

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 (Photo 1). The lake's aquatic plant community is exceptionally diverse with 54 native species located during surveys in 2012. 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.



Photo 1. Squash Lake, Oneida County, Wisconsin.

Hand-harvesting using paid scuba divers began during the 2010 growing season, and have since been carried out through the growing seasons of 2011-2015. At the end of each season, Onterra ecologists visited Squash Lake to remap the EWM population and assess the hand-harvesting efforts. 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. Because 2014 marked five years since EWM was discovered in Squash Lake, the EWM control program transitioned from an EDR Program to an Established Population Control (EPC) Program. In February 2014, the SLA successfully applied for a WDNR EPC-Grant to aid in funding continued EWM control and monitoring from 2014-2016. In addition, a whole-lake point-intercept survey will be conducted in the final year of the project (2016) to reassess the EWM and native plant populations and to update the aquatic plant portion of Squash Lake's lake management plan.

In addition to implementing hand-harvesting with paid scuba divers in 2014, the SLA also contracted with Many Waters, LLC to implement the Diver-Assisted Suction Harvesting (DASH) System to control larger, denser areas of EWM. Post-hand-harvesting assessments in 2014 found that the 2014 hand-harvesting strategy overall was successful at maintaining a low-density EWM population. While the majority of the scuba diver hand-harvesting areas saw reductions or maintenance of the EWM density delineated pre-hand-harvesting and met pre-determined success criterion, the areas where the DASH system was implemented saw slight reductions in EWM density but did not meet the pre-determined success criterion. A similar strategy utilizing both scuba diver hand-harvesters and the DASH system was proposed for 2015.

2015 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 native aquatic plant community and overall ecology, recreation, and aesthetics. A stakeholder survey was sent to Squash Lake riparians during 2012 during the development of their current Comprehensive Lake Management Plan. During this survey, 47% of respondents indicated that they were not supportive of herbicide control of aquatic plants, 37% were in favor of this technique, and the remainder of respondents (16%) were either unsure or neutral on the issue. Since a plurality of Squash Lake stakeholders were not in favor of the use of herbicides as a method of EWM control, the SLA decided to move forward with continued hand-removal of EWM in 2014-2016. In combination with hand-removal via scuba divers, the SLA again contracted with Many Waters, LLC to implement the Diver-Assisted Suction Harvesting (DASH) system in two areas of the lake containing higher levels of EWM that may be more suitable for control by a professional firm.

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 2015, 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 2015.

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 2015.

MONITORING METHODOLOGIES

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 monitored 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 2015 hand-harvesting activities on Squash Lake, qualitative assessments were completed by comparing pre-hand-harvesting data collected during the 2015 Early-Season AIS Survey with post-hand-harvesting EWM mapping data collected during the 2015 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*).

2015 EARLY-SEASON AIS SURVEY (PRE-HAND-HARVESTING)

On May 27 and 28, 2015 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 2015 ESAIS Survey, the majority of the EWM that was located had been located during the 2014 Late-Summer EWM Peak-Biomass Survey, and the density appeared to be relatively similar as well. One small plant colony that had not been located in 2014 was located in deeper water near the rock bar north of the peninsula in the southwestern area of the lake. A submersible camera was used to map EWM within the deeper proposed DASH Site B-15 as the EWM was not visible from the surface. Following this survey, a total of 31 SLA scuba diver hand-harvest sites were created comprised of 10 primary focus areas, 12 secondary focus areas, and 9 tertiary focus areas. Two sites in the northern portion of the lake containing colonized *scattered* and *highly scattered* EWM totaling 1.5 acres were proposed for DASH system implementation. The DASH Site A-15 was found to contain denser EWM compared to B-15, and it was recommended that if Many Waters had time limitations that they prioritize their efforts within A-15.

2015 SLA SCUBA DIVER HAND-HARVESTING & DASH IMPLEMENTATION

Hand-harvesting logs provided by the SLA indicate that SLA scuba divers spent approximately 714 diver hours (~65 hours/acre) between June 8 and October 3, 2015 removing a total of over 4,100 pounds of EWM from Squash Lake in 2015 (Table 1). Many Waters, LLC implemented DASH hand-removal within DASH sites A-15 and B-15 on June 10 and 11, 2015 (Appendix B). Over the course of these two days, DASH divers spent a total 11 hours in the two DASH areas removing a total of 128.5 pounds of EWM (~7.3 hours/acre) (Table 2).

