# 1.0 INTRODUCTION

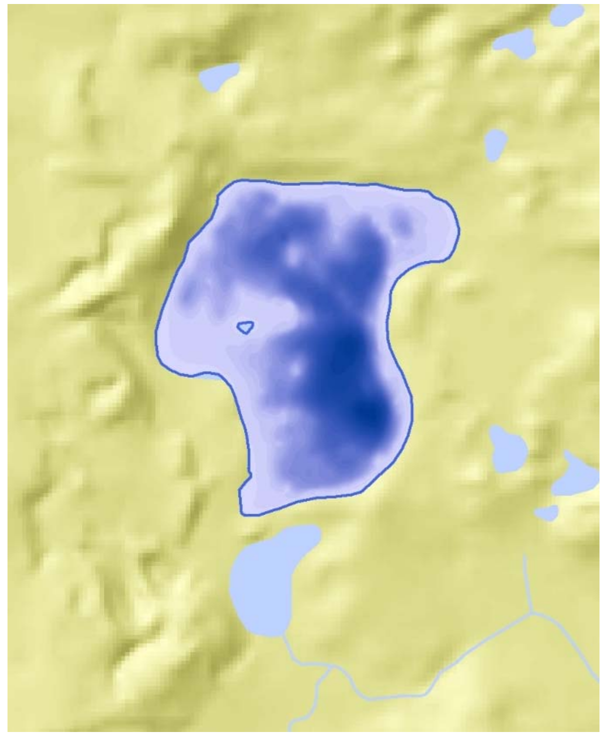

**Figure 1. Pigeon Lake, Manitowoc County, Wisconsin.**

According to the historic WDNR Lake Survey Map (date unknown), Pigeon Lake is an 82-acre seepage lake. The WDNR website indicates the lake is 80 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program (NAIP)* collected in spring 2015. Based upon heads-up digitizing the water level from that photo, the lake was determined to be 86.4 acres. During the summer of 2015, Onterra conducted an acoustic-based bathymetric study of the lake. These data indicate that the lake has a maximum depth of 66 feet.

Eurasian water milfoil (EWM) was first confirmed in Pigeon Lake in 1994. During 2013 surveys, two separate milfoil samples were sent into the Annis Water Resource Institute at Grand Valley State University in Michigan for DNA analysis. The analysis confirmed that the samples were both pure strain EWM and not a hybrid species. Hybrid water milfoil, (*M. sibiricum X spicatum*), a cross between Eurasian water milfoil and the indigenous northern water milfoil, is commonly mistaken for Eurasian water milfoil or northern water milfoil. Some strains of hybrid water milfoil have been shown to be less susceptible to biological and certain herbicide control strategies (including 2,4-D). Nearby Manitowoc County lakes with hybrid water milfoil include Silver Lake, Shoe Lake, Carstens Lake, and English Lake.

Pigeon Lake of Manitowoc County (PLMC) is the local citizen-based organization leading the management of Pigeon Lake. The PLMC has sponsored herbicide spot-treatments of EWM in Pigeon Lake 3 times since 2006, all resulting in limited seasonal control (2006[4 acres], 2010[1.7 acres], 2012 [1.4 acres]). The group has worked for years to protect and enhance the lake and in 2013 received a Lake Management Planning Grant to complete a *Comprehensive Management Plan* for the lake with assistance from WDNR Grant Funds (AEPP-401-13). The plan was completed by Onterra, and accepted by the WDNR in July 2014. One of the goals outlined in the management plan is to "Develop an EWM Monitoring and Control Strategy for Pigeon Lake."

In late 2013 when the Pigeon Lake management plan was being completed, the EWM population in the lake was known to have expanded over the prior years. With Onterra's direction, the PLMC opted to postpone herbicide management during 2014 to conduct additional monitoring to determine if further population of EWM would continue to increase or if the population would plateau. Particularly in regards to an established EWM population, some lake groups have adopted a strategy where they postpone active management until an EWM population reaches a certain threshold. This threshold may be set at a level where the EWM population is 1) suspected to cause change in the lake's historic ecologic function and/or 2) a level that reduced the lake's ability to be enjoyed by riparians prior to the EWM population.

In 2014, PLMC funds were utilized to have Onterra complete an EWM peak-biomass survey during late-summer and found that the EWM population expanded in both area and density since 2013 (Figure 2). The PLMC elected to move forward with the development of a control and monitoring strategy for a subsequent large-scale treatment.

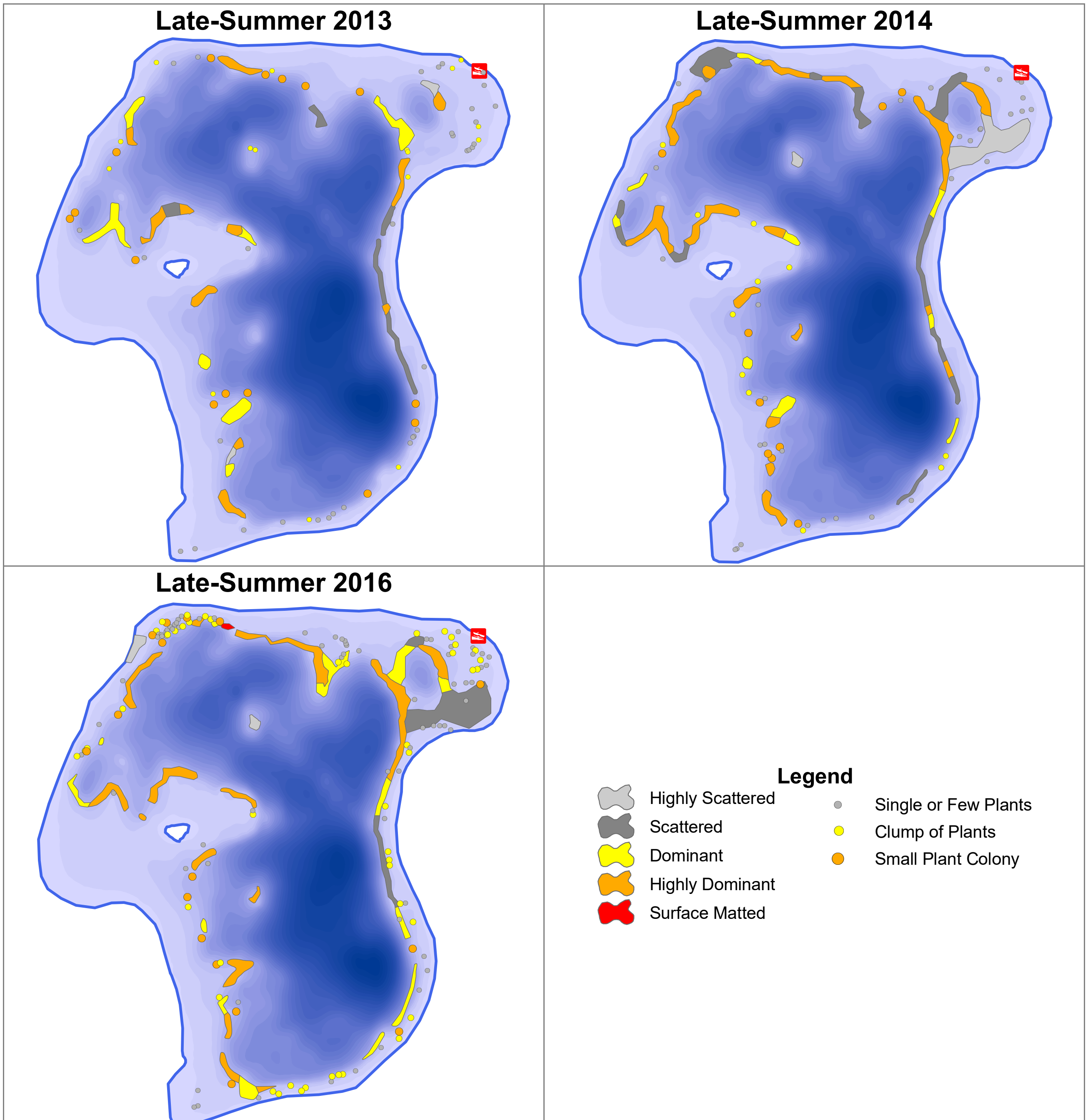


**Figure 2. Pigeon Lake 2013, 2014, 2016 Late-Summer EWM Survey Results.** EWM survey not conducted in 2015

## 1.1 2017 Whole-Lake 2,4-D Treatment & Monitoring Plan

The PLMC applied for WDNR AIS-Education, Prevention, and Planning Grants (<$10K sub-category) in December 2014 and December 2015, both attempts being unsuccessful. As the EWM population continued to increase, the PLMC authorized a full suite of pretreatment surveys to occur in 2016 with the understanding that self-funding the control and monitoring program may be a reality. The PLMC secured financial partnership from the Town of Liberty. Changes in the grant funding priorities resulted in a more favorable chance for the PLMC to receive funding within the WDNR AIS-Established Population Control (EPC) Grant Program. With Onterra's assistance, the PLMC was successfully awarded an AIS-EPC Grant from the February 2017 application cycle. This report marks the final deliverable of this grant (ACEI-191-17).

