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For the Muskellunge Lake Association

2020 Muskellunge Lake Management Plan

03/26/2021

EOR water ecology community

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1. INTRODUCTION

1.1. A Brief History of Muskellunge Lake and the Muskellunge Lake Association

A hearing was held on September 18, 1945 between the Public Service Commission of Wisconsin and the residents of Muskellunge Lake to determine the normal water level of the lake. At this hearing various testimonies were given regarding the water level of the lake. This hearing established the normal water level with reference to specific benchmarks described at this hearing. In the fall of 1948, the Muskellunge Lake Property Owners Association was granted permission to construct, maintain and operate a dam to maintain water/lake levels (as decided in 1945 by the Public Service Commission of Wisconsin) for conservation of the lake. A review of historical aerial imagery from 1933 suggests that the footprint of Muskellunge has remained relatively unchanged in comparison with current aerial imagery.

Figure 1. Muskellunge Lake Aerial Imagery (1933 Left and 2018 Right).

Aerial photos from the Forestry Department show a significant increase in shoreline structures from 1950 – 2000. In 1950, there were approximately 16 structures including two resorts. By 2000, there were at least 85 buildings/structures. Today, there are 116 taxing entities (lots) with shoreline lake frontage. Of that, there are only five properties that are not developed with buildings and thus do not have a fire number address.

By 1990, Muskellunge Lake residents saw an increasing need to form the Muskellunge Lake Association (MLA) and on October 20, 1990, an organizational meeting was held with 47 people (including 37 property owners) in attendance to establish the Muskellunge Lake Association. Guest speakers from the DNR and the Wisconsin Federation of Lakes Inc. spoke on who and why to establish a lake association. By-laws were approved and the MLA was formed under the collective mission to maintain, protect and enhance the quality of the lake and its surroundings for the collective interest of the members and residents of Muskellunge Lake.

1.2. Lake Setting

Muskellunge Lake (Water ID: 128570), is a 272-acre lake located in Vilas County. Muskellunge Lake has a maximum depth of 19 feet, a mean depth of 9.3 feet and is classified as a shallow, lowland drainage lake. Visitors have access to the lake from a public boat landing off Musky Landing Road via Balsalm Lane and Highway G northwest of Eagle River, Wisconsin. The total contributing drainage area to Muskellunge Lake is approximately 2,320 acres (Figure 2). Snipe Lake is the largest lake within the contributing drainage area to Muskellunge Lake. Muskellunge Lake outlets via Muskellunge Creek to Little St. Germain Lake, which is one of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs.

1.3. Development and Need for Lake Management Plan

Tourism has always played an important role for Muskellunge Lake given its proximity to Eagle River (6 miles west) and location within Vilas County, a renowned vacation destination with the 3rd highest tourism intensity of any County in Wisconsin. Visitor spending in Vilas County was estimated at $203.1 million (2013 dollars) annually (UW-Extension, 2015). Tourism has continued on today with countless people traveling to the greater Eagle River area each year. With growing tourist populations and travel between lakes on the rise, the need to develop a lake management plan that guides Muskellunge Lake for the next 10 years is as urgent now as perhaps at any point in the recent past. The listing of Muskellunge Lake on the impaired waters list in 2014 combined with the arrival and subsequent rapid expansion of Eurasian watermilfoil (EWM) has further highlighted the need for a comprehensive lake management plan that prioritizes protection and restoration strategies for Muskellunge Lake.

In 2019, EOR worked with the MLA to secure a Large Scale Lake Management Planning Grant to help offset costs associated with development a comprehensive lake management plan for Muskellunge Lake. The lake management plan leverages and builds upon existing lake management plans and studies developed for Muskellunge Lake including but not limited to the following reports:

1) 2012 Town of Cloverland Lakes Study Completed by Onterra LLC
2) 2005 Lake Management Study Developed by Steve McComas of Blue Water Science
3) 2003 USGS Study of Water Quality and the Effects of Changes in Phosphorus Loading to Muskellunge Lake, Vilas County, Wisconsin
4) Annual Reports from 2017- 2019 (Appendix F-H)

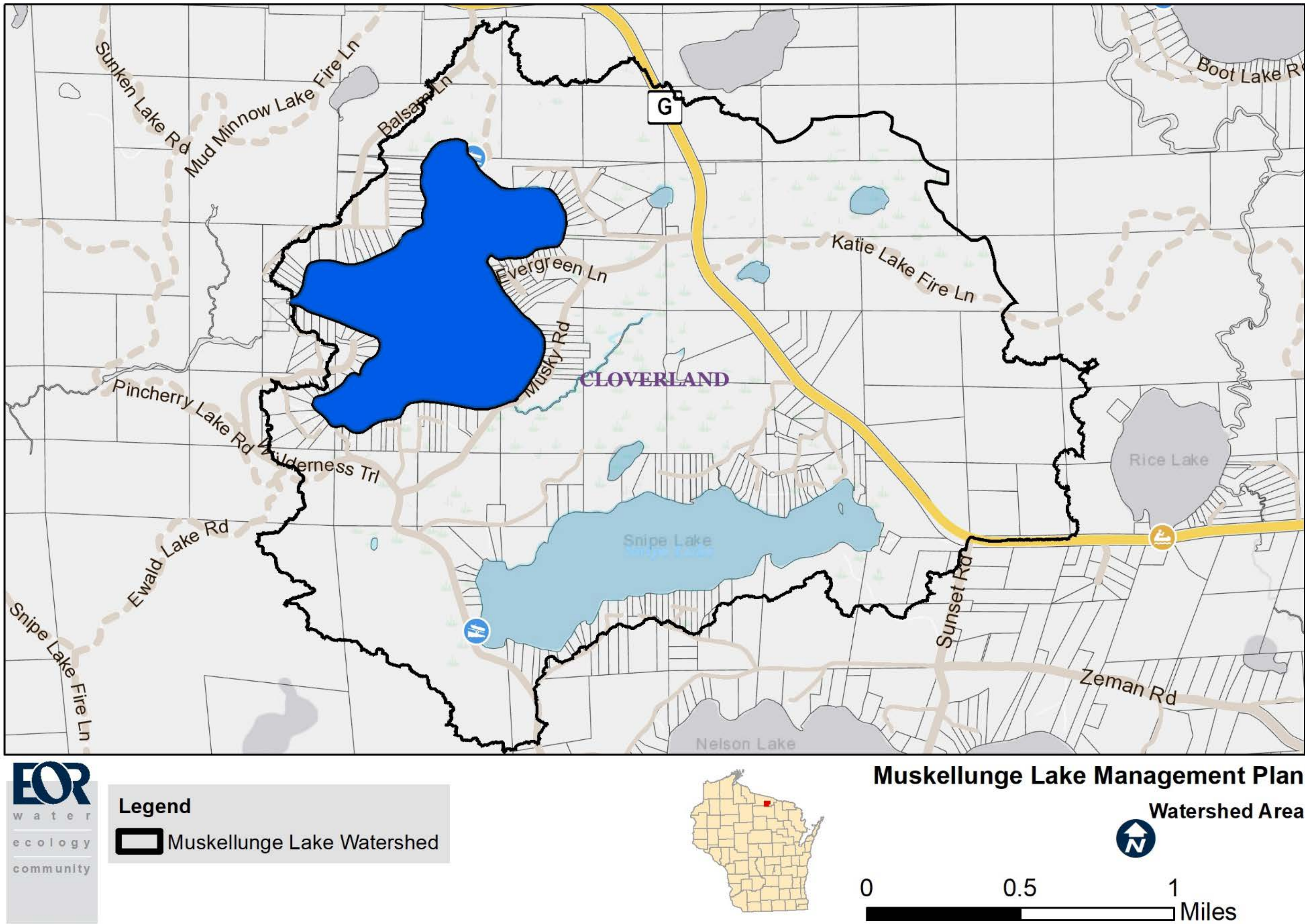


Figure 2. Muskellunge Lake Watershed

2. PROBLEM STATEMENT

2.1. Eurasian Watermilfoil

Eurasian Watermilfoil (EWM) was discovered in Muskellunge Lake in 2016. Despite volunteer and professional hand-harvesting efforts in 2017 and 2018, and Diver Assisted Suction Harvesting (DASH) efforts in 2019, the total area of the lake with established EWM populations has expanded. No treatments were enacted in 2020 as the extent of the EWM infestation exceeded the capacity for physical removal techniques to provide a viable solution. As of August 2020, the cumulative area of the lake containing established populations of EWM exceeds 17 acres.

A brief summary of the history of EWM in Muskellunge Lake, its life cycle, its impacts on the ecology of Muskellunge Lake, regulations associated with the AIS, and recommended control measures is presented in Appendix B: Eurasian Watermilfoil (EWM) Management.

2.2. Water Quality Impairment

Muskellunge Lake was listed on the 303(d) impaired waters list in 2014 due to excess algae growth. A Total Maximum Daily Load (TMDL) study for the lake has not yet been completed; the source of the impairment is currently listed as an unknown pollutant. Muskellunge Lake outlets to Muskellunge Creek which has been identified as the leading source of phosphorus to Little St. Germain Lake. Little St. Germain Lake is one of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs used to maintain water levels in the Wisconsin River. Little St. Germain Lake was added to the 2020 Impaired Waters List for Eutrophication and Excess Algae Growth. Implementation measures aimed at improving the water quality of Muskellunge Lake will likely result in downstream water quality benefits to Little St. Germain Lake as well as the Wisconsin River.

3. SHALLOW LAKE BIOLOGY AND WATER QUALITY

Lakes like Muskellunge Lake are considered shallow when most (>80%) of the lake area is less than 15 feet deep. In shallow lakes, sunlight can penetrate to the lake bottom and support aquatic plant growth. In addition, all the living organisms in shallow lakes are concentrated in a smaller volume than in deeper lakes. Consequently, the relationship between phosphorus concentration and the amount of algae growth (measured by chlorophyll-*a* pigments and water transparency) is often different in shallow lakes as compared to deeper lakes. In deeper lakes, algae abundance is often controlled by physical and chemical factors such as light availability, temperature, and nutrient concentrations. The biological components of the lake (such as microbes, algae, aquatic plants, zooplankton and other invertebrates, and fish) are distributed throughout the lake, along the shoreline, and on the bottom sediments. In shallow lakes, the biological components are more concentrated into less volume and exert a stronger influence on the ecological interactions within the lake. There is a denser biological community at the bottom of shallow lakes than in deeper lakes because oxygen is replenished in the bottom waters and light can often penetrate to the bottom. These biological components can control the relationship between phosphorus and the response factors.

The result of this impact of biological components on the ecological interactions is that **shallow lakes normally exhibit one of two ecologically alternative stable states (Figure 3): the turbid water, algae-dominated state, and the clear water, aquatic plant-dominated state.** The clear state is the most preferred, since algae communities are held in check by diverse and healthy zooplankton and fish communities. In addition, rooted plants stabilize the sediments, lessening the amount of sediment stirred up by the wind.

Figure 3. Clear and turbid water states in shallow lakes

As shown in Figure 4, the transition in water quality of shallow lakes from clear to turbid is often abrupt. When shallow lakes have historically been in the clear water state and dominated by submerged aquatic vegetation, they are capable of assimilating large amounts of phosphorus loading without becoming dominated by algae. That is to say, they are stable in a clear-water state. They may experience some periods of turbid water conditions, but tend to revert to clear water conditions. However, as phosphorus loading increases, the stability of the clear-water state declines until the lake is stable in a turbid-water state. Consequently, drastic reductions in nutrients or changes in the biological community of a shallow lake are needed to promote a clear-water state (Figure 11).

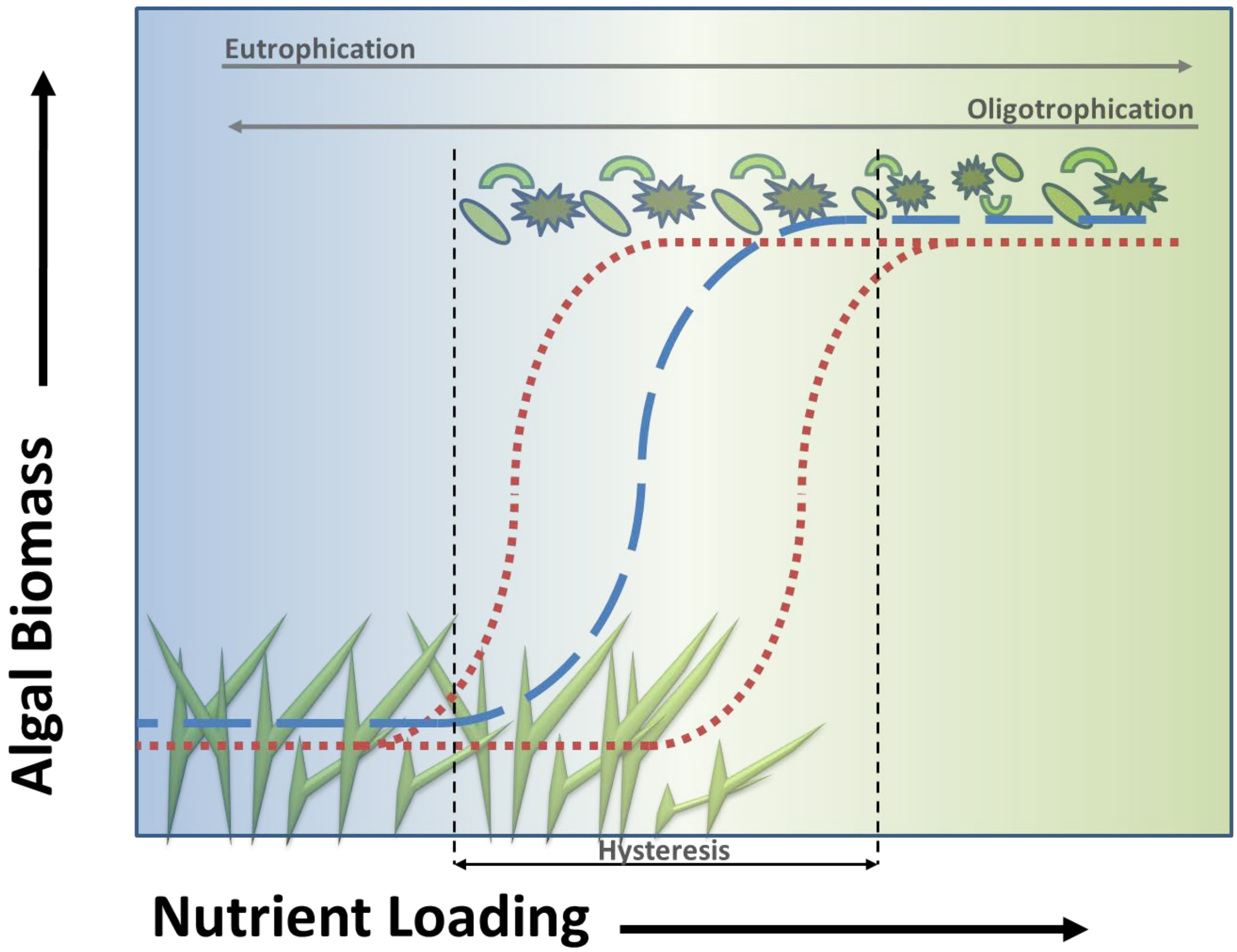


Figure 4. Trophic state shifts in shallow lakes in response to changes in nutrient loading

4. WATER QUALITY STATUS & TRENDS

4.1. Trophic State

One method of evaluating the productivity of a lake is by computing water-quality indices such as Trophic State Indices (TSIs) which takes into account Chlorophyll–a (CHL-A), Total Phosphorus (TP), and Secchi depth (water clarity). The State of Wisconsin uses a mathematical formula that produces a TSI score that ranges from 0 to 110, with lakes that are less fertile having a low TSI. In Wisconsin, the overall TSI score is based on the Chlorophyll TSI because the TSI is used to predict biomass. This makes chlorophyll the best indicator.

Eutrophic lakes, like Muskellunge Lake, have TSIs greater than 50, are nutrient rich with correspondingly severe water-quality problems, such as frequent seasonal algal blooms, oxygen depletion in the deeper areas of the lakes, and poor clarity. Lakes with TSIs greater than 60 are considered hypereutrophic and usually have extensive algal blooms during summer. The WDNR Trophic State Index Graph for Muskellunge Lake shows all three indices (TP, CHL-A, Secchi) are indicative of eutrophic or hypereutrophic conditions.

Figure 5 shows that TSI (SD) = TSI (CHL) = >TSI (TP). Based on this analysis, it can be concluded that algae dominate light attenuation and that algae biomass is controlled by phosphorus (Carlson, 1992). This means that Muskellunge Lake has historically not been in the ecologically preferred clear water; aquatic plant dominated state. Reductions of in-lake TP concentrations will be required to reduce algae biomass. Algal bloom biomass should therefore respond rapidly to reductions in TP loading.

Figure 6 provides a multivariate comparison of TSI scores. Points above the Y-axis represent instances where there is more chlorophyll (algae) than predicted by the observed TP concentration. In contrast, points below the Y-axis suggest instances where there is less algae than predicted by TP. Points lying on the X-axis to the right of the Y-axis indicate instances where there is more chlorophyll (algae) than predicted by secchi disk. This most often occurs when the dominant species of algae is large filamentous or clumps of blue-green algae because larger algae particles attenuate less light in comparison with an equal biomass of smaller algal particles (Edmondson 1980). Points on the X-axis to the left of the Y-axis indicate instances where TSI for secchi-disk over-predicts the TSI for chlorophyll. This typically occurs when light is scattered or absorbed by very small particles such as suspended particles (fine silty clays) or by dissolved color (tannins).

Implications from this analysis suggest that there may be period of time when phosphorus is limiting and other times when it is available in surplus. A review of TSI (CHL) versus TSI (TP) on a month by month basis suggests that phosphorus concentrations are more likely to be limiting algae from July-September in comparison with May and June (Figure 7). The greatest opportunity to reduce in-lake TP concentrations from July-September is by reducing internal nutrient loading.

4.2. Limiting Nutrient

The average nitrogen-to-phosphorus ratio in Muskellunge Lake has historically ranged from 15:1 to 20:1 (USGS, 2003). Therefore, phosphorus should be considered the nutrient limiting algal growth in the lake and the nutrient to focus on when considering management efforts to improve water quality.

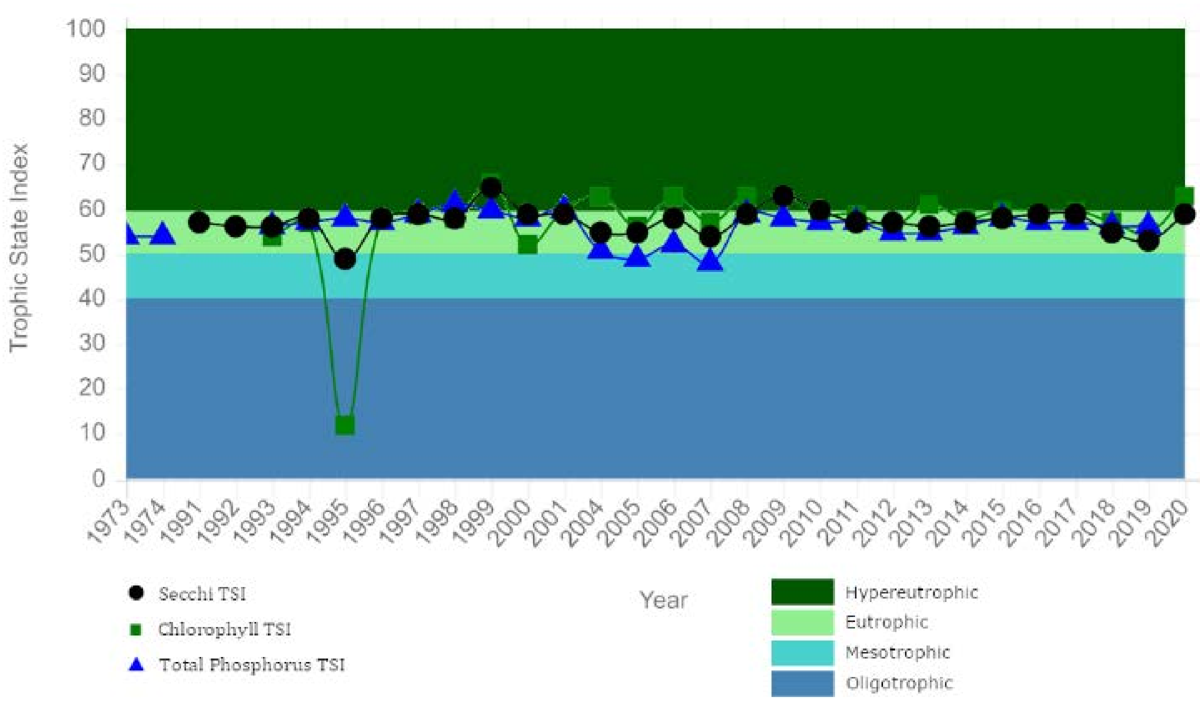


Figure 5. WDNR Muskellunge Lake [Trophic State Index Graph]

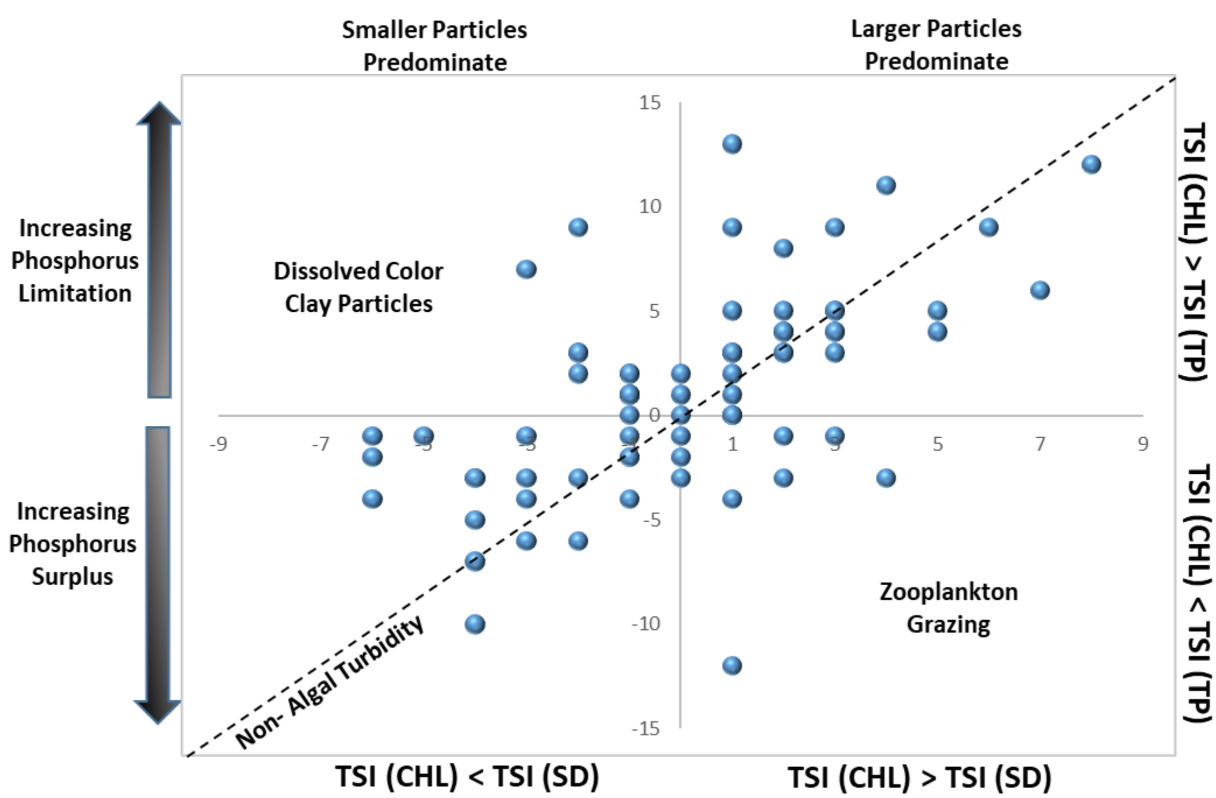


Figure 6. Muskellunge Lake TSI Multivariate Comparison

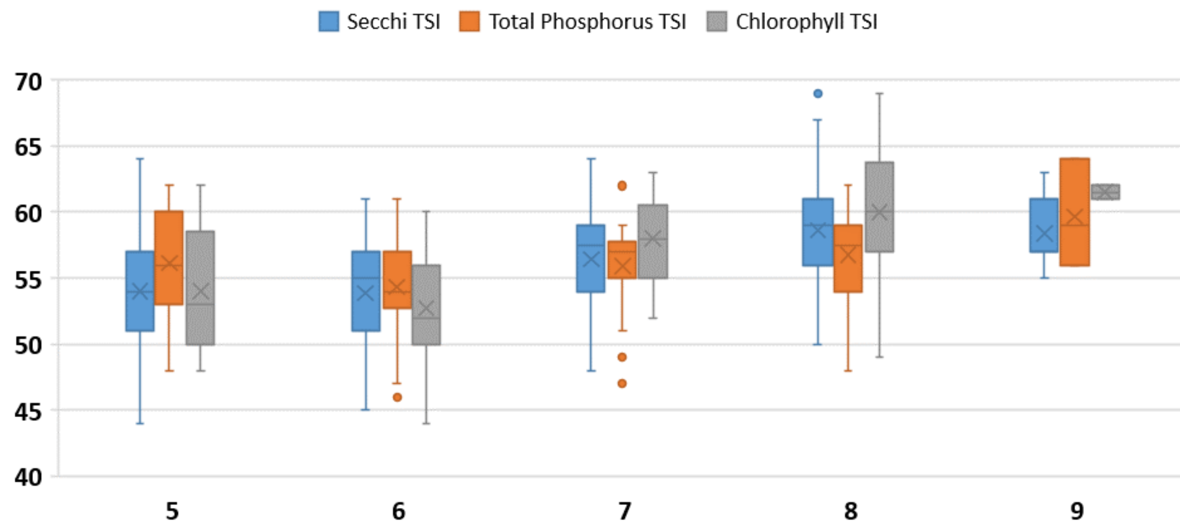


Figure 7. Monthly plot of TSI values for Total Phosphorus (TP), Secchi, and Chlorophyll-a pigments (CHL-A).

4.3. Water Quality Trends

Year-to-year weather variations affect water quality observation data; for this reason, interpreting long-term data trends minimizes year-to-year variation and provides insight into changes occurring in a water body over time. For Muskellunge Lake, data collection relies heavily on volunteers from the MLA, and incorporates any relevant agency and partner data submitted to the Wisconsin DNR Surface Water Integrated Monitoring System (SWIMS) Database. The water clarity trends were calculated using a Seasonal Kendall statistical test for measurements during the growing season (June-September).

Analyzing the full data record (August 1992 – July 2020; a small number of measurements from 1973-1975 were not included in this analysis) shows no statistically significant trend in total phosphorus.

The data do reveal a period of approximately 5 years (July 2004 through June 2008) during which total phosphorus was much lower than during the remaining portions of the record. Within this period the average measurement was 0.017 mg/l, while the average of the remaining record is 0.049 mg/l. This raises the questions (1) what caused the low measured P levels during this 5 year period, and (2) did this period change residents' baseline assumption about "normal" water quality in the lake, contributing to the perception that water quality is declining?

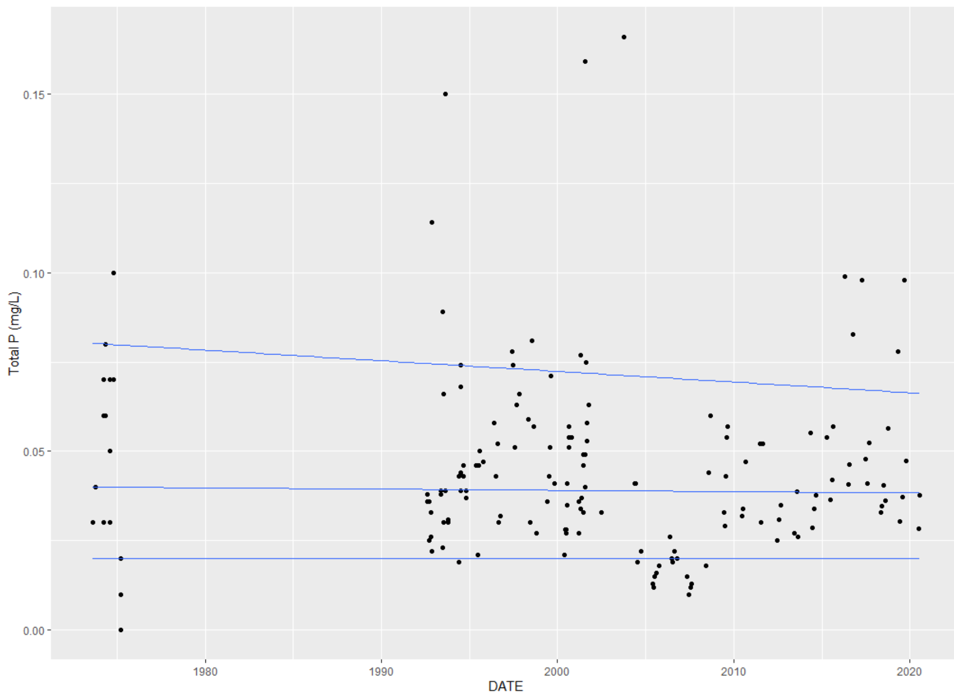


Figure 8 Observed Total P measurements from Muskellunge Lake. Blue lines represent the 10th, 50th, and 90th percentiles.

Additional data available from 1973-1975 shows no clear difference from the more recent samples, with both periods averaging 0.045 mg/l. These data do not have the same clear provenance as the later data, and should probably be treated as less reliable than the more recent data.

There has been a slight increase in annual precipitation over the period of record, but no variation that explains the reduced P levels during 2004-2008.

Looking just at the time period 2004-present, there is a statistically significant upward trend in total phosphorus in the lake, rising 58% over that period. The reason for this trend is unclear, however the highest recorded P levels are all prior to this time, so it does not appear that the lake is undergoing a long-term increase in P loading, but simply multi-decadal variation.

Secchi depth does not display a statistically significant trend over the period of record, either. This suggests that water clarity is relatively stable year-over-year over the observational period.

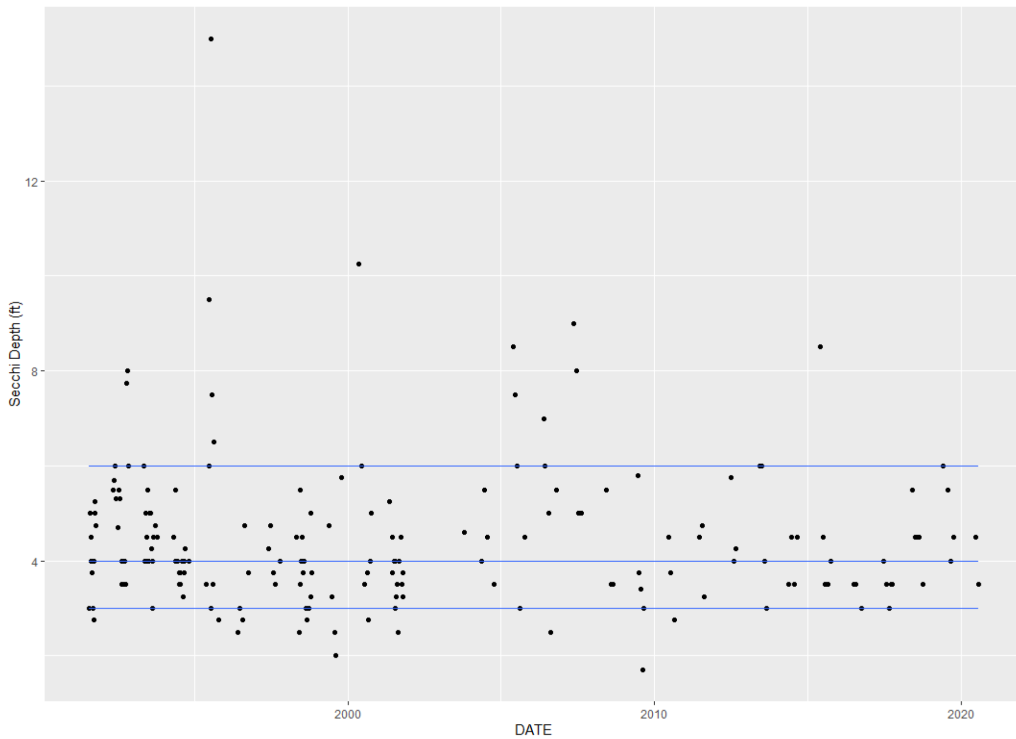


Figure 9 Secchi depth observations from Muskellunge Lake. Blue lines represent the 10th, 50th, and 90th percentiles.

Stakeholder perceptions of a decline in water quality, then, likely have to do with the recent appearance of Eurasian Water Milfoil and increased awareness of water quality issues, rather than increases in phosphorus loading or decreases in water clarity.

Long-duration, high-quality datasets are all too rare in situations like this, and so continuing to collect this data is critical to the successful management of the resource. The dataset does lack samples gathered during the winter months, however, and in particular few samples have been taken during April and September, when lake turnover and stratification are occurring (Fig. 8). Moving forward, efforts should be made to increase sampling during these periods to help understand the seasonal nature of water quality in the lake.

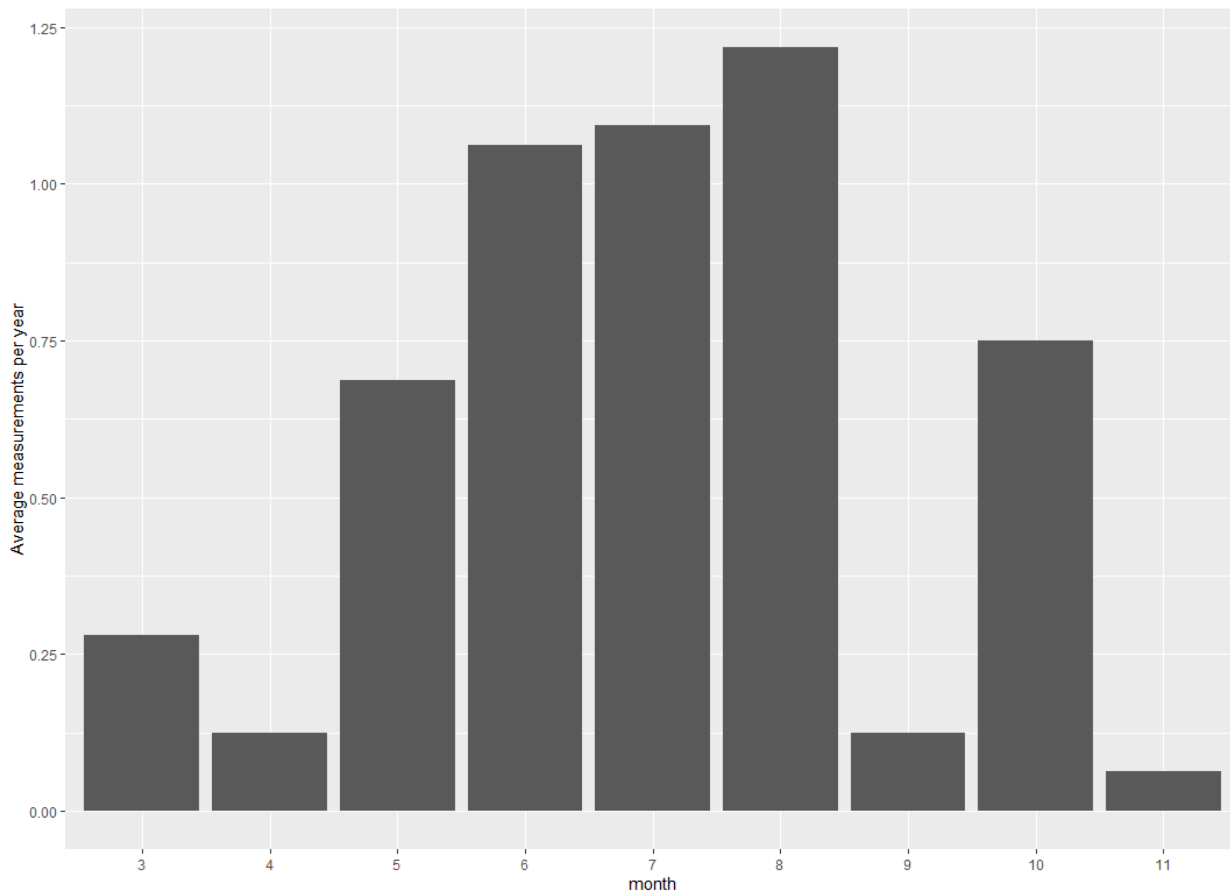


Figure 10 Average annual Phosphorus measurements by month. No measurements were recorded December-February

5. STAKEHOLDER PARTICIPATION

5.1. Management Plan Review and Adoption Process

5.2. Stakeholder Survey

A 2010 US Census found that 61.5% of homes in Vilas County are classified as seasonal, a higher percentage than any other county in Wisconsin. On Muskellunge Lake, only 24 out of 116 (20%) of properties have a mailing address of Eagle River indicating likely full-time residents, the remaining 92 (80%) properties are largely seasonal residences. To target the greatest percentage of lakeshore owners, the Muskellunge Lake Association distributed an online survey to all lakeshore owners on Muskellunge Lake. The survey was designed by the Muskellunge Lake Association with help from EOR staff and reviewed by a WDNR social scientist.

The survey received 78 full or partial responses for a usable response rate of 67%. Roughly a quarter of these (20/77) are year-around residents, with another 16% (12/77) spending more than 100 days per year on the lake. Length of residence showed an interesting bimodal response with the most common length of residence being 20+ years at 41%, followed by 0-5 years at 23%. It is unclear whether this represents the true makeup of the residents, or whether it reflects a response bias towards "lifers" and new residents.

Only five of 76 respondents report using their property for short-term rentals, indicating that owners are directly and personally invested in the wellbeing of the lake and don't primarily view their properties as an investment vehicle. In spite of this, short term rentals were cited several times in the free- response sections as a threat to the lake.

Significant pluralities report that water quality near their property "needs improvement", and refer to the overall water quality in the lake as "fair". It is notable that while few think the water quality is "good" (and none "excellent"), only two (3%) rank the overall water quality as "very poor", and only 12% report their near-shore water quality as "unacceptable".

A majority (53%) report that water quality has "somewhat degraded" since they first visited Muskellunge Lake, and 12% say it has "severely degraded".

Residents top reported concern is the presence of aquatic invasive species in the lake, with 90% reporting that AIS have a "great" or "moderate" negative impact on the lake. This is followed by the related issues of excessive aquatic plants (81% indicating great or moderate impact) and algae blooms (68% great or moderate impact). Watercraft traffic is cited by 43% as having moderate or great impact, and was also mentioned a number of times in the open-ended responses, often in the context of boat traffic tearing up rooted plants and spreading weeds.

Most residents agree that Eurasian Water Milfoil (EWM) growth is outstripping control efforts, but free-form answers suggest people do see benefits from the efforts:

> *The weeds have been a problem for years on the lake. We were happy when the lake association did the weed harvesting some years back. We think that it helped quite a bit.*

A large majority (94%) said efforts to control AIS species such as EWM are “probably” or “definitely” necessary. Opinions on the appropriate form of control seems mixed, with a plurality (47%) strongly supporting spot control with herbicides, and moderate levels of support expressed for other options, such as manual removal by owners, hand removal by divers, or diver assisted suction harvesting. One owner admitted lacking the knowledge to assess the options (“*I believe that we need to take aggressive action, but at this point I am not educated enough on the pluses & minuses of each treatment”*) while another expressed the view that the weeds must be controlled at almost any cost)“*We need to do whatever we can of course within reason to get the problem under control.”)* In response to a separate question, 73% of respondents moderately or strongly supported the use of herbicides in the lake.

Residents are strongly supportive of the Muskellunge Lake Association, with 80% reporting positive or strongly positive feelings about the lake association’s management. This suggests that the MLA is well positioned to deliver messages to residents and steer management decisions.

There is a strong interest amongst respondents in investing time, money and effort into understanding and addressing issues on the lake, primarily EWM. Provided a list of possible lake management subjects, only three respondents reported no interest in learning more; 72% were interested in learning about AIS and smaller but significant percentages selected other topics (How to be a good lake steward, 48%; Enhancing lake habitat, 54%; Benefits of shoreline restoration and preservation, 52%, understanding lake biology and chemistry, 60%). In addition, 43% are open to donating money, and 34% are prepared to volunteer their time towards conservation projects.

Taken together these paint a picture of a population that likes their lake, feels a personal connection to it, and while they express concerns about the water quality state and trend, most seem to resist picking the most negative options. They see the lake on a downward track, but don’t see the situation as hopeless, and are prepared to invest time, money, and effort into improving things. They see aquatic invasives (specifically Eurasian Water Milfoil) as the primary threat to the lake.

6. AQUATIC PLANTS

In general, when aquatic plants are present in shallow lakes, the water is clear (Figure 11). Diverse, aquatic vegetation is critically important to the wide variety of fish, insects, and wildlife that live in Muskellunge Lake. Numerous studies have also shown that native aquatic plants can sustain good light penetration and water quality.

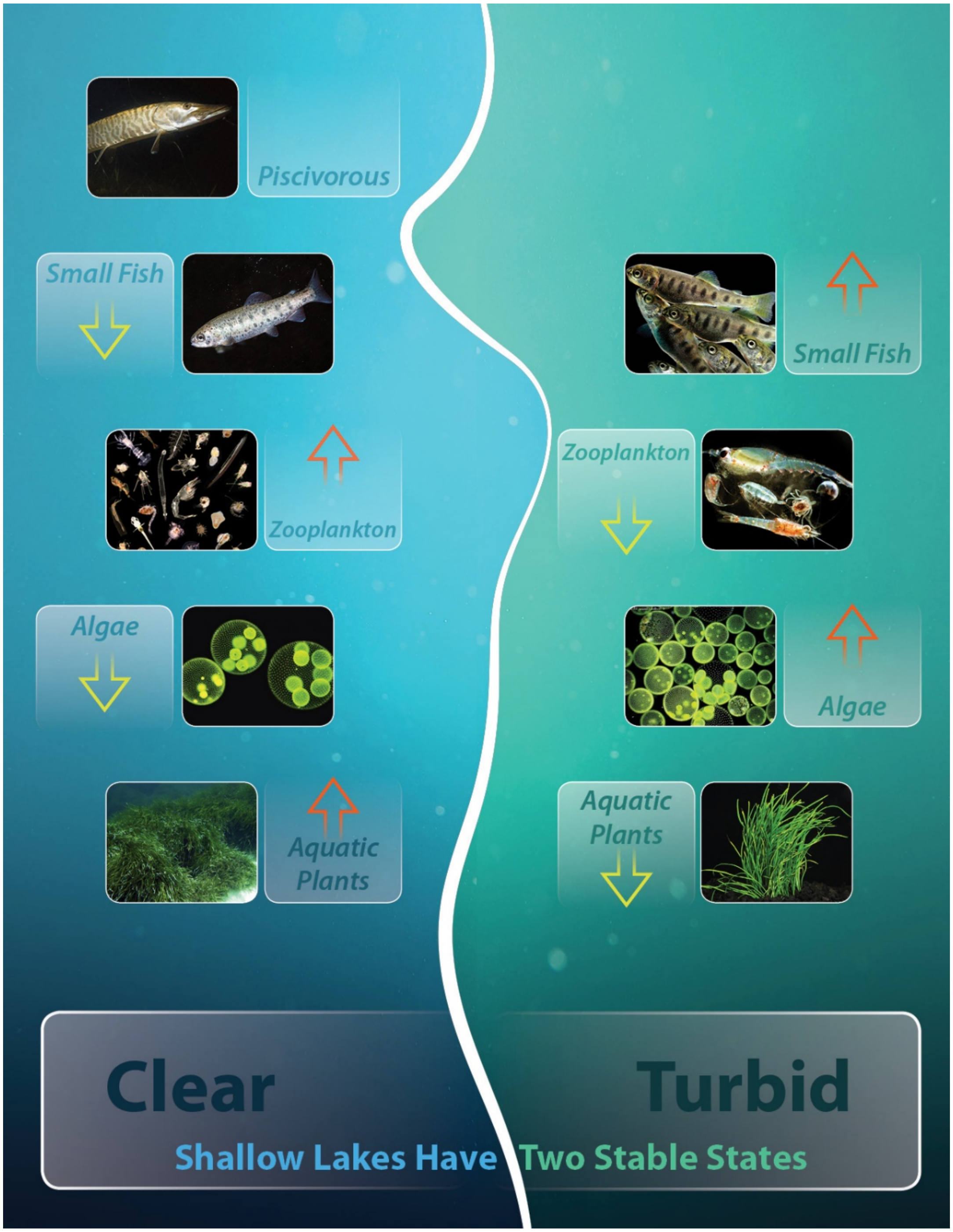


Figure 11. Cascading biological communities in shallow lakes under clear and turbid water states.

While aquatic plants are vital to maintaining the ecologically-preferred clear water state, invasive species like Eurasian watermilfoil (EWM) can quickly alter the ecology of a shallow lake and prevent or restrict lake users from enjoying certain recreational activities such as boating and swimming. Therefore, the challenge for Muskellunge Lake is to concurrently reduce EWM coverage and protect lake water quality by maintaining a clear-water, aquatic plant dominated state. Results from point-intercept surveys completed in 2009, 2017, and 2020 and EWM focused meander surveys conducted from 2017-2020 are presented in the following paragraphs. Results from the 2009 survey provides a valuable reference point for understanding what the aquatic plant community looked like prior to the arrival of EWM. Having a valid reference point is vital to defining realistic, quantifiable goals that concurrently protect the ecology of the lake and the interests of those who value Muskellunge Lake as a water resource.

6.1. Muskellunge Lake Point Intercept Surveys

The point-intercept method is considered the standard protocol by WDNR for sampling macrophytes because it offers a methodology that is quantitative (e.g., frequency of occurrence), repeatable (can be used to track trends in aquatic plant communities over time), and georeferenced (can be used to compare plant communities within different areas of a lake). From this data, a Floristic Quality Index (FQI) was calculated that measures the diversity and health of the aquatic plant community. Additional statistical analysis performed included the Simpson's Diversity Index, which accounts for both species diversity and species evenness.

The FQI calculation is based on both the quantity of species observed (species richness) as well as the quality of each individual species. Every aquatic plant in Wisconsin has been assigned a coefficient of conservatism value (c-value) ranging from 0 to 10. The c-value of all aquatic plants sampled from a lake is used to determine the FQI for a given lake. Species with a c-value of 0 include non-native species such as curly-leaf pondweed (*Potamogeton crispus*) that are indicative of a highly disturbed environment. In comparison, the native species Oakes pondweed (*Potamogeton oakesainus*) has a c-value of 10 because this species is extremely rare and only found in undisturbed, pristine waterbodies.

Healthy aquatic plant communities contain a large number *and* variety of aquatic plant species that are largely evenly distributed across the entire lake. Lakes containing a diverse distribution of aquatic plant species provide a more complex habitat that is suitable for a wider range of aquatic organisms including a variety of fish and macroinvertebrate species. In comparison, ***moderately*** healthy aquatic plant communities may contain a comparatively large number of species but are often dominated by one or two species, this metric is referred to as ***species evenness*** and is another means of measuring how diverse a lake's aquatic plant community is and can be measured using Simpson's Diversity Index.

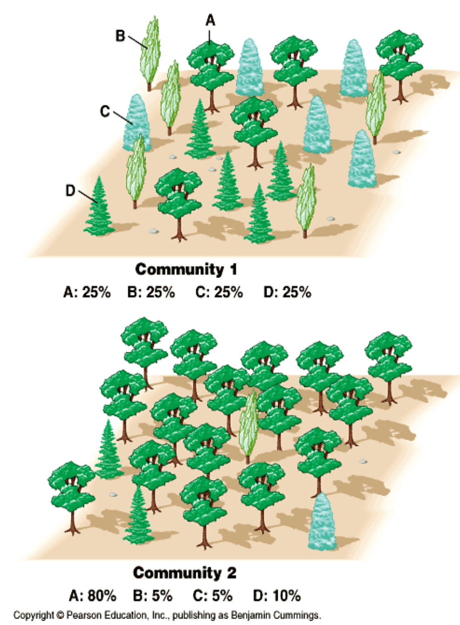


Figure 12. Species Evenness

6.1.1. Results

Results of the 2009, 2017, and 2020 point-intercept survey for Muskellunge Lake and associated FQI and Simpson's Diversity Index (SDI) scores are summarized in Table 1. FQI scores for Muskellunge Lake have remained stable, ranging from a high of 31.2 in 2009 to a low of 29.0 in 2020. Please note that shoreline species associated with habitats that bordered the lake were excluded from the FQI calculation. The results presented in Table 1 focus on the in-lake aquatic plant community. The FQI score from all three point-intercept surveys was greater than the Northern Lakes and Forests – Lakes (NLFL) ecoregion of 24.3 ±6 (Nichols, 1999), suggesting a highly diverse aquatic plant community. However, the average observed c-value from all three surveys is below the average c-value score for lakes in the NLFL ecoregion of 6.7±1. The average c-value for Muskellunge Lake is indicative of a disturbed system and is lower than every other lake in Cloverland Township except Boot Lake (Onterra, LLC, 2011).

In eutrophic waterbodies, it is not uncommon to see **one or two species** become overly prolific, thereby reducing the average number of species found at any one point within the lake, which ultimately reduces the overall complexity and variety of habitats, a lake system offers. Aquatic plant species that are most likely to become overly abundant in Muskellunge Lake include coontail and EWM. It should be noted that EWM was **not** observed during the 2009 survey and was only observed at four locations during the 2017 survey. EWM was observed at 50% of vegetated points (78 occurrences) during the 2020 survey, making it the second most commonly observed species in Muskellunge Lake behind only coontail.

According to data obtained by Onterra, LLC from WDNR Science Services, the median SDI for lakes in the NLFL ecoregion is 0.89 (0.82 – 0.90). Therefore, SDI values of 0.86 and 0.82 from the 2009 and 2017 surveys are within the range of expected values relative to other lakes in the NLFL ecoregion while the 2020 SDI value of 0.91 is indicative of a more diverse environment. For perspective, a SDI score or 0.91 means that if two plants were randomly selected from the **entire** lake, there is a 91% probability that the two individuals would be of a different species. This statistic must be placed into context as the calculation considers both emergent species and submergent species.

The FOO of EWM in Muskellunge Lake has increased from 0.74% in 2017 to 49.4% in 2020. Currently, coontail(c-value = 3), EWM(c-value = 0), and fern pondweed (c-value = 8) have the highest Frequency of Occurrence (FOO) in Muskellunge Lake (Figure 13). In comparison, in 2009, the species with the highest FOO were coontail(c-value = 3), common waterweed(c-value = 3), and flat-stem pondweed (c-value = 6).

From 2009-2020, species with a decrease in FOO of more than 5%, include coontail, common waterweed, northern watermilfoil, white-stemmed pondweed, and flat-stem pondweed, (average c-value = 5.4). From 2009-2020 species with an increase in FOO of more than 5%, include spatterdock, fern pondweed, large-leaf pondweed, small pondweed, and water celery (average c-value = 6.8).

From 2017-2020, the FOO of coontail and flat-stem pondweed decreased by more than 5%, (average c-value = 4.5). From 2017-2020, the FOO of watershield, common waterweed, large-leaf pondweed, white-stemmed pondweed, small pondweed, and water celery increased by more than 5%, these (average c-value = 6.2). Future surveys are needed to fully validate if observed changes in the FOO of individual species are statistically significant.

Table 1. Muskellunge Lake Point-Intercept Survey Results Comparison

Scientific Name	Common Name	C-Value	2009 FOO	2017 FOO	2020 FOO	> 5% Change in FOO 2009 vs. 2017	> 5% Change in FOO 2009 vs. 2020	> 5% Change in FOO 2017 vs. 2020
Bidens beckii	Water marigold	8	4	1	1	----	----	----
Brasenia schreberi	Watershield	6	----	1	8	----	----	7% Increase
Calla palustris	Water arum	9	Visual	Visual	Visual	----	----	----
Carex comosa	Bristly sedge	5	Visual	----	----	----	----	----
Ceratophyllum demersum	Coontail	3	90	74	65	16% Decrease	25% Decrease	9% Decrease
Chara	Muskgrasses	7	4	3	6	----	----	----
Eleocharis palustris	Creeping spikerush	6	Visual	1	1	----	----	----
Elodea canadensis	Common waterweed	3	56	22	35	34% Decrease	21% Decrease	13% Increase
Equisetum fluviatile	Water horsetail	7	Visual	Visual	Visual	----	----	----
Heteranthera dubia	Water stargrass	6	2	----	----	----	----	----
Lemna minor	Lesser duckweed	5	1	----	----	----	----	----
Myriophyllum sibiricum	Northern water milfoil	7	24	----	3	24% Decrease	21% Decrease	----
Najas flexilis	Slender naiad	6	8	10	15	----	----	----
Nitella spp.	Stoneworts	7	2	----	----	----	----	----
Nuphar variegata	Spatterdock	6	13	10	19	----	6% Increase	----
Nymphaea odorata	White water lily	6	5	4	13	----	----	----
Potamogeton amplifolius	Large-leaf pondweed	7	16	7	28	----	12% Increase	21% Increase
Potamogeton foliosus	Leafy pondweed	6	9	2	2	----	----	----
Potamogeton gramineus	Variable pondweed	7	<1	<1	----	----	----	----
Potamogeton praelongus	White-stem pondweed	8	32	2	18	30% Decrease	14% Decrease	16% Increase
Potamogeton pusillus	Small pondweed	7	0	3	18	----	18% Increase	15% Increase
Potamogeton richardsonii	Clasping-leaf pondweed	5	<1	----	----	----	----	----
Potamogeton robbinsii	Fern pondweed	8	5	49	47	45% Increase	42% Increase	----
Potamogeton zosteriformis	Flat-stem pondweed	6	66	48	20	18% Decrease	46% Decrease	28% Decrease
Sagittaria latifolia	Common arrowhead	3	Visual	----	----	----	----	----
Schoenoplectus acutus	Hardstem bulrush	6	----	1	6	----	----	----
Schoenoplectus tabernaemontani	Softstem bulrush	4	1	----	----	----	----	----
Sparganium angustifolium	Narrow-leaf bur-reed	9	<1			----	----	----
Sparganium eurycarpum	Common bur-reed	5	2	1	1	----	----	----
Sparganium fluctuans	Floating-leaf bur-reed	10		1	1	----	----	----
Typha latifolia	Broad-leaved cattail	1			1	----	----	----
Utricularia vulgaris	Common bladderwort	7	4		1	----	----	----
Vallisneria americana	Wild celery	6	7	9	22	----	15% Increase	13% Increase
Floristic Quality Index (FQI) FQI = C*√S C= Mean C- value S= Number of species in sample	**Average C-Value**		6.2	6.4	6.3			
	Number of species		25 (30)*	21 (32)*	21 (30)*			
	FQI		31.2	29.2	29.0			
Simpson's Diversity Index (1-D): $D=\sum(n / N)^2$ n = # of instances of a particular species N = the total # of instances of all species D = Value between 1 and 0	**Simpson's Diversity Index**		0.86	0.82	0.91			

FOO = Frequency of Occurrence. * Number of species included in FQI calculation does not include near-shore species that were visually identified but not sampled.

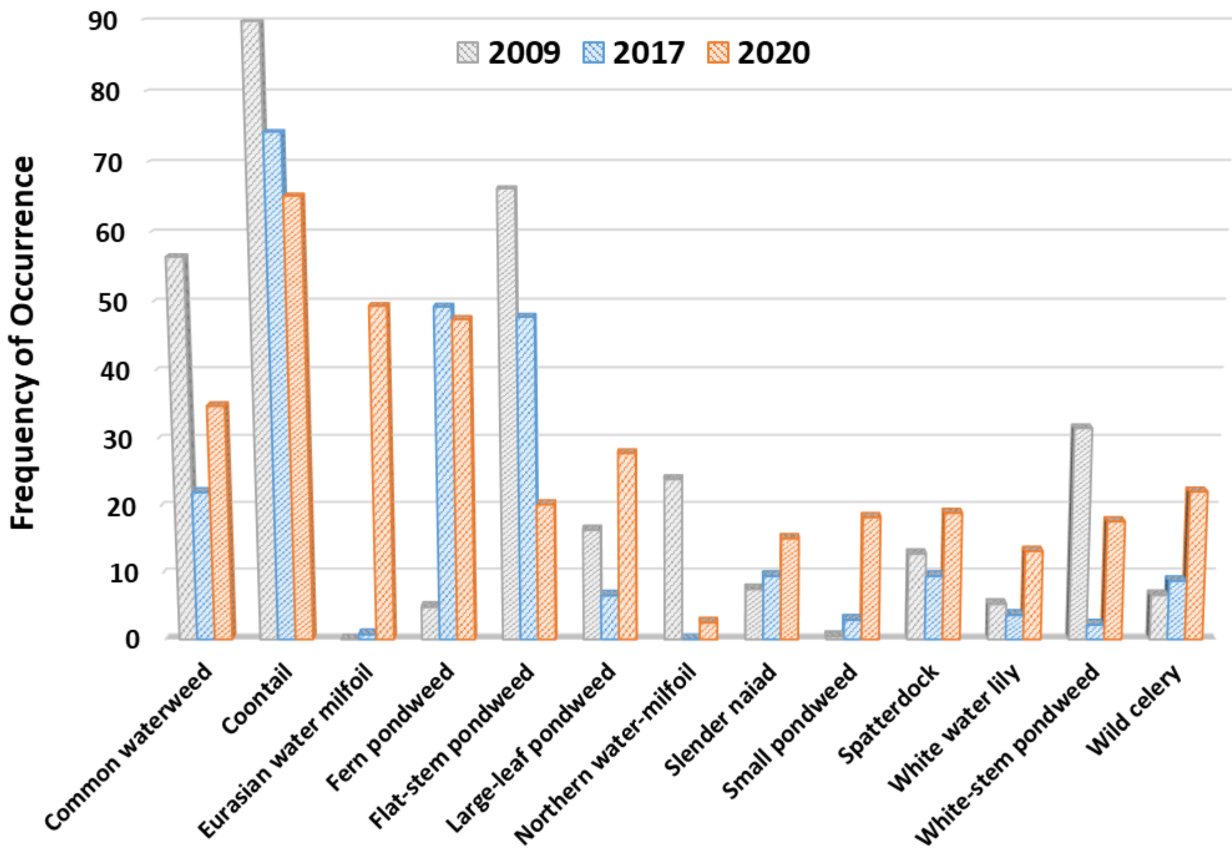


Figure 13. Frequency of Occurrence of Common Aquatic Plant Species 2009-2020.

6.2. EWM Focused Meander Surveys

6.2.1. 2019 Focused Meander Surveys

Members of the Muskellunge Lake Association accompanied EOR staff on June 2 and June 5, 2019 to conduct a focused (EWM presence) meander survey of the entire littoral zone using a sub-meter differential Global Positioning System (GPS) and the ArcGIS Collector App to collect and publish EWM location data in real-time. Polygons were mapped around all well-established colonies while point-based techniques were used to record locations that were considered pioneer colonies which contained only a few plants or a single plant. All points and polygons collected in the field were immediately transferred (published) to the Muskellunge Lake ArcGIS Online map depicting survey results. Water clarity was exceptionally clear allowing for a visual inspection of the entire water column.

Results from the survey reconfirmed that the center bar contained the densest stands of EWM with plants reaching the surface by June 2, 2019 despite below average temperatures in the month preceding the survey. Based on these results, an executive decision was made by EOR and MLA to focus DASH efforts solely on the 0.81-acre center bar given it is the primary vector for EWM within Muskellunge Lake.

Following DASH efforts conducted on June 5 and June 9, members of the Muskellunge Lake Association accompanied EOR staff on July 7 to conduct a focused (EWM presence) meander survey of the entire littoral zone using the same techniques used to conduct the pre-treatment survey. Prior to conducting the post-treatment survey, volunteers from the Muskellunge Lake Association had identified a new EWM infestation adjacent to a shallow water hazard buoy located in the northeast bay of Muskellunge Lake. Delineation of the extents of this new EWM infestation represented a significant point of emphasis for the post-treatment survey as this area did not contain EWM during previous surveys. Water clarity was exceptionally clear on July 7, allowing for a visual inspection of the entire water column to be made in addition to sampling conducted using the sampling rake. The presence of clear water and calm winds greatly enhanced the ability to identify new EWM stands that were often interspersed with native species.

The presence of one or more EWM plants was documented at a total of 171 unique locations during the post-treatment survey; furthermore, EWM was found in nearly every bay of Muskellunge Lake. The boundaries of the EWM infestation were determined by re-meandering the boat around the boundaries of the 171 unique sampling points to visually inspect and reconfirm the extent of the EWM population. As previously discussed, exceptional water clarity and calm winds helped to identify and verify the extents of the infestation. As of the July, 7 survey, the total acreage delineated was determined to be approximately 8.5 acres, equivalent to the management threshold that the MLA established in 2018 following communication with the DNR.

EOR documented a significant reduction in both the distribution and abundance of EWM in the 0.3-acre area in which the DASH took place. Furthermore, EOR documented the presence of large-leaf pondweed in the areas where the DASH took place. Given that the post-treatment survey occurred only one month after the DASH took place, a second post treatment survey was conducted on August 29, 2019 to more thoroughly document the impacts of the DASH effort.

6.2.2. Post-Treatment Focused Biomass Evaluation Survey

On August 29, 2019 members of the Muskellunge Lake Association accompanied EOR staff to conduct a biomass evaluation survey focused exclusively on areas both within and immediately adjacent to the areas where the DASH took place. Despite torrential rainfall during the survey, EOR worked with Muskellunge Lake Association volunteers to rank EWM biomass on a scale from 1-3 at 35 randomly selected points including 13 points outside of the treatment area and 22 points from within the DASH treatment area. A total of 19 biomass samples were collected at the 35 randomly selected sites including 10 from within the treatment area and 9 outside of the treatment area.

The 2019 DASH did not completely eliminate EWM within the treated area, this was not the intent of the DASH effort. More importantly, the treatment area had significantly less EWM biomass in comparison with areas outside of the treatment area (Figure 14, Figure 15, Figure 16). Results are also represented spatially in the Muskellunge Lake ArcGIS Online Map. Large-leaf pondweed, coontail, and water celery were observed both within the treated area and immediately outside the treatment area.

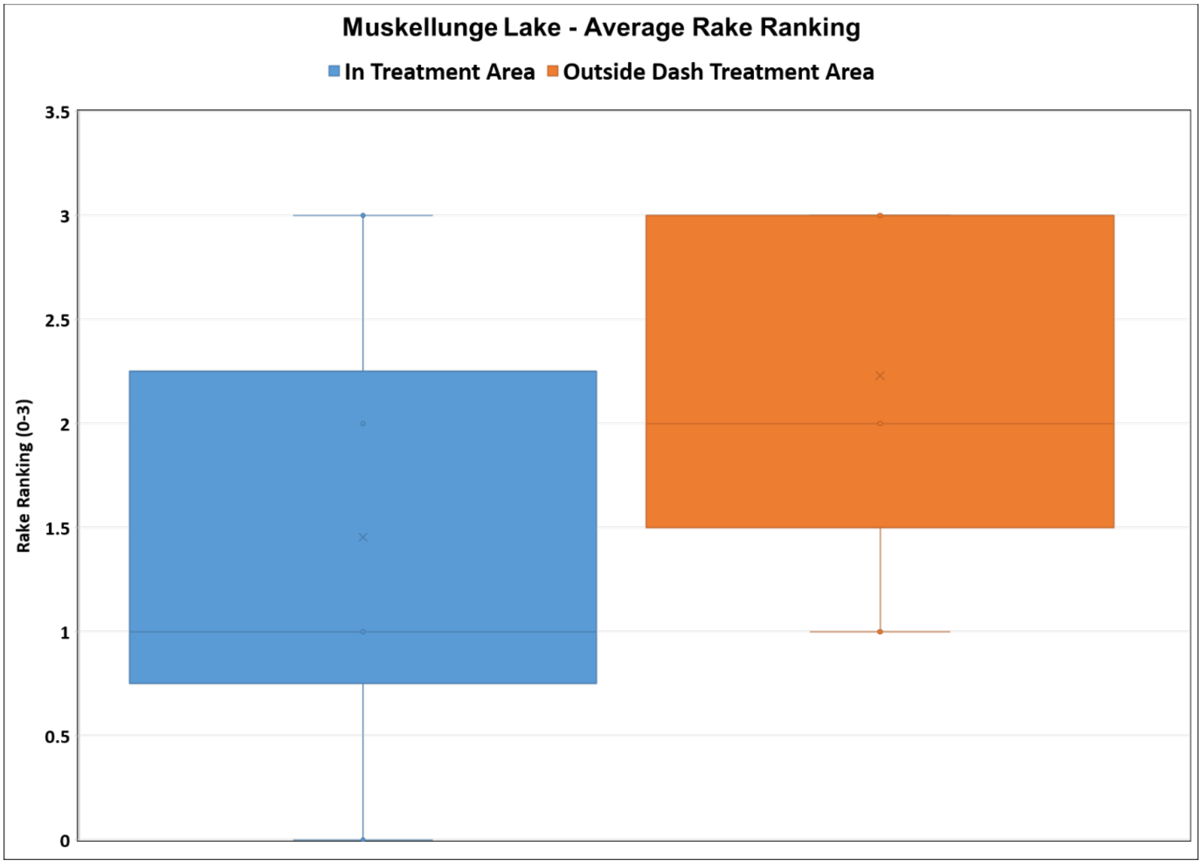


Figure 14. Muskellunge Lake Focused Biomass Evaluation Survey - Rake Ranking Comparison

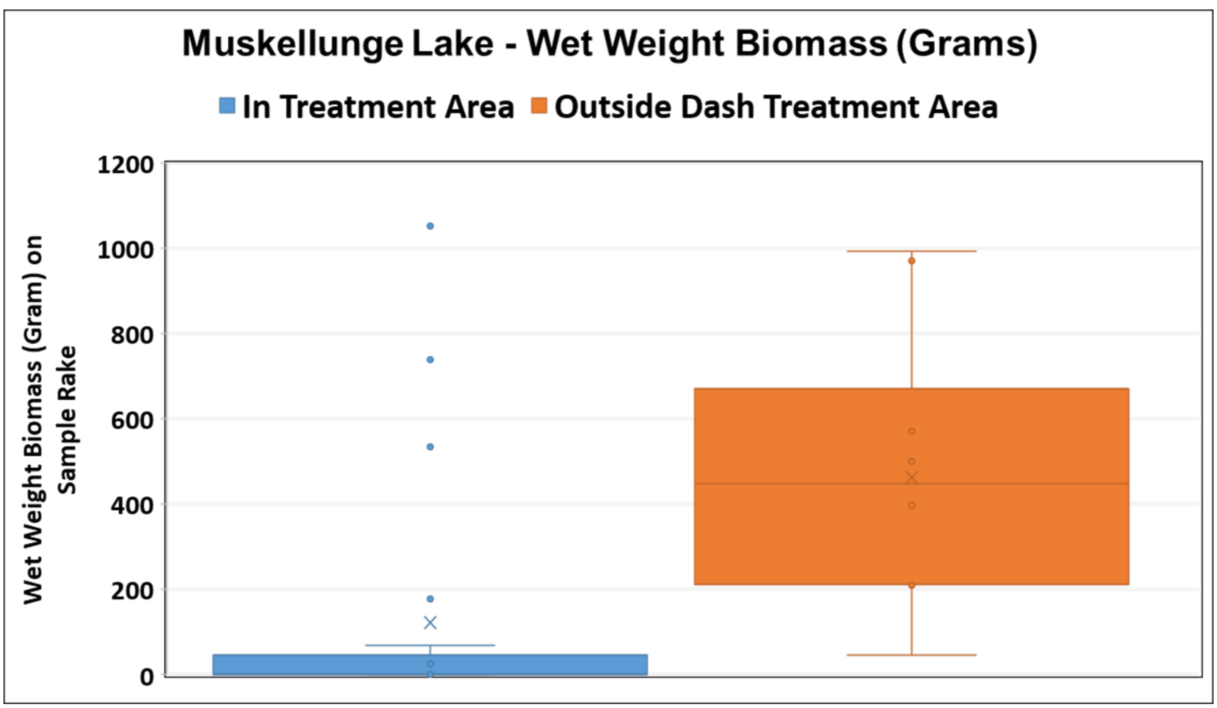


Figure 15. Muskellunge Lake Focused Biomass Evaluation Survey - Wet Weight Biomass

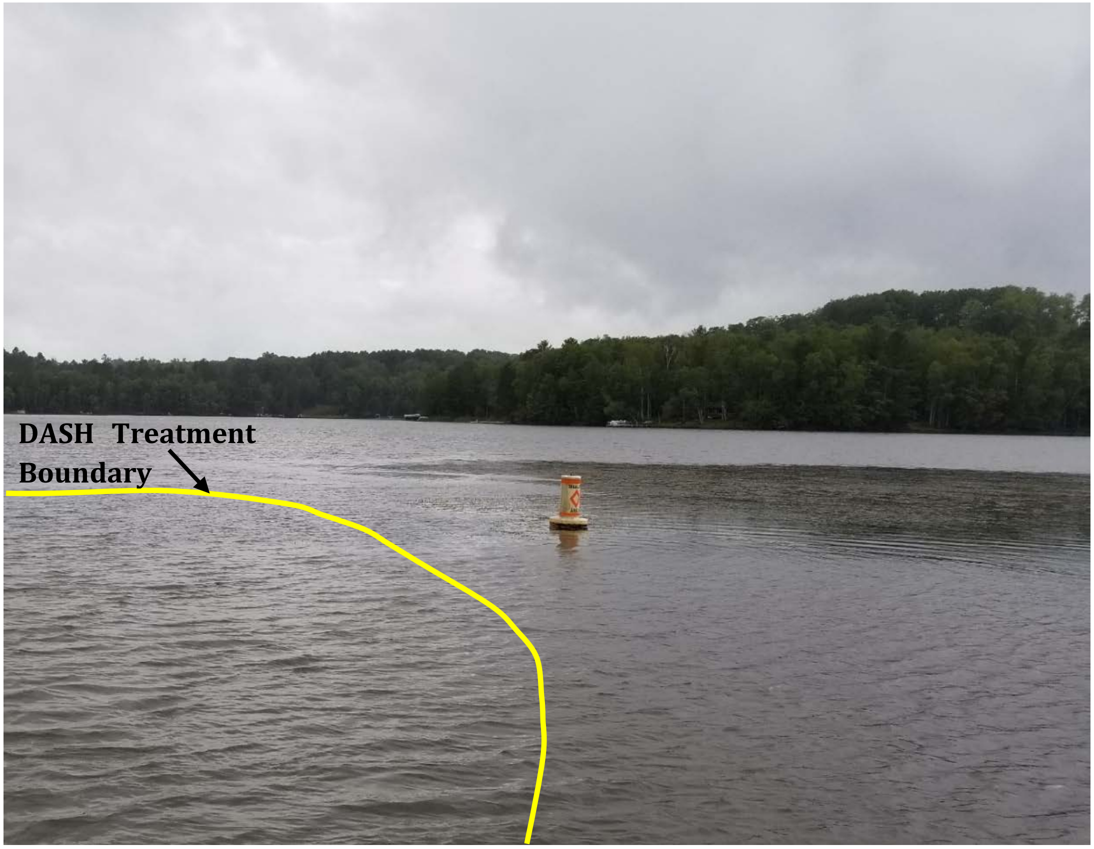


Figure 16. Muskellunge Lake Focused Biomass Evaluation Survey – Treatment Boundary

6.2.3. 2020 Focused Meander Surveys

Members of the Muskellunge Lake Association conducted bi-weekly focused meander surveys of the Muskellunge Lake littoral zone from June 1 – September 22, 2020 taking geo-referenced photos and recording GPS coordinates of all locations in which EWM was identified. Site photos and accompanying GPS coordinates were published to the Muskellunge Lake ArcGIS Online map depicting survey results. During the bi-weekly surveys, MLA members collected information on new EWM locations and recorded semi-qualitative data on the abundance of EWM at each sampling point.

Observations

1) DASH treatments were not effective at preventing EWM re-growth in 2020. Focused meander surveys conducted near the center bar found no difference in EWM abundance in treatment areas versus control areas just one year post-treatment (Figure 17). Due to the rock/gravel substrate at the center bar, Aquatic Plant Management, LLC found it difficult to remove the entire root crown, suggesting DASH may not be an effective control strategy for this area.
2) There are approximately 26 acres of concentrated EWM growth spread across 12 treatment polygons. Each polygon has been prioritized for management action based upon the severity of the EWM infestation and native species abundance (Table 2).
3) The treatment areas represent the focal point of future management efforts on Muskellunge Lake. Recommended EWM management for each treatment area can be found in Section 5.

