Half Moon Lake

Lincoln County, Wisconsin

Comprehensive Management Plan

October 2015

Sponsored by:

Half Moon Lake Protection & Rehabilitation District

WDNR Grant Program

LPL-1533-14

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Onterra LLC
Lake Management Planning

Half Moon Lake
Lincoln County, Wisconsin

Comprehensive Management Plan
October 2015

Created by: Dan Cibulka and Brenton Butterfield
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Funded by: Half Moon Lake Protection and Rehabilitation District
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This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

Half Moon Lake Planning Committee

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1.0 INTRODUCTION

Half Moon Lake, Lincoln County, is a 104-acre seepage lake with a maximum depth of 14 feet and a mean depth of five feet (Map 1). This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Half Moon Lake contains 34 native plant species, of which small purple bladderwort is the most common plant. No exotic plant species are known to exist in Half Moon Lake.

Field Survey Notes

Dense watershield noted in some areas of the lake. Sediment primarily lightly colored muck or sandy, abundant isoetid species present.

Photograph 1.0-1 Half Moon Lake, Lincoln County

Lake at a Glance - Half Moon Lake

Morphology	
Acreage	104
Maximum Depth (ft)	14
Mean Depth (ft)	5
Shoreline Complexity	2.8
Vegetation	
Curly-leaf Survey Date	June 12, 2014
Comprehensive Survey Date	July 21, 2014
Number of Native Species	34
Threatened/Special Concern Species	Snail-seed pondweed, Small purple bladderwort
Exotic Plant Species	N/A
Simpson's Diversity	0.88
Average Conservatism	7.3
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	6.36
Sensitivity to Acid Rain	Yes
Watershed to Lake Area Ratio	2:1

The Half Moon Lake Protection and Rehabilitation District (HMLPRD) was formed in 1992 to plan for the long-term management of the lake. Since its inception, the district has worked to protect Half Moon Lake, educate the people that use and care for the lake, and manage the lake through professional and volunteer monitoring. The district is a member of the Lincoln County Lakes Association, routinely sends members to the annual Wisconsin Lakes Partnership Convention, and represents the lake during county variance requests. The group has supported numerous management projects, including the completion of the lake's first management plan using Lake Management Planning Grant funds in 1994, district member surveys, a barley-straw feasibility study, participation in the Citizen Lake Monitoring Network, and a county-wide lake seminar on invasive species, shoreland plantings, fisheries, and wetland protection. In 2012, the HMLPRD initiated a new Adopt-a-Shoreline program. As a part of this program, volunteers monitor specific sections of the Half Moon Lake shoreline for invasive species.

From the time the district was formed, its members have been concerned with the lake's nutrient content and resulting algal abundance. Additionally, in recent years the group has become more concerned with a perceived increase in watershield (*Brasenia schreberi*) within the lake, which had reportedly reduced recreation and navigability in some areas of the lake.

In 2013, members of the HMLPRD contacted Onterra, LLC regarding completion of a Lake Management Planning project. In August of 2013, the HMLPRD submitted a grant application to the Wisconsin Department of Natural Resources (WDNR), which included a proposal of studies to be completed by Onterra in 2014-2015. This project would include a study design that would examine Half Moon Lake from a ecosystem perspective, taking inventories of the lakes' plants, watershed, shoreline condition, and water quality. Stakeholder input was a critical component of the project as well, through the inclusion of project meetings and a stakeholder survey which was circulated to all District members.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting

On June 21, 2014, a project kick-off meeting was held at to introduce the project to the general public. The meeting was announced through a mailing and personal contact by HMLPRD board members. The attendees observed a presentation given by Dan Cibulka, an aquatic ecologist with Onterra. Mr. Cibulka'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 June 12, 2015, Dan Cibulka and Brenton Butterfield of Onterra met with members of the Half Moon Lake Planning Committee. During the meeting, Mr. Cibulka and Mr. Butterfield went through the results from the scientific studies that had taken place on the lake in 2014. Additionally, many questions were discussed on topics such as water quality, aquatic plant communities and aquatic invasive species.

Planning Committee Meeting II

On June 24, 2015, Mr. Cibulka and Mr. Butterfield met again with members of the HMLPRD planning committee. The focus of this meeting was to formulate management goals and actions that the HMLPRD would follow as part of this management plan. The majority of the meeting focused upon the topic of nuisance conditions of watershield, low winter oxygen conditions, water quality monitoring and District educational activities.

Project Wrap-up Meeting

The project's Wrap-up Meeting was held on August 29, 2015. *Onterra ecologist Dan Cibulka presented the project's summary results to members of the HMLPRD, as well as outlined the Management Goals and Actions the planning committee had adopted. The meeting lasted nearly two hours, with a questions and answers portion occurring after the formal presentation.*

Management Plan Review and Adoption Process

Onterra ecologists met with the Half Moon Lake Planning Committee in June of 2015, at which time the Results Section (3.0) was presented to the group and subsequently reviewed. During the second Planning Committee meeting, the Implementation Plan was developed. The first draft of the Implementation Plan was approved by the Half Moon Lake Planning Committee on August 18, 2015. In addition, the Implementation Plan was approved by the HMLPRD at the District's general membership meeting on August 29, 2015. In October of 2015, WDNR regional lake coordinator Jim Kreitlow received a copy of the draft report and provided comments for Onterra staff. A final report was produced later that month.

Stakeholder Survey

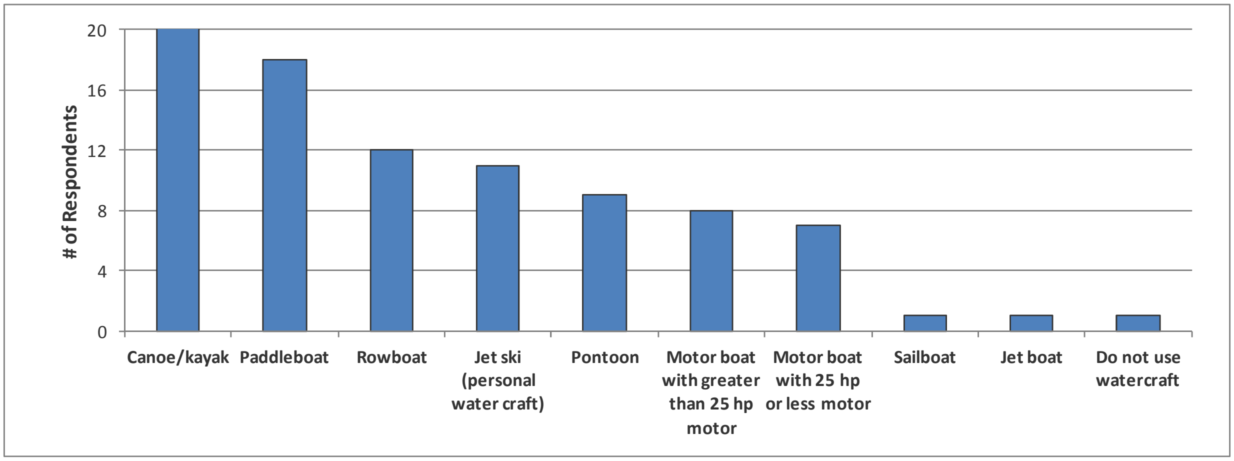
During October of 2014, a seven-page, 28-question survey was mailed to 78 Half Moon Lake riparian property owners as well as all Half Moon P&R District members. 46 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Half Moon Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Half Moon Lake. The majority of stakeholders (49%) live on Half Moon Lake seasonally, while 28% have a year-round residence and 28% responded that they visit on weekends throughout the year. 64% of stakeholders have owned their property for over 15 years, and 31% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a canoe/kayak or paddleboat on the lake (Question 12). As seen on Question 13, several of the top recreational activities on the lake may involve boat use. Watercraft traffic was however ranked low by Half Moon Lake stakeholders as a factor potentially impacting Half Moon Lake in a negative manner (Question 20) or as a concern regarding the lake (Question 21).

A concern of stakeholders noted throughout the stakeholder survey (see Questions 20 and 21 as well as – Appendix B) was accumulating sediment as well as excessive aquatic plant growth and aquatic invasive species introduction. Winter fish kills was added as a concern by several stakeholders. These topics are touched upon in the appropriate Results & Discussion Section, Summary & Conclusions Section and within the Implementation Plan.

Question 12: What types of watercraft do you currently use on the lake?



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

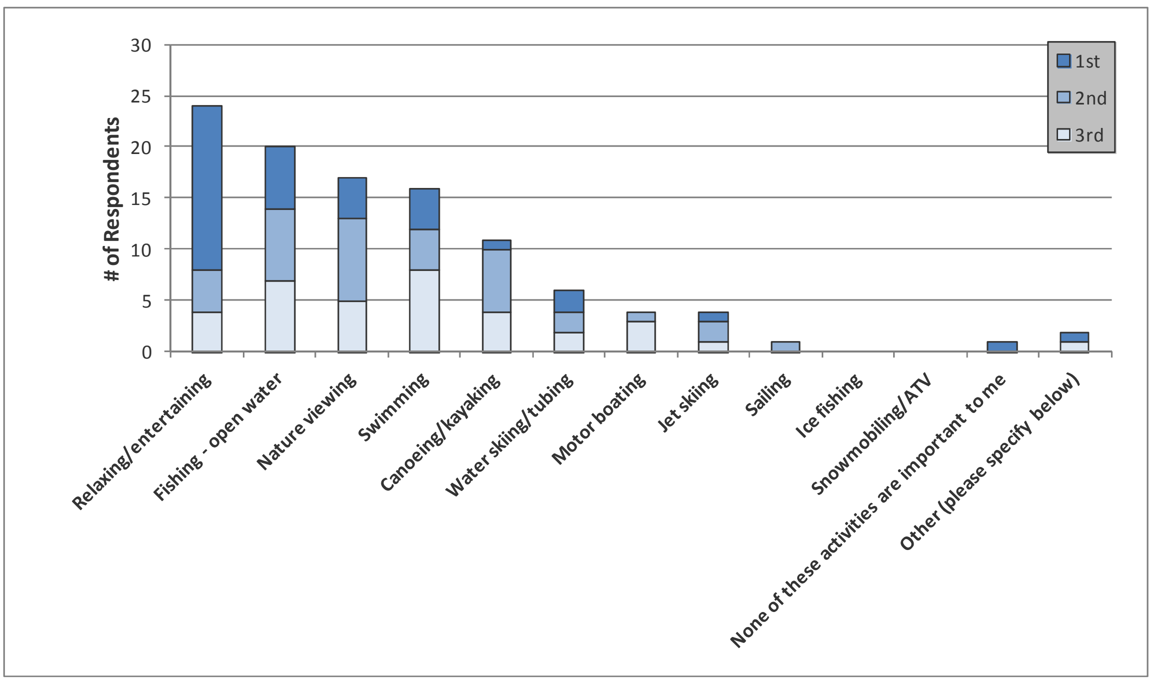
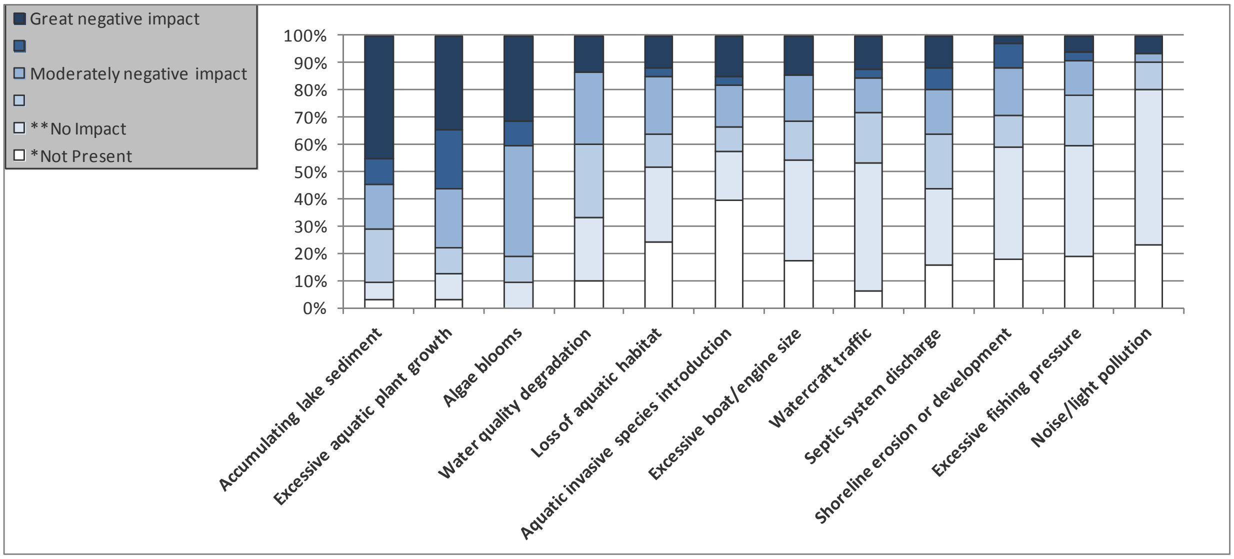


Figure 2.0-1. Select survey responses from the Half Moon Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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



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

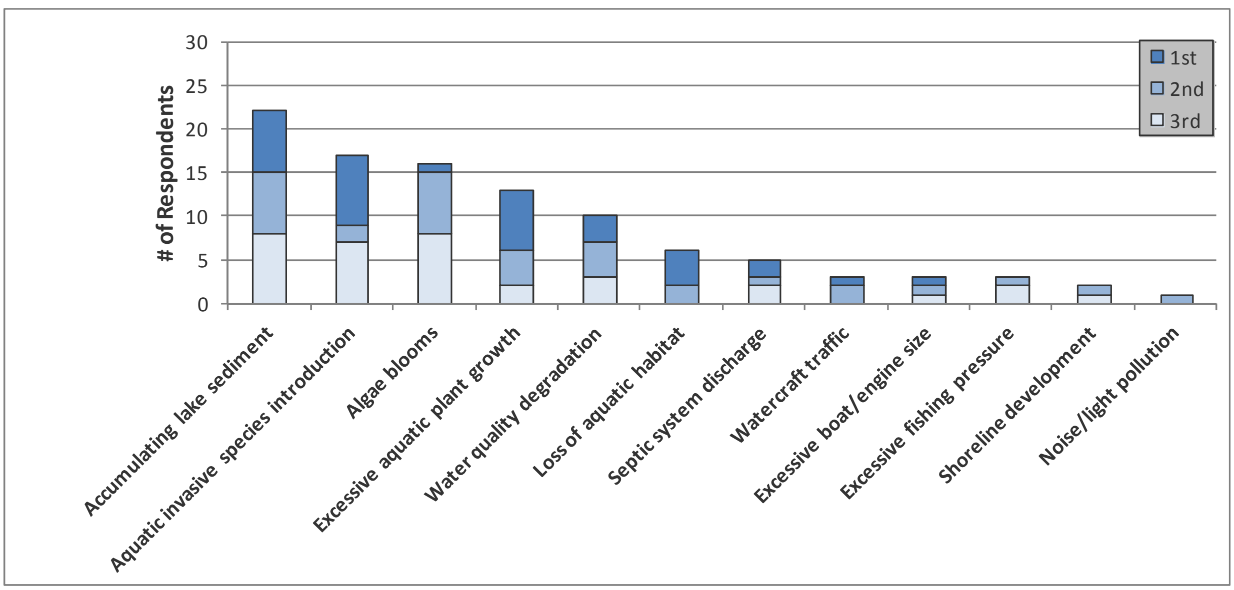


Figure 2.0-2. Select survey responses from the Half Moon Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

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

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 μg/L.
- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013A) 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 Half Moon Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, hydrology. 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.

