Squash Lake

Oneida County, Wisconsin

AIS Control & Prevention Project Results & Updated Aquatic Invasive Species Management Strategy

January 2017

Created by: Brenton Butterfield, Eddie Heath, and Tim Hoyman
Onterra, LLC
De Pere, WI

Funded by: Squash Lake Association, Inc.
Wisconsin Department of Natural Resources
(ACEI-156-14)

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOS

MAPS

APPENDICES

INTRODUCTION

Squash Lake, Oneida County, is an approximate 396-acre oligo-mesotrophic seepage lake with a maximum depth of 74 feet and a mean depth of 22 feet (Figure 1). The lake sustains a species-rich aquatic plant community with 63 native species documented, many of which are considered to be sensitive to environmental degradation. The most abundant plants within the lake include fern pondweed (*Potamogeton robbinsii*), slender naiad (*Najas flexilis*), and stoneworts (*Nitella* spp.).

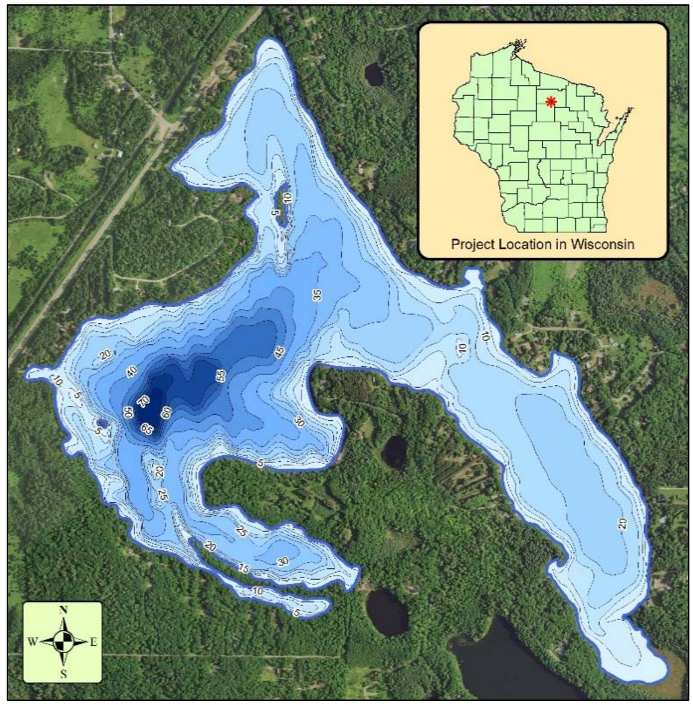


Figure 1. Squash Lake, Oneida County, Wisconsin.

In 2009, the non-native, invasive plant Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was discovered in Squash Lake. Following its discovery, the Squash Lake Association, Inc. (SLA) contracted with Onterra, and in September of 2009 Onterra ecologists completed a lake-wide meander-based survey aimed at locating and mapping locations of EWM. The 2009 survey revealed that EWM was present within near-shore areas around the lake, but in very low abundance. The results of this survey along with potential management options were presented to members of the SLA. After reviewing these options, the association decided to move forward with an aggressive hand-harvesting effort in hopes of reducing/maintaining a low-density EWM population in Squash Lake.

Hand-harvesting efforts using paid scuba divers and professional monitoring of EWM began in 2010 and both have occurred annually since. The hand-harvesting efforts through 2013 were funded with multiple Wisconsin Department of Natural Resources (WDNR) Aquatic Invasive Species (AIS) Early Detection and Response (EDR) Grants. Five years following the discovery of EWM, the control program transitioned from an EDR program to an Established Population Control (EPC) program. In February of 2014 the SLA successfully applied for a WDNR AIS-EPC Grant to aid in funding continued hand-harvesting of EWM and professional monitoring from 2014-2016. One of the primary goals of this project was to determine if a hand-harvesting strategy is a feasible method for controlling EWM at a lake-wide level. As hand-harvesting of EWM is a relatively new control method, this project aimed to determine the level of hand-removal effort that is needed to obtain successful EWM control and what techniques are most effective.

Over the course of this three-year project, Onterra ecologists mapped EWM throughout Squash Lake twice on an annual basis; once in early summer to guide hand-harvesting efforts, and once in late summer to assess the efficacy of hand-harvesting (Maps 1-4). In 2016, in addition to the EWM mapping surveys, a whole-lake aquatic plant point-intercept survey and emergent/floating-leaf aquatic plant community mapping survey were also completed to reassess the lake's EWM and native aquatic plant population following the three-year hand-harvesting project.

In summary, the hand-harvesting efforts in Squash Lake have been largely successful in maintaining a small population of EWM within the lake. As is discussed further in this report, the 2016 whole-lake aquatic point-intercept survey which consisted of 1,076 sampling locations across the littoral zone yielded an EWM littoral frequency of occurrence of 0.0%. In other words, while EWM is still present within the lake, its current population is at a level at which went undetected during the point-intercept survey. Statistical comparison of the 2016 point-intercept data to point-intercept data collected in 2009 and 2012 indicate that occurrence of EWM within the lake over this time period has not changed, indicating hand-harvesting has been highly effective at preventing the expansion of the EWM population.

This report serves as the final report under the 2014-2016 WDNR-EPC funded project (ACEI-156-14) as well as an update to the Squash Lake Management Plan (Onterra 2014) regarding the lake's invasive aquatic plant management strategy. The projects methods and results from the 2016 surveys are discussed within this report. Results from the 2014 and 2015 hand-harvesting efforts can be found in the respective annual reports. The results of these studies will be used to guide the SLA in developing management strategies for continued protection of the lake's native aquatic plant community as well as continued management of EWM within the lake.

2016 EWM CONTROL STRATEGY

The objective of EWM management on Squash Lake is not to eradicate EWM from the lake, as that is impossible with current tools and techniques. The objective is to maintain an EWM population that exerts little to no detectable impacts on the lake's ecology and ecosystem services (i.e. recreation and aesthetics). In an anonymous stakeholder survey distributed to Squash Lake riparians in 2012 as part of the lake management planning project indicated that 47% of respondents were not supportive of utilizing aquatic herbicides to control aquatic plants in Squash Lake while 37% were in favor of this technique.

Since the largest percentage of Squash Lake stakeholders were not in favor of the use of herbicides as a method of EWM control in combination with the fact that herbicides would likely not be effective given the low level of EWM within the lake, the SLA elected to move forward with continued hand-removal during the 2014-2016 project. Along with SLA-paid scuba divers, the SLA also again contracted with Many Waters, LLC to implement diver-assisted suction harvesting (DASH) in two areas of the lake in 2016 that contained larger, denser areas of EWM.

The DASH system involves scuba divers removing EWM plants by hand and feeding them into a suction hose which delivers them to up to a pontoon boat. The DASH system allows for a more rapid and efficient removal of larger, colonized areas of EWM. It was believed that by targeting the largest, densest areas of EWM with the DASH system, the SLA scuba divers would be able to focus their efforts on areas of the lake containing lesser amounts of EWM. The hope of the integration of the professionally-operated DASH system into the SLA's hand-harvesting program was to make the program more efficient and cost-effective. In 2016, the SLA received a WDNR mechanical harvesting permit to have the DASH system implemented in two locations in the northern portion of the lake in 2016.

In addition to integrating the DASH system to improve the program's efficiency, starting in 2014 the SLA scuba diver hand-removal sites were prioritized based upon the level of EWM within each area. Sites containing *small plant colonies* were classified as areas requiring the greatest need for hand-removal, or primary focus sites. Areas containing *clumps of plants* and *single or few plants* were classified as secondary focus sites. This method was intended to focus the efforts of the hand-harvesters in areas where EWM was most likely to expand into colonized areas if hand-removal did not occur, and was utilized again in 2016.

AQUATIC PLANTS

Importance in the Aquatic Community

Although the occasional lake user considers aquatic plants (macrophytes) to be weeds and are often considered as a nuisance to the recreational use of the lake, these plants are an essential element in a healthy and functioning lake ecosystem (Photo 1). It is important that lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative effects on it.

Photo 1. Native aquatic plant community in Loon Bay, Squash Lake. Photo credit Onterra.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and seeds of floating-leaf pondweed (*Potamogeton natans*) both serve as excellent food sources for migratory waterfowl. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*). In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source.

Aquatic plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreland erosion and the resuspension of bottom sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing nutrient levels that may lead to phytoplankton blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance phytoplankton blooms.

Because most aquatic plants are rooted in place and are unable to relocate in the wake of environmental change, they are often the first aquatic community to indicate that changes may be occurring within the system. For this reason, aquatic plants are used as indicators of environmental health. Aquatic plant communities can respond in variety of ways; there may be increases or reductions in the occurrence of sensitive 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.

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

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

Aquatic Plant Survey Methods

Eurasian Water Milfoil Qualitative Monitoring

Normally, EWM control programs (mainly with herbicides) incorporate both established qualitative (EWM mapping) and quantitative (sub-sample point-intercept survey) evaluation methodologies. However, quantitative monitoring of hand-removal areas using sub-sample point-intercept methodology was not applicable at this time as there were no areas of EWM large enough to attain the number of sampling locations required to meet the assumptions of statistical analysis. Therefore, each hand-removal site was only monitored annually using comparative GPS-guided pre- and post-hand-harvesting qualitative EWM mapping surveys.

Using sub-meter GPS technology, EWM locations were mapped by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *Highly Scattered* to *Surface Matting*. Point-based techniques were applied to EWM locations that were considered as *Small Plant Colonies* (<40 feet in diameter), *Clumps of Plants*, or *Single or Few Plants*.

To assess the 2014-2016 hand-harvesting activities on Squash Lake, qualitative assessments were completed by comparing pre-hand-harvesting data collected during the June Early-Season AIS Survey with post-hand-harvesting EWM mapping data collected during the September Late-Summer EWM Peak-Biomass Survey. Squash Lake Association scuba diver hand-removal sites were deemed successful if the level of EWM within the hand-removal areas were at least maintained at the point-based mapping level; for example, a site would be considered unsuccessful if it contained *single or few plants* (point-based mapping) prior to hand-harvesting and expanded to contain colonized EWM (polygons) following hand-harvesting. Sites of colonized EWM that were targeted with the DASH system were deemed successful if they were reduced by at least two density ratings (e.g. *highly dominant* to *scattered*).

Hand-removal programs for EWM are relatively new and measuring the success of hand-harvesting activities, particularly with low-density EWM occurrences, can be complex and requires revision as the project progresses. As stated, the success criterion developed at the beginning of this project for DASH sites was a reduction of at least two density ratings. However, after three years of evaluating DASH implementation on Squash Lake along with other lakes in the northern Wisconsin, it is believed that the expectation of reducing EWM by two density ratings is unrealistic for this management technique. Therefore, the success criterion for the 2016 DASH site has been revised to a qualitative reduction of the EWM population of at least one density rating

Aquatic Plant Quantitative Monitoring

Although annual control strategy assessments were only made with using qualitive methodologies (i.e. comparing EWM pre- and post- EWM mapping surveys), quantitative lake-wide populations assessments occurred during this project. In the summer of 2016, Onterra ecologists completed a whole-lake aquatic plant point-intercept survey using the same sampling locations and methodology as the surveys that were completed in 2009 (WDNR) and 2012 (Onterra). The aquatic plant point-intercept survey method as developed by the WDNR Bureau of Science Services (Hauxwell et al. 2010) was used in Squash Lake in 2016. Based upon guidance from the WDNR, sampling locations were spaced 33 meters apart resulting in a total of 1,478 sampling locations.

At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediments, sand, or rock/gravel), and the plant species sampled along with their relative abundance on the sampling rake was recorded (Figure 2). A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 15 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 15 feet. Depth information was collected using graduated marks on the pole of the rake or using an onboard sonar unit at depths greater than 15 feet. Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately feel the bottom with this sampling device. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

The **Littoral Zone** is the area of the lake where sunlight is able to penetrate to the sediment providing aquatic plants with sufficient light to carry out photosynthesis.

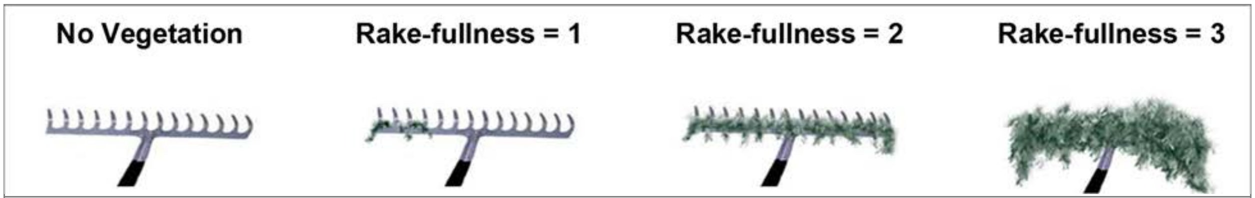


Figure 2. Aquatic plant rake fullness ratings. Adapted from Hauxwell et al (2010).

Emergent & Floating-Leaf Aquatic Plant Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within the lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Squash Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy, and the results are compared to the same survey completed in 2012.

Data Interpretation

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed on Squash Lake since 2009. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake as determined from the whole-lake point-intercept survey. 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 Squash 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 Squash Lake to be compared through time as well as to other lakes within the region and state.

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

Species Diversity

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index values from Squash Lake are compared to data collected by Onterra and the WDNR Science Services on 212 lakes withn the Southeast Wisconsin Till Plain ecoregion and on 392 lakes throughout Wisconsin.

Aquatic Plant Survey Results

2016 EWM Control Strategy & Qualitative Assessment Results

On June 14 and 15, 2016 Onterra ecologists conducted the Early-Season AIS (ESAIS) Survey on Squash Lake. While EWM surveys are typically conducted later in the summer to coincide with its peak growth, this early-summer meander-based survey was conducted to locate and map areas of EWM so these data could be relayed to SLA and Many Waters hand-harvesters. This provides the hand-harvesters with the most up-to-date and accurate information regarding locations of EWM within the lake. In addition, the hand-harvesters could better allocate their time to removing EWM rather than searching the lake for suitable areas to conduct hand-removal. The results of the ESAIS Survey were digitally formatted into a basemap that was loaded onto the association's GPS unit for their use. As discussed, the ESAIS Survey also serves as a pre-hand-harvesting survey where the data gathered prior to the implementation of hand-harvesting can be compared to data collected after hand-harvesting during the Late-Summer EWM Peak-Biomass Survey.

During the 2016 ESAIS Survey, most of the EWM that had been located in September 2015 had been relocated (Map 2 and Map 3). However, the approximately 2.0-acre area of highly scattered EWM located in the northern portion of the lake in 2015 was found to have declined to a smaller scattered area of approximately 0.4 acres in June 2016. Water levels had increased from 2015 to 2016, and it is possible that this caused the decline of EWM observed in this deeper area of the lake. A small 0.05-acre colony of dominant EWM was also located in June 2016 in the northern portion of the lake (Map 3). Following the 2016 ESAIS Survey, a total of 14 SLA scuba diver hand-harvest sites were created totaling approximately 3.3 acres (Map 3). Four of these hand-harvest sites were deemed priority hand-harvest sites while the remaining ten sites were deemed secondary priority sites. The 0.4-acre colony of scattered EWM in the northern portion of the lake was proposed for DASH system implementation (Map 3).

