1.0 INTRODUCTION

Photo 1. Silver Lake, Waushara County, Wisconsin.

[Big] Silver Lake, Waushara County, is a seepage lake with a maximum depth of 48 feet and a mean depth of 21 feet (Photo 1). The lake area as determined through a heads-up digitization of the lake from a 2015 aerial photograph is approximately 360.3 acres, whereas the WDNR website lists the lake as 328 acres. This mesotrophic lake has a relatively small watershed when compared to the size of the lake (3.5:1). Only when water levels are near full pool does water exchange occur with Irogami Lake via a culvert under State Hwy 21. Four exotic species are known to exist in Silver Lake: banded mystery snail, curly-leaf pondweed (*Potamogeton crispus,* CLP), Eurasian water milfoil (*Myriophyllum* spicatum, EWM), and zebra mussel. Genetic analysis confirms that the invasive milfoil population is comprised of both EWM and hybrid water milfoil (*M. spicatum x sibiricum*, HWM). Subsequent discussion using "HWM" will represent the collective invasive milfoil population of Silver Lake unless specifically referenced otherwise.

The concept of heterosis, or hybrid vigor, is important in regards to HWM management on Silver Lake. The root of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. Hybrid water milfoil typically has thicker stems, is a prolific flowerer, and grows faster than pure-strain EWM (LaRue et al. 2012). These conditions likely contribute to this plant being particularly less susceptible to biological (Enviroscience personal comm.) and chemical control strategies (Glomski and Netherland 2010, Poovey et al. 2007).

The Silver Lake Management District (SLMD) is the local citizen-based organization leading the management of Silver Lake. The group has worked for years to protect and enhance the lake, including an increased effort in recent years to control HWM within the lake. The SLMD realizes that in order to effectively control the HWM population in Silver Lake, aggressive herbicide strategies need to be implemented, which could have increased collateral effects on the native aquatic plant community compared with more-typical use rates employed for pure-strain EWM control projects.

2.0 2014 HWM MANAGEMENT

The 2014 Aquatic Plant Management (APM) Plan recommended the SLMD initiate a large-scale (aka whole-lake) herbicide treatment targeting HWM in Silver Lake. Based on discussion with industry professionals and following herbicide challenge testing (SePRO, unpublished), two large-scale herbicide use patterns were discussed within the APM Plan: liquid fluridone and combination treatment of 2,4-D and endothall. Both of these strategies were not commonly used in Wisconsin at that time, so an additional herbicide, granular triclopyr, was also entertained during discussions that occurred in late-winter of 2013-14 between Stantec, SLMD, and WDNR. Ultimately, a large-scale granular triclopyr (Renovate OTF®) treatment occurred in early-June 2014 targeting 180-200 ppb acid equivalent (ae) lake-wide.

Triclopyr concentrations fell short of achieving target levels, with the following hypotheses formulated by Onterra: uneven lake-wide mixing, expansion of mixing zone (i.e. epilimnion) following weather events, inaccurate bathymetric data which calculations were based off, herbicide granules releasing below epilimnion, and granules releasing into sediment pore-water. The point-intercept data indicate that HWM was reduced lake-wide from 33.5% in 2013 (*year before treatment*) to 7.8% in 2014 (*year of treatment*); a 76.7% decline. SLMD members suspect that if the point-intercept survey would have occurred a month or two later in 2014, the HWM frequency of occurrence would have been higher as HWM was in the process of rebounding during the late-August survey. It is clear from 20.0% frequency recorded in the 2015 point-intercept survey (*year after treatment*) that the 2014 treatment resulted in only seasonal HWM control, likely greatly injuring HWM during the *year of treatment* but the population was in the process of recovering during 2015.

3.0 CONTROL STRATEGY DEVELOPMENT

Silver Lake riparian property owners have voiced increased frustration over the 2014 treatment results and the overall historic lack of success controlling HWM within the lake. In response, the SLMD contracted with Onterra, LLC during May 2015 to provide technical direction as they pursued their goal to implement a large-scale herbicide treatment strategy during spring of 2016. Onterra developed a preliminary three-year control and monitoring strategy in which a large-scale herbicide treatment would occur in year two of the project.

Three herbicide use patterns were investigated for applicability on Silver Lake in 2016: combination of liquid 2,4-D/endothall, liquid fluridone, and pelletized fluridone. Ultimately, the SLMD decided to move forward with a pelletized fluridone to target HWM in Silver Lake in 2016.

Fluridone is a systematic herbicide that disrupts photosynthetic pathways (carotenoid synthesis inhibitor). The herbicide degrades via photolysis (some microbial degradation may also occur) and requires long exposure times (>90 days) to cause mortality to HWM. Herbicide concentrations within the lake are kept at target levels by periodically adding additional herbicide ("bump treatment") over the course of the summer based upon herbicide concentration monitoring results.

While liquid fluridone treatments result in a high initial concentration that tapers off over time as the herbicide degrades, pelletized fluridone treatments gradually reach peak concentrations over time (extended release) and result in a lower, sustained lake-wide herbicide concentration. This use-pattern of fluridone appears to demonstrate increased selectivity towards native plants in some field trials.

For Silver Lake, SePRO recommended a 4 ppb initial treatment, with an understanding that the measured concentrations within the lake would be approximately 2-3 ppb because of the extended release rate, herbicide degradation, and plant uptake. Once measured herbicide concentrations from the lake fall below 2 ppb, additional bump treatments would occur to keep the concentration between 2-3 ppb. The water levels at the time of the treatment planning were too low for water exchange with Irogami Lake to be a factor in herbicide dissipation.

4.0 CONTROL MONITORING STRATEGY

4.1 Point-Intercept Survey

The WDNR completed point-intercept surveys on Silver Lake in 2012-2015. Comparing HWM frequency of occurrence data from before the treatment with data collected following the treatment (2017 and 2018) would allow a quantitative measurement of efficacy to be made. Please note that a point-intercept survey was not completed in 2016, as the lake was still in the process of being treated (i.e. had active herbicide concentrations).

Along with understanding the level of HWM control achieved from the control action, the point-intercept data will also allow an understanding of non-target native plant impacts from the treatment.

4.2 Hybrid Water Milfoil Peak-Biomass Mapping Survey

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake and will continue to be collected annually, it does not offer a full account (census) of where a particular species exists in the lake. As the name implies, the HWM Peak-Biomass Survey is a meander-based mapping survey conducted when the plant is at its peak growth stage, allowing for a true assessment of the amount of this exotic within the lake.

Photo 2. HWM *Surface Matted* colony on Silver Lake.

On August 12-13, 2015, Onterra ecologists conducted the HWM Peak-Biomass Survey on Silver Lake. During the survey, the HWM population was mapped using sub-meter GPS technology 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 HWM locations that were considered as *Small Plant Colonies* (<40 feet in diameter), *Clumps of Plants*, or *Single or Few Plants*.

As discussed above, HWM of varying densities was located throughout the littoral zone of Silver Lake (Map 1). In total, 52 acres of colonized HWM were delineated with approximately 21 of the acres being comprised of *Dominant, Highly Dominant,* or *Surface Matted* HWM populations (Photo 2). The results of the 2015 HWM Peak-Biomass Survey guided where the herbicide application areas were constructed for the spring 2016 treatment. Replicate HWM mapping surveys conducted after the large-scale treatment occurs will allow an understanding of treatment efficacy and guide follow-up active management activities such as hand-harvesting or herbicide spot treatments. A HWM Peak-Biomass Mapping Survey was also not completed in 2016, as the lake was still in the process of being treated (i.e. had active herbicide concentrations).

5.0 HERBICIDE TREATMENT PLANNING & IMPLEMENTATION

5.1 Acoustic Survey

On September 3-4, 2015, Onterra ecologists systematically collected continuous, advanced sonar data across Silver Lake. One result of this survey produced an updated bathymetric map of the lake (Map 2). The success of properly planning and implementing large-scale treatments rely on accurate bathymetric information with which advanced water volume calculations are conducted. This ensures meeting target concentrations outlined within the dosing strategy, which is devised to provide HWM control while balancing native plant selectivity. Volume calculations utilizing the data obtained from the acoustic data indicate the water volume of Silver Lake to be approximately 7,486 acre-feet, which is about 5% more than the 7,096 acre-feet reported from the 1976 recording sonar WDNR Lake Survey Map.

The acoustic survey also created a baseline understanding of the submerged aquatic vegetation in Silver Lake (Map 1). While the map output does not differentiate between aquatic plant species, it indicates where high bio-volumes of vegetation exist in the lake. Conducting bio-volume surveys before and after herbicide treatments can also allow an understanding of how the macrophyte structure (aka lakescape) was influenced by the treatment, a set of data that have particular interest of fisheries managers.

5.2 Finalized Dosing Strategy for Initial Treatment

In order to finalize the dosing volume for the 2016 treatment, it was necessary to understand the volume of water in which the herbicide is expected to mix within. As the water warms, a thermal barrier develops in many lakes essentially separating the lake into an upper epilimnion with warmer water temperatures and a lower hypolimnion with cooler water temperatures. The transitional area separating the upper and lower portions of the water column or metalimnion. In recent years, it has become common for lake managers to predict the mixing volume of a lake based on the middle/upper-middle of the metalimnion, understanding that some amount of herbicide will be lost to the metalimnion.

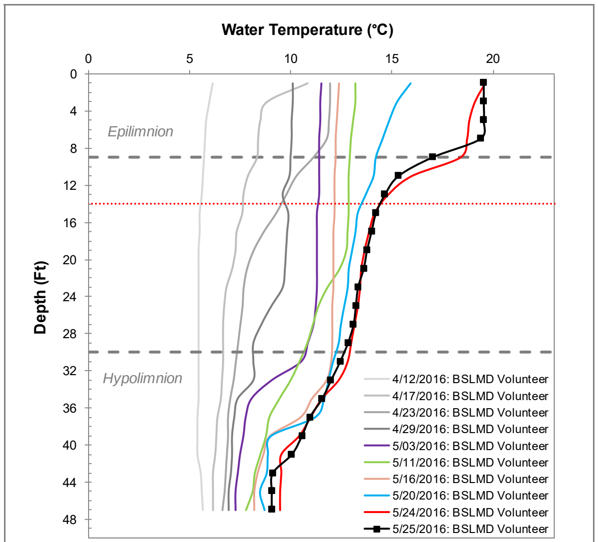


Figure 1. Pre-Treatment Temperature Profiles Collected on Silver Lake.

