Long Lake

Fond du Lac County, Wisconsin

Aquatic Plant Management Plan Update

July 2019

Sponsored by:

Long Lake Preservation Association

WDNR Surface Water Grant Program

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Onterra LLC
Lake Management Planning

Long Lake

Fond du Lac County, Wisconsin

Aquatic Plant Management Report

July 2019

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1.0 INTRODUCTION

Long Lake, Fond du Lac County, is a 454-acre lowland drainage lake with a maximum depth of 47 feet and a mean depth of 22 feet. This mesotrophic lake has a relatively large watershed, with a watershed to lake area ratio of 27:1. This natural lake also has a small dam artificially elevating water levels by a few feet. The State Forest Campground (~200 sites with toilets and showers) contains two launching lanes, with Americans with Disabilities Act (ADA) accessibility features and 30+ vehicle/trailer parking spots.

The Long Lake Preservation Association (LLPA) maintains a landing in Chinatown. Long Lake has two public beaches, an ADA fishing pier, and 30% of its shoreland is under state ownership through the Kettle Moraine State Forest Northern Unit (Figure 1.0-1, Map 1). The Boy Scouts of America own and operate a camp on Long Lake, owning approximately 13% of the lake's frontage.

The LLPA completed a WDNR-approved *Long Lake Comprehensive Management Plan* (March 2015) in which 42 native aquatic plant species were identified from the lake and adjacent shoreline areas. Six exotic (non-native) plant species are known to exist in Long Lake including two submergent species, curly-leaf pondweed (CLP) and Eurasian watermilfoil (EWM).

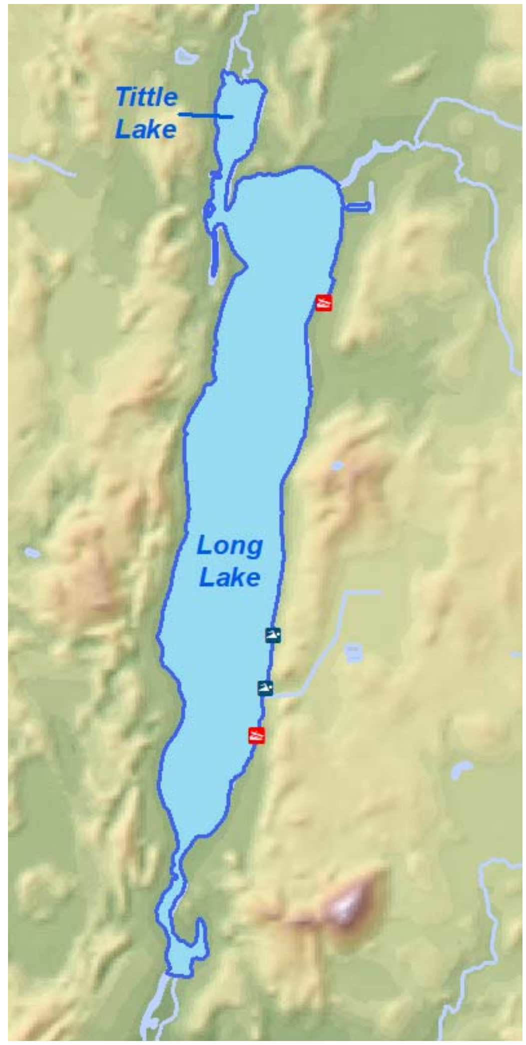

Figure 1.0-1. Long Lake, Fond du Lac County.

CLP was first documented from Long Lake in 2007 and EWM was first documented in 2002. It was later verified in 2013 that hybrid watermilfoil (HWM) also exists in Long Lake – hybrid watermilfoil is a cross between the invasive Eurasian watermilfoil (*Myriophyllum spicatum*) and native Northern watermilfoil (*Myriophyllum sibiricum*). There can be much genetic variability within hybrid milfoils because a different amount of each parents' genetic material is contributed to the offspring. Ongoing research is attempting to quantify the amount of genetic variation of hybrid milfoils within a particular lake. Some strains of hybrid watermilfoil have been shown to be less susceptible to certain herbicide control strategies. In this report, all references of EWM, whether pure-strain or hybrid, will be referred to as Hybrid watermilfoil (HWM).

The LLPA received an AIS-EDR in Feb 2008 to cover herbicide spot treatments towards CLP from 2008-2010. In 2011, the LLPA initiated a 3-yr project aimed at reducing the CLP and HWM populations on a lake-wide basis (ACEI-087-11) through targeted spot treatments. Following the completion of the *Long Lake Comprehensive Management Plan* (March 2015), and a 4-year AIS grant was given to help implement the AIS management actions outlined within the *Plan* through 2018 (ACEI-159-15). This report serves as the final deliverable for this grant-funded project.

2.0 AQUATIC PLANTS

2.1 Primer on Aquatic Plant Data Analysis & Interpretation

Photo 2.1-1. Native aquatic plants.

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 (Photo 2.1-1). 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 a 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 certain 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.

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) have been conducted by the WDNR in 2007, 2010, and 2013, and by Onterra in 2018. Based upon guidance from the WDNR, a point spacing (resolution) of 50 meters was used resulting in 725 sampling points being evenly distributed across the lake (Map 1). At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance 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 (at depths < 15 ft) or using an onboard sonar unit (at depths > 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.

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 whole-lake point-intercept surveys completed in Long 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

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

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 Long 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 Long Lake to be compared to other lakes within the region and state.

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

Long Lake falls within the Southeastern Wisconsin Till Plains (SWTP) *ecoregion* (Figure 2.1-1), and the floristic quality of its aquatic plant community will be compared to other lakes within this ecoregion as well as the entire State of Wisconsin. Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems within the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Ecoregional and statewide medians were calculated from whole-lake point-intercept surveys conducted on 392 lakes throughout Wisconsin by Onterra and WDNR ecologists.

Figure 2.1-1. Location of Long Lake within the ecoregions of Wisconsin. After Nichols 1999.

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 where 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 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. Some managers believe a lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with lower diversity. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan et al. 2018).

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
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 Long Lake is compared to data collected by Onterra and the WDNR Science Services on 77 lakes and flowages within the Southeast Wisconsin Till Plains Ecoregion and on 392 lakes throughout Wisconsin.

2.2 Long Lake Aquatic Plant Survey Results

The whole-lake aquatic plant point-intercept survey was conducted on Long Lake on July 16-17, 2018 by Onterra. Table 2.2-1 includes the list of aquatic plant species which were located during surveys completed in 2007, 2010, 2013, and 2018. A comparison of the 2018 aquatic plant survey data to these historical datasets is discussed later in this section. Appendix A contains the full matrix of aquatic plant frequencies from the point-intercept surveys. The population of CLP and HWM will be discussed in detail within the subsequent section (Section 2.3).

Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available. In 2015, Onterra ecologists completed an acoustic-based modeling survey on Long Lake primarily to assist in creating a more-defined mechanical harvesting strategy. Cost coverage of the *Long Lake Mechanical Harvesting Plan* (April 2016) was included within this project and is included as Appendix B.

Data pertaining to Long Lake's submersed aquatic vegetation bio-volume, substrate composition, and bathymetry (depth contours) were recorded during the acoustic-based survey (Figure 2.2-1). The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments. These data are then modeled using spatial interpolation techniques. Please note that these data are not ground-truthed and the accuracy of some data, especially in shallow water, is unknown. These data show hard sandy areas in near-shore areas of the lake, particularly along the eastern shoreline. Distinct areas of softer organic sediments are observed just lakeward from these shoals, supporting more leafy and high-biomass vegetation. Softer sediments can also be observed in front of the lake's northeastern inlet, a delta effect from this tributary.

While not as comprehensive as the acoustic-based modeling method, sediment hardness data was also collected as part of the point-intercept method. At each point-intercept sampling location that was sampled with a pole rake (approx. 15 feet or less), sediment was categorized as either soft (i.e. muck), rock, or sand. Within this subset of points, 62% of the point-intercept sampling locations contained fine, organic matter (muck), 37% contained sand, and less than 1% was rocky substrate.

Table 2.2-1. Aquatic plant species located on Long Lake during whole-lake point-intercept surveys in 2007, 2010, 2013, and 2018. This list does not include some of the emergent and floating-leaf species that were discovered during other surveys (i.e. community mapping survey in 2014).

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2007 (WDNR)	2010 (WDNR)	2013 (WDNR)	2018 (Onterra)
Emergent	*Eleocharis robbinsii*	Robbins' spike-rush	10		X		
	Phalaris arundinacea	Reed canary grass	Exotic			X	
	Schoenoplectus acutus	Hardstem bulrush	5	X	X		X
	Schoenoplectus acutus	Hardstem bulrush	5	X	X		
	Sparganium sp.	Bur-reed species	N/A	X			
FL	*Brasenia schreberi*	Watershield	7			X	
	Nuphar variegata	Spatterdock	6	X	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X	X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	X			
Submergent	*Bidens beckii*	Water marigold	8		X	X	X
	Ceratophyllum demersum	Coontail	3	X	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	X	X
	Heteranthera dubia	Water stargrass	6	X	X	X	X
	Myriophyllum heterophyllum	Various-leaved water milfoil	7		X	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X	X	X
	Myriophyllum sibiricum X spicatum	Hybrid water milfoil	Exotic				X
	Najas flexilis	Slender naiad	6			X	X
	Nitella spp.	Stoneworts	7	X	X	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X	X	X	X
	Potamogeton foliosus	Leafy pondweed	6	X			X
	Potamogeton friesii	Fries' pondweed	8	X	X		X
	Potamogeton illinoensis	Illinois pondweed	6		X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X		X
	Ranunculus aquatilis	White water-crowfoot	8	X	X		X
	Sagittaria sp. (rosette)	Arrowhead rosette	N/A	X			
	Stuckenia pectinata	Sago pondweed	3	X	X	X	X
	Utricularia vulgaris	Common bladderwort	7	X	X	X	X
	Vallisneria americana	Wild celery	6	X	X		X
	Isoetes spp.	Quillwort spp.	8				X
FF	*Lemna minor*	Lesser duckweed	5	X	X	X	X
	Lemna trisulca	Forked duckweed	6	X	X	X	X
	Spirodela polyrhiza	Greater duckweed	5	X	X		X
	Wolffia sp.	Watermeal species	N/A	X		X	X
S/E	*Sagittaria* sp.	Arrowhead sp.	N/A			X	X

FL = Floating-leaf; FL/E = Floating-leaf & Emergent; FF = Free-floating; S/E = Submergent & Emergent

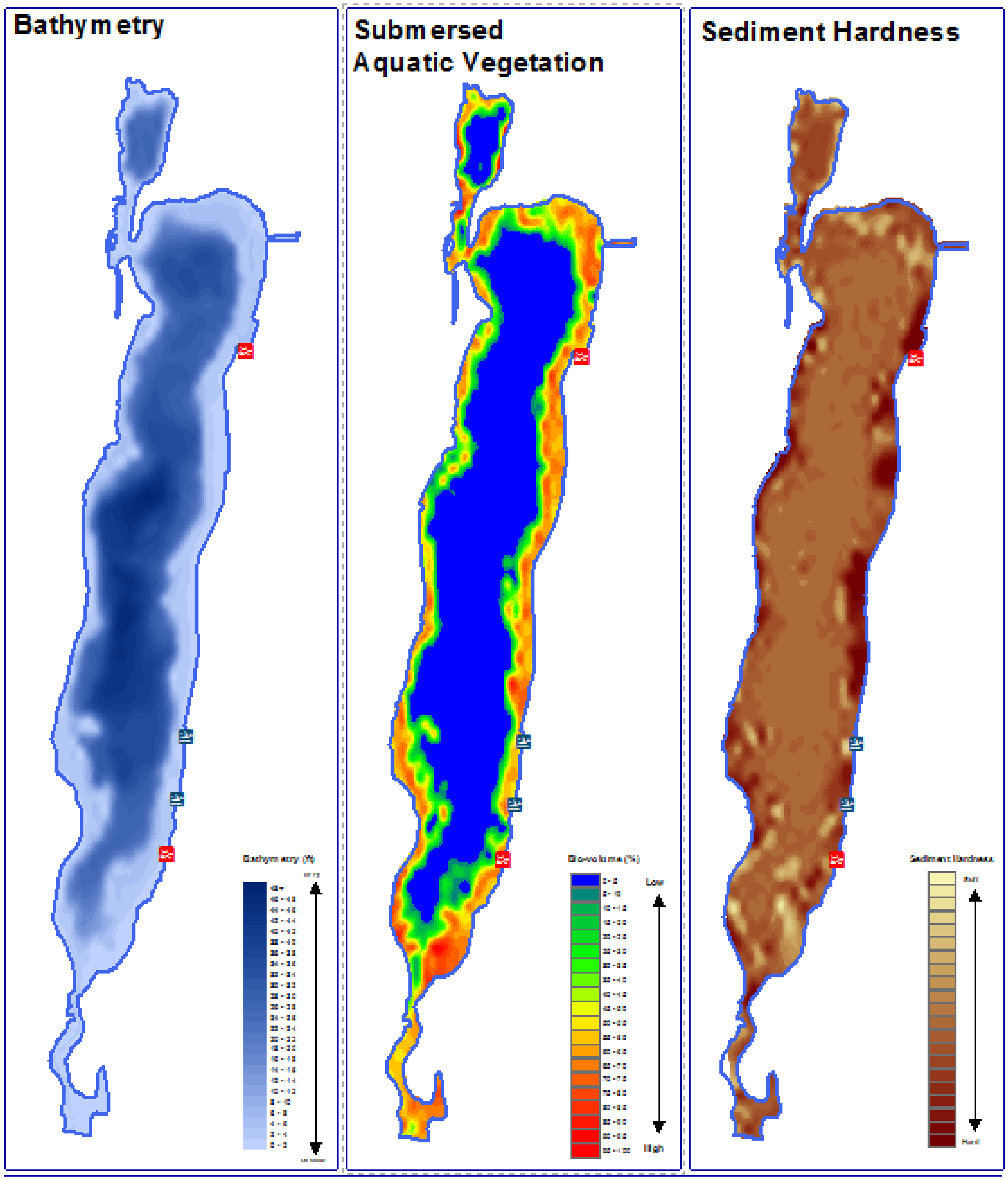

Figure 2.2-1. Long Lake bathymetry (left), aquatic plant bio-volume (center), and substrate hardness (right). Modeled using data from Onterra 2015 acoustic survey.