The awarded AIS-EPC Grant included a three-year control and monitoring strategy in which a whole-lake 2,4-D treatment would occur in year two (2017) of the project. Map 1 outlines the large-scale treatment on Pigeon Lake. The application areas were constructed by placing a 60-ft buffer on mapped EWM colonies. Less than a 60-foot shoreward buffer was placed on application areas in some instances for logistical reasons (i.e. docks, shallow shoals, etc.). It was expected that within a few days after treatment (DAT), herbicide from the application areas would dissipate to reach a target lake-wide epilimnetic equilibrium of 0.375 ppm acid equivalent (ae).

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

Because the 2017 treatment on Pigeon Lake was anticipated to have whole-lake effects, the whole-lake point-intercept method as described by the WDNR Bureau of Science Services (PUB-SS-1068 2010) will be used to complete a quantitative evaluation of the occurrences of non-native and native aquatic plant species. To monitor the treatment's efficacy, a whole-lake point-intercept survey was conducted in 2016 (*year prior to treatment*), 2017 (*year of treatment*), and 2018 (*year following treatment*).

The success criteria of a whole-lake treatment would be a 70% reduction in EWM littoral frequency of occurrence comparing point-intercept surveys from the *year prior to the treatment* (2016) to the *year after the treatment* (2018). Understanding the EWM population in 2017 (*year of treatment*) is important, but an insufficient time had passed to make official judgements if EWM control occurred or if the plants were simply injured for that season and can quickly rebound.

Qualitative monitoring was conducted annually through EWM mapping surveys on Pigeon Lake 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 are applied to locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.
In-lake herbicide concentrations are also monitored as a part of some treatment strategies, especially those involving anticipated whole-lake impacts. In Pigeon Lake, 2,4-D concentrations were monitored to determine if the target concentrations had been met. With this type of monitoring, water samples are

collected by trained volunteers from multiple locations over the course of numerous days following treatment. Water samples were to be collected at four sites (Map 1, Figure 3) at time intervals of approximately 1, 3, 5, 7, 14, 21, 28, 35 & 49 days after treatment (DAT) using an integrated sampler or Van Dorn sampler. The samples were fixed (preserved) with acid and shipped to the Wisconsin State Lab of Hygiene (SLOH) where the herbicide analysis is completed.

In the summer of 2016 prior to treatment, Onterra ecologists conducted an acoustic survey of Pigeon Lake that was primarily aimed at obtaining accurate bathymetric data for the proposed 2017 treatment to ensure accurate herbicide dosing (Figure 3). This ensures that the dosing strategy is appropriate to impact the target plant and to minimize collateral effects on the native plant community. Volume calculations utilizing the data obtained from the acoustic survey indicated the water volume of Pigeon Lake to be approximately 1,634 acre-feet.

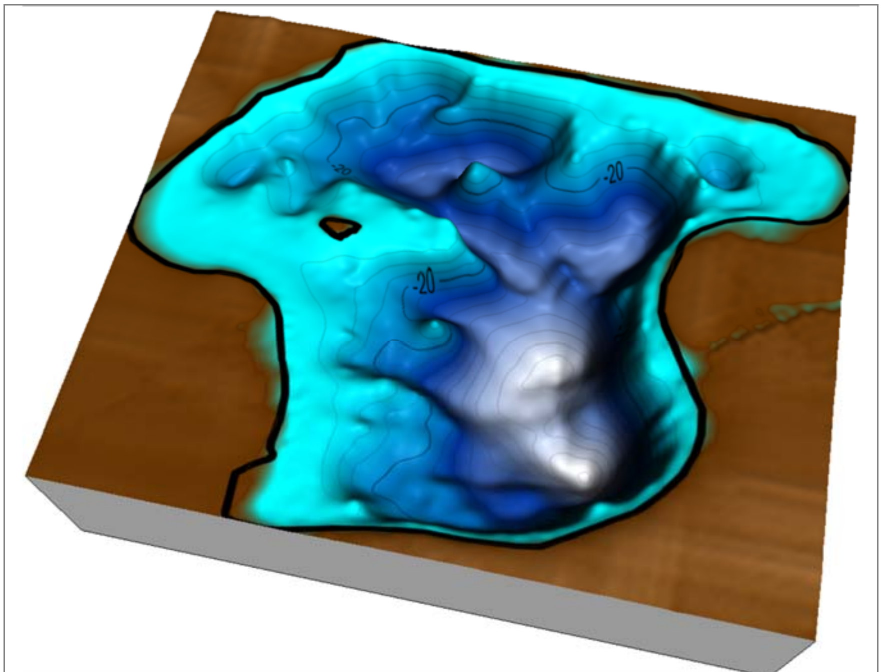


**Figure 3. 3-D model of Pigeon Lake's Bathymetry.** Bathymetry model based on 2016 acoustic survey.

Typical large-scale (aka whole-lake) EWM herbicide treatment strategies target whole-lake concentrations between 0.275 and 0.400 ppm ae, balancing "acceptable" impacts to the native plant community with a high level of control of EWM. Concentrations below 0.275 ppm ae have provided short-term EWM control, but a relatively quick population recovery. In lakes that have achieved average 1-7 DAT concentrations above 0.4 ppm ae, 90-100% EWM control was observed. However, this was coupled in most instances with high level of native plant damage, some of which has not recovered 4-5 years following the treatment.

The whole-lake 2,4-D treatment and associated monitoring in 2017 were carried out as planned with observed herbicide concentrations starting near, but slightly above, target concentrations (Figure 4). Herbicide persistence was longer than anticipated, with concentrations exceeding the irrigation threshold (0.1 ppm ae) for almost 100 days. Through a linear regression analysis ($r^2$=0.94), the 2,4-D half-life for the 2017 treatment in Pigeon Lake was found to be 67 days, meaning that every 67 days, the herbicide degraded into half of its original concentration. Nault et al. 2018 indicated the 2,4-D half-life was shown to range from 4-76 days within the 28 lakes studies, with the "rate of herbicide degradation to be slower in lower-nutrient seepage lakes." Adding 18 additional Onterra-monitored projects to this dataset yields a median 2,4-D half-life of approximately 29.5 days (Figure 4, right frame). The 67-day half-life from Pigeon Lake in 2017 falls within the 86$^{th}$ percentile of this dataset.

Additional discussion about the planning and implementation of the 2017 whole-lake 2,4-D treatment of Pigeon Lake can be found within the *Pigeon Lake 2017 EWM Control & Monitoring Report* (Feb21-2018).

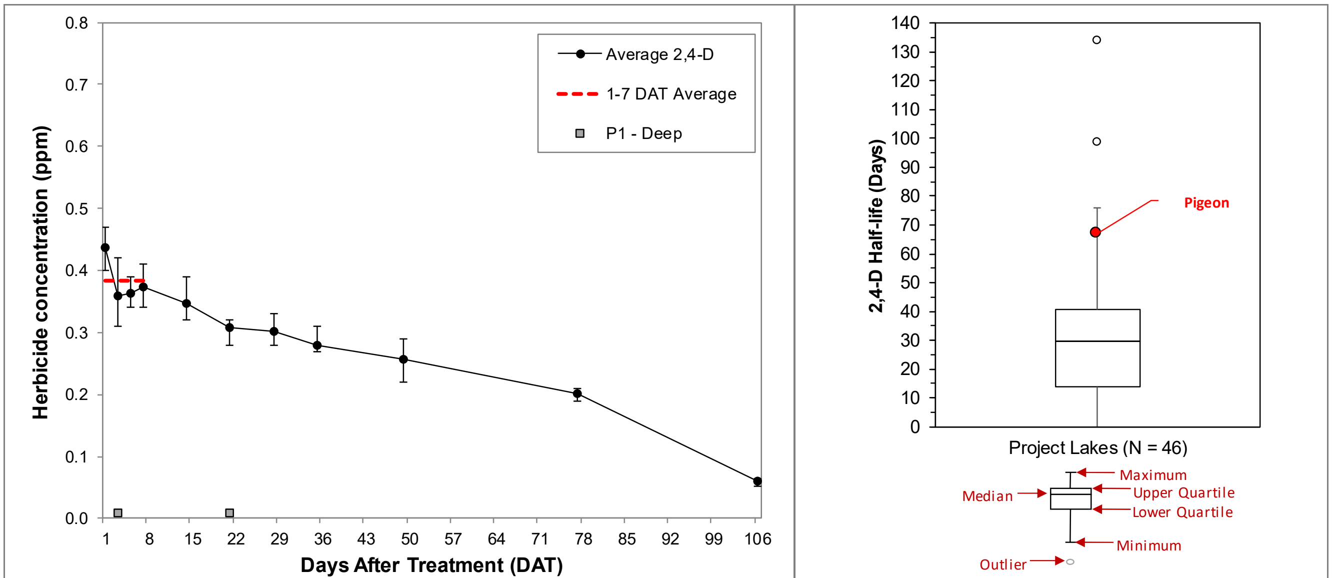


**Figure 4. 2017 Pigeon Lake average surface 2,4-D concentrations (left frame) and 2,4-D half-life analysis compared to other state-wide lakes that completed whole-lake 2,4-D treatments (right frame).** State-wide half-life data from WDNR sources.