Because of its depth, small watershed and hydrology, Half Moon Lake is classified as a shallow, seepage lake (category 6 on Figure 3.1-1).

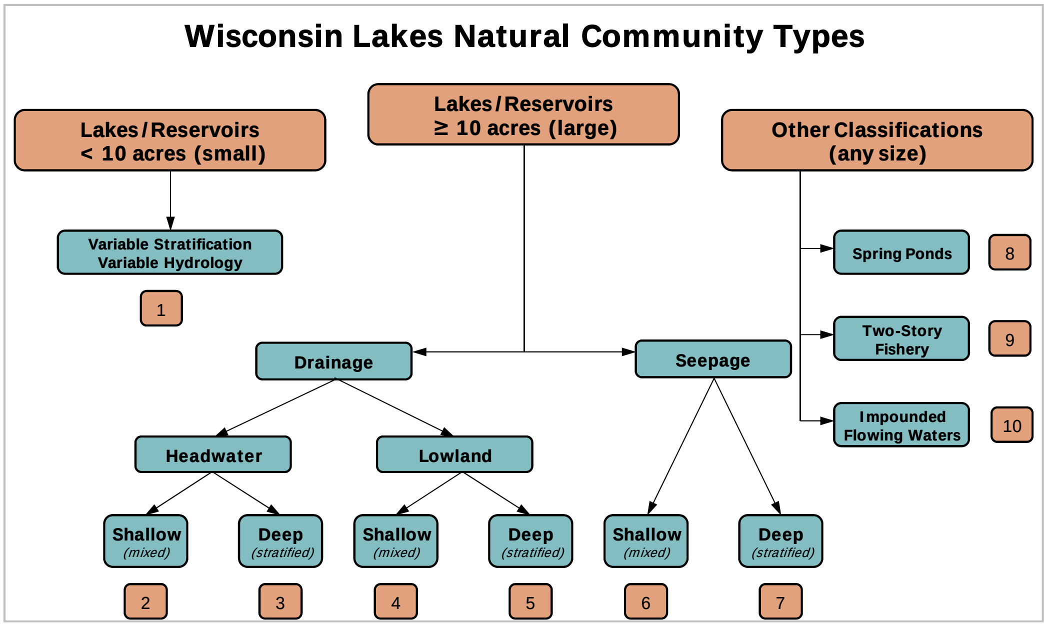


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

Garrison, et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the 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. Half Moon Lake is within the Northern Lakes and Forests ecoregion.

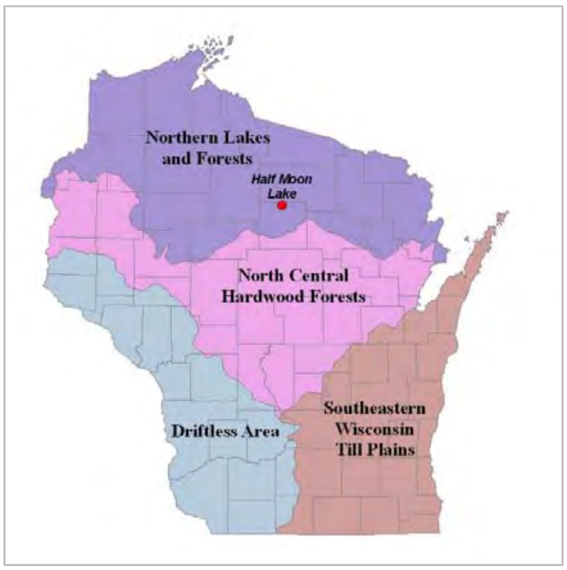


Figure 3.1-2. Location of Half Moon Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2014 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

These data along with data corresponding to statewide natural lake averages, historic, current, and average data from Half Moon Lake 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.

Half Moon Lake Water Quality Analysis

TSI Parameters

As part of this study, Half Moon Lake stakeholders were asked how they perceived the water quality of the lake. About 50% of respondents indicated they believe the water quality is “Good”, while 14% responded “Very Poor” to “Poor”, 22% responded “Fair” and 14% responded “Excellent” (Appendix B, Question #14). When asked if water quality conditions had changed since they first visited the lake, responses were quite mixed with 36% indicating they lake had “Severely” or “Somewhat” degraded, 25% responding the lake had “Somewhat” improved, 33% stating the lake had remained the same and 6% of respondents indicating they were “Unsure” (Question #15).

As described previously, three water quality parameters are of most interest include total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Total phosphorus data from Half Moon Lake are contained in Figure 3.1-3. These figures contain data collected by Half Moon Lake volunteers, professionals involved with a 1995 lake management planning project, WDNR staff and Onterra staff (2014-2015). A weighted average across the years of data indicates that summer concentrations are comparable to the median concentration for similar shallow, headwater drainage lakes across the state of Wisconsin, and less than the median value for lakes within the Northern Lakes and Forests ecoregion (Figure 3.1-3). Overall, phosphorus levels in Half Moon Lake can be described as ranking in the WQI category of *Excellent* to *Good* for this parameter.

Total phosphorus surface and bottom lake concentrations are compared in Figure 3.1-4. Phosphorus release from lake sediments may play a great role in the nutrient budgets of some Wisconsin lakes, particularly when these nutrients are released to the upper water column, where warmer temperatures allow for greater algae growth. As indicated in Figure 3.1-4, phosphorus concentrations in the bottom waters of the lake were similar to those in the upper water column, with the exception of during a late May sample. This occurrence is quite normal in Wisconsin lakes; as explained prior, concerns arising from sediment phosphorus release generally are not seen until hypolimnetic phosphorus values reach 200 μg/L.

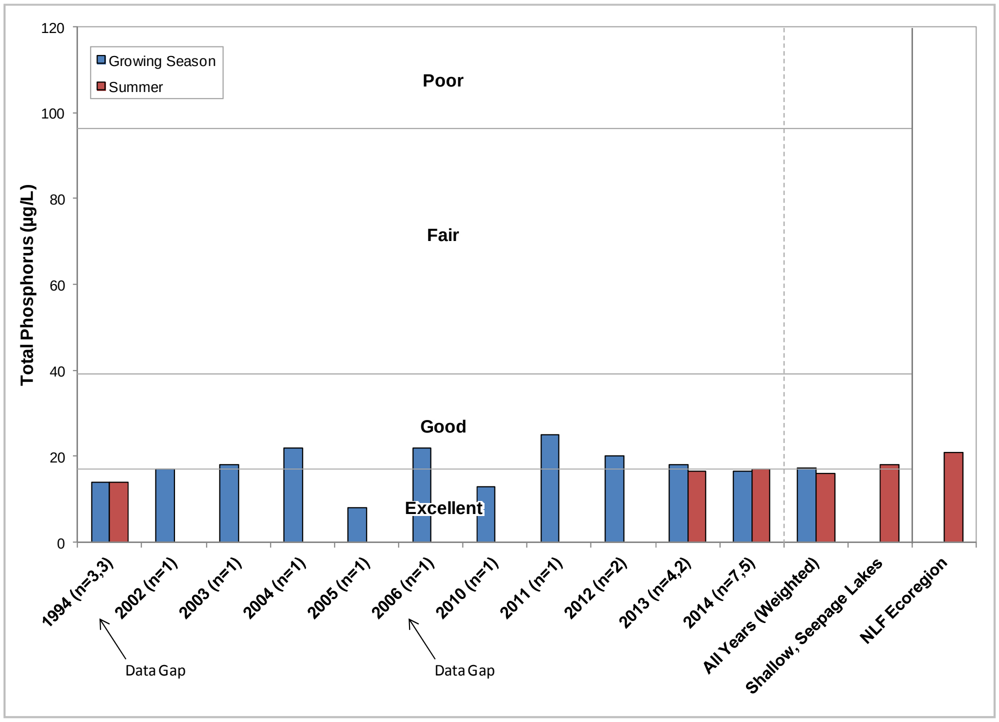


Figure 3.1-3. Half Moon Lake, state-wide class 6 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

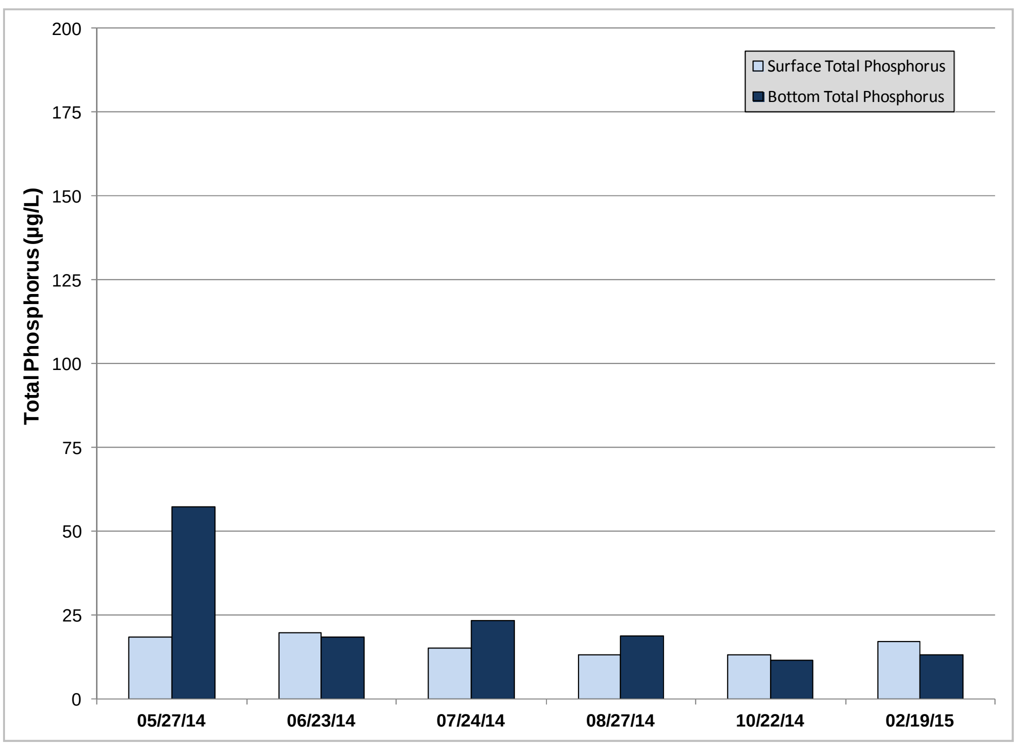


Figure 3.1-4. Half Moon Lake surface and bottom phosphorus concentrations, 2014-2015. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a* data has been collected only a handful of times from Half Moon Lake (Figure 3.1-4). A weighted summer mean across these years (5.2 µg/L)suggests that the concentration of algae in Half Moon Lake is similar to the median value for similar lakes across the state (4.7 µg/L) as well as lakes within the Northern Lakes and Forests ecoregion (5.6 µg/L). These values fall into a category of *Good* to *Excellent* for the lake type (shallow, seepage lakes).

It is important to state that while chlorophyll-*a* data is correctly used to describe the general algal conditions in a lake, these samples are collected periodically throughout the growing season. Thus, the potential exists for the sampling design to miss periodic events where algae are elevated in the lake. Known as algae blooms, these events are triggered by a multitude of factors that create optimal conditions for algae growth and may last only a few days. These occurrences may or may not be observed through data collection; they are highly dependent on the timing of sample collection. As outlined further below in the text describing the Secchi disk clarity data, this is believed to be the case with the single 2012 value represented on Figure 3.1-4.

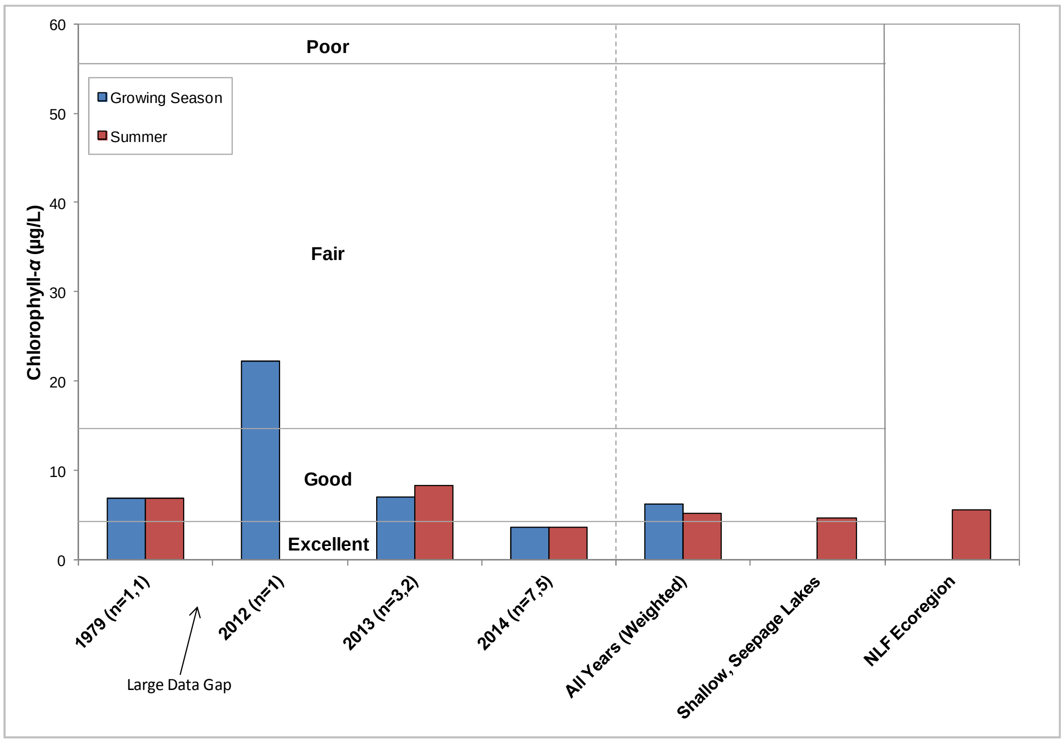


Figure 3.1-5. Half Moon Lake, state-wide class 6 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Freshwater algae are incredibly diverse, with some groupings being found floating within the water column, some fixed to plants or the lake sediment, others being found in long filamentous strands. During 2012, algae samples were collected by Half Moon Lake volunteers and send to Jim Kreitlow (WDNR). Mr. Kreitlow identified 27 species of algae, the most abundant being *Staurastrum paradoxum* (green algae), *Dinobyron sertularia* (golden brown algae), *Synura uvella* (golden brown algae) and *Kirchneriella sp* (green algae). These species are not of the blue-green variety, which is a grouping of freshwater algae that may bloom and produce the toxins that has gained exposure in Wisconsin lakes within recent years. It is believed the

Staurastrum was causing the green water that was observed during the time the volunteer sample was collected.