Aquatic plants were found growing to a depth of 21 feet during the 2018 point-intercept survey. Of the 725 point-intercept sites, 314 of them were littoral, meaning they fell at or within the maximum depth where plants grow. Of these 314 sampling locations in 2018, approximately 81% of them contained aquatic vegetation. This compares to 96% in 2007, 92% in 2010, and 97% in 2013 (Figure 2.2-3).

Figure 2.2-2 also shows a semi-quantitative analysis of the abundance of aquatic plants through looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). Aquatic plant rake fullness data collected in 2018 indicates that 27% of the 314 littoral sampling locations contained vegetation with a total rake fullness (TRF) rating of 1, 11% had a TRF rating of 2, and 44% had a TRF rating of 3 (Figure 2.2-3). The total rake fullness ratings indicate that where plants occurred in Long Lake in 2018, they were of relatively high biomass.

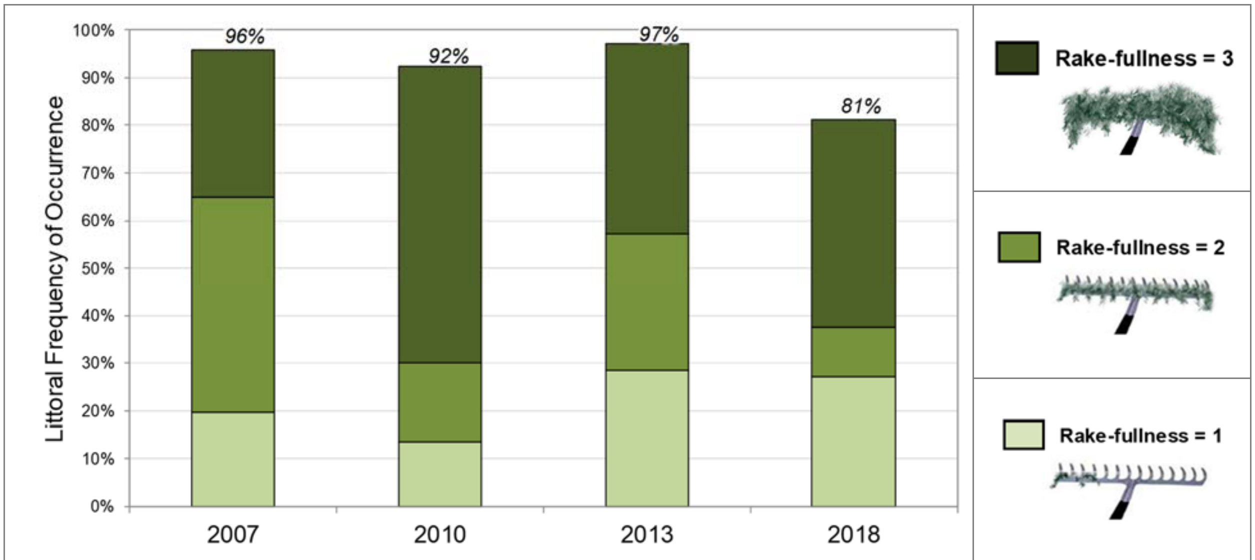

Figure 2.2-2. Aquatic plant frequency of occurrence and total rake fullness (TRF) ratings in Long Lake from the 2006, 2012, and 2017 surveys.

Of the 30 aquatic plant species recorded on the rake during the 2018 point-intercept survey, muskgrasses, coontail, and various-leaved watermilfoil (native species) were the three-most frequently encountered species (Figure 2.2-3).

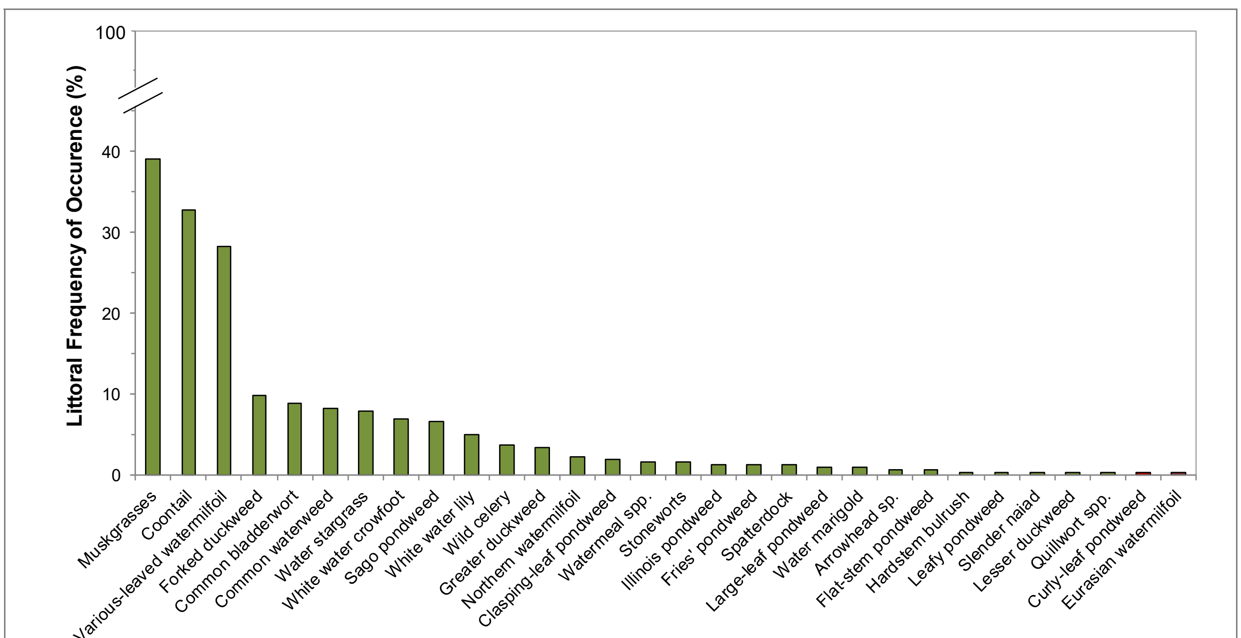

Figure 2.2-3. 2018 Littoral frequency of occurrence of aquatic plants in Long Lake.

Muskgrasses are a type of of macroalgae, and were the most common species to be found during the 2018 point-intercept survey with a littoral frequency of occurrence (LFOO) of 39.2% (Figure 2.2-4). This was a statistically valid decrease from the 2013 LFOO of 48.6%; however, it is still higher than the 2007 LFOO which was 36.1%. These macroalgae require lakes with good water clarity, and their large beds stabilize bottom sediments (Photo 2.2-1). Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which form on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002).

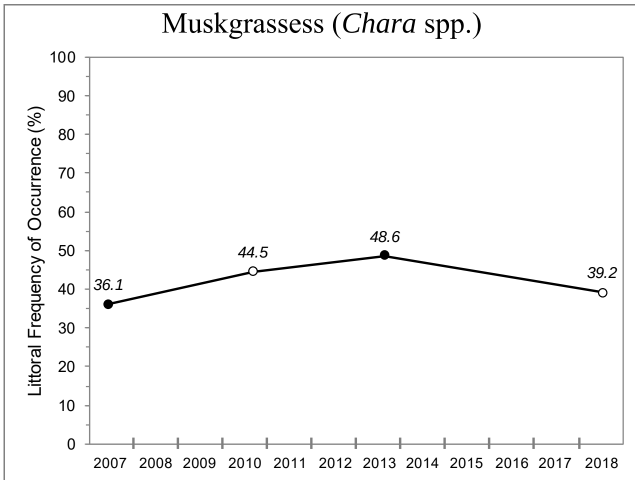

Figure 2.2-4. Littoral frequency of occurrence of muskgrasses. Open circle represents statistically valid change from previous survey. (Chi-Square α = 0.05).

Photo 2.2-1. The aquatic macroalgae muskgrasses (Chara spp.). Photo credit Onterra.

Coontail was the second-most frequently encountered aquatic plant during the 2018 point-intercept survey in Long Lake with a LFOO of 32.8%. After a statistically significant increase between 2007 and 2010, the LFOO of coontail stayed fairly consistent between the 2010 (35.2%), 2013 (35.1%), and 2018 (32.8%) surveys (Figure 2.2-5). Coontail is arguably the most common aquatic plant species in Wisconsin. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives all of its nutrients directly from the water (Gross et al. 2013). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in waterbodies with higher nutrients and lower water clarity. Coontail provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish,

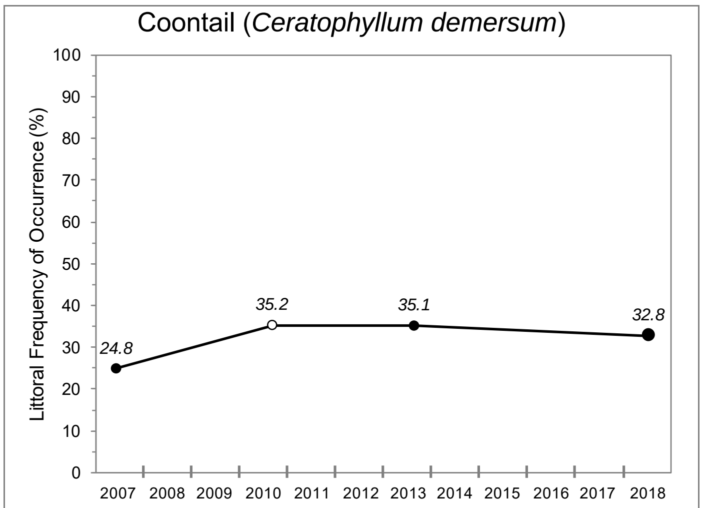

Figure 2.2-5. Littoral frequency of occurrence of coontail. Open circle represents statistically valid change from previous survey. (Chi-Square α = 0.05).

especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and thus helps to improve water clarity.

The LFOO values for all native species of watermilfoils were combined, although the majority of watermilfoil found during the 2018 point-intercept survey was identified as various-leaved watermilfoil (*Myriophyllum heterophyllum*). This grouping of species represents the third most commonly encountered aquatic plant found during the 2018 survey with a LFOO of 30.6% (Figure 2.2-6). A statistically valid decline between 2007 and 2010 can be seen. However, comparing these four years of data, it must be noted that the 2007 survey was conducted in early June, while the latter surveys were completed toward the middle of the growing season (July-August). Various-leaved watermilfoil has dense whorls of finely-dissected leaves which provide valuable structural habitat for aquatic organisms (Photo 2.2-2). However, in some areas of Long Lake, there are watermilfoil beds that mat on the surface and can hinder navigation. Because of this, Onterra had sent samples of the plants for DNA analysis in the past, where they were confirmed to be of the native variety.

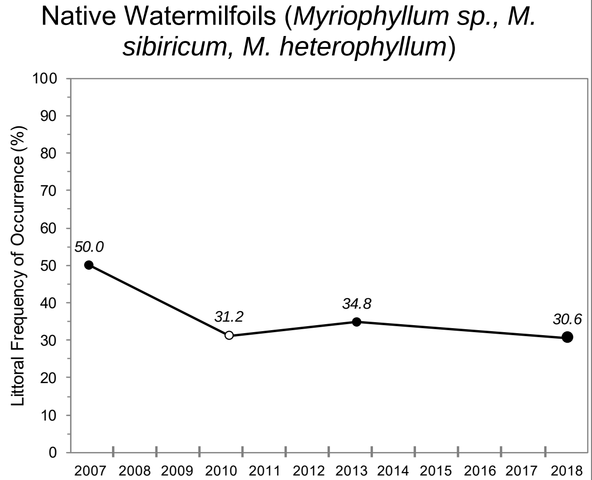

Figure 2.2-6. Littoral frequency of occurrence of native watermilfoils. Open circle represents statistically valid change from previous survey. (Chi-Square α = 0.05).

Photo 2.2-2. Various-leaved water milfoil (*Myriophyllum heterophyllum*) in Long Lake.

Figure 2.2-7 shows how some of the dicot species in Long Lake not already mentioned above have changed over time. The population changes that are seen for white water crowfoot and common bladderwort could be largely due to the surveys being completed at different times of the season. White water crowfoot is typically more abundant early in the growing season and then dies back as the summer progresses. Conversely, common bladderwort is usually less abundant earlier in the growing season. Since the survey in 2007 was completed in early June and the other three surveys were completed later in the growing season this could be why white water crowfoot appears to have declined overall and common bladderwort appears to have increase overall between the four surveys.

