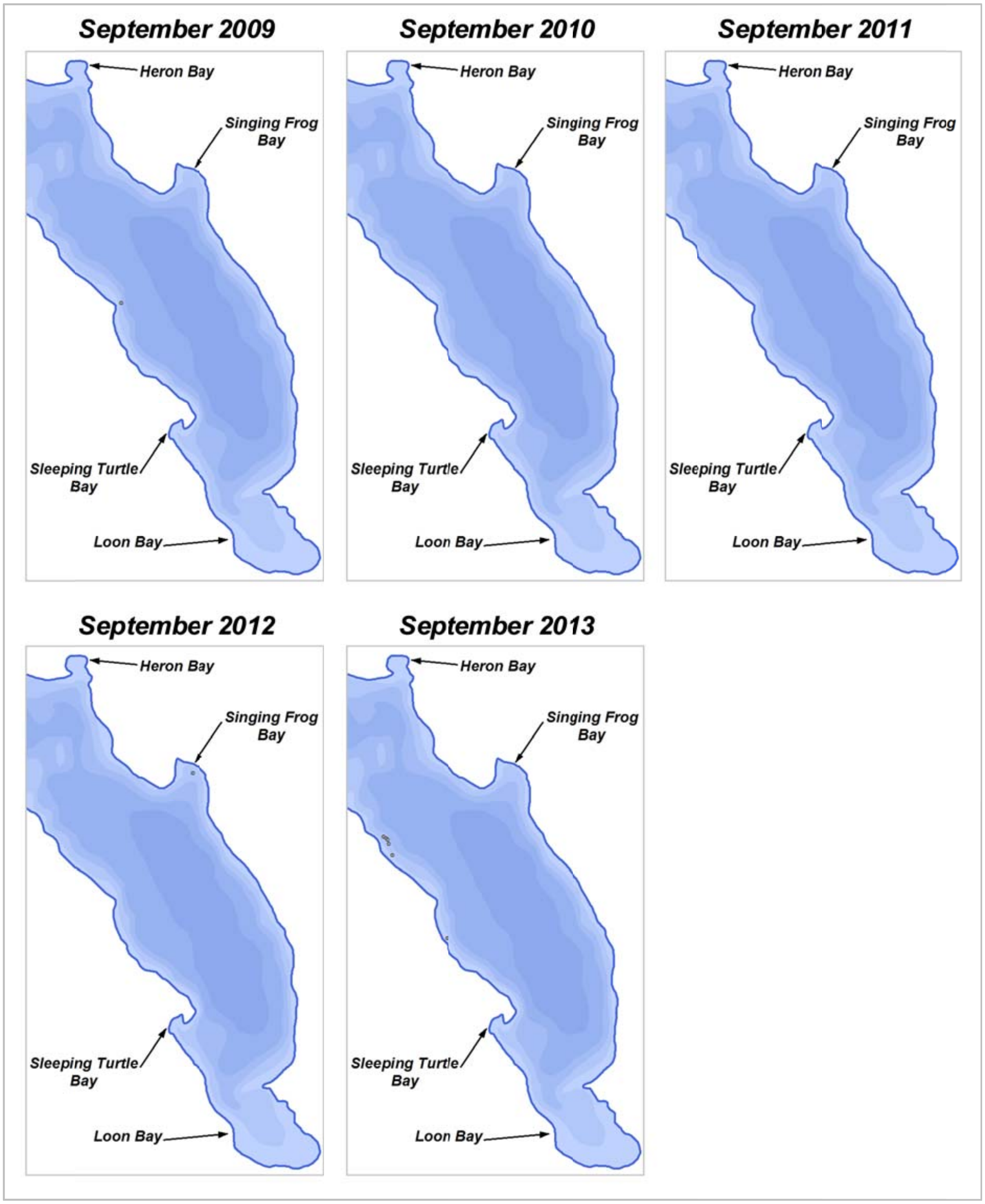

Figure 3.4-11. Squash Lake-East EWM locations from September 2009 – September 2013 Peak-Biomass Surveys. *Gray Point = Single Plant; Yellow Point = Clumps of Plants; Orange Point = Small Plant Colony; Gray Polygon = Scattered; Yellow Polygon = Dominant; Orange Polygon = Highly Dominant.*

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 Squash Lake. The goal of this section is to provide an 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 SLA 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 2013 & GLIFWC 2013A and 2013B).

Squash Lake Fishery

Squash Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing ranked highly within a list of activities stakeholders enjoy on Squash Lake (Question #14). Roughly 35% of survey respondents indicated they have fished the lake for over 25 years (Question #8). Though 45% of respondents believe the quality of fishing on Squash Lake is fair (Question #11), 63% believe this quality has gotten worse since they began fishing the lake (Question #12). Bluegill/sunfish ranked as the species residents enjoy catching the most, followed by walleye and then bass (Question 10).

Table 3.5-1 shows the popular game fish that are present in the system. When examining the fishery of a lake, it is important to remember what "drives" that fishery, or what is responsible for determining its mass and composition. The gamefish in Squash Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

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

Table 3.5-1. Gamefish present in the Squash Lake with corresponding biological information (Becker, 1983)**.**

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

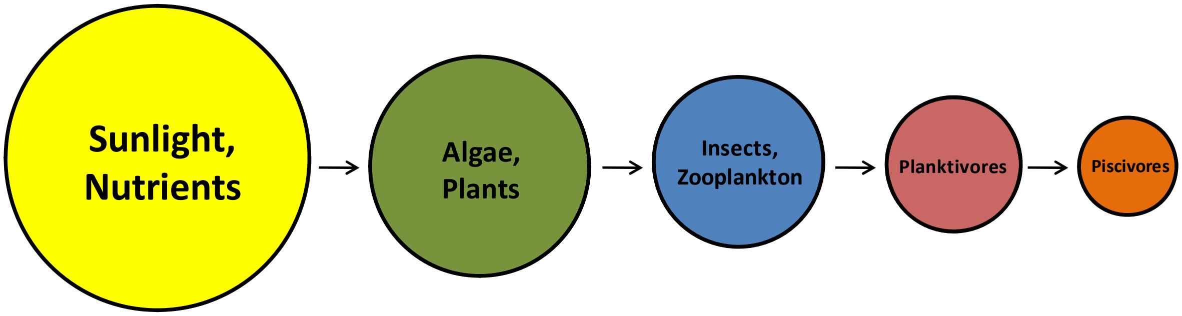

Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Squash Lake is upper oligotrophic/lower mesotrophic, meaning it has high water clarity, but a relatively low amount of nutrients and thus lower primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscivores) because the supporting food chain is relatively small.