Considerably more historical data exists for the third primary water quality parameter – Secchi disk clarity. For a number of years, these data were collected by a volunteer on the lake through the Citizen Lake Monitoring Network, a state-sponsored, volunteer-based monitoring program. In general, these data show that the water clarity in Half Moon Lake can be described as *Excellent* in most years (Figure 3.1-5). The data are comparable to the median value for other shallow, seepage lakes in the state as well as what is typically seen in the northern lakes and forests ecoregion.

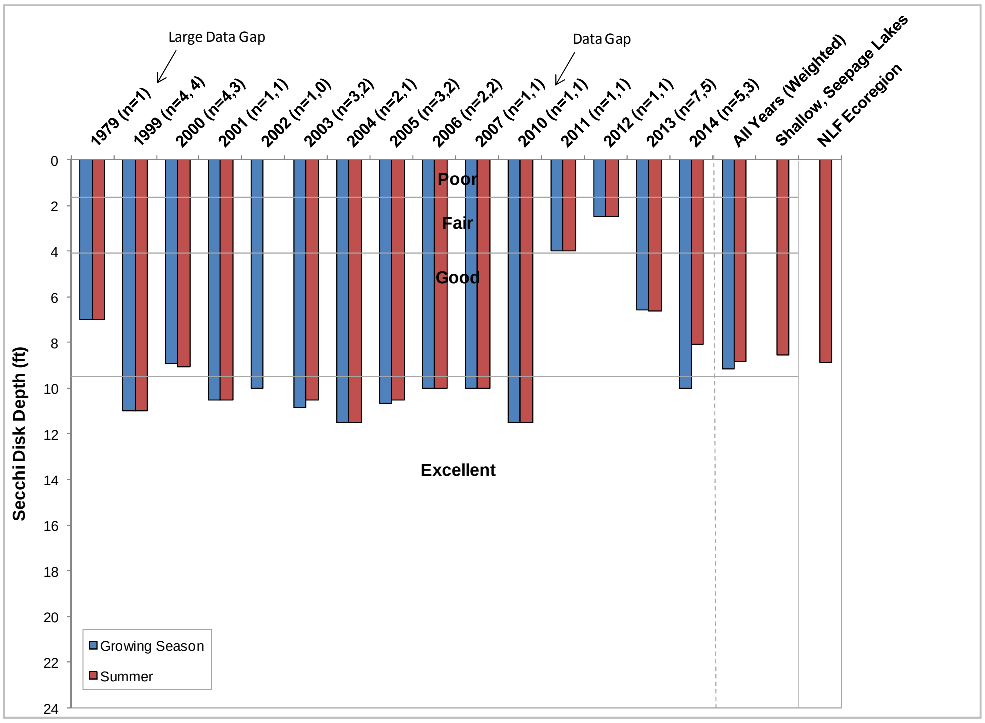


Figure 3.1-6. Half Moon Lake, state-wide class 6 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Figure 3.1-5 includes two years of data in which the Secchi disk clarity appears to be quite low (2011 – 4.0 ft and 2012 – 2.5 ft). These data include only a single clarity reading; the 2011 data was collected on 8/16/11 by Citizens Lake Monitoring Network volunteers while the 2012 data was collected on 8/27/12 by AIS Coordinator John Preuss. On 11/2/11, another Secchi disk clarity reading was collected by volunteers through the Citizens Lake Monitoring Network. This clarity reading was recorded at 8.0 ft – more in line with what the typical clarity appears to be in Half Moon Lake. Note that the November data is not included within Figure 3.1-5 because it falls outside of the summer season (June 1 – August 31) as well as the growing season (April 1 – October 31). While no phosphorus or chlorophyll-*a* data exists for these sampling days, these parameters were collected days later in 2012, on 9/5/12 by Citizens Lake Monitoring Network volunteers. On 9/5/12, total phosphorus concentrations were relatively high (25 µg/L) within the lake while chlorophyll-a values were also relatively high, at 22.3 µg/L. No Secchi disk clarity data was found for that date.

It is suspected that the 2011 and 2012 clarity data may have been collected during a late summer algae bloom, in which the clarity was reduced for a small period of time. This is evidenced by the elevated chlorophyll-*a* and total phosphorus concentrations found days later in 2012, as well as the deviation of these data from a dataset that commonly averages 10 ft of Secchi depth during the summer months.

While one of the primary factors determining the clarity of a lake is algal abundance, the clarity of the water in lakes is also influenced partly by dissolved organic acids that are transported to the lake from the area's wetlands. These weak, natural acids (sometimes called "tannins") are the byproduct of decomposition of organic matter, particularly debris from pine trees. This is often the cause of water in lakes that display a "root beer" or "tea" color. "True color" measures the dissolved organic materials in water. Water samples collected in 2014 were measured for this parameter, and were found to be at 15 Platinum-cobalt units (Pt-co units, or PCU) in May and 30 Pt-co in July. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color. In other words, the higher a PCU value is, the more a lake's water clarity may be impacted. Because of the relatively low color value, it is likely algae concentration that regulates the clarity in Half Moon Lake as opposed to dissolved organics.

Limiting Plant Nutrient of Half Moon Lake

Using midsummer (July) nitrogen and phosphorus concentrations from Half Moon Lake, a nitrogen:phosphorus ratio of 35:1 was calculated. This finding indicates that Half Moon Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Half Moon Lake Trophic State

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

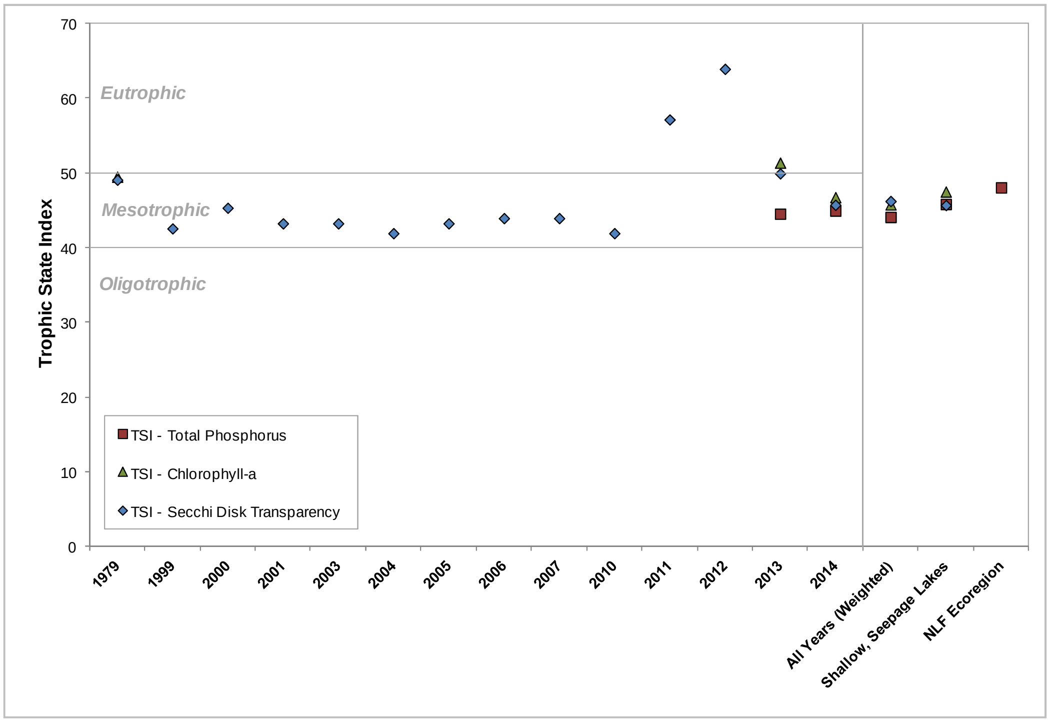


Figure 3.1-7. Half Moon Lake, state-wide class 6 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Half Moon Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Half Moon Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-8. Most Wisconsin lakes mix during the spring and fall, when changing water temperatures and winds break down any thermal differences that existed between the upper layers of water (epilimnion) and the bottom layers of water (hypolimnion). During the summer, the epilimnion will warm while the bottom of the lake may not. During this time a temperature gradient may form, as observed in the July and August profile. Summer winds may mix the water column at some point and disperse these thermal gradients. The oxygen reduction that takes place in the summer is due to bacteria breaking down organic matter that is found at the bottom of the lake.

During the winter, thermal stratification will occur except in the opposite manner as it does in the summer. Water is most dense at 4°C, so water of this temperature may be found at the bottom of the lake while the coldest water is found at the surface, in the solidified form we know as ice. Dissolved oxygen may decrease during this time as bacteria decompose organic material near the bottom of the lake. The ice cover reduces reintroduction of oxygen from the atmosphere. In February of 2015, dissolved oxygen was found to be quite low – low enough to stress or cause mortality in most Wisconsin game fish species.

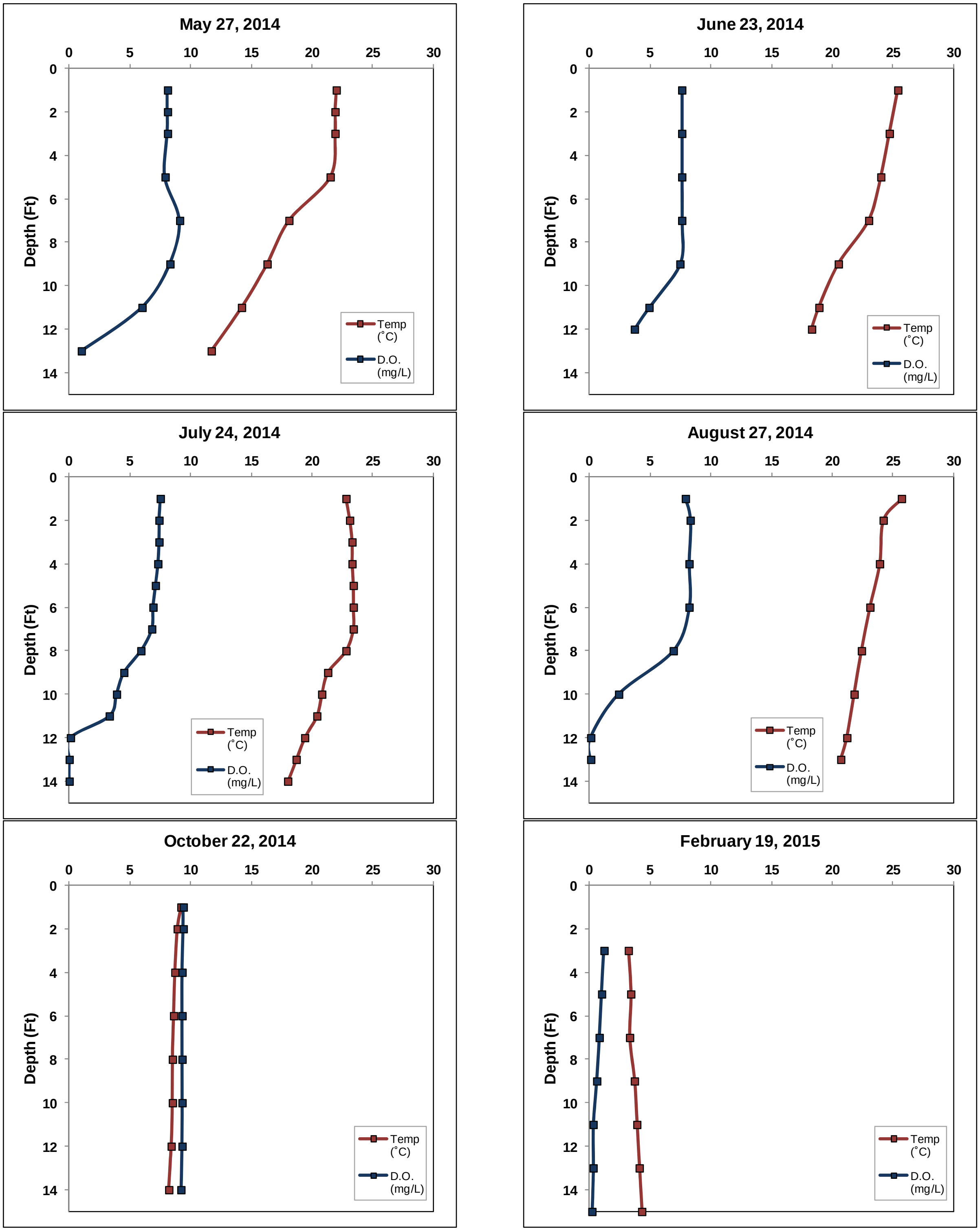


Figure 3.1-8. Half Moon Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Half Moon Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in Half Moon Lake was measured at 6.3 in May of 2014 and 6.4 in July of 2014. These values are below neutral, indicating slightly acidic water.

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 Half Moon Lake was measured at 4.91 (mg/L as $CaCO_3$) in May 2014 and 4.14 (mg/L as $CaCO_3$) in July 2014, indicating that the lake does not have substantial capacity to resist fluctuations in pH and is 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 Half Moon Lake's pH of 6.3-6.4 falls outside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Half Moon Lake was found to be 1.47 mg/L, falling outside the range for zebra mussel suitability.

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 water bodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Half Moon Lake was not considered suitable for mussel establishment.

Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. No zebra mussel veligers (larval form of zebra mussels) were found within these samples.

Half Moon Lake 2014 Sediment Core Study

As a part of this project, a sediment cores were collected from Half Moon Lake's deep hole on June 24, 2014. As organisms grow and die, their body structures sink to the bottom of lakes and become entrapped within the sediment. These sediment layers build upon each other year after year within a lake. Thus, the sediment in a lake holds clues on the chemical composition and biological community that persisted in the lake years ago.

Photograph 3.1-1. Sediment core from Half Moon Lake. Pictured are a WDNR staff member and HMLPRD volunteer.

