Boot Lake

Vilas County, Wisconsin

Aquatic Plant, Shoreland Condition, & Water Quality Report

October 2017

Sponsored by:

Boot Lake Association

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Onterra, LLC
Lake Management Planning

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Included as a separate electronic document.

1.0 INTRODUCTION

Boot Lake, Vilas County, is a 295-acre, eutrophic drainage lake with a maximum depth of 14 feet and a mean depth of 9 feet. The lake's surficial watershed encompasses an area of approximately 14,650 acres, yielding a large watershed to lake area ratio of 49:1. The lake is fed by two main tributaries, Pickerel Creek and Brazell Creek. The lake is drained by Boot Creek which flows into downstream Rice Lake and eventually the Wisconsin River. Plant surveys completed on Boot Lake have identified 41 native species, of which slender naiad was the most frequently encountered in 2016. Two non-native, invasive plants have been recorded in Boot Lake and include Eurasian watermilfoil and purple loosestrife.

Field Survey Notes

Lake harbors large populations of emergent and floating-leaf aquatic plants including hardstem bulrush, creeping spikerush, white water lily, watershield, spatterdock, and sedges. Water is heavily stained and water clarity is low.

Photograph 1.0-1 Boot Lake, Vilas County

Lake at a Glance - Boot Lake

Morphology	
Acreage	295
Maximum Depth (ft)	14
Mean Depth (ft)	9
Shoreline Complexity	1.8
Vegetation	
Comprehensive Survey Date	July 26, 2016
Number of Native Species	41
Threatened/Special Concern Species	None Located
Exotic Plant Species	Eurasian watermilfoil & Purple loosestrife
Simpson's Diversity	0.93
Average Conservatism	6.5
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	-
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	49:1

Boot Lake is a well-known recreation destination, particularly for its Category 2 muskellunge fishery. The lake is part of several summer fishing tournaments, and receives heavy boat traffic during this time. In order to be successful, many fishermen visit several lakes in the area, including Boot Lake, during a several day period. This greatly increases the risk of aquatic invasive species (AIS) transmittance from lake to lake. The lake is accessible through a single public boat launch.

A management plan was completed for Boot Lake by Onterra in 2011 as a part of the Town of Cloverland Management Planning Project. In 2012, the Boot Lake Association received a WDNR AIS-Established Population Control Grant for Eurasian watermilfoil management. However, monitoring indicated that the Eurasian watermilfoil population was declining, so no control actions were required. The grant funds were reallocated in 2016 to allow the Boot Lake Association (BLA) to collect updated information on the lake's water quality and aquatic plant community as well as complete a shoreland condition assessment which was not completed as part of the plan completed in 2011. These studies were completed on Boot Lake during the growing season of 2016, and this report discusses the results of these studies.

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. On September 9, 2017, an informational meeting was held at the Christofferson residence where Onterra ecologist Brenton Butterfield presented the results of the 2016 studies to Boot Lake stakeholders. In addition, Catherine Higley, the Invasive Species Coordinator with the Vilas County Land and Water Department, also gave a presentation on the importance of maintaining a natural shoreline as well as the steps and opportunities riparian property owners can take to initiate restoration projects on their shorelands to increase habitat, reduce erosion, and protect water quality. Kevin Gauthier, a WDNR Water Resources Management Specialist for Vilas and surrounding counties also attended the meeting to answer questions and provide input on the ongoing management of Boot Lake. The presentations delivered by Brenton and Catherine can be found in Appendix A.

Following Catherine's presentation, she met with six Boot Lake riparians who expressed interest in improving the shoreland areas on their property. Of these six, four would like to pursue improving their shorelands through native plantings, while the other two were interested in reducing stormwater runoff from their property. These Boot Lake riparians will continue to work with the Boot Lake Association and Catherine Higley to determine cost-sharing options to improve their shorelands on Boot Lake.

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 Boot 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 Boot 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

> 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.

state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production.

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a more clear understanding of the lake's trophic state while facilitating clearer long-term tracking. 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 epilimnion 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, fish kills 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 stratification, whether throughout the summer or periodically between mixing events, 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 turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal 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 determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days or weeks 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 2013) 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 Boot 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, large watershed and hydrology, Boot Lake is classified as a shallow, lowland drainage lake (category 4 on Figure 3.1-1).

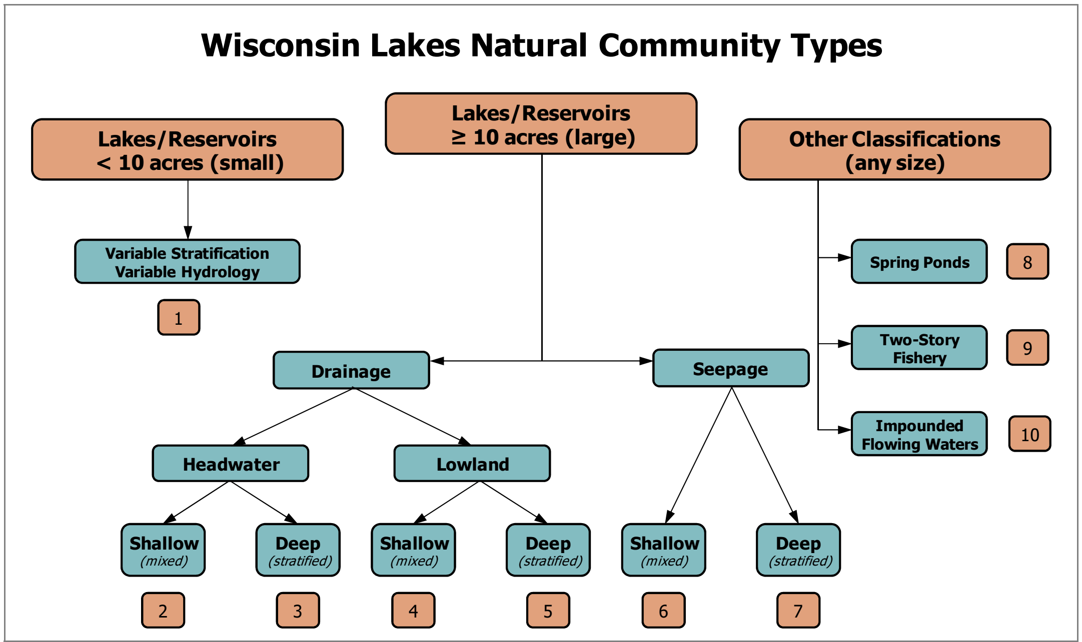


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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 (Table 3.1-1). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Boot Lake is within the Northern Lakes and Forest (NFL) ecoregion.

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.

Boot Lake Water Quality Analysis

Water quality data was collected from Boot Lake on three occasions in summer of 2016. Onterra staff sampled the deepest point in the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen.

Boot Lake Secchi disk depths ranged from 1.9 to 3.4 feet, and averaged 2.6 feet in summer 2016 (Figure 3.1-2). These readings are considerably lower when compared to Wisconsin lakes statewide and within the NLF region. The summer and growing season average Secchi disk clarity depths rank in the Water Quality Index (WQI) as *fair*. The Secchi disk readings were negatively correlated with chlorophyll-*a* concentrations. For example, in August of 2016 Secchi disk clarity was at its lowest within the years of available data, while chlorophyll-*a* concentrations were at their highest (discussed further below). This relationship is common in lakes for the reason that as algae growth increases the visibility within the water column will decrease. With decreasing algal populations, we would consequently expect the visibility to increase.

Total phosphorus concentrations averaged 45.7 µg/L and chlorophyll-*a* concentrations averaged 27.9 µg/L in Boot Lake during summer 2016 (Figure 3.1-2). While the phosphorus concentrations fall into *good* category, the chlorophyll-*a* average ranks as *fair*. Both parameters fall above average for Wisconsin natural lakes and those lakes within the Northern Lakes and Forests (NLF) ecoregion. The average summer total phosphorus concentration in 2016 was slightly higher than the average measured in 2009 while the average summer chlorophyll-*a* concentration in 2016 was lower than the average measured in 2009. The average summer Secchi disk depth in 2016 was similar to what was measured in 2009 and lower than the average measured in 2011.

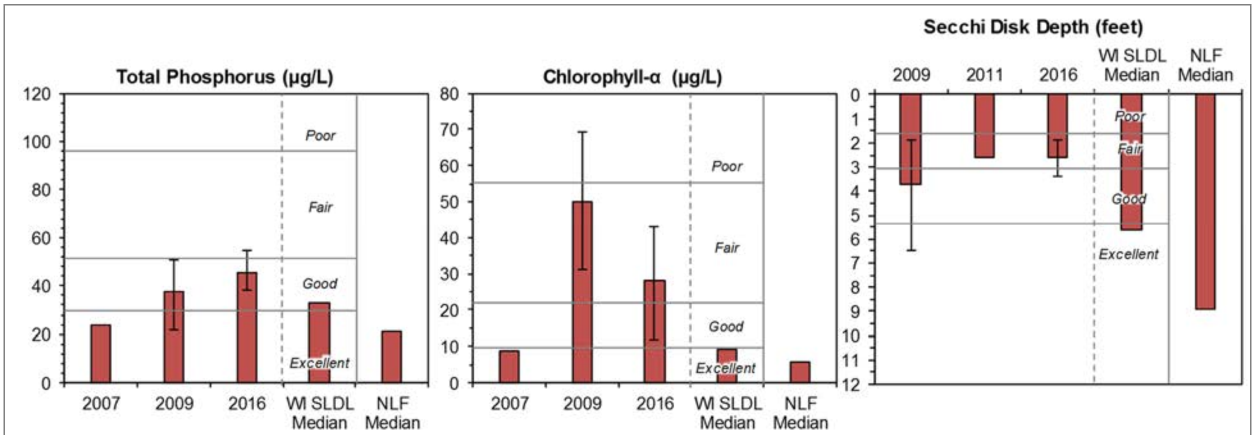


Figure 3.1-2. Boot Lake average summer total phosphorus, chlorophyll-*α*, and Secchi disk depth measured at the deep hole sampling location. Error bars represent minimum and maximum values. SLDL = Shallow, Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion.

The higher concentrations of phosphorus and chlorophyll-*a* in Boot Lake when compared to other lakes in the NLF ecoregion are most likely the result of internal nutrient recycling, inputs from adjacent wetlands, inputs from upstream lakes or combination of these factors. Internal nutrient recycling involves the release of phosphorus (and other nutrients) from lake bottom sediments when the overlying water becomes anoxic or devoid of oxygen. Decomposition of organic matter in deeper waters consumes oxygen, and due to thermal stratification in the summer oxygen is not mixed down and replenished resulting in anoxia. Under anoxic conditions, phosphorus is released from bottom sediments into the overlying water. In shallow lakes like Boot Lake, this sediment-released phosphorus can get mobilized to the surface in the summer during wind events which disrupt stratification and mix the water column. Shallow lakes which experience multiple periods of stratification and mixing during the growing season are termed *polymictic* lakes. In contrast, deeper lakes which maintain stratification during the summer and mix only twice per year – once in spring and once in fall – are termed *dimictic lakes*. Periodic stratification and mixing in polymictic lakes can act as a "phosphorus pump", periodically delivering pulses of sediment-released phosphorus to the surface where it becomes available to algae.

In 2016, phosphorus concentrations near the bottom were measured on one sampling occasion in July. During this sampling event, near-bottom waters were found to be anoxic and phosphorus concentrations were measured at 346 µg/L, over nine times higher than concentrations measured near the surface. The high concentration of phosphorus measured in anoxic bottom waters in Boot Lake is an indication that phosphorus is being released from bottom waters into the overlying water during periods of anoxia. However, given the limited data collected as part of this project, it cannot be said to what extent internal nutrient recycling in Boot Lake has on phosphorus concentrations at the surface.

To quantify the extent to which internal nutrient recycling affects Boot Lake's water quality, a more detailed and advanced water quality study would need to be completed. For example, a two-year, advanced water quality study was completed on Kentuck Lake (Forest and Vilas counties) in an effort to quantify the impact of internal nutrient recycling on the lake. This project involved the collection of water quality samples from multiple locations throughout the lake and at multiple depths every other week from May through October of each year by lake district volunteers. This intensive sampling effort yielded significant information about internal nutrient recycling in Kentuck Lake and the factors which lead to algal blooms. However, as stated previously, with the available data from Boot Lake it cannot be said that internal nutrient recycling is occurring and to what extent.

The upstream lakes which feed into Boot Lake are also polymictic systems, and potential internal nutrient recycling within these waterbodies could also be contributing to the higher nutrient levels in Boot Lake. Another possibility is also nutrient-rich groundwater is being delivered to Boot Lake from adjacent wetlands. Studies completed on nearby Muskellunge Lake indicated that approximately 58% of the phosphorus entering the lake on an annual basis originates from groundwater passing through anoxic wetlands (Robertson et al. 2010). The amount of phosphorus naturally entering the lake was sufficient to maintain eutrophic conditions with high concentrations of nutrient and algae. Without a detailed study being done to quantify the sources of phosphorus to Boot Lake, it cannot be said if one or a combination of these factors create the higher nutrient and algae conditions found within the lake.

Limiting Plant Nutrient of Boot Lake

Using midsummer nitrogen and phosphorus concentrations from Boot Lake, a nitrogen:phosphorus ratio of 16:1 was calculated. This finding indicates that Boot Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that phosphorus is the primary nutrient regulating phytoplankton production and reductions in phosphorus would likely result in lower phytoplankton abundance.

Boot Lake Trophic State

Figure 3.1-3 contains the weighted average Trophic State Index (TSI) values for Boot Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in Boot Lake indicate the lake is currently in a eutrophic state. The TSI values are relatively similar, indicating phosphorus regulates phytoplankton growth and phytoplankton abundance largely determines water clarity. Boot Lake's productivity is higher when compared to other shallow lowland drainage lakes in Wisconsin and to lakes within the NLF ecoregion.

Dissolved Oxygen and Temperature in Boot Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Boot Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-4. These data indicate that Boot Lake does not strongly stratify during the summer. In mid-summer, water temperature was relatively uniform from the surface to approximately 10 feet, while water temperature was slightly cooler from 10 feet to the bottom. This weak thermal stratification allowed for water from 10 feet to the bottom to become anoxic (devoid of oxygen). By August, temperature and dissolved oxygen data indicate that water column had completely mixed at some point between the July and August sampling events. As discussed earlier, this periodic mixing is termed *polymixis*.