Table 1. Squash Lake 2015 SLA scuba diver hand-harvesting hours and amount of EWM removed. Created using diver logs provided to Onterra by the SLA.

| Date | # Divers | Hours/Diver | Combined Diver Hours | EWM Removed (lbs) | Priority | 2015 Hand-Removal Site | | |
|--------------|----------|------------------|-------------------------|----------------------|---------------------------|------------------------|-------------------------------|------|
| | | | | | | Secondary | Tertiary | DASH |
| 6/8/2015 | 5 | 6 | 30.00 | 52 | | | | |
| 6/9/2015 | 4.5 | 6 | 27.00 | 300 | A-15 | | | |
| 6/10/2015 | 5 | 6 | 30.00 | 380 | A-15; B-15 | | | |
| 6/11/2015 | 5 | 6 | 30.00 | 220 | B-15; C-15; | M-15 | | |
| 6/15/2015 | 5 | 5 | 25.00 | 50 | A-15; B-15 | | | |
| 6/16/2015 | 5 | 5.5 | 27.50 | 120 | B-15; D-15 | O-15 | | |
| 6/17/2015 | 5 | 5.75 | 28.75 | 80 | B-15; C-15; D-15 | O-15 | Z-15 | |
| 6/18/2015 | 4.5 | 5 | 22.50 | 230 | C-15; D-15 | O-15 | | |
| 6/23/2015 | 5 | 5.25 | 26.25 | 45 | J-15 | | | |
| 6/24/2015 | 5 | 6.5 | 32.50 | 20 | | T-15 | | |
| 6/25/2015 | 5 | 6 | 30.00 | 115 | | M-15 | | |
| 6/29/2015 | 4 | 6.5 | 26.00 | 370 | H-15 | | | |
| 6/30/2015 | 4.5 | 5.75 | 25.88 | 145 | H-15; J-15; G-15 | U-15 | | |
| 7/1/2015 | 5 | 4.75 | 23.75 | 85 | F-15 | P-15; S-15 | | |
| 7/2/2015 | 5 | 5.5 | 27.50 | 130 | | P-15 | AB-15 | |
| 7/7/2015 | 5 | 6.25 | 31.25 | 80 | | | AD-15; AE-15; AA-15; AC-15 | |
| 7/8/2015 | 4 | 5.25 | 21.00 | 60 | | M-15 | X-15; Y-15 | |
| 7/9/2015 | 5 | 5.75 | 28.75 | 160 | | M-15 | W-15 | |
| 7/14/2015 | 4.5 | 1 at 3; 4 at 5.5 | 25.00 | 160 | | | W-15 | B-15 |
| 7/15/2015 | 5 | 5.75 | 28.75 | 180 | | | W-15 | B-15 |
| 7/16/2015 | 5 | 5.75 | 28.75 | 55 | | K-15 | AC-15 | B-15 |
| 7/20/2015 | 5 | 5.75 | 28.75 | 50 | | Q-15; R-15 | | |
| 7/21/2015 | 5 | 6.25 | 31.25 | 85 | A-15; B-15; H-15 | N-15; S-15; Q-15 | | |
| 7/22/2015 | 4.5 | 6.5 | 29.25 | 70 | B-15; C-15; D-15; E-15 | M-15; V-15 | | |
| 8/11/2015 | 3 | 6.5 | 19.50 | 85 | F-15; J-15 | P-15; T-15 | AB-15; W-15 | |
| 9/20/2015 | 2 | 6.5 | 13.00 | 275 | E-15; J-15 | V-15 | | B-15 |
| 9/26/2015 | 1 | 5 | 5.00 | 225 | | M-15 | | B-15 |
| 10/3/2015 | 2 | 5.75 | 11.50 | 300 | | M-15 | W-15 | |
| Total | | | 714 | 4,127 | | | | |

Table 2. Hours of time spent implementing DASH system and amount of EWM removed in Squash Lake in 2015. Created using data provided by Many Waters, LLC (Appendix B).