# 2.0 AQUATIC PLANT MONITORING RESULTS

## 2.1 Point-Intercept Survey

The WDNR completed the 2005 and 2012 whole-lake point-intercept surveys on Pigeon Lake and Onterra completed the most recent surveys in August 2016-2018. To monitor the treatment's efficacy, a whole-lake point-intercept survey was conducted in 2016 (*year prior to treatment*), 2017 (*year of treatment*), and 2018 (*year following treatment*). The 2016 survey yielded an EWM littoral frequency of occurrence of 23.2% (Figure 5). The 2017 and 2018 point-intercept surveys found EWM frequency of occurrence to be 0%, representing a statistically valid 100% decrease the EWM population from 2016 to 2017. As discussed within the methods section, the success criteria of the treatment would be to have a 70% reduction in EWM littoral frequency of occurrence comparing point-intercept surveys from the *year prior to the treatment* (2016) to the *year after the treatment* (2018).

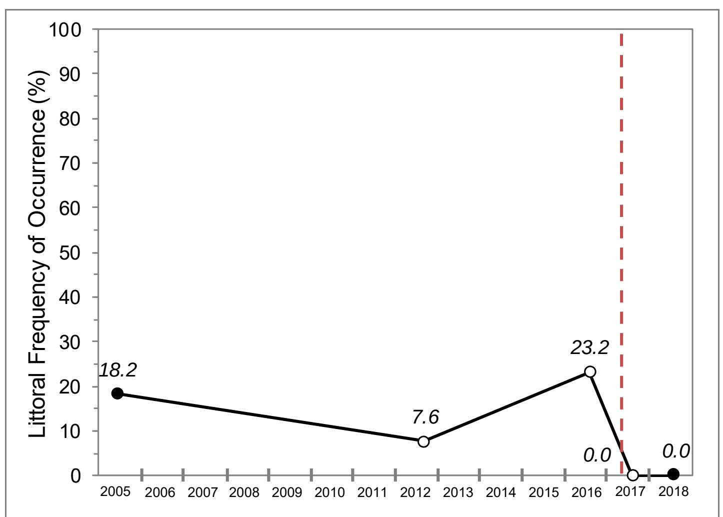


**Figure 5. Pigeon Lake Eurasian water milfoil littoral frequency of occurrence from 2005-2018.** Open circle indicates that occurrence is statistically different from previous survey (Chi-Square α = 0.05). Dashed line indicates large-scale treatment.

Figure 6 shows the average number of native aquatic plant species present at each littoral sampling site. The average number of native plant species per sampling site was reduced slightly during 2017 (*year of treatment*), but this metric increased in 2018 increased to levels higher than previous surveys.

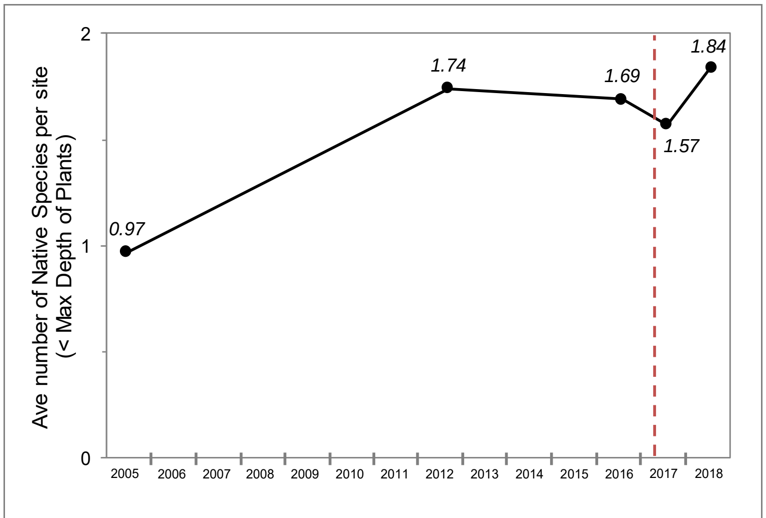


**Figure 6. Average number of native aquatic plant species per littoral sampling site (2005-2018) in Pigeon Lake.** Dashed line indicates large-scale treatment.

Figure 7 shows the number of sampling locations during each of the point-intercept surveys, along with the distribution of how many sites contained either native plants, EWM, or both native plants and EWM. In 2016, there were a total of 198 littoral sampling locations, 46 of which (23%) contained EWM. In 2017 there were 212 sampling locations, and in 2018 there were 223 – none of which for either year contained EWM.

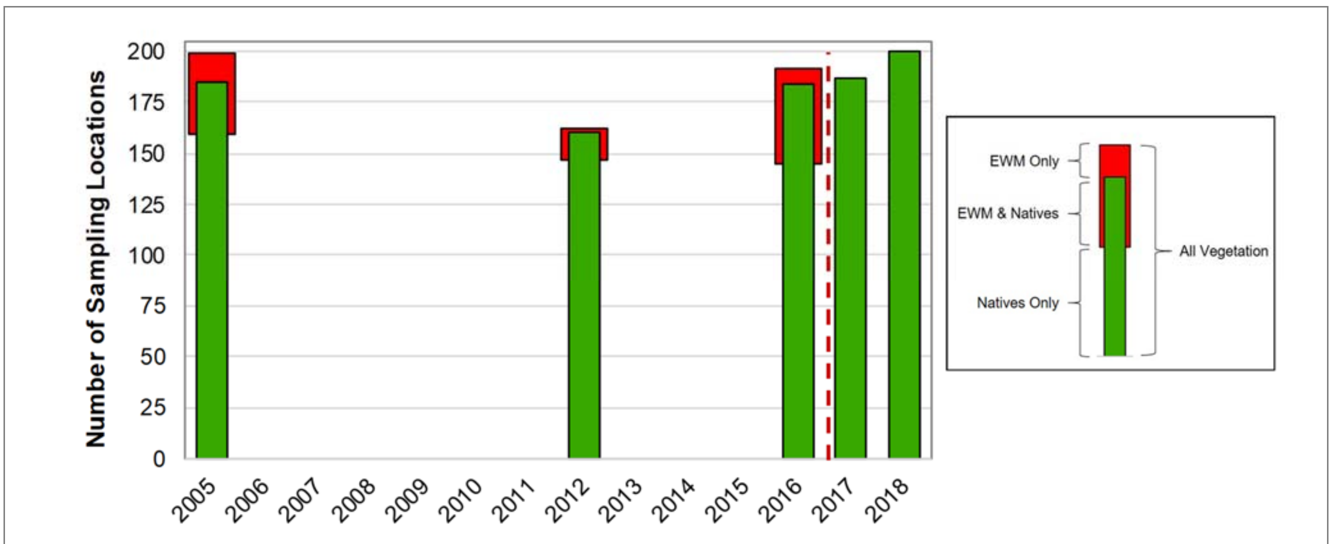


**Figure 7. Number of point-intercept sampling locations that contained native plants, EWM, or native plants and EWM during surveys completed from 2005-2018 in Pigeon Lake.** The red-dashed line indicates the 2017 whole-lake herbicide treatment.

Figure 8 shows a semi-quantitative analysis of the abundance of native aquatic plants by looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). Its important to note that Figure 7 shows the number of point-intercept points and Figure 8 shows the percent of littoral sampling locations. A slightly expanded littoral zone was noted in 2018. In 2012, 80% of the point-intercept sampling locations within the littoral zone contained vegetation compared to 97% in 2016, 88% in 2017, and 90% in 2018. It is important to note that the aquatic plant fullness in 2017 and 2018 is completely comprised of native plant species, whereas EWM was a contributor to the aquatic plant biomass in 2012 and 2016.