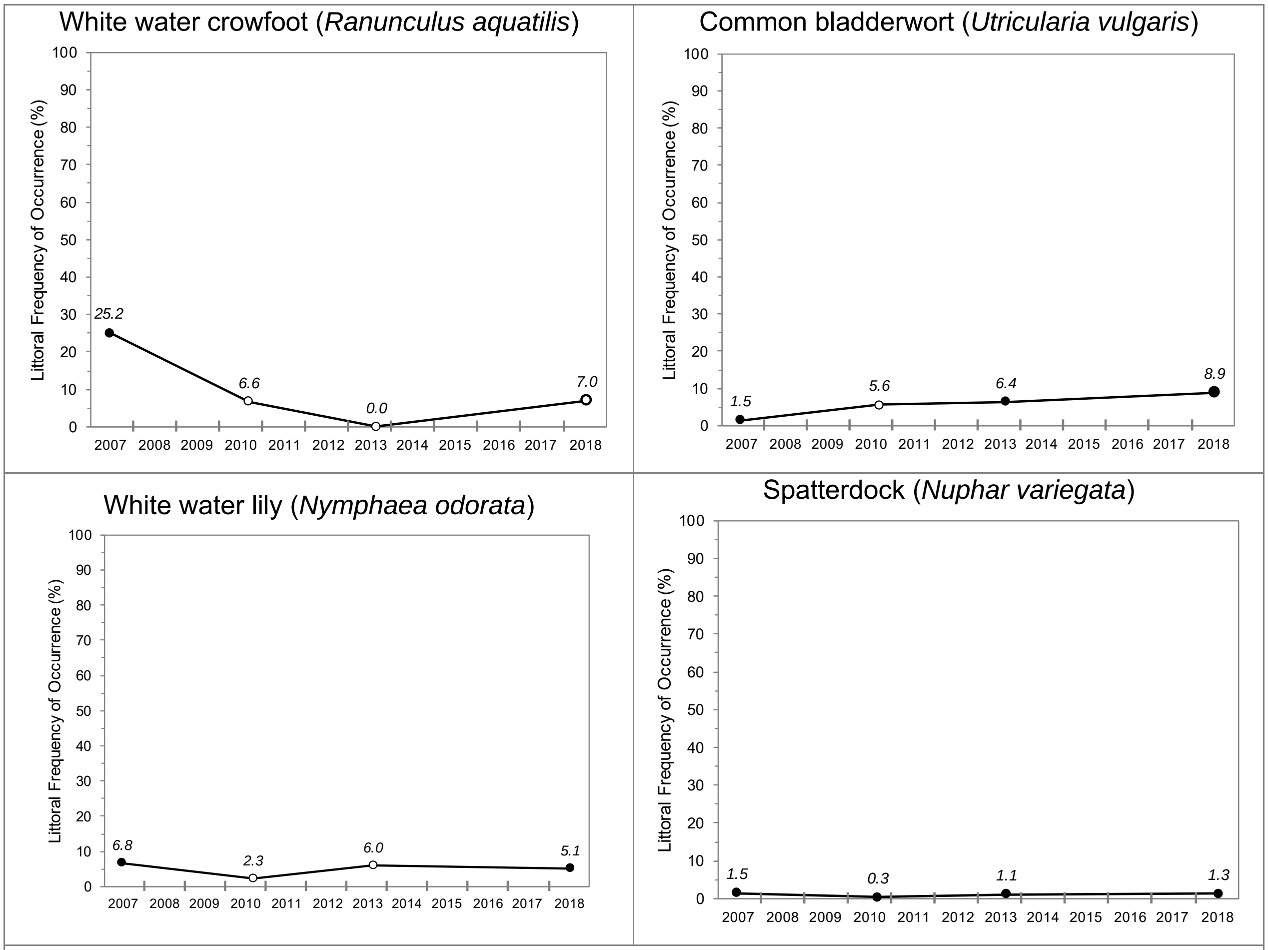

Figure 2.2-7. Littoral frequency of occurrence of native dicot aquatic plant species in Long Lake. Open circle represents statistically valid change from previous survey. (Chi-Square α = 0.05).

Please note that some plant species were grouped to account for difficult field identification (thin-leaved pondweeds). This grouping of plants includes leafy pondweed, Fries' pondweed, and another unidentified species of small pondweed (Figure 2.2-8). The LFOO for this grouping of species was 10.9% in 2007, and was down to 1.6% in 2018. Thin-leaved pondweed species have been shown to be sensitive to aquatic herbicides use to control CLP. The past herbicide use pattern on Long Lake has been restricted to a few locations and is unlikely to cause the lake-wide changes observed.

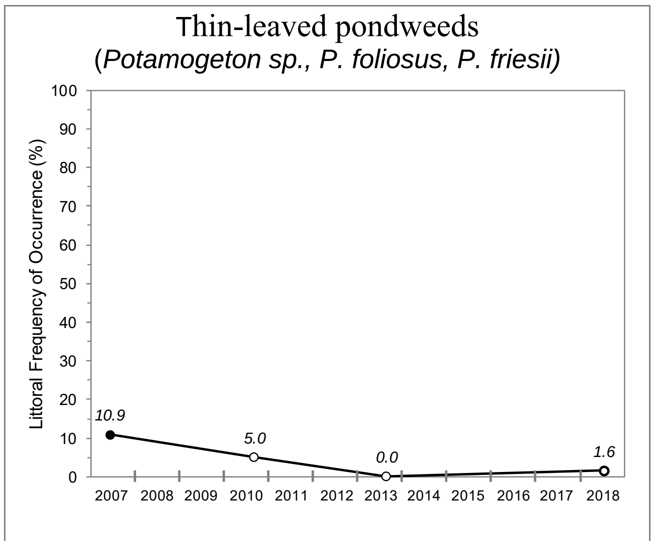

Figure 2.2-8. Littoral frequency of occurrence of thin-leaved pondweeds from 2007-2018. Open circle represents statistically valid change from previous survey. (Chi-Square α = 0.05).

Figure 2.2-9 displays the LFOO for additional select native monocot plant species from the four point-intercept surveys conducted on Long Lake. These species maintained relatively low populations over this time period.

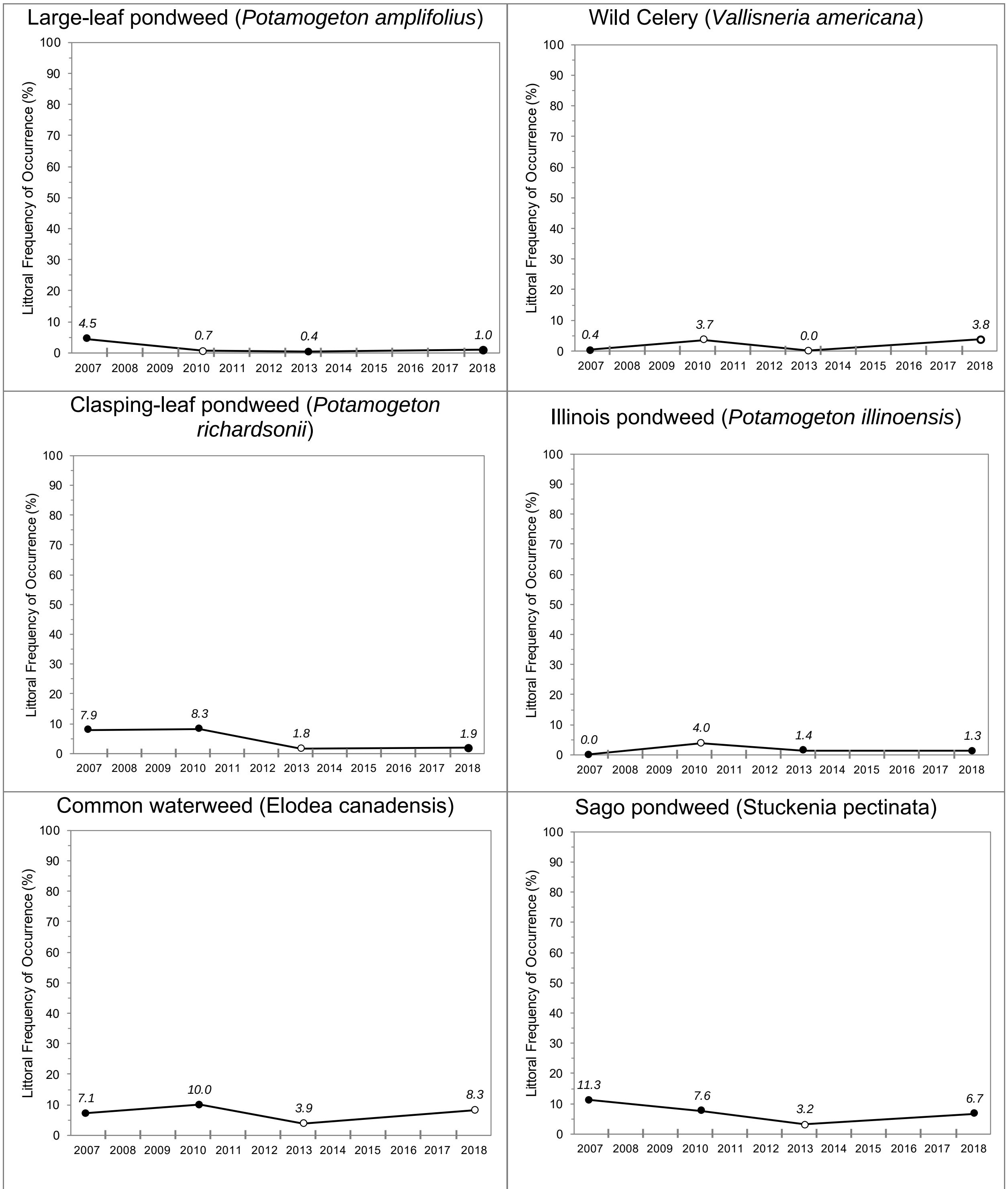

Figure 2.2-9. Littoral frequency of occurrence of select native monocot aquatic plant species from 2007-2018. Open circle represents statistically valid change from previous survey. (Chi-Square α = 0.05).

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, and disease among other factors. It is not known which factor(s) caused the detected changes in occurrence of the aquatic plant species discussed in Long Lake. Small fluctuations in the occurrence of certain species over time are to be expected. However, if large reductions in occurrence, or a complete loss of species were observed, it may indicate an environmental disturbance such as pollution or displacement from invasive species. As previously discussed, some of the changes in abundances seen could be due in part to natural interannual variation.

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. The native aquatic plant species located on the rake during the point-intercept surveys from 2007 to 2018 and their conservatism values were used to calculate the FQI for each year. Native plant species richness has ranged from 20 (2013) to 27 in 2018 with an average of 24 species (Figure 2.2-10). Native plant species richness in all four survey years in Long Lake fell above the median values for other lakes within the SWTP ecoregion (15) and for lakes throughout Wisconsin (19).

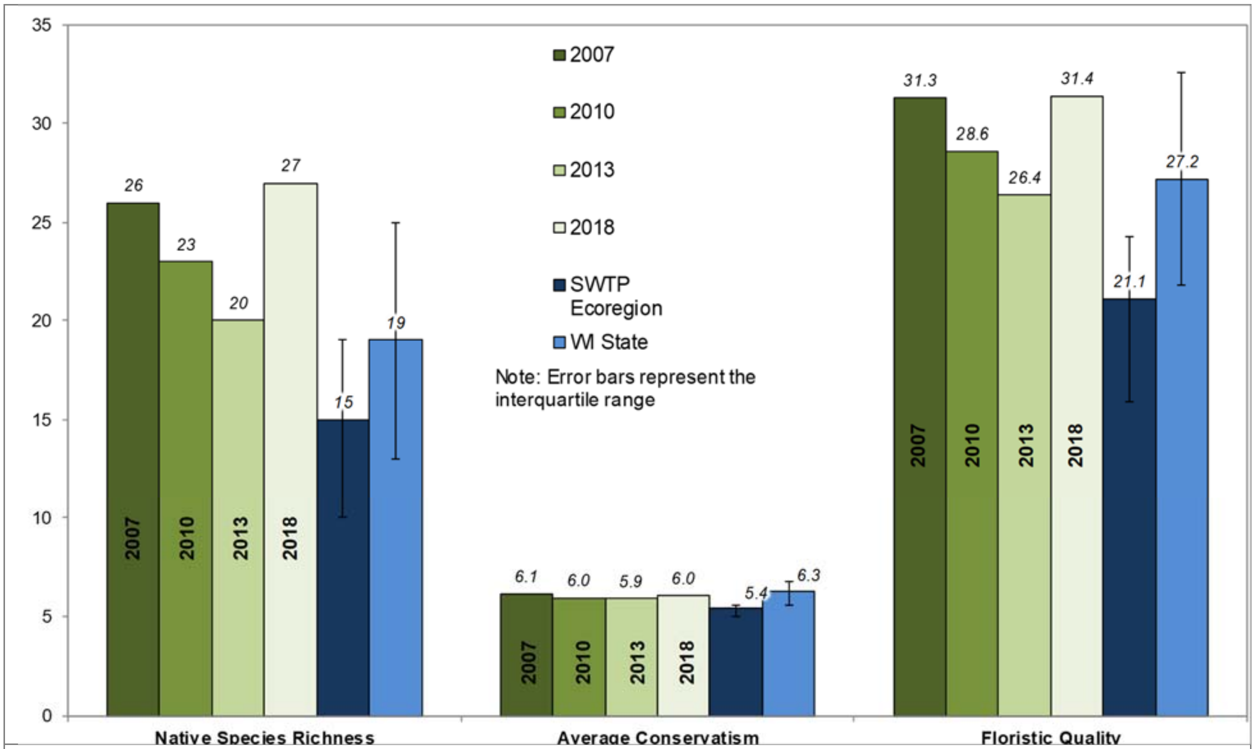

Figure 2.2-10. Long Lake Floristic Quality Assessment. Created using data from 2007, 2010, 2013, and 2018 surveys. Analysis following Nichols (1999) where SWTP = Southeastern Wisconsin Till Plains Ecoregion.

Average species conservatism ranged from 5.9 (2013) to 6.1 (2007) with an average of 6.0, falling above the median value for lakes in the SWTP ecoregion (5.4), but below lakes within the state (6.3) (Figure 2.2-11). Using Long Lake's annual species richness and average conservatism to calculate the annual FQI yielded values ranging from 26.4 in 2013 to 31.4 in 2018 with an average of 29.4. The average FQI value for Long Lake's aquatic plant community falls above the median value for lakes within the SWTP ecoregion (21.1) as well as for lakes throughout Wisconsin (27.2). The only year where the FQI value fell below the state median was 2013.

