1.0 INTRODUCTION

Upper Kaubashine Lake is a 190-acre spring lake in Oneida County. Eurasian watermilfoil (EWM) was first discovered in the lake in July of 2013 along the lake's northwest side. Genetic analysis has indicated that of the few samples tested to date, all are were confirmed as pure-strain EWM rather than a hybrid variety.

Photo 1. Upper Kaubashine Lake, Oneida County. Photo by Onterra, August 22, 2018.

The Upper Kaubashine Property Owners Association (UKPOA) partnered with the Town of Hazelhurst and were awarded a three-year Aquatic Invasive Species (AIS) Early Detection & Response (EDR) in February 2014 (AIRR-169-14) to initiate monitoring and hand-removal actions in 2014-2016. In 2014-2015, the UKPOA contracted with a professional hand-harvesting firm that removed approximately 1,300 gallons of EWM from the lake. These efforts provided some seasonal reductions in the EWM population in the areas where removal actions took place, but ultimately were shown to be insufficient to maintain or reduce the EWM population in the lake.

During a July 2015 UKPOA annual meeting, Onterra and UKPOA representatives discussed the increasing concerns regarding the EWM population in the lake. Control strategies were discussed including addition of a Diver Assisted Suction Harvest (DASH) component to the hand-harvesting. The use of spot and large-scale herbicide treatments was also discussed. The AIS-EDR grant category is intended to provide funding to lake groups to "*provide early identification and control of pioneer populations of AIS*". In the WDNR's review, it was stated that actions such as the use of DASH or herbicide spot treatment would not be in line with the AIS-EDR's intended goal as the population progressed past a pioneer phase and therefore were disallowed from the project.

The WDNR also voiced concerns about the lack of an approved lake management plan for Upper Kaubashine Lake. A lake management plan would document the current state of the lake in terms of various biologic factors (e.g. water quality, watershed, aquatic plants, fisheries) in addition to drawing off historical information on these parameters. A lake management plan would also create an implementation plan which would help guide management and monitoring actions in the future, which on Upper Kaubashine Lake would include the development of a management strategy for EWM. To aid in the planning process, a stakeholder survey is often sent to lake riparians to understand riparian sentiments on the direction of management and their level of support for various management strategies (e.g. herbicide treatment). The WDNR granted a second AIS-EDR Grant (AIRR-208-16) in February 2016 to offset the costs of continued EWM monitoring as well a portion of the tasks required to create an Aquatic Plant Management Plan.

The EWM population was monitored in 2016 and 2017 during which the population continued to expand in the lake (Map 1). A late-summer 2016 EWM mapping survey indicated that the population expanded to include approximately 26.5 acres of colonized plants in addition to numerous smaller sized occurrences mapped with point-based methodologies. By the late-summer of 2017, the population was found to cover approximately the same footprint, however an increase in density was evident in many colonies as more colonies were described as either *dominant*, *highly dominant,* and *surface matting* in densities. Quantitative monitoring in the form of whole-lake point-intercept surveys showed an increasing littoral frequency of occurrence of the EWM population from 0% in 2013 to over 35% in 2017.

The expanding EWM population in Upper Kaubashine Lake led to the UKPOA to consider various management strategies for Upper Kaubashine Lake during the creation of the lake management plan. The *Upper Kaubashine Lake Comprehensive Management Plan* was finalized and approved by the WDNR in December 2018. This document contains 21 pages (pg 51-72) of expanded discussion specific to EWM management within Upper Kaubashine Lake. The Implementation Plan Section (5.0) of the Comprehensive Management Plan contains management goals and associated management actions, including those the association constructed to manage and monitor the EWM population of Upper Kaubashine Lake. Reference to the *Upper Kaubashine Lake Comprehensive Management Plan* (Dec2018) will improve understanding of this document.

On June 28, 2017 the UKPOA Planning Committee voted 4 (in favor) to 2 (against) pursuing large-scale herbicide treatment strategy to present to the membership for consideration. Prior to the 2017 UKPOA annual meeting, the Planning Committee with review from Onterra and the WDNR, distributed a *10 Eurasian Watermilfoil Myths and Facts* factsheet. At the meeting, both dissenting Planning Committee members were given an opportunity to explain to the attendees why they were not in favor of a large-scale herbicide control strategy. Some other UKPOA members then voiced their opinion, either for or against herbicide use. The UKPOA membership voted 72 *for* and 18 *against* to give the Board of Directors permission to make the decision on how to proceed. The board voted to move forward with a whole-lake 2,4-D treatment during the spring of 2018.

The UKPOA and the third-party applicator selected by the association, Clean Lakes, started the WDNR permit application process during mid-March 2018. A component of the permit application includes publishing a notice of the permit request in the local newspaper, including acknowledgement that the applicant would hold a public information meeting if requested by five or more individuals or entities. Fifteen individuals, largely from Lower Kaubashine Lake, submitted letters to the WDNR during the five days following the notice requesting a public informational meeting. According to WDNR administrative code, the individuals requesting the public information meeting set the agenda, so a representative of the Lower Kaubashine Lake Association provided that agenda in the form of a series of questions. The meeting was held on April 17, 2018 at the Hazelhurst Town Hall, with representatives from WDNR and Onterra addressing the questions posted as the agenda, as well as follow-up questions from the approximately 80 attendees. The meeting was facilitated by an impartial moderator.

The WDNR approved the UKPOA's permit application on May 10, 2018. No individuals or entities challenged the permit issuance. This report discusses the planning, monitoring, and implementation of the 2018 whole-lake 2,4-D treatment on Upper Kaubashine Lake during the *year of treatment* (2018).

1.1 Whole-Lake 2,4-D Treatment Strategy

From an ecological perspective, large-scale treatments are those where the herbicide may be applied to specific sites, but when the herbicide dissipates from where it was applied and reaches equilibrium within the entire mixing volume of water (within the epilimnion of the lake); it is at a concentration that is sufficient to cause mortality to the target plant within that entire volume. An article by Nault et al. 2018 investigated 28 large-scale herbicide treatments in Wisconsin and found that "herbicide dissipation from the treatment sites into surrounding untreated waters was rapid (within 1 day) and lake-wide low-concentration equilibriums were reached within the first few days after application." In other words, the herbicide dissipates out of the application area and reaches a lake-wide equilibrium concentration within a few days after the treatment occurs. Further, the subsequent herbicide concentration in the lake is largely driven by the rate of microbial degradation. In some lakes that have an outlet, herbicide dissipation out of the lake can also influence in-lake herbicide concentrations.

The control strategy developed for Upper Kaubashine Lake included the application of liquid 2,4-D amine over approximately 34 acres of high-density EWM in order to achieve a target lake-wide epilimnetic concentration of 0.300 ppm acid equivalent (ae). Onterra typically recommends a target lake-wide 2,4-D concentration between 0.300 ppm ae and 0.375 ppm ae for pure-strain EWM large-scale 2,4-D treatments. The target concentration prescribed for Upper Kaubashine is toward the lower range of Onterra's current dosing strategies to account for a potentially slower degradation pattern due to the moderate productivity (mesotrophic biological parameters) of the system. While Upper Kaubashine has an outlet, the herbicide loss from this source was hypothesized to have minimal impact on the in-lake concentrations. The strategy also accounts for the western basin being targeted in a manner that would aid in even herbicide concentration in this protected part of the lake that might not experience the water exchange patterns as the main body of the lake

In the summer of 2017, Onterra ecologists conducted an acoustic survey of Upper Kaubashine Lake to obtain accurate bathymetric data for the proposed 2018 treatment to ensure accurate herbicide dosing (Figure 1). This ensures that the dosing strategy is appropriate to impact the target plant and to minimize collateral effects on the native plant community. These data are particularly important for Upper Kaubashine Lake as small changes in anticipated herbicide mixing depth can have large differences in water volumes. Volume calculations utilizing the data obtained from the acoustic data indicate the entire water volume of Upper Kaubashine Lake to be approximately 5,092 acre-feet.

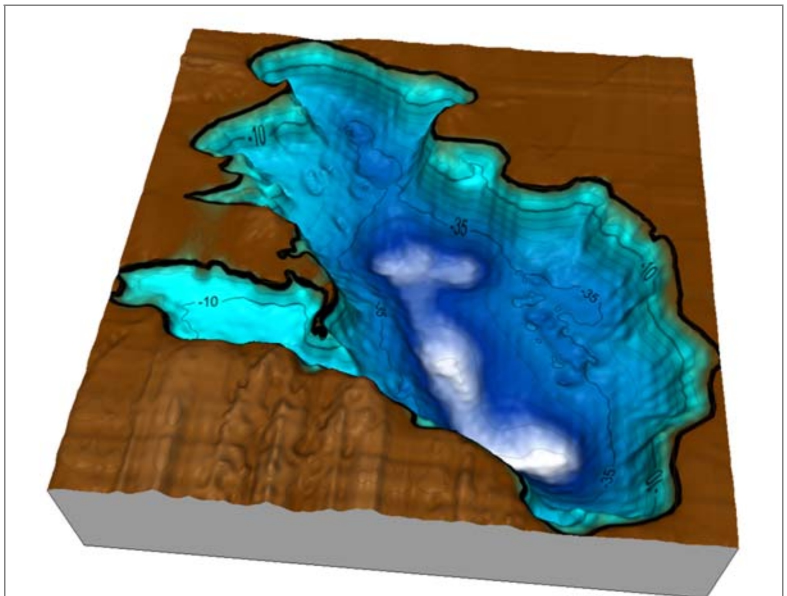


Figure 1. 3-D model of Upper Kaubashine Lake's Bathymetry. Bathymetry model based on 2017 acoustic survey. Model not applied to surrounding shorelands.

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 2018 treatment on Upper Kaubashine Lake was anticipated to have whole-lake affects, 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 2017 (*year prior to treatment*), 2018 (*year of treatment*), and planned for 2019 (*year following treatment*).

As outlined within the *Upper Kaubashine Lake Comprehensive Management Plan* (Dec2018), the success criteria of a whole-lake 2,4-D treatment on Upper Kaubashine Lake would be a 70% reduction in EWM littoral frequency of occurrence comparing point-intercept surveys from the *year prior to the treatment* (2017) to the *year after the treatment* (2019). Understanding the EWM population in 2018 (*year of treatment*) is important, but an insufficient time has 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 will be conducted annually through EWM mapping surveys on Upper Kaubashine 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 association with the 2018 treatment in Upper Kaubashine Lake, 2,4-D concentrations were monitored to determine if the target concentrations had been met as well as to evaluate concentrations in the downstream waterbodies including Kaubashine Creek and Lower Kaubashine Lake. 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 eight sites (Figure 2) at time intervals of approximately 1, 3, 5, 7, 14, 21, 35, 49,70, and 100 days after treatment (DAT) using an integrated sampler or Van Dorn sampler. The samples were preserved with acid and shipped to the Wisconsin State Lab of Hygiene (SLOH) where the herbicide analysis is completed. A volunteer from Lower Kaubashine Lake assisted with the collection of water samples at LK1, LK2, and LK3. A volunteer from Upper Kaubashine Lake collected the water samples in Upper Kaubashine Lake and in the outlet beaver pond (KC).