| Site | Time Underwater (Hours) | EWM Removed (lbs) |
|--------------|----------------------------|----------------------|
| DASH A-15 | 8.75 | 96.5 |
| DASH B-15 | 2.25 | 32.0 |
| Total | 11.00 | 128.5 |

EWM MONITORING RESULTS

2015 SLA Hand-Removal Efficacy

On September 21, 2015, Onterra ecologists conducted the Late-Summer EWM Peak-Biomass Survey on Squash Lake to assess the hand-harvesting areas and map EWM throughout the lake. Like the ESAIS Survey, this survey is a meander-based survey of the lake's littoral zone designed to locate and map occurrences of EWM. This survey revealed that overall the 2015 SLA scuba diver hand-harvesting effort was met with success with 29 of the 31 SLA hand-harvesting sites (94%) meeting the pre-determined success criterion of maintaining or decreasing the density of EWM within the site (Table 3 and Figures 1-4).

Of the ten primary focus hand-harvest areas, only one, G-15, did not see an observed reduction in EWM. Eleven of the 12 secondary focus areas met the success criterion, with M-15 being the only secondary focus area to see an observed increase in EWM following hand-harvesting. All nine of the tertiary focus areas met the success criterion and maintained EWM at the point-based level. The SLA hand-harvest sites encompassed approximately 11 acres in 2015, resulting in an effort of approximately 65 diver hours per acre in 2015.

Table 3. Squash Lake May 2015 pre- and September 2015 post-hand-harvesting results within SLA hand-harvesting areas.

| | Site Name | May 2015 EWM (Pre-Hand-Harvesting) | September 2015 EWM (Post-Hand-Harvesting) | Change | Success Criteria Met |
|-----------------------|-----------------|--|--|--------|-------------------------|
| Primary Focus Areas | A-15 | Colonized (dominant) | Point-based (C,S) | ↓ | Yes |
| | B-15 | Point-based (SPC,C,S) | Point-based (S) | ↓ | Yes |
| | C-15 | Point-based (SPC,S) | Point-based (S) | ↓ | Yes |
| | D-15 | Point-based (SPC,S) | Point-based (S) | ↓ | Yes |
| | E-15 | Colonized (highly scattered) & Point-based (C,S) | Point-based (S) | ↓ | Yes |
| | F-15 | Point-based (SPC) | No EWM | ↓ | Yes |
| | G-15 | Colonized (highly scattered) | Colonized (scattered) & Point-based (C,S) | - | No |
| | H-15 | Colonized (scattered) & Point-based (S) | Point-based (S) | ↓ | Yes |
| | I-15 | Point-based (SPC,C,S) | Point-based (C,S) | ↓ | Yes |
| | J-15 | Point-based (SPC,C,S) | Point-based (S) | ↓ | Yes |
| Secondary Focus Areas | K-15 | Point-based (C) | Point-based (S) | ↓ | Yes |
| | L-15 | Point-based (C) | Point-based (C) | - | Yes |
| | M-15 | Point-based (C,S) | Colonized (scattered) & Point-based (C,S) | ↑ | No |
| | N-15 | Point-based (C) | Point-based (S) | ↓ | Yes |
| | O-15 | Point-based (CS) | No EWM | ↓ | Yes |
| | P-15 | Point-based (C,S) | Point-based (S) | ↓ | Yes |
| | Q-15 | Point-based (C,S) | Point-based (S) | ↓ | Yes |
| | R-15 | Point-based (C,S) | Point-based (S) | ↓ | Yes |
| | S-15 | Point-based (C) | Point-based (C) | - | Yes |
| | T-15 | Point-based (C,S) | Point-based (S) | ↓ | Yes |
| | U-15 | Point-based (C,S) | No EWM | ↓ | Yes |
| V-15 | Point-based (C) | No EWM | ↓ | Yes | |
| Tertiary Focus Areas | W-15 | Point-based (S) | Point-based (SPC,C,S) | ↑ | Yes |
| | X-15 | Point-based (S) | Point-based (S) | - | Yes |
| | Y-15 | Point-based (S) | Point-based (S) | - | Yes |
| | Z-15 | Point-based (S) | Point-based (S) | - | Yes |
| | AA-15 | Point-based (S) | No EWM | ↓ | Yes |
| | AB-15 | Point-based (S) | Point-based (C,S) | ↑ | Yes |
| | AC-15 | Point-based (S) | Point-based (S) | - | Yes |
| | AD-15 | Point-based (S) | Point-based (S) | - | Yes |
| AE-15 | Point-based (S) | Point-based (C,S) | ↑ | Yes | |

