INTRODUCTION


Photo 1. White Lake, Waupaca County.

White Lake, Waupaca County, is a 1,024-acre eutrophic, shallow, drainage lake with a maximum depth of 10 feet and watershed to lake area ratio of 2:1 (Photo 1). In 2015, the lake was found to contain 32 native plant species, of which southern naiad was the most common plant. White Lake contains extensive emergent plant communities comprised of southern wild rice, hardstem and softstem bulrush, cattails, and water willow.

The non-native, invasive plant curly-leaf pondweed (*Potamogeton* crispus; CLP) was first discovered in White Lake in 1992. Curly-leaf pondweed surveys completed by Onterra ecologists in early June of 2010 - 2012, found that while CLP was widespread throughout the lake, the population was mainly comprised of single plants that were likely having little impact on the lake's ecology; however, some large areas comprised of dense, colonized CLP were located that were likely causing localized ecological and recreational use impacts. During the management planning project completed in 2012, control alternatives were discussed and the planning committee developed a control strategy for the dense areas while continuing to monitor the CLP within the remainder of the system.

The White Lake Preservation Association (WLPA) completed a management plan in 2012 (*White Lake Comprehensive Management Plan, Onterra, May 2012*). The plan created new thresholds and triggers for the continued control of CLP and Eurasian water milfoil (*Myriophyllum spicatum*; EWM) within White Lake. In August 2012, the WLPA successfully applied for its first Wisconsin Department of Natural Resources (WDNR) Aquatic Invasive Species (AIS) Established Population Control Grant to initiate a four-year project implementing the goals and actions outlined within the plan.

This report discusses the final year of this project, which involved an 18.9-acre endothall treatment targeting the densest colonies of CLP within the lake as well as continued monitoring of the EWM population. Additionally, comprehensive studies of the native aquatic plant populations that were conducted in 2010 were replicated in 2015, the final year of the project. By comparing the aquatic plant communities between the two surveys, an understanding of the native plant populations' response to the CLP management program can be formulated.

PRIMER ON DATA ANALYSIS & DATA INTERPRETATION

Aquatic Plant Sampling Methodology and Data Analysis

Surveys were conducted on White Lake in 2015 to assess the aquatic plant communities following numerous years of herbicide treatments to control CLP and EWM. Native aquatic plants are an important element in every healthy aquatic ecosystem, providing food and habitat to wildlife, improving water quality, and stabilizing bottom sediments. Because most aquatic plants are rooted in place and are unable to relocate in wake of environmental alterations, they are often the first community to indicate that changes may be occurring within the system. Aquatic plant communities can respond in variety of ways; there may be increases or declines in the occurrences of some species, or a complete loss. Or, certain growth forms, such as emergent and floating-leaf communities may disappear from areas of the waterbody. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide relevant information for making management decisions. During the course of this project, native and non-native plants were inventoried and assessed utilizing three survey methodologies, as described below.

Point-intercept survey

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was used to complete the whole-lake point-intercept surveys on White Lake Lake in 2010 and 2015. Based upon guidance from the WDNR, a point spacing (resolution) of 82 meters was used resulting in 640 sample locations (Map 1).

At each point-intercept location within the littoral zone, information regarding the depth, substrate type (muck, sand, or rock), and the plant species sampled along with their relative abundance (Figure 1) on the sampling rake was recorded. A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 15 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 15 feet. Depth information was collected using graduated marks on the pole of the rake or using an onboard sonar unit at depths greater than 15 feet. Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately feel the bottom with this sampling device. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

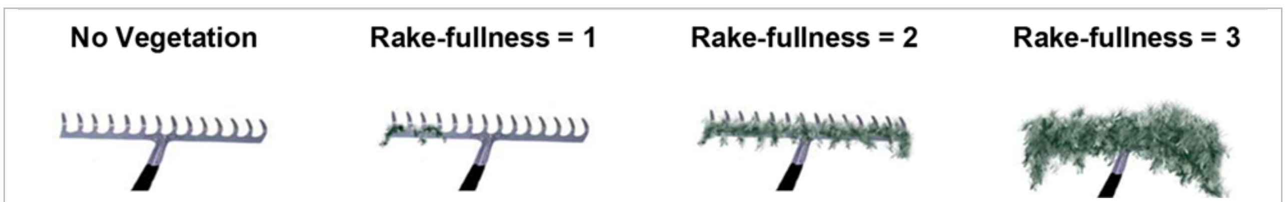


Figure 1. Aquatic plant rake-fullness ratings. Adapted from Hauxwell et al (2010).

When appropriate, a modified point-intercept sub-sampling methodology was used within EWM treatment areas in an effort to quantitatively evaluate success of the treatment. These efforts are discussed thoroughly in annual treatment reports produced for the White Lake 2013 and 2014.

Community mapping survey

The point-intercept methodology is very useful for capturing the species richness and diversity (discussed below) of a submersed aquatic plant community. However, often the presence of emergent or floating-leaf vegetation is not adequately sampled with this survey type. Emergent and floating-leaf vegetation are often found within shallow reaches of a lake and thus can be hard to access in watercraft. To document the presence of these aquatic plant communities, a community mapping survey was conducted on White Lake in 2010 and replicated in 2015. During these surveys, emergent and floating-leaf aquatic plant communities were documented with sub-meter accuracy GPS technology in two formats, point-based and polygon-based methods. A single GPS waypoint was taken at the location of smaller communities (less than 40 ft diameter or length) while polygons were delineated around larger communities. Species presence was also documented in order of most prevalent within the community to least prevalent. As previously discussed, differences in these communities between time periods may indicate environmental disturbances or recoveries in a lake ecosystem.

Aquatic invasive species peak-biomass surveys

When studying invasive plants like CLP and EWM, methodologies such as the point-intercept survey can be difficult to properly assess abundance and distribution of these species due to their often low abundance in the lake and the tendency for these species to form colonies. To adequately assess the CLP population within White Lake, Onterra staff carried out an Early-Season AIS Survey in the early summer of 2015. Surveys to locate CLP are normally conducted in early summer because this is when this plant reaches its peak growth before senescing (dying back) in late June to early July. A CLP treatment did occur in White Lake in 2015 so a spring pretreatment survey occurred to assess the CLP before treatment. The Early-Season AIS Survey was then used to assess CLP at its peak growth as well as an indicator for treatment success. In contrast to CLP, EWM reaches its peak growth in late summer, and to assess the EWM population, Onterra ecologists conducted Late-Summer Peak-Biomass Surveys annually on White Lake from 2010-2015.

During these surveys, plants are denoted with either point-based or polygon-based methods as described above in the community mapping discussion. Point-based CLP/EWM locations are described as *Single or Few Plants, Clumps of Plants* or as a *Small Plant Colony*. Polygon-base distinctions include *Highly Scattered* and *Scattered* for lightly dense areas, with *Dominant¸ Highly Dominant* and *Surface Matted* left to describe denser CLP/EWM colonies. These surveys produce maps which depict success/failures of herbicide treatments based upon qualitative observations. Additionally, they produce information that is vital for management planning for the following year.

Species List

The species list is simply a list of all of the species, both native and non-native, that were located during the whole-lake point-intercept and community mapping surveys in 2015 on White Lake. 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 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 surveys conducted in 2010 and 2015 on White Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these points, an estimate of occurrence of each plant species can be determined. In this section, the occurrences of aquatic plant species are displayed as their littoral frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the sampling sites that are within the littoral zone, and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake is calculated using its species richness and average species conservatism. Species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values (C-value) for each of those species in its calculation. A species coefficient of conservatism value indicates that species' likelihood of being found in an undisturbed system. The values range from 1 to 10. Species that can tolerate environmental disturbance and are can be located in disturbed systems have lower coefficients, while species that are less tolerant to environmental disturbance and are restricted to high quality systems have higher values. For example, coontail (*Ceratophyllum demersum*), a submergent native aquatic plant species with a C-value of 3, has a higher tolerance to disturbed conditions, often thriving in lakes with higher nutrient levels and low water clarity, while other species like algal-leaf pondweed (*Potamogeton confervoides*) with a C-value of 10, are intolerant of environmental disturbance and require high quality environments to survive.

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. White Lake falls within the North Central Hardwoods Forest Ecoregion of Wisconsin, and the floristic quality of its aquatic plant community in 2010 and 2015 will be compared to other lakes within this ecoregion as well as the entire state (Figure 2).

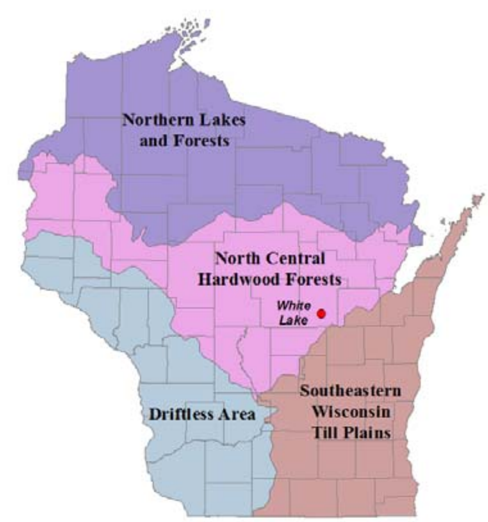


Figure 2. Location of White Lake within the ecoregions of Wisconsin. After Nichols (1999).

Species Diversity

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

An aquatic system with high species diversity is much 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. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity. Simpson's diversity index is used to determine this diversity in a lake ecosystem.
Simpson's diversity (1-D) is calculated as:

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to White Lake. Comparisons will be displayed showing median values and upper/lower quartiles of lakes in the same ecoregion (Figure 2) and in the state.

NATIVE AQUATIC PLANT SURVEY RESULTS

Comprehensive aquatic plant inventories were completed on White Lake twice – once in 2010 and 2015 by Onterra. A total of 46 aquatic plant species were located from White Lake, three of which are considered to be a non-native and invasive species: Eurasian water milfoil, curly-leaf pondweed, and purple loosestrife (Table 1).

During the 2015 point-intercept survey, aquatic plants were found growing to a maximum depth of 10 feet in White Lake. Data collected by Citizen Lake Monitoring Network volunteers indicates that average Secchi disk transparency was 6.3 feet during the summer. Water clarity (light penetration) determines how deep aquatic plants can grow, and in general, aquatic plants grow two to three times the depth of the average Secchi disk depth. The maximum depth of aquatic plants within White Lake in 2015 follows this relationship (Figure 3).

Of the points that fell within the littoral zone in 2015 (littoral frequency), 87% contained aquatic vegetation, compared to 93% in 2010. Plants were found to be growing to a maximum depth of 10 feet in both 2010 and 2015.

Figure 3 illustrates the distribution of aquatic plants in White Lake from the 2010 and 2015 surveys, and shows that distribution of aquatic plants was similar between these two surveys. Aquatic vegetation total rake fullness (TRF) ratings recorded in 2015 also indicate that where vegetation is present, it is also moderately dense, with 46% of the littoral sampling locations containing aquatic plants with TRF ratings of 2 or 3 (Figure 4).