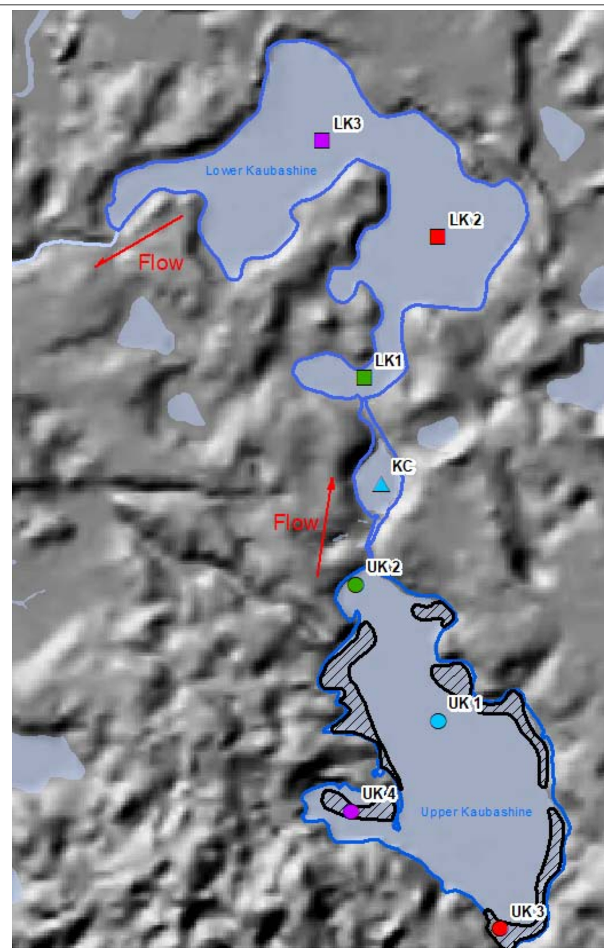


Figure 2. Herbicide concentration monitoring plan.

2.0 PRETREATMENT SURVEY AND FINAL DOSING

In order to finalize the dosing volume for the 2018 treatment, it was necessary to understand the volume of water in which the herbicide is expected to mix. As the water warms, a thermal barrier develops in many lakes essentially separating the lake into an upper epilimnion with warmer water temperatures and a lower hypolimnion with cooler water temperatures (Figure 3). The transitional area separating the upper and lower portions of the water column or metalimnion, is used to calculate the dosing volume for the herbicide treatment. Volunteers from the UKPOA provided numerous temperature profiles in the days and weeks leading up to the whole-lake herbicide treatment on Upper Kaubashine Lake (Figure 4).

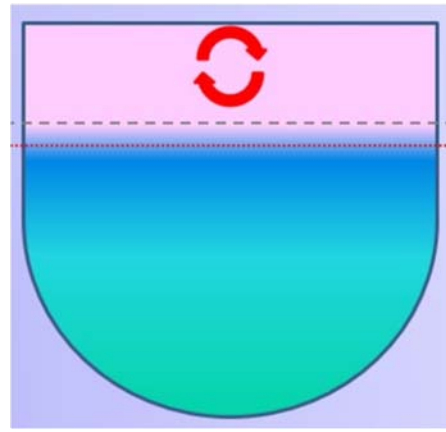


Figure 3. Mixing zone of a stratified lake. Grey dashed line indicates start of metalimnion. Red dashed line indicates mixing volume used in dosing calculations.

On May 24, 2018, Onterra ecologists conducted the Spring Pre-treatment Confirmation and Refinement Survey on Upper Kaubashine Lake. During this survey, the presence of actively growing EWM was confirmed within the proposed treatment sites. A temperature profile indicated the near-surface water temperature in the lake was 66°F and the lake was weakly stratified between approximately 9 and 15 feet (Figure 4). No alterations were made to the herbicide application areas following the pre-treatment survey, however continued monitoring of the thermal stratification parameters was required.

Based upon profiles collected in June 2017, Upper Kaubashine Lake's top water layer (epilimnion) mixed down to 15 feet. For planning purposes during the winter of 2017-2018, discussions were based off stratification down to 18 feet to ensure the lake group was financially prepared if it stratified a little deeper in 2018 compared to 2017. Early projections in mid-May 2018 indicated that Upper Kaubashine Lake was starting to stratify at a depth of approximately 15 feet. However, the cool spring followed by a late-May heat wave resulted in a different stratification pattern emerging. The late-May 2018 temperature profiles suggested the epilimnion only extended down about 6 feet. Acknowledging that some herbicide will undoubtedly mix into the middle water layer (metalimnion), Onterra typically predicts the herbicide mixing depth a few feet below the bottom of the epilimnion.

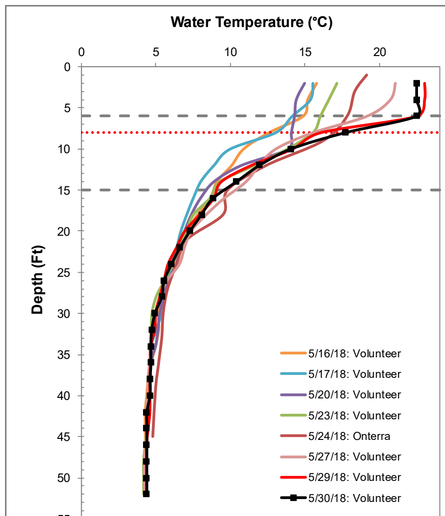


Figure 4. Pre-Treatment Temperature Profiles on Upper Kaubashine Lake. Red dotted line indicates dosing depth used for 2018 treatment (8ft).

For Upper Kaubashine Lake in 2018, Onterra recommended a mixing volume that extends down 8 feet (Figure 4). Onterra indicated that it was likely that surface waters of Upper Kaubashine Lake would cool and the epilimnion may extend a little deeper. This would result in the potential for a slightly lower herbicide concentration. With the potential for a slower 2,4-D degradation pattern on Upper Kaubashine Lake, Onterra's position was that it would be better to be slightly below targets than risk having too high of concentrations that could have greater impacts to the native plant community of the lake. Onterra was averse to postponing the treatment any longer for concerns of increased potential impact to native plant communities as the season progressed.

Map 2 displays the final whole-lake 2,4-D treatment designed for Upper Kaubashine Lake in 2018. The treatment included application of liquid 2,4-D at between 0.9-2.1 ppm acid equivalent (ae) over 34.3 acres of the lake. It was expected that the herbicide would mix throughout the entire epilimnion of the lake (8 feet) following the application, resulting in a target whole-lake epilimnetic 2,4-D concentration of 0.300 ppm ae.

Due to the later than usual ice-off in spring 2018, the WDNR wanted to evaluate whether the EWM population may be suppressed in 2018 if left untreated. To accomplish this task, WDNR staff completed a pretreatment whole-lake point-intercept survey on May 24, 2018. This survey would allow for a quantitative assessment of the EWM population as well as provide insight as to which native aquatic plant species were present prior to the herbicide treatment. If the data showed a minimal EWM population, consideration for postponing the herbicide treatment strategy would be made.

The results of the survey found EWM to be present on 72 of the 231 sampling sites that were within the littoral area of the lake resulting in a littoral frequency of occurrence of 31.2%. At 31.2%, the EWM population documented during this survey was similar to the 35.2% occurrence that was observed during the summer 2017 point-intercept survey and suggested that the EWM population was likely to be of a similar footprint in 2018 as was observed in 2017. Native aquatic plants were also recorded during the survey and found that the most common species at the time of the survey included common waterweed (23.8% occurrence), muskgrasses (19.5% occurrence), and coontail (17.3% occurrence).

The herbicide treatment was conducted by Clean Lakes, Inc on May 31, 2018 using a liquid formulation of 2,4-D amine (DMA 4 IVM). The herbicide was applied to the upper half of the water column through sub-surface injection using weighted hoses. The applicator reported a near-surface water temperature of approximately 73-74°F and westerly winds (1-12 mph) at the time of application.

3.0 2018 MONITORING RESULTS

3.1 Herbicide Concentration Monitoring in Surface Waters

Figure 5 shows the results of the volunteer-based 2,4-D monitoring that occurred in association with the 2018 large-scale treatment on Upper Kaubashine Lake. Herbicide concentrations were near the application target in three of the four surface samples during the 1 DAT interval. Concentrations were fairly uniform by about 3 DAT indicating that mixing had occurred within the lake-wide (or basin-wide) epilimnion. Herbicide monitoring following the treatment found that the mean 1-14 DAT concentration was 0.180 ppm ae (Figure 4).

Herbicide persistence was similar to predicted, with concentrations exceeding the irrigation threshold (0.1 ppm ae) for at least 21 days (model suggest 25 DAT). Through a log-linear regression analysis (r^2=0.93), the 2,4-D half-life for the 2018 treatment in Upper Kaubashine Lake was found to be 22.5 days, meaning that every 22.5 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

22.75 days. The 22.5-day half-life from Upper Kaubashine Lake in 2018 falls within the 48th percentile of this dataset (i.e. similar to the median).

Herbicide concentrations exceeded the irrigation threshold (0.1 ppm ae) through approximately 21 DAT. Concentrations degraded to approximately 0.05 ppm ae by 35 DAT and were sustained at approximately that level through 70 DAT. The black square symbols on Figure 4 represent the samples that were collected from the UK 1 deep hole site from a depth of 30 feet. The herbicide concentrations from each of the deep samples confirm that minimal 2,4-D migrated below the thermal temperature gradient separating the epilimnion from the hypolimnion between the time of application and at least 21 DAT.