Hand-harvesting logs recorded by the SLA scuba divers indicate that they spent a total of approximately 527 diver hours between June 13 and August 23 removing a total of 1,884 pounds of EWM from Squash Lake in 2016 (Table 1). The SLA divers were able to harvest EWM within all 14 of the 2016 hand-harvest sites and also harvested areas of EWM outside of these locations. On July 20, 21, and 22, 2016, Many Waters, LLC spent a total of 14.0 dive hours implementing the DASH system on DASH site A-16 removing a total of 200.5 pounds of EWM (Table 2). A detailed report created by Many Waters, LLC detailing their 2016 hand-harvesting efforts can be found in Appendix A.

Following the hand-harvesting efforts, Onterra ecologists conducted the Late-Summer EWM Peak-Biomass Survey on September 20, 2016 to assess the hand-harvesting areas and map EWM throughout the lake. This survey revealed that the 2016 hand-harvesting efforts were largely successful at reducing EWM within the hand-harvest areas and maintaining a small EWM population primarily comprised of single plant occurrences (Figures 3-6 and Map 4). One hundred percent of the 14 SLA hand-harvest sites met the pre-determined success criterion, and 12 saw a reduction in EWM occurrence while two maintained a similar level of EWM mapped prior to hand-harvesting (Table 2). The DASH site A-16 which contained an approximate 0.5-acre colony of scattered EWM prior to harvesting was found to contain a similar-sized colony of highly scattered EWM following hand-harvesting. This represents a reduction of one density rating and meets the revised success criterion for DASH sites.

Table 1. Squash Lake 2016 SLA diver- and Many Waters, LLC DASH diver hours and total EWM removed. Created using data provided by SLA divers and Many Waters, LLC.

2016 Control Strategy	Diver Hours	EWM Removed (lbs)
Hand-Removal (SLA Divers)	548.5	1,882.0
Mechanical Removal (DASH Divers)	14.0	200.5
Total	**562.5**	**2,082.5**

Table 2. Squash Lake June 2016 pre- and September 2016 post-hand-harvesting results within SLA divers and DASH EWM harvesting areas.

	SLA Hand-Harvest Site	June 2016 EWM (Pre-Hand-Harvesting)	September 2016 EWM (Post-Hand-Harvesting)	Change	Success Criterion Met
Primary	A-16	Colonized (dominant) & Point-Based (C,S)	Point-Based (S)	↓	Yes
	B-16	Point-Based (SPC,S)	Point-Based (C,S)	↓	Yes
	C-16	Point-Based (SPC,C,S)	Point-Based (S)	↓	Yes
	D-16	Point-Based (SPC,S)	Point-Based (S)	↓	Yes
Secondary	E-16	Point-Based (C,S)	Point-Based (C,S)	-	Yes
	F-16	Point-Based (C,S)	Point-Based (C,S)	-	Yes
	G-16	Point-Based (C,S)	Point-Based (S)	↓	Yes
	H-16	Point-Based (C,S)	Point-Based (S)	↓	Yes
	I-16	Point-Based (C,S)	No EWM Located	↓	Yes
	J-16	Point-Based (C)	No EWM Located	↓	Yes
	K-16	Point-Based (C,S)	Point-Based (S)	↓	Yes
	L-16	Point-Based (C,S)	No EWM Located	↓	Yes
	M-16	Point-Based (C)	No EWM Located	↓	Yes
	N-16	Point-Based (C)	No EWM Located	↓	Yes
	DASH Site	**June 2016 EWM (Pre-Hand-Harvesting)**	**September 2016 EWM (Post-Hand-Harvesting)**	**Change**	**Success Criterion Met**
	DASH A-16	Colonized (scattered)	Colonized (highly scattered)	↓	Yes

SPC = Small plant colony; C = Clumps of plants; S = Single or few plants

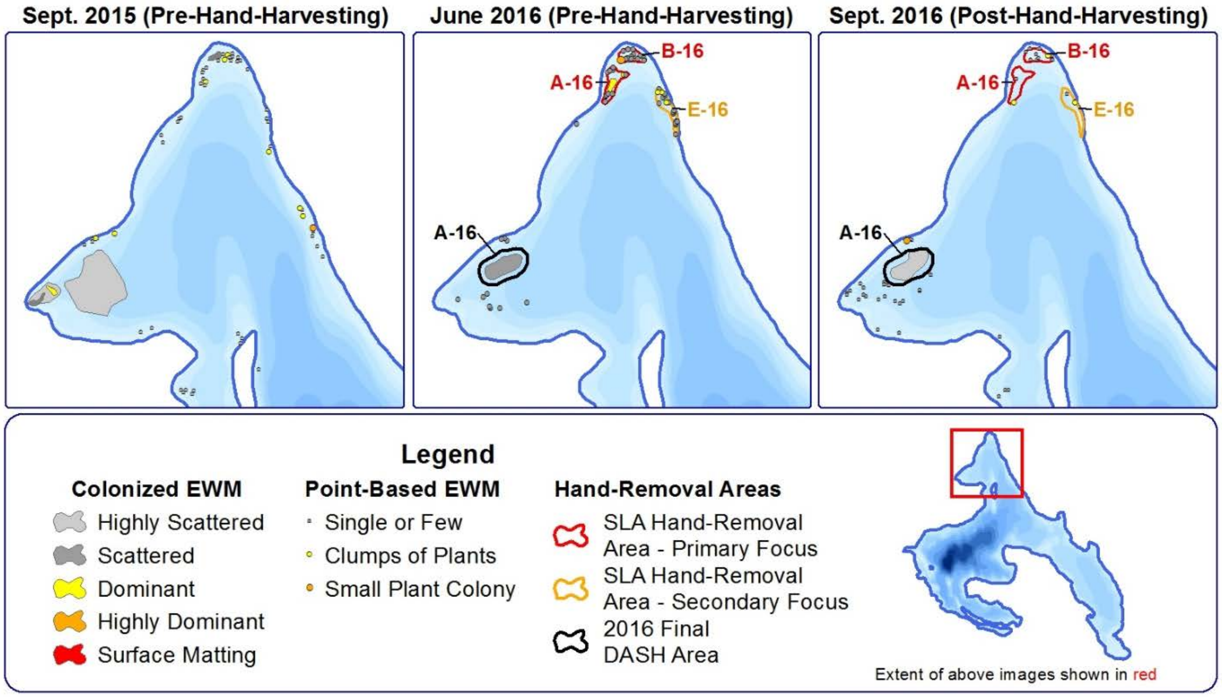


Figure 3. Squash Lake-North EWM locations from September 2015 and June 2016 pre- and September 2016 post-hand-harvesting.

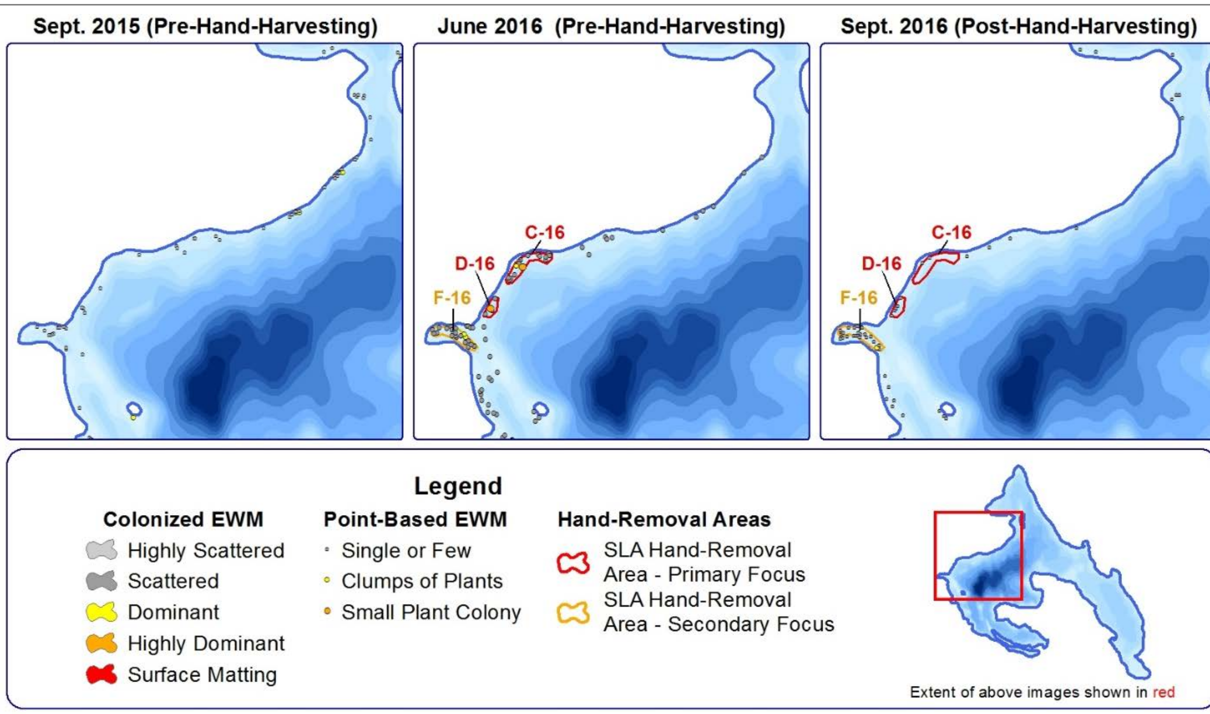


Figure 4. Squash Lake-Northwest EWM locations from September 2015 and June 2016 pre- and September 2016 post-hand-harvesting.

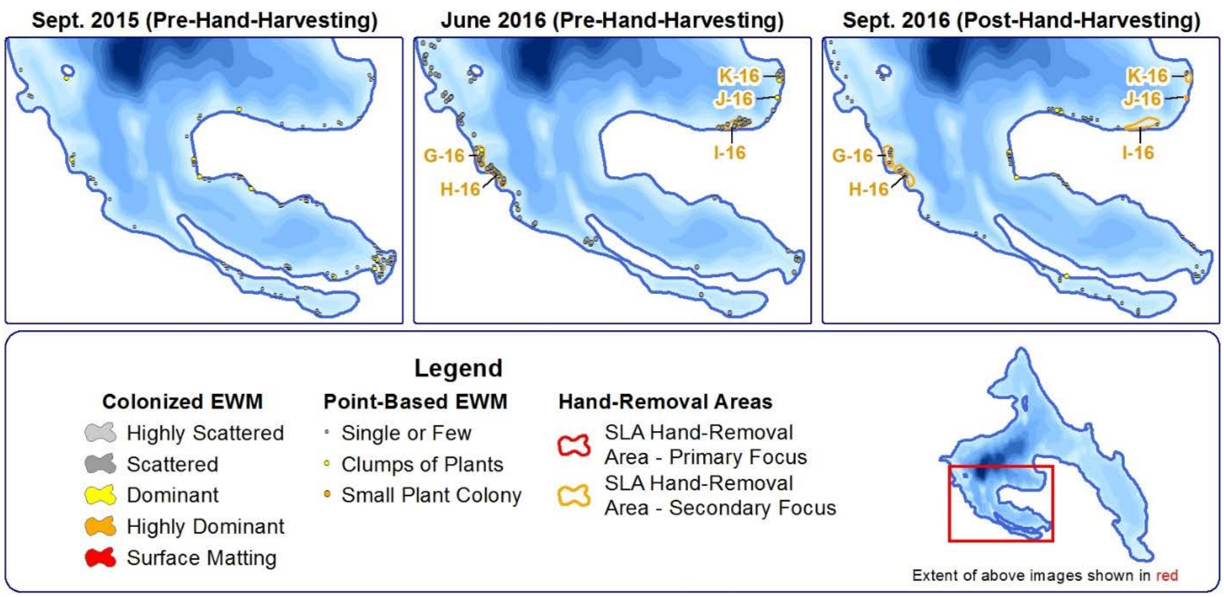


Figure 5. Squash Lake-Southwest EWM locations from September 2015 and June 2016 pre- and September 2016 post-hand-harvesting.

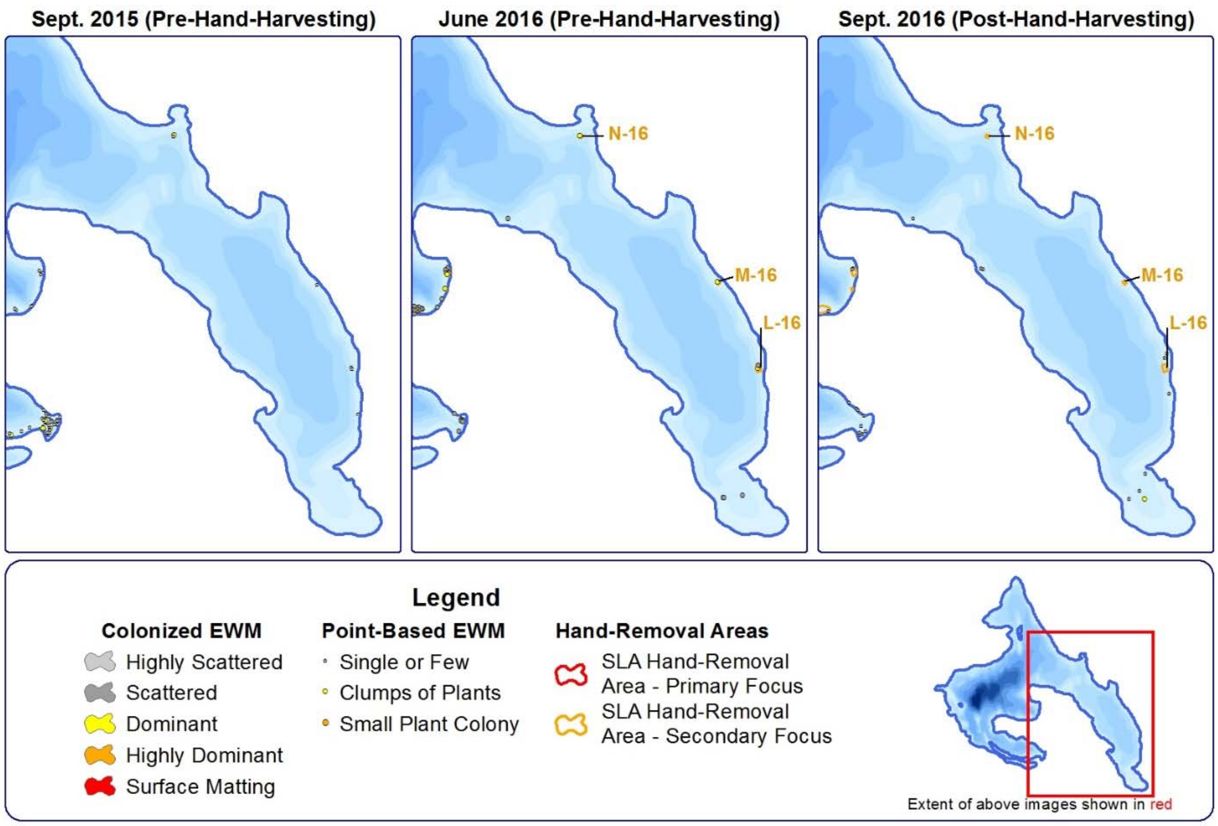


Figure 6. Squash Lake-Southeast EWM locations from September 2015 and June 2016 pre- and September 2016 post-hand-harvesting.