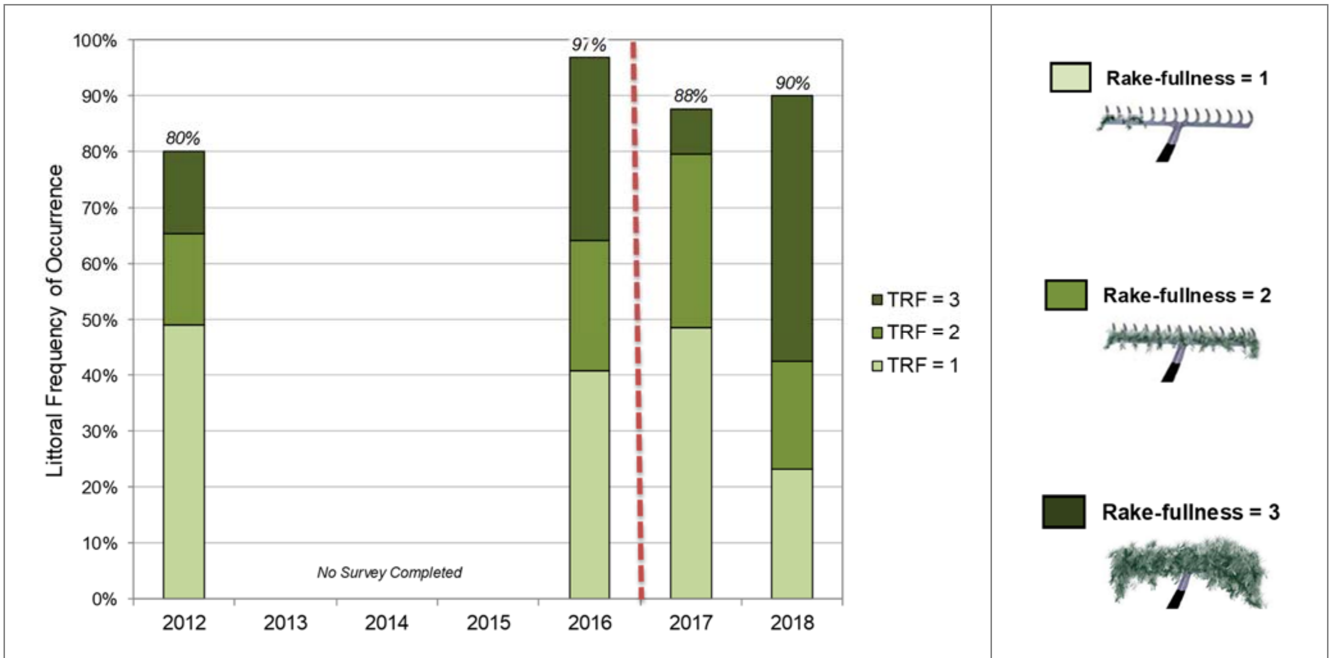


**Figure 8. Pigeon Lake total rake fullness ratings from 2012 – 2018.** Rake fullness ratings were not attributed during the 2005 survey. The red-dashed line indicates the 2017 whole-lake herbicide treatment.

Based upon the point-intercept surveys conducted between 2005-2018, Figure 9 shows mean littoral frequency of occurrence of each species (square black symbol), the population range (extent bars), and the 2018 littoral frequency of occurrence (red circle). These data indicate that most species have had littoral frequency of occurrence in 2018 similar to or greater the mean of this period.

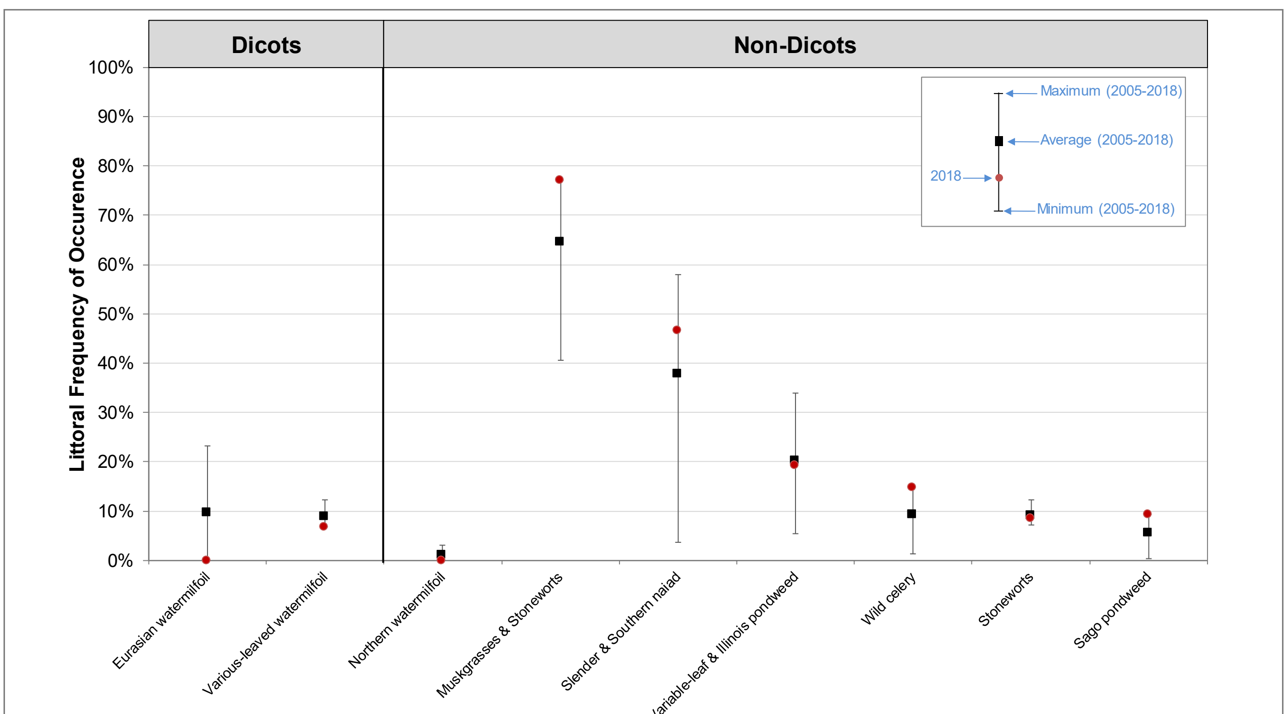


**Figure 9. Historic average aquatic plant frequencies (2005, 2016, 2017, & 2018) in Pigeon Lake.** Only species with a mean frequency of occurrence ≥2% are shown.

Figures 10-14 further investigates the littoral frequency of occurrence of specific aquatic plant species in Pigeon Lake from 2005-2018. Only species that exhibited at least a 2% littoral frequency of occurrence in at least one survey are displayed. A full matrix of all species through a chi-square analysis is included as an appendix.

EWM is a dicot (broad-leaved plant) and the herbicides (2,4-D) which have been used in Pigeon Lake in an effort to control EWM were historically believed to only have impacts to dicot species. Research conducted by the US Army Corps of Engineers, the WDNR, and private consultants have shown that certain non-dicot native plants are sensitive as well (Nault et al. 2018). Figure 10 shows how the two dicot species that had a littoral frequency of occurrence (LFOO) greater than 2% in any survey in Pigeon Lake have changed over time. Reductions in both various-leaved watermilfoil and northern watermilfoil were documented, although the difference in various-leaved watermilfoil populations were not statistically valid (Figure 4). Northern watermilfoil occurrences have not been noted post treatment.

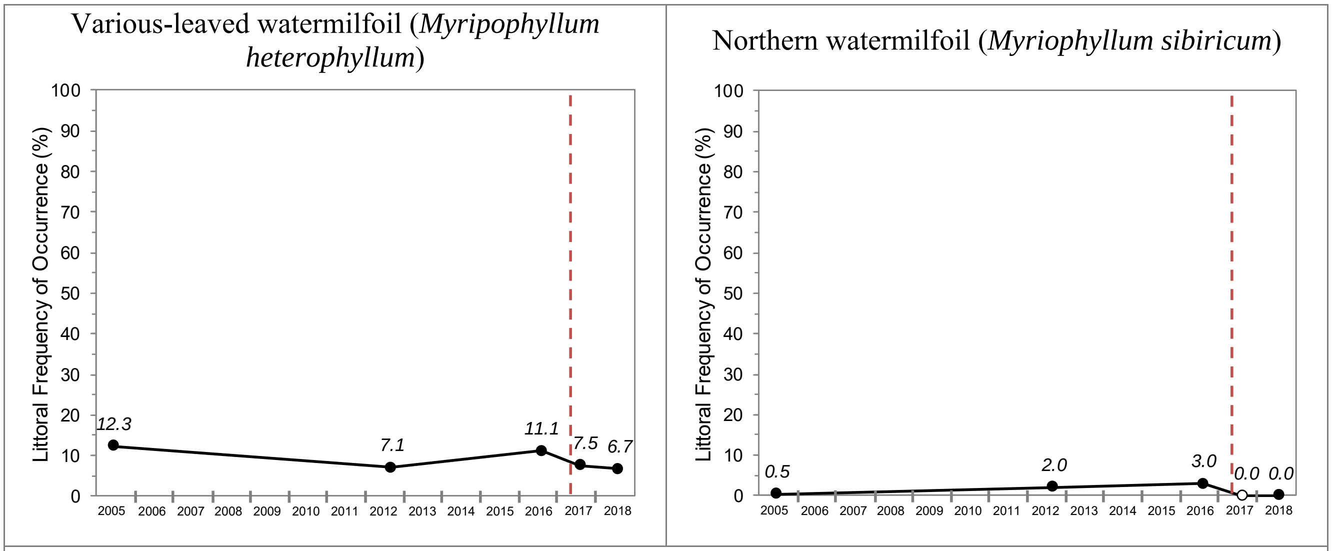


**Figure 10. Littoral occurrence of dicot species in Pigeon Lake.** Open circle indicates that occurrence is statistically different from previous survey (Chi-Square α = 0.05). Dashed line indicates large-scale treatment.