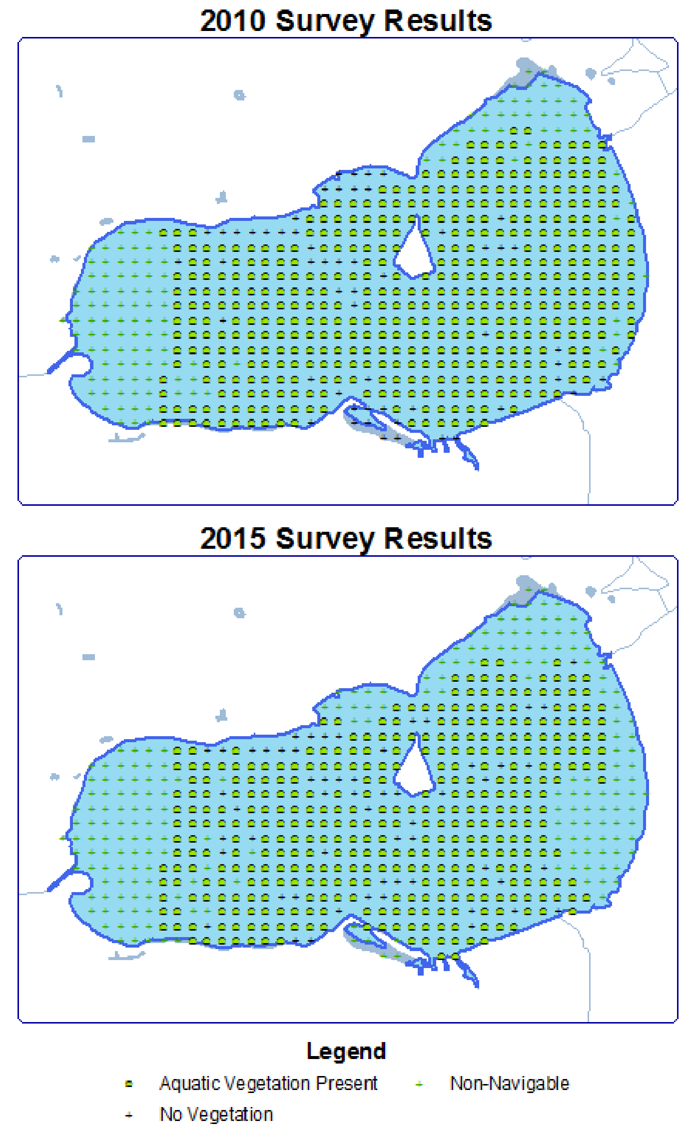


Figure 3. Distribution of aquatic vegetation in White Lake in 2008 and 2013. Created using data from 2010 and 2015 point-intercept surveys.

Table 1. Aquatic plant species found in White Lake during 2010 and 2015 studies.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2010 Onterra	2015 Onterra
Emergent	*Pontederia cordata*	Pickerelweed	9	X	
	Schoenoplectus acutus	Hardstem bulrush	5	X	X
	Typha latifolia	Broad-leaved cattail	1	X	
	Typha angustifolia	Narrow-leaved cattail	Exotic/Naturalized	X	
	Typha spp.	Cattail spp.	1		X
	Zizania spp.	Wild rice sp.	8	X	X
FL	*Brasenia schreberi*	Watershield	7	X	X
	Nymphaea odorata	White water lily	6	X	X
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3		X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3		X
	Isoetes spp.	Quillwort spp.	8		X
	Lobelia dortmanna	Water lobelia	10	X	
	Myriophyllum verticillatum	Whorled water milfoil	8	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	
	Myriophyllum spicatum	Eurasian water milfoil	Exotic/Invasive	X	
	Nitella spp.	Stoneworts	7	X	
	Najas guadalupensis	Southern naiad	7	X	X
	Potamogeton hybrid 1	Pondweed Hybrid 1	N/A	X	X
	Potamogeton friesii	Fries' pondweed	8		X
	Potamogeton crispus	Curly-leaf pondweed	Exotic/Invasive	X	
	Potamogeton pusillus	Small pondweed	7	X	
	Potamogeton strictifolius	Stiff pondweed	8	X	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X	
	Potamogeton natans	Floating-leaf pondweed	5	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Potamogeton illinoensis	Illinois pondweed	6	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton praelongus	White-stem pondweed	8	X	X
	Stuckenia pectinata	Sago pondweed	3	X	X
	Utricularia minor	Small bladderwort	10	X	X
	Utricularia gibba	Creeping bladderwort	9	X	
	Utricularia vulgaris	Common bladderwort	7	X	X
	Utricularia purpurea	Large purple bladderwort	9		X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	
	Sagittaria cristata	Crested arrowhead	9	X	X

FL = Floating-leaf; FL/E = Floating-leaf and Emergent; S/E = Submergent and Emergent; FF = Free-floating
X = Located on rake during point-intercept survey

During the 2015 whole-lake point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake. These data indicate that 91% of the point-intercept locations contained soft sediments (muck) and 9% contained sand (Figure 5).

The variations in substrate type provide different habitats for aquatic plants, and along with other varying characteristics among White Lake such as water chemistry, clarity, and depth, create an aquatic plant species-rich environment. Of the 32 native aquatic plant species located during 2015 surveys on White Lake, 27 were physically encountered on the rake during the whole-lake point-intercept survey. The remaining 5 species were located incidentally. Of the 27 native species encountered on the rake in 2015, southern naiad, wild celery, and white-stem pondweed were the three most frequently encountered (Figure 6).

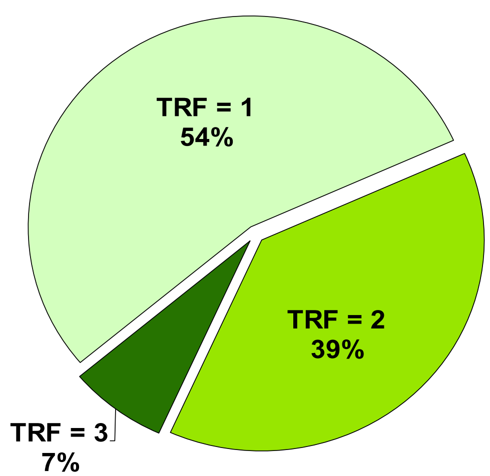


Figure 4. White Lake 2015 aquatic plant total rake fullness (TRF) ratings. Created using data from the 2015 point-intercept survey.

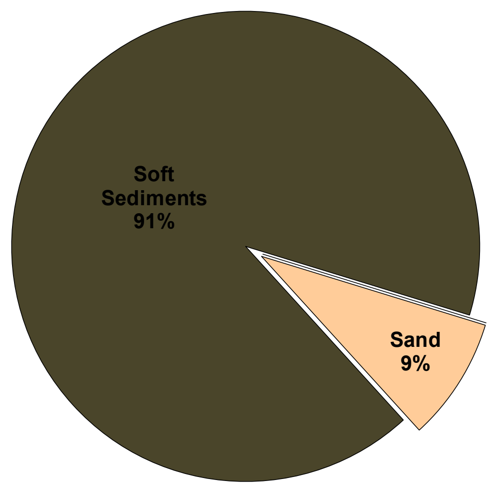


Figure 5. White Lake 2015 proportion of substrate types. Created using data from the 2015 point-intercept survey.

With a littoral frequency of occurrence of 31%, southern naiad was the most frequently encountered aquatic plant in White Lake in 2015 (Figure 6). While closely related to slender naiad, southern naiad is often perennial and lacking fruit (Les et al. 2010). Southern naiad can cause navigation conflicts and is the target of mechanical harvesting on many Wisconsin waterbodies.

Wild celery was the second-most abundant aquatic plant in White Lake in 2015 with a littoral frequency of occurrence of approximately 23% (Figure 6). The long, tapering leaves of wild celery provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments (Photo 2). Additionally, the leaves, fruit, tubers, and winter buds are food sources for numerous species of waterfowl and other wildlife.

Photo 2. Wild celery.

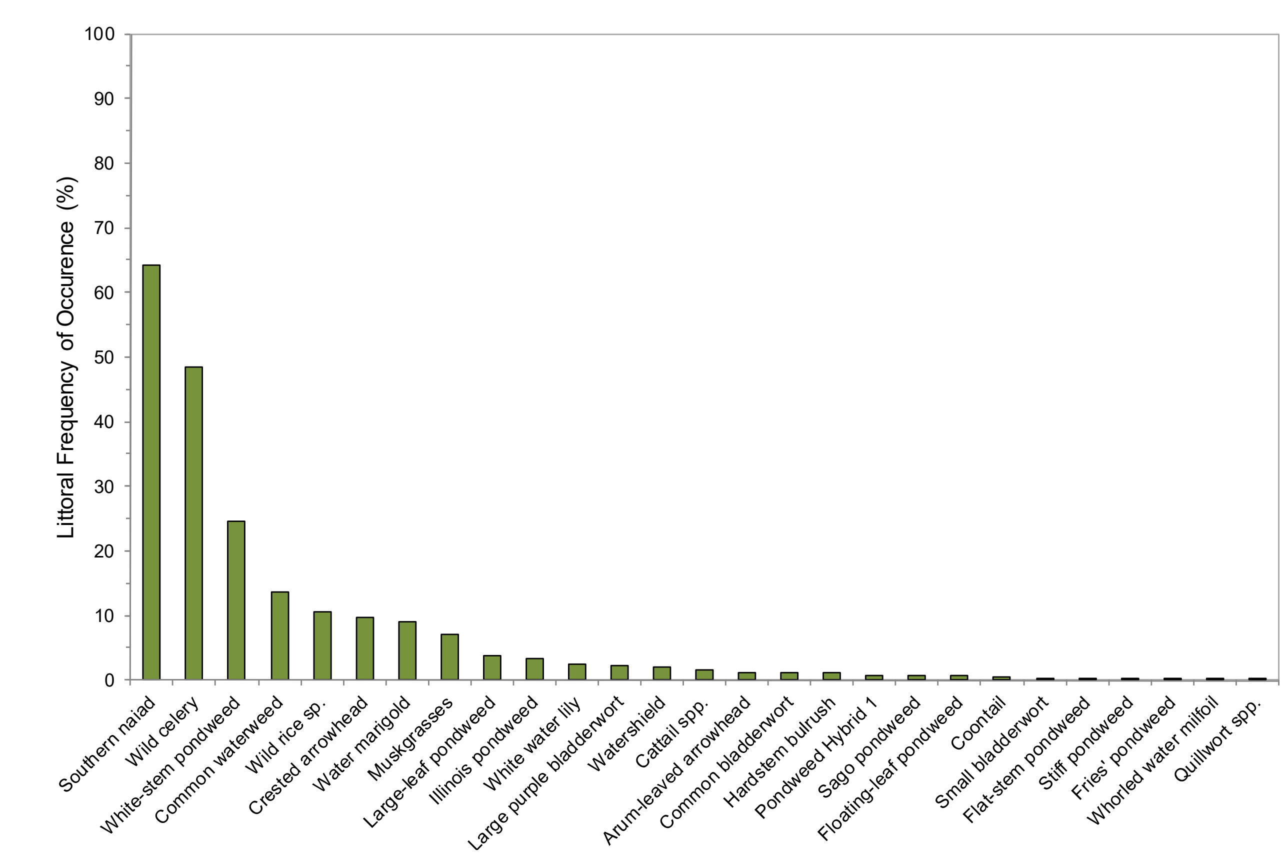


Figure 6. 2015 littoral frequency of occurrence of aquatic plant species in White Lake. Created using data from 2015 aquatic plant point-intercept survey.

White-stem pondweed, with a littoral frequency of occurrence of approximately 12%, was the third-most frequently encountered aquatic plant in White Lake in 2015 (Figure 6). White-stem pondweed is known for its zig-zag stem and keeled leaf tips (Photo 3). White-stem pondweed easily hybridizes with many of the other pondweeds. It is a good source of food and habitat for many fish and waterfowl.

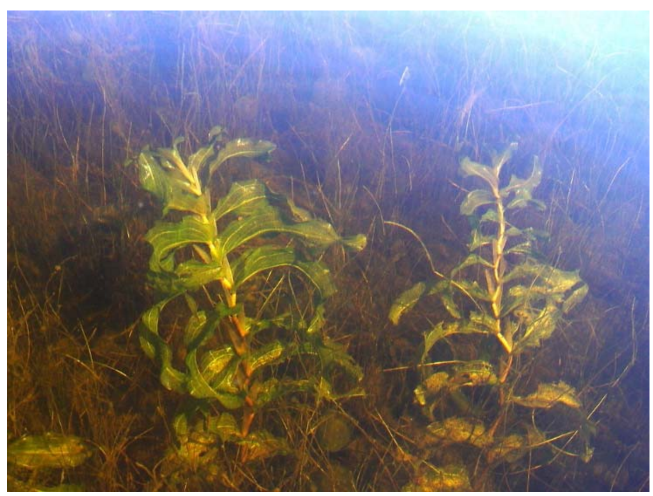


Photo 3. White-stem pondweed.