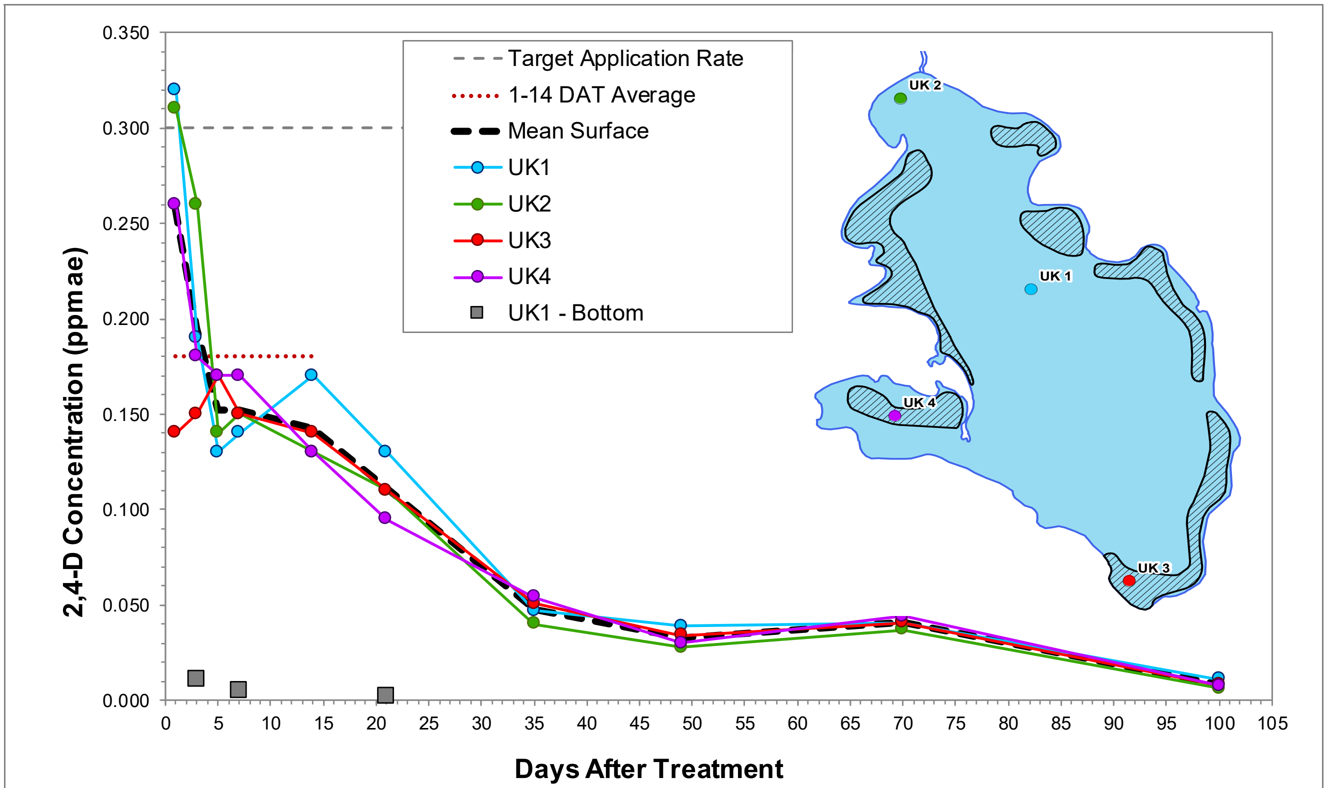


Figure 5. Upper Kaubashine Lake 2018 Herbicide Concentration Monitoring Results from five monitoring locations.

Water samples in the downstream Kaubashine Creek beaver pond (KC) and Lower Kaubashine Lake (LK1-LK3) were also collected to determine 2,4-D concentrations (Figure 6). Herbicide concentrations in the beaver pond were 0.13-0.14 ppm ae during the 3 DAT and 7 DAT sampling events, respectively. By 21 DAT, the concentrations were at 0.023 ppm ae and below detection at 49 DAT. Onterra believes the concentrations observed in the beaver pond may have been sufficient to have impacts (likely sub-lethal impacts) to some sensitive native plants if present, but do not anticipate impacts to floating-leaf (i.e. water lilies) or nearshore emergent plants at these concentrations.

Herbicide concentrations within the upstream part of Lower Kaubashine peaked at 0.71 ppm ae at 7 DAT and were found at below 0.005 ppm ae at all subsequent sampling events. Herbicide concentrations in LKI2 and LK3 were not observed above 0.005 ppm ae in any of the samples.

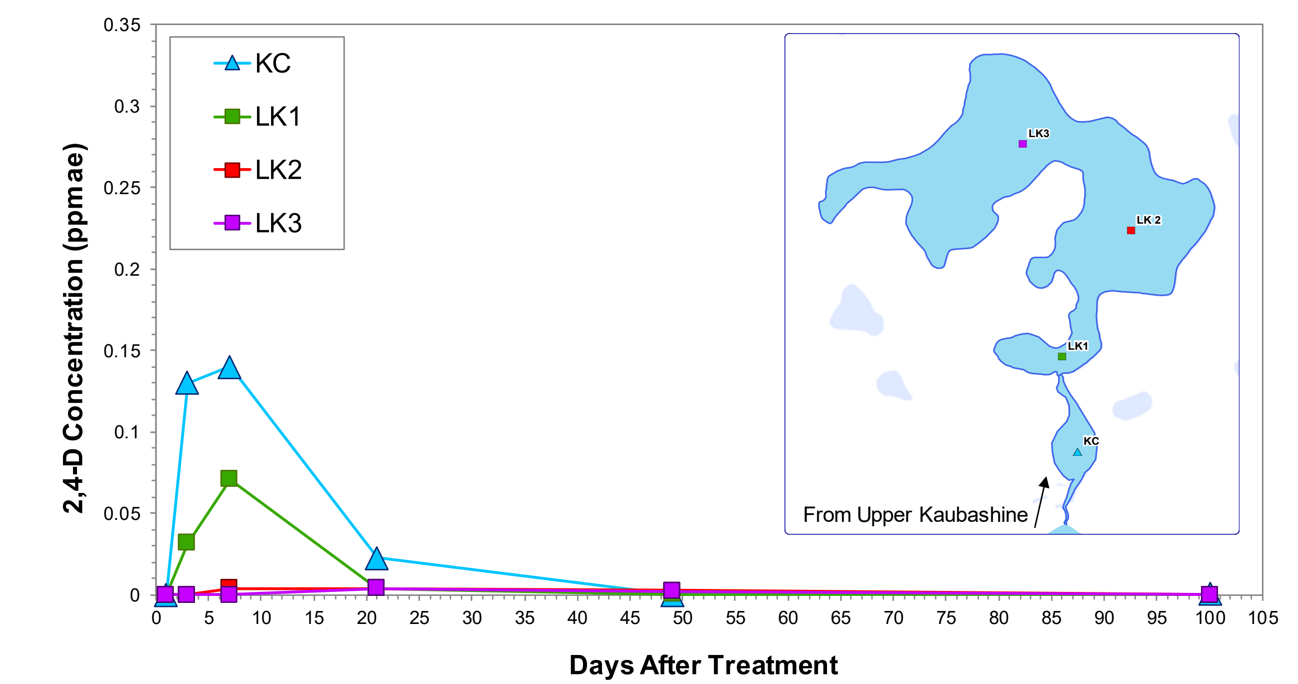


Figure 6. Kaubashine Creek and Lower Kaubashine Lake 2018 Herbicide Concentration Monitoring Results from four monitoring locations. Whole-lake 2,4-D treatment occurred on upstream waterbody (Upper Kaubashine Lake).

Temperature profiles collected before the treatment and at each herbicide concentration sampling interval indicate that the lake was stratified to approximately eight feet in the profiles collected up to 8 days after treatment. Limnologists understand thermal stratification as occurring when there is a change of 1°C within 1 meter of water depth. As is displayed on the isotherm on Figure 7(left frame), the thermal stratification that was in place around the time of the herbicide treatment appeared to have shifted somewhat deeper over the duration of the post-treatment sampling into September. The deeper shift in stratification resulted in a larger water volume for the herbicide to mix within resulting in a dilution of the herbicide and ultimately the lower concentrations observed.

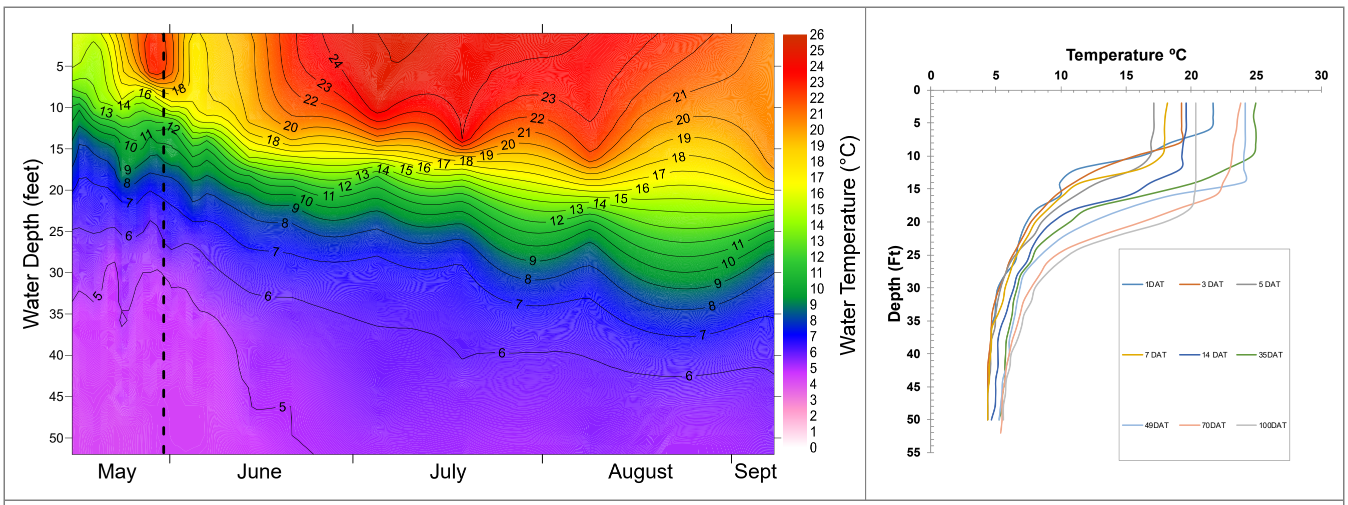


Figure 7. Temperature Isotherm (left) and Profiles (right) Collected from Upper Kaubashine Lake after the 2018 Herbicide Treatment. Dashed line on isotherm represents treatment date.

3.2 Herbicide Concentration Monitoring in Ground Waters

Authored by WDNR Staff

Some landowners expressed concern about herbicide from the proposed whole-lake treatment moving into the groundwater adjacent to the lake and being found in well water. WDNR Groundwater program staff helped to provide feedback on the shoreline areas surrounding the lake which would be most likely to receive groundwater moving from the lake. They used information on topography, lake elevation, and glacial geology from the area to describe the most likely flow direction of water from the lake to the groundwater.