As a part of this project, a sediment cores were collected from Half Moon Lake's deep hole on June 24, 2014. Onterra staff were assisted by a HMLPRD volunteer and WDNR Bureau of Science Services researcher Paul Garrison in collection of this sediment core (Photograph 3.1-1). Mr. Garrison oversaw the examination of the sediment core contents and produced a report, which can be found in Appendix C. A synopsis of Mr. Garrison's report is found below.

Mr. Garrison's report examined diatoms, a species of algae that have silica-rich cell walls, from sediments that were deposited in the lake over 100 years ago as well as the top sediments, which are indicative of current conditions. Researchers know what environmental conditions these species prefer, so they can extrapolate the conditions that were present when that specific algae community was present. Mr. Garrison's conclusions on the Half Moon Lake study are included below:

- The diatom communities found in the top and bottom of the sediment core are indicative of low pH, low nutrient conditions. This indicates the lake naturally has a low pH.
- Slight differences were observed in the species that were present historically versus currently. These differences suggest that:
    - Water clarity at present time is slightly less than historical time
    - pH, phosphorus and dissolved organic carbon are slightly higher than historic levels
    - Submerged aquatic vegetation likely has not changed in abundance since historic levels

Historic Sediment Studies

In 1992, a sediment study was conducted by Northern Lake Service, Inc. The study consisted of recording water depth and soft sediment depth at 111 grid-pattern sampling locations on Half Moon Lake. Soft sediments would have accumulated within the lake basin following the glaciations of upper Wisconsin, which scientists estimate occurred 30,000 to 9,500 years before present. Sediment accumulation in lakes is controlled by a number of factors, including lake area, depth, shoreline length, climate conditions, land use in the watershed, watershed size and others. Additionally, the rate of sedimentation is influenced heavily by the composition of plants and animals that are present within the lake. In plant dominated lakes, partially decomposed plant fragments may dominate the substrate type, while in lakes dominated by phytoplankton (algae) a fine detritus substrate will dominate.

The 1992 study found soft sediment ranging from 0 ft to over 23 ft, though the vast amount of the lake has soft sediment less than 10-15 ft in thickness. Considering the age of this lake, the sediment that has accumulated is not a tremendous amount – some lakes in the area have accumulated over 40 ft of soft sediment in this same approximate time frame. Considering Half Moon Lake is a seepage lake, the rate of sediment accumulation would be minimal from external sources; this rate would be higher in a lake that has a tributary input, which would load to the lake sediment, nutrients and other organic materials. That being said, it is widely recognized amongst lake managers that annual sediment deposition rates have increased in the past 50-70 years, as development has increased along lake shorelines.

Besides accumulating material that has originated from Half Moon Lake's shorelines, the accumulation of material within the lake likely has originated from within the lake itself. This would include the mortality and subsequent decomposition of plants, fish and algae. Half Moon Lake is considered mesotrophic (moderate productivity), so it is expected that the sediment accumulation rate would be minimal to moderate when compared to nearby eutrophic lakes. As later discussed in the Aquatic Plant Section, most of the lake's bottom holds aquatic plants, however the species that are present are ones that hold relatively little biomass and are short-statured.

In conclusion, the water chemistry and ecological setting of Half Moon Lake are characteristic of that of a mesotrophic, or moderately productive ecosystem. It is expected that sediment accumulation in the lake is minimal to moderate and that accelerations of this rate would be largely brought about by shoreland development.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Half Moon Lake Watershed

Half Moon Lake's watershed consists of 341 acres, an area that is roughly twice the lake's size (watershed to lake area ratio of 2:1). Half Moon Lake is a seepage lake; seepage lakes typically do not have a tributary inlet but nor an outlet stream. They are primarily fed through precipitation and groundwater, and water leaves the lake through evaporation as well as groundwater flow. Thus, these lakes often show the stress of seasonal or longer term droughts first, indicated through highly fluctuating water levels. The watershed, often called the "catchment" or "drainage basin", is quite small so this means there is less land to feed surface water runoff to the lake. This makes the lake heavily dependent upon its two primary water sources (precipitation and groundwater). With the amount of land draining towards the lake, WiLMS calculated that Half Moon Lake is able to completely exchange its volume of water 0.47 times per year (lake flushing rate).

The land within Half Moon Lake's watershed is mostly undeveloped, with 45% of it consisting of forest, 33% as the lake's surface, 10% as wetlands, 6% as pasture or grass land and the final 6% being rural residential (Figure 3.1-2, Map 2).

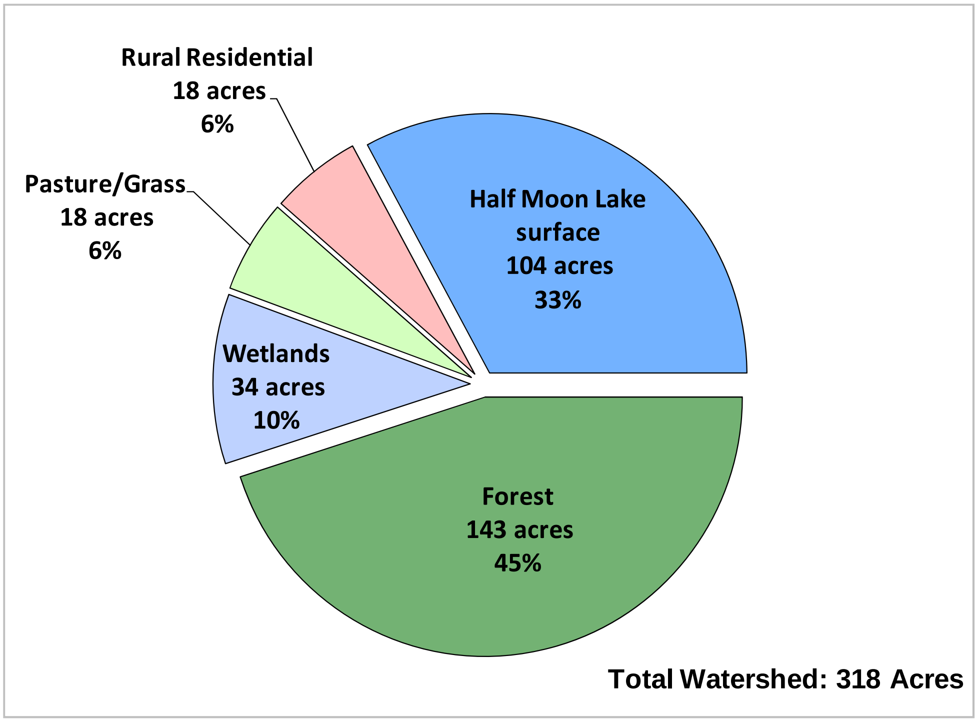


Figure 3.2-1. Half Moon Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Modeling of the Half Moon Lake watershed was conducted using the lake response model WiLMS (Appendix D). The model predicted external phosphorus sources from the watershed to total roughly 55 lbs annually. The lake's surface collects the largest portion of the annual load, with atmospheric deposition accounting for 29 lbs (52%) of the total (Figure 3.2-2). Forested land, comprising 45% of the watershed, accounts for 20% of the annual phosphorus load. Pasture and grass land account for 8%, and rural residential land as well as wetlands contribute 4% each. Data collected on housing use by HMLPRD property owners (stakeholder survey, Appendix B, Question #1) was utilized to estimate septic system use and potential phosphorus contribution to the lake. The 7 lbs depicted in Figure 3.2-2 is based upon a rough estimate of property use, and assumes all septic systems are functioning normally. The model also assumes generally consistent soil properties around the lake and cannot account for spatial location of residences (proximity to lake) nor the flow of groundwater, which likely flows to the lake in some areas and away from the lake in others.

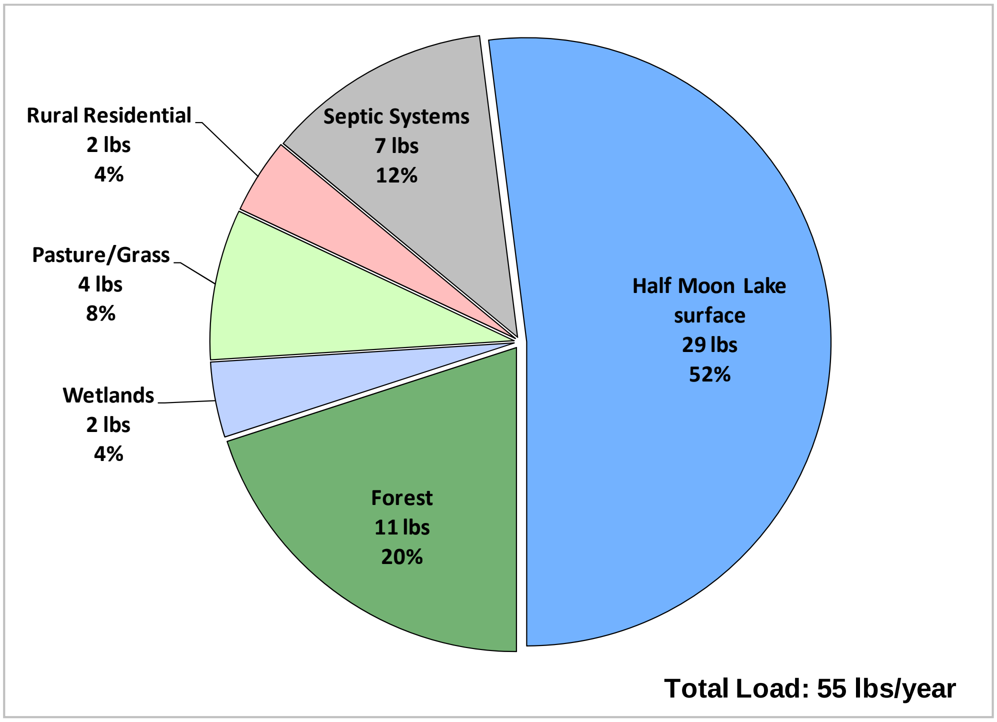
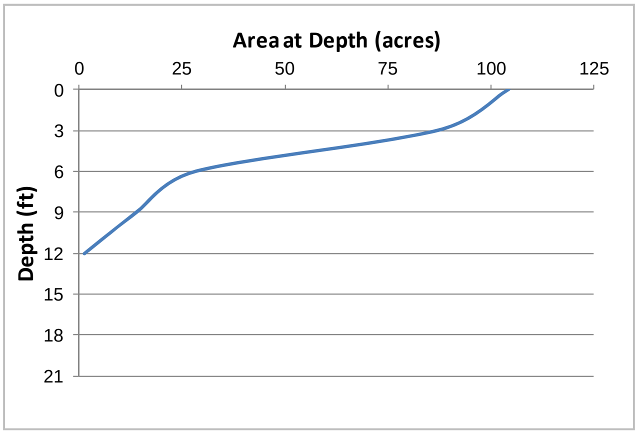


Figure 3.2-2. Half Moon Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

WiLMS Calibration and Summary

During modeling procedures, WiLMS compares observed (measured in the field) and predicted (model-calculated) growing season mean and spring overturn phosphorus concentrations to determine the accuracy of the model. The growing season mean phosphorus concentration is defined as the mean of all surface water data collected from March 31-November 1. The spring overturn phosphorus concentration is defined as the concentration of phosphorus that is collected while the lake is completely mixed. This value is typically a good representation of the phosphorus content of the lake, because during this time the water is thoroughly mixed which means phosphorus is fairly similar within the entire water column.

Utilizing land cover types proportions and hydrologic data, WiLMS was able to predict what the phosphorus content of Half Moon Lake should be and then compare these values to observed values obtained through water quality sampling. WiLMS examines several lake response models during this process. Some, such as the commonly used Canfield-Bachman (1981) model estimated that the growing season mean value should be most likely higher than the in-lake observed values (29 ug/L estimated vs 17.8 ug/L observed). These results indicate the phosphorus loading to the lake is not as much as what would be expected. This is perhaps part of the case due to Half Moon Lake's hydrology; it would be expected that a seepage lake would have less runoff than a drainage lake, which has a tributary input. Another reason for the discrepancy could be Half Moon Lake's morphometry. As the charts in Figure 3.2-3 indicate, Half Moon Lake is a largely shallow system, with 96% of the lake being nine feet or shallower.



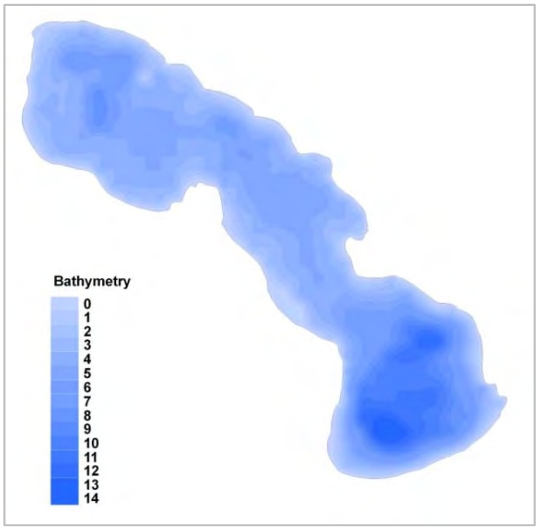


Figure 3.2-3. Half Moon Lake hypsographic curve and bathymetry

Half Moon Lake was modeled using Vollenweider's 1982 lake response model, which is a model developed for shallow lakes. The modeled result (22 ug/L) is comparable to the annual average phosphorus concentration (19.4 ug/L), though still slightly higher. In summary, through these modeling efforts it is believed that Half Moon Lake receives a minimal and potentially less than expected phosphorus load from its watershed.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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

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, a revised 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. The revised NR 115 was once again examined in 2012 after some Wisconsin counties identified some provisions that were unclear or challenging to implement. The revisions proposed through Board Order WT-06-12 went into effect in December of 2013. These policy regulations require each county a 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:

- 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. No permit is required for removal of vegetation that meets any of the above criteria. 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 entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- 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.

- For county-specific requirements on this topic, it is recommended that lake property owners contact the county's regulations/zoning department.

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

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

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

National Lakes Assessment

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

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

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

Native Species Enhancement

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

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

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

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

Cost

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

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

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

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

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

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

Half Moon Lake Shoreland Zone Condition

Shoreland Development

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

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

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

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

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

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

Figure 3.3-1. Shoreland assessment category descriptions.