Squash Lake Spear Harvest Records

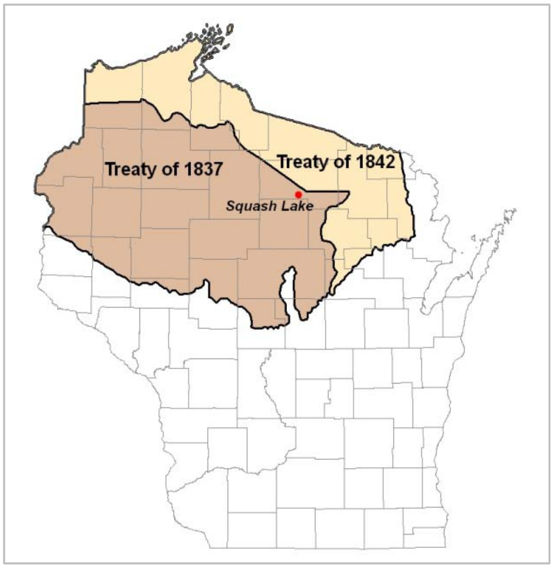

Figure 3.5-2. Location of Squash Lake within the Native American Ceded Territory (GLIFWC 2013A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-2). Squash Lake falls within the ceded territory based on the Treaty of 1837. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a “total allowable catch” is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake’s known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the “safe harvest level”. Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2013B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Records indicate that members of the Mole Lake tribe have harvested walleye since 1989 through this open water spearing season. Walleye open water spear harvest records are provided in Figure 3.5-3. One common misconception is that the spear harvest targets the large spawning females. Tribal spearers may only take two walleyes over 20 inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2013B). This regulation limits the harvest of the larger, spawning female walleye. In 2012, the sex was determined in 132 out of 155 harvested walleye. Of those, 120 of these fish were male, 11 were unable to be sexed and a single fish was determined to be female (data provided by T. Cichosz, WDNR, personal communication).

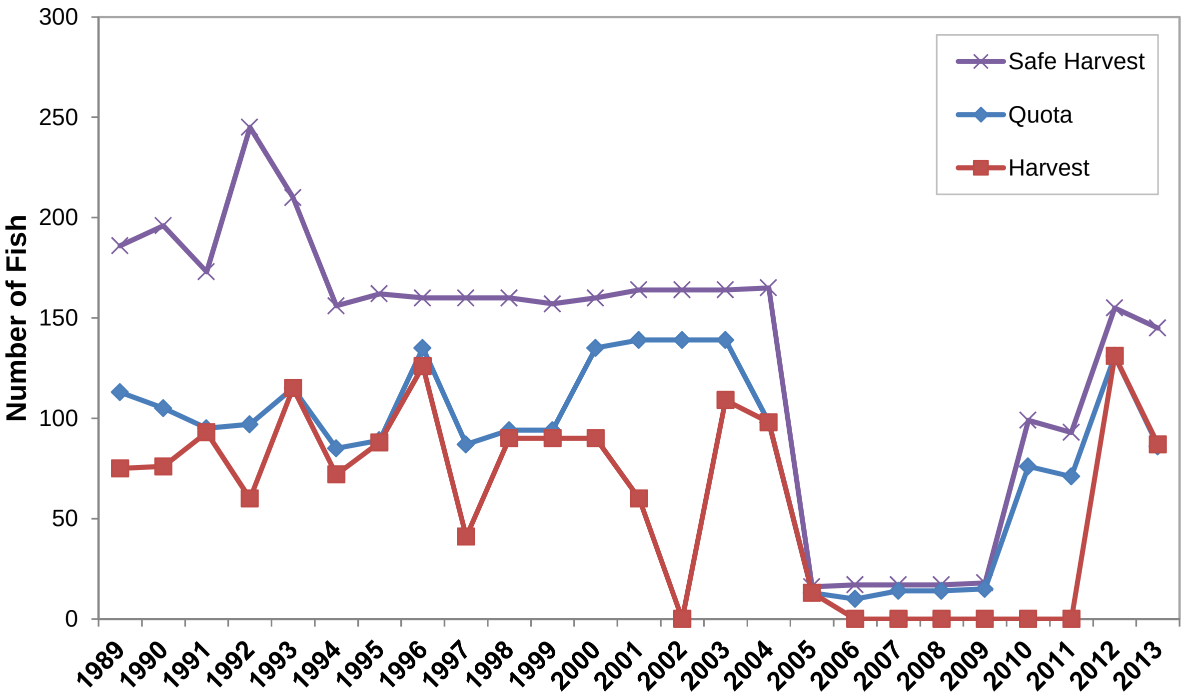

Figure 3.5-3. Squash Lake walleye spear harvest data. Annual walleye spear harvest statistics are displayed since 1989 from WDNR datasets (T. Cichosz, personal communication).

Squash Lake Substrate and Near Shore Habitat

Just as forest wildlife require proper trees and understory growth to flourish, fish prefer certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Indeed, lakes with primarily a silty/soft substrate and much aquatic plants and coarse woody debris may produce a completely different fishery than lakes that are largely sandy and contain few aquatic plant species or coarse woody habitat.