S = Single or Few Plants; C = Clumps of Plants; SPC = Small Plant Colony

2015 DASH Efficacy

During the 2015 Late-Summer EWM Peak-Biomass Survey, Onterra ecologists also assessed the 2015 DASH areas, A-15 and B-15. As discussed previously, 8.75 and 2.25 hours were spent harvesting EWM in sites A-15 and B-15, respectively. Prior to DASH implementation, site A-15 was delineated as containing *scattered* EWM (Figure 1). Following DASH implementation, the September EWM survey revealed that a portion of this area was reduced to *highly scattered*, a small portion increased to *dominant*, and a small portion remained *scattered*. The pre-determined success criterion for DASH sites is a reduction in EWM of at least two density ratings, and in this instance A-15 would have needed to be reduced to point-based levels (i.e. clumps of plants) to be deemed successful. While a portion of A-15 was reduced by one density rating, the other portions remained the same or increased in density, and for this reason it cannot be said that site A-15 was met with success.

Prior to DASH implementation, site B-15 contained approximately 1.2 acres of *scattered* and *highly scattered* EWM (Figure 1). Following DASH implementation, it was found that the entire area was reduced to *highly scattered* but the area had expanded to approximately 1.9 acres. While B-15 was reduced slightly in density, it did not meet the pre-determined success criterion of a reduction of at least two density ratings.

