Lac Sault Dore

Price County, Wisconsin

Comprehensive Management Plan

June 2013

Sponsored by:

Lac Sault Dore United Association

WDNR Grant Program

AEPP-239-10

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1.0 INTRODUCTION

Lac Sault Dore, Price County, is 561-acre flowage with a maximum depth of 21 feet and a mean depth of six feet (Map 1). This eutrophic lake has a relatively large watershed when compared to the size of the lake. Lac Sault Dore contains 55 native plant species and one non-native species, Eurasian water milfoil.

Field Survey Notes

Abundant wildlife observed during surveys of this coffee-water stained flowage. Many different types of habitat observed both within the lake and along shorelines. Eurasian water milfoil observed in very dense conditions during 2010, some of the densest Onterra ecologists have ever encountered.

Photograph 1.0-1 Water marigold on Lac Sault Dore, Price County

Lake at a Glance - Lac Sault Dore

Morphology	
Acreage	561 (WDNR Definition)
Maximum Depth (ft)	21
Mean Depth (ft)	6
Shoreline Complexity	21.8
Vegetation	
Curly-leaf Survey Dates	June 30 & July 1, 2010
Comprehensive Survey Dates	August 17-18, 2010; August 18-19, 2011; August 14-15, 2012
Number of Native Species	55
Threatened/Special Concern Species	Robbins' Spikerush, Vasey's pondweed
Exotic Plant Species	Eurasian water milfoil
Simpson's Diversity	2010: 0.87; 2011: 0.94. 2012: 0.89
Average Conservatism	2010: 6.5; 2011: 6.7. 2012: 6.9
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.2 – 8.1
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	276:1

Lac Sault Dore (Lac Sault Dore) is a highly sought after location amongst recreationists and anglers. Several public access locations are located on the lake, while the lake may also be accessed via the Elk River, which flows into the system from the Phillips Chain of Lakes to the east. The Elk River then exits Lac Sault Dore on the west side of the flowage, spilling over Wiemers Dam, which was constructed in 1939.

Eurasian water milfoil was first detected in Lac Sault Dore in 2004. Since that time, it had spread throughout the lake, reaching nuisance levels in much of the water between two and eight feet of water depth. Stakeholders and lake managers held numerous discussions regarding a control strategy that might be implemented for Eurasian water milfoil control. An opportunity arose when operators at the Wiemers Dam received a Wisconsin Department of Natural Resources (WDNR) cost share grant to perform maintenance work on the dam. This would require a six to seven foot drawdown starting after Labor Day (September 7th) of 2010. The water would be drawn down at a rate of approximately six inches per day, and the work was estimated to be completed one month following the start of the drawdown. At that time of the year, the lake's amphibians and reptiles would already have begun burrowing into the lake sediments and hibernating (Personal Comm. Scott Provost, WDNR). Altering the water level either up or down at that time would be detrimental to these organisms and therefore the system would not be brought back to its original height until May 2011.

Water level drawdowns had been used in the past on Lac Sault Dore to increase recreational opportunities that were hindered by dense aquatic vegetation and to consolidate the highly organic sediments found in the lake. While the purpose of the planned drawdown was for dam maintenance, an opportunity to combat Eurasian water milfoil was identified through the freezing and desiccation (drying out) of the plants. Within this comprehensive management planning project, aquatic plant studies were drafted to assess both the native and non-native populations as well as the water quality and sediment condition before and after the drawdown.

2.0 STAKEHOLDER PARTICIPATION

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

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

Draw Down Meeting
On May 13, 2010, a public information meeting was held at the Phillips High School Gym in Phillips, WI to discuss the scheduled maintenance-related drawdown. Discussions took place between the County Dams Committee, WDNR representatives, Onterra ecologists, Lac Sault Dore stakeholders and other resource managers regarding the potential to influence Eurasian water milfoil using the drawdown. The project, with anticipated benefits and risks, was explained to the public and a question and answer session followed.

Kick-off Meeting
On June 25, 2011, a project kick-off meeting was held to introduce the project to the general public. The meeting was announced through a mailing and personal contact by SLUA board members. The attendees observed a presentation given by Eddie Heath, an aquatic ecologist with Onterra. Mr. Heath's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I
On April 19th, 2012 Eddie Heath and Brenton Butterfield of Onterra met with five members of the Soo Lake United Association Planning Committee. Jim Kreitlow, the WDNR Lake Coordinator was also in attendance. In advance of this meeting, a draft copy of the Results & Discussion Sections (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 drawdown monitoring results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed.

Planning Committee Meeting II
On June 28th, 2012, Eddie Heath met with five members of the Planning Committee to discuss the stakeholder survey results and begin developing management goals and actions for the Soo Lake United Association's Comprehensive Lake Management Plan. One of the major topics of discussing was related to EWM management and the development of thresholds (triggers) of when specific management actions would be enacted.

Project Wrap-up Meeting
Has not yet occurred.

Management Plan Review and Adoption Process
In December 2012, a draft of the Implementation Plan Section (5.0) was provided to the Planning Committee for review. Comments were provided to Onterra and a second draft of the Implementation Plan Section was sent to the Planning Committee for Review. The Implementation Plan Section of this report is based upon integration of the Planning Committee's comments of that draft.

Stakeholder Survey
During October 2011, a seven-page, 31-question survey was mailed to 374 riparian property owners in the Lac Sault Dore watershed. Fifty-three percent of the surveys were returned and those results were entered into a spreadsheet by members of the Lac Sault Dore 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 Lac Sault Dore. As far as property ownership and use on Lac Sault Dore is concerned, a nearly equal amount of stakeholders consider their property use seasonal during the summer (30%), year-round residence (28%), or a weekends throughout the year residence (26%) (Question #1). Fifty-nine of stakeholders have owned their property for over 15 years, and 36% have owned their property for over 25 years (Question #4).

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 pontoon boat on Lac Sault Dore, while motor boats were another popular option (Question #12). As seen on Question #13, several of the top recreational activities on the lake involve boat use. As will be discussed in the Aquatic Plant Section, survey respondents indicated within the stakeholder survey that aquatic plants were negatively impacting their navigation and enjoyment of the lake prior to the drawdown, but this had improved by 2011, following the drawdown.

A concern of stakeholders noted throughout the stakeholder survey (see Question #19, #20 and survey comments) was the presence of aquatic invasive species and excessive aquatic plant growth. These topics are touched upon in the Aquatic Plant Section, Summary & Conclusions Section and within the Implementation Plan.

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

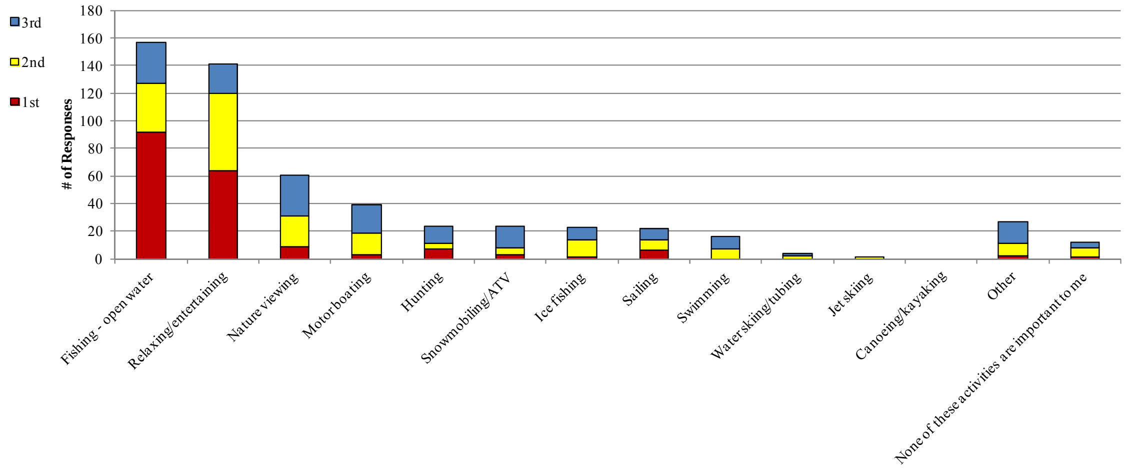
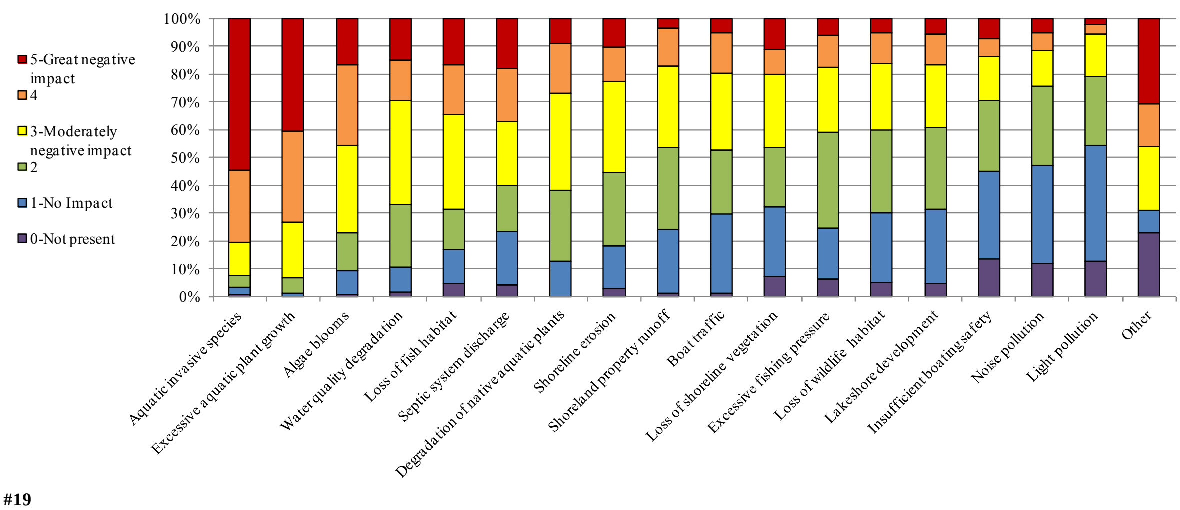


Figure 2.0-1. Select survey responses from the Lac Sault Dore Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question #19: To what level do you believe these factors may be negatively impacting Lac Sault Dore?



Question #20 Please rank your top three concerns regarding Lac Sault Dore.

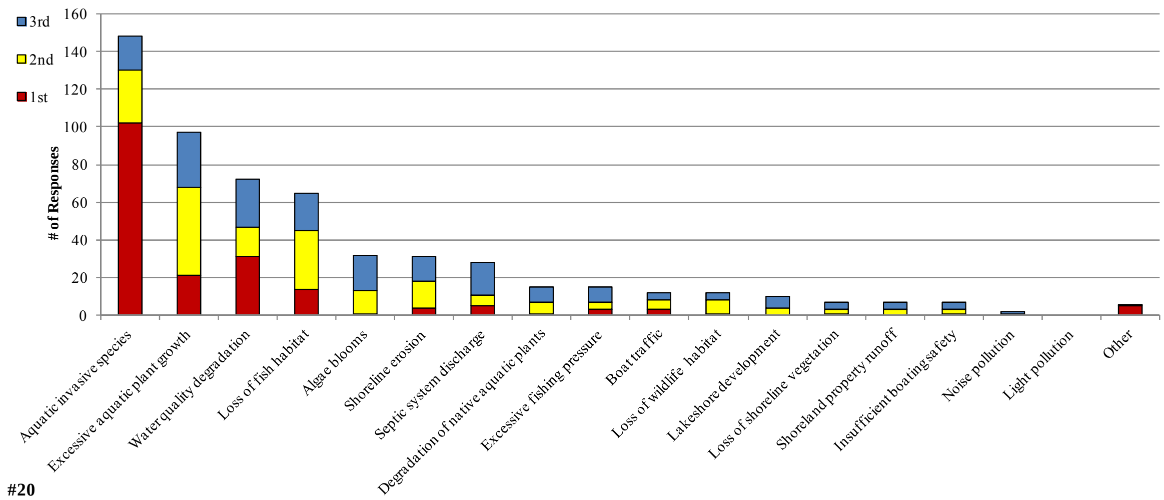


Figure 2.0-2. Select survey responses from the Lac Sault Dore Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Lac Sault Dore 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 Lac Sault Dore'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 Lac Sault Dore will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

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

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
> > Headwater drainage lakes have a watershed of less than 4 square miles.
> >
> > Lowland drainage lakes have a watershed of greater than 4 square miles.

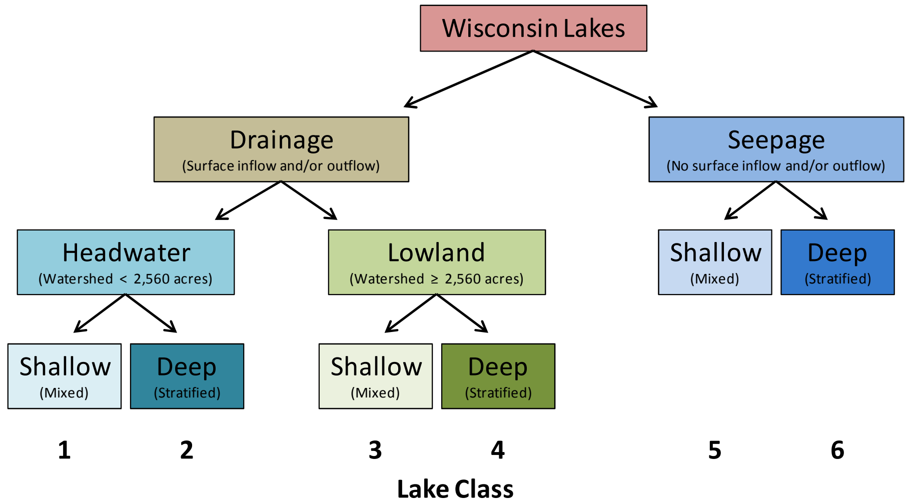


Figure 3.1-1. Wisconsin Lake Classifications. Lac Sault Dore is classified as a shallow (mixed), lowland drainage lake (Class 3). Adapted from WDNR PUB-SS-1044 2008.

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. Lac Sault Dore is within the Northern Lakes and Forests ecoregion.

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

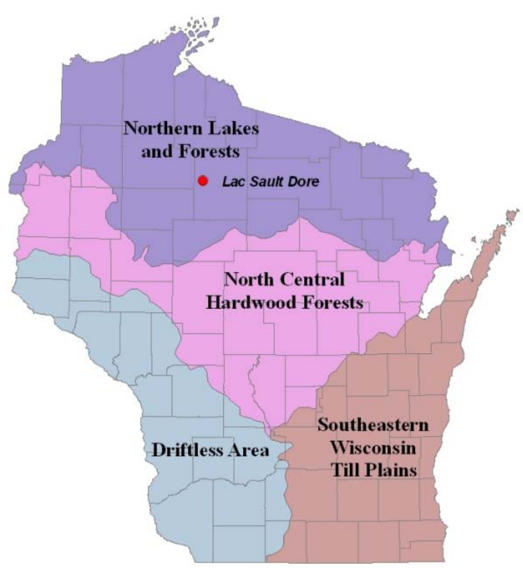


Figure 3.1-2. Location of Lac Sault Dore within the ecoregions of Wisconsin. After Nichols 1999.

Onterra LLC Lake Management Planning

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Lac Sault Dore is displayed in Figures 3.1-3 - 3.1-7. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Lac Sault Dore Water Quality Analysis

Lac Sault Dore Long-term Trends

As part of the stakeholder survey associated with this project, lake residents were asked questions regarding their perspectives on the water quality of Lac Sault Dore. Most respondents (49%) indicated they believed the water quality in the lake was either *Poor* or *Fair* (Appendix B, Question #14). About 50% also indicated that the water quality had gotten worse since they first visited the lake, while 11% believe the water quality had improved and 26% believe it has remained the same (Question #15). Algae blooms ranked as 3rd and water quality degradation was tied for 4th in a list of factors Lac Sault Dore stakeholders believe are negatively impacting their lake (Question #19). Furthermore, water quality degradation ranked as third on a list of the top three concerns stakeholders have regarding the lake (Question #20).

Volunteers from Lac Sault Dore have collected water quality samples through the WDNR's Citizen Lake Monitoring Network since 1990. As seen in the charts below, these efforts have produced an incredible dataset. This is valuable information, as it provides a scientific basis for making management decisions for the system. Additionally, it helps to dispel perceptions lake stakeholders may have concerning the water quality in the system. Anecdotal accounts that the lake is "getting better" or "getting worse" can be proven or disproven by looking at data which analyzes these claims from a scientific perspective. The efforts of the Lac Sault Dore volunteers are to be commended, and should be continued in the years to come.

Phosphorus, as discussed in the preceding text of this section, is an essential nutrient and the most commonly analyzed nutrient when examining the water quality of a freshwater lake or stream. Total phosphorus, a measurement of both dissolved and particulate forms of this nutrient, has been monitored on Lac Sault Dore during the growing season and summer months since 1993 (Figure 3.1-3). Average annual summer concentrations largely fall within water quality categories of *Good* or *Fair*. A weighted summer average over all years (55.2 μg/L) is higher than the median for similar lakes statewide. Average summer values were as low as 39.0 and 31.0 μg/L in 2004 and 2005, however reached highs of 87.0, 70.0 and 98.0 μg/L in 1998, 2008 and 2010, respectively. Often, lake water quality is subject to fluctuations in environmental conditions such as precipitation, temperature, sunlight, etc. While fluctuations in total phosphorus (and algal content as discussed below) certainly have fluctuated in the past 20 years, there is not conclusive evidence that a trend is occurring.