Figure 7 displays the 2010 and 2015 frequency of occurrence of native aquatic plant species in White Lake that had an occurrence of at least 5% in one of the two surveys. Eurasian water milfoil, southern naiad, wild celery and flat-stem pondweed exhibited a statistically valid reduction in their occurrence from 2010 to 2015, while common waterweed, crested arrowhead and muskgrasses had statistically valid increases over this time period.

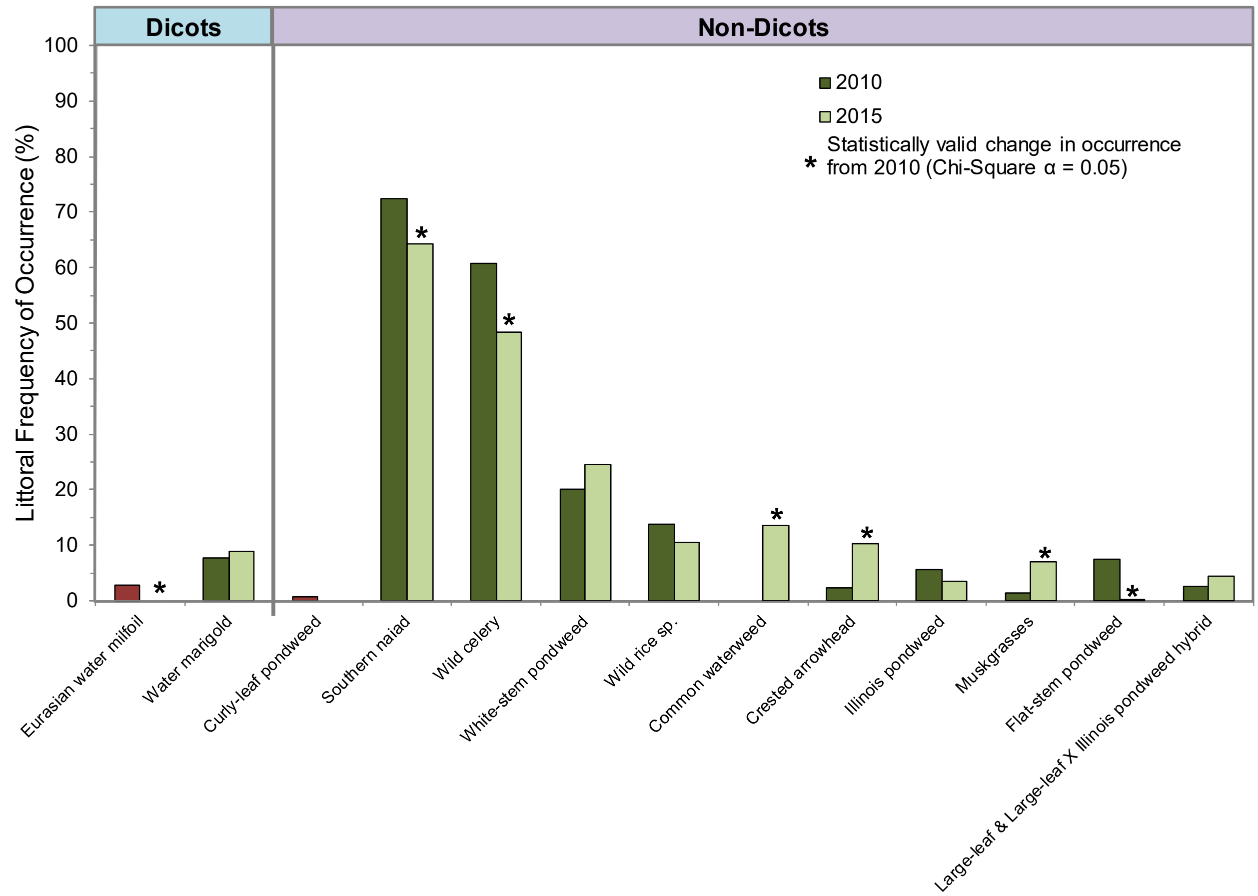


Figure 7. White Lake 2010 and 2015 frequency of occurrence of native aquatic plants. Species with an occurrence of at least 5% in either survey represented. Created using data from 2010 and 2015 point-intercept surveys.

It is plausible that the herbicide treatment strategy conducted on White Lake caused the slight declines observed to select native species from 2010 to 2015. Unpublished data indicates that fern pondweed and flat-stem pondweed are particularly vulnerable to endothall treatments. It is important to note that while a reduction of a select few native aquatic plants was observed, the magnitude of their declines in most instances was quite minimal. Ongoing research indicates that some native species rebound quickly following impact from herbicide treatment, whereas other species are slower to recover. Continued monitoring will be important to tease out the inter-annual population fluctuations of these plants versus the true collateral effects the herbicide treatment strategy is causing to these valuable plant species. More acute discussion of native plant impacts from the 2013-2015 herbicide treatment program will be discussed in a separate section.

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 32 native aquatic plant species were located in White Lake during the 2015 surveys, 27 were encountered on the rake during the point-intercept survey. These 27 native species and their conservatism values were used to calculate the FQI of White Lake's aquatic plant community in 2015.

Figure 8 compares the FQI components of White Lake from the 2010 and 2015 point-intercept surveys to median values of lakes within the North Central Hardwood Forests (NCHF) Ecoregion as well as the entire State of Wisconsin. Both surveys' species richness values exceed the upper quartile values for lakes in the NCHF Ecoregion and for lakes throughout Wisconsin. Littoral area, water clarity, depth and sediment variation, shoreline complexity, and water chemistry are all factors that influence aquatic plant species richness.

The average conservatism values for White Lake's aquatic plant community were 6.9 in 2010 and 6.5 in 2015 (Figure 8). These values fall around the median value (5.8) for lakes in the NCHF Ecoregion and the median value for lakes throughout Wisconsin, indicating White Lake Lake's aquatic plant community is of similar quality to other lakes' in the north central region and most lakes' in the state. Combining the high native species richness and the moderate average conservatism values yields FQI values that exceed the upper quartile values for lakes in the NCHF Ecoregion and for lakes throughout Wisconsin.

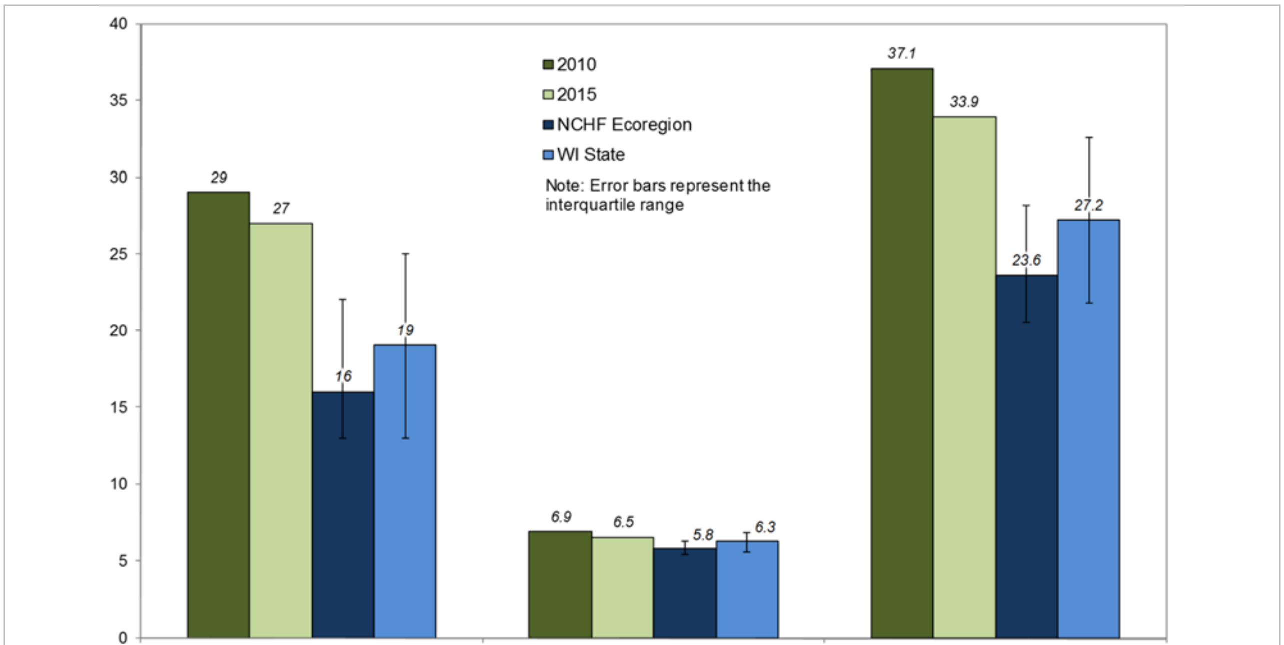


Figure 8. White Lake Lake Floristic Quality Assessment. Created using data from 2010 and 2015 point-intercept surveys.

As explained earlier, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because White Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, as discussed, 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 White Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 85 lakes within the NCHF Ecoregion (Figure 9). Using the data collected from the 2010 and 2015 point-intercept surveys, White Lake's aquatic plant community was shown to have moderate species diversity in 2010 and 2015 with a Simpson's diversity values of 0.84 and 0.83. In other words, if two individual aquatic plants were randomly sampled from White Lake in 2015, there would be an 83% probability that they would be different species.

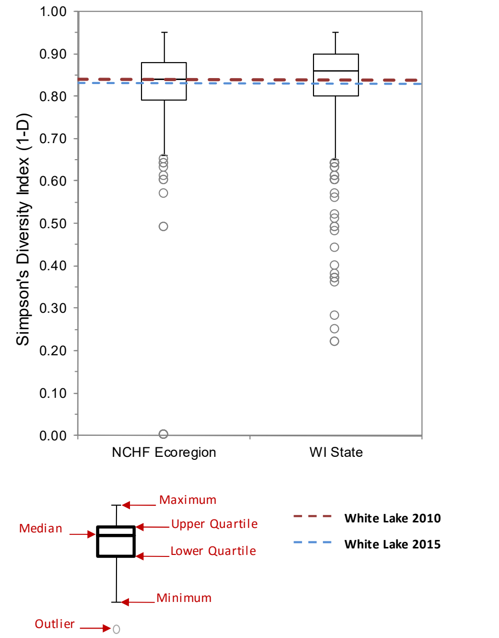


Figure 9. White Lake Simpson's Diversity Index. Created using data from 2010 and 2015 point-intercept surveys.

As explained earlier, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while southern naiad was found at approximately 64% of the littoral sampling locations in White Lake in 2015, its relative frequency of occurrence is 31%. Explained another way, if 100 plants were randomly sampled from White Lake, 31 of them would be southern naiad. Figure 10 displays the relative occurrence of aquatic plant species from White Lake in 2015, and illustrates that the aquatic plant community is dominated by two species, southern naiad (31%) and wild celery (23%) which leads to a moderate species diversity.