EWM Quantitative Assessment Results

On August 16, 2016, Onterra ecologists completed the whole-lake aquatic plant point-intercept survey on Squash Lake to quantitatively assess the EWM and native aquatic plant populations. As discussed previously, the data collected during this survey are compared to previous point-intercept surveys completed in 2012 (Onterra) and 2009 (WDNR). Of the 1,478 sampling locations in Squash Lake, 1,076 fell at or shallower than the maximum depth of plant growth (30 feet) in 2016 (Figure 7). Of the 1,076 littoral locations sampled in 2016, none were found to contain EWM, yielding an EWM littoral frequency of occurrence of 0.0% in 2016 (Figure 8). While EWM is present within the lake and was observed during this survey, it was not physically encountered on the rake at any of the sampling locations. This indicates that at the lake-wide level, the EWM population in Squash Lake remains very small.

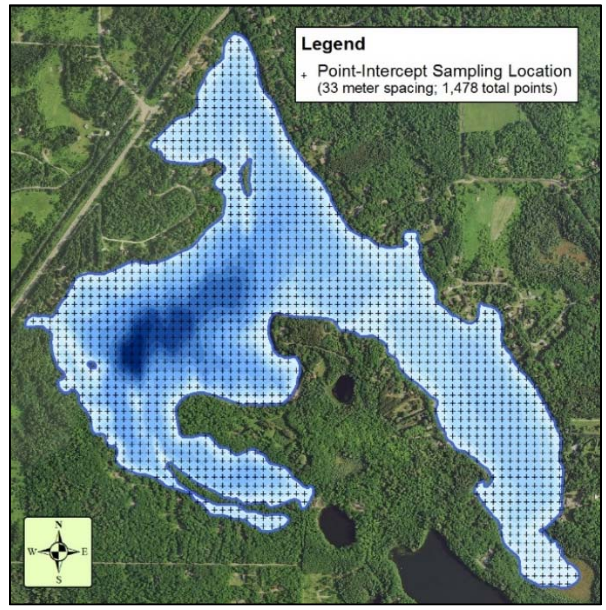


Figure 7. Squash Lake whole-lake point-intercept survey sampling locations. Created using guidance from the WDNR.

Comparing the 2016 data with the data collected in 2009 and 2012 shows that EWM has not exhibited a statistically valid change in its littoral occurrence over this time period (Chi-Square α = 0.05). These data collected over this seven-year period show that the hand-harvesting on Squash Lake has been effective at maintaining a small lake-wide population of EWM and has prevented its expansion. In addition, the hand-harvesters on Squash Lake have shown to be effective at removing small but dense colonized areas of EWM such as the dominant colony located in A-16. It is believed these monotypic colonies have the most adverse impacts on lake ecology due to habitat alteration and being large sources for new plants. The hand-harvesters were able to effectively remove these colonies after they were located, and they have prevented large, monotypic stands of EWM from developing. Hand-harvesting in Squash Lake has been able to maintain a small EWM population primarily comprised of single plant occurrences.

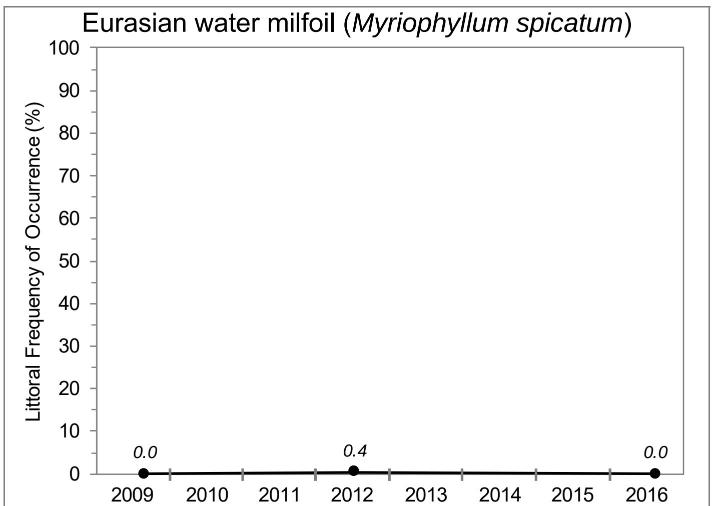


Figure 8. Littoral frequency of occurrence of EWM in Squash Lake from 2009-2016. Changes in littoral occurrence are not statistically valid (Chi-Square α = 0.05). Created using data from WDNR 2009 (N = 1,088) and Onterra 2012 (N = 1,087) and 2016 (N = 1,076) whole-lake point-intercept surveys.

Native Aquatic Plant Quantitative Assessment Results

The whole-lake aquatic plant point-intercept survey conducted on Squash Lake in 2016 was also used to assess native aquatic plant populations. In 2016, a total of 54 native aquatic plant species were located in Squash Lake (Table 3). Of these 54 species, 41 were physically encountered on the rake during the point-intercept survey. This is the same number of native aquatic plant species located on the rake (41) during the 2012 point-intercept survey and higher than the number recorded in 2009 (32). The maximum depth of aquatic plant growth in 2016 (30 feet) was the same maximum depth recorded in 2009 and 2012, and is a testament to Squash Lake's high water clarity.

Of the 1,076 sampling locations that fell within the littoral zone in 2016, 63% contained aquatic vegetation compared to 76% and 74% in 2009 and 2012, respectively (Figure 9 and Map 5). The littoral frequency of occurrence of vegetation in Squash Lake in 2016 represents a statistically valid decline of 5.3% when compared to 2012 and 7.8% when compared to 2009. The reduction the littoral occurrence of aquatic vegetation in 2016 was primarily driven by reductions in three species: stoneworts, common waterweed, and small/slender pondweed. As is discussed further in this section, this small decline in the littoral occurrence of vegetation in Squash Lake was likely driven by natural factors.

The littoral frequency of occurrence of aquatic plant species which had a littoral occurrence of at least 5% in one of the three point-intercept surveys are displayed in Figure 10 while the littoral frequency of occurrence of remaining species can be found in Table 3. Due to their morphologic similarity and often difficulty in identification, the occurrences of common (*E. canadensis*) and slender (*E. nuttallii*) waterweeds were combined for this analysis. The same was also done with the occurrences of small (*P. pusillus*) and slender (*P. berchtoldii*) pondweeds. Four aquatic plant species have exhibited statistically valid changes in their littoral occurrence in Squash Lake between 2009 and 2016. Stoneworts, common/slender waterweed, and small/slender pondweed have exhibited declines in their littoral occurrence while fern pondweed exhibited an increase.

In 2009 and 2012, stoneworts were the most frequently encountered aquatic plant in Squash Lake with a littoral frequency of occurrence of 35% and 31%, respectively (Figure 10). In 2016, stoneworts were the third-most frequently encountered aquatic plant with a littoral frequency of occurrence of 17%, representing a statistically valid reduction in occurrence of 47% from 2012.

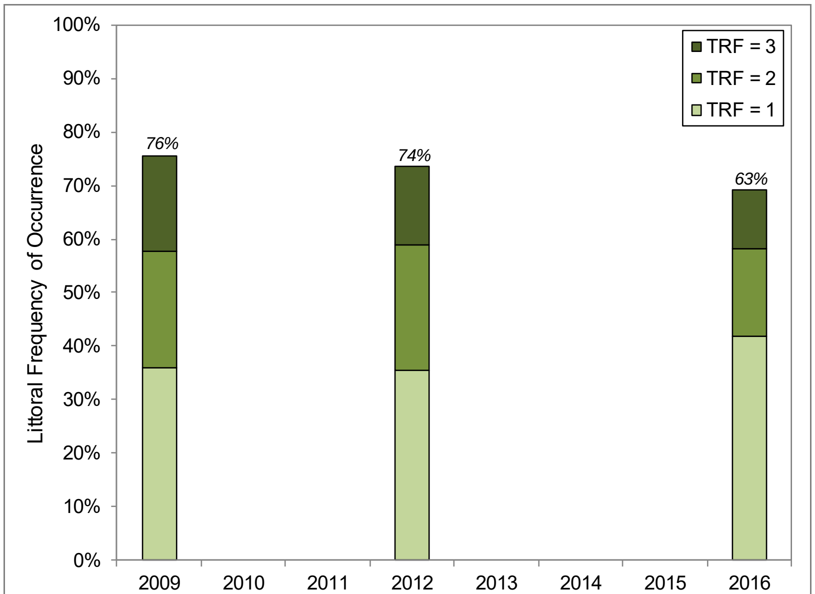


Figure 9. Squash Lake 2009, 2012, and 2016 littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) ratings. The occurrence of vegetation in 2016 is statistically different from occurrences in 2009 and 2012 (Chi-Square α = 0.05).

Table 3. Aquatic plant species located in Squash Lake during WDNR 2009 and Onterra 2012 and 2016 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism	Littoral Frequency of Occurrence 2009	2012	2016
Emergent	*Carex gynandra*	Nodding sedge	6		I	I
	Carex hystericina	Porcupine sedge	3		I	I
	Carex lasiocarpa	Narrow-leaved woolly sedge	9			I
	Carex vesicaria	Blister sedge	7			I
	Drosera intermedia	Narrow-leaved sundew	8		I	
	Dulichium arundinaceum	Three-way sedge	9		0.1	0.2
	Eleocharis palustris	Creeping spikerush	6		0.2	0.3
	Equisetum fluviatile	Water horsetail	7		I	
	Iris versicolor	Northern blue flag	5		I	I
	Juncus effusus	Soft rush	4		0.1	I
	Pontederia cordata	Pickerelweed	9		0.2	I
	Schoenoplectus acutus	Hardstem bulrush	5		I	0.1
	Schoenoplectus pungens	Three-square rush	5		I	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		0.1	0.1
	Scirpus cyperinus	Wool grass	4		I	
	Sparganium sp.	Bur-reed sp.	N/A	0.1		
	Typha latifolia	Broad-leaved cattail	1			I
Floating-leaf	*Brasenia schreberi*	Watershield	7	0.9	1.4	1.4
	Nuphar variegata	Spatterdock	6	0.1	0.2	0.3
	Nymphaea odorata	White water lily	6	0.2	0.2	0.2
	Persicaria amphibia	Water smartweed	5			I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	0.3	0.6	0.1
	Sparganium fluctuans	Floating-leaf bur-reed	10		0.1	I
FL/E	*Sparganium americanum*	American bur-reed	8		I	I
Submergent	*Bidens beckii*	Water marigold	8		0.2	1.1
	Ceratophyllum echinatum	Spiny hornwort	10		0.2	0.2
	Chara spp.	Muskgrasses	7	14.4	17.0	13.3
	Elatine minima	Waterwort	9	1.0	0.8	1.0
	Elodea canadensis	Common waterweed	3	10.5	8.6	6.8
	Elodea nuttallii	Slender waterweed	7	5.1	5.9	1.8
	Eriocaulon aquaticum	Pipewort	9	0.3	0.4	0.5
	Gratiola aurea	Golden pert	10			0.1
	Isoetes spp.	Quillwort spp.	8	1.2	1.3	1.7
	Lobelia dortmanna	Water lobelia	10	0.2	1.3	0.9
	Myriophyllum alterniflorum	Alternate-flowered water milfoil	10	1.8	3.2	1.2
	Myriophyllum sibiricum	Northern water milfoil	7			0.2
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	I	0.4	I
	Myriophyllum tenellum	Dwarf water milfoil	10	4.6	3.2	4.5
	Najas flexilis	Slender naiad	6	18.1	15.5	20.3
	Nitella spp.	Stoneworts	7	35.4	31.1	16.5
	Potamogeton amplifolius	Large-leaf pondweed	7	6.9	4.7	4.8
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	0.2	0.4	0.6
	Potamogeton foliosus	Leafy pondweed	6	0.5	0.7	0.8
	Potamogeton gramineus	Variable-leaf pondweed	7	0.4	0.4	0.8
	Potamogeton natans	Floating-leaf pondweed	5	0.3	0.5	0.7
	Potamogeton praelongus	White-stem pondweed	8			0.1
	Potamogeton berchtoldii & *P. pusillus*	Small & Slender pondweed	7	10.8	15.3	6.5
	Potamogeton robbinsii	Fern-leaf pondweed	8	17.6	19.8	24.3
	Potamogeton spirillus	Spiral-fruited pondweed	8	3.5	3.7	5.5
	Potamogeton strictifolius	Stiff pondweed	8		0.6	2.6
	*Potamogeton vaseyi**	Vasey's pondweed	10	2.3	0.5	0.3
	Potamogeton zosteriformis	Flat-stem pondweed	6		0.1	
	Ranunculus flammula	Creeping spearwort	9	0.8	1.0	0.5
	Sagittaria cristata	Crested arrowhead	9	0.1	0.5	0.3
	Utricularia cornuta	Horned bladderwort	10		I	
	Utricularia gibba	Creeping bladderwort	9			0.1
	Utricularia intermedia	Flat-leaf bladderwort	9	0.1	0.1	
	Utricularia vulgaris	Common bladderwort	7	0.1		
	Vallisneria americana	Wild celery	6	1.5	0.6	3.7
S/E	*Eleocharis acicularis*	Needle spikerush	5	3.6	3.7	1.3
	Juncus pelocarpus	Brown-fruited rush	8	3.3	3.1	3.6
	Sagittaria graminea	Grass-leaved arrowhead	9		I	
	Schoenoplectus subterminalis	Water bulrush	9		0.1	0.2

FL/E = Floating-leaf/Emergent; S/E = Submergent/Emergent
I = Incidentally located
** = Species listed as special concern by WDNR Natural Heritage Inventory*

Stoneworts are the deepest-growing aquatic plants in Squash Lake growing primarily between 15 and 30 feet of water. Their measured decline in 2016 is not the result of bycatch during hand-harvesting as the majority of EWM in Squash Lake grows in water shallower than 15 feet. Stoneworts require high water clarity and have been shown to decline when water clarity is reduced. Secchi disk transparency data collected by the Squash Lake Citizen Lake Monitoring Network (CLMN) volunteers indicate that no trends in water clarity, positive or negative, have occurred between 2009 and 2016.

However, water depth recorded at littoral point-intercept sampling locations indicate that water levels in Squash Lake were approximately 1.0 foot higher in 2016 when compared to 2012. The increase in water level may have reduced light availability in deeper areas inhabited by stoneworts causing a reduction in their occurrence. Additionally, fern pondweed was found to have increased in abundance in 2016 primarily between 15 and 20 feet of water, the depth zone which saw the largest decline in stoneworts. The fluctuating water levels, or some other environmental factor(s), have favored the increase of fern pondweed and a decline in stoneworts in deeper areas of Squash Lake's littoral zone. Fern pondweed was the most frequently encountered aquatic plant in Squash Lake in 2016 with a littoral occurrence of 24%, representing a statistically valid increase in occurrence of 23% when compared to 2009 (Figure 10).

Slender/small pondweed had a littoral frequency of occurrence of 11% in 2009, 15% in 2012, and declined to 7% in 2016, representing a statistically valid reduction in occurrence of 57% from 2009 to 2016 (Figure 10). In 2012, slender/small pondweed was most prevalent between 5.0 and 20.0 feet of water, and the largest decline in the occurrence of this plant in 2016 occurred between 15.0 and 20.0 feet. The decline in slender/small pondweed may be result of water fluctuations and/or competition with fern pondweed which increased in abundance within this depth zone.