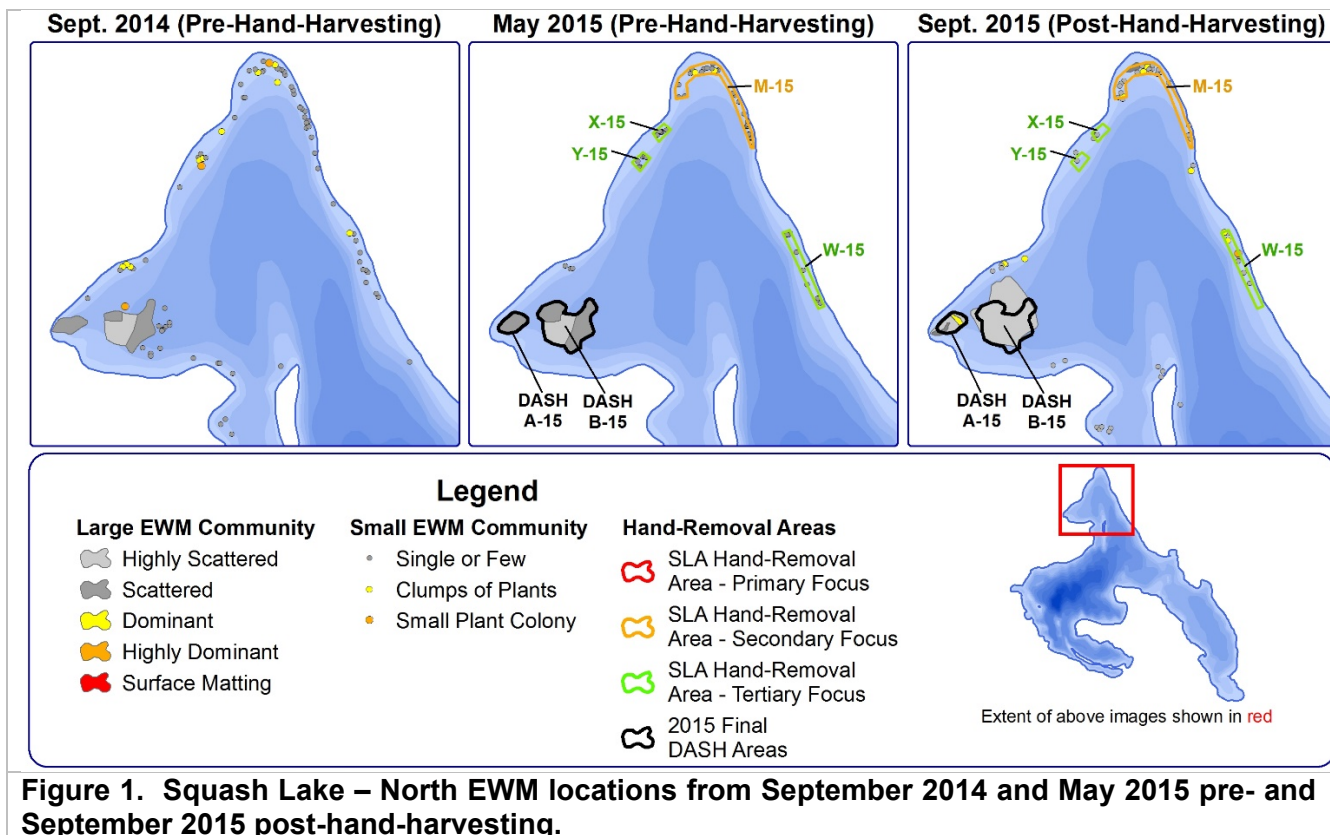


Figure 1. Squash Lake – North EWM locations from September 2014 and May 2015 pre- and September 2015 post-hand-harvesting.

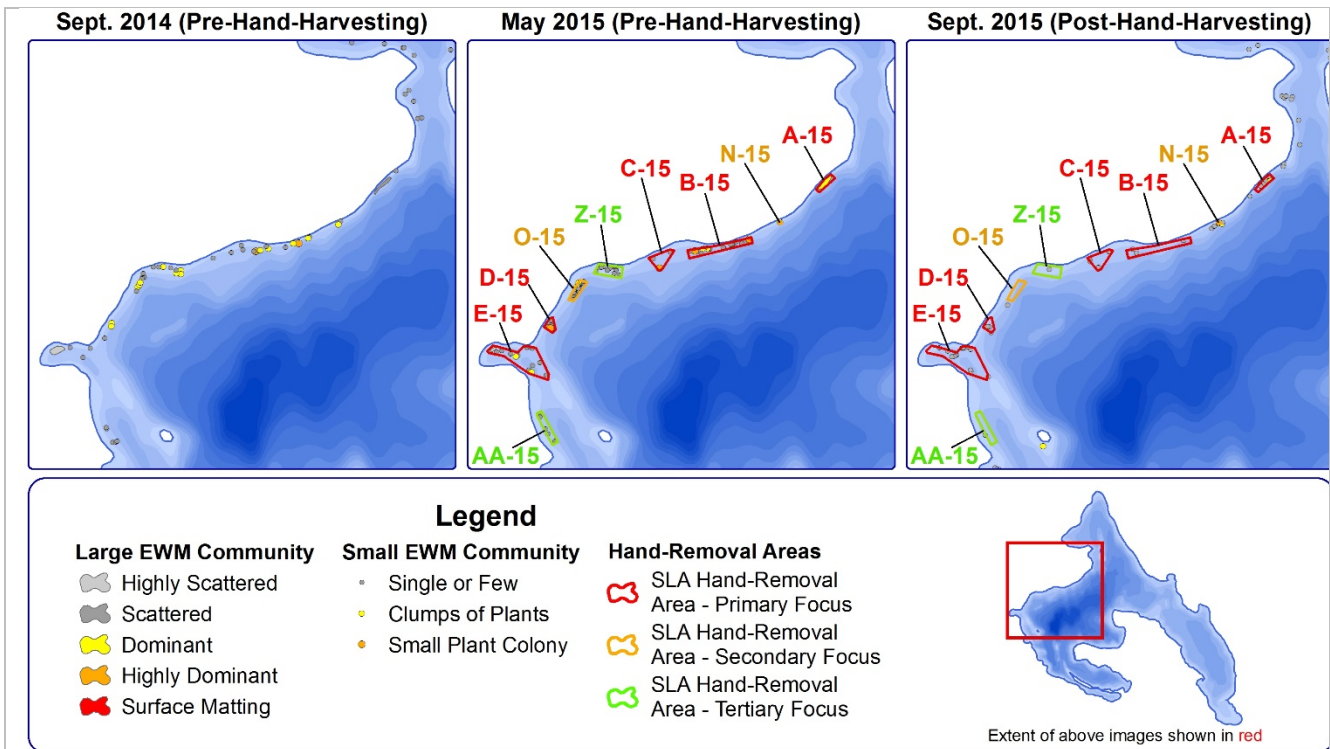


Figure 2. Squash Lake – Northwest EWM locations from September 2014 and May 2015 pre- and September 2015 post-hand-harvesting.