When observing the total phosphorus data for Lac Sault Dore, it is apparent that this nutrient is always in good supply, but highly variable within the lake. Considerably high concentrations were seen in 1998, 2008 and 2010. As mentioned above, fluctuations such as these may be environmental in nature, but may be a signal of other issues as well such as septic tank discharge, internal nutrient loading from bottom sediments, or, on lakes that have heavy infestations of curly-leaf pondweed, a mid-summer die off of this exotic plant. Curly-leaf pondweed is not known to exist within the lake, so this issue is not a potential cause of high phosphorus concentrations. The bottom of the lake probably stays oxygenated due to the high flow rate of this system, so internal nutrient loading from bottom anoxic sediments cannot be a factor either. As indicated on the stakeholder survey, many of the riparian property owners on the lake have a septic system (48% conventional system, 29% holding tank, 9% mound – Appendix B, Question #4). However, 81% of these property owners have their septic tanks pumped every 2-4 years or less (Question #5). At this time, there is not a clear understanding as to why these large spikes in phosphorus concentrations are occurring; however, the role of environmental variability likely plays a large part.

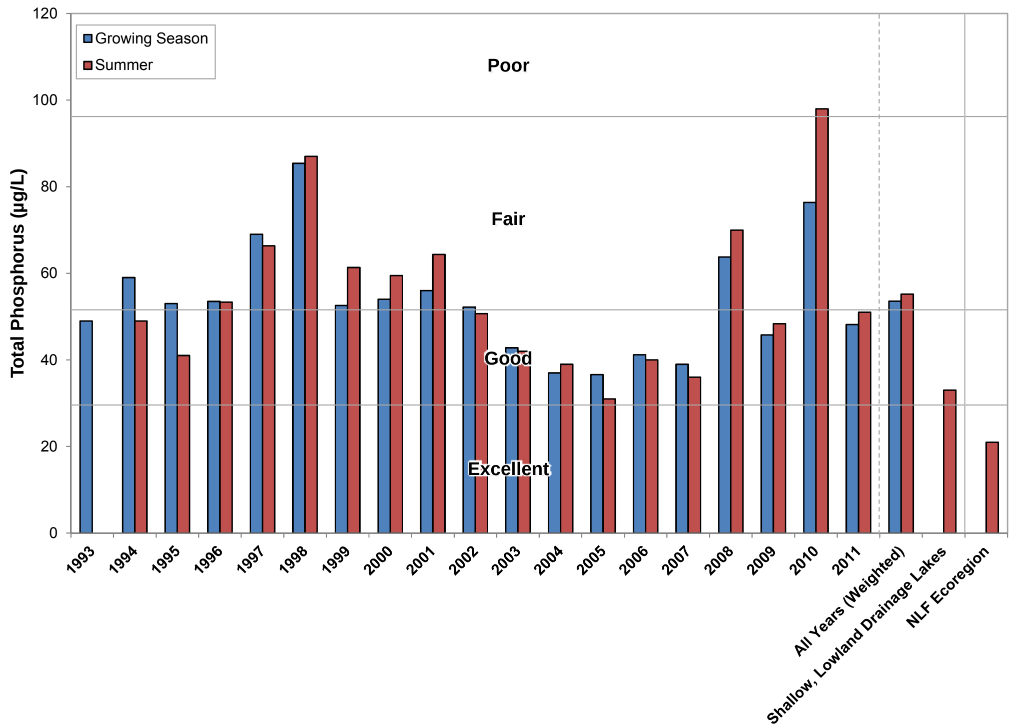


Figure 3.1-3. Lac Sault Dore, state-wide class 3 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Along with total phosphorus, chlorophyll-*a* has been sampled from Lac Sault Dore since 1993 as well (Figure 3.1-4). Average annual summer concentrations for this parameter have fallen in water quality categories spanning from *Excellent* to *Fair*, and a weighted average of all years is much higher than the median for other shallow, headwater drainage lakes. Interestingly, several years during and following the late 1990's experienced rather high chlorophyll-*a* concentrations during the summer months (1996-1999, and 2001). Comparatively, average concentrations in the past seven years (2005 to present) have been nearly half that of the concentrations in the late 1990's. On some years, the higher chlorophyll-*a* concentrations correlate well with higher observed phosphorus concentrations (1997, 1998, 2001). However, in several years this expected correlation is not seen, particularly in 2008 and 2010 when phosphorus values were observed to be quite high. There are likely other factors at play in determining algal content within the lake, such as water clarity and the high flushing rate of Lac Sault Dore.

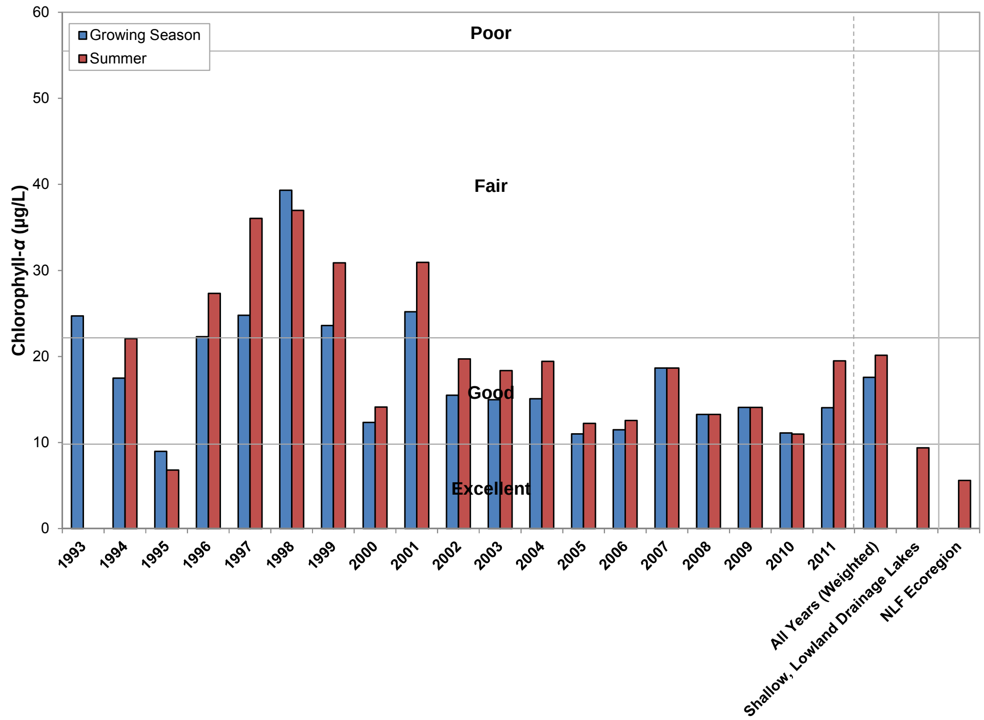


Figure 3.1-4. Lac Sault Dore, state-wide class 3 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water clarity, as discussed below, may limit the amount of light penetrating into the water column and thus reduce algal abundance, though may only happen to a minimal extent. The factor most likely limiting algal production in the lake is the high flow of the system. As mentioned in the next section (Watershed Section), the water in Lac Sault Dore is fully flushed (replaced) every seven days. With new water rushing into the lake, these algae cells are expelled downstream before they can build in their numbers.

The Secchi disk clarity dataset spans over decades (1990-present) and includes numerous measurements (often between 10 and 20) taken each year (Figure 3.1-5). There is little fluctuation in this dataset, though some of the lowest readings were taken when chlorophyll-*a* values were at their highest. Overall, average annual measurements rank as either *Good* or *Fair* during all of these two decades, and a weighted average is below the median value for similar lakes statewide.

This low water clarity is not uncommon for northern Wisconsin lakes, particularly flowages with large watersheds that are located in this region. Systems with large watersheds (discussed further in the Watershed Section) drain many acres of forested lands and wetlands. When water drains these tracts of land into the lake, naturally occurring organic acids accumulate and stain the lake water a dark brown color. This is the cause of Lac Sault Dore's "root beer" color. Furthermore, it is this factor that is limiting light penetration into the waters of the lake which in turn limits algal production as well as the depth of aquatic plant growth (see the Aquatic Plant Section).

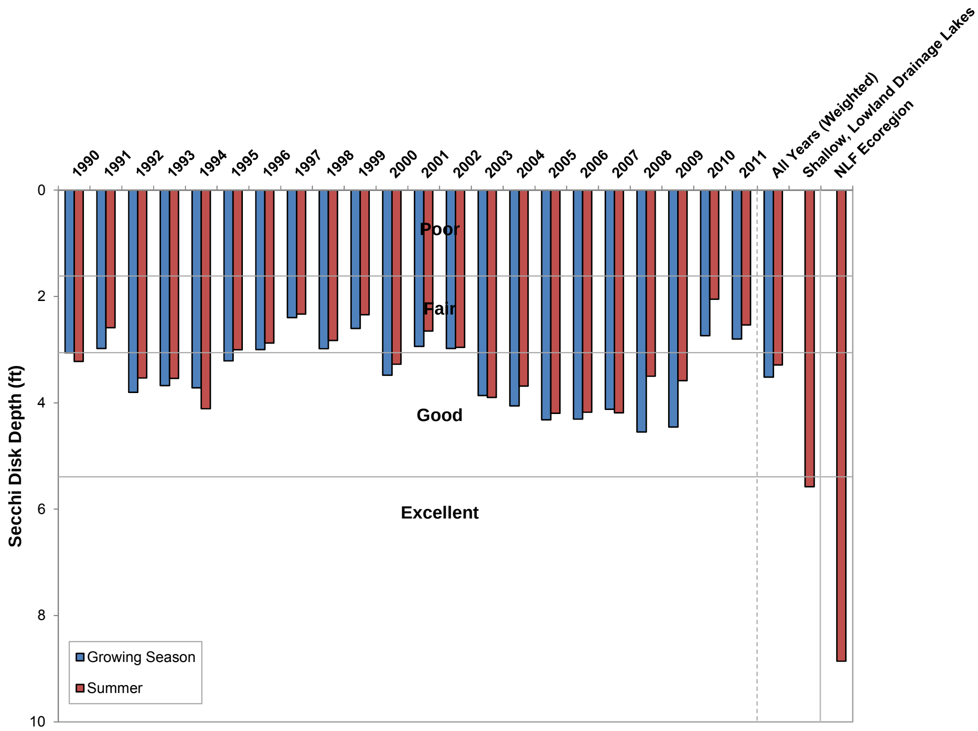


Figure 3.1-5. Lac Sault Dore, state-wide class 3 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Lac Sault Dore

Using midsummer nitrogen and phosphorus concentrations from Lac Sault Dore, a nitrogen:phosphorus ratio of 12:1 was calculated. This finding indicates that Lac Sault Dore fluctuates between nitrogen and phosphorus limitation.

Lac Sault Dore Trophic State

Figure 3.1-5 contain the WTSI values for Lac Sault Dore. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values fall primarily within the eutrophic range. In general, the best values to use in judging a lake's trophic state are total phosphorus and cholorophyll-*a* because water clarity can be affected by many factors, therefore, relying primarily on these twoWTSI values, it can be concluded that Lac Sault Dore is in a eutrophic state.

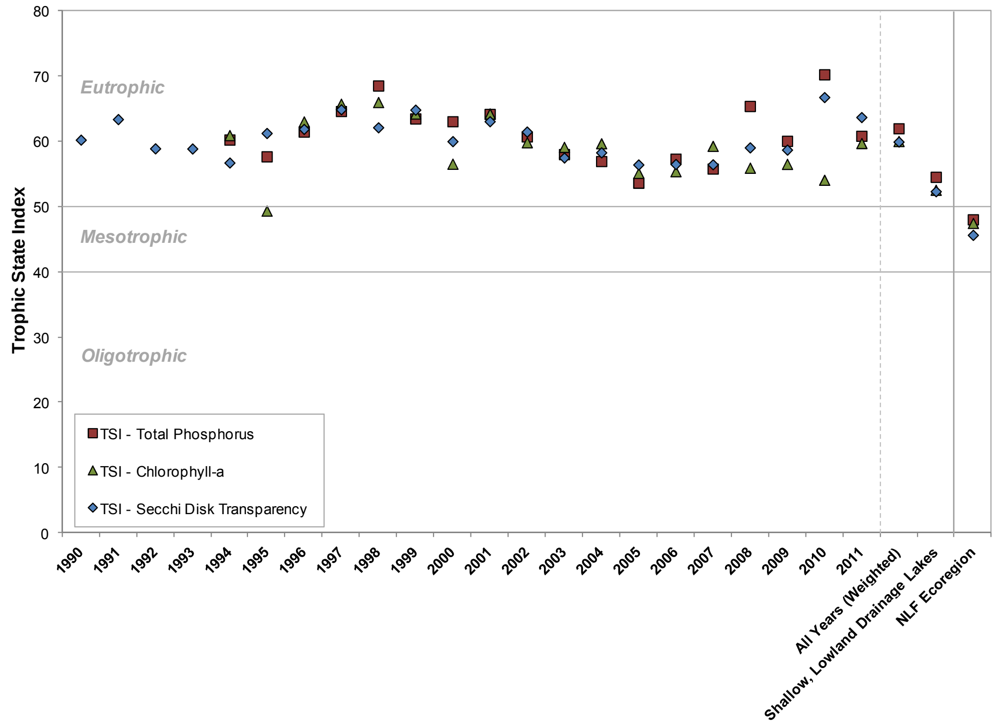


Figure 3.1-6. Lac Sault Dore, state-wide class 3 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Lac Sault Dore

Dissolved oxygen and temperature were measured during water quality sampling visits to Lac Sault Dore by Onterra staff. Additionally, these parameters were measured during the winter drawdown of 2011 by SLUA volunteers. Profiles depicting these data are displayed in Figure 3.1-7

During the winter drawdown, dissolved oxygen content within the smaller volume of Lac Sault Dore was a concern of stakeholders as well as the WDNR and Onterra ecologists. However, the flow of water from the Elk River was sufficient to keep the lake well oxygenated throughout the winter months. During the late winter, oxygen levels hovered around 7 to 9 mg/L, concentrations that are more than enough to support warm water species of fish in Wisconsin.

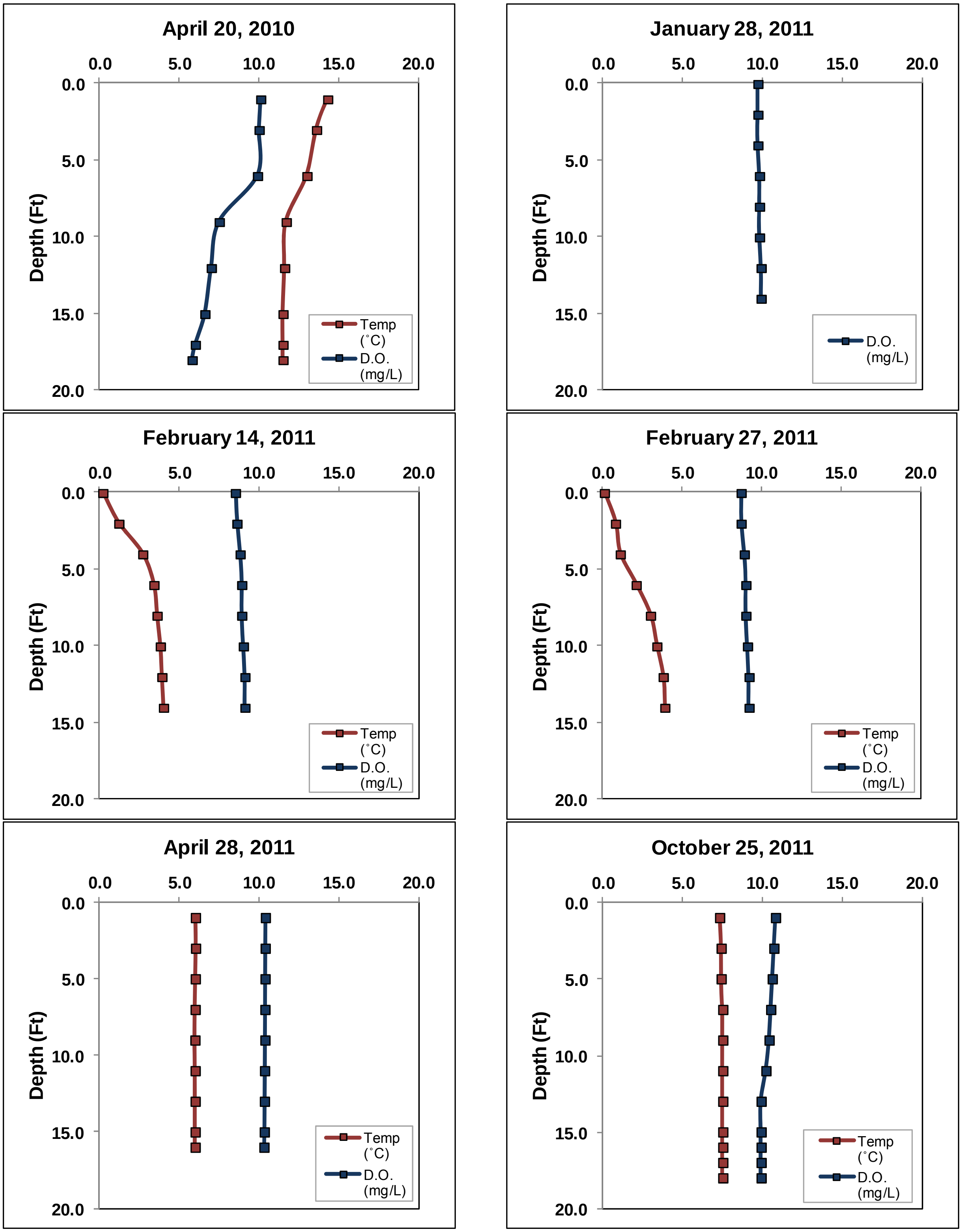


Figure 3.1-7. Lac Sault Dore dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Lac Sault Dore

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Lac Sault Dore'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 Lac Sault Dore was found to be near neutral with a value of 7.3, and falls within the normal range for Wisconsin Lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Lac Sault Dore was measured at 29.0 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Lac Sault Dore's pH (7.2-8.1) 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 Lac Sault Dore was found to be 9.1 mg/L, falling well below the optimal range for zebra mussels. Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Lac Sault Dore was considered borderline suitable for 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.