Common/slender waterweed had a littoral frequency of occurrence of 15% and 14% in 2009 and 2012, respectively. In 2016, common/slender waterweed had a littoral frequency of occurrence of 9%, a statistically valid reduction of 38% when compared to 2009. In 2012, common/slender had a similar occurrence over most of the littoral zone between 5.0 and 24.0 feet of water. In 2016, common/slender waterweed was found to have declined in occurrence evenly across this same depth zone. It is not known if water level fluctuations or combination of other natural factors caused a reduction in the common/slender waterweed population in Squash Lake. Michelle Nault (personal comm. 2014) of the WDNR has reported that common waterweed populations on long-term study lakes in northern Wisconsin have exhibited large interannual fluctuations in occurrence. The WDNR's long-term data indicate common waterweed populations have the capacity to fluctuate markedly from year to year; however, the conditions which drive these fluctuations are not understood.

The littoral frequency of occurrence analysis allows for an understanding of how often each plant species 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 fern pondweed was found at 24% of the littoral sampling locations in Squash Lake in 2016, its relative frequency of occurrence was 19%. Explained another way, if 100 plants were randomly sampled from Squash in 2016, 19 would be fern pondweed. Figure 11 displays the relative occurrence of aquatic plant species from Squash from the 2009, 2012, and 2016 whole-lake point-intercept surveys.

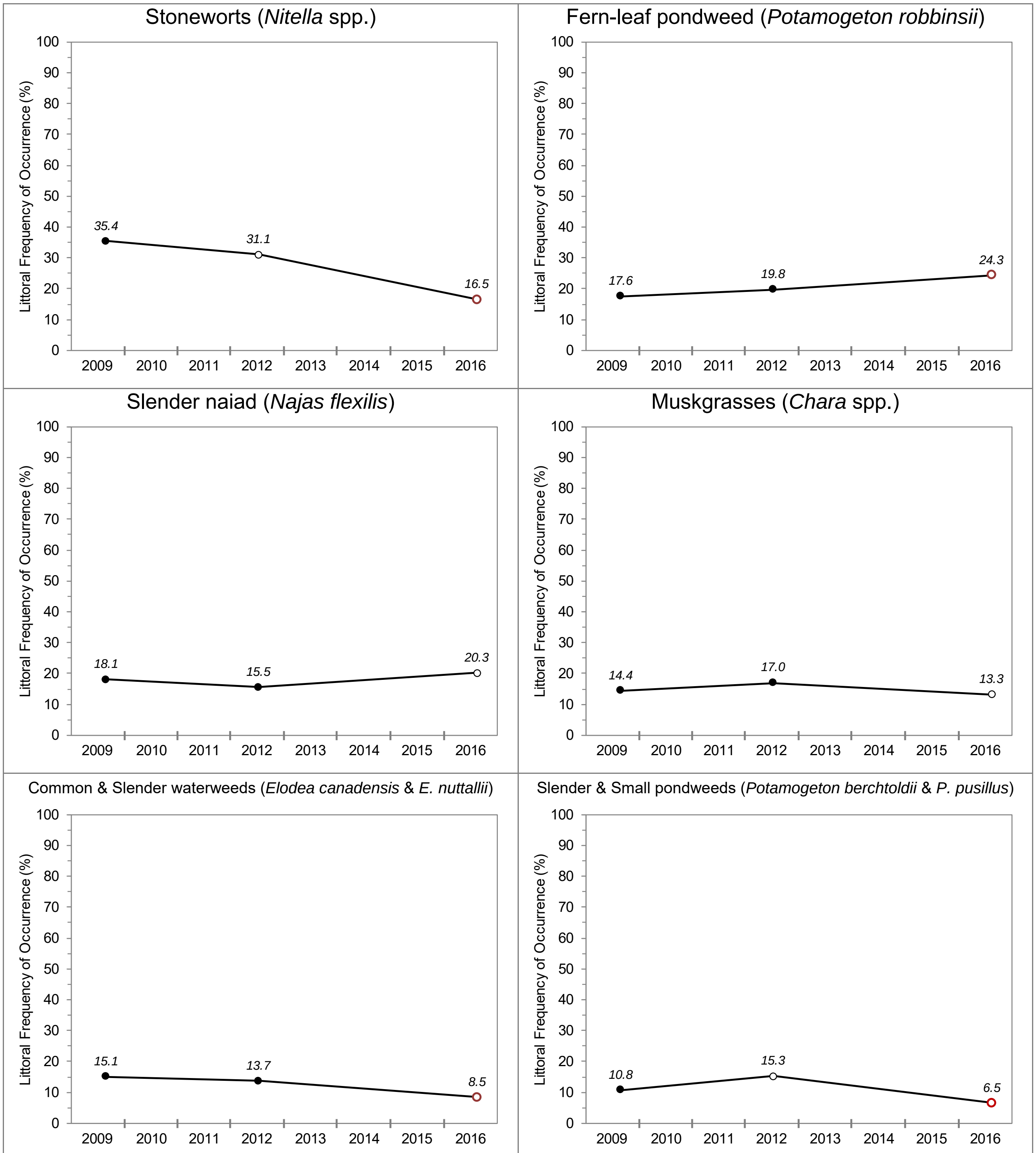


Figure 10. Littoral frequency of occurrence of select native aquatic plant species in Squash Lake from 2009-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2009 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from WDNR 2009 (N = 1,088) and Onterra 2012 (N = 1,087) and 2016 (N = 1,076) whole-lake point-intercept surveys.

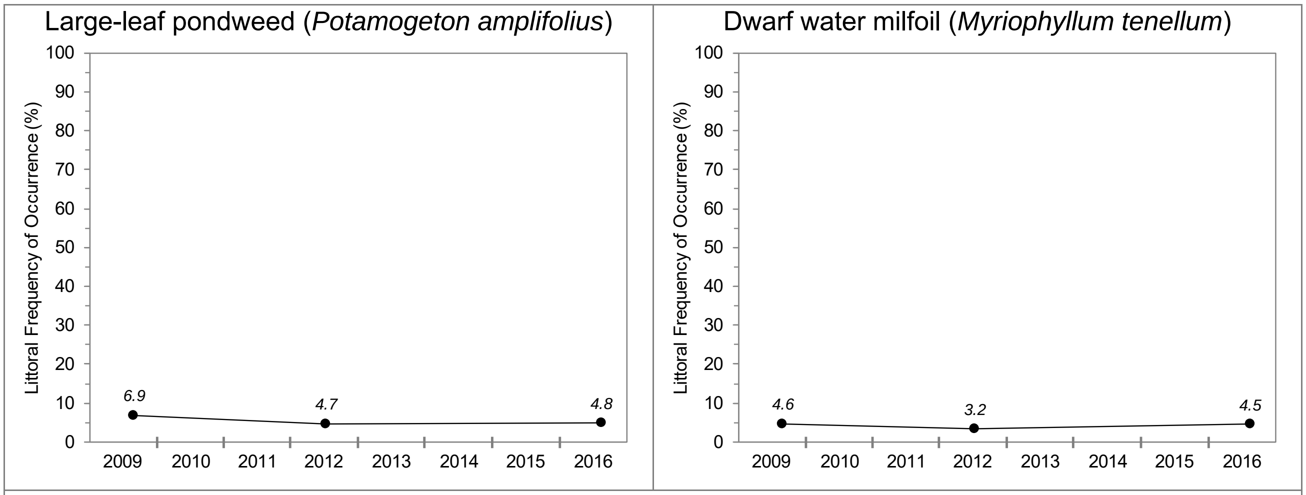


Figure 10 continued. Littoral frequency of occurrence of select native aquatic plant species in Squash Lake from 2009-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2009 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from WDNR 2009 (N = 1,088) and Onterra 2012 (N = 1,087) and 2016 (N = 1,076) whole-lake point-intercept surveys.

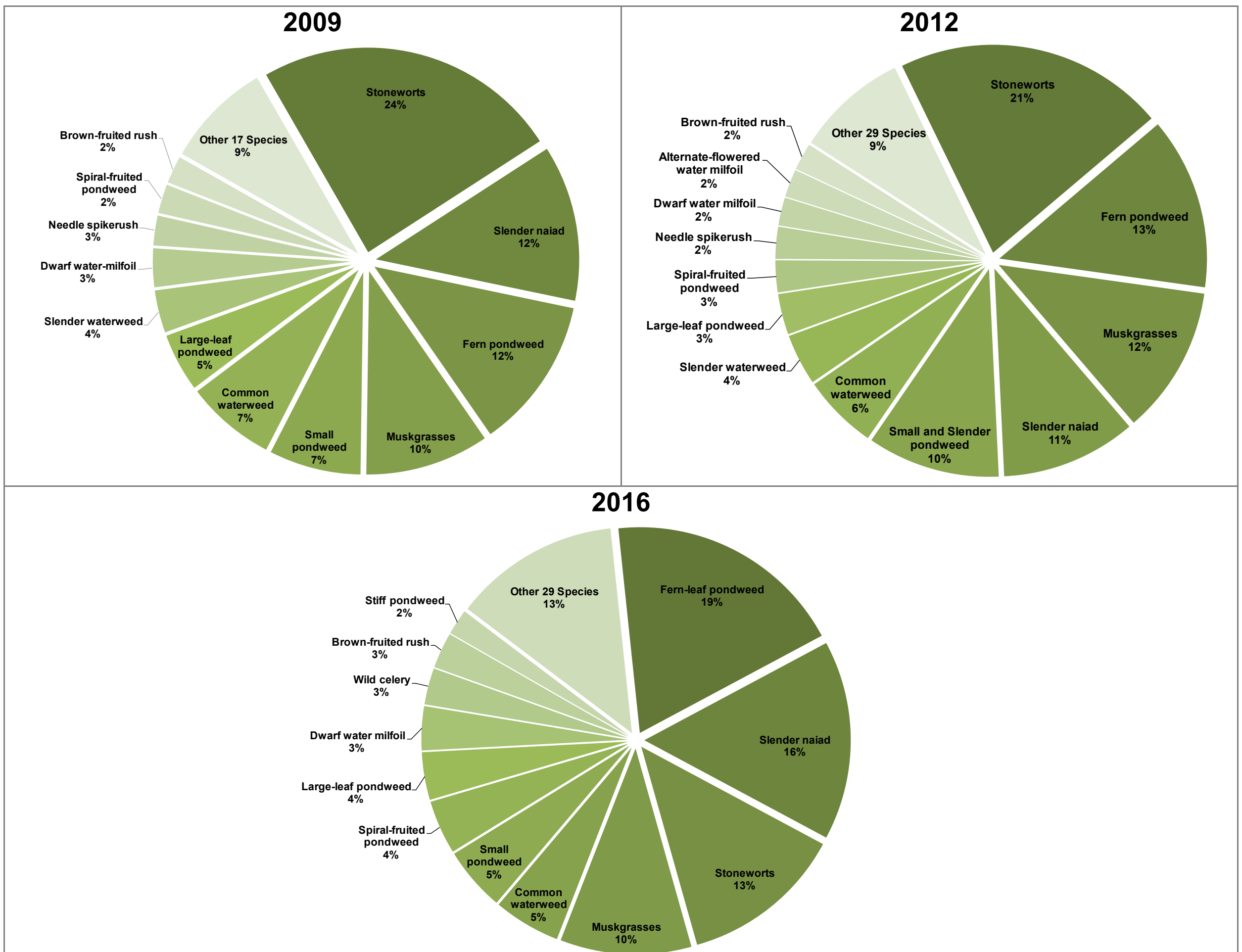


Figure 11. Relative frequency of occurrence of aquatic plant species in Squash Lake from 2009-2016. Created using data from WDNR 2009 and Onterra 2012 and 2016 point-intercept surveys.

As discussed in the primer section (pages 7-8), the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during each point-intercept survey and does not include incidentally-located species. The native species encountered on the rake during the 2009, 2012, and 2016 point-intercept surveys and their conservatism values were used to calculate the FQI of Squash Lake's aquatic plant community.

Figure 12 compares Squash Lake's FQI components to median values of lakes within the Northern Lakes and Forests – Lakes (NLFL) ecoregion and lakes throughout Wisconsin. Native aquatic plant species richness ranged from 32 in 2009 to 41 in both 2012 and 2016. The native aquatic plant species richness of Squash Lake in 2012 and 2016 falls within the 97th and 98th percentiles for lakes within the NLFL ecoregion and lakes throughout Wisconsin, respectively. Squash Lake's average conservatism has remained similar over the course of the three surveys, with values of 7.5, 7.5, and 7.6 in 2009, 2012, and 2016, respectively (Figure 12). Squash Lake's average conservatism in 2016 falls within the 93rd percentile for lakes within the NLFL ecoregion and the 88th percentile for lakes throughout the state. This indicates that Squash Lake contains a higher number of environmentally-sensitive species than the majority of lakes within the region and the state.

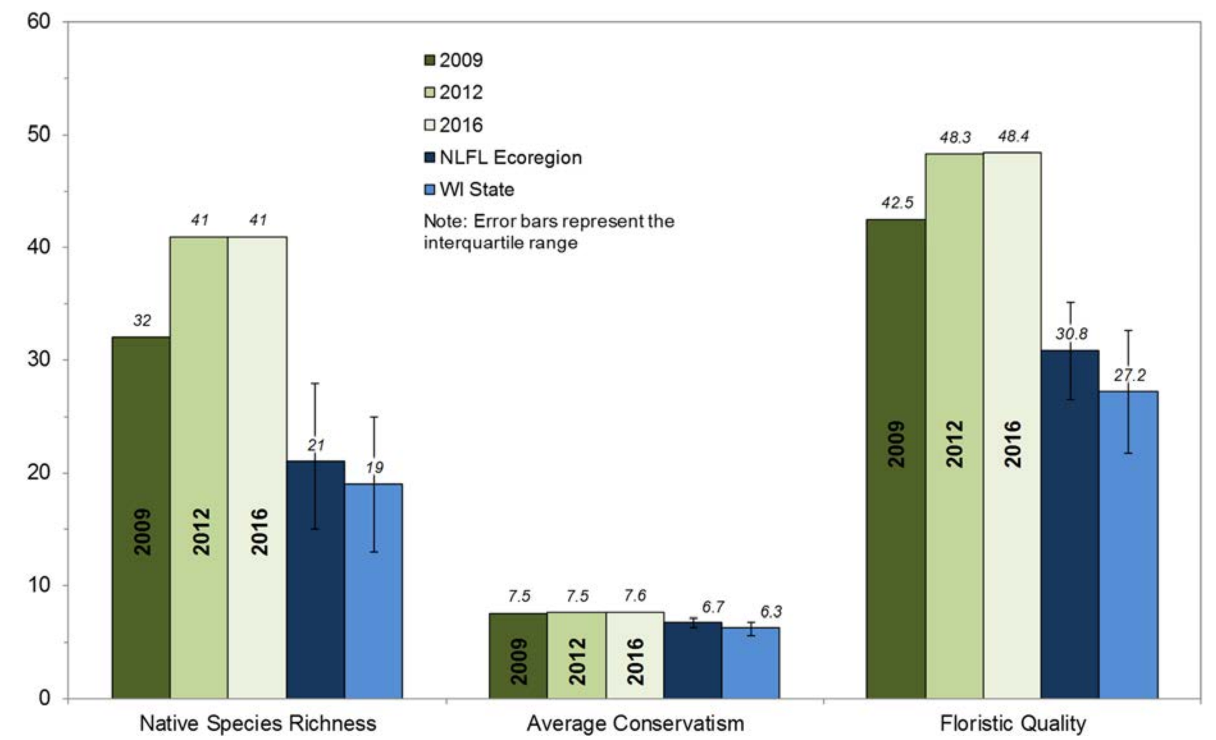


Figure 12. Squash Lake Floristic Quality Analysis. Created using data from WDNR 2009 and Onterra 2012 and 2016 whole-lake point-intercept surveys. Analysis follows Nichols (1999).