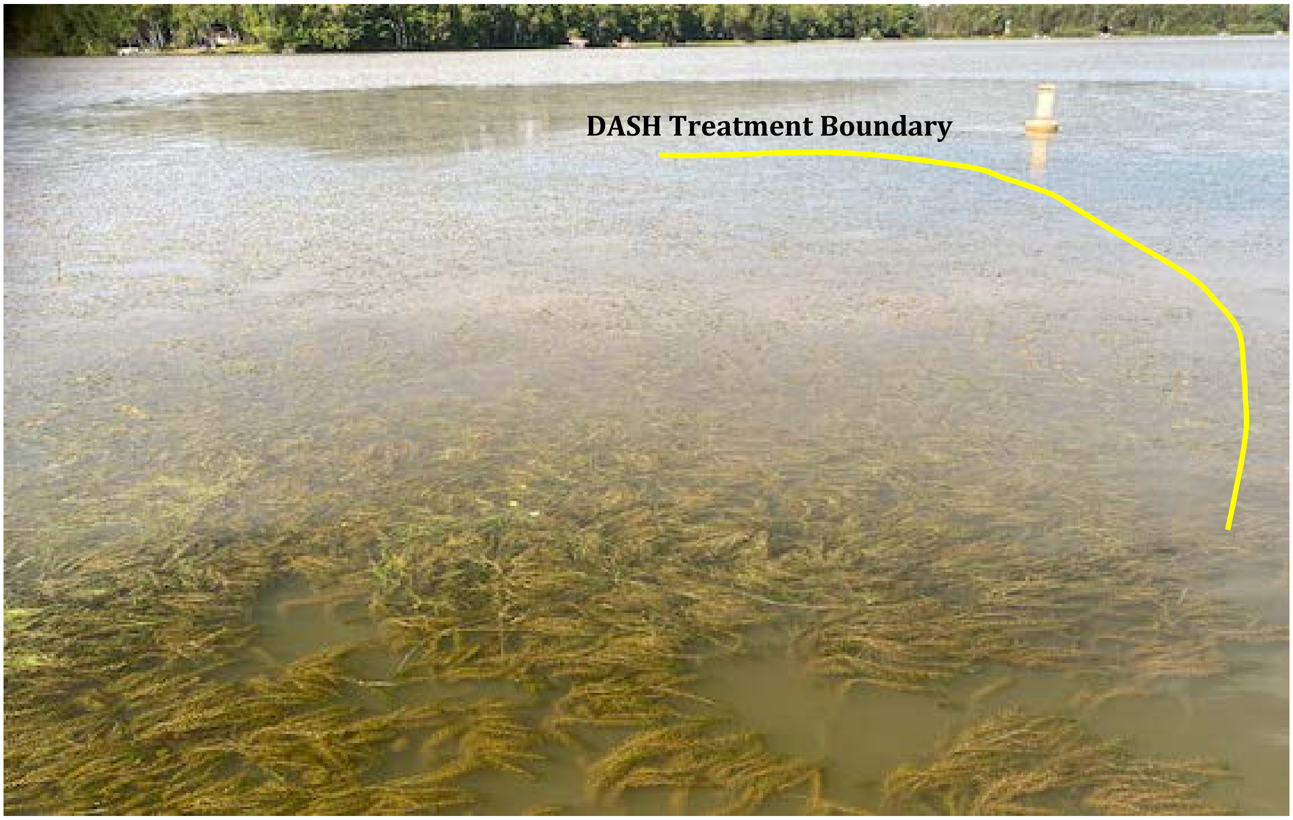


Figure 17. Muskellunge Lake Focused Meander Survey – 2020 Center Bar

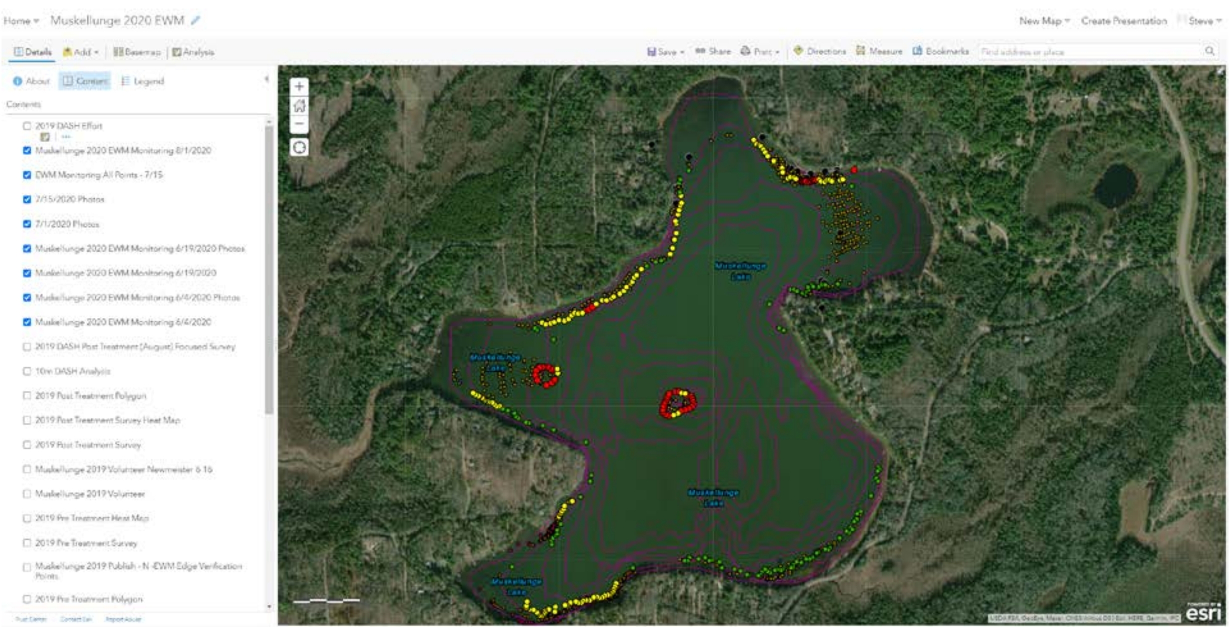


Figure 18. Screenshot Muskellunge Lake ArcGIS Online Map

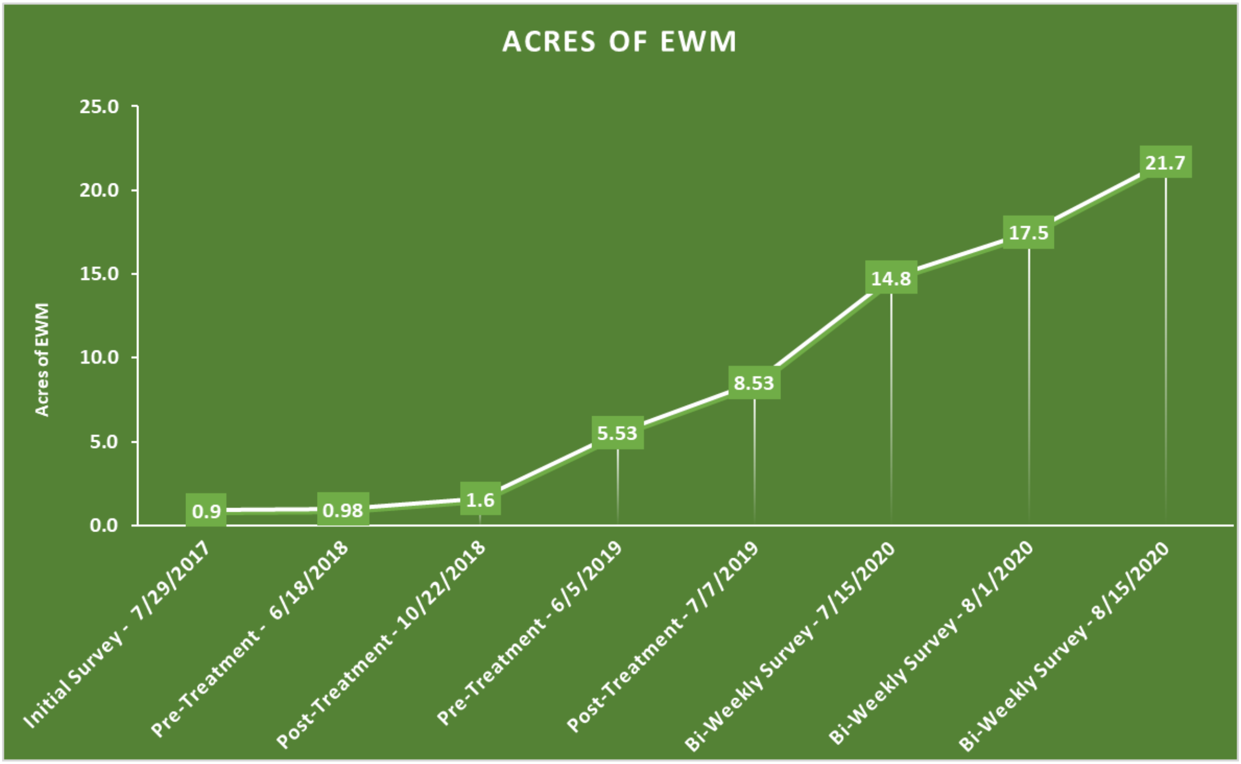
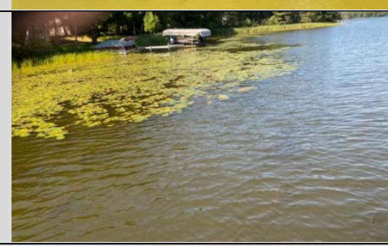


Figure 19. Estimated surface area of EWM infestation on Muskellunge Lake from 2017-2020.

Table 2. EWM Management Areas Triaged by Priority

Treatment Area	Management Priority	Acres*	Native Species	Current Image
1	Tier 1 -Highly Dominant/Surface Matted	1.12	Sparse	
2	Tier 1 -Highly Dominant/Surface Matted	1.30	Sparse	
3	Tier 3 - Co-Dominant	5.52	Common	
4	Tier 1 -Highly Dominant/Surface Matted	1.84	Scattered	
5	Tier 3 - Co-Dominant	1.22	Common	
6	Tier 1 -Highly Dominant/Surface Matted	3.12	Common	

7	Tier 3 - Co-Dominant	6.67	Sparse	
8	Tier 3 - Co-Dominant	1.93	Sparse	
9	Tier 2 - Dominant	1.04	Scattered	
10	Tier 3 - Co-Dominant	0.19	Sparse	
11	Tier 2 - Dominant	0.90	Scattered	
12	Tier 3 - Co-Dominant	1.77	Sparse	
Total	**Tier 1 – Highest Priority For Management**			**7.38 Acres**
	Tier 2 – High Priority for Management			**1.94 Acres**
	Tier 3 – Moderate/Long-Term Management			**17.31 Acres**

*The 26.6 acre-area does not include every single location in which EWM has been located that information is available on the ArcGIS Online map.

7. AQUATIC PLANT MANAGEMENT

7.1. Case Study Review

The arrival and subsequent rapid expansion of EWM has impacted the native plant community and decreased the recreational usability of Muskellunge Lake. This section of the lake management plan will critically re-evaluate the role of aquatic plant management, especially EWM management in protecting Muskellunge Lake for future generations.

Historically, aquatic plant management in many Midwest lakes has operated in a reactive nature, often responding to control nuisance aquatic plant growth that limits the recreational use of a waterbody whether it be impeding navigation, altering fishing, or preventing swimming. This reactive approach to aquatic plant management rarely, if ever, results in a sustainable long-term solution.

Case studies are presented for each of the lakes to 1) identify a timeline of short-term and long-term aquatic plant management activities over the next 5 years for Muskellunge Lake 2) identify potential costs, 3) determine relevancy to Muskellunge Lake and 4) identify potential funding mechanisms for recommended treatment options.

1) Kathan Lake – Saint Germain, Wisconsin
2) Big Marine Lake – Marine on St. Croix, Minnesota
3) Anvil Lake – Washington, Wisconsin
4) Boot Lake – Cloverland, Wisconsin
5) Upper Buckatabon Lake – Conover, Wisconsin
6) North and South Twin Lake – Conover, Wisconsin
7) Long Lake - Marine on St. Croix, Minnesota

7.1.1. Case Study #1: Kathan Lake, St. Germain Wisconsin

Setting

Kathan Lake is located approximately 7 miles south from Muskellunge Lake near the border of Vilas and Oneida County. Kathan Lake was chosen as a representative case study due to similar water quality and morphometry (shallow lake) to Muskellunge Lake.

Background

Following initial discovery, EWM expanded rapidly, covering nearly all of the suitable littoral zone in just 4 years. By 2009, many owners reported an inability to secure recreational use of the lake. Results from a 2009 point intercept study conducted by the WDNR indicated that EWM had become the predominant species in the lake. In 2010, a lake-wide 2, 4-D treatment was conducted that targeted the 115-acre portion of the lake that is deeper than 5 feet. Post-treatment monitoring indicated exceptional EWM control, furthermore, many of the native species observed prior to the treatment quickly recovered following the lake-wide treatment of EWM although some damage to non-target species was observed. Anecdotal report of fish kills following the treatment have surfaced, but not documented.

A second lake-wide 2,4-D treatment was conducted in 2016 as part of a study led by Dan Isermann, Ph.D., of the Wisconsin Cooperative Fishery Research Unit, College of Natural Resources, UW-Stevens Point. Results from this research suggested the treatment was effective at reducing EWM and according to Dr. Dan Isermann had “no meaningful treatment level effects, as the growth rate of young yellow perch in the treatment area was “basically” similar to that of the non-treatment lakes that served as reference points”. According to Dr. Dan Isermann, no conclusions should be made on potential long-term effects of repeated applications of 2,4-D on fish and/or zooplankton. Observations and lessons learned from Kathan Lake are summarized in Table 5.

7.1.2. Case Study #2: Big Marine Lake, Marine on St. Croix, Minnesota

Setting

Big Marine Lake is a 1,800-acre lake with 1,172 littoral acres located approximately in Washington County, Minnesota near the border of Wisconsin and Minnesota. The Big Marine Lake Association’s innovative approach to managing EWM provides a refreshing example of pro-active EWM management that has resulted in the successful reduction of EWM coverage from 38.6 acres in 2014 to 3.8 acres in 2020 (pre-treatment).

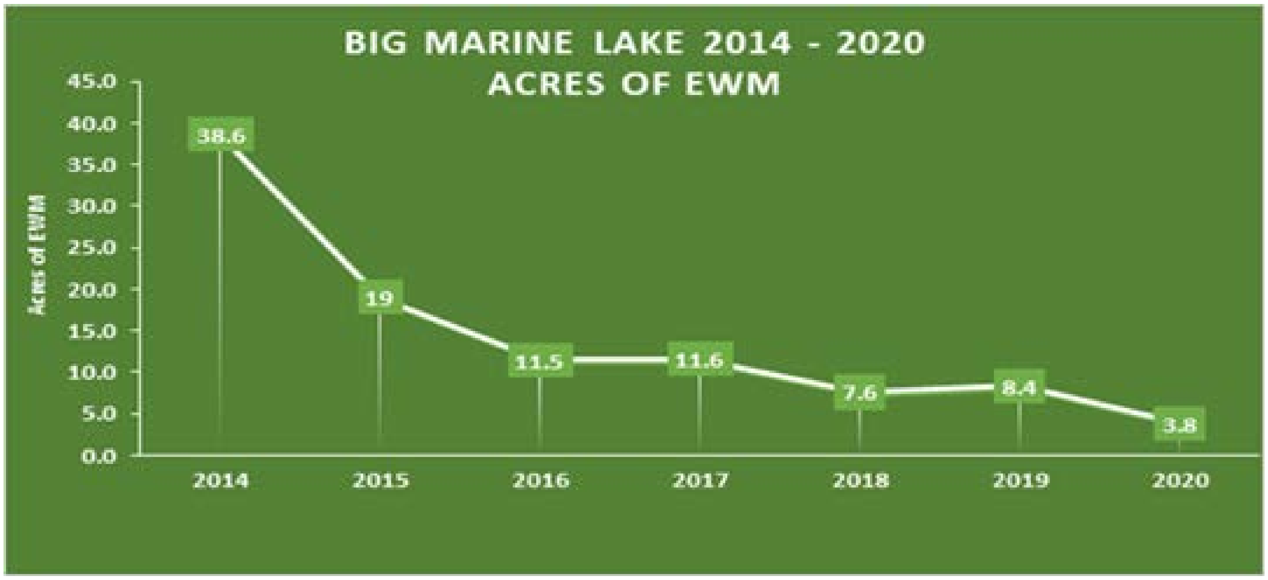


Figure 20. Delineated EWM coverage on Big Marine Lake from 2014-2020

Background

EWM was first discovered in Big Marine Lake (BML) by scuba divers in 2004. By 2014, there were nearly forty acres of EWM. A 2014 sediment analysis conducted by Steve McComas of Blue Water Science suggested the lake could support at least 300 acres of EWM.

During the period from 2009 to 2014, Big Marine Lake Association (BMLA) president Michael Blehert read approximately 50 research papers and with other board members attended 15 or more seminars, workshops, other AIS discussion meetings and attended other lake association meetings to see what they were doing. By 2014, the BMLA board, with help and encouragement from Professors at the MAISRC (U of M Aquatic Invasive Species Research Center), Steve Mc Comas of Blue Water Science, Patrick Selter of PLM, LLC, and DNR AIS Specialists Keegan Lund, and Kylie Cattoor came up with a novel approach to not only control EWM, in BML, but to "kill it". The following paragraphs describe the approach used and lessons learned.

Starting in 2015, the BMLA worked with AIS Specialists Keegan Lund and Kylie Cattoor of the MN DNR to introduce a multiple treatment in one-day protocol to evaluate the effectiveness of various herbicides and exposure times on spot treatment of EWM through herbicide concentration monitoring and pre/post treatment invasive plant delineations. The purpose of this research was to ensure the herbicide concentration would remain high enough over a 24-hour period to kill the EWM by building upon work previously done by the US Army Corps of Engineers (Figure 21).

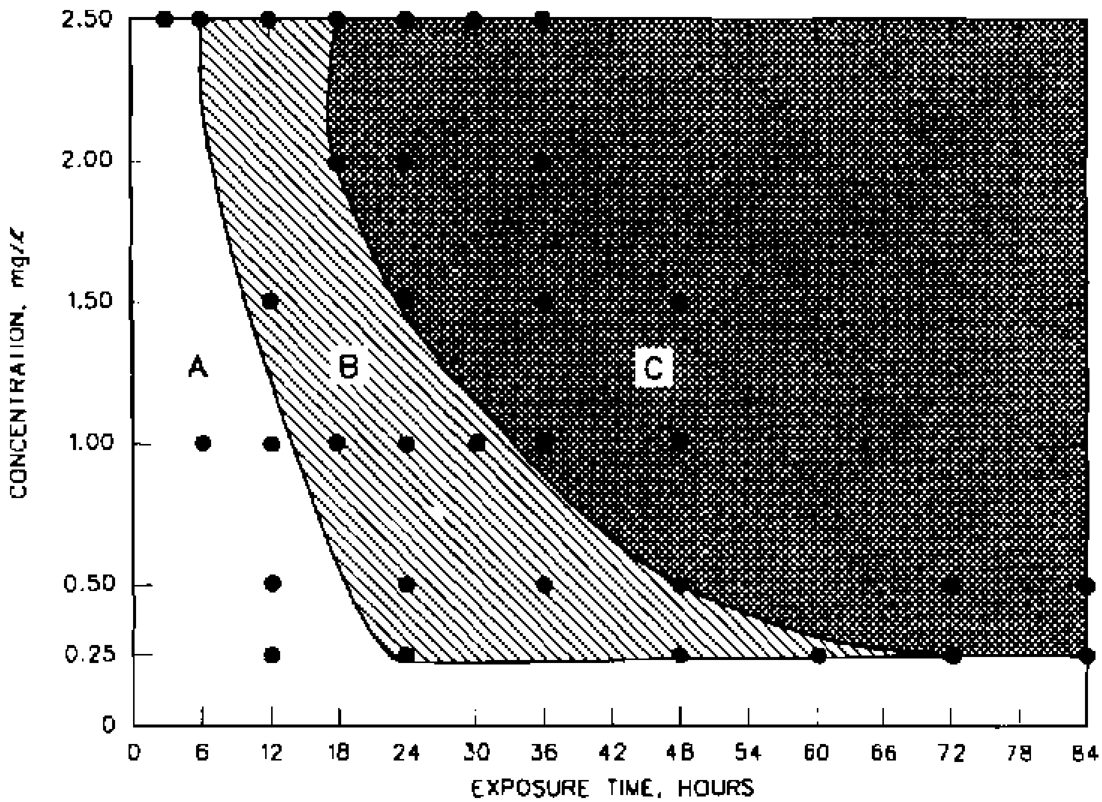


Figure 21. Summary of triclopyr concentration/exposure time (CET) relationships for control of Eurasian watermilfoil – Source: Netherland and Getsinger, 1992

After reviewing previous studies, the BMLA recognized that the CET (Concentration Exposure Time) to effectively kill EWM using herbicides like Tricoplyr or 2,4-D is about 20 to 24 hours. According to Figure 21, a concentration of 2ppm of the herbicide must be maintained for approximately 20 hours to be on the edge of the kill zone. Zone B indicates a moderate level of control while zone A represents damage to the plants that are likely to recover in a month or two. Beginning in 2018, the BMLA treated EWM with ProcellaCor, which has a CET of only 3 to 6 hours, effectively minimizing concerns about dilution. While more expensive in comparison with Tricoplyr or 2, 4-D, ProcellaCOR has shown promising results. Table 3 provides a list of all treatments enacted on Big Marine Lake from 2011-2020. More information about BMLA's integrated pest management EWM treatment program including project goals, objectives, and impressive results is available in the 2019 Initiative Foundation Final Report.

Table 3. Invasive Plant Management Summary. Characteristics and history of herbicide treatment for Big Marine Lake (DOW# 82005200), Total acres: 1799, Littoral acres: 1278, 15% Littoral acres: 191.7.

Date	Treatment [W,P,N]	Target Species	Total Acres Treated	Herbicide	Licensed Commercial Applicator	Post –Treatment Survey EWM Control
JUN 2011	P	EWM	14.5	Triclopyr	Lake Management	Poor, EWM Expanding
JUN 2012	P	EWM	11	2,4-D	Lake Management	Poor, EWM Expanding

JUL 2012	P	EWM	27	2,4-D	Lake Management	Poor, EWM Expanding
JUN 2013	P	EWM	27	2,4-D	Lake Management	Poor, EWM Expanding
AUG 2013	P	EWM	30	2,4-D	Lake Management	Poor, EWM Expanding
JUL 2014	P	EWM	39	2,4-D	PLM Lake & Land Management Corp	Very Good in two 10 –acre areas
JUN 2015	P	EWM	19	2,4-D (liquid & granular)	PLM Lake & Land Management Corp	Very Good, 60% EWM killed
JUN 2016	P	EWM	11.5	Triclopyr	PLM Lake & Land Management Corp	Very Good, 70% EWM killed
JUN 2017	P	EWM	11.65	Triclopyr	PLM Lake & Land Management Corp	Very Good, 70% EWM killed
JUN 2018	P	EWM	7.6	Triclopyr	PLM Lake & Land Management Corp	Very Good, 70% EWM killed
JUN 2019	P	EWM	8.4 acres -14 small spots	ProcellaCor & Diquat	PLM Lake & Land Management Corp, BMLA	Excellent, 90% EWM killed
JUN 2020	P	EWM	3.76	ProcellaCor & Diquat	PLM Lake & Land Management Corp, BMLA	TBD

7.1.3. Case Study #3: Boot Lake – Cloverland, Wisconsin

Setting

Boot Lake resembles Muskellunge Lake in many ways with a surface area of 295 acres and maximum depth of 14 feet. Geographically, the lakes are located less than 3 miles from each other and both are eutrophic, shallow lakes. Both are drainage lakes with generally low water clarity. It should be noted that the sediment composition of Boot Lake contains a significantly higher level of sand and gravel (75% sand, 5% gravel) and lower level of muck (20%) in comparison with Muskellunge Lake, which is 80% muck, 15% sand and 5% gravel.

Background

EWM was discovered in Boot Lake in 2000 and hit a high of 30% littoral content between 2005 and 2010 (Figure 22). Starting in 2007, WDNR Science Services began conducting annual point-intercept surveys on a set of lakes with known EWM infestations, including Boot Lake (Nault, 2016). Interestingly, they found that like other plants, EWM populations are dynamic and subject to annual changes in frequency even without management (Figure 23). Despite no management efforts, the amount of EWM delineated as dominant, highly dominant, or surface matted decreased from a high of 27.4 acres in 2009 to a low of only 0.24 acres in 2016 (Onterra, LLC, 2017).

Boot Lake did temporarily experiment with biological control using milfoil weevils (*Euhrychiopsis lecontei*). There was already an established weevil population in Boot Lake. Weevils were raised and introduced to two beds, with two others used as a control. Although the supplier went out of business half way through the experiment, there was no significant impact noted in the first 2 years.

Applicability to Muskellunge Lake

Nine members of the MLA attended an Aquatic Plant and Weevil identification workshop hosted by Cathy Higley – Vilas County Lake Conservation Specialist on July 14, 2017. The five-hour workshop focused on collecting and analyzing EWM and northern watermilfoil specimens from Muskellunge Lake for evidence of weevil damage. While no adults, larvae, or pupae were found, several of the EWM stems contained blast holes, which indicated that weevils might be present in the lake. If present, the native milfoil weevil population in Muskellunge Lake is likely very low as native northern watermilfoil was only observed at five locations in Muskellunge Lake in the 2017 point-intercept survey despite being the fifth most commonly observed plant during the 2009 survey.

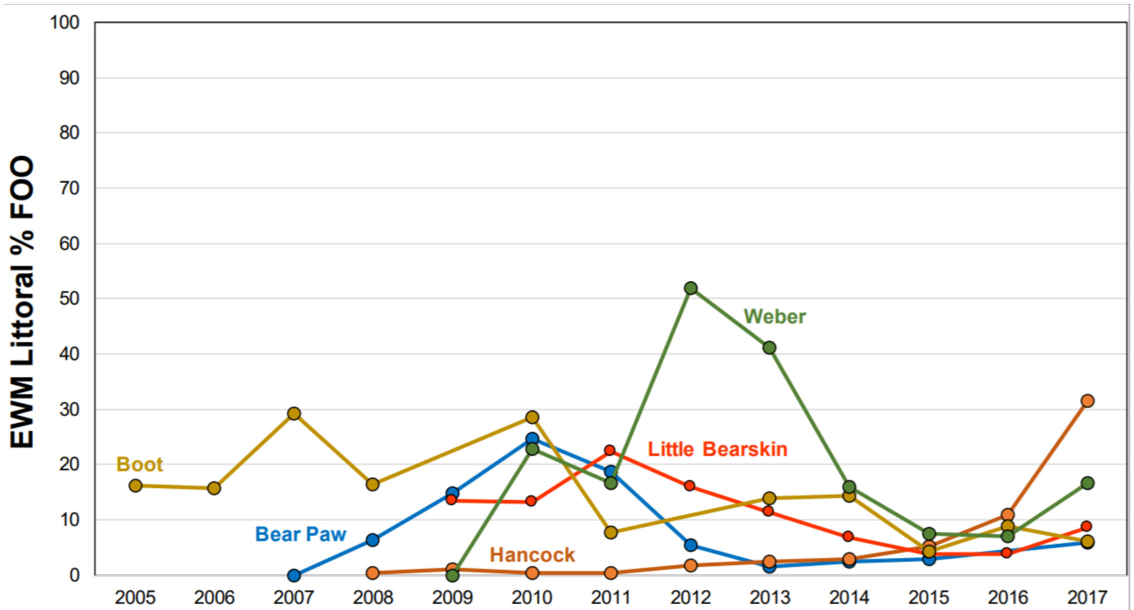


Figure 22. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data Source: Boot Lake 2017 Aquatic Plant, Shoreland Condition, & Water Quality Report – Onterra, LLC, 2017

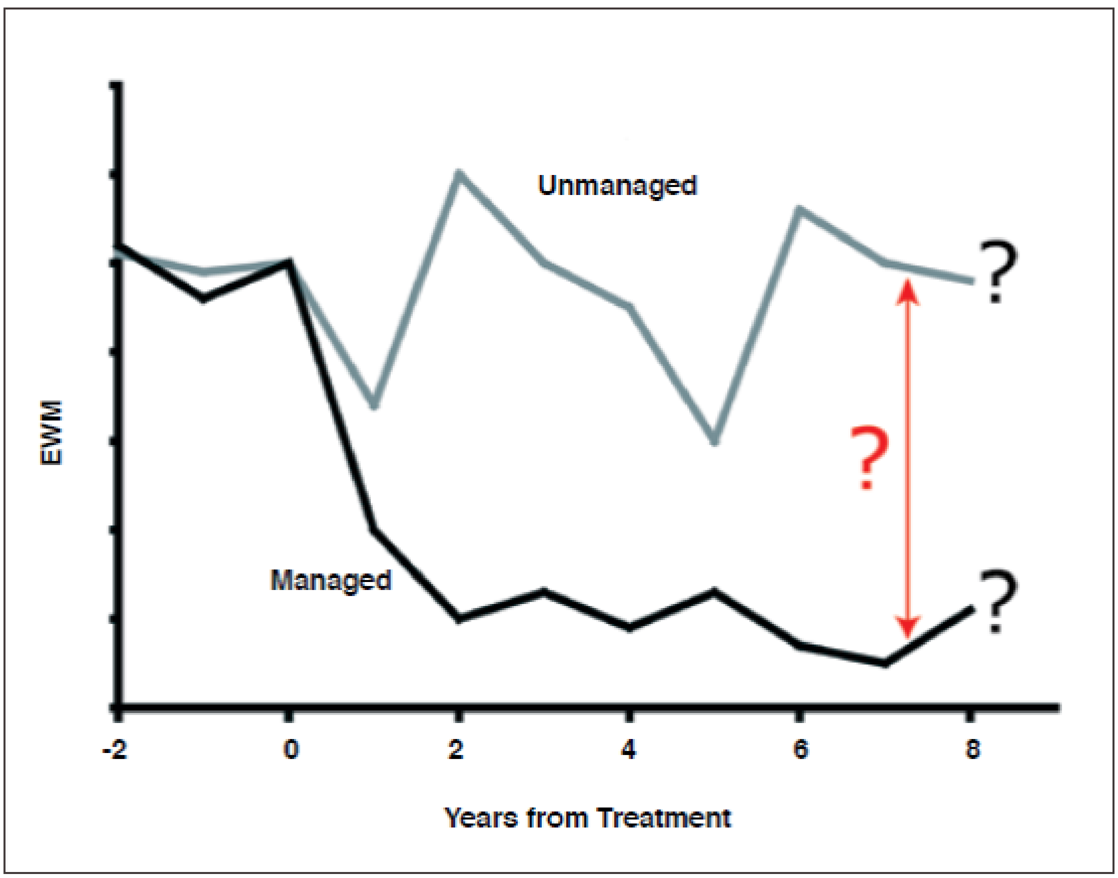


Figure 23.Conceptual figure showing the relationship between the abundance of EWM over time, subject to management or not. Source Michelle Nault, 2016

7.1.4. Case Study #4: North and South Twin Lakes – Phelps, Wisconsin

Setting

North and South Twin Lakes, Vilas County, are approximately 2,788-and 642-acre drainage lakes, respectively. North Twin Lake flows into South Twin Lake. South Twin Lake outlets via the Twin River into Pioneer Lake. The outlet is controlled by a dam operated by the Wisconsin Valley Improvement Corporation. The North and South Lake District was formed in 1995 and has been the primary management entity of the Twin Lakes.

Background

EMW was first discovered in North and South Twin in 2001. In 2019, the Lake District secured a 3-year AIS control grant. The grant was designed to aggressively gain control over the extremely adverse condition of South Twin where 40% of the littoral zone contained significant dense surface matting. Additional goals included the identification and control of emerging EWM colonies on North Twin. The 3-year grant included funds for a whole lake treatment of South Twin, consistent DASH activities on emerging colonies of North Twin as well as control over a large dense 14+ acre colony via ProcellaCOR treatment.

Treatment Plan, Results and Implications for Muskellunge Lake:

The initial results of the 2019 ProcellaCOR treatment on the 14-acre colony of dense EWM growth are very encouraging with EWM only occurring sparsely in fall underwater pictures. Post-treatment surveys identified strong native plant population, however some damage to northern watermilfoil was observed. In comparison to Muskellunge Lake, the costs involved for this treatment did require an increased product use because of water volume increased from a depth of 7' to 8'. EWM in Muskellunge Lake is rarely found beyond 7 feet, with the densest EWM patches occurring between 2.5-7 feet. Therefore, costs for implementing a ProcellaCOR treatment on Muskellunge Lake would likely be less expensive in comparison to North and South Twin as the Prescription Dose Unit recommendations are highly effected by the depth of water being treated.

In North and South Twin, the combination of the product increases in these two activities exceeded the grant budget by approximately $28,000. The again targeted 11-acre dense colony using DASH. The DASH, while being effective, when using it on a large/dense colony is quite costly.

In 2018 and 2019, the North and South Twin Lake District employed approximately 20 days of DASH, which have managed less than 10 acres at a cost of over $60,000. Based on these activities, they believe that DASH in a dense area requires a minimum of 2 days/acre or a cost/acre of approximately $6,000-$7,000. In contrast, the ProcellaCOR treatment on 14+acres of N Twin was completed at a cost of $39,000 or $2,800/acre.

Observations Learned:

Both Dash and the ProcellaCOR treatment appear to be successful, the immediacy of the ProcellaCOR results, combined with a cost of 40% of what DASH is per acre, makes ProcellaCOR the more logical future strategy for 5+acre colonies which exhibit moderate, dense or dominant EWM.

The Lake Management District treated with ProcellaCOR first and then used DASH after the treatment of ProcellaCOR . They have been using these forms of treatment for 1-1/2 years and so far are quite pleased either the outcome. Of 500 surveys sent out, 200 responded with only two negative responses on using chemical treatment.

7.1.5. Case Study #5: Upper and Lower Buckatabon Lake – Conover, Wisconsin

Setting

Upper Buckatabon Lake is slightly larger than Muskellunge Lake at 493 acres and is a mesotrophic type lake. Lower Buckatabon is 378 acres and is mesotrophic. Both lakes are drainage lakes and are located less than five miles from Muskellunge Lake. Both Muskellunge Lake and Lower Buckatabon are on a similar time line as far as EWM detection (2016, 2015 respectively) and both have seen large increases in EWM abundance following initial detection. Both lakes have implemented hand-harvesting and Diver Assisted Suction Harvesting (DASH).

Background

EMW was first discovered in 2015, by 2017 the EWM coverage was still classified as "sparse". In 2015 the chosen strategy for management based on the current condition included hand removal using diving and diver assisted suctions harvesting (DASH). Diving efforts would focus on isolated areas of very sparse locations, whereas, DASH efforts would focus on larger sites with greater abundance. There has been significant expansion of EWM since 2018, with one whole bay in Upper Buckatabon Lake now completely canopied with EWM.

Upper Buckatabon is currently undergoing a biological control project using weevils. Cathy Higley of the DNR has created a budget cost estimate of the weevil project for Buckatabon. Total cost could be over $15,000 as shown in Table 4. The majority of the costs (over half) are in the professional assistance and culturing of the Weevils at the start of the project. If successful, the methods used to rear milfoil weevils in Upper Buckatabon Lake could be replicated at a potentially lower cost for Muskellunge Lake. There is a 3-5 year commitment for the lake and costs for the following years will annually be approximately half of the startup year.

Table 4. Example weevil materials budget. Source – Personal Communication w/ Cathy Higley

Type	Item	Rate	Units	Cost
Culturing	10 gallon fish tank	$ 15.00	2	$ 30.00
Culturing	tank heaters	$ 13.00	2	$ 26.00
Culturing	tank thermometers	$ 10.00	2	$ 20.00
Culturing	aerators	$ 20.00	2	$ 40.00
Culturing	Golden Sands RC&D professional culturing fee	$ 6,874.09	1	$ 6,874.09
Monitoring	glass baking pan	$ 15.00	2	$ 30.00
Monitoring	Light tables	$ 150.00	2	$ 300.00
Monitoring	Carson microbrite plus 60x-120x	$ 40.00	2	$ 80.00
Monitoring	Lamps	$ 30.00	2	$ 60.00
Monitoring	tweezers	$ 5.00	2	$ 10.00
Monitoring	Eyedroppers	$ 5.00	2	$ 10.00
Monitoring	Probes	$ 5.00	2	$ 10.00
Monitoring	Isopropanol 70%	$ 90.00	1	$ 90.00
Rearing	Cattle water troughs	$ 100.00	4	$ 400.00
Rearing	fiberglass screen roll 48"x100ft	$ 80.00	1	$ 80.00
Rearing	binder clips	$ 5.00	1	$ 5.00
Rearing	lathing strips 1x2	$ 5.00	4	$ 20.00
Rearing	Staple gun	$ 20.00	1	$ 20.00
Rearing	saw horses	$ 15.00	2	$ 30.00
Rearing	4-Fot Diameter Kiddie pools	$ 20.00	3	$ 60.00
Rearing	T-posts for fencing	$ 5.00	20	$ 100.00
Rearing	Deer fencing (8 ft tall x 100 ft roll)	$ 100.00	2	$ 200.00
Rearing	deer fence post extenders	$ 3.00	20	$ 60.00
Rearing	Thermometers for troughs	$ 10.00	4	$ 40.00
Rearing	Hose set up	$ 80.00	1	$ 80.00
FTE Wages	FTE Buckatabon weevil assistance	$ 24.00	57	$ 1,368.00
FTE Wages	FTE create report of weevil rearing, monitoring, and results, including maps & share results	$ 24.00	50	$ 1,200.00
LTE Wages	LTE Buckatabon weevil assistance (office & field)	$ 16.00	200	$ 3,200.00
Mileage	Buckatabon weevil mileage	$ 0.580	1500	$ 870.00
Total				**$ 15,313.09**

Table 5. Eurasian Watermilfoil Case Study Control Effort Results and Observations

Lake Characteristics	EWM Control Strategy	Impact to Non-Target Species	Cost/Funding Mechanism	Observations / Lesson Learned
Lake Name Kathan Lake **Morphometry** 189 Acres, Max Depth: 15 Feet, **Trophic Status** Eutrophic **Water Clarity** 3 feet **Sediment Composition** 74% Muck, 24% Sand, 3% Rock	*2010 –Whole-lake 2,4-D treatment targeting the 115 acres of the lake > 5 feet.*	1. Minor collateral effects on native aquatic plants 2. *Native aquatic plant have rebounded* 3. *Anecdotal reports of fish kills*	2010 - $30,000 – self funded 2016 – University funded	1) While a whole lake treatment was effective, a one-time lake wide treatment is not a sustainable plan. 2) Ongoing measurement, control, management, and measuring progress towards measurable goals is essential. 3) After controls have suitably reduced the EWM, A means to use marker buoys and restrict watercraft use in the areas of remaining colonies is important to control broad spread of fragments. 4) Hand pulling and raking are effective but in small scale and in shallow water, near piers, etc. It is not effective on any broad scale in this lake. 5) Second lake-wide treatment conducted in 2016 was successful at reducing EWM abundance and had "no meaningful treatment level effects, as the growth rate of young yellow perch in the treatment area was "basically" similar to that of the non-treatment lakes that served as reference points". 6) No conclusions should be made on potential long-term effects of repeated applications of 2,4-D on fish and/or zooplankton.
Lake Name Big Marine Lake **Morphometry** 1,800 Acres, Max Depth: 50 Feet, **Trophic Status/** Mesotrophic **Water Clarity** 12 to 14 feet **Sediment Composition** N/A	*See Table 2*	1. *Increase in the number of submersed native species from 18 in 2010 to a 28 in 2017 (last survey)*	1. $780/acre in 2015 with DMA4 liquid and granular. 2. Renovate OTF multiple treatments in 24 hours- $2300/acre 3. Procellacor single application costs about $2400/acre. AIS Funds received from 2015-2020 through Washington County - $130,000	1. Aggressive at spot treating of single plants, plant groupings and spots up to 0.1 acres helped slow the spread. 2. The BMLA built or purchased equipment to apply both liquid and granular herbicide and to inject EWM root balls per the DNR open water permit. 3. In 2018, late season (Aug 30th in 2019) treatment with Diquat of still viable EWM killed the plant and the rootlets. Based on 2020 delineation, best estimate is that at least 50% of the 2.4 acres treated with Diquat in Aug 2019 did not survive the winter. 4. Since BML is 1800 acres with a large littoral area of 1,170 acres, the BMLA records EWM locations at least twice prior to Steve McComas early June trip to delineate the EWM and prepare a permit map. If we did not provide this guidance, it is unlikely that S. McComas would be able to make an accurate map in a 1/2 day visit. 5. Root ball injection with liquid DMA4 herbicide was introduced in the spring of 2017 when the EWM was less than three feet tall. Treatment areas were marked with stakes and treated under the supervision of a DNR observer. Result: 100% kill in the 50 to 200 square-foot areas or larger areas with low-density single plants in water seven or less feet deep.

Lake Characteristics	EWM Control Strategy	Impact to Non-Target Species	Cost/Funding Mechanism	Observations / Lesson Learned
Lake Name Boot Lake **Morphometry** 279 Acres, Max Depth: 15 Feet, **Trophic Status** Eutrophic **Water Clarity** 3.5 feet **Sediment Composition** 75% sand, 5% gravel, 20% muck	*Milfoil weevils introduced for 2 yeas*	*N/A*	*N/A*	1. Despite no management efforts, the amount of EWM delineated as dominant, highly dominant, or surface matted decreased from a high of 27.4 acres in 2009 to a low of only 0.24 acres in 2016
Lake Name N/S Twin Lakes **Morphometry** 3,430 Acres, Max Depth: 60 Feet, **Trophic Status** Mesotrophic **Water Clarity** 15feet **Sediment Composition** 55% sand, 5% gravel, 20% muck	*ProcellaCor/DASH*	*None*	*DASH – 60,000 or $6,500/acre* *ProcellaCor - $39,000 or $2,800/acre Funding - Series of grants (ACEI-223-19), (AEPP-578-19)*	1. Both Dash and the ProcellaCOR treatment appear to be successful, the immediacy of the ProcellaCOR results, combined with a cost of 40% of what DASH is per acre, makes ProcellaCOR the more logical future strategy for 5+acre colonies which exhibit moderate, dense or dominant EWM.
Lake Name Upper/Lower Buckatabon **Morphometry** 841 Acres Combine, Max Depth: 60 Feet, **Trophic Status** Mesotrophic **Water Clarity** 47 feet **Sediment Composition** 50% sand, 15% gravel, 15% rock, 20% muck	*Milfoil Weevil/ DASH/Hand pulling*	*none*	*See Table 5*	1. There is a 3-5 year commitment to get a weevil program up and running with the majority of expenditures occurred at the start of the project. Costs for the following years will annually be approximately half of the startup year.

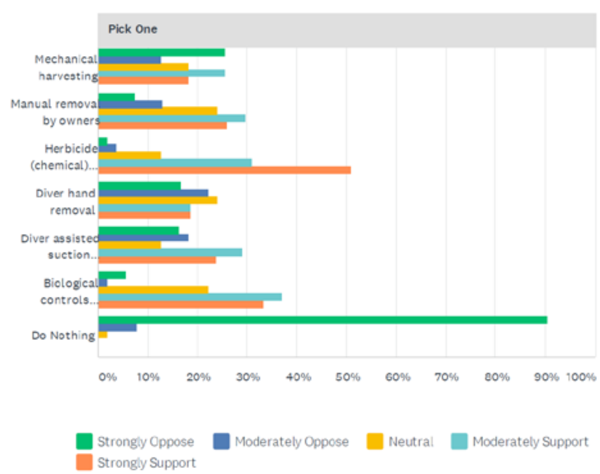
7.2. Scientific Review of Aquatic Vegetation Management Options

Muskellunge Lake has numerous tools at its disposal for managing nuisance aquatic vegetation including mechanical, chemical, and biological control options. The use of all three of these tools in the appropriate space and time is the basis for an effective integrated pest management (IPM) program that delivers desirable environmental outcomes. Simultaneously, each control tool has limitations and associated shortcomings.

One of the most common shortcomings of aquatic plant management is that the desired outcome from the implementation of a given tool is not always clearly defined and/or understood by stakeholders. To address this concern, the Muskellunge Lake Association asked lake residents to rate their level of support for various aquatic plant management options including the "do nothing" approach. Interestingly, more than 90% of residents strongly opposed the do nothing approach. The use of chemical herbicides was the most strongly supported management technique.

Q16 Aquatic plants can be managed using many techniques. What is you level of support for the following techniques? (Rate Each: Strongly oppose, Moderately oppose, Neutral, Moderately support, Strongly support)

Answered: 56 Skipped: 10



Pick One

	STRONGLY OPPOSE	MODERATELY OPPOSE	NEUTRAL	MODERATELY SUPPORT	STRONGLY SUPPORT	TOTAL
Mechanical harvesting	25.45% 14	12.73% 7	18.18% 10	25.45% 14	18.18% 10	55
Manual removal by owners	7.41% 4	12.96% 7	24.07% 13	29.63% 16	25.93% 14	54
Herbicide (chemical) control – Spot treatment	1.82% 1	3.64% 2	12.73% 7	30.91% 17	50.91% 28	55
Diver hand removal	16.67% 9	22.22% 12	24.07% 13	18.52% 10	18.52% 10	54
Diver assisted suction harvesting	16.36% 9	18.18% 10	12.73% 7	29.09% 16	23.64% 13	55
Biological controls (milfoil weevil)	5.56% 3	1.85% 1	22.22% 12	37.04% 20	33.33% 18	54
Do Nothing	90.38% 47	7.69% 4	1.92% 1	0.00% 0	0.00% 0	52

Figure 24. Stakeholder opinions on Aquatic Plant Management Options.

7.3. Available Approaches for Managing Aquatic Vegetation

The following sections provide a scientific review of three most common control tools (Mechanical, Chemical, and Biological) and a recommended management approach for where, when, and why these tools should be implemented in accordance with the following MLA goals:

1. Management activities will maintain or increase native aquatic plants and water quality as appropriate.
2. Management activities will leverage available funds to the maximum extent possibly by implementing controls that provide the best return (reduction of EWM coverage) on investment (dollars spent).
3. Management activities will be refined annually based on data collected from continued professional and volunteer AIS monitoring and continued coordination with the WDNR.

The following section also includes a risk assessment for the recommended management approach.

7.3.1. Mechanical Treatments

Mechanical Harvesting: Mechanical harvesting equipment comes in a wide variety of designs, however, most harvesters operate with the common goal of cutting, collecting, and subsequently removing aquatic plant material from a given portion of a waterbody. In most waterbodies, mechanical harvesting is viewed as a maintenance technique, although in some cases (e.g., Madison Lakes Chain, Dane County, WI) it is used as a long-term management strategy and has been effective at selectively controlling EWM.

7.3.2. Positive and Negative Aspects of Mechanical Harvesting

A list of positive and negative aspects of mechanical harvesting are shown in Table 6 and Table 9. An overview of case studies, which highlight potentially positive and negative impacts of mechanical harvesting, is shown in Table 6.

7.3.3. Mechanical Harvesting Risk Assessment

The following potentially negative impacts are associated with mechanical harvesting on Muskellunge Lake:

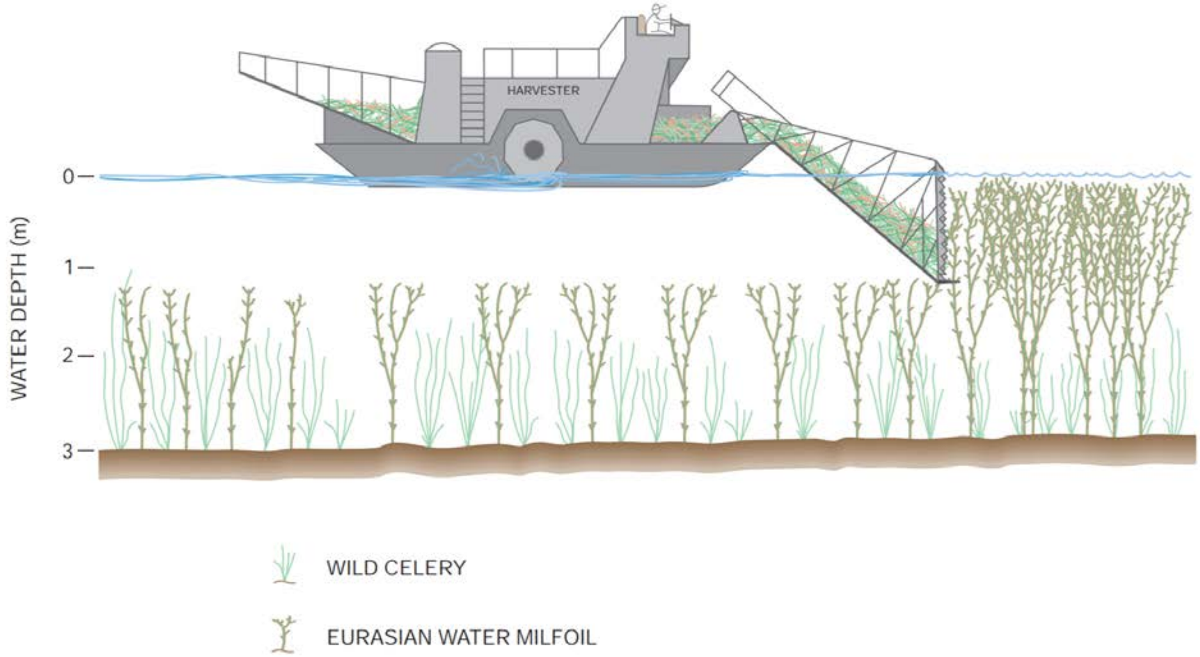
1. Mechanical harvesters are not selective and remove native plants along with target weeds. However, most native plants will likely return by the next growing season or before.
2. Resuspension of sediment in shallow areas leads to a decrease in water clarity/quality.
3. Floating plant fragments produced during mechanical harvesting can be a concern because aquatic plants, including EWM, can regrow from even small pieces of fragmented vegetation.
4. Regrowth of cut vegetation can occur quickly. For example if EWM can grow 1 to 2 inches per day as reported, a harvest that cuts 5 feet deep could result in plants reaching the water surface again only one to two months after harvesting. Speed of regrowth depends of the target plant, time of year harvested, water clarity, water temperature and other factors.

Table 6. Advantages and disadvantages of mechanical harvesting (Personal Communication – Steve McComas Blue Water Science).

Advantages
Water can be used immediately following harvest treatment. Some aquatic herbicides have restrictions on use of treated water for drinking, swimming, and irrigation.
Harvesting takes the plant material out of the water so the plants do not decompose slowly in the water column as they do with herbicide treatment. Additionally, oxygen content of the water is generally not affected by mechanical harvesting, although turbidity and water quality may be affected in the short term.
Nutrient removal can occur but is usually minimal in comparison to the lake's overall nutrient load because only small areas of lakes (1 to 2%) are typically harvested. It has been estimated that aquatic plants contain less than 30% of the annual nutrient loading that occurs in lakes.
The plant community is altered but remains largely intact because most harvesters do not completely remove submersed plants all the way to the lake bottom. Like mowing a lawn, clipped plants remain rooted in the sediment and regrowth typically begins soon after the harvest.
Mechanical harvesting is site specific because plants are only removed where the harvester operates.
Mechanical harvesting is perceived to be environmentally neutral by the public whereas concerns over the safety and long-term toxicology of herbicide applications remain despite widespread research and registration requirements that are enforced by regulatory agencies.
Disadvantages
Mechanical harvesting equipment has limited production, therefore repair and replacement costs can be expensive and are therefore passed on to the consumer of services (e.g., Lake Association).
The area that can be harvested in a day depends on the size of the harvester, transport time, distance to disposal site, and density of the plants being harvested. These factors result in a wide range of costs. The cost of harvesting is site-specific, but mechanical harvesting is generally more expensive that other plant control methods.
Mechanical harvesters are not selective and remove native plants along with target weeds. However, most native plants will likely return by the next growing season or before.
By-catch, or the harvesting of non-target organisms such as fish, crayfish, snails, macro invertebrates, along with weeds can be a concern. If the total area of the lake is less than 10% of the lake's area, this will likely be of little consequence.
Regrowth of cut vegetation can occur quickly. For example if Eurasian milfoil can grow 1 to 2 inches per day as reported, a harvest that cuts 5 feet deep could result in plants reaching the water surface again only one to two months after harvesting. Speed of regrowth depends of the target weed, time of year harvested, water clarity, water temperature and other factors.
Floating plant fragments produced during mechanical harvesting can be a concern because aquatic weeds can regrow vegetatively from even small pieces of vegetation. Homeowners downwind of the harvesting site may not appreciate have to regularly rake weeds and floating fragments off their beaches.
Disposal of harvested vegetation can be an expensive and difficult. It takes time and additional money to transport the plants to shore, load the material and dispose of the cut material off site.
Costs of moving the cut vegetation from the harvester to shore will add significantly to the cost of operation. Harvesters move relatively slow, so the extra time traveling to and from the off load site must be factored into the operation.

Table 7. Positive and negative impacts of mechanical harvesting and associated case studies.

Positive Impacts
✓ Olson et al. (1998) studied the impact of mechanical harvesting of aquatic macrophytes on fish in four Minnesota lakes. Based on the results they concluded that changing the strategy of harvesting from clear-cutting the top meter of vegetation to selectively cutting deep channels throughout the lake may simultaneously improve the fishery and recreational value of a lake **Case Study: Managing Macrophytes to Improve Fish Growth: A Multi-lake Experiment**
✓ Macrophyte harvesting can be a cost-effective means to remove phosphorus from an urban shallow lake system, and this management tool has the potential to factor into dynamic and creative lake and watershed management plans. A 2004 study conducted by Three Rivers Park District on Lake Minnetonka found that the mechanical harvesting program removes approximately 510 pounds of phosphorus per year at an estimated cost of $204 per pound, significantly lower than the estimated phosphorus removal costs for most watershed BMPs. **Case Study 1: Phosphorus Removal by Plant Harvesting on Lake Minnetonka** **Case Study 2: Aquatic plant harvesting: An economical phosphorus removal tool in an urban shallow lake**
✓ Mechanical harvesting conducted over an extended time period has the potential to result in a positive change in the aquatic plant community from watermilfoil to low growing native species that typically stay below the maximum, harvested depth. Repeated harvesting of EWM prevents it from forming a canopy and shading out other vegetation (Figure 25). **Case Study: Delevan Lake, Wisconsin Aquatic Plant Management Plan**
✓ Selective cutting of channels, paths, or openings is an effective means of creating valuable edge habitat (Engel 1995). Larger fish often associate with plant bed edges (Engel 1987) where macroinvertebrate prey resources are mostly concentrated (Sloey et al. 1997). Thus a reduction in dense vegetation, rather than eradication, should increase predator-prey interactions, improve fish growth (Bettoli et al. 1992, Bettoli et al. 1993) and augment fish production (Smith 1993). **Case Study: Delevan Lake, Wisconsin Aquatic Plant Management Plan**
✓ Study illustrated that early season deep-cut harvesting can be selective for EWM and help promote native plants. However, successive years of treatment may be necessary to begin to achieve good control. **Case Study: Turville Bay, Lake Monona**
Negative Impacts
✓ Mechanical harvesting can potentially have a significant negative impact on the abundance of the milfoil weevil (*Euhrychiopsis lecontei)* depending on the scale of harvesting efforts relative to the size of the lake **Case Study: The Effects of Harvesting Eurasian Watermilfoil on the Aquatic Weevil *Euhrychiopsis lecontei***
✓ Research on fish catch during mechanical harvesting of submersed vegetation has noted that the impact is likely to vary tremendously between lakes, due to the differences in aquatic macrophytes, their densities, and different fish stocks. Haller et al. (1980), Mikol (1985), and Wile (1978) found that harvesting removed predominantly small sunfish or yellow perch **Case Study: The interaction between biology and the management of aquatic macrophytes**
✓ Mechanical harvesting can also incidentally remove vertebrates inhabiting the vegetation and lead to shifts in aquatic plant community composition **Case Study: Vertebrates removed by mechanical weed harvesting in Lake Keesus, Wisconsin. Journal of Aquatic Plant Management**



NOTE: Selective cutting or seasonal harvesting can be done by aquatic plant harvesters. Removing the canopy of Eurasian water milfoil may allow native species to reemerge.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 25. Plant Canopy Removal with a Mechanical Harvester.

7.3.4. Chemical Treatments

Herbicides:

Aquatic herbicides can be divided into two groups, including 1) systemic herbicides and 2) contact herbicides (Table 8). Contact herbicides kill only the part of the plant which comes in direct contact with the herbicide. The root system is not killed and the plant may grow back from the roots. Systemic herbicides are absorbed by the plants and taken into the root system, so the whole plant can be killed. Systemic herbicides are specifically designed to minimize damage to non-target species whereas contact herbicides will damage all species in which they come into contact with, including native species. Sometimes an herbicide application is effective for several years but more frequently, it is an annual control. Rarely does an application result in the complete eradication of the target plant.

Table 8. Summary of common aquatic herbicides and corresponding characteristics

Herbicide	Trade Name	Formulation and Contact or Systematic	Mode of Action	Advantages	Disadvantages	Systems Where Used Effectively	Plant Species Response	Use Rate (active ingredient)	Half-life
Copper Complexes (algaecide)	Cutrine-plus Cleatigate Captain Komeen K-tea	Various complexing agents **Contact**	Plant cell toxicant	Inexpensive rapid action, approved for drinking water	Doesn't biodegrade, but bio inactivates in sediments	Lakes higher exchange rates	Broad spectrum, acts in 7-10 days, up to 4-6 weeks	1 mg/l	2-8 Days
2-4, D	Navigate Aqua-Kleen	BEE salt DMA, liquid **Systemic**	Selective- plant growth regulator	Inexpensive, systemic	Non-target may be affected	Lakes and slow flow areas	Selective to broadleaf, acts in 5-7 days or up to 4-6 weeks	to 1.0mg/L	2-6 days
Diquat	Reward Weedtrine-D	Liquid **Contact**	Disrupts plant cell membrane integrity	Rapid action, limited drift	Does not affect underground portions	Shoreline, localized treatments, higher exchange rate areas	Broad spectrum, acts in 7 days	0.1-0.5 mg/L	< 48 hours
Endothall	Aquathol K Aquathol Super K Hydrothol 191	Liquid or granular **Contact**	Inactivates plant protein synthesis	Rapid action, limited drift	Does not affect underground portions	Shoreline, localized treatments, higher exchange rate areas	Broad spectrum, acts in 7 days	2-4mg/L	1-7 days
Flumioxazin	Clipper	**Contact**	Inhibits chlorophyll synthesis	Controls duckweed		Ponds and lakes	Broad spectrum	0.1-0.4 mg/l	
Fluridone	Sonar AS, SRP, PR, Q Avast!	Liquid or granular **Contact**	Disrupts carotenoid synthesis	Very low dosage required, systemic	Very long contact period	Small lakes, slow flow systems	Broad spectrum acts in 30-90 days	0.005-0.020 mg/l	20-80 Days
Florpyrauxifen-benzyl	ProcellaCOR	Liquid **Systemic**	Selective- plant growth regulator	Short contact time, systemic	1) Data on non-target impacts and long-term efficacy is not readily available. 2) Native species may be susceptible (coontail, watershield, native milfoils)	Lakes higher exchange rates	Initial symptoms within a few days, plant death 2-3 weeks.	1-5 PDU	1-6 days
Glyphosate	Rodeo, AquaPro Aquamaster Aqua Neat Touchdown	Liquid **Systemic**	Disrupts synthesis of amino acids	Widely used, systemic	Very slow action, no submersed control	Emergent and floating leaf plants only	Broad spectrum, acts in 7-10 days up to 4 weeks	0.5-0.5 mg/L	
Imazamox	Clearcast	Liquid **Systemic**	Disrupts synthesis of amino acids	Systemic	Growth regulation of submersed plants, not death	Quiescent bodies of water	Growth regulation of submersed plants, acts in 1-2 weeks or more for foliar applications	Up to 0.5 mg/l	7-14 days
Imazapyr	Habitat	**Systemic**	Disrupts synthesis of amino acids	Systemic	Not recommended for submerged species	Emergent and floatingleaf plants only	Acts in several weeks	1.5 lbs ai/acre	
Penoxsulam	Galleon SC	Liquid **Systemic**	Disrupts synthesis of amino acids	Selective, few label restrictions, systemic	Very long contact period	Quiescent bodies of water	broad spectrum, acts in 60- 120 days	0.15 mg/l	
Triclopyr	Garlon 3A Renovate 3 Renovate OTF	Liquid **Systemic**	Selective plant growth regulator	Selective, inexpensive	Can injure other nearby broadleaf species	Lakes and slow flow areas	Selective to broadleaves acts in 5-7 days up to 2 weeks	1.0mg/L	12-72 hours

7.3.5. Mechanical Harvesting Comparison with Herbicides

Table 9. Comparison of mechanical harvesting vs. herbicides.

Effectiveness of Control	Mechanical Harvesting	Herbicides
Reliability	Never fails [to remove plants]	Can fail
Time to relief	Immediate	7 to 21 days
Vegetation is collected and removed from the lake	Yes (Nutrients in plants are also removed from lake)	No (Nutrients in plants are NOT removed from lake)
Duration of control (and need for multiple treatments)	Usually shorter, multiple treatments needed for control	Longer, but multiple treatments may be required
Creation of channels	Good	Not so good
Control of plants over a large area	Not so good	Good
Additional Considerations	**Mechanical Harvesting**	**Herbicides**
Cost	Often higher	Often lower
Percentage of cost attributable to labor	high	low
Capital investment	high	None [for customer]
Duration of work	Longer, sometimes continues over the season	One or a few days
Variability in cost	higher	lower
Disposal of harvested plants	Can be difficult to find a place where plants can be delivered	Not applicable (plants decompose in lake)
Potential spread within a lake	Should not be employed on lakes or portions of lakes where the distribution of milfoil is limited	Can be employed on lakes where the distribution of milfoil is limited
Effects on non-target organisms or lake ecosystem	**Mechanical Harvesting**	**Herbicides**
Removes invertebrates, fish, frogs, snakes, turtles, etc	Yes	No
When target plant is an exotic, removal or destruction of native vegetation	Yes	Yes or no, depending on particular herbicide used, native vegetation
Increased fragmentation	More	Less
Disturbs sediment and causes suspension of sediment in the water column, which in turn may reduce water clarity	Often does, likely to a greater extent	May do so, likely to a lesser extent
Potential negative effects of introducing chemicals into the aquatic environment	No	Yes
Restrictions on use of water after treatment	No	In some cases
Selectivity	Limited or none	Some are, some are not
Wisconsin Regulations	**Mechanical Harvesting**	**Herbicides**
Small area can be treated without a permit to control milfoil or other submersed aquatic plants	Requires a mechanical aquatic plant management permit unless the body of water is 10 acres or less and is entirely confined on the property of one person with the permission of that property owner.	**No –** The use of herbicides always requires a permit from the DNR
Types of Treatment/Permitting Requirements	**Large-scale Treatment:** Treatments > 10 acres or10% of littoral zone **Lake-wide Treatment:** Treatments > 160 acres or 50% of littoral zone	

7.3.6. Biological Treatments

Milfoil Weevil: The milfoil weevil (*Euhrychiopsis lecontei*) is a native insect found in many Midwestern lakes with native watermilfoil. The milfoil weevil has since adopted EWM as its preferred host following the introduction of EWM to North America. Research conducted by the University of Minnesota has found that the weevil performs best on EWM and poorest on the native northern watermilfoil. Interestingly, weevil performance on hybrid watermilfoil is better than on the native watermilfoil and may be better (Borrowman et al. 2015) or worse than on EWM (Roley and Newman 2006).

Historical Context: EOR has previously conducted research on studies that used milfoil weevils to control EWM including research performed on Lake Minnetonka in the early 1990's by the MNDNR and Dr. Ray Newman at the University of Minnesota. Results from previous studies on Lake Minnetonka have shown that the milfoil weevil can control EWM when sufficient densities of the weevil are attained and maintained throughout the summer (Creed and Sheldon 1995, Newman 2004). However, milfoil weevil populations are typically not maintained at sufficient (<0.25/stem or <25/m2) enough density to fully control the plant (Newman 2004). In Muskellunge Lake, the presence of an abundant sunfish and bluegill (*Lepomis spp.*) population is likely to **negatively influence** weevil populations. Milfoil weevils are not currently commercially available for stocking; however, Dr. Sallie Sheldon, a professor at Middlebury College in Vermont has developed simple propagation methods. Using Dr. Sheldon's methodology, a student led effort on Christmas Lake; (Hennepin County) apparently reduced EWM abundance on Christmas Lake in 2019.

Recommendation

EOR and MLA have previously reached out to Dr. Sheldon and have acquired her relatively simple and low cost propagation methods and have kept lines of communication open with Cathy Higley of Vilas County since 2018. EOR and MLA will continue to work with Cathy Higley and WDNR to evaluate lessons learned from Upper and Lower Buckatabon Lake as well as their applicability to Muskellunge Lake.

Risk Assessment

The following potentially negative impacts are associated with the recommended management approach:

1. Milfoil weevils are not supplied/stocked in a sufficient density or predation by bluegills/sunfish results in a low-density weevil population that is not capable of providing adequate control of EWM leading to an expansion of EWM in Muskellunge Lake.

7.3.7. Muskellunge Lake Recommendation

Mechanical harvesting is **not recommended** for Muskellunge Lake due to the risk of spreading EWM fragments throughout the lake and likelihood for re-growth. EOR will re-explore the use of biological control methods following a future review of results from Upper and Lower Buckatabon and continued communication with Vilas County, WDNR, and Dr. Sallie Sheldon of Middlebury College in 2021. For 2021 and 2022, the use of aquatic herbicides, specifically ProcellaCOR should be the primary mechanism for control of EWM in Muskellunge Lake for the following reasons:

1. The advent of new herbicides and continued research of existing herbicides has reduced risk to non-target species, new herbicides also require shorter contact times.
2. Documented case studies have provided quantifiable reductions in EWM frequency.
3. With the advent of herbicides like ProcellaCOR that are highly- selective for EWM, the impact to non-target species can be minimized by using herbicides as the primary control technique.
4. Wide, expansive areas like the Treatment Areas identified in Table 2 are most cost effectively managed with herbicides, thereby meeting the MLA goal of leveraging available funds.

7.3.8. Chemical Treatment Risk Assessment

No aquatic plant management option is without risk. The following paragraphs outline potentially negative impacts associated with the recommended herbicide treatment as well as mitigating factors

1. Decomposing vegetation can lead to fluxes in dissolved oxygen and the release of nutrients, which can lead to reduced water clarity and algae blooms.
    a. *Mitigating Factor: The recommended treatment area (26.62 acres) is less than 10% of the surface area of Muskellunge Lake. Furthermore, herbicide treatments conducted early in the year when plant biomass is still relatively low can prevent the decomposition of large volumes of plant material that in turn will minimize the risk of dissolved oxygen crashes, nutrient pulses, and algae blooms (Nault et al., 2012).*
2. Aquatic herbicides can dissipate away from the targeted treatment area due to wind, waves.
    a. *Mitigating Factor: ProcellaCOR has a shorter exposure time requirement, allowing for effective spot treatment and applications to higher exchange sites*
3. Repeated use of herbicides with the same mode of action can lead to herbicide-resistance. Certain hybrid Eurasian watermilfoil genotypes have been documented as resistant.
    a. *Mitigating Factor: Recommended approach will incorporate an adaptive management strategy that seeks to constantly refine EWM management efforts on a 1-2 year basis based on results from continued volunteer and professional AIS monitoring following the implementation of EWM control measures with an ultimate goal of transitioning away from herbicides by 2024.*
4. Research indicates that the use of 2, 4-D herbicides at current recommended concentrations (<2ppm whole lake; <4ppm spot treatment) could present risks to fathead minnow larval survival (Dehnert et. al., 2018).
    a. *Mitigating Factor: EOR is not recommending 2, 4-D.*

7.4. Implications for Muskellunge Lake

7.4.1. Management Trigger

Based upon previous communication with the DNR, the MLA has identified a trigger of 5% littoral FOO to **start discussions** with DNR on management efforts that **may** include herbicide use. The littoral zone (area) for Muskellunge Lake is defined as that portion of the lake that is less than 10 feet, equivalent to the maximum depth of recorded aquatic plant growth in Muskellunge Lake. It should be noted that aquatic plant growth beyond 8 feet is extremely limited in Muskellunge Lake. The portion of Muskellunge Lake that is less than 10 feet deep equates to an area of 169 acres, or approximately 63% of the total surface area of the lake (270 acres). When the 5% EWM littoral zone trigger is met (total area of EWM infestation **exceeds 8.5 acres**), the MLA will work cooperatively with the DNR using an adaptive management approach that may include the use of herbicides. The 5% management trigger aligns with the point at which EWM would reduce the recreational value of the waterbody, potentially restricting boat access in portions of this largely shallow lake. In comparison with other lakes in Vilas County, the 5% littoral zone criteria represents an ambitious target. However, based on a review of case studies presented above, achieving this target using proven management techniques is achievable. In general, delineated areas less than 1 acre in size may not be suitable for chemical spot treatment based on a lack of efficacy in such a small area and/or potential impacts to natives in the area weighing out the reduction of the invasive species (EWM).

7.4.2. Financial Implications

The MLA operates on a small budget, with income generated solely through the donations of annual dues from willing lakeshore owners. Furthermore, results from professional and volunteer AIS monitoring efforts conducted in 2019 and 2020 suggest that the population of EWM in Muskellunge Lake has expanded to an area where alternative management practices beyond physical removal efforts alone will be required. The MLA acknowledges that the DASH effort was temporarily effective at reducing EWM in 2019 within the 0.30-acre treatment area, however, new growth was observed in 2020 such that there was no difference in EWM abundance in treatment areas versus control areas just one year post-treatment.

DAS

Based on the case studies presented, the immediacy of the ProcellaCOR results, combined with a cost of 40% of what DASH is per acre, makes ProcellaCOR the more logical future strategy for colonies that exhibit moderate, dense or dominant EWM growth.

7.4.3. Recommended Management Procedures

Table 10 identifies initial treatment costs for Muskellunge Lake and remaining EWM acreage assuming a 50% reduction in the distribution of EWM within each treatment area. Future updates, including the addition or removal of treatment polygons based on continued AIS monitoring will provide a means of documenting progress towards stated goals in an effort to identify the EWM management strategy(s) that provide the best return (reduction in EWM) on investment (dollars spent).

Table 10. Recommended Management Targets and Procedures

Treatment Area	Existing EWM Coverage (Acres)	Treatment Method	Cost/Acre ($)	Year 1 Treatment Costs	1-Year Remaining EWM Acres (50 % Reduction)
1	1.12	ProcellaCOR	$2,200	$2,464	0.56
2	1.30	ProcellaCOR	$2,200	$2,860	0.65
3	5.52	Monitor*	-----	-----	5.52
4	1.84	ProcellaCOR	$2,200	$4,048	0.92
5	1.22	Monitor*	-----	-----	1.22
6	3.12	ProcellaCOR	$2,200	$6,864	1.56
7	6.67	Monitor*	-----	-----	6.67
8	1.93	Monitor*	-----	-----	1.93
9	1.04	ProcellaCOR	$2,200	$2,288	0.52
10	0.19	Monitor*	-----	-----	0.19
11	0.90	ProcellaCOR	$750	$675	0.45
12	1.77	Monitor*	-----	-----	1.77
Total	**26.62**	**------**	**------**	**$19,199**	**22.0**

* If areas identified as Tier 3 in 2020 are identified as Tier 1 or Tier 2 areas in 2021, they will be recommended for ProcellaCOR treatment.

Goal Statement

Having quantifiable goals is important to maintain accountability and to assess the effectiveness of implemented treatment options. It is important to recognize that progress towards improving the quality of an aquatic plant community through the reduction of invasive species like EWM is often slow. At the same time, the MLA is not interested in “controlling” EWM or operating in a reactionary nature to periodic increases in EWM abundance. Rather, the techniques recommended represent a strategy to significantly reduce the abundance of EWM by 50% in year 1 with a long-term goal of reducing EWM abundance below the 5% EWM littoral occurrence threshold. Once achieved, the primary control measure would move away from herbicides and towards a long-term solution that relies on biological and/or physical controls. The MLA will continuously update management strategies by incorporating lessons learned from area lakes including Upper and Lower Buckatabon Lakes. As part of documenting progress, the MLA will work with the DNR and its consultant to continuously monitor and graph the total surface area of EWM present in Muskellunge Lake.

8. SHORELAND CONDITIONS

8.1. Shoreline Habitat Survey & Planning Level Assessment

A shoreline habitat survey was conducted at Muskellunge Lake by DNR staff in 2017. The goal of a shoreline habitat survey is to assess the suitability of shoreline to support wildlife by characterizing each property parcel adjacent to the lake by describing the level of tree canopy present, the land use at the shoreline, and to inventory the features adjacent to the lake, such as human structures, runoff concerns, and other features in the near shore zone.

The types of land cover noted in the shoreline habitat survey can be a good predictor of potential for surface runoff from the land to the water for each property. For example, as Figure 26 notes, if a property adjacent to the shoreline has more tree canopy and less developed, impervious areas, more rainfall will be intercepted by trees and infiltrated by pervious areas thereby eliminating nutrients from reaching the lake.

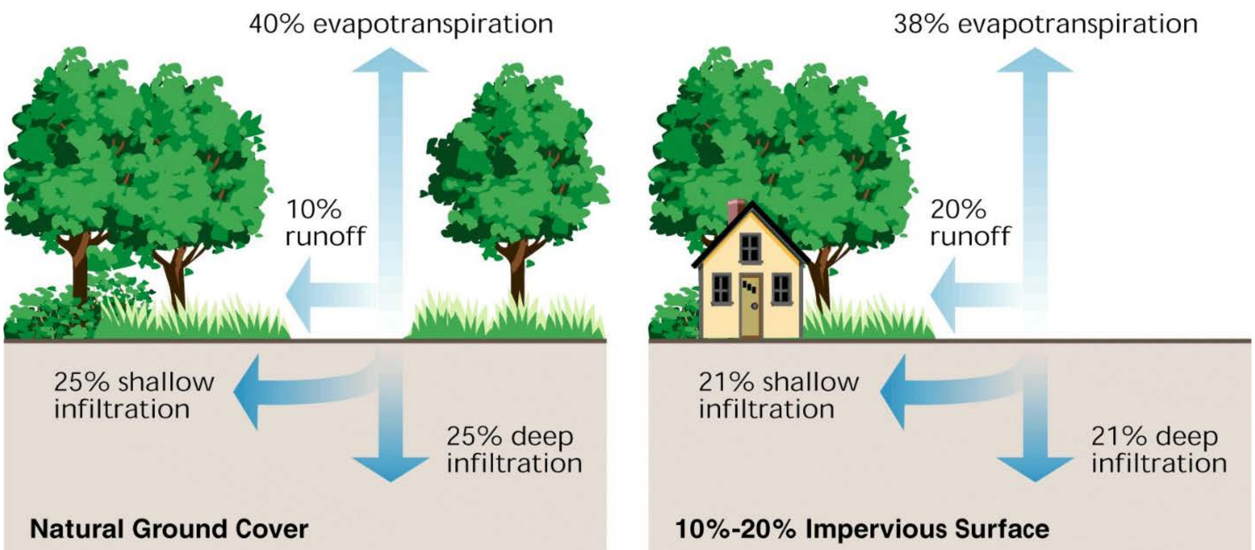


Figure 26. Schematic of Land Cover its Effect on Potential Surface Runoff

EOR used this shoreline habitat survey data to develop a rating scale of the potential of each property to either mitigate or contribute to nutrient (phosphorus) export to the lake. A reduction in nutrient loads from lakeshore parcels will require both protecting high quality, natural parcels and implementing shoreline best management practices (BMPs) such as vegetated shoreline buffers, rain gardens, etc. on parcels that are either highly impervious or contain manicured lawns.

EOR developed a rating scale based on the level of tree canopy present, and the percentage of impervious surfaces and manicured lawns adjacent to the lake to identify properties where siting a shoreline BMP could be advantageous in mitigation nutrient export to the lake. Each parcel was given a score of '1', '2', or '3' based on its tree canopy, amount of manicured lawn and impervious area present in the shoreline area. A rating was given to each of these criteria then the scores were averaged to give an overall score to each parcel. Figure 28 shows examples of what a typical shoreline looks like with each rating.

Figure 27. Examples of Green, Yellow, and Red Shoreline Ratings, Respectively (*L-R*)

A shoreline with a rating of '1' was pictorially given a 'green' designation on the map shown in Figure 28. An example of this type of shoreline is shown in the photo above on the left. The 'green' shoreline has a well-established swath of native plants as well as a high amount of overhead tree canopy. There is little to no area of manicured lawn or impervious area in a shoreline given this rating. The dense area of native plants and canopy intercept rainfall and decrease amount of nutrient laden surface runoff that reaches the lake by allowing runoff to evapotranspire via plants and trees and to infiltrate into the ground.

Shorelines with a medium amount of tree canopy, manicured lawns, and impervious areas were given a rating of a '2' and are represented in Figure 28 in yellow. A typical property with this rating is shown in the middle picture above. Note the mix of native vegetation and manicured lawn at the water's edge and significant amount of tree canopy.

Lots with a higher degree of developed shoreline have larger amounts of impervious areas and manicured lawns adjacent to the water and have a lower or nonexistent tree canopy, as shown in the photo on the right, above. These lots were given a rating of a '3' and are represented in Figure 28 with red. The area-weighted percentage of Tier 1 natural shorelines is depicted in Appendix C.

Table 11 - Shoreline Habitat Assessment Rating Scheme

Rating	Color Designation on Map	Description	Rating Criteria		
			Tree Canopy	Manicured Lawn	Impervious Area
Tier 1 - Natural	Green	Parcel with Lower Potential for Nutrient Export	80 - 100%	0 - 20%	0 - 5%
Tier 2 - Moderate	Yellow	Parcel with Medium Potential for Nutrient Export - Shoreline BMP Recommended	40 - 80%	20 - 40%	5 - 20%
Tier 3 - Developed	Red	Parcel with Higher Potential for Nutrient Export - Shoreline BMP Highly Recommended	0 - 40%	40 - 100%	20 - 100%

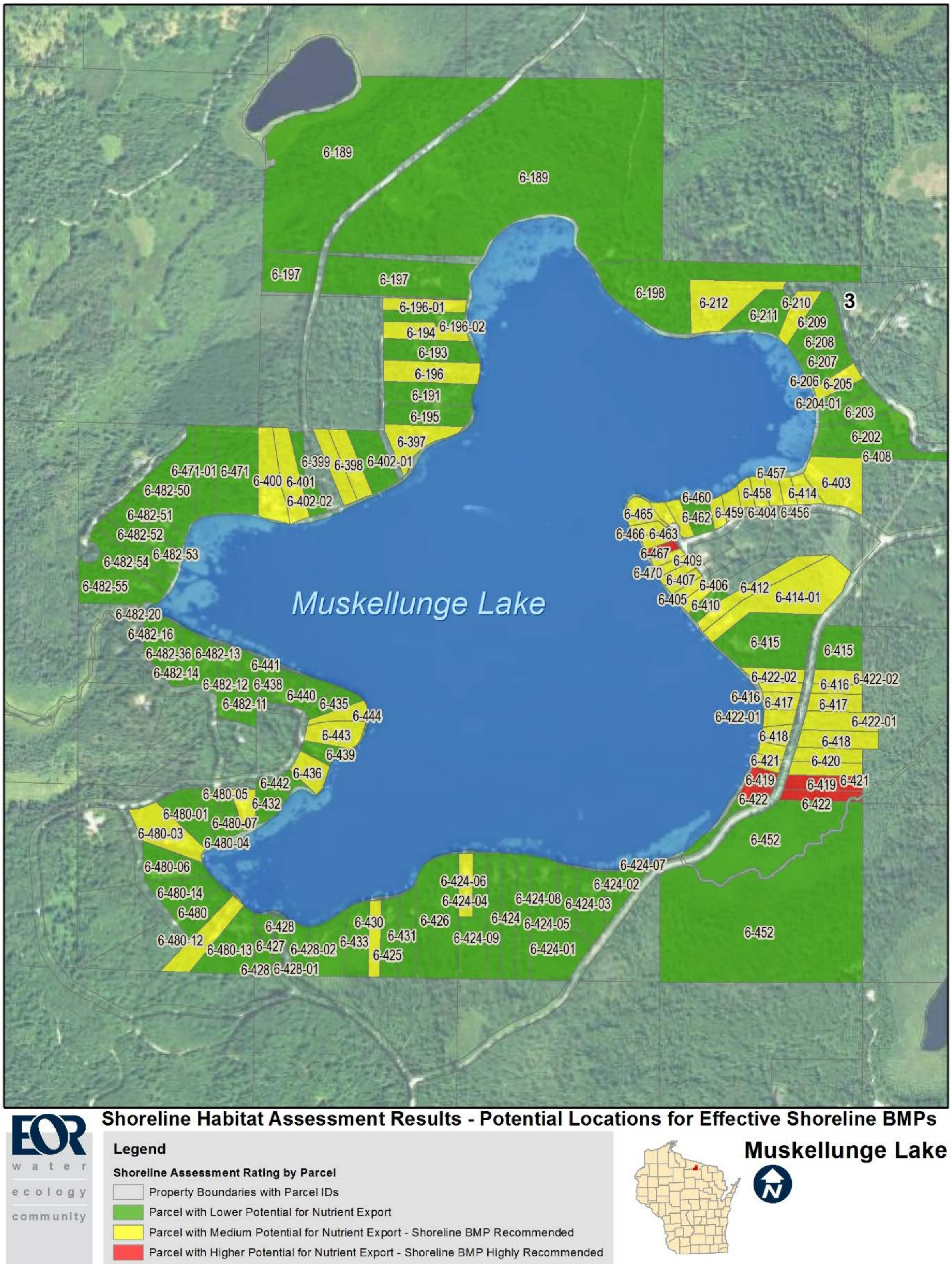


Figure 28. Shoreline Habitat Assessment Results.