On Half Moon Lake, the development stage of the entire shoreland was surveyed during late summer of 2014, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Half Moon Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.1 miles of natural/undeveloped and developed-natural shoreland (46%) were observed during the survey (Figure 3.2-4). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.6 miles of urbanized and developed–unnatural shoreland (23%) were observed. If restoration of the Half Moon Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

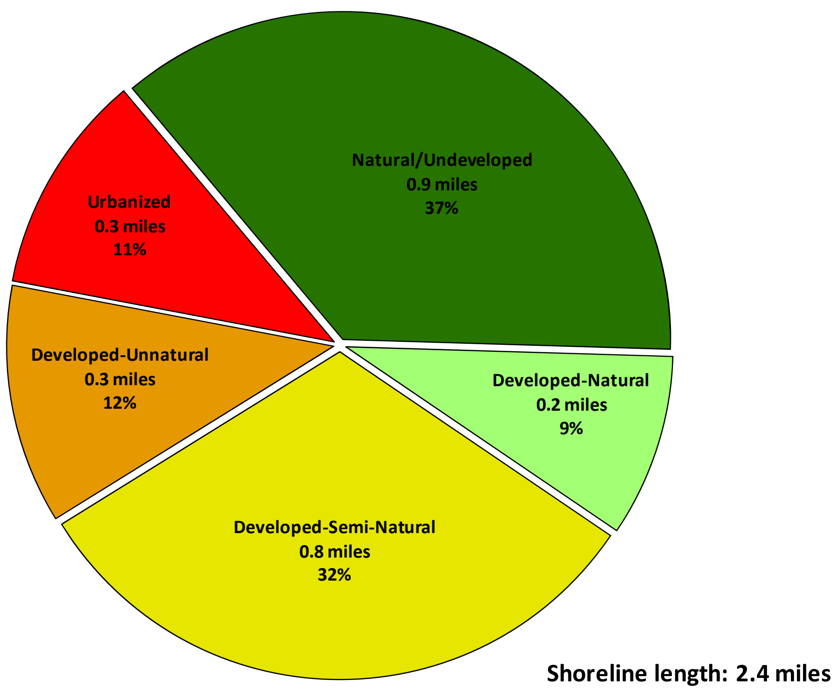


Figure 3.3-2. Half Moon Lake shoreland categories and total lengths. Based upon a late summer 2014 survey. Locations of these categorized shorelands can be found on Map 3.

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

Coarse Woody Habitat

Half Moon Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 31 total pieces of coarse woody habitat were observed along 2.4 miles of shoreline, which gives Half Moon Lake a coarse woody habitat to shoreline mile ratio of 13:1. Locations of coarse woody habitat are displayed on Map 4. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

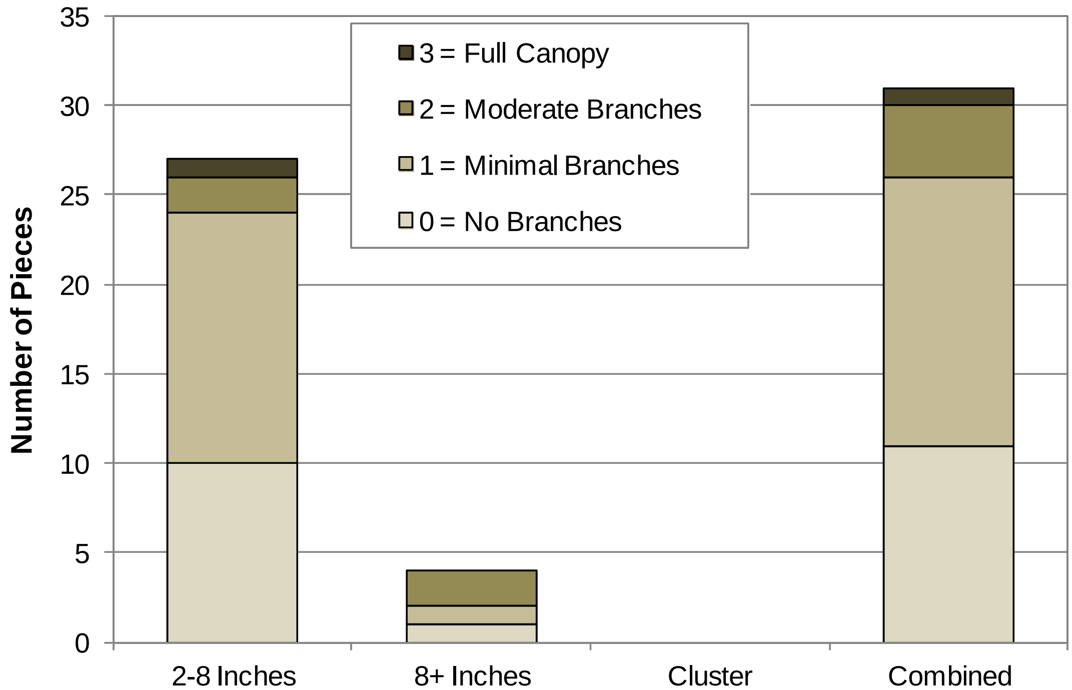


Figure 3.3-3. Half Moon Lake coarse woody habitat survey results. Based upon a late summer 2014 survey. Locations of Half Moon Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

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

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

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

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

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

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

Cost

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

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

Herbicide Treatment

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

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

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

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

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

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

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

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

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

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

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

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

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

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

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

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

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

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

Species Diversity and Richness

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2014, WDNR Science Services and Onterra ecologists conducted point-intercept surveys on 392 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 and Onterra dataset will be compared to Half Moon Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-1) and in the state.

A 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.

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

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Half Moon Lake will be compared to lakes in the Northern Lakes and Forests Ecoregion and Wisconsin.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species or those encountered during other aquatic plan surveys.

Community Mapping

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

Exotic Plants

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

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

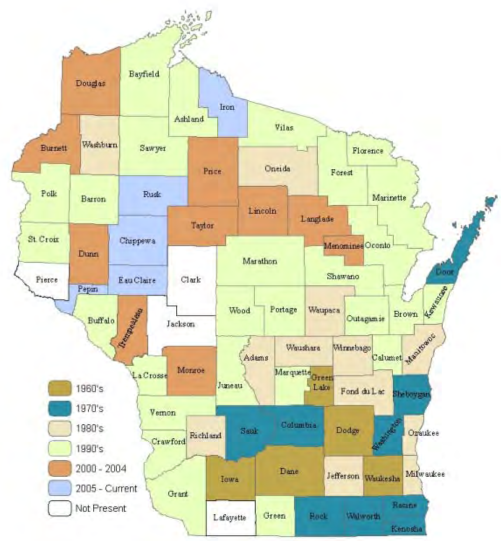


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

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.

As mentioned previously, numerous plant surveys were completed as a part of this project. On June 12, 2014, an Early-Season AIS (ESAIS) Survey was completed on Half Moon Lake that focused upon locating any potential occurrences of the non-native curly-leaf pondweed. During this meander-based survey of the *littoral zone*, no occurrences of this invasive plant were located. It is believed that curly-leaf pondweed is currently not present in Half Moon Lake or it exists at an undetectable level. The whole-lake aquatic plant point-intercept and community mapping surveys were conducted on Half Moon Lake on July 21, 2014 by Onterra (Appendix E). During these surveys, a total of 34 aquatic plant species were located, all of which are considered to be native, or indigenous species; no non-native aquatic plants were located (Table 3.4-1).

Information regarding Half Moon Lake's substrate type was collected during the 2014 whole-lake point-intercept survey with a pole-mounted rake. These data show the majority (79%) of sampling locations contained soft sediments, 21% contained sand, and 0% were found to contain rock (Figure 3.4-2). Most of the areas containing sand were located in shallower, near-shore areas while softer sediments are present in deeper areas of the lake (Figure 3.4-2). Like terrestrial plants, aquatic plants vary in their preference for a particular substrate type; some species are usually only found growing in soft sediments, others only course substrates like sand, while some are more generalists and can be found growing in either. Lakes with varying types of substrates generally support a higher number of aquatic plant species because of the different habitat types that are available.

During the 2014 point-intercept survey, aquatic plants were found growing out to a maximum depth of 11 feet, indicating the majority of Half Moon Lake is comprised of littoral area. Of the 294 point-intercept sampling locations that fell within the littoral zone in 2014, 82% contained aquatic vegetation indicating Half Moon Lake's littoral zone is highly vegetated. Aquatic plant total rake fullness data collected in 2014 indicates that 57% of the point-intercept sampling locations contained rake fullness ratings of 1, 18% had a total rake fullness rating of 2, and 7% had a total rake fullness of 3 (Figure 3.4-2). The total rake fullness data indicates that the density or biomass of aquatic plants in Half Moon Lake is relatively low.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 3.4-1). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000). In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 3.4-1). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum sibiricum*) are classified as elodeids.

Table 3.4-1. Aquatic plant species located on Half Moon Lake during 2014 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2014 (Onterra)
Emergent	*Calamagrostis canadensis*	Blue-joint grass	5	I
	Carex comosa	Bristly sedge	5	I
	Carex utriculata	Common yellow lake sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Glyceria canadensis	Rattlesnake grass	7	I
	Iris versicolor	Northern blue flag	5	I
	Juncus alpinoarticulatus	Northern green rush	6	I
	Juncus effusus	Soft rush	4	I
	Myrica gale	Sweet gale	9	I
	Pontederia cordata	Pickerelweed	9	X
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Scirpus cyperinus	Wool grass	4	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	X
Submergent	*Chara* spp.	Muskgrasses	7	X
	Elatine minima	Waterwort	9	X
	Eriocaulon aquaticum	Pipewort	9	X
	Isoetes spp.	Quillwort species	8	X
	Lobelia dortmanna	Water lobelia	10	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	*Potamogeton bicupulatus**	Snail-seed pondweed	9	I
	Utricularia geminiscapa	Twin-stemmed bladderwort	9	X
	Utricularia gibba	Creeping bladderwort	9	X
	*Utricularia resupinata**	Small purple bladderwort	9	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Galium tinctorium	Stiff bedstraw	5	I
	Juncus pelocarpus	Brown-fruited rush	8	X
	Sagittaria cristata	Crested arrowhead	9	X
	Schoenoplectus subterminalis	Water bulrush	9	X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as 'special concern' in Wisconsin by WDNR Natural Heritage Inventory*

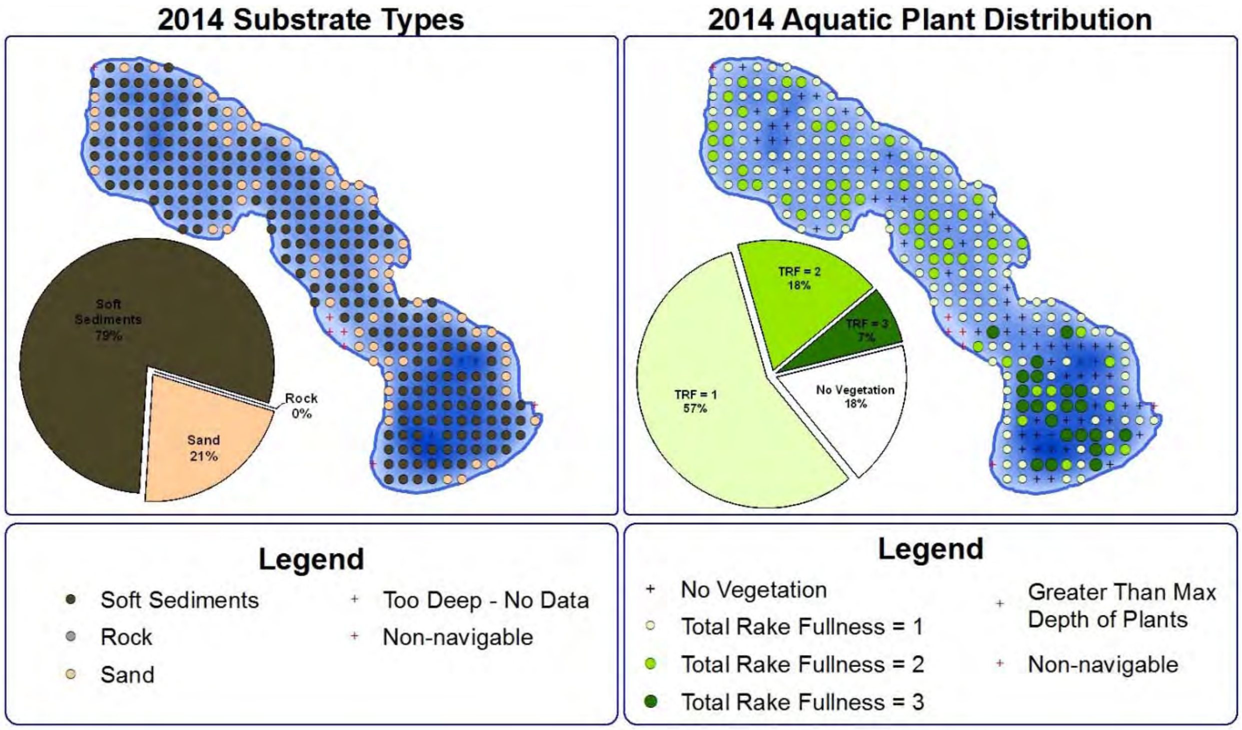


Figure 3.4-2. Half Moon Lake 2014 substrate types (left), aquatic vegetation distribution, and total rake fullness (right). Created using data from Onterra 2014 whole-lake point-intercept survey.

Photo 3.4-1. Variable aquatic plant life forms. Photos display lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left), fern pondweed (*Potamogeton robbinsii*) and variable pondweed (*Potamogeton gramineus*) of the elodeid growth form (right).

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate. Aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids.

As discussed in the Water Quality Section, Half Moon Lake was found to have low alkalinity in 2014 with values of around 4.0-5.0 mg/L as $CaCO_3$. Consequently, isoetids dominate the submersed aquatic plant community in Half Moon Lake. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

While most of the submersed aquatic plants in Half Moon Lake are isoetids, there are some elodeids present that have adaptations to grow in a carbon-limited environment. Two elodeid species in Half Moon Lake, snail-seed pondweed and slender pondweed, have very thin and long leaves to maximize leaf surface area and thus the amount of area to uptake what little dissolved carbon dioxide exists within the water. Other plants in Half Moon Lake, like the three species of bladderworts, are carnivorous and supplement their nutrients by trapping and digesting zooplankton. The emergent and floating-leaf aquatic plants have leaves above the water's surface and can obtain carbon dioxide directly from the atmosphere.

Two aquatic plant species in Half Moon Lake, small purple bladderwort (isoetid) and snail-seed pondweed (elodeid) (Photo 3.4-2) are listed as species of special concern by the WDNR Natural Heritage Inventory due to their rarity in Wisconsin and vulnerability to habitat degradation (WDNR 2014). Small purple bladderwort was the most frequently encountered aquatic plant species within the lake in 2014 with a littoral frequency of occurrence of 31% (Figure 3.4-3) and was most abundant between 1-4 feet of water. Snail-seed pondweed was encountered less frequently with a littoral occurrence of 5% and was located in 3-6 feet of water within the northern portion of the lake. The presence of these species in Half Moon Lake is an indicator of a high quality aquatic ecosystem.

Photo 3.4-2. Half Moon aquatic plant species of special concern. Photos display the flower of small purple bladderwort (left) and floating-leaves of snail-seed pondweed (right).