Information from the DNR and Wisconsin Geological and Natural History Survey (WGNHS) well construction databases were used to examine the depths of wells constructed near the lake. In addition, nitrate data from wells near the lake were used to show that nitrate (originating from surface water) concentrations decreased substantially around 40 feet depth. Therefore, shallow wells (near or less than 40 feet in depth) were also prioritized for monitoring.

Finally, an estimation of groundwater specific capacity and soil hydraulic conductivity was made using well pump test data from the well databases. This data was combined with an estimate of groundwater velocity to estimate how long it would take for water moving from the lake to reach the wells at a certain distance and depth. This information allowed us to set well monitoring dates that should capture the timeframe of herbicide that would be moving from the lake to the groundwater near the selected wells.

WDNR and the UKPOA asked for landowners that wanted their well water tested. Homes/cabins along the western/northwestern shoreline that were fairly close to the lake and/or were shallow were included. Ultimately five wells were monitored along the west shore of the lake on four dates between August 9 and October 4, 2018 (Figure 8). Samples were sent to Davy Laboratories in La Crosse, WI to be analyzed for 2,4-D using EPA drinking water analysis method 515.3. The detection limit of the analysis was 0.000093 ppm (0.093 ug/L) and the maximum contaminant level allowed for 2,4-D in drinking water 0.07 ppm (70 ug/L). No 2,4-D was detected in any of the wells over this time period.

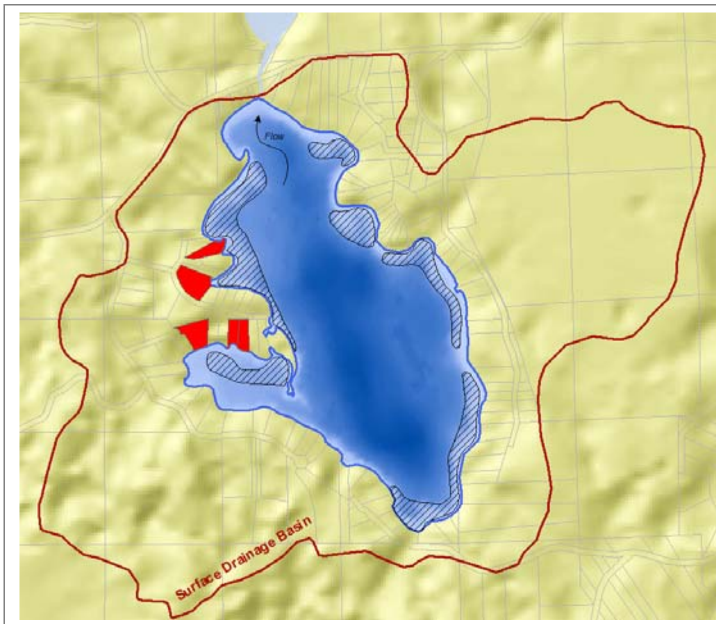


Figure 8. Well testing locations. Properties with wells tested highlighted in red.

3.3 Point-Intercept Survey

A point-intercept aquatic plant survey was first conducted on Upper Kaubashine Lake in 2013 by the WDNR. Although EWM was present in the lake during the 2013 point-intercept survey, no occurrences were physically sampled on the rake. Only plants that are sampled on the survey rake are used for analysis purposes and thus the littoral frequency of occurrence (LFOO) of EWM in 2013 was 0%. Additional point-intercept surveys were completed in 2016, 2017, and 2018 by Onterra as a part of the current WDNR grant-funded project. The LFOO of EWM was found to have increased to 22.9% by 2016 and to 35.2% in 2017 (Figure 9). Following the spring 2018 large-scale 2,4-D treatment, the EWM LFOO was reduced to 0% in the August 2018 point-intercept survey representing a 100% decrease since 2017. Understanding the EWM occurrence in 2018 is important, however, the 2019 littoral frequency of occurrence will be used to determine if the large-scale treatment meets the quantitative success criterion of a 70% decline from the *year before treatment* (2017) to the *year after treatment* (2019).

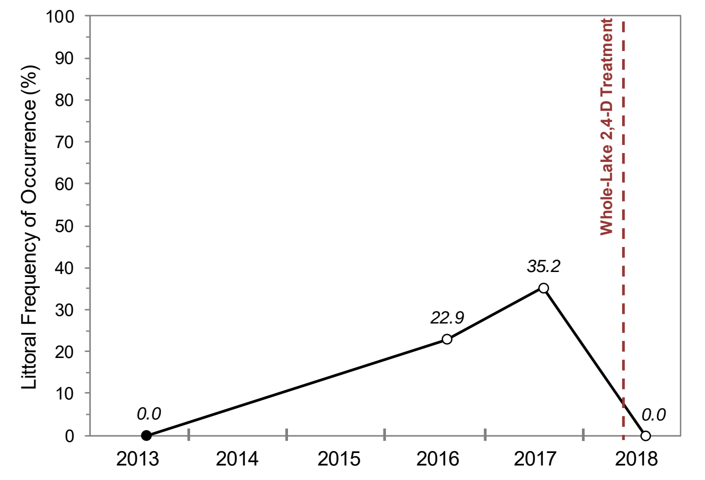


Figure 9. Upper Kaubashine Lake EWM littoral frequency of occurrence from 2013-2018. Open circles on represent a statistically valid change from previous survey.

Figure 10 investigates the average number of native plant species at each point-intercept sampling location. These data show a downward trend in native plant population from 2013 to 2017 when no chemical treatments occurred. Aquatic plant populations are known to fluctuate over time and continued monitoring would be needed to understand if these changes are in response to the increased EWM population or if they are related to other environmental factors. Following the whole-lake herbicide treatment, the average number of native species per sampling site decreased further from 1.27 in 2017 to 0.92 in 2018.

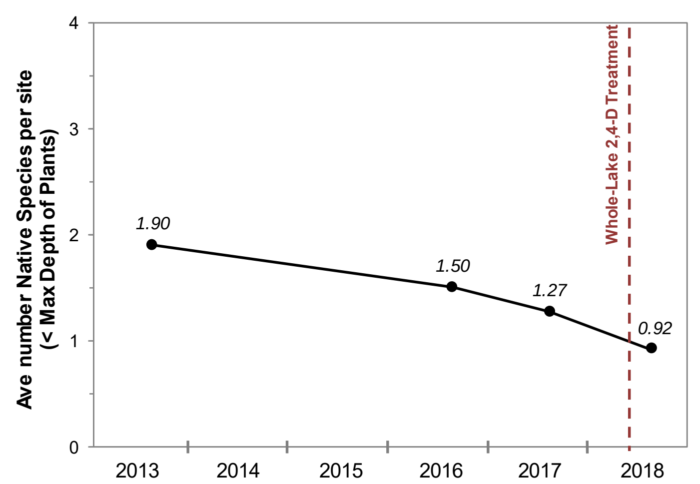


Figure 10. Average number of native aquatic plant species per littoral sampling site (2013-2018) in Upper Kaubashine Lake.

Figure 11 displays the number of point-intercept survey sampling locations that contained either native plants only, EWM plants only, or native plants and EWM plants from surveys completed in 2013-2018 in Upper Kaubashine Lake. An increase in sampling points that contained vegetation, both native and EWM, is evident between the 2013 and 2016 surveys. After the whole-lake treatment, the number of sampling points with native plants decreased slightly from 134 points in 2017 to 126 points in 2018, whereas the number of sampling points with EWM decreased from 76 in 2017, to zero sampling points in 2018.

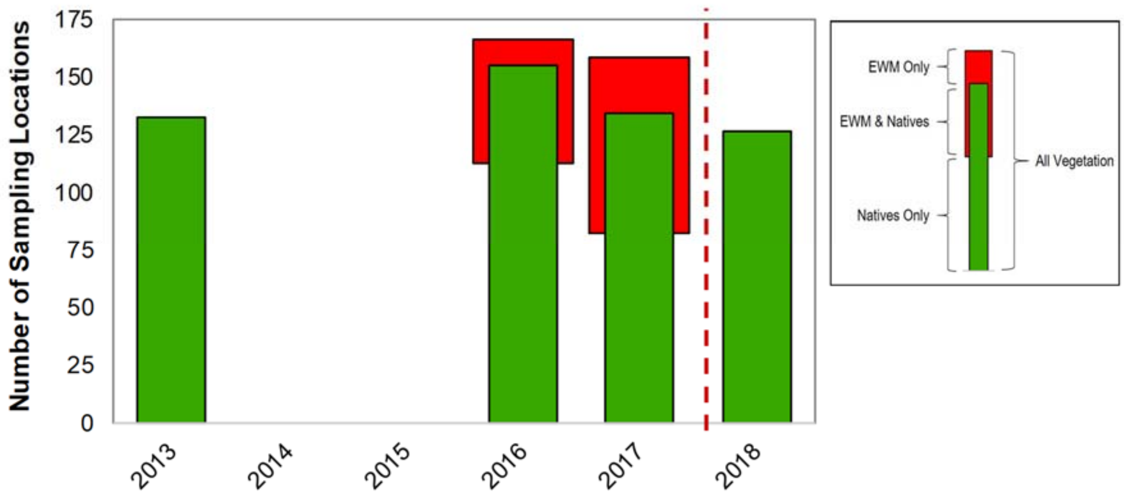


Figure 11. Number of point-intercept sampling locations that contained native plants, EWM, or native plants and EWM during surveys completed from 2013-2018 in Upper Kaubashine Lake. Red-dashed line indicates whole-lake herbicide treatment.

Based upon the point-intercept surveys conducted between 2013-2018, Figure 12 shows mean littoral frequency of occurrence of each aquatic plant species (square black symbol), the population range (extent bars), and the 2018 littoral frequency of occurrence (red circle). These data indicate the northern watermilfoil, common waterweed, muskgrasses, and wild stargrass had 2018 populations near the lower end of their population range of this period. The 2018 population of other species are near the average of this time period.