When compared to other lakes in the SWTP ecoregion, Long Lake has a higher number of native aquatic plant species and a higher number of conservative species, or species that are sensitive to environmental degradation. When compared to other lakes in Wisconsin, Long Lake has a higher number of native aquatic plant species. Overall, the FQI analysis indicates that the native plant community of Long Lake is of higher quality when compared to regional lakes and to lakes throughout the state.

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 Long Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the SWTP Ecoregion (Figure 2.2-11). Using the data collected from the 2007-2018 whole-lake point-intercept surveys, Long Lake's aquatic plant species diversity ranged from 0.79 in 2013 to 0.92 in 2007. The 2007, 2010, and 2018 species diversity values fall at or above the upper quartile value (0.87) for lakes within the SWTP ecoregion, indicating high species diversity. Only 2013 species diversity (0.79) fell below the ecoregion median of 0.82.

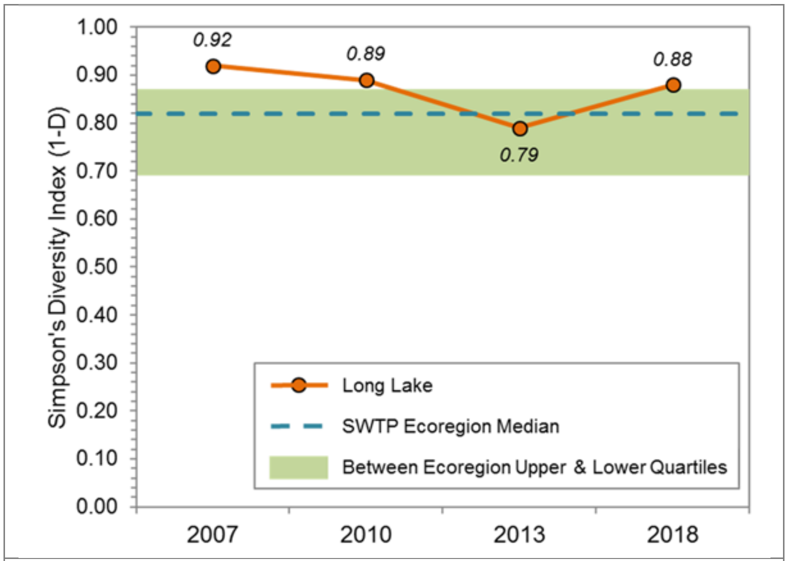

Figure 2.2-11. Long Lake 2007-2018 Simpson's Diversity Index. Created using data from 2007-2018 whole-lake point-intercept surveys.

As explained earlier 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 muskgrasses was found at 48% of the sampling locations in Long Lake in 2018, its relative frequency of occurrence was approximately 22% (Figure 2.2-12). Explained another way, if 100 plants were randomly sampled from Long Lake, 22 of them would be muskgrasses. This analysis can demonstrate how the aquatic plant community has shifted over this time period.

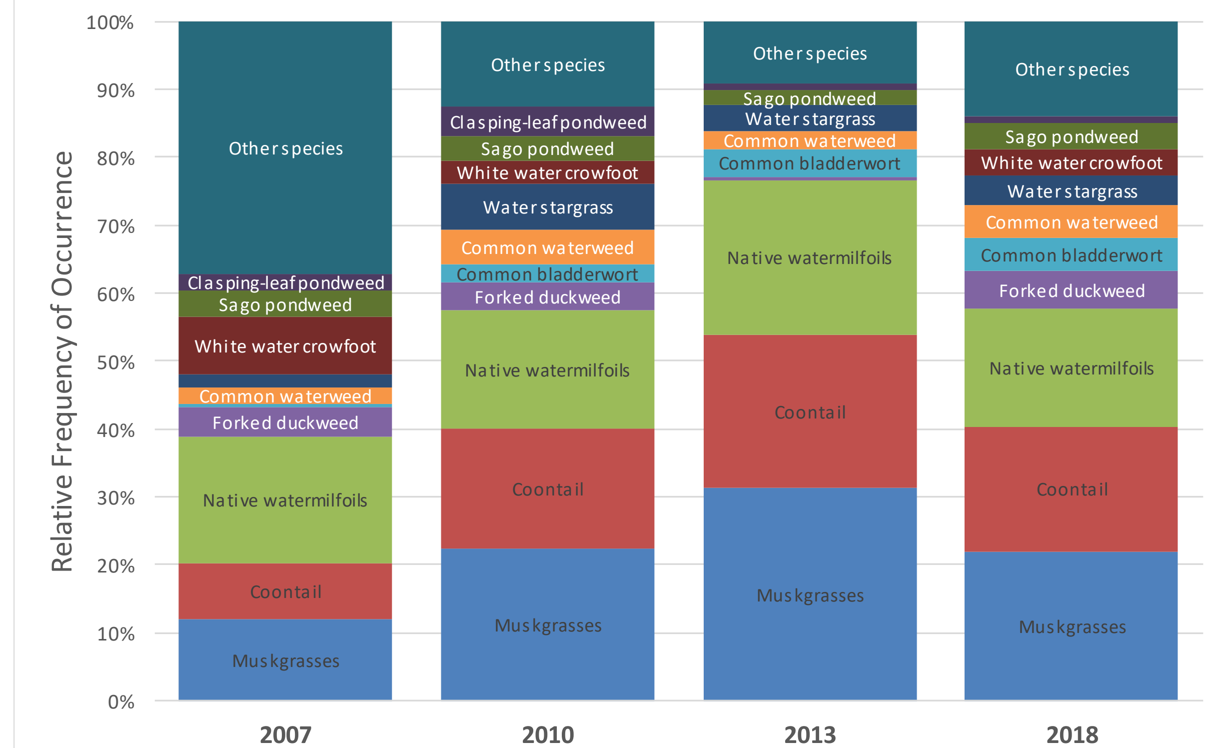

Figure 2.2-12. Relative frequency of occurrence analysis of Long Lake.

2.3 Non-native Aquatic Plants in Long Lake

Primer on EWM and CLP

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties. 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, EWM 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 sometimes 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. However, in some lakes, EWM/HWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

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. The plants begin rapidly growing almost immediately after, if not before, ice-out and by early-summer they reach their peak growth. As they are growing, each plant produces numerous turions (asexual reproductive structures) which break away from the plant and settle to the bottom following the plant's senescence in early July (Photo 2.3-1). The deposited turions lie dormant until autumn when a portion of them sprout to produce small winter foliage, and they remain in this state until spring foliage is produced. The portion of turions that do not sprout can remain dormant for at least 5 years (likely longer) and still sprout (Johnson et al. 2012).

Photo 2.3-1. Curly-leaf pondweed turion. Photo credit: Onterra.

The advanced growth in spring gives the plant a significant head start over native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition (James et al. 2002). However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

Long Lake Historic HWM and CLP Management

Herbicide treatments were completed between 2000-2006 to control nuisance growth of native aquatic plants, including algae, to improve navigation in specific areas of the lake. All of these treatments were less than five acres in size and used a variety of herbicides and algaecides. The first herbicide treatment in Long Lake aimed at controlling HWM and CLP was in 2007.

On Long Lake, 2,4-D applications targeting HWM occurred in 2007, 2013, and 2014, whereas endothall treatments targeting CLP occurred every year except one from 2007-2018 (Figure 2.3-1). Specifics regarding historic herbicide treatments as well as past projects on Long Lake can be found in the *Long Lake Comprehensive Management Plan* (March 2015) and is housed on the WDNR website:

https://dnr.wi.gov/lakes/grants/project.aspx?project=99027324

The following sections will present the overall findings of the HWM and CLP control and monitoring activities completed during the current project. Finer-scale analysis and discussion can be found in each years' respective annual *AIS Monitoring & Control Strategy Assessment Report*. Reports from 2015, 2016, and 2017 can be found on the WDNR website:

https://dnr.wi.gov/lakes/grants/project.aspx?project=115661305

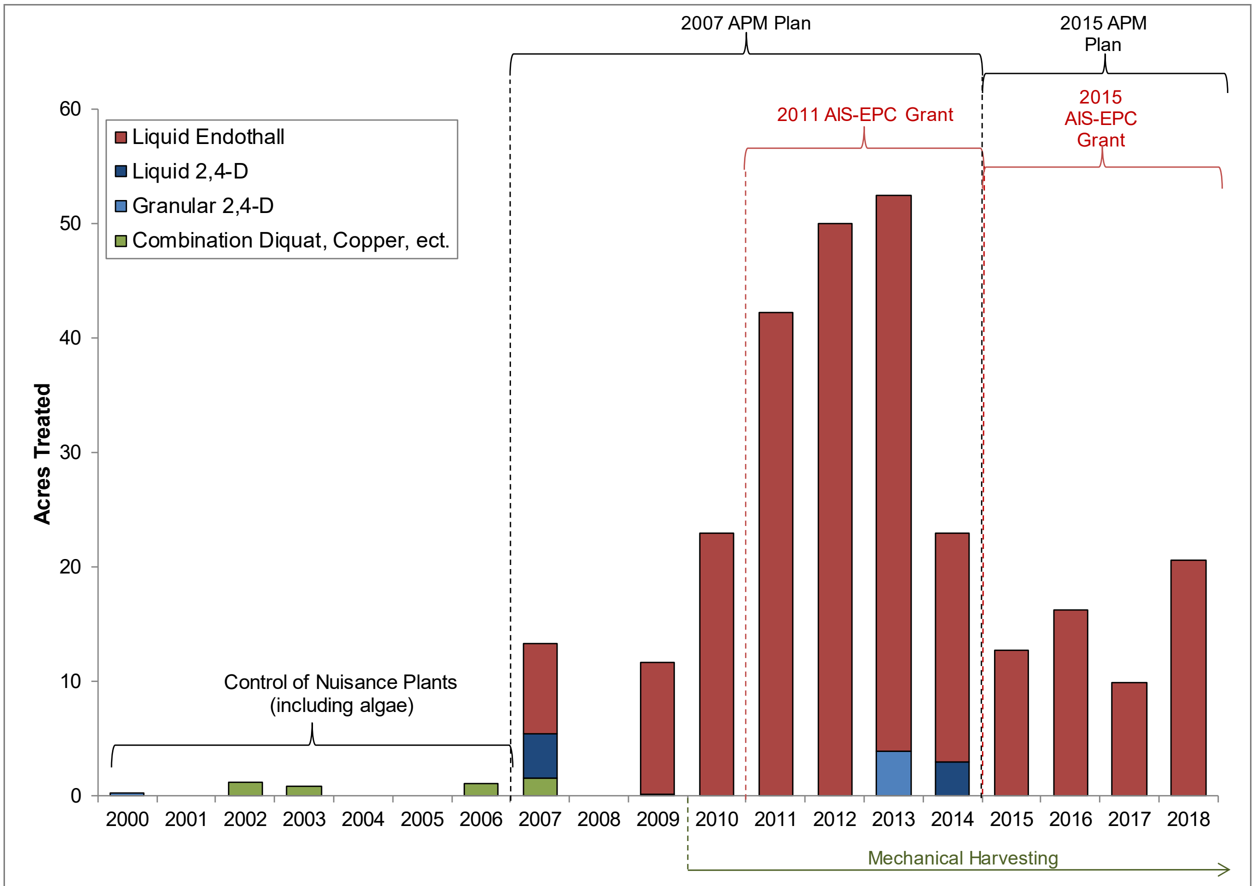

Figure 2.3-1. Long Lake historical treatment acreage.

2015-2018 Eurasian Watermilfoil Control & Monitoring

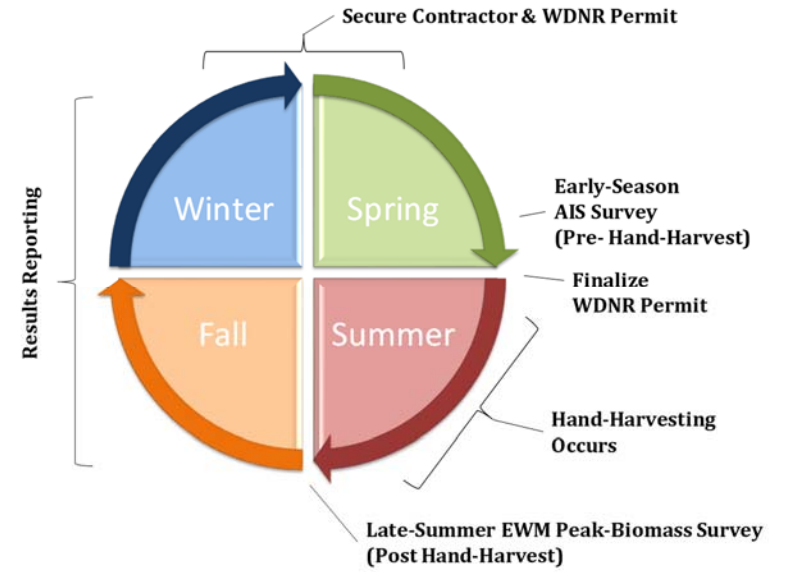

Figure 2.3-2. Hand-harvesting project timeline diagram.

The HWM population has remained relatively low since discovery and was targeted for control with a professional hand-harvesting effort in 2017-2018. A set of HWM mapping surveys were used within this project to coordinate and qualitatively monitor the hand-harvesting efforts (Figure 2.3-2). The first monitoring event each year was the Early Season Aquatic Invasive Species Survey (ESAIS). This late-spring/early-summer survey provides an early look at the lake to help guide the hand-harvesting management to occur on the system. Following the hand-harvesting, Onterra ecologists completed the Late-Summer EWM Peak-Biomass Survey, the results of which serve as a post-treatment assessment of the hand-harvesting. The hand-removal program would be considered successful if the density of HWM within the hand-removal areas was found to have decreased from the ESAIS Survey to the Late-Summer Peak-Biomass Survey.