Squash Lake's floristic quality index values were calculated using native aquatic plant species richness and the average conservatism (Figure 12). Squash Lake's floristic quality increased from 42.5 in 2009 to 48.3 and 48.4 in 2012 and 2016, respectively. The lower floristic quality in 2009 was driven by the lower number of native aquatic plant species recorded during that survey. Squash Lake's floristic quality in 2016 exceeds the 99th percentile for lakes within the NLFL ecoregion and for lakes throughout Wisconsin. The floristic quality analysis indicates that Squash Lake harbors one the highest-quality aquatic plant communities in the state in terms of the number of native species present and the number of environmentally-sensitive species (high conservatism values). These data also indicate that the quality of Squash Lake's aquatic plant community has not degraded over the time period (2009-2016) for which hand-harvesting of EWM has occurred.

As explained in the primer section, lakes with diverse aquatic plant communities are believed to have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Squash Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

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 Squash Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 13). Using the data collected from the 2009, 2012, and 2016 point-intercept surveys, Squash Lake's aquatic plant community is shown to have high species diversity with values of 0.88, 0.89, and 0.90 in 2009, 2012, and 2016, respectively. Squash Lake's Simpson's Diversity value of 0.90 falls within the 80th percentile for lakes within the NLFL ecoregion. Squash Lake's aquatic plant species diversity has changed little over the time period from 2009-2016.

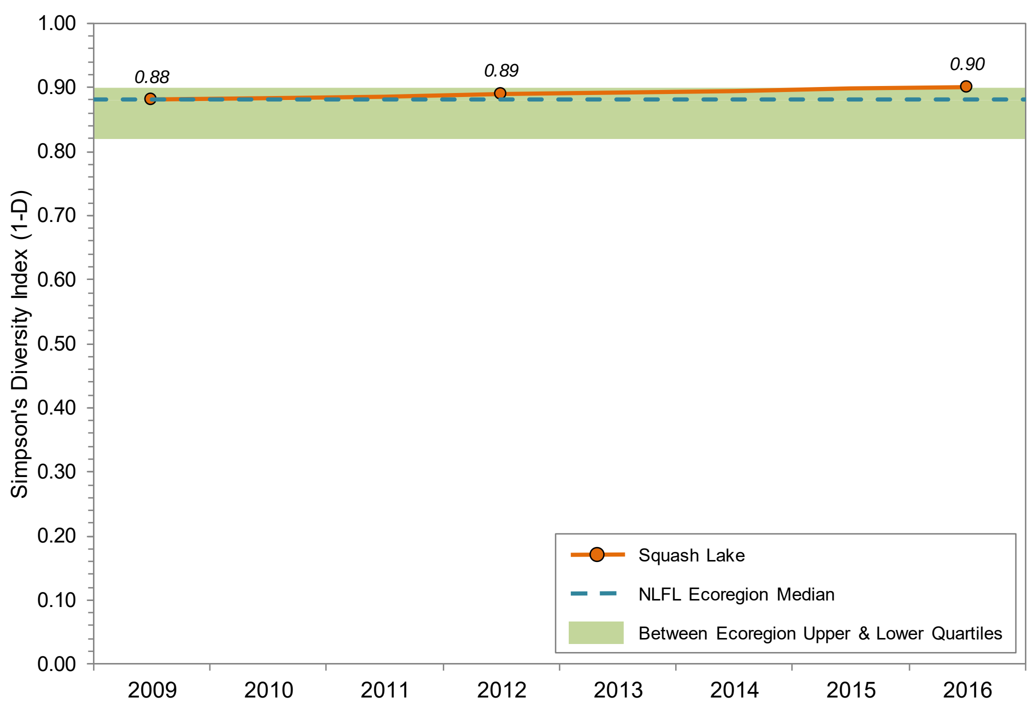


Figure 13. Squash Lake Simpson's Diversity Index. Created using data from WDNR 2009 and Onterra 2012 and 2016 whole-lake point-intercept surveys.

The aquatic plant surveys completed in 2009 and 2012 found that Squash Lake contains a small population of Vasey's pondweed, a native aquatic plant listed as special concern by the WDNR Natural Heritage Inventory due to its rarity and uncertainty regarding its population status in Wisconsin (Photo 2). Vasey's pondweed was relocated during the 2016 point-intercept survey at three sampling locations, and its occurrence remained unchanged when compared to 2012.

Photo 2. Vasey's pondweed, a native aquatic plant listed as special concern found in Squash Lake. Photo credit Onterra.

Emergent & Floating-Leaf Community Mapping Results

Onterra ecologists mapped locations of emergent and floating-leaf aquatic plant communities in Squash Lake on August 17, 2016 using the same methodologies employed in 2012 to map these communities. The data collected in 2016 shows that emergent and floating-leaf plant communities in Squash Lake have expanded by approximately 4.6 acres over this four-year period (Table 4, Map 6 and Map 7). The majority of the large emergent and floating-leaf aquatic plant communities mapped in 2012 (polygons) were found to have expanded, primarily lakeward, in 2016. In addition, a number of new colonies were also located in 2016, mainly comprised of watershield.

Water levels play a key role in determining the establishment and expansion of emergent and floating-leaf aquatic plant communities (Coops et al. 2004). Natural water fluctuations promote healthy emergent and floating-leaf aquatic plant communities. As water levels decline, these communities are able to expand and establish lakeward. Once established, these communities are often able to persist as water levels increase. Like many seepage in northern Wisconsin, Squash Lake has seen lower water levels as a result of reduced precipitation. Lowering water levels likely allowed emergent and floating-leaf aquatic plant communities to expand lakeward. Water levels have only recently begun to increase in Squash Lake and other area lakes in the past couple years, and these plant communities will likely persist for some time.

Table 4. Acres of emergent and floating-leaf aquatic plant communities in Squash Lake from 2012 and 2016. Created using data from Onterra 2012 and 2016 community mapping survey.

	Acres	
Plant Community	**2012**	**2016**
Emergent	0.8	6.4
Floating-leaf	0.9	6.6
Mixed Emergent & Floating-leaf	11.8	5.1
Total	**13.5**	**18.1**

Continuing the analogy that the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Squash Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines. Fortunately, the two surveys aimed at mapping these communities on Squash Lake have revealed an expansion from 2012 to 2016. The SLA should continue to educate Squash Lake riparians on the benefits these communities provide to the lake and that they should be protected.

SUMMARY AND CONCLUSIONS

The objective of this project was not to eradicate EWM from Squash Lake as that is highly improbable with current control techniques. The primary objective of this project was to maintain an EWM population that exerts little to no detectable impacts on the lake's native aquatic plant community and ecosystem services by employing non-chemical methods. Qualitative mapping of EWM during each year of this project and the lake-wide quantitative assessment of the EWM population in 2016 indicate that the hand-harvesting methods employed in Squash Lake were met with success. From 2014-2016, a total of nearly six tons of EWM were removed from Squash Lake. A total of 2,442 hours were spent harvesting by SLA divers who removed approximately 11,400 pounds of EWM, while a total of 34 hours were spent by DASH divers who removed approximately 540 pounds of EWM.

The littoral frequency of occurrence of EWM in 2016 was 0.0%, and comparison of the 2016 data with data collected in 2009 and 2012 indicate that the level of hand-harvesting was sufficient to maintain a small lake-wide population of EWM and prevent the population from expanding. Annual mapping in Squash Lake has shown that the EWM has the capacity to form dense, monotypic colonies over short periods of time, and the SLA divers have proven to be effective at removing these colonies soon after their discovery. As of 2016, the EWM population in Squash Lake is largely comprised of single-plant occurrences and no colonized areas with a dominant density rating or higher were present.

The 2016 quantitative assessment of Squash Lake's native aquatic plant community shows that the lake continues to harbor one of the highest-quality plant communities in the state in terms of species richness, diversity, and the number of sensitive species present. While the occurrences of stoneworts, common/slender waterweed, and small/slender pondweed were lower when compared to 2009 and 2012, these declines are believed to due to natural factors most likely related to fluctuating water levels over this time period. Fern pondweed, the most frequently encountered aquatic plant in 2016, saw an increase in its occurrence when compared to 2009 and 2012. Mapping of emergent and floating-leaf aquatic plants revealed that these communities expanded by almost five acres from 2012 to 2016, likely a result of the recent low-water level period.

As is discussed in detail in the next section, the SLA has elected to build on their success at managing Squash Lake's EWM population by continuing hand-harvesting of EWM in 2017. In December 2016, the SLA has applied for a WDNR AIS-Education, Planning and Prevention (EPP) Grant to aid in funding professional monitoring of EWM and control strategy development for 2017-2019. Because AIS-EPP Grants cover the costs of monitoring but not of the control strategy, the SLA will also be applying for a WDNR AIS-Established Population Control (EPC) Grant in February 2017 to aid in funding the annual costs of hand-removal from 2017-2019.

REVISED AQUATIC PLANT MANAGEMENT STRATEGY

The aquatic plant management goal presented in this section represents a revision Management Goal 1 from the Squash Lake Comprehensive Management Plan finalized in 2014 and was created through the collaborative efforts of the SLA and Onterra ecologists. It represents the path the SLA will follow for managing EWM in Squash Lake from 2017-2019 to maintain the integrity of the lake's native aquatic plant community and the ecosystem services the lake provides. This revised goal is a living document in that it will be under constant review and adjustment depending on the status of EWM within the lake, the availability of funds, level of volunteer involvement, and the needs of the Squash Lake stakeholders.

Revised Management Goal 1: Control Existing and Prevent Further Introductions of Aquatic Invasive Species to Squash Lake

Management Action:	Continue scuba diver hand-harvesting strategy to control Eurasian water milfoil population in Squash Lake.
Funding Source(s):	WDNR AIS-Education, Planning and Prevention Grant and WDNR AIS-Established Population Control Grant
Timeframe:	Continuation of current effort
Facilitator:	SLA Board of Directors (suggested)
Description:	As is discussed in the results section of this report, the combination of manual harvesting (SLA scuba divers) and mechanical harvesting (DASH) of EWM in Squash Lake has been highly successful in maintaining a small population within the lake which has little impact on the lake's ecology and the ecosystem services it provides. Squash Lake stakeholders are not in favor of the use of herbicides as a method for EWM control at that time as indicated by the 2012 anonymous stakeholder survey distributed as part of the lake management plan development, and the SLA would like to move forward with non-chemical methods for EWM control. Additionally, herbicide control would not be an applicable strategy given that the EWM population at present is primarily comprised of single plant occurrences. The 2016 whole-lake point-intercept survey indicates that the EWM population remains very small (littoral occurrence of 0.0%) and has remained unchanged when compared to surveys in 2009 and 2012. The SLA's aggressive hand-removal program has removed nearly six tons of EWM from the lake since 2014, and has prevented this invasive plant's population from expanding. No hand-harvesting program in Wisconsin has seen the level of organization and effort like that of the SLA and they continue to be a model for hand-harvesting programs in the state. The SLA understands that in order to be eligible for AIS-EPC funds, their program requires the creation of defined success criteria to assess the efficacy of hand-removal. The hand-removal methodology also needs to be optimized to ensure that the desired level of EWM control is reached while expending a reasonable amount of time and effort.

	Like the 2014-2016 project, the objective of this management action is not to eradicate EWM from Squash Lake as that is highly improbable with current control methods. The objective is to maintain an EWM population that exerts little to no detectable impacts on the lake's native aquatic plant community and overall ecology, recreation, and aesthetics (EWM littoral frequency of occurrence < 3.0%). Monitoring is a key aspect of any AIS control project, both to prioritize areas for control and to monitor the strategy's effectiveness. The monitoring also facilitates the "tuning" or refinement of the control strategy as the control project progresses. The ability to tune the control strategies is important because it allow for the best results to be achieved within the plan's lifespan. The same series of monitoring steps that were used in the 2014-2016 project will be completed in the 2017-2019 project. This series includes: 1. Onterra ecologists complete an Early-Season AIS (ESAIS) Survey (pre-hand-harvesting) in June of each year to map EWM lake-wide and to guide hand-harvesting strategies during the summer. Large, colonized areas of EWM would again be targeted using the diver-assisted suction harvest (DASH) system (see next management action). By targeting the largest and densest areas of EWM with the DASH system, the SLA scuba divers will be able to focus their efforts on areas of EWM that are less dense and more suitable for manual removal. Following the ESAIS Survey, Onterra will provide the SLA with a map displaying locations proposed for DASH for use in the mechanical harvesting permit application. Onterra will also load the EWM and hand-harvesting site locations on the SLA's GPS for their use during the summer. The SLA scuba diver hand-removal sites would be prioritized based upon the level of EWM within each area. Sites containing *small plant colonies* would be classified as areas requiring the greatest need for hand-removal, or primary focus sites, while areas containing *clumps of plants* and only *single or few plants* would be classified as secondary and tertiary focus sites, respectively. The SLA scuba divers will need to record the name of the hand-harvesting site location (e.g. A-16), the time (hours) each diver spends underwater harvesting at that site, and the amount of EWM (pounds) removed from that site. The SLA scuba divers will also need to record a GPS location and information previously mentioned at sites which hand-harvesting occurs outside of the pre-determined harvesting sites. 2. Hand-harvesting of EWM occurs June through September.

	3. Onterra ecologists complete the Late-Summer EWM Peak-Biomass Survey (post-hand-harvesting) in early to mid-September when EWM is at or near its peak growth. The EWM would be remapped throughout the lake and the hand-harvesting sites would be assessed to determine hand-harvesting efficacy. Typically, AIS control programs (mainly with herbicides) incorporate both established qualitative (EWM mapping) and quantitative (sub-sample point-intercept survey) evaluation methodologies. However, quantitative monitoring of hand-removal areas using sub-sample point-intercept methodology will likely not applicable as there are no areas of EWM large enough to attain the number of sampling locations required to meet the assumptions of statistical analyses. Therefore, each hand-removal site would be monitored using qualitative methods. Qualitative assessments would be completed by comparing pre-hand-harvesting EWM results from the June ESAIS survey to post-hand-harvesting results obtained during the September Peak-Biomass survey. The SLA hand-removal sites will be deemed successful if they meet the following criteria: 1) if the site contains EWM mapped at a point-based mapping level (e.g. single or few plants) prior to hand-harvesting and the level of EWM is maintained at the point-based mapping level following hand-harvesting, or 2) if the site contains colonized EWM (mapped using polygons) prior to hand-harvesting and the site is reduced by one density rating following hand-harvesting (e.g. dominant to scattered). Sites containing larger areas of colonized EWM that are targeted with the DASH system would be deemed successful if they are reduced by one density rating (e.g. dominant to scattered) following harvesting. 4. Reports generated on hand-removal success and recommendations for following year's strategy. In the final year of the project (2019), a whole-lake point-intercept survey would be conducted to quantitatively assess the EWM and native aquatic plant populations at the lake-wide level. The data from this survey would be statistically compared to the surveys completed in 2009, 2012, and 2016.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR AIS-EPP Grant in December 2016 to aid in funding of EWM monitoring and control strategy development from 2017-2019.