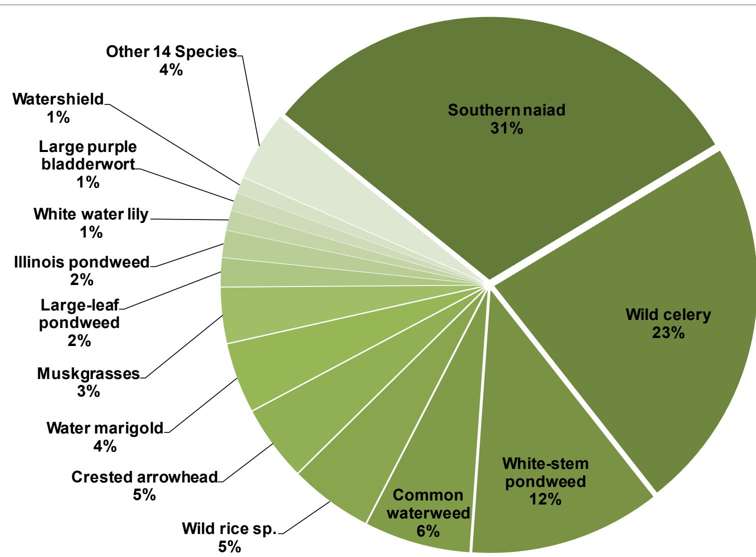


Figure 10. 2015 relative frequency of occurrence of aquatic plant species in White Lake. Created using data from 2015 point-intercept survey.

A major limitation of the point-intercept method is the inability to use this technique to evaluate emergent and/or adjacent wetland areas due to the inability to navigate in these areas. These communities serve as a different, and sometimes preferred, type of habitat within a lake environment for mammals, birds, amphibians and fish. These communities are often impacted by recreational lake use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

During 2010, Onterra ecologists completed a Community Mapping Survey (discussed within the Primer Section) to delineate the extents of floating-leaf and emergent communities within White Lake. This survey was replicated in 2015 to understand if these communities have expanded or contracted during this timeframe. Map 2 overlays the two surveys. While some differences can be observed by looking at the map, the overall acreage of these communities was within 8 acres between the 2 surveys (488 acres in 2010, 480 acres in 2015).

WILD RICE

During the planning stages of the *White Lake Comprehensive Management Plan, Onterra, May 2012,* concerns about expanding wild rice communities surfaced. Wild rice growth, in particular, was the number one concern of White Lake residents per the 2011 stakeholder survey that was part of the Plan (Question #18 & #19). Over 91% of stakeholder respondents indicated that wild rice was having a *moderate* to *great negative impact* to White Lake (Question #18).

Wild rice is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers. Wild rice has cultural significance to the Chippewa Tribal Communities where the grain historically was an important component of Native American diets. Wild rice is also an important diet component for waterfowl, muskrats, deer, and many other species. Established wild rice plant communities can provide valuable nursery and brooding habitat for wetland bird and amphibian species as well as spawning habitat for various fish. Perhaps one of the most overlooked benefits of having established wild rice communities is their ability to utilize excessive plant nutrients, stabilize soils, and form natural wave breaks to protect shoreland areas.

Because wild rice is an annual plant and relies solely on seed for population sustenance, variations in seed production in a given year will impact the size of rice bed in subsequent years. Other factors, such as spring temperatures and water levels, also impact rice populations by affecting seed germination. According to Aiken et al. (1988), over the course of four years it is likely that there will be a boom year, a bust year, and a couple of average years. However, it has been documented that in systems with higher rates of water flow, rice production and population dynamics are more consistent over time.

The community mapping survey can be used to understand the differences in wild rice populations between the two years. As shown in Figure 11, the solid pink areas are the plant communities where wild rice was either the first or second dominant plant in that community in 2015. The red-hatched areas are where wild rice wild rice was the first or second dominant plant in that community in 2010. These data indicate that some areas have expanded wild rice, whereas other areas have contracted. Continuing to monitor the wild rice populations over time will reveal if the populations changes are cyclic or is a trend towards expansion (or contraction) is being observed. As indicated within White Lakes Plan, this survey should be replicated every 5 years.

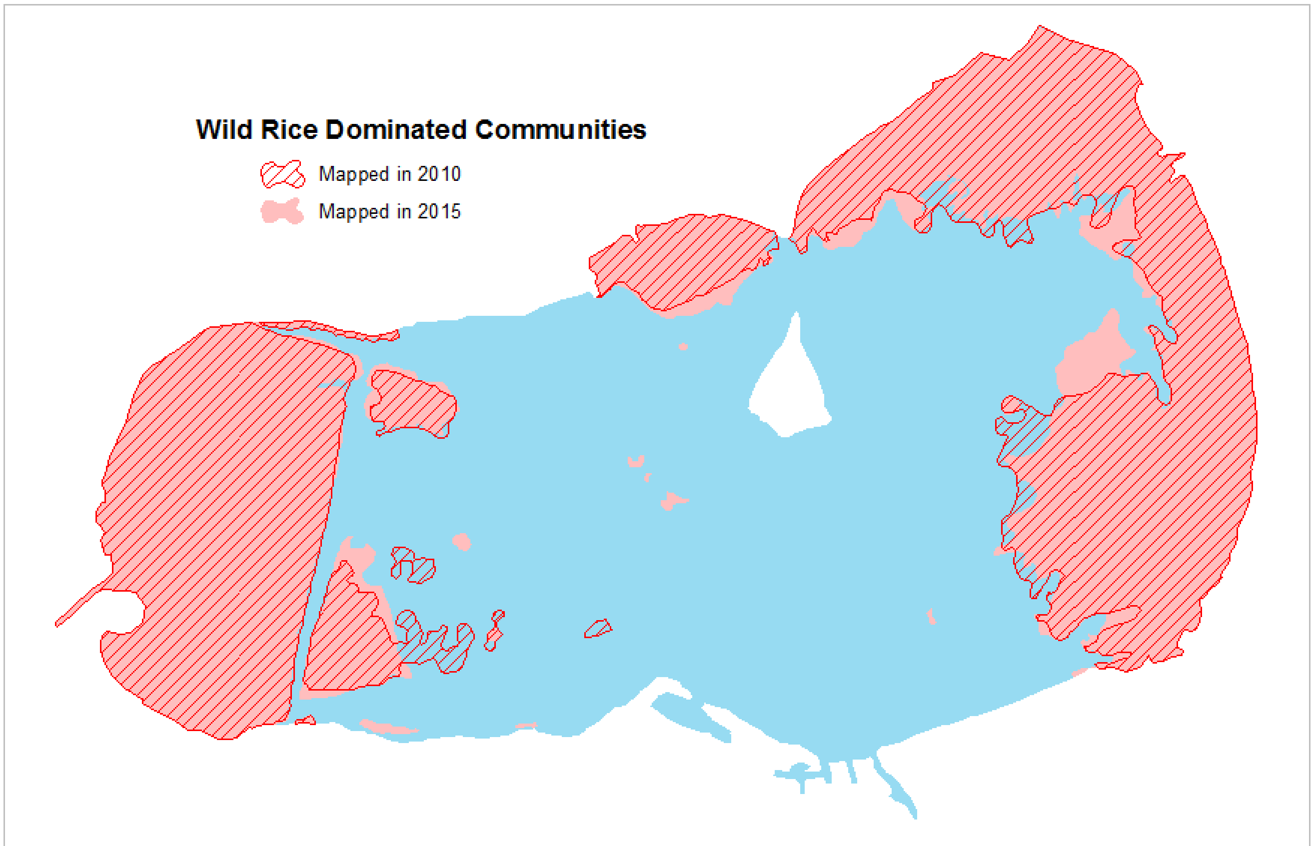


Figure 11. White Lake wild rice populations in 2010 and 2015.

PURPLE LOOSESTRIFE

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. Purple loosestrife occurrences have been noted in 2010 and 2015 (Map 2).

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. At this time, hand removal by volunteers is still the best option.

2015 CLP TREATMENT STRATEGY

Understanding concentration-exposure times are important considerations for implementing successful control strategies utilizing 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 a joint research project between the WDNR, USACE, and private consultants. Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) whole-lake treatments, and 2) spot treatments.

Whole-lake, or basin-wide, treatments are those where the herbicide is applied to specific sites, but the goal of the strategy is for the herbicide to reach a target concentration when it equally distributes throughout the entire volume of the lake (or lake basin, or within the epilimnion of the lake or lake basin). The application rate of whole-lake treatments is dictated by the volume of water in which the herbicide will reach equilibrium with. Because exposure time is so much greater, effective herbicide concentrations for whole-lake treatments are significantly less than required for spot treatments. Whole-lake treatments are typically utilized when the target plants are widespread throughout the lake or lake basin. The distribution of the CLP population within White Lake has not warranted the use of this strategy.

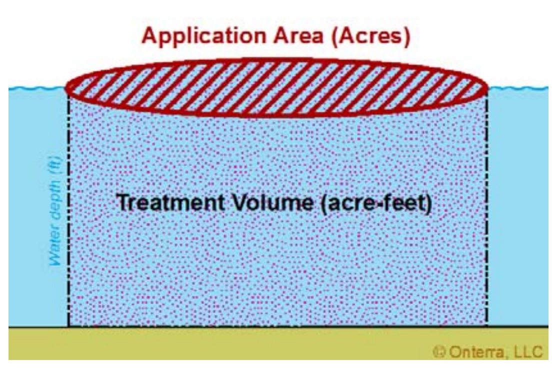


Figure 12. Herbicide Spot Treatment diagram.

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 effects outside of that area. Ongoing research indicates that herbicide quickly dissipates and dilutes from spot treatments, especially small spot treatments (less than five acres). In order for mortality of the target plants to occur, the short exposure time (often hours) needs to be offset by the plants being exposed to a high herbicide concentration. Herbicide application rates for spot treatments are formulated volumetrically. This means that sufficient endothall is applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal the desired concentration. This standard method for determining spot treatment use rates is not without flaw, as no physical barrier keeps the herbicide within the *Treatment Volume* and herbicide dissipates horizontally out of the area before reaching equilibrium (Figure 12). While lake managers may propose that a particular volumetric dose is used, such as 1.5-3.0 ppm endothall ai (acid equivalent), it is understood that actually achieving those concentrations within the water column is not likely due to dissipation and other factors. This has been the treatment strategy utilized in the past on White Lake.

Traditionally, CLP control consists of numerous annual herbicide treatments conducted in May/June of each year. This will kill each year's plants before they are able to produce turions (asexual reproductive structures). After multiple years of treatment, the turion base within the sediment becomes exhausted and the CLP population decreases significantly. Normally, a control strategy such as this includes five or more years of treatments of the same area. The WDNR grant-funded CLP project was designed such that roughly 31 acres of White Lake would be targeted for three consecutive years with liquid endothall at the standard rate of 1.5 ppm ai (active ingredient) (Figure 13). Using the observed effects from the 2013 and 2014 herbicide treatments, the endothall dose was increased slightly to 2.0 ppm ai for the 2015 treatment.