Muskgrasses and stoneworts are genera of macroalgae of which there are multiple species in Wisconsin (Photo 1). Dominance of the aquatic plant community by these charophytes is common in hardwater lakes like Pigeon Lake, and these macroalgae have been found to be more competitive against vascular plants (e.g. pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002; Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002). Due to their lack of vascular tissue, muskgrasses and stoneworts are unable to translocate herbicides; therefore, they are typically unaffected by herbicide use. As shown in Figure 11, muskgrasses and stoneworts were largely unimpacted by the 2017 control action and actually had a statistically valid population increase between 2016 and 2017, and a non-statistically valid population increase between 2017 and 2018.

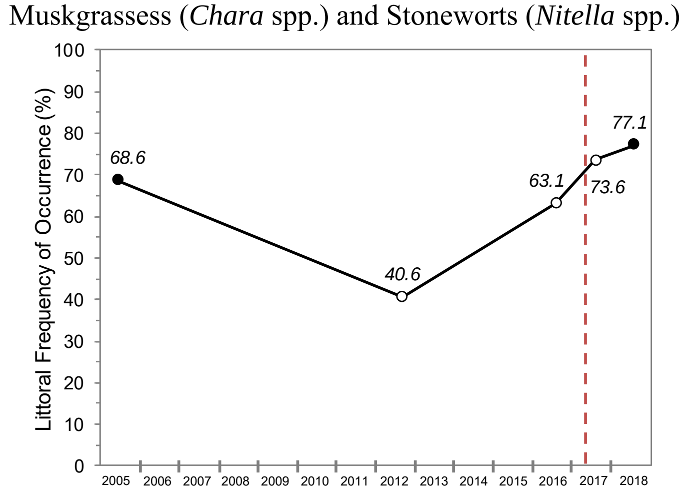


**Figure 11. Littoral occurrence of charophytes in Pigeon Lake.** Open circle indicates that occurrence is statistically different from previous survey (Chi-Square α = 0.05). Dashed line indicates large-scale treatment.

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

Together, naiad species are the most frequently encountered true-plants within Pigeon Lake. Slender naiad is a submersed annual plant that produces numerous seeds. Slender naiad is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 2014). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Southern naiad is similar to slender naiad, and they are often difficult to separate (Photo 2). While southern naiad is native to North America, observations have been indicating that populations of this plant have been expanding and behaving invasively, particularly in northern Wisconsin lakes. It is not known if this behavior represents recent introductions of these plants to waterbodies where it was not found naturally, or if certain environmental conditions are favoring the expansion of southern naiad.

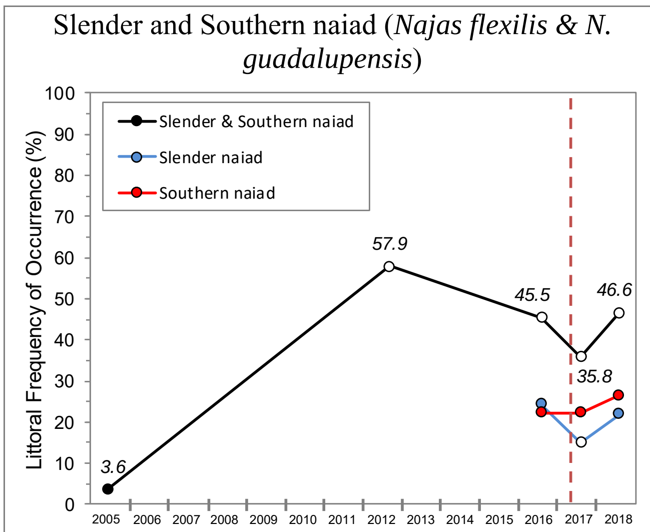


**Figure 12. Littoral occurrence of naiad species in Pigeon Lake.** Open circle indicates that occurrence is statistically different from previous survey (Chi-Square α = 0.05).

**Photo 2. Slender naiad (*Najas flexilis*; left) and southern naiad (*N. guadalupensis*; right).** Photo credit Onterra.

Slender naiad has been shown to be particularly susceptible to large-scale 2,4-D treatments during the year of treatment (Nault et al. 2018). Onterra's experience is that slender naiad populations often rebound as early as the year after treatment, often exceeding pretreatment levels. Southern naiad is typically more resilient to large-scale 2,4-D treatments but can be greatly impacted by other herbicides (e.g. fluridone). Point-intercept surveys in 2005 and 2012 did not differentiate between the two naiad species, therefore the analysis on Figure 12 shows how the pooled population of these species (black) over time as well as comparisons between 2016, 2017, and 2018 where the two naiad species were differentiated. Figure 6 suggests that slender naiad populations (blue) were impacted by the 2017 2,4-D treatment on Pigeon Lake, whereas the population of southern naiad remained unchanged (red). The 2018 point-intercept survey showed an increase in the populations of both naiad species, and a grouped value of occurrence which rebounded to an even higher value than in 2016 before the treatment.

Wild celery (Photo 3) emerges a little later than many native plant species and perhaps is dormant during the highest concentrations of the early-season treatment and thus less susceptible to its impacts. Towards the late-summer when water celery is at its peak growth stage, it is easily uprooted by wind and wave activity. The wild celery can then pile up on shorelines depending on the predominant wind direction. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife and are an important component of the Pigeon Lake ecosystem. Wild celery populations were statistically unchanged between 2016 and 2017, and saw a non-statistically valid increase in occurrence between 2017 and 2018 (Figure 13).

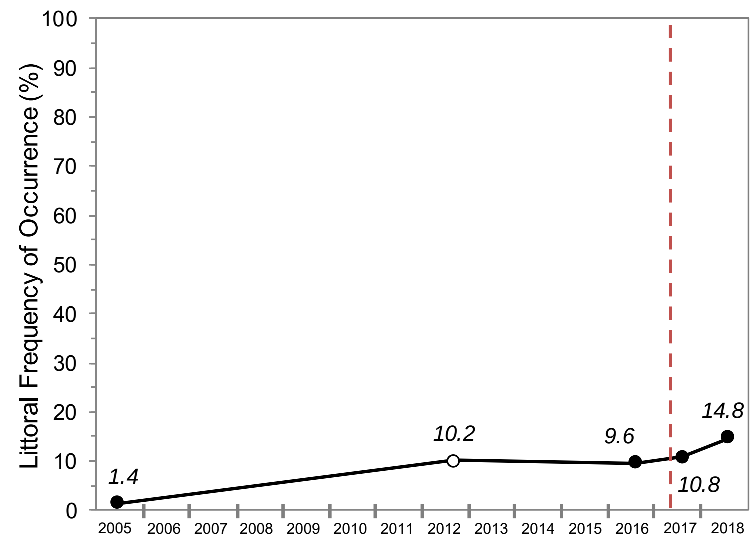


**Figure 13. Littoral occurrence of wild celery in Pigeon Lake.** Open circle indicates that occurrence is statistically different from previous survey (Chi-Square α = 0.05). Dashed line indicates large-scale treatment.

**Photo 3. Wild celery.** Photo credit Gary Fewless.

Within the point-intercept surveys, four pondweed species were found to have a population greater than 2% LFOO in one of the surveys (Figure 14). Three of the species are within the *Potamogeton* genus, whereas the fourth species is within the closely related *Stuckenia* genus. Onterra's experience is that some pondweed species have been relatively resilient to 2,4-D treatments, such as those with wider leaves like Illinois pondweed, variable pondweed, and large-leaf pondweed (not found in Pigeon Lake) while some of the narrow-leaved pondweeds like stiff pondweed are particularly vulnerable to this form of management.