According to the point-intercept survey conducted by Onterra in 2012 on Squash Lake, 71% of the point-intercept locations shallower than 14 feet contained sand, 15% being classified as soft organic mulch and 14% being classified as rock. Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone.

Squash Lake Regulations and Management

Because Squash Lake 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 Squash Lake. In 2013, the daily bag limit was set at two fish for the lake. Currently, there is no minimum length limit on walleye but only one fish over 14" is allowed to be kept.

Because Squash Lake is located within the northern region of Wisconsin, special regulations may occur that differ from those in other areas of the state. For example, Squash Lake is in the northern large and smallmouth bass management zone. Table 3.5-2 displays the 2013-2014 regulations for species that may be found in Squash Lake. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.5-2. WDNR fishing regulations for Squash Lake, 2013-2014.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth and smallmouth bass	May 4, 2013 to June 14, 2013	Fish may not be harvested (catch and release only)
Largemouth and smallmouth bass	June 15, 2013 to March 4, 2014	The minimum length limit is 14" and the daily bag limit is 5.
Northern pike	May 4, 2013 to March 2, 2014	No minimum length limit and the daily bag limit is 5.
Walleye, sauger, and hybrids	May 4, 2013 to March 2, 2014	No minimum length limit, but only 1 fish over 14" is allowed. Daily bag limit is 2 fish.
Bullheads	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.

In a March 2010 fisheries survey report, WDNR fisheries biologist John Kubisiak reported that populations of gamefish appeared to be in good condition within the lake. Walleye relative weight (a measurement of fish condition) had increased from 1991 to 2009 in both males and females, indicating walleye are better fed than they were two decades ago. Between these time periods, largemouth bass had increased in abundance over what was previously a strong smallmouth population. Some studies, cited within Mr. Kubisiak's report, have associated high largemouth abundance with a decline in walleye abundance. Coupled with this, natural reproduction seems to be weak to moderate for walleye. During this 2010 report, Mr. Kubisiak recommended that an 18" minimum length limit be implemented for Squash Lake to allow walleye to grow to a larger size and reproduce more before potentially being harvested. Furthermore, if the lake is to be managed for walleye, encouraging harvest of largemouth bass and eliminating the 14" minimum length limit may be appropriate.

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 Squash Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian water milfoil.
3) Collect sociological information from Squash Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The three objectives were fulfilled during the project and have led to a good understanding of the Squash Lake ecosystem, the people who care about the lake, and what needs to be completed to protect and enhance it.

Through the studies conducted on Squash Lake, it is clear that overall the ecosystem is in a very healthy condition. As discussed within the Water Quality Section, Squash Lake's water quality is exceptional. The lake holds low levels of nutrients which limits algal production and creates the high clarity conditions that are present. The Secchi disk transparency data collected by SLA CLMN volunteers indicates that Secchi disk transparency averages approximately 18 feet annually. Of course, some fluctuations exist in the dataset, however these are most likely attributable to fluctuations in annual environmental conditions. Understanding these fluctuations and any potential trends in the water quality of Squash Lake can only be achieved through continued monitoring of the lake's water. Thus, the Implementation Plan that follows outlines a strategy to continue water quality monitoring in Squash Lake.

A lake's water quality is largely a reflection of its drainage basin, or watershed. Seepage lakes like Squash Lake generally have a small surface watershed when compared to the size of the lake. Squash Lake's surface watershed encompasses approximately 1,110 acres and results in small watershed to lake area ratio of 2:1. That, in combination with a watershed that is mainly comprised of intact forests, results in minimal amounts nutrients and sediments delivered to the lake. The majority of Squash Lake's immediate shoreland zone is completely natural or undeveloped. In regards to protecting Squash Lake, conserving the existing natural shoreline and restoring areas of disturbed shoreline may be one of the best options at this time.

A concerning aspect of the lake that was voiced by stakeholders within the stakeholder survey was the water level in Squash Lake. As discussed, Squash Lake is a seepage lake, meaning that it does not have a tributary feeding water to the lake; its primary sources of water includes surface water flow, groundwater, and direct deposition by precipitation. Seepage lakes typically have water levels that are controlled by the elevation of the groundwater, which is, in turn, controlled by the amount of precipitation that falls and soaks into the ground over long periods of time. During times of extended drought or a less than average rate of precipitation, the groundwater table lowers and thus, the water level within a seepage lake will also lower.

While a lower water level does not appeal to property owners or those trying to navigate the lake, this condition does not necessarily impact the lake's ecological health in a negative manner. When the water recedes from a shoreline, loose sediment may consolidate. Additionally, new habitats may be created for smaller shoreline plants, shorebirds or fish species. In fact, some plants and animals depend upon fluctuating water levels for some or all of their life cycle and thrive under these conditions. In the long-term, the fluctuating water levels in a seepage lake like Squash Lake enhance the ecosystem by increasing diversity.

The aquatic plant community within the lake and along the shorelines of Squash Lake was found to be of exceptional quality. The overall plant community contains a very high number of native aquatic plant species, many of which are indicative of a high-quality, undisturbed system. One of these plants, Vasey's pondweed (*Potamogeton vaseyi*) is considered to be rare in Wisconsin and is on the Natural Heritage Inventory's special concern list. The richness and diversity of aquatic plants in Squash Lake can be attributed to the lake's varying habitat types (sediment, light, etc.), water chemistry (moderate alkalinity), and minimal human disturbance. The benefits of Squash Lake stakeholders may see from protecting this plant community include the presence of diverse fish habitat, maintaining the lake's excellent water quality, and providing competition against non-native, invasive plants like Eurasian water milfoil.

The robust native aquatic plant community in Squash Lake is likely aiding in reducing the rate of spread and colonization of Eurasian water milfoil within the lake. The 2012 surveys indicated that Eurasian water milfoil is still in very low abundance in Squash Lake, mainly comprised of single plants and clumps of plants. The annual efforts of hand-harvesting since 2010 by the SLA are believed to be the primary reason Eurasian water milfoil has remained at these low levels. Eradication of Eurasian water milfoil is certainly a difficult, if not impossible task with what is currently known about aquatic invasive species management. The SLA has been incredibly proactive in preventing future invasive species introductions into Squash Lake along with the hand-harvesting efforts to control the current Eurasian water milfoil population.