As mentioned, of the 34 aquatic plant species located in Half Moon Lake in 2014, small purple bladderwort was the most frequently encountered (Figure 3.4-3). The second-most frequently encountered aquatic plant species in Half Moon Lake in 2014 was quillwort spp. with a littoral frequency of occurrence of 22%. Quillworts are spore-bearing isoetids that are related to clubmosses. Two species of quillworts are present in Wisconsin and observation of their spores under a microscope is necessary to differentiate between the two. The specimen that was collected from Half Moon Lake was identified as spiny-spored quillwort (*Isoetes echinospora*); however, because all of the plants encountered in Half Moon Lake could not be examined with a microscope, both species may be present. Quillworts are common in lakes with low alkalinity in northern Wisconsin and stabilize bottom sediments with the long roots and provide structural habitat for aquatic organisms.

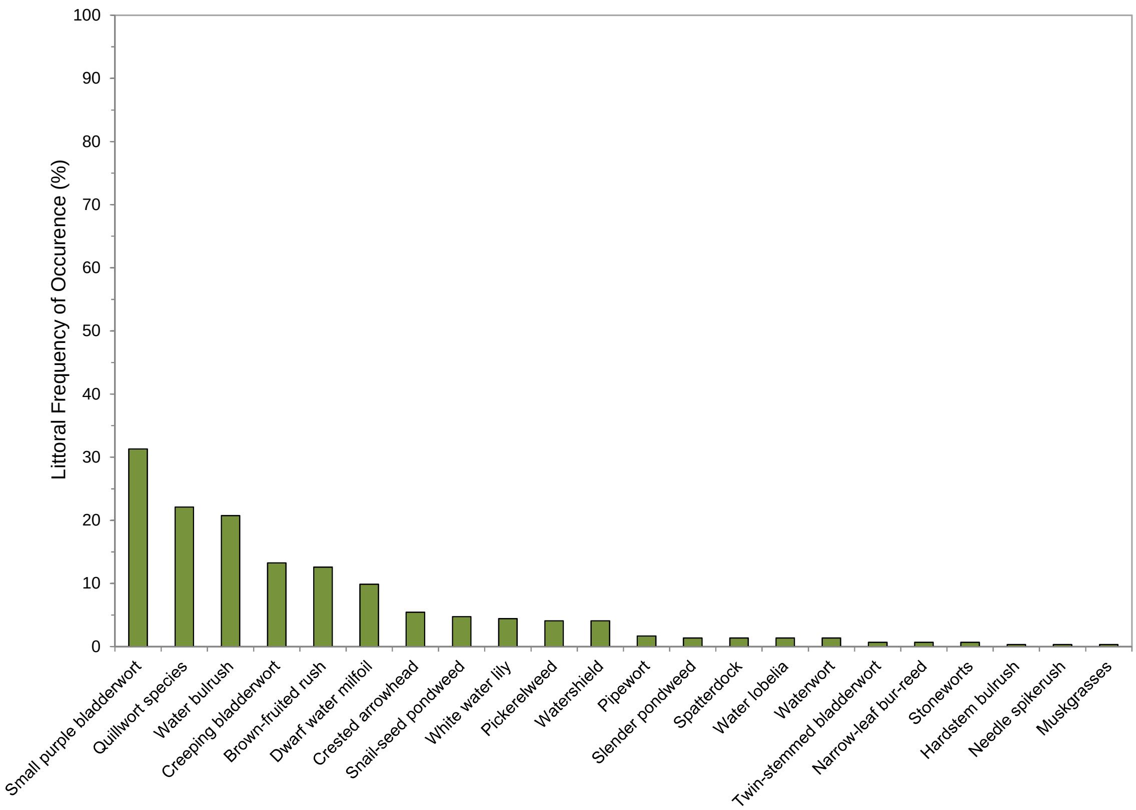


Figure 3.4-3. Half Moon Lake 2014 littoral frequency of occurrence of aquatic plant species. Created using data from 2014 whole-lake point-intercept survey.

Water bulrush was the third-most frequently encountered aquatic plant in Half Moon Lake in 2014 with a littoral frequency of occurrence of 21% (Figure 3.4-3). Water bulrush is the only bulrush species in Wisconsin that can be found growing completely underwater. Like snail-seed and slender pondweed, water bulrush has long, narrow leaves to maximize uptake of dissolved carbon dioxide. Water bulrush requires good water quality and its long leaves provide structural habitat for aquatic wildlife. In Half Moon Lake, water bulrush was most abundant between 4-8 feet of water.

The fourth-most frequently encountered aquatic plant in Half Moon Lake in 2014 was creeping bladderwort with a littoral frequency of occurrence of 13% (Figure 3.4-3). Like small purple bladderwort, creeping bladderwort is a carnivorous plant which traps small zooplankton for nutrients. However, unlike small purple bladderwort, creeping bladderwort is not rooted in the sediment and grows free-floating at the surface or below the surface along the bottom or entangled amongst other plants. In Half Moon Lake, creeping bladderwort was observed forming large and dense beds along the bottom in 8-11 feet of water.

As discussed in the primer section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The aquatic species encountered on the rake during the 2014 point-intercept survey and their conservatism values were used to calculate the FQI of Half Moon Lake's aquatic plant community (equation shown below).

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

Figure 3.4-4 compares the 2014 FQI components of Half Moon Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion and lakes throughout Wisconsin. The number of native plant species found in Half Moon Lake, or the species richness, falls slightly above the median values for lakes in the NLFL ecoregion and lake throughout Wisconsin. Half Moon Lake has a relatively low shoreline complexity value of 1.7, meaning that the lake has a lower ratio of shoreline perimeter relative to its area. Lakes with higher shoreline complexity generally have higher species richness given the presence of more backwater areas and other variances in habitat. However, despite its low shoreline complexity, Half Moon Lake still has high species richness. This higher species richness is likely largely driven by the lake's differences in substrate types and differences in light availability with depth which create different habitat types.

The average conservatism value for Half Moon Lake's aquatic plant community was 8.0 in both 2014, exceeding the 75th percentile for lakes within the NLFL ecoregion and lakes throughout the state (Figure 3.4-4). This high average conservatism value indicates that Half Moon Lake contains a high number of aquatic plant species that require a high-quality environment to persist and are sensitive to environmental degradation. Combining the native species richness and average conservatism values yields exceptionally high FQI values of 37.5 which exceeds the 75th percentile for lakes in the NLFL Ecoregion and lakes throughout the state. This analysis indicates that the aquatic plant community of Half Moon Lake is of higher quality than most of the lakes in the NLFL ecoregion and lakes throughout all of Wisconsin.

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 Half Moon Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

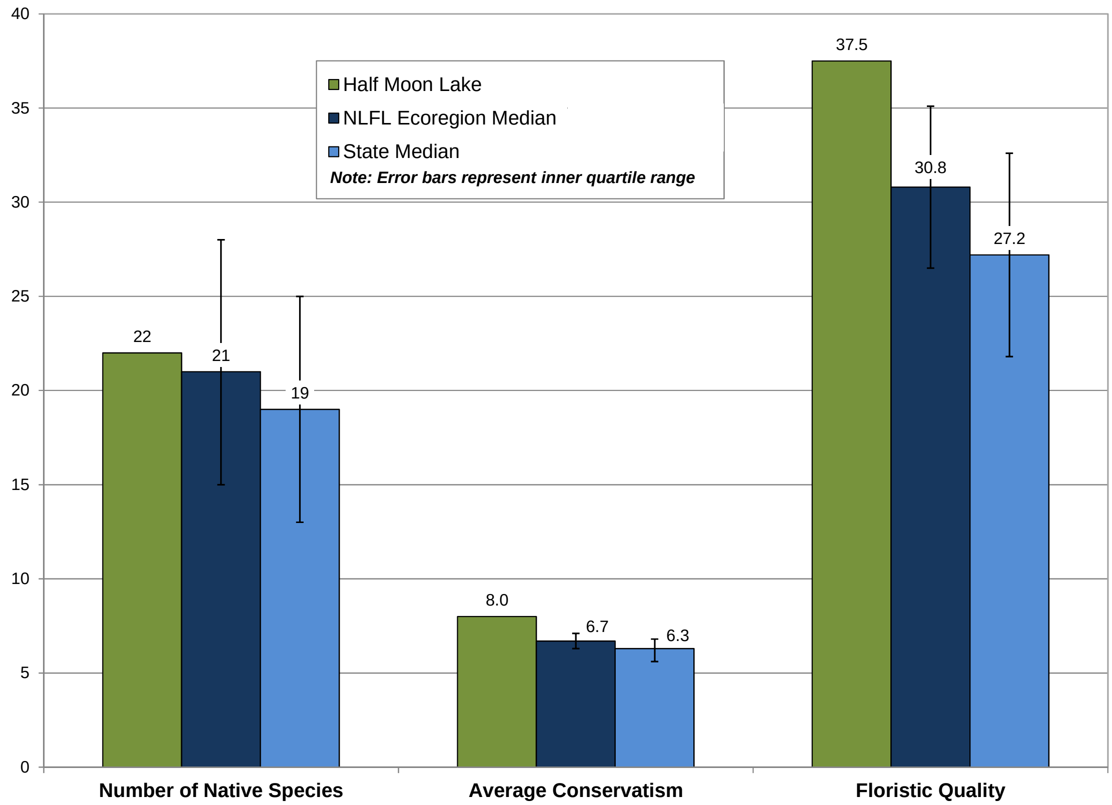


Figure 3.4-4. Half Moon Lake Floristic Quality Assessment. Created using data from the July 2014 whole-lake point-intercept survey. Analysis following Nichols (1999) where NLFL = Northern Lakes and Forest Lakes Ecoregion. Ecoregion and state data calculated using data from WDNR Science Services and Onterra.

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 Half Moon Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.4-5). Using the data collected from the 2014 point-intercept survey, Half Moon Lake's aquatic plant community was shown to have relatively high species diversity with a Simpson's diversity values of 0.88. This diversity value falls above the median values for lakes in the NLFL ecoregion and for lakes throughout Wisconsin. In other words, if aquatic plants were randomly sampled from two different locations in Half Moon Lake in 2014, there would be an 88% probability that they would be different species.

As explained earlier, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while small purple bladderwort was found at 31% of the littoral sampling locations in Half Moon Lake in 2014, its relative frequency of occurrence is 22%. Explained another way, if 100 plants were randomly sampled from Half Moon Lake, 22 of them would be small purple bladderwort. Figure 3.4-6 displays the relative occurrence of aquatic plant species from Half Moon Lake in 2014, and illustrates the plant community is not overlydominated by one or two species. This more even distribution of species within the community leads to higher species diversity value.

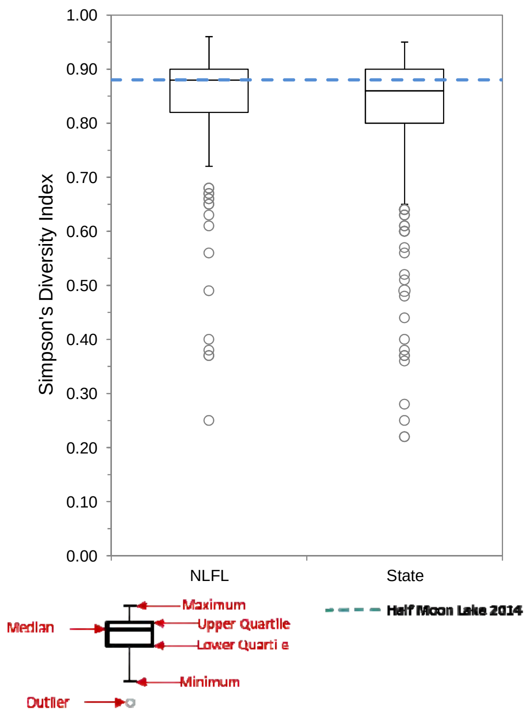


Figure 3.4-5. Half Moon Lake species diversity index. Created using data from July 2014 whole-lake point-intercept survey. Ecoregion data created using data from WDNR Science Services and Onterra.

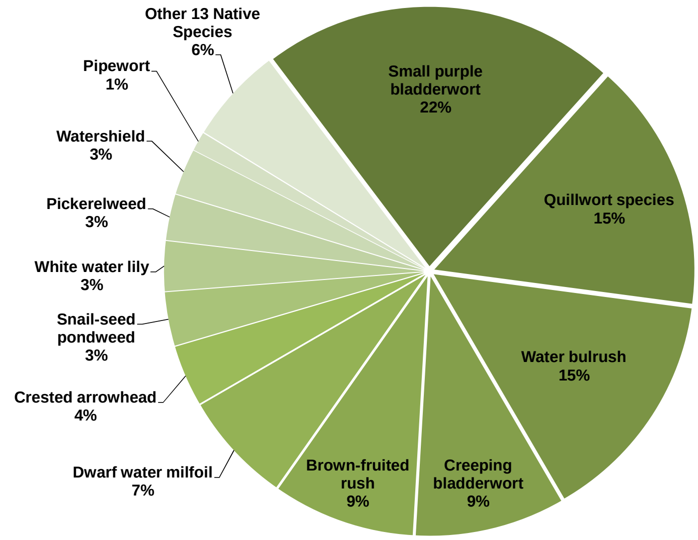


Figure 3.4-6. Half Moon Lake 2014 relative frequency of occurrence of aquatic plant species. Created using data from July 2014 whole-lake point-intercept survey.

The 2014 aquatic plant community mapping survey indicated that approximately 12.3 acres (12%) of Half Moon Lake's 104 acres contain emergent and floating-leaf aquatic plant communities (Table 3.4-2 and Map 5). These communities were comprised of seventeen emergent and/or floating-leaf aquatic plant species (Table 3.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can become stranded above the receding water line.

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

Table 3.4-2. Half Moon Lake acres of emergent and floating-leaf aquatic plant communities in 2014. Created from a July 2014 community mapping survey.

Plant Community	Acres
Emergent	1.1
Floating-Leaf	0.7
Mixed Emergent & Floating-Leaf	10.5
Total	**12.3**

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 Half Moon Lake. The goal of this section is to provide an overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the HMLPRD 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 2015, Dave Seibel personal communication and GLIFWC 2014A / 2014B).

Half Moon Lake Fishery

Half Moon Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second highest activity ranked by Half Moon Lake stakeholders (Question #13), with largemouth bass, bluegill and sunfish being their favorite species to target (Question #9). Approximately 31% of respondents indicated the fishing was "Very Poor" on Half Moon Lake" (Question #10). 65% of respondents believe that the fishing has gotten "Much" or "Somewhat" worse since they began fishing the lake, while 16% indicated the fishing has remained the same (Question #11).