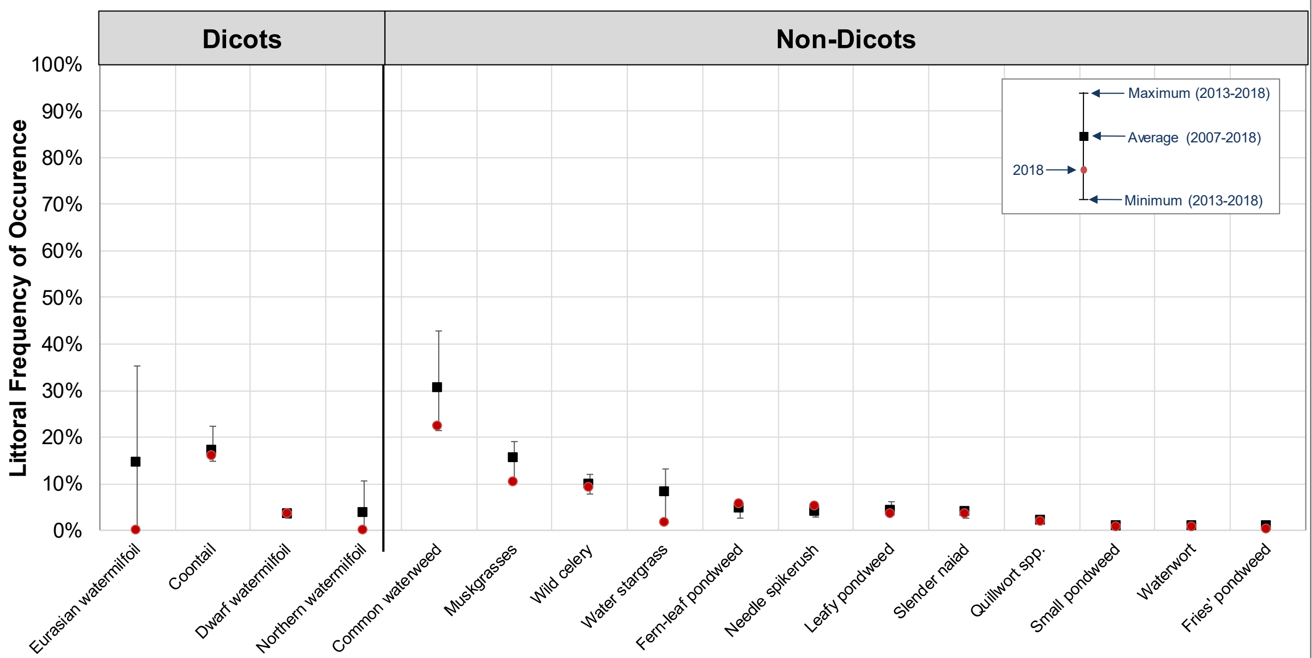


Figure 12. Historic average aquatic plant frequencies (2013-2018) in Upper Kaubashine Lake. Only species with a mean frequency of occurrence ≥2% are shown.

Figures 13-15 provide a population trend analysis from 2013-2018 of the native species in Upper Kaubashine Lake. Figure 12 displays the littoral frequency of occurrence (LFOO) of native species that exhibited a statistically valid decrease in occurrence between the 2017 and 2018 surveys in Upper Kaubashine Lake and Figures 14-15 display the remainder of the species that did not show a statistically valid decline in population. A full matrix of all species is included as an appendix.

Northern water milfoil (*Myriophyllum sibiricum*) and water stargrass (*Heteranthera dubia*) exhibited statistically valid decreases in littoral frequency between the 2017 and 2018 surveys (Figure 13). Northern water milfoil has been known to be extremely susceptible to early-season 2,4-D use patterns. No occurrences of northern water milfoil were recorded during the 2018 point-intercept survey. Water stargrass exhibited an 85.4% decrease in occurrence between 2017 and 2018. Continued monitoring of these important native species will serve to evaluate any potential longer-term impacts of the 2018 treatment strategy.

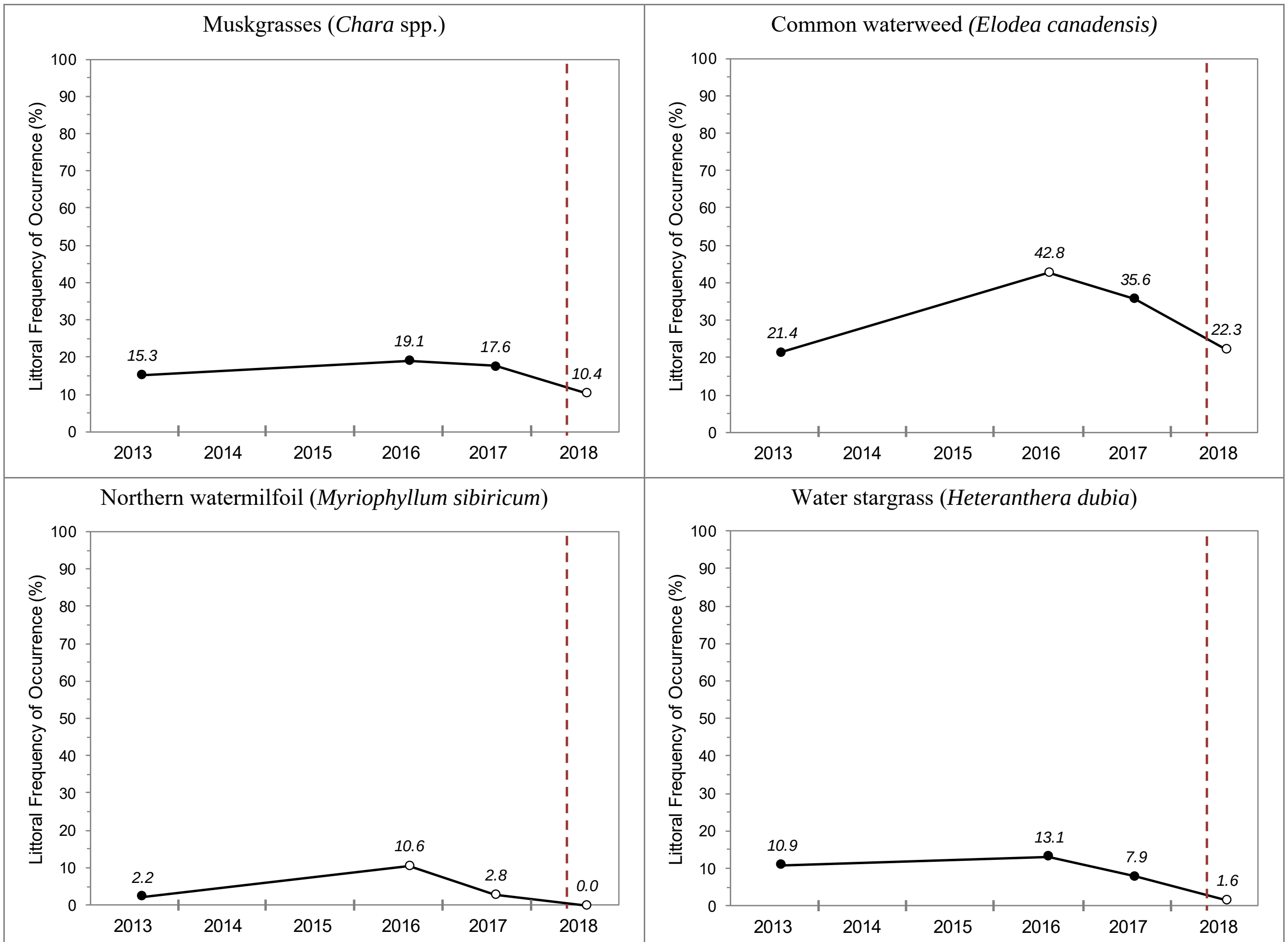


Figure 13. Littoral occurrence of native species that exhibited a statistically valid decrease in occurrence between 2017-2018. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Dashed line indicates whole-lake herbicide treatment.

Muskgrasses (*Chara* spp.) are actually macroalgae and due to their lack of vascular tissue are unable to translocate herbicides; therefore, they are typically unaffected by their use. These macroalgae require lakes with good water clarity, and their large beds stabilize bottom sediments. Muskgrasses exhibited a statistically valid decrease in population between 2017 and 2018 (Figure 13).

Common waterweed (*Elodea canadensis*) is arguably one of the most common species in Wisconsin's inland lakes, and has been one of the most commonly encountered species on point-intercept surveys in Upper Kaubashine Lake with littoral frequencies ranging from approximately 21-43%. (Figure 13) Common waterweed exhibited a statistically valid 37.4% decrease in occurrence between the 2017 and 2018 surveys. Common waterweed is a free-floating or loosely rooted plant species that can utilize the biomass of other plant species as a "substrate" in which they become entangled and grow. It is suspected that with the loss of structural habitat previously being supplied by the robust EWM population, may have compounded the direct impacts from the herbicide treatment strategy. The WDNR spring 2018 point-intercept survey (pre-treatment) indicated common waterweed had a 23.8% littoral frequency. Common waterweed had the highest LFOO (22.3%) of any species in the 2018 survey and the population remains relatively robust. The 2018 LFOO was similar to the 2013 point-intercept survey (Figure 12).

Figure 14 shows three species that are often impacted by whole-lake 2,4-D treatment, but did not have statistically valid declines in 2018 on Upper Kaubashine Lake.