8.2. Coarse Woody Habitat Assessment

WNDR staff conducted a coarse woody habitat survey at Muskellunge Lake in 2017. The objective of the survey is to identify the number of coarse woody structures and tree fragments (living and dead) that have fallen into the lake, either by natural or human caused processes. The more limbs, branches, roots and wood fragments that are present in a lake, the more habitat opportunities are present for aquatic organisms in the lake. Coarse woody debris in a lake also provides additional benefits to lake health by preventing suspension of organic sediments and provides surfaces for certain vegetation that promote populations of various aquatic organisms.

Over the years, as properties have been developed along the lake shore, much of the natural occurring coarse woody debris and habitat has been removed as property owners develop their properties by clearing woody debris from shallow areas of the lake adjacent to the shoreline for lake access and recreation purposes. The most recent coarse woody habitat survey counted a total of 22 pieces of woody debris in the roughly 2-mile perimeter of the lake. A study of Wisconsin lakes conducted in 1996 showed on average, undeveloped lakes had roughly 345 pieces of coarse woody debris per mile of shoreline, while lakes with houses built adjacent to the shore had 92 logs per mile of shoreline (Christensen et al. 1996). Muskellunge Lake showed 11 pieces of woody debris per mile which indicated that there is a good opportunity to create more habitat for aquatic organisms and improve water quality by encouraging landowners to increase woody habitats in the lake by promoting more fallen logs, fish sticks, and other management practices to increase coarse woody debris in the lake.

The coarse woody habitat survey notes whether certain characteristics that promote habitat are present in the of the woody debris encountered during the survey. As shown in the pie charts below, the survey records the degree of branches encountered on the woody debris, whether the woody debris contacts the shore or crosses the High Water Level (HWL), and if more than 5 feet of the woody debris is submerged. Of the 22 pieces of woody debris present in Muskellunge Lake, the figures below show what percentage of the logs encountered were observed with the various characteristics.

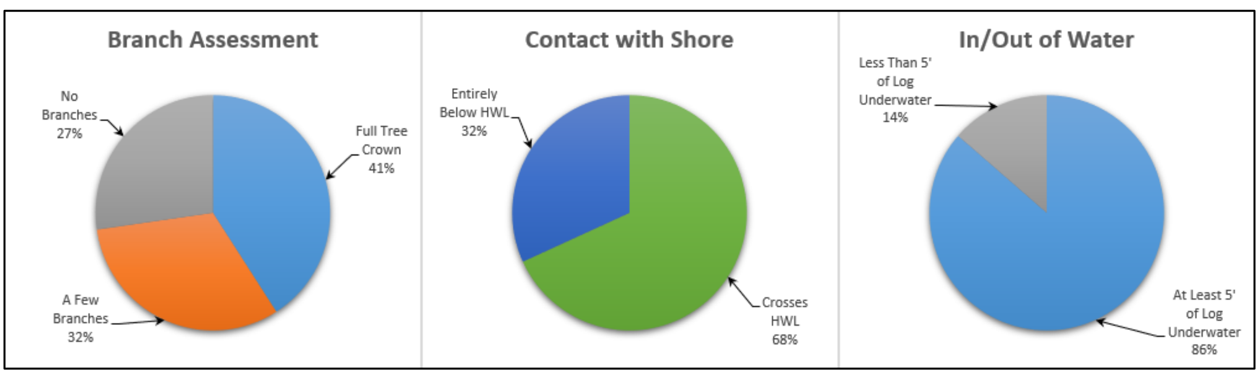


Figure 29 - Coarse Woody Habitat Results - Various Characteristic Assessments

The more branches on a fallen log, the more habitat is present as there is more shelter provided to fish and other organisms, and more opportunities for surface and water interfaces for aquatic organisms. Similar reasoning applies to logs that contact both the shore and water and how much woody debris is submerged. The more contact with the land and water and more logs are submerged and are out of the water, the more habitat is provided to organisms.

9. FISHERY

The DNR has conducted several fisheries assessments of Muskellunge Lake since 2000. In the 2005 Muskellunge Lake Management Plan, Steve McComas of Blue Water Science identified an overabundant bluegill population as a potential factor affecting water quality. The 2005 report also identified low catch rates for walleye and muskellunge. Surveys conducted since 2000 have primarily focused on gamefish species including walleye, musky, northern pike and largemouth bass. Healthy gamefish populations can provide top-down control over bluegill; therefore, maintaining a healthy gamefish population is critically important to maintaining the clear water, aquatic plant dominated state.

Muskellunge Lake has historically been managed for musky and walleye although largemouth bass and northern pike are also important gamefish species. Changes in the diatom community indicate that the aquatic plant community has increased in Muskellunge Lake over the last 100 years (USGS, 2003). An increase in the abundance of aquatic plants coupled with the arrival and subsequent expansion of EWM in Muskellunge Lake is more likely to favor an increase in northern pike and largemouth bass abundance, as these species tend to flourish in shallow lakes with abundant aquatic vegetation. According to the DNR, "Largemouth Bass abundances have increased throughout Wisconsin, possibly in response to changes in harvest regulations, angler behavior, and potentially other environmental drivers" (Hansen et al., 2015). The DNR has found that increases in largemouth bass abundance has negative impacts on growth and may be negatively affecting walleye stocks (Hansen et al., 2015). While largemouth bass populations appear to be increasing, a study of walleye populations in 473 Wisconsin Lakes found that walleye production has declined considerably since 1990. The following paragraphs outline results from fishery surveys conducted since 2000.

9.1. April 28 - May 02, 2011 Fyke Net Survey Results

Results from the 2011 Fyke Net survey must be viewed in the context that the target species was Muskellunge. The timing and location of Fyke nets were selected specifically to catch as many muskellunge as possible. Therefore, observations about the presence/absence and or abundance of other species are provided below only as anecdotal data. These observations may or may not be a representative evaluation of the population, abundance, and/or size distribution of these species. The total number of net nights (20) was determined by multiplying the number of Fyke nets (5) by the number of consecutive days (4) in which the Fyke nets were deployed.

9.1.1. Muskellunge

Thirty-one musky were captured over the course of 20 net nights equating to a catch per net night of 1.6, indicative of a moderate density musky population. Musky captured ranged in size from 11 to 47 inches with an average size of 36.13 inches (Figure 30). Proportional stock density (PSD) for Muskellunge Lake was calculated using the proportion of muskellunge larger than 30” that are also larger than 34”. Twenty-six of the 31 muskies captured were greater than 34”, resulting in a PSD score of 93. It should be noted that the survey targeted muskellunge during spawning time and in likely spawning locations. Therefore, this survey method is biased towards catching adult fish and may not be representative of size distribution of Muskellunge in the lake.

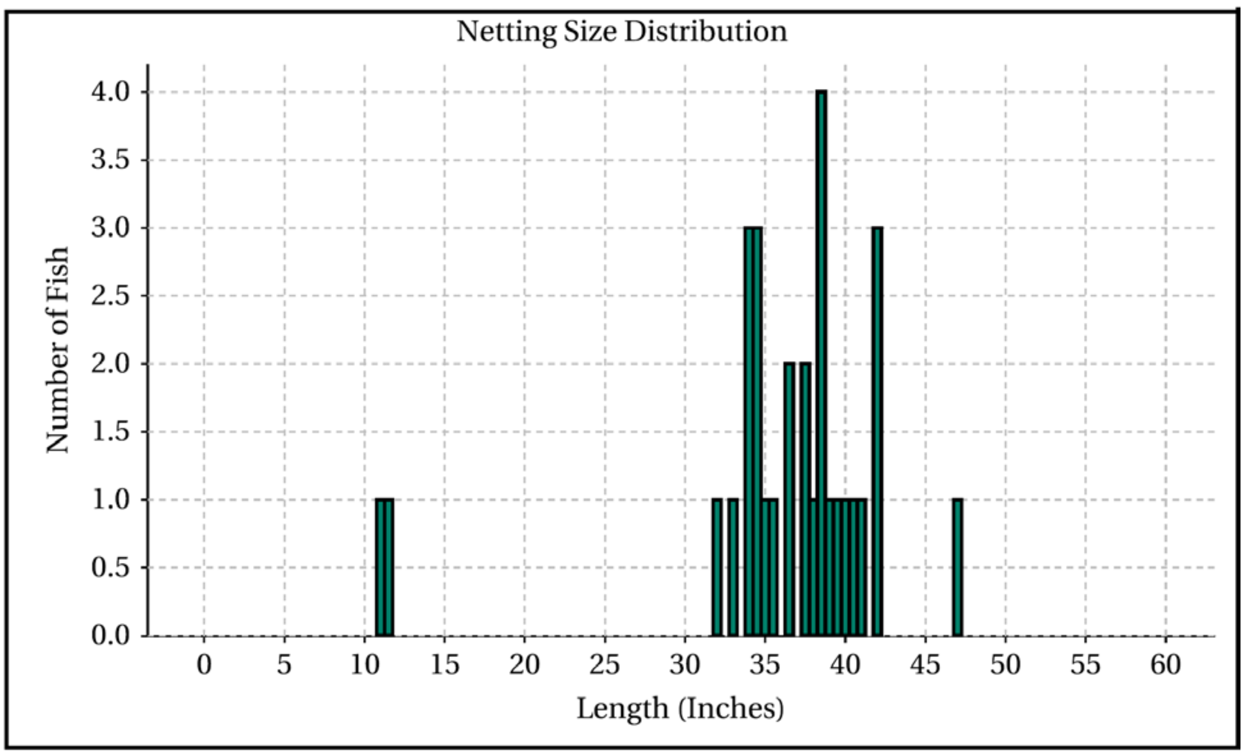


Figure 30. 2011 Muskellunge netting size distribution.

9.1.2. Walleye

Seventy adult walleye were captured over the course of 20 net nights equating to a catch per net night of 3.50, indicative of a low-density walleye population. Walleye captured ranged in size from 12 to 26 inches with an average size of 18.02 inches (Figure 31). The size structure of walleye in a given lake can be described using the proportional stock density (PSD) calculation. PSD measures the number of walleyes that are greater than *quality size* divided by the number of walleyes that are of *stock size*. The WDNR considers *quality size* as 15 inches and *stock size* as 12 inches. The PSD score of 92 is significantly above the average PSD score for lakes in the Ceded Territory (Figure 32). This finding suggests that walleye in Muskellunge Lake are healthy and reaching sizes that are desirable to anglers. This is also an indication that stocking walleye in Muskellunge Lake has produced a low-density population that has not produced any natural reproduction. Again, these results should be interpreted with caution, as walleye were not the primary focus of the 2011 survey.

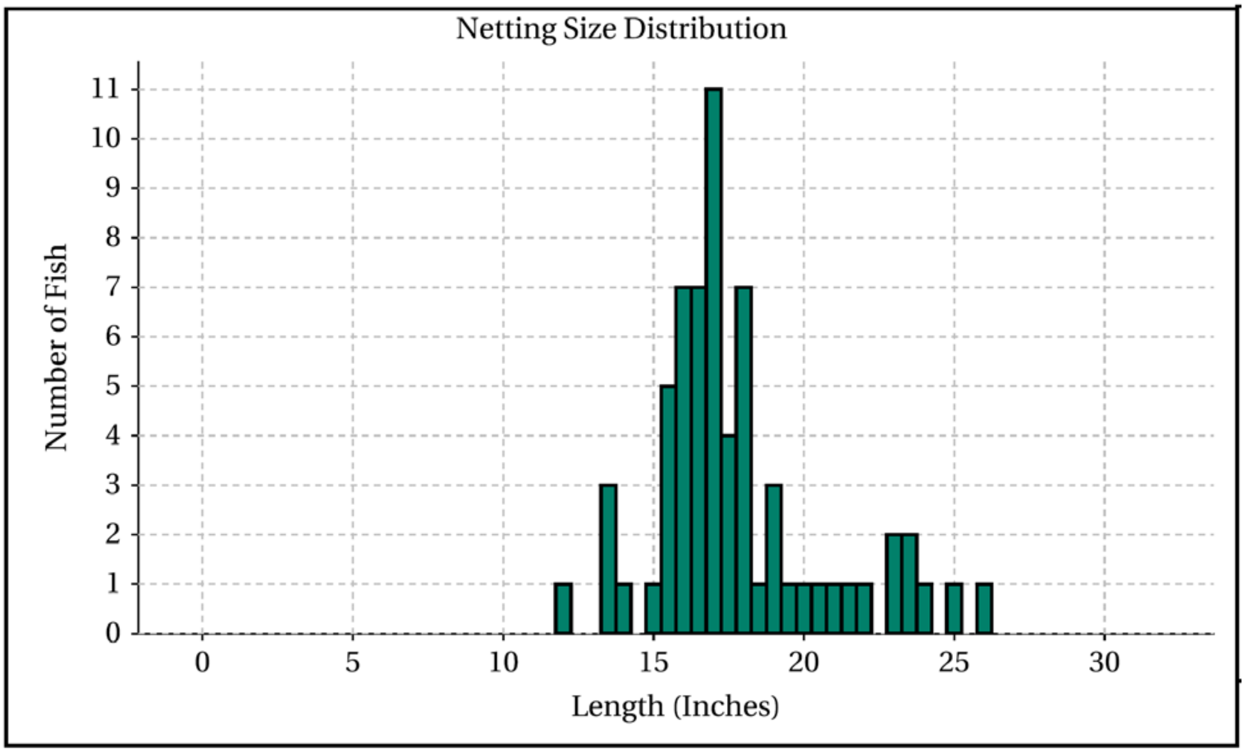


Figure 31. 2011 Walleye netting size distribution.

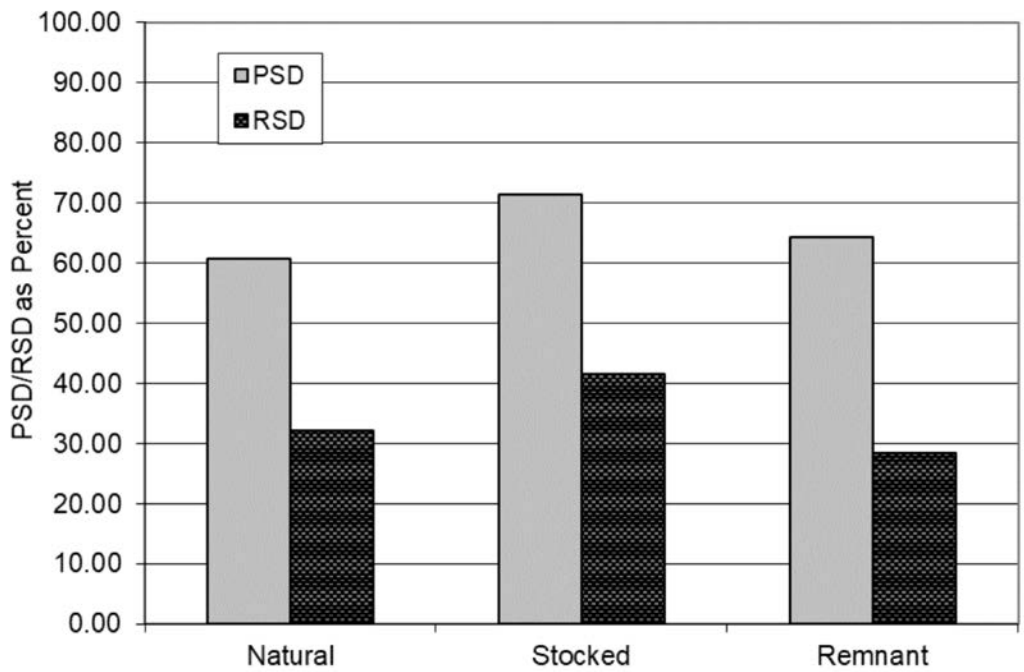


Figure 32. Comparison of mean PSD and RSD-18 values across lakes in various walleye recruitment models for lakes sampled in 2017. Source: [WDNR 2017-2018 Ceded Territory Fishery Assessment Report.]()

9.1.3. Northern Pike

Twenty-seven northern pike were captured over the course of 20 net nights equating to a catch per net night of 1.4, indicative of a low-density pike population. Northern pike captured ranged in size from 10.5 to 25.5 inches with an average size of 17.42 inches (Figure 33). Only five of the 27 northern pike captured were greater than 21 inches. Again, these results should be interpreted with caution, as northern pike were not the primary focus of the 2011 survey.

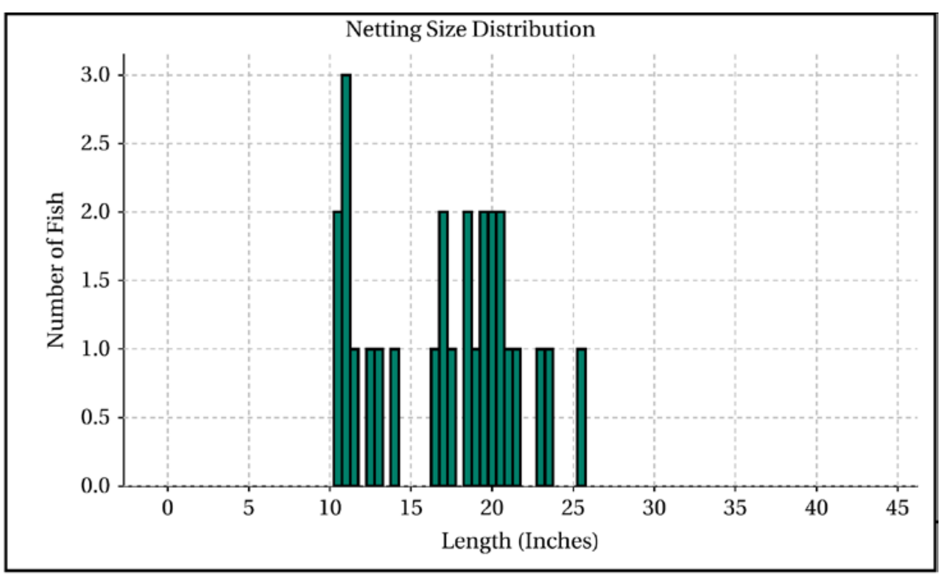


Figure 33. 2011 Northern Pike netting size distribution.

9.1.4. Largemouth Bass

Fourteen largemouth bass were captured over the course of 20 net nights equating to a catch per net night of 0.7, indicative of a low-density bass population. Largemouth bass captured ranged in size from seven to 16.5 inches with an average size of 12.89 inches (Figure 30). Eleven of the 14 largemouth bass captured were greater than 12 inches (quality size), indicative of a population consisting mostly of adult fish. Again, these results should be interpreted with caution, as largemouth bass were not the primary focus of the 2011 survey.

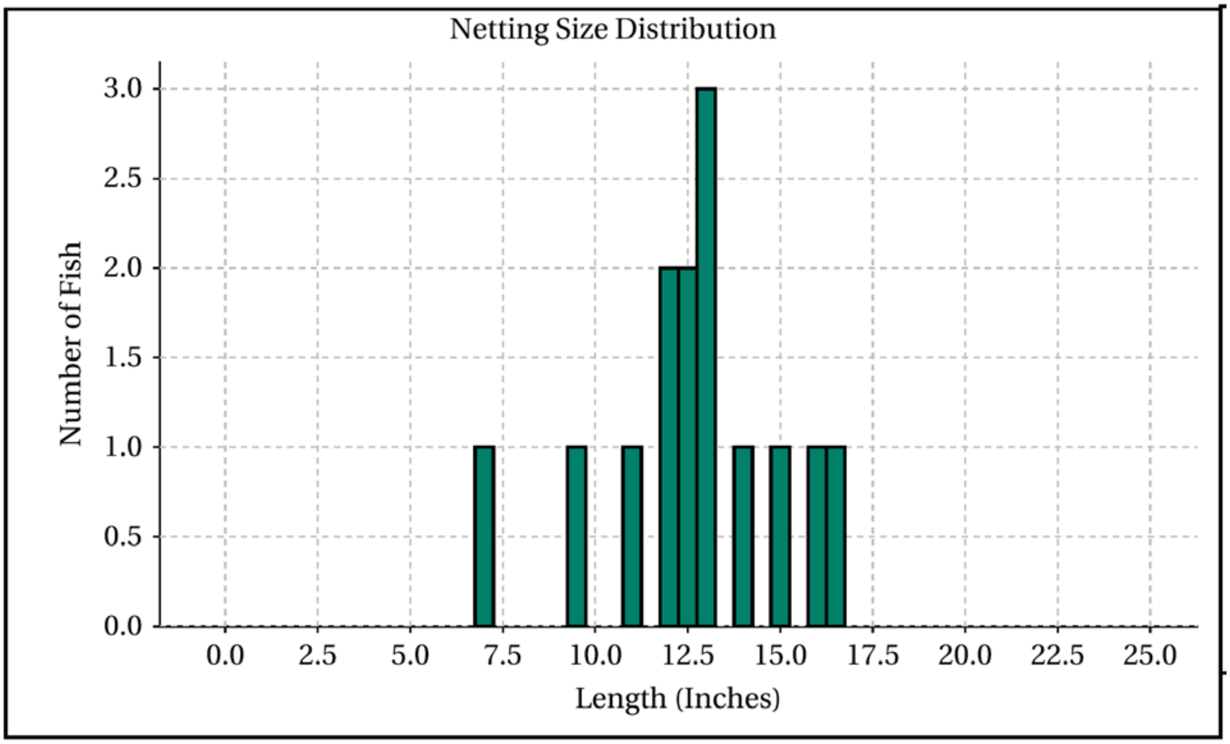


Figure 34. 2011 Largemouth bass netting size distribution.

9.2. 2014 – 2018 Fall Electrofishing Survey Results

The WDNR conducted electrofishing surveys annually each fall from 2014-2018. Primary sampling objectives of this survey were to assess juvenile walleye (age-0 and age-1) populations, therefore, observations about the presence/absence and or abundance of other species are provided below only as anecdotal data. The following paragraphs provide a brief summary of the survey results in comparison with a 2000 WDNR electrofishing survey of Muskellunge Lake. All surveys, including the 2000 survey made a single pass around the entire 4.0-mile perimeter of Muskellunge Lake and all surveys used a boat-mounted boom-shocker as the sampling technique.

Important findings:

1) The DNR has not documented natural reproduction and that stocking returns from extended growth fingerling walleye is on the low end.
2) The number of walleye caught per mile dropped from a high of 14.4 walleye per mile in 2000 to less than six walleye per mile in every survey from 2014-2018 (Figure 35).
3) The number of largemouth bass caught per mile increased from less than 1 per mile during the 2000 survey to more than 3 per acre during every survey from 2014-2018.
4) Northern Pike and Muskellunge were not captured in sufficient numbers during the 2000 survey to allow for a meaningful comparison with the 2014-2018 surveys.
5) There is a lack of data on the abundance and size structure of panfish species (bluegill, perch, and crappie) in Muskellunge Lake.

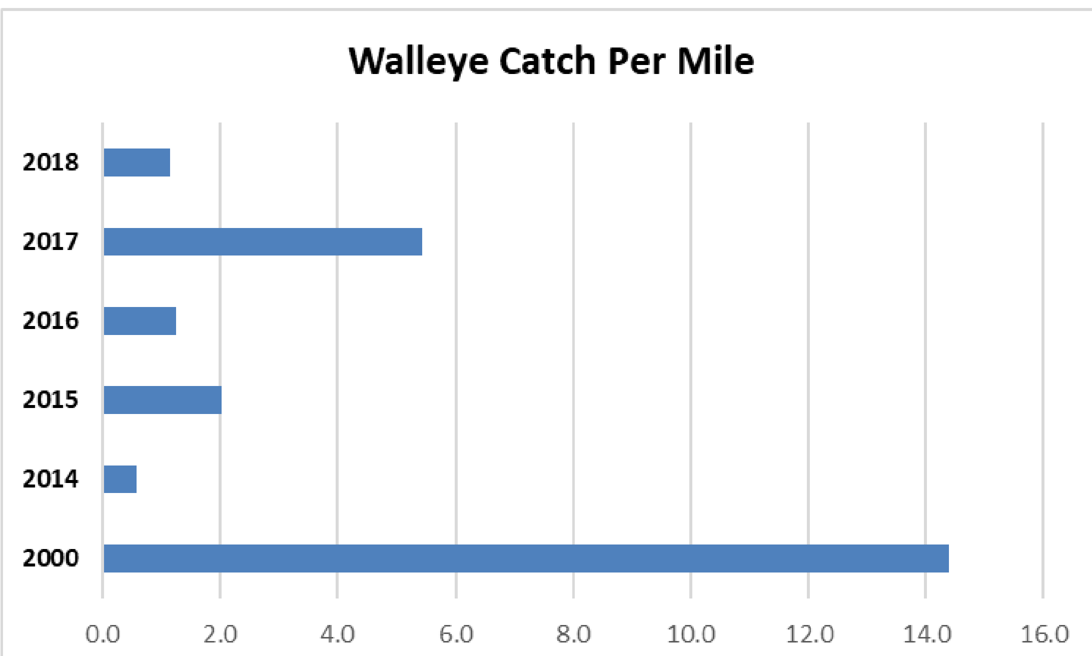


Figure 35. Walleye Catch per Mile.

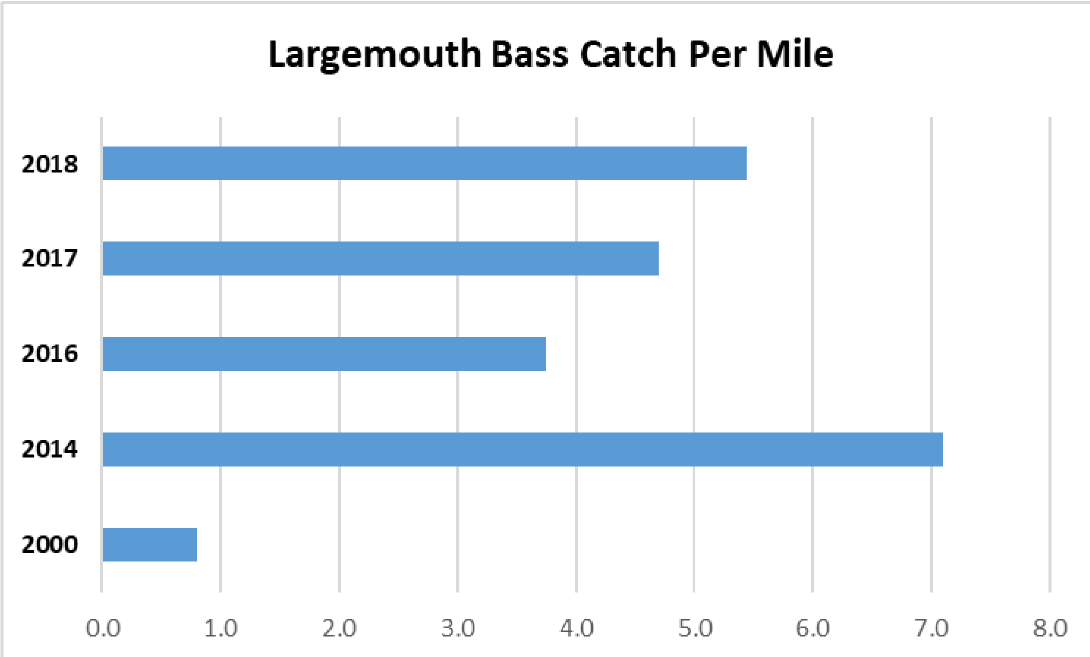


Figure 36. Largemouth Bass Catch per Mile.

9.3. 2019 Mark-Recapture Survey

The WDNR surveyed Muskellunge Lake from April 25- April 28, 2019. The primary objective of the mark-recapture survey was to assess the status of the adult walleye population; however, several other gamefish species were captured during the course of the survey.

9.3.1. Walleye

Results from the 2019 fisheries survey found a healthy, but low abundance (1.1/acre) adult walleye population. Two hundred-twenty-nine adult walleye were captured over the course of the three-day survey. A follow-up electrofishing survey captured 31 adult walleye, 25 of which bore the fin clip given during the fyke netting. Based on these results, the total population of adult walleye in Muskellunge Lake was estimated at 287 (1.1/acre). For comparison, the 1.1 adult walleye/acre falls somewhere in the middle to lower end of stocked lakes in the Ceded Territory (Figure 37). Interestingly, 89% of adult walleye were 15 inches or longer. The largest walleye captured was a 29.2-inch female.

Figure 37. Adult walleye density estimates for lakes sampled by WDNR in spring 2010 based on primary population recruitment source. Source: WDNR 2017-2018 Ceded Territory Fishery Assessment Report.

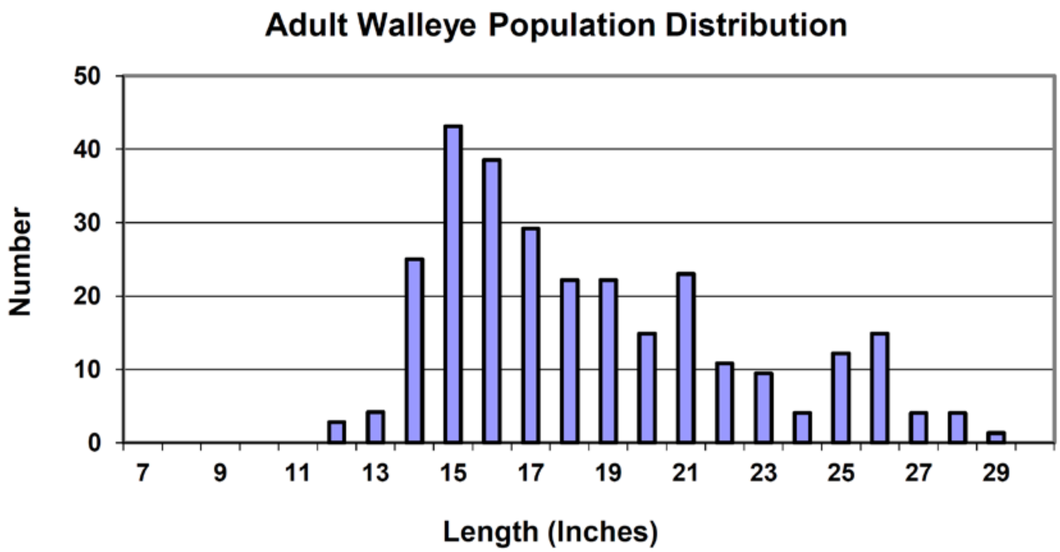


Figure 38. 2019 Adult Walleye Population Distribution: Source – WDNR.

9.3.2. Muskellunge

Muskellunge were not specifically targeted during the 2019 survey. However, five adult musky were captured including two individuals larger than 40 inches.

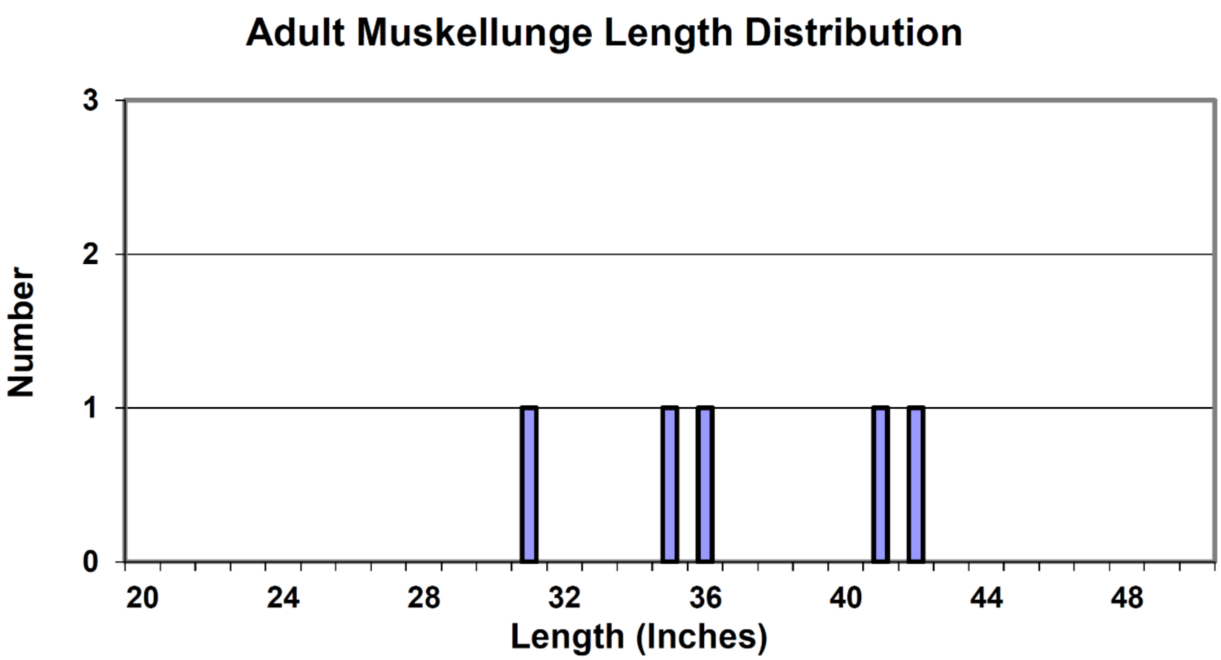


Figure 39. 2019 Adult Muskellunge Length Distribution: Source – WDNR.

9.3.3. Northern Pike

One hundred eighty-five adult northern pike were captured during the 2019 survey. Northern pike captured ranged in size from 10 to 28.7 inches. Only 11 (6%) of the 185 pike captured were greater than 26 inches.

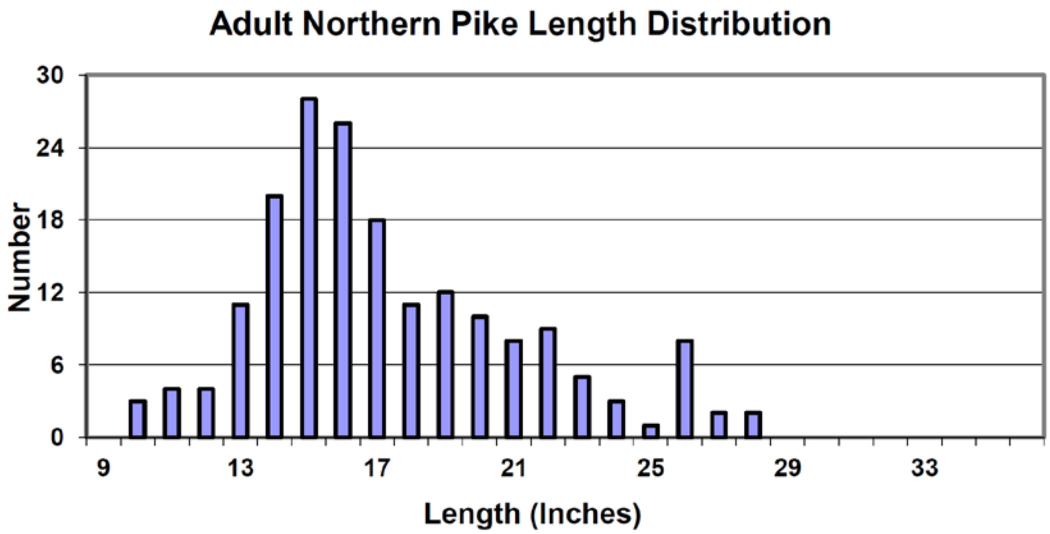


Figure 40. 2019 Northern Pike netting size distribution.

9.3.4. Largemouth Bass

Forty-nine largemouth bass were captured during the 2019 survey despite not being a primary target of the survey. The implication being that a larger number of largemouth bass would have been sampled if largemouth bass were targeted. Largemouth bass captured ranged in size from nine to 18.7 inches. Thirty-one (63%) of the 49 bass captured were greater than 14 inches.

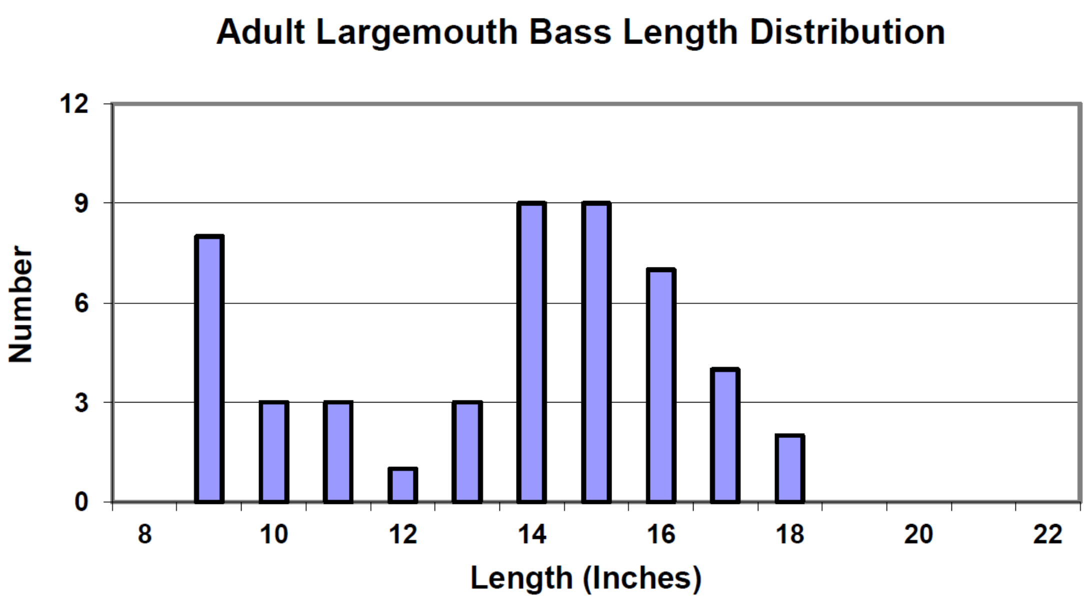


Figure 41. 2019 Largemouth bass netting size distribution.

9.3.5. Other Species

Nine additional fish species were captured during the 2019 survey. The most commonly observed species included yellow perch, bluegill, and black crappie. Additional species observed included pumpkinseed, rock bass, yellow bullhead, white sucker, golden shiner, and creek chub.

9.3.6. Stocking

Muskellunge

Fingering (3-10”) muskellunge (musky) were stocked in Muskellunge Lake every 2-3 years from 1972 – 1999. No musky were stocked in Muskellunge Lake from 2000 through 2012. Large Fingerling (10-12”) musky were stocked in 2012, 2014, and 2016 (Figure 42).

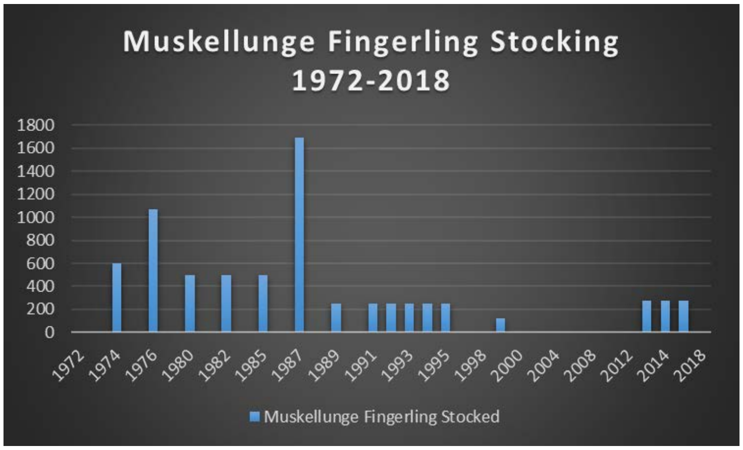


Figure 42. Muskellunge Fingerling Stocking 1972-2018

Walleye

Fingering (2-4”) walleye were stocked in Muskellunge Lake annually from 1972 – 1994. Large Fingerling (3-7”) walleye were stocked in 1997, 2010, 2014, and 2018. Small Fingerling (1-2”) walleye were stocked every other year from 1998- 2012.

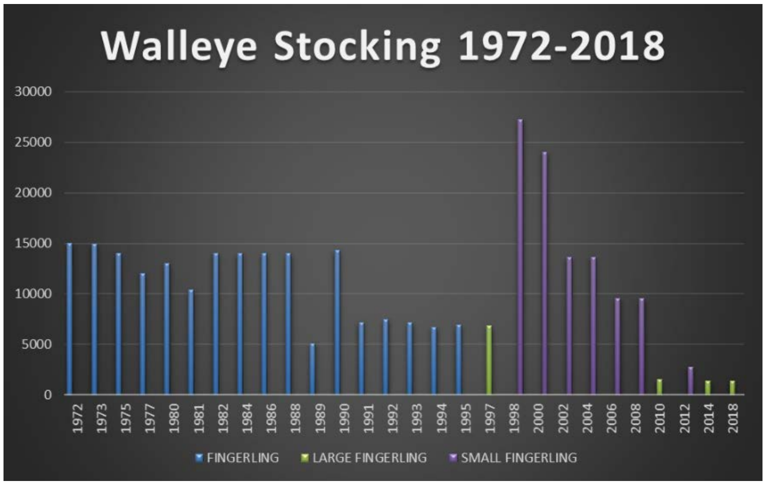


Figure 43. Walleye Stocking 1972-2018

9.4. Implications for Muskellunge Lake

Top- down control refers to the stocking of piscivorous (fish that eat other fish) fish, such as bass, muskellunge, walleye or northern pike to control (reduce) the abundance of smaller, planktivorous fish such as bluegill. The reduction of bluegill or other planktivorous fish species in turn leads to an abundance of zooplankton and a decline in phytoplankton (algae) abundance and subsequently increased water clarity. At the same time, the overharvest of piscivorous fish could lead to increased abundance of planktivorous fish and a decrease in zooplankton abundance, leading to increased algal abundance and reduced clarity. Most importantly, research has consistently demonstrated that top-down control in shallow lakes is more important in shallow lakes than in deep lakes (Jeppesen, et al., 1997).

The primary gamefish species that could potentially provide top-down control of bluegill in Muskellunge Lake include muskellunge, northern pike, largemouth bass, and walleye. In general, piscivorous fish species are able to grow rapidly in shallow, productive lakes like Muskellunge Lake due to presence of an ample forage base. A review of walleye, muskellunge, and largemouth bass size structure suggest these species grow quickly in Muskellunge Lake, making these species prime candidates for controlling bluegill abundance.

The size distribution of northern pike in Muskellunge Lake is poor. Only 11 (6%) of the 185 pike captured during the 2019 survey were greater than 26 inches and the largest northern pike sampled in any survey was only 28.7 inches. Given that there is an ample forage base present in Muskellunge Lake, the lack of northern pike greater than 28 inches points to overharvest by anglers. Monitoring of angler harvest and fish communities over time has led fisheries managers to conclude that over-harvest of medium and large pike (for example, fish greater than 24 inches) has been a major factor leading to many pike populations having high densities of smaller fish with fewer fish above 24 inches (MN DNR, 2008).

Figure 44 shows that the maximum prey body depth (width) for a 21-inch (530 mm) northern pike is approximately 65 mm or approximately 2.5 inches (Nilsson and Brönmark, 2000). Given that the majority of northern pike in Muskellunge Lake are less than 21 inches, it is unlikely that the existing northern pike population is capable of providing adequate top-down control of the bluegill population given that bluegill are a deep-bodied species and even small bluegill have body depth that exceeds 2.5 inches. Increasing the harvest of small northern pike that are not capable of exerting top-down control of bluegill while protecting larger northern pike that are capable of feeding on bluegill should be a point of emphasis for Muskellunge Lake.

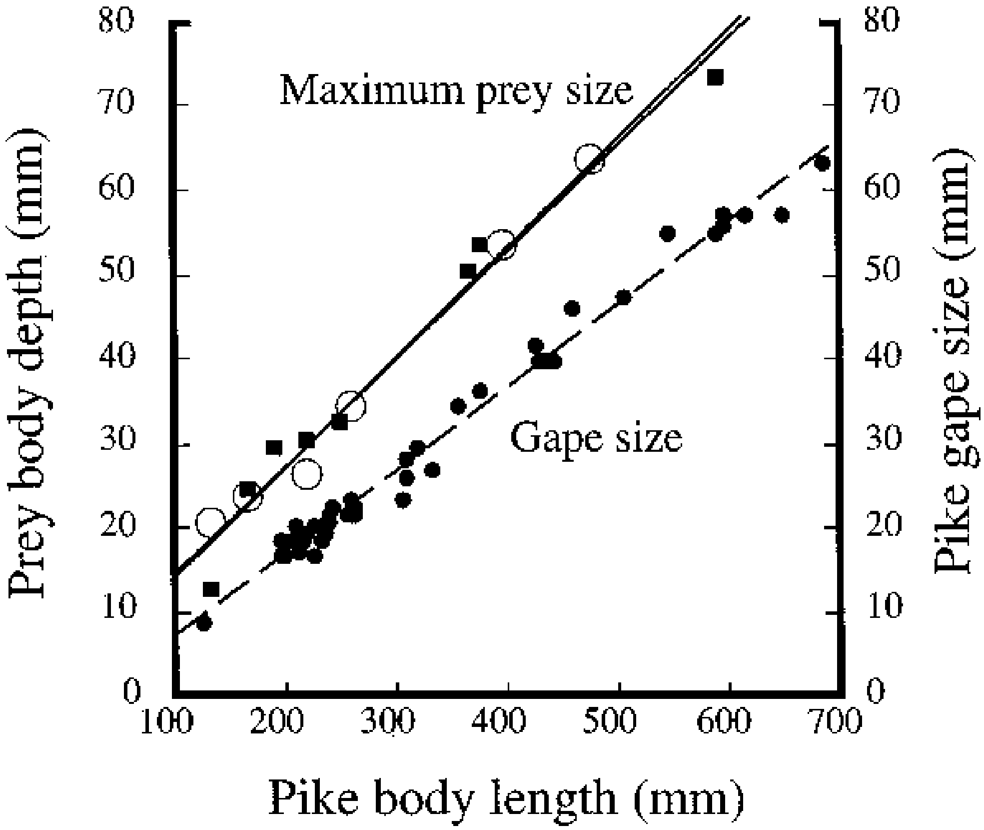


Figure 44. Pike body length versus maximum prey body depth (width).

9.4.1. Recommended Management

The Wisconsin DNR has developed a Fish, Wildlife, and Habitat Management Plan for all Waters of the State. Specific management goals and administrative rules affecting fish are found in NR 20 – 26 within the Wisconsin State Legislature (Table 12). In general, Muskellunge Lake is meeting the majority of fishery management goals identified in Table 8. However, the 1.1 adult walleye/acre finding from the 2019 survey is well below the three adult walleye per acre threshold, widely regarded as the standard for a good walleye fishery for most northern Wisconsin lakes. For comparison purposes, the Wisconsin DNR enacted a 5-year moratorium on walleye harvest in the Minocqua Chain of Lakes in 2015 when the adult walleye population was around one adult walleye/acre. Surveys conducted in the spring of 2019 found the adult walleye population in Minocqua Lake had rebounded to 3.78 adult walleye per acre. While mandatory catch and release restrictions are not initially popular, a recent survey showed 90 percent of respondents were supportive of maintaining the catch and release only regulation on the Minocqua chain. Muskellunge Lake is currently part of a statewide walleye stocking study, adjustments to stocking rates will not be able to be completed until that is complete.

From 1999-2005, anglers reported catching one musky for every 10 hours of directed angling effort. Since 2005, anglers report an average catch rate of one musky for every 30 hours of directed angling effort (personal communication, MLA). More research is needed to evaluate overall abundance and size structure of the musky population. While not a primary target of the 2019 survey, Fyke netting is a common method of sampling any fish species that uses littoral zone habitats (including musky). Despite this, only five musky were captured during the 2019 Fyke-net survey.

Based on these findings, the following management practices are recommended for Muskellunge Lake:

1) Revisit stocking of walleye and walleye harvest regulations following the completion of DNR statewide study. Work with DNR Fisheries Biologists to implement fisheries management efforts to help Muskellunge Lake reach stated goals. It should be noted that the average density for a stocked fishery is the range of 1.5-2.0 adult walleye per acre. Managing Muskellunge Lake for an adult walleye population of 2.0 walleye per acre may provide additional top-down control of bluegill given that the adult walleye observed during the 2019 survey was 1.1 adult walleye/acre.
2) Implement a slot limit designed to protect northern pike between 24 and 30 inches in an effort to increase the average size of northern pike. Larger northern pike are more likely to be capable of consuming deeper bodied fish species like bluegill.
    a. Population goal of 0.8 northern pike >24 inches per acre. This equates to a lake-wide population of approximately 220 northern pike >24 inches.
3) Increase stocking of muskellunge to maintain a minimum catch rate of one muskellunge per 25 hours of muskellunge angling through continued stocking efforts.
4) Conduct a comprehensive fisheries assessment to evaluate population size and distribution of all fish species including bluegill, crappie, perch, and aforementioned gamefish species.

Table 12. Wisconsin DNR Fish, Wildlife, and Habitat Management Plan

Species	Management Goal	Goal Met
Walleye	There are 3 or more adult walleye per acre and total harvest is less than 35% of the adult population.	N
	25% of all adult walleye longer than 10 inches are 15 inches or larger in northern lakes	Y
	25% of all walleye longer than 10 inches are 18 inches or larger on stocked lakes	Y
	Survey all walleye lakes larger than 100 acres with public access at least once every twelve years	Y
Muskellunge	30% of all adult musky larger than 30 inches are 38 inches or larger	Y
	Complete an update of the musky management plan every two years	Y
	Manage Class A2 waters for a catch rate of 1 muskellunge (any size) per 25 hours of muskellunge angling	N
	Muskellunge Lake is a Class 2, Category 3 waterbody meaning that stocking is required to maintain the fishery. Continue stocking muskellunge at a rate of 1-2 Muskellunge/acre.	N
Largemouth Bass	50% of spring electrofishing surveys find at least 13 largemouth bass greater than 8 inches per mile of shoreline and 1.5 largemouth bass larger than 15 inches per mile of shoreline.	Y
	All bass lakes over 100 acres are sampled at least once every twelve years.	Y
Bluegill/ Crappie	30% of all adult bluegills over three inches are six inches or larger	Y
	30% of all adult black crappie over five inches are eight inches or larger	Y

9.5. Dissolved Oxygen

The major sources of dissolved oxygen in shallow lakes includes diffusion from the atmosphere, wind mixing (wave action), and photosynthesis from aquatic plants. The major uses of dissolved oxygen include respiration and decomposition. Respiration is essentially the act of breathing; when aquatic organisms breathe, they consume oxygen and release carbon dioxide. Decomposition is the breakdown of organic matter by invertebrates, bacteria, and fungi, which consumes oxygen. During the winter, shallow lakes can become anoxic (without oxygen) as oxygen consuming activities (respiration and decomposition) continue under the ice without any new sources of oxygen from the air or plant photosynthesis.

9.5.1. Thermal Stratification

Understanding lake stratification is important to the development of both the nutrient budget for a lake as well as ecosystem management strategies. Dissolved oxygen profiles collected on Muskellunge Lake suggests the lake displays a weak thermal stratification during both the summer and winter months with often only a few degree difference in temperature from top to bottom. Because the difference in water temperature is not significant, stratification is often broke down intermittently during cooling periods or periods of high winds. During winter, weak thermal stratification is also present throughout the lake, even during the operation of the aeration system.

Muskellunge Lake is a polymictic waterbody, meaning that it may become temporarily stratified and then mix from top to bottom multiple times per year. Polymictic lakes have very different nutrient budgets than deeper lakes that are more strongly stratified or very shallow lakes that are completely mixed all year. Typically, temperature drives the stratification of a lake because water density changes with water temperature. However, the larger impact usually lies with the dissolved oxygen profile. As cooler, denser water is trapped at the bottom of a lake, it can become devoid of oxygen, affecting both aquatic organisms and the sediment biogeochemistry. The bottom portion of the lake can be referred to as the *hypolimnion*. The hypolimnion is the deeper portion of a lake that forms during periods of stratification where the water is stagnant and essentially uniform temperature. In this zone, the water down near the sediment can become oxygen deprived as accumulated organic matter is broken down by microorganisms. In these modified conditions, the natural ability of sediments to bind with phosphorus is altered and the phosphorus is released to the water column becoming available to algae. In polymictic lakes, it can be difficult to distinguish internal from external loads because the water column is more subject to becoming vertically mixed in comparison with a deep lake that remains stratified throughout the summer (Søndergaard et al. 2005). When periodic mixing events occur, phosphorus can be released from bottom sediments into the mixed overlaying water where it can be taken up by algae. In comparison, a large proportion of phosphorus is often trapped (retained) in the stagnant summer hypolimnion of deeper stratified lakes that only mix during the spring and fall turnover. Consequently, internal loading is more likely to affect surface water quality in shallow polymictic lakes throughout the summer, whereas in deeper lakes, we see this phenomenon only occurring in the spring or fall in lakes that remain stratified (Nürnberg, 2009).

Summer Hypolimnion Sampling

On August 14, 2018, the MLA conducted a dissolved oxygen profile in the deepest portion of Muskellunge Lake (19 feet; Table 13). Oxygen concentrations in the bottom 7 feet of the water column (12-19 feet) were less than 0.1 mg/L, indicative of anoxic conditions resulting from thermal stratification. A Van Dorn sampler was used to collect a water quality sample from the bottom 1-foot of the lake in an effort to identify the Dissolved Reactive Phosphorus (DRP) concentration in this portion of the water column. The water quality sample was sent to the Wisconsin State Laboratory of Hygiene for analysis. This analysis identified a DRP concentration of 20.5 ug/L (0.0205 mg/L). Cooling temperatures and increased wind/wave action in the weeks following the August 14 sampling event resulted in a mixing event that presumably released the biologically available phosphorus to the water column where it could be consumed by algae. These periods of intermittent stratification followed by vertical mixing are not uncommon on Muskellunge Lake.

Table 13. Water Depth

Water Depth (Feet)	Dissolved Oxygen (mg/L)	Water Quality Sample
3	8.93	✓ Rotten egg (Sulfur) smell ✓ Clear, but stained ✓ Dissolved Reactive Phosphorus Concentration – **20.5 ug/L**
6	8.95	
7	2.8	
8	1.4	
9	0.20	
12	0.07	
15	0.06	
17	0.05	

Winter Dissolved Oxygen Monitoring

The USGS collected dissolved oxygen profiles in late winter (March 2001, 2002) when oxygen depletion is expected to be most extreme (USGS 2003). In 2001, dissolved oxygen concentrations at the deep-hole sampling site, a short distance from the aerator, were above 9 mg/L even just above the bottom. These concentrations were well above the Wisconsin state standard of 5 mg/L for dissolved oxygen in warm-water lakes (Shaw and others, 1993). In comparison, dissolved oxygen concentrations observed in March of 2002 when the aerator was not operated were significantly less despite a late freeze and a moderately warm winter with little snow cover. In 2018, the MLA conducted later winter (March) dissolved oxygen monitoring using a calibrated Yellow Springs Instruments (YSI) dissolved oxygen meter from the Vilas County Conservation office in the deep holes of each bay of the lake to determine how well the aeration system is maintaining oxygenated conditions throughout the lake. Results from this analysis found that dissolved oxygen concentrations just 50 feet west from open water were only 2.4 mg/l at the surface with little or no oxygen present in the bottom seven feet (12-19 feet) of the water column. Observing dissolved oxygen concentrations so close to the aerator provides evidence to suggest that large portions of the lake are likely going anoxic during the winter. During spring turnover, this nutrient rich water is mixed with surface water.

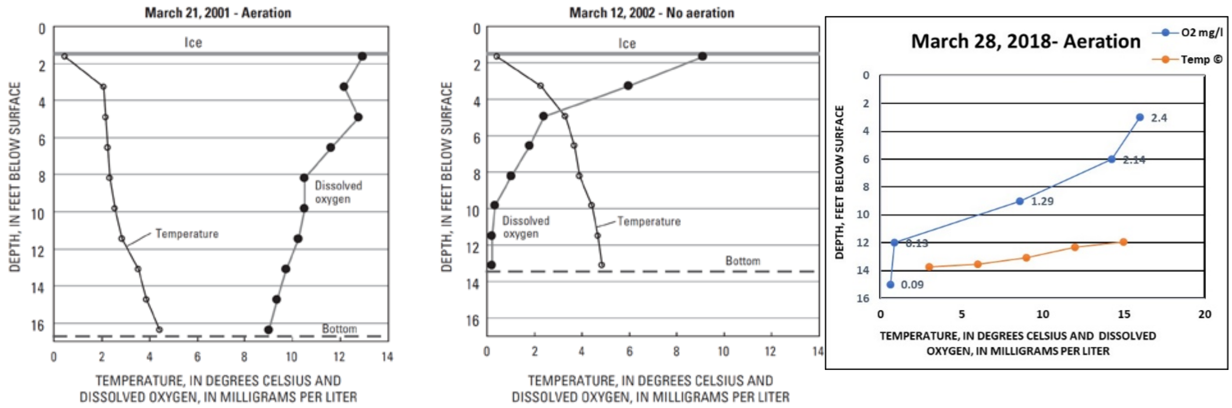


Figure 45. Dissolved oxygen monitoring results from under the ice sampling events conducted in late winter from 2001-2018.

9.5.2. Implications for Muskellunge Lake

Individual fish species have different dissolved oxygen level requirements in water (Figure 46). Certain gamefish species, such as northern pike and yellow perch, are better suited for periodic low levels of dissolved oxygen than other gamefish species, such as walleye, musky, bass, and bluegills. Multiple year classes of walleye, musky, bluegill, and bass are present, providing evidence to suggest that the aeration system is maintaining adequate levels of dissolved oxygen. However, the existing aeration system does not appear to be preventing portions of the lake from going anoxic. Figure 47 shows that the average monthly total phosphorus concentration is highest during the month of April, a month that often coincides with spring turnover.

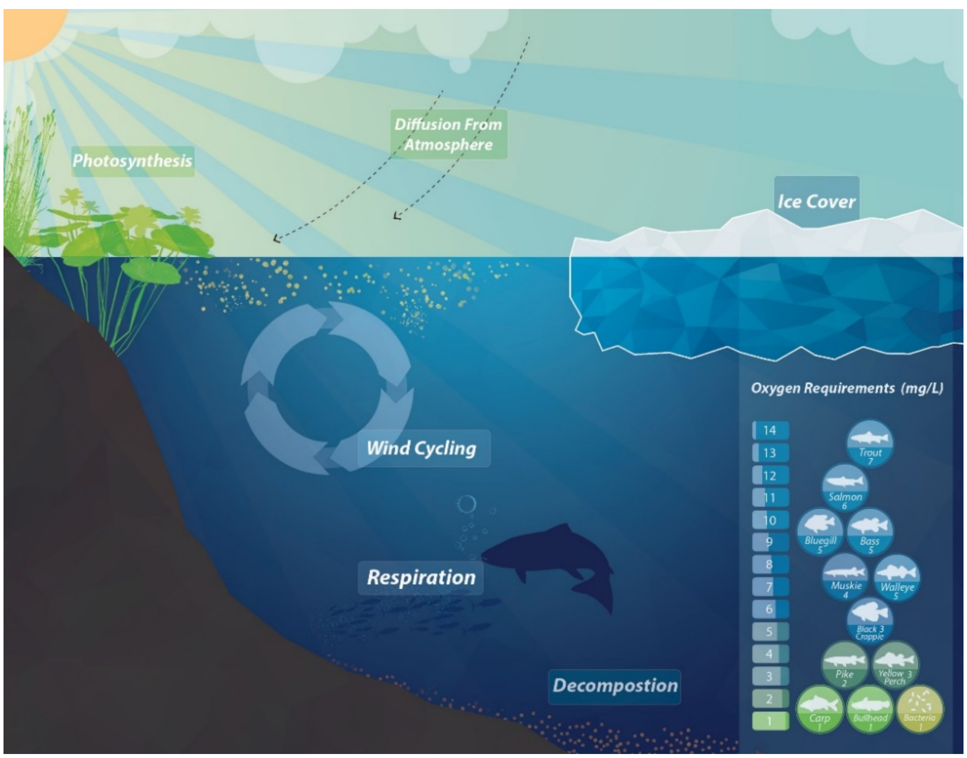


Figure 46. Dissolved oxygen dynamics in shallow lakes

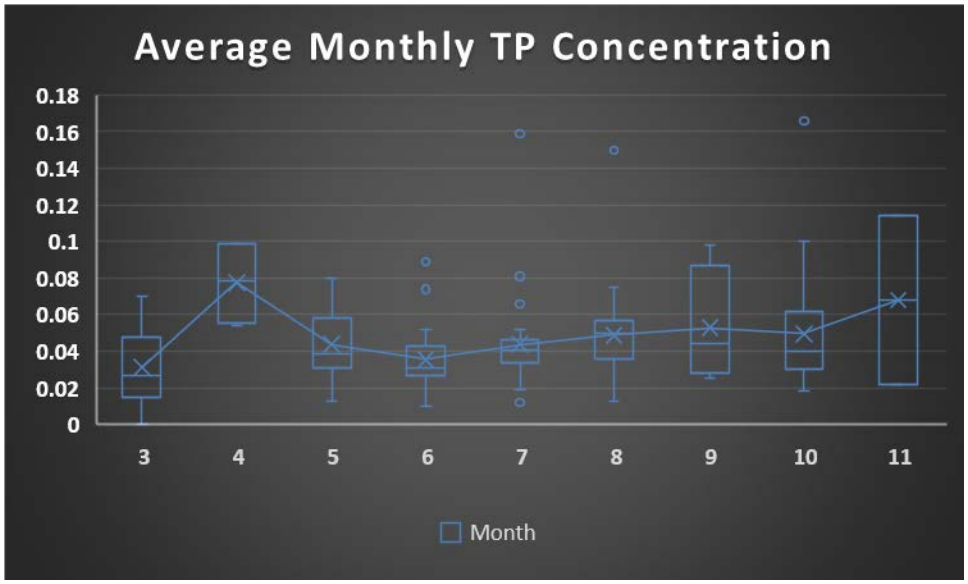


Figure 47. Average Monthly Total Phosphorus (TP) Concentrations

10. MUSKELLUNGE LAKE WATERSHED

Results from a 2003 USGS study of the Muskellunge Lake watershed provided the most comprehensive insight into the water balance and nutrient (phosphorus) budget for Muskellunge Lake (Robertson, 2003). The study found that most of the water that enters Muskellunge Lake is through ground water and precipitation; however, a small tributary on the southeast side of the lake and over-land flow episodically discharge water to the lake. The USGS study suggested that the direct surface water drainage area to Muskellunge Lake was 550 acres with a total contributing ground water area of 2,200 acres.

EOR re-evaluated this assumption through the use of remote sensing techniques that incorporated the 1) Model My Watershed (MMW) Tool and 2) An analysis of high-resolution (2-meter) Light Detection and Ranging (LiDAR) Digital Elevation Data. Analysis of LiDAR data was performed using the Natural Resources Conservation Service (NRCS) GIS Engineering toolbox.

10.1. Watershed Delineation

10.1.1. Model My Watershed (MMW)

The Model my Watershed Web Application for Muskellunge Lake used a 30-meter resolution Digital Elevation Model (DEM) to move downhill from the Muskellunge Lake Outlet and ultimately to snap onto the nearest point and calculates the watershed upstream of this point using a 30-meter resolution flow direction grid. Results from this analysis identified a total contributing watershed area of 2,336 acres (2,860 acres if including the open water area associated with Snipe Lake and Muskellunge Lake).

Figure 48. Muskellunge Lake Watershed. Source – Model my Watershed Web Application

10.1.2. NRCS GIS Engineering Toolbox

The NRCS toolbox is a Python-based collection of tools primarily designed for hydrologic and terrain-based analysis of high resolution elevation data in the ArcGIS environment. The toolbox was used to delineate watershed and sub-watershed boundaries using a hydro-corrected 2-meter resolution DEM as input. Hydro correction of the DEM was performed by "burning in" culverts following a culvert flow direction inventory conducted by volunteers from the Muskellunge Lake Association. The process of "burning in" refers to artificially lowering the DEM along the culvert to allow flow accumulation through/under the digital dam (e.g., surface elevation of the road). Members of the MLA also conducted a field visit to ground-truth delineated watershed boundaries. Results from this analysis identified a 2,320-acre watershed (2,592 acres if including the open water area associated with Muskellunge Lake) that was then further subdivided into fifteen unique subbasins (subwatersheds) that collectively drain to Muskellunge Lake (Appendix D).

The NRCS toolbox was also used to identify topographic depressions that may retain water during storm events (wetlands), and the flow direction of all overland flow paths with a minimum upstream drainage area of five acres.

10.2. Phosphorus Budget

10.2.1. External Phosphorus Sources

The Muskellunge Lake Watershed is predominantly forest and wetlands, although areas of low-density residential development are present and increasing with only five undeveloped lots remaining. The soils in the area consist mainly of well-drained sand and sandy loams and are thought to be naturally high in phosphorus content (Wisconsin Department of Natural Resources, 1985).

The nutrient load originating from external sources in the Muskellunge Lake watershed was calculated using a weight of evidence approach that leveraged existing models of the watershed including 1) 2003 USGS Study, 2) Wisconsin River TMDL SWAT model, and 3) Model my Watershed Web Application and monitoring data from USGS Stream Gauge 05390685 located on Muskellunge Creek near the confluence with Little St. Germain Lake. External loads were further divided by subwatershed (Table 20; Appendix C) in an effort to identify the portions of the watershed that are contributing the greatest proportion of the external nutrient (phosphorus) load from which future implementation measures can be prioritized.

2003 USGS Study

The 2003 USGS Study contains a detailed phosphorus budget that was computed using surface and groundwater data collected over a 1-year period (November 2000 - October 2001). The relative magnitude of various sources of phosphorus entering the lake from the 2,200 acre watershed is shown in Table 14. Phosphorus concentrations were measured approximately monthly and more frequently during flow events in the southeast tributary. Concentrations were generally lowest from October through June (20–40 µg/L) and then steadily increased throughout summer, reaching about 90 µg/L in late August. During a high-flow event in July, however, a concentration of 177 µg/L was measured. Daily phosphorus concentrations in the southeast tributary were obtained by linearly interpolating between measurements. The phosphorus concentration in runoff from the remaining nearshore areas that are predominantly forested was assumed 100 μg/L, based on six intensively monitored, forested plots in Vilas County (D. Graczyk, U.S. Geological Survey, 2002). Over 50 percent of the phosphorus loading from surface inflow occurred in April and May. The total output of phosphorus from Muskellunge Creek was estimated to be 206 pounds, suggesting that Muskellunge Lake retains approximately 231 pounds of phosphorus per year or 53% of the TP yield to the lake.

Table 14. Relative magnitude of external phosphorous sources – 2003 USGS Study.

Phosphorus Source	Phosphorus Load (pounds/year)
Precipitation	13.2
Southeast Tributary	65.3
Remaining nearshore areas	35.6
Ground water	253.5*
Septic Systems	69.4
Total Watershed Phosphorus Yield to Muskellunge Lake	**437**
Total Watershed Load Leaving Muskellunge Lake	**206**
Total Watershed Phosphorus Yield to Muskellunge Lake (pounds/acre/year)	**0.19**
Total Watershed Load Leaving Muskellunge Lake (pounds/acre/year)	**0.089**

*USGS Study used eight shallow piezometers installed around Muskellunge Lake watershed to help define areas contributing ground water to the lake and determine the phosphorus concentrations in the ground water entering the lake. Most comprehensive evaluation of groundwater contributions.

Wisconsin River Watershed TMDL Soil & Water Assessment Tool (SWAT) Model

In 2019, the WDNR published a Total Maximum Daily Load Study for TP for the entire Wisconsin River Basin. A Soil and Water Assessment Tool (SWAT) model was selected as the primary model to simulate and calibrate watershed pollutant loads because it has a history of successful implementation throughout Wisconsin and has been used in several sediment and nutrient TMDLs (Cadmus, 2011). The Muskellunge Lake watershed was explicitly modeled within the SWAT model as Subbasin 127, which contains both Snipe Lake and Muskellunge Lake. Output from the SWAT model was calibrated to the pollutant loads at the Muskellunge Lake **outlet** (Personal Communication, Patrick Oldenburg, WDNR). Therefore, an additional 231 pounds of phosphorus was added to this yield to account for the portion of the phosphorus that is retained by Muskellunge Lake based on data collected during 2003 USGS study.

Table 15. Relative magnitude of external phosphorous sources – 2019 Wisconsin River SWAT model.

Phosphorus Source	Total Phosphorus Load (pounds/year)
Natural Background Land Uses Forests, Wetlands	84
Non-permitted Urban/Single Family Residences	69
Total Watershed Phosphorus Yield at Muskellunge Lake Outlet	153*
Total Watershed Phosphorus Yield to Muskellunge Lake (Corrected for Muskellunge Lake Retention)	**384**
Total Watershed Phosphorus Yield at Muskellunge Lake Outlet (pounds/acre/year)	0.065*
Total Watershed Phosphorus Yield Corrected for Muskellunge Lake Retention (pounds/acre/year)	**0.16**

* The SWAT results at the outlet were likely lower due to lower groundwater TP concentrations used in the SWAT model.

Model my Watershed Web Application

The Model my Watershed Web Application is a watershed-modeling web application developed by the Stroud Water Research Center that enables citizens and water resource professionals the ability to model stormwater runoff (water quantity) and water-quality impacts using professional-grade models without having to have the subject matter expertise needed to fully understand the intricacies of watershed modeling. The model uses real land use data from the National Land Cover Dataset and soil data from the NRCS Soils Survey Geographic database to compare how different land use practices, or implementation of conservation or development scenarios could modify runoff and water quality.

The web-application uses an enhanced version (GWLF-E) of the Generalized Watershed Loading Function (GWLF) model first developed by researchers at Cornell University (Haith and Shoemaker, 1987. The GWLF model provides the ability to conduct multi-year simulations of runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed based on the land use practices that are present in the watershed (e.g., agricultural, forested, and developed land) and estimates of soil nutrient concentrations based on USGS Geochemical and Mineralogical Maps for Soils of the Conterminous United States.

The application also has algorithms for calculating septic system loads – an important component of the overall nutrient load to Muskellunge Lake. It is a continuous simulation (multi-year) model that uses real-world daily precipitation data for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on the daily water balance and are accumulated to monthly values. Phosphorus yields were compared to export coefficients from a 2003 USGS study (Table 17) that evaluated the hydrology, nutrient concentrations, and nutrient yields from developed (lawns, rooftops, sidewalks, driveways) and undeveloped (woods) near shore areas of four lakes (Kentuck, Lower Ninemile, Butternut, and Anvil) in Vilas County (Gracyk et al., 2003). Output from the model was calibrated to pollutant loads at the Muskellunge Lake **outlet.** Yield estimates (Table 16) were corrected by adding the phosphorus load (231 pounds/year) that is retained by Muskellunge Lake.

Table 16. Relative magnitude of external phosphorous sources – Model my Watershed Web Application.

Phosphorus Source	Total Phosphorus Yield (pounds/acre/year)	Literature Value Total Phosphorus Yield (pounds/acre/year)	Total Phosphorus Load (pounds/year)
Low-Density Mixed	0.04	(0.025-1.75)	**0.51**
Low-Density Open Space	0.04	(0.025-0.20)	**6.66**
Farm Animals (Horses)	----	----	**0.3**
Open Land	0.01	0.003 (Woods)	**14.91**
Septic Systems	----	----	**58**
Stream Bank Erosion	----	----	**2.2**
Subsurface Flow	----	----	**35.8**
Wetlands	0.01	0.003 (Woods)	**8.51**
Wooded Lands	0.003	0.003 (Woods)	**3.6**
Total Watershed Phosphorus Yield at Muskellunge Lake Outlet			130.5*
Total Watershed Phosphorus Yield Corrected for Muskellunge Lake Retention			**361.5**
Total Watershed Phosphorus Yield at Muskellunge Lake Outlet			0.056*
Total Watershed Phosphorus Yield Corrected for Muskellunge Lake Retention (pounds/acre/year)			**0.15**

* Modeled TP loads were likely lower due to lower groundwater TP concentrations used in the model.

Table 17. Comparison of nutrient yields from previous studies throughout the country and from the 2003 USGS Study conducted on four lakes in northern Wisconsin. Source – Gracyk et al., 2003

Previous study	Land use	Total phosphorus yield
King and others, 2001	Stream draining turf	0.33
Kussow, W.R., University of Wisconsin—Department of Soil Sciences, written communication 2002	Turf	0.40
Dennis, 1986	Residential	1.75
Rechow and others, 1980	Residential	1.10
Panuska and Lillie, 1995	Urban	0.52
Thomann, 1987	Urban	1.0
Panuska, J.C., Wisconsin Department of Natural Resources, written commun., 2002	Rural residential	0.10
Panuska and Lillie, 1995	Woods	0.09
Thomann, 1987	Woods	0.40
Dennis, 1986	Woods	0.19
Panuska, J.C., Wisconsin Department of Natural Resources, written commun., 2002	Residential woods	0.08
Rechhow and others, 1980	Residential woods	0.20
David J. Graczyk and others, 2003	Lawn	0.025
David J. Graczyk and others, 2003	Woods	0.003

USGS Stream Gauge 05390685

USGS Stream Gauge 05390685 is located on Muskellunge Creek near the confluence with Little St. Germain Lake. The total contributing drainage area to the stream gauge is 4,806.4 acres. One hundred-sixty five water quality samples were analyzed for total phosphorus concentration between 1997 and 2016. Total phosphorus concentration data was paired with stream discharge data in 2012 and 2016 in an effort to calculate the total phosphorus load. Total phosphorus yields (pounds/acre) were then calculated by dividing the annual phosphorus load by the contributing drainage area.

Table 18. USGS Stream Gauge 05390685 on Muskellunge Creek Total Phosphorus Yield

Year	Phosphorus Load (pounds/year)
2012	736
2016	1,003
Contributing Drainage Area (Acres)	4,806
Total Watershed Phosphorus Yield (pounds/acre/year)	**2012 – 0.15 pounds/acre** **2016 – 0.21 pounds/acre**

10.3. Model Comparison

Monitoring data collected at USGS gauge 05390685 and monitoring data from the 2003 USGS study provide evidence to suggest that the Wisconsin River Watershed SWAT Model and the Model my Watershed Web Application under predicted contributions of phosphorus from groundwater. Furthermore, data collected during the 2003 USGS study suggests that Muskellunge Lake retains approximately 231 pounds of phosphorus per year or 53% of the TP yield. For comparison purposes, watershed phosphorus yield estimates from the SWAT and MMW Web Application were corrected by adding the amount of phosphorus that is retained by Muskellunge Lake (231 pounds/year). Accounting for phosphorus that is retained by Muskellunge Lake provided a high level of certainty that the average annual external total phosphorus load from both groundwater and surface water is between 0.15 and 0.19 pounds/acre/year, equivalent to 361.5 – 443.8 pounds/year (Table 19).

The Map my Watershed Web Application was useful in verifying phosphorus yields on a per acre basis from each land use (e.g., forest, low density residential, wetlands, etc.). Modeled phosphorus yields for each land use were closely aligned with data collected from the 2003 USGS Study (Gracyk et al., 2003). Phosphorus contributions from each of the 15 sub-watersheds were calculated by multiplying the total acreage of each land use present in a given subwatershed by the phosphorus yield for each land use.

Table 19. Total Phosphorus Loading Model by Model Comparison

Model	Total Watershed Phosphorus Yield at Muskellunge Lake Outlet (pounds/acre/year)	Corrected Total Watershed Yield to Muskellunge Lake (pounds/acre/year)	Total Phosphorus Load (pounds/year)
2003 USGS Study	0.089	0.19	443.8
Wisconsin River Watershed SWAT Model*	0.06	0.16	373.8
Model my Watershed Web Application*	0.05	0.15	361.5
USGS Stream Gauge 05390685	0.18	0.18	420.5

* These models likely under represented phosphorus contributions from groundwater resources.