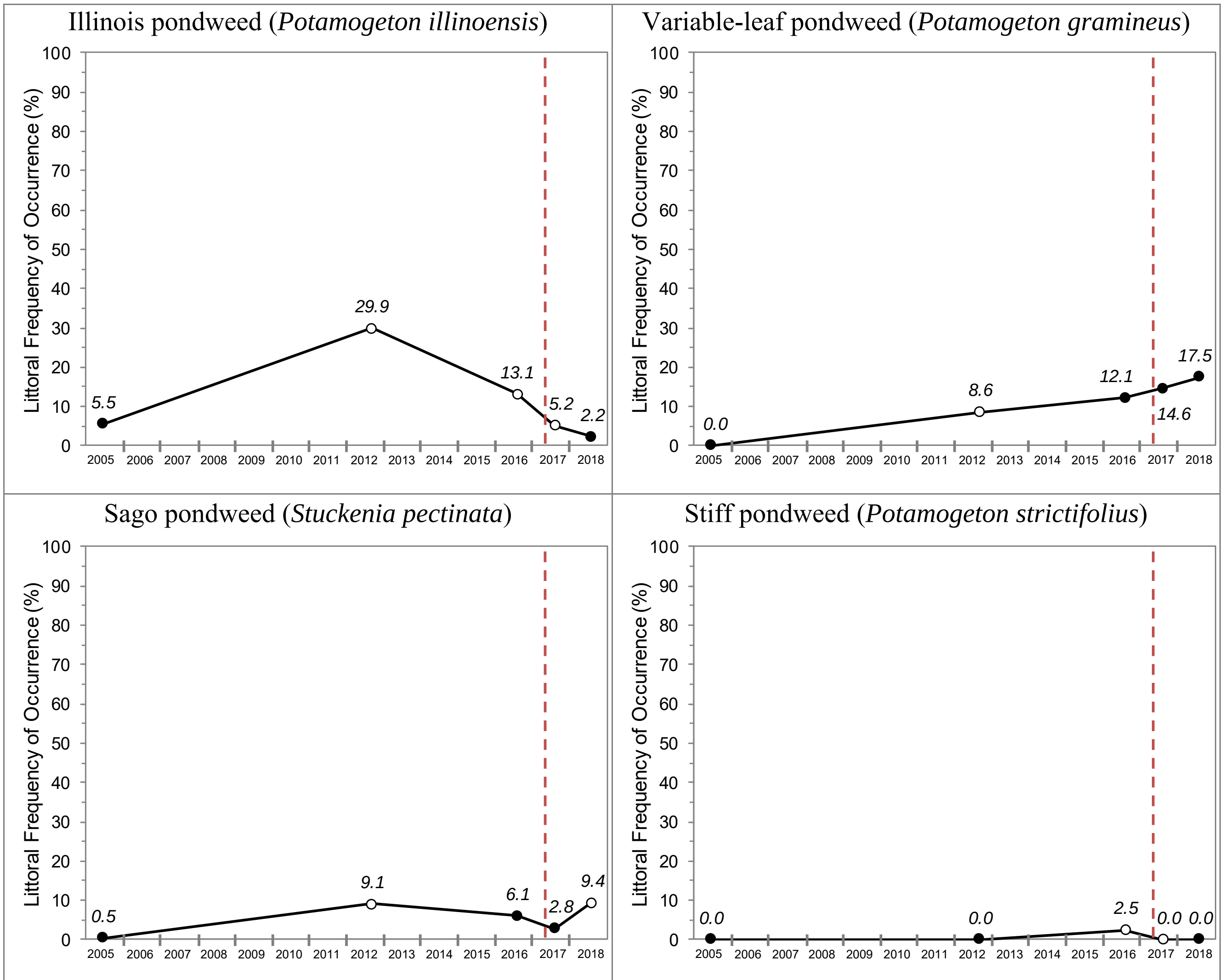


**Figure 14. Littoral occurrence of pondweed species in Pigeon Lake.** Open circle indicates that occurrence is statistically different from previous survey (Chi-Square α = 0.05). Dashed line indicates large-scale treatment.

On Pigeon Lake, Illinois pondweed populations peaked at approximately 30% in 2012 only to decline to 13.1 % in 2016 during a period with no herbicide management. Further reductions in this species' population occurred between 2016 and 2017, at least partially attributable to the large-scale 2,4-D treatment. A further non-statistically valid decline was seen between 2017 and 2018. Interestingly, populations of variable-leaf pondweed have been steadily increasing over time and appear to be unimpacted by the 2017 control strategy. Both sago pondweed and stiff pondweed both had population reductions between 2016 and 2017, although only the latter was statistically valid. In 2018, the occurrence of sago pondweed saw a statistically valid increase, to a value higher than seen in any of the previous surveys. Like in 2017, stiff pondweed was again not located in 2018.

## 2.2 EWM Mapping Surveys

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake. During 2018, a series of meander-based surveys were conducted to locate any EWM rebounding from the 2017 herbicide treatment. During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat. Field crews supplemented the visual survey by deploying a submersible camera along with periodically doing rake tows at locations in which dense EWM colonies were mapped in 2016 prior to the treatment (Figure 2).

The Early-Season AIS (ESAIS) Survey occurred on June 5, 2018. This late-spring/early-summer survey provides an early look at the lake to help guide any hand-harvesting management that may occur on the system during the summer months. Typically, the water clarity is higher at this time of year and the native plants have not progressed to their full biomass, allowing for easier detection of any EWM that may exist in the system. No EWM was located during this survey.

Onterra ecologists visited Pigeon Lake again on August 6, 2018 to conduct the Late-Summer EWM Peak-Biomass Survey to map the EWM population at its peak growth stage. Typically, at this time of year, EWM has progressed to its full potential and can easily be observed through surface-viewing. Again, no EWM was located during this survey.

## 2.3 Acoustic Bio-Volume Surveys

Onterra ecologists have also conducted acoustic-based surveys to measure the bio-volume of aquatic plants throughout the lake. While the map output does not differentiate between aquatic plant species, it indicates where high bio-volumes of vegetation exist in the lake. Conducting bio-volume surveys before and after herbicide treatments can also allow an understanding of how the macrophyte structure was influenced by the treatment, a set of data that have particular interest of fisheries managers.

During 2016, an acoustic survey was conducted to create a baseline understanding of the submersed aquatic vegetation in Pigeon Lake (Figure 15, left frame). This survey shows dense vegetation in red, likely EWM, in slightly deeper parts of the lake. The 2018 survey shows that native vegetation is still contained in most of these areas, but of more moderated density (orange) than pretreatment. The survey also shows increase of bio-volume in shallower waters, potentially corresponding with the increases of water celery and muskgrasses.

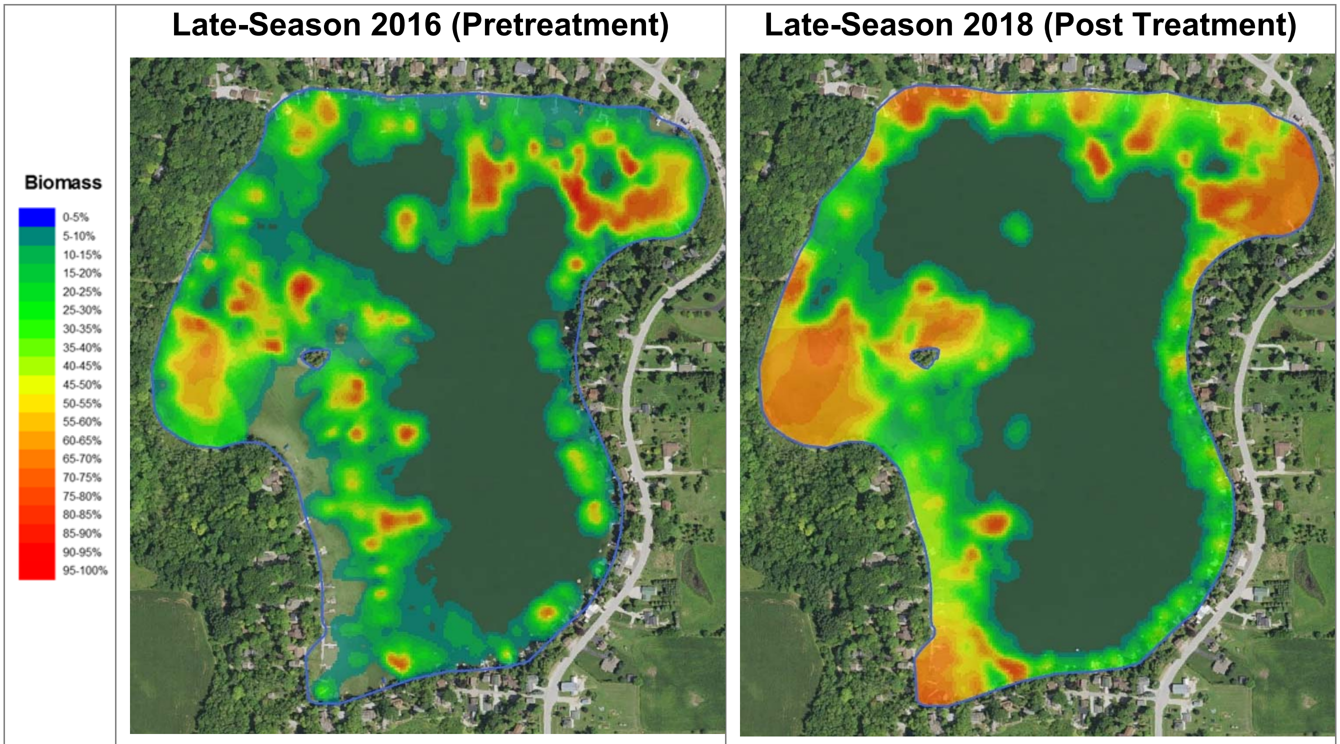


**Figure 15. Bio-acoustic survey results from Late-Summer 2016 & 2018 on Pigeon Lake.**

## 3.0 CONCLUSION AND DISCUSSION

The 2017 large-scale treatment was highly effective on controlling EWM, with no EWM being located during the *year of treatment* (2017) or the *year after treatment* (2018). While some impacts to the native aquatic plant population were noted, the magnitude of decline was less than anticipated by Onterra and less than was discussed with the PLMC during the pretreatment risk assessment.

Many lake groups initiate a whole-lake herbicide strategy with the intention of implementing smaller-scale control measures (e.g. herbicide spot treatments, hand-removal) when EWM begins rebounding. This is referred to as Integrated Pest Management (IPM). This approach has shown promise on some lakes. However, the EWM population rebounds on some lakes in a lake-wide fashion that does not lend well to these methods.