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

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

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

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

Most flowage systems contain very large watersheds, and Lac Sault Dore is no exception to this. The watershed surrounding Lac Sault Dore contains land that drains to the Phillips Chain of Lakes, as well as Musser Lake, located east of the town of Phillips. Overall, this watershed is 165,981 acres in size (Map 2). Of this area, 127,981 acres of this land comprises the Phillips Chain of Lakes' watershed, while the remaining 38,000 acres of land drains directly to Lac Sault Dore from its direct watershed (Figure 3.2-1). Not surprisingly, the majority of land within this watershed is classified as forest (10% or 16,721 acres of Lac Sault Dore's immediate watershed) or wetland (9% or 14,388 acres). A smaller amount of row crops (3%) and pasture/grass lands (1%) exist within the watershed, as well as other insignificant classifications including the Lac Sault Dore lake surface (599 acres), urban lands of various density, and rural residential lands. Altogether, the land draining to Lac Sault Dore is 276 times larger than the lake itself, making for a watershed to lake area ratio of 276:1. This, of course, means that the size of the watershed is the most significant variable in determining the water quality of Lac Sault Dore – more so than the proportions of land cover types the area holds.

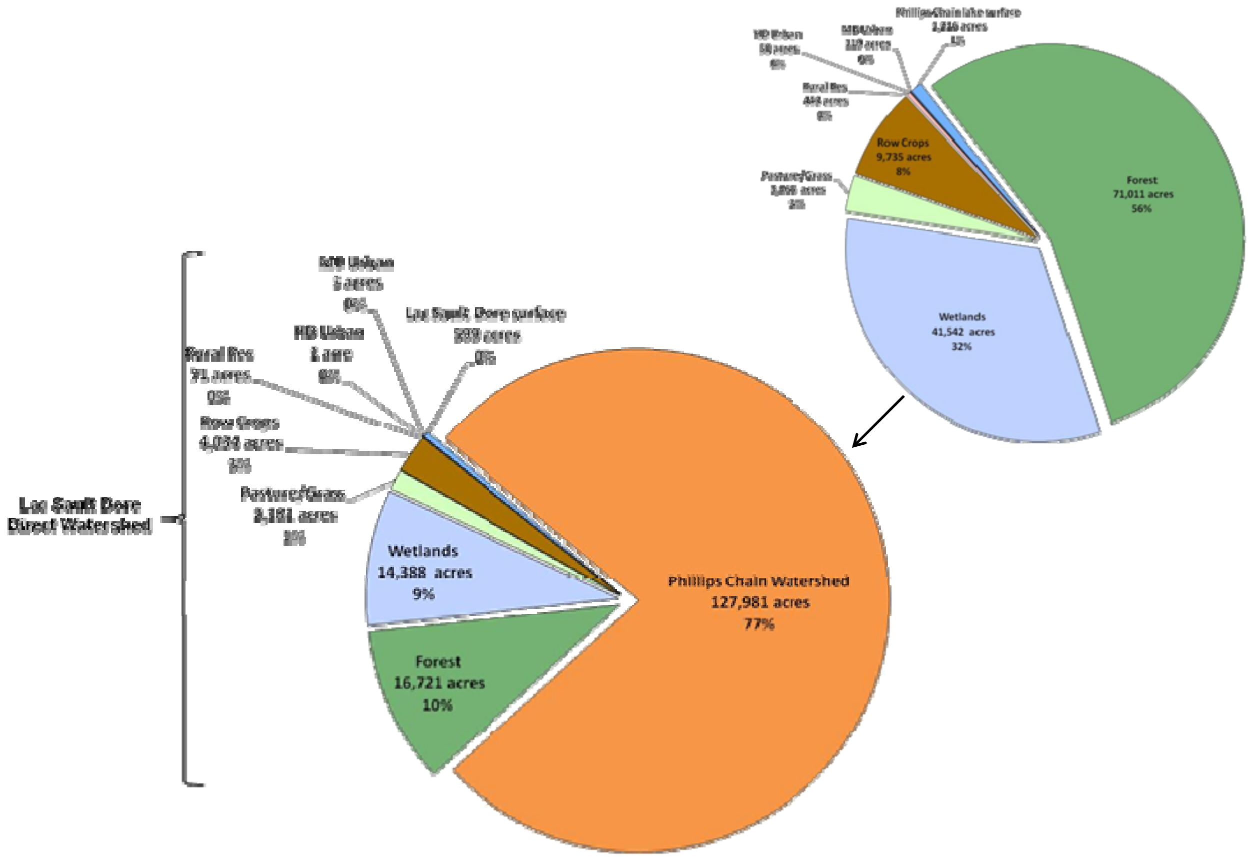


Figure 3.2-1. Lac Sault Dore watershed land cover types in acres. Based upon information obtained through the National Land Cover Database (NLCD – Fry et. al 2011).

WiLMS was utilized to estimate the phosphorous loading to Lac Sault Dore from the direct watershed downstream of the Phillips Chain of Lakes, and upstream sources that flow through the Phillips Chain. The combined total of these two estimated sources is approximately 22,190 lbs per year, 6,982 lbs of which is derived from the direct watershed and 15,207 lbs of which travels down the Elk River from the Phillips Chain (Figure 3.2-2). WiLMS predicted a mean growing season phosphorus value of 39 µg/L within Lac Sault Dore. This value is slightly lower than the observed growing season phosphorus value of 48 µg/L obtained through water quality sampling conducted by Citizen Lake Monitoring Network volunteers. The small discrepancy between observed and predicted phosphorus values indicates there may be an unaccounted phosphorus source to the lake, potentially from faulty septic systems, unknown agricultural drain tile lines entering the lake, internal nutrient loading from bottom sediments or several other potential sources. However, as discussed in the Water Quality Section, unaccounted sources of phosphorous are probably not entering the lake, and this discrepancy may stem from the sheer size of the watershed, as it is difficult to model watersheds of this size accurately with relatively minimal information. Another compounding factor may be the hydrology of the lake; Lac Sault Dore is a flowage system, meaning it resembles that of a river more so than a typical lake. WiLMS estimates that Lac Sault Dore's flushing rate is 0.02 years, meaning that 100% of the water volume within Lac Sault Dore is replaced every seven days, approximately. Because every seven days there is completely different water flowing through Lac Sault Dore, the potential for highly variable data exists. This issue was discussed within the Water Quality Section as well.

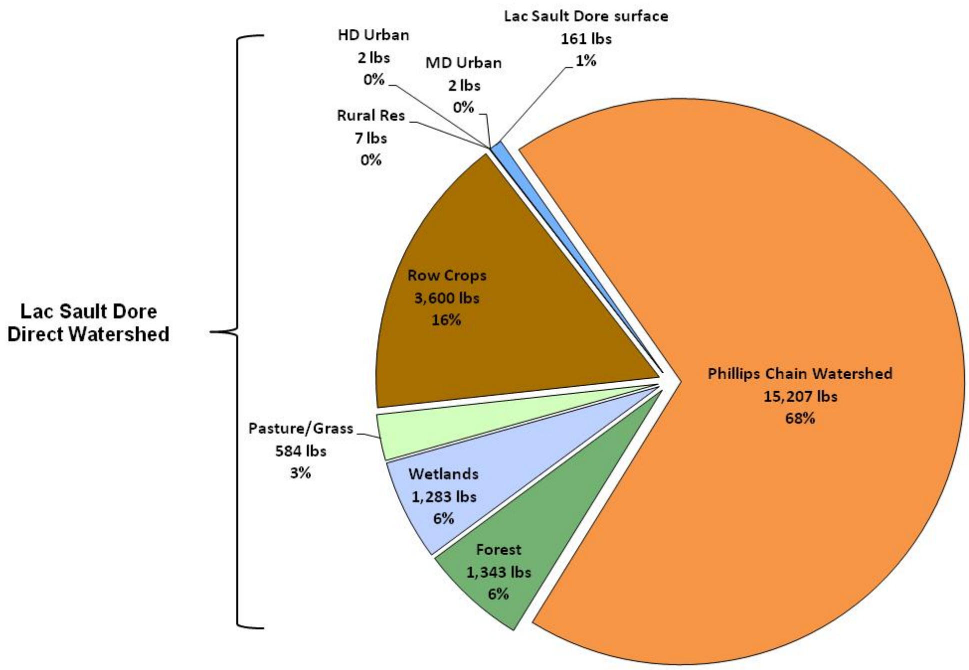


Figure 3.2-2. Lac Sault Dore watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Shoreland Condition Assessment

The Importance of a Lake's Shoreland Zone

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only)..
- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface (but not more than 30%) on a lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner.

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

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

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

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

Native Species Enhancement

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

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

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

Cost

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

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper or their county land conservation department. 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. Owner's 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.
    - A 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.

Lac Sault Dore Shoreland Zone Condition

Shoreland Development

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

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

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

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

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

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

Figure 3.3-1. Shoreline assessment category descriptions.

On Lac Sault Dore, the development stage of the entire shoreline was surveyed during fall of 2011, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Lac Sault Dore has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 6.8 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 4.5 miles of urbanized and developed–unnatural shoreline were observed. If restoration of the Lac Sault Dore shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreline lengths around the entire lake.

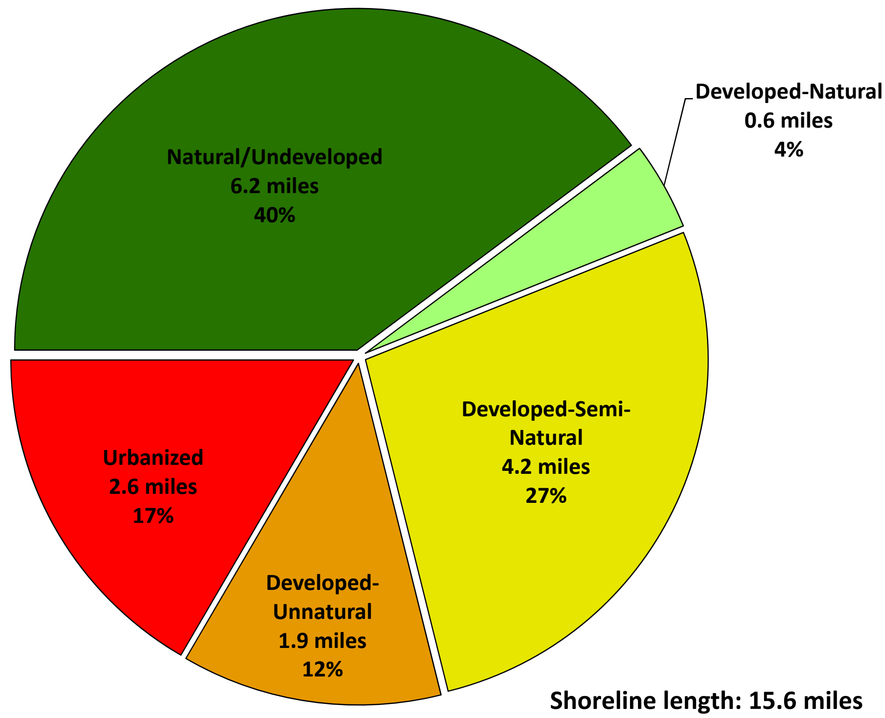


Figure 3.3-2. Lac Sault Dore shoreland categories and total lengths. Based upon a fall 2011 survey. Locations of these categorized shorelands can be found on Map 3.

3.4 Aquatic Plants

Introduction

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

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

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

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

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

Cost

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

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

Bottom Screens

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

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

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

Water Level Drawdown

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

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

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

Mechanical Harvesting

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

Costs

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

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

Herbicide Treatment

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

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

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

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

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

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

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

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

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

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

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

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

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

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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

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

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

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

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

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

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

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, 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 Lac Sault Dore; 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 Lac Sault Dore, 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: frequency of occurrence and relative frequency of occurrence. Frequency of occurrence is used to describe how often each species occurred in the plots that were sampled in in all three of the point-intercept surveys. Frequency of occurrence is displayed as a percentage. Relative frequency of occurrence uses the frequency of occurrence for each species compared to the sum of the 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.

Floristic Quality Assessment

> **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. 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 plant surveys.

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

In this section, the floristic quality of the Lac Sault Dore will be compared to median values from lakes in the same ecoregion and in the state as calculated by Nichols (1999). The same ecoregions used in the water quality comparison are utilized for this purpose (Water Quality section, Figure 3.1-2). However, the comparative data within this ecoregion has been divided into two groupings: Northern Lakes and Forest Lakes (NLFL) and Northern Lakes and Forest Flowages (NLFF). Lac Sault Dore is a flowage system and therefore will be compared to other flowage lakes within the NLFL ecoregion.

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. As discussed above, 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.

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

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

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

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.

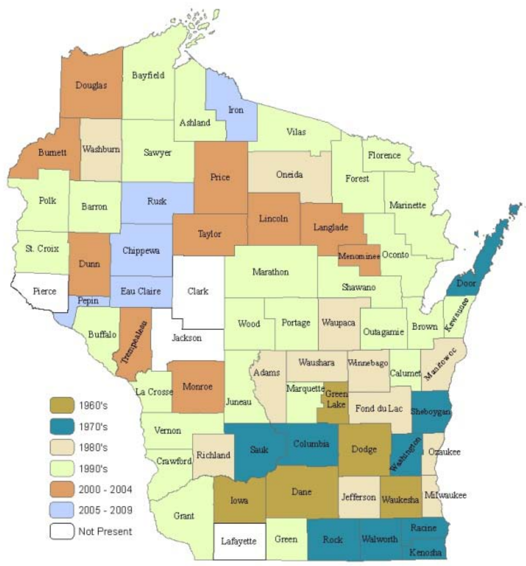


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2009 mapped by Onterra.

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.

2010-2011 Winter Drawdown

Winter water level drawdowns have been implemented in the past on Lac Sault Dore to increase recreational opportunities that were hindered by dense aquatic vegetation. On March 3, 1987 a hearing examiner ruled on the water level regime of Lac Sault Dore, establishing an official operating order. The operating order for the Weimers Dam states that the water level be held at full pool (95.50 ft PSC datum) from May 1 through September 30 but could be lowered 4 feet (91.50 ft PSC datum) from October 1 to April 30 for the purpose of "controlling excessive aquatic vegetation." While a 4-foot drawdown would not require a WDNR permit, written WDNR approval is required. Two winter drawdowns have occurred in the recent history on Lac Sault Dore (1987-88/1993-94) for nuisance aquatic plant control. Anecdotally, these drawdowns were believed to be successful at alleviating nuisance plant conditions; however no formal evaluations of the drawdowns occurred.

Eurasian water milfoil was first documented in Lac Sault Dore in 2004, and quickly spread to nuisance levels throughout much of the system by 2010 (Map 4). Stakeholders and lake managers held numerous discussions evaluating control strategies until an opportunity arose when Price County received a WDNR cost share grant to perform maintenance work on the Weimers Dam which impounds Lac Sault Dore. The maintenance work required a 6-foot drawdown and was scheduled to occur during the autumn of 2010 to minimize recreation and tourism effects that may be associated with a summer drawdown. While the maintenance work would only take a month to complete, it was determined appropriate to keep the lake drawdown over winter.

Refilling the lake late in the autumn would potentially have detrimental impacts to reptiles (e.g. turtles) and amphibians (e.g. frogs, salamanders). These species would have chosen shallow, muddy areas of the dewatered system to burrow into ground and hibernate. If the water levels are brought back up 6 feet at this time of the year, these species will certainly drown.

It is also believed that a winter drawdown could be ecologically beneficial for the system in reducing the Eurasian water milfoil population. Surveys conducted by Onterra in 2010 indicated that 94% of the Eurasian water milfoil population inhabited areas of six feet of water or less, so it was believed that a six-foot water level drawdown would expose the majority of the population to desiccation and freezing. Greenhouse studies conducted by Stanley (1976) found that the biomass of dewatered Eurasian water milfoil shoots and roots decreased by 99% when exposed to temperatures just below freezing for 96 hours. In addition, Eurasian water milfoil plants that were left submersed (10 cm of water) and exposed to subfreezing temperatures for 96 hours saw a 35% decrease in biomass (Stanley 1976). Compared to many of Wisconsin's native aquatic plants which overwinter via turions (vegetative reproductive structures), seeds, or tubers, Eurasian water milfoil generally overwinters as a whole plant. Because of this, it is believed that winter drawdowns would have a greater impact on Eurasian water milfoil, especially in dewatered and shallow areas (Olson et al. 2012).

A few studies have examined the responses of native aquatic plant species to winter drawdown. Beard (1969) conducted surveys pre- and post-drawdown on Murphy Flowage in Rusk County and found that the occurrences of a number of the more dominant species within the lake had declined following the drawdown. He found that fern pondweed, spatterdock, and milfoil species exhibited declines in their occurrence following the drawdown, while coontail and large-leaf pondweed could not be located following the drawdown. No change was observed in the occurrence of slender naiad, while common bladderwort increased slightly in occurrence (Beard 1969).

A similar study conducted by Nichols (1975) on the Mondeaux Flowage in Taylor County found similar responses to these native aquatic plant species. Reductions in the occurrences of fern pondweed, coontail, spatterdock, large-leaf pondweed, and common waterweed were recorded following winter drawdown. The total occurrence of vegetation within the flowage declined, with 100% of their quadrats containing vegetation prior to drawdown compared to 57% post-drawdown (Nichols 1975).

The drawdown began after Labor Day 2010 at a rate of six inches per day to allow for soon-to-be hibernating reptiles and amphibians migrate with the receding water levels. In late September when water levels were drawn down just over five feet, a large rainfall event completely filled the system and even exceeded full pull water levels by nine inches (Figure 3.4-2). Water levels were then drawn down to the maximum six feet; and again in late October, a large rainfall event raised water levels back up to approximately two feet below full pull. Water levels remained at six feet below pool for the remainder of the winter and water levels returned to full pool in late April 2011.