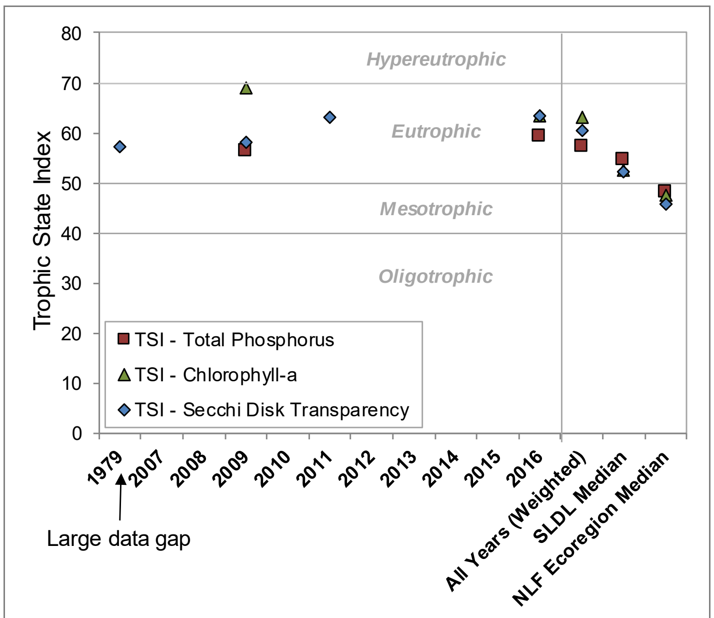


Figure 3.1-3. Boot Lake, state-wide shallow lowland drainage lakes (SLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

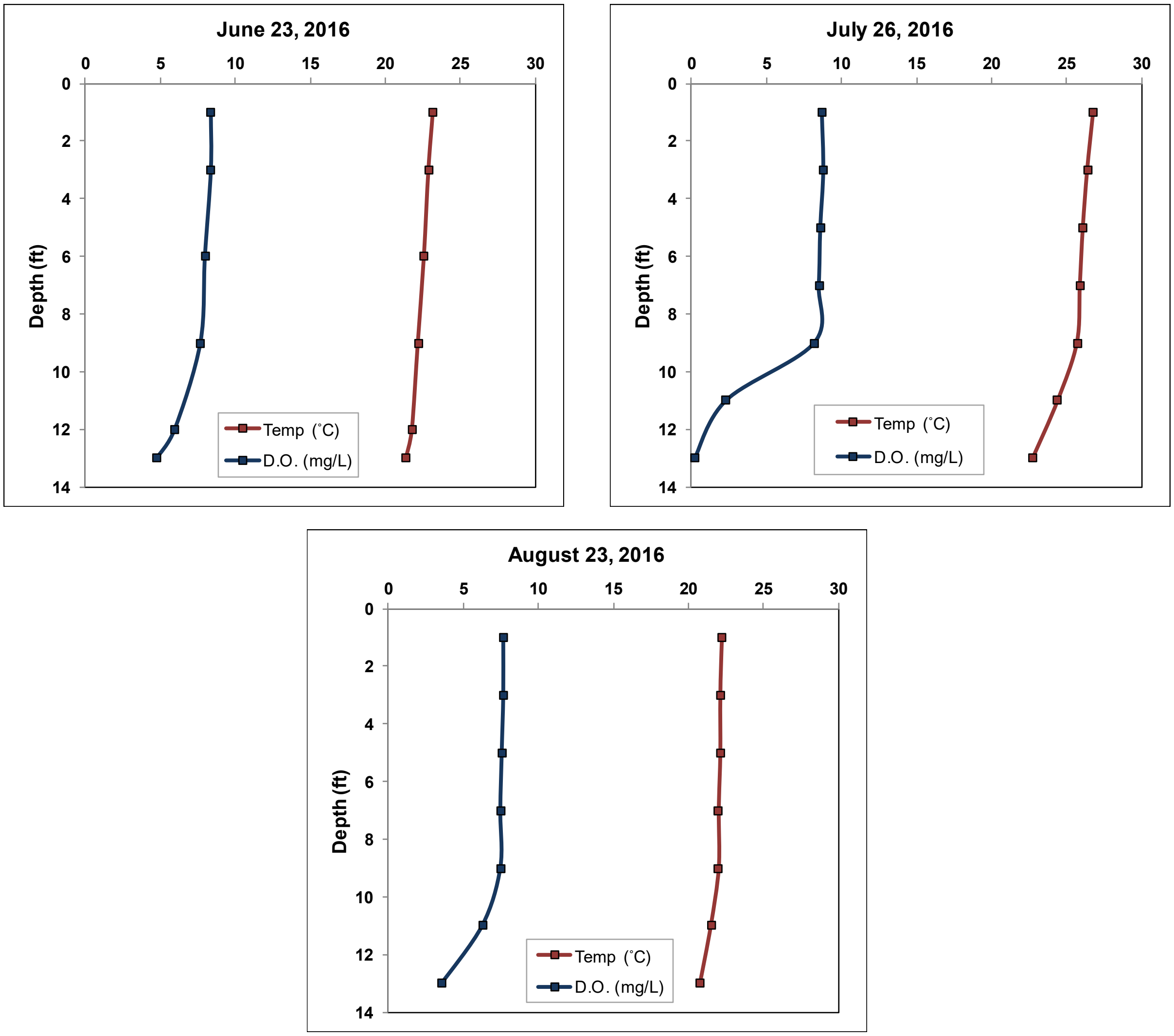


Figure 3.1-4. Boot Lake dissolved oxygen and temperature profiles.

3.2 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 masonry, 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 stricter shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

- 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 35 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit.

- 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. 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 the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
  - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
  - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: 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.

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. Groundwater 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.

Photograph 3.2-1. Example of coarse woody habitat in a lake.

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 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.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to 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 3.2-2. 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 not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. 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.

Boot Lake Shoreland Zone Condition

Shoreland Development

Boot 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 3.2-1 displays a diagram of shoreland categories, from “Urbanized”, meaning the shoreland zone is completely disturbed by human influence, to “Natural/Undeveloped”, meaning the shoreland has been left in its original state.

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

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

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

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

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

Figure 3.2-1. Shoreland assessment category descriptions.

On Boot Lake, the development stage of the entire shoreland was surveyed during Fall of 2016, 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 3.2-1.

Boot Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.4 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.4 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Boot 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 2 displays the location of these shoreland lengths around the entire lake.

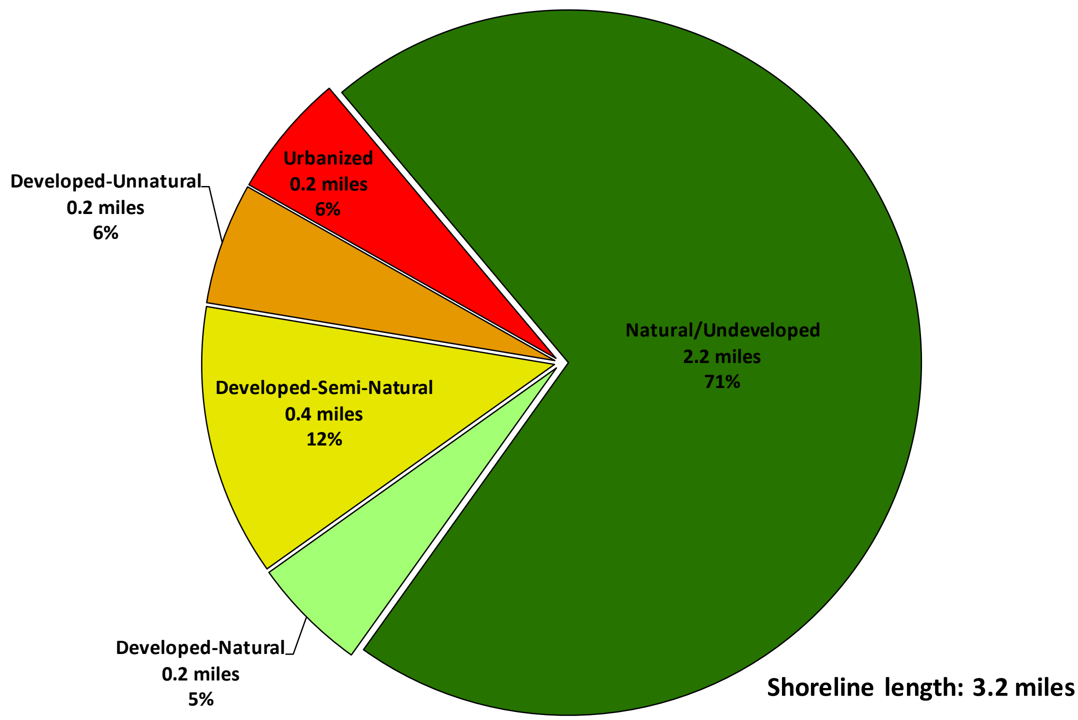


Figure 3.2-2. Boot Lake shoreland categories and total lengths. Based upon a Fall 2016 survey. Locations of these categorized shorelands can be found on Map 2.

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, un-sloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

Boot Lake was surveyed in 2016 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, 15 total pieces of coarse woody habitat were observed along 3.2 miles of shoreline, which gives Boot Lake a coarse woody habitat to shoreline mile ratio of 5:1. This ratio is quite low of lakes throughout Wisconsin, especially ones with so much natural shoreline. As will be discussed in the Aquatic Plant Section, Boot Lake has a large amount of wetlands surrounding the shallow portions of the lake, which is great habitat for aquatic organisms but does not allow for much coarse woody habitat. Locations of coarse woody habitat are displayed on Map 3. 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).

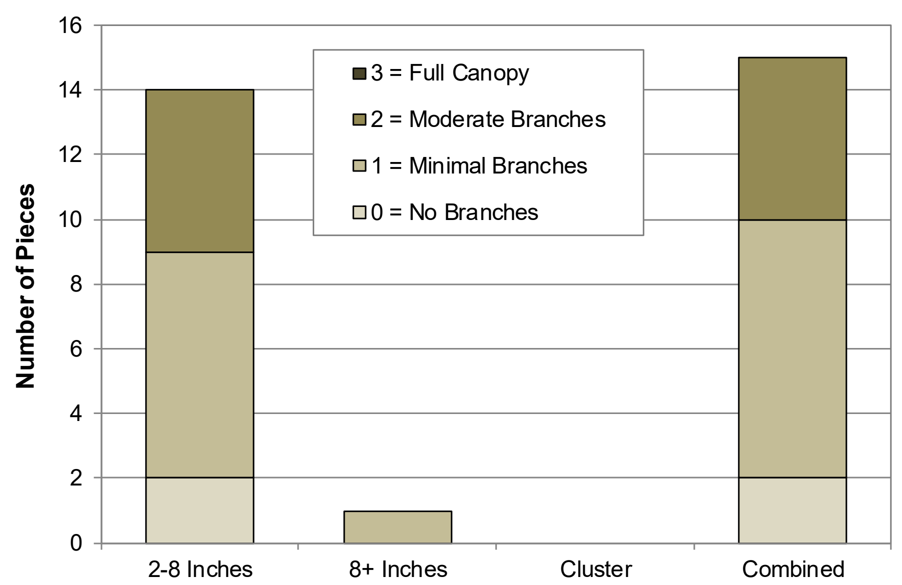


Figure 3.2-3. Boot Lake coarse woody habitat survey results. Based upon a Fall 2016 survey. Locations of Boot Lake coarse woody habitat can be found on Map 3.

3.3 Aquatic Plants

Introduction

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

Photograph 3.3-1. Example of emergent and floating-leaf communities.

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 watermilfoil (*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 species will be discussed further in depth in the Aquatic Invasive Species section. 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 Boot 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 Boot 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

Photograph 3.3-2. Example of aquatic plants that have been removed manually.

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 watermilfoil 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

Photograph 3.3-3. Mechanical harvester.

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

Photograph 3.3-4. Granular herbicide application.

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 watermilfoil. • 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 fish kills 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 watermilfoil 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 watermilfoil 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 watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

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 watermilfoil 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 Boot 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 aquatic plant species, both native and non-native, that were located during the surveys completed in Boot Lake in 2016. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common 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 growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant 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 the whole-lake point-intercept survey completed on Boot Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

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 surveys (equation shown below). This assessment allows the aquatic plant community of Boot Lake to be compared to other lakes within the region and state.

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

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

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. The Simpson's Diversity Index value from Boot Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes withn the Northern Lakes and Forest Lakes ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within each lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Boot Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

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 watermilfoil are the primary targets of this extra attention.

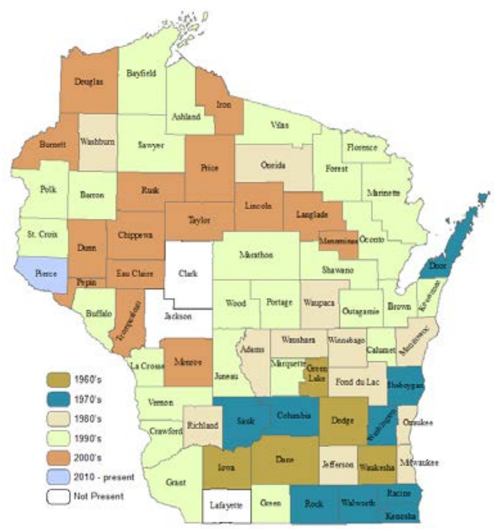


Figure 3.3-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.3-1). Eurasian watermilfoil 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 watermilfoil 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 watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

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

During the aquatic plant surveys completed on Boot Lake in 2016, a total of 41 species of plants were located in Boot Lake, two of which are considered non-native, invasive species: Eurasian watermilfoil and purple loosestrife (Table 3.3-1). Because the non-native plants found in Boot Lake have the ability to negatively impact lake ecology, recreation, and aesthetics, the populations of these plants are discussed in detail within the Non-Native Aquatic Plants in Boot Lake Section. The whole-lake aquatic plant point-intercept survey was conducted on Boot Lake on July 26, 2016 by Onterra. The emergent and floating-leaf aquatic plant community mapping survey was completed by Onterra on July 27, 2016.

Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition. The sediment within littoral areas of Boot Lake is very conducive for supporting lush aquatic plant growth. Data from the point-intercept survey indicate that approximately 81% of the sampling locations located within the littoral zone contained fine organic sediment (muck) and 19% contained sand (Figure 3.3-2).