Table 20. Relative phosphorus contribution by subwatershed based on land-use alone. Loads do not include contributions from septic systems, groundwater sources, or streambank erosion.

	Subwatershed														
Landuse	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Developed Open Space	0.2	3.1	6.4	5.1	3.1	3.6	11.3	93.6	4.0	8.9	2.9	2.2	3.8	0.9	0.0
Developed, Low Intensity-	0.2	0.0	0.4	1.3	0.0	0.0	0.0	11.0	0.0	2.0	0.0	0.0	0.4	0.0	0.0
Developed, Medium Intensity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deciduous Forest	0.2	1.1	0.7	0.0	7.3	4.7	10.9	239.7	0.0	3.8	0.2	2.7	0.2	0.9	0.0
Evergreen Forest	0.9	0.0	4.0	1.1	0.0	0.7	0.0	25.4	0.7	15.3	0.9	1.3	7.3	1.3	0.0
Mixed Forest	4.0	6.9	5.3	4.0	8.7	13.6	22.0	499.1	4.9	39.4	2.2	6.9	23.8	7.8	0.7
Shrub/Scrub	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grassland/Herbaceous-	0.0	0.9	0.0	0.7	0.9	0.0	0.0	87.8	0.0	10.2	0.0	0.0	2.9	0.0	0.0
Pasture/hay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	0.0	3.6	33.6	14.2	5.3	0.0	15.1	529.3	8.5	46.3	3.6	10.5	66.1	26.7	1.1
Emergent Herbaceous Wetlands-	0.0	0.0	0.2	0.2	0.0	0.0	0.0	33.8	0.2	4.4	0.0	0.0	0.0	0.0	0.2
Subbasin Acres	5.6	15.6	50.7	26.7	25.4	22.5	59.4	1,541.6	18.2	130.3	9.8	23.6	104.5	37.6	2.0
% Natural (Undeveloped)	92%	80%	86%	76%	88%	84%	81%	93%	78%	92%	70%	91%	96%	98%	100%
TP Load - Pounds/Year	0.03	0.19	0.64	0.42	0.23	0.20	0.70	16.54	0.26	1.22	0.16	0.23	0.95	0.33	0.02
TP Yield - Pounds/Acre/Year	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01

11. INTERNAL NUTRIENT SOURCES

Internal phosphorus loading from lakes has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year.

11.1. Aquatic Plants

Aquatic plants can contribute to the internal phosphorus load of lakes in two ways. First, the physical breakdown of plant biomass can potentially result in a large release of phosphorus into the water. Second, the decay of plant materials can also strip oxygen from the water column and cause a release of phosphorus from the sediments. As plant decay rates rise with an increase in the eutrophic nature (or fertility) of a lake, the bacteria involved in the decay of plant matter can also consume oxygen in the lake. Plant decay under ice cover is one of the mechanisms by which oxygen can become depleted in the winter and cause a fish kill.

11.2. Sediment Internal Loading

Internal loading from bottom sediments can occur via:

1. *Chemical release from the sediments:* Caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (greater than 9). If a lake's hypolimnion (bottom area) remains anoxic for a portion of the growing season, the P released due to anoxia will be mixed throughout the water column when the lake loses its stratification at the time of fall mixing. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently.
2. *Physical disturbance of the sediments*: Caused by bottom-feeding fish behaviors (such as carp and bullhead), motorized boat activity, and wind-driven mixing. This is more common in shallow lakes than in deeper lakes.

Internal loading due to the anoxic release from the sediments of each lake was estimated based on the expected release rate of P from the lakebed sediment, the lake anoxic factor (AF), and the lake area. Internal loading due to physical disturbance is difficult to reliably estimate and was therefore not included in the lake P analyses.

Internal loading from sediment can be estimated using measured anoxic sediment P release rates with the method of Nürnberg (2005), which entails calculating an anoxic factor for each lake from lake morphometry and dissolved oxygen data. The average AF calculated for Muskellunge Lake was 53 days.

Estimates of sediment phosphorus release rates for Muskellunge Lake (8.8 mg/m^2-day) were based on sediment core data collected on six Wisconsin Lakes including Little St. Germain Lake (Bortleson, 1974). Internal load is estimated as the product of (anoxic factor) x (sediment phosphorus release rate) x (lake area that goes anoxic). For Muskellunge Lake that equates to an internal load estimate of (53) x (8.8 mg/m^2-day) x (101 Acres or 408,702m^2) = 420 pounds. BATHTUB modeling results presented in Section 12 suggest this is an over prediction of internal nutrient loading.

12. PHOSPHORUS BUDGET ANALYSIS

12.1. BATHTUB - Lake Response Model

The United States Army Corps of Engineers (USACE) BATHTUB lake model was used to predict 1) the existing total phosphorus budget and 2) the required reduction needed to meet the Shallow Lake Lowland Drainage **40 ug/L** Recreational threshold. Model coefficients were developed and calibrated using data collected during the growing season (June-September) from 2011-2020 and used to predict lake responses to observed total phosphorus loading from the 2003 USGS study.

A publicly available model, BATHTUB was developed by William W. Walker for the U.S. ACOE (Walker 1999). It has been used successfully in many lake studies throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed P loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance P model that accounts for water and P inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and groundwater; and outputs through the lake outlet, water loss via evaporation, and P sedimentation and retention in the lake sediments.

Model Equations

BATHTUB allows a choice among several different P sedimentation models. The Canfield-Bachmann Lake P sedimentation model (Canfield and Bachmann 1981) best represents the lake water quality response of most Upper Midwest (Minnesota, Wisconsin) lakes, and is the model used by the majority of lake TMDL studies in Minnesota and Wisconsin. In order to perform a uniform analysis, Canfield-Bachmann Lakes was selected as the standard equation for the study. However, the Canfield-Bachmann Lakes P sedimentation model tends to under-predict the amount of internal loading in shallow, frequently mixing lakes. Therefore, an explicit internal load is added to shallow lake models to improve the lake water quality response of the Canfield-Bachmann Lakes P sedimentation model.

Model Calibration

The models were calibrated to existing water quality data collected during the months of June - September from 2011-2020, and then were used to determine the P loading capacity (TMDL) of each lake. The Nurnberg internal loading estimates and the excess internal load estimates used to calibrate the BATHTUB models were ***higher*** than the BATHTUB excess internal load estimate, potentially because the sediment phosphorus release rate was based on data collected on Little St. Germain Lake. EOR recommends collecting lake sediment samples on Muskellunge Lake and testing for concentration of TP and bicarbonate dithionite extractable phosphorus (BD-P), which analyzes iron-bound P. Phosphorus release rates can then be calculated using statistical regression equations, developed using measured release rates and sediment P concentrations from a large set of North American lakes (Nürnberg 1988; Nürnberg 1996). This information would be helpful to 1) validate internal loading estimates and 2) identify if certain areas of the lake contain relatively higher or lower phosphorus concentrations.

Determination of Lake Loading Capacity

Using the calibrated existing conditions model as a starting point, internal loads were reduced until the model indicated that the TP state standard for shallow, lowland drainage lakes (40 ug/L) was met, to the nearest tenth of a whole number. External watershed loading was not adjusted because observed contributions from external sources are representative of typical phosphorus concentrations observed from forested watersheds in Vilas County. In terms of a cost-benefit ratio, reducing internal loading represents the most cost effective solution to achieving the needed phosphorus reductions. A portion of the necessary Total Phosphorus reductions can also be achieved via septic system improvements. Once the TP goals are met, Chl-*a* and Secchi transparency standards will also likely be met. With this process, three BATHTUB models were developed (Table 21).

1) **Existing Conditions Model**: Model is based on an internal loading rate of 420.3 lbs/year based on the Nurnberg equation.
2) **Calibrated Model**: Model calibrated to the average observed growing season Total Phosphorus concentration (41 ug/L) from 2011-2020. Requires a reduction of internal loading from 124.1 pounds/year to 55.7 pounds/year. Suggests that internal loading is less than what the Nurnberg equation predicted which means that either in-lake sediment concentrations are lower or the number of anoxic days is likely less than 53.
3) **Goal Model**: Model that is consistent with the shallow, lowland drainage standard (40 ug/L). Requires an internal load reduction from 124.1 pounds/year to 88.6 pounds/year (36 pounds/year).

Table 21. Muskellunge Lake BATHTUB Analysis

Muskellunge Lake Predicted TP (ug/L)	56	41	40	Required Reduction	
Phosphorus Loads (lb/yr)	**Existing**	**Calibrated**	**Goal**	**%**	**Pound**
Southeast Tributary	65.3	65.3	65.3	0%	0
Remaining Nearshore Areas	*35.6*	*35.6*	35.6	0%	0
Septic	*69.4*	*69.4*	69.4	0%	0
Total Nearshore	105.0	105.0	105.0	0%	0
Groundwater	253.5	253.5	253.5	0%	0
Atmospheric Deposition	13.2	13.2	13.2	0%	0
Excess Internal Load	420.3	124.1	88.6	35%	148
Total	**857.3**	**561.1**	**525.7**	**17%**	**148**

13. IMPLEMENTATION PLAN

The implementation plan presented below includes the prioritized protection and restoration strategies developed through the collaborative efforts of the Muskellunge Lake Association, Wisconsin Department of Natural Resources, and engineers, ecologists, and planners from Emmons and Olivier Resources. The plan summarizes priority areas for targeting actions to improve water quality, control existing invasive species (EWM) populations, prevent further invasive species introductions, and improve the overall ecology of the lake including the fishery.

Because many of the strategies outlined in this section rely on voluntary implementation by landowners, lake users, and residents of the watershed, it is imperative to create social capital (trust, networks and positive relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective ongoing civic engagement is a part of the overall plan for moving forward.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts, the latest science regarding aquatic plant management and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation and course correction.

13.1. Management Goal 1: Reduce the abundance of EWM in Muskellunge Lake and prevent the introduction of new AIS through CBCW inspections.

13.1.1. Description:

The 2016 arrival and subsequent rapid expansion of EWM has negatively affected the native plant community, altered the shallow lake ecology, and decreased the recreational usability of Muskellunge Lake in less than 4 years. The innovative solution proposed for Muskellunge Lake builds upon successes from multiple case studies including results from an integrated, pest-management treatment program on Big Marine Lake (Washington County, Minnesota). The Big Marine Lake Association's innovative approach to managing EWM provides a refreshing example of pro-active EWM management that has resulted in the successful reduction of EWM coverage from 38.6 acres in 2014 to 3.8 acres in 2020 (pre-treatment).

EWM management efforts on Muskellunge Lake will reduce the total acreage of Tier 1 and Tier 2 EWM growth by 50% in 2021 (e.g. reduction of 10 acres of Tier 1 growth to 5 acres) using an integrated pest management strategy that combines Clean Boats Clean Waters (CBCW) prevention, volunteer surveillance, water quality monitoring, and herbicide concentration monitoring. Supplementary data collected will include plant monitoring of the wild rice beds and/or herbicide concentration testing on Muskellunge Creek to provide documentation as to potential unintended negative impacts. EWM management efforts on Muskellunge Lake will further reduce the total acreage of Tier 1 and Tier 2 EWM growth by an **additional** 50% in 2022 (e.g., 5 acres of Tier 1 growth to 2.5 acres). Shallow lakes dominated by submergent aquatic vegetation are more capable of assimilating large amounts of phosphorus. Because a healthy native aquatic plant community is so critical to the ecology of Muskellunge Lake, additional goals of the recommended EWM management approach include:

1) Maintain 70% or greater frequency of occurrence of aquatic vegetation in the areas of lake that are less than 10 feet deep.
2) Post-treatment surveys document no negative changes to aquatic plant diversity following EWM management. Herbicide use will be terminated if negative changes are observed.

The MLA will work cooperatively with the DNR using an adaptive management approach that may include the use of herbicides. Given the risk behind managing EWM with herbicides, herbicides will primarily be used to control delineated areas greater than 1-acre in size. Smaller polygons, less than 1-acre in size may not be suitable for chemical spot treatment due to a lack of efficacy and/or potential impacts to natives in the area weighing out the potential reduction of EWM.

Between 2006 and 2018, 2,419 watercraft inspections were completed on Muskellunge Lake over the course of 2,991 hours. This equates to an average of 0.8 watercraft inspected/hour. Eighty-five percent of boaters reported visiting a lake in Oneida or Vilas County prior to visiting Muskellunge Lake, suggesting that local waterbodies are the most likely vector for new invasive species. The MLA will continue to work with Vilas and Oneida County to fund Clean Boat Clean Waters Efforts at the Muskellunge Lake boat landing as well as other area lakes. Specific implementation strategies, interim milestones, suggested 1-10-year goals, and personnel units with primary responsibility are shown in Table 22.

Table 22. Management Goal 1 Implementation Strategies

Specific Implementation strategy	Recommended strategy – Current adoption	Interim 1-3 year Milestone	Suggested 3-10 year Goal(s)	Governmental/ Private Sector Units with Primary Responsibility
1. Integrated pest management for EWM using ProcellaCOR to control Tier 1, Tier 2 EWM stands **2.** Conduct inspections to identify areas where Tier 3 EWM stands are expanding. **3.** Continue volunteer and paid CBCW watercraft inspections **4.** Monitor downstream water resources **5.** Professional and volunteer aquatic plant monitoring will continue/expand as described under Management Goal 2	**1.** Work with WDNR to secure AIS Control Grant **2.** Work with WDNR to secure AIS Control Grant **3.** Secure grant funding to increase the number of CBCW watercraft inspections **4.** Trained MLA volunteers collect water quality samples to evaluate/screen for impacts to downstream resources. Professional monitoring of the health of wild rice beds in Muskellunge Creek. **5.** Continue to work with DNR to refine professional and volunteer aquatic plant monitoring protocols to ensure native plants are protected and EWM management is achieving desired results.	**1.** Reduce Tier 1/Tier 2 Eurasian Watermilfoil (EWM) by 50% annually. **2.** No increase in Tier 3 Eurasian Watermilfoil (EWM) growth by the end of 2022. **3.** Secure funding to continue Clean Boats Clean Waters watercraft inspections. Supplement paid inspections with volunteer watercraft inspections conducted by trained members of the MLA. **4.** No negative impacts to downstream water resources. **5.** 1) Maintain 70% or greater frequency of occurrence of vegetation. 2) Post-treatment surveys confirm EWM management has not negatively affected aquatic plant diversity.	**1.** Transition away from herbicide control measures by 2024, move towards biological or physical control measures **2.** Work with Cathy Higley/Upper and Lower Buckatabon lakes to evaluate use of milfoil weevils in Muskellunge Lake **3.** No new invasive species in Muskellunge Lake **4.** No negative impacts to downstream water resources. **5.** - Maintain 70% or greater frequency of occurrence of vegetation. - EWM management actions do not negatively affect species diversity.	- DNR - MLA - Private Consultant/ Contactor

13.2. Management Goal 2: Conduct professional and volunteer aquatic plant monitoring to ensure AIS management activities maintain or increase native aquatic plants.

13.2.1. Description:

Members of the MLA have attended AIS training and aquatic plant identification and weevil identification workshops hosted by Vilas County. Since receiving this training, members of the Muskellunge Lake Association have conducted bi-weekly focused meander surveys of the Muskellunge Lake littoral zone taking geo-referenced photos and recording GPS coordinates of all locations in which EWM was identified. MLA members will continue to conduct bi-weekly inspections from May 1 – August 30. Trained MLA members will recruit and train new volunteers.

Volunteer monitoring efforts will be supplemented with professionally led comprehensive point-intercept studies conducted every two years and sub-point intercept studies conducted pre and post-treatment annually. Results from all monitoring efforts will be published to the Muskellunge Lake ArcGIS Online map and shared with all project partners including the DNR and Vilas County to monitor for changes in species diversity, quality, or Frequency of Occurrence of native aquatic plant species found in Muskellunge Lake.

Professional and volunteer monitoring will also be conducted to evaluate/screen for impacts to downstream resources including wild rice beds in Muskellunge Creek. Supplementary data collected will include plant monitoring of the wild rice beds and/or herbicide concentration testing on Muskellunge Creek to provide documentation as to potential unintended negative impacts. Specific implementation strategies, interim milestones, suggested 1-10-year goals, and personnel units with primary responsibility are shown in Table 23.

Table 23. Management Goal 2 Implementation Strategies

Specific Implementation strategy	Recommended strategy – Current adoption	Interim 1-3 year Milestone	Suggested 3-10 year Goal(s)	Governmental/ Private Sector Units with Primary Responsibility
1. Volunteer-led focused meander surveys every two weeks from May 1-August 30 annually. **2.** Supplemental professionally led comprehensive point-intercept studies every 2 years with sub-point intercept studies conducted pre and post treatment annually. **3.** Maintain and update the Muskellunge Lake ArcGIS Online Map to track the spread of EWM in Muskellunge Lake as well as the distribution and abundance of native species.	**1.** Trained MLA members will conduct volunteer surveys and recruit new volunteers to help with future surveys.	**1.** Results from volunteer and professional monitoring demonstrates no negative change in species diversity, quality, or Frequency of Occurrence of native aquatic plant species found in Muskellunge Lake or downstream in Muskellunge Creek.	**1.** Results from volunteer and professional monitoring demonstrates increase in species diversity, quality, and/or relative frequency of native aquatic plant species found in Muskellunge Lake or downstream in Muskellunge Creek.	- DNR - MLA - Private Consultant/ Contactor

13.3. Management Goal 3: Expand Water Quality Monitoring Efforts to Identify Strategies That Improve Current Water Quality Conditions

13.3.1. Description:

The collection of current land and water data is an important component to both assess progress, and inform management and decision-making. Furthermore, early detection of negative trends is vital to preventing further degradation of the water resource. For improved in-lake and watershed management to work in Muskellunge Lake, there needs to be reliable data that can be used to generate information. For Muskellunge Lake, the primary focus of an expanded water quality effort includes

1. Expansion of existing volunteer-led water quality data collection efforts to collect additional water quality samples from April-November to better characterize seasonal trends in water quality.
2. As hypolimnetic dissolved oxygen becomes depleted, the bond between iron oxyhydroxides (Fe-OOH) and phosphate becomes broken, resulting in the diffusion of Fe2+ and PO4 3- into the sediment porewater and eventually into the anoxic hypolimnion.
    a. The collection of bi-weekly dissolved oxygen and temperature profile data throughout the year to better characterize the frequency of stratification and water column mixing events.
    b. The collection of phosphorus and iron data during periods of stratification to better characterize the magnitude of internal nutrient loading.

It is the intent of the implementing organizations in the Muskellunge Lake watershed to identify the most cost-efficient strategies to reduce in-lake phosphorus concentration. Reductions of in-lake phosphorus concentrations will ultimately lead to the delisting of Muskellunge Lake from the impaired waters list as well as contribute to the reduction in phosphorus contributed to Little St. Germain Lake and the Wisconsin River. The response of the lake should be monitored and subsequently evaluated as management practices are implemented. Data will be evaluated and decisions will be made as to how to proceed for the next five years. The management approach to achieving the goals should be adapted as new monitoring data is collected and evaluated (Figure 49).

Continued monitoring and “course corrections” responding to water quality monitoring results are the most appropriate strategy for attaining water quality goals. Management activities will be changed or refined to efficiently meet the goal of delisting Muskellunge Lake from the impaired waters list. Factors that may mean slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., internal loading due to polymictic nature, invasive species) and unfavorable climatic factors. Conversely, there may be faster progress, especially where high-impact fixes (e.g., alum treatment, hypolimnetic aeration) are slated to occur. Specific implementation strategies, interim milestones, suggested 1-10-year goals, and personnel units with primary responsibility are shown in Table 24.

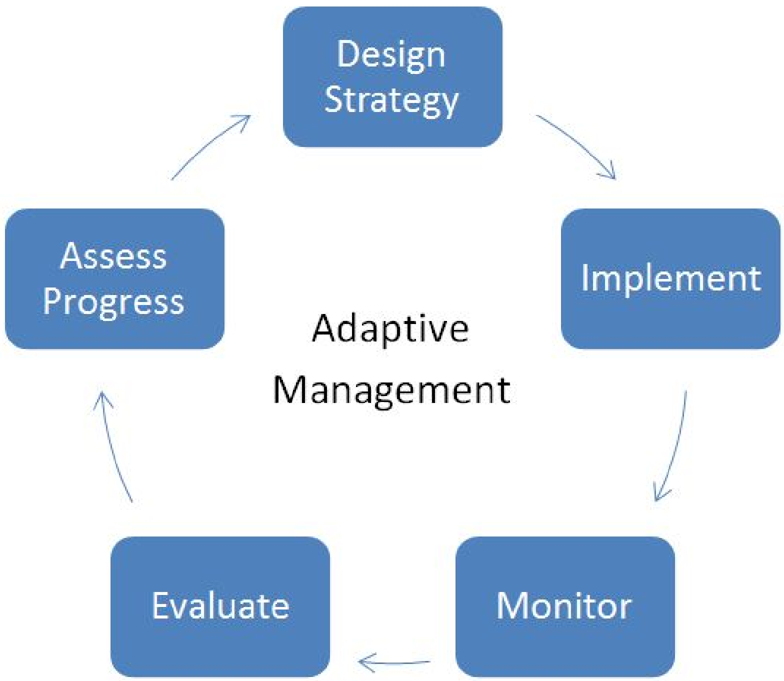


Figure 49. Adaptive Management

Table 24. Management Goal 3 Implementation Strategies

Specific Implementation strategy	Recommended strategy – Current adoption	Interim 1-3 year Milestone	Suggested 3-10 year Goal(s)	Governmental/ Private Sector Units with Primary Responsibility
1. Members of the MLA have been trained on the collection of water quality data.	**1.** Expansion of existing volunteer-led water quality data collection efforts to collect in-lake and tributary samples from ice-off to ice on (April-November) will help to better characterize trends in water quality. **2.** Dissolved oxygen and temperature profile data collected throughout the year	**1**. Data collected will help to identify seasonal in-lake water quality trends and validate external (watershed) contributions of phosphorus. **2.** Dissolved oxygen monitoring data used to better evaluate magnitude of phosphorus contribution from internal sources	**1.** Collection of water quality data leads to implementation of best management practices that reduces external loads. **2.** Dissolved oxygen-monitoring leads to implementation of alum treatment, hypolimnion aeration, or other in-lake best management practice that reduces internal nutrient load in Muskellunge Lake.	- DNR - MLA - Private Consultant/ Contactor

13.4. Management Goal 4: Improve Fishery

13.4.1. Description:

Top- down control refers to the stocking of piscivorous (fish that eat other fish) fish, such as bass, muskellunge, walleye or northern pike to control (reduce) the abundance of smaller, planktivorous fish such as bluegill. The reduction of bluegill or other planktivorous fish species in turn leads to an abundance of zooplankton and a decline in phytoplankton (algae) abundance and subsequently increased water clarity. The primary gamefish species that could potentially provide top-down control of bluegill in Muskellunge Lake include musky, northern pike, largemouth bass, and walleye. Specific implementation strategies, interim milestones, suggested 1-10-year goals, and personnel units with primary responsibility are shown in Table 25.

Table 25. Management Goal 4 Implementation Strategies

Specific Implementation strategy(s)	Recommended strategy – Current adoption	Interim 1-3 year Milestone	Suggested 3-10 year Goal(s)	Governmental/ Private Sector Units with Primary Responsibility
1. Increase stocking of walleye and/or reduce angler harvest until adult walleye abundance reaches three adult walleye per acre. **2.** Implement a slot limit designed to protect northern pike between 24 and 30 inches in an effort to increase the average size of northern pike. Larger northern pike are more likely to be capable of consuming deeper bodied fish species like bluegill. **3.** Muskellunge Lake is a Class 2, Category 3 waterbody meaning that stocking is required to maintain the fishery. Continue stocking muskellunge at a rate of 1-2 Muskellunge/acre. **4.** Conduct a comprehensive fisheries assessment to evaluate population size and distribution of all fish species including bluegill, crappie, perch, and aforementioned gamefish species.	**1.** Adult Walleye Abundance – 1.1/Acre **2.** 6% of Northern Pike larger than 26 inches **3.** Anecdotal evidence collected by anglers suggests Musky populations are lower than historically **4.** Comprehensive fisheries survey not available.	**1.** Adult Walleye Abundance =2/Acre **2.** 0.4 northern pike >24 inches per acre. This equates to a lake-wide population of approximately 110 northern pike >24 inches. **3.** Maintain a minimum catch rate of one muskellunge per 25 hours of muskellunge angling through continued stocking efforts. **4.** Comprehensive fishery survey every 3-5 years to evaluate the population size and distribution of all fish species.	**1.** Adult Walleye Abundance =3/Acre **2.** 0.8 northern pike >24 inches per acre. This equates to a lake-wide population of approximately 220 northern pike >24 inches. **3.** Maintain a minimum catch rate of one muskellunge per 25 hours of muskellunge angling through continued stocking efforts. **4.** Results from comprehensive fishery survey demonstrate an improved fishery with piscivorous species providing adequate top-down control over omnivorous species, especially bluegill.	- DNR - MLA

13.5. Management Goal 5: Protect and Restore Natural Shoreline Habitats

A planning level assessment of the natural shoreline habitats present at Muskellunge Lake was discussed in Section 8 of the document. Based on the shoreline and coarse woody habitat surveys conducted by DNR staff in 2017, properties that could improve lake quality by improving and/or restoring shoreline habitats are shown by subwatershed in Appendix D.

Highly developed lots with greater areas of impervious areas such as hardscaped walkways and docks, as well as manicured lawns and riprap adjacent to the lake provide little habitat benefit to aquatic organisms and fisheries. They also allow nutrient laden rainfall runoff to enter the lake, thereby degrading water quality by exacerbating algal blooms. Lakeshore homes with private septic systems located immediately adjacent to the lake can represent a direct source of nutrients to the lake. Permanent, lakeshore residences with failing septic systems contribute approximately 7.6 pounds per year Tetra Tech (2002, 2009). However, Vilas County requires every septic tank associated with a permanent residence to be pumped every 2-3 years to help reduce phosphorous loading to the septic system drain field. Furthermore, of the 111 residences on Muskellunge Lake, only 24 are full-time residences. The remaining 87 residences are seasonal properties

To improve, restore, and expand coarse woody habitat shoreline habitat, landowners can coordinate with WDNR and use the information from Wisconsin's Healthy Lakes & Rivers Implementation Plan which provides information on simple and inexpensive best practices that landowners with shoreline properties can implement to improve habitat. Some of the best practices available to shoreline landowners include fish sticks, native planting, installing of runoff diversions, rock infiltration practices and rain garden installation. Funding is available for some of these shoreline improvements and are discussed in the Wisconsin's Healthy Lakes & Rivers Implementation Plan (https://healthylakeswi.com/wp-content/blogs.dir/16/files/2016/03/WI_Healthy_Lakes_Implementation_Plan.pdf).

The program is intended to provide grant funding for simpler projects. Projects that are more advanced may require engineering design and alternative funding sources may be available elsewhere, perhaps through Vilas County. Highlights of the programs funding opportunities can be seen below:

Healthy Lakes & River grant funding highlights:

- Competitive grant funding is available for eligible grantees that apply on behalf of property owners with the possibility to include multiple lakes and rivers. State funding for each best practice is capped at $1000, and the total grant award is capped at $25,000. The grant application includes an option for applicants to add 10% of the state share of the best practice costs for technical assistance, project management, and/or education and communication costs.
- Grantees must match 25% of the total grant award amount. This 25% match can be in the form of volunteer labor, equipment, and cash from participating property owners or other partners. The grantee may determine individual property owner cost share rates, provided the state's share of the individual best practice caps ($1000) and state's contribution to the project (75% of total costs) are not exceeded.
- Grantees are allowed the standard two-year grant timeline to complete projects; this encourages shovel-ready projects. Grantees can use small-scale lake planning or river planning grants to develop projects, including recruiting property owners and completing initial site visits.
- Property owners may sign a participation pledge to document strong interest in completing the project.
- Application and reporting forms and process are standardized.
- Grantees will use a standard deliverable checklist, including a signed landowner contract with operation and maintenance information and 10-year requirement to leave practices in place. Also:
  - Native plantings must remain in place according to local shoreland zoning standards.
  - Fish Sticks projects require a 350 ft^2 native planting at the lakeshore edge or commitment not to mow, if the property does not comply with the shoreland vegetation protection area (i.e., buffer) standard described in the local shoreland zoning ordinance.
- The Healthy Lakes & Rivers Team and/or local DNR staff will complete site visits on at least 10% of funded projects annually, and there may also be a future self-reporting process to verify projects, collect program feedback, and celebrate success.

Figure 50 – Grant Funding Highlights from the WI Healthy Lakes & Rivers Action Plan

13.6. Management Goal 6: Maintain 75% or Higher Protected Land Uses

13.6.1. Description:

Lake water quality depends largely on land use in their watersheds. Agricultural and urban (residential) runoff contains significantly more nutrients such as phosphorus and nitrogen than undisturbed forests, grasslands, and wetlands. Lake watersheds with undisturbed lands lie primarily in the forested ecoregions and generally provide good water quality. Fisheries research has shown that healthy watersheds with intact forests are fundamental to good fish habitat. Modeling of over 1,300 lakes by the Minnesota DNR Fisheries Research Unit (Cross and Jacobsen 2013 – Lake and Reservoir Management 29: 1-12) has revealed that phosphorus concentrations in lakes are directly related to land use disturbance in the watershed. Phosphorus concentrations start to become elevated when land use disturbance reaches 25% of the lake's watershed and are greatly elevated when land use disturbances exceed 60%. If land in the watershed is less than 25% disturbed and the remaining 75% is permanently protected forest, the lakes and streams in the watershed will have a high probability of sustaining a healthy ecosystem. Using land use disturbance and protection status allows for the categorization of lakes into a protection vs. restoration framework:

Vigilance: Lakes with watershed disturbance less the 25% and protection greater than 75% can be considered sufficiently protected. (Vigilance status is largely due to keeping public lands forested)

Protection: Lakes with watershed disturbances less than 25%, but levels of protection less than 75% are excellent candidates for protection efforts.

Full Restoration: Lakes with watersheds that have moderate levels of disturbance (25%-60%) have realistic chances for full restoration of water quality to natural levels.

Partial Restoration: Restoration of lake with intensive urban and agricultural watersheds (>60% disturbance) to natural levels may not be realistic. The suggested approach for these lakes is partial restoration of water quality that restores some degree of ecological integrity.

Figures 41-55 indicate that all subwatersheds in the Muskellunge Lake watershed are currently in protection mode, meaning there is the opportunity to reach or exceed 75% protection threshold to make this watershed sufficiently protected. The Wisconsin Department of Natural Resources' (WDNR's) Wisconsin Forest Landowner Grant Program (WFLGP) reimburses qualified landowners for up to 50 percent of the cost of eligible practices, such as writing a forest stewardship plan, planting trees and regenerating forest, controlling invasive species, and protecting soil and water quality. Landowners must own between 10 and 500 continuous acres of non-industrial, private forestland. Public access to land enrolled in WFLGP **is not** required under this cost-share program. Specific implementation strategies, interim milestones, suggested 1-10-year goals, and personnel units with primary responsibility are shown in Table 26.

Table 26. Management Goal 6 Implementation Strategies

Specific Implementation strategy(s)	Recommended strategy – Current adoption	Interim 1-3 year Milestone	Suggested 3-10 year Goal(s)	Governmental/ Private Sector Units with Primary Responsibility
1. Enroll >3 landowners in the WFLGP. **2.** Keep public lands forested.	**1.** Not Known **2.** Public lands are sufficiently forested	**1.** > 1 landowners enrolled in WFLGP **2.** No loss of publicly owned lands	**1.** > 3 landowners enrolled in WFLGP **2.** No loss of publicly owned lands	- DNR - MLA

14. APPENDIX A: REFERENCES

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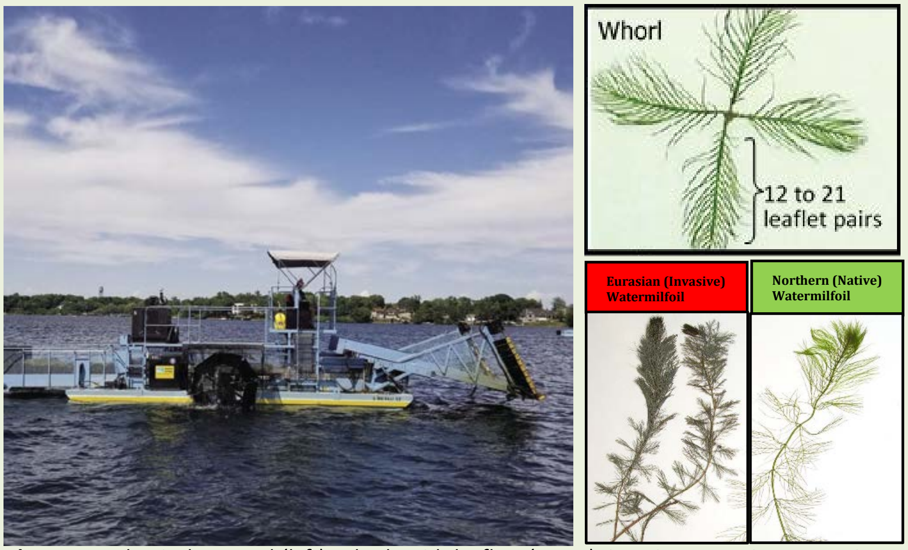
15. APPENDIX B: EURASIAN WATERMILFOIL (EWM) MANAGEMENT



Photos. *Mechanical removal (left), whorls with leaflets (upper), invasive vs. native comparison (lower)*

Characteristics:

- 3-5 feathery leaves arranged in whorls
- Each leaf has 12-21 leaflets.
- Stems are long, stringy, and limp when out of water
- Flowers: small, reddish, above water surface by mid-summer

Can be mistaken for

Northern watermilfoil, coontail

History:

Eurasian watermilfoil (EWM) was first discovered in Muskellunge Lake in 2016. EWM is now widespread throughout Muskellunge Lake. In response, the MLA has worked with EOR since 2017 to track the spread of EWM in Muskellunge Lake through our interactive Muskellunge Lake ArcGIS Online Website. The MLA is working collaboratively with the WDNR and others on pioneering efforts to reduce the abundance of EWM on Muskellunge Lake.

Life Cycle:

Eurasian watermilfoil is capable of reproducing from both fragments and seeds. EWM is also capable of hybridizing with native northern watermilfoil. Although reproduction from seeds was thought to be uncommon, the presence of hybrids suggests that sexual reproduction does occur. EWM naturally auto-fragments in mid to late summer, allowing small branches of the plant to break off and form roots at new locations. Any fragment of the plant stem that includes a whorl of leaves is capable of producing a new viable plant.

Impacts:

- Establishes dense mats at surface of water
- Outcompetes natives & can lower diversity in the lake in the short term. Long-term impacts are variable.
- Interferes with recreation, inhibits water flow, impedes navigation (MAISRC, 2018)

Regulations:

EWM is classified as a "prohibited invasive species" in the state of Wisconsin. It is unlawful to possess, import, purchase, transport, or introduce except under a permit for disposal, control, research, or education.

Control:

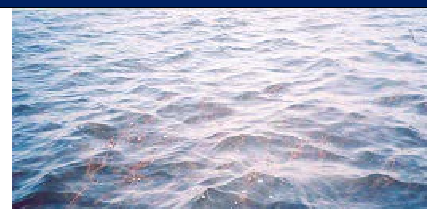
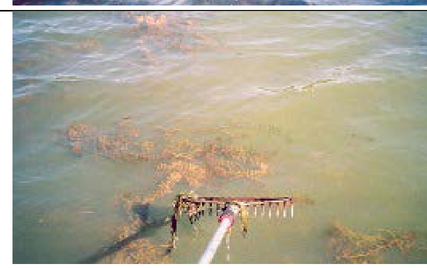
There are three methods of control:

1) Mechanical Control
   –Mechanical harvesting, hand pulling, suction dredging, DASH
2) Herbicide control
   – Systemic: Examples include 2,4-D, ProcellaCOR, Sonar
– Contact: Diquat, Endothall
3) Biological Control
   –Milfoil Weevil (*Euhrychiopsis lecontei*)

Distribution:

Data within the Muskellunge Lake ArcGIS Online Website represents the collective mapping efforts from surveys conducted by the Muskellunge Lake Association and Emmons and Olivier Resources. Where possible, the distribution and density for each sampling point containing EWM was ranked on a scale from 0-3, where a density ranking of 1 indicates only a few individual plants at a sample site while a ranking of 3 indicates an abundance of plants. Results from survey efforts conducted in 2020 found that the EWM growth was mostly light to moderate and often found to be intermixed with native species. A comparison of EWM growth conditions is shown in Table 27. The portions of the lake in which EWM was found at a ranking of 2 or 3 represent the priority for future management efforts.

Table 27. Eurasian Watermilfoil Growth Characteristics:

EWM Presence (Growth Condition)	Description	Rake Density Equivalent	Stem Density/ Biomass	Example Image
Rare (Light)	Plants rarely reach the surface. Navigation and recreational activities generally are not hindered.	1, 2	**Stem density:** 0 - 40 stems/m2 **Biomass:** 0-51g-dry wt/m2	
Common (Moderate)	Broken surface canopy conditions. However, stems are usually unbranched. Navigation and recreational activities may be hindered. **Lake users may opt for control.**	2, 3	**Stem density:** 35 - 100 stems/m2 **Biomass:** 30-90g-dry wt/m2	
Abundant (Heavy)	Solid or near solid surface canopy conditions. Stems typically are branched near the surface. **Control is necessary for navigation and/or recreation.**	3	**Stem density:** 250 + stems/m2 **Biomass:** >285g-dry wt/m2	

15.1.1. Recommended Management Procedures

Table 28 identifies initial treatment costs for Muskellunge Lake and remaining EWM acreage assuming a 50% reduction in the distribution of EWM within each treatment area in 2021. Future updates, including the addition or removal of treatment polygons based on continued AIS monitoring will provide a means of documenting progress towards stated goals in an effort to identify the EWM management strategy(s) that provide the best return (reduction in EWM) on investment (dollars spent).

Table 28. Recommended Management Targets and Procedures

Treatment Area	Existing EWM Coverage (Acres)	Treatment Method	Cost/Acre ($)	Year 1 Treatment Costs	1-Year Remaining EWM Acres (50 % Reduction)
1	1.12	ProcellaCOR	$2,200	$2,464	0.56
2	1.30	ProcellaCOR	$2,200	$2,860	0.65
3	5.52	Monitor*	-----	-----	5.52
4	1.84	ProcellaCOR	$2,200	$4,048	0.92
5	1.22	Monitor*	-----	-----	1.22
6	3.12	ProcellaCOR	$2,200	$6,864	1.56
7	6.67	Monitor*	-----	-----	6.67
8	1.93	Monitor*	-----	-----	1.93
9	1.04	ProcellaCOR	$2,200	$2,288	0.52
10	0.19	Monitor*	-----	-----	0.19
11	0.90	ProcellaCOR	$750	$675	0.45
12	1.77	Monitor*	-----	-----	1.77
Total	**26.62**	**------**	**------**	**$19,199**	**22.0**

* If areas identified as Tier 3 in 2020 are identified as Tier 1 or Tier 2 areas in 2021, they will be recommended for ProcellaCOR treatment.

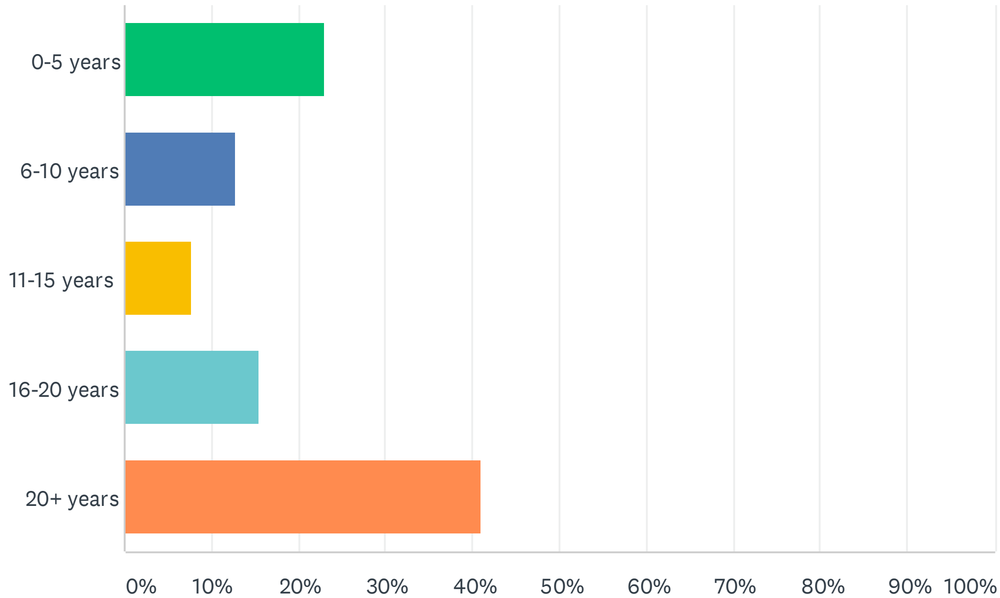
Goal Statement

Having quantifiable goals is important to maintain accountability and to assess the effectiveness of implemented treatment options. It is important to recognize that progress towards improving the quality of an aquatic plant community through the reduction of invasive species like EWM is often slow. At the same time, the MLA is not interested in "controlling" EWM or operating in a reactionary nature to periodic increases in EWM abundance. Rather, the techniques recommended represent a strategy to significantly reduce the abundance of EWM by 50% in year 1 with a long-term goal of reducing EWM abundance below the **5% EWM littoral occurrence threshold.** Once achieved, the primary control measure would move away from herbicides and towards a long-term solution that relies on biological and/or physical controls. The MLA will continuously update management strategies by incorporating lessons learned from area lakes including the milfoil weevil work being performed on Upper and Lower Buckatabon Lakes. As part of documenting progress, the MLA will work with the DNR and its consultant to continuously monitor and graph the total surface area of EWM present in Muskellunge Lake.

16. APPENDIX C: STAKEHOLDER SURVEY RESULTS

Q1 How many years have you owned property on Muskellunge Lake?

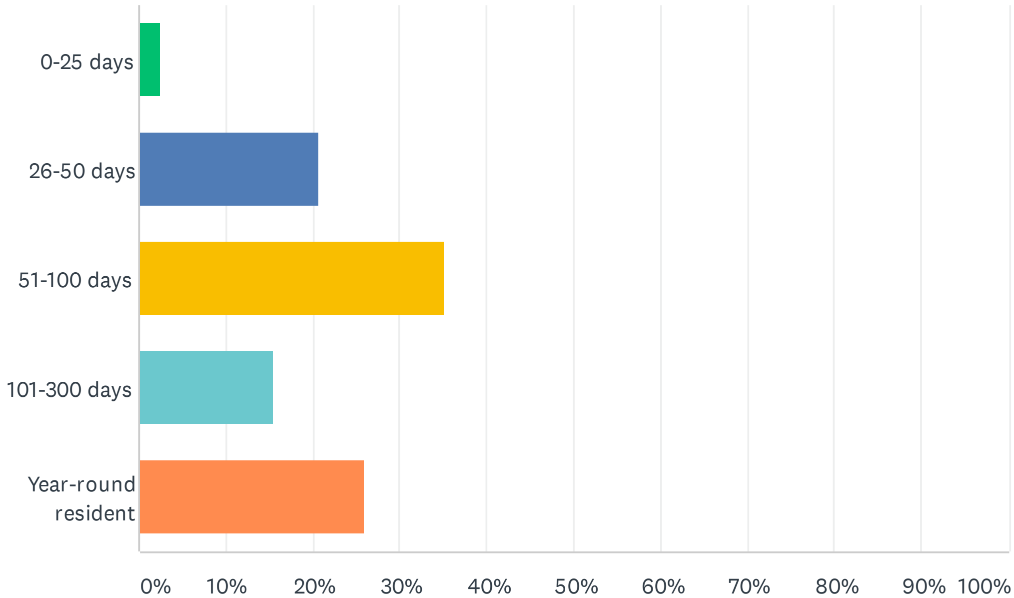
Answered: 78 Skipped: 1



ANSWER CHOICES	RESPONSES	
0-5 years	23.08%	18
6-10 years	12.82%	10
11-15 years	7.69%	6
16-20 years	15.38%	12
20+ years	41.03%	32
TOTAL		78

Q2 How many days each year is your property used by you and others?

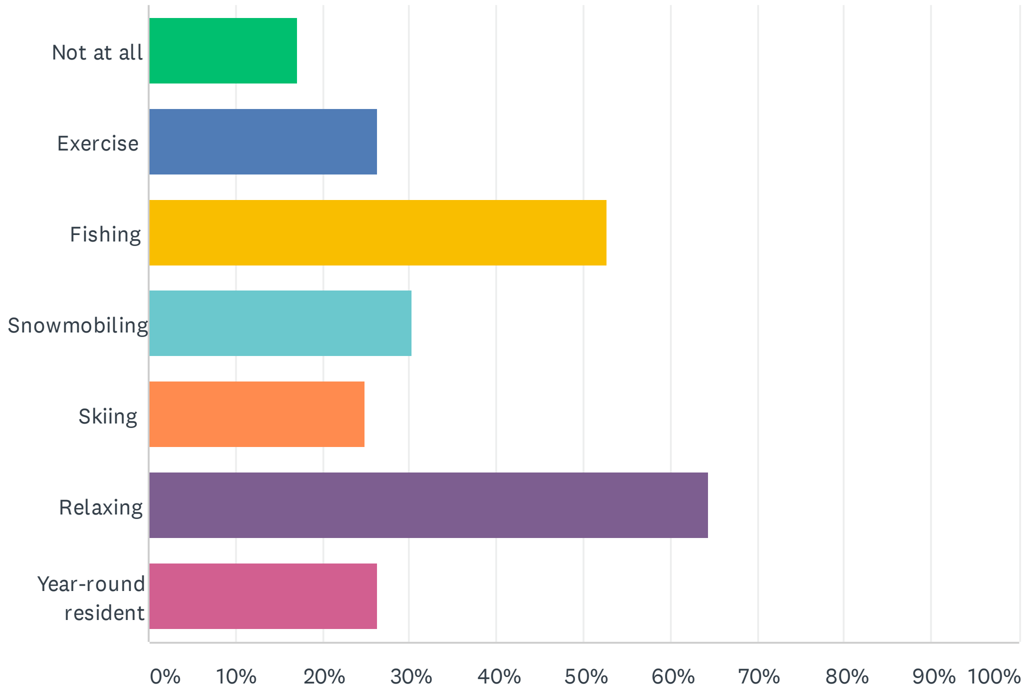
Answered: 77 Skipped: 2



ANSWER CHOICES	RESPONSES	
0-25 days	2.60%	2
26-50 days	20.78%	16
51-100 days	35.06%	27
101-300 days	15.58%	12
Year-round resident	25.97%	20
TOTAL		77

Q3 How do you use your property and the lake in the winter season? (select all that apply)

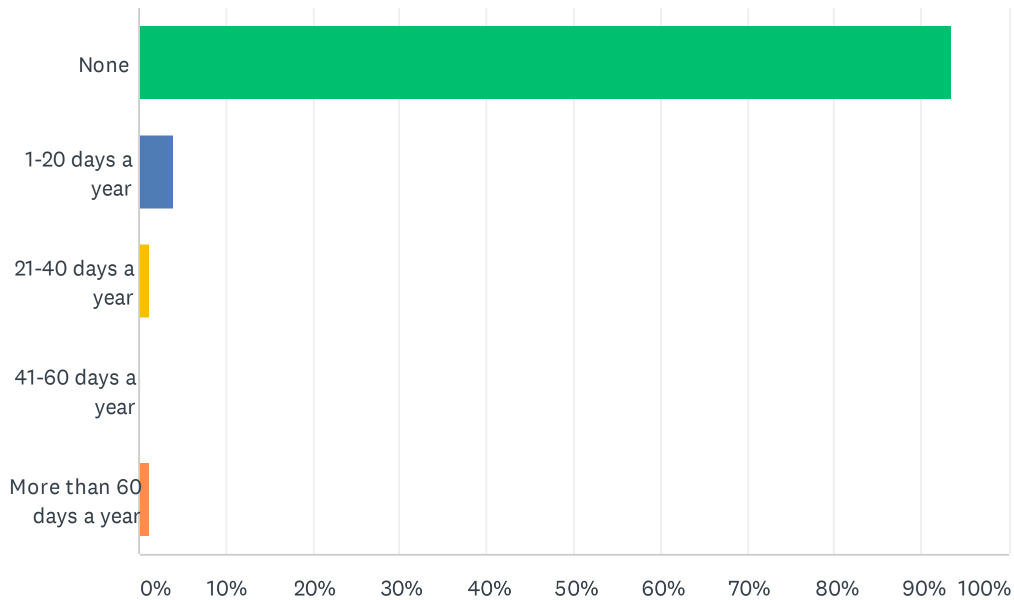
Answered: 76 Skipped: 3



ANSWER CHOICES	RESPONSES	
Not at all	17.11%	13
Exercise	26.32%	20
Fishing	52.63%	40
Snowmobiling	30.26%	23
Skiing	25.00%	19
Relaxing	64.47%	49
Year-round resident	26.32%	20
Total Respondents: 76		

Q4 Do you intend to use your property for short term rental purposes? If so, how many days is it likely rented?

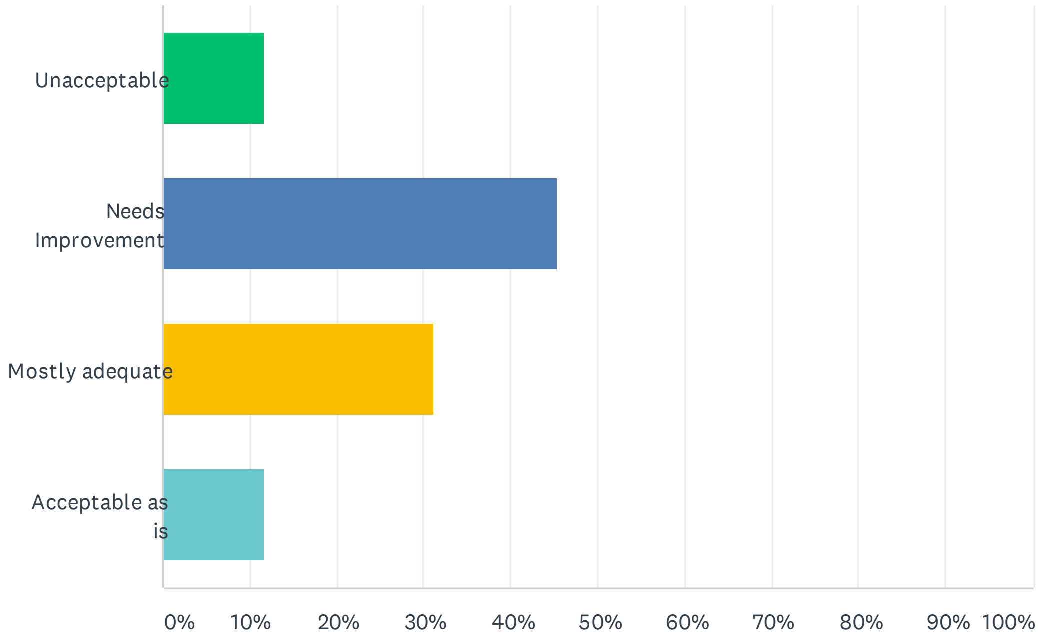
Answered: 76 Skipped: 3



ANSWER CHOICES	RESPONSES	
None	93.42%	71
1-20 days a year	3.95%	3
21-40 days a year	1.32%	1
41-60 days a year	0.00%	0
More than 60 days a year	1.32%	1
TOTAL		76

Q5 Does the near shore water quality and clarity near your property meet your expectations?

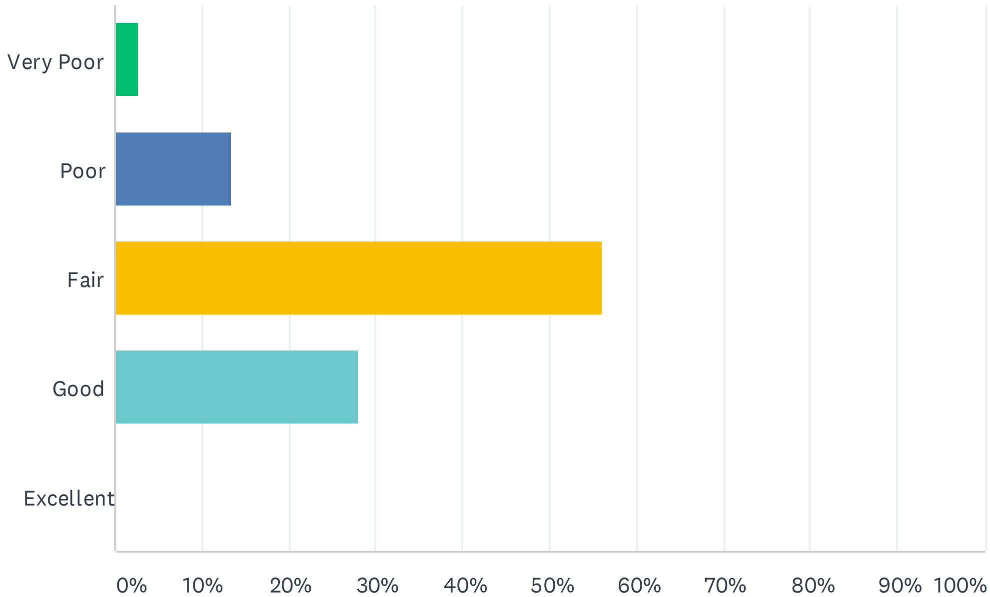
Answered: 77 Skipped: 2



ANSWER CHOICES	RESPONSES	
Unacceptable	11.69%	9
Needs Improvement	45.45%	35
Mostly adequate	31.17%	24
Acceptable as is	11.69%	9
TOTAL		77

Q6 How would you describe the overall current water quality of Muskellunge Lake?

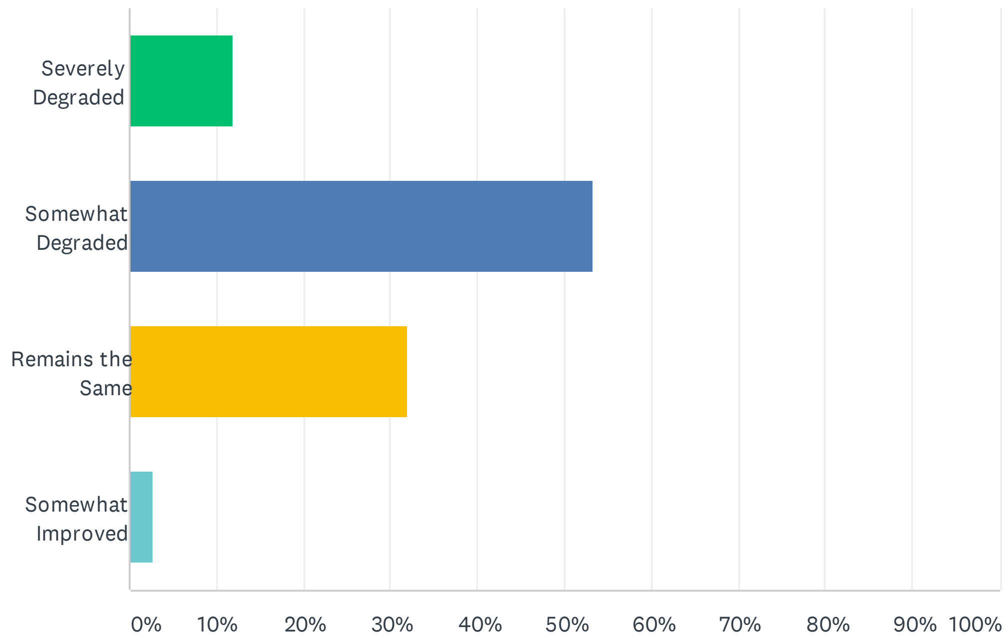
Answered: 75 Skipped: 4



ANSWER CHOICES	RESPONSES	
Very Poor	2.67%	2
Poor	13.33%	10
Fair	56.00%	42
Good	28.00%	21
Excellent	0.00%	0
TOTAL		75

Q7 How has the water quality changed since you first visited Muskellunge Lake?

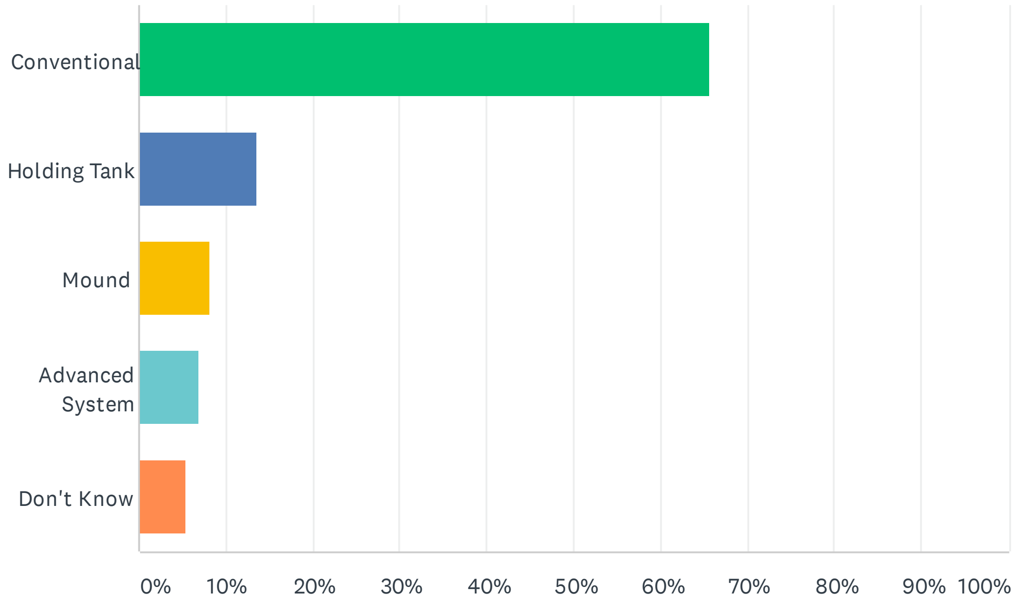
Answered: 75 Skipped: 4



ANSWER CHOICES	RESPONSES	
Severely Degraded	12.00%	9
Somewhat Degraded	53.33%	40
Remains the Same	32.00%	24
Somewhat Improved	2.67%	2
TOTAL		75

Q8 What type of septic system does your property utilize?

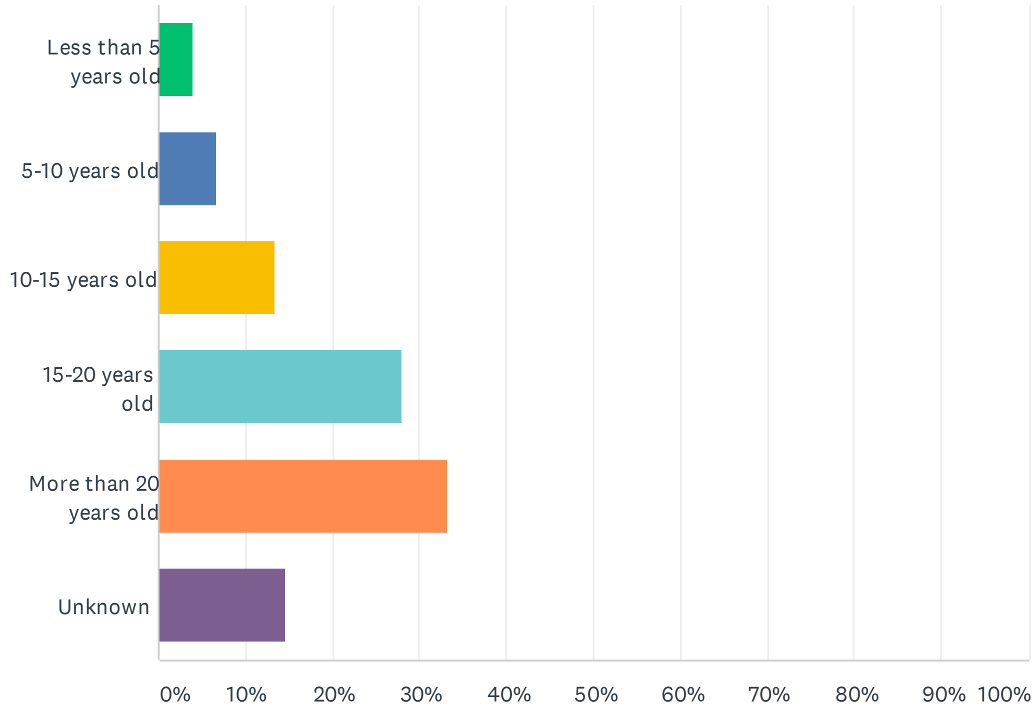
Answered: 73 Skipped: 6



ANSWER CHOICES	RESPONSES	
Conventional	65.75%	48
Holding Tank	13.70%	10
Mound	8.22%	6
Advanced System	6.85%	5
Don't Know	5.48%	4
TOTAL		73

Q9 How old is your system?

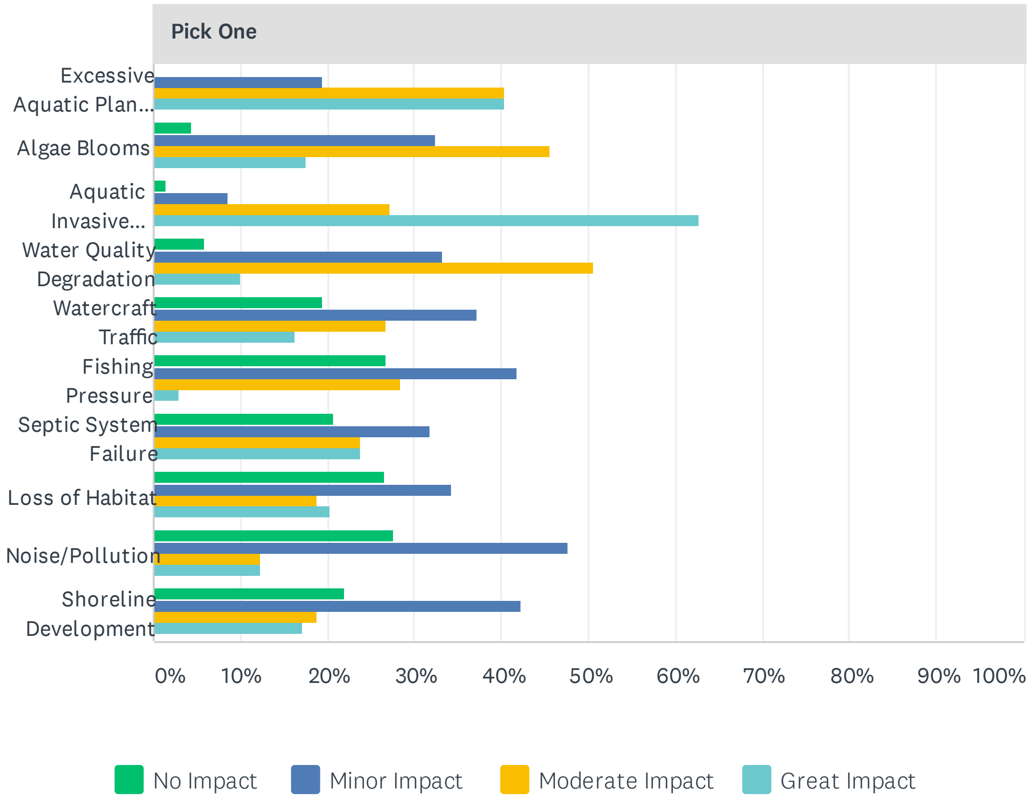
Answered: 75 Skipped: 4



ANSWER CHOICES	RESPONSES	
Less than 5 years old	4.00%	3
5-10 years old	6.67%	5
10-15 years old	13.33%	10
15-20 years old	28.00%	21
More than 20 years old	33.33%	25
Unknown	14.67%	11
TOTAL		75

Q10 To what level do you believe the following factors may currently be negatively impacting Muskellunge Lake? (For each select: No impact, Minor impact, Moderate impact, Great impact)

Answered: 70 Skipped: 9

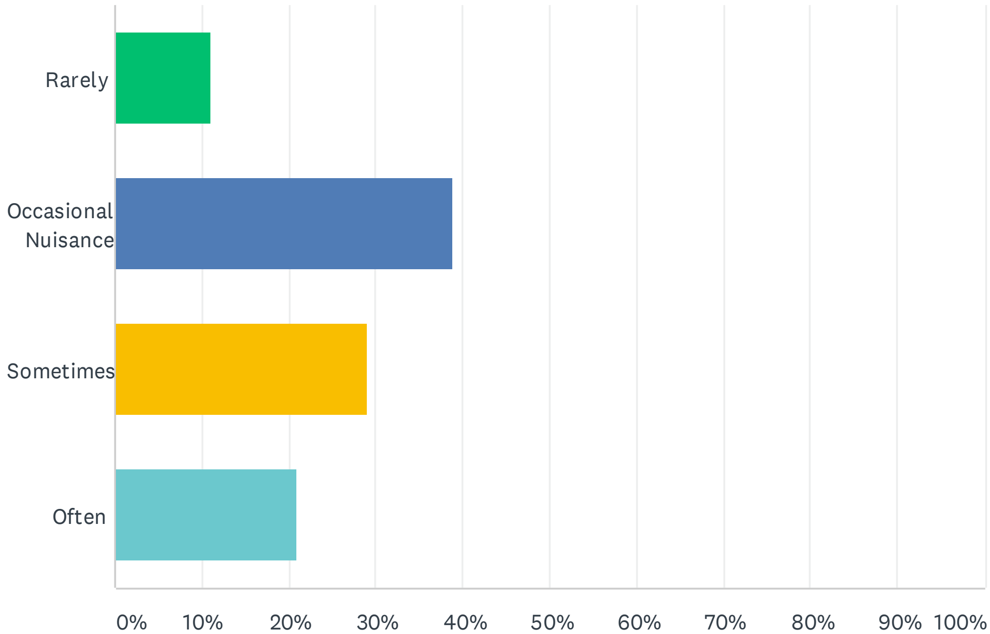


Pick One					
	NO IMPACT	MINOR IMPACT	MODERATE IMPACT	GREAT IMPACT	TOTAL
Excessive Aquatic Plant Growth	0.00% 0	19.40% 13	40.30% 27	40.30% 27	67
Algae Blooms	4.41% 3	32.35% 22	45.59% 31	17.65% 12	68
Aquatic Invasive Species	1.43% 1	8.57% 6	27.14% 19	62.86% 44	70
Water Quality Degradation	5.80% 4	33.33% 23	50.72% 35	10.14% 7	69
Watercraft Traffic	19.40% 13	37.31% 25	26.87% 18	16.42% 11	67
Fishing Pressure	26.87% 18	41.79% 28	28.36% 19	2.99% 2	67
Septic System Failure	20.63% 13	31.75% 20	23.81% 15	23.81% 15	63
Loss of Habitat	26.56% 17	34.38% 22	18.75% 12	20.31% 13	64
Noise/Pollution	27.69% 18	47.69% 31	12.31% 8	12.31% 8	65
Shoreline Development	21.88% 14	42.19% 27	18.75% 12	17.19% 11	64

#	OTHER (PLEASE SPECIFY)	DATE
1	no buffer zone of 20-40feet from shoreline	8/19/2020 3:24 PM
2	The shoreline is fully developed unless some developer would purchase one shoreline property and then purchase other land near by and give lake access to all happens all over state WI	8/15/2020 11:20 PM
3	There has always been an abundance of native aquatic plants. More so in some bays as compared to others. It would be beneficial if boaters stayed outside the weed beds in deeper water, if possible.	8/15/2020 9:13 AM
4	People not following rules Such as no wake hours. resulting in deterioration of lake. (Renters and landing traffic)	8/11/2020 4:14 PM
5	Jet skis are not good for the lake. One hour in the morning and one hour in the evening should be added to existing no wake period.	8/11/2020 8:39 AM
6	SHORT TERM RENTALS!!! THERE ARE TWO ON OUR LAKE NOW. By allowing large parties to gather, they are increasing the numbers of those who use the lake AND most likely will not care what they do to the lake - septic use, boating (esp when they are not boaters), chemical use. Terrible that homes have been rented out.	8/8/2020 6:25 PM
7	The weeds are so bad in the summer, there is very little activity That can be enjoyed on the lake and The property taxes don’t account for loss activity on The lake the lake. Don’t get me wrong the lake is beautiful but the weeds make activities very limited.	8/8/2020 3:03 PM
8	The weeds have been a problem for years on the lake. We were happy when the lake association did the weed harvesting some years back. We think that it helped quite a bit. We also feel that the lake is too small for jet skis, wave runners. Most of the people that ride them are running too close to shore and into all of the bays ripping up all of the weeds including the Eurasian Milfoil. That certainly is not helping our current problem what so ever. We thought that renting out your property was against the lake association rules. We actually agree strongly with not renting out your property. Most renters don't have any respect for rules or regulations which may be why we are seeing more and more folks not abiding by the no wake hours.	8/8/2020 2:24 PM
9	The fishing tournaments that include our lake ultimately does effect our lake. The boat motor size and type effects our lake. (Too large and inboard) The rules and laws that are in place to protect our shoreline is not being followed and is very hard to inforce. Lack of curtesy some fisher people have when fishing our shoreline needs to improve. i.e. Fishing near docks and boats at docks. Casting towards these and hitting the dock or boat.	8/8/2020 1:30 PM

Q11 How often does unrooted vegetation negatively impact your enjoyment of the lake?

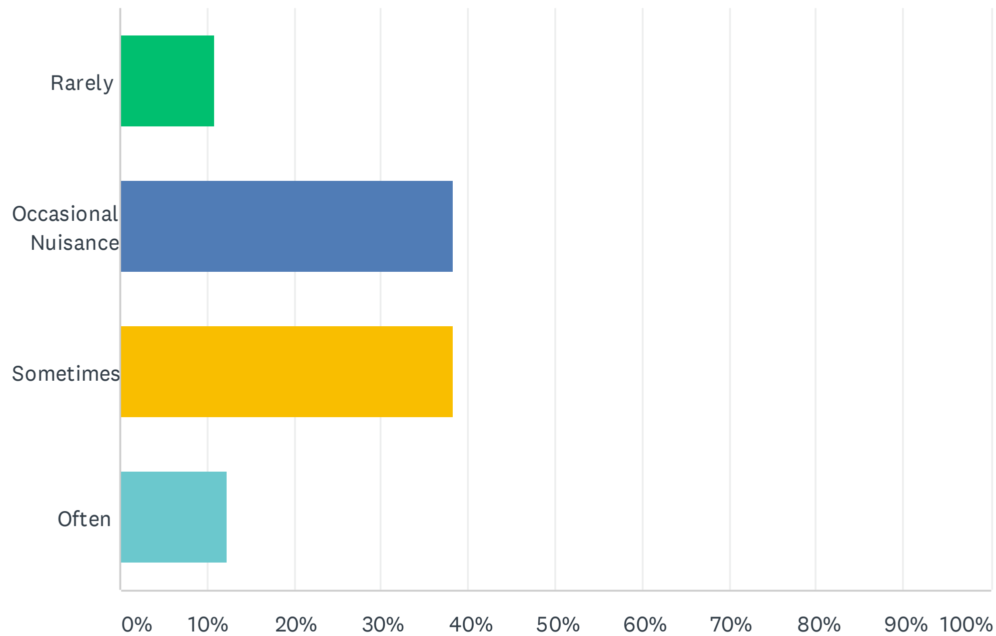
Answered: 72 Skipped: 7



ANSWER CHOICES	RESPONSES	
Rarely	11.11%	8
Occasional Nuisance	38.89%	28
Sometimes	29.17%	21
Often	20.83%	15
TOTAL		72

Q12 How often does free floating algae or algae blooms negatively impact your enjoyment of the lake?

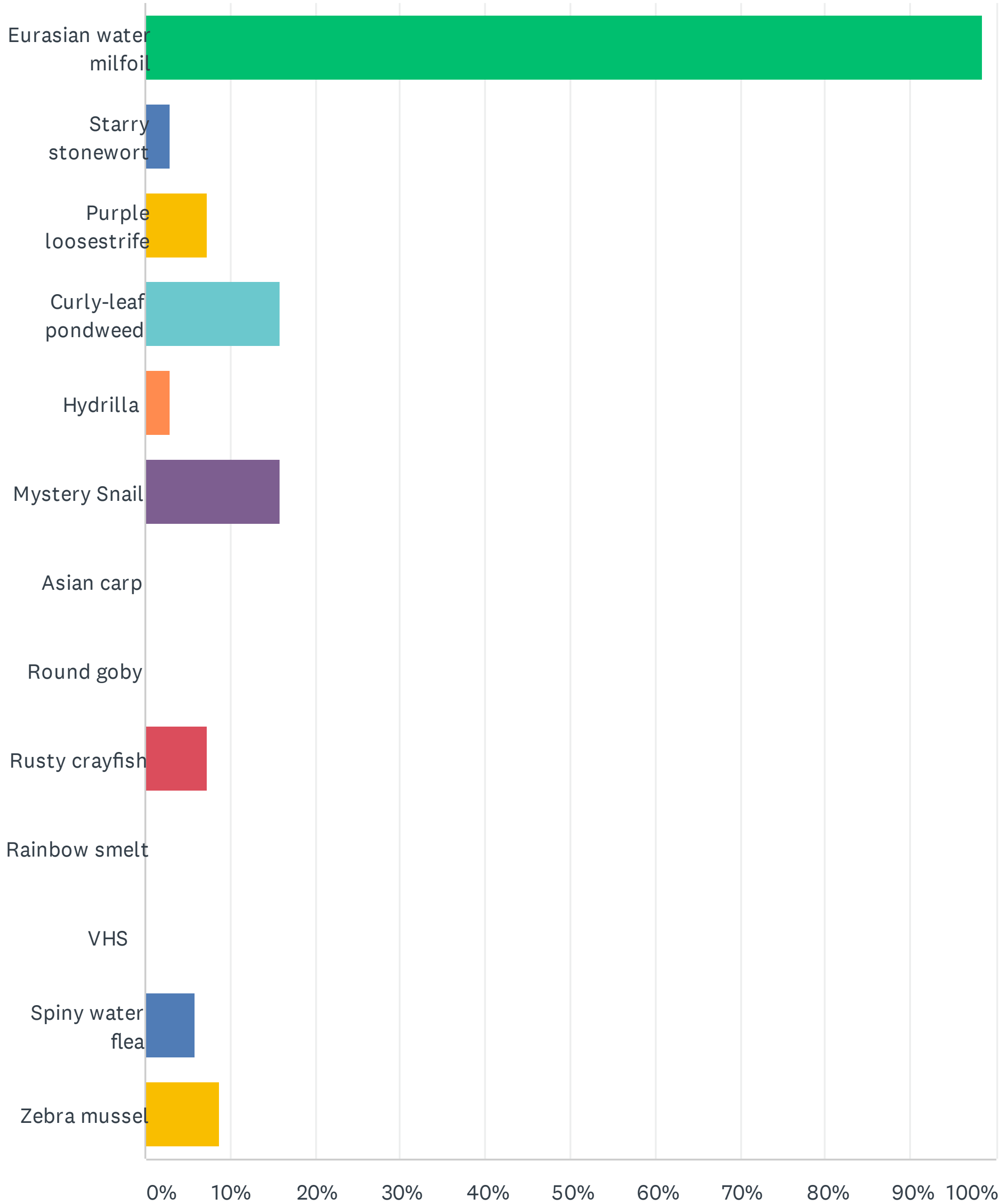
Answered: 73 Skipped: 6



ANSWER CHOICES	RESPONSES	
Rarely	10.96%	8
Occasional Nuisance	38.36%	28
Sometimes	38.36%	28
Often	12.33%	9
TOTAL		73

Q13 Which aquatic invasive species do you believe are in this lake? (select all that apply)

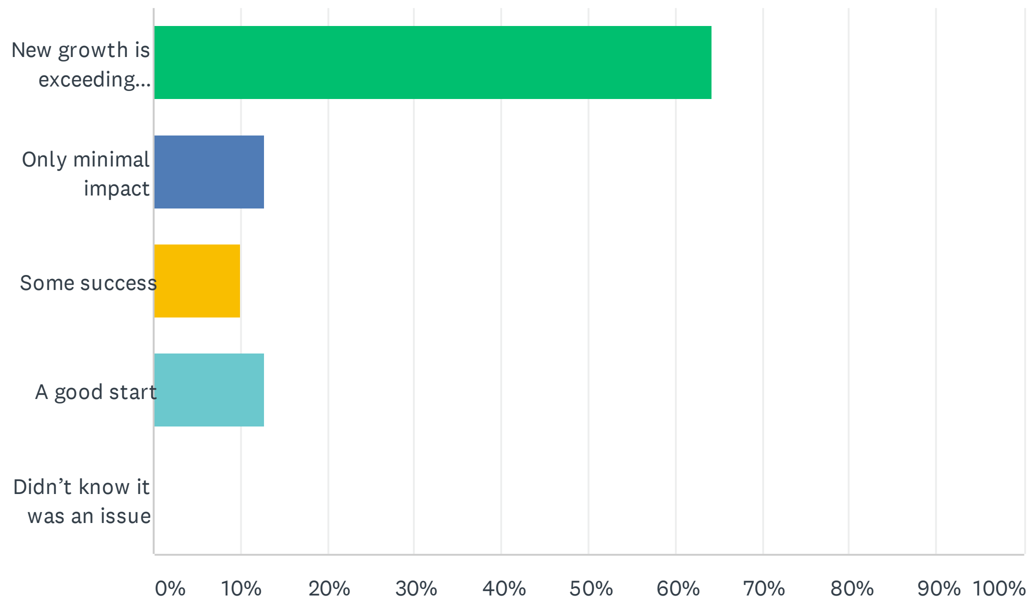
Answered: 69 Skipped: 10



ANSWER CHOICES	RESPONSES	
Eurasian water milfoil	98.55%	68
Starry stonewort	2.90%	2
Purple loosestrife	7.25%	5
Curly-leaf pondweed	15.94%	11
Hydrilla	2.90%	2
Mystery Snail	15.94%	11
Asian carp	0.00%	0
Round goby	0.00%	0
Rusty crayfish	7.25%	5
Rainbow smelt	0.00%	0
VHS	0.00%	0
Spiny water flea	5.80%	4
Zebra mussel	8.70%	6
Total Respondents: 69		

Q14 Have existing measures to control Eurasian Water Milfoil (EWM) on Muskellunge Lake been successful?