3.	Apply for a WDNR AIS-EPC Grant in February 2017 to aid in funding of hand-harvesting activities from 2017-2019.
4.	Initiate control plan.
5.	Modify control plan methodology annually, as needed.
6.	Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Action:	SLA to contract with Many Waters, LLC, or a similar firm, to conduct diver-assisted suction harvesting (DASH) of colonized areas of EWM in Squash Lake.
Timeframe:	Continuation of current effort.
Facilitator:	SLA Board of Directors (suggested)
Description:	The 2014-2016 EWM control project showed that using a combination of manual and mechanical removal of EWM was highly effective. The data collected from 2014-2016 shows that the DASH system is able to remove on average three times more EWM (pounds) per hour when compared to manual hand-removal. Employing the DASH system over larger areas of EWM proved to be effective at reducing the density of EWM within these large areas while allowing the SLA scuba divers to focus their efforts and smaller areas of EWM around the lake. The SLA will continue to integrate the professionally-operated DASH system in 2017-2019 as appropriate. Following the June ESAIS survey, Onterra ecologists will provide the SLA with a map displaying proposed DASH locations for their use in applying for a mechanical harvesting permit.
Action Steps:	
1.	Contact Many Waters, LLC (715.617.4688/barb@manywatersconsulting.com) to determine availability for harvesting each year.
2.	Obtain mechanical harvesting permit following ESAIS survey if DASH locations are proposed.

Management Action:	Continue assessment of shoreline and littoral areas of the lake for aquatic invasive species (AIS) via Volunteer AIS Monitors.
Timeframe:	Continuation of current effort.
Facilitator:	Marjory Mehring (suggested)
Description:	Early detection of new aquatic invasive species infestations commonly leads to successful control, and in cases of small infestations, possibly even eradication. Currently, SLA volunteers perform a considerable amount of aquatic invasive species (AIS) monitoring in which the volunteers monitor the entire areas of the system in which plants can grow (littoral zone) annually in search of invasive species that aren't currently in the lake like curly-leaf pondweed. This program uses an

	approach where volunteers are responsible for surveying specified areas of the system and report their findings. In order for accurate data to be collected during these surveys, volunteers must be able to identify non-native species like curly-leaf pondweed. Distinguishing these plants from native look-a-likes is very important. Additionally, the collection of suspected invasive plant would need to be collected for verification, and, if possible, GPS coordinates should be collected. Each year, the SLA holds volunteer training sessions led by Oneida County and/or a previously-trained SLA member (Marjory Mehring) on AIS identification and monitoring.
Action Steps:	
1.	Volunteers from SLA update their skills by attending a training session conducted by the AIS Coordinator for Oneida County (Stephanie Boismenue – 715.369.7835) and SLA member Marjory Mehring.
2.	Trained volunteers recruit and train additional association members.
3.	Complete surveys following protocols.

Management Action:	Initiate aquatic invasive species rapid response plan upon discovery of new infestation.
Timeframe:	Initiate upon exotic infestation
Facilitator:	Planning Committee with professional help as needed
Description:	In the event that another aquatic invasive species, such as curly-leaf pondweed, is located by the trained volunteers, the areas would be marked using GPS and would serve as focus areas for professional ecologists. Those focus areas would be surveyed by professionals during that plant specie's peak growth phase (early summer for curly-leaf pondweed) and the results would be used to develop potential control strategies. Small isolated infestations of curly-leaf pondweed can most appropriately be controlled using manual removal methods, likely through scuba or snorkeling efforts. In order for this technique to be successful, the entire plant (including the root) needs to be removed from the lake. During manual extraction, careful attention would need to be paid to all plant fragments that may detach during the control effort.
Action Steps:	
1.	See description above.

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at Squash Lake public access location.
Timeframe:	Continuation of current effort

Facilitator:	SLA Board of Directors (suggested)
Description:	Currently the SLA monitors the public boat landing using training provided by the Clean Boats Clean Waters program. Squash Lake is an extremely popular destination for recreationalists and anglers given its proximity to Rhinelander, making it vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasives from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasives that originated in Squash 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.
Action Steps:	
1.	See description above as this is an established program.

LITERATURE CITED

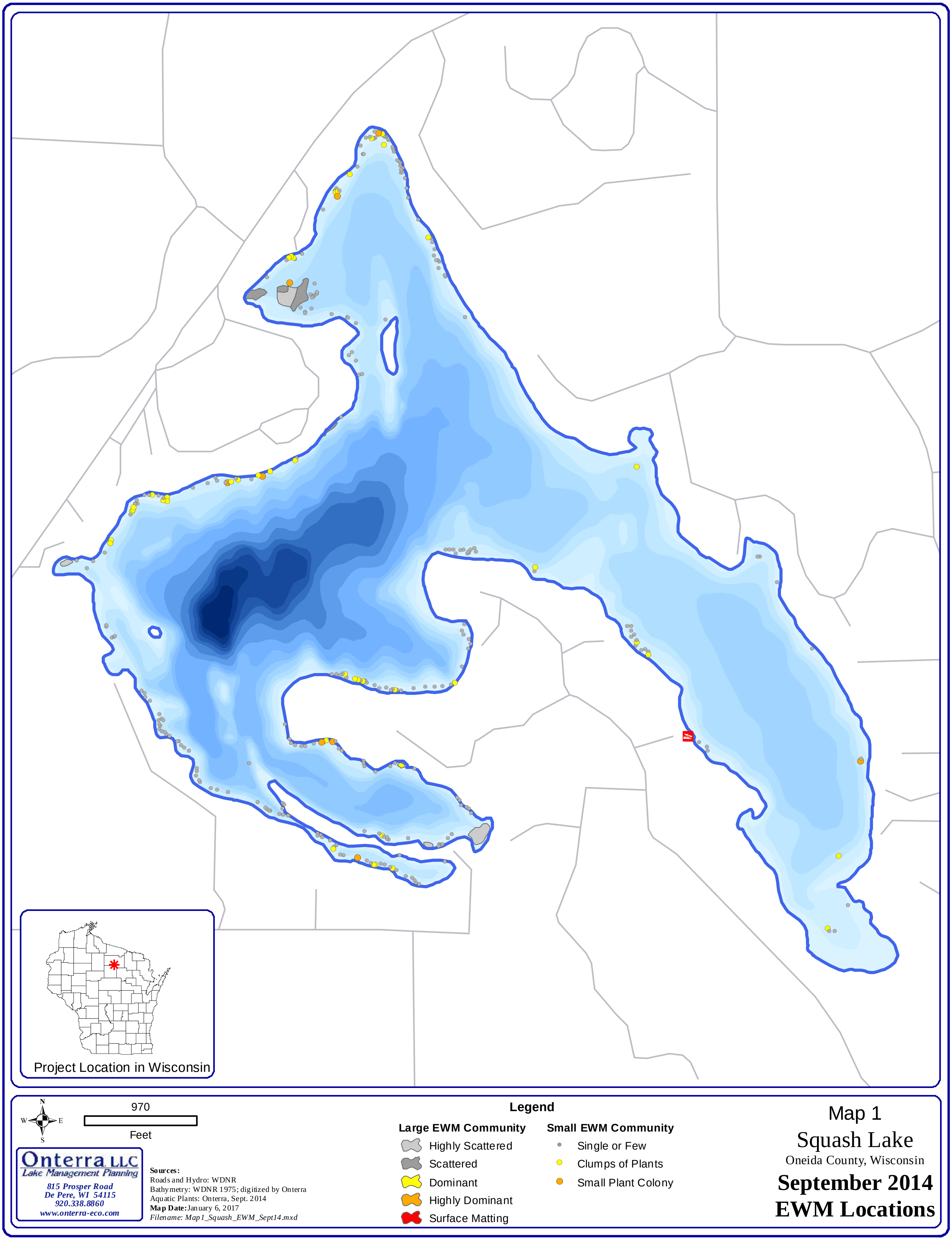
Butterfield, B., T. Hoyman, D. Cibulka, and E. Heath. 2014. Squash Lake Comprehensive Management Plan. AEPP-324-12.

Coops, H., J.T. Vulink, and E.H. van Nes. 2004. Managed water levels and the expansion of emergent vegetation along a lakeshore. Limnologica. Vol. 34 (1-2) pp. 57 – 64.

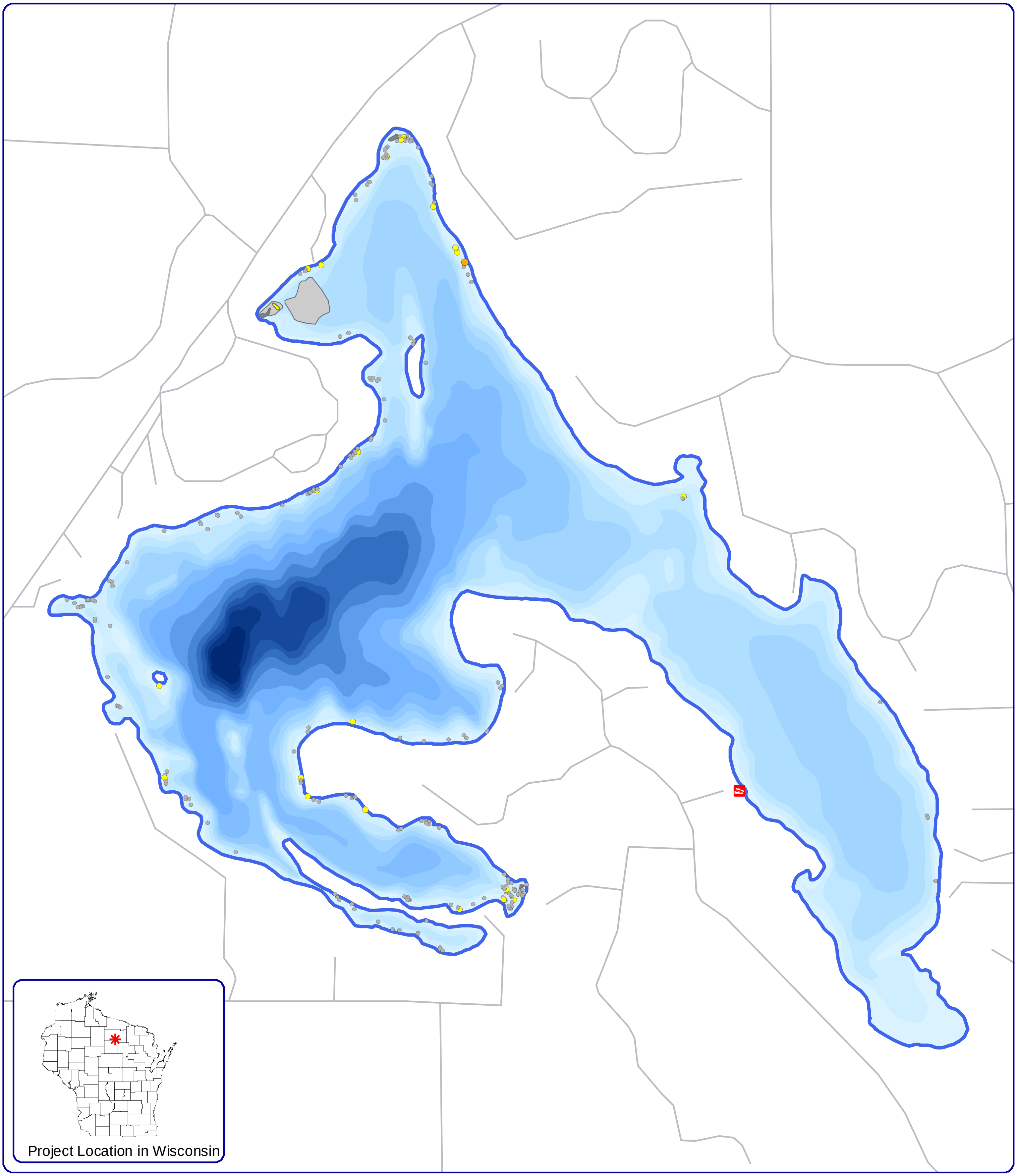
Hauxwell, J., S. Knight, K.I. Wagner, A. Mikulyuk, M.E. Nault, M. Porzky and S. Chase. 2010. Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data entry and Analysis, and Applications. WDNR, Madison, WI. PUB-SS-1068 2010.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2): 133-141

Radomski P. and T.J. Goeman. 2001. Consequences of Human Lakeshore Development on Emergent and Floating-leaf Vegetation Abundance. North American Journal of Fisheries Management. 21:46–61.



Project Location in Wisconsin
N
S
E
W
970
Feet
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1975; digitized by Onterra
Aquatic Plants: Onterra, Sept. 2014
Map Date: January 6, 2017
Filename: Map1_Squash_EWM_Sept14.mxd
Legend
Large EWM Community
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Small EWM Community
Single or Few
Clumps of Plants
Small Plant Colony
Map 1
Squash Lake
Oneida County, Wisconsin
September 2014
EWM Locations



N
W
E
S
970
Feet

Legend

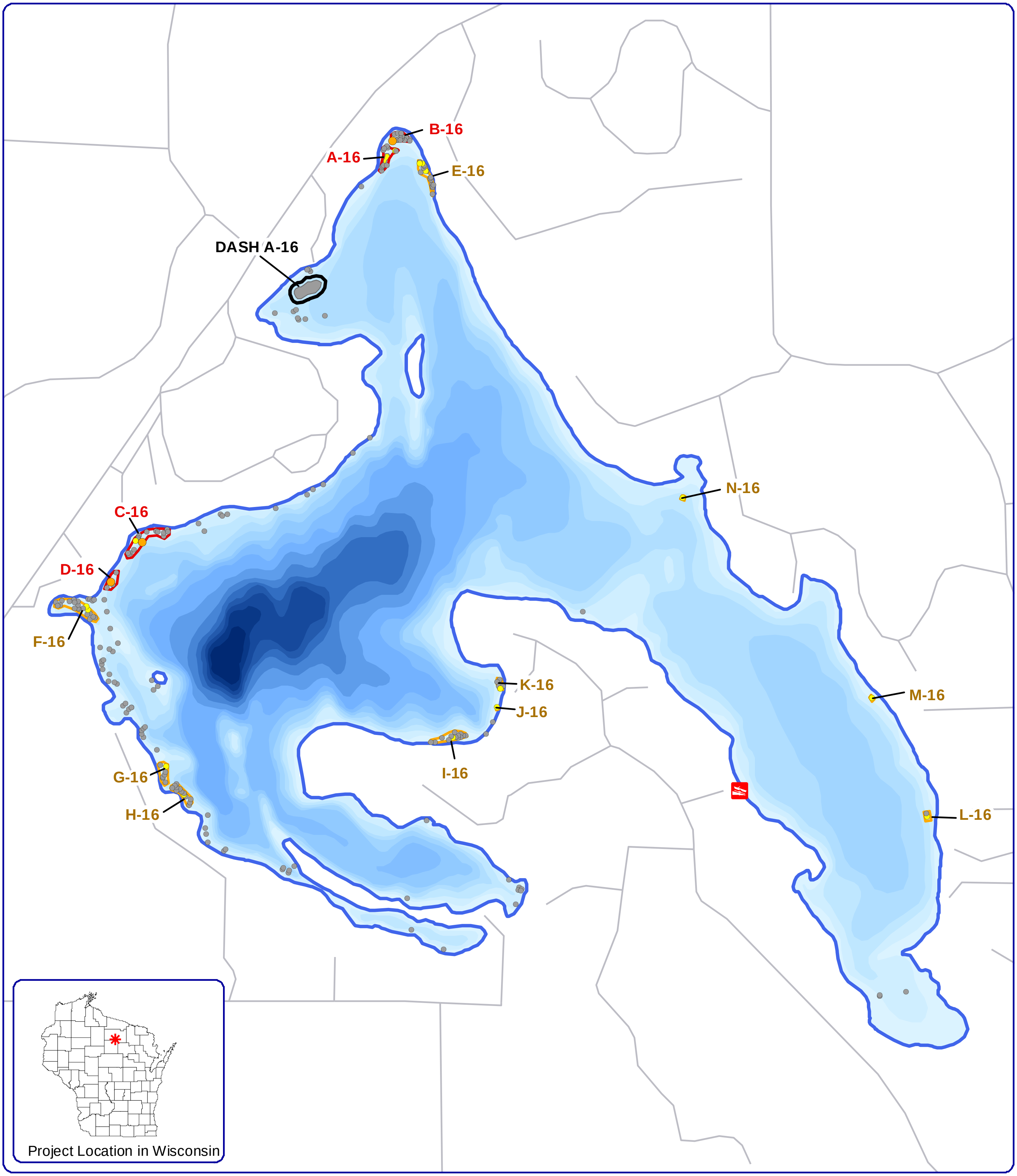
Large EWM Community
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting