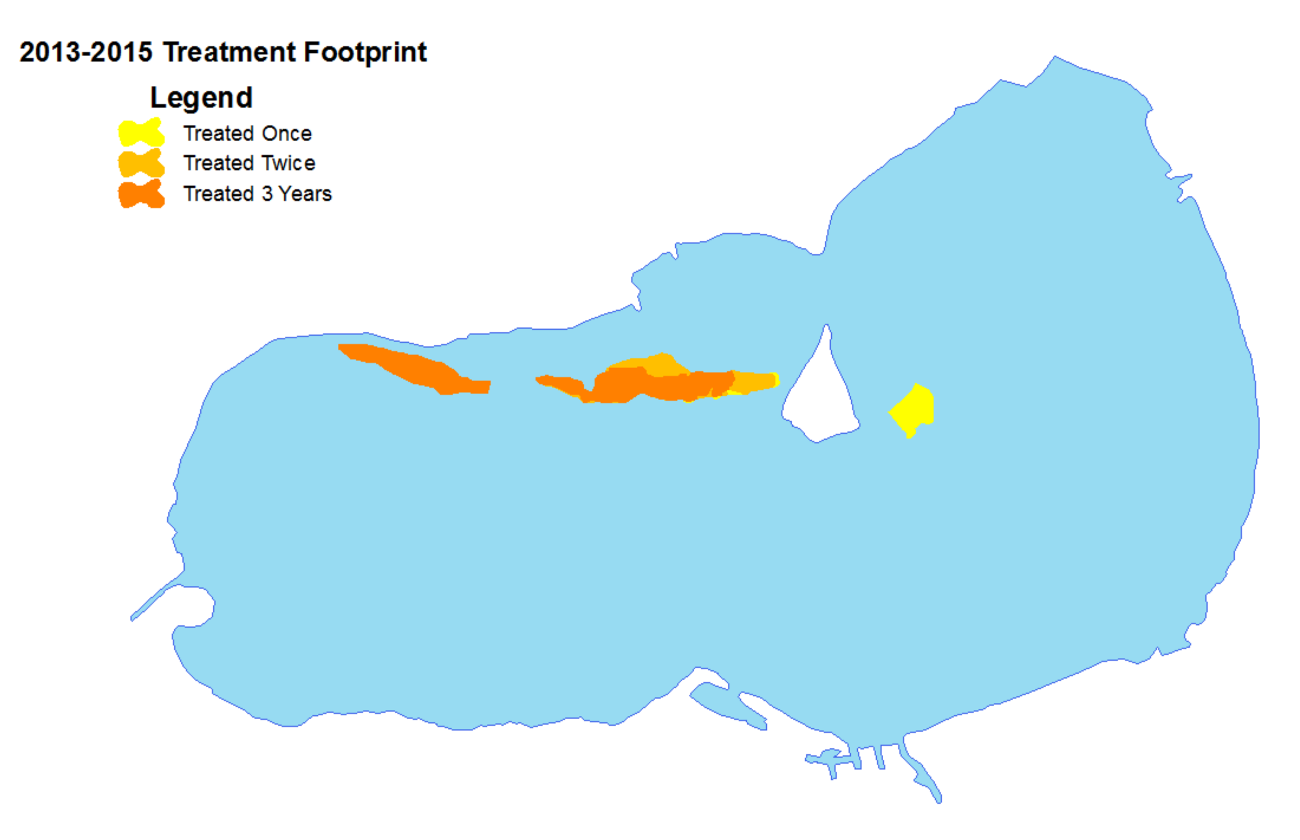


Figure 13. White Lake treatment footprint, 2013-2015..

PRETREATMENT CONFIRMATION & REFINEMENT SURVEY

On, April 28th, 2015, Onterra staff visited White Lake to conduct a Pretreatment Confirmation and Refinement Survey. Overall, conditions were good for viewing CLP in the relatively shallow treatment areas. During this survey, a temperature profile was taken at the lake's deep hole (11 feet). Water temperature was approximately 14°C (57°F) at the surface and 12°C (54°F) near the bottom (Figure 14).

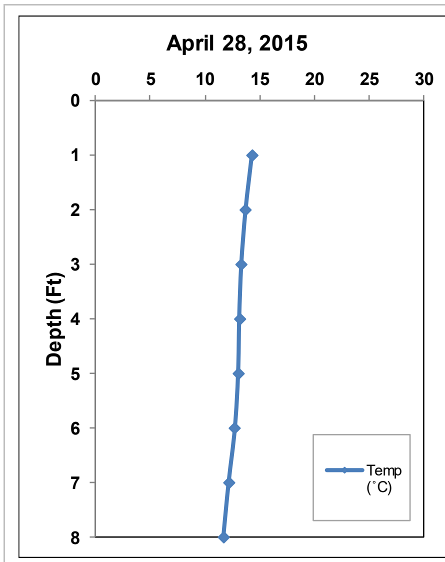


Figure 14. Pretreatment profiles from White Lake. Data collected on April 28, 2015.

Curly-leaf pondweed was observed growing within proposed treatment sites A-15 and B-15. The eastern portion of B-15 was removed from the final treatment strategy due to no CLP being found in that part of the site (Map 3). The initially proposed 20.7 acres targeted for herbicide treatment was reduced to 18.9 acres following the pre-treatment survey.

The final treatment areas totaling 18.9 acres were treated with liquid endothall at a rate of 2.0 ppm ai by Stantec, Inc. on May 7, 2015. The applicator reported a near-surface water temperature of 66°F and south winds of approximately 5-10 mph at the time of application. According to the treatment record, the application started at 8:45 am when wind speeds were low (Figure 15). Higher wind speeds in the later part of the treatment as well as after the treatment may have caused the herbicide to dissipate more quickly from the treatment areas.

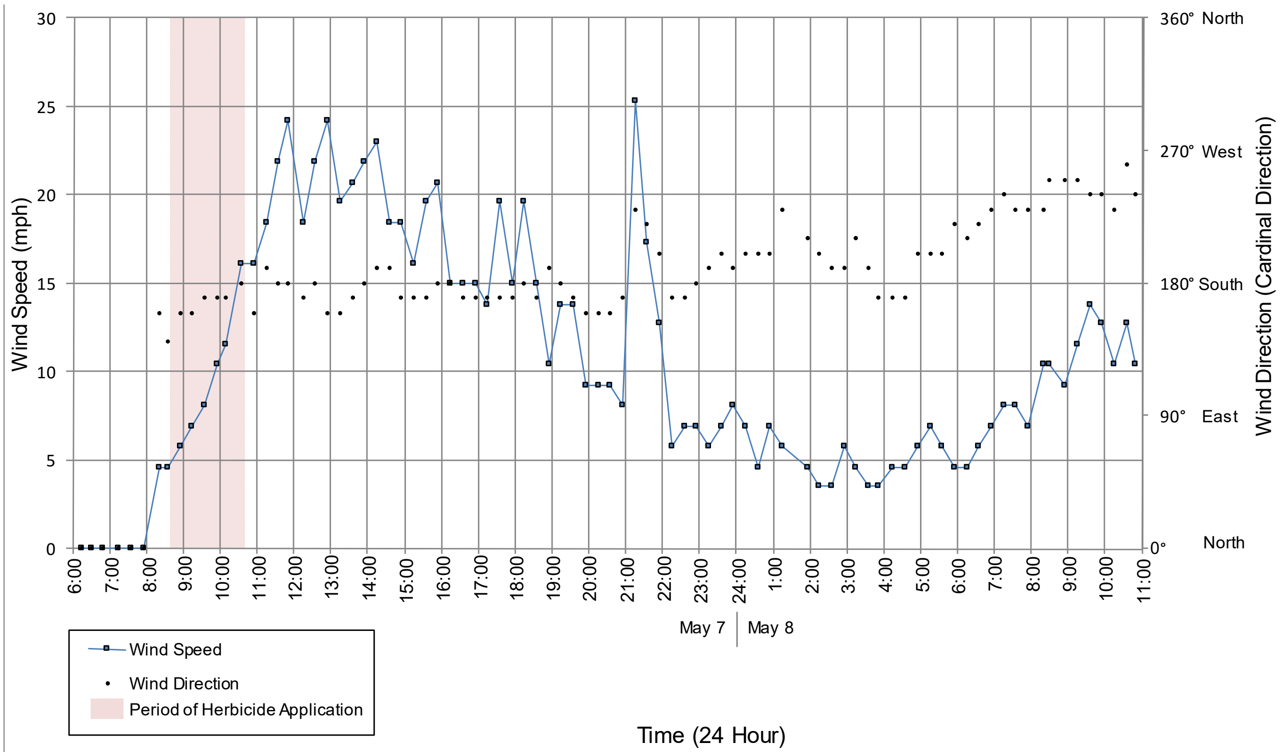


Figure 15. Wind speed and direction recorded in Waupaca on May 7, 2015. Created using data from the weatherunderground.com.

MONITORING METHODOLOGIES

The objective of any herbicide treatment strategy is to maximize target species (CLP) mortality while minimizing impacts to valuable native aquatic plant species. Monitoring herbicide treatments and defining their success incorporates both quantitative and qualitative methods. As the name suggests, quantitative monitoring involves comparing number data (or quantities) such as plant frequency of occurrence before and after the control strategy is implemented. Qualitative monitoring is completed by comparing visual data such as AIS colony density ratings before and after the treatments.

Qualitative CLP Monitoring

Using sub-meter GPS technology, CLP populations have been delineated on White Lake since 2010. To coincide with the peak growing stage (peak biomass) of CLP, these surveys are conducted approximately in June each year. The CLP population is mapped by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *Highly Scattered* to *Surface Matting*. Point-based techniques were applied to CLP locations that were considered as *Small Plant Colonies* (<40 feet in diameter), *Clumps of Plants*, or *Single or Few Plants*.

As shown on Figure 15, large and dense CLP colonies were observed along the northern shore of White Lake in 2012. An herbicide treatment was conducted in May of 2013 and almost no CLP was located approximately one month following the treatment. In 2014, no CLP was located within the treatment areas approximately one month following the treatment. In 2015, a *single plant* was found within the treatment areas, indicating successful control from the herbicide strategy (Figure 16; Map 3).

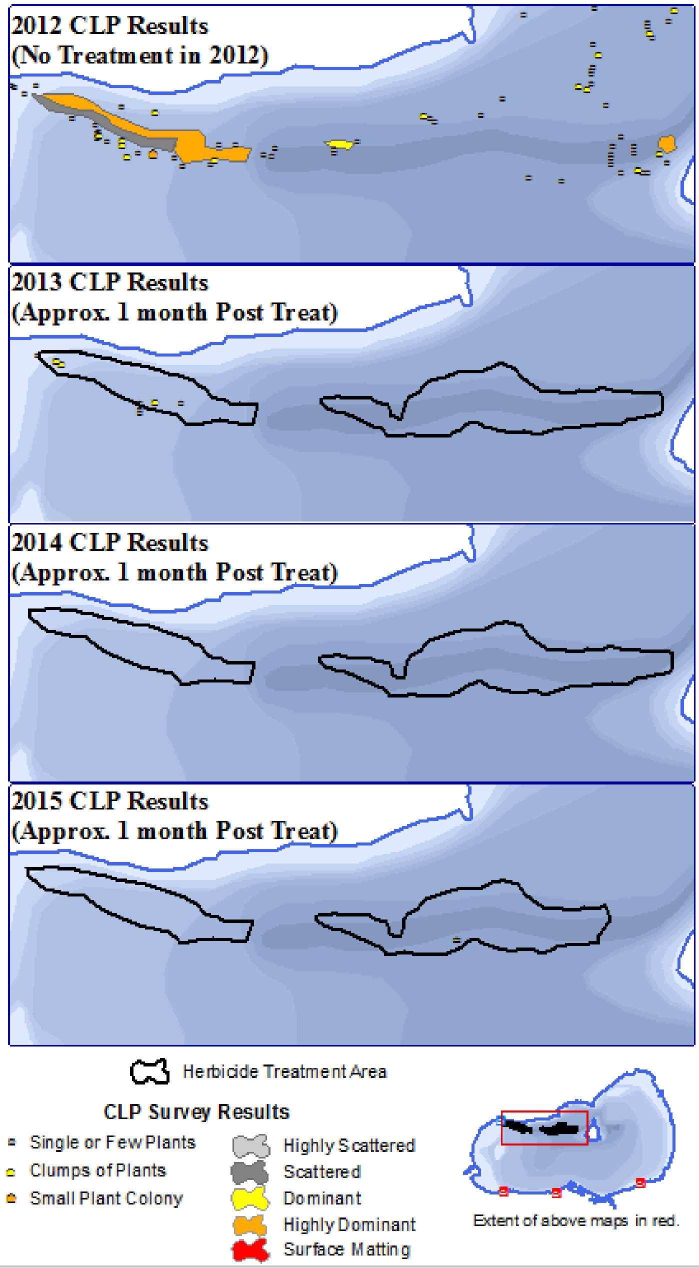


Figure 16. Qualitative CLP Monitoring Results.