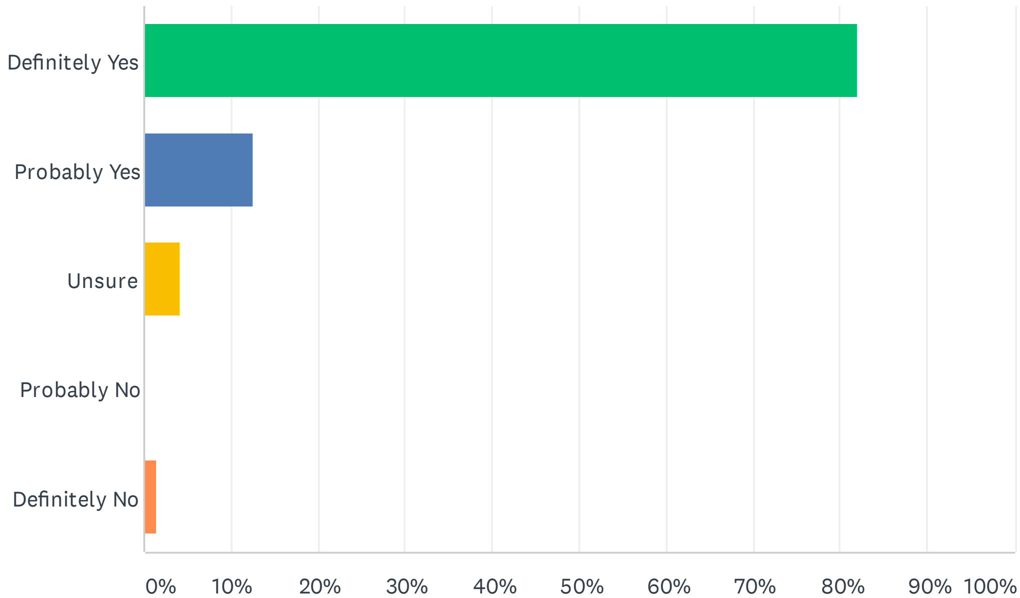
Answered: 70 Skipped: 9



ANSWER CHOICES	RESPONSES	
New growth is exceeding control efforts	64.29%	45
Only minimal impact	12.86%	9
Some success	10.00%	7
A good start	12.86%	9
Didn't know it was an issue	0.00%	0
TOTAL		70

Q15 Considering your prior answers, do you believe the control of Invasive Species such as Eurasian Water Milfoil is necessary on Muskellunge Lake?

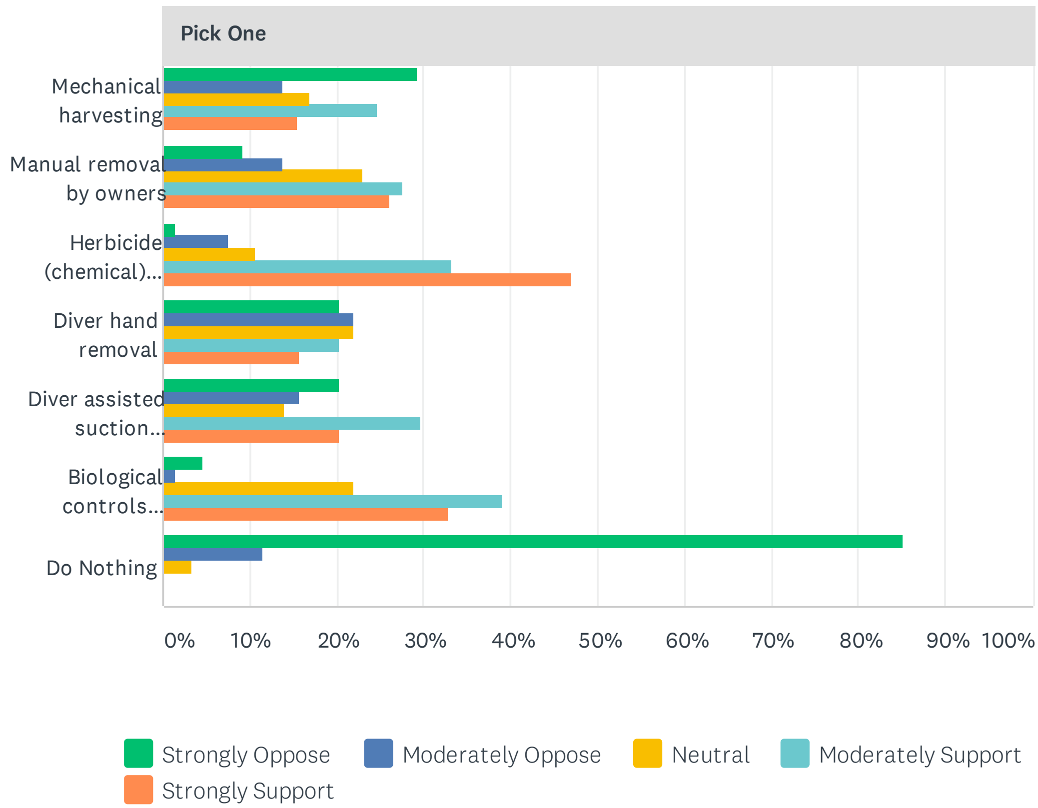
Answered: 72 Skipped: 7



ANSWER CHOICES	RESPONSES	
Definitely Yes	81.94%	59
Probably Yes	12.50%	9
Unsure	4.17%	3
Probably No	0.00%	0
Definitely No	1.39%	1
TOTAL		72

Q16 Aquatic plants can be managed using many techniques. What is you level of support for the following techniques? (Rate Each: Strongly oppose, Moderately oppose, Neutral, Moderately support, Strongly support)

Answered: 68 Skipped: 11



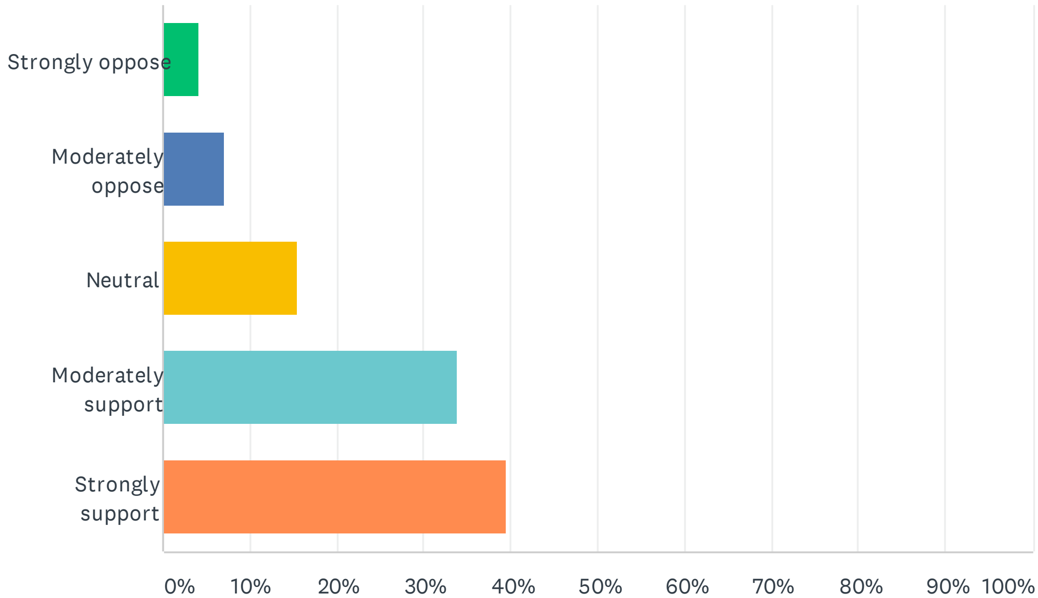
Pick One

	STRONGLY OPPOSE	MODERATELY OPPOSE	NEUTRAL	MODERATELY SUPPORT	STRONGLY SUPPORT	TOTAL
Mechanical harvesting	29.23% 19	13.85% 9	16.92% 11	24.62% 16	15.38% 10	65
Manual removal by owners	9.23% 6	13.85% 9	23.08% 15	27.69% 18	26.15% 17	65
Herbicide (chemical) control – Spot treatment	1.52% 1	7.58% 5	10.61% 7	33.33% 22	46.97% 31	66
Diver hand removal	20.31% 13	21.88% 14	21.88% 14	20.31% 13	15.63% 10	64
Diver assisted suction harvesting	20.31% 13	15.63% 10	14.06% 9	29.69% 19	20.31% 13	64
Biological controls (milfoil weevil)	4.69% 3	1.56% 1	21.88% 14	39.06% 25	32.81% 21	64
Do Nothing	85.25% 52	11.48% 7	3.28% 2	0.00% 0	0.00% 0	61

#	OTHER (PLEASE SPECIFY)	DATE
1	I was told a Boot Lake was infested up to about 80% Eurasian Milfoil and with not much action taken back down to around 20% ?	8/15/2020 11:20 PM
2	My response above is in reference to invasive plants. Native plant should be left alone. Except perhaps minor removal by home owners. However, the lilly pads should be left alone in all cases.	8/15/2020 9:13 AM
3	Deal with boat traffic in shallow bays. Reduce speed. Bouys? DNR approval required.	8/11/2020 4:14 PM
4	I am in favor of spot treatment with chemicals if needed. I am opposed to a lake-wide systemic chemical application.	8/11/2020 3:57 PM
5	I believe that we need to take aggressive action, but at this point I am not educated enough on the pluses & minuses of each treatment.	8/9/2020 5:15 PM
6	We are losing our enjoyment on our lake.	8/8/2020 3:03 PM
7	Owners unable to get to deeper weeds and often break off plants and leave roots.	8/8/2020 2:40 PM
8	We need to do whatever we can of course within reason to get the problem under control. The lake is a very important resource for all of us to enjoy.	8/8/2020 2:24 PM

Q17 How do you feel about the use of herbicides in Muskellunge Lake?

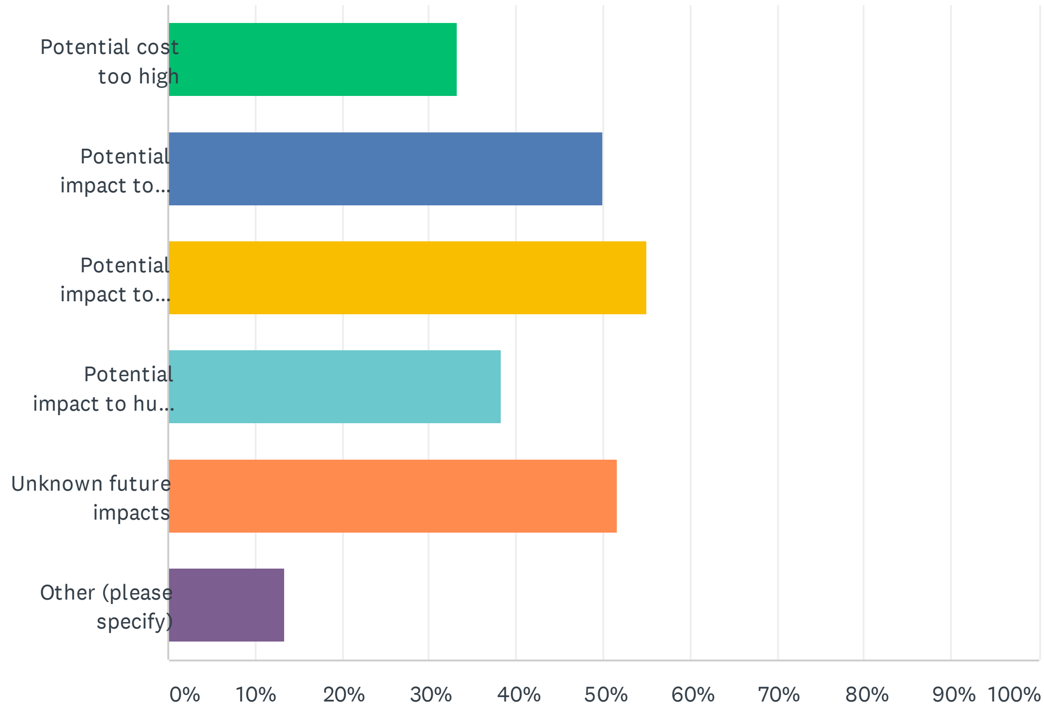
Answered: 71 Skipped: 8



ANSWER CHOICES	RESPONSES	
Strongly oppose	4.23%	3
Moderately oppose	7.04%	5
Neutral	15.49%	11
Moderately support	33.80%	24
Strongly support	39.44%	28
TOTAL		71

Q18 What is the reason(s) you might oppose the use of herbicides to target Eurasian Water Milfoil in Muskellunge Lake? (Select all that apply)

Answered: 60 Skipped: 19

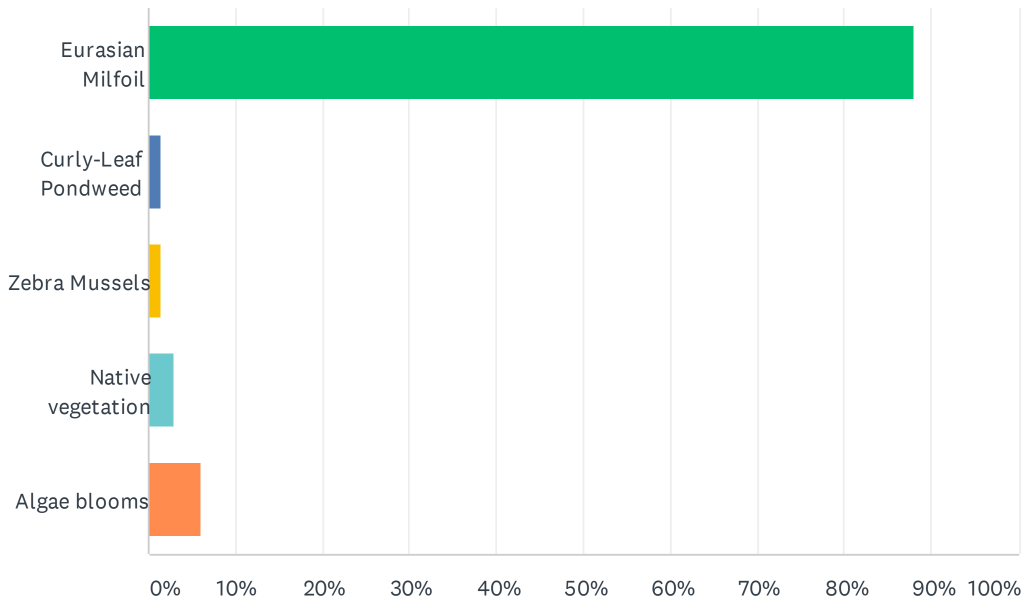


ANSWER CHOICES	RESPONSES	
Potential cost too high	33.33%	20
Potential impact to native plants	50.00%	30
Potential impact to non-plant species (fish, insects)	55.00%	33
Potential impact to human health	38.33%	23
Unknown future impacts	51.67%	31
Other (please specify)	13.33%	8
Total Respondents: 60		

#	OTHER (PLEASE SPECIFY)	DATE
1	I would need to know the track record of herbicide use in other lakes similar to ours to make an informed decision.	8/12/2020 10:11 PM
2	I support the usage!	8/10/2020 8:51 AM
3	P	8/9/2020 10:44 AM
4	It’s going to really get out of control in the future and chemicals might be the only way to control the milfoil. The lake is so small and not deep that it could get very ugly.	8/8/2020 9:44 PM
5	Anything is In improvement	8/8/2020 3:03 PM
6	Do we have any data that shows the impact of herbicides regarding any of the above reasons from any other lakes in the area.	8/8/2020 2:24 PM
7	I don’t have any reason herbicide are the answer look at what help it did on the Eagle River chain	8/8/2020 1:47 PM
8	Not opposed	8/4/2020 7:56 PM

Q19 In your opinion, which of the following pose the greatest threat to your enjoyment of Muskellunge Lake?

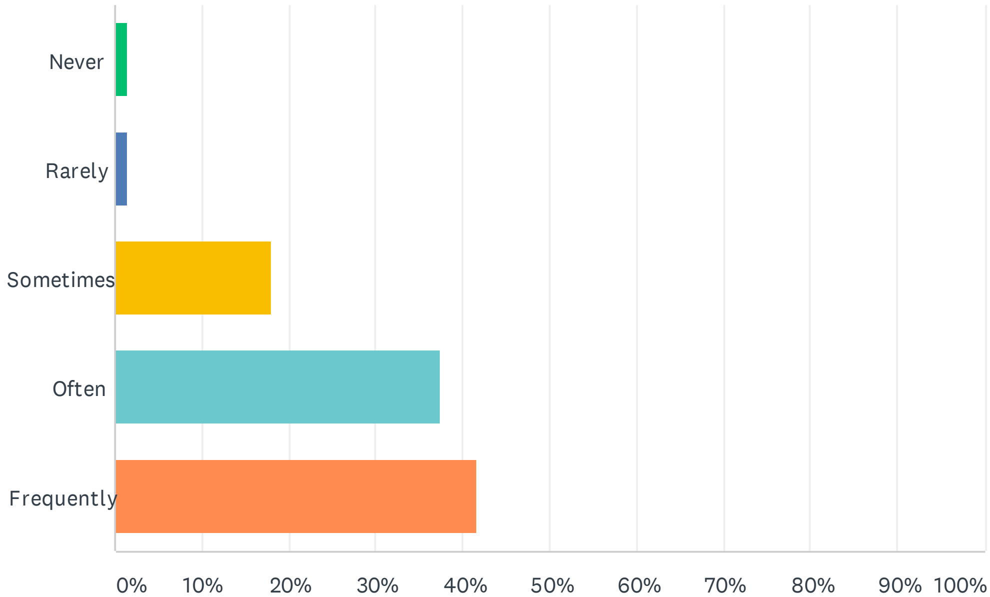
Answered: 67 Skipped: 12



ANSWER CHOICES	RESPONSES	
Eurasian Milfoil	88.06%	59
Curly-Leaf Pondweed	1.49%	1
Zebra Mussels	1.49%	1
Native vegetation	2.99%	2
Algae blooms	5.97%	4
TOTAL		67

Q20 Prior to this survey, how often have you heard, seen or read information about aquatic invasive species (AIS).

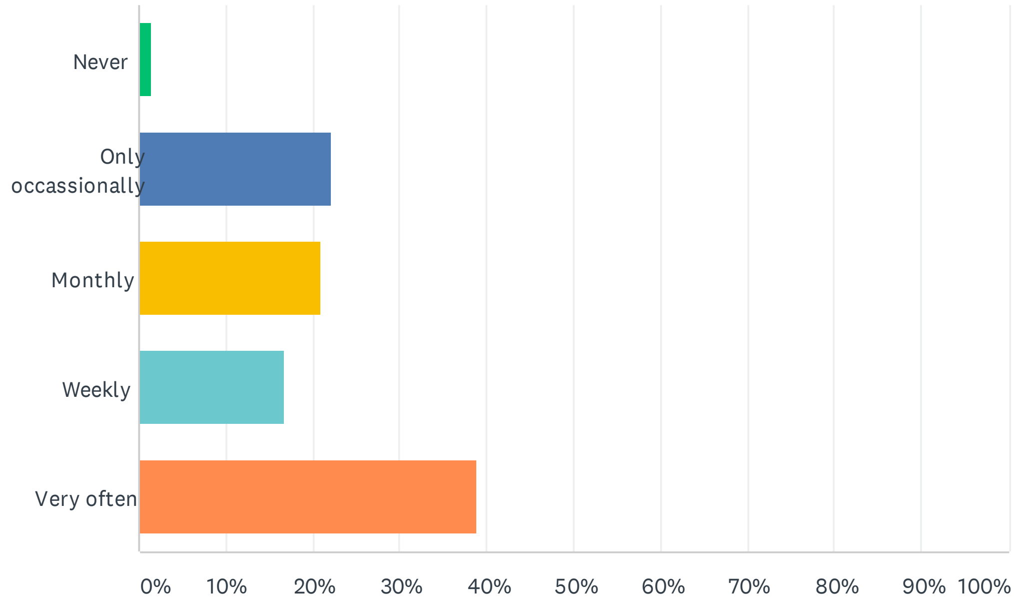
Answered: 72 Skipped: 7



ANSWER CHOICES	RESPONSES	
Never	1.39%	1
Rarely	1.39%	1
Sometimes	18.06%	13
Often	37.50%	27
Frequently	41.67%	30
TOTAL		72

Q21 How often have you gone fishing on the lake?

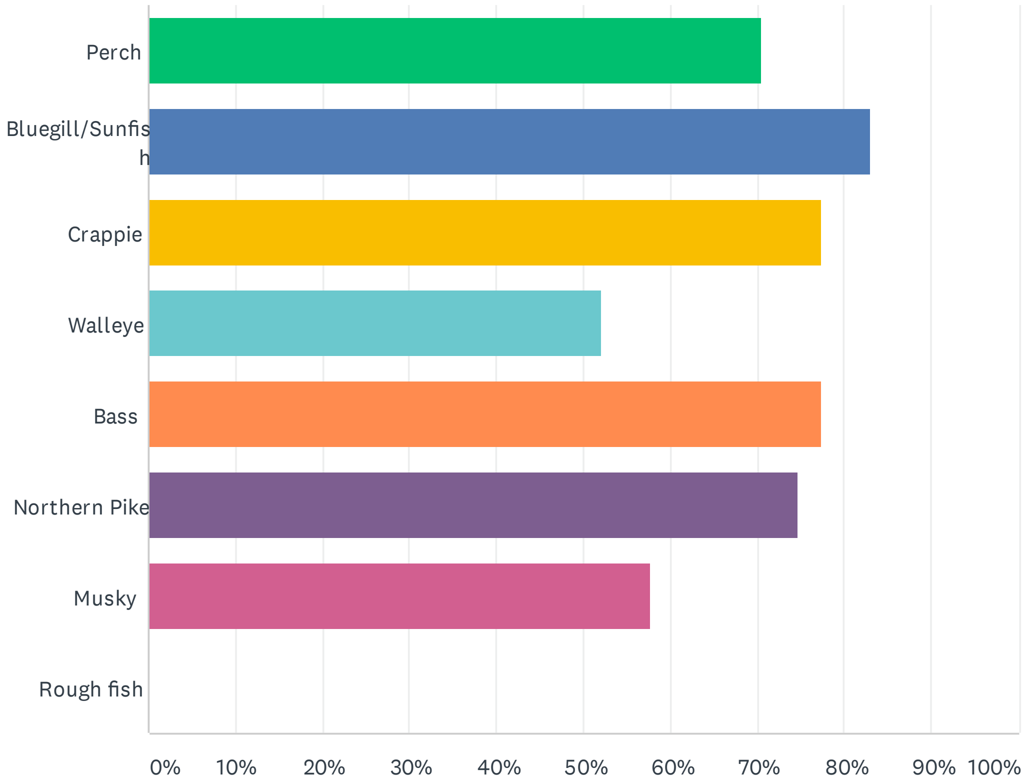
Answered: 72 Skipped: 7



ANSWER CHOICES	RESPONSES	
Never	1.39%	1
Only occassionally	22.22%	16
Monthly	20.83%	15
Weekly	16.67%	12
Very often	38.89%	28
TOTAL		72

Q22 What species of fish do you catch on Muskellunge Lake? (select all that apply)

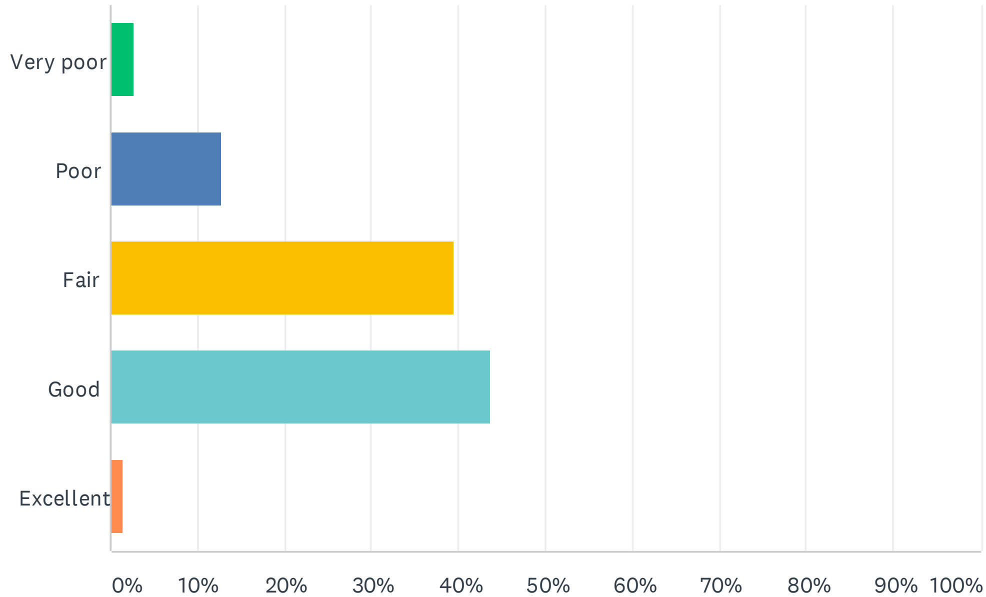
Answered: 71 Skipped: 8



ANSWER CHOICES	RESPONSES	
Perch	70.42%	50
Bluegill/Sunfish	83.10%	59
Crappie	77.46%	55
Walleye	52.11%	37
Bass	77.46%	55
Northern Pike	74.65%	53
Musky	57.75%	41
Rough fish	0.00%	0
Total Respondents: 71		

Q23 How does the quality of your current fishing experiences meet your expectations?

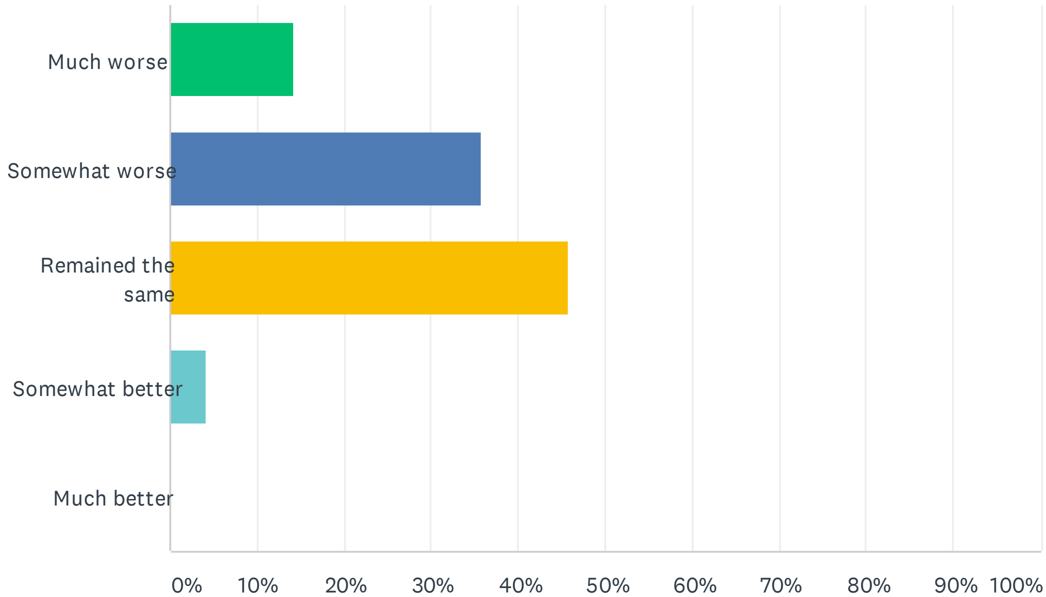
Answered: 71 Skipped: 8



ANSWER CHOICES	RESPONSES	
Very poor	2.82%	2
Poor	12.68%	9
Fair	39.44%	28
Good	43.66%	31
Excellent	1.41%	1
TOTAL		71

Q24 How has the quality of fishing changed since you started fishing Muskellunge Lake?

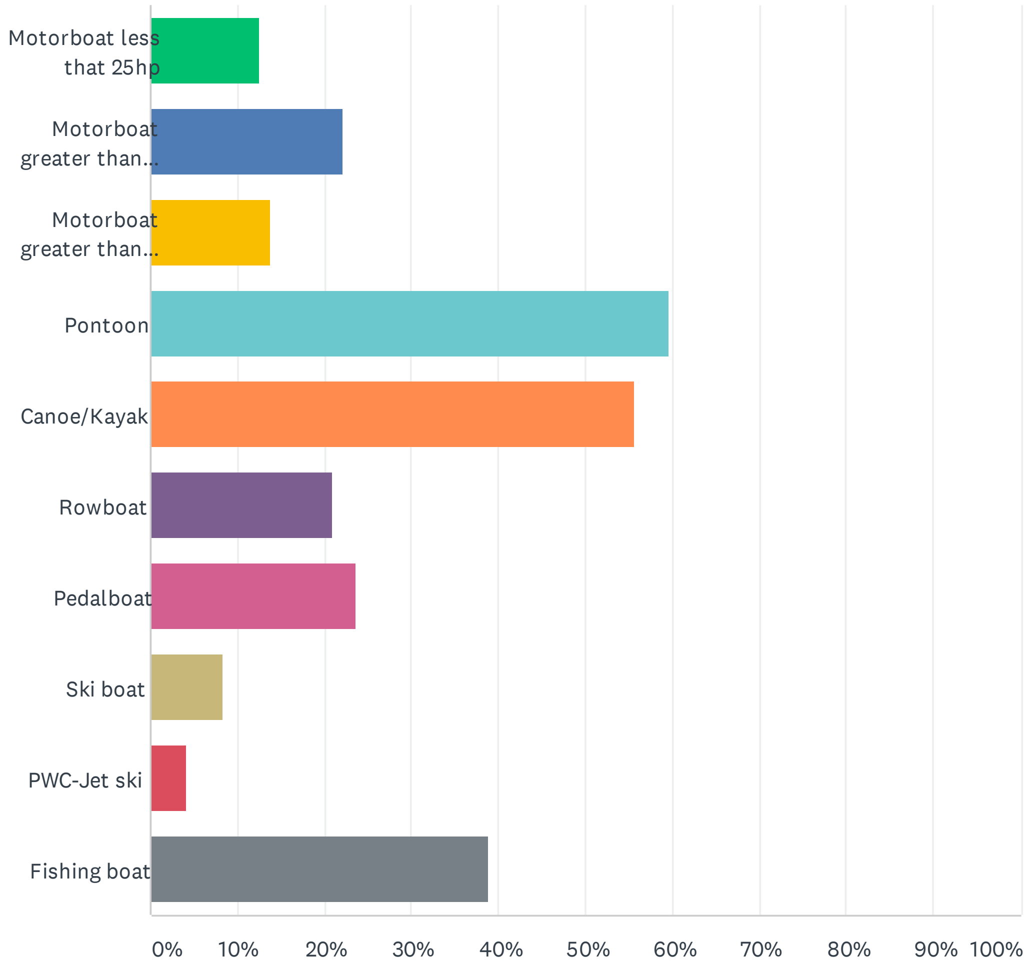
Answered: 70 Skipped: 9



ANSWER CHOICES	RESPONSES	
Much worse	14.29%	10
Somewhat worse	35.71%	25
Remained the same	45.71%	32
Somewhat better	4.29%	3
Much better	0.00%	0
TOTAL		70

Q25 What types of watercraft do you currently use? (check all that apply)

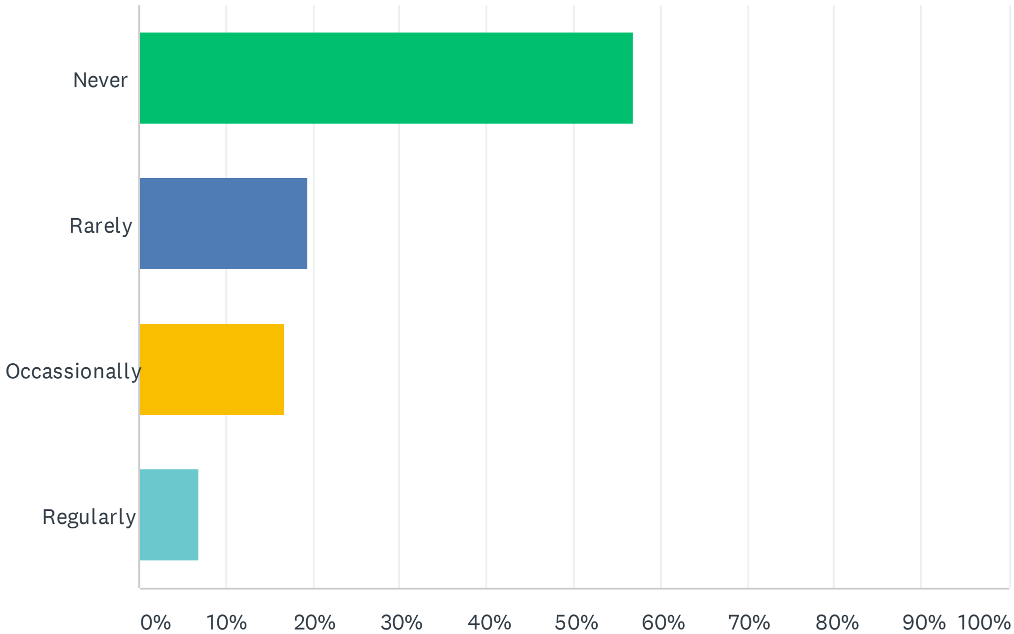
Answered: 72 Skipped: 7



ANSWER CHOICES	RESPONSES	
Motorboat less that 25hp	12.50%	9
Motorboat greater than 25hp	22.22%	16
Motorboat greater than 100hp	13.89%	10
Pontoon	59.72%	43
Canoe/Kayak	55.56%	40
Rowboat	20.83%	15
Pedalboat	23.61%	17
Ski boat	8.33%	6
PWC-Jet ski	4.17%	3
Fishing boat	38.89%	28
Total Respondents: 72		

Q26 Do you use your watercraft on other waters than Muskellunge Lake?

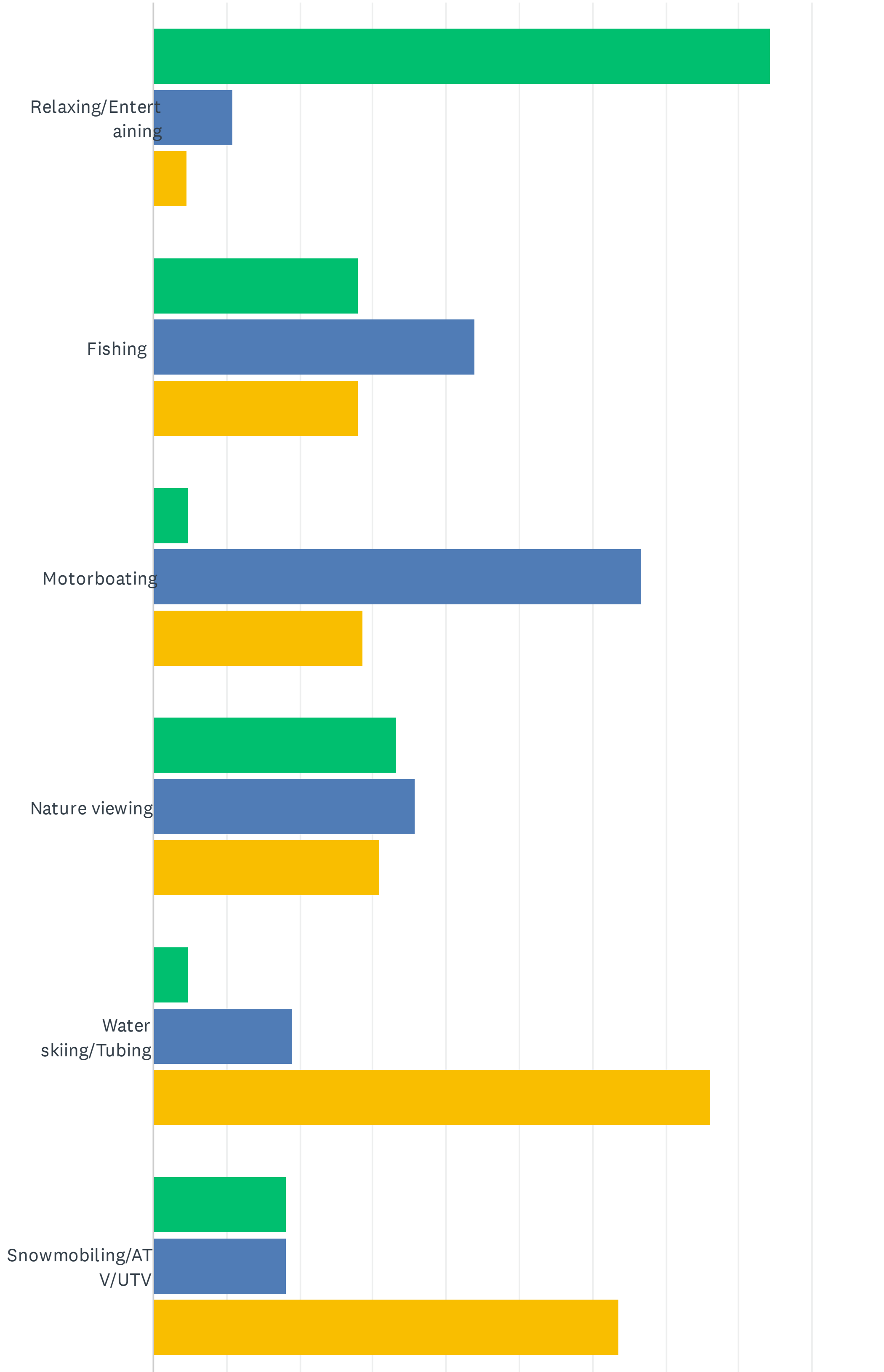
Answered: 72 Skipped: 7

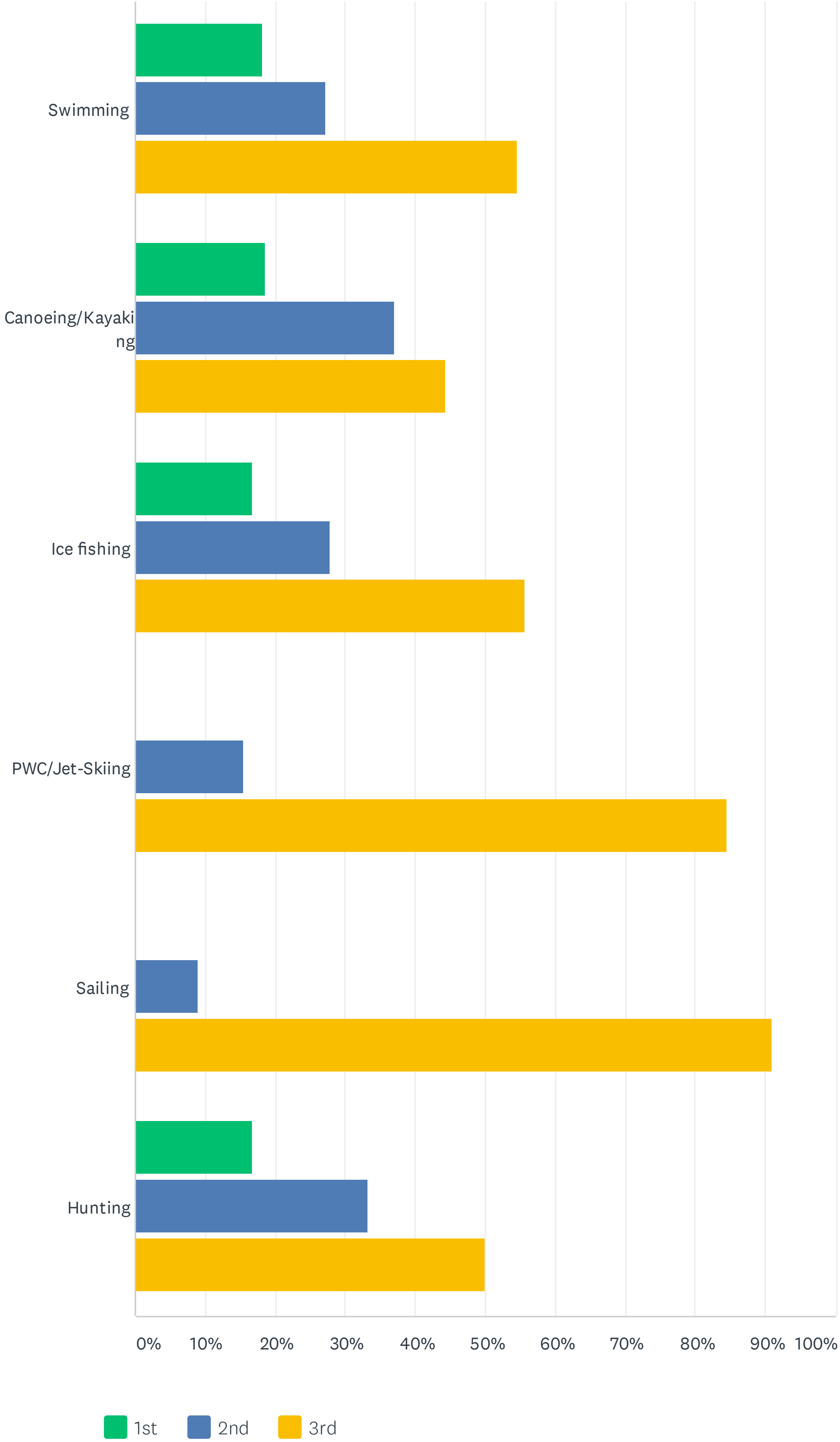


ANSWER CHOICES	RESPONSES	
Never	56.94%	41
Rarely	19.44%	14
Occassionally	16.67%	12
Regularly	6.94%	5
TOTAL		72

Q27 From the list below, rank the top three activities that are an important reason for owning property here. (1st, 2nd, 3rd)

Answered: 72 Skipped: 7



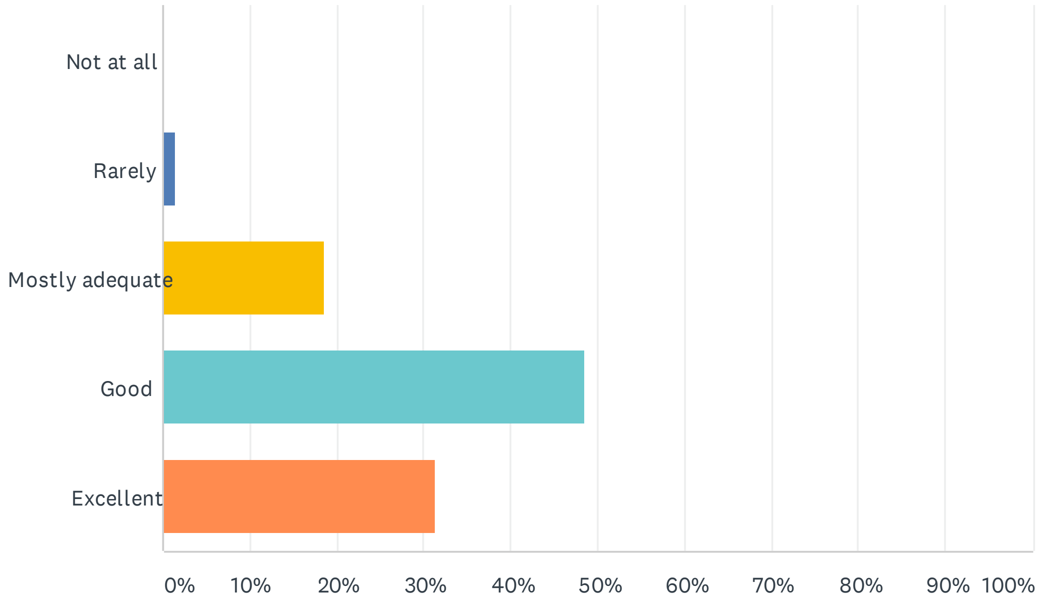

Swimming
Canoeing/Kayaking
Ice fishing
PWC/Jet-Skiing
Sailing
Hunting
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
1st
2nd
3rd

	1ST	2ND	3RD	TOTAL
Relaxing/Entertaining	84.38% 54	10.94% 7	4.69% 3	64
Fishing	28.07% 16	43.86% 25	28.07% 16	57
Motorboating	4.76% 1	66.67% 14	28.57% 6	21
Nature viewing	33.33% 14	35.71% 15	30.95% 13	42
Water skiing/Tubing	4.76% 1	19.05% 4	76.19% 16	21
Snowmobiling/ATV/UTV	18.18% 4	18.18% 4	63.64% 14	22
Swimming	18.18% 4	27.27% 6	54.55% 12	22
Canoeing/Kayaking	18.52% 5	37.04% 10	44.44% 12	27
Ice fishing	16.67% 3	27.78% 5	55.56% 10	18
PWC/Jet-Skiing	0.00% 0	15.38% 2	84.62% 11	13
Sailing	0.00% 0	9.09% 1	90.91% 10	11
Hunting	16.67% 2	33.33% 4	50.00% 6	12

#	OTHER (PLEASE SPECIFY)	DATE
1	By motor boating I mean pontooning.	8/12/2020 10:15 PM
2	Been Muskie fishing here for 17 years. We've caught over 140 muskies on this lake. The last 3 years have been awful.	8/8/2020 9:47 PM
3	We enjoy many of these activities. We could have picked about 7 things as number one.	8/8/2020 2:34 PM
4	Nature viewing	8/8/2020 12:05 PM

Q28 Does current direction of the management of the lake association meet your expectations?

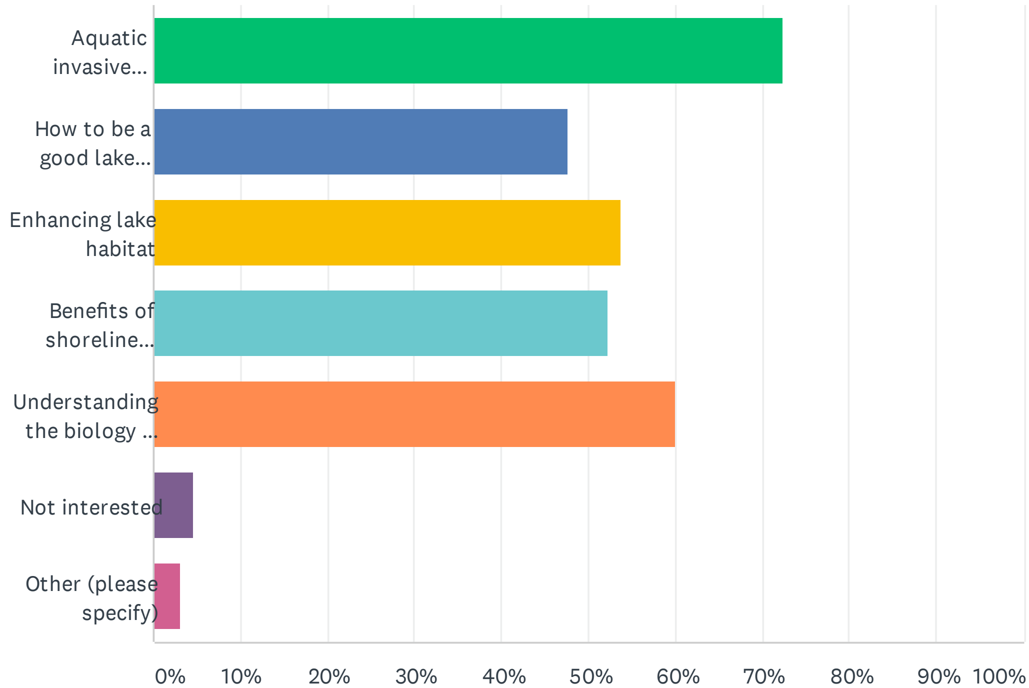
Answered: 70 Skipped: 9



ANSWER CHOICES	RESPONSES	
Not at all	0.00%	0
Rarely	1.43%	1
Mostly adequate	18.57%	13
Good	48.57%	34
Excellent	31.43%	22
TOTAL		70

Q29 Stakeholder communication is an important part of our efforts. Which of these subjects would you like to learn more about? (select all that apply)

Answered: 65 Skipped: 14

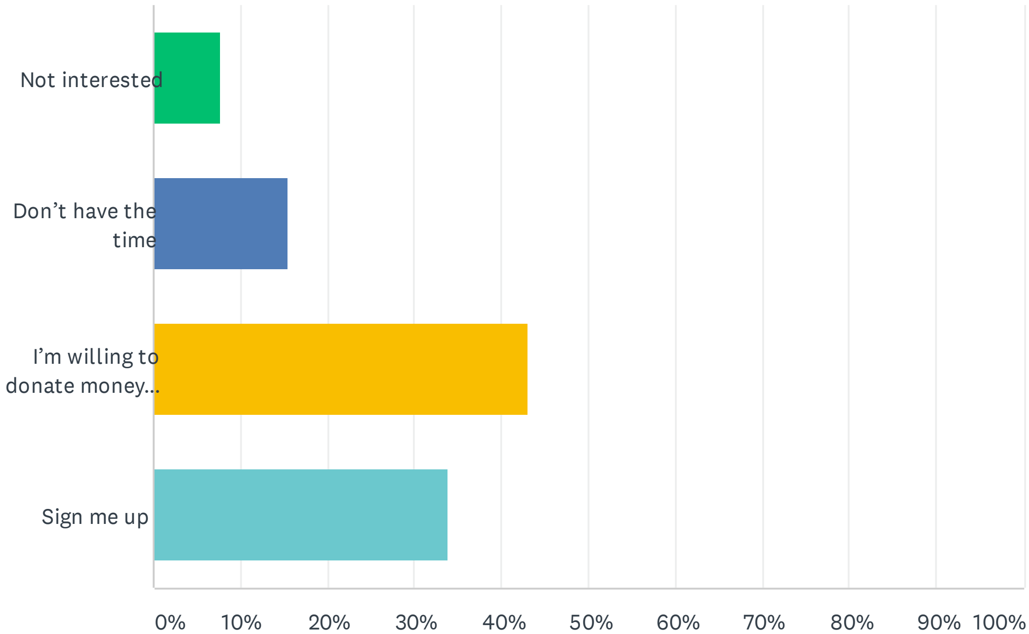


ANSWER CHOICES	RESPONSES	
Aquatic invasive species identification-control-impacts	72.31%	47
How to be a good lake steward	47.69%	31
Enhancing lake habitat	53.85%	35
Benefits of shoreline restoration and preservation	52.31%	34
Understanding the biology and chemistry relationship in this lake	60.00%	39
Not interested	4.62%	3
Other (please specify)	3.08%	2
Total Respondents: 65		

#	OTHER (PLEASE SPECIFY)	DATE
1	This "other" option is in regards to question 30. I will be interested in volunteering my time once retired in about 14 months from now.	8/12/2020 10:22 PM
2	Do not spend to much time on the lake.	8/8/2020 3:22 PM

Q30 Are you willing to volunteer on projects that will benefit Muskellunge Lake?

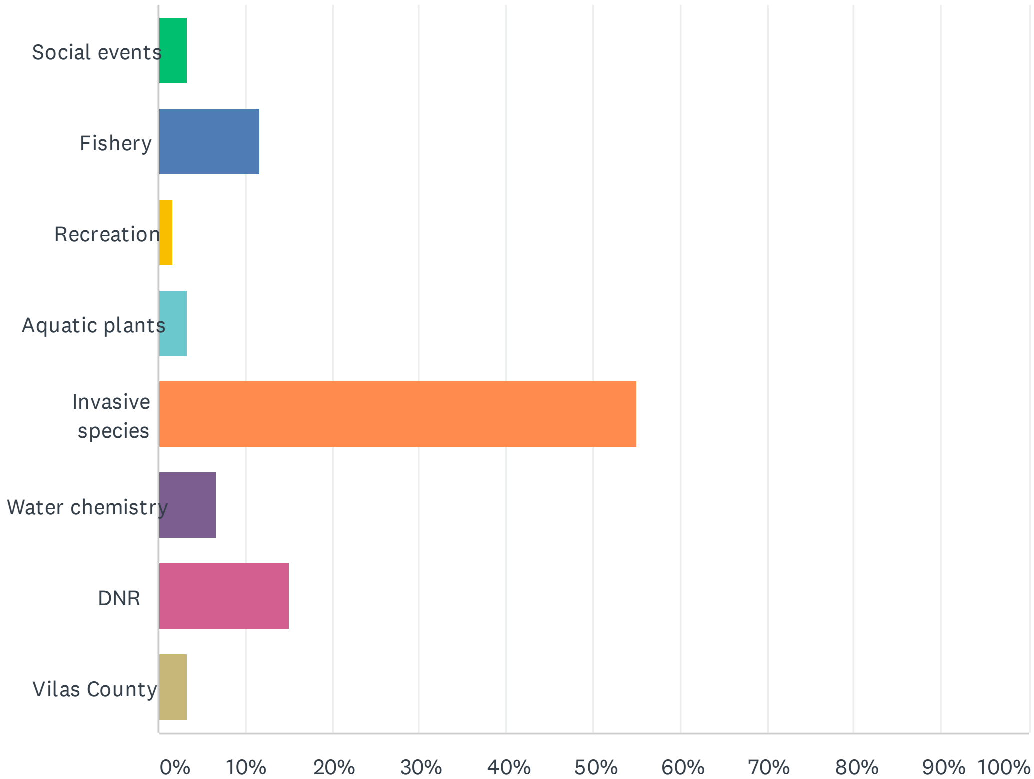
Answered: 65 Skipped: 14



ANSWER CHOICES	RESPONSES	
Not interested	7.69%	5
Don't have the time	15.38%	10
I'm willing to donate money instead of volunteer time	43.08%	28
Sign me up	33.85%	22
TOTAL		65

Q31 MLA should increase its influence in/with…

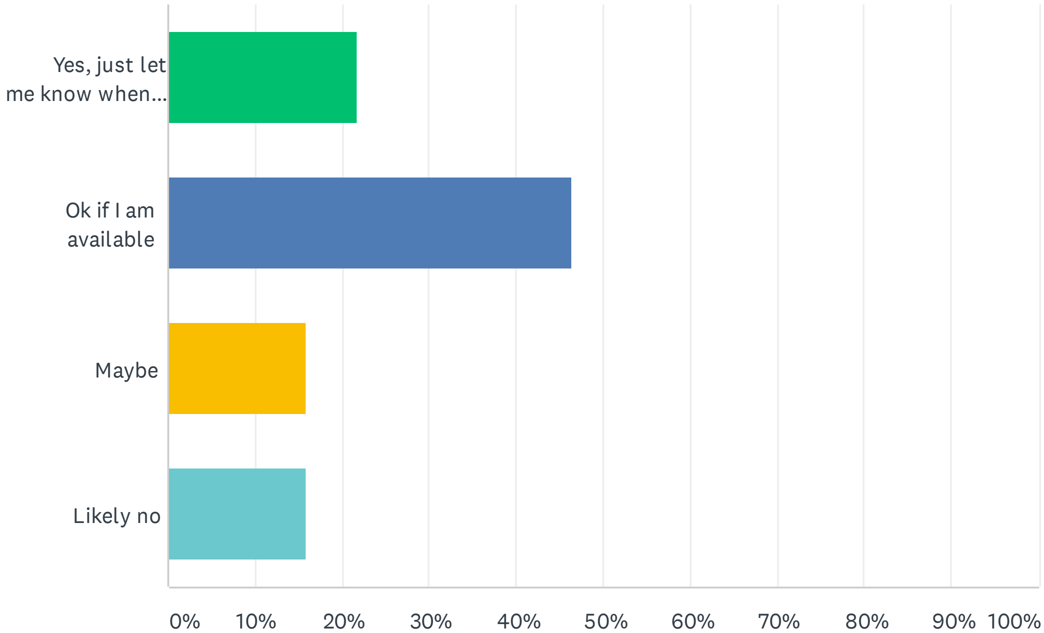
Answered: 60 Skipped: 19



ANSWER CHOICES	RESPONSES	
Social events	3.33%	2
Fishery	11.67%	7
Recreation	1.67%	1
Aquatic plants	3.33%	2
Invasive species	55.00%	33
Water chemistry	6.67%	4
DNR	15.00%	9
Vilas County	3.33%	2
TOTAL		60

Q32 Grants often require a percent of the costs to be paid by the MLA. Many times, payment can include In-Kind payments based on our labor or use of equipment. Are you willing to work on lake projects or use your equipment and talents to help offset these costs?

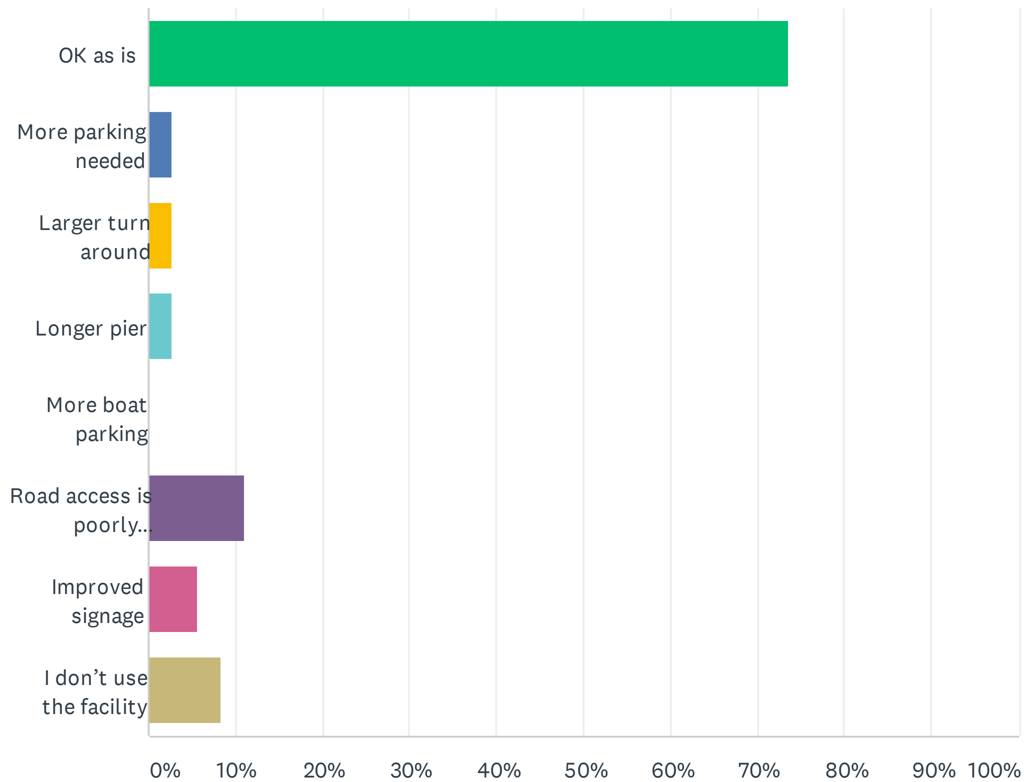
Answered: 69 Skipped: 10



ANSWER CHOICES	RESPONSES	
Yes, just let me know when and where	21.74%	15
Ok if I am available	46.38%	32
Maybe	15.94%	11
Likely no	15.94%	11
TOTAL		69

Q33 Is the existing boat landing area adequate for your needs? (Select any)

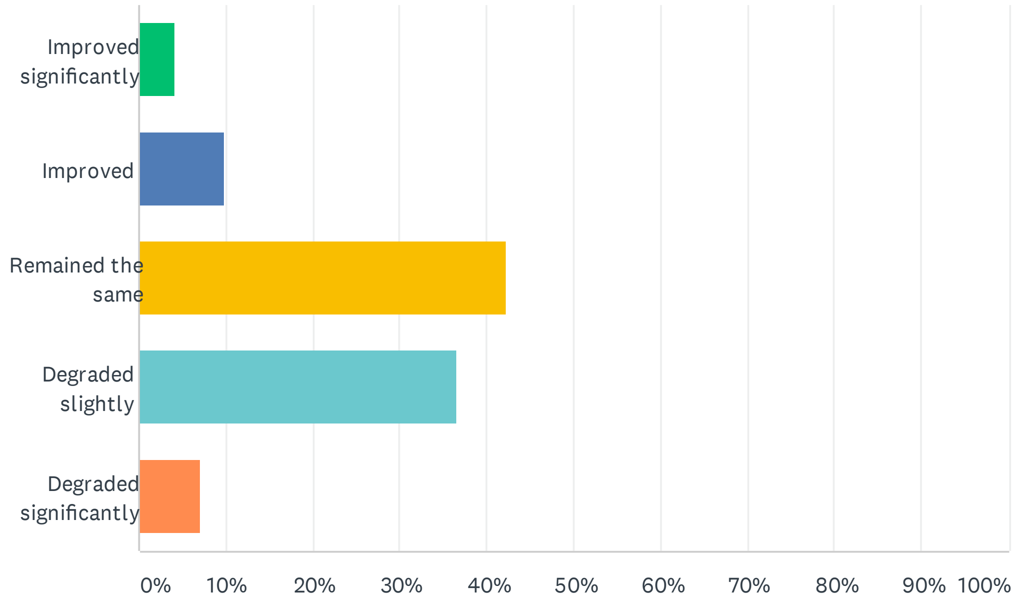
Answered: 72 Skipped: 7



ANSWER CHOICES	RESPONSES	
OK as is	73.61%	53
More parking needed	2.78%	2
Larger turn around	2.78%	2
Longer pier	2.78%	2
More boat parking	0.00%	0
Road access is poorly maintained	11.11%	8
Improved signage	5.56%	4
I don't use the facility	8.33%	6
Total Respondents: 72		

Q34 How has the overall quality of your experience changed since you have been on the lake?

Answered: 71 Skipped: 8



ANSWER CHOICES	RESPONSES	
Improved significantly	4.23%	3
Improved	9.86%	7
Remained the same	42.25%	30
Degraded slightly	36.62%	26
Degraded significantly	7.04%	5
TOTAL		71

Q35 What specific things would you like changed or improved on/in Muskellunge Lake?

Answered: 38 Skipped: 41

#	RESPONSES	DATE
1	Keep doing a good job	8/22/2020 7:20 PM
2	Millfoil will only get worse until we are willing to use chemicals. All other suggested control methods are a waste of money and time.	8/20/2020 8:15 AM
3	Continue to learn, identify and combat aquatic invasive species, while maintaining preferable water quality and recreational standards.	8/19/2020 3:49 PM
4	Limit size of boats and motors.	8/19/2020 3:28 PM
5	The Eurasian milfoil is most important for me because with it I think other problems come to with it in somewhat control because we know its never going to be 100% gone other problems are less	8/15/2020 11:37 PM
6	Require boaters to remain outside the weeds beds.	8/15/2020 9:17 AM
7	Weed control - milfoil, spadderdock.	8/13/2020 7:06 AM
8	cleaner shore line less weeds	8/13/2020 7:02 AM
9	Fish stocking	8/13/2020 6:22 AM
10	The mitigation of Eurasian milfoil.	8/12/2020 10:26 PM
11	Manage the invasive species reduce the amount of weeds in some of the bays. The quality of the lake and our ability to enjoy it on many levels will directly impact the values of our properties	8/12/2020 9:00 PM
12	I sincerely appreciate the hard work the Board and volunteers are doing and have done.	8/12/2020 7:24 PM
13	More movement through bay areas, weeds are out of control!!!! Weeds along shore are out of control. Something needs to be done. Perhaps a weed machine boat.	8/12/2020 4:23 PM
14	Control the weed	8/12/2020 1:24 PM
15	No more rental units!!!	8/12/2020 7:46 AM
16	I’d like to see owners and visitors be more respectful of our lake and understand how fragile it is and how human activities impact it. We need more effort on following rules. Our lake is totally being loved to death. I don’t have much hope for this lake. I feel very sad that it is deteriorating so badly.	8/11/2020 4:27 PM
17	See previous comments.	8/11/2020 8:45 AM
18	Walleye back.	8/10/2020 12:21 PM
19	I would like to see the lake weeds be removed and the lake cleaned up for the residences that live and pay taxes on this lake.	8/10/2020 8:56 AM
20	Water clarity & eradication/management of invasive species.	8/9/2020 5:20 PM
21	Remove Eurasian watermilfoil from the lake	8/9/2020 7:00 AM
22	What I’m really aggravated at is some of the people who run their boats and jet skis on our lake and they absolutely don’t care about going through the shallows ripping up all the weeds and spreading the milfoil. It’s ridiculous. That has to change on our small lake.	8/8/2020 9:58 PM
23	I would suggest a voluntary boat launch fee to assist with MLA funding if permissible by County. Enforcement of no wake law already in place.	8/8/2020 8:25 PM
24	More info for lake residents on what impacts our lake. Encouraging owners not rent out! Rules of boating, taking care of shoreline, water quality, etc.	8/8/2020 6:31 PM
25	Walleye habits and add small mouth, dredge to remove sludge and weeds. Need to dig up sections to restore the balance, treat the lake lake a overgrown pond	8/8/2020 6:10 PM
26	Weed control and control of invasive species.	8/8/2020 4:06 PM
27	Control public landing	8/8/2020 3:50 PM
28	Better control of boaters speeding after 6:00pm and in bays.	8/8/2020 2:49 PM

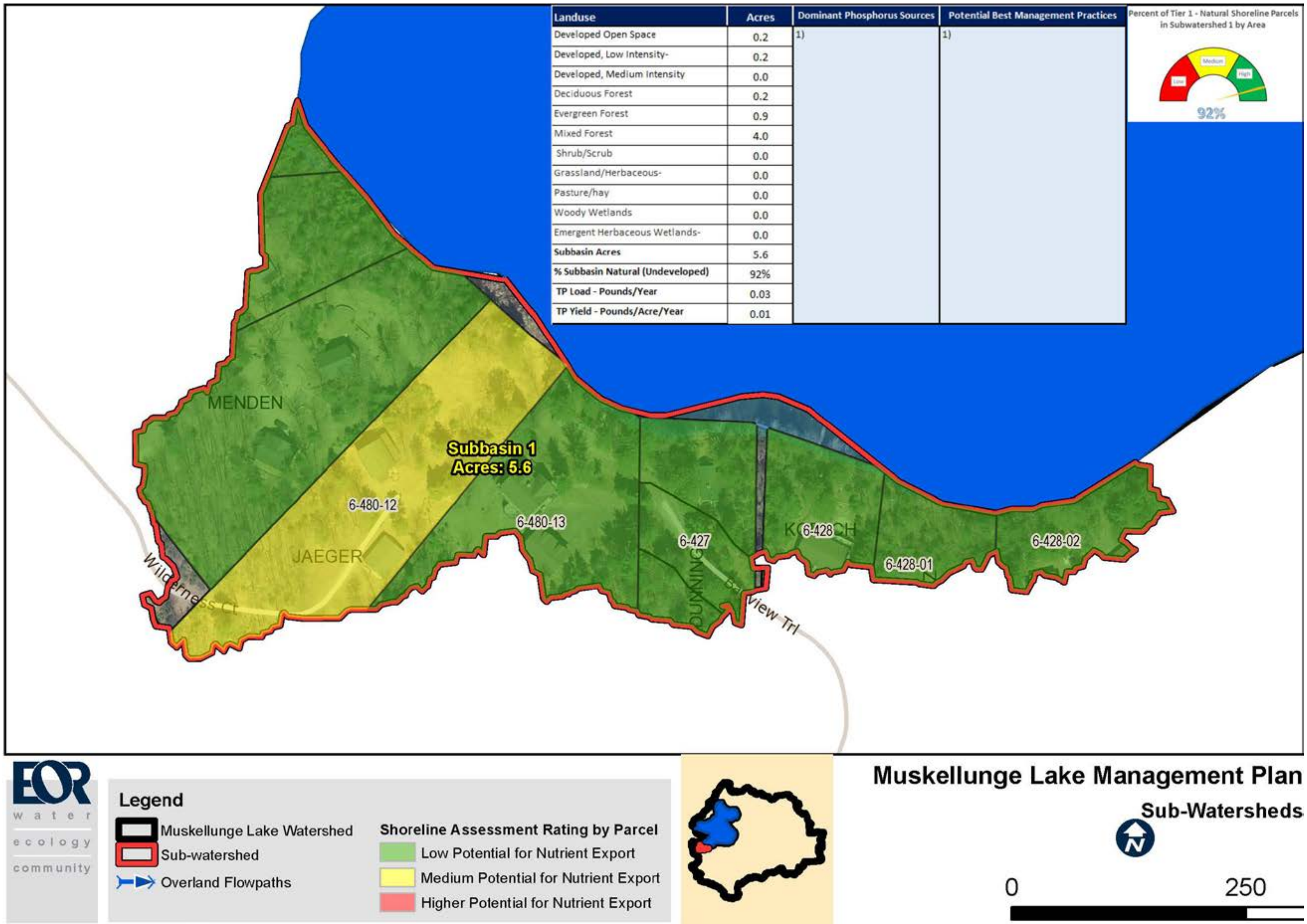
29	Weed control which should cut down the degree of algae bloom. Shoreline restoration	8/8/2020 2:49 PM
30	better control of boats going into bays at high rate of speed.jet skis going past your shoreline 50-100' from it.	8/8/2020 2:20 PM
31	The weeds and lillypads are the biggest problem and they are getting worse	8/8/2020 1:56 PM
32	Musky stock	8/8/2020 1:40 PM
33	Boating regulations inforced. Be good if we had someone on lake who could inforce this. Mail a copy of the cloverland no wake ordinance to every land owner. Put reminders of this in news letters. Until Milfoil is under control no jet skis, and limit inboard motors. We need to put bouy's around areas of Milfoil. Inform all land owners not to fish inside these bouy's.	8/8/2020 1:32 PM
34	Ridding the lake of invasive species	8/8/2020 12:49 PM
35	Remove and Keep milfoil in check/Fish stocking	8/8/2020 12:20 PM
36	Use herbicides to kill EM.	8/8/2020 11:57 AM
37	Reduction in natural aquatic plants. They seem more invasive.	8/8/2020 10:35 AM
38	Water quality	8/4/2020 8:01 PM

Q36 Do you have a specific talent, resources or experience that may be beneficial to the MLA?