The productivity of Squash Lake in terms of its water chemistry and aquatic plant community and its areas of sand and rock is perfect for producing a quality and self-sustaining fishery, particularly walleye. WDNR studies have shown that ample natural reproduction of top game fish species such as walleye and smallmouth bass occurs in Squash Lake, and that populations of these species are ample.

Through the process of this lake management planning effort, the SLA has learned much about their lake, both in terms of its positive and negative attributes. Overall, the lake is healthy, but there are certain aspects which require attention. It is now the SLA's responsibility to maximize the positive attributes while minimizing the negative attributes as much as possible. The Implementation Plan that follows this section stems from discussions between Onterra ecologists and the SLA Planning Committee on which action items the association may implement to properly maintain and care for this resource.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Squash Lake Association (SLA) Planning Committee and ecologist/planners from Onterra. It represents the path the SLA 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 Squash Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Control Existing and Prevent Further Introductions of Aquatic Invasive Species to Squash Lake

Management Action:	Continue scuba diver hand-harvesting strategy to control Eurasian water milfoil population in Squash Lake.
Timeframe:	Continued from 2010
Facilitator:	Stephanie Boismenue
Description:	While Eurasian water milfoil has become more widespread in Squash Lake since its discovery in 2009, its abundance remains very low as evidenced by the 2012 point-intercept survey (EWM littoral occurrence of 0.4%) and the annual EWM Peak-Biomass Surveys. The fact that the majority of the EWM in Squash Lake remains comprised of single plants and clumps of plants can be attributed to aggressive hand-removal efforts that have been undertaken by the SLA annually since 2010. Squash Lake stakeholders are not in favor of the use of herbicides as a method of EWM control, as indicated by the 2012 stakeholder survey (Appendix B, Question #24), and the SLA wants to continue managing the EWM within Squash Lake utilizing non-chemical (hand-removal) methods. As discussed earlier, 75% of the cost of utilizing paid scuba divers to hand-harvest EWM in Squash Lake has been funded through WDNR AIS Early Detection and Response (EDR) Grants awarded to the SLA in 2009 and 2011. In February 2013, the SLA received their final AIS-EDR Grant to fund hand-harvesting and associated monitoring through 2013. Because 2014 marks five years since EWM was discovered in Squash Lake, the EWM control program is transitioning from an EDR Program to an Established Population Control (EPC) Program. No hand-harvesting program in Wisconsin has seen the level of organization and effort like that of the SLA and they continue to be a model for hand-harvesting programs in the state. However, the SLA understands that in order to be eligible for AIS-EPC funds, their program requires the creation of defined success criteria to assess the

efficacy of hand-removal. The hand-removal methodology also needs to be optimized to ensure that the desired level of EWM control is reached while expending a reasonable amount of time and effort.

The objective of this management action is not to eradicate EWM from Squash Lake, as that is impossible with our current tools and techniques. The objective is to maintain an EWM population that exerts little to no detectable impacts on the lake's native aquatic plant community and overall ecology, recreation, and aesthetics. Monitoring is a key aspect of any AIS control project, both to prioritize areas for control and to monitor the strategy's effectiveness. The monitoring also facilitates the "tuning" or refinement of the control strategy as the control project progresses. The ability to tune the control strategies is important because it allow for the best results to be achieved within the plan's lifespan. It must be noted that hand-removal methodology is still experimental, and success criteria for assessing the efficacy of hand-removal have never been defined. Because of this, the following series of steps to manage EWM via hand-removal in Squash Lake should remain flexible to allow for modifications as the project progresses. The series includes:

1. A lake-wide assessment of EWM (Peak-Biomass Survey) completed while the plant is at or near its peak growth (late summer 2014-2017). This meander-based survey of the lake's littoral zone is designed to locate all possible occurrences of EWM, and the findings would be compared to results from the previous summer's Peak-Biomass Survey to assess the efficacy hand-harvesting.

2. Using EWM findings from the most recent Peak-Biomass Survey, professional ecologists will work with the SLA to delineate defined EWM hand-harvesting sites (Site A, B, etc.). The paid scuba divers will then be able to record the amount of hours (effort) spent within each site, allowing for a more accurate assessment of the level of effort spent within each area.

   Colonized areas of EWM (polygons) exert the greatest ecological strain as they are the largest sources for future spread and displace valuable native plant species. Because of the level of EWM within these areas, a large amount of effort (hours) are needed to remove/reduce the EWM via manual hand-removal. Starting in 2014, the use of the Diver-Assisted Suction Harvest (DASH) system to target colonized areas of EWM in Squash Lake will be tested (see next Management Action). By targeting the largest and densest areas of EWM with the DASH system, the SLA paid scuba divers will be able to focus their efforts on areas of EWM that are less dense and more suitable for manual hand-removal. The SLA paid scuba diver hand-removal sites would be categorized based upon the level of EWM within each area. Sites containing *small plant colonies* would be classified as areas requiring the greatest need for hand-removal, or primary focus sites, while areas containing *clumps of plants* and only *single or few plants* would be classified as secondary and tertiary focus sites, respectively.

3. Hand-removal efforts begin in the spring of 2014-2017.

4. A lake-wide assessment of EWM (Early-Season AIS Survey) would be completed in early June to reassess areas of EWM located during the previous year's Peak-biomass Survey to ensure the presence of EWM within these areas and refine/re-prioritize hand-removal areas if necessary.

5. If the SLA scuba divers locate additional EWM in areas that it was not located during the previous year's Peak-Biomass Survey or in the June ESAIS Survey, they may opt for an additional lake-wide assessment of EWM in July 2014-2017 by professional ecologists. This would allow for the most accurate picture of EWM within the lake and enable Onterra ecologists and SLA scuba divers to re-focus their efforts to different locations if necessary.