Approximately 82% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth (8.0 feet), or the littoral zone, contained aquatic vegetation. The maximum depth of plants has varied from 6.5 feet to 11.0 feet from 2005 to 2016. This variability is most likely attributed to changes in water clarity. As is discussed in the Water Quality Section, water clarity in 2016 was approximately 1.0 feet lower when compared to 2009. The reduction in light availability may have resulted in a reduction in aquatic plant growth in deeper areas of Boot Lake. Map 4 shows that the majority of the aquatic vegetation in Boot Lake is restricted to shallow, near-shore areas where light availability is highest. In 2016, the majority of the aquatic vegetation in Boot Lake was encountered between 1.0 and 7.0 feet.

Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 90 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2016, approximately 82% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 47% of the 90 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 20% had a

TRF rating of 2, and 16% had a TRF rating of 3 (Figure 3.3-3). The TRF data indicates that where aquatic plants are present in Boot Lake, they were not overly dense.

Table 3.3-1. Aquatic plant species located on Boot Lake during the 2016 Onterra surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2016 (Onterra)
Emergent	*Carex utriculata*	Common yellow lake sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	X
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Phragmites australis subsp. *americanus*	Common reed	5	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Sparganium eurycarpum	Common bur-reed	5	I
	Typha latifolia	Broad-leaved cattail	1	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Sparganium angustifolium	Narrow-leaf bur-reed	9	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
FL/E	*Sparganium* sp.	Bur-reed sp.	N/A	I
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes spp.	Quillwort spp.	8	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Sagittaria graminea	Grass-leaved arrowhead	9	I

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

Of the 41 aquatic plant species located in Boot Lake in 2016, 27 were encountered directly on the rake during the whole-lake point intercept survey. The remaining 17 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of 27 species encountered on the rake, slender naiad was the most frequently encountered, followed by wild celery, and common waterweed (Figure 3.3-4).

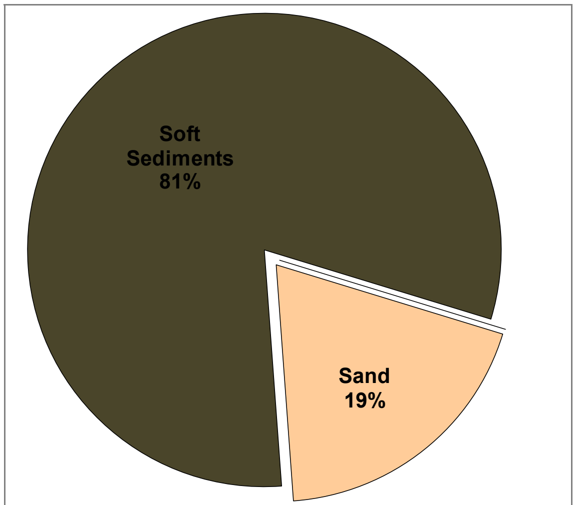


Figure 3.3-2. Boot Lake proportion of substrate types within littoral areas. Created using data from July 2016 aquatic plant point-intercept survey.

Slender naiad, the most frequently encountered aquatic plant in 2016 with a littoral frequency of occurrence of 40% (Figure 3.3-4), is a submersed, annual plant that produces numerous seeds. Slender naiad is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 2014). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Wild celery, also known as tape or eel grass, was the second-most frequently encountered aquatic plant species with a littoral frequency of occurrence of 29% during the 2016 point-intercept survey (Figure 3.3-4). Wild celery is relatively tolerant of low-light conditions and is able to grow in deeper water. Its long leaves provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. Additionally, the leaves, fruit, tubers, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife. In Boot Lake, wild celery was most abundant between 3.0 and 5.0 feet of water.

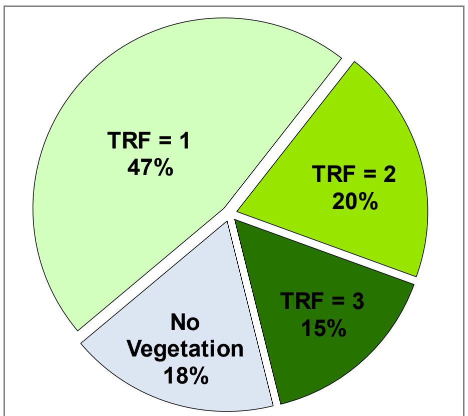


Figure 3.3-3. Boot Lake 2016 aquatic vegetation total rake fullness (TRF) ratings within littoral areas. Created from data collected during the 2016 whole-lake aquatic plant point-intercept survey.

Common waterweed, the third-most frequently-encountered aquatic plant with a littoral frequency of occurrence of 24%, is an aquatic plant species with a wide distribution across North America which obtains the majority of its nutrients directly from the water. While common waterweed can be found growing in many of Wisconsin's waterbodies, excessive growth of common waterweed is often observed in waterbodies which receive excessive amounts of nutrients. It can tolerate the low light conditions found in eutrophic systems better than many other aquatic plant species. For these reasons, common waterweed has competitive advantages over other aquatic plant species that favor its growth in highly eutrophic systems such as Boot Lake.

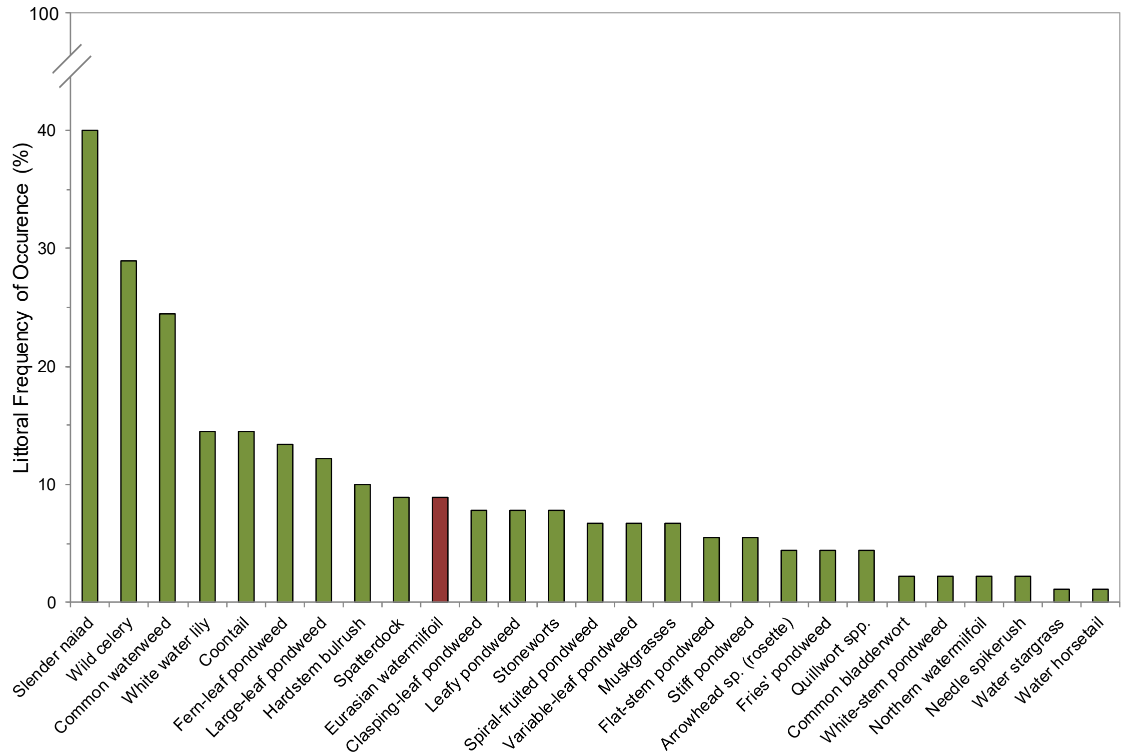


Figure 3.3-4. Boot Lake aquatic plant littoral frequency of occurrence. Created using data from July 2016 surveys.

Aquatic plant point-intercept datasets are also available from 2005, 2006, 2007, 2008, 2010, 2011, 2013, 2014, and 2015 in Boot Lake, and the methodology and sampling locations were the same as the survey completed in 2016. The WDNR has been conducting long term studies on Boot Lake due to the presence of EWM. These datasets can be statistically compared to determine if any significant changes in the overall occurrence of vegetation or in species' abundance have occurred over this time period.

Figures 3.3-5 display the littoral frequency of occurrence of aquatic plant species from the 2005 to 2016 point-intercept surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one of the ten surveys are displayed. Because of their morphological similarity and often difficulty in differentiating between them, the occurrences of muskgrasses (*Chara* spp.) and stoneworts (*Nitella* spp.) were combined for this analysis. In total, six native aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence between 2005 and 2016 (Figure 3.3-5). White water lily, slender naiad, wild celery, and Fries' pondweed increased in their littoral occurrence from 2005-2016, while flat-stem pondweed and forked duckweed decreased. The occurrence of coontail, spatterdock, common waterweed, fern-leaf pondweed, hardstem bulrush, large-leaf pondweed, muskgrasses and stoneworts, clasping-leaf pondweed, white-stem pondweed, variable-leaf pondweed, water horsetail, spiral-fruited pondweed, water stargrass, creeping spikerush, and small pondweed were not statistically different over this time period.

The littoral occurrence of slender naiad was not statistically different in the years from 2005-2015 (Figure 3.3-5). However, in 2016, the littoral occurrence of slender naiad increased by a statistically valid 84% (Chi-square $\alpha = 0.05$). Long-term studies of aquatic plant communities on other lakes also show that slender naiad populations can have high interannual variability in their abundance. This is likely largely due to the fact that slender naiad is an annual, relying on yearly seed production to maintain its population. Natural changes in the conditions which regulate seed production and/or germination will determine the abundance of slender naiad from year to year. Environmental conditions, whatever they may be, we favorable for abundant growth of slender naiad in Boot Lake in 2016.

The littoral occurrence of white water lily was not statistically different from 2005 to 2008, but its occurrence increased by a statistically valid 291% from 2008 to 2010 (Figure 3.3-5). Since 2010, the littoral occurrence of white water lily has ranged from 6.4% in 2015 to 19.1% in 2013. In 2016, the littoral occurrence of white water lily was 14.4%, approximately 832% higher than its occurrence of 1.6 % in 2005. The littoral occurrence of wild celery has averaged approximately 17% since 2005, and in 2016 this plant had the highest recorded littoral occurrence since 2005 of 28.9% (Figure 3.3-5). The data collected since 2005 indicate the occurrence of wild celery can be variable from year to year, and conditions were favorable for increased growth of this plant in 2016. Fries' pondweed is not abundant in Boot Lake, but did exhibit a statistically valid increase in occurrence from 0.0% in 2005 to 4.4% in 2016.

Flat-stem pondweed and forked duckweed both saw statistically valid declines in their littoral occurrence from 2005 to 2016 (Figure 3.3-5). Forked duckweed was one of the most frequently encountered aquatic plants in Boot Lake in 2005 with a littoral occurrence of 27.1%. Between 2007 and 2008, forked duckweed occurrence declined by 67% and has not been detected in Boot Lake since 2011. Like other duckweeds, forked duckweed is a free-floating aquatic plant and is found growing in lakes with higher nutrient content. However, unlike the other duckweed species found in Wisconsin which float on the water's surface, forked duckweed is usually found growing along the bottom or entangled amongst other plants below the surface. While forked duckweed requires water with higher nutrient content, it also requires moderate water clarity to obtain sufficient light near the bottom where it grows. Studies have shown that decreases in water clarity due to increased phytoplankton production have caused declines in forked duckweed populations (Toivonen 1985). The rapid decline and possible extirpation of forked duckweed from Boot Lake may be an indication that phytoplankton production has increased and water clarity has declined since 2007. As is discussed in the Water Quality Section (Section 2.1), water quality data from Boot Lake are limited but do indicate that chlorophyll-*a* concentrations have increased from 2007 to 2016.

Flat-stem pondweed saw an increasing trend in its littoral occurrence from 2005-2008 before decreasing in occurrence in 2010 and 2011 (Figure 3.3-5). Its occurrence increased in 2013 but has since declined to its lowest recorded occurrence of 5.6% in 2016. Flat-stem pondweed is typically tolerant of low-light conditions like those found in Boot Lake, and it is not known if its recent decline represents a trend that will continue or a naturally-occurring cyclical pattern for this plant.

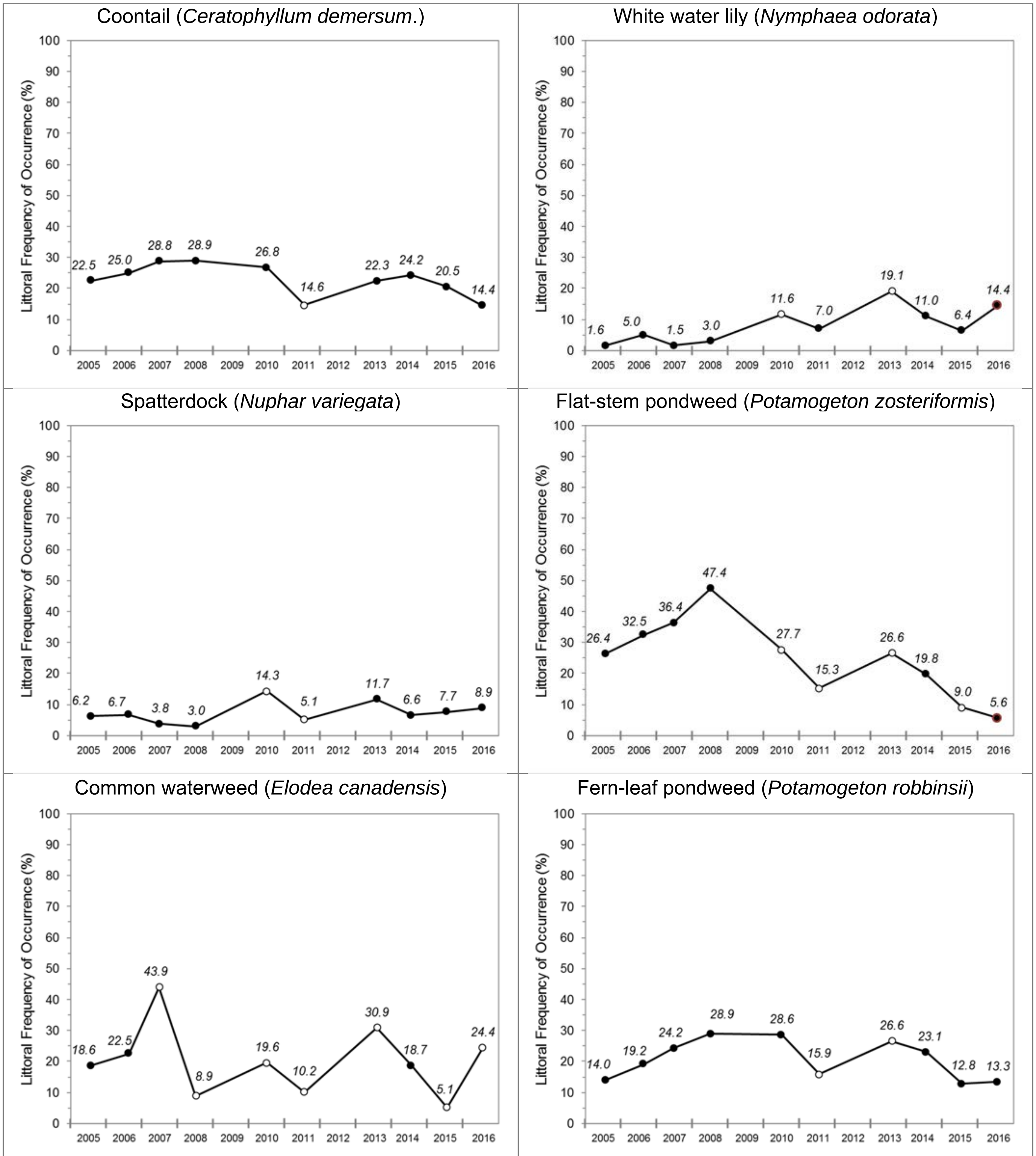


Figure 3.3-5. Littoral frequency of occurrence of select native aquatic plant species in Boot Lake from 2005-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from the 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys whole-lake point-intercept surveys.