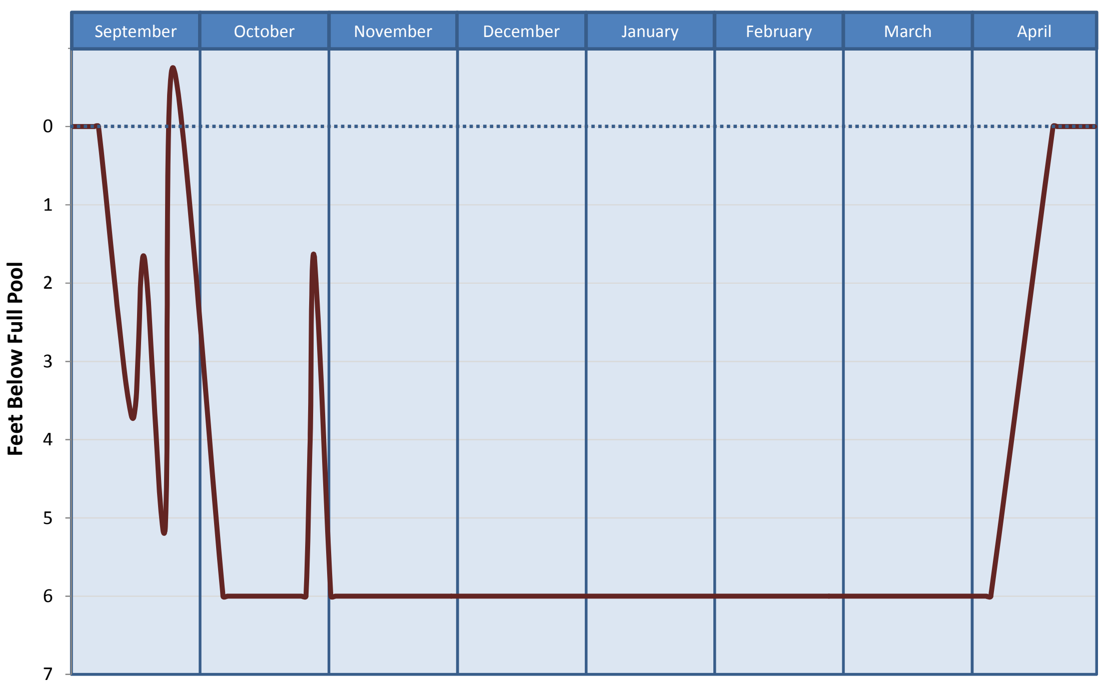


Figure 3.4-2. Lac Sault Dore Water Levels from September 2010 to May 2011. Created using Weimers Dam gauge data as reported by the Price County Dams Tender.

Aquatic Plant Survey Results

As discussed, numerous aquatic plant surveys were completed on Lac Sault Dore as part of this project. On June 30, 2010 a survey was completed on Lac Sault Dore that focused upon location any potential occurrences of the non-native plant curly-leaf pondweed. This meander-based survey of the *littoral zone* did not locate any occurrences of this invasive plant. It is believed

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.

that curly-leaf pondweed is currently not present in Lac Sault Dore or it exists at an undetectable level. However, established populations exist upstream in Solberg, Big Dardis, and Musser Lakes, so Lac Sault Dore users should familiarize themselves with this plant so if any occurrences are discovered they can be reported and quick action can be taken.

The pre-drawdown point-intercept survey was conducted on August 17 and 18, 2010. The two post-drawdown point-intercept surveys were conducted on August 18 and 19, 2011 and August 14 and 15, 2012. The community mapping surveys were also completed during these times in 2010 and 2011; community mapping was not conducted in 2012. While the point-intercept survey included 799 sampling locations distributed across the lake (Map 1), due to the inability to navigate to certain locations because of vegetation or other obstacles, 771, 752, and 760 points were sampled in 2010, 2011, and 2012, respectively. Of the 799 sampling points, the same 735 were sampled in all three years, and data collected from these 735 points is used in the following analyses.

During the point-intercept surveys, the dominant sediment type at each location was recorded and classified into one of three general categories: muck, sand, or rock. Figure 3.4-3 shows that prior to the drawdown in 2010, approximately 69% of the point-intercept sampling locations contained a dominant substrate type of muck, 26% contained sand, and 5% contained rock. Data collected one year following the drawdown in 2011 shows that point-intercept sampling locations that contained muck decreased to approximately 58%, while those with sand increased to 37%, and rock remained the same (Figure 3.4-3). Figure 3.4-4 illustrates that areas near the mouths of the Elk River and Chase/Crane Creek had higher amounts of sand post-drawdown. This is likely due to the water level drawdown increasing the velocity of water in these areas which scoured off the fine-organic sediments. However, point-intercept data collected in 2012 shows that the proportions of sediment types were more similar to those pre-drawdown, with point-intercept location containing muck increasing to approximately 73%, areas of sand decreasing to 22%, and rock remaining unchanged at 5% (Figure 3.4-3).

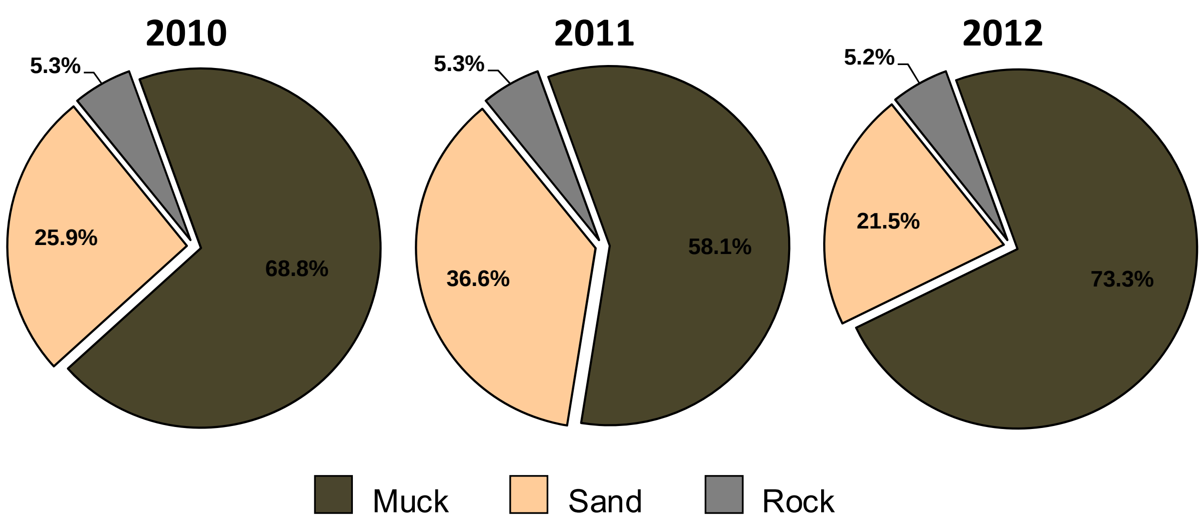


Figure 3.4-3. Lac Sault Dore proportions of substrate types in 2010, 2011, and 2012. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys.

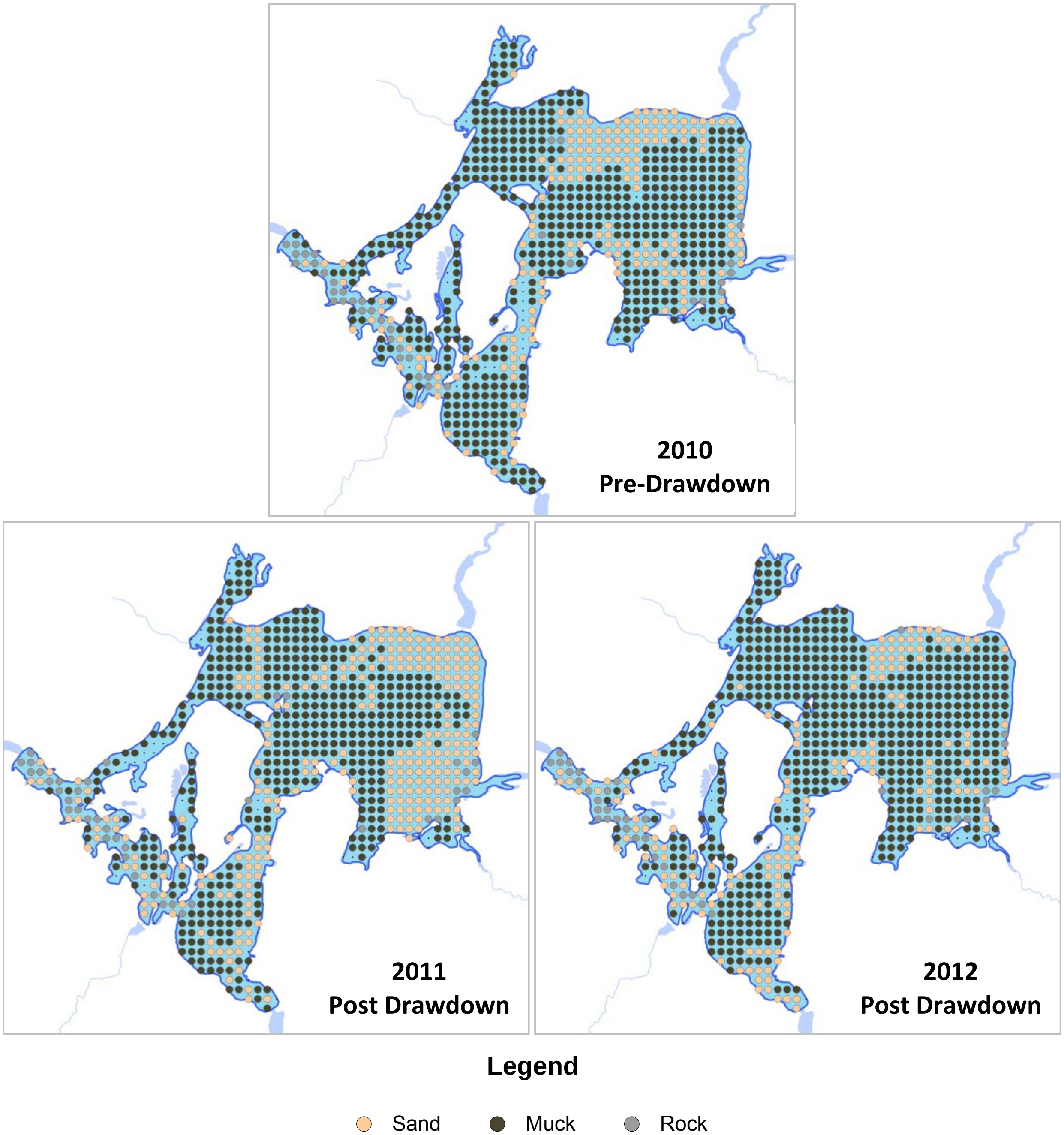


Figure 3.4-4. Lac Sault Dore distribution of substrate types in 2010, 2011, and 2012 point-intercept surveys. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys.

In 2010 prior to the drawdown, approximately 65% of the 735 point-intercept sampling locations contained aquatic vegetation (Figure 3.4-5). Breaking the data down further shows that 28% of the 735 point-intercept locations contained only native vegetation, 22% contained both native vegetation and Eurasian water milfoil, and 16% contained only Eurasian water milfoil. Following the drawdown in 2011, only 28% of the 735 point-intercept locations contained aquatic vegetation. Previous drawdown studies (Beard 1969, Nichols 1975) have documented significant declines in the occurrence of native vegetation following winter drawdown; however, this was contrary to what was documented in Lac Sault Dore Lake. The occurrence of point-intercept locations that only contained native vegetation remained virtually the same pre- and two years post-drawdown (Figure 3.4-5).

The point-intercept data suggests that the majority of locations that lost vegetation following the drawdown were those that contained Eurasian water milfoil, regardless if other native vegetation was present at those locations or not. As Figure 3.4-5 and Figure 3.4-6 illustrate, the majority of Eurasian water milfoil (73%) in 2010 was located at depths of five feet or greater, while the majority of native vegetation (90%) was located at depths of five feet or less. Figure 3.4-7 displays this spatial relationship. While Eurasian water milfoil was widespread throughout Lac Sault Dore in 2010, its population was not well integrated with the native aquatic plant community (Figures 3.4-5 – 3.4-7). Following its introduction into Lac Sault Dore, Eurasian water milfoil was likely able to colonize deeper areas of the lake that were sparsely inhabited by native plants (i.e. exploit the open niche).

As mentioned, following the drawdown, the locations dominated by native vegetation remained proportionally (Figure 3.4-5) and spatially (Figure 3.4-7) similar. During the two years' post-drawdown surveys, Eurasian water milfoil was not found to be re-colonizing areas of the lake that it inhabitated in 2010. While native vegetation was also lost following the drawdown in areas that contained both Eurasian water milfoil and native vegetation (Figure 3.4-7), most of this native vegetation was comprised of one species, coontail, which was found at approximately 73% of these locations. Coontail is a rootless, free-floating aquatic plant which derives its nutrients directly from the water, and it is believed the tall, surface-matted colonies of Eurasian water milfoil provided new areas of habitat for coontail to become entangled and grow. While coontail was lost in areas with Eurasian water milfoil, it was likely not present in these areas before Eurasian water milfoil's colonization.

During the 2010-2012 surveys, a total of 56 aquatic plant species were located in Lac Sault Dore (Table 3.4-1). Only one species, clasping-leaf pondweed, which had a frequency of occurrence of 0.1% in 2010, was not located following the drawdown. However, 10 species not located on the rake during the 2010 point-intercept survey were located post-drawdown in either 2011 or 2012 (Table 3.4-1).

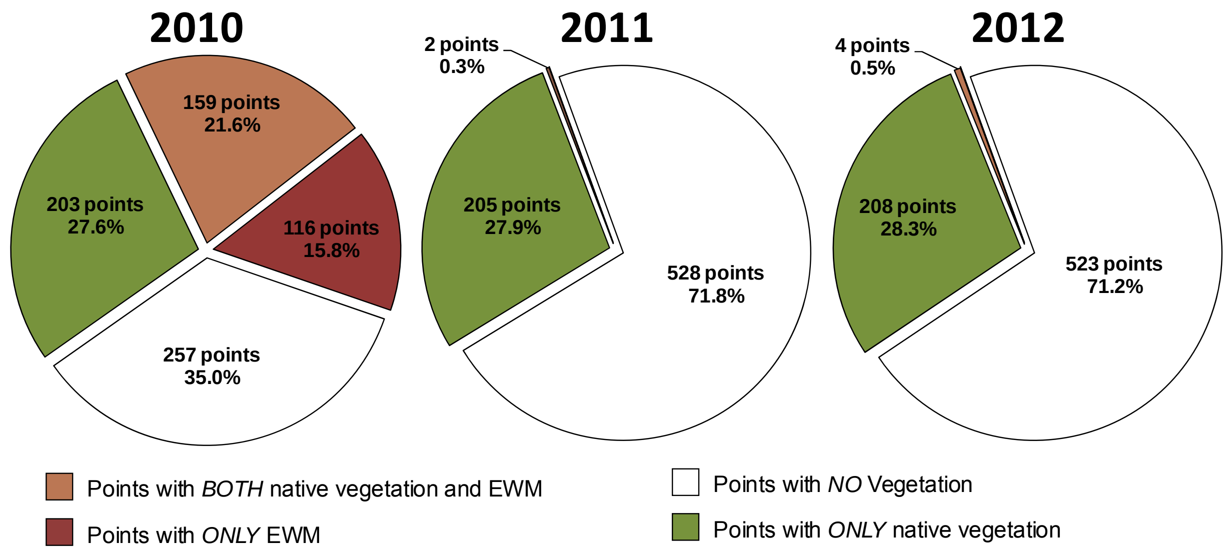


Figure 3.4-5. Lac Sault Dore proportions of native and non-native vegetation in 2010, 2011, and 2012 point-intercept surveys. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys.

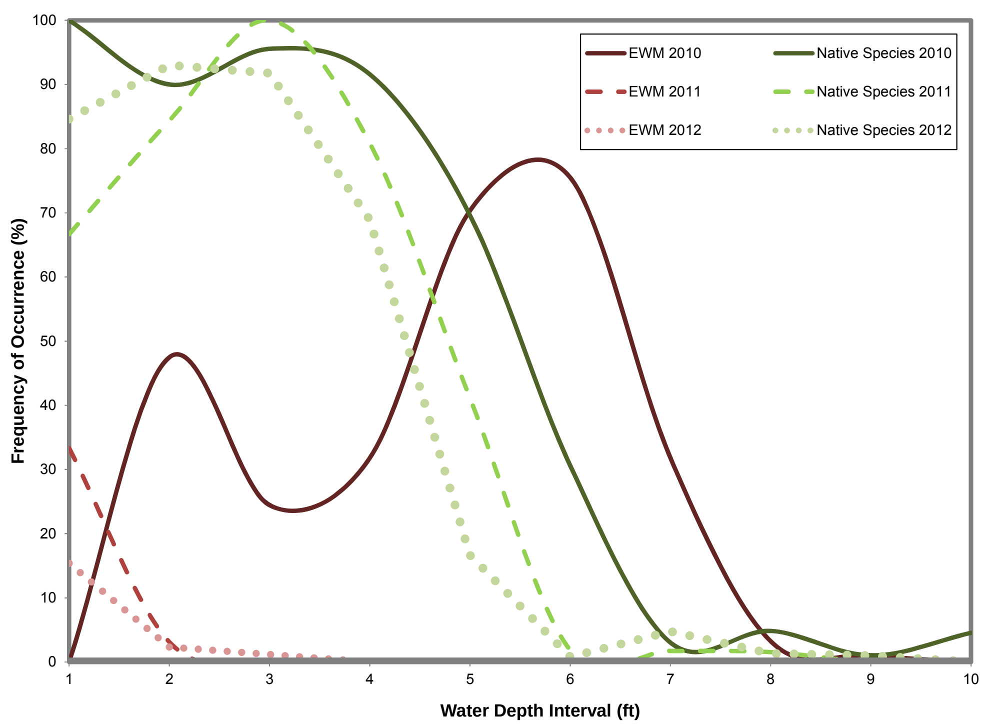


Figure 3.4-6. Distribution of native vegetation and Eurasian water milfoil across littoral depths in Lac Sault Dore. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys.