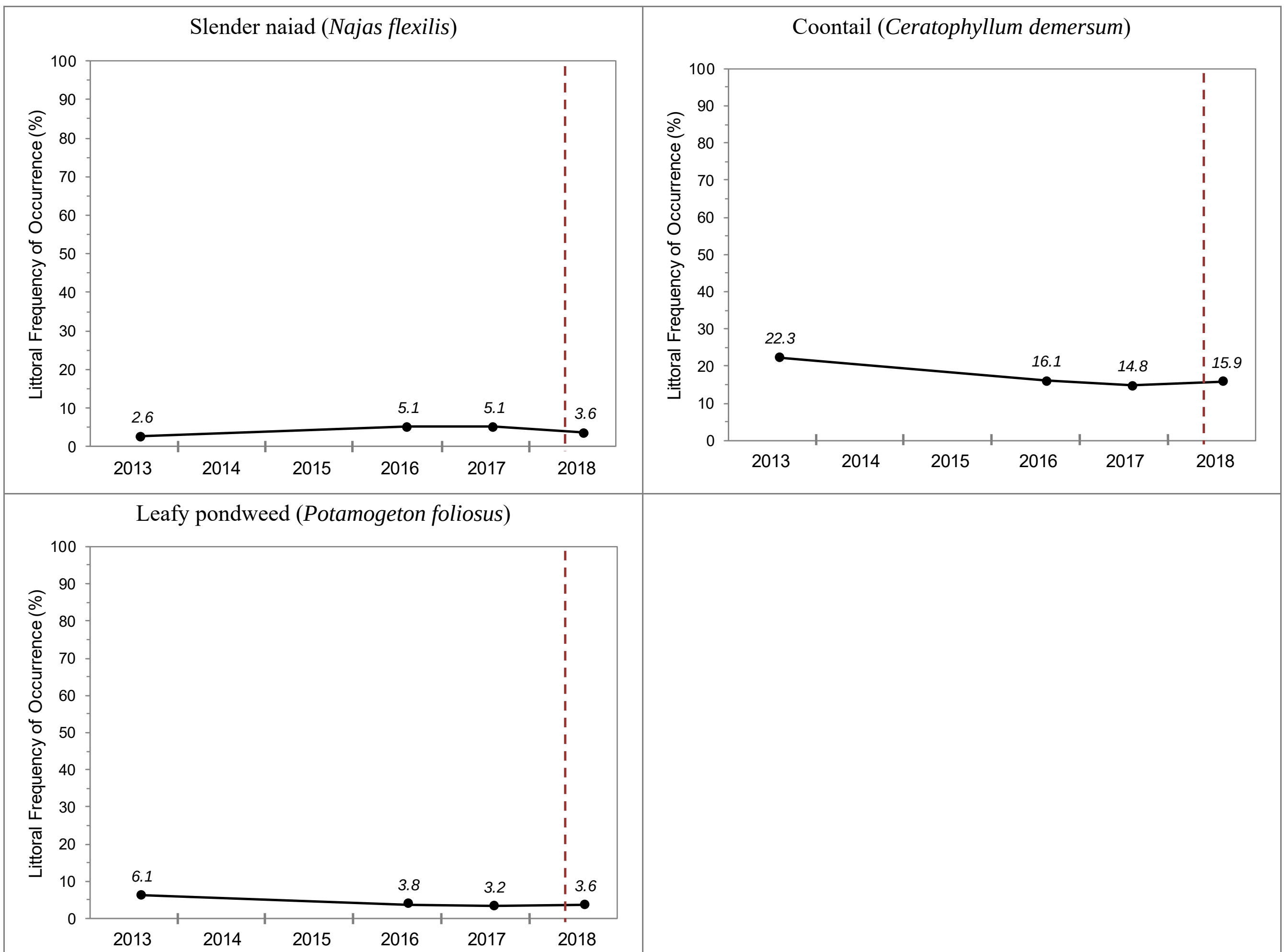


Figure 14. Littoral occurrence of native species that did not have a statistically valid change in occurrence between 2017-2018. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Dashed line indicates whole-lake herbicide treatment.

The LFOO of coontail has been relatively stable in recent years at around 15-16% (Figure 14). Like common waterweed, coontail is a largely unrooted plant that can be directly impacted by 2,4-D treatments and indirectly impacted as the EWM "substrate" is removed. Coontail (*Ceratophyllum demersum*) was the second-most frequently encountered species in the 2018 survey with a LFOO of 15.9%.

Slender naiad is an annual that relies on seed production and has been shown to be particularly susceptible to whole-lake auxin herbicide treatments (e.g. 2,4-D, triclopyr). During the *year of treatment*, slender naiad populations off decline substantially with quick rebound the following year, sometimes above pretreatment levels. On Upper Kaubashine Lake, slender naiad populations remained relatively unchanged from 2017-2018 (Figure 14).

Thin-leaved pondweeds, like leafy-pondweed, are also often impacted by whole-lake 2,4-D treatments. Population recovery of these morphologically similar species often takes a number of years. On Upper Kaubashine Lake, leafy pondweed population remained relatively stable from 2017-2018 (Figure 14).

Onterra's experience is that wild celery (Photo 2) emerges a little later than many native plant species and perhaps is dormant during the highest concentrations of an early-season whole-lake treatment and thus less susceptible to its impacts. Wild celery is relatively tolerant of low-light conditions and is able to grow in deeper water. Its long leaves provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. 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 Upper Kaubashine Lake ecosystem. Wild celery populations were statistically unchanged over the period of study (Figure 15).

Photo 2. Wild celery. Photo credit Gary Fewless.

The term isoetid encompasses a number of unrelated aquatic plant species which share similar morphological features and adaptations to their environment and superficially resemble the quillworts (*Isoetes* spp.). Plants of the isoetid growth form are small, inconspicuous, and slow-growing with succulent-like leaves (Photo 3). These diminutive plants are typically found growing in shallower water over areas of sand and rock. Needle spikerush, dwarf watermilfoil, and quillworts are the more common isoetid species in Upper Kaubashine Lake. These species remained statistically unchanged over the period of study (Figure 15).

Photo 3. Quillwort. Photo credit Onterra

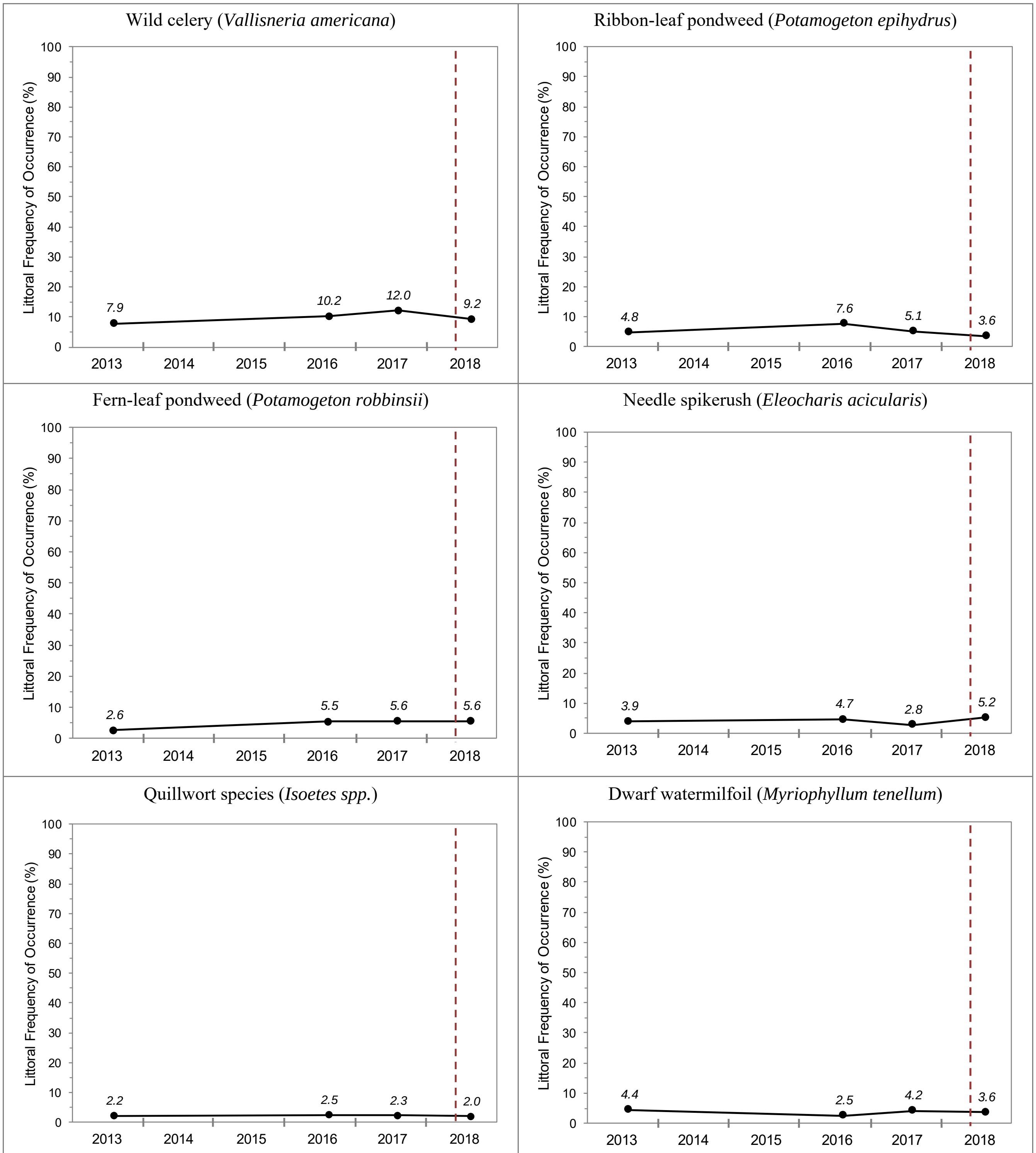


Figure 15. Littoral occurrence of native species that did not have a statistically valid change in occurrence between 2017-2018. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Red-dashed line indicates whole-lake herbicide treatment.

Another way to look at the aquatic plant community composition is through the relative frequency of occurrence analysis. Because each sampling location may contain numerous plant species, relative frequency of occurrence is a tool to evaluate how often each plant species is found in relation to all other species found (composition of the population). Explained another way, if 100 plants were sampled from Upper Kaubashine Lake in 2017, 20 would be EWM (Figure 16). This means that prior to the treatment, one out of every five plants was EWM and four out of five were native plants. Even though the littoral frequency of occurrence of common waterweed declined in 2018, it proportionally contributes a slightly higher relative frequency of occurrence in 2017 due to the reduction of the EWM population.

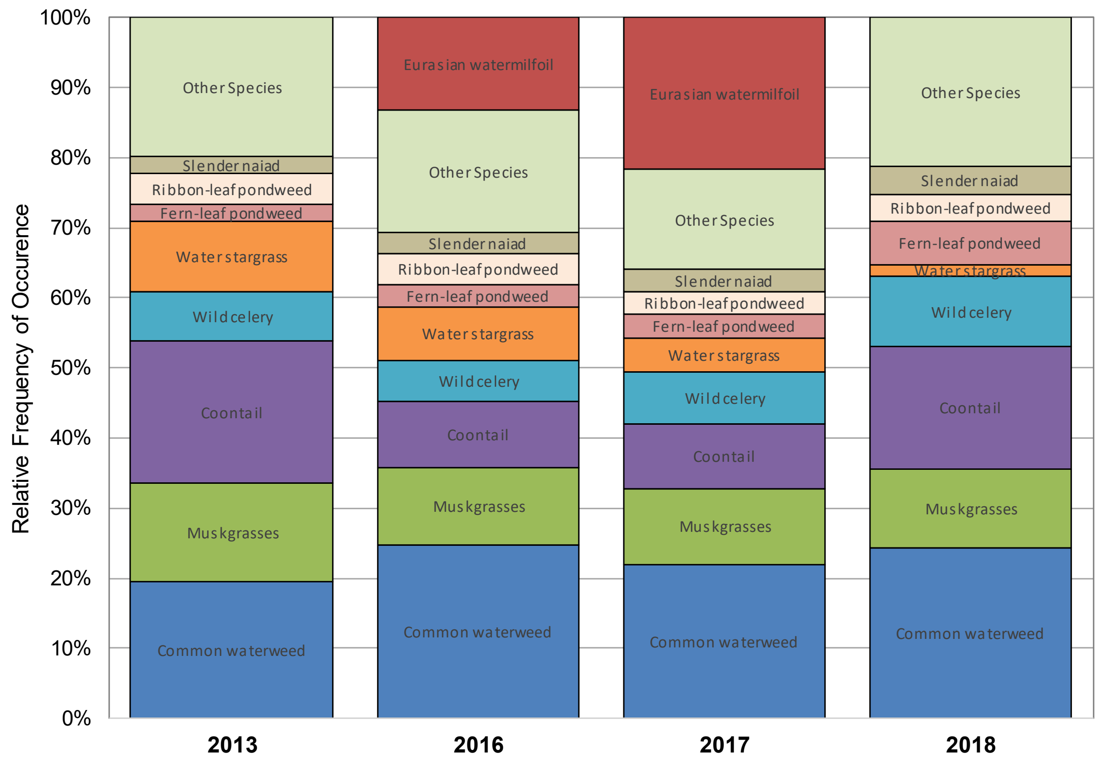


Figure 16. Relative frequency of occurrence analysis of aquatic plants in Upper Kaubashine Lake from 2013, 2016-2018.