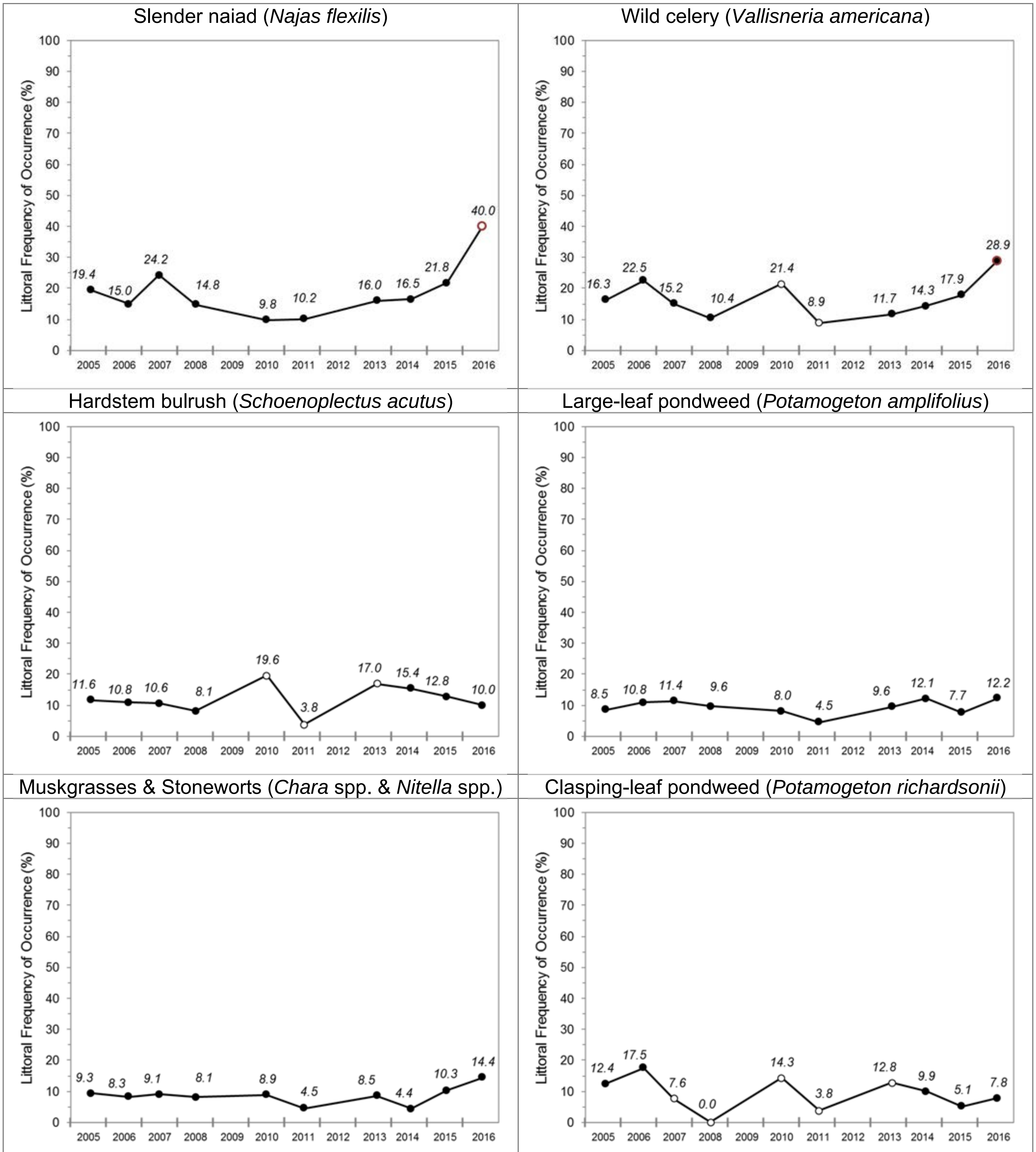
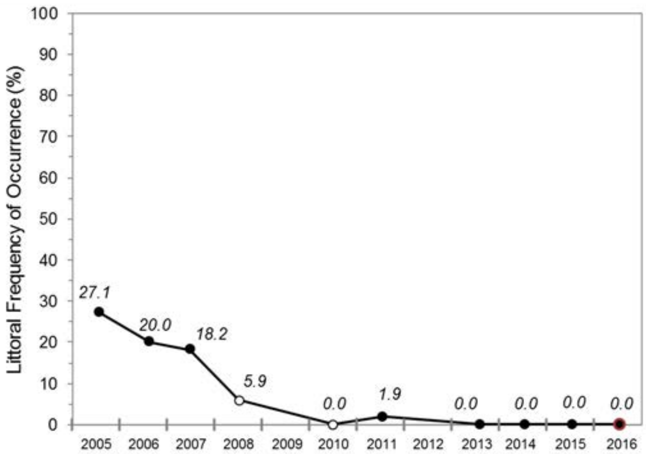
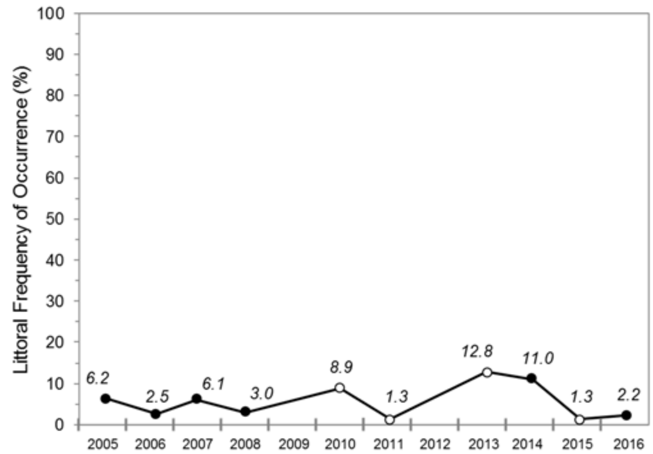


Figure 3.3-5 continued. Littoral frequency of occurrence of select native aquatic plant species in Boot Lake from 2005-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from the 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys whole-lake point-intercept surveys.

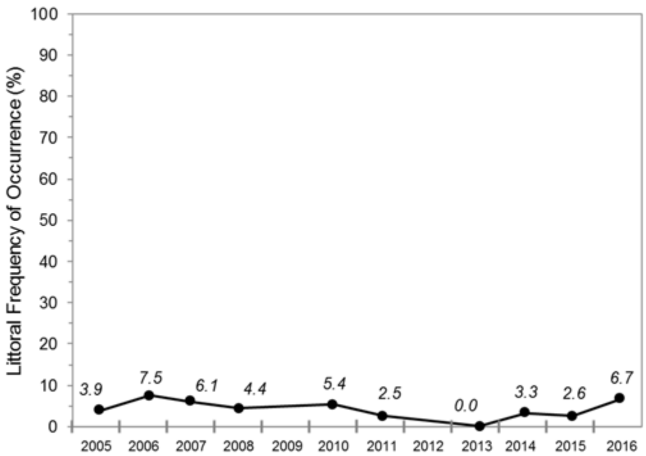
Forked duckweed (*Lemna trisulca*)



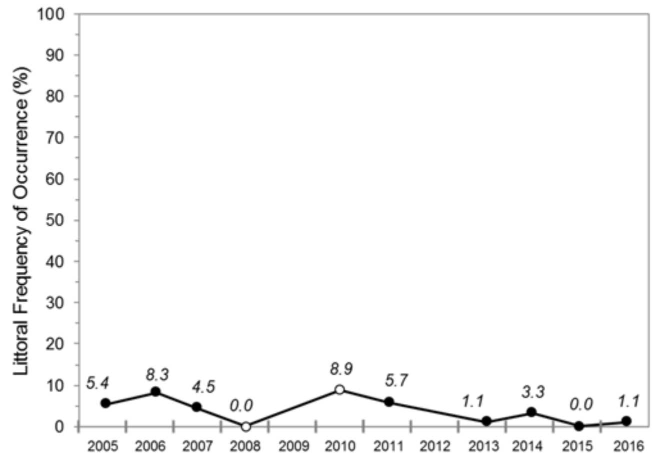
White-stem pondweed (*Potamogeton praelongus*)



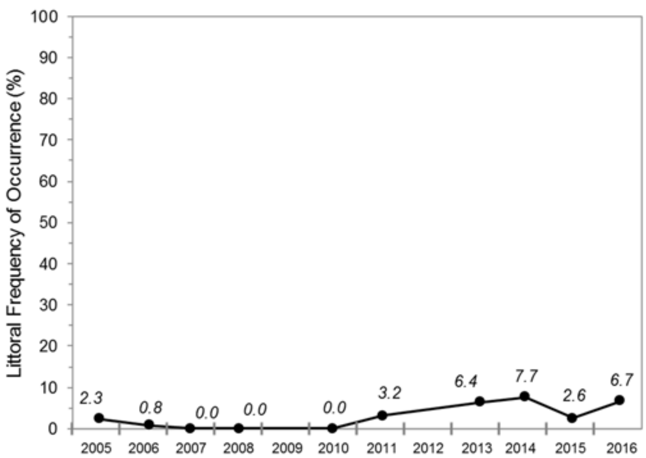
Variable-leaf pondweed (*Potamogeton gramineus*)



Water horsetail (*Equisetum fluviatile*)



Spiral-fruited pondweed (*Potamogeton spirillus*)



Fries' pondweed (*Potamogeton friesii*)

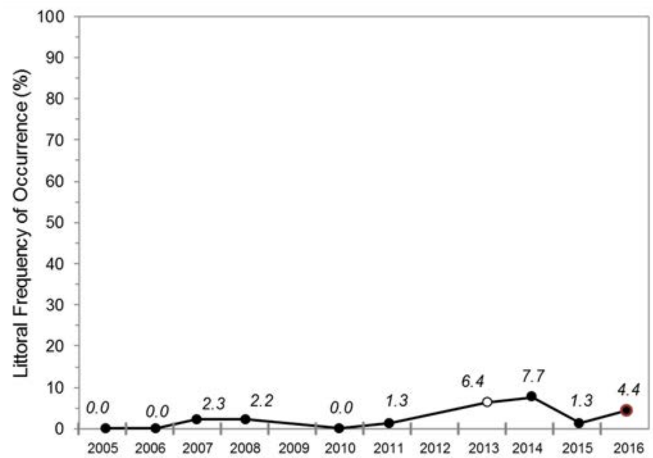


Figure 3.3-5 continued. Littoral frequency of occurrence of select native aquatic plant species in Boot Lake from 2005-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from the 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys whole-lake point-intercept surveys.