Volunteers from the SLMD provided numerous temperature profiles in the days and weeks leading up to the large-scale herbicide treatment on Silver Lake (Figure 1). During April and early-May, the lake was warming but not developing separate strata. Between May 20 and May 24, stratification parameters finally became apparent around 9 feet. The final dosing was based upon a mixing zone of the top 14 feet of the lake. The lake was also considered to be approximately 1 foot higher than when the early-September acoustic survey took place and was accounted for within the calculations.

Map 2 displays the final large-scale herbicide treatment design and dosing strategy for Silver Lake in 2016. The treatment includes application of 941.5 lbs of pelletized fluridone (Sonar One ®, SePRO) over 86.4 acres of the littoral zone known to contain HWM (based on the 2015 HWM Peak-Biomass Mapping Survey (Map 1). The initial herbicide treatment was conducted by Clean Lakes on May 26, 2016 using a Vortex gas powered spreader system. The applicator reported a near-surface water temperature of approximately 68°F and west winds of 2-8 mph at the time of application. A representative from SePRO was at the lake during the application.

5.3 Bump Treatment Dosing Strategy

Temperature profiles collected before the treatment and at each herbicide concentration sampling interval indicate that the lake remained thermally stratified through mid-September when temperature profiles no longer were collected (Figure 2). Limnologists, scientists that study inland waters, understand thermal stratification as occurring when there is a change of 1°C within 1 meter. The closely spaced water temperature contours on the isotherm (Figure 2, left frame) indicate a thermal gradient separating the epilimnion and hypolimnion beginning at approximately 9 feet on the treatment date and extended to about 19-20 feet by the beginning of July. This can also be observed on the temperature profiles (Figure 2, right frame), where uniform temperatures were observed down to about 19-20 feet before getting much colder in a short amount of depth.

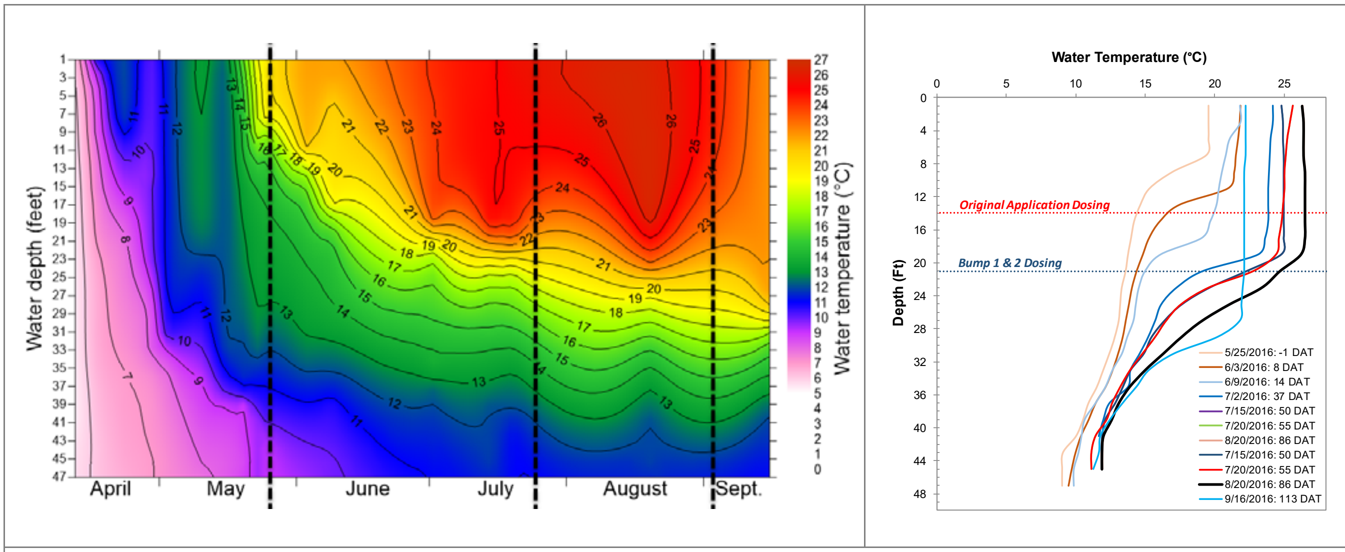


Figure 2. Temperature Isotherm (left) and Profiles (right) Collected from Silver Lake Following the 2016 Herbicide Treatment. Dashed line on isotherm represents treatment dates.

Based upon reviewing the measured herbicide concentration during the summer (Figure 3) as well as technical advice from SePRO, 2 ppb bump treatments of pelletized fluridone (Sonar One®) were conducted on July 21 and September 1 by Clean Lakes. The final dosing of these treatments was based on a mixing zone down to 21 feet (Figure 2, right frame) and includes application of 655.9 lbs of pelletized fluridone over the same 86.4 acres where the initial application occurred.

Figure 3 shows the results of the fluridone monitoring that occurred in association with the 2016 large-scale treatment on Silver Lake. Gauged by the size of the error bars (representing range of results), surface herbicide concentrations were fairly uniform between the five monitoring sites, indicating that horizontal mixing had occurred within the lake-wide epilimnion including at Site BS2 and BS4 where no herbicide was directly applied. Hypolimnetic samples were collected at each sampling interval into

September with no herbicide (i.e. below detection limits) being observed. Samples collected in November after the lake had likely mixed (i.e. fall turnover) indicated fluridone levels were just below 2 ppb. It was anticipated that herbicide degradation would be minimal over the winter as fluridone is primarily broken down by sunlight, specifically UV-B (300-320 nm), but also by UV-A (320-380) spectrums. These wavelengths are absorbed by ice and snow, not allowing much penetration to fluridone in the lake during the winter. Average surface herbicide concentrations following the ice-out event on Silver Lake were basically unchanged to before ice-on levels. Based upon discussions with SePRO, it is likely that fluridone concentrations within the lake will degrade to below detectable levels by late-spring. A July 7, 2017 herbicide concentration sample (407 days after initial application) confirmed that fluridone was still present within the lake, but only slightly above the detection levels (Figure 3).

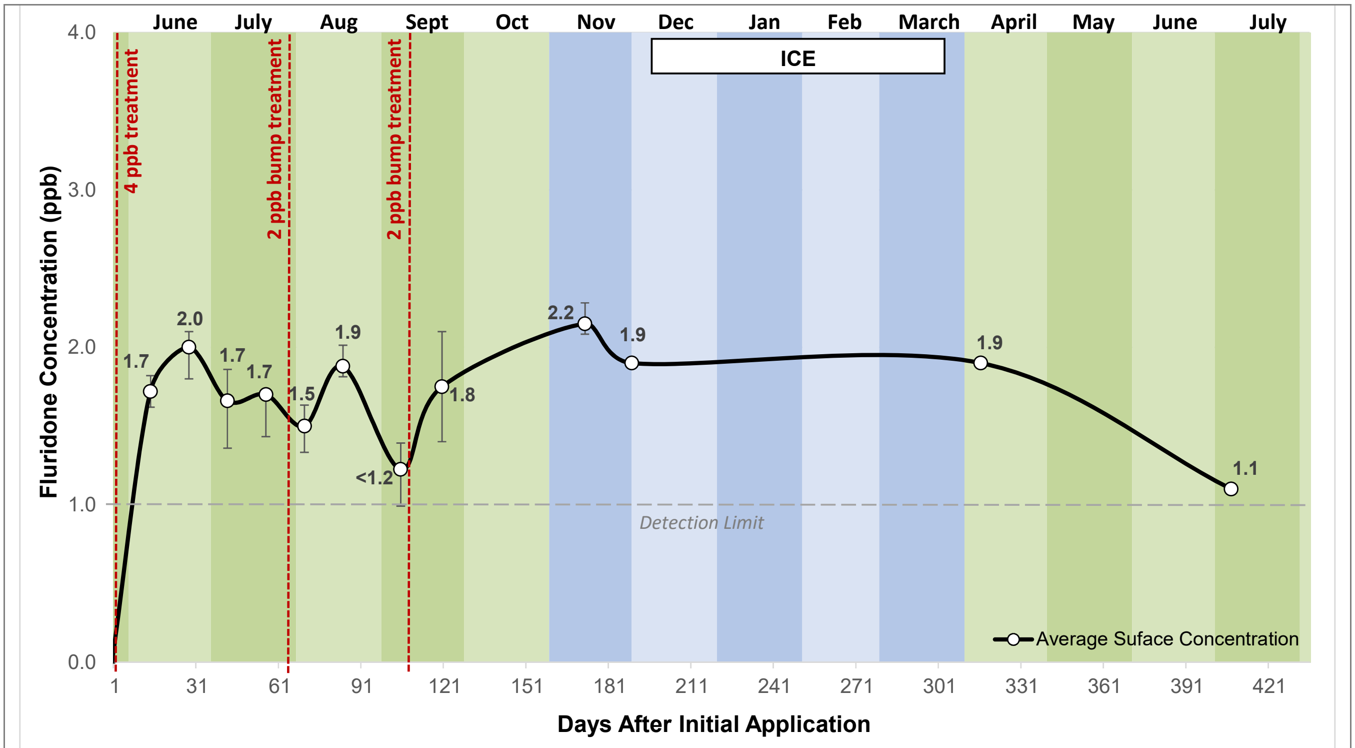


Figure 3. Silver Lake Herbicide Concentration Monitoring Results from five monitoring locations.