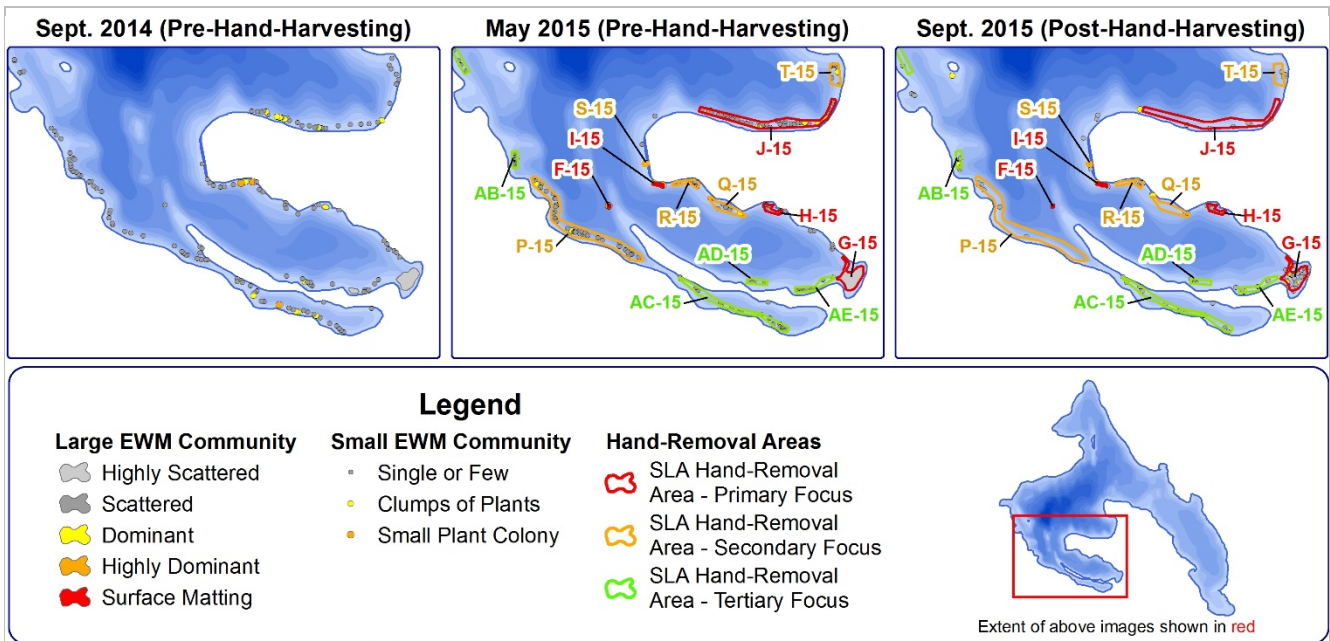


Figure 3. Squash Lake – Southwest EWM locations from September 2014 and May 2015 pre- and September 2015 post-hand-harvesting.