Quantitative Aquatic Plant Monitoring

To monitor the CLP efficacy of the treatment, point-intercept sub-sample data were collected, as described by the WDNR Bureau of Science Services (Hauxwell et al. 2010). These locations were sampled during the spring of 2015 prior to the treatment and again in June following the treatment. Prior to the treatment, only the presence of AIS was documented at each location as most native aquatic plants are not actively growing at that time. In White Lake, quantitative evaluation was made through the collection of data at 77 point-intercept sub-sample locations all located within the areas of CLP where herbicide was directly applied during the three-year project (Figure 17). At each of these locations, the presence (or absence) of CLP was recorded.

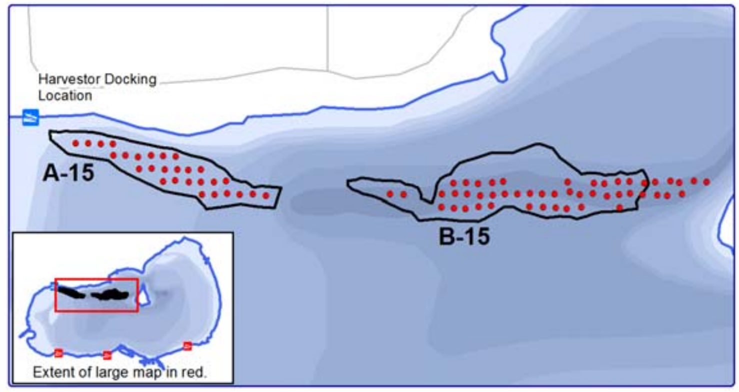


Figure 17. Quantitative monitoring plan for the 2015 CLP treatment on White Lake. N=77.

It is difficult, if not impossible, to assess the efficacy of a single year of treatment on a lake's CLP population. Curly-leaf pondweed naturally senesces (dies back) in early summer, making it is difficult to determine if a reduction in CLP following a spring treatment was caused by the treatment, natural senescence, or both. However, quantitative data collected annually immediately before the treatment takes place allows for a determination if the CLP population is being reduced in the lake over time. The goal of CLP management is to annually kill the plants before they are able to produce and deposit new turions, and thus, overtime, deplete the existing turion bank within the sediment. Over the course of multiple annual CLP treatments, annual point-intercept surveys should quantitatively document a reduction in CLP occurrence as the turion base is depleted.

Comparing the spring pretreatment point-intercept survey data with the June post treatment data is difficult to determine CLP control due to factors of natural die off (senescence) discussed above. But certainly if CLP exist within the treatment areas following treatment, a failed treatment is likely to have occurred. The data in Figure 18 indicated that the 2014 treatments were more impactful that the 2013 treatment. Following the 2013 treatment and the volunteer-based herbicide concentration monitoring that took place, an increased endothall dose was used during 2014 and 2015 in an effort to overcome the dilution that was observed.

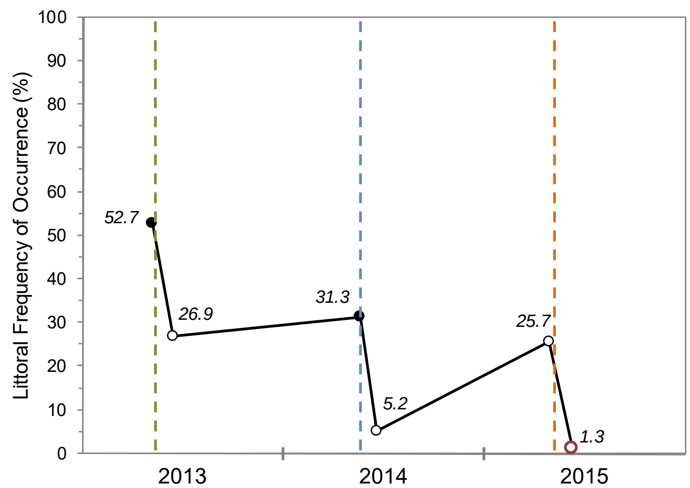


Figure 18. CLP sub-sample frequency of occurrence within treatment sites A-15 and B-15. Dashed-lines indicate herbicide treatment. Statistically valid changes are indicated by open circles. (n=131)

Comparing the three pretreatment point-intercept surveys results, CLP has decreased each year from 52.7% in 2013 to 30.3% in 2014 and 25.7% in 2015. The pretreatment data is a reflection of how many turions sprouted into CLP plants that year. The reduction of observed CLP each year potentially reflects a reduction in viable CLP turions over time.

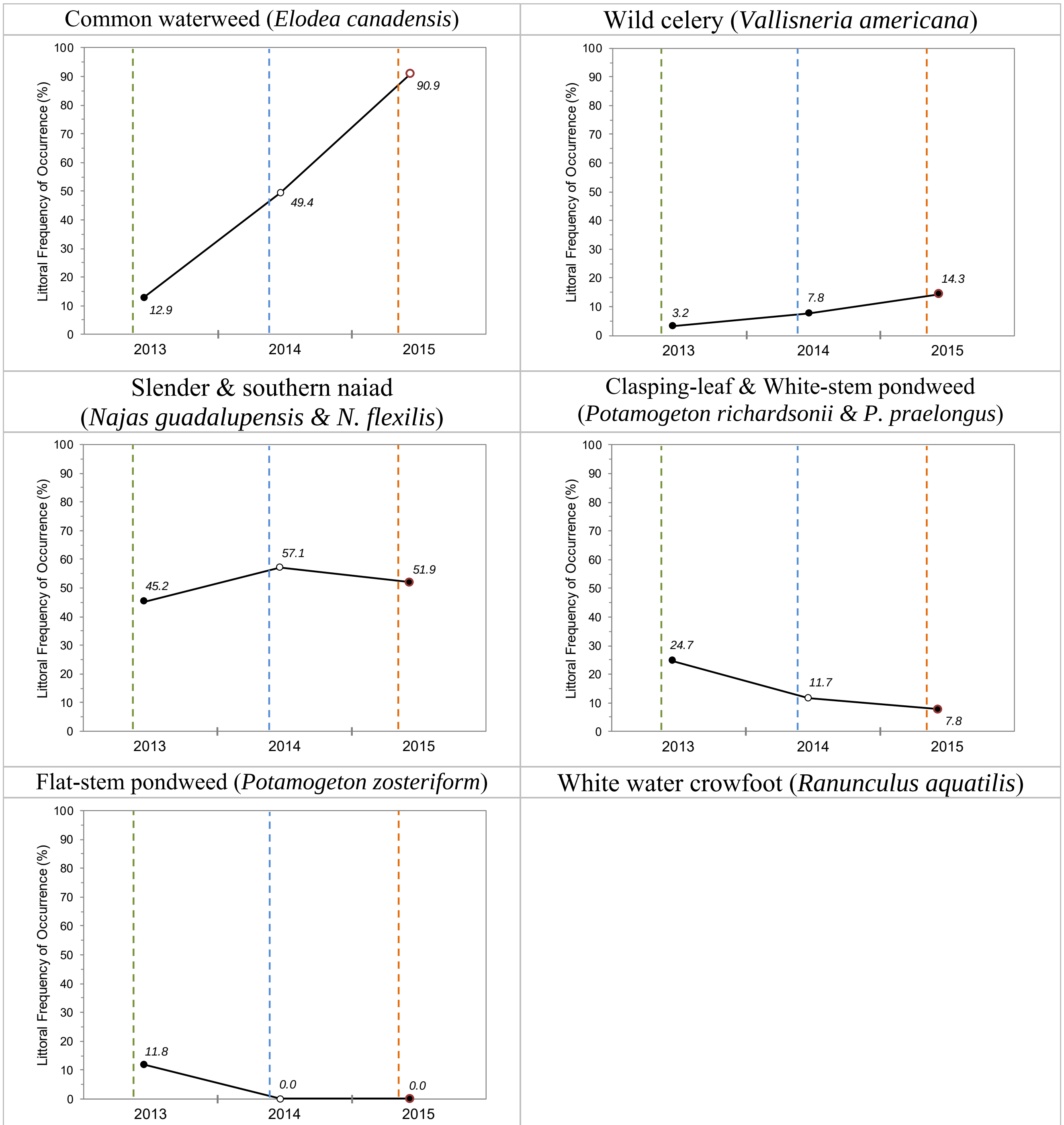


Figure 19. 2013-2015 sub-sample frequency of native plants within treatment sites A-15 and B-15. Open circle represents a statistically valid change in occurrence from previous survey and red outline in 2015 indicates statistically valid change compared to 2013 (Chi-squared α = 0.05). Dashed-lines indicate herbicide treatment. (n=131)

The littoral frequencies of occurrence of native aquatic plant species available from the June 2013, June 2014 and June 2015 surveys are shown in Figure 19. Common waterweed was shown to drastically increase its population during this time period. While counterintuitive, common waterweed populations have been shown to increase following endothall treatments. Actually, the 2010 whole-lake point-intercept survey did not yield any common waterweed (it was noted as an incidental). The 2015 whole-lake point-intercept survey noted common waterweed at 13.6% of sampling locations.

While wild celery populations were observed to decline lake-wide between 2010 and 2015, their population was shown to increase within the areas treated. This suggests that the lake-wide declines are not related to the herbicide treatment program. Southern naiad populations also declined slightly between 2010 and 2015 whole-lake point-intercept surveys. This trend was also not observed within areas treated in 2013-2015.

While typically clasping-leaf pondweed and white-stem pondweed can be distinguished during field surveys, these species during late-June can be difficult to differentiate and were lumped together within this analysis. Also, these species are known to hybridize, which may also be the case in White Lake. The sub-sample point-intercept data indicate that along with flat-stemmed pondweed, these species have declined in occurrence during this time period. Onterra's experience indicates that clasping-leaf pondweed and flat-stemmed pondweed are fairly sensitive to endothall treatments, whereas white-stemmed pondweed is fairly resilient. The lake-wide point-intercept survey noted a population reduction in flat-stemmed pondweed between 2010 and 2013, whereas white-stemmed and clasping-leaf pondweed populations did not experience statistically valid changes.

2015 EWM MONITORING RESULTS

In 1989, the WDNR discovered EWM during an aquatic plant study of White Lake. In 2003, the WLPA contracted with Aquatic Biologists, Inc. to complete a management plan for the lake. Also in 2003, the association obtained partial funding through the AIS Rapid Response Program to complete a 20-acre treatment of EWM. In 2009, an additional EWM treatment occurred within the mechanical harvesting lanes. The 2009 treatment was considered a success.

Onterra ecologists mapped EWM on White Lake in June of 2010 as well as annually during June of 2012-2015 through various WDNR-funded projects. The 2010 survey located *single* EWM plants, *clumps*, and *small plant colonies* scattered throughout the entire lake causing EWM to be noted as widespread throughout White Lake. However, there were no large colonies that were considered candidates for an herbicide treatment. During the June 2015 Early Season AIS Survey, all EWM occurrences observed within White Lake were mapped (Map 4). A Late-Summer Peak Biomass survey was completed in September 2015. Less EWM was found in September than found in June (Map 5). The amounts found during both surveys were similar to 2014.