6.0 2017 AQUATIC PLANT MONITORING RESULTS

6.1 July 2017 Early-Season AIS Survey (ESAIS)

The control and monitoring strategy for Silver Lake included an early-season AIS survey in 2017. The purpose of the survey was to assess the HWM population in order to determine if hand-harvesting actions should be implemented during the summer of 2017 to address any HWM that has begun to rebound since the herbicide treatment. The timing of this survey in early summer also coincides with the expected peak growth stage of CLP and thus, occurrences of this exotic plant were mapped during the ESAIS survey. During the survey, the entire littoral area of the lake was surveyed through visual observations from the boat and the HWM & CLP populations were mapped. Submersible video and/or rake tows may be used for setting colony extents, but these methods are not appropriate as the sole method for locating a colony or determining density. The HWM population would be mapped again in late-summer to evaluate the hand-harvesting efforts and correspond with the expected peak growth stage of the plant.

The curly-leaf pondweed (CLP) population identified during the July 5, 2017 survey was found to be relatively low with plants being located only in the southeastern end of the lake and consisted of a *small plant colony*, *clump of plants* and a few *single or few plants* (Map 3). Subsequently, during a late-summer visit to the lake, a few additional *single or few* CLP plant occurrences were mapped in other portions of the lake and are also displayed on Map 3.

During the ESAIS survey, a small amount of HWM was visible during the survey within the portion of the lake known as Foxtail Bay on the southeastern end of the lake (Figure 4). No HWM was visible from the surface within the main body of the lake. Field crews supplemented the visual survey by deploying a submersible camera along with periodically doing rake tows at locations in which dense HWM colonies were mapped in previous surveys. No HWM was found using these survey methods within the main body of the lake during the ESAIS survey.

Figure 4. Early Season AIS Survey HWM mapping results. Survey conducted July 5, 2017 (Onterra). Area depicted locally known as Foxtail Bay.

Following discussions with the SLMD, a professional hand-harvesting strategy was devised such that divers would remove the HWM located during the ESAIS survey in Foxtail Bay and then conduct scuba reconnaissance surveys at various locations around the lake where dense colonies of HWM had been mapped during the 2015 growing season. This strategy is outlined on Figure 5 in which 36 sites were designated for professional diving evaluations and corresponding hand-removal if HWM was located. Onterra provided the spatial data reflecting the ESAIS results and search areas to the professional harvesting firm to aid in the removal efforts.

6.2 Professional Hand-Harvesting Actions

During the first visit to the lake (July 20, 2017), DASH, LLC conducted EWM hand-removal in Foxtail Bay that was discovered during the July 5th ESAIS Survey as well as started investigating the first scuba reconnaissance area. Six subsequent days of scuba reconnaissance (July 31, Aug 1, Aug 18, Aug 22, Aug 29, Sept 12) allowed DASH, LLC to visit all 36-designated search areas, spending a total of 38.95 hours underwater (Figure 5). Divers encountered varying amounts of milfoil (presumably all HWM but difficult identification at this growth stage is noted) at the different search areas and ranged from zero plants to several hundred plants at some locations. The number of plants harvested by DASH, LLC at each site are totaled and displayed on Figure 6. The hand-harvesting firm indicated the plants that they removed were typically small single-stalked plants that did not appear to be growing out of a large root crown. It is unclear if this represents plants that survived the treatment or was a result of germination from a seedbank or sprouting from asexual turions (i.e. winter buds).

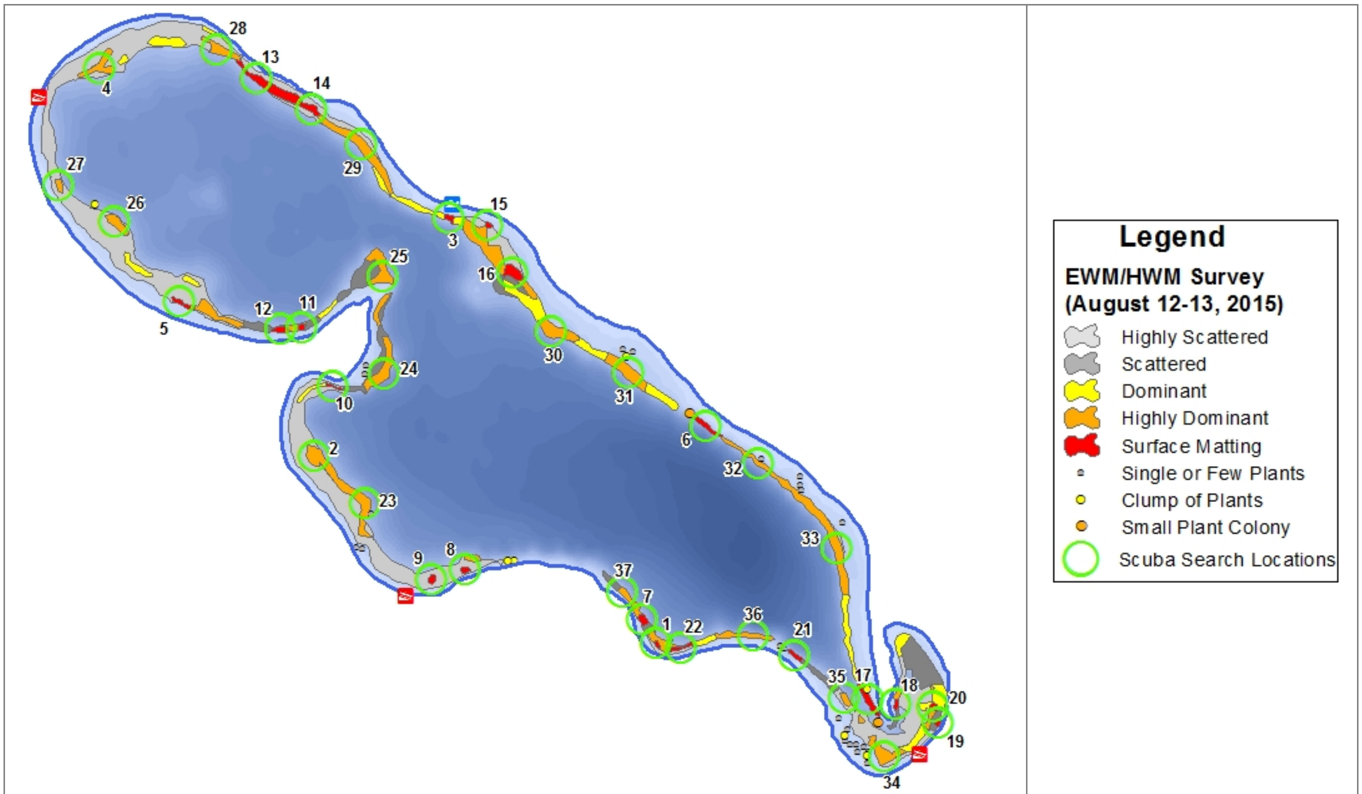


Figure 5. 2017 Professional scuba reconnaissance survey in Silver Lake. Thirty-six Search areas designated based on Onterra 2015 HWM mapping survey.

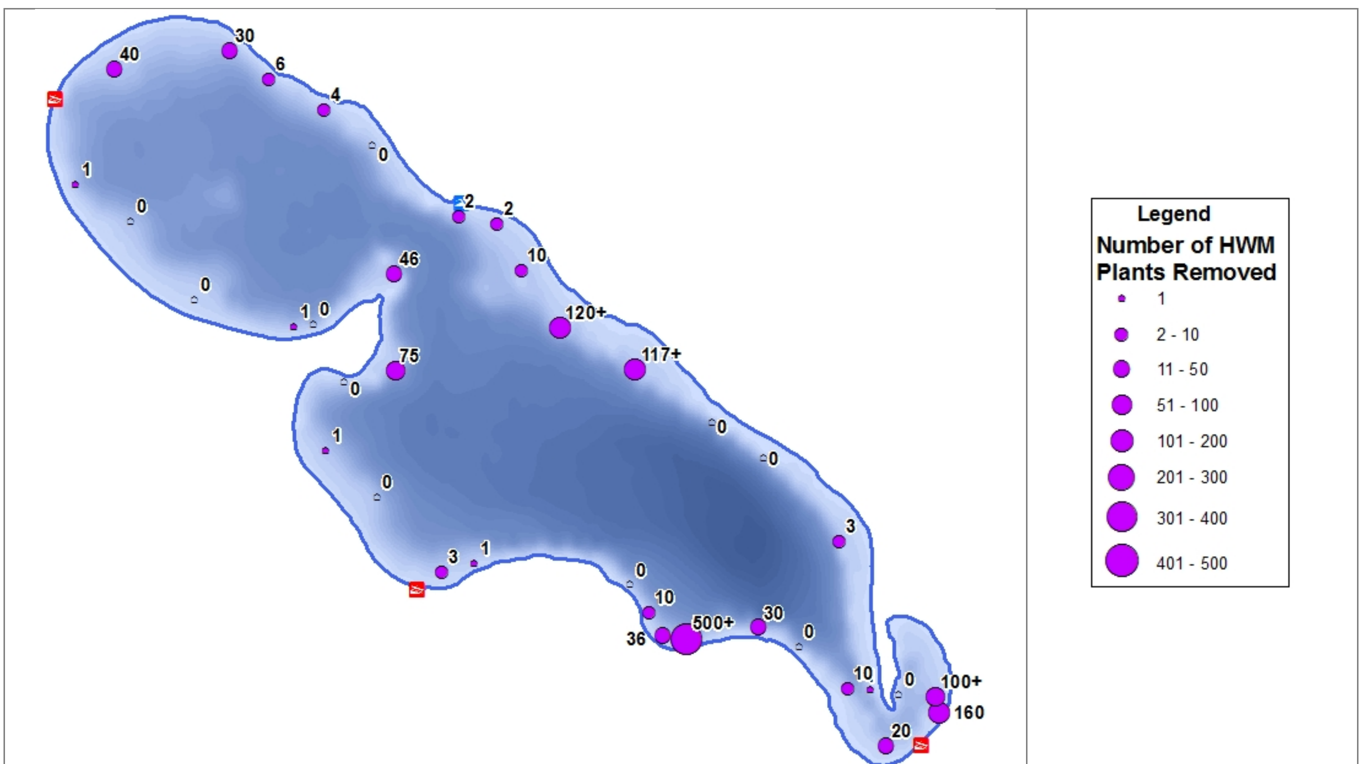


Figure 6. Professional hand-harvesting HWM yield from Silver Lake scuba reconnaissance survey in 2017. Data compiled from DASH, LLC dive summary.