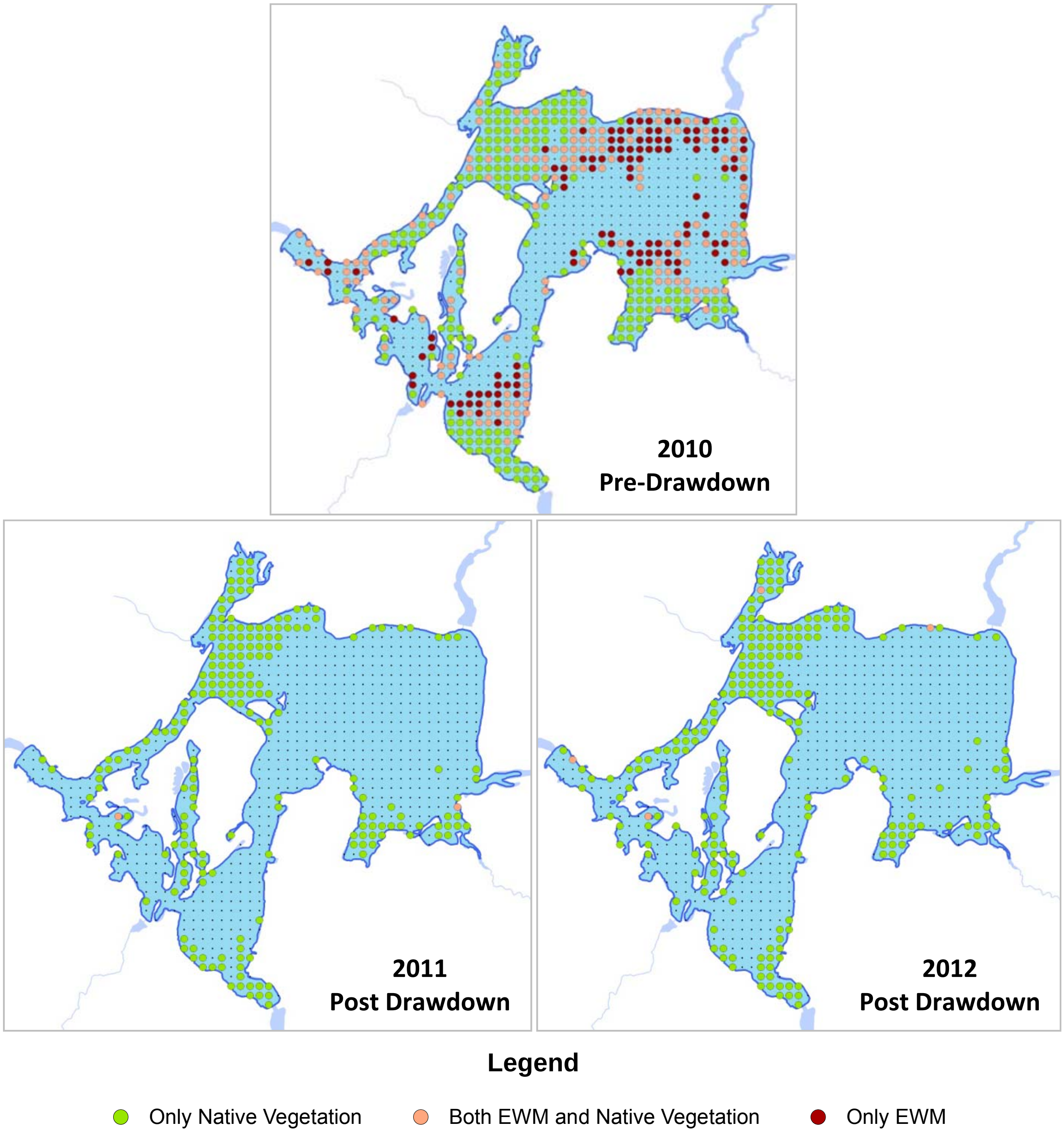


Figure 3.4-7. Lac Sault Dore distribution of native and non-native vegetation in 2010, 2011, and 2012 point-intercept surveys. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys.

Table 3.4-1. Aquatic plant species located in Lac Sault Dore during 2010 pre- and 2011/2012 post-drawdown point-intercept surveys.

Life Form	Scientific Name	Common Name	Coeffecient of Conservatism (C)	2010 (Pre-drawdown)	2011 (Post-drawdown)	2012 (Post-drawdown)
Emergent	*Carex utriculata*	Common yellow lake sedge	7	I		
	Acorus americanus	Sweetflag	7	I		
	Carex comosa	Bristly sedge	5	I		
	Dulichium arundinaceum	Three-way sedge	9	I		
	Eleocharis palustris	Creeping spikerush	6	X		
	Eleocharis robbinsii	Robbins' spikerush	10	I		X
	Pontederia cordata	Pickerelweed	9	X	X	X
	Sagittaria latifolia	Common arrowhead	3	I		
	Sagittaria rigida	Stiff arrowhead	8	X	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I		
	Zizania palustris	Northern wild rice	8	I		
FL	*Brasenia schreberi*	Watershield	7	I	X	X
	Nuphar variegata	Spatterdock	6	X		X
	Nymphaea odorata	White water lily	6	X	X	X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9			X
	Sparganium emersum	Short-stemmed bur-reed	8	I		
	Sparganium eurycarpum	Common bur-reed	5	X	X	X
	Sparganium fluctuans	Floating-leaf bur-reed	10		X	
	Sparganium natans	Little bur-reed	9	I		
Submergent	*Bidens beckii*	Water marigold	8	X	X	X
	Ceratophyllum demersum	Coontail	3	X	X	X
	Ceratophyllum echinatum	Spiny hornwort	10	I		
	Chara spp.	Muskgrasses	7	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	X
	Elodea nuttallii	Slender waterweed	7	X	X	X
	Myriophyllum heterophyllum	Various-leaved water milfoil	7	X	X	X
	Myriophyllum sibiricum	Northern water milfoil	7		X	
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X	X
	Myriophyllum verticillatum	Whorled water milfoil	8			X
	Najas flexilis	Slender naiad	6	X	X	X
	Nitella spp.	Stoneworts	7	X	X	X
	Potamogeton alpinus	Alpine pondweed	9			X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X	X
	Potamogeton foliosus	Leafy pondweed	6		X	
	Potamogeton friesii	Fries' pondweed	8		X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X	X
	Potamogeton nodosus	Long-leaf pondweed	7	X	X	X
	Potamogeton obtusifolius	Blunt-leaf pondweed	9			X
	Potamogeton pusillus	Small pondweed	7	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X		
	Potamogeton robbinsii	Fern pondweed	8	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8		X	X
	Potamogeton strictifolius	Stiff pondweed	8	X	X	X
	Potamogeton vaseyi	Vasey's pondweed	10	X	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X	X	X
	Utricularia minor	Small bladderwort	10	X		X
	Utricularia vulgaris	Common bladderwort	7	X	X	X
	Vallisneria americana	Wild celery	6	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5		X	
FF	*Lemna trisulca*	Forked duckweed	6	X	X	X
	Lemna turionifera	Turion duckweed	2	X	X	
	Riccia fluitans	Slender riccia	7	I		
	Spirodela polyrhiza	Greater duckweed	5	X	X	X
	Wolffia columbiana	Common watermeal	5	I		

FL = Floating-leaf; FL/E = Floating-leaf/Emergent; S/E = Submergent/Emergent; FF = Free-floating
X = Present on rake during point-intercept survey; I = Incidental species not located on rake during point-intercept survey
Note: Incidental species were not recorded during post-drawdown surveys

Following the drawdown, 14 aquatic plants with a frequency of occurrence of greater than 3% in at least one of the three surveys exhibited statistically valid changes in occurrence (Figure 3.4-8). Most notably was the target species, Eurasian water milfoil, which decreased from a pre-drawdown occurrence of 37.4% in 2010 to post-drawdown occurrences of 0.3% and 0.5% in 2011 and 2012, respectively. The 2010, 2011, and 2012 Eurasian water milfoil peak-biomass maps (Maps 4-6) illustrate the dramatic decline in Lac Sault Dore's Eurasian water milfoil population following the drawdown.

The drastic decline the Lac Sault Dore's Eurasian water milfoil population following the drawdown went far beyond expectations. Surprisingly, the only Eurasian water milfoil that was observed in 2011 and 2012 following the drawdown was located in shallow (< 2 feet), near-shore areas of the lake, while none was located within deeper areas. It was expected that little to no Eurasian water milfoil would be located in areas that were dewatered (< 6 feet) and that most of the Eurasian water milfoil growing in areas that were not dewatered (> 6 feet) would have survived the drawdown.

The fact that Eurasian water milfoil saw the largest decrease in occurrence of any plant within Lac Sault Dore supports the theory by Stanley (1976) and Goldsby et al. (1978) that Eurasian water milfoil is more susceptible to winter drawdowns because it overwinters as a whole plant. It is believed that the Eurasian water milfoil plants growing in areas that were not dewatered were stressed to a point where they could not regrow upon refilling in the spring. The Eurasian water milfoil plants that were observed growing in very shallow water following the drawdown are believed to have grown from seed. In 2010, the areas of surface matted Eurasian water milfoil were observed producing numerous flowers and seeds. Laboratory studies have shown that Eurasian water milfoil seeds are still viable following a period of desiccation and freezing (Hartleb et al. 1993), and it is possible the seeds were able to receive enough light and germinate in shallow areas of the lake following the drawdown.

The native aquatic plants coontail, fern pondweed, flat-stem pondweed, and various-leaved water milfoil displayed statistically valid reductions in occurrence one year following the drawdown, and their occurrences remained at these levels two years post-drawdown. These declines of these species were consistent with studies conducted by Beard (1969) and Nichols (1975). Wild celery, white water lily, and water marigold exhibited statistically valid reductions in occurrence one year following the drawdown, but they exhibited statistically valid increases in their occurrences two years after the drawdown to levels similar to pre-drawdown levels.

Small pondweed, ribbon-leaf pondweed, slender naiad, stoneworts, and muskgrasses all exhibited statistically valid increases in occurrence one year post-drawdown. However, while the occurrences of small pondweed and ribbon-leaf pondweed remained unchanged two years post-drawdown, slender naiad, stoneworts, and muskgrasses saw statistically valid reductions in occurrences to levels that were similar to pre-drawdown. Waterweeds (*E. canadensis* and *E. nuttallii*) did not exhibit a statistically valid change in occurrence one year post-drawdown, but more than doubled their occurrences two years post drawdown, representing a statistically valid increase of 138% from 2011 to 2012 (Figure 3.4-8).

A point-intercept survey was conducted by the WDNR in 2006 on Lac Sault Dore Lake in 2006, and all of the species located during that survey were located in the 2010-2012 surveys. During that survey, various-leaved water milfoil (*Myriophyllum heterophyllum*), a native milfoil to

Wisconsin, was found to be the most abundant aquatic plant species within the lake with a littoral occurrence of 35%. Four years later, the 2010 pre-drawdown point-intercept survey indicated the occurrence of this species had declined greatly to a littoral occurrence of approximately 5%. Over this same period, Eurasian water milfoil had increased in littoral occurrence from 0.6% in 2004 to approximately 37% in 2010.

While one may assume that Eurasian water milfoil out-competed and displaced the various-leaved water milfoil, this is not the case. Comparing spatial data from the 2006 and 2010 point-intercept surveys shows that the various-leaved water milfoil population was growing within areas outside of where the vast majority of Eurasian water milfoil was growing in 2010. The reason for the drastic decline in the various-leaved water milfoil population from 2006 to 2010 is unclear, but coontail and fern pondweed saw large increases in their occurrences over this same time period. It is possible that certain environmental conditions were unfavorable for various-leaved water milfoil and favored the growth of coontail and fern pondweed.

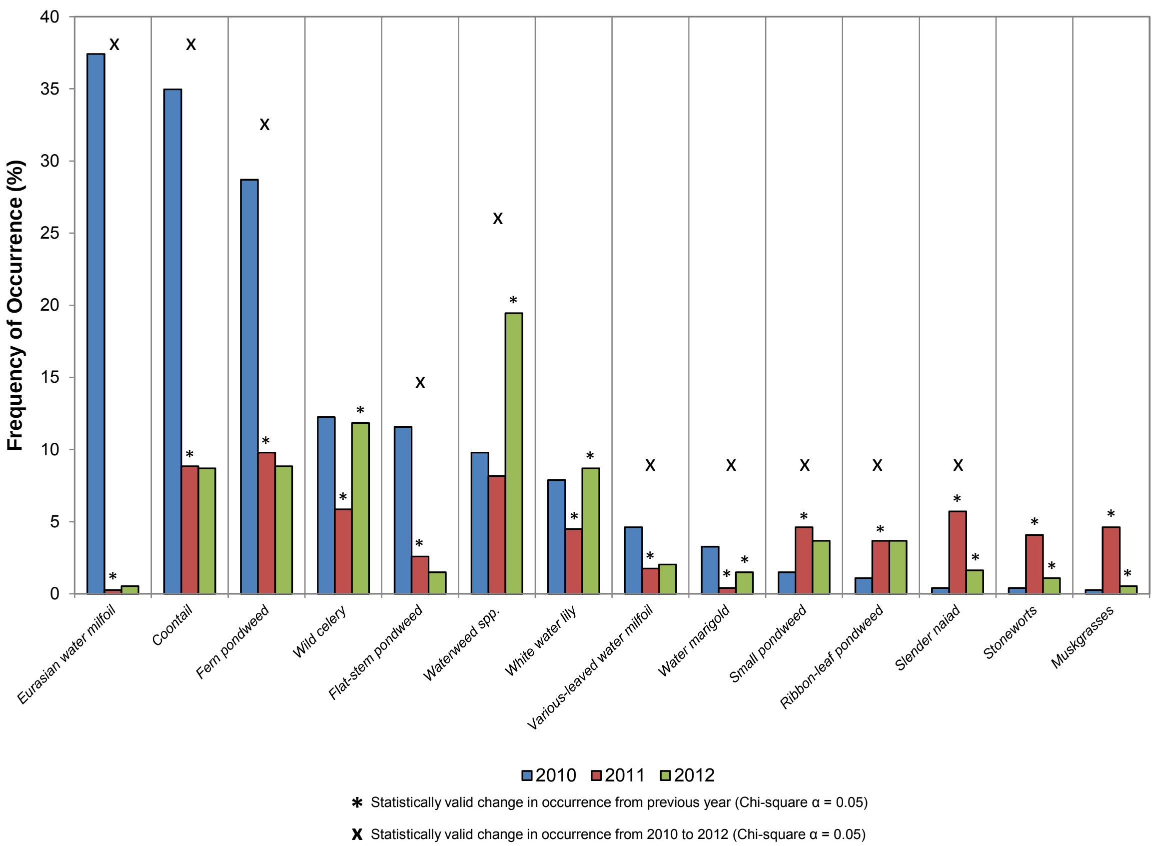
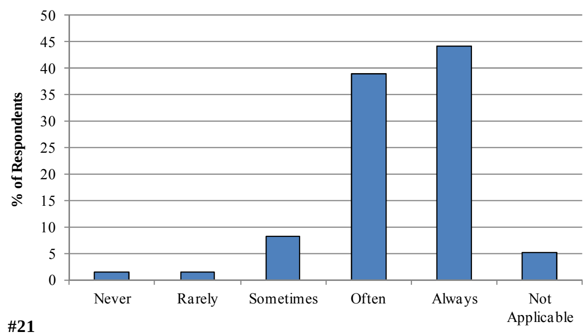


Figure 3.4-8. Distribution of native vegetation and Eurasian water milfoil across littoral depths in Lac Sault Dore. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys.

As discussed within the Stakeholder Participation Section, a stakeholder survey was sent out to Lac Sault Dore stakeholders in October of 2011. Relating to aquatic plant growth in Lac Sault Dore, respondents were asked how often did aquatic plant growth (including algae) negatively impact their enjoyment on Lac Sault Dore prior to the drawdown and one year following the drawdown. Eighty-three percent of respondents indicated that aquatic plant growth had *often* or *always* negatively affected their enjoyment of the lake prior to the 2010/2011 drawdown (Figure 3.4-9). Following the drawdown, this dropped to 15% of respondents, while the remaining 85% indicated that aquatic plant growth *sometimes*, *rarely*, or *never* impacts their enjoyment of the lake. The decline of the Eurasian water milfoil population following the drawdown not only alleviated stress on the ecology of Lac Sault Dore, but also alleviated recreational interferences.

Question #21: Before the drawdown over the winter of 2010/2011, how often did aquatic plant growth, including algae, negatively impact your enjoyment of Lac Sault Dore during the open water season?



Question #22: How often does aquatic plant growth, including algae, negatively impact your enjoyment of Lac Sault Dore during the open water season of 2011?

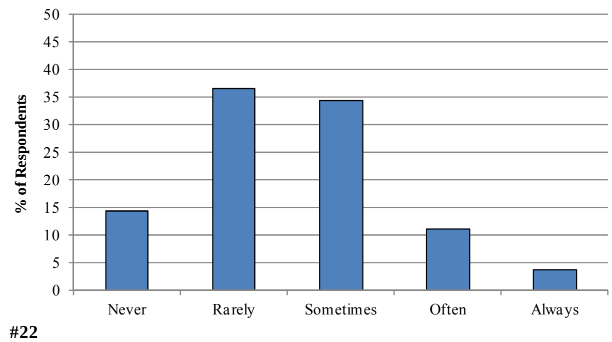


Figure 3.4-9. Select survey responses from the Lac Sault Dore Stakeholder Surveys. Additional questions and response charts may be found in Appendix B.

As discussed previously, the calculations used for 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 surveys and does not include incidental species. The native species encountered on the rake during the point-intercept surveys and their conservatism values were used to calculate the FQI of Lac Sault Dore pre- and post-drawdown (equation shown below).