6. EWM Peak-Biomass Survey conducted to determine hand-removal efficacy and hand-removal sites/strategy for the following year. The crux of this activity is included within Step 1.

7. Reports generated on hand-removal success and recommendations for following year's strategy.

Normally, AIS control programs (mainly with herbicides) incorporate both established qualitative (EWM mapping) and quantitative (sub-sample point-intercept survey) evaluation methodologies. However, quantitative monitoring of hand-removal areas using sub-sample point-intercept methodology is likely not applicable at this time as there are no areas of EWM large enough to attain the number of sampling locations required to meet the assumptions of statistical analyses. Therefore, each hand-removal site would be monitored using qualitative methods.

The qualitative monitoring would be completed by comparing pre-hand-harvesting (summer before hand-harvesting) with post-hand-harvesting (summer immediately following hand-harvesting) EWM Peak-Biomass Surveys. An SLA manual hand-removal site will be deemed successful if the level of EWM is maintained at the point-based mapping level; for example, a site would be considered unsuccessful if it contained *single or few plants* (point-based mapping) prior to hand-harvesting and expanded to contain colonized EWM (polygons) following hand-harvesting. Sites of colonized EWM that will be targeted with the DASH system will be deemed successful if they are reduced by at least two density ratings (e.g. *highly dominant* to *scattered*) following the implementation of the DASH system.

In the final year of the project (2017), a whole-lake point-intercept survey would be conducted on Squash Lake to reassess the EWM population and native aquatic plant population at the lake-wide level. The results of these studies would be compared to studies conducted as part of this management planning project.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2. Apply for a WDNR AIS-EPC Grant based upon developed project design.
3. Initiate control plan.
4. Modify control plan methodology annually, as needed.
5. Update management plan to reflect changes in control needs and those of the lake ecosystem.

<u>Management Action:</u> SLA to contract with Many Waters, LLC, or a similar firm, to conduct Diver-Assisted Suction Harvesting (DASH) of colonized areas of EWM in Squash Lake.

Timeframe: Initiate 2014

Facilitator: Squash Lake Board of Directors

Description: It is believed that integrating the professionally-operated Diver-Assisted Suction Harvesting (DASH) system into the SLA’s hand-harvesting program may make the program more efficient and cost-effective. The DASH system involves scuba divers removing EWM plants by hand and feeding them into a suction hose attached to a pontoon boat for removal. It is believed that the DASH system will be able to remove/reduce areas of colonized EWM more efficiently than standard manual removal via scuba divers. SLA scuba divers experienced the use of the DASH system in Squash Lake in the summer of 2013 and found that it was an efficient method for removal of EWM in larger, colonized areas. By targeting the largest, densest areas of EWM with the DASH system, the SLA scuba divers will be able to focus their efforts on areas around the lake with less-dense EWM.

Action Steps:

1. Contact Many Waters, LLC (715.617.4688/barb@manywatersconsulting.com)
2. Obtain mechanical harvesting permit from WDNR using Map 16.

Management Action: Continue assessment of shoreline and littoral areas of the lake for aquatic invasive species (AIS) via Volunteer AIS Monitors.

Timeframe: Continuation of current effort.

Facilitator: Stephanie Boismenue

Description: Early detection of new aquatic invasive species infestations commonly leads to successful control, and in cases of small infestations, possibly even eradication. Currently, SLA volunteers perform a considerable amount of aquatic invasive species (AIS) monitoring in which the volunteers monitor the entire areas of the system in which plants can grow (littoral zone) annually in search of invasive species that aren't currently in the lake like curly-leaf pondweed. This program uses an approach where volunteers are responsible for surveying specified areas of the system and report their findings.

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

Each year, the SLA holds a volunteer training session at the Squash Lake boat landing, where Oneida County AIS Coordinator Michele Saduaskas and SLA member Stephanie Boismenue conduct AIS identification training and monitoring for volunteers.

Action Steps:

1. Volunteers from SLA update their skills by attending a training session conducted by the AIS Coordinator for Oneida County (Michele Saduaskas – 715.365.2750) and SLA member Stephanie Boismenue.
2. Trained volunteers recruit and train additional association members.
3. Complete surveys following protocols.

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

Timeframe: Initiate upon exotic infestation

Facilitator: Planning Committee with professional help as needed

Description: In the event that another aquatic invasive species, such as curly-leaf pondweed, is located by the trained volunteers, the areas would be marked using GPS and would serve as focus areas for professional ecologists. Those focus areas would be surveyed by professionals during that plant specie's peak growth phase (early summer for curly-leaf pondweed) and the results would be used to develop potential control strategies.

Small isolated infestations of curly-leaf pondweed can most appropriately be controlled using manual removal methods, likely through scuba or snorkeling efforts. The use of this technique is well supported by SLA stakeholders as indicated by approximately 87% of stakeholder survey respondents indicating that they are at least moderately supportive of a manual removal program (Appendix B, Question #24). In order for this technique to be successful, the entire plant (including the root) needs to be removed from the lake. During manual extraction, careful attention would need to be paid to all plant fragments that may detach during the control effort.

Action Steps:

1. See description above.

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Squash Lake public access location.

Timeframe: Continuation of current effort

Facilitator: Squash Lake Board of Directors

Description: Currently the SLA monitors the public boat landing using training provided by the Clean Boats Clean Waters program. Squash Lake is an extremely popular destination for recreationalists and anglers given its proximity to Rhinelander, making it vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasives from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasives that originated in Squash Lake. The goal would be to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread.

Due to the large number of activities that volunteers are called upon on Squash Lake (Hand-removing, AIS monitoring, stakeholder education, etc.), paid watercraft inspectors would be sought to monitor the Squash Lake's single public boat landing. In 2013, SLA volunteers monitored Squash Lake's boat landing for approximately 375 hours.