6.3 Late-Summer HWM Peak-biomass Survey

The HWM population was mapped on September 26, 2017 following the completion of the hand-harvesting effort. During the survey, Onterra field crews meandered the littoral zone of the lake and mapped HWM populations using sub-meter GPS technology. Conditions were favorable during the survey with overcast skies and light winds. In addition to visually scouring the lake from the surface, Onterra lowered a submersible camera at each of the scuba reconnaissance survey locations. All HWM occurrences located during the survey consisted of *single or few plants*. The largest concentration of plants was found in the shallower waters in Foxtail Bay, with a few other occurrences located sparingly throughout the main body of the lake (Map 4). No colonized HWM requiring area-based mapping methodologies were located anywhere in the lake during the survey. It is possible that some HWM escaped detection during the survey in cases where new growth characterized by short-statured plants would not have been visible.

6.4 Acoustic Survey Results

In the summer of 2015 prior to treatment and the summer of 2017 following the treatment, Onterra ecologists conducted acoustic surveys with two primary goals: 1) to obtain accurate bathymetric data for the proposed 2016 treatment to ensure accurate herbicide dosing, and 2) to document the change in aquatic plant bio-volume from before and after the treatment. An additional benefit of the acoustic survey allowed quantitative comparisons of water levels and volumes between 2015 and 2017.

As reported by the Milwaukee Journal Sentinel, January 1 through July 31 was Wisconsin's wettest year on record (records date back 123 years). The acoustic data confirms the water volume in 2017 was much higher than in 2015 as a result of the record precipitation. Volume calculations utilizing the data obtained from the 2017 survey indicated the water volume to be approximately 8,791 acre-feet, approximately 1,275 acre-feet or 17% greater than the volume calculated from the 2015 acoustic survey. This correlates to about a 3.5-foot increase in water levels, which was approximately confirmed by difference in the maximum depth located in the 2015 (50 feet) and 2017 (53 feet) acoustic surveys. These climactic conditions can impact water clarity, water levels and flow, nutrient levels, etc. that need to be included as factors that impacted the aquatic plant population of Silver Lake. For the first time in many years, water levels were high enough that it flowed through the culvert connecting Silver Lake to Irogami Lake.

Aquatic plant bio-volume is measured as a percentage of the water column that is occupied by aquatic plants. The results of these surveys are displayed in Figure 7. Prior to treatment, approximately 15.2% of the lake area contained a bio-volume 50% or greater, compared to approximately 3.1% for the same parameters in 2017 (Figure 7). These high biovolume areas in 2015 corresponded with the dense colonies of HWM (Map 1) that were greatly impacted by the fluridone treatment.

The 2015 acoustic survey showed approximately 60% of the lake area contained between a 0-10% bio-volume compared to 77.9% in 2017 that had a bio-volume between 0 and 10% (Figure 7). These data indicate that the lake has more areas with no/low vegetation in 2017 than in 2015. A portion of this increase is caused by a reduction in deeper areas that contained vegetation in 2015 that were unable to support vegetation in 2017 now that the lake-levels were increased by 3-3.5 feet. For example, deeper areas of the northwestern lobe of the lake contained areas with greater than 10% biovolume in 2015 but not in 2017.

Continuing this dataset into the future will be helpful to document changes in water levels, changes in aquatic plant biomass, and conduct trend analysis to better understand the macrophyte habitat of Silver Lake.

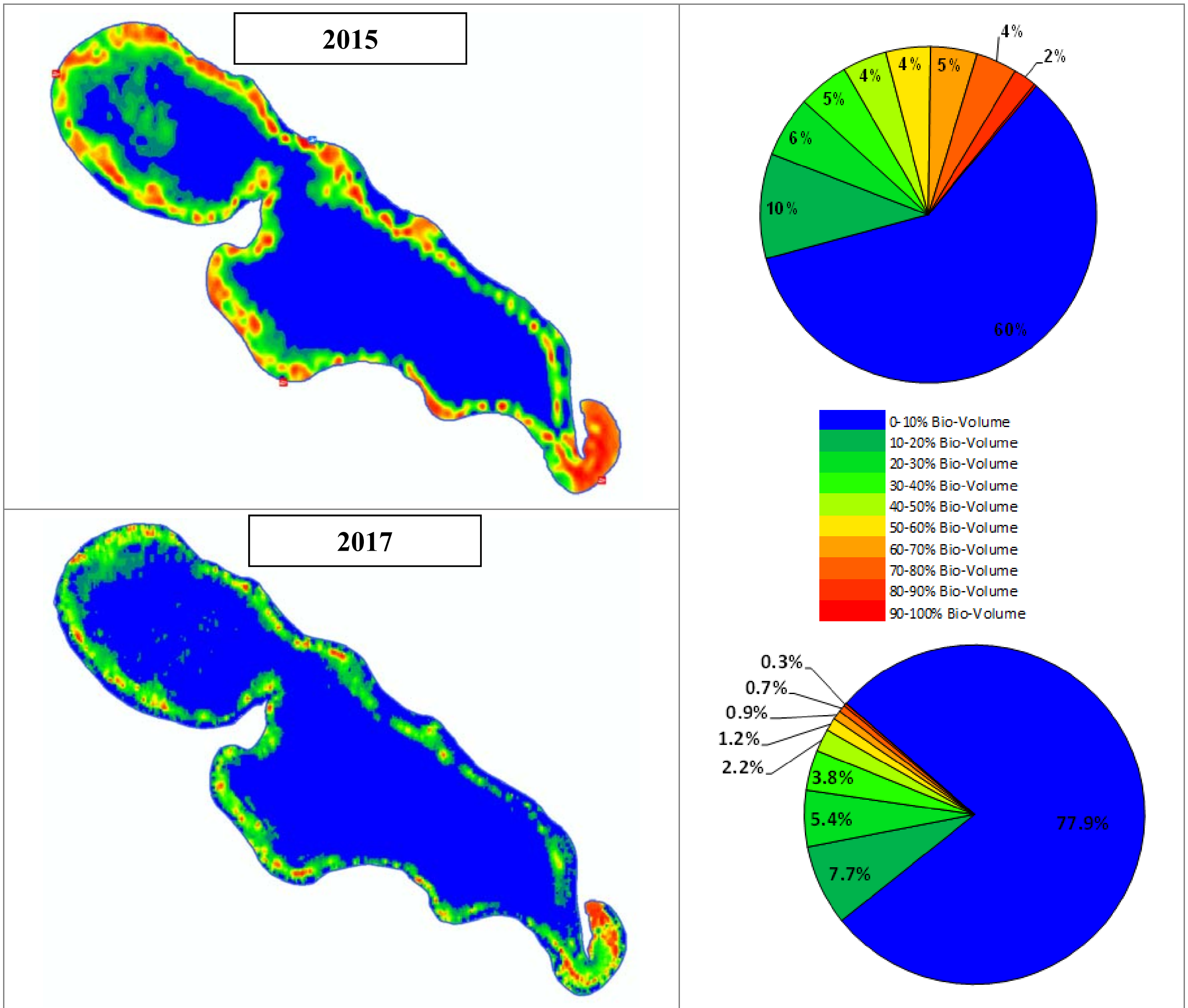


Figure 7. Bio-volume of aquatic vegetation within Silver Lake from bioacoustics surveys conducted in 2015 and 2017.

6.5 2017 Point-Intercept Survey Results

One occurrence of HWM was recorded on the August 18 and August 21, 2017 point-intercept survey in Silver Lake, represented a littoral frequency of occurrence of 0.2% The littoral frequency of occurrence of HWM exhibited a 99% decrease since the 2015 survey in which an occurrence of 20.0% was recorded (Figure 8). The 99% decrease in occurrence from 2015 (*year prior to treatment*) to 2017 (*year after treatment*) met lake managers expectation for successful control.

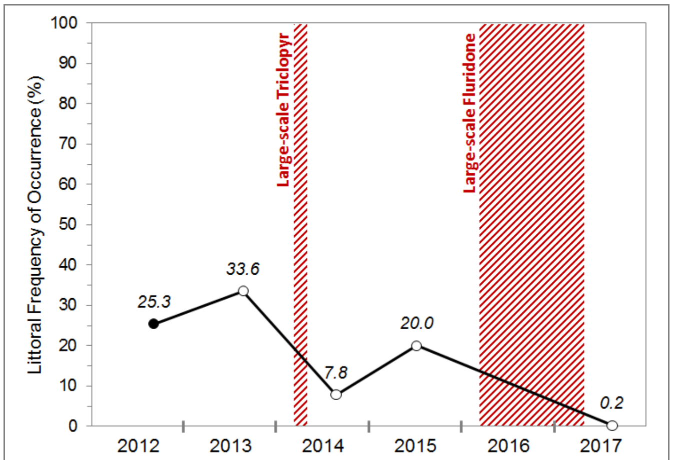


Figure 8. Littoral frequency of occurrence of HWM in Silver Lake. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05).

Along with understanding the level of HWM control achieved from the control action, the point-intercept data will also allow an understanding of non-target native plant impacts from the treatment. A chi-square analysis for all species identified in the point-intercept surveys is included as an appendix to this report (Appendix A).

Eight species exhibited a statistically valid decrease in occurrence from the 2015-2017 point-intercept surveys (Figure 9). The frequency of occurrence of common waterweed (*Elodea canadensis,* -100%) and coontail (*Ceratophyllum demersum,* -44.3%) represents a statistically valid decrease from 2015 to 2017. According to a fluridone susceptibility analysis completed by the WDNR Science Service Department, common waterweed and coontail were shown to be particularly sensitive to fluridone treatments. Both coontail and common waterweed are free-floating or loosely rooted plant species that can utilize the biomass of other plant species as a "substrate" in which they become entangled and grow. It is suspected that with the nearly complete loss of structural habitat previously being supplied by the robust HWM population, may have compounded the direct impacts from the herbicide treatment strategy. A relatively robust population of coontail remained present in the lake during the 2017 point-intercept survey in which coontail was the second most common species with a frequency of 20.2%.