Onterra recommends the PLMC continue to monitor Pigeon Lake in 2019 to search for rebounding EWM to initiate an IPM program in an effort to preserve the gains made from the whole-lake treatment. Conducting a Late-Summer EWM Mapping Survey in 2019 would be advised, as this survey would be the best chance for detecting EWM and setting up an IPM strategy for 2020. Consideration should also be given to conducting an Early-Season AIS Survey, as this survey would be conducted early enough to initiate IPM activities in 2019 if appropriate. The point-intercept survey is a great way to track the population of native plants in Pigeon Lake, but would be less helpful in detecting EWM than the mapping surveys.

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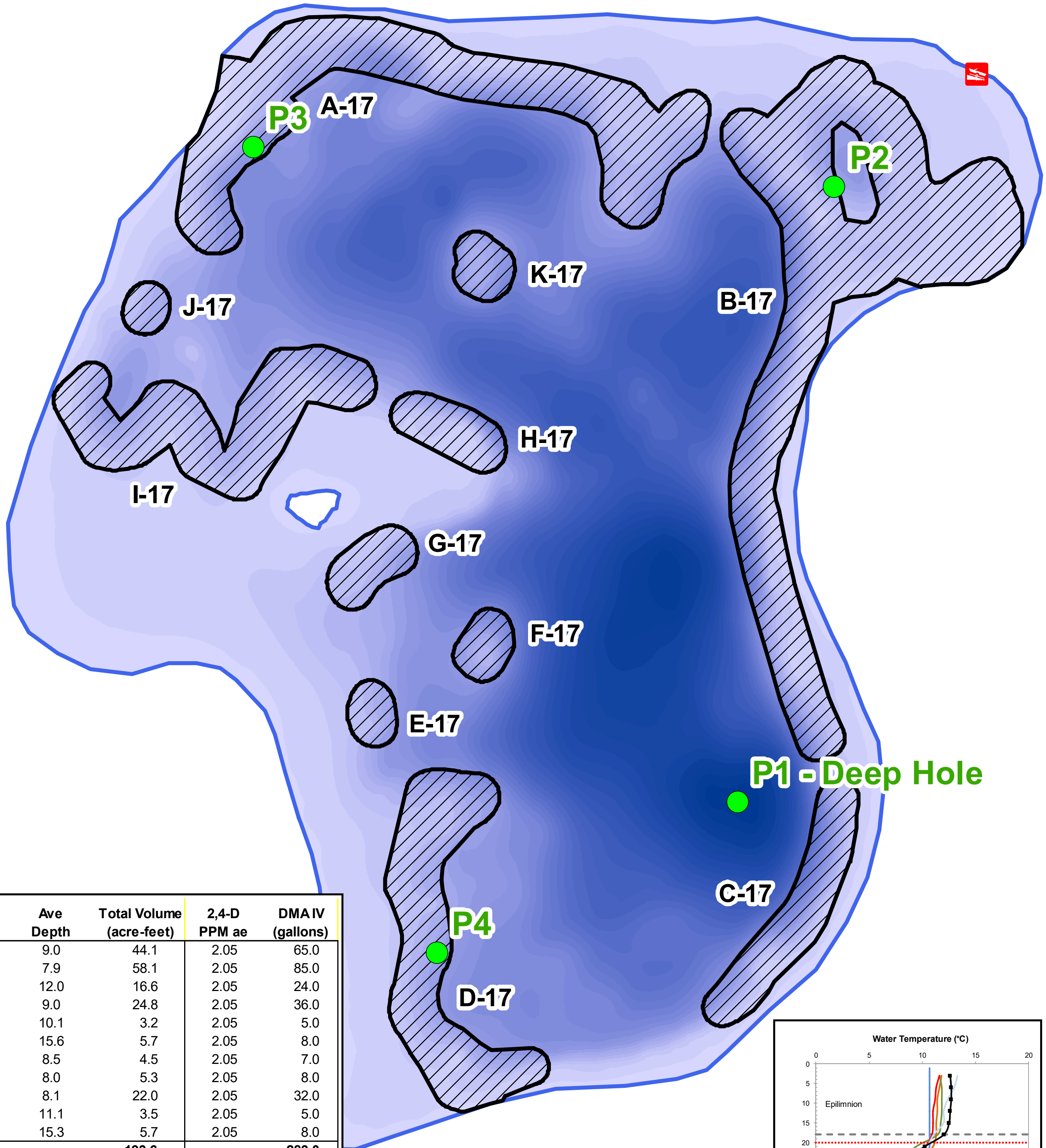
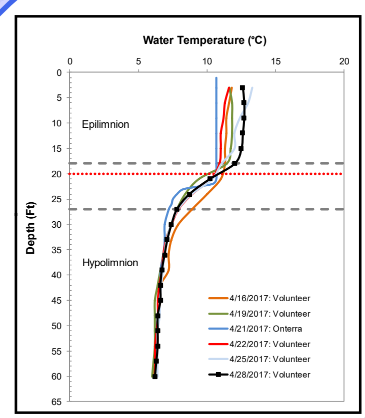



| Site | Acres | Ave Depth | Total Volume (acre-feet) | 2,4-D PPM ae | DMA IV (gallons) |
|---|---|---|---|---|---|
| A-17 | 4.9 | 9.0 | 44.1 | 2.05 | 65.0 |
| B-17 | 7.4 | 7.9 | 58.1 | 2.05 | 85.0 |
| C-17 | 1.4 | 12.0 | 16.6 | 2.05 | 24.0 |
| D-17 | 2.7 | 9.0 | 24.8 | 2.05 | 36.0 |
| E-17 | 0.3 | 10.1 | 3.2 | 2.05 | 5.0 |
| F-17 | 0.4 | 15.6 | 5.7 | 2.05 | 8.0 |
| G-17 | 0.5 | 8.5 | 4.5 | 2.05 | 7.0 |
| H-17 | 0.7 | 8.0 | 5.3 | 2.05 | 8.0 |
| I-17 | 2.7 | 8.1 | 22.0 | 2.05 | 32.0 |
| J-17 | 0.3 | 11.1 | 3.5 | 2.05 | 5.0 |
| K-17 | 0.4 | 15.3 | 5.7 | 2.05 | 8.0 |
| **Total** | **21.7** | | **193.6** | | **283.0** |

| *Method* | *Area (acres)* | *Epilimnetic Volume* | *Epilimnetic 2,4-D ppm ae* |
|---|---|---|---|
| 1966 WDNR Bathy Map (Trapezoidal) | 86.4 | 1061.6 | 0.373 |
| 2015 Acoustic (Trapezoidal) | 86.4 | 1063.0 | 0.372 |
| 2015 Acoustic (Histogram) | 85.8 | 1047.7 | 0.378 |

| | | | |
|---|---|---|---|
| Epilimnetic Depth (ft) | 20 | *Target:* | 0.375 |




N
W E
S

300
Feet

**Onterra LLC**
*Lake Management Planning*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*De Pere, WI 54115*
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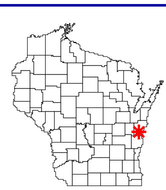
**Sources:**
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016
**Map Date:** April 18, 2017
*Filename: Pigeon_EWM_T2017_Perm1.mxd*



Project Location in Wisconsin

**Legend**

2017 Herbicide Application Area

Herbicide Concentration Sampling Location

Map 1

Pigeon Lake

Manitowoc County

**2017 Final EWM Treatment Strategy**

**From:** Josephine Barlament
**Sent:** Thursday, August 22, 2019 1:56 PM
**To:** Steve Meidl
**Subject:** Pigeon Lake (Manitowoc County) 2019 EWMPB Survey Results

Hi Steve,

On Monday I, along with one of Onterra's summer interns, conducted the Late-Season Eurasian Watermilfoil Mapping Survey on Pigeon Lake in Manitowoc County. Weather conditions were excellent with 10% cloud cover, temperatures in the low 80's and nearly no wind. A Secchi disk reading of 9.6 ft was taken during the survey. In addition to our visual survey, we used a rake pole and underwater camera to check previously known locations of dominant EWM colonies from before the treatment. Ultimately one EWM occurrence, which contained a couple plant stalks, was found on Pigeon Lake in 8 feet of water; see map attached with this location indicated as *single or few plants*. This plant was viewable from the surface and partially pulled with a rake for positive ID during the survey. After the plant was partially pulled (and a positive ID was discovered) we attempted to remove the root crown of the plant, however, the now shorter plant was lost within the dense native plant community. The plant biomass was reduced but the root crown was not removed. This occurrence was found in front of a parcel owned by the Elizabeth M Naylon Revoo Liv Trust according to our 2016 parcel data to give you an idea of location. Native vegetation was observed from the surface in 10ft of water or less including variable pondweed (*Potamogeton gramineus*), sago pondweed (*Stuckenia pectinata*), wild celery (*Vallisneria americana*), and northern watermilfoil (Myriophyllum sibiricum) to name a few.

Moving forward we suggest continued monitoring of the EWM population with particular attention to the known area found this year. An aggressive approach could be to hire a company to investigate the area with scuba gear and remove any EWM encountered. We could pass along some names; the costs may be a$1.5-$2K for a day. Another route would be to find some trained volunteers to investigate this area. As you most likely know, Tom Ward may be a good contact for training or knowing some trained folks.