On June 6-7, 2018 Onterra ecologists completed the early-season AIS survey using the standard point and polygon-based mapping methodologies as previously used on Long Lake. Survey conditions were noted as favorable. Numerous *single or few* HWM occurrences were found around the lake with the majority being in littoral areas of the north and south ends of Long Lake and in Tittle Lake. Eleven *clumps of plants* and three *small plant colonies* of HWM were also found within these same areas. Only one small 0.04-acre was mapped with a polygon and classified as *dominant.* This was located on the far northwestern end of Long Lake and shown in Figure 2.3-3 below. From the results of the ESAIS survey, the HWM hand-harvesting control strategy was finalized to include targeting two sites totaling approximately 1.5 acres where the largest known concentrations of HWM were located in the lake (Map 2). Onterra provided the spatial data from the survey to the professional hand-harvesting firm to aid in removal efforts.

Due to a successful pilot professional hand-harvesting program in 2017, the LLPA again contracted with Eco Waterway Services LLC in 2018 to continue hand removal of HWM in Long Lake. The hand-removal program would again be considered successful if the density of HWM within the hand-removal areas was found to have decreased from the early-season AIS (ESAIS) Survey to the late-summer peak-biomass (EWMPB) survey. Onterra provided spatial data from the ESAIS survey to the professional hand-harvesting firm to aid in the removal efforts. Using a Diver Assisted Suction Harvest (DASH) unit, Ecowaterways removed a total of 13,050 pounds of aquatic plants over four days in June 2018. According to a report provided by Eco Waterway Services, the removed vegetation consisted of approximately 90% non-native plants, and 10% native plants. Additional details of the DASH harvesting efforts are included within a summary report created by Eco Waterway Services and are included as an appendix to this report (Appendix C).

Onterra ecologists completed the late-season HWM survey on October 11, 2018 (Map 3). Crews noted fair visibility along the west shoreline, but poor visibility on the east shoreline due to high winds coming from the west creating waves and ripples on the surface. However, being somewhat protected from the wind, visibility in the hand-harvest areas was good. Again, numerous *single or few* HWM occurrences were located throughout Long Lake, but mostly in the same far north and far south ends of the lake. Nine *clumps of plants* were located in these same areas as well. No small plant colonies, or polygons were mapped.

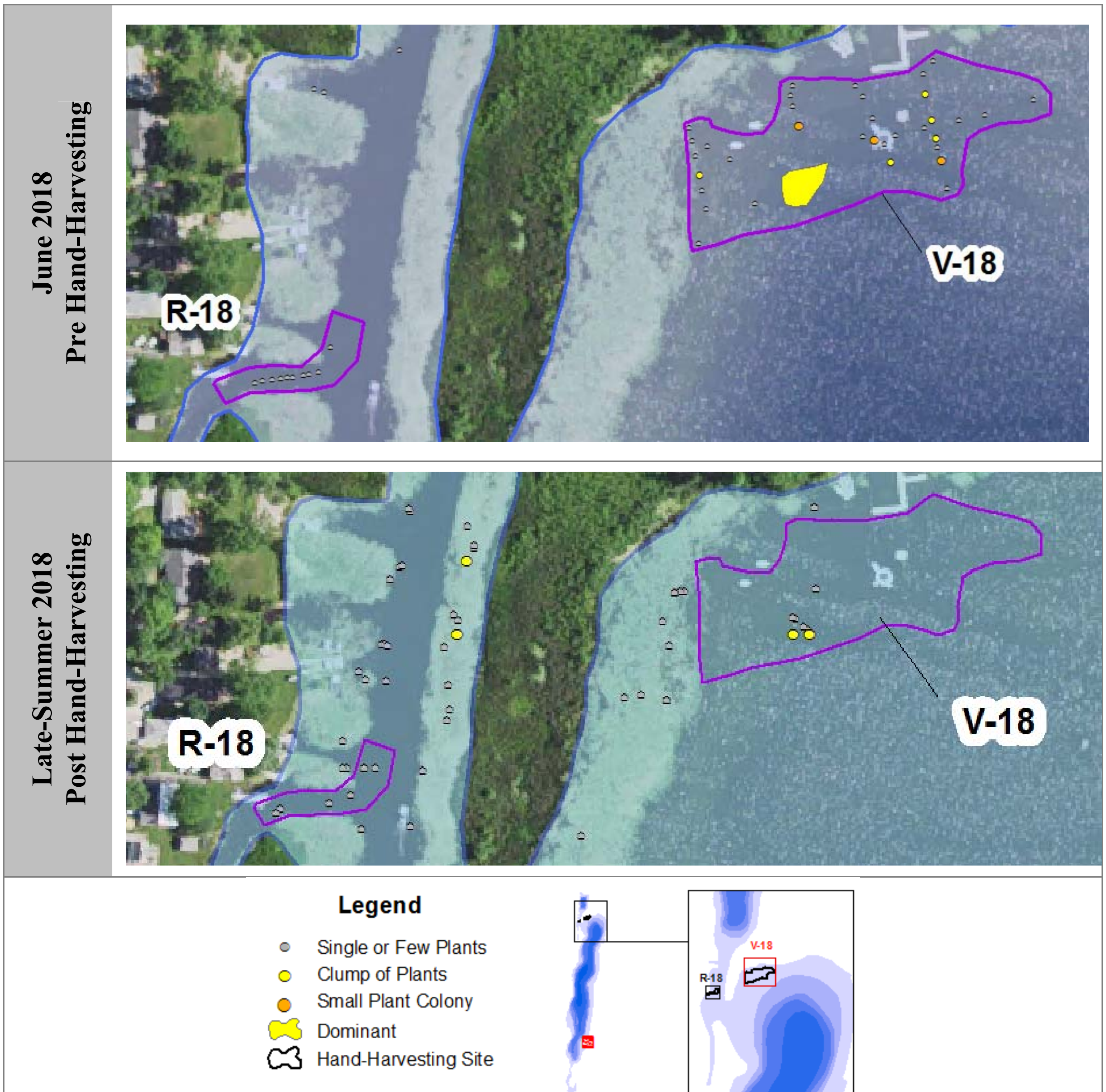

Figure 2.3-3. Hand-Harvesting Evaluation for Focus Sites in Long Lake. HWM locations from June 2018 pre- and October 2018 post-hand-harvesting surveys.

Within the hand-harvest areas, HWM populations were found to have decreased between the ESAIS and EWMPB surveys. In site R-18 where there were 10 *single or few* occurrences during the ESAIS, only 6 *single or few* plants were found during the EWMPB. In site V-18, during the ESAIS, there were numerous *single or few* plants, five *clumps of plants*, three *small plant colonies*, and a small *dominant* colony. During the EWMPB, site V-18 only contained two *clumps of plants* and five *single or few* plants. Because of the significant decrease of HWM between the early and late season surveys within the hand-harvest areas, the DASH program would again be considered a success for 2018.

A succession map of the late-season HWM surveys completed between 2015-2018 can be found at the end of this report (Map 4). This provides a visual of how the HWM population has changed over the course of this project. Overall, the HWM population of Long Lake has remained relatively low which may be a function of the active management that has taken place to date. Unknown attributes of Long Lake may also contribute to HWM not becoming overly abundant and remain below levels where the ecosystem function, navigation, recreation, and aesthetics become impacted.

2015-2018 Curly-Leaf Pondweed Control & Monitoring

Figure 2.3-4 shows the CLP-directed herbicide spot treatments that occurred on Long Lake from 2016-2018. The area only treated once near the east shore in front of the State Park was first targeted in 2018 and sub-sample point-intercept data was not added to this site. Most other areas were treated in part or entirely for three straight years as part of the current project.

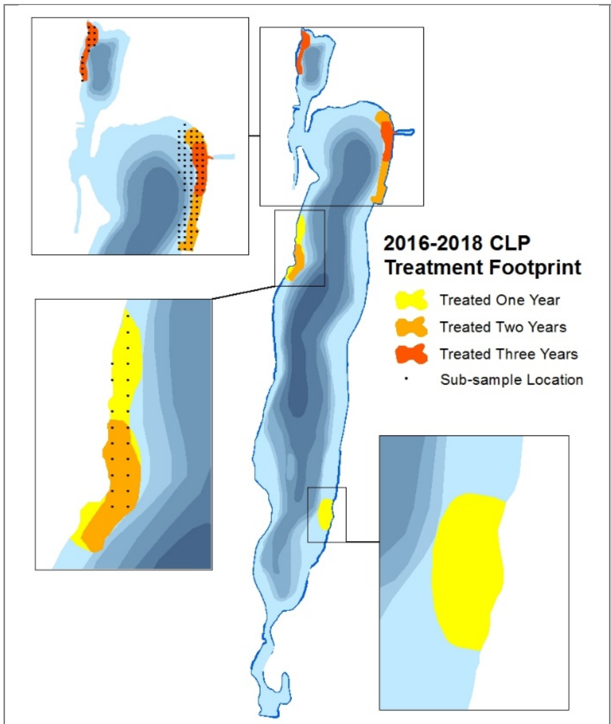

Figure 2.3-4. 2016 – 2018 treatment footprint and sub-sample monitoring grid. 137 sub-sample locations within CLP treatment areas of Long Lake.

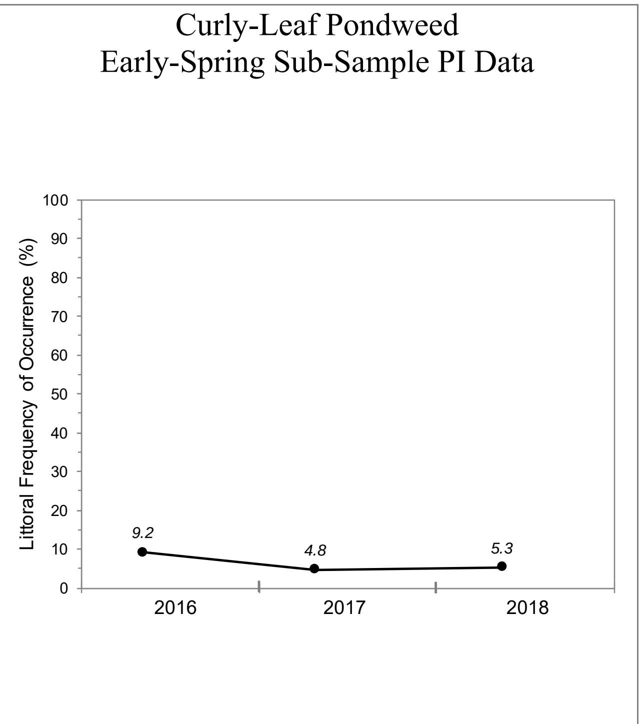

Figure 2.3-5. CLP annual spring pretreatment point-intercept sub-sample data. 137 sub-sample locations within CLP treatment areas of Long Lake.

Figure 2.3-5 shows the results of the spring pretreatment sub-sample point-intercept surveys between 2016-2018. The littoral frequency of occurrence of CLP during the spring of 2017 and 2018 were approximately 5% compared to approximately 9% during the spring of 2016.

Starting in 2011, late-June CLP mapping surveys commenced using a consistent density rating system (Figure 2.3-6). In 2011, approximately 19 acres of colonized CLP was located in the lake with numerous additional locations of CLP marked with point-based data being located within the littoral zone. Please note that this figure represents only the acreage of mapped CLP polygons, not CLP mapped within point-based methodologies (*Single or Few Plants, Clumps of Plants,* or *Small Plant Colonies*). In 2011, almost the entirety of the colonized acreage was comprised of CLP with *dominant* or *highly dominant* density ratings.

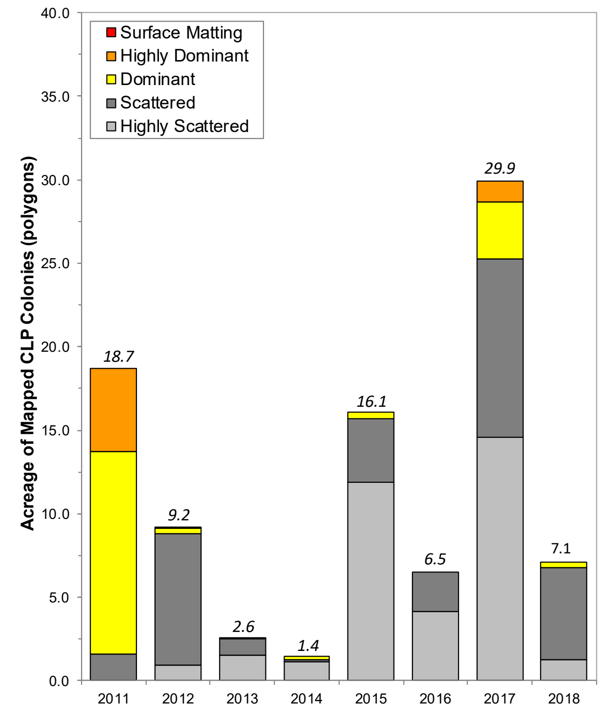

Figure 2.3-6. Acreage of mapped CLP colonies on Long Lake from 2011 to 2018. Data from Onterra early-season AIS surveys.

Colonized acreage of CLP has varied over the timeframe of study, likely in response to annual herbicide management and environmental factors that drive turion sprouting each spring (Map 5). It is also important to note that since 2011, almost the entirety of the CLP acreage has been comprised of low-density colonies.