Small EWM Community
Single or Few
Clumps of Plants
Small Plant Colony

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1975; digitized by Onterra
Aquatic Plants: Onterra, Sept. 2015
Map Date: January 6, 2017
Filename: Map2_Squash_EWM_Sept15.mxd

Map 2
Squash Lake
Oneida County, Wisconsin
September 2015
EWM Locations



N
W E
S
970
Feet

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

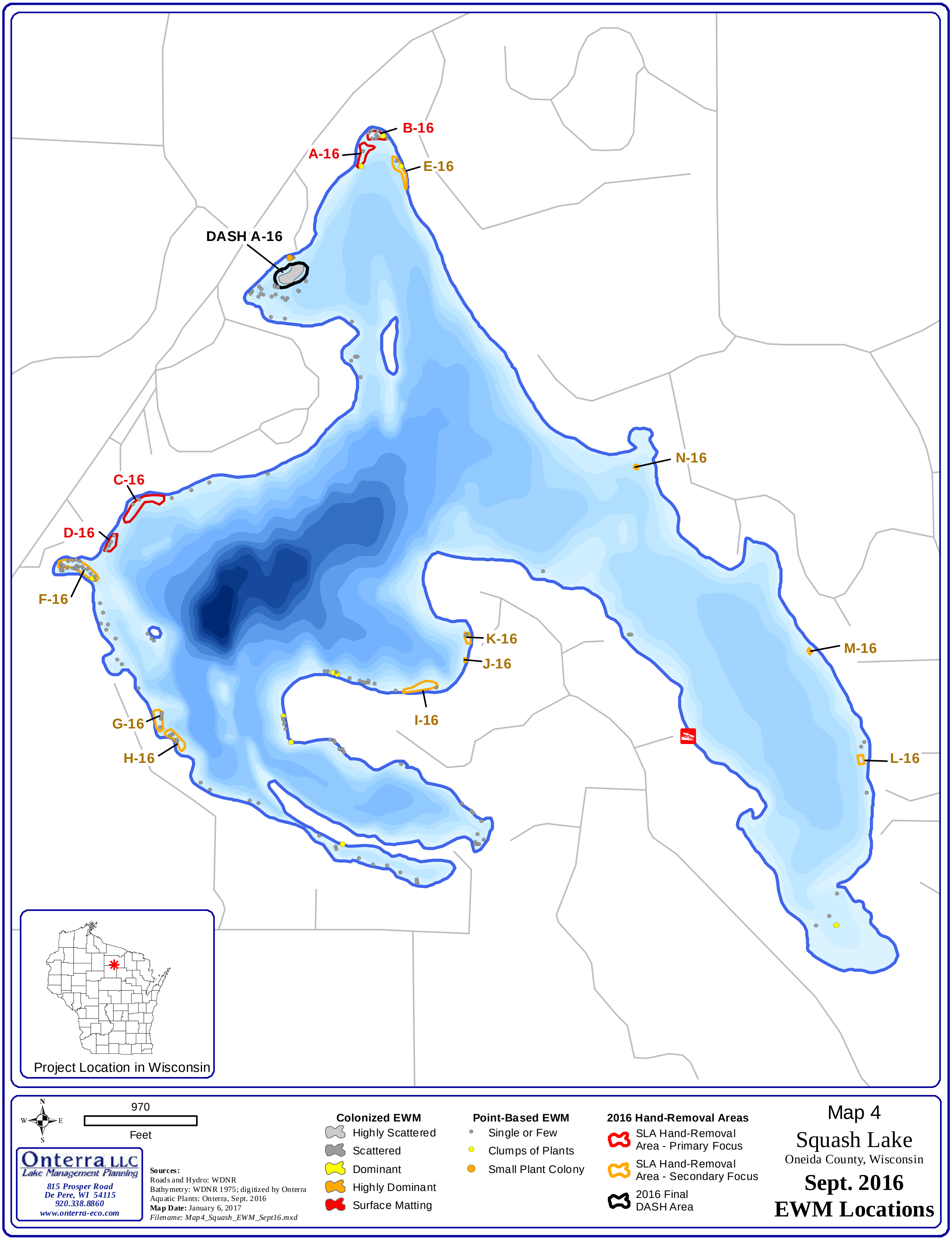
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1975; digitized by Onterra
Aquatic Plants: Onterra, June 2016
Map Date: January 6, 2017
Filename: Map3_Squash_EWM_June16.mxd

Colonized EWM
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting

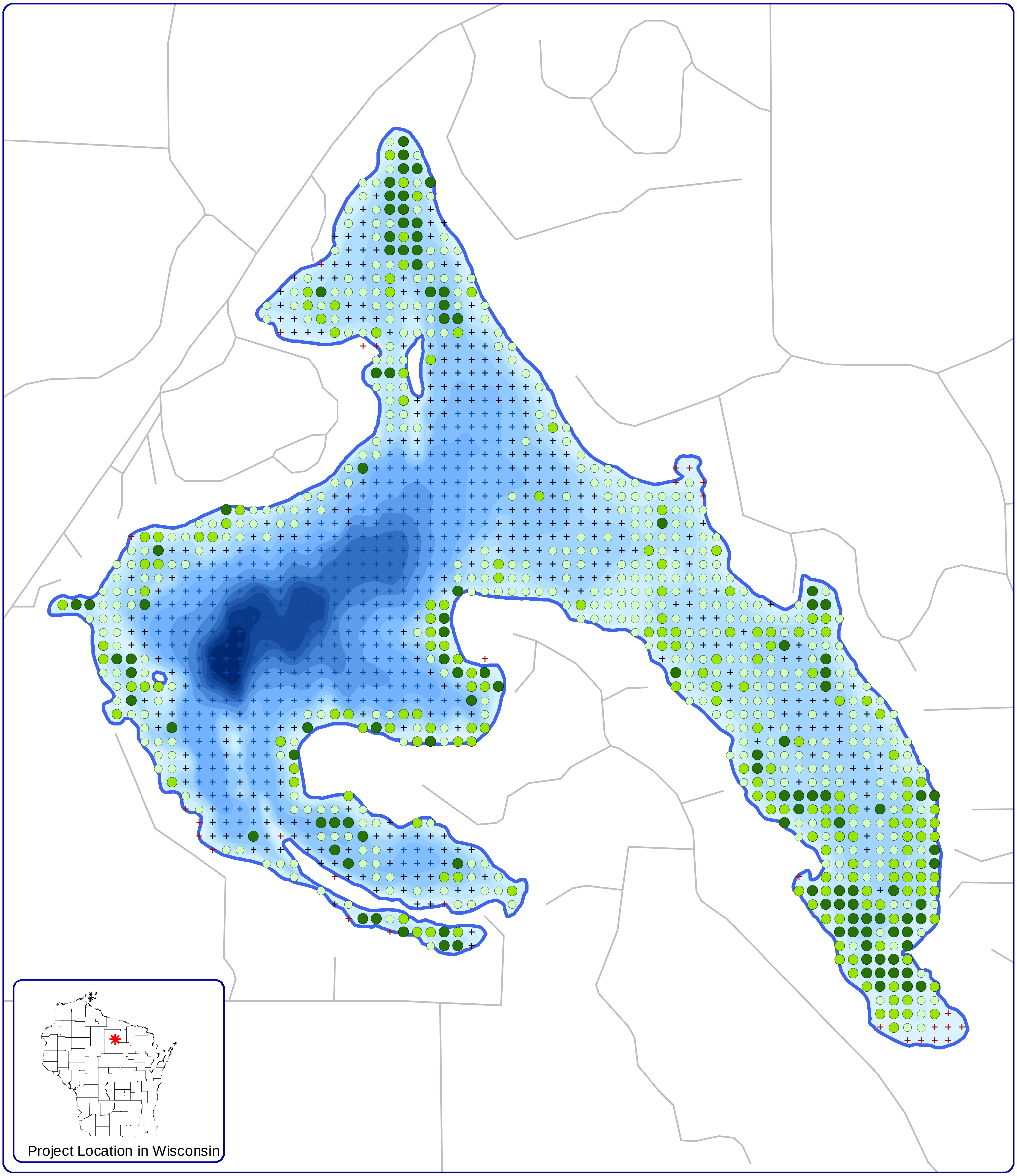
Point-Based EWM
- Single or Few
- Clumps of Plants
- Small Plant Colony

2016 Hand-Removal Areas
- SLA Hand-Removal Area - Primary Focus
- SLA Hand-Removal Area - Secondary Focus
- 2016 Final DASH Area

Map 3
Squash Lake
Oneida County, Wisconsin
June 2016
EWM Locations



B-16
A-16
E-16
DASH A-16
N-16
C-16
D-16
F-16
K-16
J-16
M-16
I-16
G-16
H-16
L-16
Project Location in Wisconsin
N
W
E
S
970
Feet
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1975; digitized by Onterra
Aquatic Plants: Onterra, Sept. 2016
Map Date: January 6, 2017
Filename: Map4_Squash_EWM_Sept16.mxd
Colonized EWM
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Point-Based EWM
Single or Few
Clumps of Plants
Small Plant Colony
2016 Hand-Removal Areas
SLA Hand-Removal Area - Primary Focus
SLA Hand-Removal Area - Secondary Focus
2016 Final DASH Area
Map 4
Squash Lake
Oneida County, Wisconsin
Sept. 2016
EWM Locations



N
W E
S

970

Feet

Legend

- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- + No Vegetation
- + Deeper than Max Depth of Plants
- + Non-Navigable/Obstacle

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

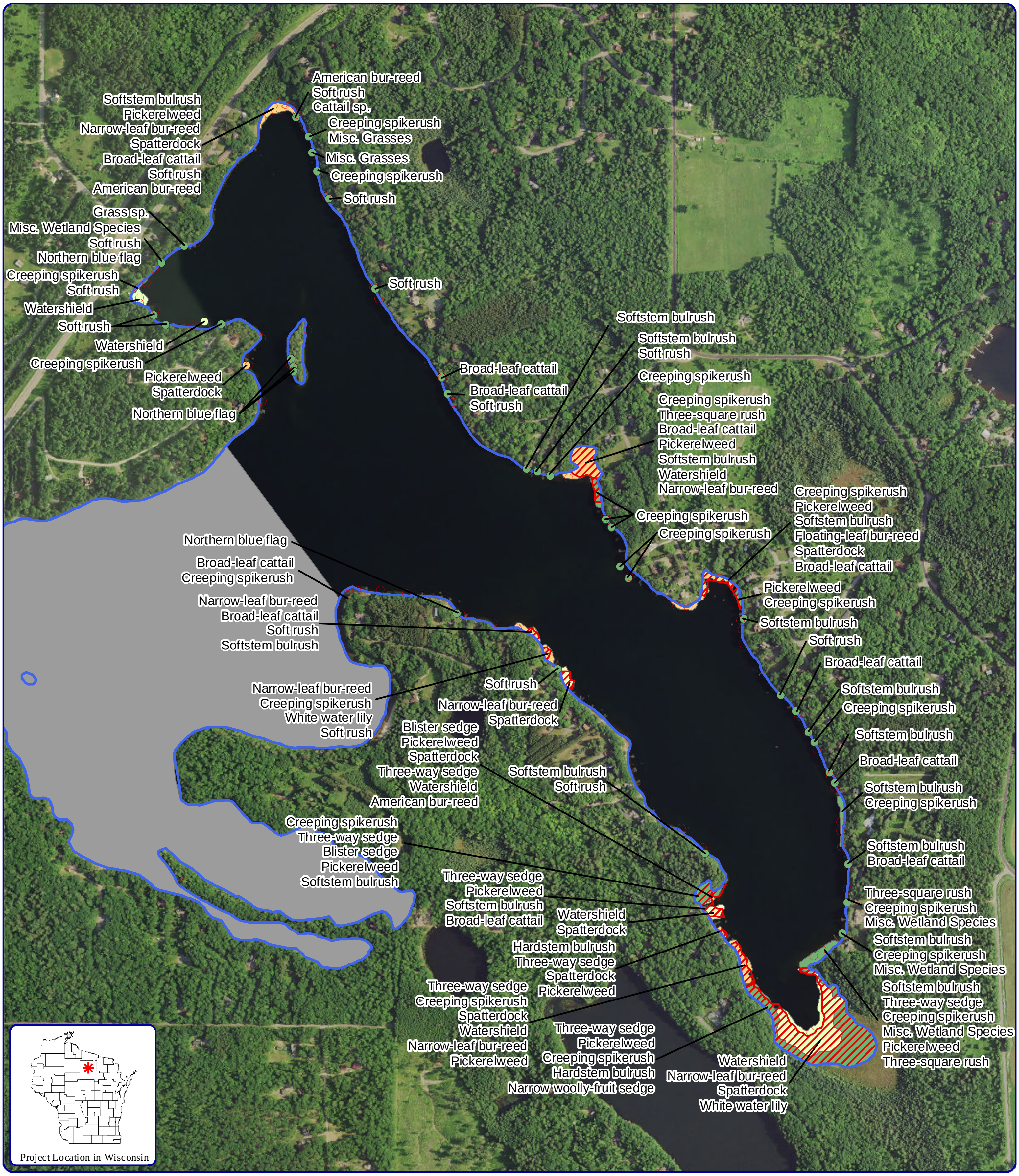
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1975; digitized by Onterra
Aquatic Plants: Onterra, August 2016
Map Date: January 6, 2017
Filename: Map5_Squash_TRFPI_2016.mxd