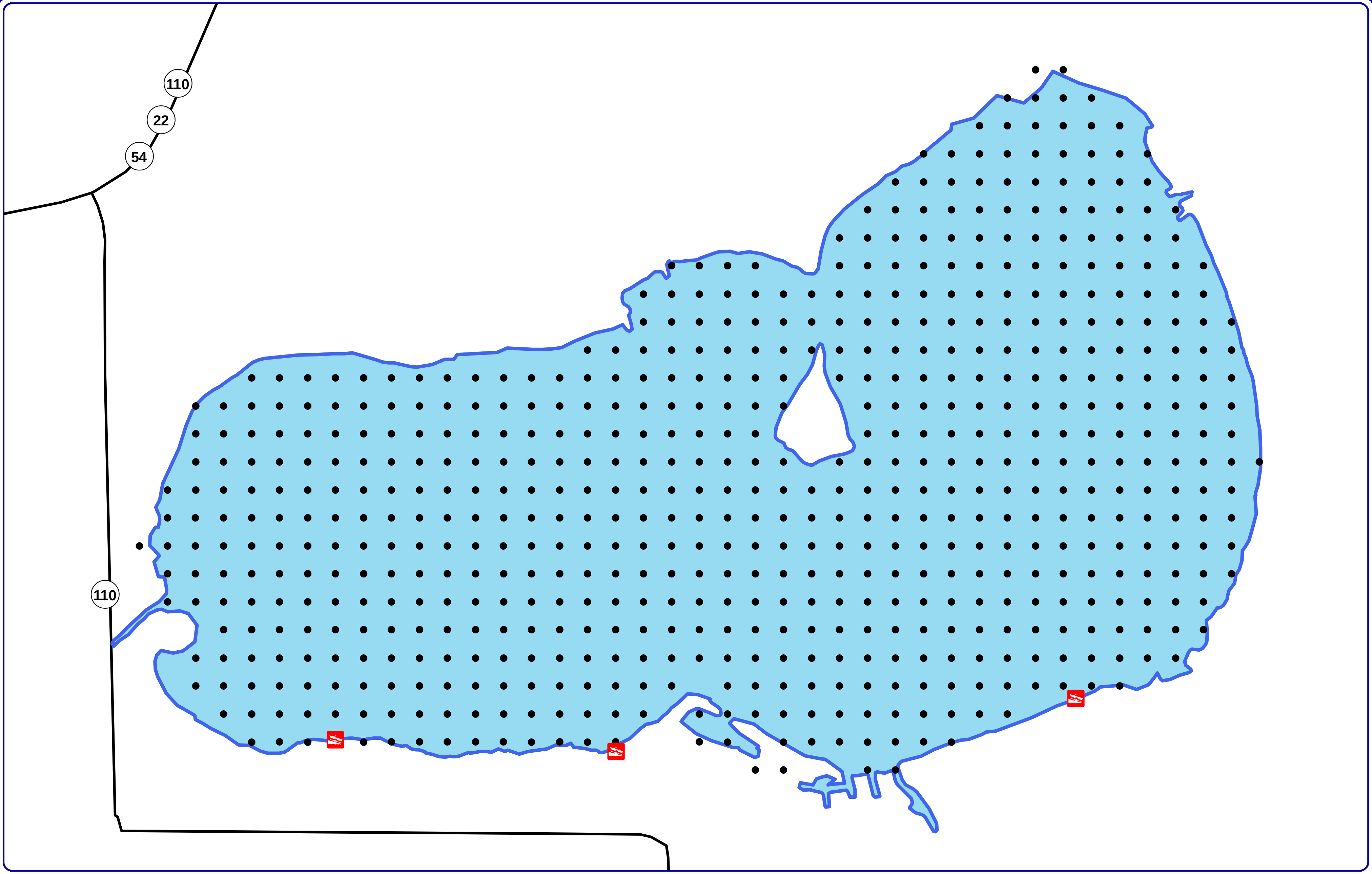
CONCLUSIONS AND DISCUSSION

The liquid endothall treatments on White Lake appeared to be effective at controlling CLP within the herbicide application areas. The 2015 mapping data indicate that the CLP population in White Lake is at its lowest levels since mapping began in 2010. Quantitative monitoring data collected during the course of the three year CLP control program demonstrate a declining CLP population as the turion base has become more depleted. A CLP turion base may remain within the sediment in the areas targeted for treatment in 2013-15.

In regards to CLP management, Onterra proposes two options to the WLPA. Aside from the small footprint of the lake that has been treated during 2013-2015, no other areas of the lake contain CLP populations that are causing ecological impacts or recreational/navigational conflicts. The WLPA may consider not conducting a treatment in 2016. In the absence of herbicide control in 2016, the CLP population within the areas treated in 203-2015 will be allowed to grow to its full potential from which a better understanding of the current CLP population can be understood. A professional mapping survey during late-June could document the CLP at its peak growth stage to develop a modified control strategy moving forward. Understanding that the WLPA has limited financial resources, this may be the preferred strategy for 2016.

As noted above, turions likely remain within the 2013-2015 treated areas that will sprout in 2016 and beyond. Actually, the 2015 pretreatment sub-sampling point-intercept survey yielded over 25% of the locations contained CLP (sprouted turions). The second option is to continue to conduct herbicide treatments on Sites A and B for a few more years. Typically, CLP treatment strategies target the same area for 5 years. If the WLPA's intentions are to continue actively managing the CLP with White Lake in 2016, it is recommended to use the 2015 final treatment areas as the proposed 2016 strategy. It would also be advised to continue at least a portion of the monitoring components that were conducted in 2013-2015 during active management in the future.

At the current time, the EWM population within White Lake is not forming dense colonies that are impacting the ecology nor the recreational use of the lake. Populations of EWM have decreased in White Lake without any active management over the past three years. It remains unclear what factors (e.g. weather, native plant competition) contributed to the observed reduction of this species in White Lake. It is recommended to continue monitoring the population of EWM within White Lake during future years.



N
W E
S

1,250

Feet

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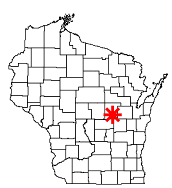
Sources:
Roads & Hydro: WDNR
Map Date: February 22, 2016
Filename: Map1_White_Location.mxd


Project Location in Wisconsin

Legend

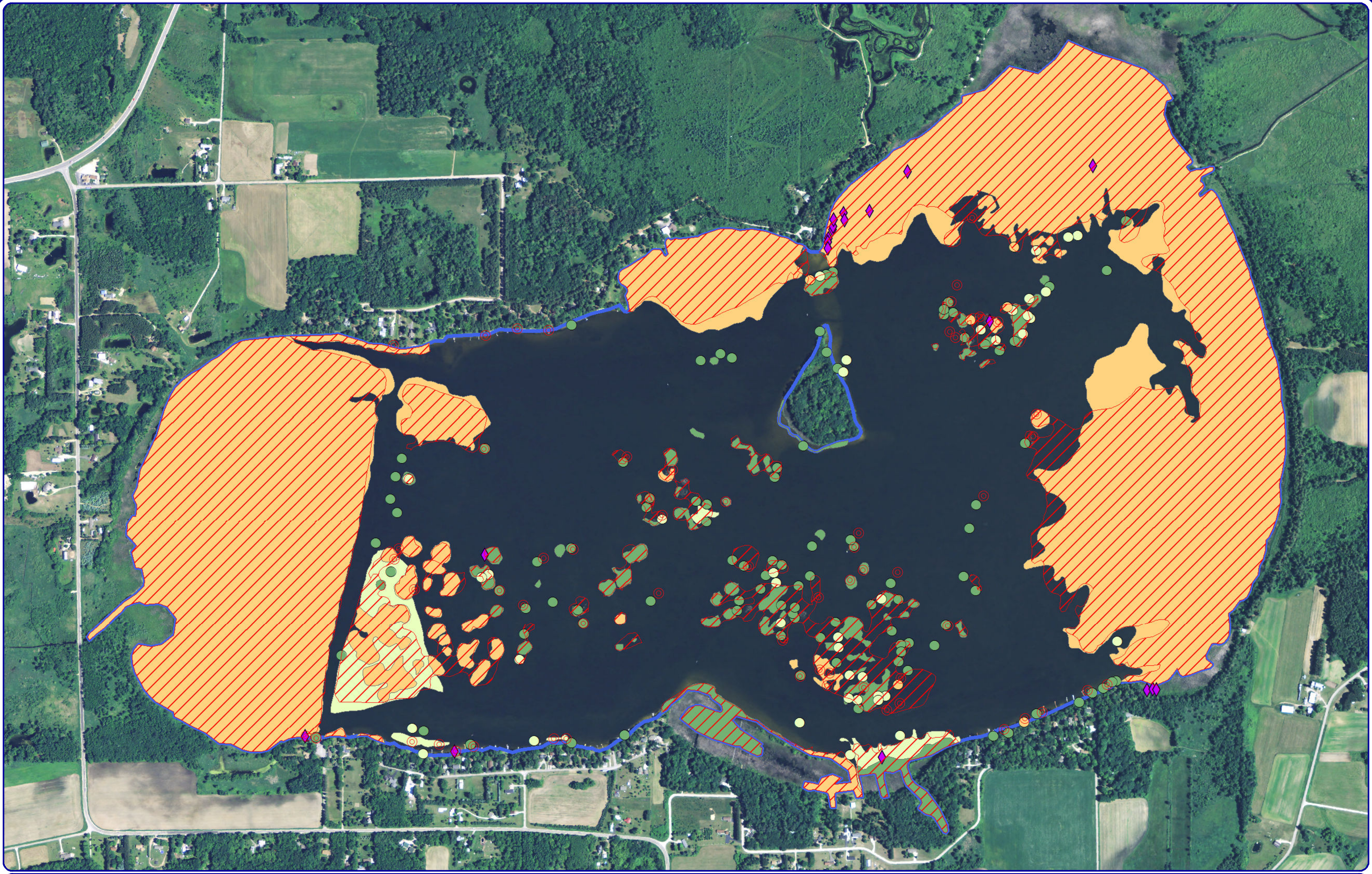
White Lake ~1,026 acres
WDNR Definition

Point-Intercept Survey Location
82-meter spacing, 640 total points

Public Boat Landing

Map 1
White Lake
Waupaca County, Wisconsin

Project Location
& Lake Boundaries



Legend

2010 Communities
- Large Plant Community
- Small Plant Community

Delineated during Summer 2015

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

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

N W E S

1,200
Feet

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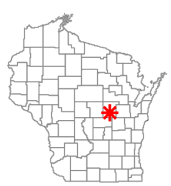
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2010 &2 015
Orthophotography: NAIP, 2013
Map date: February 17, 2016
Filename: White_Comm_2010&2015.mxd



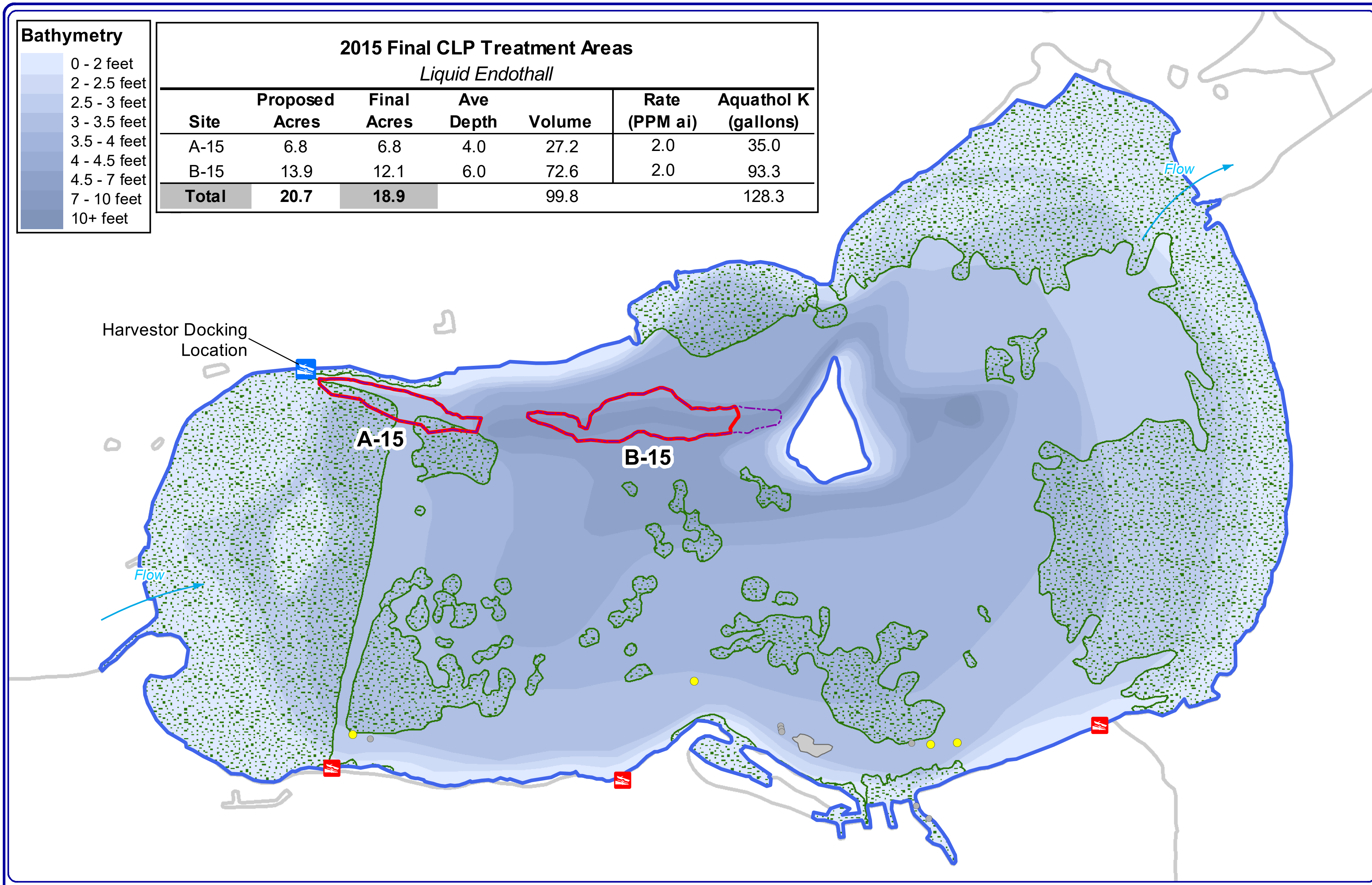
Project Location shown in red.