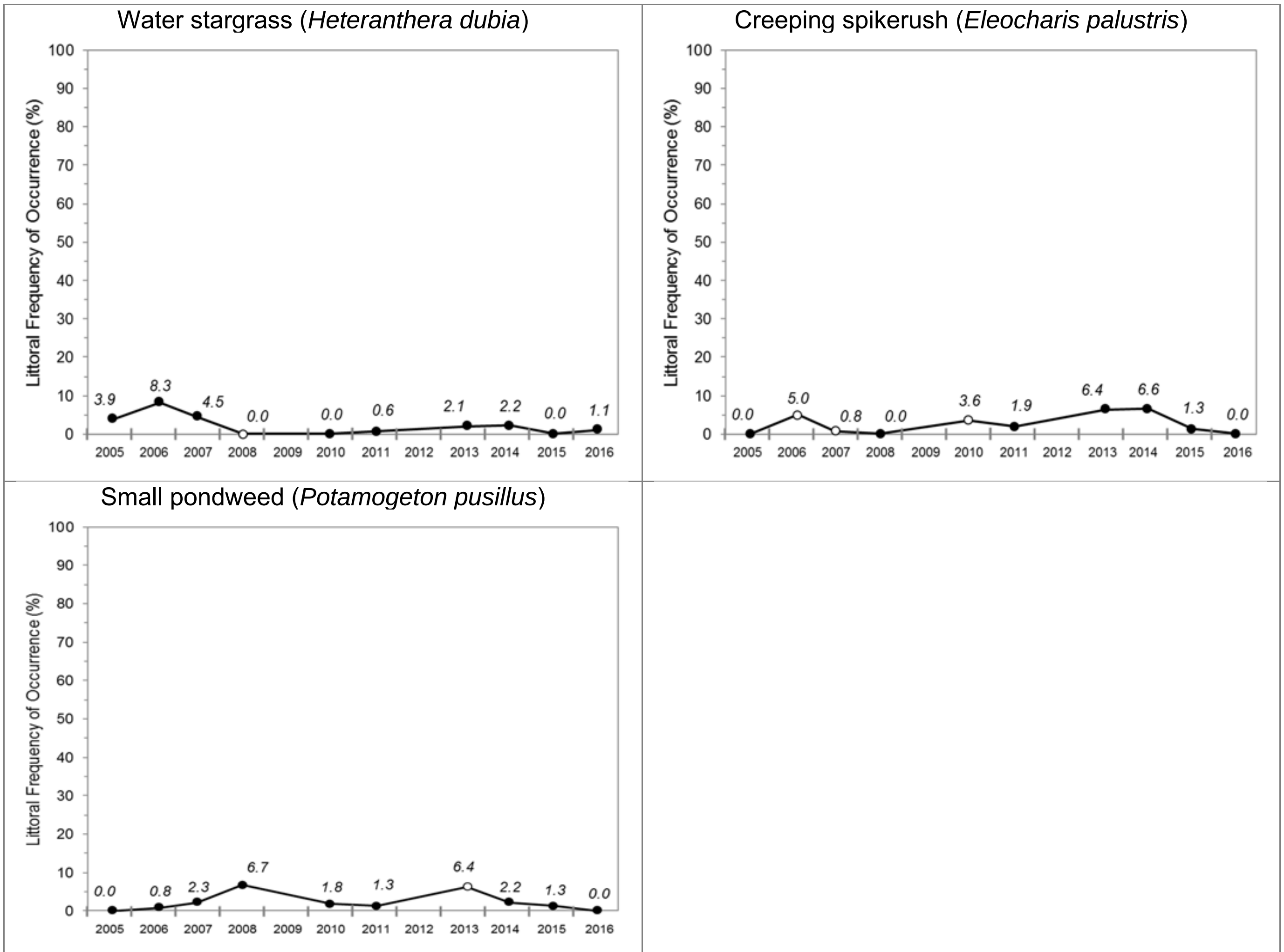


Figure 3.3-5 continued. Littoral frequency of occurrence of select native aquatic plant species in Boot Lake from 2005-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from the 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys whole-lake point-intercept surveys.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total of 39 native aquatic plant species were located in Boot Lake during the 2016 surveys, 26 were directly encountered on the rake during the point-intercept survey. Boot Lake's native aquatic plant species richness in 2016 (27) is above the median value for both lakes within the Northern Lakes and Forests Lakes (NLF) ecoregion and lakes throughout Wisconsin (Figure 3.3-6). The species richness recorded in 2016 was lower than that recorded during the 2006 (31), 2007 (30), 2010 (28), and 2011 (31) but higher than the 2005 (26), 2008 (20), 2013 (25), 2014 (26) and 2015 (22) point-intercept surveys. Overall, this variance in native species richness is not uncommon and 2016 seems to have been an average year for Boot Lake.

The average conservatism of the 27 native aquatic plants recorded on the rake in 2016 was 6.4, falling just below the median value (6.7) for lakes within the NLF ecoregion and just above the median value (6.3) for lakes throughout Wisconsin (Figure 3.3-7). This indicates that Boot Lake has a slightly lower number of native aquatic plant species with high conservatism values when compared to the majority of lakes within the NLF ecoregion. Average conservatism in 2016 was the same as 2005, 2006, 2008, 2010, 2014 but lower than 2007 (6.6), 2011 (6.5), and 2015 (6.5).

Using Boot Lake's 2016 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 33.3, which is above the median value for lakes within the NLF ecoregion and the state (Figure 3.3-8). This indicates that Boot Lake's aquatic plant community is of higher quality in terms of species richness and community composition than half the of lakes within the ecoregion and the state. Given that native species richness and average conservatism were higher in 2016 when compared to 2005, 2008, 2013. 2014, and 2015 but lower than 2006, 2007, 2010, and 2011, the 2016 Floristic Quality Index value was reflective of those values.

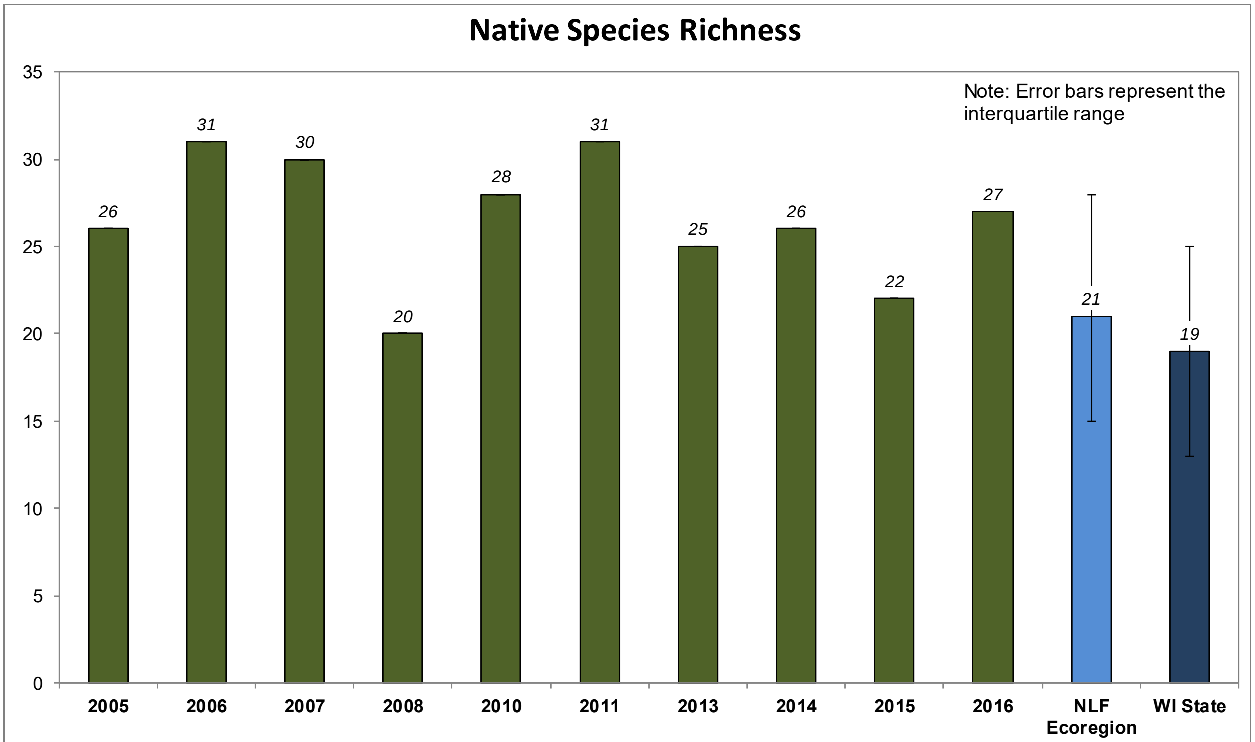


Figure 3.3-6. Boot Lake Native Species Richness. Created using data from 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys. Analysis following Nichols (1999) where NLF = Northern Lakes and Forest Lakes Ecoregion.

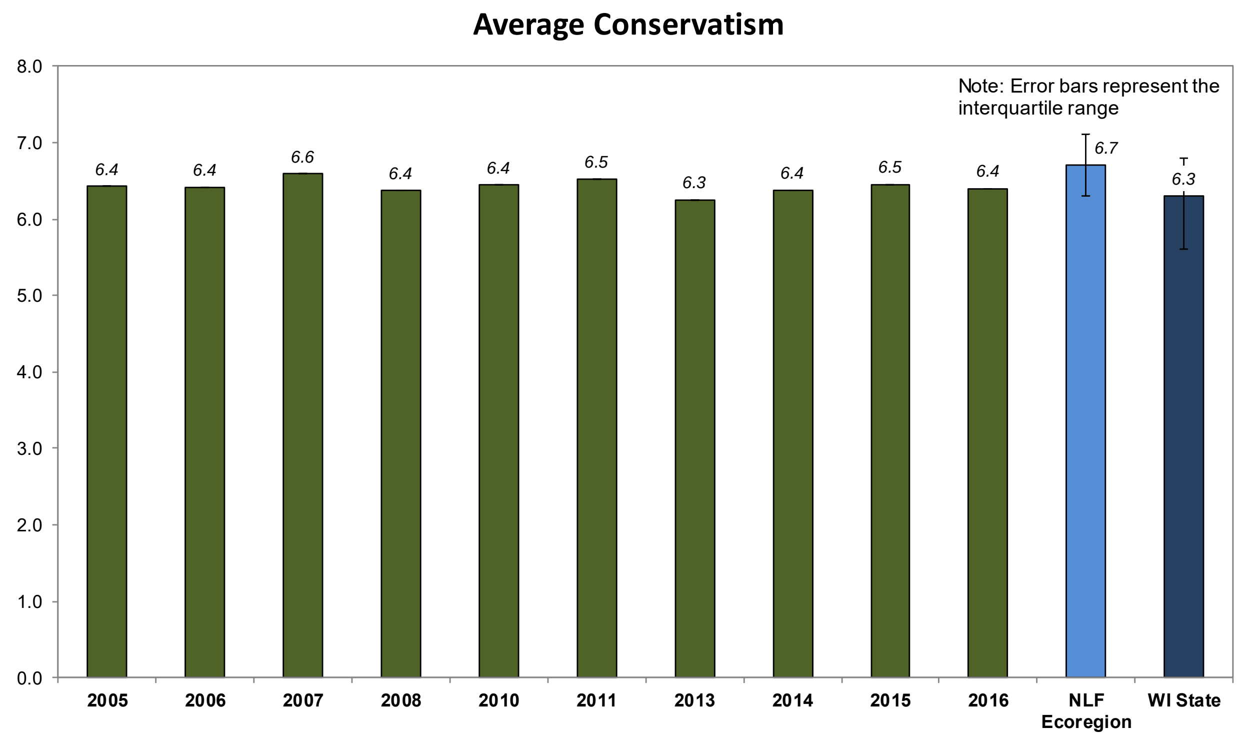


Figure 3.3-7. Boot Lake Average Conservatism. Created using data from 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys. Analysis following Nichols (1999) where NLF = Northern Lakes and Forest Lakes Ecoregion.

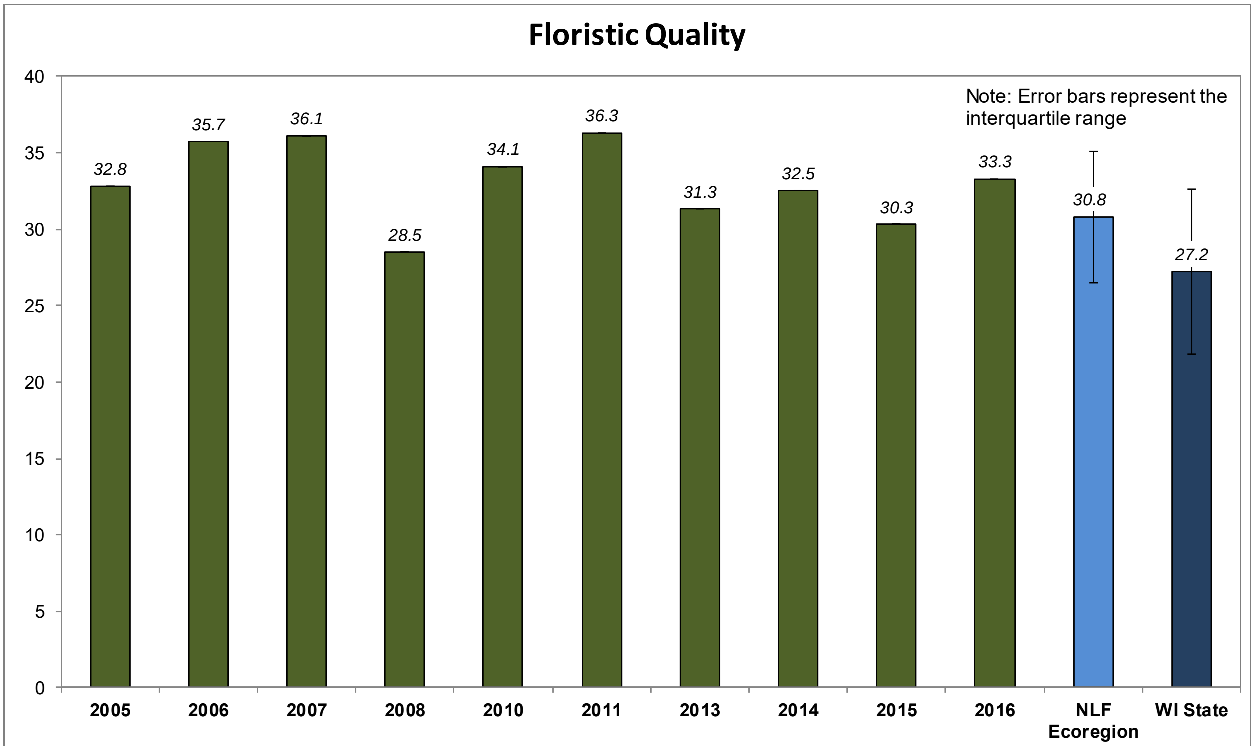


Figure 3.3-8. Boot Lake Floristic Quality. Created using data from 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys. Analysis following Nichols (1999) where NLF = Northern Lakes and Forest Lakes Ecoregion.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Boot Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF ecoregion (Figure 3.3-9). Using the data collected from the 2005-2016 point-intercept surveys, Boot Lake's aquatic plant community is shown to have relatively high species diversity. Simpson's Diversity Index values were 0.90 or above from 2005-2016 with five of the years having a Simpson's Diversity Index of 0.94. All diversity value fall at or above the upper quartile value of 0.90 for lakes in the NLF ecoregion.