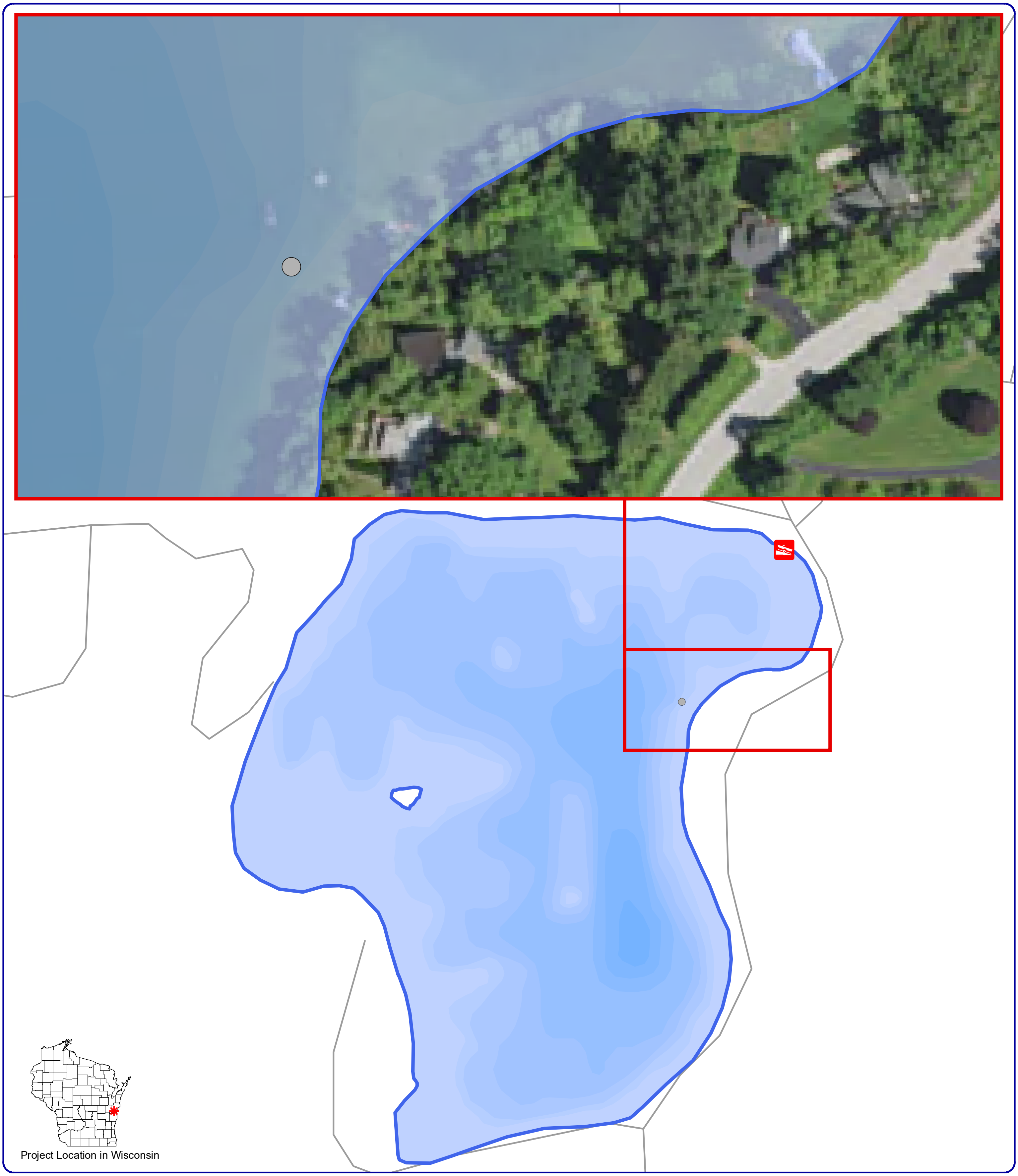
Based upon how your group would like to move forward, we can discuss if you would like Onterra to conduct surveillance surveys again next year. Eddie is on vacation next week, but would be glad to assist with these discussions upon his return.

Please share this information with the lake group as appropriate.

Thank you,

Jo

**Josephine Barlament**
Aquatic Field Technician
*Onterra, LLC*




# Legend

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

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**Sources:**
Roads and Hydro:WDNR
Aquatic Plants: Onterra, 2019
**Map Date:** August 19, 2019
*Filename: Pigeon_EWM_PB_Aug19.mxd*

Pigeon Lake
Manitowoc County

**August 2019 EWMPB Survey Results**

**From:** Heather Lutzow
**Sent:** Wednesday, August 5, 2020 2:25 PM
**To:** Steve Meidl
**Subject:** Pigeon of Manitowoc County - AIS survey

Good afternoon Steve,
Just wanted to follow up with you on our EWM survey results even though we saw each other toward the tail end of the survey today. It was perfect weather for an AIS survey!
Two different people on the lake stopped us today to ask about the water clarity. I did note that there had been an algae bloom there so the water was not as clear as usual, but visibility was sufficient to complete the survey.
The whole littoral area of the lake was visually surveyed, and no EWM was located. We did spend some extra time over by where the single point was taken in 2019. We did some transects using our submersible camera and only saw native plants. We also did some rake tows while over the 2019 point, and again only native plants came up.
Please pass the good news on to the rest of your group, and feel free to let us know if you have any other questions.

Thank you!

Heather

*Heather Lutzow*
Aquatic Field Technician
Onterra, LLC

# APPENDIX A

| | Scientific Name | Common Name | LFOO (%) 2005 | 2012 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| Dicots | *Myriophyllum spicatum* | Eurasian watermilfoil | 18.2 | 7.6 | 23.2 | 0.0 | 0.0 |
| | *Myriophyllum heterophyllum* | Various-leaved watermilfoil | 12.3 | 7.1 | 11.1 | 7.5 | 6.7 |
| | *Nymphaea odorata* | White water lily | 0.5 | 1.5 | 0.5 | 0.5 | 1.8 |
| | *Myriophyllum sibiricum* | Northern watermilfoil | 0.5 | 2.0 | 3.0 | 0.0 | 0.0 |
| | *Ceratophyllum demersum* | Coontail | 1.4 | 0.5 | 0.0 | 1.4 | 0.9 |
| | *Nuphar variegata* | Spatterdock | 0.0 | 0.5 | 0.0 | 0.5 | 0.4 |
| | *Myriophyllum tenellum* | Dwarf watermilfoil | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 |
| Non-dicots | *Potamogeton crispus* | Curly-leaf pondweed | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Chara spp. & Nitella spp.* | Muskgrasses & Stoneworts | 68.6 | 40.6 | 63.1 | 73.6 | 77.1 |
| | *Chara spp.* | Muskgrasses | 60.9 | 35.5 | 55.6 | 63.2 | 70.4 |
| | *Najas flexilis & N. guadalupensis* | Slender & Southern naiad | 3.6 | 57.9 | 45.5 | 35.8 | 46.6 |
| | *Najas flexilis* | Slender naiad | 3.6 | 57.9 | 24.2 | 15.1 | 22.0 |
| | *Potamogeton gramineus & P. illinoensis* | Variable-leaf & Illinois pondweed | 5.5 | 34.0 | 23.2 | 19.3 | 19.3 |
| | *Najas guadalupensis* | Southern naiad | 0.0 | 0.0 | 22.2 | 22.2 | 26.5 |
| | *Potamogeton gramineus* | Variable-leaf pondweed | 0.0 | 8.6 | 12.1 | 14.6 | 17.5 |
| | *Vallisneria americana* | Wild celery | 1.4 | 10.2 | 9.6 | 10.8 | 14.8 |
| | *Potamogeton illinoensis* | Illinois pondweed | 5.5 | 29.9 | 13.1 | 5.2 | 2.2 |
| | *Nitella spp.* | Stoneworts | 10.0 | 7.1 | 7.6 | 12.3 | 8.5 |
| | *Stuckenia pectinata* | Sago pondweed | 0.5 | 9.1 | 6.1 | 2.8 | 9.4 |
| | *Filamentous algae* | Filamentous algae | 0.0 | 0.0 | 0.5 | 2.4 | 1.8 |
| | *Fissidens spp. & Fontinalis spp.* | Aquatic Moss | 0.0 | 0.0 | 1.0 | 1.4 | 1.8 |
| | *Schoenoplectus acutus* | Hardstem bulrush | 0.0 | 0.0 | 1.0 | 0.5 | 1.3 |
| | *Potamogeton natans* | Floating-leaf pondweed | 0.9 | 0.0 | 0.0 | 0.0 | 0.9 |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 |
| | *Potamogeton strictifolius* | Stiff pondweed | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 |
| | *Typha spp.* | Cattail spp. | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| | *Potamogeton pusillus* | Small pondweed | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| | *Freshwater sponge* | Freshwater sponge | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 |
| | *Schoenoplectus tabernaemontani* | Softstem bulrush | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 |
| | *Eleocharis acicularis* | Needle spikerush | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 |