Answered: 24 Skipped: 55

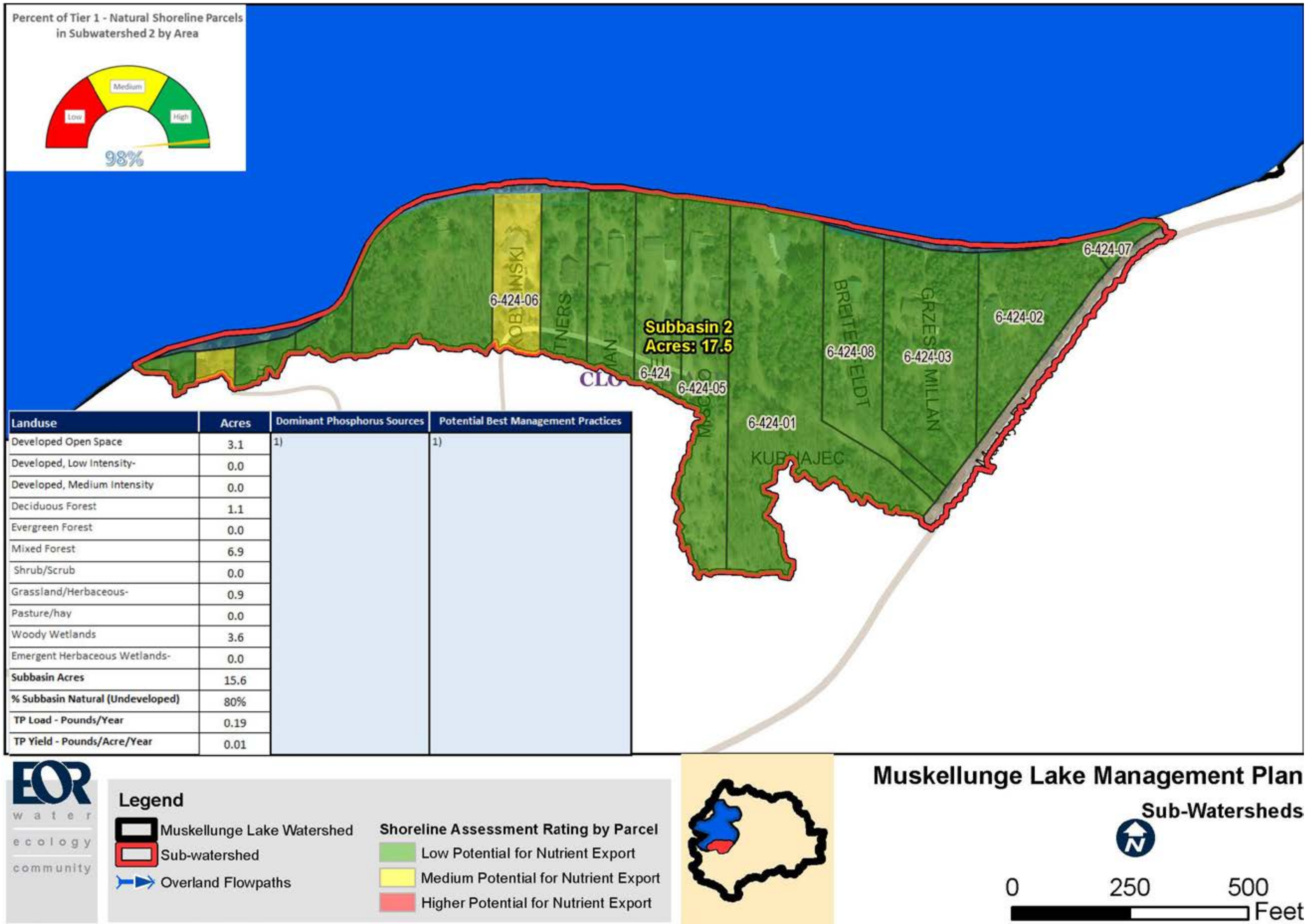
#	RESPONSES	DATE
1	You decide...I have a BS in Natural Resource mgt. - Environmental Law Enforcement. Experience related to water is broad, but have conducted water testing/Flow/etc. on lakes and streams in the past 5 years. I have also performed duties as a research assistant for over 2 years, including manual data entry from surveys.	8/19/2020 3:49 PM
2	Have some ideas would like to try for removal that the association could maybe try on own and have a older pontoon to work with but too long to right about hear	8/15/2020 11:37 PM
3	Strong back, weak mind.	8/15/2020 9:17 AM
4	We don't have specific/talents. Plus, we're aging, :) yet have enjoyed he lake..	8/13/2020 9:16 AM
5	Just time and some financial support. BS Degree in Wildlife Biology from UW Madison	8/13/2020 7:06 AM
6	construction type of work	8/13/2020 7:02 AM
7	Nothing in a professional manner pertinent to invasive species other than contributing money or volunteer time.	8/12/2020 10:26 PM
8	I can write, can contact government people, DNR etc, donate money towards improving our Lake	8/12/2020 7:24 PM
9	Help fund anything that can help	8/12/2020 1:24 PM
10	Time and money and willingness to learn.	8/11/2020 4:27 PM
11	Not that I know of.	8/10/2020 12:21 PM
12	unfortunately, no.	8/9/2020 5:20 PM
13	We are just a family that will help where needed.	8/9/2020 7:00 AM
14	Not really and it’s harder because I don’t live their.	8/8/2020 9:58 PM
15	Not at this time, but hope to do more in a few years.	8/8/2020 6:31 PM
16	Unknown	8/8/2020 6:10 PM
17	No	8/8/2020 4:06 PM
18	not really	8/8/2020 3:50 PM
19	???	8/8/2020 1:40 PM
20	No	8/8/2020 1:32 PM
21	We are willing to help whenever we can	8/8/2020 12:49 PM
22	Handy with projects, running & repairing equipment, Figuring out easier ways to get things done	8/8/2020 12:20 PM
23	No.	8/8/2020 11:57 AM
24	willing to help where needed	8/4/2020 8:01 PM

17. APPENDIX D: SUBWATERSHED LOADING



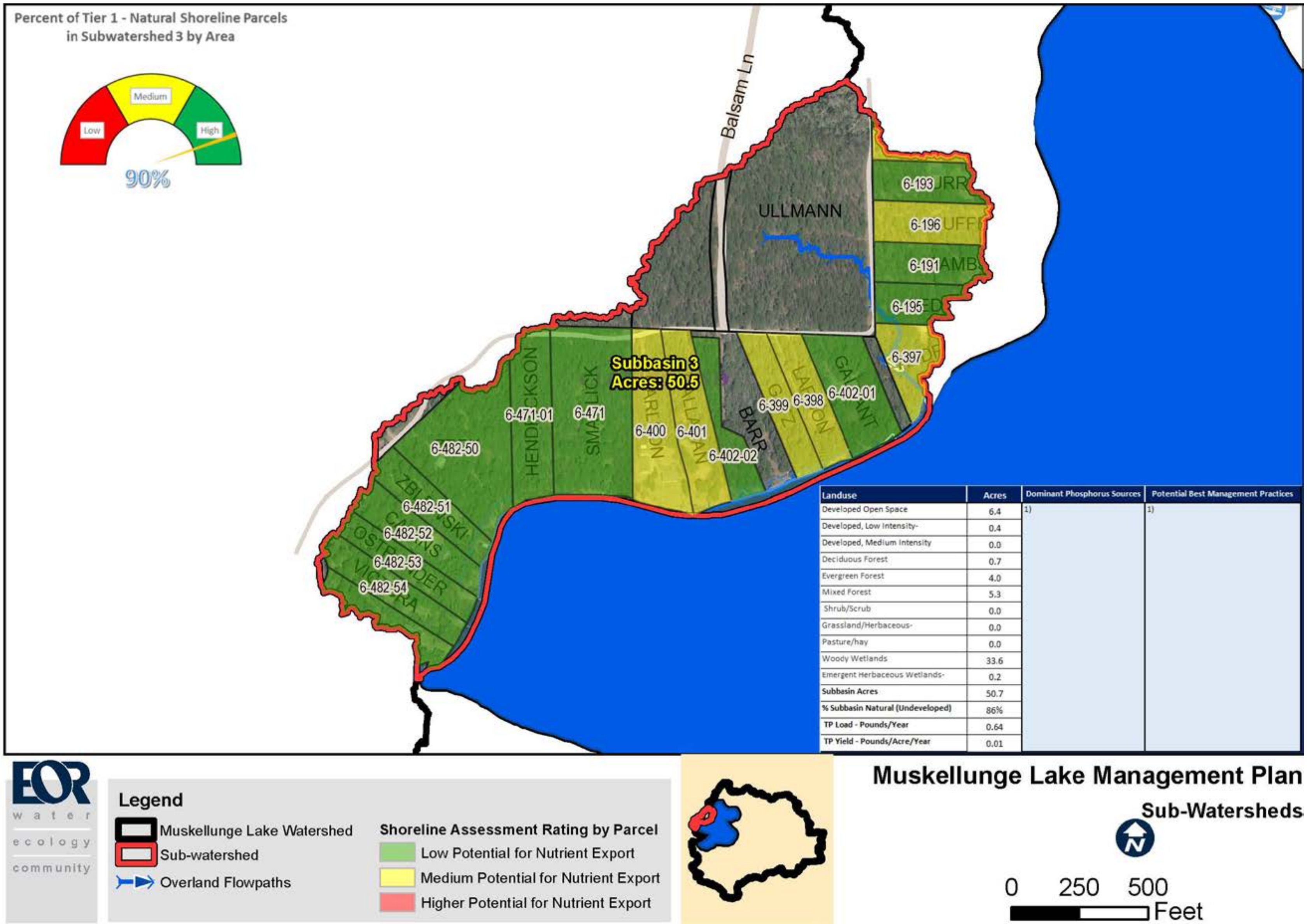
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	0.2	1)	1)
Developed, Low Intensity-	0.2		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.2		
Evergreen Forest	0.9		
Mixed Forest	4.0		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	0.0		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	5.6		
% Subbasin Natural (Undeveloped)	92%		
TP Load - Pounds/Year	0.03		
TP Yield - Pounds/Acre/Year	0.01		

Figure 51. Subwatershed 1 Loading with Shoreline Assessment Rating by Parcel



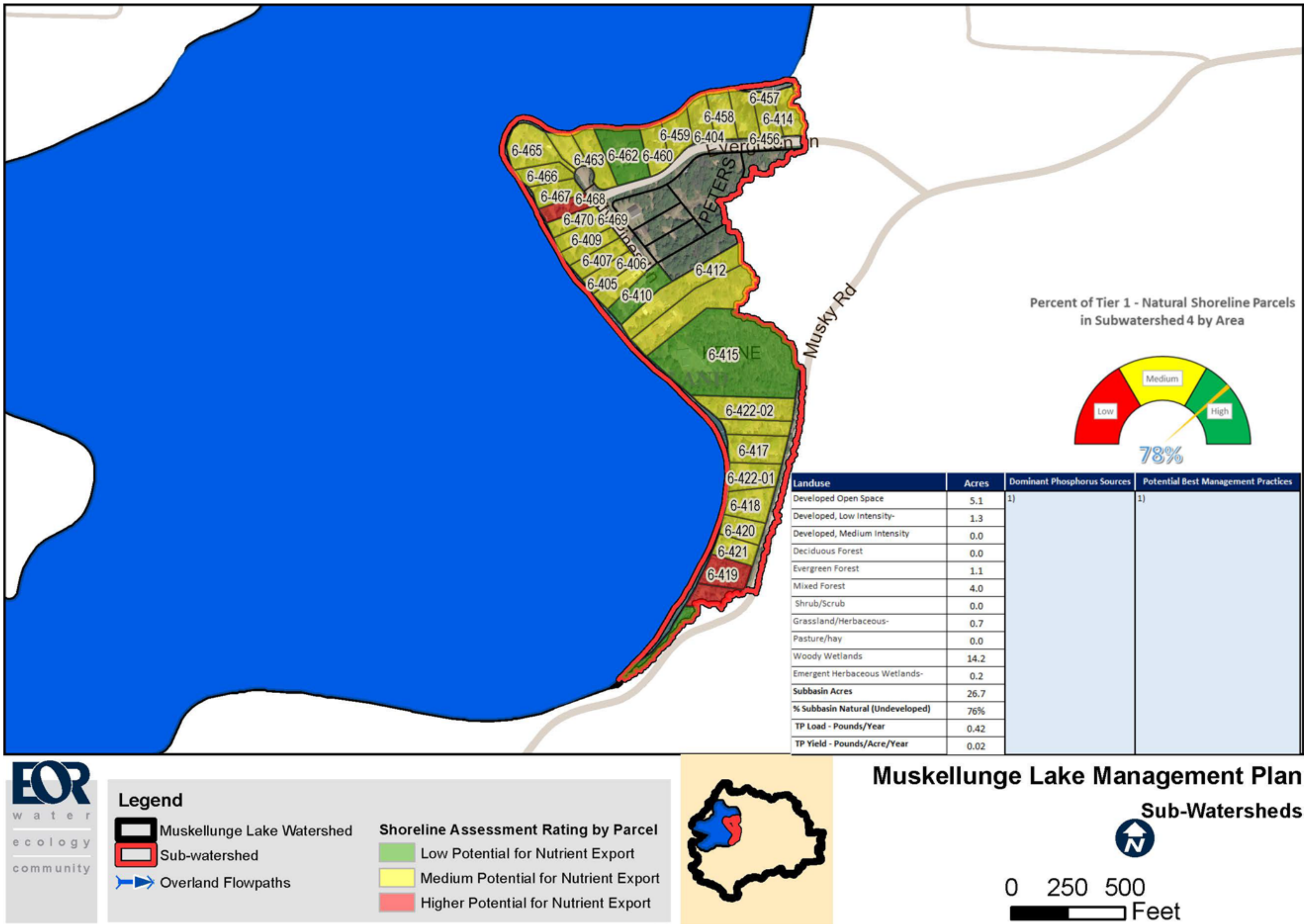
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	3.1	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	1.1		
Evergreen Forest	0.0		
Mixed Forest	6.9		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.9		
Pasture/hay	0.0		
Woody Wetlands	3.6		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	15.6		
% Subbasin Natural (Undeveloped)	80%		
TP Load - Pounds/Year	0.19		
TP Yield - Pounds/Acre/Year	0.01		

Figure 52. Subwatershed 2 Loading with Shoreline Assessment Rating by Parcel



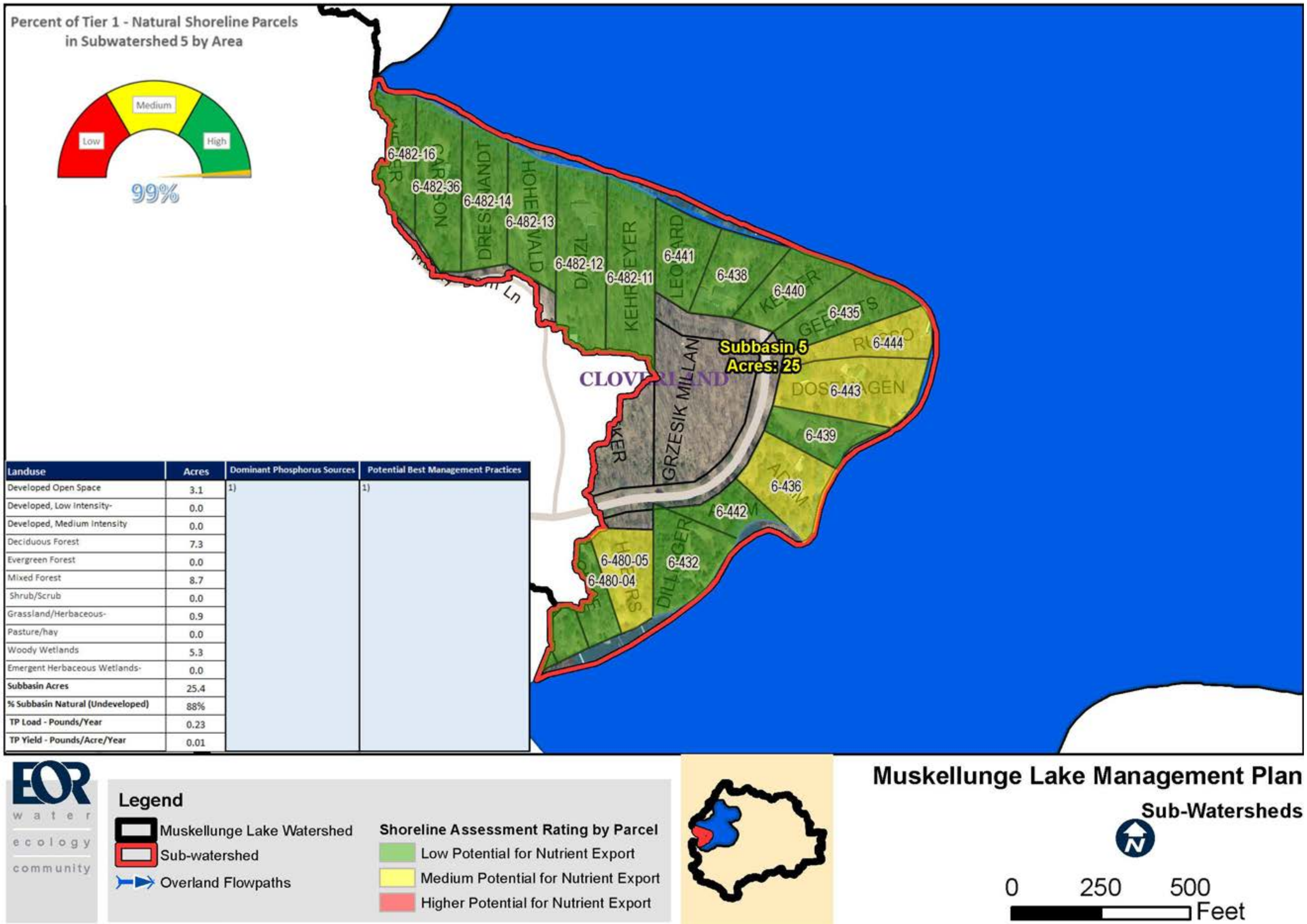
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	6.4	1)	1)
Developed, Low Intensity-	0.4		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.7		
Evergreen Forest	4.0		
Mixed Forest	5.3		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	33.6		
Emergent Herbaceous Wetlands-	0.2		
Subbasin Acres	50.7		
% Subbasin Natural (Undeveloped)	86%		
TP Load - Pounds/Year	0.64		
TP Yield - Pounds/Acre/Year	0.01		

Figure 53. Subwatershed 3 Loading with Shoreline Assessment Rating by Parcel



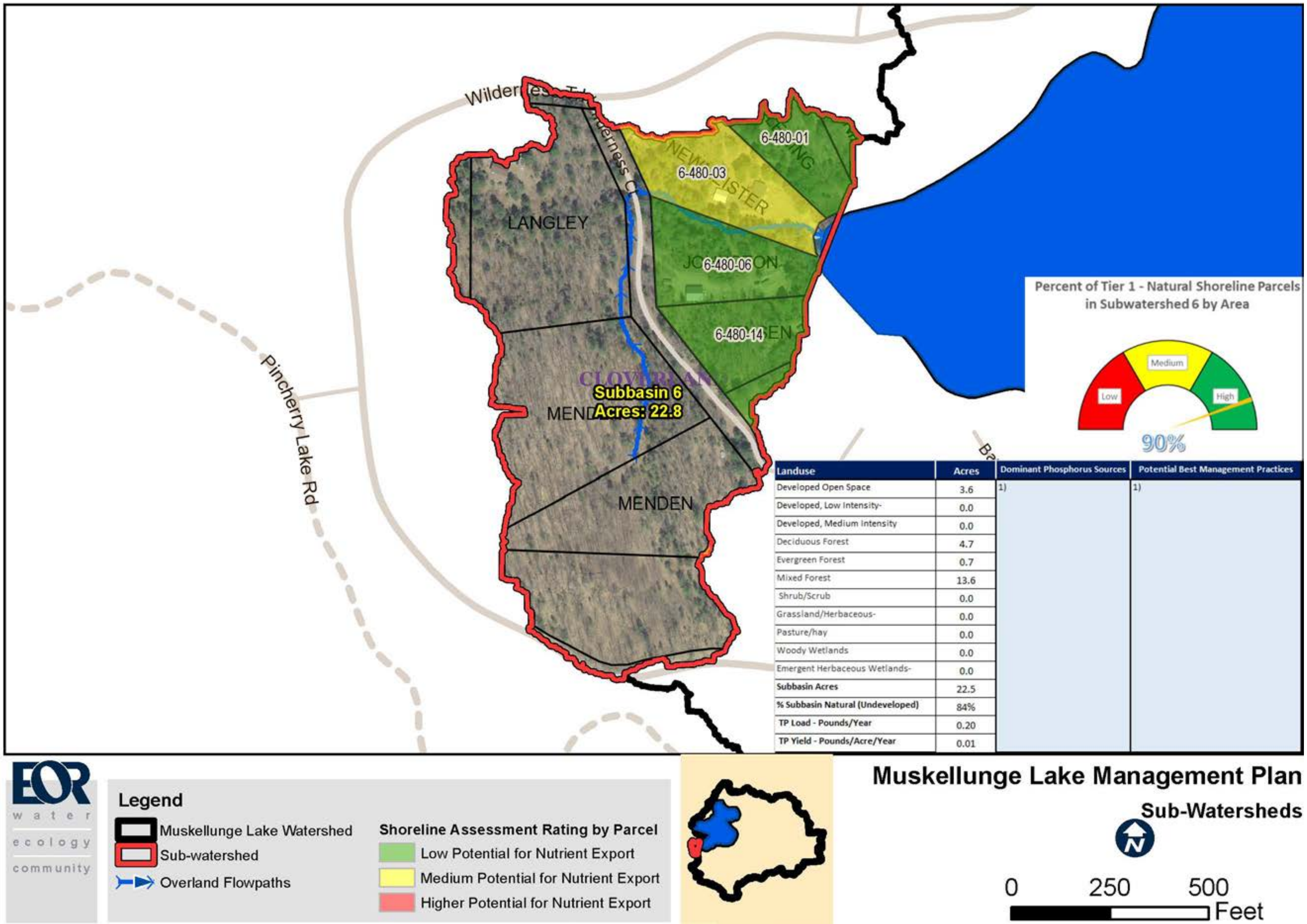
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	5.1	1)	1)
Developed, Low Intensity-	1.3		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.0		
Evergreen Forest	1.1		
Mixed Forest	4.0		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.7		
Pasture/hay	0.0		
Woody Wetlands	14.2		
Emergent Herbaceous Wetlands-	0.2		
Subbasin Acres	26.7		
% Subbasin Natural (Undeveloped)	76%		
TP Load - Pounds/Year	0.42		
TP Yield - Pounds/Acre/Year	0.02		

Figure 54. Subwatershed 4 Loading with Shoreline Assessment Rating by Parcel



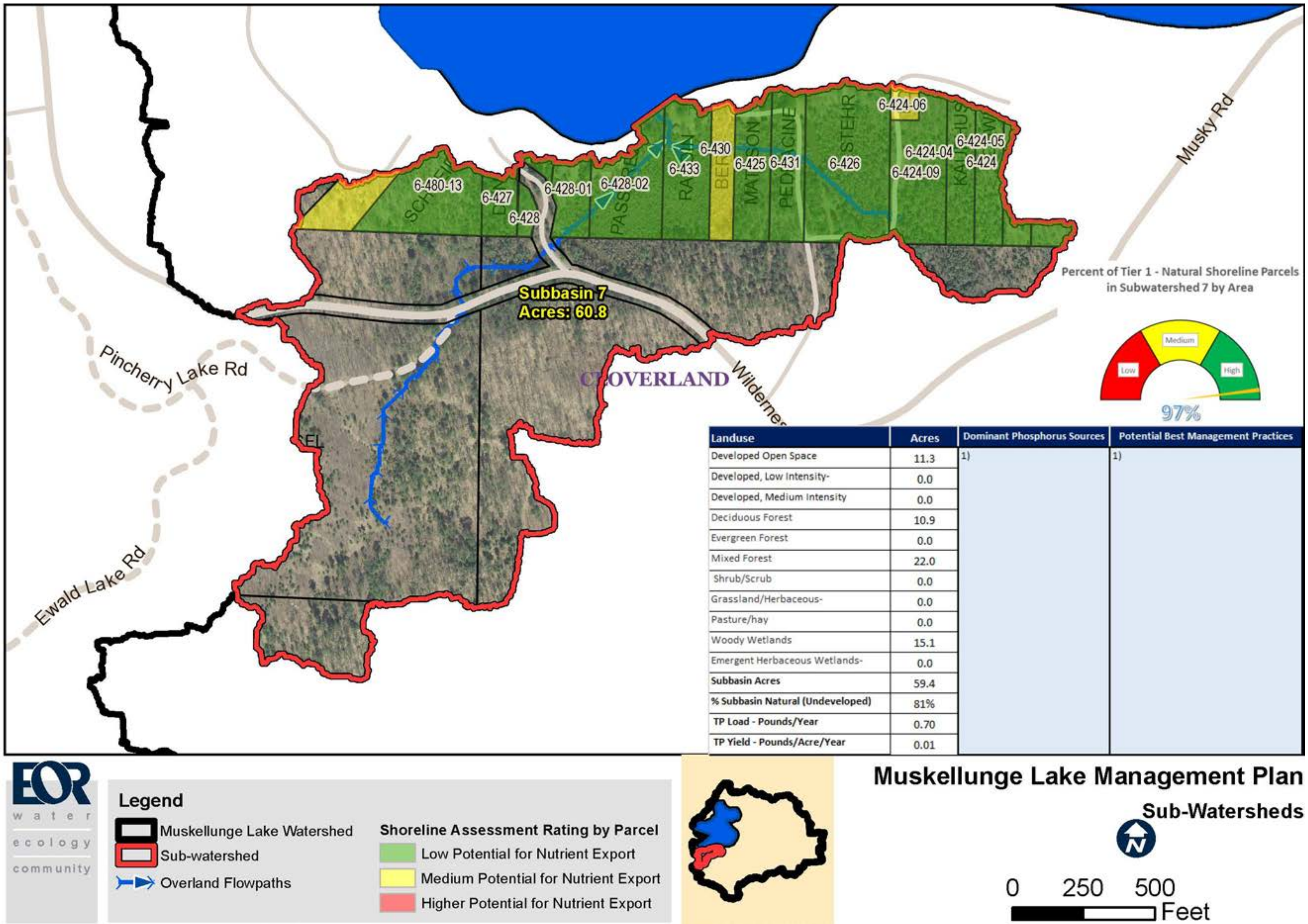
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	3.1	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	7.3		
Evergreen Forest	0.0		
Mixed Forest	8.7		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.9		
Pasture/hay	0.0		
Woody Wetlands	5.3		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	25.4		
% Subbasin Natural (Undeveloped)	88%		
TP Load - Pounds/Year	0.23		
TP Yield - Pounds/Acre/Year	0.01		

Figure 55. Subwatershed 5 Loading with Shoreline Assessment Rating by Parcel



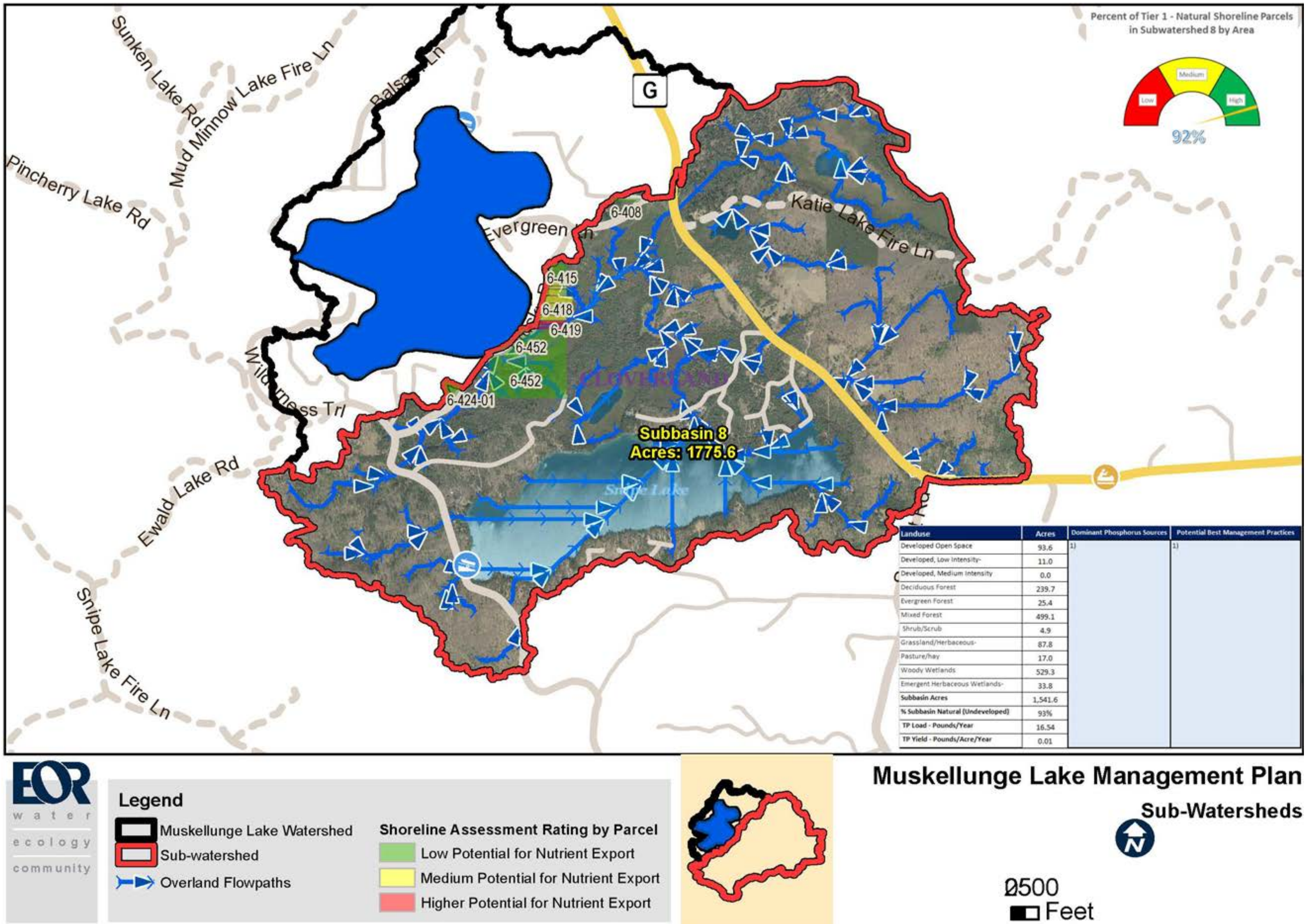
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	3.6	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	4.7		
Evergreen Forest	0.7		
Mixed Forest	13.6		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	0.0		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	22.5		
% Subbasin Natural (Undeveloped)	84%		
TP Load - Pounds/Year	0.20		
TP Yield - Pounds/Acre/Year	0.01		

Figure 56. Subwatershed 6 Loading with Shoreline Assessment Rating by Parcel



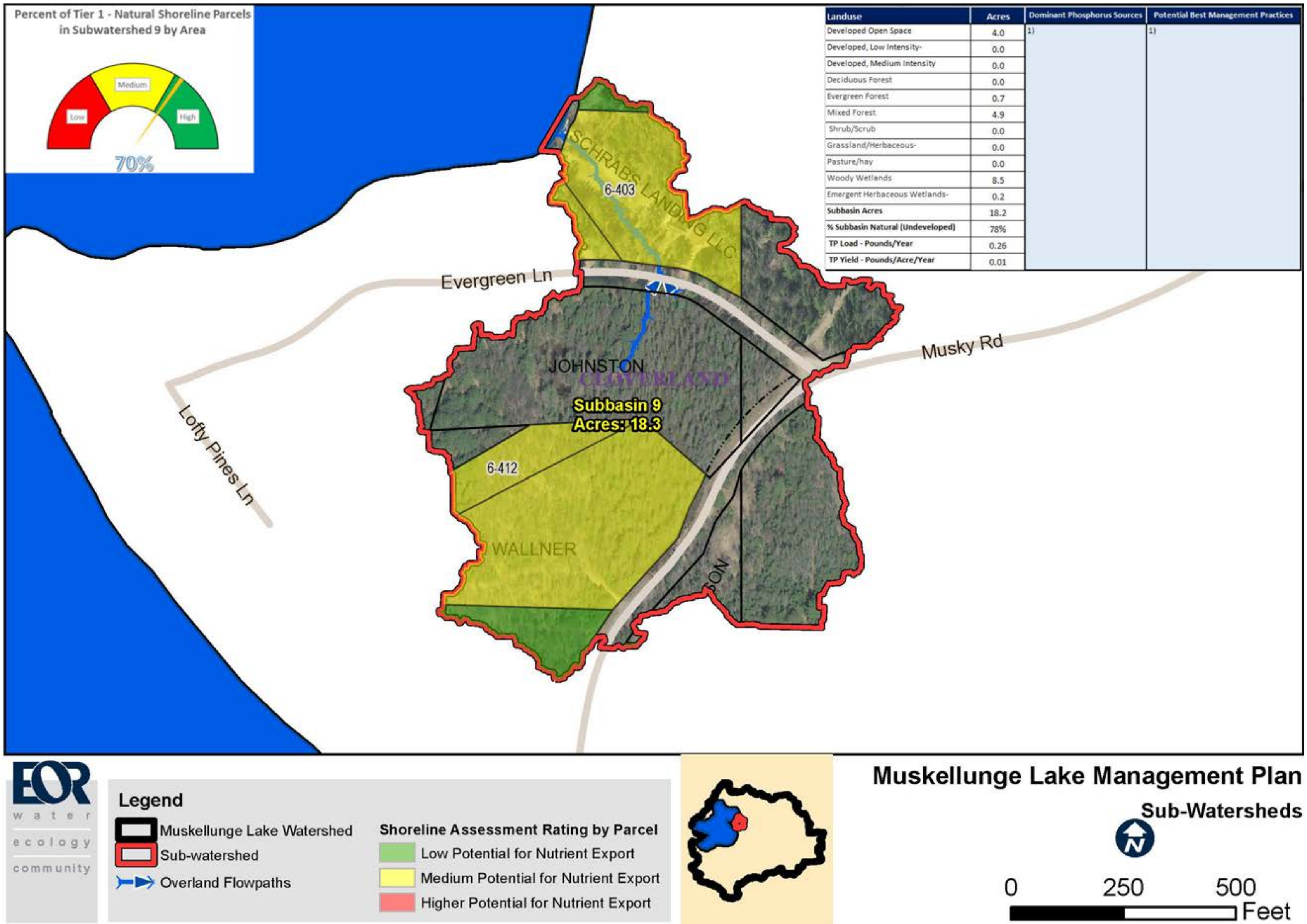
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	11.3	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	10.9		
Evergreen Forest	0.0		
Mixed Forest	22.0		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	15.1		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	59.4		
% Subbasin Natural (Undeveloped)	81%		
TP Load - Pounds/Year	0.70		
TP Yield - Pounds/Acre/Year	0.01		

Figure 57. Subwatershed 7 Loading with Shoreline Assessment Rating by Parcel



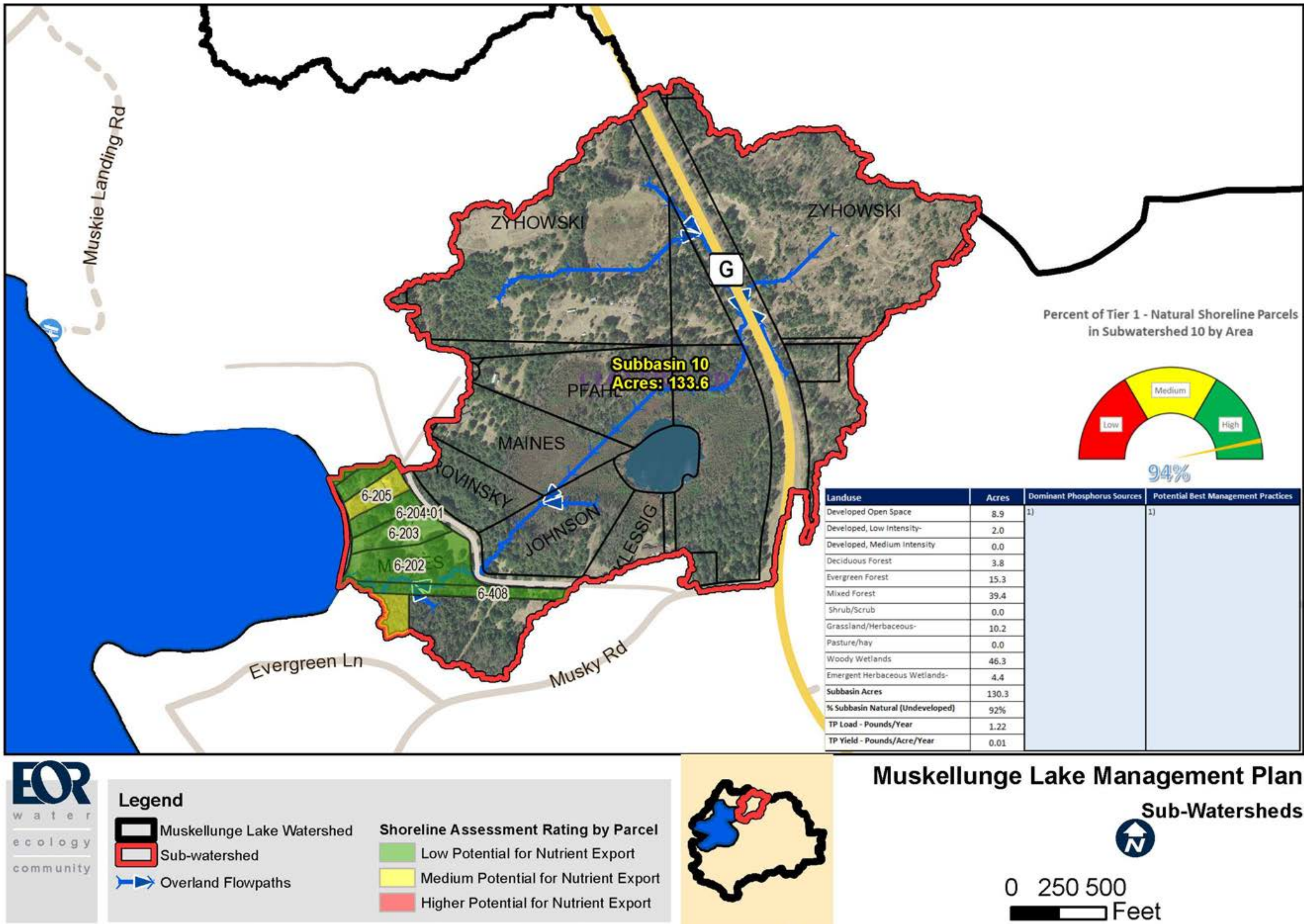
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	93.6	1)	1)
Developed, Low Intensity-	11.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	239.7		
Evergreen Forest	25.4		
Mixed Forest	499.1		
Shrub/Scrub	4.9		
Grassland/Herbaceous-	87.8		
Pasture/hay	17.0		
Woody Wetlands	529.3		
Emergent Herbaceous Wetlands-	33.8		
Subbasin Acres	1,541.6		
% Subbasin Natural (Undeveloped)	93%		
TP Load - Pounds/Year	16.54		
TP Yield - Pounds/Acre/Year	0.01		

Figure 58. Subwatershed 8 Loading with Shoreline Assessment Rating by Parcel



Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	4.0	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.0		
Evergreen Forest	0.7		
Mixed Forest	4.9		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	8.5		
Emergent Herbaceous Wetlands-	0.2		
Subbasin Acres	18.2		
% Subbasin Natural (Undeveloped)	78%		
TP Load - Pounds/Year	0.26		
TP Yield - Pounds/Acre/Year	0.01		

Figure 59. Subwatershed 9 Loading with Shoreline Assessment Rating by Parcel



Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	8.9	1)	1)
Developed, Low Intensity-	2.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	3.8		
Evergreen Forest	15.3		
Mixed Forest	39.4		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	10.2		
Pasture/hay	0.0		
Woody Wetlands	46.3		
Emergent Herbaceous Wetlands-	4.4		
Subbasin Acres	130.3		
% Subbasin Natural (Undeveloped)	92%		
TP Load - Pounds/Year	1.22		
TP Yield - Pounds/Acre/Year	0.01		

Figure 60. Subwatershed 10 Loading with Shoreline Assessment Rating by Parcel

Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	2.9	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.2		
Evergreen Forest	0.9		
Mixed Forest	2.2		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	3.6		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	9.8		
% Subbasin Natural (Undeveloped)	70%		
TP Load - Pounds/Year	0.16		
TP Yield - Pounds/Acre/Year	0.02		

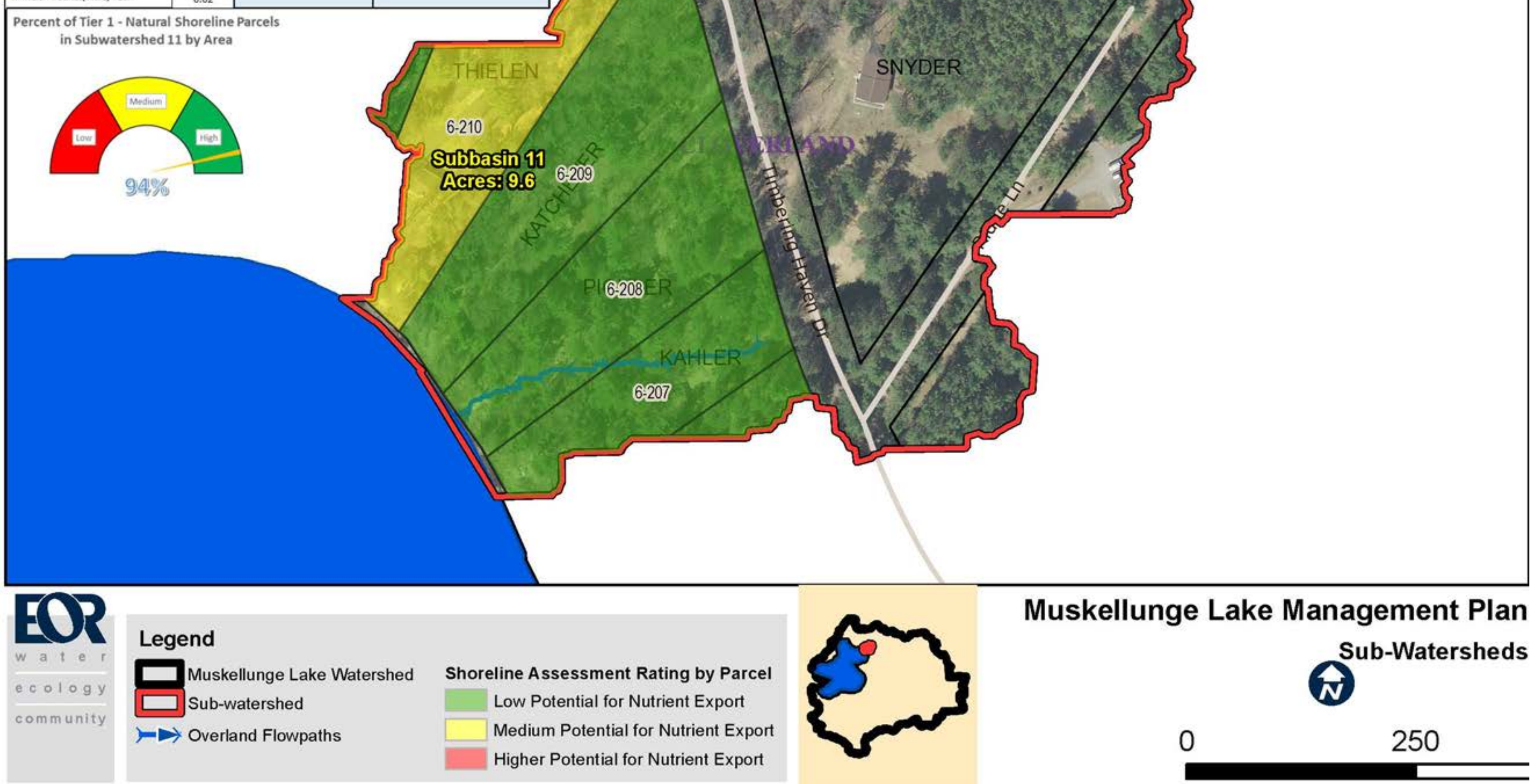
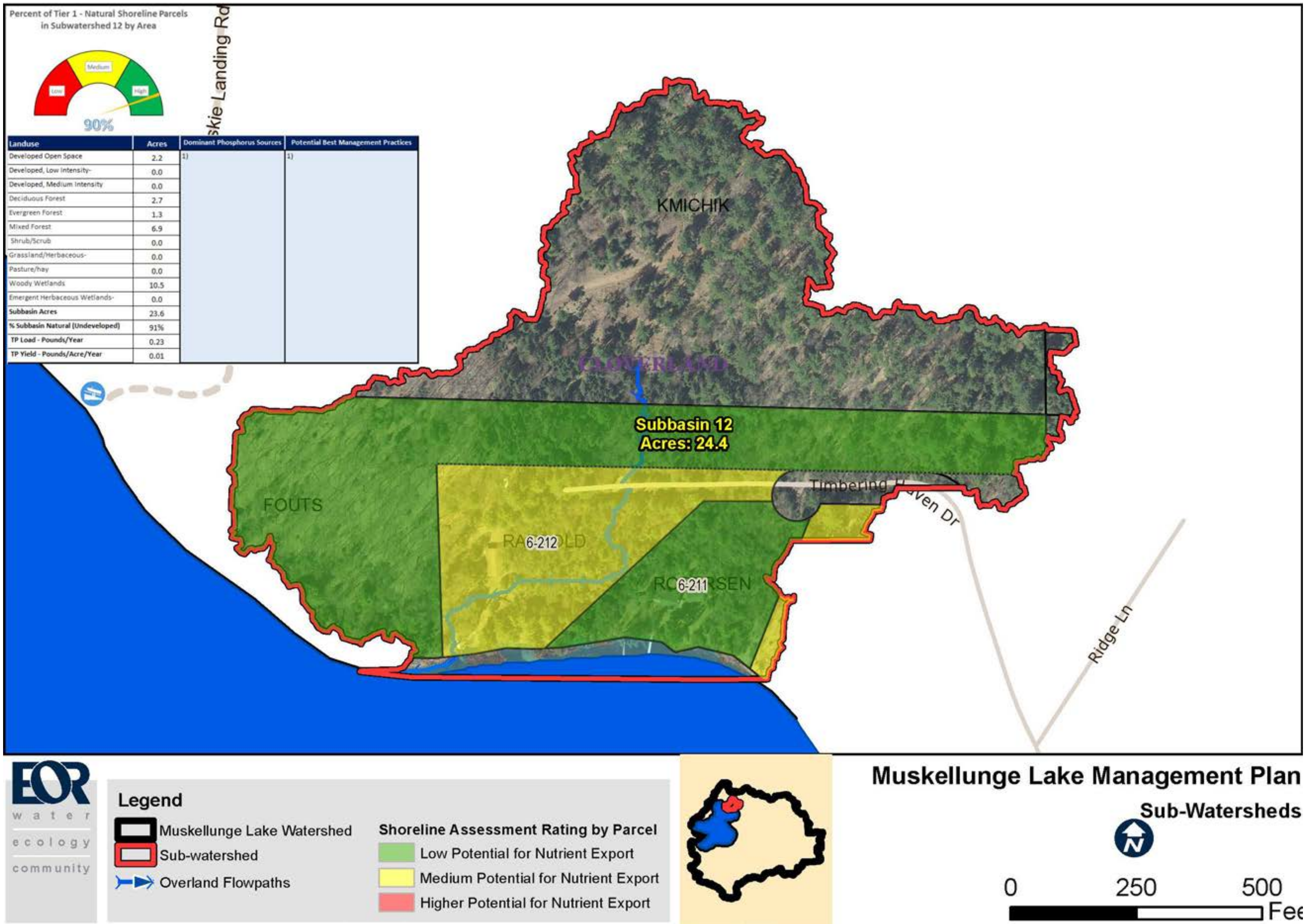
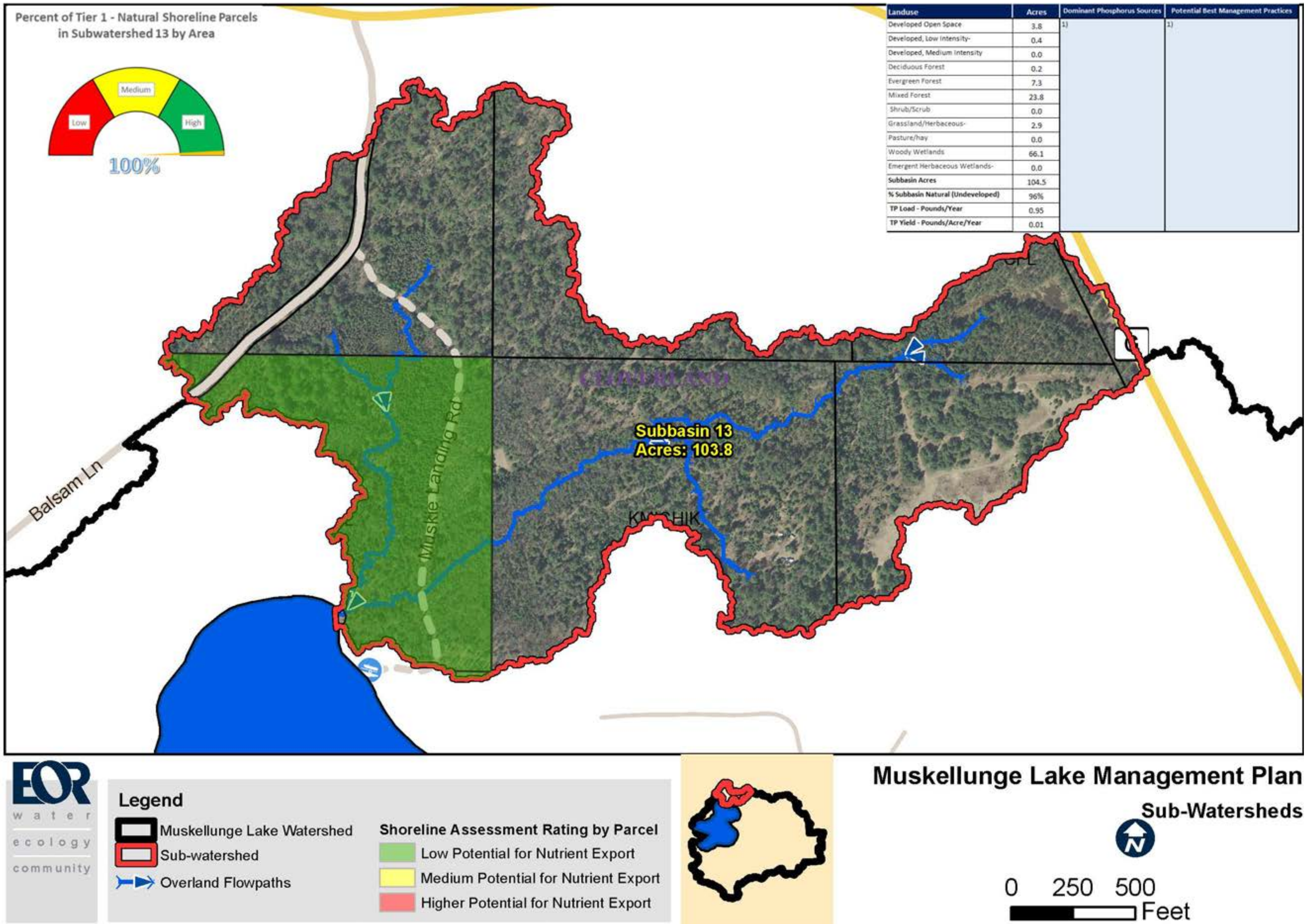


Figure 61. Subwatershed 11 Loading with Shoreline Assessment Rating by Parcel



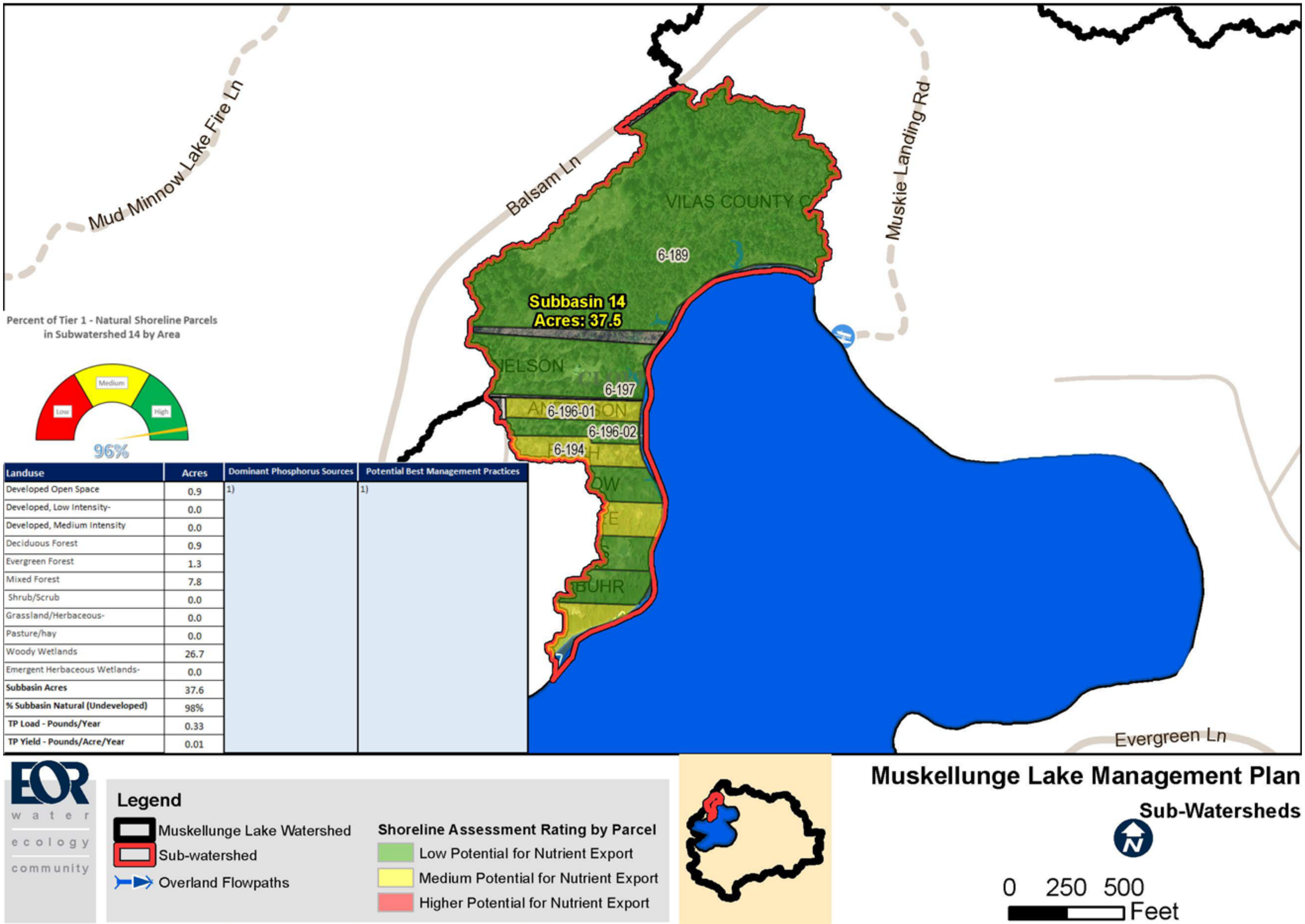
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	2.2	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	2.7		
Evergreen Forest	1.3		
Mixed Forest	6.9		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	10.5		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	23.6		
% Subbasin Natural (Undeveloped)	91%		
TP Load - Pounds/Year	0.23		
TP Yield - Pounds/Acre/Year	0.01		

Figure 62. Subwatershed 12 Loading with Shoreline Assessment Rating by Parcel



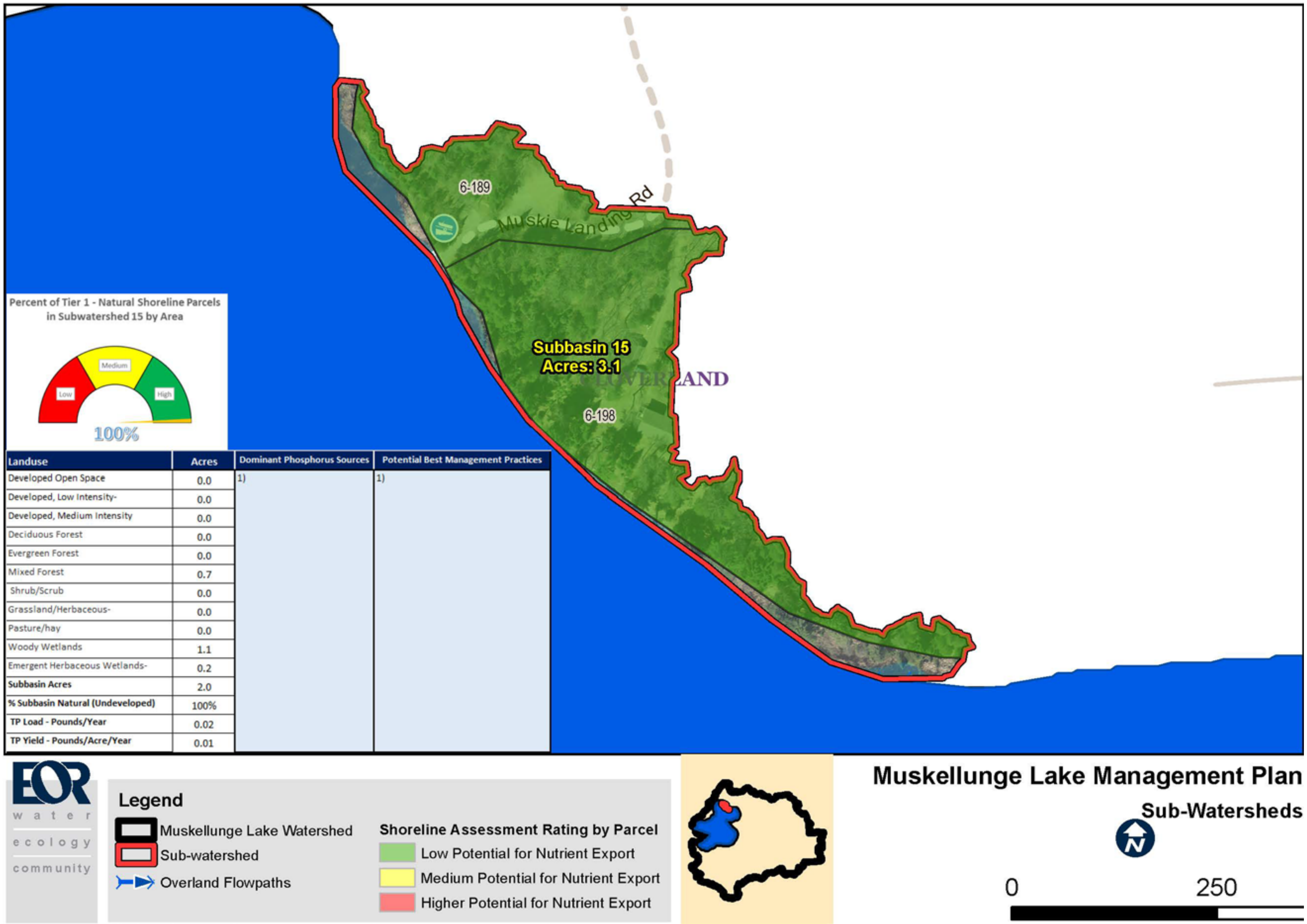
Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	3.8	1)	1)
Developed, Low Intensity-	0.4		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.2		
Evergreen Forest	7.3		
Mixed Forest	23.8		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	2.9		
Pasture/hay	0.0		
Woody Wetlands	66.1		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	104.5		
% Subbasin Natural (Undeveloped)	96%		
TP Load - Pounds/Year	0.95		
TP Yield - Pounds/Acre/Year	0.01		

Figure 63. Subwatershed 13 Loading with Shoreline Assessment Rating by Parcel



Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	0.9	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.9		
Evergreen Forest	1.3		
Mixed Forest	7.8		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	26.7		
Emergent Herbaceous Wetlands-	0.0		
Subbasin Acres	37.6		
% Subbasin Natural (Undeveloped)	98%		
TP Load - Pounds/Year	0.33		
TP Yield - Pounds/Acre/Year	0.01		

Figure 64. Subwatershed 14 Loading with Shoreline Assessment Rating by Parcel



Landuse	Acres	Dominant Phosphorus Sources	Potential Best Management Practices
Developed Open Space	0.0	1)	1)
Developed, Low Intensity-	0.0		
Developed, Medium Intensity	0.0		
Deciduous Forest	0.0		
Evergreen Forest	0.0		
Mixed Forest	0.7		
Shrub/Scrub	0.0		
Grassland/Herbaceous-	0.0		
Pasture/hay	0.0		
Woody Wetlands	1.1		
Emergent Herbaceous Wetlands-	0.2		
Subbasin Acres	2.0		
% Subbasin Natural (Undeveloped)	100%		
TP Load - Pounds/Year	0.02		
TP Yield - Pounds/Acre/Year	0.01		

Figure 65. Subwatershed 15 Loading with Shoreline Assessment Rating by Parcel

18. APPENDIX E: RESPONSE TO COMMENTS

18.1. Introduction

The following comments are a compilation of many reviewers. EOR/MLA has provided a response to each comment and has included recommendations on where readers can find more information within the lake management plan.

18.2. GLIFWC Comments:

There is very little tribal harvest that occurs on Muskellunge, however, the outlet at Muskellunge Creek is only a third of a mile from a rice bed on the creek (and about 3.4 miles from an important fishery water, Little St Germain - but that is probably outside the scope of this plan).

That said, here's a thought and I wonder how you feel about it. Their 3-year plan has some really small treatment polygons. I'm still not totally onboard with repeated micro-treatments which will require some pretty high application rates to get the CET needed. These will ultimately affect more than the target species and potentially wash down the creek. Good to see they aren't promoting some often-used 2,4-D formulations; I'm interested to see the results that come out of other ProcellaCor treatments since those seem to be on the increase; but we tend to discourage the use of Diquat.

My biggest take-home to the authors would be to consider and incorporate the downstream consequences and impacts to the natural resources within and beyond the lake-proper that will undoubtedly be impacted by any/all of their chemical aquatic plant management treatment(s). miigwech

Lisa A. David, GLIFWC Wild Rice Specialist

Response:

The MLA acknowledges GLIFWCs concerns regarding potential unintended consequences to Little Saint Germain Lake and to the wild rice beds on Muskellunge Creek. We have removed the use of Diquat as a recommended strategy for Muskellunge Lake.

Section 13.1 and Section 13.2 provide an overview of the integrated pest management strategy for Muskellunge Lake that includes plant monitoring and/or herbicide concentration testing on Muskellunge Creek to provide documentation as to potential unintended consequences. The DNR will provide the MLA and contractors with information regarding the current location and health of the wild rice bed on Muskellunge Creek. Herbicide concentration monitoring and aquatic plant surveys will be conducted following all treatment efforts.

18.3. WI DNR Comments:

- 2.1: Would be helpful to include some details here which better quantify the hand-removal and DASH efforts which were implemented in 2017, 2018, & 2019 (i.e., how many days/hours, how many volunteers, lbs of plants removed, etc.).

Response:

See Annual Reports from 2017 (Appendix E), 2018 (Appendix F), and 2019 (Appendix G) for detailed information on how hand-removal and DASH efforts were implemented.

- 4.1: Muskellunge Lake is shallow and the TSI data indicates that it is eutrophic to hypereutrophic (the lake is also currently 303d listed due to excess algae). Section 3 in the report talks about shallow lake biology and alternative stable states. The suggested management strategy to chemically treat numerous areas of EWM around the lake (and potentially have non-target impacts to native aquatic plants while doing such) may very well result in more turbid waters and more extensive algae blooms in the future (especially if this chemical strategy is implemented for 3-5 consecutive years). There needs to be more of a critical discussion on how the goal of managing AIS fits into the goal of improving/protecting WQ and preventing a sudden shift to an algae dominated state.

Response:

The frequency of occurrence of plants at sites shallower than the maximum depth (9-10 feet) of plant growth has increased by approximately eight percent since the 2017 survey. The portion of Muskellunge Lake that is less than 10 feet deep equates to an area of 169 acres, or approximately 63% of the total surface area of Muskellunge Lake. Multiplying 8% by the 169-acre portion of Muskellunge Lake that is less than 10 feet deep equates to an increase in the portion of Muskellunge Lake that is now supporting aquatic plants of approximately 13.5 acres. The total treatment area targeted for 2021 is approximately 26 acres. If control efforts successfully reduce EWM abundance in these targeted areas by 50%, approximately 13 acres of EWM or other native species not affected by the treatment that has replaced EWM will be remaining. This does not take into account the potential for native species to also reintegrate themselves into the niche that is vacated by the reduction in EWM. Because a healthy native aquatic plant community is so critical to the ecology of Muskellunge Lake, additional goals of the recommended EWM management approach include:

1) *Maintain 70% or greater frequency of occurrence of aquatic vegetation in the areas of lake that are less than 10 feet deep.*

2) *EWM management actions do not negatively affect the diversity of the aquatic plant species in Muskellunge Lake.*

Year	2020	2017	2009
Total number of sites visited	**234**	**226**	**314**
Total number of sites with vegetation	**158**	**136**	**225**
% of sites w/ vegetation	**67.5%**	**60.2%**	**72%**
Max depth of aquatic plant growth	**9**	**9**	**12**
Frequency of occurrence at sites shallower than maximum depth of plants	**80.2%**	**72.7%**	**72.1%**

Furthermore, a review of TSI data as presented in section 4.1 shows that TSI (TP) = (Chl) = TSI (Secchi). Based on this analysis we concluded that algae dominate light attenuation and that algae biomass is controlled by phosphorus (Carlson, 1992).

This means that Muskellunge Lake has historically not been in the ecologically preferred clear water; aquatic plant dominated state. Reductions of in-lake TP concentrations will be required to reduce algae biomass. If we can reduce in-lake algae concentrations through reductions in internal or external loading, we may observe an expanded littoral zone and a switch to a clear water aquatic plant dominated state.

- 5.1: Stakeholder survey response rate was 51%. Jordan P. used to state that a 60% response rate was required in order to confidently state that the survey results reflects the 'majority'? If so, a disclaimer statement should be added in this section, and some re-wording of the results may also be warranted (i.e., I don't think it's appropriate to use the word 'majority'?). Also, when was this survey conducted in the planning process? Was there any education/outreach efforts on management options prior to this survey being sent out? Some of the free-form responses seem to indicate that some riparians are '*not educated enough on the pluses & minuses of each treatment*' and that '*we need to do whatever it takes*', which adds some uncertainty to the validity of the survey results presented. NOTE: Jordan P. retired and we are still waiting for comments from his interim replacement.

  Response rate was 67%. Survey was conducted in August of 2020, prior to the development of the plan. MLA has conducted several meetings and maintains a website with all relevant information. The comment from the landowner not being educated enough on the pluses and minuses of each treatment comes from a landowner who just moved to Muskellunge Lake in 2020. Muskellunge Lake webmaster Jeff Rappold has reached out to the individual and provided them with additional information following this response.

  6.1.1: Do you have an electronic excel copy of the most recent PI data from 2020 which you can forward us? Doesn't have to be ASAP, just want to be sure we eventually get a copy of it for our statewide database (we do have the 2009 & 2017 PI data already).
  Sent to Carol Warden on 9/22

- Table 1: How was the "noteworthy change in relative frequency" determined? Was there a statistical analysis done (and if so, which one?). Also, we typically examine trends in the littoral %FOO over time (vs. the relative % frequency over time which is presented in this report). The text notes that '*the relative frequency of coontail, fern pondweed, and flat-stem pondweed decreased significantly'* and attributes this change to the '*arrival of EWM*'. However, the text neglects to also mention that the relative frequency of northern watermilfoil, large-leaf pondweed, wild celery, and white water lily all <u>increased</u> during this same exact timeframe. The average C-value of the three species which declined is 5.66, while the average C-value of the four species which increased is 6.5; a more balanced and unbiased discussion of the dynamic nature of plants is important to include here.

  Changed discussion from relative frequency to Frequency of Occurrence (FOO). See Section 6.1.1 for additional details/discussion.

- 6.2.3: The wet biomass data presented in the prior section (Fig 12) indicated that the DASH areas had significantly less EWM biomass than untreated reference areas. However, Observation #1 then states that one year post-treatment there was no difference in EWM abundance in DASH treatment areas versus reference areas. Was there similar biomass/rake fullness data collected in 2020 that was statistically compared to 2019? If so, that data should be presented here (and if not, it should be made clear that this observation is anecdotal). Also, the word 'ineffective' in this sentence is not necessary.

  Removed the word 'ineffective'. Added Figure 17 in Section 6.2.3. It was immediately clear that EWM Biomass had completely recovered from 2019 DASH efforts. No biomass *samples were taken as it became clear that DASH represented an in-effective solution for this area.*

- Table 2: The 22 individual treatment polygons encompass 21.7 acres. Since the lake is 272 acres, this may potentially be a borderline whole lake treatment if all of these areas were treated with herbicide during a single application (i.e., 21.7/272 = 8% lake surface area). It is also unclear what each of the three tiers necessarily means? Are *all* of these areas slated for management, or only some? (The footnote also indicates that this doesn't include every single EWM location? How were these 22 treatment areas determined?). The 'current image' column is also blank (assuming there's site photos or links which belong here?).

  The 22 treatment polygons were consolidated into 12 larger polygons that collectively represent the portions of Muskellunge Lake that contain concentrated stands of EWM. Future updates, including the addition or removal of treatment polygons will be based on an adaptive management strategy that seeks to constantly refine our recommended approach on a 1-2 year basis based on results from continued volunteer and professional AIS monitoring following EWM management.

- 7.2.1: The intent of this section is to provide a 'scientific review' of all available management options, but there is a very clear bias in the way much of this section is currently written (i.e., the first paragraph basically states that 'chemical control *should* be the primary mechanism' for controlling EWM on Muskellunge since it's a technique that has been commonly used in WI & MN; applying a 'one size fits all' approach to management is not good science). This section needs some major revision if the authors are claiming that it's a 'scientific review'.

  Revised – see sections 7.2, 7.3

- Table 3: There isn't a single 'disadvantage' listed under ProcellaCOR. At minimum, the author could add: "*data on non-target impacts and long-term efficacy is not readily available*" as well as "*relatively expensive*" (~$2800/acre is not cheap). Also the blanket statement that ProcellaCOR is 'selective for EWM' is not necessarily true. The herbicide label lists several native species as susceptible (i.e., coontail, watershield, native milfoils, etc.), and data on non-target impacts is still ongoing. More comments to come on Table 3.

  Revised – see Table 3

- 7.2.2.: There isn't a single 'advantage' listed for mechanical harvesting (only negatives) – need a more balanced discussion of both pros & cons. There are many lakes in WI (beyond the Madison Lakes) which utilize mechanical harvesting as part of a long-term integrated management strategy. The Turville Bay study illustrated that early season deep-cut harvesting *can* be selective for EWM and help promote native plants. What is the scientific source of this statement "*if EWM can grow 1 to 2 inches per day as reported*"?
  Revised – see Section 7.3.2

- 7.2.3: There isn't a single 'advantage' listed for biological control with weevils (only negatives) – need a more balanced discussion of both pros & cons.
  Revised – EOR has been in discussions w/ Cathy Higley and DNR regarding milfoil weevils since 2018. We are committed to incorporating lessons learned from Upper and Lower Buckatabon into future recommendations for Muskellunge Lake.

- 7.3: How were these seven lakes selected to include as 'case studies'? How relevant are these lakes in comparison to Muskellunge (in terms of lake type, lake depth, trophic status, invasion timeline, native plant communities, etc.)?

  Kathan Lake – *Chosen due to similar size, location, and morphometry to Muskellunge Lake. Also served as a representative Case Study of the whole-lake treatment approach.*

  Big Marine Lake – *Chosen due to refreshing, proactive approach to EWM management and commitment to advancing the science of aquatic plant management. The Big Marine Lake Association's innovative approach to managing EWM provides a refreshing example of pro-active EWM management that has resulted in the successful reduction of EWM coverage from 38.6 acres in 2014 to 3.8 acres in 2020 (pre-treatment), less than 2 acres (post-treatment) – results pending. More information on the Big Marine available on the Initiative Foundation website here: https://www.ifound.org/community/aquatic-invasive-species/*

  EOR has had similar successes (EWM reduction) on nearby Long Lake in Washington County, MN. Long Lake has similar size and water quality characteristics to Muskellunge Lake. On 9/24/2020, EOR provided DNR with a document showing how EWM reductions were achieved on Long Lake through the use of an adaptive management approach.

  Boot Lake – *Chosen due to similar size, location, and morphometry to Muskellunge Lake. Also served as a representative Case Study of the "no-treatment approach".*

  North/South Twin– *Chosen because it was one of the only lakes in Vilas County that have experimented with an integrated strategy that combines ProcellaCOR and DASH. Muskellunge Lake Association is interested in a similar integrated approach that uses ProcellaCOR for 1+acre colonies which exhibit moderate, dense or dominant EWM and DASH to control <1 acre colonies that exhibit low density, scattered EWM growth.*

  Upper/Lower Buckatabon– *Chosen because it is a Vilas County Lake that is located in close proximity to Muskellunge Lake that is experimenting with Milfoil Weevils and may therefore have a high degree of relevancy to Muskellunge Lake.*

- 7.3.1: The 2009 Kathan Lake PI survey was conducted by WDNR Science Services (not Onterra). Northern watermilfoil was never a dominant species on Kathan (and wasn't even found at all during the most survey years), so there is actually no evidence that EWM 'replaced' NWM. Kathan Lake does not have public access (and thus aren't eligible for an AIS control grant, which it states was denied?). Kathan actually did conduct another whole-lake 2,4-D treatment in 2016 as part of the UWSP research project with Dan Isermann et al.

  Updated – see Section 7.1.1

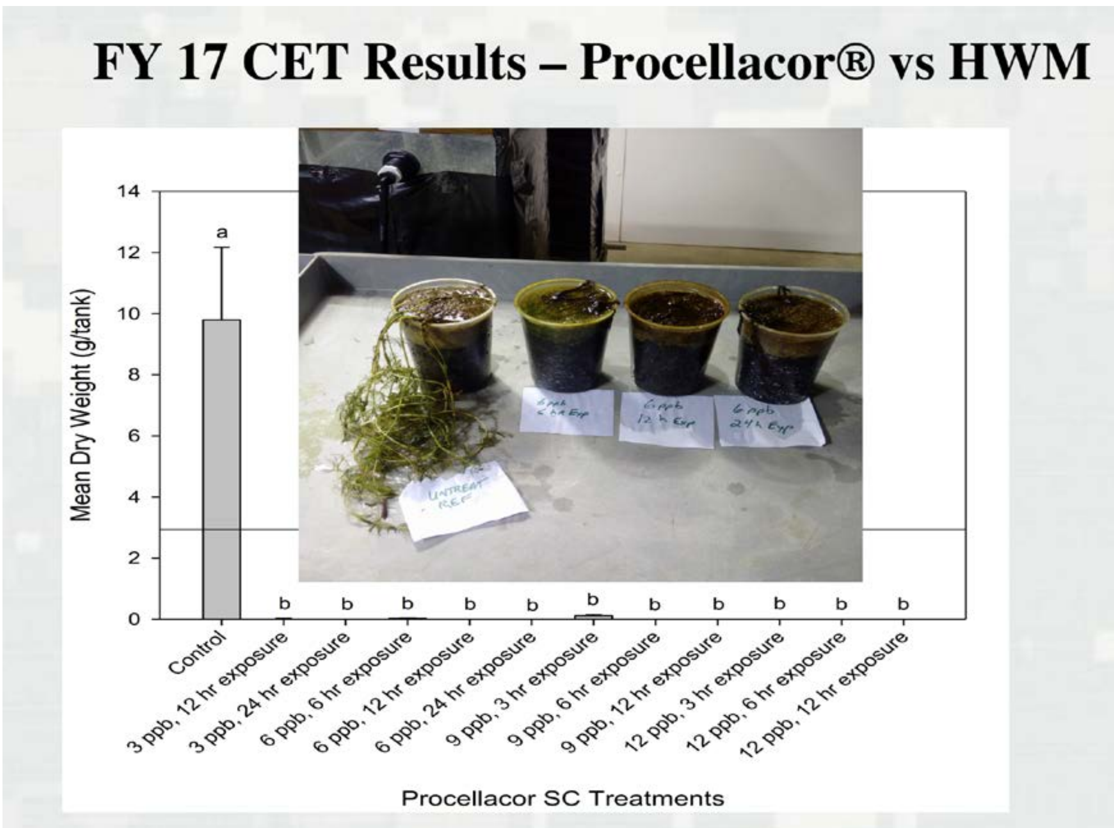
- 7.3.2: Big Marine Lake is 1800 acres with a max depth of 60 feet. Is this really comparable to Muskellunge (272 acres, 15 ft max depth)?

  Big Marine was chosen as an example commitment to advancing the science of EWM management. EOR has had similar successes on nearby Long Lake in Washington County, MN using ProcellaCOR. Long Lake has similar size and water quality *characteristics to Muskellunge Lake. On 9/24/2020 EOR provided DNR with a document showing how EWM reductions were achieved on Long Lake through the use of an adaptive management approach.*

Also, what is the source for the statement that ProcellaCOR has a CET of only 3 to 6 hours (and at what concentration)? Our team is aware of a study that examined 6 hours of exposure (and longer), but not aware of any literature which has looked at exposure times <6 hours, which is what we would anticipate to see in a small-scale spot treatment scenario.

ERDC CET Results from 2017 study showed effective control at 3-hour exposure using a concentration of 9ppb (Figure below)

Source: https://corpslakes.erdc.dren.mil/employees/learning/webinars/18Apr25-ProcellacorAPCRP.pdf



- 7.3.3: Boot Lake LTT surveys began in 2005 (not 2007).
  Updated – see Section 7.1.3

- 7.3.4: North & South Twin Lakes are very large and quite deep (as well as oligo/mesotrophic). Is this really comparable to Muskellunge (272 acres, 15 ft max depth, eu/hyper-eu)? North Twin followed up their ProcellaCOR spot treatment with DASH in the same area (i.e., IPM approach). There *were* also impacts to native species observed post-treatment (especially Northern Milfoil).

  Chosen because it was one of the only lakes in Vilas County that have experimented with an integrated strategy that combines ProcellaCOR and DASH. Muskellunge Lake

Association is interested in a similar integrated approach that uses ProcellaCOR for 1+acre colonies which exhibit moderate, dense or dominant EWM and DASH to control <1 acre colonies that exhibit low density, scattered EWM growth.

- 7.3.5: There is no regulation which states that "biological methods cannot be used at the same time as herbicide treatments" (and again, not sure why this is in bold). There is some evidence that WI lakes which have conducted historical herbicides treatments have a lower frequency of weevils than in lakes which have not, but if a lake group wanted to integrate a small scale herbicide treatment in one area of the lake and try to utilize weevils in another area, that could potentially be a viable management option to consider. That said, WI DNR wouldn't necessarily recommend conducting a large-scale/whole lake herbicide treatment and trying to simultaneously release weevils, since you would effectively be killing off the food source that the weevils need to survive.

  Acknowledged. EOR and MLA are committed to working with Cathy Higley to apply lessons learned from Upper and Lower Buckatabon to Muskellunge Lake – see Section 7.3.6.

- 7.4.1: A management trigger of 5% littoral FOO seems very low (as we discussed in previous meetings), and is more than likely unrealistic to achieve and/or maintain over the long-term. It is also unclear what the current % EWM littoral FOO is from the 2020 survey (the relative % frequency was presented earlier, and this is calculated differently than % littoral). There is also question that the idea that a 5% EWM frequency would align with 'reduced recreational value of the waterbody' and 'restricting boat access in portions of the lake' – how was this threshold determined?
  Acknowledged. The current EWM littoral FOO from the 2020 survey is 49.37%, an increase of nearly 50% since the 2017 survey which found EWM at less than 1% of point-intercept sampling locations. To better capture the intensity of the EWM infestation, Jeff Rappold of the MLA took a trip around the entire lake on Tuesday (9/22) trying to stay near the littoral edge of any EWM growth. Jeff collected a waypoint whenever he could visually see EWM within about 10 feet of the boat. EOR published this data via ArcGIS online on 9/24 – see here: https://arcg.is/r41z5

Please note the following important observations

1) *Beyond 7 feet, there was little weed growth of any type at least nothing near the surface.*
2) *The only remaining areas of Muskellunge Lake with no EWM include:*
    - *Some areas around the western point (3-4 properties),*
    - *A short stretch in the SW bay near its north shore (2 properties),*
    - *A short stretch on the south shore (2-3 properties). The stretch from the small man-made island to the point on the east shore (10 Properties*
    - *Only areas without EWM are areas that are very sandy (rare substrate for Muskellunge Lake). In short, EWM is now nearly contiguous around the entire perimeter of the lake.*

Table 7: Please explain how the specific treatment method (i.e., ProcellaCOR or diquat) was determined for each individual treatment area in this table. For example, site #11 (5.71 acres) is

listed as ProcellaCOR, but since #17 (5.72 acres) is listed as diquat? What is the scientific rationale here? (And from an economic side, ProcellaCOR is 3x more expensive than diquat). Some of these individual areas are *really* small … there are two larger scattered beds which are each ~5 acres, but the majority of the remaining beds are <1 acre, and many of these areas are long narrow strips along exposed shorelines. Achieving adequate concentration exposure time (CET) in these *really* tiny spots will be very difficult/impossible to achieve, even with a 'fast' acting herbicide (both diquat and ProcellaCOR still need several hours of contact time, at minimum, in order to achieve decent EWM control). Applying any type of liquid herbicide into a liquid lake environment will result in dissipation off site – we have seen no evidence which indicates that diquat or ProcellaCOR dissipates any different than other common herbicides (i.e., 2,4-D & endothall) which we have thoroughly examined across multiple lakes. Since ProcellaCOR is a new herbicide it gives us 'another tool in the toolbox', but the limited cases studies which we have available illustrates that control efficacy and non-target impacts are variable, so it's in no way a 'silver bullet'. It is also not clear on how the remaining EWM acreage estimates were calculated over time. Looks like each year of treatment would results in ~60% reduction in acreage – is that really 'effective' control?