The frequency of occurrence of southern naiad *(Najas guadalupensis)* decreased by a statistically valid 77.6 % in 2017, and slender naiad *(Najas flexilis)* decreased by a statistically valid 100% for (Figure 8, Photo 3). Southern naiad is a hardy perennial that can be a nuisance at times and is suspected of expanding in population following auxin treatments (e.g. 2,4-D, triclopyr), whereas slender naiad is an annual that relies on seed production and has been shown to be particularly susceptible to auxin herbicides. However, slender naiad has shown to rebound extremely quickly in most large-scale auxin treatments, often exceeding pretreatment levels during the *year after treatment*.

Photo 3. Slender naiad (Najas flexilis; left) and southern naiad (N. guadalupensis; right). Photo credit Onterra.

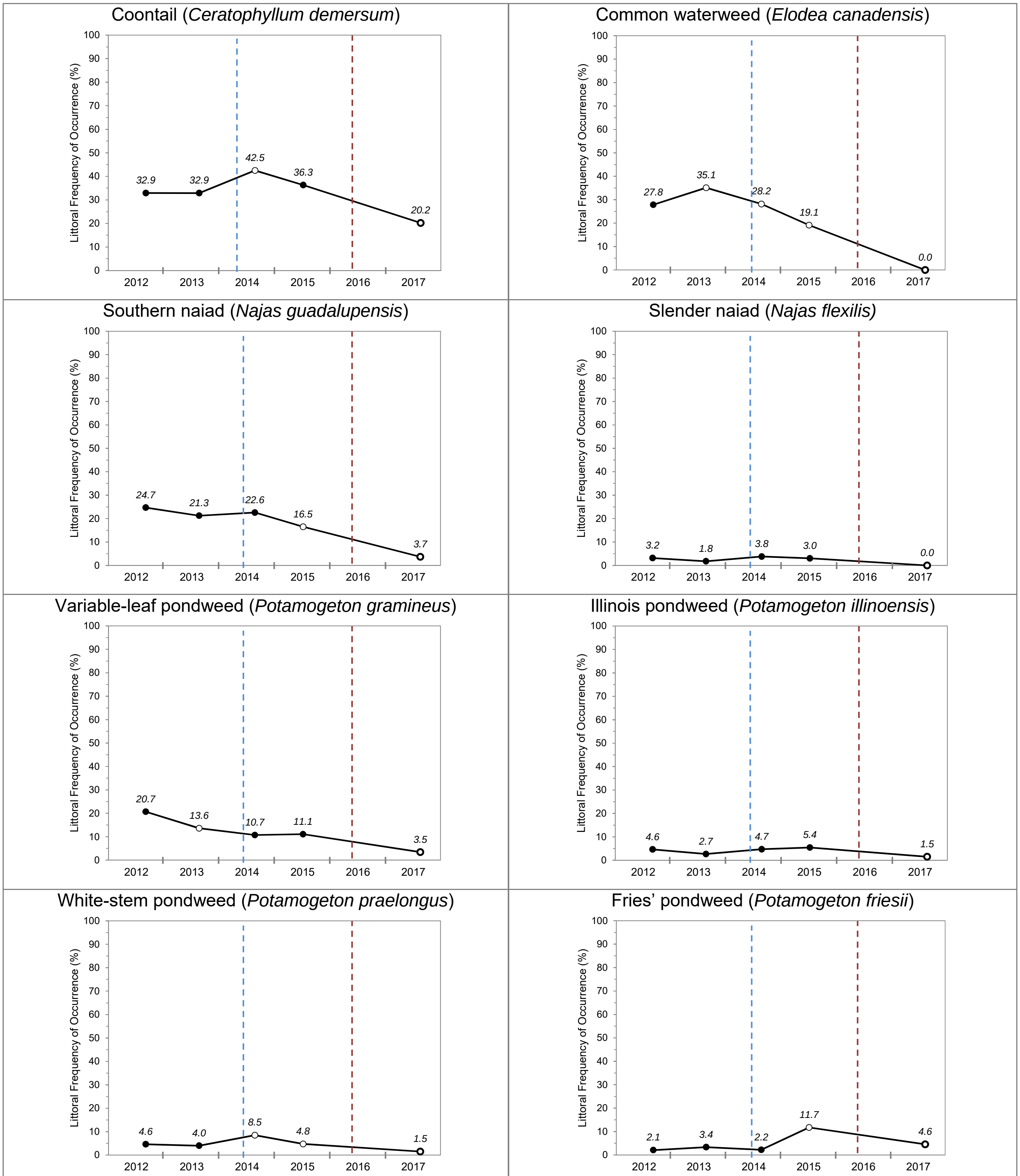


Figure 9. Littoral frequency of occurrence of native aquatic plant species that exhibited a statically valid decrease in occurrence from 2015-2017 in Silver Lake. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05). Blue dashed line indicates initiation of large-scale triclopyr treatment, red dashed line indicates initiation of large-scale fluridone treatment.

Other species that exhibited a statistically valid decrease in occurrence from 2015 to 2017 include: variable-leaf pondweed (*Potamogeton gramineus*), Illinois pondweed (*Potamogeton illinoensis*), Fries' pondweed (*Potamogeton friesii*), and white-stem pondweed (*Potamogeton praelongus*) (Figure 9). Continued monitoring in the coming years will aid in understanding the populations' recovery of these aquatic plant species following the large scale fluridone treatment.

Eight species that had at least a 2% littoral frequency of occurrence in one or more point-intercept surveys and exhibited either no statistical change or an increase in occurrence between the 2015 and 2017 surveys on Silver Lake are displayed on Figure 10. The two species that exhibited a statistically valid increase in occurrence between 2015 and 2017 include water stargrass (*Heteranthera dubia*) and flat-stem pondweed (*Potamogeton zosteriformis*) (Figure 10). Onterra's experience is the flat-stem pondweed is particularly sensitive to endothall treatments and somewhat sensitive to auxin treatments.

Wild celery (*Vallisneria americana*) and sago pondweed *(Stuckenia pectinata*) continue to be the third and fourth most dominant plants in Silver Lake. These plants remain statistically unchanged since 2012.

Muskgrasses and stoneworts are genera of macroalgae. The populations of muskgrasses and stoneworts have remained relatively stable between 2012 and 2017. In the 2017 point-intercept survey, muskgrasses had the highest littoral frequency of any species in Silver Lake (22.2%) (Figure 9). These macroalgae require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002).

Figure 11 shows a semi-quantitative analysis of the abundance of natives through looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). The TRF data collected during 2017 shows an overall reduction in rake fullness as compared to previous surveys. In 2017, 54% of the sampling points contained aquatic vegetation comparted to 80% in 2015. It is important to note that the aquatic plant fullness in 2017 is almost completely comprised of native plant species, whereas HWM was a large contributor to the aquatic plant biomass in past surveys.

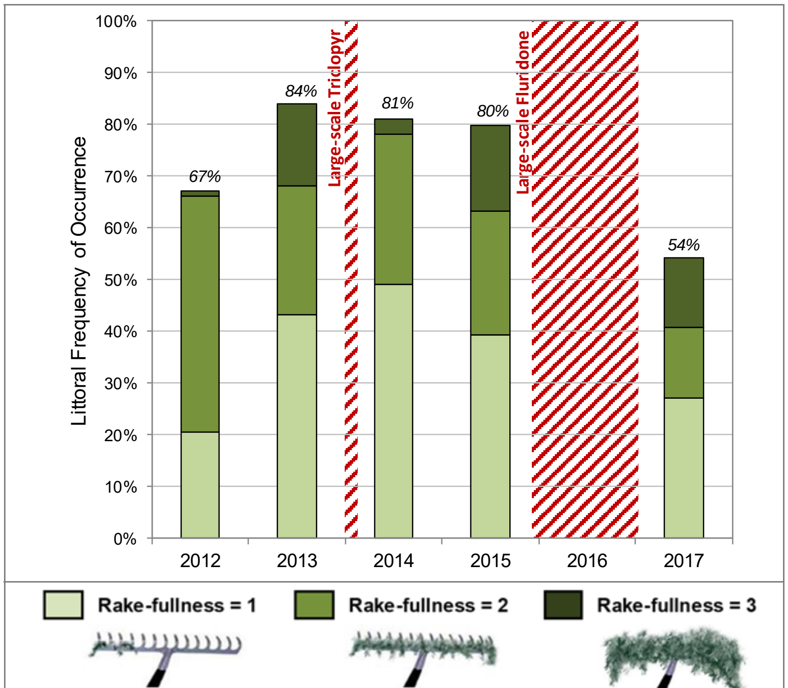


Figure 11. Silver Lake total rake fullness ratings from 2012 – 2017 point-intercept surveys. No survey was conducted in 2016.