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

Prior to the drawdown in 2010, 32 native aquatic plant species were located on the rake, while 34 and 35 were located post-drawdown in 2011 and 2012 (Figure 3.4-10). In all three years, the number of native species, or native species richness, fell above the 75th percentile for flowages in the Northern Lakes and Forests Ecoregion as well as the entire State of Wisconsin. Average conservatism values also increased following the drawdown, from 6.5 in 2010, to 6.7 and 6.9 in 2011 and 2012, respectively. Combining the species richness and average conservatism values yields exceptionally high FQI values for all three years. The FQI analysis not only shows that Lac Sault Dore's native aquatic plant community is of very high quality, but that this quality was maintained, if not enhanced, following the winter drawdown.

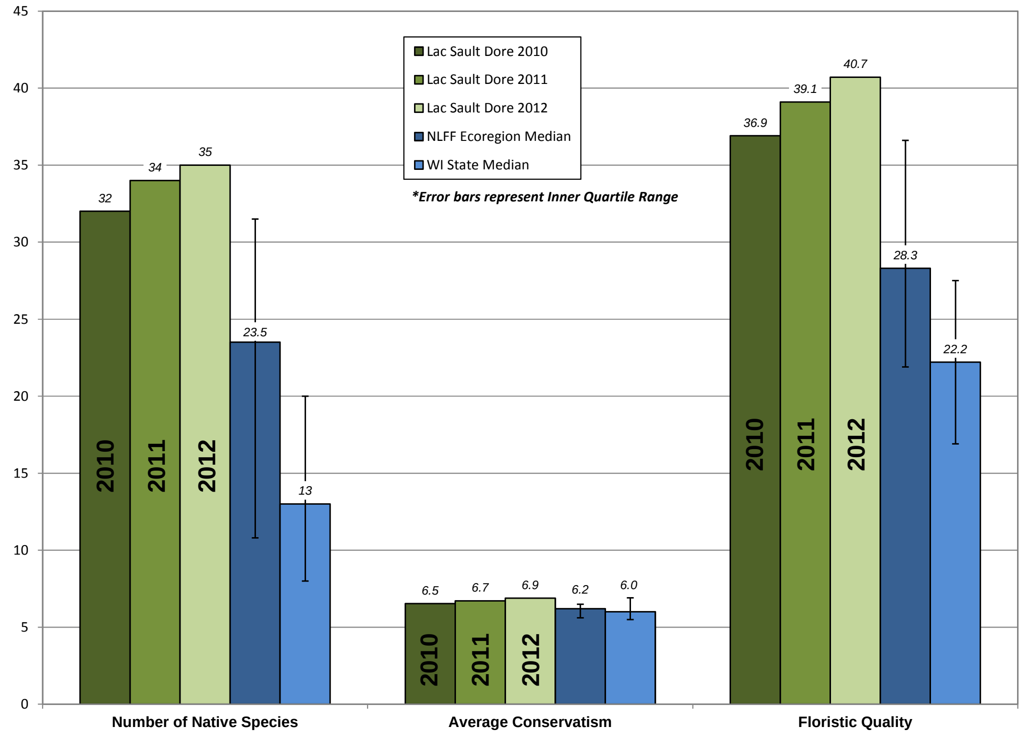


Figure 3.4-10. Distribution of native vegetation and Eurasian water milfoil across littoral depths in Lac Sault Dore. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys.

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 Lac Sault Dore 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.

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 Lac Sault Dore's diversity values rank. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the Northern Lakes and Forests Ecoregion. Using data from the three point-intercept surveys shows that the diversity of Lac Sault Dore's aquatic plant community increased dramatically from 0.87 to 0.94 one year following the drawdown, and decreased to 0.89 in 2012 (Figure 3.4-11).

The reason for these changes in Lac Sault Dore's aquatic plant community's diversity is evident in Figure 3.4-10, which displays the *relative* frequency of occurrence of aquatic plant species from the 2010, 2011, and 2012 point-intercept surveys. As discussed previously, frequency of occurrence allows for an understanding of how often each of the plant species is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool used to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while Eurasian water milfoil was located at approximately 37% of the 735 sampling locations in Lac Sault Dore in 2010, its relative frequency of occurrence was 22%. Explained another way, if 100 plants were randomly sampled from Lac Sault Dore in 2010, 22 of them would have been Eurasian water milfoil.

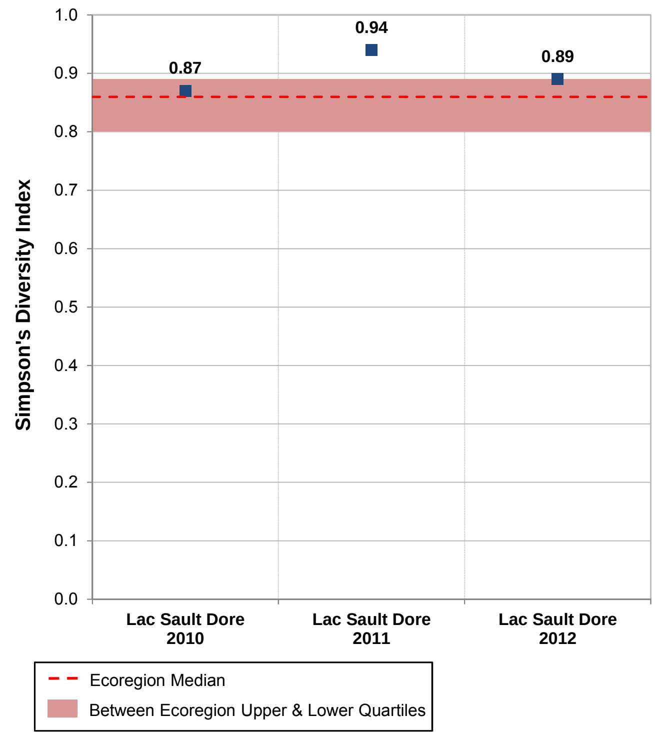


Figure 3.4-11. Lac Sault Dore 2010, 2011, and 2012 Simpson's Diversity Index. Created using data from 2010, 2011, and 2012 point-intercept surveys.

Figure 3.4-12 shows that in 2010 that the majority, nearly 60%, of Lac Sault Dore's aquatic plant community was comprised of just three species: Eurasian water milfoil, coontail, and fern pondweed. This uneven abundance of aquatic plant species accounted for the lower species diversity (0.87). Following the drawdown in 2011 and the significant reduction in Eurasian water milfoil abundance, 60% of Lac Sault Dore's aquatic plant community was now comprised of seven individual aquatic plant species. With the aquatic plant community not overly dominated by a single or few species, the community's diversity increased greatly (0.97). In 2012, increases in abundance of waterweeds, wild celery, and white water lily reflect the decreased the community's diversity (0.89) from 2011, with four species comprising 60% of the aquatic plant community.

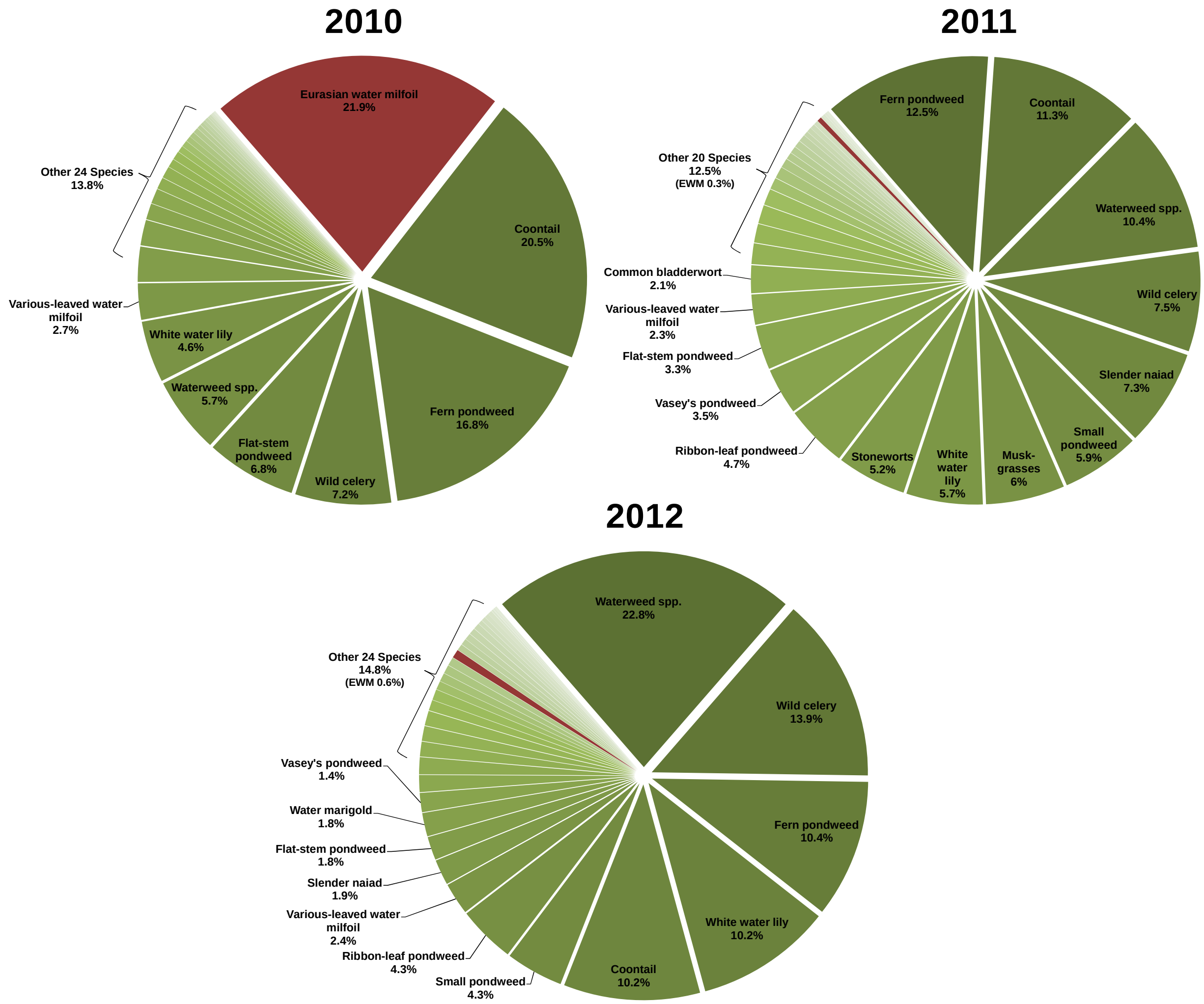


Figure 3.4-12. Lac Sault Dore aquatic plant species relative occurrence analysis. Created using data from 2010, 2011, and 2012 aquatic plant point-intercept surveys. Eurasian water milfoil is indicated with red.

The high quality of Lac Sault Dore's aquatic plant community is also indicated by the occurrence of emergent and floating-leaf plant communities that occur in the lake. These communities were mapped in 2010 and 2011 to gain an understanding of how the drawdown would affect them. Nineteen floating-leaf and emergent species were located in Lac Sault Dore over the course of these surveys (Table 3.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. Prior to the drawdown, approximately 103 acres of Lac Sault Dore contained these types of communities (Table 3.4-2, Maps 7 & 8). Following the drawdown, these communities expanded slightly and were found to occupy approximately 110 acres (Table 3.4.-2, Maps 9 & 10). While these communities were not remapped in 2012, reports of Lac Sault Dore stakeholders indicate that areas of white water lily expanded lake-ward. It is not known if this expansion is a result of the drawdown, related to extremely early ice-out and unusually warm weather experienced in 2012, or a combination of the both of these conditions.

Table 3.4-2. Lac Sault Dore acres of floating-leaf and emergent plant communities in 2010 and 2011. Created from the 2010 and 2011 community mapping surveys.

	Acres	
Plant Community	**2010**	**2011**
Emergent	1.4	0.0
Floating-leaf	19.3	21.5
Mixed Emergent & Floating-leaf	82.0	88.2
Total	**102.7**	**109.7**

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

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 Lac Sault Dore. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the SLUA stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2010 & GLIFWC 2010A and 2010B).

Lac Sault Dore Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the highest ranked important or enjoyable activity on Lac Sault Dore (Question #13). Survey respondents indicated that crappie, walleye and bluegill/sunfish were the species they enjoyed catching most on the lake (Question #10). Approximately 76% of these same respondents believed that the quality of fishing on the lake was either *fair* or *good* (Question #9); however, approximately 59% believe that the quality of fishing has gotten either *much worse* or *somewhat worse* since they began fishing the lake, and 19% believe the fishing has remained the same (Question #11). In Questions #19 and #20 of the survey, respondents ranked "loss of fish habitat" highly amongst a list of lake related concerns.

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 Lac Sault Dore 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 piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

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

Table 3.5-1. Gamefish present in the Lac Sault Dore with corresponding biological information (Becker, 1983)**.**

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

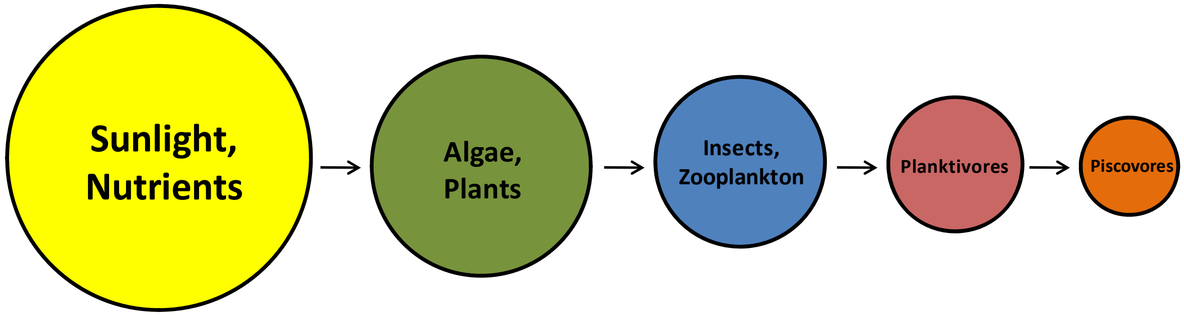


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

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). Lac Sault Dore 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. This highly structured process begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then an "allowable catch" is established, based upon estimates of a sustainable harvest of the fishing stock (age three to age five fish). This figure is usually about 35% of a lake's fishing stock, but may vary on an individual lake basis. In lakes where population estimates are out of date by three years, a standard percentage is used. The allowable catch number is then reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level". The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent, or declaration. This result is called the quota, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal quota and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

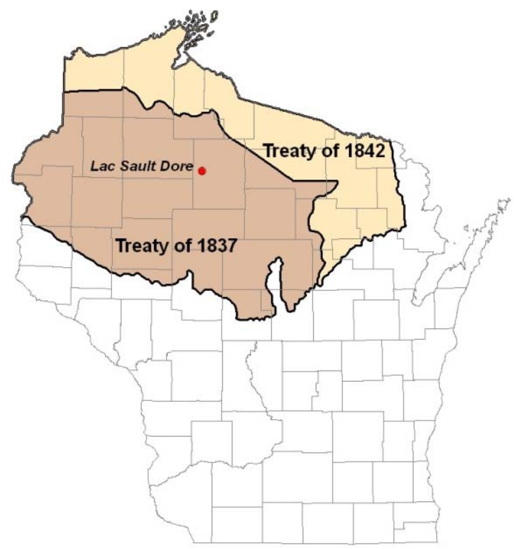


Figure 3.5-2. Location of Lac Sault Dore within the Native American Ceded Territory (GLIFWC 2010A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2010B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly quota is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the quota is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Only a single muskellunge has been harvested during six years of record on Lac Sault Dore. Spear harvests for walleye have taken place during two of these six years. These harvest records are provided in Table 3.5-2 and displayed in Figure 3.5-3. One common misconception is that the spear harvest targets the large spawning females. Table 3.5-2 clearly shows that the opposite is true with only 17% of the total walleye harvest (13 fish) comprising of female fish in 2001. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2010B). This regulation limits the harvest of the larger, spawning female walleye.

In 2002, the WDNR conducted a creels survey on Lac Sault Dore, and estimated the walleye population as well. Field survey data showed an abundance of about 7.1 walleye per acre within the lake. That same year, as determined by creel survey data, hook and line anglers harvested 1.4 fish per acre from the lake (19.4% of the total). In comparison, during 2001 the spear harvest removed 0.1 walleye per acre, or 2.0% of the estimated 2002 walleye population in Lac Sault Dore.

Because Lac Sault Dore 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 Lac Sault Dore. In 2011, the daily bag limit remained at 3 for the lake. Current regulations for the Phillips Chain, which includes the Elk River to Lac Sault Dore and Lac Sault Dore itself, include no minimum length limit for walleye. Lac Sault Dore is in the northern half of the muskellunge and northern pike management zone. Muskellunge must be 34” to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and only 5 pike may be kept in a single day. Statewide regulations apply for all other fish species.

Table 3.5-2. Spear harvest data of walleye for Lac Sault Dore (GLIFWC annual reports for Lac Sault Dore, Krueger 1998-2009).