Map 2

White Lake

Waupaca County, Wisconsin

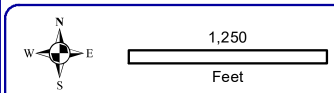
Aquatic Plant Communities



2015 Final CLP Treatment Areas

Liquid Endothall

Site	Proposed Acres	Final Acres	Ave Depth	Volume	Rate (PPM ai)	Aquathol K (gallons)
A-15	6.8	6.8	4.0	27.2	2.0	35.0
B-15	13.9	12.1	6.0	72.6	2.0	93.3
Total	**20.7**	**18.9**		99.8		128.3



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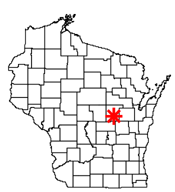
Sources:
Roads & Hydro: WDNR
Plant Survey: Onterra, April 28, 2015
Map date: February 28, 2015
Filename: White_CLP_T2015Perm1.mxd


Project location in Wisconsin

Legend

Final 2015 Treatment Area

Originally Proposed Treatment Area

CLP Survey Results ***(June 2014)***

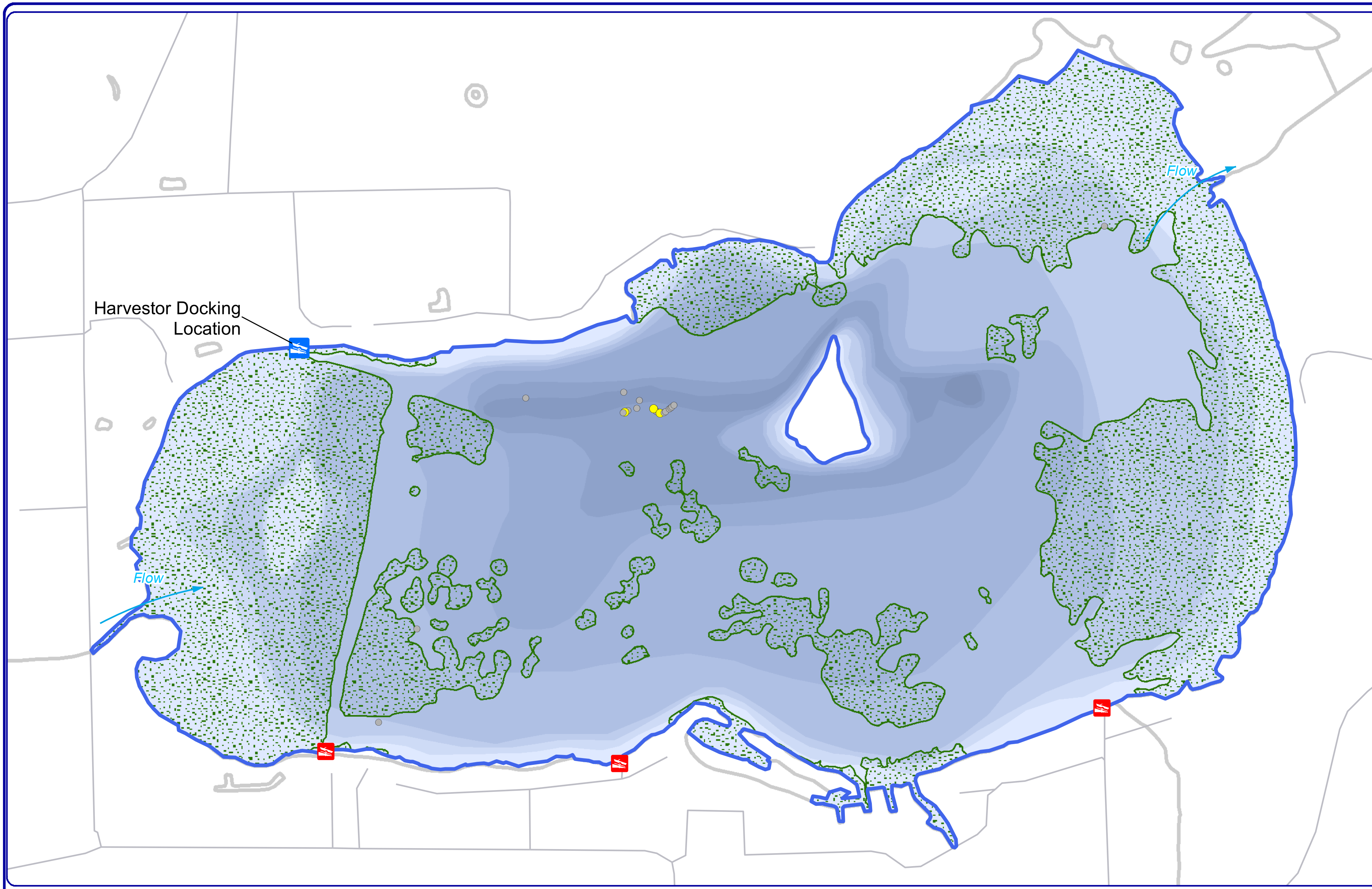
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(none)*
- Highly Scattered
- Scattered *(none)*
- Dominant *(none)*
- Highly Dominant *(none)*
- Surface Matting *(none)*

Map 3

White Lake

Waupaca County, Wisconsin

2015 Final CLP Treatment Areas



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1,200

Feet

Sources:
Roads & Hydro: WDNR
Plant Survey: Onterra, 2015
Map date: July 10, 2015
Filename: White_EWM_June15.mxd

Project location in Wisconsin

Legend

EWM Survey Results ***(June 2015)***

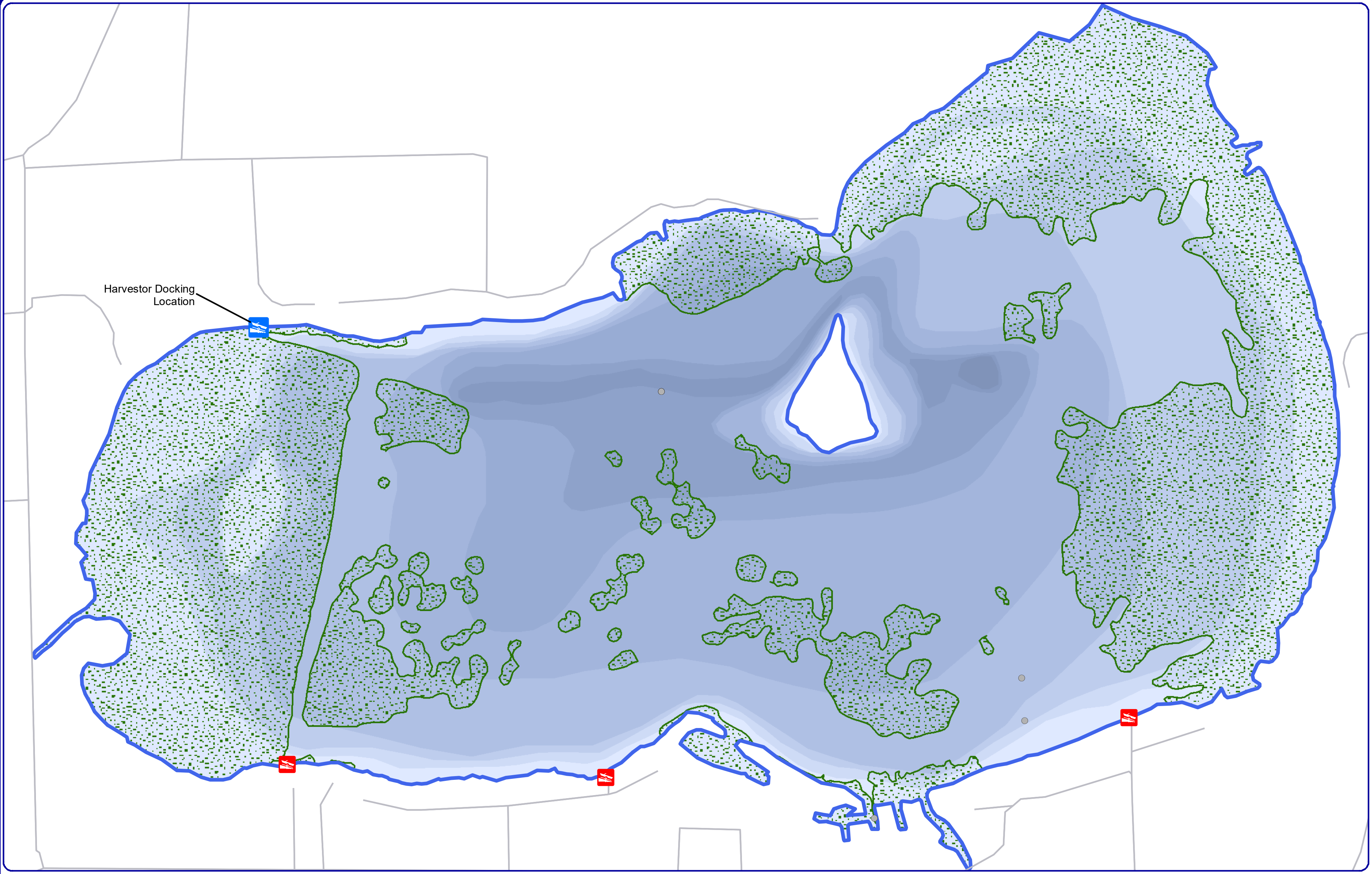
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(none)*
- Highly Scattered *(none)*
- Scattered *(none)*
- Dominant *(none)*
- Highly Dominant *(none)*
- Surface Matting *(none)*

Map 4

White Lake

Waupaca County, Wisconsin

June 2015 EWM Survey Results



1,100
Feet

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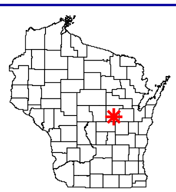
Sources:
Roads & Hydro: WDNR
Plant Survey: Onterra, 2015
Map date: October 13, 2015
File Name: White_EWM_PB_Sept15.mxd



Extent of large map shown in red.

Legend

Eurasian Water Milfoil ***September 2015***

- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Boat Landing
- Emergent Plant Community

Map 5
White Lake
Waupaca County, Wisconsin

2015 EWM PB Survey Results