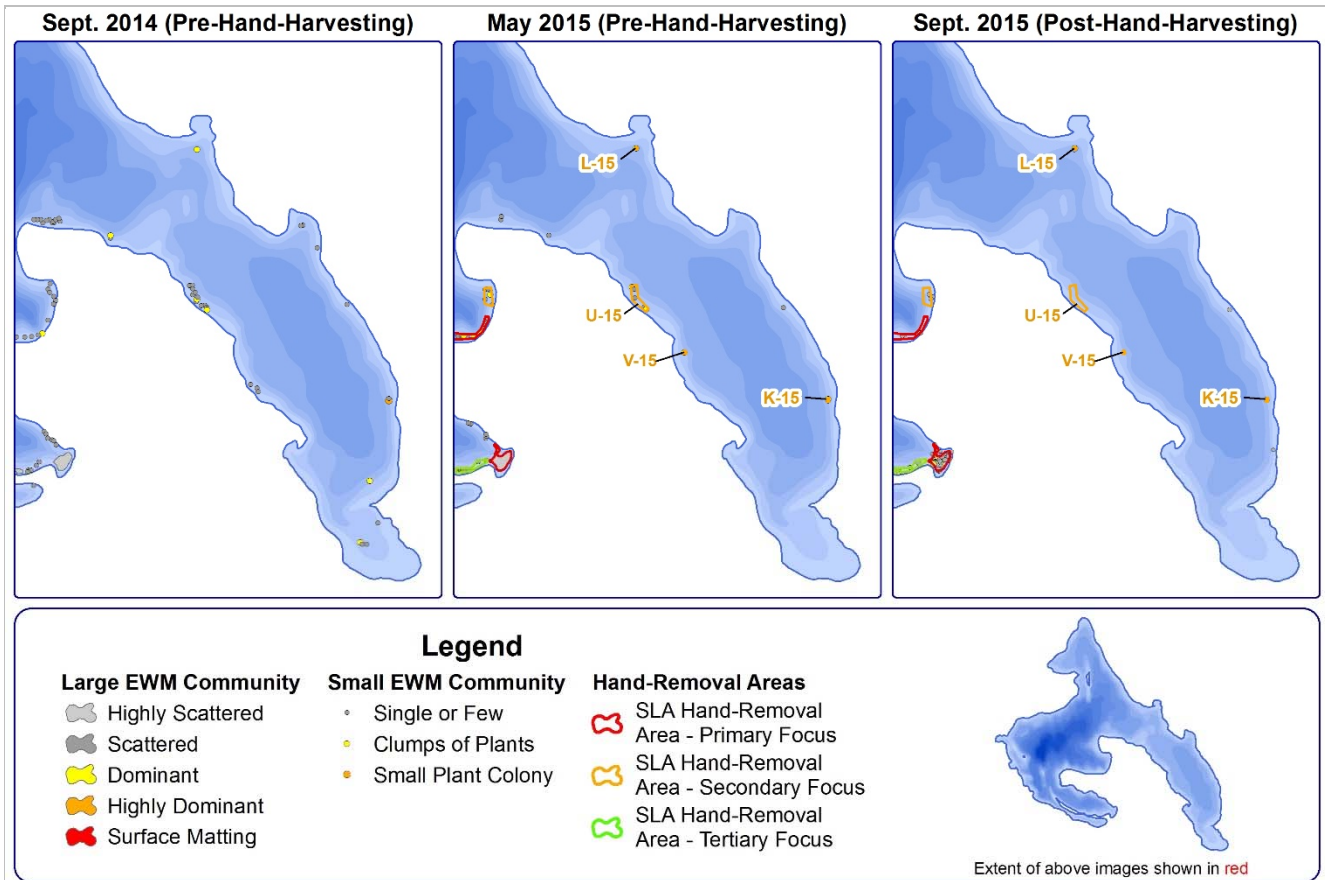


Figure 4. Squash Lake – Southeast EWM locations from September 2014 and May 2015 pre- and September 2015 post-hand-harvesting.

CONCLUSIONS AND DISCUSSION

Overall, the 2015 hand-harvesting effort of EWM on Squash Lake was met with mixed results. Hand-harvesting by SLA scuba divers at an effort of approximately 65 diver hours per acre was largely met with success, with 94% of the hand-harvesting areas meeting the pre-determined success criteria. However, the effort of 7.3 hours per acre spent within the two areas where the DASH system was implemented was insufficient to cause a reduction in EWM density of at least two density ratings, thus both sites failed to meet the pre-determined success criterion. During the 2015 Late-Summer EWM Peak-Biomass Survey, little EWM was located outside of the 2015 hand-harvesting areas, and qualitatively it appeared that there was less EWM lake-wide in September of 2015 when compared to pre-hand-harvesting levels in May 2015 and September 2014 (Maps 1-3). And as in the past, the majority of the EWM population in 2015 remains mainly of *single or few plants*, *clumps of plants*, and a few *small plant colonies* with the exception of some colonized areas comprised of *highly scattered* and *scattered* EWM.