The amount of CLP mapped with polygons in 2018 was significantly less than the total of 29.9 acres mapped in 2017 (Figure 2.3-7, Map 6). In treatment site A-18, where there were previously 10 *clumps of plants* and numerous *single or few plant* occurrences, post-treatment there were two *clumps of plants* and several, but fewer, *single or few plants.* In site B-18, pre-treatment, there was a 0.37-acre *dominant* colony connected to a 1.5-acre *scattered* colony. Post-treatment, site B-18 only contained three *single or few plants* of CLP. Site C-18 is the only treatment site that did not improve post-treatment. Pre-treatment, site C-18 had an approximately 1.0-acre *scattered* colony on the far southeast end of the treatment area along with a few *single or few plants*, and two *clumps of plants* and four *single or few plants* on the north end. Post-treatment, the scattered colony was gone, and no CLP was found at the south end of the treatment area. However, at the north end, many more point-based occurrences were mapped, including two *small plant colonies* and numerous *clumps of plants* and *single or few plants*. In addition, just outside of the treatment area, where a stream runs in to the north end of Long Lake, a *scattered* and h*ighly scattered* colony were mapped where there was previously no CLP. Treatment site D-18 pre-treatment contained a 0.33-acre *dominant* colony of CLP in between two *scattered* colonies totaling approximately 1.2 acres, with a 0.34-acre *highly scattered* colony on the south end. Post-treatment, site D-18 only contained one *single or few plant* occurrences.

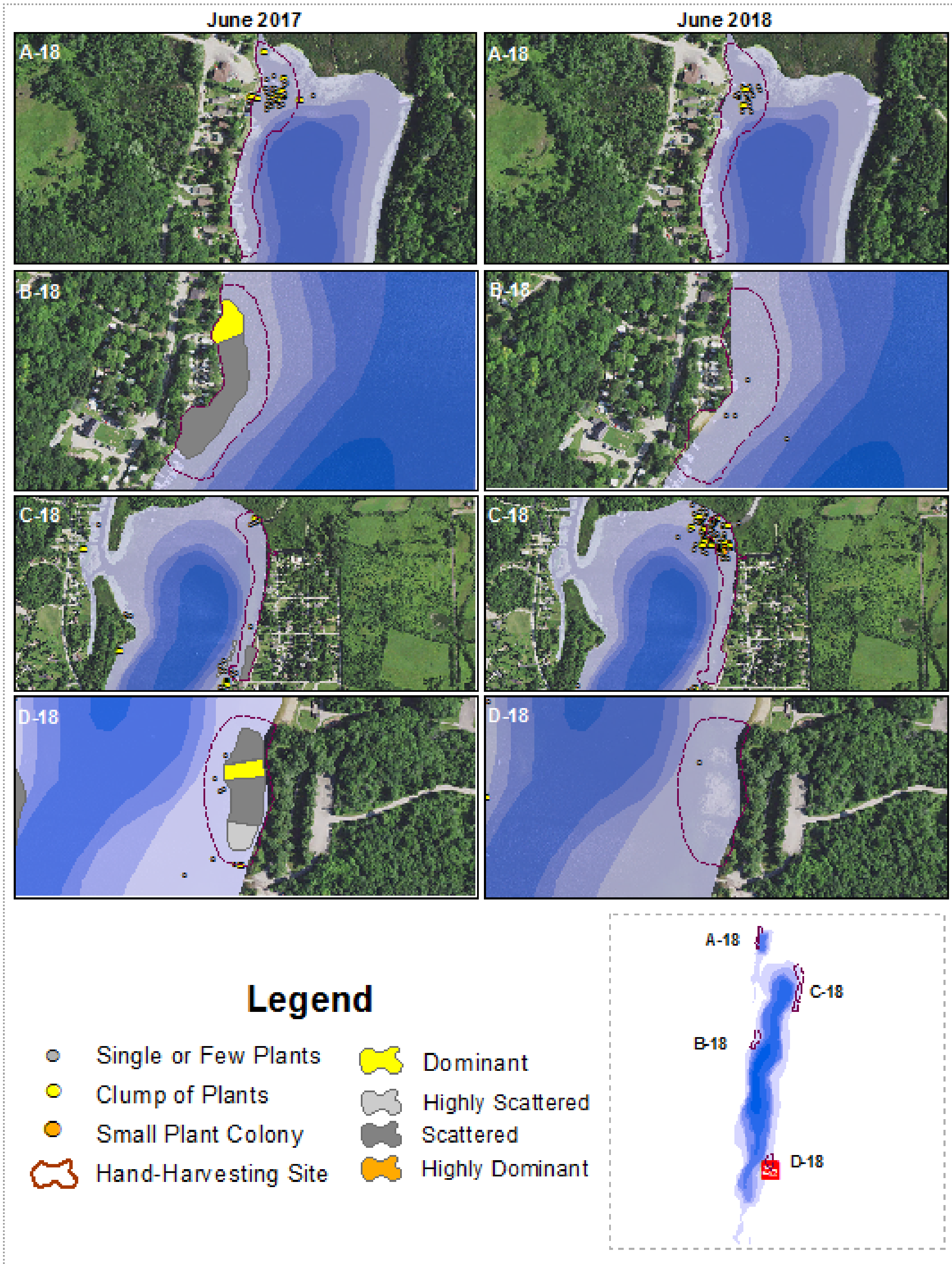

Figure 2.3-7. CLP mapped in Long Lake treatment areas in 2017 compared to 2018.

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced in one year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. As discussed above, traditionally a control strategy for an established CLP population includes 5-7 years of treatments of the same area to deplete the existing turion bank within the sediment (Jones et al 2012, Johnson et al. 2012). In practice, it is unclear how many years CLP turions can remain viable and therefore the number of consecutive years treatments are required is unknown. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species. The LLPA will need to balance a level of CLP population tolerance while not allowing population to return to pre-management levels.

3.0 AQUATIC PLANT IMPLEMENTATION PLAN SECTION

The *Long Lake Comprehensive Management Plan* was finalized and approved by the WDNR in March 2015. The Implementation Plan Section of the *Long Lake Comprehensive Management Plan* (March 2015) includes the following management goals along with specific management actions developed to help reach those goals. The *Long Lake Comprehensive Management Plan* (March 2015) can be found on the WDNR website located here:

https://dnr.wi.gov/lakes/grants/project.aspx?project=99027324

1. Increase LLPA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities
   - Use education to promote lake protection and enjoyment through stakeholder education
   - Continue LLPA's involvement with other entities that have responsibilities in managing (management units) Long Lake
2. Maintain Current Water Quality Conditions
   - Monitor water quality through WDNR Citizens Lake Monitoring Network
3. Control Existing and Prevent Further Aquatic Invasive Species Infestations within Long Lake
   - Continue Spot Treatment Herbicide Control Strategy targeting CLP on Long Lake
   - Continue Targeting EWM/HWM on Long Lake with Spot Herbicide Treatments and Hand-Harvesting, as Appropriate
   - Continue Clean Boats Clean Waters watercraft inspections at Long Lake public access location
   - Reduce occurrence of purple loosestrife on Long
   - Reduce occurrence of common reed (Phragmites) on Long Lake.
4. Improve Fishery Resource and Fishing by protecting and restoring the shoreland condition of Long Lake
   - Investigate restoring highly developed shoreland areas around Long Lake
   - Protect natural shoreland zones around Long Lake
   - Coordinate with WDNR, Boy Scout Camp, LLFC, and private landowners to expand coarse woody habitat in Long Lake
5. Maintain Navigability on Long Lake
   - Support responsible actions to gain reasonable navigational access to open water areas of Long Lake
   - Investigate conducting advanced studies to understand sedimentation within the lake

Figure 3.0-1. Long Lake management goals (numbered) and actions developed to assist in reaching the goal. *Long Lake Comprehensive Management Plan* (March 2015)

Following the completion of the *Long Lake Comprehensive Management Plan* (March 2015), and a four-year AIS grant was given to help implement the AIS management actions outlined within the *Plan* through 2018 (ACEI-159-15). As a part of that project, the LLPA would revisit their aquatic plant management-related Implementation Plan to update its content based on the lessons learned during the project, specifically Management Goal 3 (AIS Management) and Management Goal 5 (Nuisance Plant Management).

3.1 Aquatic Invasive Species Management

On November 1, 2018, a teleconference between Onterra and representatives of the LLPA took place. The focus of this strategic planning meeting was to discuss future AIS management on Long Lake, as well as various funding opportunities. The preliminary strategy developed from that meeting included a way to couple the approximately $14,000 of remaining funds from the open grant (ACEI-159-15) with a WDNR AIS-Education, Prevention, and Planning grant application to fund two additional years of EWM hand-harvesting and monitoring. CLP management would be postponed during the two additional project years. However, after continued internal discussions within the LLPA, it was determined not to pursue extension of the current project. The LLPA Board of Directors cited two main reasons for their decision:

1. The current AIS populations within Long Lake are low. Hand-harvesting is the most scale-appropriate management activity at these levels. The LLPA considers the costs of these activities very expensive and not commensurate with quantity of impact these activities provide. The maintenance of low AIS populations do not currently fit well within the WDNR's funding priorities. Without access to grant funds to offset the costs of the active management activities, the LLPA does not have the funds to continually fund these activities.
2. When involved with a WDNR grant-funded project, 200 annual hours of Clean Boats Clean Waters (CBCW) is essentially mandatory. While the LLPA has been able to meet past watercraft inspections commitments, this program has resulted in volunteer fatigue. The LLPA intends to continue CBCW inspections, but at a level supported by existing volunteerism.

The following management goal and associated management actions were modified from the *Long Lake Comprehensive Management Plan* (March 2015) and will guide the LLPA until the next update.

Management Goal 3: Manage Existing and Prevent Further Aquatic Invasive Species Infestations within Long Lake

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at critical public access locations
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	Currently the LLPA monitors the public boat landings using training provided by the Clean Boats Clean Waters program. Long Lake is a popular destination by recreationists, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its access point, but also to prevent the infestation of other waterways with invasive species Long Lake. The goal would be to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. The LLPA has approximately met their goal of 200 annual inspection hours from 2011 to 2018. The LLPA will continue conducting CBCW moving forward, but anticipates more difficulty reaching 200 annual hours due to volunteer fatigue. If the LLPA pursues future WDNR grant opportunities, they will commit to 200 hours of watercraft inspections during those years.
Action Steps:	
	See description above as this is an established program.

Management Action:	Coordinate professional monitoring of AIS
Timeframe:	Initiate 2022-2025
Facilitator:	Board of Directors
Description:	As a result of monitoring activities conducted over the past decade on Long Lake, much information has been gained in regards to EWM and CLP management on Long Lake. CLP currently exists throughout the littoral zone of Long Lake at low densities. EWM is confined to a more localized footprint, also existing at low densities. On many lakes, EWM and CLP populations will plateau at a level where the ecosystem function is not altered and navigation, recreation, and aesthetics are not impeded. The LLPA intends to postpone active management for a few years to understand the population trajectory of these species in absence of management. Unless prompted by a specific rationale, the LLPA would initiate professional AIS mapping surveys again in 3-5 years.

		For lakes that contain both EWM and CLP, an Early Season AIS Survey is typically the most informative survey that can be conducted. This June survey would include a complete meander survey of the lake's littoral zone by professional ecologists. The AIS would be categorized using a combination of point-based on polygon-based mapping methods with defined density designations. Conducting the survey at this time of year is ideal, as 1) typically, the water is clearer during the early summer allowing for more effective viewing of submersed plants, 2) EWM plants are higher in the water column than most native plants during this time of year, increasing the chances of locating this species, and 3) CLP is at peak-biomass during June and is the best time to detect this species. If the LLPA considers EWM management, a replicate meander-based mapping survey conducted late in the summer may be warranted. EWM continues to grow throughout the summer and is at its peak growth stage late in the summer. On some lakes, EWM populations can be larger and denser late in the summer compared with during the Early Season AIS Survey.
Action Steps:		
1.	After a period of 3-5 years, contract with a consulting firm to complete and Early Season AIS Survey.	
2.	Review the survey results and determine if active management of either/both species is warranted.	
3.	If active management options are pursued, develop a scale-appropriate management and monitoring strategy that embraces best management practices.	

<u>Management Action:</u>	Coordinate Periodic Quantitative Vegetation Monitoring
Timeframe:	Every 5 years – next survey in 2023
Facilitator:	Board of Directors
Description:	The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) have been conducted on Long Lake in 2007, 2010, 2013, and 2018. At each point-intercept location within the *littoral zone,* information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR generally recommends that a whole-lake point-intercept survey be conducted at least once every 5 years if a lake group wants to understand the aquatic plant community dynamics of a lake. The

	LLPA will continue collection of these data at approximately 5-year intervals.
Action Steps:	
	See description above

Management Action:	Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
Timeframe:	Every 10 years unless prompted – next survey in 2024
Facilitator:	Board of Directors
Description:	In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Long Lake, a community mapping survey would be conducted approximately every 10 years unless a specific rationale prompts a shorter interval. This survey was conducted on Long Lake in 2014. This survey would delineate the margins of floating-leaf (e.g. water lilies) and emergent (e.g. cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. The survey would identify areas of emergent invasive plants, of which purple loosestrife and giant reed have been identified from the margins of Long Lake in the past.
Action Steps:	
	See description above

3.2 Nuisance Aquatic Plant Management

The LLPA understands the importance of native aquatic vegetation on Long Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, caused largely by native vegetation such as various-leaved water milfoil (*Myriophyllum heterophyllum*). Onterra ecologists had not observed various-leaved water milfoil growing to the densities present in Long Lake. In the northeastern United States, there is an invasive strain of various-leaved water milfoil, and because of its behavior in Long Lake, Onterra ecologists sent specimens from Long Lake to the Annis Water Resources Institute at Grand Valley State University in Michigan to undergo DNA analysis. Their results revealed that the various-leaved water milfoil present in Long Lake is of the *continental* strain, the strain that is not considered to be invasive.