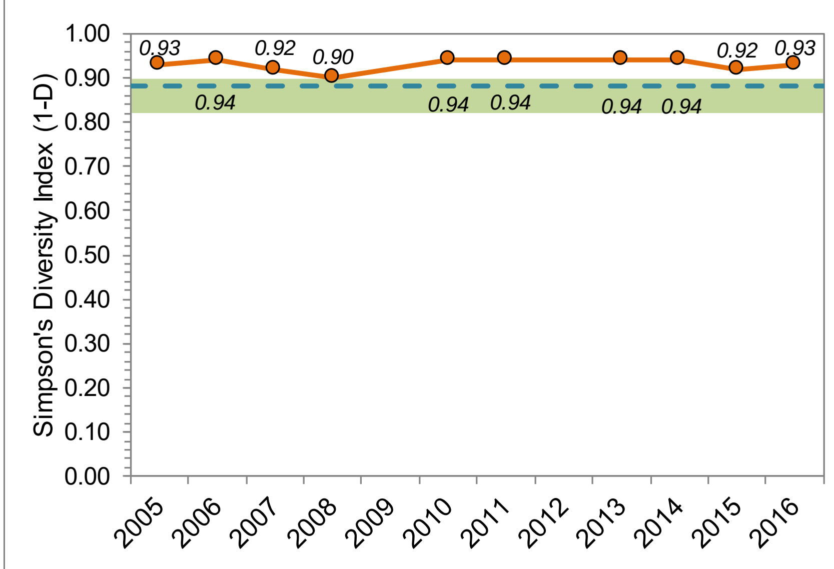


Figure 3.3-9. Boot Lake species diversity index. Created using data from 2005-2016 aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

The quality of Boot Lake's plant community is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The 2016 community map indicates that approximately 64.3 acres (21.8%) of the 295 acre-lake contain these types of plant communities (Table 3.3-2 and Map 5). This acreage is greater than found in 2009 by Onterra, 57.6 acres or 19.5%. The largest increase seen was a population of spatterdock and whitewater lily found on the southern shore of Boot Lake. There were other small increases around the lake. Map 5 displays both the 2009 and 2016 community mapped areas, allowing for comparison. Twenty floating-leaf and emergent species were located on Boot Lake, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

As explained above in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while slender naiad was found at 40% of the sampling locations in Boot Lake, its relative frequency of occurrence is 16%. Explained another way, if 100 plants were randomly sampled from Boot Lake, 16 of them would be slender naiad. Looking at relative frequency of occurrence (Figure 3.3-10), three species comprise approximately 37% of the plant community in Boot Lake while another 13 species make up an additional 19%. This speaks to the high diversity and relatively low dominance of each plant species found in Boot Lake.

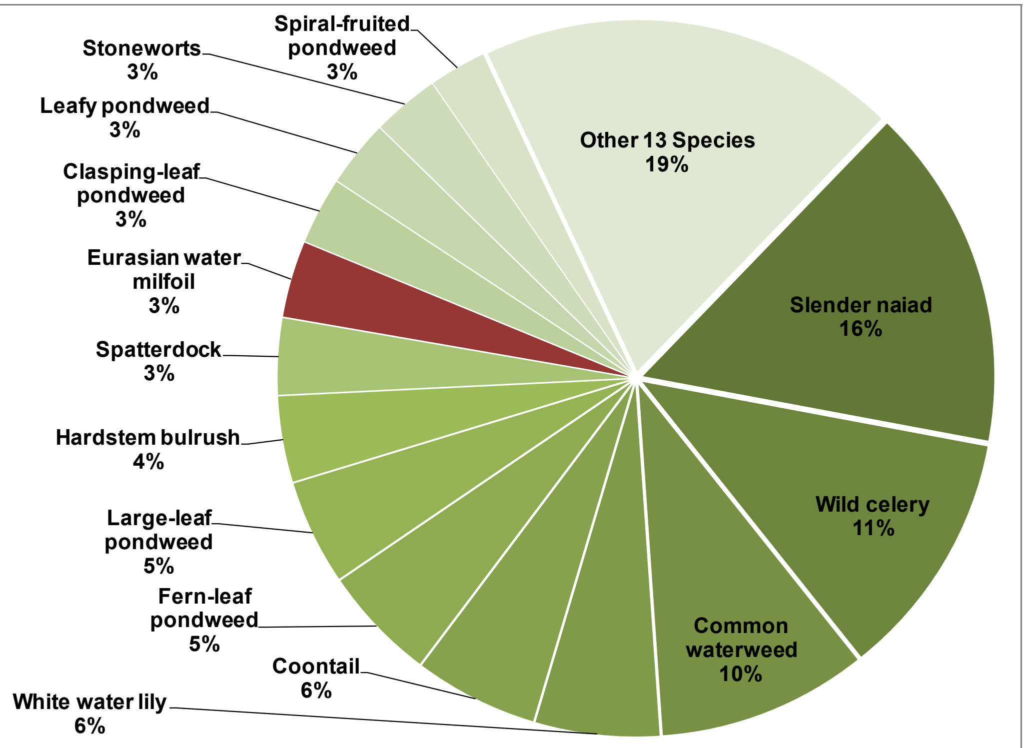


Figure 3.3-10. Boot Lake relative plant littoral frequency of occurrence. Created using data from July 2016 surveys.

Common reed, also known as *Phragmites*, has been found within Boot Lake. While there is a non-native, invasive subspecies of *Phragmites* (*Phragmites australis* subsp. *australis*) found within Wisconsin, the species found within in Boot Lake is the native subspecies (*Phragmites australis* subsp. *americanus*). In 2009, 1.1 acres of common reed were found around the lake and in 2016, approximately 2.0 acres were found (Map 6). This slight increase in acreage over seven years is not alarming and furthers the confirmation that the *Phragmites* found on Boot Lake is the native strain and not the invasive strain.

Table 3.3-2. Boot Lake acres of plant community types. Created from Onterra 2009 & 2016 community mapping survey.

Plant Community	2009 Acres	2016 Acres
Emergent	12.6	14.7
Floating-leaf	10.7	18.3
Mixed Emergent & Floating-leaf	34.4	31.3
Total	57.6	64.3

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 Boot 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.

Non-native Plants in Boot Lake

Eurasian watermilfoil

Eurasian watermilfoil (EWM) was first documented in Boot Lake in 2000. Onterra was hired in 2009 to development management plans for lakes within the Town of Cloverland, including Boot Lake. Onterra ecologists mapped the EWM in 2009, and following discussions between the Boot Lake Association (BLA), Onterra, and the WDNR, it was concluded am herbicide treatment should occur. However, since that discussion, the EWM populations has declined naturally so no treatment occurred. Figure 3.3-11 displays the EWM littoral frequency of occurrence from 2005 to 2016. While the occurrence of EWM was statistically different between some years from 2005 to 2016, statistical analysis indicates that its occurrence of 8.9% in 2016 is not statistically different from its occurrence of 16.3% in 2005.

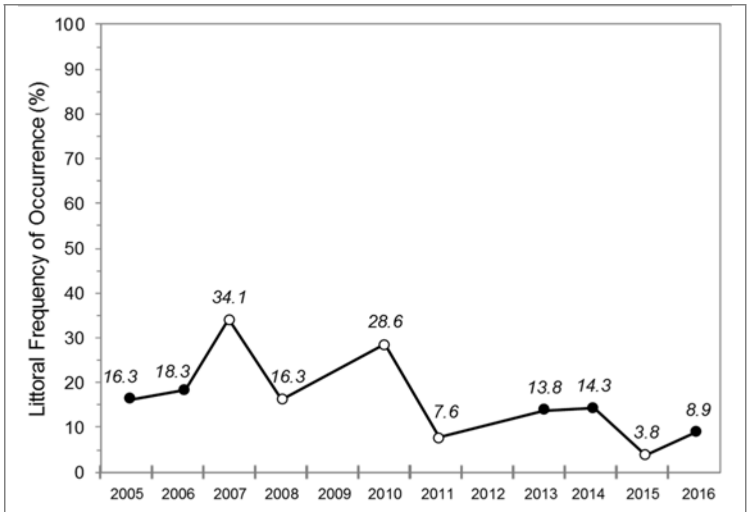


Figure 3.3-11. Littoral frequency of occurrence of in Boot Lake from 2005-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Created using data from 2005-2008 and 2011-2015 WDNR surveys and 2010 and 2016 Onterra surveys

Mapping of EWM in Boot Lake indicates that the acreage of colonized areas of EWM (polygons) has declined from 31.6 acres in 2009 to 20.5 acres in 2016 (Figure 3.3-12). In addition, the acres of EWM delineated as *dominant*, *highly dominant*, and *surface matted* also declined indicating a decrease in EWM density. In 2009, 27.4 acres of EWM were delineated with a density rating of *dominant* or greater while only 0.24 acres contained EWM with a density rating of *dominant* or greater.

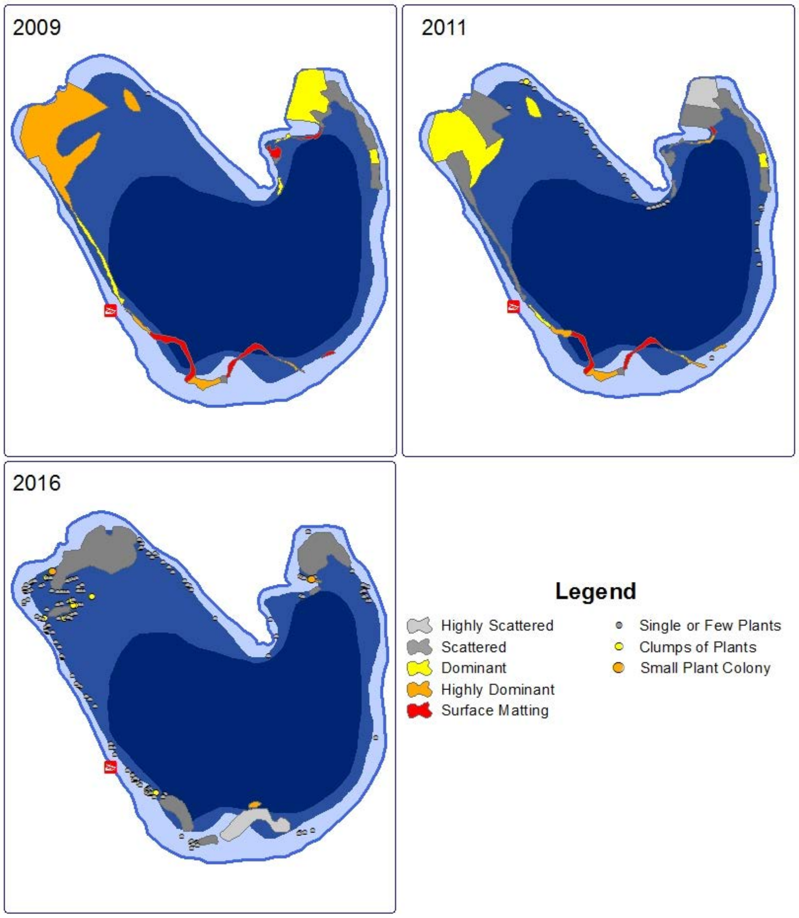


Figure 3.3-12. Boot Lake locations 2009-2016. Locations mapped during survey completed by Onterra 2009-2016.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2007, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes (including Boot Lake) to understand how EWM populations vary over time and space, as well as how management activities impact both short- and long-term EWM (and native plant) population dynamics. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes are not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 3.3-13). The upper frame of Figure 3.3-13 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected unmanaged lakes were moved into the managed category as the EWM populations were targeted for control by the local lake organization.

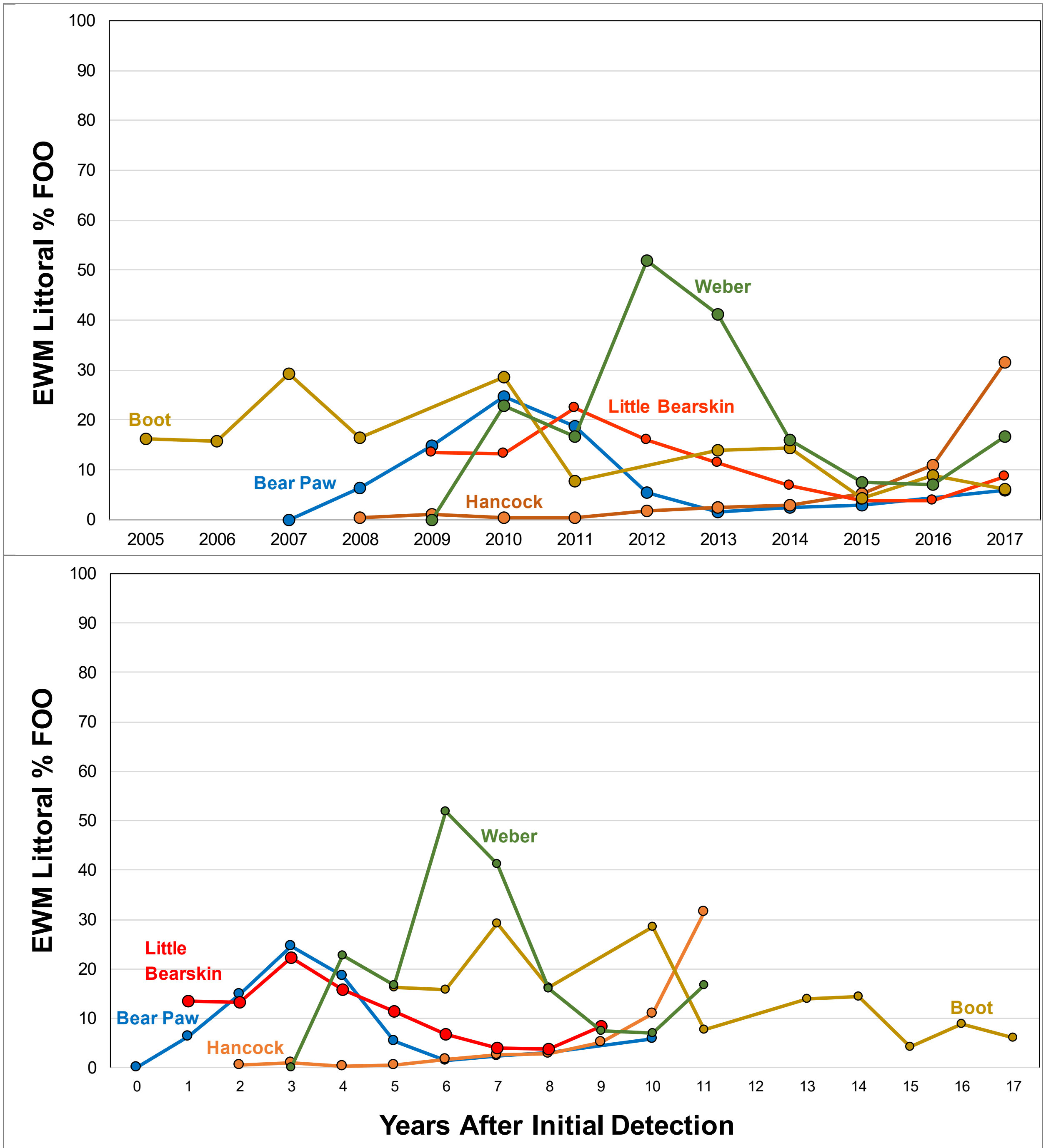


Figure 3.3-13. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

Some lakes, such as Hancock Lake, maintained low EWM populations over the study averaging a littoral occurrence of 3.3% between 2008 and 2015. At these low levels, there are likely no observable ecological impacts to the lake and are no reductions in ecosystem services to lake users. The EWM population of Hancock Lake has increased in recent years to almost 32% in 2017, which corresponds to 11 years after its initial detection.