The 22 treatment polygons have been consolidated into 12 larger polygons that collectively represent the portions of Muskellunge Lake that contain concentrated stands of EWM.

ProcellaCOR was selected for areas exhibiting Tier 1, Tier 2 growth (highest density areas). While more expensive, ProcellaCOR treatments can come with a three-year warranty from the manufacturer in many cases. To be eligible, some extensive mapping must be performed to document conditions, treatment areas have to be larger than 10 acres, and the program must be approved by SePRO. ***EOR will work with the DNR and MLA to evaluate eligibility for the 3-year warranty.***

Note: We are no longer recommending Diquat. We will not target Tier 3 areas with herbicides in 2021 and therefore will not be using Diquat.

How will efficacy of these treatments be monitored (no discussion of sub-PI surveys or other quantitative methods, are these just visual meander surveys?). How will selectivity towards native plants be monitored? What about herbicide concentration monitoring in conjunction with the ProcellaCOR treatments?

See Implementation Plan Section 13.2

- 13: EWM is classified as a restricted species under NR40 (not prohibited). Also, impacts of EWM on native plants can vary, and may not necessarily be negative (esp. when compared to native impacts in lakes which chemically manage EWM at a large scale – see the latest Mikulyuk et al. 2020 'cure/disease' paper). From the report: "*Results from survey efforts conducted in 2020 found that the EWM growth was mostly light to moderate and often found to be intermixed with native species.*" If EWM is scattered, sparse, and able to co-occur with natives then it doesn't seem to necessarily be currently causing either an ecological or recreational problem which would warrant a multi-year chemical control strategy.
  Explain EWM abundance around the lake

To better capture the intensity of the EWM infestation, Jeff Rappold of the MLA took a trip around the entire lake on Tuesday (9/22) trying to stay near the littoral edge of any

EWM growth. Jeff collected a waypoint whenever he could visually see EWM within about 10 feet of the boat. EOR published this data via ArcGIS online on 9/24 – see here: https://arcg.is/r41z5

The only remaining areas of Muskellunge Lake with no EWM include:

- *Some areas around the western point (3-4 properties),*
- *A short stretch in the SW bay near its north shore (2 properties),*
- *A short stretch on the south shore (2-3 properties). The stretch from the small man-made island to the point on the east shore (10 Properties*
- *Only areas without EWM are areas that are very sandy (rare substrate for Muskellunge Lake). In short, EWM is now nearly contiguous around the entire perimeter of the lake.*

- All Figures/Tables: Many of the Figure/Table #s listed in the text do not correspond to the correct figures/tables. A thorough QAQC of the entire document would be helpful in order to fix these typos and provide clarity.
  Acknowledged/updated.

9.1 2011 Fyke Survey Results

- It would be helpful to include a survey description. In this case the target species for the survey was muskellunge. This gives context to properly interpret the results presented. Under sections for each species, other than muskellunge, it should be noted that they were not the target species. Within the description it would also be a good idea to describe a net night or state that 5 nets were each ran daily for 4 consecutive days. Just think your average reader may be a little confused about the jargon.
- Making statements about the status of the walleye population based on this survey would not be suggested. The target species was muskellunge, so timing and location were selected specifically to catch as many muskellunge as possible. This is also true for other species discussed in this section.
- The statement that stocking walleye in Muskellunge Lake works could be reworded. Saying this makes it seem that stocking has produced a good walleye fishery when it seems to have produced a low-density population that has not produced any natural reproduction. Again, making statements about the status of the walleye population based on catch from a muskellunge survey is a reach.
- Statements made regarding the muskellunge population being almost exclusively adult fish is likely not true. The survey targeted muskellunge during spawning time and in likely spawning locations. This will bias the catch toward adult fish, so the catch will be dominated by adults.

  Acknowledged – Section 9.1 was updated accordingly.

9.2 2014-2.18 Fall Electrofishing Survey Results

- The primary objective of these surveys is to assess juvenile walleye (age-0 and age-1)
- populations. Comparisons by year should be restricted to only age-0 and age-1 catch. During our surveys we sometimes also collect other size walleye and gamefish as well, which is the case with these surveys. The takeaway from these surveys is that we have not documented natural reproduction and that stocking returns from extended growth fingerling walleye is on the low end.
- Drawing comparison of other species caught by year in these surveys may be interesting, but they are not the target species and these are not the surveys we use to assess their populations.

Acknowledged –Section 9.3 was updated accordingly.

9.3 2019 Mark-Recapture Survey

- 9.3.5. Forage Species should be relabeled as other species. The fyke nets we use for this type of survey have larger mess that allows smaller fish to escape. These small fish that escape are a large proportion of the forage base of a lake. We have other survey methods to assess forage base that were not used in this survey.

Acknowledged – Section 9.3.5 was updated accordingly.

9.4 Implications for Muskellunge Lake

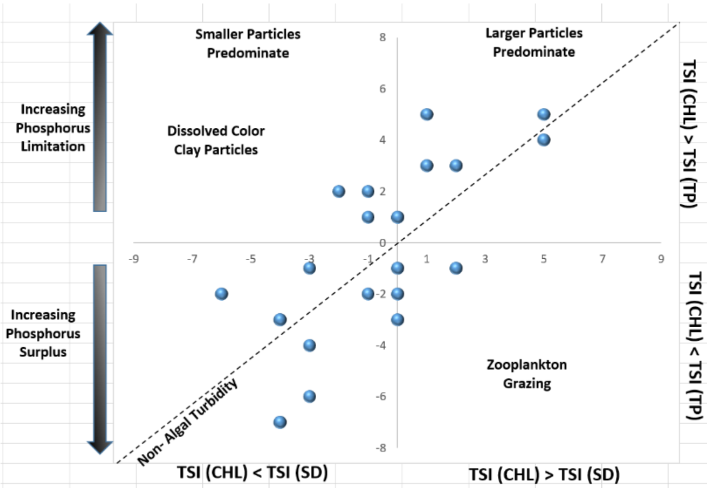
- Recommended management practice 1 – three walleye per acre is generally regarded as the bar for a good walleye fishery but not the case for a purely stocked fishery. The average density for a stocked fishery is the range of 1.5-2.0 adult walleye per acre. The Minocqua Chain example is a special case with the goal of recovering a failing walleye fishery that required a large amount of research, outreach and effort to accomplish. This not a realistic management strategy for Muskellunge Lake, a lake that has never supported an abundant NR walleye fishery. Lake Minocqua had a history of NR and historic walleye densities of 4-5 per acre. Also, the project is still ongoing, and the success has not been fully realized or evaluated completely. Note: Muskellunge Lake is part of a statewide walleye stocking study, so I would not be able to adjust stocking rates until that is complete.

Acknowledged – Section 9.4 was updated accordingly.

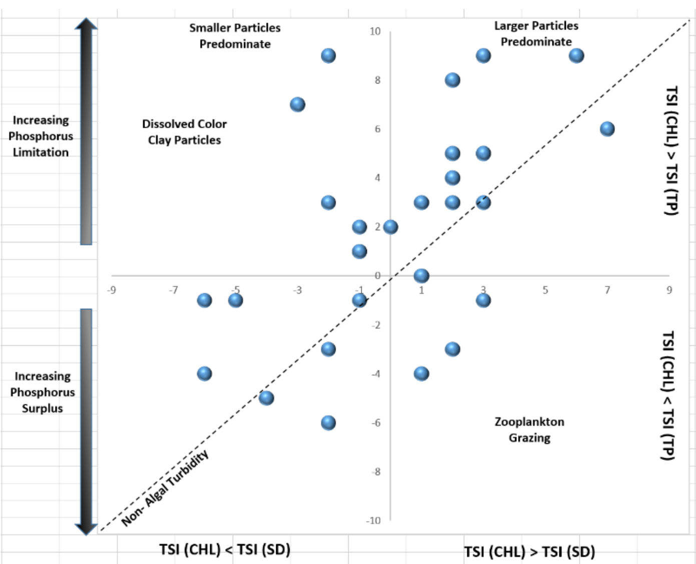
Section 4 - Since the current 303(d) listing is due to excessive algae, this section should have a more detailed discussion of chlorophyll levels, including bloom frequency distributions. Figure 6 is the approach to evaluate TSI relationships, but of limited usefulness when all data are included. Consider breaking up data to demonstrate how the relationships change during the open water season (e.g. different markers for data collected during early summer clearwater phase vs. later summer).

Muskellunge Lake is dynamic from year to year. Sometimes there is an early summer clear-water phase, but Muskellunge Lake is not in the clear-water, aquatic plant dominated state. This is because, although it is a shallow lake, there is a significant portion of the lake that is deeper than 8 feet (max depth of majority of the aquatic plant growth) where aquatic plants cannot maintain the clear-water state.

Here is the TSI relationship for **May-June** when Muskellunge Lake is most likely to be in the clear-water phase.



Here is the TSI relationship for **July-October** when Muskellunge Lake is most likely to be in the turbid, algae dominated phase:



- Figure 10 – The y axis is incorrect/confusing. For example, the graph appears to state that the average number of samples collected per year in the month of June is over 6. There are only a few years in the record where more than 1 sample is collected per month.
  EOR Response: Acknowledged. Figure 10 has been updated.

- Section 10.2 – The report states that neither the SWAT nor Model My Watershed include groundwater contributions of phosphorus. This is incorrect, both models include groundwater phosphorus loading. However, both models use a much lower groundwater phosphorus concentration than that measured in the Robertson study. It's also important to note that the SWAT numbers were calibrated to TP leaving the lake, not TP entering the lake and the Robertson study noted a net TP retention of 50%. Ultimately the SWAT results at the outlet were biased low, likely in large part to the lower groundwater TP concentration used in the SWAT model. I didn't look closely enough at the Model My Watershed documentation to see how that model handles routing to determine if that model's numbers should represent the load entering or leaving the lake.
  EOR Response: Acknowledged. Section 10.2 and 10.3 have been updated accordingly.

- Section 12.1. - This section refers to a growing season mean TP of 47 ug/L for the 2011-2020 data. It appears that this value was arrived at by averaging all data collected from 2011-2020. However, if the data are restricted to the June – September period per WisCalm, the mean TP is 41 ug/L. The difference in the two is due to the higher TP at turnover. So there needs to be a modification of the modeling approach to use it for goal setting, as the 40 ug/L goal is a June – September goal. In addition, building on previous chlorophyll comment, I recommend using the bathtub model to explore chlorophyll response to changing P inputs. From a modeling perspective, I've found that the Jones & Bachman model in Bathtub typically provides reasonable results to predict mean chlorophyll. However, since there is a lot of data from this lake, consider using the actual bloom frequency distribution rather than those in Bathtub when evaluating the % of time 20 ug/L is exceeded. Considering that the lake is apparently near the 40 ug/L TP criterion, but chlorophyll exceeds 20 ug/L over 80% of the time, it may be more appropriate to use bloom frequency rather than the TP criterion to evaluate/set water quality goals.
  EOR Response: Acknowledged. The idea of using bloom frequency is valid, but ultimately Chl-a (algae) is a response metric that relates back to phosphorus. The MPCA has mapped algal-bloom frequency as a function of total phosphorus for 170 paired measurements collected on shallow lakes. We can use this information to evaluate the likelihood for Chl-a to exceed the 20 ug/L Chl-a standard. The closer we get to the 40 ug/l standard, the less likely it will be for Muskellunge Lake Chl-a levels to exceed 20 ug/L in greater than 25% of days. Achieving the 40 ug/L goal plus a 10% margin of safety equates to a desired in-lake TP concentration of 36 ug/L. When Muskellunge Lake reaches the 36 ug/L standard, the graphs below provides evidence to suggest that Muskellunge Lake will also meet the Chl-a standard. Of the 10 water quality samples that were collected from June- September (2011-2020) when TP concentrations were at or below 36 ug/L, Chl- a was also less than 20 ug/L on 80% (8 out of 10) of days.

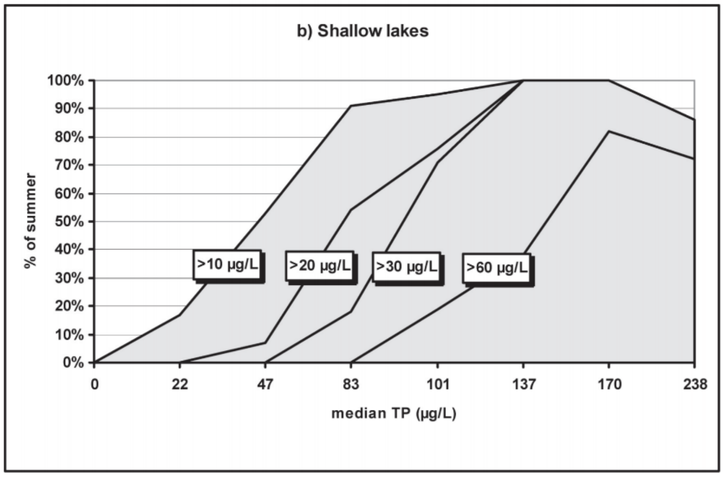
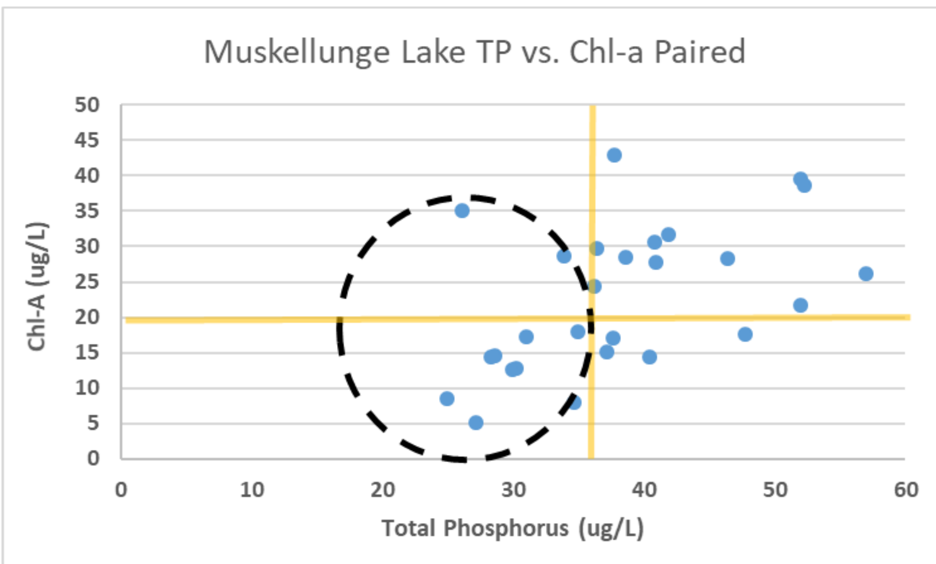


Figure 2.-Algal bloom frequency as a function of total phosphorus (TP) for: (a) reference lakes (based on 641 paired TP and Chl-*a* measurements) and (b) shallow lakes (based on 170 paired measurements). Median TP for the interval noted. Four "classes" of bloom intensity noted ranging from "mild bloom" (Chl-*a* > 10 µg/L) to "very severe nuisance blooms" (Chl-*a* > 60 µg/L).



- Section 13.3.1 – Due to the rapid drop in TP during April to mid-May, recommend that ice out date be tracked as part of the increased monitoring frequency to assist in data interpretation. Consider collection of some TP and Fe from the hypolimnion in summer as part of this effort. The data suggest that much of the phosphorus released under anoxic conditions may be rapidly recombining with iron under aerobic conditions. Note also that if destratification were to be pursued as a management strategy, a better understanding of iron loading to the lake would be needed. *EOR Response: Agreed. We have updated Section 13.3 to include a recommendation for increased TP and FE monitoring. The problem with FE is that it loses its ability to bind to phosphorus under anoxic conditions. Given the polymictic nature of Muskellunge Lake, there are likely multiple times throughout the year where the in-lake sediments are providing a source of reactive phosphorus. We documented this on 8/14/2018 – see Section 7.4.3*

This section should also discuss the impacts and associated mitigation strategies to reduce loading from nearshore areas and septics (e.g. raingardens, ensuring systems are maintained & functioning properly, etc.).

- *EOR Response: Section 13.5 and Appendix D covers mitigation strategies to reduce loading from nearshore areas. We have identified properties that could improve lake quality by improving and/or restoring shoreline habitats in Appendix D. Results are based on the shoreline and coarse woody habitat surveys conducted by DNR staff in 2017.*
- While outside of my wheelhouse, the apparent degradation of the performance of the aeration system alluded to in section 9.5 may be of concern. A running a poorly functioning system may not only be a wasting money, it may impact the ability to achieve the plan's fishery goals.

  EOR Response: Agreed. We are recommending continued dissolved oxygen monitoring data collection throughout the year to better document the performance of the aeration system throughout the year.

19. APPENDIX F: 2017 ANNUAL REPORT

Prepared by: EOR

For the Muskellunge Lake Association

2017 EWM Monitoring and Harvesting Assessment Report

12.27.2017

EOR water ecology community

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1. INTRODUCTION

1.1. Background

Muskellunge Lake (Water ID: 128570), is a 270 acre lake located in Vilas County. Muskellunge Lake has a maximum depth of 19 feet and is classified as a shallow, lowland drainage lake. Visitors have access to the lake from a public boat landing off of Landing Road via Balsalm Lane and Highway G northeast of Eagle River, Wisconsin. The lake's water clarity is low. Muskellunge Lake was listed on the 303(d) impaired waters list in 2014 due to excess algae growth. A Total Maximum Daily Load (TMDL) study for the lake has not yet been completed, the source of the impairment is currently listed as an unknown pollutant. A review of water quality data collected over the past 10 years shows an increasing trend in in-lake phosphorus concentrations.

1.2. Problem Statement

Eurasian Watermilfoil (EWM) was found for the first time on Muskellunge Lake in 2016. Genetic testing through GenPass has confirmed the identified specimen as a pure strain Myriophyllum spicatum. The original extent of the EWM infestation was thought to be confined to a few key areas including near the boat launch and at a location in the middle of the lake near the buoy that marks the shallow area near the center of the lake. Professional and volunteer AIS monitoring conducted by trained members of the Muskellunge Lake Association led to the identification of additional areas.

1.3. 2017 Goals and Objectives

The initial goal/objective of 2017 work was to train Muskellunge Lake Association (MLA) volunteers on how to identify EWM and how to conduct volunteer AIS monitoring efforts so that any new infestations can be readily identified moving forward. A secondary, related objective was to train MLA volunteers on identification of other native aquatic plants with an emphasis on distinguishing between native northern watermilfoil and the invasive EWM.

Additional goals for 2017 work included the development of an Annual Report which summarized monitoring strategies, treatments completed in 2017, and management actions for 20108. Development of the Annual Report included time spent by Emmons and Olivier Resources (EOR) staff reviewing findings from the DNR survey findings and preparing data driven maps in ArcGIS. Additional maps were created depicting results from volunteer monitoring efforts conducted by the MLA as well as maps depicting results from professional monitoring conducted by EOR.

1.4. Purpose

The purpose of this report is to document recommended monitoring strategies and prioritized management actions for 2018 based on monitoring efforts and management actions conducted in 2017. This document will also serve as a reference point for all stakeholders (MLA, the DNR, Vilas County, EOR) for future communication regarding the 2018 management approach.

2. 2017 AIS MONITORING

2.1. 2017 DNR Point-Intercept Survey

A July 10th, 2017 point-intercept study conducted by the Wisconsin DNR identified EWM at 4 of 226 (0.017%) sampling points. In places where it was found, the average rake fullness was a 1, indicating the plant was sparse in areas where it was found (Figure 1). While EWM was sparsely distributed in 2017, the verification of EWM near the boat launch and near the center buoy provided reason for concern as these areas represent high-use areas that could potentially serve as vectors for dispersal to other areas of the lake. Overall floristic quality appeared to have decreased slightly from the 2009 Point-Intercept survey in which 26 aquatic plant species were found versus 21 in 2017. Northern watermilfoil was only visually observed (not sampled on the rake) at five locations in 2017 despite being a commonly found plant in 2009 (Figure 2). The scarcity of northern watermilfoil in 2017 provided evidence to suggest that the native milfoil weevil population would likely be low in Muskellunge Lake in 2017. The 2017 point-intercept survey was used as a baseline to guide further volunteer and professional AIS monitoring efforts.

2.2. 2017 Volunteer AIS Monitoring

2.2.1. June 2014th, 2017 AIS Workshop

Ten members of the Muskellunge Lake Association (MLA) attended an AIS training and aquatic plant identification workshop hosted by Vilas County Lake Conservation Specialist Cathy Higley on June, 14th, 2017. The event was hosted on Muskellunge Lake by MLA president Mike Newmeister. The focus of the two hour workshop was on EWM identification as well as identification of other native aquatic plants, including northern watermilfoil. Following the workshop, the MLA volunteers divided Muskellunge Lake into 8 sections for the 10 participants to monitor. Volunteers sent voucher specimens of EWM to Cathy Higley for verification and collected GPS coordinates to document the location of any new EWM beds. The GPS coordinates were then sent to EOR who added the new locations to an existing ArcMap document which displayed the locations of all verified EWM infestations.

2.2.2. July 14th, 2017 Aquatic Plant and Weevil Identification Workshop

Nine members of the MLA attended an Aquatic Plant and Weevil identification workshop hosted by Cathy Higley on July 14th, 2017. The five hour workshop focused on collecting and analyzing EWM and northern watermilfoil specimens from Muskellunge Lake for evidence of weevil damage. While no adults, larvae, or pupae were found, several of the EWM stems contained blast holes which indicated that weevils may be present in the lake. Members of the MLA were further trained on aquatic plant identification during the workshop with a focus on differentiating northern watermilfoil vs. EWM. MLA member, Jeff Rappold successfully identified new stands of northern watermilfoil late in the 2017 growing season, these new areas represent potentially valuable locations for maintaining a viable weevil population if one exists.

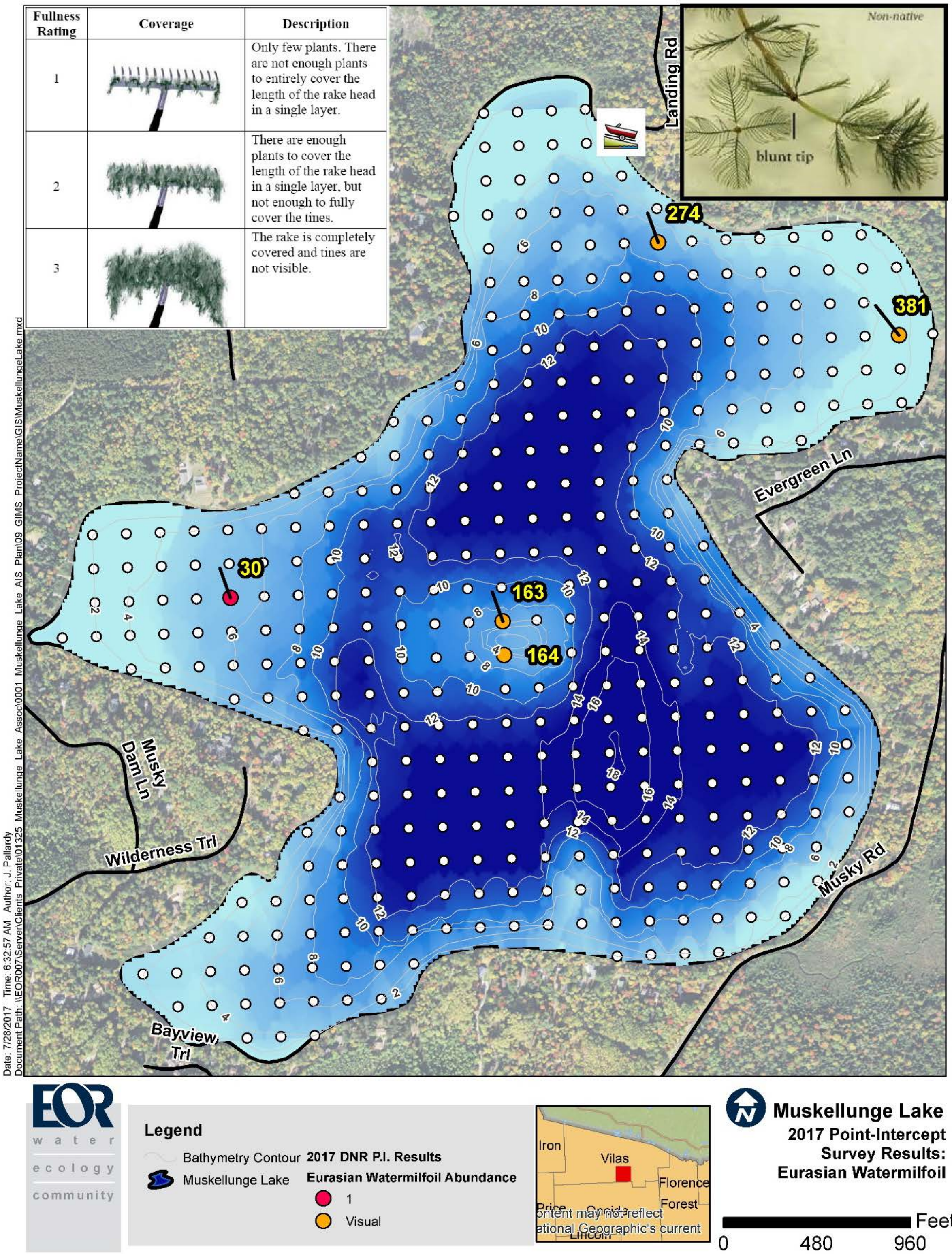


Figure 1. 2017 Muskellunge Lake Point-Intercept Survey Results: Eurasian Watermilfoil.

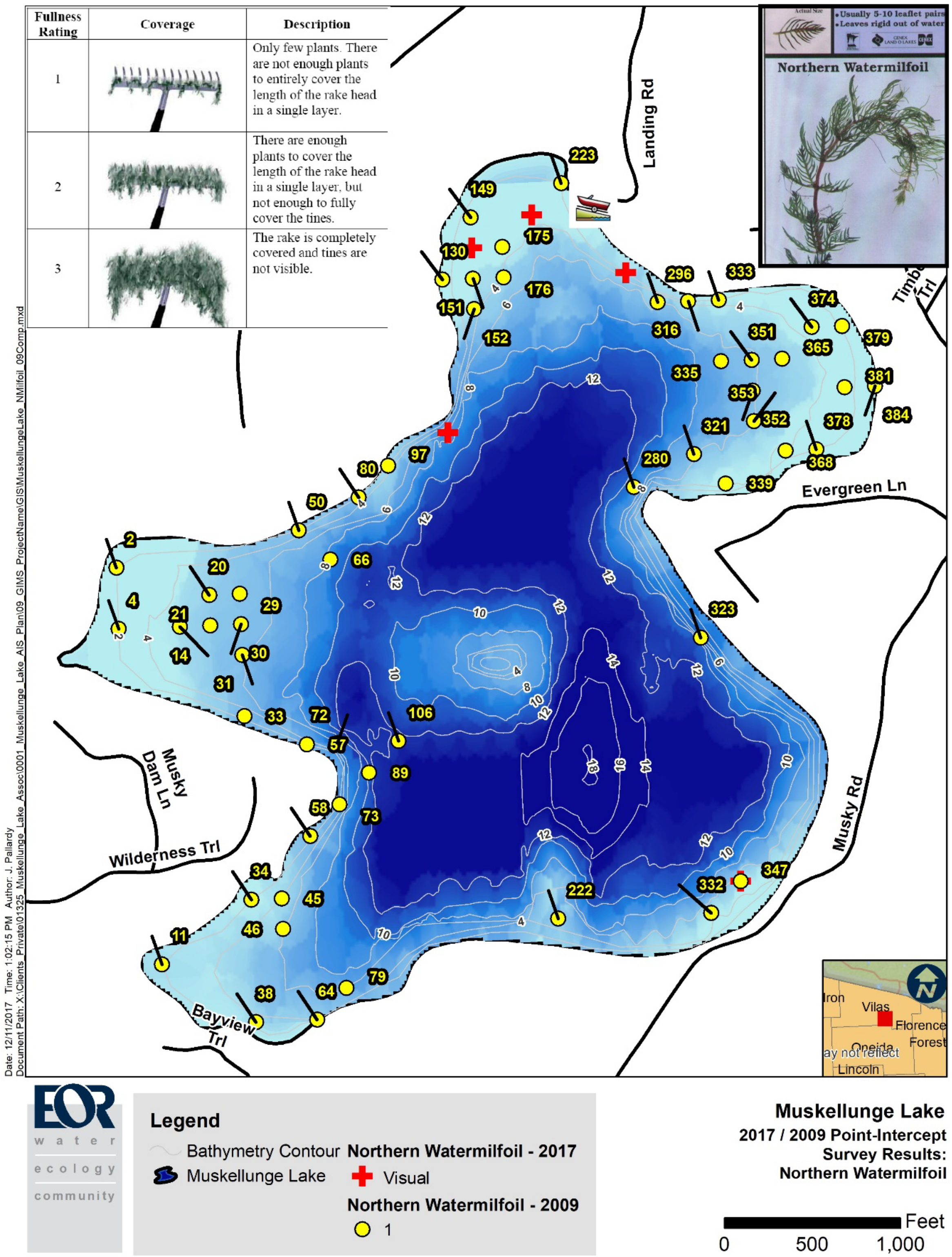
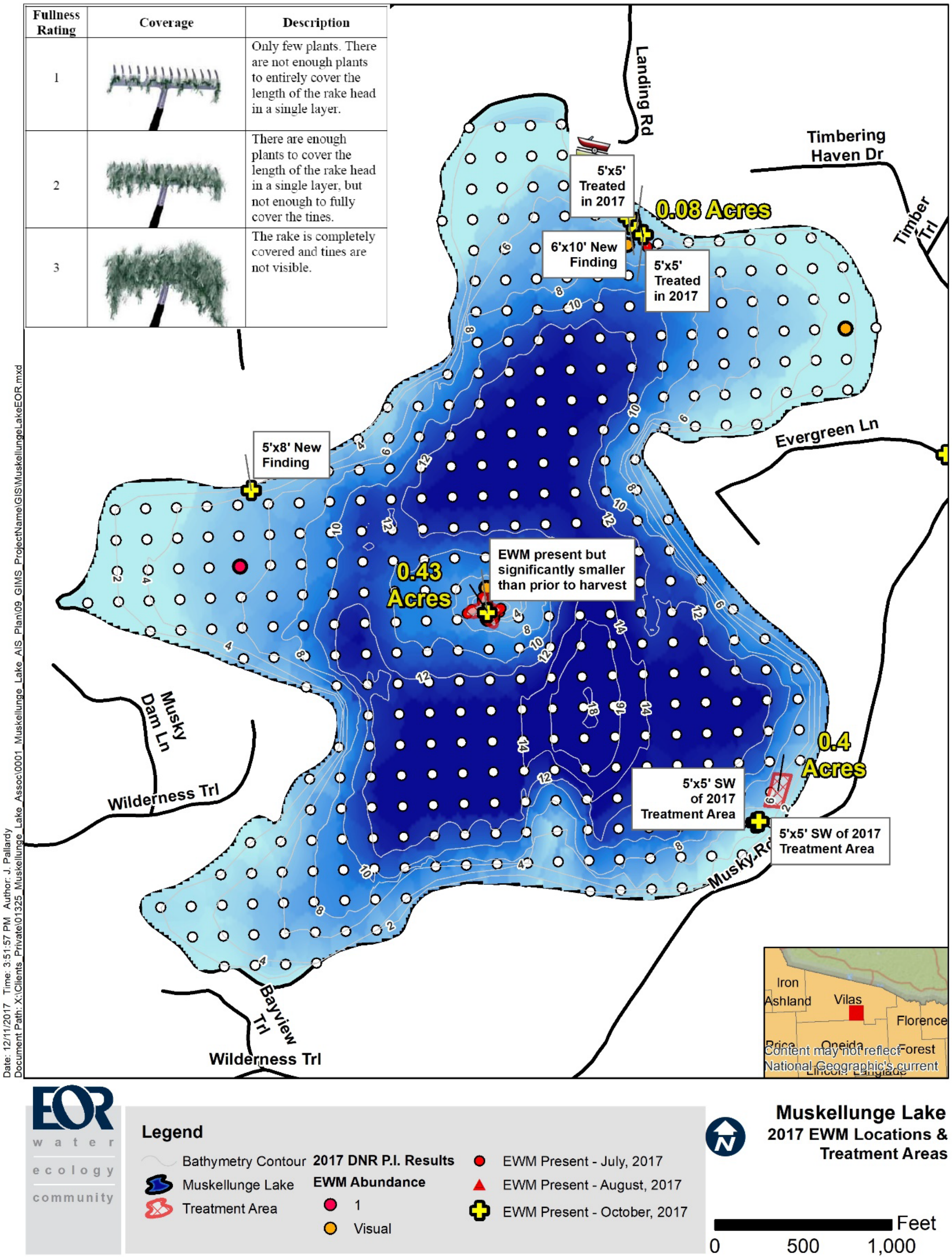


Figure 2. Northern watermilfoil was noticeably scarce in 2017 as compared with the 2009 point-intercept survey.

2.2.3. 2017 MLA Volunteer AIS Monitoring

In 2017, members of the MLA members spent 85.25 man hours conducting volunteer AIS monitoring efforts. These 85.25 hours were spent on the lake, physically identifying and recording new EWM infestations and tracking the distribution of known EWM beds. Furthermore, members of the MLA conducted an additional 145.50 attending AIS and weevil training workshops, communicating EWM concerns to landowners through the MLA website as well as through social media, and attending lake association meetings and professional presentations regarding 2017 professional AIS monitoring and options for treatment. In 2017, the MLA demonstrated their proficiency at EWM identification by successfully identifying the presence of previously unmarked EWM beds. A map showing the location of all known EWM beds including new EWM locations found in October after the professional hand harvesting occurred (August, 2017) is provided in Figure 3.



Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

Figure 3. Muskellunge Lake 2017 Confirmed EWM Locations and Hand-Harvesting Treatment Areas.

2.3. 2017 Professional AIS Monitoring

2.3.1. Delineating 2017 Treatment Polygons

EOR Water and Natural Resource Specialist Joe Pallardy worked with MLA member Jeff Rappold to delineate treatment areas around verified EWM locations on July 27th and 28th, 2017 using a sub-meter differential Global Positioning System (GPS). During the site visit, EOR staff conducted a focused meander survey around all locations where EWM had been identified during the 2017 DNR point-intercept survey and at all additional locations identified by members of the MLA. Polygons were mapped around all well-established colonies while point-based techniques were used to record locations that were considered pioneer colonies which contained only a few plants or a single plant.

All points and polygons collected in the field were transferred to ArcMap v. 10.3 Geographic Information System (GIS). Once in GIS, shapefiles of treatment polygons and points were created and subsequently converted to KML files that could be viewed using Google Earth. Two primary treatment areas were identified, a 0.43 acre area near the center buoy and a 0.08 acre area near the public boat access. These areas were identified as priority treatment areas because they represented high-use areas that could potentially serve as vectors for dispersal to other areas of the lake. The colony of EWM near the center buoy was canopied to the surface in several areas and was also very dense, thus representing the highest priority site for treatment. The EWM growth near the boat launch was scattered, and mixed in with other native submergent and emergent vegetation. A third, 0.40 acre treatment area was delineated along the southeastern corner of the lake using ArcMap v. 10.3 based on field data collected by Jeff Rappold, John Kurhajec, and Tom Cerull. The EWM growth in this area was again scattered and mixed in with other native vegetation.

2.3.2. Bathymetry and Sediment Composition Maps

EOR Water and Natural Resource Specialist Joe Pallardy utilized the Kriging tool within ArcMap v. 10.3 to create updated bathymetry and sediment composition maps based on data collected during the DNR's 2017 point-intercept survey. The Kriging tool uses point data to create (interpolate) a connected surface of raster cells that estimate likely values for the space in between points. For Muskellunge Lake, the Kriging tool used the recorded depth from the 6 closest point-intercept points to estimate the likely depth in between the points, thus creating a depth grid for the entire lake basin from which bathymetry contours could be derived. A lake sediment composition grid was developed in the same manner (Figure 4). These maps were used to identify areas where future monitoring efforts should focus on. The deepest plant growth observed during the 2017 DNR survey was 9 feet, all EWM growth found in 2017 was in less than 6 feet of water. The dominant substrate composition observed in the areas where EWM was found was a sand/muck mix. EWM grows heaviest in sediments that have a lower organic matter (3-17%). Therefore, the areas of lake that are predominantly muck (higher organic matter) will likely not support EWM growth, especially those areas that are deeper than 6 feet.

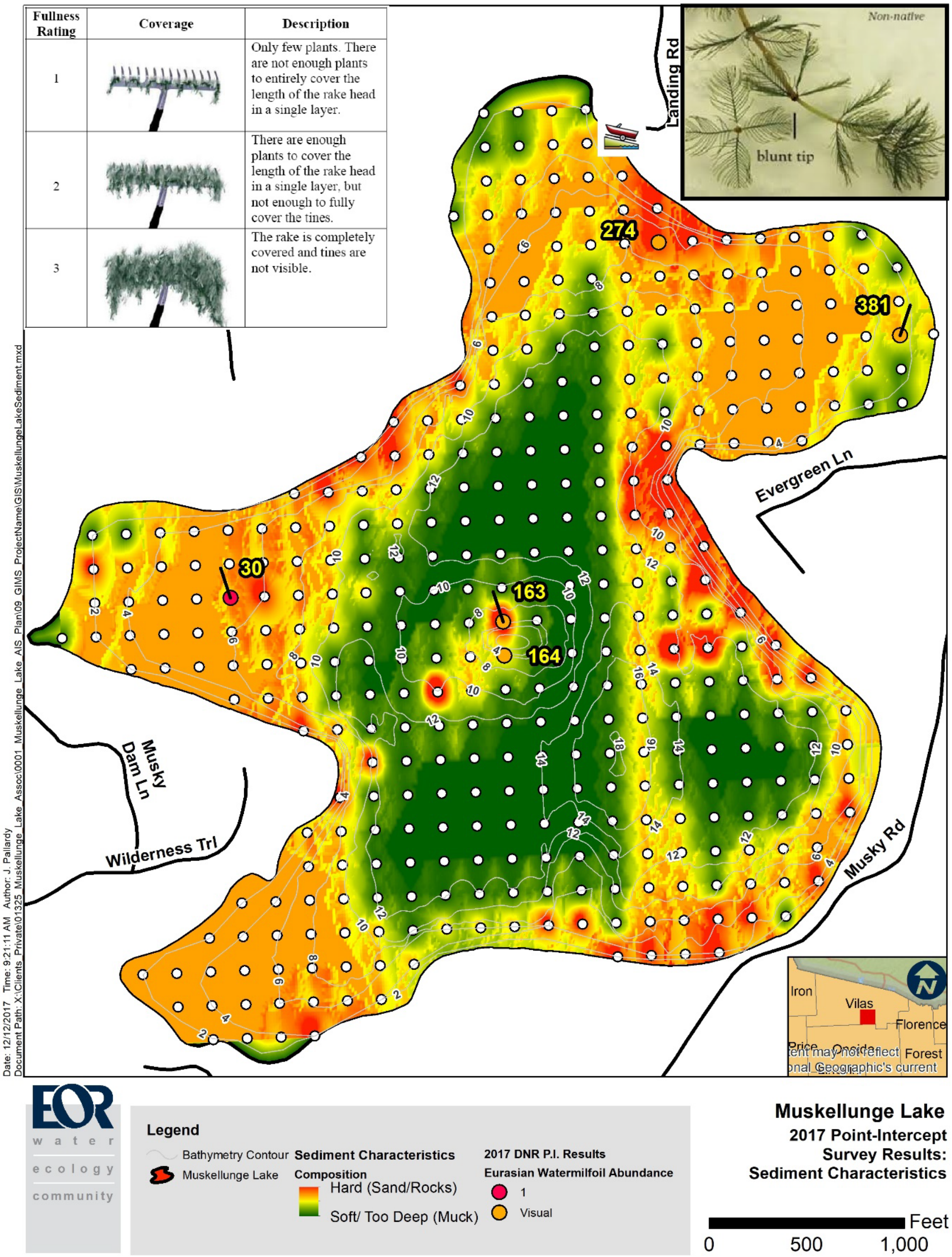


Figure 4. Muskellunge Lake sediment composition

3. 2017 PROFESSIONAL HAND-HARVESTING RESULTS

3.1. 2017 Recommendation

Results from professional and volunteer AIS monitoring efforts were used to prioritize three treatment areas with a total area of 0.91 acres. The average depth of water within the delineated treatment areas was less than 5.0 feet. Professional hand-removal was identified as the optimal treatment method because of the small size of the infestation, the shallow depth of water at the infestation, and the belief that professional hand harvesting could aggressively target the EWM beds with minimal impact on the surrounding native aquatic plant community. Aquatic Plant Management (APM), LLC of Minocqua, Wisconsin was hired to conduct the professional hand-harvesting on August 17th and 18th.

3.2. 2017 Results

Divers from APM spent a combined total of 47.65 hours on the water during which they successfully removed 31.1 cubic feet of EWM from the lake. Members of the MLA directed divers to the treatment areas and collected pictures to document progress. The majority of the time spent on 8/17/2017 was focused on targeting the areas near the rock bar at the center buoy where EWM was matted to the surface (Figure 5). Divers then moved off the rock bar, targeting single plants adjacent to the main bed within the 0.43 acre treatment area (Figure 6). The remainder of time spent on 8/17 was spent removing EWM within the 0.08 acre treatment area near the public access. The EWM was growing in approximately 3 feet of water in this area, however, most of the EWM was less than 2 feet tall. Dive conditions on 8/17 were ideal for hand-harvesting; however, secchi disk readings of 3.0 feet indicated water clarity was poor which may have obscured some smaller plants.

Professional hand removal efforts on 8/18 focused on the 0.40 acre treatment area on the south side of Muskellunge Lake. Plants within the treatment area were growing to the surface in 3.5 to 4.5 feet of water. Hand-removal efforts concluded with a revisit to the center buoy which focused on further removing individual plants from the deeper areas around the perimeter of the treatment area. Weather conditions on 8/18 were not as ideal with high winds and rain making diving more difficult. Water transparency remained the same.

Volunteer monitoring efforts conducted in the treatment areas following professional hand harvesting efforts found scattered EWM growth in all three treatment areas. Overall density and abundance of EWM within the treatment areas was significantly smaller than prior to the survey which suggests hand removal efforts met control expectations. Early-season professional AIS monitoring will be conducted in 2018 to further validate the impacts of the hand harvesting in comparison with untreated areas.

Figure 5. Aquatic Plant Management, LLC conducting professional hand-harvesting near center buoy.

Figure 6. Aquatic Plant Management, LLC conducting professional hand-harvesting adjacent to the center buoy.

4. 2018 MONITORING STRATEGIES

4.1. 2018 Monitoring Strategies

2018 Early Season Focused Meander AIS Survey

In 2018, EOR ecologists will complete an early-season focused meander AIS survey in the areas of Muskellunge Lake that are less than 9 feet deep (max depth for plant growth). The early-season survey will take place in mid to late May (dependent on the weather). The focus of this survey will be around those areas where EWM has already been found, including areas where it was treated in 2017. The survey will also include additional areas where EWM has not been found as results from volunteer AIS monitoring efforts conducted in the fall of 2017 have located additional plant beds outside of those found during previous monitoring efforts conducted earlier in 2017. EOR will map all incidences of EWM with our Trimble (sub-foot accuracy GPS) using points to map single plants or small colonies and polygons to map out any larger, or well-established colonies. EOR will also assign a density ranking to all mapped EWM colonies in accordance with DNR protocols at this time. Results from this survey will be used to prioritize areas for treatment.

2018 Post-Treatment, Peak Biomass Focused Meander AIS Survey

In 2018, EOR ecologists will complete a second, peak biomass, focused meander AIS survey in July following volunteer hand-removal efforts (or other treatment) to assess treatment effectiveness. EOR ecologists will collect biomass estimates of EWM in treated and non-treated areas to further evaluate volunteer hand-removal efforts as a viable management approach.

5. CONCLUSION AND 2018 MANAGEMENT APPROACH

Results from professional and volunteer AIS monitoring efforts conducted in 2017 on Muskellunge Lake suggest that the population of EWM in Muskellunge Lake is limited to a few key areas with a total area less than 1.0 acres (less than 1% of the total lake surface area). Based on these results, professional hand harvesting was determined to be the appropriate control mechanism. Post-treatment volunteer AIS monitoring efforts conducted within the treatment areas suggests that while professional hand harvesting efforts successfully reduced the abundance and density of EWM growth, it did not completely eradicate it. Furthermore, volunteer monitoring efforts have identified additional beds of EWM outside of those originally found in the summer of 2017.

5.1. 2018 Recommended Management Approach

EOR proposes to conduct early season professional monitoring efforts in May of 2018 (weather dependent) to fully document the extent of the infestation. Volunteer monitoring efforts will also be required in 2018 to complement the early-season survey. Volunteer hand removal efforts will be employed if the extent of delineated EWM growth remains under 2 acres and the average depth of water in delineated treatment areas is under 4.5 feet. Professional hand removal efforts will be employed if the extent of the delineated EWM growth exceeds 2 acres or the average depth of water in delineated treatment areas exceeds 4.5 feet. In some areas, a combination of professional and volunteer hand removal may be employed.

5.1.1. 2018 Volunteer Hand Removal Program

Members of the MLA have expressed their interest in conducting volunteer hand removal efforts in 2018 after observing the hand removal techniques used by Aquatic Plant Management in 2017. The MLA has confidence that they have the capacity to employ similar techniques used by Aquatic Plant Management and believes they will also do a better (or at least comparable) job at enforcing techniques that prevent fragmentation and redistribution of harvested EWM. Goals for 2018 include the development of a volunteer EWM hand removal program. The MLA will work with the DNR to add Citizen Lake Monitoring Network (CLMN) and decontamination components to the program. Stephanie Boismenue (Oneida County Aquatic Invasive Species Coordinator), Cathy Higley of Vilas County, and Paul Skawinski (DNR) are in the planning stages of developing a volunteer hand removal workshop to be held at Kemp Station. One workshop will be held in early spring, with a second workshop in early summer for those individuals who are not year round residents. Members of the MLA will attend one of the two workshops in 2018. After attending the workshop, members of the MLA will work with EOR to determine the feasibility of establishing a volunteer-led hand removal program for Muskellunge Lake. Data collected during the early season professional monitoring will ultimately be used to determine the feasibility of a volunteer-led hand removal program.

20. APPENDIX G: 2018 ANNUAL REPORT

Prepared by: EOR

For the Muskellunge Lake Association

2018 EWM Monitoring and Harvesting Assessment Report

12/10/2018

EOR water ecology community

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1. INTRODUCTION

1.1. Background

Muskellunge Lake (Water ID: 128570), is a 270 acre lake located in Vilas County. Muskellunge Lake has a maximum depth of 19 feet and is classified as a shallow, lowland drainage lake. Visitors have access to the lake from a public boat landing off of Landing Road via Balsalm Lane and Highway G northeast of Eagle River, Wisconsin. The lake's water clarity is low. Muskellunge Lake was listed on the 303(d) impaired waters list in 2014 due to excess algae growth. A Total Maximum Daily Load (TMDL) study for the lake has not yet been completed, the source of the impairment is currently listed as an unknown pollutant.

A review of water quality data collected since 2006 in comparison to the Lowland drainage 40 ug/L Recreational threshold shows an increasing trend. The average TP concentrations in the last 2 years (2017-2018) is 48 ug/L (9 total samples); less than the 2-year average from 2016-2017 of 63.5 ug/L. Samples collected in April and October indicate a potential internal nutrient source coinciding with spring and fall turnover. TP concentrations were at or below (better than) the 40 ug/L standard during every sampling event in 2018 with the exception of the October sampling event. The first sampling event from 2018 (May 5th 2018) occurred after spring turnover and therefore is not reflective of the high TP concentrations which most often occur immediately after ice out as was noted during samples collected in April of 2016 and 2017. The May 5th sample is important in demonstrating that the high nutrient concentrations observed immediately following spring turnover do not continue throughout the entire growing season.

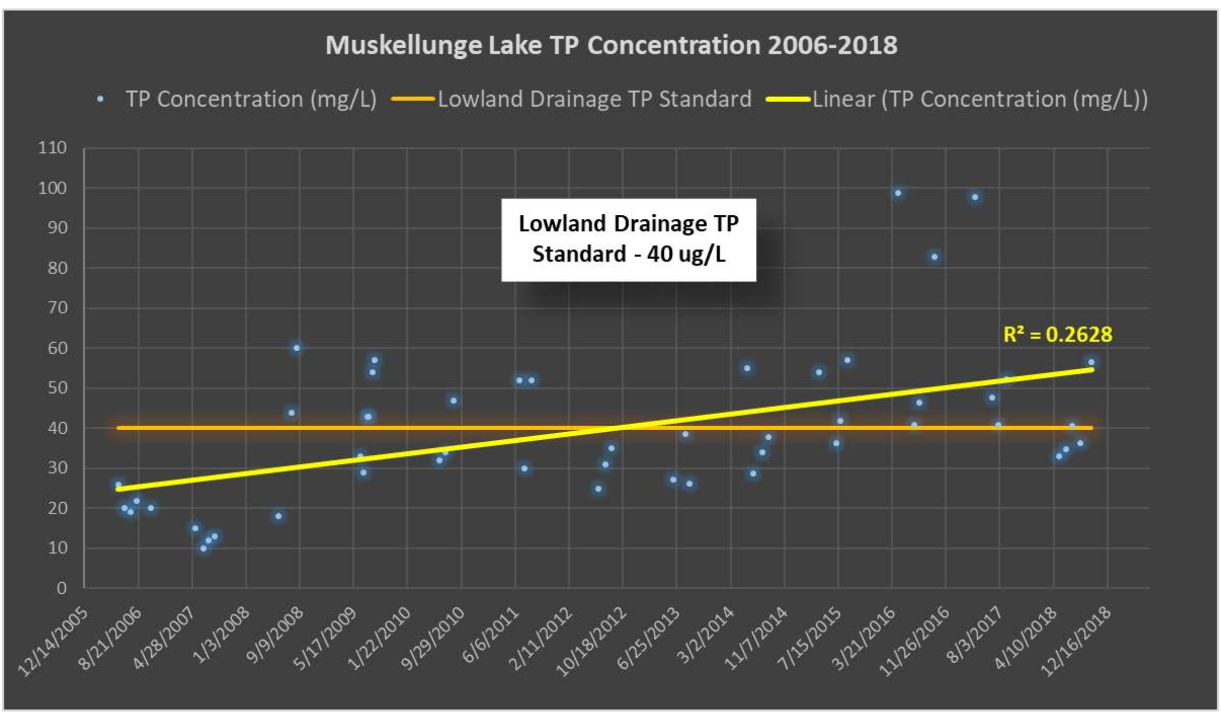


Figure 1-1. Muskellunge Lake Total Phosphorus (TP) concentrations 2006-2018.

1.2. Problem Statement

Eurasian Watermilfoil (EWM) was found for the first time on Muskellunge Lake in 2016. Despite volunteer and professional hand-harvesting efforts, the total area of the lake infested with EWM has expanded. Furthermore, the number of locations in the lake in which EWM has been documented continues to increase. A larger concern is the density of the EWM at the center bar despite continued hand-harvesting efforts, including two separate events in 2018. The location and density of EWM at the center bar is especially concerning because this area represents a major dispersal vector to other areas of the lake as the center bar has historically been an attractive spot for anglers. The existing capacity of MLA volunteers to control EWM on the center bar has recently been called into question due to water clarity and water depth challenges. EWM is now inhabiting all areas of the center bar including areas that are 5-7 feet deep. Hand-harvesting efforts in these deeper areas around the perimeter of the center bar is not feasible for volunteer-led efforts. EOR plans to work with the MLA to develop a long-term, volunteer-led hand-harvesting program that is supported initially by DASH, professional harvesting, and if necessary through the use of herbicides.

Degradation of water quality and clarity can cause shallow lakes like Muskellunge Lake to transition to an algae dominated, turbid water state. A healthy aquatic plant community can help to maintain a clear-water, aquatic plant-dominated state which is the ecologically preferred state. Maintaining a greater variety of aquatic plant species also helps to perpetuate a clear-water phase throughout the growing season given that different aquatic plant species become more or less prolific throughout the growing season. In 2018, aquatic plant growth in Muskellunge Lake was largely relegated to those portions of the lake that were less than 7 feet deep for the second year in a row. Residents of the MLA have stated that aquatic plants are not reaching as far out into the bays of the lake as "normal". This observation may be a result of increased algae abundance, a consequence of degraded water clarity. When native plant communities are stressed by degraded water quality/clarity, they are less resilient in terms of their capacity to prevent intrusion by invasive species like EWM.

Figure 1-2. Shallow Lake States

1.3. 2018 Goals and Objectives

Goals for 2018 included:

1) Build upon knowledge base acquired in 2017 through continued coordination with DNR and Vilas County AIS professionals as well as area lake associations (volunteers).
2) Evaluate volunteer-led harvesting efforts as a control option.
3) Retain volunteers within the MLA who have conducted AIS training with an ultimate goal of establishing a committee of highly Muskellunge Lake Association (MLA) volunteers.

Additional goals for 2018 work included the development of an Annual Report which summarized monitoring strategies, treatments completed in 2018, and management actions for 2019. Development of the Annual Report included time spent by Emmons and Olivier Resources (EOR) staff reviewing findings from the DNR survey findings and preparing data driven maps in ArcGIS. Additional maps were created depicting results from volunteer monitoring efforts conducted by the MLA as well as maps depicting results from professional monitoring conducted by EOR.

1.4. Purpose

The purpose of this report is to document recommended monitoring strategies and prioritized management actions for 2019 based on monitoring efforts and management actions conducted in 2018. This document will also serve as a reference point for all stakeholders (MLA, the DNR, Vilas County, and EOR) for future communication regarding the 2019 management approach.

2. 2018 AIS MONITORING

2.1. 2018 Pre-Treatment Professional AIS Monitoring

2.1.1. June 18th Focused Treatment Polygon Survey

Methods

Muskellunge Lake Association members Mike Newmeister and Jeff Rappold accompanied EOR staff on June 17th, 2018 to delineate potential treatment areas in and around previously verified EWM locations using a sub-meter differential Global Positioning System (GPS). Polygons were mapped around all well-established colonies while point-based techniques were used to record locations that were considered pioneer colonies which contained only a few plants or a single plant. All points and polygons collected in the field were transferred to ArcMap v. 10.3.1 Geographic Information System (GIS).

2.1.2. Focused Meander Survey – Littoral Zone

EOR conducted a focused (EWM presence) meander survey of the entire littoral zone on June 19th, 2018. The maximum depth of plant growth observed during the June 19th survey was 8.0 feet with the vast majority of aquatic plant growth occurring in areas that were less than 7 feet deep. A GPS log highlighting results from professional monitoring efforts is provided in Table 1. Results from 2018 Professional AIS monitoring efforts are summarized in Section 2.1.3 and spatially in Figure 2-1.

Table 1. 2018 Focused Meander Survey - Littoral Zone Results.

WPT ID	Lat N	Log W	Site Notes
1	45.95138	-89.38038	EWM Edge - Scattered (1- Rake Ranking)
2	45.95139	-89.38038	Small Patch - Dense EWM (3- Rake Ranking)
3	45.95141	-89.38036	EWM Edge - Scattered (1- Rake Ranking)
4	45.95121	-89.38026	EWM sparse, mixed with cabbage
5	45.95115	-89.38032	EWM Edge - Scattered (1- Rake Ranking)
6	45.95121	-89.38056	EWM Edge - Scattered (1- Rake Ranking)
7	45.95142	-89.38071	EWM Edge - Scattered (1- Rake Ranking)
8	45.95123	-89.38039	Dense EWM (3- Rake Ranking)
9	45.95113	-89.38031	EWM Edge - Scattered (1- Rake Ranking)
10	45.95117	-89.38001	EWM Edge - Scattered (1- Rake Ranking)
11	45.95132	-89.37999	EWM Edge - Scattered (1- Rake Ranking)
12	45.95140	-89.38024	EWM Edge - Scattered (1- Rake Ranking)
13	45.95143	-89.38039	EWM Edge - Scattered (1- Rake Ranking)
14	45.95140	-89.38060	EWM Edge - Scattered (1- Rake Ranking)
15	45.95138	-89.38076	EWM Edge - Scattered (1- Rake Ranking)
16	45.95117	-89.38074	EWM Edge - Scattered (1- Rake Ranking)
17	45.95118	-89.38042	EWM Edge - Scattered (1- Rake Ranking)
18	45.95115	-89.38000	EWM Edge - Scattered (1- Rake Ranking)
19	45.95108	-89.38045	EWM Edge - Scattered (1- Rake Ranking)
20	45.95120	-89.38081	EWM Edge - Scattered (1- Rake Ranking)
21	45.94845	-89.37387	Nothing found
22	45.94818	-89.37439	EWM Edge - Scattered (1- Rake Ranking)
23	45.94796	-89.37464	EWM Edge - Scattered (1- Rake Ranking)
24	45.94788	-89.37466	EWM Edge - Scattered (1- Rake Ranking)
25	45.94780	-89.37474	EWM Edge - Scattered (1- Rake Ranking)
26	45.94778	-89.37484	EWM Edge - Scattered (1- Rake Ranking)
27	45.94832	-89.37426	EWM Edge - Scattered (1- Rake Ranking)
28	45.95728	-89.37690	EWM Edge - Scattered (1- Rake Ranking)
29	45.95692	-89.37650	EWM Edge - Scattered (1- Rake Ranking)
30	45.95685	-89.37635	EWM Edge - Scattered (1- Rake Ranking)
31	45.95699	-89.37660	Small Patch Moderate Density EWM (2- Rake Ranking)
32	45.95709	-89.37669	EWM Edge - Scattered (1- Rake Ranking)
33	45.95329	-89.38551	EWM New Spot - Scattered (1- Rake Ranking)
34	45.95330	-89.38554	EWM New Spot - Scattered (1- Rake Ranking)
35	45.95334	-89.38557	EWM New Spot - Scattered (1- Rake Ranking)
36	45.95332	-89.38574	EWM New Spot - Scattered (1- Rake Ranking)
37	45.94780	-89.37461	EWM New Spot - Scattered (1- Rake Ranking)
38	45.95711	-89.37665	EWM New Spot - Scattered (1- Rake Ranking)
39	45.95712	-89.37661	EWM New Spot - Scattered (1- Rake Ranking)

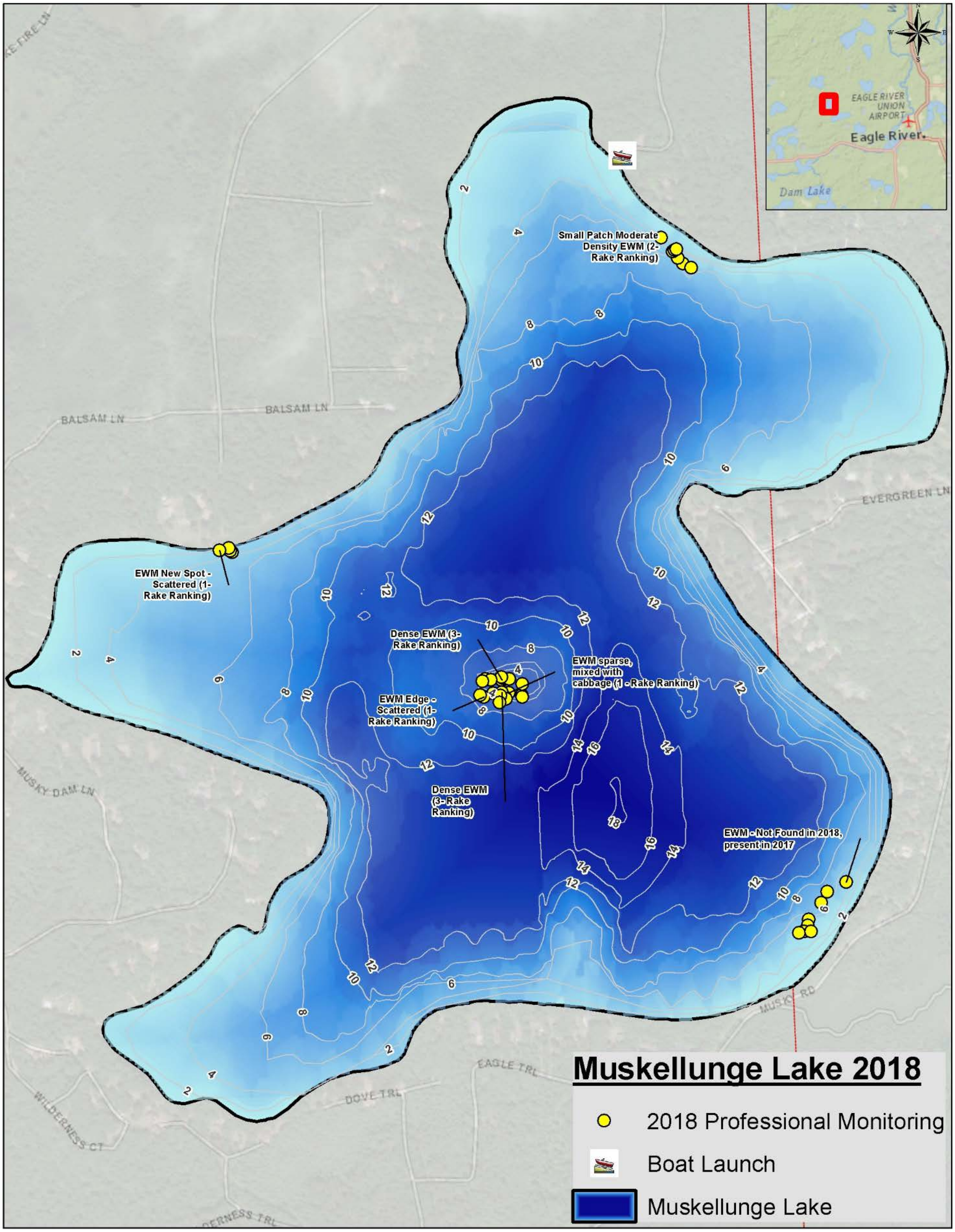
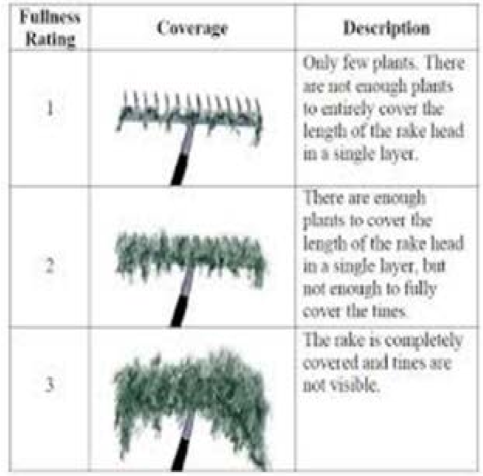


Figure 2-1. 2018 Focused Meander Survey - Littoral Zone Results.

2.1.3. 2018 Professional AIS Monitoring Results

As previously discussed, the most concerning finding was the dense patch of EWM growing in and around the center buoy which was occupying a similar space in 2018 as it was in 2017 despite the professional hand harvesting effort in 2017.



Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

Figure 2-2. Rake Rating

In the areas near the boat landing and the area adjacent to Musky Road (southeast shoreline), EWM appeared to be more spotty relative to 2017 with an average rake ranking of 1 with the occasional 2 rake ranking (Figure 2-2), suggesting that hand-harvesting may have reduced the abundance/ prevented the spread of EWM in these areas. While certain stands of EWM showed reduced densities in comparison with 2017 data, most areas remained consistent both in terms of the abundance of EWM at a given location and distribution of EWM at the lake-wide scale. A positive takeaway from the June 17th, survey was that the total area of infestation (as of June 17th) was still less than 1 acre with the vast majority of the EWM occurring in areas that were less than 4.5 feet deep. This finding would later be proved false, as EWM expanded to cover more than 1 acre later in the year.

2.2. 2018 Volunteer Efforts

2.2.1. Volunteer Hand-Harvesting Efforts

Following the professional delineation of treatment polygons, EOR met with the DNR to discuss the feasibility of a volunteer-led hand harvesting efforts. DNR staff recommended contacting the Squash Lake Association for recommendations on how to establish a volunteer-led hand harvesting program. EOR reached out to Dan Butkus at the Squash Lake Association on June 25th, 2018. Dan provided a summary of steps the Squash Lake Association is taking to control EWM on Squash Lake. While there are significant differences in water clarity in Squash Lake versus Muskellunge Lake, some of the fundamental principles of developing a volunteer hand-harvesting program were applicable to Muskellunge Lake. Lessons learned from Dan were passed onto the MLA. The MLA also expressed interest in attending a hand-harvesting training workshop held by Stephanie Boismenue at the Oneida County Land and Water Department; however this workshop never materialized.

Members of the MLA spent 84 man hours conducting volunteer-led hand-harvesting efforts in 2018. Photos of this effort are included in Appendix A. The majority of the time spent was focused on removing EWM from the center bar. Initial hand harvesting efforts were conducted on July 5th 2018, a total of 61.5 hours man hours were spent removing the EWM on the 5th. Donated equipment included 2 boats with motor which were used for a total of 3 hours, and 2 row boats which were used for an additional 3 hours. Two kayakers were also present, each equipped with nets to catch uprooted fragments.

A second volunteer led hand-harvesting effort was performed on July 29, a total of 22.5 hours were spent removing EWM, again with a focus on the center bar. Donated equipment included 2 boats with motor which were used for a total of 6.5 hours, and 1 row boats which was used for an additional 3 hours.

2.2.2. 2018 MLA Volunteer Post-Treatment AIS Monitoring

Following hand-harvesting efforts, the MLA spent 66.5 man hours conducting focused meander surveys around all locations where EWM had been identified prior to the treatment and performed shoreline inspection surveys to record any new infestations using a GPS. These surveys took place from July 12th (one-week after the harvest) through October 22nd. Point-based techniques were used to record all confirmed locations. All GPS data was transferred from the boat-mounted Garmin GPS unit to an Excel spreadsheet. The Excel spreadsheet was sent to EOR from which maps were created using ArcMap version 10.3.1. All labor and equipment used to conduct the post- treatment surveys were provided by the MLA. A GPS log highlighting results from volunteer monitoring efforts is provided in Table 1. Results from 2018 Volunteer-led AIS monitoring efforts are also presented spatially in Figure 2-3. An overall summary highlighting post-treatment monitoring results, including a comparison with 2017 data is provided in Section 3.1. MLA president Mike Newmeister also accompanied Carol Warden on a kayak trip in early November, 2018 to document the current extend of the EWM infestation on the center bar.

2.2.3. 2018 MLA AIS Sign Posting

The MLA donated more than 20 hours of their time, and provided the materials and resources needed to post signage warning users of the presence of EWM. Maps provided at the boat landing clearly demarcated areas to avoid (Figure 2-4). The MLA also placed Marker buoys around locations in which EWM had been verified through professionally-led AIS monitoring efforts.

2.2.4. 2018 MLA Water Quality Monitoring

MLA conducted 27 hours of water quality monitoring work in 2018. This work included collecting epilimetic/hypolimnetic water quality samples, conducting dissolved oxygen profiles, under-ice sampling, and taking secchi disk measurements. An additional 30 hours was spent communicating with EOR on results from both water quality and AIS monitoring efforts.

Table 2. 2018 Volunteer AIS Monitoring Results

WPT ID	Lat N	Log W	Depth (Feet)	Description	Additional Notes
92	45.95704	-89.3768	4.2	Eagle Nest area	Density is increasing
93	45.95712	-89.37672	3.1	Eagle Nest area	
94	45.95699	-89.37669	3.9	Eagle Nest area	
95	45.95699	-89.37659	3	Eagle Nest area	
96	45.9569	-89.37652	3.3	Eagle Nest area	
97	45.95707	-89.37674	3.7	Eagle Nest area	
98	45.95707	-89.37677	3.1	Eagle Nest area	
99	45.9541	-89.38239	4	NW Shore	New outbreak 20'x20'
100	45.95347	-89.38461	3.7	NW Shore	New String, about 20' wide strip
101	45.95337	-89.3849	4.3	NW Shore	
102	45.95332	-89.38531	3.8	NW Shore	
103	45.95327	-89.38538	3.7	NW Shore	
104	45.95321	-89.38562	4.1	NW Shore	
105	45.94727	-89.3793	3.8	South Shore	New finding, Several plants
106	45.94686	-89.3783	2.3	South Shore	New finding, Several plants
107	45.9469	-89.37811	3.7	South Shore	New finding, Several plants
108	45.94682	-89.37741	1.6	South Shore	New finding, Several plants
109	45.94683	-89.37767	2.9	South Shore	New finding, Several plants
110	45.94759	-89.37505	3	South Shore Inlet	New string this summer. 20' wide
111	45.94769	-89.37492	3.3	South Shore Inlet	New string this summer. 20' wide
112	45.94818	-89.37437	4.7		Several clumps of plants
113	45.94817	-89.37414	1.9		
114	45.94824	-89.37425	3.7		Not expanding
115	45.94814	-89.3744	4.1		
116	45.94811	-89.37418	2.6		
117	45.94839	-89.37407	3.8		Single plants
118	45.94853	-89.37396	3.8		Area is not expanding
119	45.94842	-89.37395	2.4		
120	45.95111	-89.38008	6.7	Center Bar	Very heavy matted at surface
121	45.9511	-89.38046	4.4	Center Bar	Spreading 30' west of point
122	45.951	-89.38064	6.8	Center Bar	Spreading 30' west of point
123	45.95105	-89.38075	5.8	Center Bar	Spreading 30' west of point
124	45.95124	-89.38081	4.9	Center Bar	Spreading 30' west of point
125	45.95129	-89.38074	4.2	Center Bar	Dense cover
126	45.95134	-89.38055	3.1	Center Bar	Dense cover
127	45.95135	-89.38032	2.4	Center Bar	Got thicker after harvest
128	45.95132	-89.38021	2.9	Center Bar	Got thicker after harvest
129	45.95129	-89.3801	3.1	Center Bar	Got thicker after harvest
130	45.95118	-89.38005	4.4	Center Bar	Got thicker after harvest
132	45.95683	-89.37604	3.8	Eagles Nest East	New area , just discovered, 20' wide
133	45.95682	-89.37596	4	Eagles Nest East	
134	45.95681	-89.37586	4.5	Eagles Nest East	
135	45.95681	-89.37583	4.5	Eagles Nest East	
136	45.95682	-89.3758	3.4	Eagles Nest East	
137	45.95688	-89.37633	3.4	Eagles Nest East	
138	45.95707	-89.37664	3.3	Eagle Nest area	
139	45.95713	-89.37684	4	Eagle Nest area	
140	45.94616	-89.38439	3	SW Shore	New discovery in August
141	45.94618	-89.38422	2	SW Shore	Several Plants
142	45.94734	-89.3756	1.9	South Shore Inlet	New string this summer. 20' wide
143	45.94752	-89.37522	3	South Shore Inlet	New string this summer. 20' wide
144	45.94757	-89.3751	2.9	South Shore Inlet	New string this summer. 20' wide
145	45.94778	-89.37473	3.7	South Shore Inlet	New string this summer. 20' wide
146	45.94807	-89.37437	4	SE Shore area	Scattered Plants

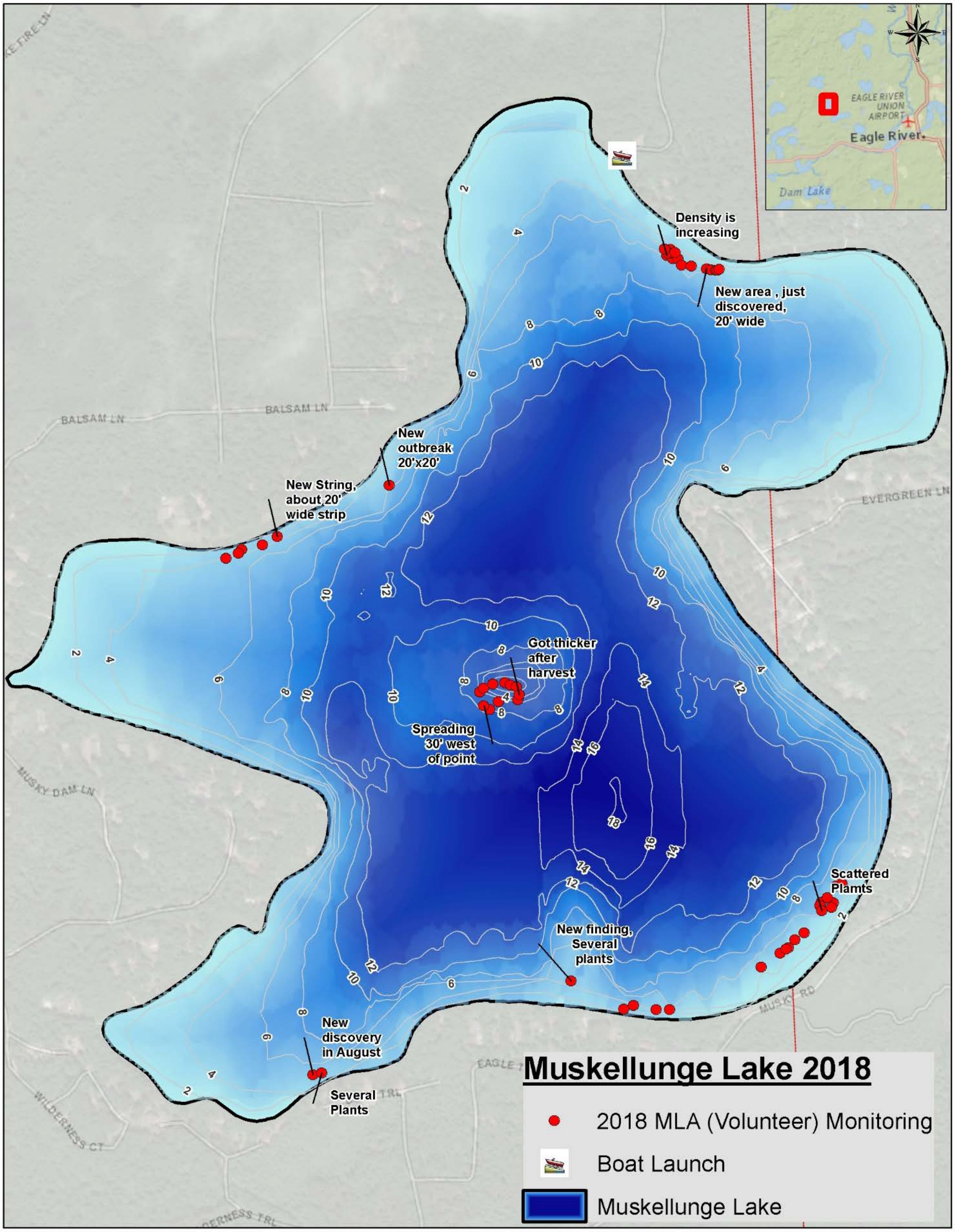


Figure 2-3. 2018 Volunteer Monitoring Results

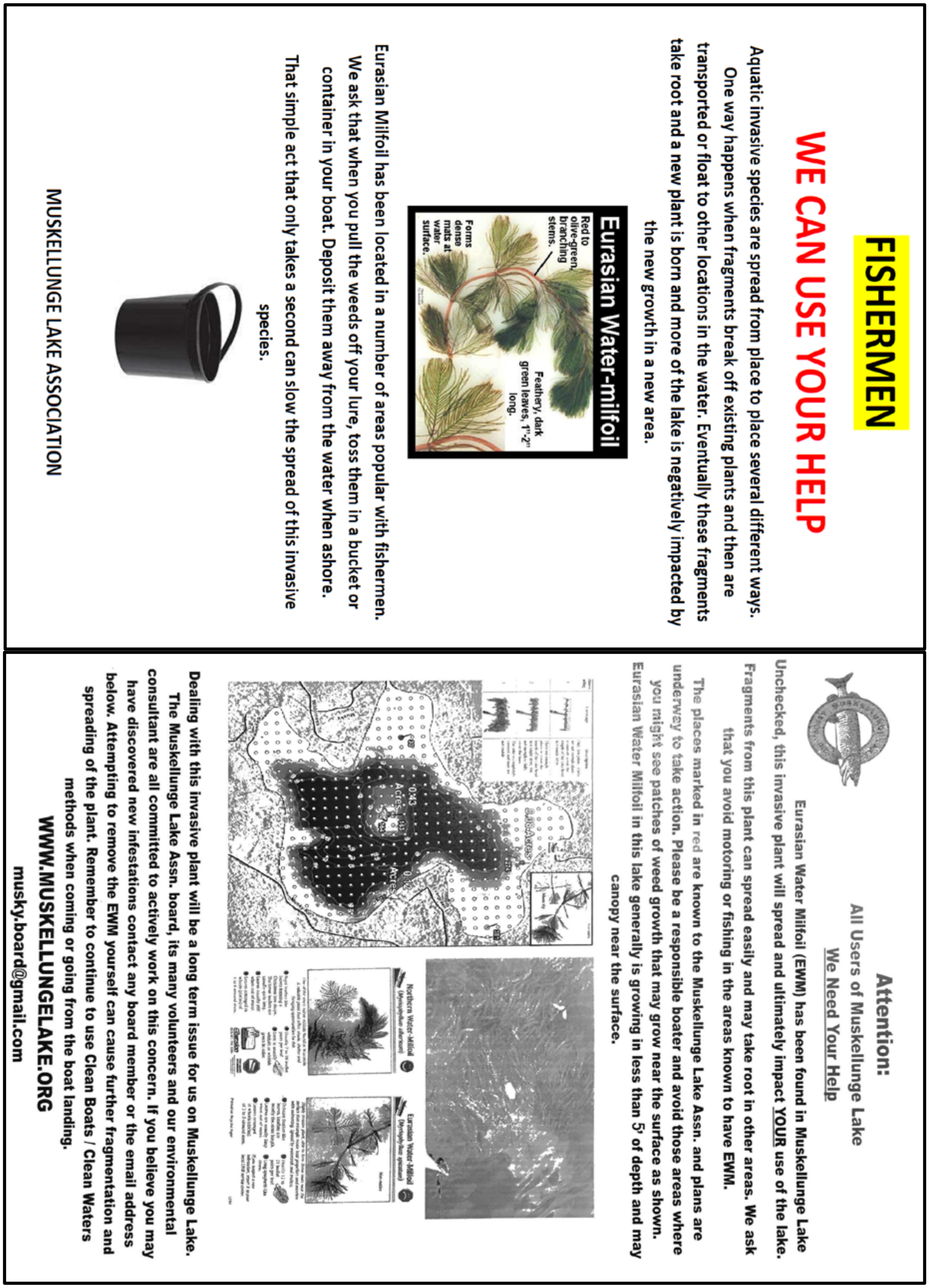


Figure 2-4. Muskellunge Lake Association EWM Warning Signs

3. 2018 POST- TREATMENT HAND-HARVESTING RESULTS

3.1. 2018 Results

Volunteer AIS monitoring efforts conducted from July 12th -October 22nd show a continued expansion of EWM in three key areas of the lake despite professional (2017) and volunteer (2018) hand harvesting efforts. Results are presented spatially and described in further detail below.