Year	Tribal Quota	Tribal Harvest	%Quota	Mean Length* (in)	%Male*	%Female*	%Unknown
2001	127	78	61.4	14.5	56.4	16.7	26.9
2002	126	0	0.0				
2003	126	8	6.3	17.2	0.0	0.0	100.0
2004	127	0	0.0				
2005	120	0	0.0				
2006	122	0	0.0				

*Based on Measured Fish

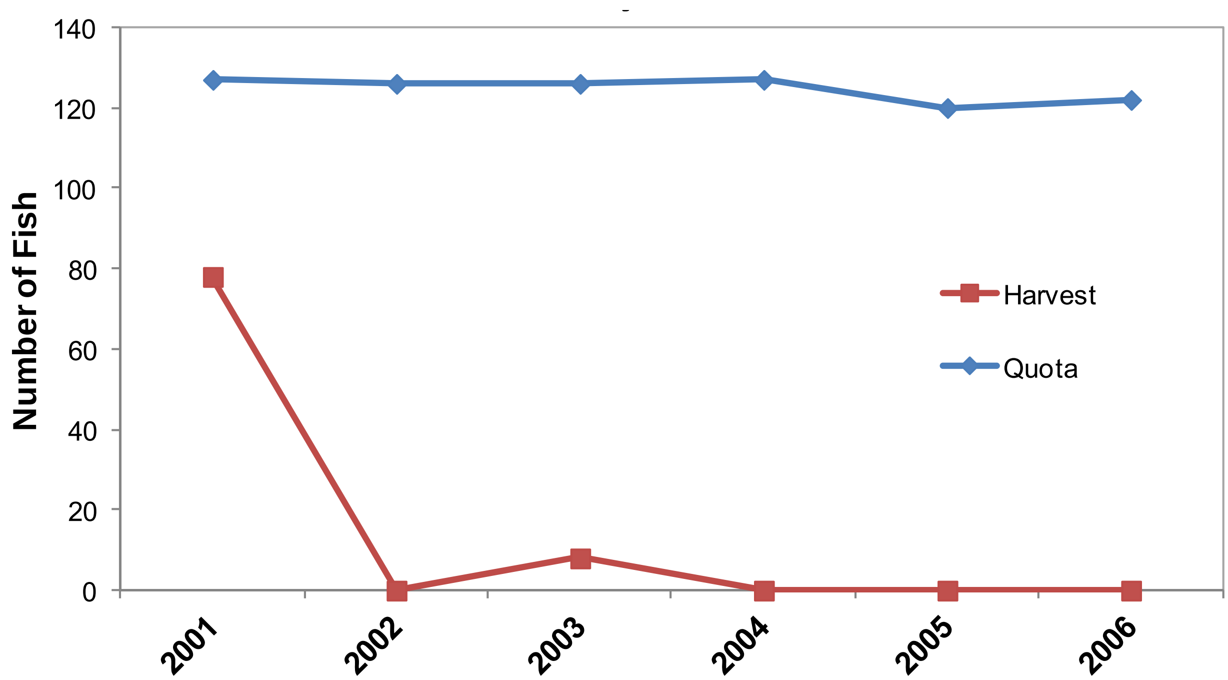


Figure 3.5-3. Walleye spear harvest data. Annual total walleye harvest and female walleye harvest are displayed since 2001 from GLIFWC annual reports for Lac Sault Dore (Krueger 1998-2009).

Lac Sault Dore Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults. Currently, the WDNR stocks Lac Sault Dore with walleye at a rate of roughly 0.5 fish per acre, on odd years (Table 3.5-3).

Table 3.5-3. Walleye stocking data available from the WDNR from 1973 to 2011 (WDNR 2011).

Year	Age Class	# Stocked	Avg. Length (inches)
1973	Fingerling	700	13
1974	Fingerling	1,535	11
1975	Fingerling	149	11
1976	Fingerling	1,890	6.33
1977	Fingerling	1,490	7
1978	Fingerling	700	11
1979	Fingerling	1,490	7
1980	Fingerling	1,432	9
1981	Fingerling	350	9
1982	Fingerling	400	13
1983	Fingerling	1,100	9
1984	Fingerling	1,033	10
1985	Fingerling	1,395	11
1986	Fingerling	1,120	11
1987	Fingerling	1,749	11
1988	Fingerling	1,120	9
1989	Fingerling	560	10
1990	Fingerling	560	11
1991	Fingerling	1,120	9.7
1992	Fingerling	1,120	10
1993	Fingerling	1,122	10.3
2000	Large Fingerling	280	9.9
2001	Large Fingerling	280	10.6
2003	Large Fingerling	280	10.9
2005	Large Fingerling	280	10.6
2007	Large Fingerling	187	12.3
2009	Large Fingerling	281	10
2011	Large Fingerling	280	9.9

Lac Sault Dore Creel Surveys

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

Table 3.5-4. Lac Sault Dore WDNR Creel Survey Summary (WDNR 2010)

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch / Acre	Harvest / Acre
Largemouth bass	2002	41.2	4.1	0.4	0.1
Muskellunge	2002	41.2	4.9	0.4	0.0
Northern pike	2002	41.2	10.3	4.5	0.6
Smallmouth bass	2002	41.2	8.6	5.7	0.3
Walleye	2002	41.2	21.8	4.2	1.4

Lac Sault Dore Substrate Type

During the point-intercept survey, an observation of the substrate type was collected at each littoral sampling location. Within the Aquatic Plant Section, Figure 3.3-3 and Figure 3.3-4 display proportional and spatial distribution, respectively, of the substrates at these point-intercept locations during 2010, 2011, and 2012.

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

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill four objectives:

1) Collect baseline data to increase the general understanding of the Lac Sault Dore 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 Lac Sault Dore stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.
4) Evaluate the ecological response to the 2010-11 winter drawdown on Lac Sault Dore.

These four objectives were fulfilled during the project and have provided detailed insights into the Lac Sault Dore ecosystem, the people who care about the lake, and what needs to be completed to protect and enhance it.

The water quality analyses conducted indicate that the lake is eutrophic, or highly productive. As discussed within the Water Quality Section, historical total phosphorus, chlorophyll-*a*, and Secchi disk transparency values were highly variable between years. Being an impoundment, Lac Sault Dore's drainage basin, or watershed, is 276 times larger than the lake itself. This immense watershed funnels an incredible amount of water into and through Lac Sault Dore, as indicated by a water residence time of only seven days. So every seven days, there is completely new water within the lake, making nutrient and algae concentrations within the lake highly variable depending on the amount of precipitation, and thus runoff, within the lake's watershed. The clarity of Lac Sault Dore's water is driven by two primary factors: free-floating algae and dissolved organic compounds within the water. In years with higher precipitation amounts, the amount of algae within the lake may be lower due to a higher flushing rate, but the amount of dissolved organic compounds within the water may be higher due to increased runoff. Conversely, in years with lower precipitation, algae may increase while dissolved organic compounds may decrease. Overall, the water quality of Lac Sault Dore is what is to be expected within a lake of its type. Its immense watershed delivers sufficient nutrients to make it a productive system, and these nutrients in turn create the lake's lush aquatic plant community and robust fishery.

Lac Sault Dore's watershed is in excellent condition with the majority being comprised of intact forest and wetlands which export minimal amounts of phosphorus. Watershed modeling was conducted on Lac Sault Dore's watershed utilizing modeling software to estimate the annual potential phosphorus load to the lake based upon the land cover types and their acreages within the watershed. This modeling predicted a slightly lower within-lake concentration of phosphorus than what has actually been measured within the lake. While this may indicate unaccounted sources of phosphorus are entering the lake, it is more likely that this discrepancy was due to limitations of the model when it comes to modeling watersheds of this size and the highly variable water quality data recorded from the lake. In addition to a mostly natural watershed, the majority of the immediate shoreline areas around Lac Sault Dore are currently in a natural or undeveloped state. These areas should be a primary focus for conservation, while restoration of more developed shoreline areas would benefit the Lac Sault Dore ecosystem by buffering runoff and providing valuable wildlife habitat.

Surveys focusing on aquatic plants in 2010 revealed that Lac Sault Dore's native aquatic plant community is of very high quality when compared to other flowages within the region and the state. However, these surveys also revealed that the invasive plant, Eurasian water milfoil, had rapidly colonized most areas between the depths of five and seven feet throughout the lake since its discovery in 2004. The Eurasian water milfoil observed in 2010 was growing at some of the highest densities that Onterra ecologists had ever observed. While Eurasian water milfoil was the most abundant plant within the lake in 2010, as discussed in the Aquatic Plant Section, it had mostly colonized deeper areas of the lake and was not well integrated with the native aquatic plant community that was mainly located in shallower water.

Due to the lake-wide distribution of Eurasian water milfoil in Lac Sault Dore in 2010, it was clear that a whole-lake scale approach would be required to control Eurasian water milfoil. While whole-lake herbicide control strategies exist, the effective use of this control strategy is dependent on long herbicide exposure times. With an extremely high flushing rate of approximately 7 days, the use of herbicides in this manner is likely not appropriate for Lac Sault Dore. The drawdown conducted on Lac Sault Dore over the winter of 2010-11 proved an effective tool for Eurasian water milfoil. Eurasian water milfoil continues to exist in Lac Sault Dore and left unmanaged, will likely increase to 2010 levels at some point in the future. At that time, a winter drawdown will likely need to be implemented. The SLUA has made it a primary objective to extend the time between drawdowns by implementing an integrated control program towards Eurasian water milfoil. At this time, directed hand-removal techniques will be the primary management action. But when the Eurasian water milfoil population exceeds what can be effectively controlled using hand-removal methods, spatially targeted herbicide spot treatments will likely be required. The likelihood of successfully controlling Eurasian water milfoil using herbicides may not be high. The enormous watershed and subsequently high flushing rate greatly decreases this technique's ability to be effective.

Data collected during the drawdown showed that oxygen levels remained at sufficient levels to support fish and other aquatic life over winter, and signage posted by the SLUA and monitoring by the WDNR helped prevent intensive harvesting of fishery. However, significant concerns with the SLUA exist relating to overfishing during future drawdowns.

Surveys of the emergent and floating-leaf aquatic plant communities in 2011 revealed that they had expanded by approximately 10 acres following the drawdown. While additional community mapping surveys were not conducted in 2012, expansion of floating-leaf communities (primarily white water lily) occurred in a few specific areas of the lake. Many riparians loudly voiced their concerns about the expansion of white water lily as it caused localized navigation impediments.

5.0 IMPLEMENTATION PLAN

During the planning meetings that took place during 2012, the Lac Sault Dore Planning Committee discussed the results of the 2010-201 management plan study with ecologists/planners from Onterra and closely examined Lac Sault Dore as well as the people who live around it. The Planning Committee discussed the strengths and weaknesses of Lac Sault Dore and its stakeholders, as well as the opportunities and threats they face. These issues were discussed in terms of 1) feasibility of addressing the issue, and 2) level of the issue's importance. As a result of the discussion, the SLUA was able to identify goals for protection and enhancing Lac Sault Dore, as well as communicating and education individuals who use the lake.

The implementation plan presented below represents the path the SLUA will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and achievable, as are the action steps required to reach these goals. The implementation plan is a living document that will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the lake's stakeholders.

Management Goal 1: Maintain Current Water Quality Conditions

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

Timeframe: Continuation of current effort.

Facilitator: Stan Gruszka and Planning Committee

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

The Citizen Lake Monitoring Network (CLMN) is a WDNR/UW Extension program in which volunteers are trained to collect data on Wisconsin's lakes are rivers. One aspect of the CLMN is the collection of water quality data. Water quality data has been actively collected on Lac Sault Lake by volunteers enrolled within the CLMN's advanced program. This program involves volunteers taking Secchi disk readings and water chemistry samples three times during the summer and once during the spring.

It is the responsibility of the current CLMN volunteer in conjunction with the SLUA Commissioners to coordinate new volunteers as needed. According to the stakeholder survey, 21% of respondents indicated they would be willing to participate in water quality monitoring (Appendix B, Question #29). When a change in the collection volunteer occurs, Kris Larsen (715.635.4072) or the appropriate WDNR/UW Extension staff should 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. Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
2. CLMN volunteer and/or SLUA Planning Committee would facilitate new volunteer(s) as needed
3. Coordinator contacts Sandy Wickman (715.365.8951) to acquire necessary materials and training for new volunteer (s)

Management Goal 2: Increase Soo Lake United Association's capacity to Communicate with lake stakeholders

Management Action: Use education to promote lake protection and enjoyment through stakeholder education

Timeframe: Continuation of current effort

Facilitator: SLUA Planning Committee

Description: Education represents an effective tool to address many lake issues. Currently, the SLUA distributes at least 6 newsletters per year to association members, as well as special mailings as appropriate. The SLUA also maintains a website (www.soolakeassociation.com). This level of communication is important within a management group because it builds a sense of community while facilitating the spread of important association news, educational topics, and even social happenings. This is exemplified by 89% of stakeholder respondents indicating that the SLUA has kept them either fairly well or highly informed regarding lake-related issues (Appendix B, Question #28). This level of communication also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well written newsletter can be used as a tool to increase awareness of many aspects of lake ecology and management among association members. By doing this, meetings can often be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the association newsletter may contain monitoring results, association management history, as well as other educational topics listed below.

In addition a variety of educational efforts will be initiated by the SLUA Planning Committee. These may include educational materials, awareness events and demonstrations (e.g. Price County Fair) for lake users as well as activities which solicit local and state government support. This committee will also investigate the use of other social media such as Facebook®. This will directly increase the association's ability to communicate with interested stakeholders by allowing them to post information and social messages.

Example Educational Topics

- Specific topics brought forth in other management actions
- Aquatic invasive species issues
  - identification and education
  - control methods
  - risks related to AIS establishment
  - risks related to AIS control methods
- Basic lake ecology
- Boating regulations
- Slow-no-wake zones
- Snowmobile regulations
- Hunting and trespassing information
- Pier rules
- Noise, air, and light pollution
- Shoreline habitat protection
- Septic system maintenance
- Fishing regulations

Action Steps:

See description above as this is an established program.

Management Goal 3: Control current Eurasian water milfoil population and prevent further aquatic invasive species introductions to Lac Sault Dore.

Management Action: Initiate volunteer-based monitoring of Eurasian water milfoil and other aquatic invasive species.

Timeframe: Begin 2013

Facilitator: Planning Committee

Description: While the Eurasian water milfoil population in Lac Sault Dore was greatly reduced following the winter 2010-2011 water level drawdown, history shows that it has the ability to rapidly spread and colonize a large majority of the lake in a short period of time. This is based on the fact that EWM was first detected from Lac Sault Dore in 2004 and within approximately 5 years, was found throughout the system and in many areas at high densities.

Monitoring of the Eurasian water milfoil population on an annual basis and reporting the findings to resource managers will yield to understanding of how the population is behaving and when the threshold for initiating a particular control strategy has been reached. In addition, volunteers will also survey for other invasive species including curly-leaf pondweed, which occurs in three upstream lakes (Solberg, Big Dardis, and Musser Lakes). Early detection and response to curly-leaf pondweed infestations commonly leads to successful control.

As previously discussed, the Citizen Lake Monitoring Network (CLMN) is a program that coordinates citizen-based data collection. Along with water quality data collection programs, the CLMN also has developed an AIS Monitoring plan. The goals of the CLMN aquatic invasive monitoring program are as follows:

- Help you become familiar with some of the more common native aquatic plants and animals in your lake.
- Help you monitor for the more common aquatic invasive species.
- Help you to communicate information to others.

Soo Lake United volunteers will conduct AIS surveillance monitoring on Lac Sault Dore Lake with coordination from the Northern Region CLMN Coordinator (Kris Larsen – 715.635.4072) and following CLMN protocols, which are outlined within the AIS Monitoring Handbook and can be found at the CLMN website:

www4.uwsp.edu/cnr/uwexlakes/clmn

The SLUA would use an "adopt-a-shoreline" approach where volunteers are responsible for surveying specified areas of the lake. In order for accurate data to be collected during these surveys, volunteers must be able to identify non-native species such as Eurasian water milfoil and curly-leaf pondweed. Distinguishing these plants from native look-a-likes is very important. SLUA members would attend CLMN workshops to gain this training. The SLUA would also encourage its volunteer monitors to purchase a field guide to aquatic plants, such as *Through the Looking Glass* (Borman et al. 1997) which can be purchased through the CLMN website under 'publications.'

Action Steps:

1. Volunteers from SLUA are trained on CLMN Aquatic Invasive Species Monitoring protocols (Kris Larsen – 715.635.4072).
2. Volunteer monitors report findings and hand-removal areas to SLUA, WDNR, and consultant (as necessary)

Management Action: Control Eurasian water milfoil populations on Lac Sault Dore Lake

Timeframe: Begin 2013

Facilitator: Planning Committee

Description: As described in the Aquatic Plant Section, one of the most pressing threats to the health of Lac Sault Dore's aquatic plant community is Eurasian water milfoil. The drawdown dramatically reduced its population, but as Maps 5 and 6 show, Eurasian water milfoil can still be found at low densities in some parts of the lake.

Hand-removal Control Strategy

If professional surveys reveal areas of Eurasian water milfoil that are comprised of single plants or clumps of plants and are not 'colonized', the SLUA will organize efforts to hand-remove the plants. In 2012, the SLUA enlisted local high school students to aid in hand-removal efforts. 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 needs to be paid to all plant fragments that may detach during the control effort. Additional guidance on hand-removal methods can be found within educational pamphlet, *Eurasian Water Milfoil Manual Removal,* co-authored by the Lumberjack Resource Conservation & Development (RC&D) Council, Inc. and Golden Sands RC&D Council, Inc. This pamphlet can be obtained by contacting the Golden Sands RC&D (www.goldensandsrcd.org).

Herbicide Control Strategy

If trained SLUA volunteers locate areas of colonized Eurasian water milfoil, this will trigger a survey by professionals to assess and map the Eurasian water milfoil within the lake. If professional mapping surveys reveal that the colonized Eurasian water milfoil is relatively isolated and contain dominant or greater (at least 50% aerial coverage) Eurasian water milfoil, the most feasible method of control will likely be herbicide applications – specifically, early spring treatments with an auxin-mimic herbicide like 2,4-D. The impacts to native submersed species are believed to occur when the non-native species reaches an aerial coverage of approximately 50%. Therefore, by minimizing the occurrence of these dense colonies, the impact on the lake's ecology and recreation will also be minimized.

Approximately 68% of stakeholder respondents indicated that they were supportive (either *moderately* or *highly*) of the responsible use of herbicide control techniques, 13% were not supportive (either *moderately not* or *not*), and the remainder were divided between having neutral or unsure preferences (Appendix B, Question #24). Seventy-three percent of stakeholder survey respondents indicated that they would like to learn more about aquatic invasive species control methods and 52% indicated they wanted to learn more about the risks of aquatic invasive species control (Question #27). The SLUA would like to address these issues through an educational initiative. SLUA members would create educational pieces within its newsletters, as well as solicit area research managers (e.g. WDNR, Price County LCD, etc) to present at association meetings.