Action Steps:

1. See description above as this is an established program.

Management Goal 2: Assure and Enhance the Communication and Outreach of the Squash Lake Association with Lake Stakeholders

Management Action: Support an Education and Communication Committee to promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Squash Lake.

Timeframe: Develop in 2014

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

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

Currently, the SLA regularly publishes and distributes a quarterly newsletter and maintains an association website that provide association-related information including current association projects and updates, meeting times, volunteer opportunities, and educational topics. Both of these mediums are an excellent source for communication and education to both association and non-association members.

While 95% of respondents indicated that the SLA keeps them either *fairly well informed* or *highly informed* regarding issues with Squash Lake and its management (Appendix B, Question #28), the SLA would like to increase its capacity to reach out to and educate association and non-association members regarding Squash Lake and its preservation. In addition to creating a quarterly newsletter, a variety of educational efforts will be initiated by the Education and Communication Committee. These may include educational materials such as a tri-fold brochure containing information about the SLA (projects, finances, etc.) as well as facts about Squash Lake and steps lake residents can take to maintain and enhance the quality of the lake, as well as quality of life for those who live and recreate on it. The Education and Communication Committee will also organize workshops and speakers surrounding lake-related topics.

Education of lake stakeholders on all matters is important. During the second planning meeting with SLA Planning Committee members, the list below of educational topics was developed. These topics can be included within the association's newsletter and/or website or distributed as separate educational materials. In addition, the SLA can invite professionals who work within these topics to come and speak at the association's annual meeting or hold workshops if available.

Example Educational Topics

- Shoreline restoration and protection
- Importance of maintaining course woody habitat
- Effect lawn fertilizers/herbicides have on the lake
- Fishing rules and regulations
- Catch-and-release fishing
- Information pertaining to Native American spear harvests in Squash Lake
- Boating regulations and safety
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community
- Respect to and maintaining a safe distance from wildlife (e.g. loons) within the lake
- Aquatic invasive species (AIS) prevention and updates for AIS in Squash Lake
- Water quality monitoring updates from Squash Lake
- Septic system maintenance
- Littering on the ice and year-round

In addition to creating educational materials for the association's newsletter and website, the Education and Communication Committee would also be responsible for greeting new residents to the lake personally, and provide them with SLA information including the benefits of being a member and the projects the SLA has undertaken to maintain and enhance Squash Lake.

Action Steps:

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

Management Action: Increase volunteerism within the SLA.

Timeframe: Begin summer of 2014

Facilitator: Board of Directors

Description: Even through lake associations consist of individuals who are passionate about the lake they reside upon, it is often difficult to recruit volunteers to complete the tasks that are necessary to protect that lake. Many lake association members are elderly and retired, often making labor intensive volunteer jobs are difficult to perform.

Other residents may only visit the lake several times during the year, often on weekends to "get away" from the pressures of the work-week back home. Some have cut back on volunteering because of recent economic downturns or concerns over the time commitment involved with various volunteer tasks, while others may simply have not been asked to lend their services.

Those that have volunteered in the past and have had a poor experience may be hesitant to volunteer again. Without good management, volunteers may become underutilized. Some may have been turned off by an impersonal, tense or cold atmosphere. Volunteers want to feel good about themselves for helping out, so every effort must be made by volunteer managers to see to it that the volunteer crews enjoy their tasks and their co-volunteers.

The SLA is proud of their active role in preserving and enhancing Squash Lake for all stakeholders; however, they are in constant need of volunteers to continue this high level of commitment. They currently highlight an outstanding volunteer in each one of their quarterly newsletters. This is an excellent way to show gratification to those who volunteer and to showcase the work that volunteers do for the SLA and Squash Lake. As a result of this lake management planning project, the association is now in need of additional help to increase the level of protection the SLA wishes to provide for the lake. In order to retain volunteer help and recruit more volunteers for these tasks, the SLA will undertake a volunteer recruitment strategy as outlined below. While volunteer recruitment for a lake association may be difficult, the following tips will be helpful in the SLA's efforts to solicit help for lake-related efforts.

Action Steps:

1. Board of directors appoints a volunteer coordinator. This should be a friendly, outgoing person who is able to engage people they may know or not know. The volunteer coordinator's duties are to recruit, train, supervise and recognize volunteers. Building and maintaining a volunteer database with names, contact information, tasks, hours completed, etc. will be necessary.
2. Coordinator will initially recruit volunteers through personal means, not via telephone, email or newsletter notification. Engaging a person in a friendly atmosphere through a personal invitation is more likely to result in a successful recruitment than through an impersonal email.
3. Coordinator will have duties outlined prior to recruiting volunteers. A volunteer's time should not be wasted! Work descriptions, timeframes and other specifics should be known by each worker prior to their shift.
4. Coordinator will be flexible in allowing volunteers to contribute towards project designs and implementation. Recruiting new leaders through delegating tasks will empower volunteers and give them

reason to continue volunteering.

5. The board of directors will continue to recognize volunteers through incentives and appreciation. Snacks, beverages, public acknowledgement and other means of expressing appreciation are encouraged.

Management Action: Enhance the SLA's involvement with other entities that manage aspects of Squash Lake.

Timeframe: Continuation of current effort.

Facilitator: Squash Lake Board of Directors

Description: The waters of Wisconsin belong to everyone and, therefore, this goal of protecting and enhancing these share resources is also held by other agencies and entities. It is important that the SLA actively engage with all management entities to enhance the association's understanding of the common management goals and to participate in the development of these goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. While not an inclusive list, the primary management units regarding Squash Lake are the WDNR (fisheries, AIS, and lake management personnel), the Chamber of Commerce, Woodboro and Crescent Townships, Oneida County Lakes & Rivers Association (OCLRA), Crescent Town Lakes Committee, Oneida County Land and Water Conservation Department, and Wisconsin Lakes. Each entity is specifically addressed in the table on the next page.