Management Goal 5: Maintain Navigability on Long Lake

Management Action:	Support responsible actions to gain reasonable navigational access to open water areas of Long Lake
Timeframe:	Continuation of Current Effort
Facilitator:	Board of Directors
Description:	The LLPA supports the reasonable and environmentally sound actions to facilitate navigability on Long Lake. For Long Lake, the most scale-appropriate management technique is contracting a mechanical harvester (i.e. weed cutter). These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore lake surface area than necessary. Finalized in April 2016, the LLPA developed a formal mechanical harvesting plan that is attached as Appendix B. The LLPA has followed this plan from 2016 to 2018, conveying that it currently meets the needs of lake users. The LLPA intends to continue to follow this plan moving forward with a few modifications with how the plan deals with avoidance of AIS. While a formal AIS mapping survey would no longer be conducted prior to mechanical harvesting, the LLPA would comply with the following: • With CLP populations now being located throughout the littoral zone, concerns of spreading this plant to new locations within the lake are much less. Areas known to contain colonized areas of CLP would not be mechanically harvested until after the plants naturally senesced, approximately after the middle of July. • EWM populations in Long Lake continue to be at low-density occurrences. Concerns of spreading EWM within Long Lake with mechanical harvesting operations is mostly focused at colonized and dense colonies with high fragment potential. Areas known to contain colonized areas of EWM would be avoided during mechanical harvesting.
Action Steps:	
	See description above

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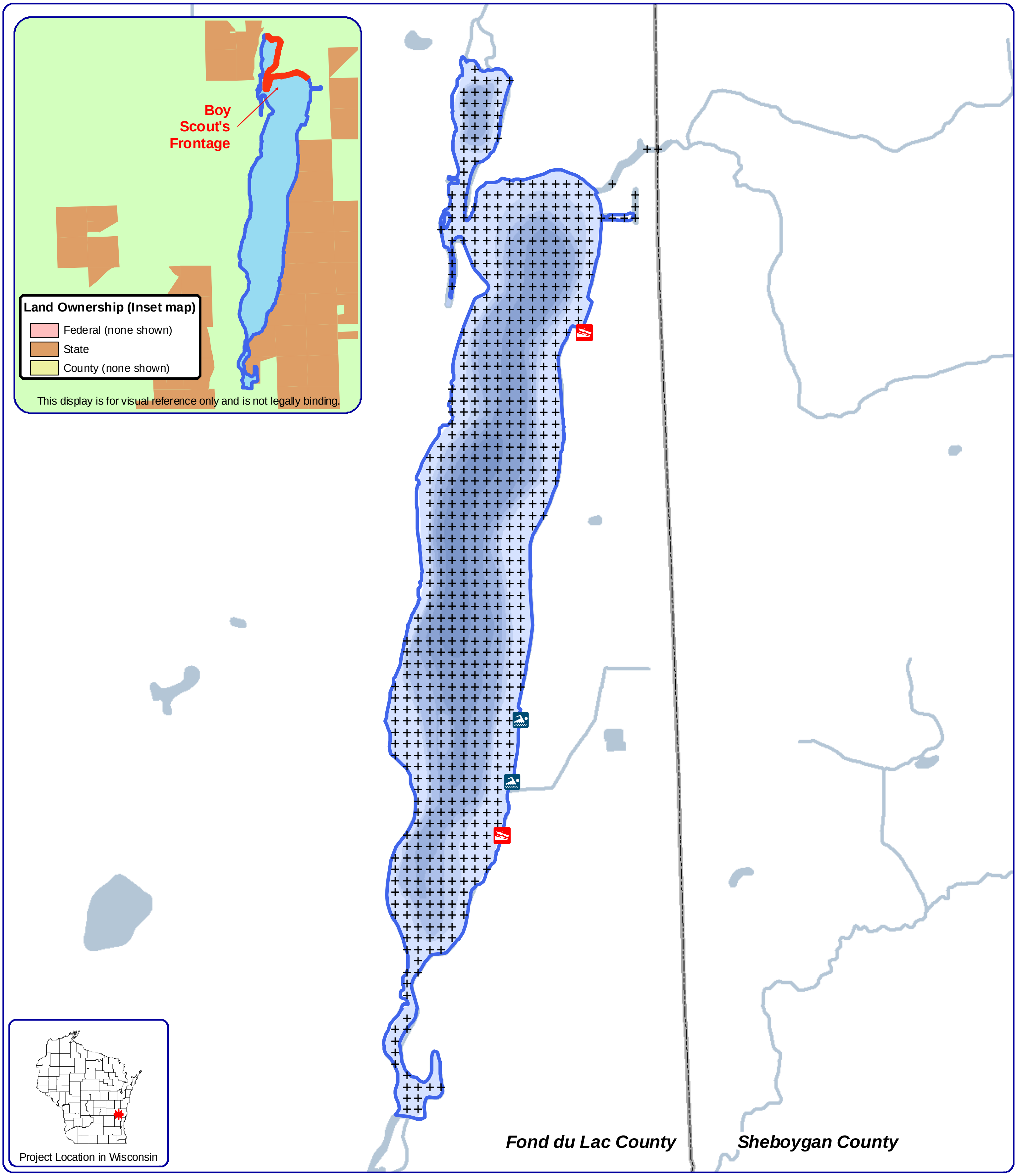

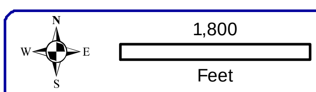

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www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1967; digitized by Onterra
Map Date: October 24, 2014
Filename: Map1_LongFDL_Location.mxd

Legend

Long Lake ~423acres
WDNR Definition

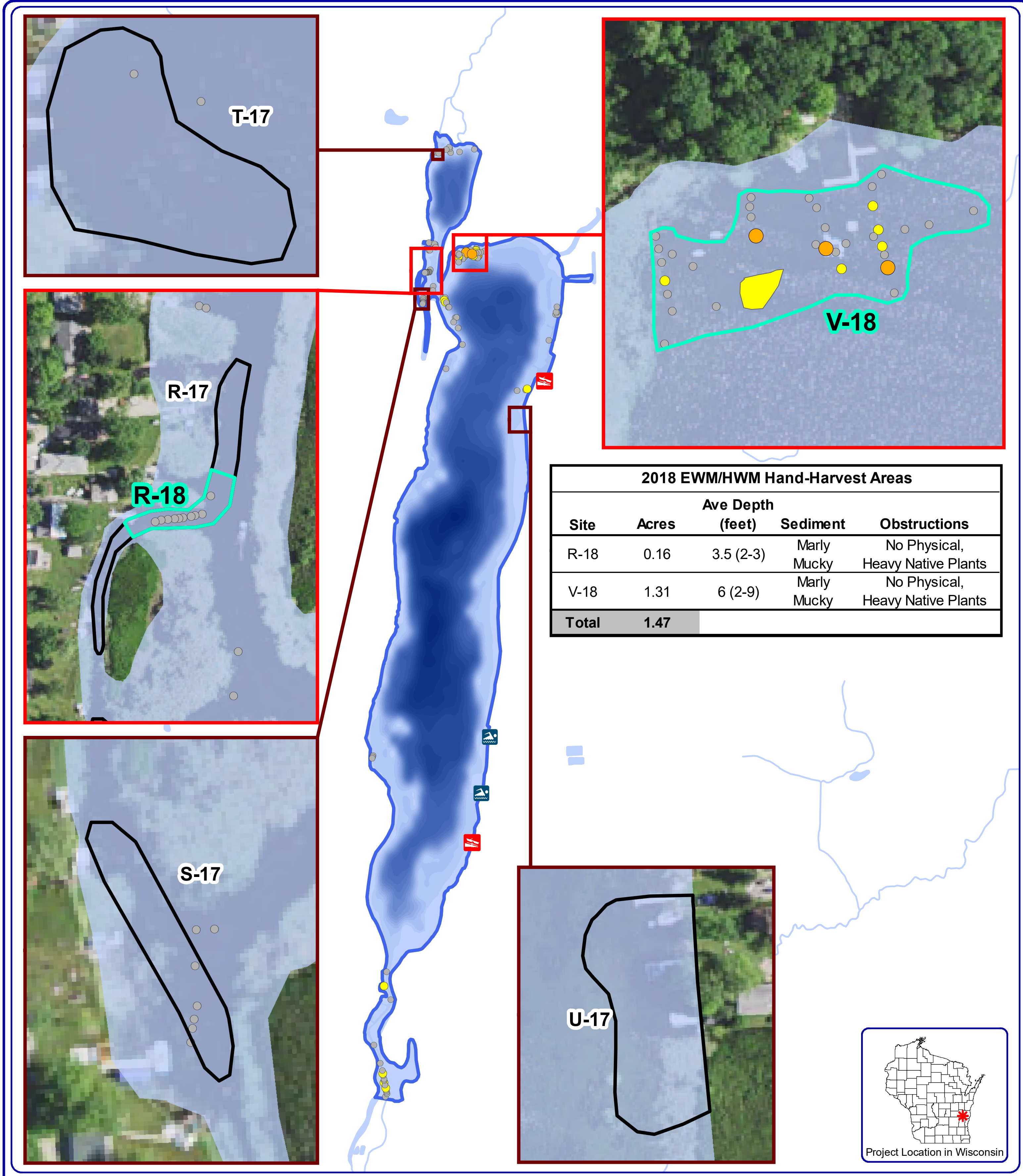
Point-Intercept Survey Location
50-meter spacing, 725 total points

Boat Landing

Public Beach

Map 1
Long Lake
Fond du Lac County, Wisconsin

Project Location & Lake Boundaries



2018 EWM/HWM Hand-Harvest Areas

Site	Acres	Ave Depth (feet)	Sediment	Obstructions
R-18	0.16	3.5 (2-3)	Marly Mucky	No Physical, Heavy Native Plants
V-18	1.31	6 (2-9)	Marly Mucky	No Physical, Heavy Native Plants
Total	1.47			

Legend

Eurasian Water Milfoil (June 2018)

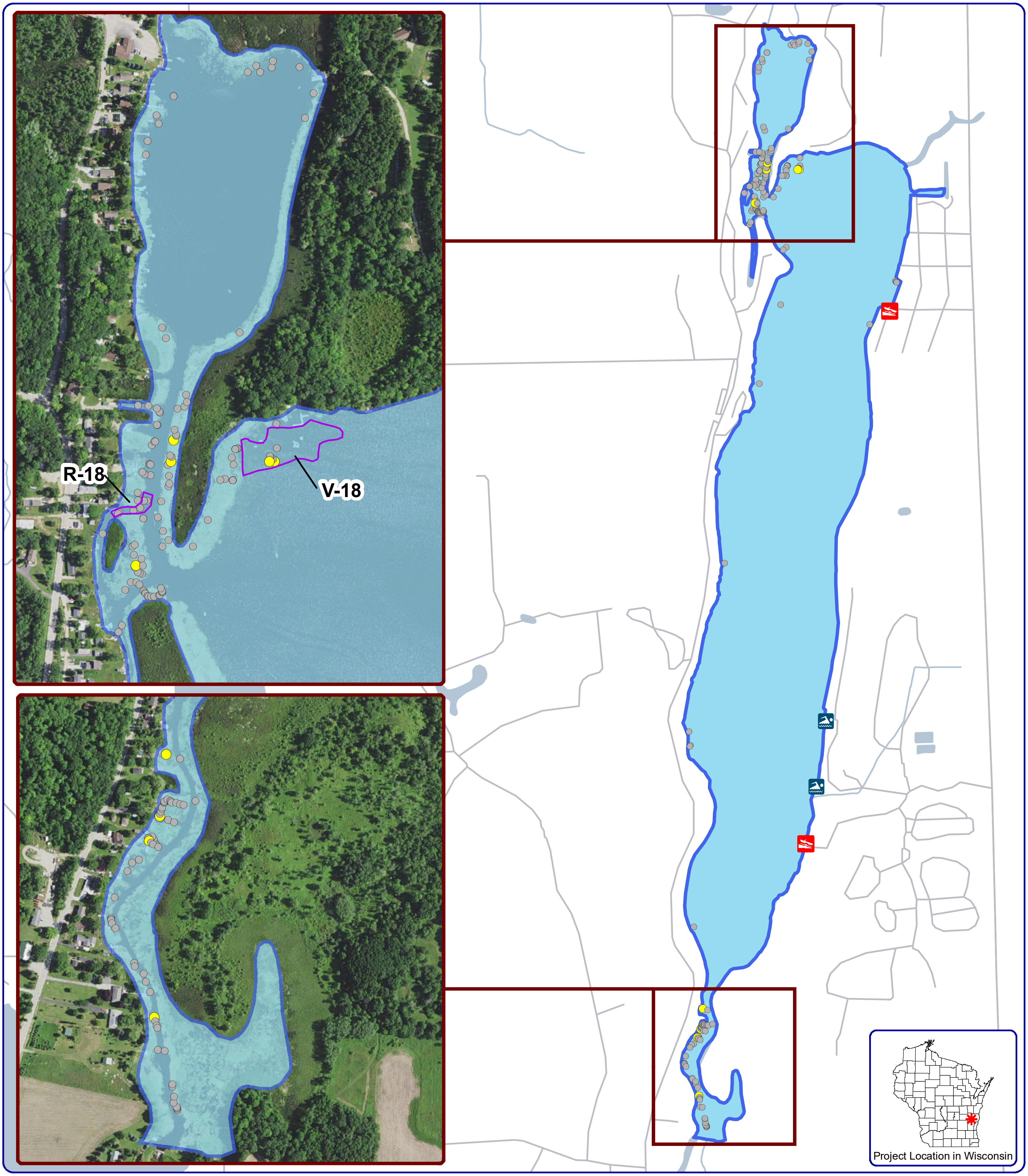
- Highly Scattered *(none found)*
- Scattered *(none found)*
- Dominant
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2017 Hand Harvest Site
- 2018 Hand Harvest Site