Eurasian watermilfoil populations in other lakes, such as Bear Paw Lake and Little Bearskin Lake, trended to almost 25% only three years following initial detection. The EWM population of Bear Paw Lake declined to below 2% by six years after detection and has increased to approximately 6% in 2017 (10 years after initial detection). The EWM population on Little Bearskin Lake followed a similar trend, but the magnitude of the decline was less and was just below 10% in 2017 (9 years after initial detection).

Boot Lake is a eutrophic system with low water clarity due to naturally-high phosphorus concentrations. It is hypothesized that water clarity conditions in some years may favor EWM growth whereas changes in these conditions may keep the population suppressed in other years. Since 2011, the EWM population of Boot Lake has stabilized around 10%, corresponding to 11-17 years following initial detection.

Rapid and large fluctuations in the occurrence of EWM like those observed on Weber Lake have also been documented. The EWM population in 2010-2011 was approximately 20% before rapidly increasing above 50% in 2012, corresponding with six years after being initially detected in the lake. Then the population declined to under 10% in 2015 and 2016, and has rebounded to approximately 17% in 2017.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Regional climatic factors also seem to be a driver in EWM populations, as many EWM populations declined in 2015 even though the lakes were at vastly different points in time following initial detection within the lake.

Purple loosestrife

Purple loosestrife (Photograph 3.3-5) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

Photograph 3.3-5. Purple loosestrife, a non-native, invasive wetland plant. Photo credit Onterra.

One purple loosestrife occurrence was located growing along the north side of Boot Lake's shoreline (Map 5). This occurrence was comprised of a single or few plants, and no large monotypic colonies were observed. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal

4.0 METHODS

Lake Water Quality

Water quality was monitored at the deepest point in Boot Lake by Onterra staff. Samples were collected at subsurface (S) depths during June, July, and August and near bottom (B) only in July. All samples requiring laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene. The parameters measured and sample collection timing are contained in Table 5.0-1.

Table 5.0-1. Water Quality Sample Parameters and Timing

Parameter	June	July		August
	S	S	B	S
Total Phosphorus	●	●	●	●
Total Nitrogen		●	●	
Chlorophyll-*a*	●	●		●

Furthermore, during each sampling event, Secchi disk transparency were recorded and a temperature and dissolved oxygen profile was completed.

Aquatic Vegetation

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Boot 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 26, 2016. A point spacing of 60 meters was used resulting in approximately 315 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Boot 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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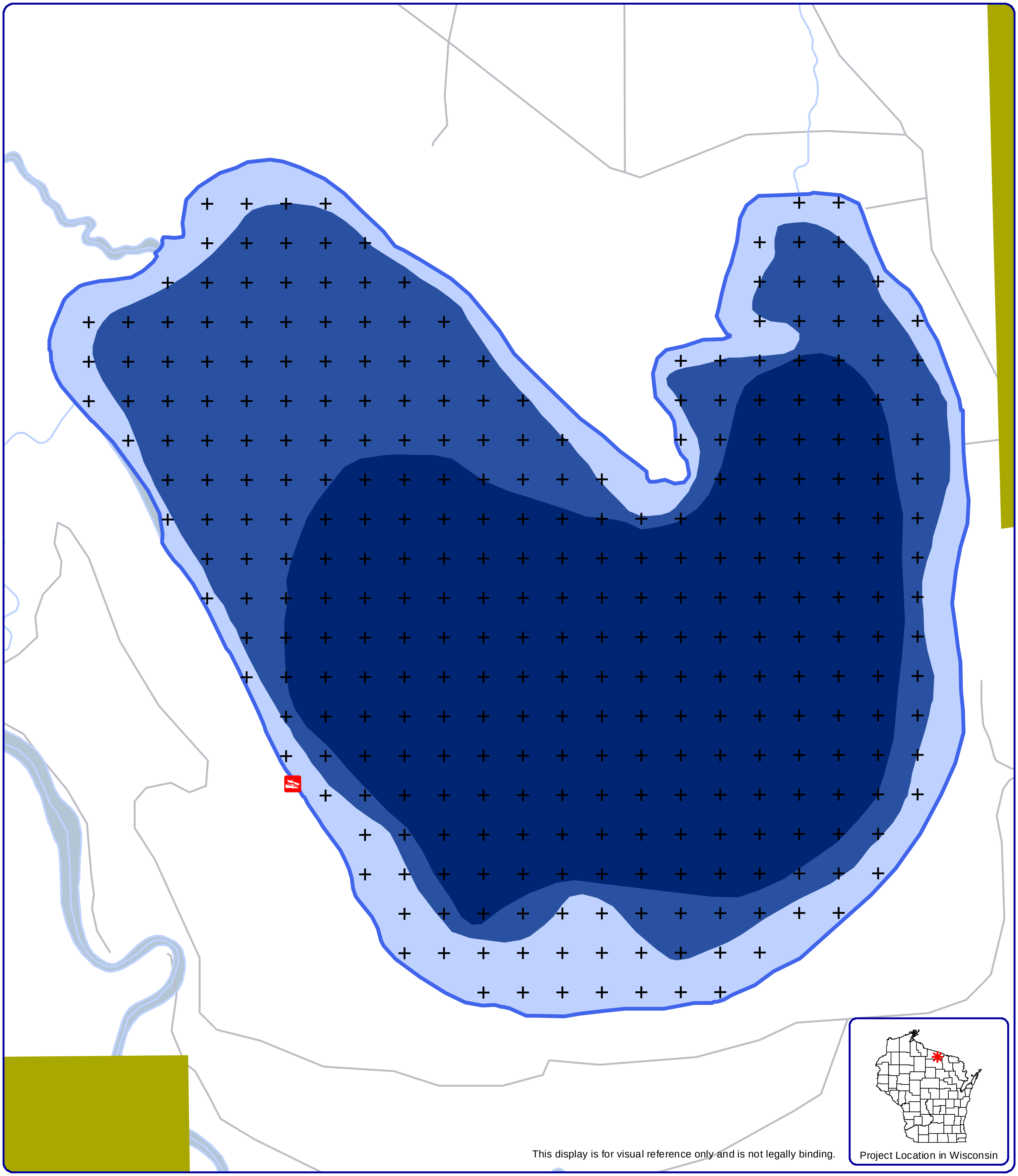

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Feet

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1967; digitized by Onterra
Map Date: December 8, 2016
Filename: Boot_Location_Boundaries.mxd

Legend

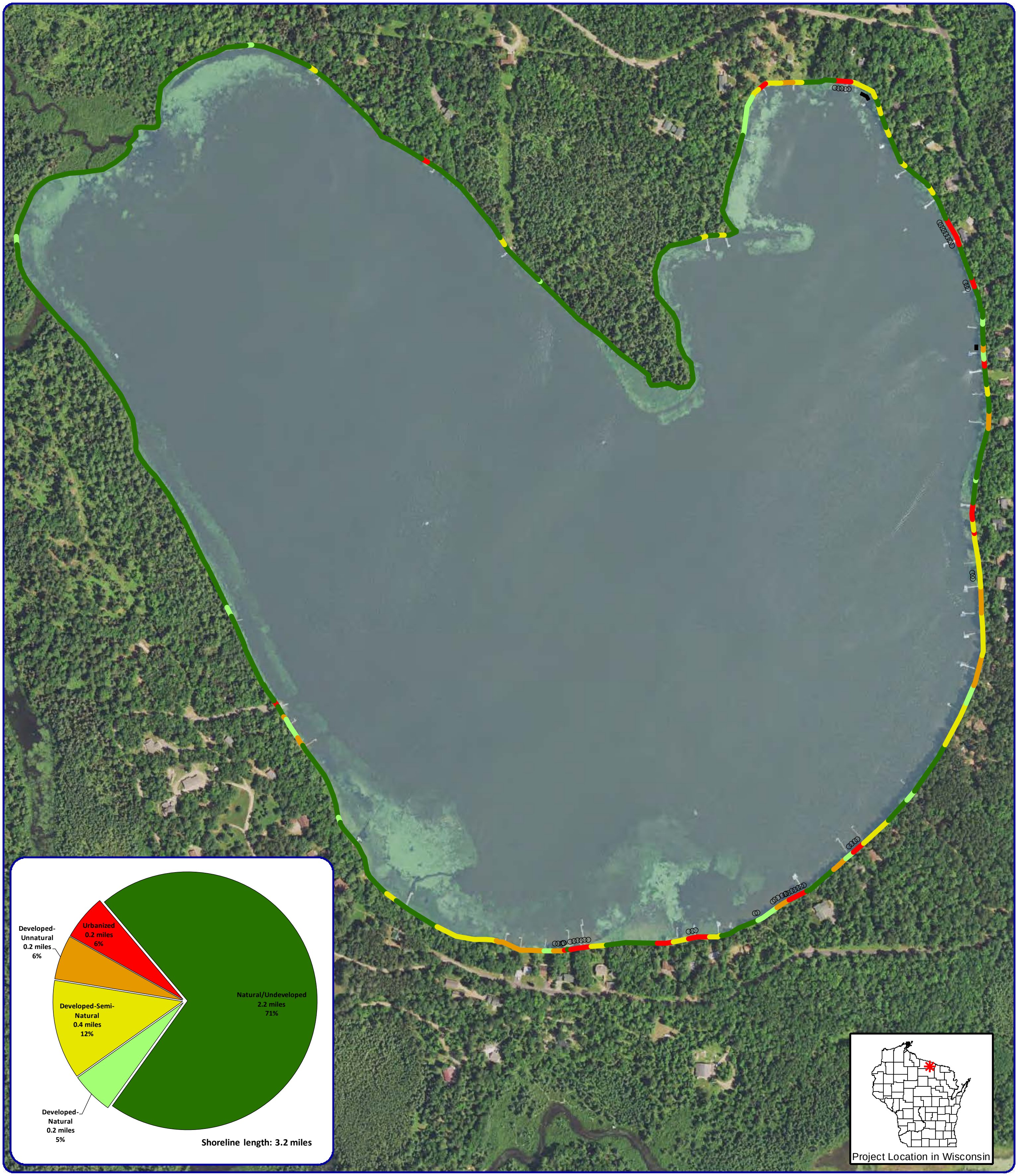
Boot Lake ~295 acres
Ortho-rectified Definition

Point-Intercept Survey Location
60-meter spacing, 315 total points

Public Boat Landing

Vilas County Forest Lands

Map 1
Boot Lake
Vilas County, Wisconsin
Project Location & Lake Boundaries



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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Orthophotograph: NAIP 2015
Map Date: November 22, 2016
Filename: Boot_SCA_2016.mxd

Legend

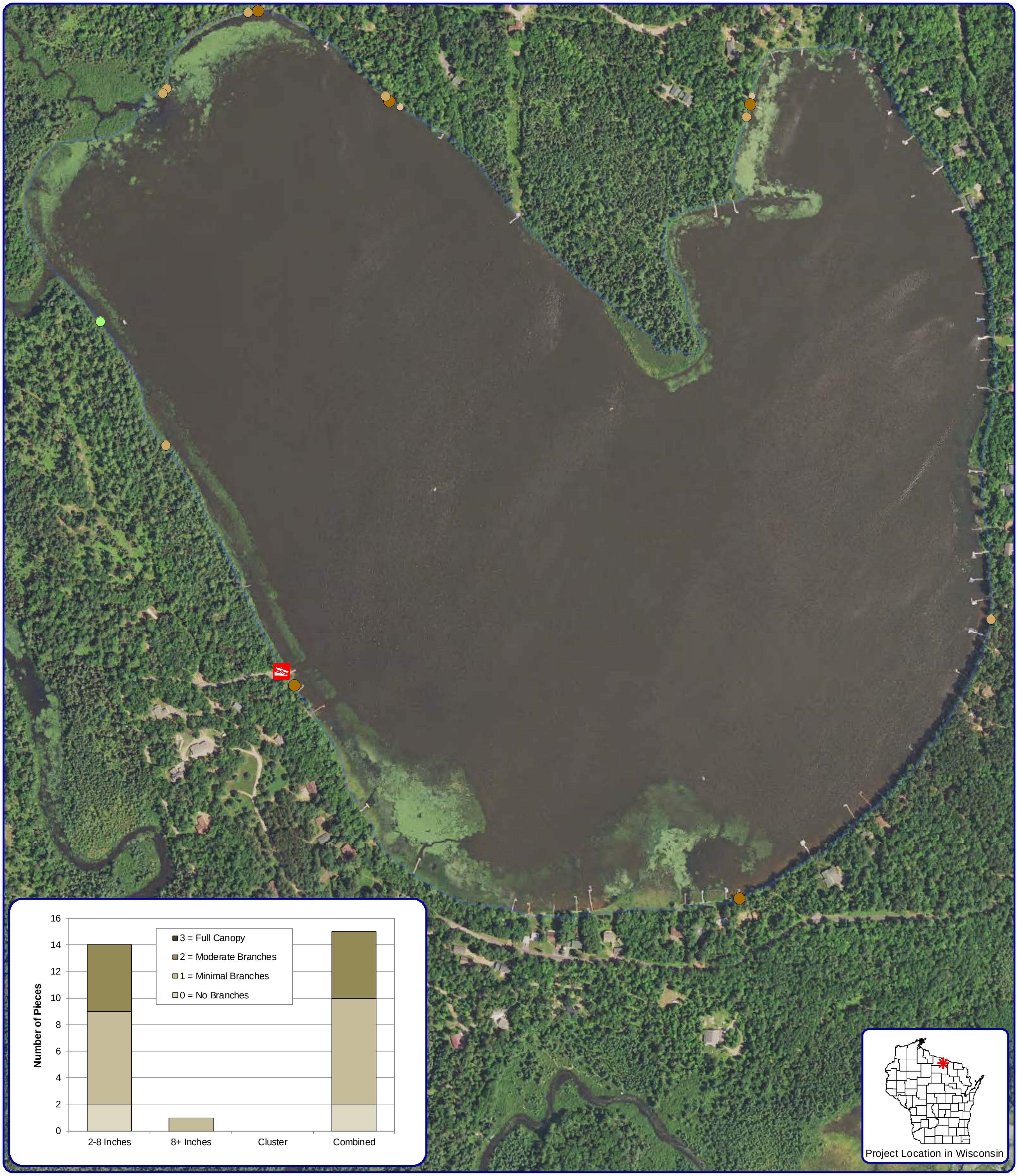
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall
Rip-Rap