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 Half Moon Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

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

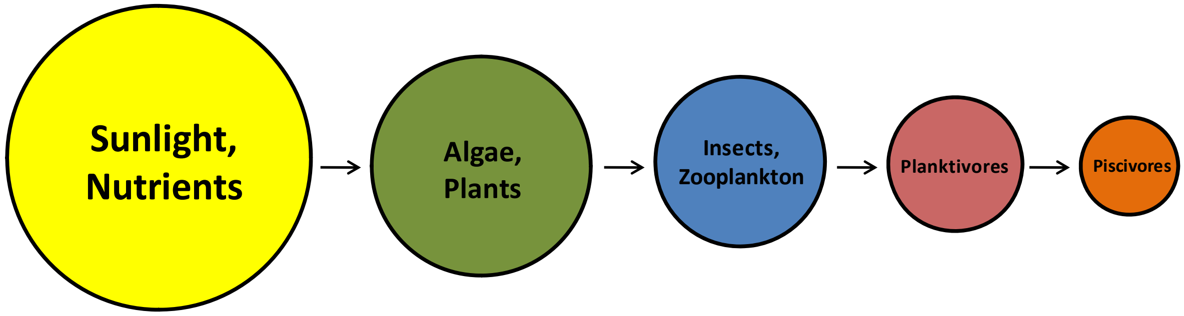


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Half Moon Lake is a mesotrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Half Moon Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.5-1 shows the common game fish that may be present in Half Moon Lake.

Table 3.5-1. Common northern Wisconsin gamefish with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pikes, crayfish, small mammals, water fowl, frogs
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, wave-washed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Half Moon Lake Spear Harvest Records

Figure 3.5-2. Location of Half Moon Lake within the Native American Ceded Territory (GLIFWC 2014A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

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

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2014B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Although Half Moon Lake has been declared as a spear harvest lake, it has not historically seen a harvest. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.

Half Moon Lake Substrate and Near Shore Habitat

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

According to the point-intercept survey conducted by Onterra, 79% of the substrate sampled in the littoral zone on Half Moon Lake was muck, with the remaining 21% being classified as sand. Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

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

Half Moon Lake Regulations and Management

Because Half Moon Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. Table 3.5-2 displays the 2015-2016 regulations for species that may be found in Half Moon Lake. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.5-2. WDNR fishing regulations for Half Moon Lake, 2015-2016.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth bass	May 2 to March 6	The minimum length limit is 14" and the daily bag limit is 5 (in combination with smallmouth bass).
Smallmouth bass	May 2 to June 19	Catch and release only
	June 20 to March 6	The minimum length limit is 14" and the daily bag limit is 5 (in combination with largemouth bass).
Northern pike	May 2 to March 6	No minimum length limit and the daily bag limit is 5.
Muskellunge	May 23 – November 30	The minimum length limit is 40” and the daily bag limit is 1.
Walleye, sauger, and hybrids	May 4 to March 2	The minimum length limit is 15”, but fish from 20” to 24” may not be kept and only 1 fish over 24” is allowed. The daily bag limit is 3.
Bullheads	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.

Through both verified documentation and anecdotal reports, Half Moon Lake has experienced winter kill quite often. This occurrence is spurred by a lack of dissolved oxygen, which as discussed in the Water Quality Section occurs during times in which more oxygen is being consumed than generated; often, this happens during the winter months when ice cover reduces atmospheric oxygen exchange. While periodic, small winterkills can benefit a fishery by removing smaller, stunted or weak individuals, a complete or large scale winterkill is very detrimental to a lake’s fishery.

Aeration is a process where air is circulated through an aquatic system for the purpose of re-oxygenating the water. To address winter oxygen depletion, aeration is a common technique. Many believe that the aeration process itself re-oxygenates a lake by providing an air source to the water. While some oxygen may be provided to the lake in this manner, the greatest oxygen accumulation actually occurs through the creation of open water during the winter months, allowing for atmospheric exchange of oxygen with the open water. The overarching goal of winter aeration is to open an area of ice for this oxygen exchange, essentially creating a refuge for fish to last through the winter months. Therefore, it is not necessary to aerate large areas of a lake. Commonly, fish biologists refer to >1 to several acres of aerated area as a “refuge” where fish can overwinter.

In general, aeration systems are best suited in waters greater than five feet of depth within several hundred feet of shoreline. Because aeration units are power operated, an electrical source must be located near the unit. The aerator must be situated on public land or on private land with the landowner’s permission. For an aeration system to be installed off of a private landowner’s property, the landowner must obtain a water regulations permit and become liable for the system, in accordance with Wisconsin Statute 167.26.

One of the most critical responsibilities of the liable party is the erection and maintaining of a barricade. Wisconsin Statute 167.26 outlines the requirements of the barricade, including height of barricade rope off the ice, spacing around the aerated area, reflective tape / ribbon requirements, etc. When a proper barricade is made and maintained, Wisconsin Statute 167.26 specifies that the responsible party for the aeration system is exempt from liability for injury or death of any person entering the ice opening. Setting up the barricade after the onset of ice and initiation of the aeration unit does not meet the standards of Wisconsin Statute 167.26; the barricade must be initiated prior to active aeration.

Appendix F is a report from a retired WDNR fisheries biologist report on aeration projects in Barron and Polk Counties, and includes a good description on when and how to erect the aerator barrier. The report within Appendix F is also good starting point for understanding these costs and time investments, though updated technology and pricing may be available elsewhere.

Aerator cost can vary based upon the type of system and the accessories that are purchased, as well as the monthly costs for electricity. Aeration units used to open a small open water in a lake may cost from $1,000 to $1,800, while electricity costs may range from $30-50 per month for a smaller unit to $120-$180 per month for a larger unit. Installation costs would vary depending upon the type of system selected; on-shore compressors typically require a housing box and tubing would need to be weighted or anchored to the sediment. Finally, the barricade could be built from materials purchased at a hardware store, which would likely run $100-$250 depending upon the expected area of open water. Annual maintenance costs should be planned for within a lake group's budget as well.

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Half Moon Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, should any be found.
3) Collect sociological information from Half Moon Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

Through the course of over a year of studies and direct discussions regarding Half Moon Lake, much has been learned about the lake's ecosystem, the desires of the people who live nearby and care for the lake, and what challenges need to be met to be done to manage and protect the Half Moon Lake ecosystem.

This project included many scientific investigations aimed at understanding the ecosystem through the analysis of baseline data. Through water quality sampling and analysis, it was found that Half Moon Lake has water quality that may be described as excellent when compared to similar lakes regionally and state-wide. Phosphorus, a nutrient of major concern to lakes across Wisconsin and the United States, was found to be in moderate abundance within the lake. Every lake requires some phosphorus, as this essential nutrient is needed for algae and aquatic plant growth. Algae and plants are in turn necessary to provide food and habitat for insects, fish, mammals, etc. However, the amount of phosphorus found in the water column of Half Moon Lake is sufficient to produce a healthy amount of algae, not an excess amount that might lead to harmful algae blooms that other lakes may experience.

A lake's water quality and quantity are often a reflection of the surrounding drainage basin, or watershed. Thus is the case for Half Moon Lake. The water quality of the lake is good partially because of the advantageous land cover types that are within the lake. The immediate shoreline is in good condition as well, with 46% found to be in a largely natural/developed-natural state and 32% considered semi-natural. Past and present research has indicated that the immediate shoreline provides many ecological services due to its being located at the interface between the aquatic and terrestrial environment. In regards to protecting Half Moon Lake, conserving the existing natural shoreline and restoring areas of disturbed shoreline is one of the best ways the HMPRD can preserve their unique resource.

The aquatic plant community is a good indicator of the lake's overall health; and to this respect, all indications are that Half Moon Lake is healthy. 34 species of native aquatic plants were found in Half Moon Lake in 2014, including two species listed as "special concern" in Wisconsin due to their rarity and preference for undisturbed habitats. One of the advantages of having a healthy aquatic plant community is its role in assuring better water quality. Aquatic plants provide habitat for small crustaceans, called zooplankton. Zooplankton are able to find cover within the aquatic plants from their primary prey – planktivorous fish. The zooplankton feed upon algae primarily. Their grazing keeps algae numbers low, which further increases the water clarity in the lake. Without the aquatic vegetation, the zooplankton are easy prey for small fish species.

The study began with an anonymous written survey of Half Moon Lake residents. Much was learned regarding how these stakeholders utilize the lake, and what issues they see as concern for the lake's health. Overall, residents of Half Moon Lake believe they have a healthy lake ecosystem that they are interested in protecting. There was overwhelming concern about several issues on the lake, namely organic sediment (muck) build-up and abundant watershield growth.

The organic material present in Half Moon Lake is the result of years and years of partial plant decay in the lake. Every summer, plant materials grow as the waters warm. Each fall, the plants die back to the sediment, where bacteria break down the structures. This decomposition process leaves behind organic material which accumulates over the years. When more plants and algae are present, more material is left behind after their death. Therefore, the sediment in Half Moon Lake is increasing, however the source is the annual plant growth within the lake. This is a naturally occurring process that all lakes undergo, as nature gradually makes them shallower and eventually fills them in.

Another unfortunate circumstance resulting from these circumstances is the decrease in dissolved oxygen that accompanies great plant growth. As these plants are decomposed by bacteria, the microbes utilize available oxygen and produce carbon dioxide. Particularly in the winter months, when the lake is ice-covered and not exposed to oxygen diffusion from the open air, oxygen depletion can occur to a great degree. In Half Moon Lake it is likely that the vast majority of the lake goes anoxic most winters. This is a problem that impacts the fish within the lake, and is compounded by the lack of depth and volume in this relatively small and shallow lake. It should be noted that during this planning process, aeration was discussed amongst the HMLPRD committee members and Onterra staff, and the determination to not pursue winter aeration was made by the committee. Should the HMLPRD wish to address this in the future, installation of an aeration unit near the lake's deep hole location would be a practical solution.

Aquatic plants vary in their substrate, water chemistry, and depth preferences. Some aspects of the Half Moon Lake sediment and water chemistry, in particular, are favorable to growth of watershield. The plant prefers clear, slightly acidic water over soft sediments in relatively shallow water. Anedotal evidence points to the species increasing in population as water levels decline in a lake; this essentially provides an increase in watershield's preferred habitat and allows it to expand. While the plant's extent is not of major navigational concern on a lake-wide basis, it is causing some residents grief in localized areas of the lake. The plant is unfortunately difficult to remove due to a thick mucilage coating it produces, which creates a slippery surface. Underground rhizomes produced by the plant allow for quick reestablishment once the top layers of stems and leaves are removed.

Half Moon Lake is a healthy ecosystem that holds unique biological features and treasured memories for those that live along its shoreline. The Implementation Plan that follows is the result of conversations between HMLPRD lake stakeholders, Onterra staff, and WDNR specialists on ways that the HMLPRD may protect this unique resource while enjoying its natural beauty at the same time.

5.0 IMPLEMENTATION PLAN

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

Management Goal 1: Maintain Environmental Integrity of Half Moon Lake

Management Action: Continue monitoring of Half Moon Lake's water quality through the WDNR Citizen Lake Monitoring Network.

Timeframe: Continuation of current effort.

Facilitator: Carla Gerstenberger

Description: Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends will likely aid in an earlier definition of what may be causing the trend.

The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the HMLPRD have collected Secchi disk clarities and water chemistry samples during this project and in the past through the CLMN. It is the responsibility of the Board of Directors to coordinate new volunteers as needed. When a change in the collection volunteer occurs, it will be the responsibility of the Board of Directors to contact Sandra Wickman or the appropriate WDNR/UW-Extension staff to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Board of Directors recruits volunteer coordinator (or selects existing volunteer).
2. Coordinator directs water quality monitoring program efforts.
3. Coordinator reports results to WDNR and HMLPRD members during annual meeting.

Management Action: Coordinate annual volunteer monitoring for aquatic invasive species.

Timeframe: Initiate summer 2016.

Facilitator: Board of Directors

Description: Aquatic invasive species have caused ecological impacts as well as reduced recreational opportunity in many Wisconsin lakes. Early detection of AIS is important, as is a plan to address the invasive plant/animal. Volunteer monitoring is the most cost-effective way the HMLPRD can survey their lake for AIS and identify early occurrences. The HMLPRD wishes to adopt a volunteer monitoring design that maximizes their volunteer’s time as well as maximizes the amount of lake area that is covered. The group has attended seminars led by Lumberjack AIS Coordinator John Preuss, in which AIS identification techniques were shared and discussed.

One way that lake residents can spot AIS is through conducting “Lake Sweeps” on their lake. During a lake sweep, volunteers monitor the entire littoral zone in search of non-native plant species. This program uses an “adopt-a-shoreline” approach where volunteers survey specified, assigned areas.

In order for accurate data to be collected during these sweeps, volunteers must be able to identify non-native species such as Eurasian water milfoil and curly-leaf pondweed. Distinguishing these plants from native look-a-likes is very important. Additionally, the collection of suspected plants is important. A specimen of the plant would need to be collected for verification, and, if possible, GPS coordinates should be collected. Lumberjack AIS coordinator John Preuss is an excellent resource to contact for assistance in developing monitoring techniques, identifying invasive aquatic plants and logging pertinent monitoring information.

Action Steps:

1. Volunteers from the HMLPRD update their skills by attending a training session conducted by Lumberjack AIS Coordinator John Preuss, as needed.
2. Trained volunteers recruit and train additional association members.
3. Complete lake surveys following designated protocols.
4. Report results to WDNR, Lumberjack AIS Coordinator and HMLPRD.

Management Action: Utilize and share manual tools for watershield control.

Timeframe: Continuation of current effort

Facilitator: Board of Directors

Description: Watershield, a floating-leaf plant with a shield or football shaped leaf, was found along the shorelines of Half Moon Lake in several areas (see the Community Map – Map 5). This plant is adapted to grow well under fluctuating water levels. With water levels fluctuating on Half Moon Lake in the past decade or so, the residents around Half Moon Lake have indicated that the extents of watershield growth have increased over time. Declining water levels allow the plant to expand its preferred habitat and put more energy into producing floating leaves. The plant also prefers clear, shallow, slightly acidic water and soft sediments – all of which are conditions present on Half Moon Lake.

Mechanical harvesting of watershield is difficult because the plant has a slippery mucilage coating on its stems, underground rhizomes, and a quick growth rate. Additionally, its preference for shallow water means that mechanical harvesters cannot typically reach these colonies, as the machine's great weight means its operating range ceases at around 3 ft of depth. Furthermore, because intensive management of native aquatic plants can be detrimental to the plant community and open niche areas for invasive plant residence, these techniques are highly discouraged by the WDNR's Aquatic Plant Management Strategy for the Northern Region (attached as Appendix F). The best applicable way for residents to achieve access to the open water areas of the lake is through manual removal of the plants. Native plant manual removal is governed through Wisconsin administrative code NR 109, which is attached within Appendix F as well. Essentially, this regulation provides for a 30 ft removal zone, extending directly out from a use area such as a dock or swim area. Floating debris that results from removal must be removed from the lake, and where wild rice may be present, a permit is required from the local WDNR aquatic plant management coordinator.