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

Sources:
Roads and Hyrdo: WDNR
Bathymetry: Onterra, 2015
Orthophotograph: NAIP, 2017
Aquatic Plants: Onterra, 2018

Map Date: June 12, 2018 - EJH

Map 2
Long Lake
Fond du Lac County, Wisconsin
June 2018 EWM Survey Results v2



N
W E
S

1,750
Feet

Legend

Eurasian Water Milfoil (October 2018)

- Highly Scattered *(None)*
- Scattered *(None)*
- Dominant *(None)*
- Highly Dominant *(None)*
- Surface Matting *(None)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(None)*
- 2018 Final Professional Hand-Harvesting Site

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
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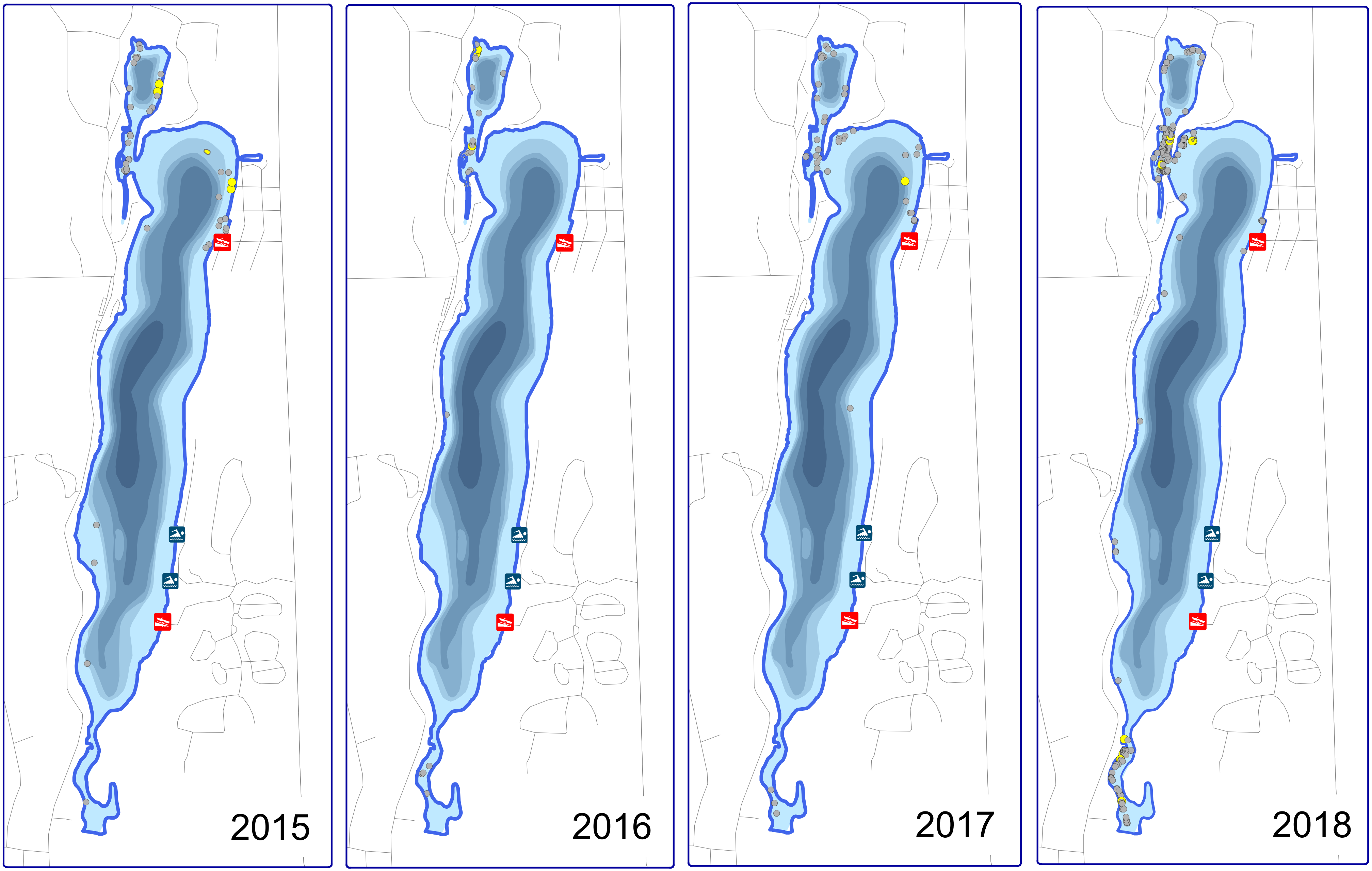
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2018
Map Date: October 12, 2018
Filename: Long_FDL_EWM_Oct18.mxd

Map 3

Long Lake

Fond du Lac County, Wisconsin

October 2018
EWM Survey Results



N
W E
S

2,500

Feet

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

Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra
Map Date: November 14, 2014
Filename: LongFDL_EWM_Series_2015-2018.mxd

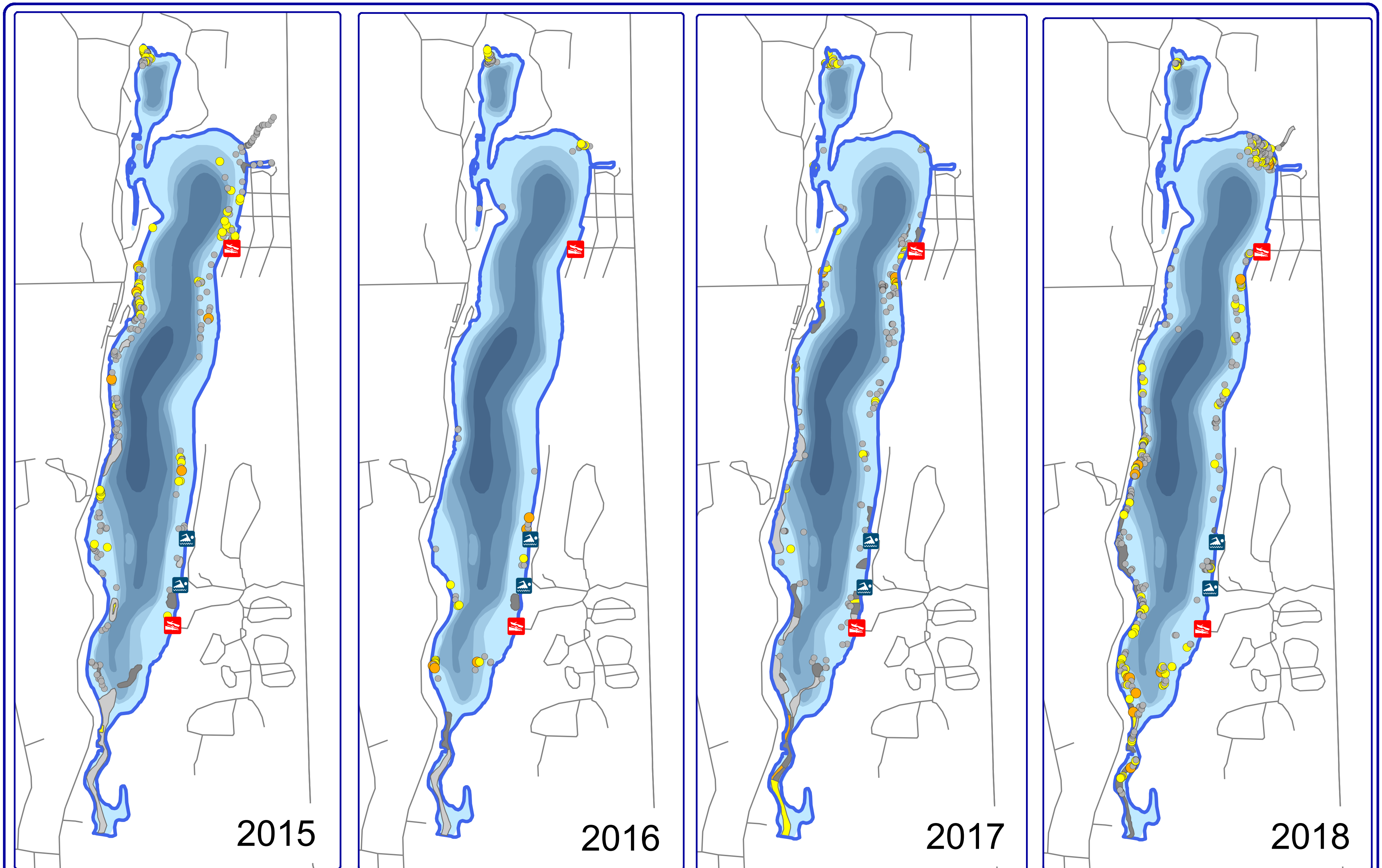
Extent of large map shown in red.

Legend

Eurasian water milfoil

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

Map 4
Long Lake
Fond du Lac County, Wisconsin
2015-2018 EWM
PB Series



Map 5
Long Lake
Fond du Lac County, Wisconsin

2015-2018 CLP PB Series

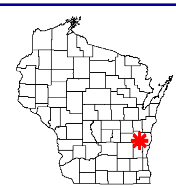
N W E S

2,500 Feet

Legend

Curly-leaf Pondweed

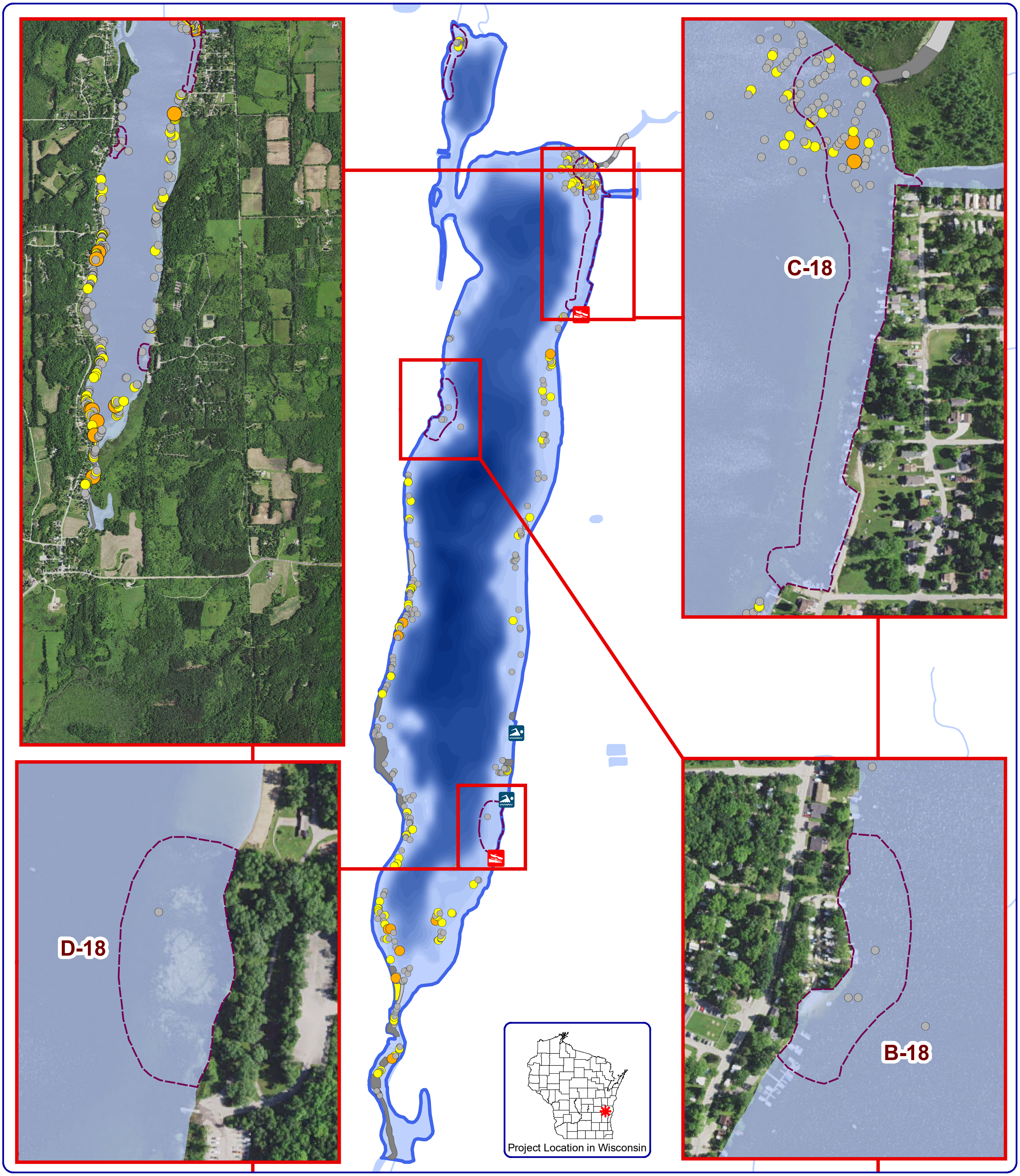
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Boat Landing
- Public Beach



Extent of large map shown in red.

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

Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra
Map Date: March 26, 2019
Filename: LongFDL_CLP_Series_2015-2018.mxd



Map 6

Long Lake

Fond du Lac County, Wisconsin

June 2018 CLP Survey Results v2

Legend

Curly-leaf pondweed (June 2018)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2018 CLP Herbicide Treatment Area

Onterra, LLC
Lake Management Planning
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De Pere, WI 54115
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Sources:
Roads and Hyrdo: WDNR
Bathymetry: Onterra, 2015
Orthophotography: NAIP, 2017
Aquatic Plants: Onterra, 2018
Map Date: June 12, 2018 - EJH