Action Steps:

1. See the following table guidelines on next page.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Rhinelander Chamber of Commerce	General staff (715.365.7464)	Provides information and networking related to the advancement of the Squash Lake community.	Once a year, or more as needed. May check website (http://www.explorerhinelander.com/chamber-info/?utm_source=browser&utm_medium=url&utm_campaign=rhinelanderchamber.com) for updates.	The Chamber of Commerce serves a valuable role in promoting local businesses, tourism, and community within the Squash Lake area.
Oneida County Lakes & Rivers Association (OCLRA)	Secretary (Connie Anderson – 715.282.5798)	Protects Oneida Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.oclra.com/) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oneida Co. waterways.
Oneida County AIS Coordinator	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.
Oneida County Land and Water Conservation Department	Conservation specialist (Jean Hansen – 715.365.2750)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	`
Town of Woodboro	Sherry A. Tichendorf (715.282.5843)	Part of Squash Lake falls within the Town of Woodboro	As needed.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Town of Crescent	William Treder (715.367.8777)	Part of Squash Lake falls within the Town of Crescent	As needed.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.

Crescent Town Lakes Committee	Chair (Joel Knutson – 608.332.5635) Committee Member (Dan Butkus – 608.628.5151) Committee Member (Stephanie Boismenue – 715.282.5079)	Provides information and networking related to the advancement of lakes within the Town of Crescent community.	As needed.	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Town of Crescent waterways.
Wisconsin Department of Natural Resources	Fisheries Biologist (John Kubisiak – 715.365.8919)	Manages the fishery of Squash Lake.	Once a year, or more as issues arise.	Scheduled surveys, survey results, and volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.8937)	Oversees management plans, grants, all lake activities.	Once a year, or more as issues arise.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Warden (Jim Jung – 715.365.8950)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day).	Contact regarding suspected violations pertaining to recreational activity on Pelican Lake, include fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	SLA 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 3: Maintain Current Water Quality Conditions

Management Action: Continue monitoring of Squash Lake's water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation of current effort.

Facilitator: Marj Mehring (Current CLMN Volunteer)

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

The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the SLA have collected water quality data on Squash Lake since 1989. The SLA realizes the importance of continuing this effort, which will supply them with valuable data about their lake. Moving forward, it is the responsibility of Marj Mehring, current CLMN volunteer, to coordinate new volunteers as needed. When a change in the collection volunteer occurs, Sandra Wickman or the appropriate WDNR/UW-Extension staff will need to be contacted 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. Marj Mehring, current CLMN volunteer, recruits new volunteer(s) as needed.
2. Volunteer contacts Sandra Wickman (715.365.8951) as needed.
3. Coordinator reports results to WDNR and SLA members during annual meeting.

Management Action: Restore highly developed shoreland areas on Squash Lake.

Timeframe: Initiate 2014

Facilitator: Squash Lake Association Board of Directors

Description: As discussed in the Shoreland Condition Section, the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. In 2012, the shoreland assessment survey indicated that 1.3 miles, or 17% of Squash Lake's 7.8-mile shoreline, consists of Urbanized or Developed-Unnatural areas.

Fortunately, restoration of the shoreland zone can be less expensive, less time-consuming and much easier to accomplish than restoration efforts in other parts of the watershed. Cost-sharing grants and Oneida County staff devoted to these types of projects give private property owners the funds and informational resources to restore quality shoreland habitat to their lakeside residence.

Map 3 indicates the locations of Urbanized and Developed-Unnatural shorelands on Squash Lake. These shorelands should be prioritized for restoration. A Board of Directors appointee will work with appropriate entities such as the Oneida County Land & Water Conservation Department to research grant programs, shoreland restoration techniques and other pertinent information that will help the SLA restore the Squash Lake shoreland. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, properties with restoration on their shorelands could serve as demonstration sites. Other lakeside property owners could have the opportunity to view a shoreland that has been restored to a more natural state, and learn about the maintenance, labor, and cost-sharing opportunities associated with these projects. The Board of Directors appointee will oversee/plan demonstration tours, as well as be a point-of-contact, for Squash Lake property owners who require more information on this topic.

Action Steps:

1. Recruit facilitator.
2. Facilitator receives proper shoreland restoration training through the UW Extension (Patrick Goggin - 715.365.8943, patrick.goggin@ces.uwex.edu).
3. Facilitator coordinates demonstration site tour (annual event or as needed) and serves as contact person for shoreland restoration questions. Facilitator puts interested parties in contact with Oneida County Land & Water Conservation Department officials.
4. Property owners complete a Cost Share application and submit it to the Oneida County Land & Water Conservation Department.
5. Conservation specialist with Oneida County works with property owners to determine site eligibility, design plans, etc.

<u>Management Action:</u> Protect natural shoreland zones along Squash Lake.

Timeframe: Initiate 2014

Facilitator: Squash Lake Board of Directors

Description: While Squash Lake has areas of urbanized and developed-unnatural shoreland areas, the majority of the shoreline (4.6 miles, 59%) was found to be either in a completely natural/undeveloped or developed-natural state. It is therefore very important that owners of these properties become educated on the benefits their shoreland is providing to Squash Lake, and that these shorelands remain in a natural state.

Already, Squash Lake has taken a proactive approach to preserving areas of natural shoreline and natural habitat surrounding the lake when Patrick Dugan and Sue Hausserman-Dugan donated a 5.62-acre site comprised of undeveloped woodlands to the Northwoods Land Trust in 2009. This area also preserved approximately 4,088 feet of natural shoreline along a narrow esker peninsula on the southwest side of the lake.

Map 3 illustrates the locations of Natural and Developed-Natural shorelands on Squash Lake. These shorelands that are not already apart of the Dugan Squash Lake Nature Preserve should be prioritized for education initiatives and physical preservation. A Board of Directors appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the SLA in preserving the Squash Lake shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of.