Map 2

Boot Lake
Vilas County, Wisconsin

2016 Shoreline Condition Assessment



N
W E
S
600
Feet

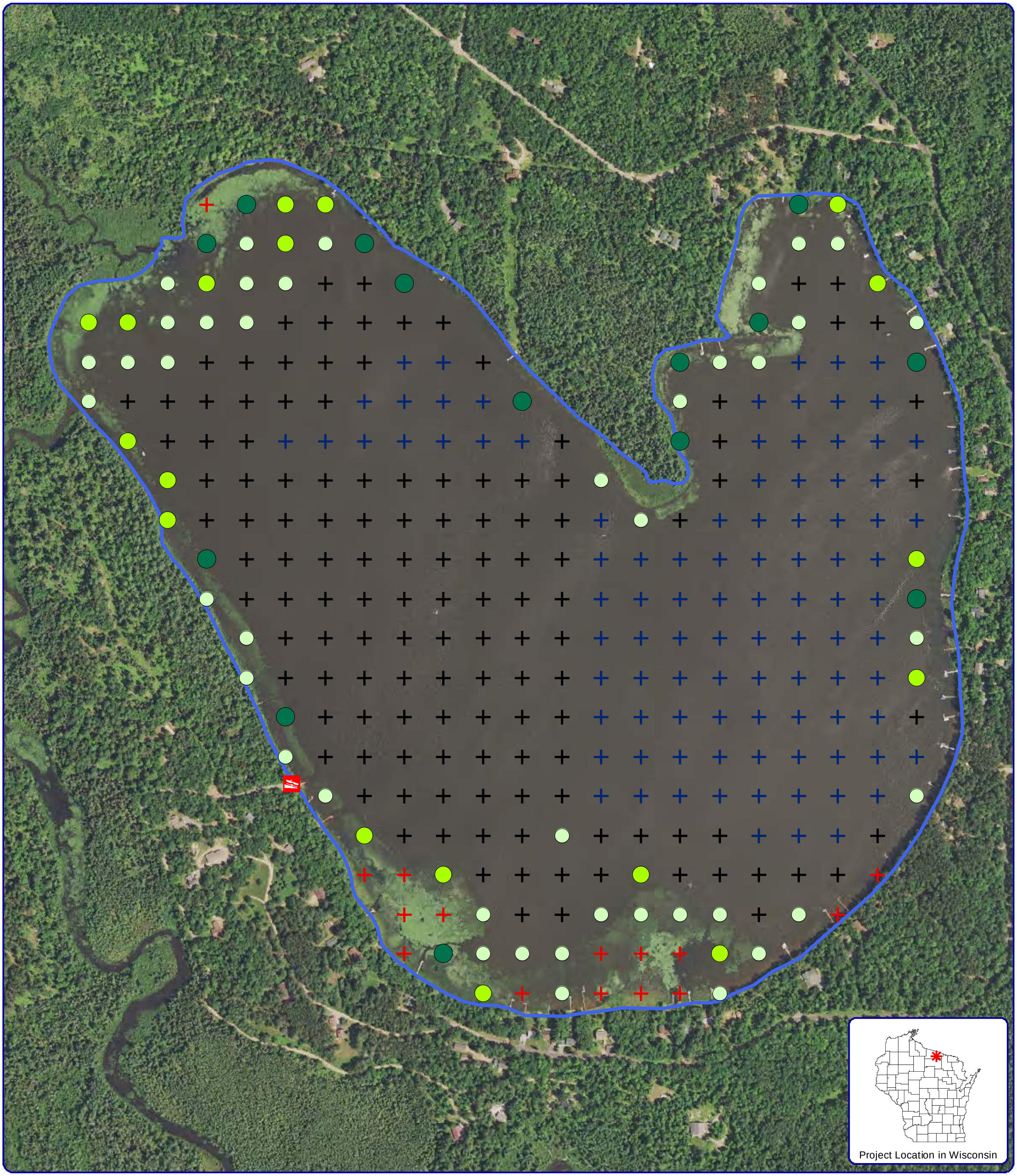
Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches *(None)*	No Branches *(None)*
Minimal Branches	Minimal Branches	Minimal Branches *(None)*
Moderate Branches	Moderate Branches *(None)*	Moderate Branches *(None)*
Full Canopy *(None)*	Full Canopy *(None)*	Full Canopy *(None)*

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Orthophotograph: NAIP 2015
Map Date: November 18, 2016
Filename: Boot_CWH_2016.mxd

Map 3
Boot Lake
Vilas County, Wisconsin
2016 Coarse Woody Habitat



N
W E
S

600

Feet

Onterra LLC
Lake Management Planning
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De Pere, WI 54115
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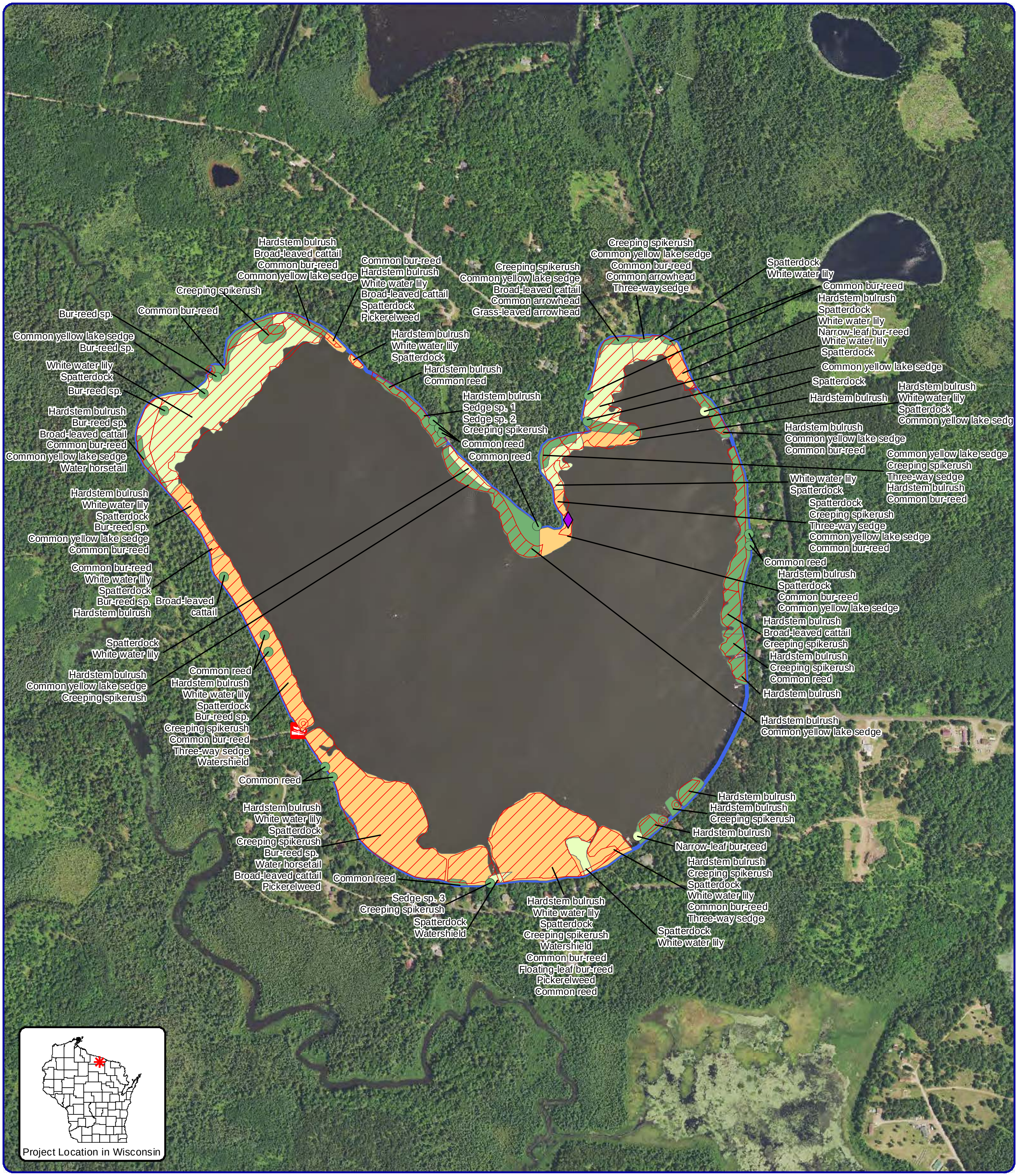
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1967; digitized by Onterra
Map Date: December 8, 2016
Filename: Map4_Boot_TRF_2016.mxd

Legend

- + No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- + Deeper than Max Depth of Plants
- + Non-navigable - No Data

Map 4
Boot Lake
Vilas County, Wisconsin

2016 Aquatic Vegetation Distribution



N
W E
S
950
Feet

Legend

2009 Plant Communities
- Small Emergent and/or Floating-leaf
- Large Emergent and/or Floating-leaf

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple loosestrife

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

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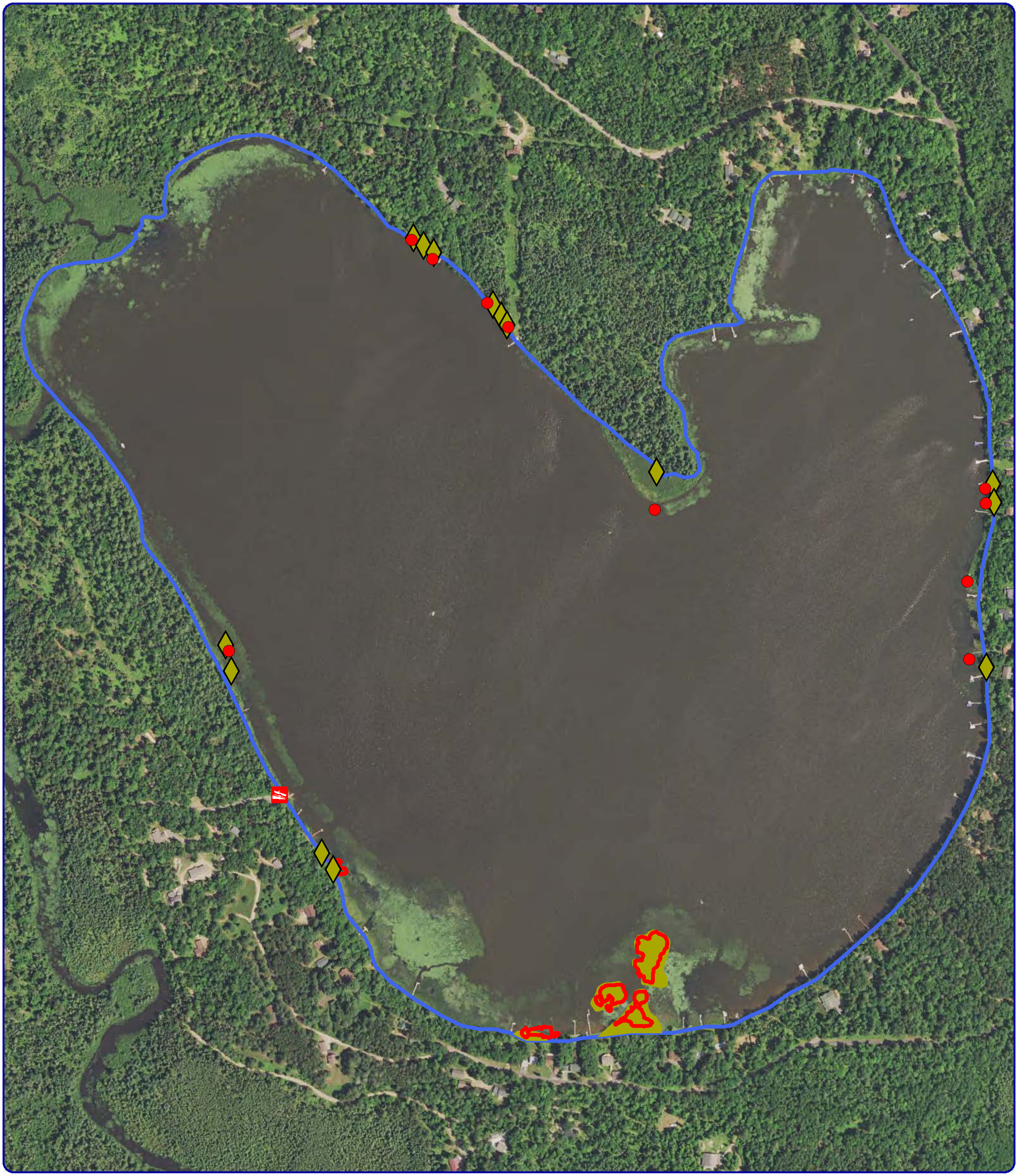
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Map Date: May 4, 2017
Filename: Boot_Comm_2016.mxd

Map 5
Boot Lake
Vilas County, Wisconsin
2016 Plant Survey: Community Mapping



600

Feet

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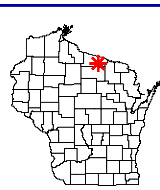
<Bol>Sources:</Bol>
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2009&2016
Map Date: May 5, 2017
Filename: Boot_NativePhrag_2009&2016.mxd



Project Location in Wisconsin

Legend

Small Plant Communities
- 2009 Phragmites
- 2016 Phragmites

Large Plant Communities
- 2009 Phragmites
- 2016 Phragmites

Map 6
Boot Lake
Vilas County, Wisconsin
Common Reed Community Map