Map 5

Squash Lake

Oneida County, Wisconsin

2016 PI Survey:
Vegetation Distribution



950
Feet

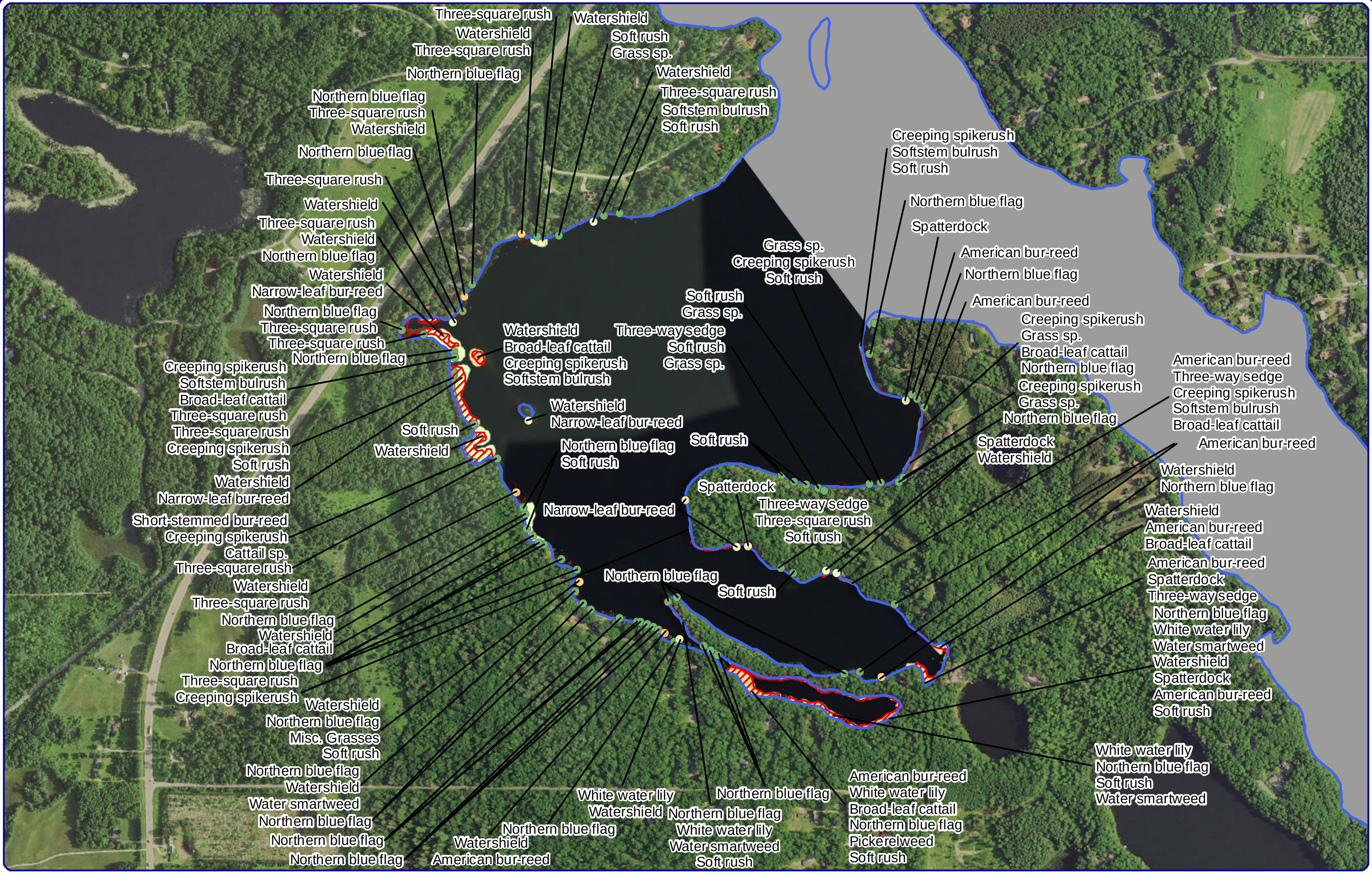
Legend

Small Plant Communities	Large Plant Communities
Emergent	Emergent
Floating-leaf	Floating-leaf
Mixed Floating-leaf & Emergent	Mixed Floating-leaf & Emergent
2012 Emergent and/or Floating-leaf	2012 Emergent and/or Floating-leaf

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

Sources:
Aquatic Plants: Onterra, 2016
Orthophotography: NAIP, 2013
Map date: October 27, 2016
Filename: Map6_Squash_Comm16_East.mxd

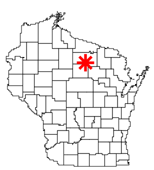
Map 6
Squash Lake - East
Oneida County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities



N
W E
S
890
Feet

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

Sources:
Aquatic Plants: Onterra, 2016
Orthophotography: NAIP, 2013
Map Date: October 28, 2016
Filename: Map7_Squash_Comm16_west.mxd



Project location in Wisconsin

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- 2012 Emergent and/or Floating-leaf

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- 2012 Emergent and/or Floating-leaf

Map 7

Squash Lake - West

Oneida County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

A

APPENDIX A

Summary of Diver Assisted Suction Harvesting Efforts
Many Waters, LLC 2016

2527 Lake Ottawa Road

Iron River, MI 49935

906.284.2198

Summary of Diver Assisted Suction Harvesting Efforts

Squash Lake – Oneida County, WI

2016 WDNR Mechanical Harvesting Permit Annual Report

Permit ID NO-2016-49-50M

Date: 7.28.2016

Submitted To:

Squash Lake Association, Inc.
and
Wisconsin Department of Natural Resources

Submitted By:

Many Waters, LLC
2527 Lake Ottawa Road
Iron River, MI 49935

Contact:
Bill Artwich: billartwich@gmail.com, 906.367.3206
Barb Gajewski: skih2o@hotmail.com, 715.617.4688

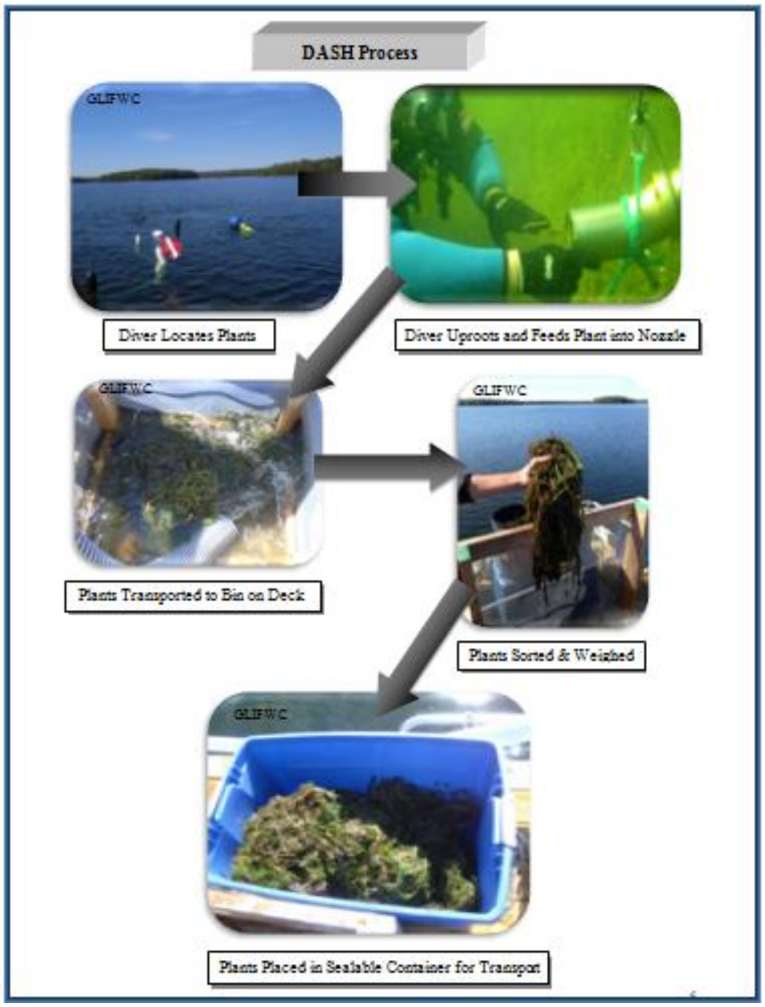
Introduction

The Squash Lake Association solicited the services of Many Waters, LLC to use Diver Assisted Suction Harvesting (DASH) to manage for Eurasian watermilfoil (EWM) on Squash Lake located in Oneida County, WI. DASH is a mechanical process and requires a mechanical harvesting permit (Form 3200-113 (R 3/04)) from the Wisconsin Department of Natural Resources (WDNR). The 2016 WDNR Permit ID is NO-2016-49-50M.

Dive Methods

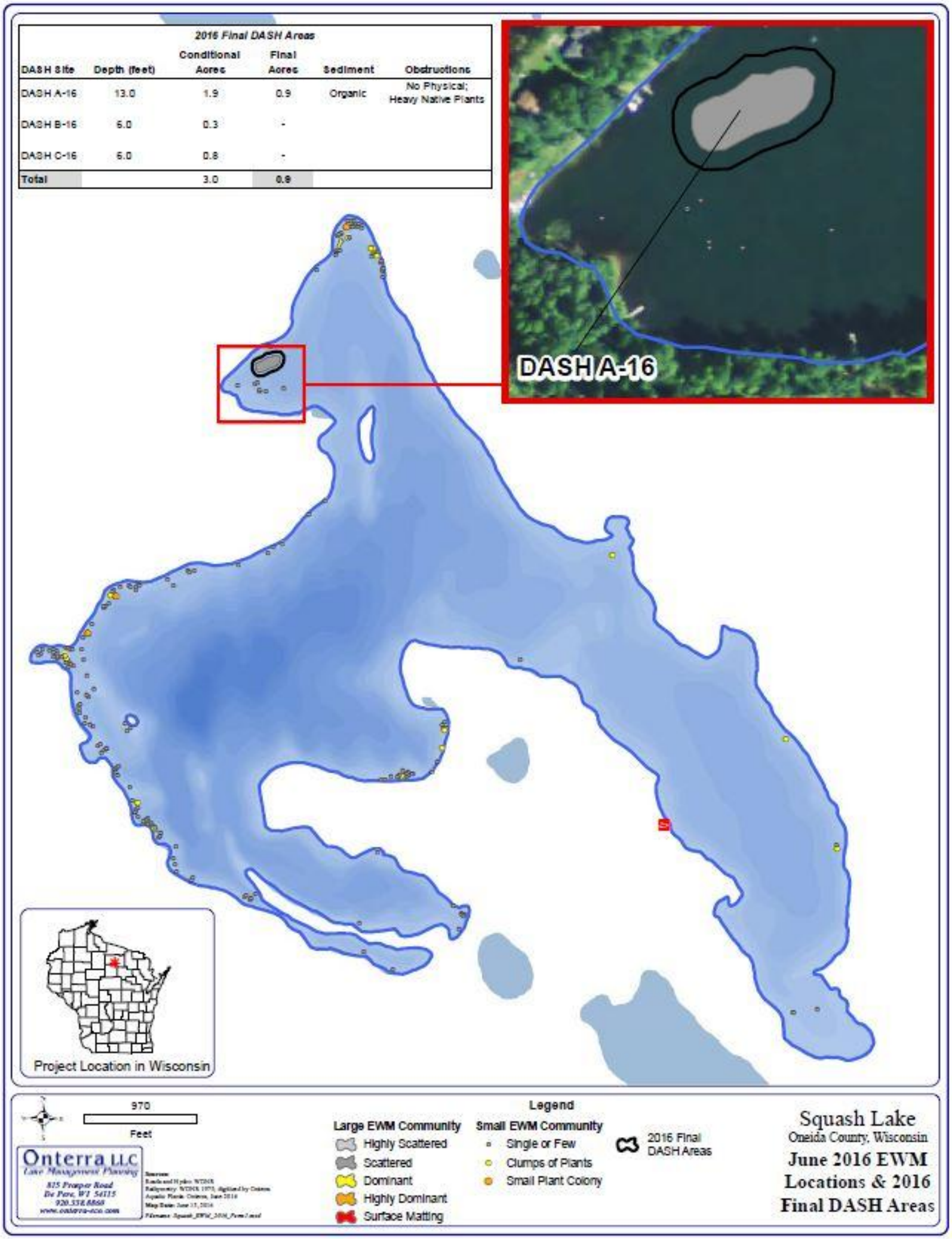
While using DASH, a diver typically will begin by locating the invasive plant such as Eurasian watermiloil from the surface, and then descend next to the plant while simultaneously lowering the nozzle. Divers works along the bottom by using fin pivots, kneeling on the bottom or hovering above the bottom at a distance where the root mass of the plant is within hands reach. The diver will either feed the top of the plant into the hose first and then uproot the plant or uproot the plant and feed it root wad first into the hose. It is very important that the diver shake as much sediment from the root wad before getting the root wad near the nozzle. Shaking the root wad away from the nozzle helps maintain visibility for the diver and minimizes debris and sediment in the holding bins. The diver carefully observes plants fed into the nozzle for possible fragments. Fragments are caught by hand and fed into the nozzle.

Work sites that have dense monotypic beds of EWM, the initial DASH efforts are quite simple. The diver will descend adjacent to the bed and begin hand pulling or harvesting systematically across the bed to dismantle the bed. Once the majority of the bed is removed, a more systematic approach follows to target remaining clustered, scattered or outlier plants in the work site. As part of our method for covering a work area while using DASH (or divers alone), a grid pattern is used. A diver will start at either the port or starboard side of the boat and work to and from the boat perpendicular to the direction the boat is facing. For example, with the boat facing north and the diver starting on the port side, the diver begins by heading west. The diver will continue to work perpendicular to the boat until reaching the end of the suction hose. The diver then works back to the boat on a new transect line. Distance between each transect is dictated by visibility, density of EWM, and obstructions. This process is repeated on the opposite side and in front of the boat. Depending on the site, once the diver has adequately covered the area, which the suction hose can reach, they will signal the deckhand to let out more anchor line or determine that the boat needs re-positioning.



Once plants reach the surface, a hose dispenses the plant material into a series of screened bins located on the deck of the boat. These bins capture plants and allow water to drain out back into the lake. Plants on deck are sorted into two categories: the targeted invasive plant and native vegetation. A wet weight of both the invasive plant and all native species combined is taken. Plants are placed in sealable containers or bags for transport to the dumping site. The dumping site is a pre-determined site upland, away from any water body.

Figure 1: 2016 DASH Work Area (Onterra, 2016)



Summary

Table 1: Daily DASH Efforts Summary

Date	Location	Size (acres)	Ave. Depth (ft)	DASH Boat Location		Dive Time (hrs)	EWM (lbs*)	Native (lbs*)	Incidental Native Plant Harvest (lbs*)	Total (lbs*)
				Lat	Long					
7/20/2016	DASH A-16	0.9	13	45.60395	89.55437	1.00	2.00	0.00	0%	2.00
				45.60403	89.55444	1.25	25.00	0.50	2%	25.50
				45.60408	89.55464	3.75	98.00	1.50	2%	99.50
7/21/2016	DASH A-16	0.9	13	45.60401	89.55479	1.50	12.00	0.25	2%	12.25
				45.60402	89.55461	1.00	7.00	0.25	4%	7.25
				45.60411	89.55425	3.50	34.50	0.75	2%	35.25
7/22/2016	DASH A-16	0.9	13	45.60405	89.55433	0.50	8.00	0.25	3%	8.25
				45.60423	89.55423	0.50	5.50	0.00	0%	5.50
				45.60413	89.55413	0.50	4.00	0.00	0%	4.00
				45.60390	89.55492	0.50	4.50	0.00	0%	4.50
						14.00	200.50	3.50	1% (ave.)	204.00

* wet weight

Daily Conditions

July 20th 2016 Weather – Mostly sunny, 80˚F, winds 5-10 mph with 15+ gusts

Six hours of dive time removed 125 pounds of EWM. Incidental harvest of native plant species consisted of fern pondweed (*P. robbinsii*), large leaf pondweed (*P. amplifolius*), waterweed species, (*Elodea* sp.) and *Chara* sp.

July 21st 2016 Weather- 70˚F, humid, partly sunny, storms threatening

Six hours of diving removed 53.5 pounds of EWM. Incidental harvest of native plant species remained similar to the previous day.

July 22nd 2016 Weather - 75˚F, increasing clear skies, light and variable wind

Two hours of dive time removed 22 pounds of EWM. Incidental harvest of native plant species remained similar to the previous days.