Valuable resources for this type of conservation work include the WDNR, UW-Extension, Oneida County Land & Water Conservation Department, and the Northwoods Land Trust. Several websites of interest include:

- Wisconsin Lakes website:
  (www.wisconsinlakes.org/shorelands)
- Conservation easements or land trusts:
  (www.northwoodslandtrust.org)
- UW-Extension Shoreland Restoration:
  (http://www.uwex.edu/ces/shoreland/Why1/whyres.htm)
- WDNR Shoreland Zoning website:
  (http://dnr.wi.gov/topic/ShorelandZoning/)
- The Northwoods Land Trust Website:
  (www.northwoodslandtrust.org)

Action Steps:

1. Recruit facilitator (potentially same facilitator as previous management action).
2. Facilitator receives proper shoreland restoration training through the UW Extension (Patrick Goggin - 715.365.8943, patrick.goggin@ces.uwex.edu)
3. Facilitator gathers appropriate information from sources described above. These include biological research, as well as grant/funding opportunities.
4. Facilitator assists residents that are interested in shoreland restoration with the process of contacting shoreland restoration specialists (public or private) and carrying out restoration plan.
5. Completed projects potentially considered as a “model’ for other residents who may be interested in restoring their shorelands.

Management Goal 4: Enhance the Fishery of Squash Lake

Management Action: Work with fisheries managers to enhance the fisher of Squash Lake.

Timeframe: Ongoing

Facilitator: Squash Lake Board of Directors

Description: The results of the stakeholder survey indicate that fishing is a popular activity on Squash Lake. Open-water fishing was ranked 4th on a list of reasons property owners reside on Squash Lake (Appendix B, Question #14). Approximately 77% of survey respondents indicate they have fished on Squash Lake (Question #8), and 35% of these same respondents have done so for longer than 25 years (Question #8).

However, the SLA and other riparian property owners have concerns over the fishery. Approximately 45% of survey respondents indicate the quality of fishing is only fair on the lake (Question #11), and 63% indicated that the quality of fishing has become either much or somewhat worse since they began fishing (Question #12).

Understanding the limitations and stresses on the Squash Lake ecosystem is the first step in developing a realistic solution to angler concerns. From there, realistic goals and actions may be developed. Part of this process involves educating Squash Lake property owners on the fishery. Specifically, information within this document may be summarized and presented to residents through the Educational Initiative described in Management Goal 2. Residents must have an understanding of how much fishing pressure Squash Lake receives, and how important intact and diverse habitats (plant-filled bays, rocky areas, coarse woody habitat, etc.) are to the fishery.

Squash Lake is currently overseen by WDNR fisheries biologist John

Kubisiak. In order to keep informed of survey studies that are occurring on Squash Lake, a volunteer from the SLA should contact Mr. Kubisiak at least once a year (perhaps during the winter months when field work is not occurring) for a brief summary of activities. Additionally, the SLA may discuss options for improving the fishery in Squash Lake, which may include changes in angling regulations and habitat enhancements.

During the Squash Lake 2012 Course Woody Habitat Survey, many pieces of course woody habitat were located along the shorelines in the southwestern portion of the lake, but very few pieces were located elsewhere around the lake (Map 4). Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation, shore-fishing, or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition and Fisheries Data Integration Section discuss the benefits of coarse woody habitat in detail.

The SLA may elect to work with John Kubisiak of the WDNR to improve coarse woody habitat along the shoreland areas of Squash Lake through strategic tree-drops or other means. Please note that WDNR permits and approval would be required for this action to be taken.

Action Steps:

1. See description above.

Management Goal 5: Monitor Frog Population in Squash Lake

Management Action: Initiate volunteer-based frog monitoring program to conduct annual surveys to track populations over time.

Timeframe: Initiate 2014

Facilitator: Karen Isebrands Brown

Description: Wisconsin is home to 12 frog species, all of which require water to breed and carry out their life cycle. Because frogs spend a portion of their time in the water and on land, they are often used as indicators of environmental health. They possess permeable skin and eggs, making them susceptible to environmental contaminants, and are often the first animals to decline following environmental alterations.

In fact, frog and other amphibian populations have been on the decline worldwide since the 1970s, for what is likely a multitude of different reasons, most of which are still unknown (Blaustein et al. 1990). However, habitat loss and contamination are the biggest anthropogenic factors leading to declines in amphibians. Observed declines in amphibian populations within a certain waterbody or region may indicate some type of environmental degradation is occurring.

The SLA recognizes that frogs are an important indicator of water quality and the overall environmental quality of Squash Lake, as well as an integral part of the aquatic and terrestrial ecosystems. Because of this, the SLA would like to initiate a volunteer-based frog monitoring program for the wetland on the southeast side of Squash Lake as part of the Wisconsin Frog and Toad Survey.

This citizen-based monitoring program is coordinated by the WDNR, United States Geological Survey (USGS), and North American Amphibian Monitoring Program (NAAMP), with a goal of determining the status and long-term trends of Wisconsin's frog species. Not only will the information on the frog species in Squash Lake be monitored on an annual basis, but the information gathered will contribute to the overall status of Wisconsin's frog populations.

The Wisconsin Frog and Toad Survey has established routes that volunteers regularly monitor. Volunteer monitors on Squash Lake will have to contact the Wisconsin Frog and Toad Survey and get on their waiting list for the creation of a new sampling route.

Action Steps:

1. Contact Wisconsin Frog and Toad Survey (WFTS@wisconsin.gov) to inquire about creating a new frog monitoring route around the wetland on the southeast side of Squash Lake.
2. Visit the Wisconsin Frog and Toad Survey at http://wiatri.net/inventory/FrogToadSurvey/ to get required information and training for new volunteer monitors.
3. Conduct frog monitoring surveys at specified times (based on water temperature) annually and report results to SLA and Wisconsin Frog and Toad Survey.

6.0 METHODS

Lake Water Quality

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

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

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

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Squash Lake during a June 6, 2012 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Squash Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on July 10 and 11, 2012. A point spacing of 33 meters was used resulting in 1,478 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Squash Lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium.

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