3.4 Late-Summer EWM Peak-biomass Survey

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. As the name implies, the Late-Summer EWM Peak-Biomass survey is a meander-based survey conducted when the plant is at its peak growth stage, allowing for a true assessment of the amount of this exotic within the lake.

Onterra ecologists visited Upper Kaubashine Lake on August 22, 2018 to conduct the Late-Summer EWM Peak-Biomass Survey to map the EWM population at its peak growth stage and to qualitatively assess the large-scale treatment. The crews noted favorable conditions during the survey with sunny skies. During the survey, no EWM was visible from the surface in the lake. The field crew deployed submersible cameras in all areas that previously were known to harbor EWM and observed some native vegetation. No EWM was observed anywhere in the lake during 2018 post treatment surveys. Areas of dense EWM prior to the treatment were noted as having filamentous algae (spirogyra). It is hypothesized that the decreases in EWM populations in these areas allowed increased light penetration to the sediment which spurred the increase of these populations.

3.5 Acoustic 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 allow an understanding of how the macrophyte structure was influenced by the treatment, a set of data that have particular interest to some fisheries manager

As illustrated on Figure 17, areas where aquatic plants occupy most or the entire water column are indicated in red, while areas of little to no aquatic plant growth are displayed in blue. The bio-volume data indicate that much of the aquatic plant growth in Upper Kaubashine Lake is present near the shore. Fewer areas were comprised of the highest bio-volume percentages in 2018 as compared to 2017, likely explained by the 100% decline in EWM between the two surveys. A decline in some native aquatic plants also contribute to the lower bio-volume present in 2018. The 2018 survey shows that native vegetation is still contained in most of these areas, but of more moderated density (orange and green) than pretreatment.

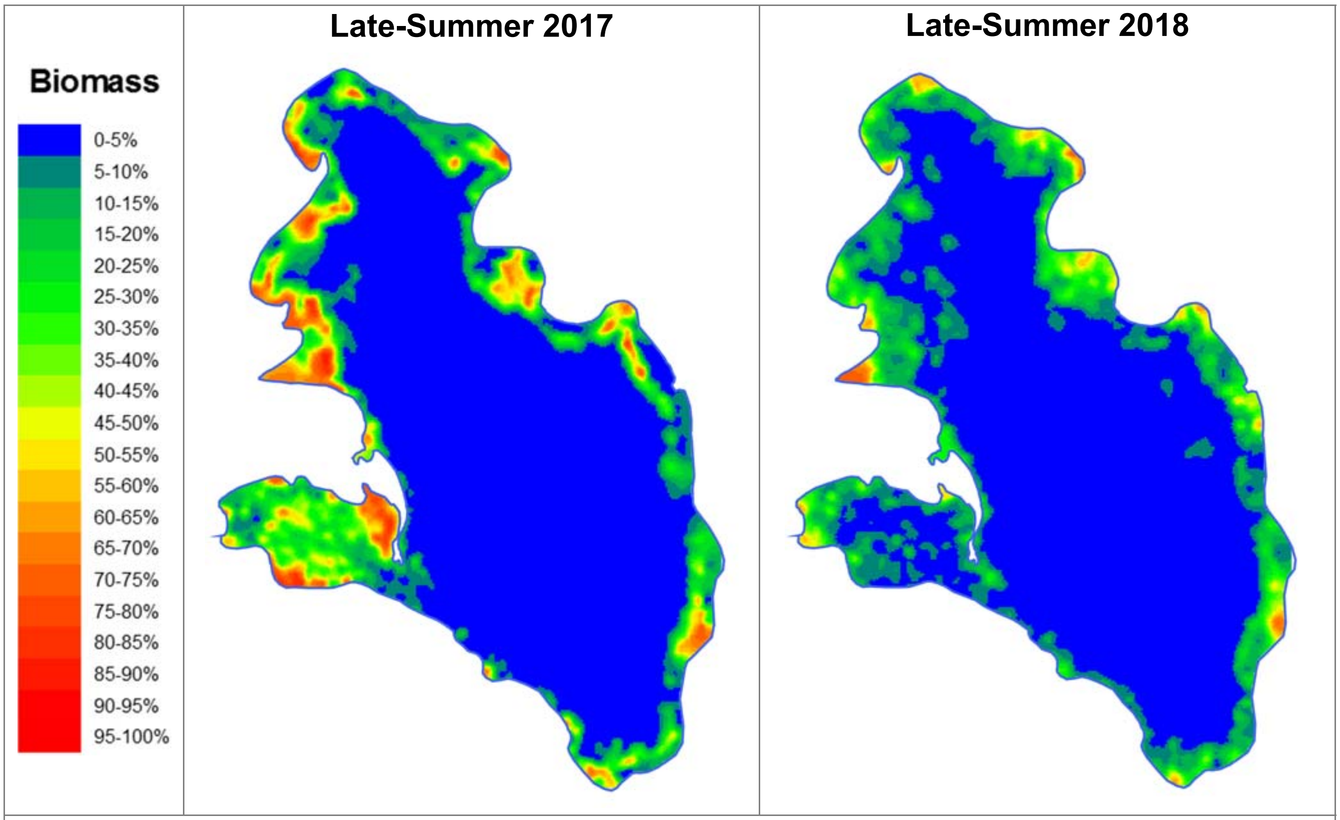


Figure 17. Acoustic bio-volume survey results from Late-Summer 2017-2018 on Upper Kaubashine Lake.