If large populations of aquatic invasive species are located and the SLUA would like to initiate an herbicide control program, a formal monitoring strategy consistent with the Appendix D of the WDNR Guidance Document, *Aquatic Plant Management in Wisconsin* (WDNR 2010) would need to be developed. This form of monitoring is required by the WDNR for all large scale herbicide applications (exceeding 10 acres in size or 10% of the area of the water body that is 10 feet or less in depth) and grant-funded projects where scientific and financial accountability are required.

In the event that herbicide applications were to occur over colonies of Eurasian water milfoil in Lac Sault Dore, a cyclic series of steps is used to plan and implement the treatment strategies. The series includes:

1. A lake-wide assessment of Eurasian water milfoil completed while the plant is at peak biomass (August-September)
2. Creation of control strategy for the following spring (December-February).
3. Verification and refinement of treatment plan immediately before control strategies are implemented (April-May)
4. Completion of control strategy (May)
5. Assessment of control strategy (August-September)

Once Step 5 is completed, the process would begin again that same summer with the completion of a peak biomass survey. The survey results would then be used to create the next spring's control strategy (Step 2).

The herbicide treatments would occur during the spring when surface water temperatures are between 50-60°F. If Eurasian water milfoil colonies are located within channelized areas with higher rates of water flow, these herbicide treatments may not be a feasible option as the exposure time of the herbicide to the plants would be greatly reduced and would likely be ineffective. If the SLUA moves forward with an herbicide control project, they would also conduct herbicide concentration monitoring in association with the control strategy. Through a partnership between the WDNR and United States Army Corps of Engineers (USACE), volunteer-collected water sampling would occur at different time periods and locations following the treatment following a monitoring strategy devised by these entities. This information would indicate whether or not the proper combination of concentration and exposure times can be reached on this flowage.

Two types of aquatic plant monitoring would be completed to determine treatment effectiveness; 1) quantitative monitoring using WDNR protocols, and 2) qualitative monitoring using observations at individual treatment sites and on a treatment wide basis. Results of both of these monitoring strategies would be used to create the subsequent treatment strategies. Comparing the monitoring results from the pretreatment and post treatment surveys would determine the effectiveness of the treatment on a site-by-site basis and on a treatment-wide basis. Qualitatively, a successful treatment on a particular site would include a reduction of exotic density as demonstrated by a decrease in density rating. Quantitatively, a successful treatment would include a significant reduction in Eurasian water milfoil frequency following the treatments as exhibited by at least a 50% decrease in exotic frequency from the pre- and post-treatment point-intercept sub-sampling.

Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program may be sought to partially fund this control program. Specifically, funds would be applied for under the Established Population Control classification on February or August 1st of each year.

Winter Drawdown Control Strategy

If ecologists conducting the peak-biomass survey feel that the Eurasian water milfoil population is increasing to levels where herbicide treatments are no longer feasible and it is beginning to interfere with recreational activities on the lake (approaching 'nuisance' levels) this would trigger a professional whole-lake aquatic plant point-intercept survey to be conducted.

This point-intercept survey would be used to determine the frequency of occurrence of Eurasian water milfoil. If the frequency of Eurasian water milfoil was 30% or greater, this would trigger the process of implementing another winter water level drawdown. In the event that a drawdown takes place, the data collected from the point-intercept survey would be used as a pre-drawdown survey.

Currently, the operating order of the Wiemers Dam only allows for a 4-foot drawdown, likely not sufficient to control Eurasian water milfoil on a lake-wide basis. According the WDNR Dam Safety/Floodplain engineer (Terry Cummings personal comm.), a drawdown greater than four feet would require a WDNR Chapter 31 permit ($500) or a revision to the current order. This one-time process would involve a public notice component, possibly including a public hearing if one is requested. According to WDNR administrative code NR150, an Environmental Assessment may also be required.

The same surveys associated with the monitoring of the 2010-11 drawdown (e.g. whole-lake point-intercept surveys, Eurasian water milfoil mapping surveys, etc.) would accompany future drawdowns.

Action Steps:

Hand-removal: Initiate hand-removal methods as applicable with guidance from the Hand Removal Pamphlet co-authored by the Lumberjack Resource Conservation & Development (RC&D) Council, Inc. & Golden Sands RC&D Council, Inc (2012).

Herbicide Applications:

a) If colonized Eurasian water milfoil is discovered by volunteers, then a professional survey of Eurasian water milfoil within Lac Sault Dore would be initiated.
b) If professional survey locates isolated colonies of Eurasian water milfoil with a density rating of dominant or greater, an herbicide control project with the designs mentioned above would be developed.
c) The SLUA would apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
d) Initiate control plan.
e) Update management plan to reflect changes in control needs and those of the lake ecosystem.

Winter Drawdown:

a) If professional survey reveals Eurasian water milfoil is approaching nuisance levels and herbicide applications are not feasible, a whole-lake point-intercept survey would be conducted to determine frequency of occurrence of Eurasian water milfoil.
b) If Eurasian water milfoil frequency of occurrence is 30% or greater, the process to conduct a winter water level drawdown would be initiated.
c) SLUA acts to change the operating order of the Wiemers Dam to allow for a 6-foot drawdown to control Eurasian water milfoil and/or nuisance aquatic plants.
d) SLUA receives proper permit(s) to conduct the drawdown.
e) Post treatment evaluations of the drawdown would occur.

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Lac Sault Dore public access locations.

Timeframe: Continuation of current effort

Facilitator: Planning Committee

Description: Currently the SLUA monitors the public boat landing using training provided by the Clean Boats Clean Waters program. Lac Sault Dore is an extremely popular destination by recreationists and anglers, making the lake 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 Lac Sault Dore. The goal would be to cover the landings 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.

The SLUA utilized over 100 hours of volunteer monitoring over the past two years. However, they are currently experiencing volunteer fatigue, and will increase volunteerism by engaging lake stakeholders and with educational materials and workshops. According to the stakeholder survey, watercraft inspections were ranked as the top activity (31% of respondents) that respondents would be willing to participate it (Appendix B, Question #29).

Action Steps:

See description above as this is an established program.

Management Goal 4: Maintain Navigability on Lac Sault Dore

Management Action: Support reasonable and responsible actions by shoreland property owners to gain navigational access to open water areas of Lac Sault Dore

Timeframe: Summer 2013

Facilitator: Planning Committee

Description: Following the winter drawdown of 2010-2011, some riparians have expressed concerns regarding increased populations of floating-leaf aquatic plant communities, particularly comprised of white water lily. It remains unknown if the increased populations can be solely attributed to the winter drawdown, or some other environmental factor.

This management goal has been included here as a place holder in the event that white water lily populations continue to increase to levels that the SLUA needs to entertain this type of strategy. By including this goal within the management plan, an amended plan will not be required to implement these activities in the future.

The SLUA supports reasonable and environmentally sound actions to facilitate access to open water areas of Lac Sault Dore by shoreland property owners. These actions would target nuisance levels of native aquatic plants in order to restore watercraft access of property owners to reach open water area from their property. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area required to permit the access. These actions do not include areas that can be controlled through manual removal such as swimming areas and areas around piers and boatlifts. *Aquatic Plant Management Strategy, Northern Region WDNR* (Appendix F) clearly states that no individual permits will be issued by the WDNR and if a permit for aquatic plant control is required, the lake organization is the applicant of the permit. If documentation of impairment exists, this plan must be amended to specifically delineate the areas requiring control and a permit must be obtained by the association.

Three possibilities exist to maintain access to open water from the impacted riparian properties.

1. Riparian manually remove 30-foot (length of shore) area without a permit, but all manually removed plants must be taken to shore and the area must include any docks, piers, or swimming areas on the property. This 30-foot wide area cannot vary from year to year.
2. Contract to have the plants removed manually, possibly by an aquatic plant nursery or landscaping company, without a permit in the area listed above.

Only applicable when the above possibilities do not feasibly yield lake access

3. Obtain a WDNR permit and contract to have the plants cut and removed through mechanical harvesting.

<u>Conditions of Mechanical Harvesting Permit (#3 above)</u>
A single permit application from the SLUA would be applied for annually on an as-needed basis from the WDNR and actions would subject to the following conditions

- A WDNR site visit would occur each year prior to implementation of the permitted activities to ensure that navigation is impeded beyond what can be hand-removed without a permit.
- All removed plants be collected, taken out of the lake, and disposed of properly.
- Mechanical harvest summary report is provided to the WDNR annually after each season in which wild aquatic plants have been under a WDNR permit.

<u>Activities do not include:</u>
- Removing large areas (clear cutting) for any reason
- Removing plants to increase a riparians ability to fish off of their dock
- Creating an access lane from a riparian's property if there is already a sufficient alternative (i.e. path to the lake)
- Creating access lanes to areas where riparian access is not the sole justification for the activity (i.e. to gain access to a fishing spot)

At this time it is unknown if a contractor exists that is able to manually remove the plants in feasible manner that would create navigation lanes to open water from the shoreland properties. Local landscaping companies may fill this niche as more lakes seek this service. It is also unknown if mechanical harvesting is possible in these area due to shallow water and type of plants that would be targeted. Typically floating-leaf plants are not targeted for mechanical control due to the nature of their re-growth (i.e. from buried tubers) and the shallow water they reside in (harvesters typically cannot operate in less than 3 feet of water).

Regardless of the technique used, the action's impact on the native plant community will be minimized by removing only as much native habitat as necessary in order gain access to open water. No more than a 30-foot wide navigation lane will be cleared in any area and the shortest route possible will be used.

Excessive plant growth is associated with increased nutrient levels. Best management practices for shoreland properties to reduce their nutrient loads are to have buffer areas of native plant species at least 35 feet wide along their shorelines. These improvements would provide important shoreline habitat improvement and acute sources of nutrients. If mechanical control methods are sought, the WDNR may require that all affected riparians initiate shoreland restoration to mitigate the losses of the floating-leaf habitat that would be removed by the control action.

It is likely that mechanical harvesting costs may be too costly to implement. Based upon the perceived need of mechanical harvesting, a rough cost estimate of contracting these activities would be approximately $1,340 for a single cutting of approximately one acre. This is based off a contractor being able to cut 0.5 acres per hour at a cost of $170 per hour and $1000 to mobilize the equipment needed to complete the task (e.g. mechanical harvester, off-loading conveyor, dump truck, etc). It may also be difficult to identify a company that would be willing to conduct these activities at this scale.

As with all aquatic plant management techniques, harvesting has its advantages and disadvantages. Advantages include the removal of plants and associated nutrients from the waterbody, immediate relief of nuisance plants, harvesting is less controversial than chemical use, and specific areas can be targeted accurately. Disadvantages include sediment re-suspension, fragmentation of plants, need for repeated treatments within a single year, and no ability to select specific plant species for treatment. Mechanical harvesting in areas that contain aquatic invasive species may increase the rate of spread of these species as it 'drags' cut fragments to other parts of the system.

Action Steps:

See description above

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Lac Sault Dore (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 SLUA members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, winter, and fall. Although SLUA 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.

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

♦ 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 Lac Sault Dore'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 Lac Sault Dore during a June 30 & July 1, 2010 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Lac Sault Dore to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. These surveys were also used to assess the effects of the drawdown on the lake's aquatic plant community. 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 these studies on August 17 and 18, 2010, August 18 and 19, 2011, and August 14 and 15, 2012. A point spacing of 55 meters was used resulting in approximately 799 points.

Community Mapping

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

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium. A set of samples was also provided to the SLUA.

7.0 LITERATURE CITED

Beard, T.D. 1969. Impact of an overwinter drawdown on the aquatic vegetation in Murphy Flowage, Wisconsin. Research Report, vol 43. Department of Natural Resources, Madison, WI, USA.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press. London, England.

Borman, S., R. Korth, J. Temte. 1997. Through the Looking Glass. WDNR Publication FH-207-97.

Canter, L.W., D.I. Nelson, and J.W. Everett. 1994. Public Perception of Water Quality Risks – Influencing Factors and Enhancement Opportunities. Journal of Environmental Systems. 22(2).

Carpenter, S.R., Kitchell, J.F., and J.R. Hodgson. 1985. Cascading Trophic Interactions and Lake Productivity. BioScience, Vol. 35 (10) pp. 634-639.

Carlson, R.E. 1977 A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Dinius, S.H. 2007. Public Perceptions in Water Quality Evaluation. Journal of the American Water Resource Association. 17(1): 116-121.

Elias, J.E. and M.W. Meyer. 2003. Comparisons of Undeveloped and Developed Shorelands, Northern Wisconsin, and Recommendations of Restoration. Wetlands 23(4):800-816. 2003.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Garn, H.S. 2002. Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Two Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigations Report 02-4130.

Gettys, L.A., W.T. Haller, & M. Bellaud (eds). 2009. *Biology and Control of Aquatic Plants: A Best Management Handbook.* Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp. Available at http://www.aquatics.org/bmp.htm.

Goldsby, T.L., Bates, A.L., and R.A. Stanley. 1978. Effect of water fluctuation and herbicide on Eurasian water milfoil in Melton Hill Reservoir. Journal of Aquatic Plant Management. 16: 34 – 38.

Graczyk, D.J., Hunt, R.J., Greb, S.R., Buchwald, C.A. and J.T. Krohelski. 2003. Hydrology, Nutrient Concentrations, and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999-2001. USGS Water-Resources Investigations Report 03-4144.

Great Lakes Indian Fish and Wildlife Service. 2010A. Interactive Mapping Website. Available at http://www.glifwc-maps.org. Last accessed March 2010.

Great Lakes Indian Fish and Wildlife Service. 2010B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Enforcement/regulations.html. Last accessed March 2010.

Hanchin, P.A., Willis, D.W. and T.R. St. Stauver. 2003. Influence of introduced spawning habitat on yellow perch reproduction, Lake Madison South Dakota. Journal of Freshwater Ecology 18.

Hartleb, C.F., Madsen, J.D., and C.W. Boylen. 1993. Environmental factors affecting seed germination in Myriophyllum spicatum L. Aquatic Botany. 45: 15 – 25.

Jennings, M. J., E. E. Emmons, G. R. Hatzenbeler, C. Edwards and M. A. Bozek. 2003. Is littoral habitat affected by residential development and landuse in watersheds of Wisconsin lakes? Lake and Reservoir Management. 19(3):272-279.

Krueger, J. 1998-2007. Wisconsin Open Water Spearing Report (Annual). Great Lakes Indian Fish and Wildlife Commission. Adminstrative Reports. Available at: http://www.glifwc.org/Biology/reports/reports.htm. Last accessed March 2010.

Lathrop, R.D., and R.A. Lillie. 1980. Thermal Stratification of Wisconsin Lakes. Wisconsin Academy of Sciences, Arts and Letters. Vol. 68.

Lindsay, A., Gillum, S., and M. Meyer 2002. Influence of lakeshore development on breeding bird communities in a mixed northern forest. Biological Conservation 107. (2002) 1-11.

Lumberjack Resource Conservation & Development (RC&D) Council, Inc. & Golden Sands RC&D Council, Inc. 2012. Eurasian Water Milfoil Manual Removal. Can be accessed at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5373240.pdf

Netherland, M.D. 2009. Chapter 11, "Chemical Control of Aquatic Weeds." Pp. 65-77 in *Biology and Control of Aquatic Plants: A Best Management Handbook*, L.A. Gettys, W.T. Haller, & M. Bellaud (eds.) Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp

Newbrey, M.G., Bozek, M.A., Jennings, M.J. and J.A. Cook. 2005. Branching complexity and morphological characteristics of coarse woody structure as lacustrine fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 62: 2110-2123.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2): 133-141

Nichols, S.A. 1975. The use of overwinter draw down for aquatic vegetation management. Water Resources Bulletin. 11(6).

Olson, E.R., Ventura, S.J., and J.B. Zedler. 2012. Merging geospatial and field data to predict the distribution and abundance of an exotic macrophyte in a large Wisconsin reservoir. Aquatic Botany. 96: 31 – 41.

Panuska, J.C., and J.C. Kreider. 2003. Wisconsin Lake Modeling Suite Program Documentation and User's Maunal Version 3.3. WDNR Publication PUBL-WR-363-94.

Radomski P. and T.J. Goeman. 2001. Consequences of Human Lakeshore Development on Emergent and Floating-leaf Vegetation Abundance. North American Journal of Fisheries Management. 21:46–61.

Reed, J. 2001. Influence of Shoreline Development on Nest Site Selection by Largemouth Bass and Black Crappie. North American Lake Management Conference Poster. Madison, WI.

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In: Gene E. Likens, (Editor) Encyclopedia of Inland Waters. Vol. 1, pp. 60-69 Oxford: Elsevier.

Scheuerell M.D. and D.E. Schindler. 2004. Changes in the Spatial Distribution of Fishes in Lakes Along a Residential Development Gradient. Ecosystems (2004) 7: 98–106.

Shaw, B.H. and N. Nimphius. 1985. Acid Rain in Wisconsin: Understanding Measurements in Acid Rain Research (#2). UW-Extension, Madison. 4 pp.

Smith D.G., A.M. Cragg, and G.F. Croker.1991. Water Clarity Criteria for Bathing Waters Based on User Perception. Journal of Environmental Management.33(3): 285-299.

Spangler, G.R. 2009. "Closing the Circle: Restoring the Seasonal Round to the Ceded Territories". Great Lakes Indian Fish & Wildlife Commission. Available at: *www.glifwc.org/Accordian_Stories/GeorgeSpangler.pdf*

Stanley, R.A. 1976. Response of Eurasian water milfoil to subfreezing temperature. Journal of Aquatic Plant Management. 14: 36 – 39.

United States Department of the Interior – Bureau of Indian Affairs. 2007. Fishery Status Update in the Wisconsin Treaty Ceded Waters. Fourth Edition.

Vander Zanden, M.J. and J.D. Olden. 2008. A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65 (7): 1512-22.

Wisconsin Department of Natural Resources. 2010. Aquatic Plant Management in Wisconsin. Can be accessed at: www4.uwsp.edu/cnr/uwexlakes/ecology/APMguide.asp

Woodford, J.E. and M.W. Meyer. 2003. Impact of Lakeshore Development on Green Frog Abundance. Biological Conservation. 110, pp. 277-284.