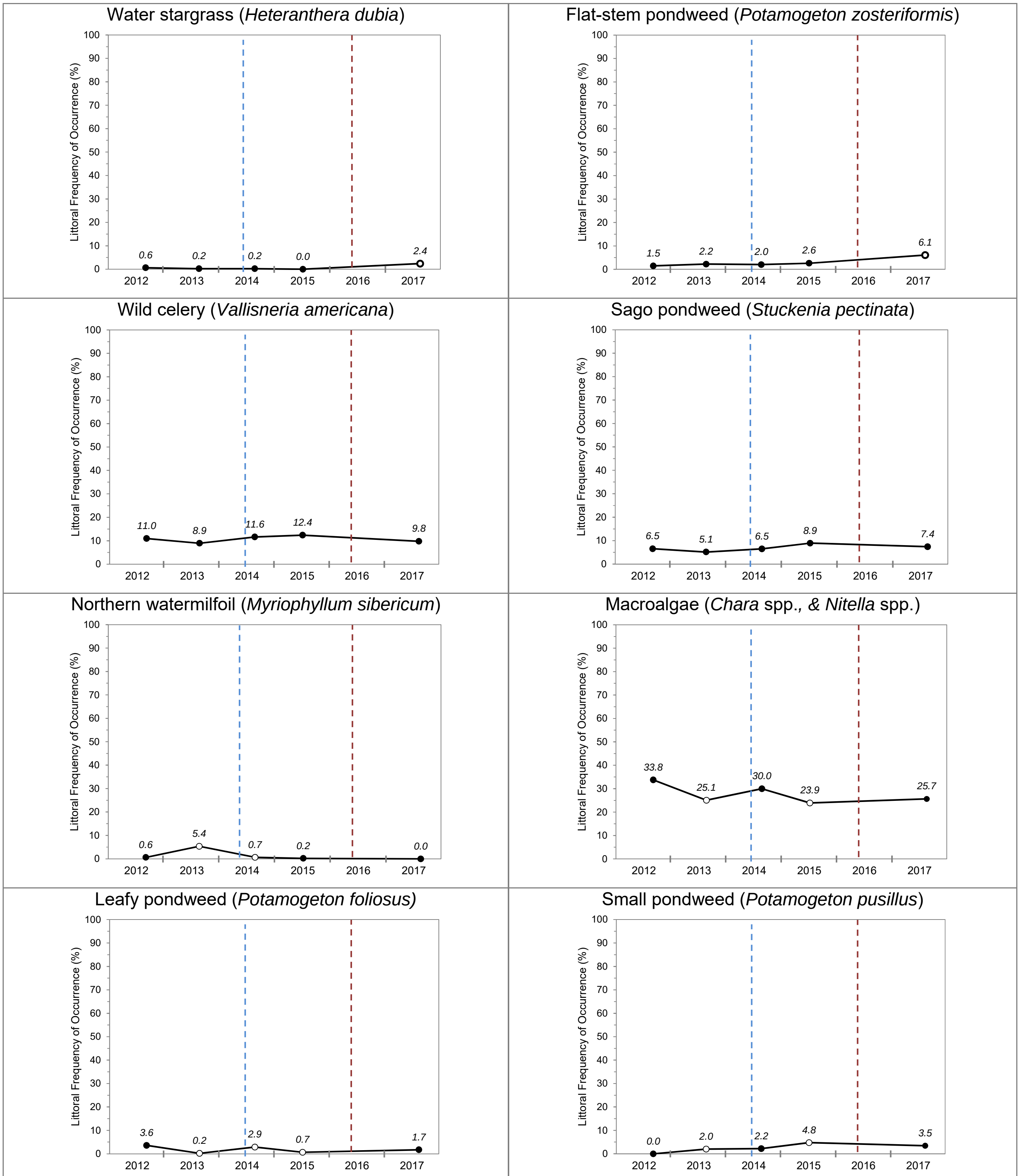


Figure 10. Littoral frequency of occurrence of native aquatic plant species that exhibited a statically valid increase in occurrence or no change in occurrence from 2015-2017 in Silver Lake. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05). Blue dashed line indicates initiation of large-scale triclopyr treatment, red dashed line indicates initiation of large-scale fluridone treatment.

As was discussed above, the water levels in Silver Lake were significantly higher during the 2017 growing season compared to previous years. The increased water depth of approximately 3 to 3.5 feet would have impacts to the littoral area of the lake (zone in which light is able to penetrate the water column allowing for plant growth). With a shifting littoral zone, plants that had been established at depths within the littoral zone most conducive to its growth may have been unable to adapt to the increased water level and decreased light availability. This factor may have compounded the impacts from the herbicide treatment in 2016 and may have contributed to the reduction in overall aquatic plant growth observed in 2017.

7.0 CONCLUSIONS AND DISCUSSION

Surveys conducted in 2017 on Silver Lake show that the large-scale herbicide treatments conducted in 2016 were successful in meeting the control objectives. The native plant community exhibited some reduction in 2017, likely from a combination of the large scale fluridone treatment and environmental factors from the large amounts of precipitation and corresponding increase in water levels. Large scale fluridone treatments of a similar design to Silver Lake were completed on Grass and Pine Lakes of the Cloverleaf Chain in Shawano County in 2016. The fluridone concentrations were slightly higher on this system compared to Silver Lake, and the impacts to the native plant community were considerably less in magnitude. The Cloverleaf Chain saw relatively stable water levels during this period and therefor it is theorized that water level changes in Silver Lake were an added stressor to the aquatic plant community during 2017. Continued point-intercept surveys in the following years will determine the longer-term plant population dynamics as species recover from the active management that has occurred on the lake.

The first monitoring proposed to be conducted on Silver Lake in 2018 is an Early Season AIS Survey (ESAIS Survey). This would be a meander-based survey of the entire lake in early- to mid-June to see if any HWM can be detected from surface viewing. Based on the results of the ESAIS Survey, a follow-up hand-harvesting (potentially with diver-assisted suction harvesting) will likely be recommended (Figure 12). This would also include a layer of scuba reconnaissance surveys similar to what occurred in 2017 on Silver Lake.

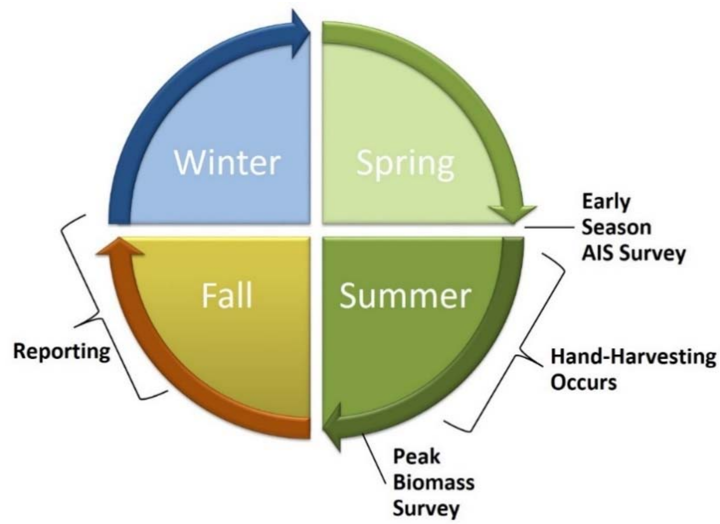


Figure 12. 2017 HWM Monitoring Strategy. Includes potential hand-harvesting efforts which may or may not take place.

Most lake groups initiate a large-scale herbicide strategy with the intention of implementing smaller-scale control measures (e.g. herbicide spot treatments, hand-removal) when HWM begins rebounding. This approach has shown promise on some lakes. However, the HWM population rebounds on many lakes in a lake-wide fashion that does not lend well to these methods. After the summer hand-harvesting operations cease, a Late-Summer HWM Peak-Biomass Survey will be conducted in 2018 serving as a post-hand-harvesting assessment. To be considered successful, the population size and/or density of HWM within the hand-removal areas would need to decrease from the 2018 ESAIS survey (pre) to the 2018 Late-Summer Peak-Biomass Survey (post).

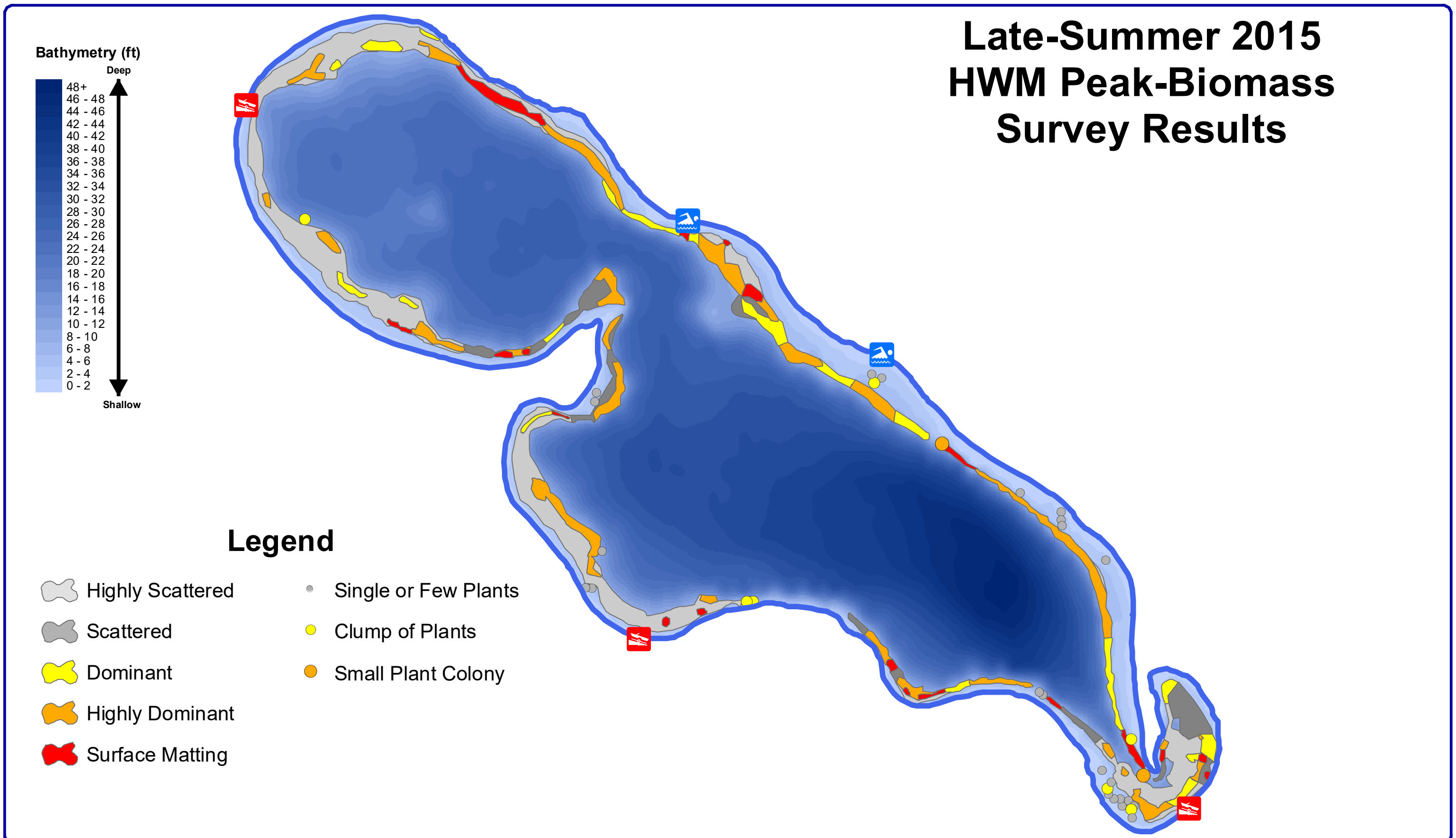
Additionally, a point-intercept survey will be conducted in the summer of 2018 to be compared to previous surveys which will be valuable for understanding the aquatic plant populations two years following treatment.