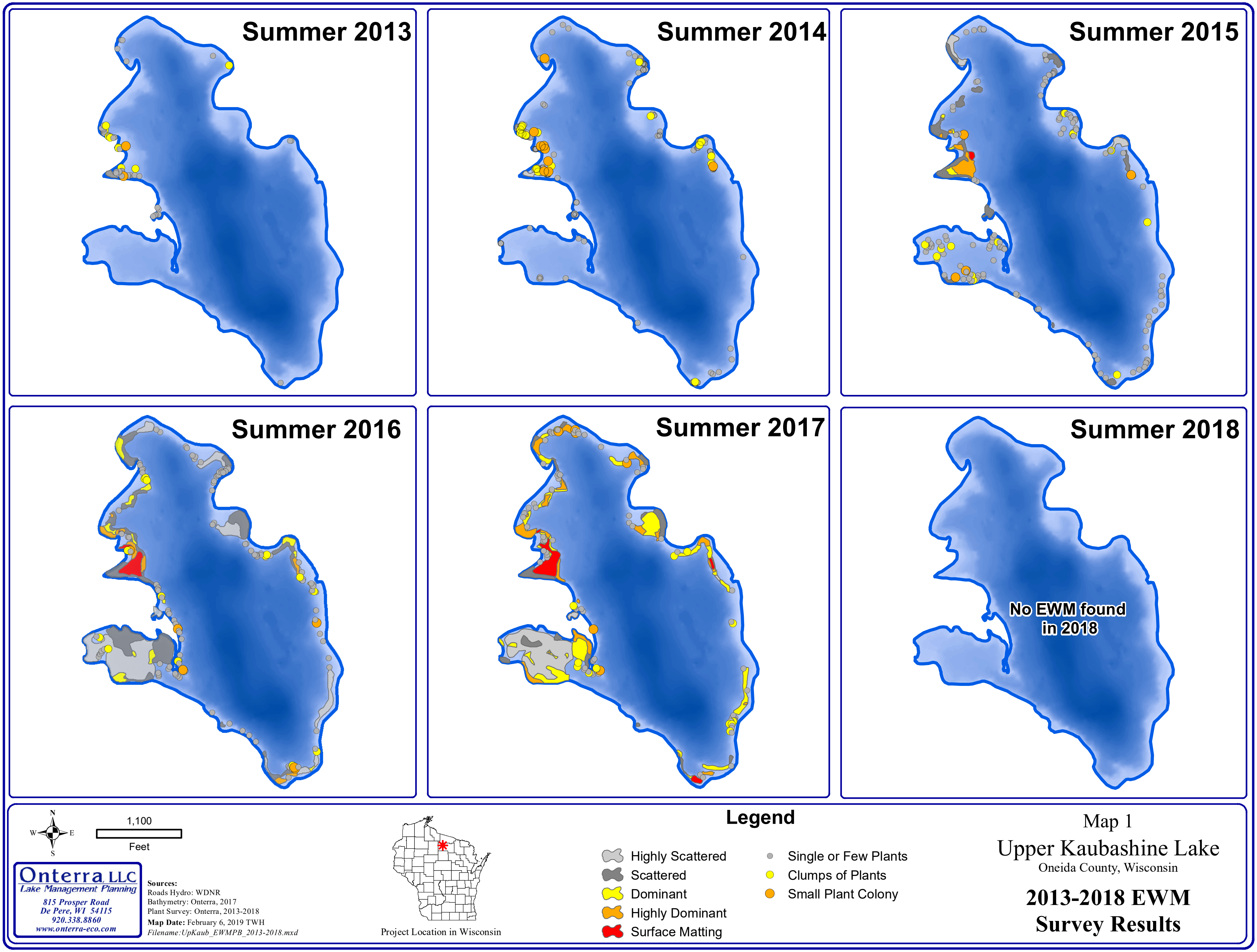
4.0 CONCLUSIONS & DISCUSSION

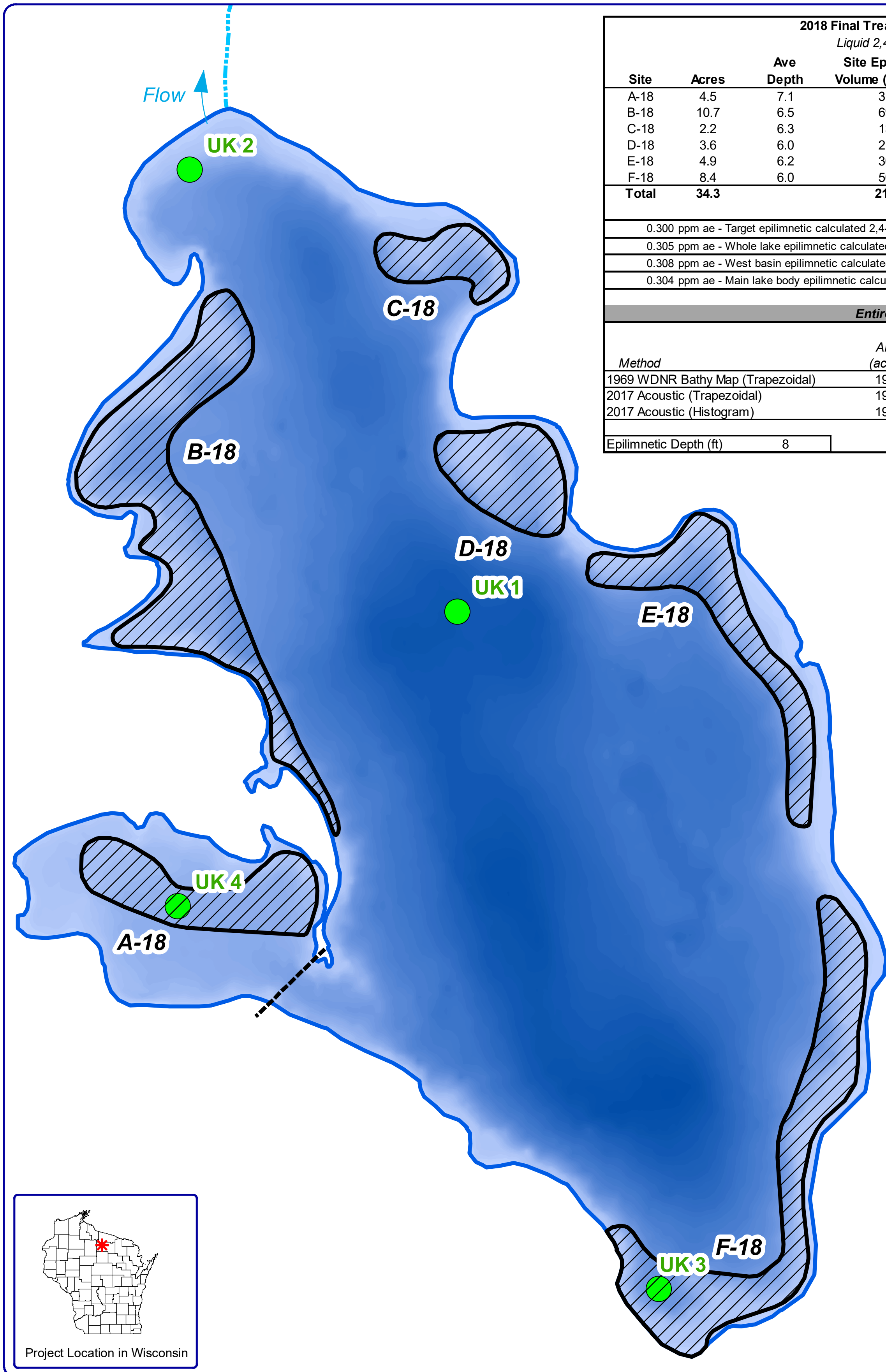
Aquatic plant monitoring surveys conducted in 2018 indicate that the large-scale 2,4-D treatment led to a high level of EWM population reduction. Understanding the EWM population in the *year-of-treatment* (2018) is important, however surveys completed in the *year-after-treatment* (2019) will determine whether the herbicide treatment met the pre-determined criteria for a success. Herbicide concentration monitoring showed 2,4-D concentrations remained above approximately 0.1ppm ae for at least 21 days after treatment. Low levels of 2,4-D were detected in the downstream sampling locations between Upper Kaubashine Lake and Lower Kaubashine Lake. Herbicide concentrations in Kaubashine Creek, nearest to Upper Kaubashine Lake, were found to be above 0.1ppm ae for a period of at least several days during which some impacts to less tolerant native aquatic plant species cannot be ruled out. The minimal levels of herbicide that were detected in Lower Kaubashine Lake are not believed to be high enough to cause impacts to aquatic plants.

Four native species were shown to decrease from 2017 to 2018, with northern watermilfoil not being located during the post treatment assessments. Some species recover faster than others following large-scale treatments. Continued aquatic plant monitoring through the point-intercept survey in 2019 will be valuable in documenting the populations recovery or lack-thereof following the herbicide treatment as well as document inter-annual population dynamics.

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. The UKPOA would give preference to non-herbicide control measures following the whole-lake 2,4-D treatment to preserve the gains as long as possible. This would likely include hand-harvesting with Diver-Assisted Suction Harvesting

The UKPOA intends to continue to monitor Upper Kaubashine 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. A 2019 late-Summer EWM Mapping Survey (August-September) is currently scheduled, 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 in June 2019, as this survey would be conducted early enough to initiate IPM activities in 2019 if appropriate. This survey could be triggered if UKPOA volunteers locate rebounding invasive milfoil during volunteer-based reconnaissance monitoring.


Summer 2013
Summer 2014
Summer 2015
Summer 2016
Summer 2017
Summer 2018
No EWM found in 2018
N
W
E
S
1,100
Feet
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2017
Plant Survey: Onterra, 2013-2018
Map Date: February 6, 2019 TWH
Filename:UpKaub_EWMPB_2013-2018.mxd
Project Location in Wisconsin
Legend
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony
Map 1
Upper Kaubashine Lake
Oneida County, Wisconsin
2013-2018 EWM Survey Results



2018 Final Treatment Strategy

Liquid 2,4-D amine

Site	Acres	Ave Depth	Site Epilimnetic Volume (acre-feet)	2,4-D PPM ae	2,4-D amine (gallons)
A-18	4.5	7.1	31.9	0.9	21.0
B-18	10.7	6.5	69.4	2.1	104.0
C-18	2.2	6.3	13.8	2.1	21.0
D-18	3.6	6.0	21.8	2.1	33.0
E-18	4.9	6.2	30.4	2.1	46.0
F-18	8.4	6.0	50.2	2.1	75.0
Total	**34.3**		**217.6**		**300.0**

0.300 ppm ae - Target epilimnetic calculated 2,4-D concentration

0.305 ppm ae - Whole lake epilimnetic calculated 2,4-D concentration

0.308 ppm ae - West basin epilimnetic calculated 2,4-D concentration

0.304 ppm ae - Main lake body epilimnetic calculated 2,4-D concentration

Entire Lake

Method	*Area (acres)*	*Epilimnetic Volume*	*Epilimnetic 2,4-D ppm ae*
1969 WDNR Bathy Map (Trapezoidal)	191.3	1319.9	0.318
2017 Acoustic (Trapezoidal)	191.3	1370.5	0.306
2017 Acoustic (Histogram)	191.3	1376.9	0.305

Epilimnetic Depth (ft)	8	*Target:*	0.300

N W E S

550

Feet

Legend

2018 Herbicide Application Area

Herbicide Concentration Monitoring Location

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

Sources:
Hydro and Roads: WDNR
Bathymetry: Onterra, 2017
Aquatic Plant Survey: Onterra, 2017
Map Date: May 30, 2018 EJH
Filename: UpKaub_Oneida_T2018_Perm1.mxd

Map 2

Upper Kaubashine Lake

Oneida County, Wisconsin

2018 Final EWM Treatment Strategy

APPENDIX

	Scientific Name	Common Name	LFOO (%)			
			2013	2016	2017	2018
Dicots	*Myriophyllum spicatum*	Eurasian watermilfoil	0.0	22.9	35.2	0.0
	Ceratophyllum demersum	Coontail	22.3	16.1	14.8	15.9
	Myriophyllum tenellum	Dwarf watermilfoil	4.4	2.5	4.2	3.6
	Myriophyllum sibiricum	Northern watermilfoil	2.2	10.6	2.8	0.0
	Nuphar variegata	Spatterdock	0.4	0.4	0.5	0.8
	Nymphaea odorata	White water lily	0.4	0.0	0.0	0.0
Non-dicots	*Potamogeton crispus*	Curly-leaf pondweed	0.0	0.0	0.0	0.0
	Elodea canadensis	Common waterweed	21.4	42.8	35.6	22.3
	Chara spp.	Muskgrasses	15.3	19.1	17.6	10.4
	Filamentous algae	Filamentous algae	10.5	9.3	0.9	13.5
	Vallisneria americana	Wild celery	7.9	10.2	12.0	9.2
	Heteranthera dubia	Water stargrass	10.9	13.1	7.9	1.6
	Potamogeton robbinsii	Fern-leaf pondweed	2.6	5.5	5.6	5.6
	Potamogeton epihydrus	Ribbon-leaf pondweed	4.8	7.6	5.1	3.6
	Eleocharis acicularis	Needle spikerush	3.9	4.7	2.8	5.2
	Potamogeton foliosus	Leafy pondweed	6.1	3.8	3.2	3.6
	Najas flexilis	Slender naiad	2.6	5.1	5.1	3.6
	Isoetes spp.	Quillwort spp.	2.2	2.5	2.3	2.0
	Potamogeton pusillus	Small pondweed	0.0	1.7	1.9	0.8
	Elatine minima	Waterwort	0.4	1.3	1.4	0.8
	Potamogeton friesii	Fries' pondweed	0.9	0.8	1.9	0.4
	Potamogeton gramineus	Variable-leaf pondweed	0.4	0.4	0.9	0.4
	Potamogeton amplifolius	Large-leaf pondweed	0.0	0.8	0.0	0.8
	Nitella spp.	Stoneworts	0.0	0.4	1.4	0.4
	Juncus pelocarpus	Brown-fruited rush	0.0	0.0	0.0	0.8
	Fissidens spp. & Fontinalis spp.	Aquatic Moss	0.0	0.0	0.9	0.4
	Persicaria amphibia	Water smartweed	0.4	0.0	0.0	0.0