The HMLPRD has purchased several aquatic plant cutting units, which use two sharp edges to slice through aquatic plant stems as they are dragged through the water. These units, though requiring ample manual labor, can be effective at controlling watershield on the short-term. Repeated use may be necessary through the summer, much like mowing a lawn is necessary every week or other week during the growing season.

Action Steps:

1. HMLPRD continue to loan aquatic plant cutters to Half Moon Lake residents on a check-out system.
2. Board of Directors determine level of financial commitment to maintaining and replacing the aquatic plant cutting units.

Management Action: Investigate feasibility of other watershield control methods.

Timeframe: Winter 2015 / 2016

Facilitator: Board of Directors

Description: During the planning meetings associated with this project, Onterra staff discussed watershield control with the HMLPRD planning committee members. The watershield control methods discussed included herbicide, mechanical removal and manual removal. A brief summary of each method is provided below:

1. Herbicide use can be effective on watershield, but is very rarely permitted by the Wisconsin DNR on native plant communities. The reason is that the watershield in Half Moon Lake provides natural habitat for fish/insects, as well as a means of dampening waves that would otherwise work to erode the shoreline. The watershield is one of only several plant species that provide these benefits in the lake as the others are small, fragile and less prevalent. More information on native aquatic plant management may be found in the WDNR's Northern Region Aquatic Plant Management Strategy document (Appendix F). This was not determined to be a suitable method for watershield control on Half Moon Lake.

2. Mechanical harvesters may be used to control nuisance conditions of aquatic plants. These units are quite costly to purchase, running anywhere from $45,000 to $100,000. Harvesters may be contracted through a few companies. There are several issues with operating a mechanical harvester. First, a Wisconsin DNR permit is required. These permits are distributed when significant navigational or recreational impairment is documented. Typically, permits are created to harvest multiple acres of navigation lanes in a lake; this is often required when significant navigational impairment is present. The conditions on Half Moon Lake would likely not be considered significant navigational impairment, as watershield occupies a relatively small proportion of the lake surface area (Map 5). So, it may be difficult to convince the WDNR that navigational concerns are warranted to approve of this permit. This is due to the benefits the watershield plant communities are providing (discussed in the Aquatic Plant Section and Summary/Conclusions Section). Second, mechanical harvesters are usually quite heavy and can only operate in deeper than 3-4 feet of water. The shallow areas present by the shore and people's docks may not be able to be harvested. Lastly, harvesting contractors have reported to Onterra that they typically have reservations on using this technique on watershield because the slippery stems of watershield do not

allow for good cutting and watershield grows back quite quickly, meaning repeated visits would be necessary.

3. Manual removal can be done through rakes or the Y-shaped blades, which the District currently owns. Wisconsin administrative code NR 109 states that property owners may remove a 30-ft swath of plants in front of their property, as far out in the lake as necessary to gain access to open water. Plant material must be removed from the lake, and no Wisconsin DNR permit is needed so long that wild rice is not present. This is no doubt a labor-intensive task, and the slippery stems of the plant do not make it easier. It was, however, the most appropriate means of dealing with watershield in Half Moon Lake when compared to the alternative methods.

Despite the roadblocks discussed for non-manual watershield removal methods, the HMLPRD want to remain educated and diligent on this issue. There is great concern within members of the group that should water levels decrease further, watershield will inhabit deeper areas of the lake and further reduce navigability. Therefore, the HMLPRD board wishes to continue to investigate mechanical harvesting technologies as a future feasible control method for watershield. They will accomplish this by remaining in contact with WDNR officials and aquatic equipment manufacturers, while attending educational events (Wisconsin Lakes Convention, etc.) to learn more about aquatic plants and aquatic plant control methods.

Action Steps:

1. HMLPRD Board continues conversations with other management entities on watershield concerns.
2. Continue to learn of emerging lake management technologies and assess them for applicability to Half Moon Lake.

Management Goal 2: Increase HMLPRD's Capacity to Communicate with and Educate Lake Stakeholders

Management Action: Support an Education Committee to promote environmental awareness, public safety and quality of life on Half Moon Lake.

Timeframe: Begin spring 2016

Facilitator: Board of Directors

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

Currently, the HMLPRD has several educational initiatives in place for Half Moon Lake stakeholders. The association holds an annual meeting each June, and provides the meeting minutes to all District members. An annual newsletter is distributed to all District members as well, along with the UW-Extension's quarterly issue of "Lake Tides". An annual banquet is held to bring the HMLPRD members together for food, fun and conversation. Guest speakers and conversations on lake protection topics are common amongst these meetings and newsletters.

The HMLPRD have decided that the Board of Directors will take on the responsibility of also functioning as the group's Education Committee. Their task will be to continue to come up with new and innovative ways of educating Half Moon Lake stakeholders on the matters pertaining to their lake. Example educational topics include:

- Aquatic invasive species monitoring updates
- Boating safety and ordinances
- Catch and release fishing
- Shoreland restoration and protection
- Septic system maintenance
- Fishing Rules

The board will be responsible for reaching out to state or local affiliates which can provide them with educational pamphlets, other materials or ideas. These partners may be some of those included in the table found under Management Goal 3. Additional resources may be found below:

Fishing Regulations
http://dnr.wi.gov/topic/fishing/regulations/index.html

Wisconsin Lakes FAQ (water quality, levels, lake health)
http://dnr.wi.gov/lakes/commonquestions/Default.aspx

Shoreland zoning and health
http://dnr.wi.gov/topic/shorelandzoning/

Citizens Lake Monitoring Network
http://dnr.wi.gov/lakes/clmn/

General Resources
http://www.wisconsinlakes.org/
http://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/default.aspx

Action Steps:

1. The HMLPRD Board of Directors will identify a base level of annual financial support for educational activities to be undertaken.
2. Reach out to assisting management entities (see table under Management Goal 3, Action 1) for resources to help educate District members.

Management Action: Create District membership database

Timeframe: Begin fall 2015

Facilitator: Board of Directors

Description: The HMLPRD currently has several means of distributing information to lake stakeholders (described in the previous Management Action). The District currently does not utilize a website or email distribution system to disseminate information. At the two planning meetings associated with this project, it was determined that these two information delivery systems were not necessary for the District. One topic discussed however was the need for a membership database. The database would hold the names, addresses, and contact information of all District members. Additional information, such as volunteer activity tracking, payment activity, etc., would be included as necessary.

Action Steps:

1. Board of Directors to identify volunteer with database experience.
2. Volunteer maintains electronic version of membership database. May use resources such as Town of Bradley staff to develop the database.

Management Action: Create “Welcome Wagon” for new home owners in District

Timeframe: Begin fall 2015

Facilitator: Board of Directors

Description: New residents may be unfamiliar with their neighbors, the HMLPRD or the tremendous effort that has gone into protecting the health of Half Moon Lake. A volunteer from the HMLPRD will pay a personal visit to each new lake resident for a friendly introduction. During this visit, the HMLPRD member may discuss the matters the District is involved with, as well as how the new resident may manage their property to have minimal impact on Half Moon Lake.

Action Steps:

1. Board of Directors to identify a volunteer to discuss lake-friendly property management and HMLPRD events with new residents.

Management Action: Increase awareness of slow-no-wake zones in Half Moon Lake.

Timeframe: Initiate spring 2016

Facilitator: Board of Directors

Description: Question #12 on the Half Moon Lake Stakeholder Survey indicates that the majority of residents utilize passive watercraft (canoes, kayaks, paddleboats, etc.) on Half Moon Lake. However, some residents do operate personal watercraft and motorized boats as well. Question #13 of the survey indicates that a variety of activities are undertaken by residents, including relaxing/entertaining, fishing, swimming, canoeing/kayaking and motor boating or jet skiing.

The HMLPRD acknowledges that a variety of recreational activities take place on Half Moon Lake. While allowing all stakeholders to enjoy Half Moon Lake the way they see fit, the HMLPRD wishes to ensure that all recreationalists are displaying a high level of safety and awareness at all times and are obeying all boating regulations. The HMLPRD will work to keep all lake residents and visitors aware of regulations that exist on Half Moon Lake. This will be done through appropriate postings in the annual newsletter, announcements at association meetings, and perhaps signage at the lake's public access point.

Wisconsin Act 31 states that it is illegal to operate a boat at a speed faster than slow-no-wake while within 100 feet, or a personal watercraft within 200 feet, from a shoreline, pier, raft or buoyed area. As indicated on Map 6, watercraft must stay near the center of the lake in order to maintain this distance from the shoreline and piers. Please note that the map indicates distances from the shoreline, not piers or other structures which may require further distance be kept.

The HMLPRD, wishing to make this knowledge more readily available to watercraft users, will utilize Map 6 in an appropriate manner such as posting at the public access location, local establishments, within the annual newsletter, etc. The HMLPRD will explore other options to notify watercraft operators of the slow-no-wake conditions in this area as they arise.

Action Steps:

1. Distribute Map 6 as appropriate.

Management Goal 3: Strengthen Association Relationships, Effectiveness and Lake Management Capability

Management Action: Enhance HMLPRD's involvement with other entities that have a hand in managing Half Moon Lake.

Timeframe: Continuation of existing efforts

Facilitator: Board of Directors

Description: The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. It is important that the HMLPRD actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities reduce the duplication of efforts. While not an inclusive list, the pertinent parties for Half Moon Lake range from those located locally (Town of Bradley) to those at the County level (Lumberjack AIS Coordinator, Lincoln County Lakes & Rivers Association) and at the level of the State of Wisconsin (WDNR). Each entity is specifically addressed in the table on the next page.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Lincoln County Lakes and Rivers Association	President (A.J. Theiler – 715.453.0010)	Protects Lincoln County waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Lincoln County lakes.
Lumberjack Aquatic Invasives Coordinator	AIS Coordinator (John Preuss – 715.369.9886)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: Report activities to Mr. Preuss.
UW-Extension	Director and Lake Specialist (Eric Olson – 715-346-2192)	Helps lake groups communicate and collaborate for healthy lakes	Twice a year or more as needed.	Contact for educational material, working through organizational issues, utilizing grant funds.
Town of Bradley	Town Chair (Keith Koth – 715-612-8124)	Oversees ordinances and other items pertaining to town.	As needed.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Wisconsin Department of Natural Resources	Fisheries Biologist (David Seibel – 715.623.4190)	Manages the fishery of Half Moon Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, winter fishkill reports.
	Lakes Coordinator (Jim Kreitlow– 715.365.8947)	Oversees management plans, grants, all lake activities.	Annually, or more as necessary.	Information on updating a lake management plan (every 5-10 years) or to seek advice on other lake issues.
	Warden (Ronald Nerva – 715.456.2188)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day).	Contact regarding suspected violations pertaining to recreational activity on Half Moon Lake, include fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	HMLPRD members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Action: Increase volunteerism within HMLPRD

Timeframe: Initiate spring 2016

Facilitator: Board of Directors

Description: Even through lake associations consist of individuals who are passionate about the lake they reside upon, it is often difficult to recruit volunteers to complete the tasks that are necessary to protect that lake. Many lake association members are elderly and retired, so sometimes labor intensive volunteer jobs are difficult to perform. Other residents may only visit the lake several times during the year, often on weekends to "get away" from the pressures of the work-week back home. Some have cut back on volunteering because of recent economic downturns, have concerns over the time commitment involved with various volunteer tasks, while others may simply have not been asked to lend their services.

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

The HMLPRD is proud of their active role in preserving Half Moon Lake for all stakeholders; however, they are in constant need of volunteers to continue this high level of commitment. As a result of this lake management planning project, the association is now in need of additional help to increase the level of protection the HMLPRD wishes to provide for the lake. In order to retain volunteer help and recruit more volunteers for these tasks, the HMLPRD will undertake a volunteer recruitment strategy as outlined below. While volunteer recruitment for a lake association may be difficult, the following tips will be helpful in the HMLPRD's efforts to solicit help for lake-related efforts.

Action Steps:

1. Board of Directors appoints a volunteer coordinator. This should be a friendly, outgoing person who is able to engage people they may know or not know. The volunteer coordinator's duties are to recruit, train, supervise and recognize volunteers. Building and maintaining a volunteer database with names, contact information, tasks, hours completed, etc. will be necessary.
2. Coordinator will initially recruit volunteers through personal means, not via telephone, email or newsletter notification. Engaging a person in a friendly atmosphere through a personal invitation is more likely to result in a successful recruitment than through an impersonal email.

3. Coordinator will have duties outlined prior to recruiting volunteers. A volunteer's time should not be wasted! Work descriptions, timeframes and other specifics should be known by each worker prior to their shift.
4. Coordinator will be flexible in allowing volunteers to contribute towards project designs and implementation. Recruiting new leaders through delegating tasks will empower volunteers.
5. The board of directors will recognize volunteers through incentives and appreciation. Snacks, beverages, public acknowledgement and other means of expressing appreciation are encouraged.

Management Goal 4: Work With WDNR Fisheries Biologist to Manage Half Moon Lake Fishery

Management Action: Continue high level of communication pertaining to surveying and stocking on Half Moon Lake.

Timeframe: Continuation of current effort

Facilitator: Garth Gerstenberger

Description: Fishing was ranked as the second most important activity by Half Moon Lake stakeholders in a 2014 survey (Appendix B, Question #13). The vast majority (89%) of survey respondents indicated they have fished the lake within the past three years (Question #7), and indicated that bass and panfish (bluegill/sunfish) were their favorite species were their favorite to fish for (Question #9).

To keep realistic expectations about the Half Moon Lake fishery, an understanding of the habitat and population dynamics is important. WDNR Dave Seibel is a tremendous resource on fisheries and fish habitat, and although he oversees many lakes in the area, does visit Half Moon Lake occasionally to reassess the population structure.

The HMLPRD would like to continue to strengthen its relationship with the Mr. Seibel, and learn of the monitoring studies he is conducting. Additionally, the HMLPRD may ask Mr. Seibel to come to an annual meeting to present upon fishery research or Half Moon Lake findings. Finally, with much interest in stocking the lake, the HMLPRD will continue conversations on stocking feasibility and strategies, as well as potential habitat improvements that could be implemented.

Action Steps:

1. The HMLPRD Board of Directors will identify a base level of annual financial support for fisheries management activities to be undertaken.
2. The Board will appoint an individual to act as liaison between the District and the WDNR, as well as other entities. Garth Gerstenberger has been appointed for this position.

6.0 METHODS

Lake Water Quality

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

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

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Half Moon Lake during a June 12, 2014 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 Half Moon Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on July 21, 2014. A point spacing of 37 meters was used resulting in approximately 311 points.

Community Mapping

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

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

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