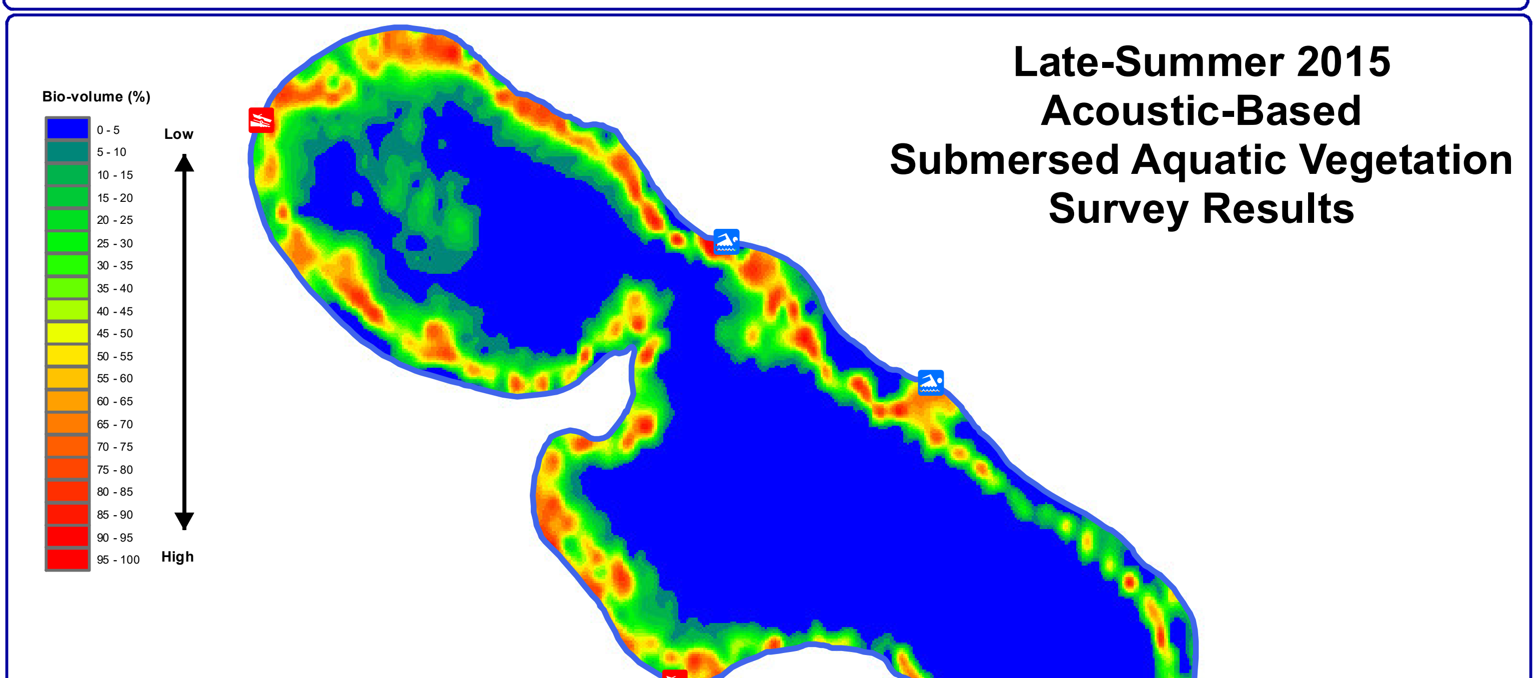
APPENDIX A

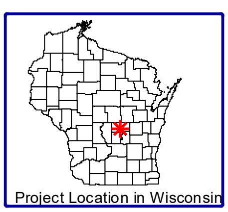
Table 1. Silver Lake Chi Square Analysis.

			LFOO (%)					2015-2017	
	Scientific Name	Common Name	2012	2013	2014	2015	2017	% Change	Direction
Dicots	*Myriophyllum spicatum*	Eurasian w atermilfoil	25.3	33.6	7.8	20.0	0.2	-98.9	▼
	Ceratophyllum demersum	Coontail	32.9	32.9	42.5	36.3	20.2	-44.3	▼
	Myriophyllum sibiricum	Northern w atermilfoil	0.6	5.4	0.7	0.2	0.0	-100.0	▼
	Bidens beckii	Water marigold	0.0	0.0	0.2	0.0	0.4		▲
	Ranunculus aquatilis	White w ater crow foot	0.0	0.0	0.2	0.4	0.0	-100.0	▼
	Ceratophyllum echinatum	Spiny hornw ort	0.0	0.0	0.0	0.0	0.2		▲
	Nymphaea odorata	White w ater lily	0.2	0.0	0.0	0.0	0.0		-
Non-dicots	*Potamogeton crispus*	Curly-leaf pondw eed	0.2	0.0	0.0	0.2	1.1	400.0	▲
	Chara spp & Nitella spp.	Muskgrasses & stonew o	33.8	25.1	30.0	23.9	25.7	7.3	▲
	Chara spp.	Muskgrasses	28.7	15.9	19.2	17.4	22.2	27.5	▲
	Elodea canadensis	Common w aterw eed	27.8	35.1	28.2	19.1	0.0	-100.0	▼
	Najas guadalupensis	Southern naiad	24.7	21.3	22.6	16.5	3.7	-77.6	▼
	Vallisneria americana	Wild celery	11.0	8.9	11.6	12.4	9.8	-21.1	▼
	Potamogeton gramineus	Variable-leaf pondw eed	20.7	13.6	10.7	11.1	3.5	-68.6	▼
	Nitella spp.	Stonew orts	8.0	9.4	11.4	8.5	3.7	-56.4	▼
	Stuckenia pectinata	Sago pondw eed	6.5	5.1	6.5	8.9	7.4	-17.1	▼
	Potamogeton friesii	Fries' pondw eed	2.1	3.4	2.2	11.7	4.6	-61.1	▼
	Filamentous algae	Filamentous algae	7.0	2.2	3.8	13.3	1.1	-91.8	▼
	Fissidens spp. & Fontinalis spp.	Aquatic Moss	5.5	10.1	7.4	4.8	0.0	-100.0	▼
	Potamogeton praelongus	White-stem pondw eed	4.6	4.0	8.5	4.8	1.5	-68.2	▼
	Potamogeton zosteriformis	Flat-stem pondw eed	1.5	2.2	2.0	2.6	6.1	133.3	▲
	Potamogeton illinoensis	Illinois pondw eed	4.6	2.7	4.7	5.4	1.5	-72.0	▼
	Potamogeton pusillus	Small pondw eed	0.0	2.0	2.2	4.8	3.5	-27.3	▼
	Najas flexilis	Slender naiad	3.2	1.8	3.8	3.0	0.0	-100.0	▼
	Potamogeton foliosus	Leafy pondw eed	3.6	0.2	2.9	0.7	1.7	166.7	▲
	Heteranthera dubia	Water stargrass	0.6	0.2	0.2	0.0	2.4		▲
	Potamogeton strictifolius	Stiff pondw eed	0.0	0.0	0.0	0.0	1.5		▲
	Potamogeton natans	Floating-leaf pondw eed	0.0	0.7	0.4	0.9	0.0	-100.0	▼
	Eleocharis acicularis	Needle spikerush	0.0	0.0	0.2	0.7	0.4	-33.3	▼
	Potamogeton amplifolius	Large-leaf pondw eed	0.6	0.0	0.7	0.0	0.0		-
	Spirodela polyrhiza	Greater duckw eed	0.0	0.0	0.0	0.0	0.4		▲
	Potamogeton spirillus	Spiral-fruited pondw eed	0.0	0.0	0.0	0.0	0.4		▲
	Elodea nuttallii	Slender w aterw eed	0.0	0.4	0.0	0.0	0.0		-
	Freshwater sponge	Freshw ater sponge	0.2	0.0	0.0	0.0	0.0		-

▲ or ▼ = Change Statistically Valid (Chi-square; α = 0.05)
▲ or ▼ = Change Not Statistically Valid (Chi-square; α = 0.05)