The current WDNR-EPC Grant covers EWM control and monitoring costs on Squash Lake through 2016. Given that one of the goals of this project is to assess the efficacy of hand-removal to control a lake-wide population of EWM, it is recommended that a combination of SLA paid scuba hand-harvesters and professionally-operated DASH hand-harvesters be utilized again in 2016. Colonized areas of EWM (polygons) exert the greatest ecological strain as they are the largest sources for future spread and

displace valuable native plant species. Because of the level of EWM within these areas, a large amount of effort (hours) is needed to remove/reduce the EWM via manual hand-removal. The implementation of the Diver-Assisted Suction Harvest (DASH) system to target these colonized areas of EWM in Squash Lake is recommended. By targeting the largest and densest areas of EWM with the DASH system, the SLA-paid scuba divers will be able to focus their efforts on areas of EWM that are less dense and more suitable for manual hand-removal. The same areas where DASH was implemented in 2015 are proposed to for DASH implementation again in 2016, totaling approximately 2.1 acres. However, the 11 hours (7 hours/acre) of DASH implementation in 2015 was insufficient to reduce EWM to desired levels within these areas. If the DASH divers are only able to spend 11 hours harvesting again in 2016, it is recommended they focus all of their efforts on site A-16.

Squash Lake Association 2016 scuba diver hand-harvesting areas will be created following Onterra's 2016 ESAIS Survey which will occur sometime in late-May or early-June. The areas will again be classified as either *primary focus*, *secondary focus*, or *tertiary focus*. Primary focus areas contain either smaller colonized areas of EWM (polygons) or point-based mapping data with at least one *small plant colony*, secondary focus areas contain at least one *clumps of plants*, and tertiary areas contain only *single or few plants*. The finalized hand-harvesting sites will be provided to the SLA-paid scuba divers in a native Garmin GPS basemap format to guide their hand-harvesting efforts.

The hand-harvesting in 2015 was the first year in which Onterra delineated hand-harvesting areas based upon priority to increase the effectiveness of hand-removal by having the scuba divers spend more of their time removing EWM rather than searching the lake for it. Onterra recommended that the SLA scuba divers spend their time harvesting in priority focus areas first, and they should not move on to secondary or tertiary sites until they were confident all of the EWM had been removed in those areas. This strategy appears to have been largely effective in 2015, and it is recommended that the SLA divers follow this strategy again in 2016.

The SLA scuba divers were diligent in keeping diving records in 2015; however, the site name (e.g. A-15) was often not recorded and the SLA-created grid location and/or latitude/longitude were recorded. In 2016 the SLA divers should record 1) the Onterra-created site they are harvesting, 2) how many divers are harvesting, 3) how much time (hours) each diver spent at the site, and 4) how much EWM (pounds) was removed from that site. Following the 2015 hand-harvesting efforts, Onterra will conduct the Late-Summer EWM Peak-Biomass Survey sometime in late-August or early-September to assess the hand-removal areas and map EWM throughout the lake.

Currently, the SLA will likely not be able to qualify for another AIS-EPC grant to continue funding the cost of hand-harvesting given the low lake-wide occurrence of EWM. If the occurrence of EWM is less than 10% within the littoral zone (Squash Lake 2012 EWM occurrence was 0.4%) the lake is considered to be in maintenance and containment mode, and the SLA would likely only be eligible for an AIS-Maintenance and Containment Grant which is designed to provide funding for projects that have reduced the AIS population and now ongoing maintenance is needed to prevent reestablishment and spread to other waterbodies. The AIS-Maintenance and Containment Grant reimburses permit fees that are issued by the WDNR (e.g. mechanical harvesting permit fees).

Onterra is scheduled to conduct another whole-lake point-intercept survey on Squash Lake in 2016, and it is believed that the littoral occurrence of EWM will likely be $\leq 1\%$, likely making the SLA ineligible

for AIS-EPC funds. Following hand-removal and surveys in 2016, Onterra will work with the SLA to develop an EWM management strategy moving forward. The SLA may be able to apply for an AIS-Education, Planning and Prevention (EPP) Grant which would cover the costs of monitoring and planning, but it would not cover the costs of hand-removal. It is Onterra's understanding that the WDNR will be working on a code revision for AIS-EPC grants in an effort to make the transition from EPC projects to Maintenance and Control projects easier. However, it is not known if this revision will be applicable for the February 2017 grant cycle.