N S E W

700
Feet

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

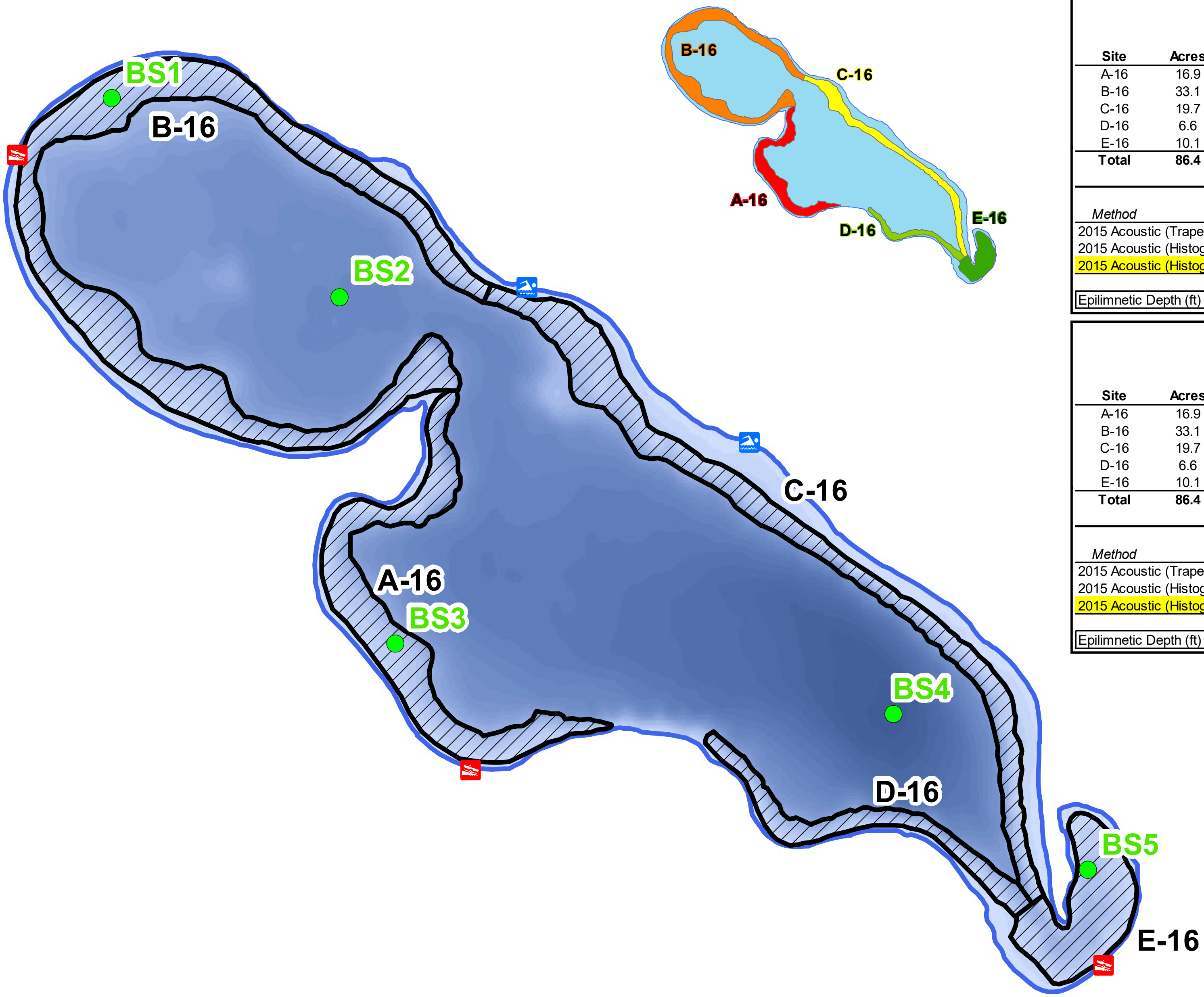
Sources:
Roads and Hydro: WDNR
Acoustic Survey: Onterra, 2015
Map Date: May 9, 2017
Filename: Map1_SilverW_Summer15_HWMPB_AcousticSAV.mxd

Legend

Boat Landing
Private Beach

Map 1
Silver Lake
Waushara County, Wisconsin

Summer 2015 HWMPB & Acoustic Survey



Site	Acres	Ave Depth	Total Volume (acre-feet)	Initial Application: Applicaiton Area Dose ppb	Initial Application: Pellatized Fluridone lbs
A-16	16.9	8.3	140.3	26	198.3
B-16	33.1	7.6	253.1	26	357.7
C-16	19.7	9.3	183.9	26	259.9
D-16	6.6	9.4	61.9	26	87.5
E-16	10.1	6.9	70.0	10	38.1
Total	**86.4**		**709.2**		**941.5**

Method	*Epilimnetic Volume*	*Epilimnetic fluridone ppb*	
2015 Acoustic (Trapezoidal acreage)	4032.7	4.29	
2015 Acoustic (Histogram)	3987.8	4.34	4 ppb Target
2015 Acoustic (Histogram + 1ft deeper)	4339.4	3.99	

Epilimnetic Depth (ft) 14

Site	Acres	Ave Depth	Total Volume (acre-feet)	Bump Applications: Applicaiton Area Dose ppb	Bump Applications: Pellatized Fluridone lbs
A-16	16.9	8.3	140.3	18	137.3
B-16	33.1	7.6	253.1	18	247.7
C-16	19.7	9.3	183.9	18	179.9
D-16	6.6	9.4	61.9	18	60.6
E-16	10.1	6.9	70.0	8	30.4
Total	**86.4**		**709.2**		**655.9**

Method	*Epilimnetic Volume*	*Epilimnetic fluridone ppb*	
2015 Acoustic (Trapezoidal acreage)	5480.4	2.20	
2015 Acoustic (Histogram)	5510.4	2.19	2 ppb Target
2015 Acoustic (Histogram + 1ft deeper)	5862.0	2.06	

Epilimnetic Depth (ft) 21

N W E S

1,000

Feet

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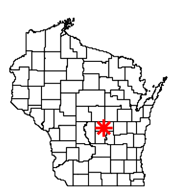
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2015

Map Date: April 6, 2016
Filename: SilverW_T2016_Cond1.mxd



Project Location in Wisconsin

Legend

Final Whole-Lake Treatment Application Areas

Herbicide Concentration Sampling Location

Map 2

Silver Lake

Waushara County, Wisconsin

Final 2016 HWM Control Strategy

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1,000
Feet

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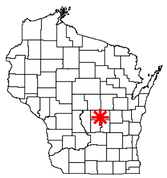
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2015
Aquatic Plants: Onterra, 2017
Map Date: December 27, 2017



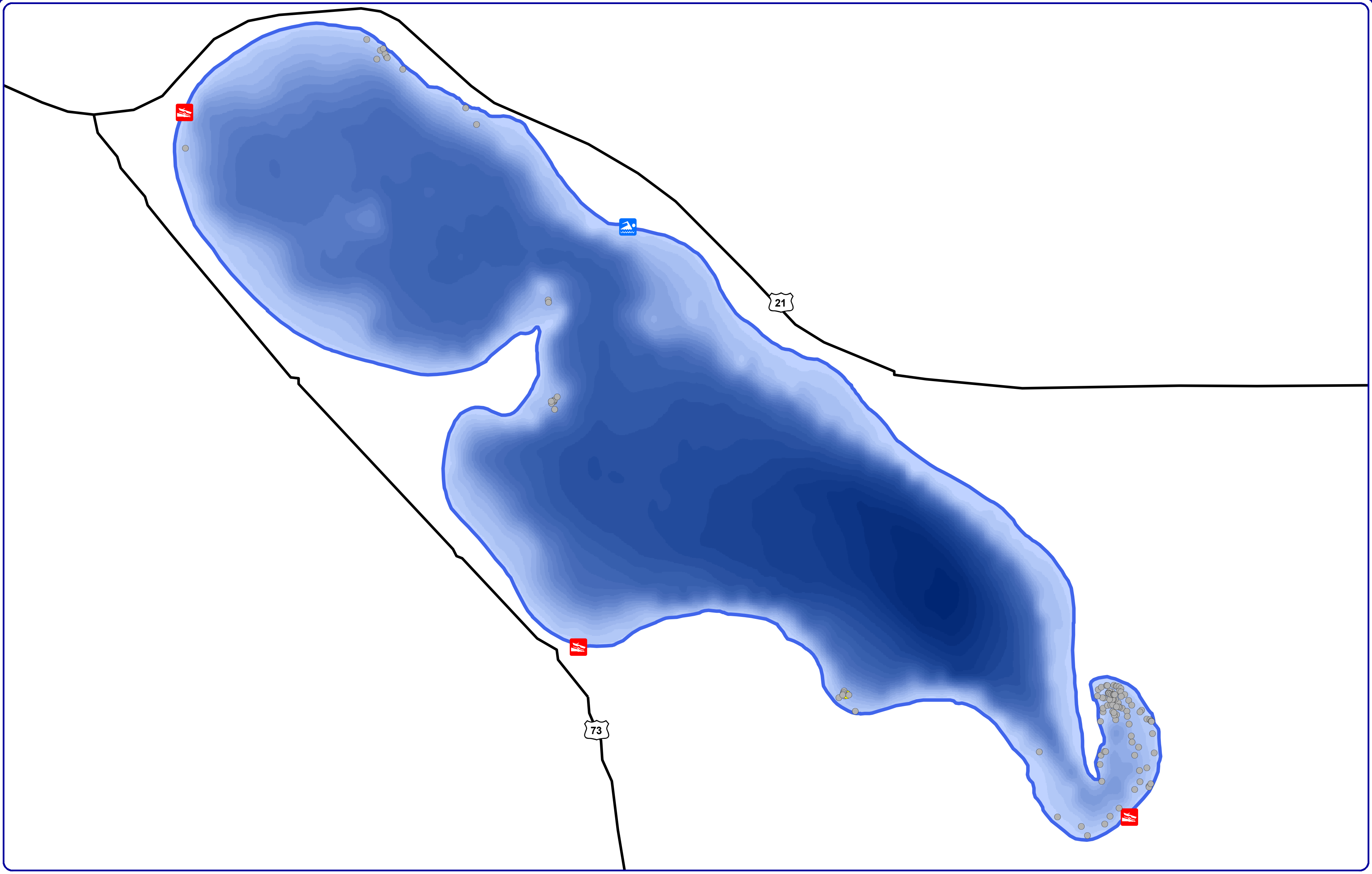
Project location in Wisconsin shown in red.

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 3
Silver Lake
Waushara County, Wisconsin

2017 CLP
Survey Results



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950
Feet

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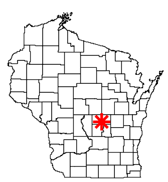
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2015
Aquatic Plants: Onterra, 2017
Map Date: October 11, 2017



Project location in Wisconsin.

Legend

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

Map 4
Silver Lake
Waushara County, Wisconsin

September 2017
HWM Survey Results