1) Center Bar – Figure 3-1
    a. Red Areas = 2017 Delineated polygons **(0.43 Acres)**, Yellow Areas = Summer 2018 Delineated Polygons **(0.56 acres)**, Green Areas = Fall, 2018 Delineated Polygons **(0.66 acres)**
2) Southeastern EWM expansion - Figure 3-2
    a. Red Areas = 2017 Delineated polygons **(0.4 Acres)**, Yellow Areas = Summer 2018 Delineated Polygons **(0.29 acres)**, Green Areas = Fall, 2018 Delineated Polygons **(0.51 acres)**
3) Northeastern (Near Boat Launch) EWM expansion - Figure 3-3
    a. Red Areas = 2017 Delineated polygons **(0.08 Acres)**, Yellow Areas = Summer 2018 Delineated Polygons **(0.13 acres)**, Green Areas = Fall, 2018 Delineated Polygons **(0.29 acres)**

Center Bar

By late August, EWM had migrated into water that was too deep for volunteers to manually harvest without dive gear. At this time, any evidence of 2018 hand-harvesting efforts was absent. By Labor Day, the density of EWM at the center bar had increased, forming a dense canopy across the surface. By late September, EWM was matted across all areas of the center bar that were less than 5 feet deep. Furthermore, approximately 50% of the infestation occurred in water that was greater than 5 feet deep. With 2018 secchi disk readings of 3-5 feet or less, visibility even with dive gear is difficult in these area. Locating EWM in these areas of the lake becomes especially difficult after the bottom sediment becomes re-suspended during harvesting efforts.

Expansion in other Areas

As depicted in Figure 3-2 and Figure 3-3, the two nearshore infestations continued to expand despite professional and volunteer harvesting efforts. Furthermore, EWM was located at 6 new spot areas in 2018. The center bar is the most likely dispersal vector to these near shore locations. The total area of infestation as of October, 22nd, 2018 is approximately 1.48 acres with additional pioneer infestations (single plants) encompassing an additional 0.1 to 0.3 acres.

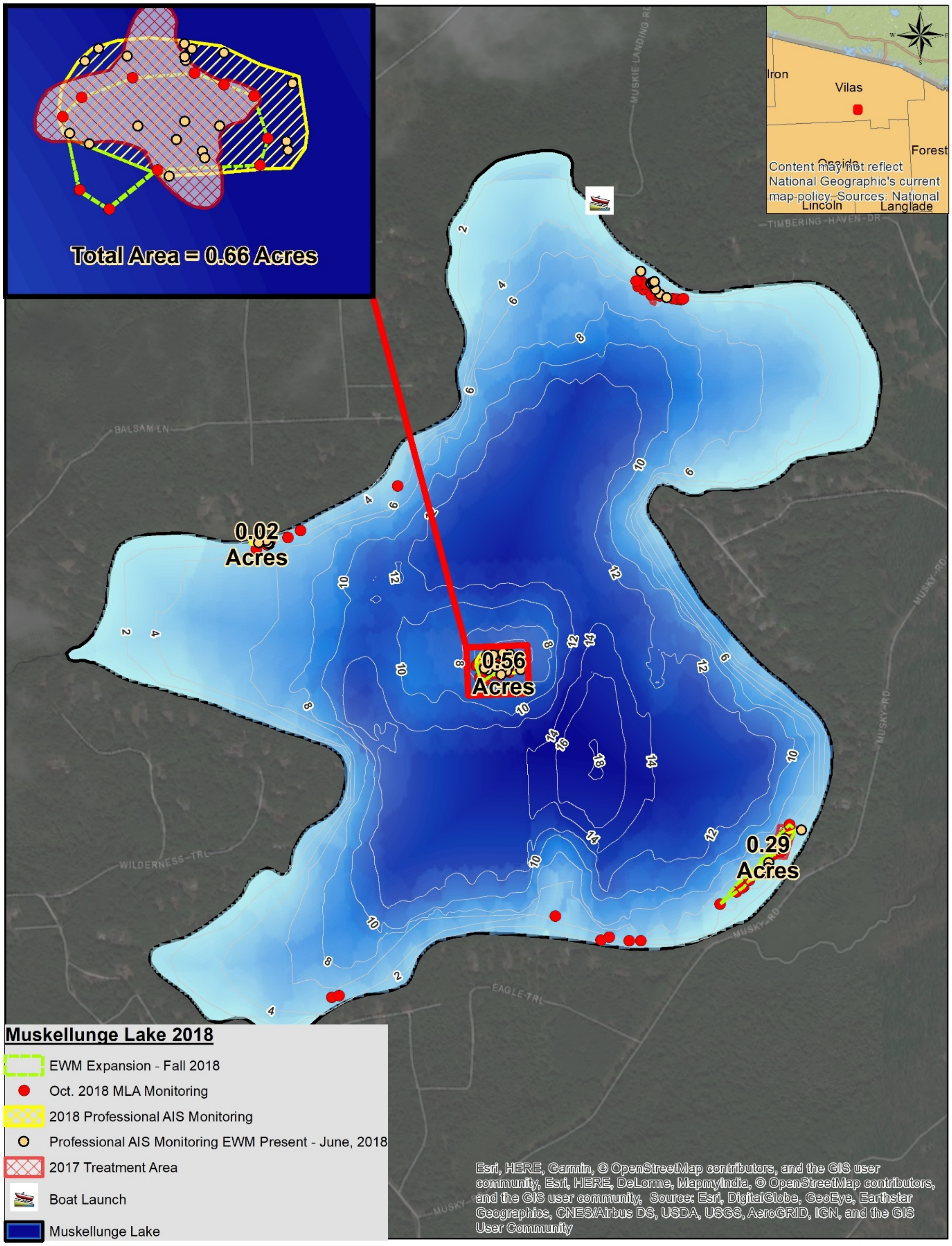


Figure 3-1. Expansion of EWM at the center bar from 0.43 acres (2017 Professional Survey) to 0.66 acres – 2018 Post-Treatment Survey (Volunteer Monitoring).

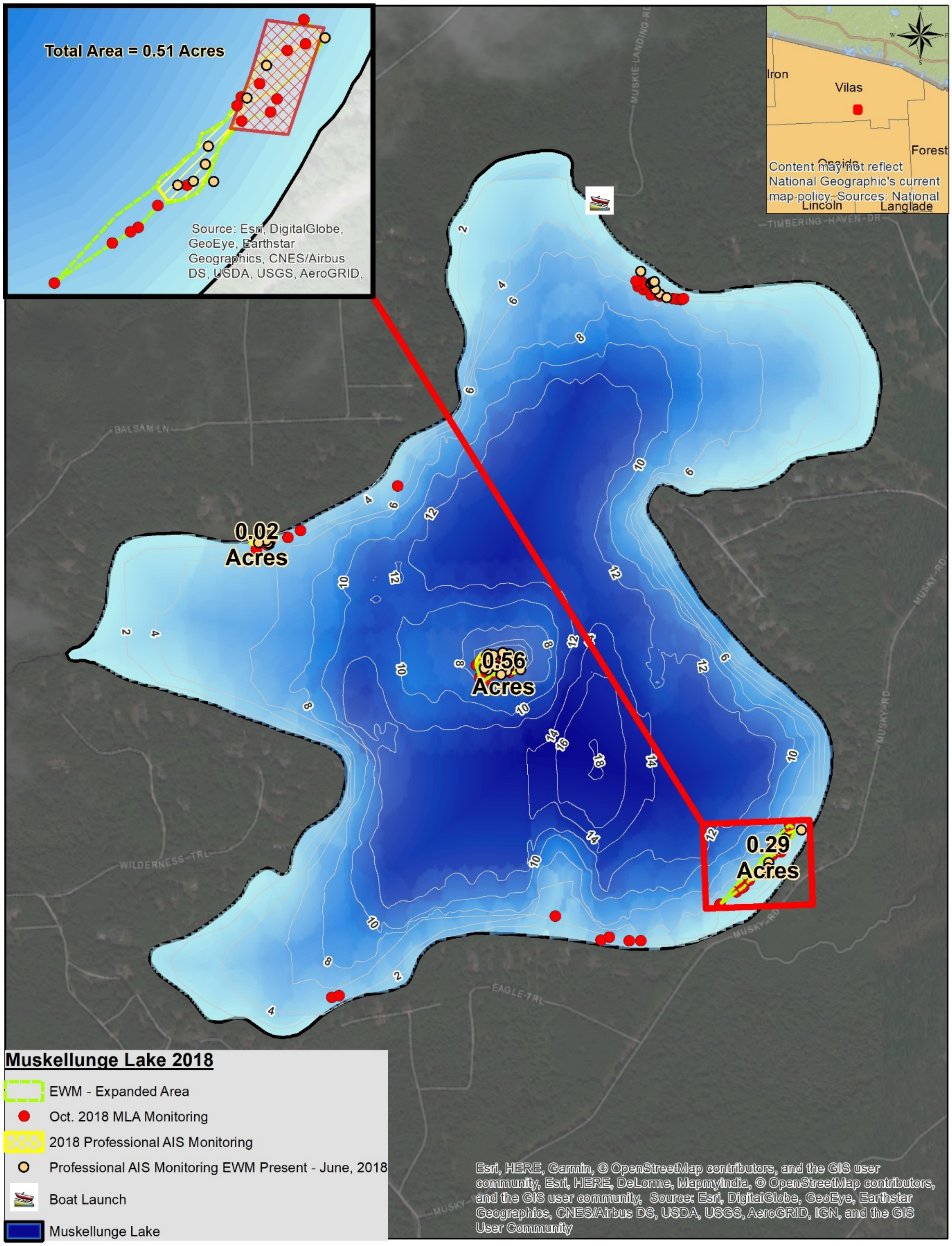


Figure 3-2. Expansion of EWM along the southeastern corner from 0.4 acres (2017 Professional Survey) to 0.51 acres – 2018 Post-Treatment Survey (Volunteer Monitoring).

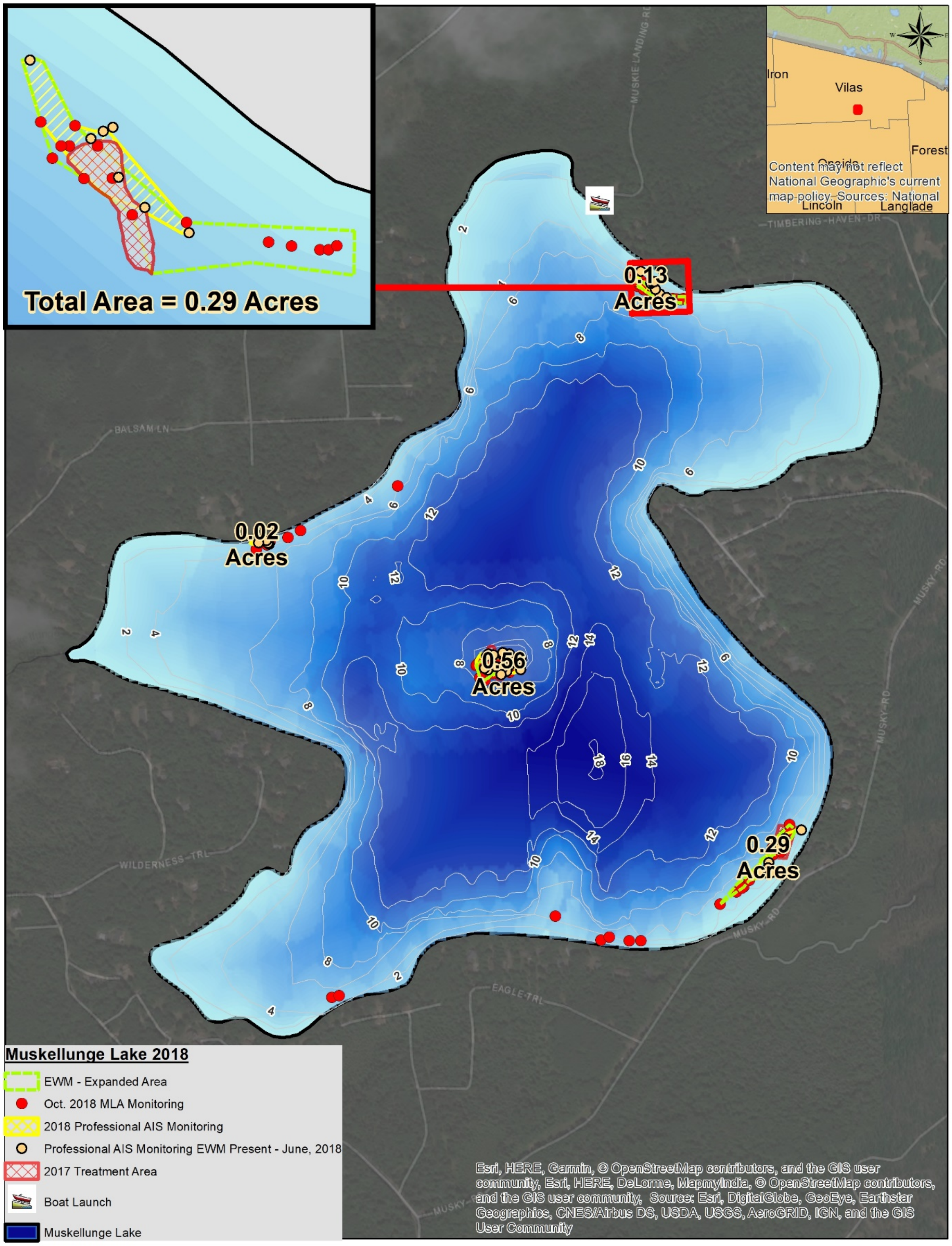


Figure 3-3. Expansion of EWM along the northeastern corner (near boating landing) from 0.08 acres (2017 Professional Survey) to 0.29 acres – 2018 Post-Treatment Survey (Volunteer Monitoring).

4. 2019 MONITORING STRATEGIES

4.1. 2019 Monitoring Strategies

2019 Early Season Focused Meander AIS Survey

In 2019, EOR staff will complete an early-season focused meander AIS survey in the areas of Muskellunge Lake that are less than 10 feet deep (max depth for plant growth). The early-season survey will take place in late May or early June (within 3-6 weeks of ice-out; weather dependent). The focus of this survey will be in and around those areas where EWM has previously been found, including those areas which were treated in 2017 and 2018. Polygons will be mapped around all well-established colonies using geolocated target species bed coordinates (sub-meter accuracy Trimble), and semi-qualitative estimates of target plant presence and abundance (i.e. sparse, moderate, dense).Point-based techniques will be used to record locations that are considered pioneer colonies which contain only a few plants or a single plant. Results from this survey will be used to prioritize areas for treatment in 2019.

2019/2020 Post-Treatment Surveys

In 2019, EOR staff will work with the MLA to complete a second, peak biomass, focused meander AIS survey in late June or early July (within 2-4 weeks of implementation of DASH treatment) to assess initial treatment effectiveness. Results from this survey will be used to determine if additional treatment efforts are warranted and if necessary to prioritize and target remaining EWM stands not adequately controlled through the DASH treatment (see Section 5 for complete details highlighting 2019 Management approach).

It should be noted that the ultimate success/failure of any treatment approach (hand-harvesting, DASH, herbicide, etc.) cannot always be readily determined immediately following the recommended treatment. As was seen in 2018, hand-removal efforts while initially successful in reducing EWM abundance were largely undetectable by late-fall. As such, the DNR recommends waiting a full-year following treatment (vs. within the year of treatment), to conduct comprehensive post-treatment surveys.

In 2020, EOR will conduct a second early-season focused meander survey to provide a point of comparison that will help to guide future management approaches. Results and comparisons from both the 2019 and 2020 surveys will be summarized and communicated to the DNR. The 2019 and 2020 surveys will include the collection of quantitative data on all native and target (EWM) plant species to determine the impact of the recommended treatment approach on both native species and EWM. To accomplish this task EOR will rank each individual species (using scale shown in Figure 2-1) observed at each sampling point both before and after treatment.

5. CONCLUSION AND 2019 MANAGEMENT APPROACH

Results from professional and volunteer AIS monitoring efforts conducted in 2018 on Muskellunge Lake suggest that the population of EWM in Muskellunge Lake has expanded to include areas that are not easily harvested by volunteers. Based on these results, volunteer hand-harvesting alone is not likely to accomplish the targeted goal of minimizing the spread of EWM within Muskellunge Lake. The following management approach is based on continued communication with the DNR and lessons learned from other lake associations in the area.

5.1. 2019 Management Approach

An integrated management approach will be used on Muskellunge Lake in 2019 which focuses on the use of Diver Assisted Suction Harvesting (DASH) to remove EWM from a 0.60 to 0.70 acre area near the center buoy (Figure 5-1). Aquatic Plant Management, LLC will conduct the DASH on Wednesday, June 5th. EOR will be present along with members of the MLA to oversee the DASH efforts, quantify EWM removal totals, and collect photos. EOR will also conduct a lake-wide pre-treatment survey on Saturday June 1st or Sunday June 2nd (weather dependent) to document the extent of the EWM infestation on Muskellunge Lake prior to the DASH treatment. Polygons will be mapped around all well-established colonies using geolocated target species bed coordinates (sub-meter accuracy Trimble), and semi-qualitative estimates of target plant presence and abundance (i.e. sparse, moderate, dense).Point-based techniques will be used to record locations that are considered pioneer colonies which contain only a few plants or a single plant.

A follow-up survey will be conducted by EOR with help from MLA volunteers within two weeks of the DASH treatment to prioritize any remaining EWM stands not adequately controlled through the initial DASH treatment. Polygons will be mapped around all well-established colonies using geolocated target species bed coordinates (sub-meter accuracy Trimble), and semi-qualitative estimates of target plant presence and abundance (i.e. sparse, moderate, dense).Point-based techniques will be used to record locations that are considered pioneer colonies which contain only a few plants or a single plant.

EOR will evaluate the need for follow-up management based on results from the post-treatment survey and continued volunteer AIS monitoring efforts. Follow-up management may include professional and/or volunteer-led hand-harvesting efforts or DASH (or other method at DNR's discretion) to remove remaining biomass or target areas of re-growth.

Based upon previous communication with the DNR, the MLA has identified a management trigger of 5% EWM littoral occurrence. The littoral zone (area) for Muskellunge Lake is defined as that portion of the lake which is less than 10 feet, equivalent to the maximum depth of recorded aquatic plant growth in Muskellunge Lake. The portion of Muskellunge Lake that is less than 10 feet deep equates to an area of 169 acres, or approximately 63% of the total surface area of the lake (270 acres). When this trigger is met (total area of EWM infestation exceeds 8.5 acres), the MLA would consider other viable management activities including chemical herbicides. The 5% management trigger aligns with the point at which EWM would reduce the recreational value of the waterbody, potentially restricting boat access in portions of this largely shallow lake.

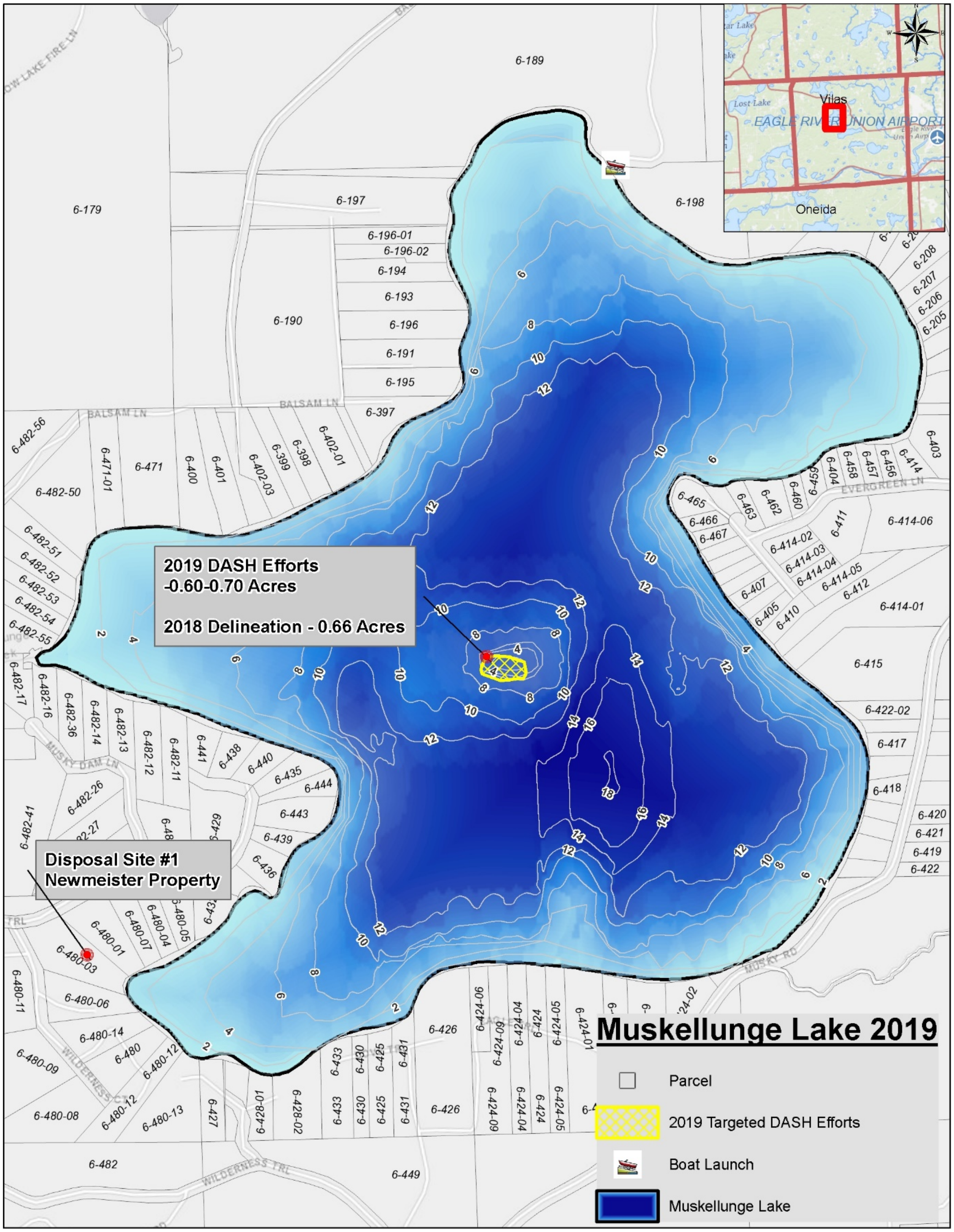


Figure 5-1. 2019 Targeted DASH Efforts

6. APPENDIX A: 2018 VOLUNTEER HAND HARVESTING IMAGES

Figure 6-1. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

Figure 6-2. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

Figure 6-3. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

Figure 6-4. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

Figure 6-5. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

Figure 6-6. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

Figure 6-7. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

Figure 6-8. MLA Volunteer Hand-Harvesting Efforts – July 5th, 2018

21. APPENDIX H: 2019 ANNUAL REPORT

Prepared by: EOR

For the Muskellunge Lake Association

2019 EWM Monitoring and DASH Assessment Report

08/10/2019

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1. INTRODUCTION

1.1. Background

Muskellunge Lake (Water ID: 128570), is a 270 acre lake located in Vilas County. Muskellunge Lake has a maximum depth of 19 feet and is classified as a shallow, lowland drainage lake. Visitors have access to the lake from a public boat landing off of Landing Road via Balsalm Lane and Highway G northeast of Eagle River, Wisconsin. The lake's water clarity is low. Muskellunge Lake was listed on the 303(d) impaired waters list in 2014 due to excess algae growth. A Total Maximum Daily Load (TMDL) study for the lake has not yet been completed, the source of the impairment is currently listed as an unknown pollutant.

1.2. Problem Statement

Eurasian Watermilfoil (EWM) was first found on Muskellunge Lake in 2016. Despite volunteer and professional hand-harvesting efforts in 2017 and 2018, and Diver Assisted Suction Harvesting (DASH) efforts in 2019, the total area of the lake with established EWM populations has expanded. As of July 2nd, 2019, the cumulative area of the lake containing established populations of EWM was 8.5 acres. The cumulative area of the EWM infestation (8.5 acres) represents a **570% increase** in the extent of infestation in comparison with 2018 where only 1.48 acres was delineated. The most likely reason for the rapid increase in EWM coverage was increased water clarity in 2019. In 2019, Secchi disk readings exceeded 6 feet during the month of June. A Secchi disk reading collected on July 27th, 2019 was 5.5 feet; this is uncharacteristically clear for Muskellunge Lake during the month of July.

From 2017 - 2018, aquatic plant growth in Muskellunge Lake was largely relegated to those portions of the lake that were less than 7 feet deep. Residents of the MLA stated that aquatic plants are not reaching as far out into the bays of the lake as "normal". This observation may have been a result of increased algae abundance, a consequence of degraded water clarity following two years of higher than normal observed total phosphorus concentrations. When native plant communities are stressed by degraded water quality/clarity, they are less resilient in terms of their capacity to prevent intrusion by invasive species like EWM. The increased water clarity in 2019 after two years of poor water clarity may have created an open niche which allowed for a rapid expansion of EWM in Muskellunge Lake.

EOR has created an ArcGIS Online map to document the location of EWM in Muskellunge Lake based on results from professional AIS monitoring efforts conducted on June 2nd, June 5th (pre-DASH) and July 7th, August 29th (post-DASH). Users of the ArcGIS Online map can view results from pre and post treatment surveys by turning on/off layers at their discretion by clicking on the Contents tab (Figure 1-1). In addition to the expansion of EWM coverage, the number of sites in which EWM has been verified in Muskellunge Lake has meaningfully increased to include the majority of littoral zone. It should be noted that in many of these new locations, EWM was found to be intermixed with native species. In other areas of the lake where EWM has been established for a longer period of time, it was most often the dominant species observed.

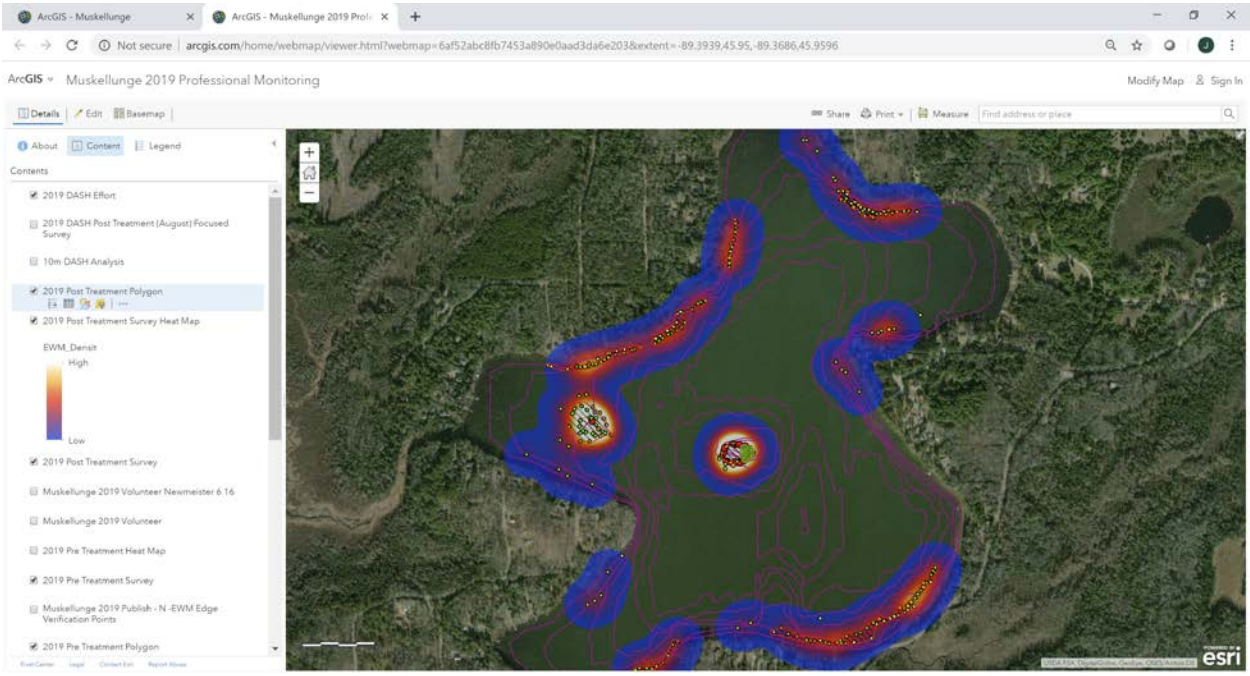

Figure 1-1. Muskellunge Lake ArcGIS Online Map

1.3. 2019 Goals and Objectives

Goals for 2019 included:

1) Evaluate Diver Assisted Suction Harvesting (DASH) efforts as a control option.
2) Retain volunteers within the MLA who have conducted AIS training with an ultimate goal of establishing a committee of highly trained Muskellunge Lake Association (MLA) volunteers.
3) Continue to map the progression of EWM using ArcGIS collector to obtain real-time information on the location of EWM. Post findings to ArcGIS Online to allow stakeholders easy access to information in an effort to engage and maintain transparency with stakeholders. Provide MLA members with an interactive, living map containing up to date information.
    a. Based upon previous communication with the DNR, the MLA has identified a management trigger of 5% EWM littoral occurrence; equivalent to a total area of EWM infestation of 8.5 acres. The MLA would consider other viable management activities including chemical herbicides. The 5% management trigger aligns with the point at which EWM would reduce the recreational value of the waterbody, potentially restricting boat access in portions of this largely shallow lake.
4) Develop Annual Report summarizing monitoring results, treatments completed in 2019 and recommended management actions for 2020.

1.4. Purpose

The purpose of this report is to document recommended monitoring strategies and prioritized management actions for 2020 based on monitoring efforts and management actions conducted in 2019. This document will also be referenced in the Muskellunge Lake Management Plan which will be completed in 2021. Finally, this document serves as a reference point for all stakeholders (MLA, the DNR, Vilas County, and EOR) for future communication regarding the 2020 management approach.

2. 2019 AIS MONITORING

2.1. 2019 Professional AIS Monitoring Methods

2.1.1. June 2nd, 5th Pre-Treatment Focused Meander Survey

Members of the Muskellunge Lake Association accompanied EOR staff on June 2nd and June 5th, 2019 to conduct a focused (EWM presence) meander survey of the entire littoral zone using a sub-meter differential Global Positioning System (GPS) and the ArcGIS Collector App to collect and publish EWM location data in real-time. Polygons were mapped around all well-established colonies while point-based techniques were used to record locations that were considered pioneer colonies which contained only a few plants or a single plant. All points and polygons collected in the field were immediately transferred (published) to a free, publicly accessible ArcGIS Online map depicting survey results. Water clarity was exceptionally clear on both June 2nd and June 5th allowing for a visual inspection of the entire water column.

2.1.2. July 7th Post-Treatment Focused Meander Survey

Following DASH efforts conducted on June 5th and June 9th, members of the Muskellunge Lake Association accompanied EOR staff on July 7th to conduct a focused (EWM presence) meander survey of the entire littoral zone using the same techniques used to conduct the pre-treatment survey. Prior to conducting the post-treatment survey, volunteers from the Muskellunge Lake Association had identified a new EWM infestation adjacent to a shallow water hazard buoy located in the northeast bay of Muskellunge Lake. MLA volunteers provided GPS coordinates of the new infestation which were added to 2019 Muskellunge Lake ArcGIS Online Map. Delineation of the extents of this new EWM infestation represented a significant point of emphasis for the post-treatment survey as this area did not contain EWM during previous surveys. Water clarity was exceptionally clear on July 7th, allowing for a visual inspection of the entire water column to be made in addition to sampling conducted using the sampling rake. The presence of clear water and calm winds greatly enhanced the ability to identify new EWM stands which was often found to be interspersed with native species.

2.1.3. August 29th Post-Treatment Focused Biomass Evaluation Survey

On August 29th, members of the Muskellunge Lake Association accompanied EOR staff to conduct a biomass evaluation survey focused exclusively on areas both within and immediately adjacent to the areas where the DASH took place. Despite torrential rainfall during the survey, EOR worked with Muskellunge Lake Association volunteers to rank EWM biomass on a scale from 1-3 (Figure 2-1) at 35 randomly selected points including 13 points outside of the treatment area and 22 points from within the DASH treatment area. A total of 19 biomass samples were collected at the 35 randomly selected sites including 10 from within the treatment area and 9 outside of the treatment area. The discrepancy between the number of sampling points recorded in the treatment area and the number of points outside of the treatment area may be a result of the DASH effort actually having a smaller footprint than reported and many of the sampling points took place on what was a.

Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

Figure 2-1. Aquatic Plant Biomass Rake Ranking

2.2. 2019 DASH Effort

2.2.1. June 5th DASH

Following the pre-treatment survey, EOR provided Aquatic Plant Management, LLC with GPS coordinates demarcating the 0.81 acre area surrounding the center bar which contained the densest stands of EWM. EOR was onsite during the June 5th DASH effort to collect photos of the DASH, document harvesting progress, and work with the MLA to transport harvested aquatic plant biomass to the offload site in an attempt to maximize the amount of time divers spent in the water. Divers noted that while the biomass of EWM was very dense near the surface, the majority of EWM was found to be disseminating from a more scattered distribution of roots along the lake bottom. Therefore, overall EWM density within the dive site was considered medium. Complete removal of the root crown was difficult at times due to the rock and gravel substrate found within the dive site. In certain areas, EWM was found to be growing from beneath large rocks/boulders which further slowed diver progress.

Figure 2-2. Aquatic Plant Management, LLC conducting harvesting on Muskellunge Lake.

In total, the three-person crew employed by Aquatic Plant Management, LLC harvested 41.5 cubic feet of EWM from a 0.15 acre area on June 5th. In addition to harvesting EWM, by-catch of native plants species included the incidental harvest of 2.5 cubic feet of native pondweeds. The DASH effort took place over the course of 8 hours, 7.42 hours of which were spent underwater (Figure 2-4; Table 2-1). The 0.15 acre area harvested on June 5th represents less than 20% of the 0.81 acre area. As such, EOR recommended the MLA re-hire Aquatic Plant Management, LLC for a second day of DASH, again aimed at the center bar.

2.2.2. June 9th DASH

Aquatic Plant Management, LLC revisited Muskellunge Lake on June 9th to conduct a second DASH effort. In total, the three-person crew employed by Aquatic Plant Management, LLC harvested an additional 36.5 cubic feet of EWM from a 0.15 acre area located immediately adjacent to the area harvested on June 5th. By-catch of native plants species included the incidental harvest of approximately 2 cubic feet of native pondweeds. The June 9th DASH effort took place over the course of 8 hours, 6.25 of which of which were spent underwater (Figure 2-4; Table 2-1).

2.2.3. Cumulative

The cumulative area harvested over the course of two days was 0.30 acres; or approximately 37% of the 0.81 acre area. A total of 78 cubic feet of EWM were removed from this 0.30 acre area at a total cost of $5,200. The cost for conducting the DASH represented the maximum investment that the MLA was willing to spend on DASH in 2019.

Figure 2-3. Harvested EWM was consolidated in onion bags and transported by MLA volunteers to the boat landing before being transported to a compost site located on private property.

Aquatic Plant Management LLC

Map of Muskellunge Lake Dive Sites

Figure 2-4. Map of Muskellunge Lake 2019 DASH Dive Sites

Table 2-1. Detailed diving activities from DASH efforts conducted on 6/5 and 6/9/2019.

Aquatic Plant Management LLC

Detailed Diving Activities

EWM Treatment Results:

Date	Dive Location	Latitude	Longitude	Time Under-water	AIS CF Removed	AIS Density	Avg Water Depth	Native By-Catch (CF)	Native Species	Native Density	Substrate Type
6/5/19	1	45.95123	-89.37990	2.25	9.00	Low	5	0.50	Pondweeds	Low	Organic/Gravel
6/5/19	2	45.95122	-89.37992	1.42	7.00	Medium	4	0.50	Pondweeds	Low	Gravel
6/5/19	3	45.95122	-89.38001	2.33	16.50	Medium	3.5	1.00	Pondweeds	Low	Gravel
6/5/19	4	45.95123	-89.38007	1.42	9.00	Medium	3.5	0.50	Pondweeds	Low	Gravel
6/9/19	5	45.95119	-89.38018	1.08	10.00	Medium	4	<0.5	Pondweeds	Low	Gravel
6/9/19	6	45.95122	-89.37992	1.25	7.50	Medium	3.5	<0.5	Pondweeds	Low	Gravel
6/9/19	6	45.95122	-89.37992	0.5	1.00	Medium	3.5	<0.5	Pondweeds	Low	Gravel
6/9/19	6	45.95122	-89.37992	0.92	3.00	Medium	3.5	<0.5	Pondweeds	Low	Gravel
6/9/19	6	45.95122	-89.37992	1.17	7.50	Medium	3.5	<0.5	Pondweeds	Low	Gravel
6/9/19	6	45.95122	-89.37992	0.75	4.50	Medium	3.5	<0.5	Pondweeds	Low	Gravel
6/9/19	6	45.95122	-89.37992	0.58	3.00	Medium	3.5	<0.5	Pondweeds	Low	Gravel
Total				**13.67**	**78.00**						

2.3. 2019 Professional AIS Monitoring Results

2.3.1. June 2nd, 5th Pre-Treatment Focused Meander Survey

A GPS log highlighting results from professional monitoring efforts is provided in Table 2-2. Results from the pre-treatment survey are represented spatially in the 2019 Muskellunge Lake ArcGIS Online Map. Results from the survey reconfirmed that the center bar contained the densest stands of EWM with plants reaching the surface by June 2nd despite below average temperatures in the month preceding the survey (Figure 2-5). As of June 2nd, the total area of the EWM infestation at the center bar was 0.81 acres. Furthermore, EWM growth was several weeks ahead of native plant growth in the center bar, shading, and outcompeting remnant stands of large leaf pondweed (*Potamogeton amplifolius*). EWM on Muskellunge Lake appeared to be further along in comparison with other Vilas County lakes. Based on these results, an executive decision was made by EOR and MLA to focus DASH efforts solely on the center bar given it is the primary vector for EWM within Muskellunge Lake.

Figure 2-5. June 2nd, 2019 dense stands of EWM near the center bar are already at or near the surface.

Table 2-2. June 2nd, June 5th, 2019 Pre-Treatment Focused Meander Survey

Point ID #	X	Y	Rake Fullness	Point ID #	X	Y	Rake Fullness
1	-89.3792	45.9472	1	52	-89.3843	45.9489	1
2	-89.3777	45.9470	1	53	-89.3743	45.9483	2
3	-89.3772	45.9469	1	54	-89.3804	45.9514	3
4	-89.3770	45.9469	1	55	-89.3809	45.9513	3
5	-89.3777	45.9475	1	56	-89.3809	45.9512	3
6	-89.3769	45.9469	1	57	-89.3808	45.9511	3
7	-89.3766	45.9469	1	58	-89.3805	45.9511	3
8	-89.3760	45.9470	1	59	-89.3804	45.9511	3
9	-89.3758	45.9473	1	60	-89.3802	45.9511	3
10	-89.3756	45.9474	1	61	-89.3801	45.9511	3
11	-89.3754	45.9475	1	62	-89.3801	45.9511	3
12	-89.3753	45.9475	1	63	-89.3800	45.9513	3
13	-89.3751	45.9475	1	64	-89.3801	45.9514	3
14	-89.3749	45.9476	1	65	-89.3808	45.9511	3
15	-89.3748	45.9477	1	66	-89.3809	45.9513	3
16	-89.3746	45.9477	1	67	-89.3809	45.9514	0
17	-89.3741	45.9483	1	68	-89.3808	45.9514	3
18	-89.3739	45.9485	1	69	-89.3802	45.9514	3
19	-89.3748	45.9568	1	70	-89.3802	45.9510	0
20	-89.3753	45.9568	1	71	-89.3804	45.9510	3
21	-89.3756	45.9568	1	72	-89.3744	45.9544	1
22	-89.3757	45.9568	1	73	-89.3854	45.9533	2
23	-89.3758	45.9568	1	74	-89.3810	45.9512	0
24	-89.3760	45.9568	1	75	-89.3805	45.9515	3
25	-89.3761	45.9568	1	76	-89.3769	45.9571	1
26	-89.3763	45.9568	1	77	-89.3767	45.9570	1
27	-89.3764	45.9569	1	78	-89.3766	45.9570	1
28	-89.3767	45.9570	1	79	-89.3766	45.9570	1
29	-89.3767	45.9570	1	80	-89.3765	45.9570	2
30	-89.3768	45.9571	1	81	-89.3765	45.9569	2
31	-89.3768	45.9572	1	82	-89.3764	45.9569	1
32	-89.3770	45.9573	1	83	-89.3763	45.9568	1
33	-89.3805	45.9566	1	84	-89.3763	45.9568	2
34	-89.3805	45.9565	1	85	-89.3762	45.9567	2
35	-89.3807	45.9560	1	86	-89.3761	45.9567	2
36	-89.3807	45.9555	1	87	-89.3760	45.9567	2
37	-89.3823	45.9545	1	88	-89.3759	45.9567	1
38	-89.3823	45.9545	1	89	-89.3759	45.9568	2
39	-89.3824	45.9544	1	90	-89.3756	45.9568	1
40	-89.3825	45.9543	1	91	-89.3755	45.9568	1
41	-89.3826	45.9542	1	92	-89.3748	45.9568	2
42	-89.3828	45.9541	1	93	-89.3768	45.9573	2
43	-89.3830	45.9539	1	94	-89.3770	45.9571	2
44	-89.3832	45.9539	1	95	-89.3769	45.9570	2
45	-89.3844	45.9536	1	96	-89.3766	45.9569	2
46	-89.3847	45.9535	1				
47	-89.3847	45.9535	1				
48	-89.3851	45.9534	1				
49	-89.3858	45.9532	2				
50	-89.3866	45.9532	1				
51	-89.3867	45.9533	1				

2.3.2. July 7th, Post-Treatment Focused Meander Survey

A GPS log highlighting results from the post-treatment survey is provided in Table 2-3. Results from the post-treatment survey are also represented spatially in the 2019 Muskellunge Lake ArcGIS Online Map. The presence of one or more EWM plants was documented at a total of 171 unique locations during the post-treatment survey; furthermore, EWM was found in nearly every Bay of Muskellunge Lake. The boundaries of the EWM infestation were determined by re-meandering the boat around the boundaries of the 171 unique sampling points to visually inspect and reconfirm the extent of the EWM population. As previously discussed, exceptional water clarity and calm winds helped to identify and verify the extents of the infestation. As of the July, 7th survey, the total acreage delineated was determined to be approximately 8.5 acres, equivalent to the management threshold that the MLA established in 2018 following communication with the DNR.

EOR documented a significant reduction in both the distribution and abundance of EWM in the 0.3 acre area in which the DASH took place. Furthermore, EOR documented the presence of large-leaf pondweed in the areas where the DASH took place. Given that the post-treatment survey occurred only one month after the DASH took place, a second post treatment survey was conducted on August 29th to more thoroughly document the impacts of the DASH effort.

Table 2-3. July 7th, 2019 Post-Treatment Focused Meander Survey

Point ID #	X	Y	Rake Fullness	Point ID #	X	Y	Rake Fullness
115	-89.3803	45.9514	1	160	-89.3852	45.9523	1
116	-89.3804	45.9515	2	161	-89.3850	45.9522	1
117	-89.3809	45.9514	3	162	-89.3846	45.9517	1
118	-89.3806	45.9515	3	163	-89.3856	45.9515	1
119	-89.3804	45.9514	3	164	-89.3860	45.9519	1
120	-89.3801	45.9514	1	165	-89.3859	45.9522	1
121	-89.3802	45.9512	1	166	-89.3858	45.9523	1
122	-89.3802	45.9512	2	167	-89.3860	45.9514	1
123	-89.3803	45.9511	1	168	-89.3863	45.9516	1
124	-89.3805	45.9511	1	169	-89.3863	45.9523	1
125	-89.3807	45.9510	2	170	-89.3857	45.9526	1
126	-89.3808	45.9510	1	171	-89.3854	45.9526	1
127	-89.3810	45.9512	1	175	-89.3815	45.9547	1
128	-89.3810	45.9513	1	176	-89.3817	45.9547	1
129	-89.3808	45.9514	2	177	-89.3818	45.9547	1
130	-89.3806	45.9515	1	178	-89.3820	45.9545	1
131	-89.3800	45.9513	1	179	-89.3822	45.9543	1
132	-89.3800	45.9512	1	180	-89.3823	45.9541	1
133	-89.3803	45.9511	1	181	-89.3825	45.9541	1
134	-89.3806	45.9510	2	182	-89.3826	45.9540	1
135	-89.3808	45.9509	1	183	-89.3827	45.9540	1
136	-89.3810	45.9511	1	184	-89.3829	45.9539	1
137	-89.3852	45.9517	1	185	-89.3830	45.9538	1
138	-89.3855	45.9517	1	186	-89.3832	45.9538	1
139	-89.3856	45.9518	1	187	-89.3837	45.9537	1
140	-89.3857	45.9519	1	188	-89.3838	45.9536	1
141	-89.3856	45.9520	1	189	-89.3840	45.9536	1
142	-89.3853	45.9521	1	190	-89.3842	45.9536	1
143	-89.3853	45.9520	2	191	-89.3845	45.9535	1
144	-89.3853	45.9520	3	192	-89.3847	45.9534	1

Point ID #	X	Y	Rake Fullness	Point ID #	X	Y	Rake Fullness
145	-89.3851	45.9519	1	193	-89.3848	45.9534	1
146	-89.3850	45.9518	2	194	-89.3850	45.9533	1
147	-89.3851	45.9517	1	195	-89.3851	45.9533	1
148	-89.3850	45.9517	1	196	-89.3852	45.9533	1
149	-89.3849	45.9517	1	197	-89.3854	45.9532	1
150	-89.3851	45.9521	1	198	-89.3855	45.9532	2
151	-89.3853	45.9521	1	199	-89.3856	45.9532	1
152	-89.3854	45.9522	1	200	-89.3858	45.9532	1
153	-89.3852	45.9522	1	201	-89.3861	45.9532	1
154	-89.3849	45.9520	1	202	-89.3874	45.9512	1
155	-89.3848	45.9519	1	203	-89.3863	45.9509	1
156	-89.3848	45.9517	1	204	-89.3861	45.9507	1
156	-89.3853	45.9515	1	205	-89.3853	45.9505	1
157	-89.3856	45.9517	1	20	-89.3847	45.9485	1
159	-89.3856	45.9523	1	207	-89.3850	45.9480	1
208	-89.3852	45.9479	1	262	-89.3755	45.9541	2
209	-89.3854	45.9478	1	263	-89.3753	45.9541	1
210	-89.3857	45.9458	1	264	-89.3745	45.9568	1
211	-89.3856	45.9458	1	265	-89.3748	45.9568	1
212	-89.3854	45.9458	1	266	-89.3749	45.9568	1
213	-89.3850	45.9460	1	267	-89.3752	45.9568	1
214	-89.3843	45.9462	1	268	-89.3753	45.9568	1
215	-89.3838	45.9463	1	269	-89.3756	45.9567	1
216	-89.3837	45.9463	1	270	-89.3757	45.9567	1
217	-89.3834	45.9463	1	271	-89.3759	45.9567	1
218	-89.3833	45.9463	1	272	-89.3762	45.9567	1
219	-89.3831	45.9464	1	273	-89.3764	45.9568	1
220	-89.3829	45.9465	1	274	-89.3769	45.9570	1
221	-89.3827	45.9466	1	275	-89.3771	45.9573	1
222	-89.3826	45.9469	1	276	-89.3772	45.9575	1
223	-89.3824	45.9469	1	277	-89.3773	45.9576	1
226	-89.3804	45.9472	1	278	-89.3778	45.9582	1
227	-89.3800	45.9474	1	279	-89.3782	45.9584	1
228	-89.3790	45.9472	1	280	-89.3783	45.9584	1
229	-89.3788	45.9471	1	281	-89.3805	45.9565	1
230	-89.3785	45.9470	1	282	-89.3805	45.9564	1
231	-89.3782	45.9470	1	283	-89.3805	45.9563	1
232	-89.3781	45.9470	1	284	-89.3806	45.9562	1
233	-89.3779	45.9469	1	285	-89.3806	45.9560	1
234	-89.3775	45.9469	1	286	-89.3807	45.9559	1
235	-89.3774	45.9469	1	287	-89.3807	45.9558	1
236	-89.3772	45.9469	2	288	-89.3807	45.9557	1
237	-89.3771	45.9470	1	289	-89.3807	45.9556	1
238	-89.3769	45.9470	1	299	-89.3807	45.9555	1
239	-89.3765	45.9471	1				
240	-89.3764	45.9471	1				
241	-89.3762	45.9472	1				
242	-89.3760	45.9474	1				
243	-89.3758	45.9475	2				
244	-89.3751	45.9477	2				
245	-89.3748	45.9478	2				
246	-89.3747	45.9478	2				

Point ID #	X	Y	Rake Fullness	Point ID #	X	Y	Rake Fullness
247	-89.3746	45.9479	1				
248	-89.3745	45.9480	1				
249	-89.3744	45.9481	1				
250	-89.3743	45.9482	2				
251	-89.3742	45.9483	1				
252	-89.3741	45.9485	1				
253	-89.3740	45.9486	1				
254	-89.3739	45.9486	1				
255	-89.3764	45.9527	1				
256	-89.3769	45.9531	1				
257	-89.3770	45.9532	1				
258	-89.3772	45.9533	1				
259	-89.3760	45.9540	1				
260	-89.3758	45.9540	1				
261	-89.3757	45.9541	1				

2.3.3. August 29th Post-Treatment Focused Biomass Evaluation Survey

The 2019 DASH did not completely eliminate EWM within the treated area, this was not the intent of the DASH effort. More importantly, the treatment area had significantly less EWM biomass in comparison with areas outside of the treatment area (Figure 2-6, Figure 2-7, and Figure 2-8). Results are also represented spatially in the 2019 Muskellunge Lake ArcGIS Online Map. Large-leaf pondweed, coontail, and water celery were observed both within the treated area and immediately outside the treatment area.

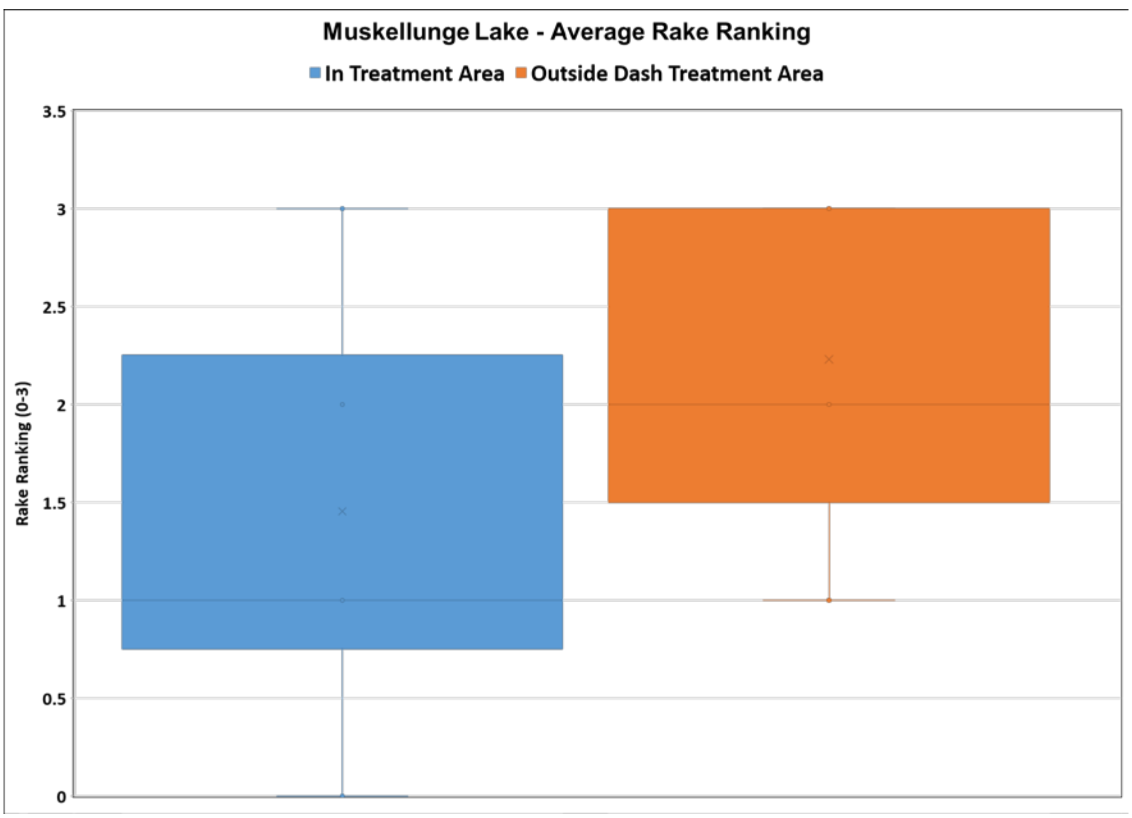

Figure 2-6. Muskellunge Lake Focused Biomass Evaluation Survey - Rake Ranking Comparison

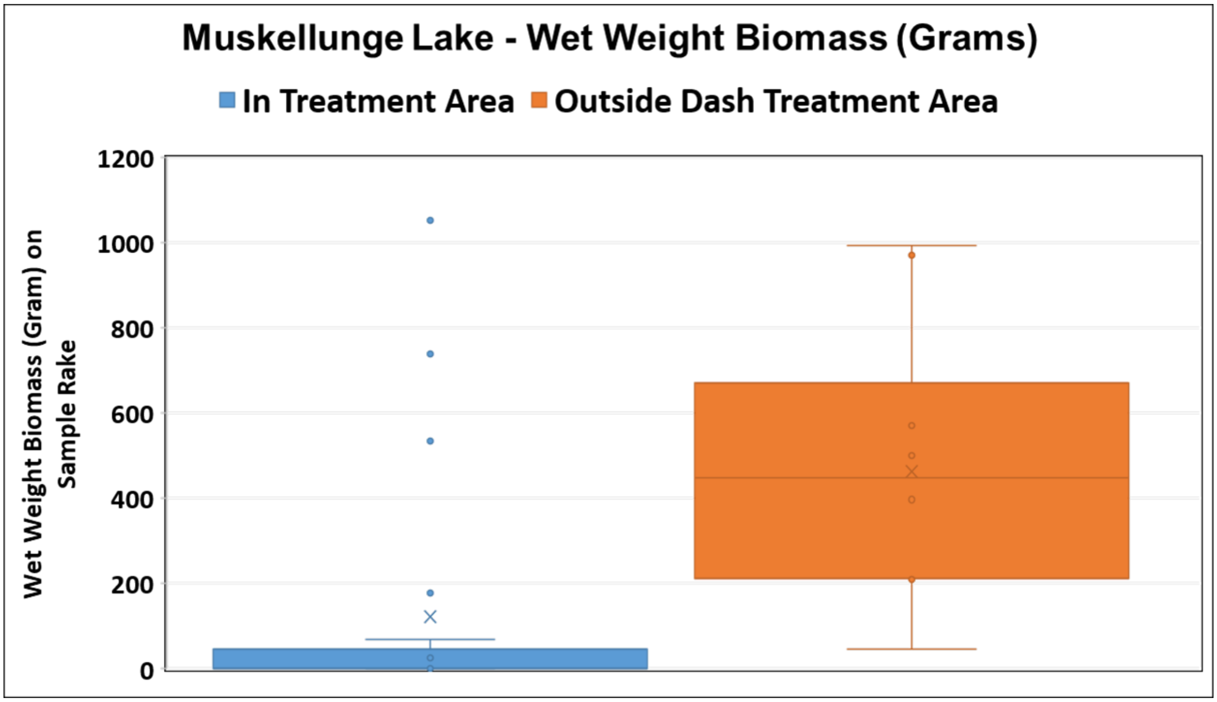

Figure 2-7. Muskellunge Lake Focused Biomass Evaluation Survey - Wet Weight Biomass

Figure 2-8. Muskellunge Lake Focused Biomass Evaluation Survey – Treatment Boundary

2.4. 2019 MLA Volunteer Efforts

The MLA spent 40 man hours conducting focused meander surveys around all locations where EWM had been identified and performed shoreline inspection surveys to record any new infestations using a GPS. These surveys took place from June through October. Point-based techniques were used to record all confirmed locations. All GPS data was transferred from the boat-mounted Garmin GPS unit to an Excel spreadsheet. The Excel spreadsheet was sent to EOR from which data points were created and ultimately uploaded to the 2019 Muskellunge Lake ArcGIS Online Map. A significant portion of the time spent by MLA volunteers was spent delineating the extents of a newly discovered EWM infestation near the second buoy located in the westernmost bay of Muskellunge Lake. Data collected by volunteers provided an extremely valuable, initial starting point for follow-up professional delineation efforts conducted in this area.

Members of the MLA also donated more than 20 hours of their time, and provided the materials and resources needed to post signage warning users of the presence of EWM. Maps provided at the boat landing clearly demarcated areas to avoid (Figure 2-9). The MLA also placed Marker buoys around locations in which EWM had been verified through professionally-led AIS monitoring efforts. Finally, one or more members of the MLA were present at each professional monitoring effort. All professionally led monitoring efforts were conducted using boats operated by MLA staff.

2.4.1. 2019 MLA Water Quality Monitoring

MLA conducted 30 hours of water quality monitoring work in 2019. This work included collecting epilimetic/hypolimnetic water quality samples, conducting dissolved oxygen profiles, under-ice sampling, taking secchi disk measurements, and working with Vilas County Lake Conservation Specialist staff to verify dissolved oxygen meters were properly calibrated. An additional 30 hours was spent communicating with EOR on results from both water quality and AIS monitoring efforts.

2.4.2. 2019 MLA Training

Members of the MLA attended multiple training sessions in 2019 as shown in Table 1.

Training Description	Date Attended	Attendees	Hours Recorded
Clean Boats Clean Waters training	June 28th	Cheryl Breitenfeldt	3
Informational meeting on 2,4-D at Trout Lake Station	July 23rd	Cheryl Breitenfeldt Wayne Breitenfeldt Larry Duffee Jeff Rappold	12

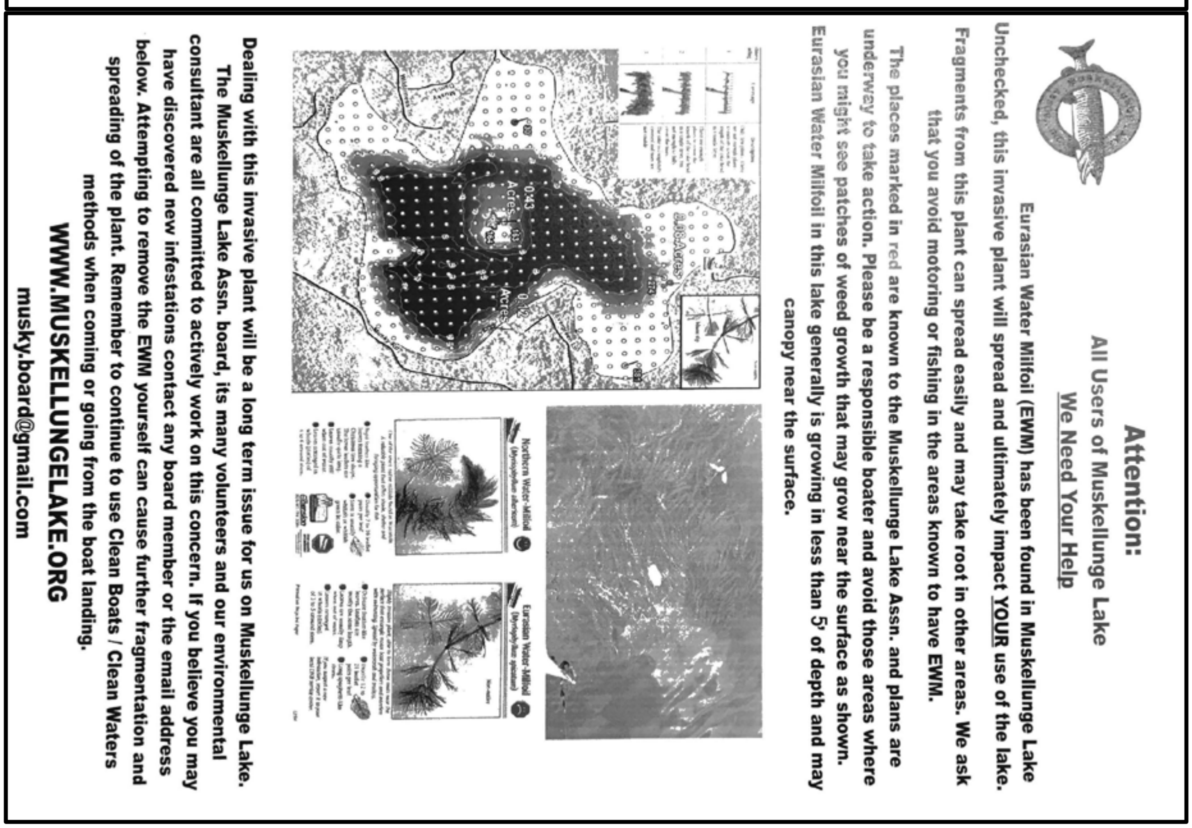

Figure 2-9. Muskellunge Lake Association EWM Warning Signs

3. CONCLUSION AND 2020 MANAGEMENT APPROACH

Based upon previous communication with the DNR, the MLA has identified a management trigger of 5% EWM littoral occurrence. The littoral zone (area) for Muskellunge Lake is defined as that portion of the lake which is less than 10 feet, equivalent to the maximum depth of recorded aquatic plant growth in Muskellunge Lake. It should be noted that aquatic plant growth beyond 8 feet is extremely limited in Muskellunge Lake. The portion of Muskellunge Lake that is less than 10 feet deep equates to an area of 169 acres, or approximately 63% of the total surface area of the lake (270 acres). When this trigger is met (total area of EWM infestation exceeds 8.5 acres), the MLA has previously determined that they would like to explore other viable management activities including chemical herbicides. The 5% management trigger aligns with the point at which EWM would reduce the recreational value of the waterbody, potentially restricting boat access in portions of this largely shallow lake. Furthermore, the MLA operates on a small budget, with income generated solely through the donations of annual dues from willing lakeshore owners.

Results from professional and volunteer AIS monitoring efforts conducted in 2019 on Muskellunge Lake suggest that the population of EWM in Muskellunge Lake has expanded to an area where alternative management practices beyond physical removal efforts will be required. While the DASH effort appeared to be effective within the 0.30 acre treatment area, DASH is not an economically scalable or feasible option to fully address the extent of the EWM infestation on Muskellunge Lake in 2020.

The proposed 2020 management approach is based on continued communication with the DNR and lessons learned from other lake associations in the area.

3.1. 2020 Management Approach

If results from an early season 2020 focused meander survey identify a EWM distribution which covers more than 5% of the littoral zone (8.5 acres), EOR recommends working with SePRO to conduct an herbicide treatment using ProcellaCOR. EOR recommends using ProcellaCOR in 2020 which requires shorter contact times in comparison with 2, 4,-D and uses 40x-100x less active ingredient. The distribution of EWM in Muskellunge Lake makes the use of 2, 4-D less practical because 2, 4-D requires an extended contact time in comparison with ProcellaCOR. Further, recent research suggests that hybrid watermilfoil can develop herbicide (2, 4-D) resistance after multiple treatments.

- Noted benefits of ProcellaCOR that are applicable to Muskellunge Lake Include:
    - Novel, low-rate, reduced-risk technology
    - Short-exposure requirements for systemic control allowing for effective spot treatment and applications to higher exchange sites
    - Excellent selectivity to promote native plant dominance
    - Potentially qualify for three-year warranty from manufacturer

3.1.1. Application Recommendations

The recommended dosage rate for invasive watermilfoils is 3-5 Prescription Dose Units (PDU) of ProcellaCOR per acre-foot. EOR will work with SePRO to evaluate the need for using a slightly higher dose to account for the products affinity to bind to organic materials as well as the potential dissipation of the chemical, especially in areas near the center buoy which are more likely to be effected by wind and wave action. However, because the majority of the EWM in Muskellunge Lake is in areas that are less than 6 feet deep, a higher dosage rate may not be required. EOR will also work with SePRO and the MLA to evaluate under what conditions the treatment would qualify for a warranty.

On September 3rd, 2019, EOR spoke with SePRO technical specialist Michael Hiatt about the use of ProcellaCOR to treat EWM in northern Wisconsin. Mr. Hiatt is responsible for making these decisions on a lake by lake basis for Minnesota and Wisconsin. Mr. Hiatt suggested that initial results from the treatment of a 14 acre area on North Twin Lake near the entrance to South Twin Lake were very promising. This portion of North Twin Lake experiences more boat traffic and has a significantly larger fetch which results in substantially more wind and wave action in comparison with any location on Muskellunge Lake. The North Twin Lake treatment used a dosage rate of 8 PDU. Given that the potential for dissipation on Muskellunge Lake is lower, and the average treatment depth on Muskellunge Lake will be less than average treatment depth for North Twin Lake (7 feet), the recommended application rate for Muskellunge Lake will likely be no more than 8 PDU.

Cost Consideration: Based on discussions with Lake Management, LLC the typical cost for a ProcellaCOR treatment range from $700-$1,400/acre. Costs are highly dependent on water depth. Given that the vast majority of EWM growth in Muskellunge Lake occurs in areas that are less than 7 feet deep, Lake Management, LLC suggested that expected costs are likely $800-$1,000/acre. Using a 10% margin of safety, a 2020 treatment would likely target no more than 10 acres of EWM. The costs associated with a ProcellaCOR treatment targeting a 10-acre area would be $8,000 -$10,000.

3.1.2. Concluding Remarks

It is important to recognize that progress towards reducing EWM abundance is often slow. The DNR's experience using herbicides to eradicate milfoil is consistent with experience elsewhere across the country, which indicates that efforts to fully eradicate EWM with herbicides are "rarely, if ever, likely to succeed" (Smith and Barko 1990). The MLA is committed to revisiting DASH efforts and other non-chemical treatment options in the future.

It is important that any management approach work towards a quantifiable target. The short-term target for Muskellunge Lake is to reduce the extent of the EWM coverage to a total surface area that is less than 3 acres. The 3 acre goal is based on a threshold at which the MLA can begin to cost effectively explore alternative management options which may include DASH, hand-pulling, or biological control options. Having a quantifiable goal also helps to maintain accountability and provides a measuring stick for assessing the effectiveness of recommended treatment options.

Ultimately, EWM will most likely reach some type of equilibrium in Muskellunge Lake with or without management. The amount of EWM that is deemed acceptable is ultimately based on the opinions of those who value Muskellunge Lake as a resource. If herbicides are used, having a quantifiable goal is therefore useful in determining if results from treatment efforts are worth the cost over broad temporal and spatial scales (Figure 3-1). As part of documenting progress, EOR has begun graphing the total surface area of EWM present in Muskellunge Lake beginning with the first survey conducted in 2017 (Figure 3-2). Graphing this type of information on an annual basis is useful in demonstrating the Return on Investment (ROI).

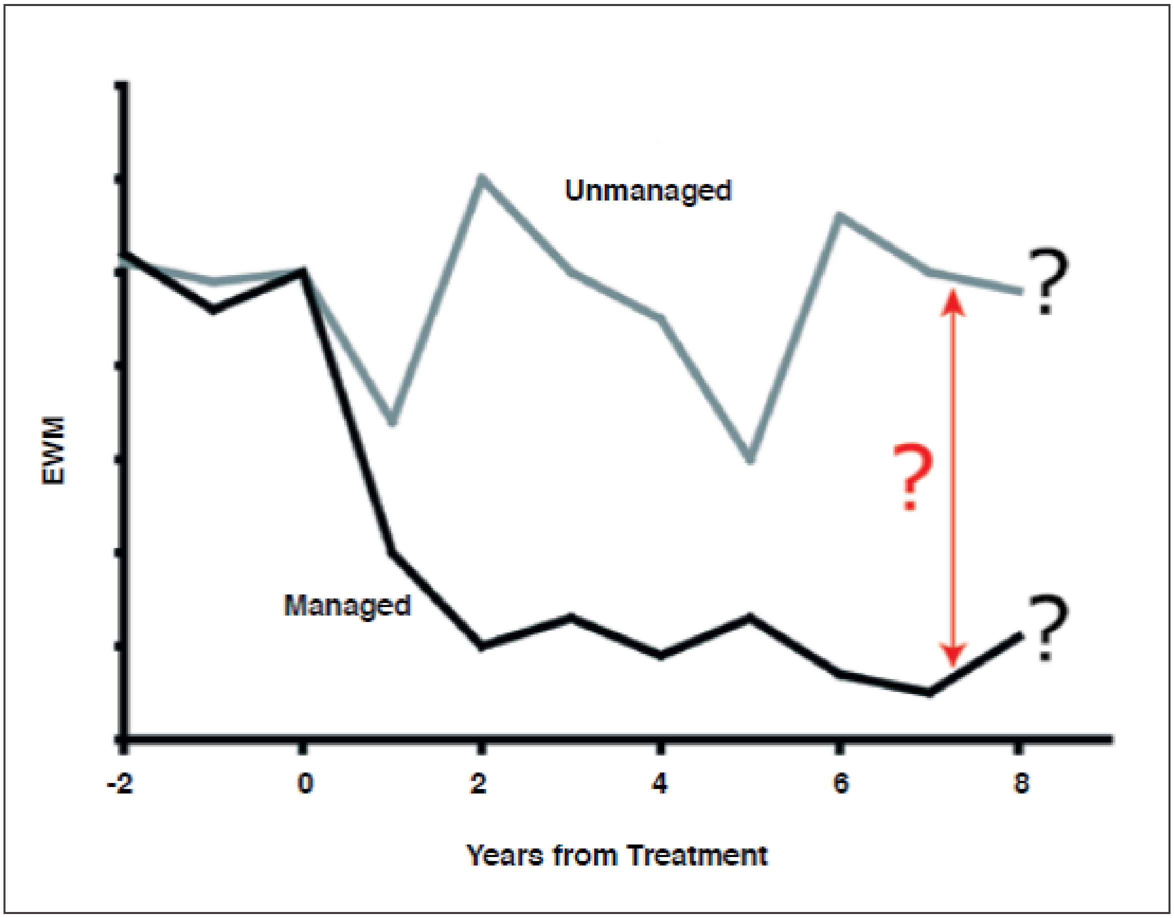

Figure 3-1. Conceptual figure showing the relationship between the abundance of EWM over time, subject to management or not. Source WDNR

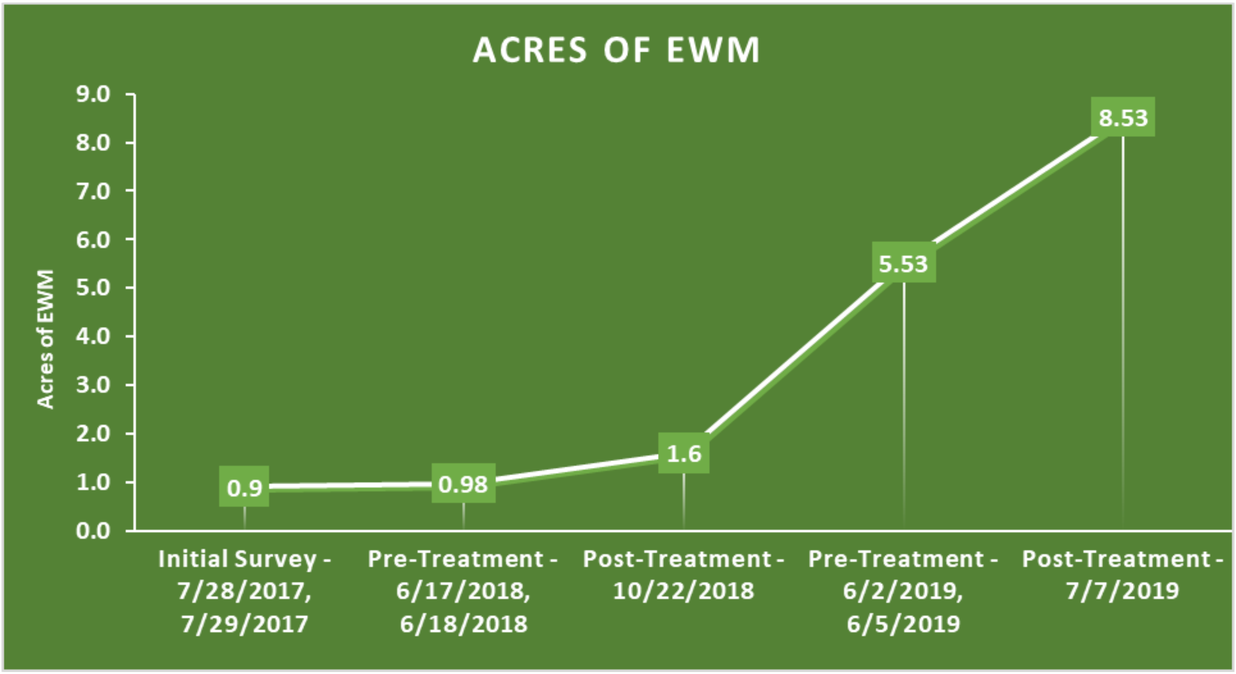

Figure 3-2. Estimated surface area of EWM infestation on Muskellunge Lake from 2017-2019.

4. 2020 RECOMMENDED MONITORING STRATEGIES

4.1. 2020 Monitoring Strategies

4.1.1. 2020 Early Season Focused Meander AIS Survey

In 2020, EOR staff will complete an early-season focused meander AIS survey in the areas of Muskellunge Lake that are less than 10 feet deep (max depth for plant growth). The early-season survey will take place in late May or early June (within 3-5 weeks of ice-out; weather dependent). The focus of this survey will be in and around those areas where EWM has previously been found, including those areas which were treated in 2017, 2018, and 2019. Polygons will be mapped around all well-established colonies using geolocated target species bed coordinates (sub-meter accuracy Trimble), and semi-qualitative estimates of target plant presence and abundance (i.e. sparse, moderate, dense). Point-based techniques will be used to record locations that are considered pioneer colonies which contain only a few plants or a single plant. Results from this survey will be used to prioritize areas for treatment in 2020.

4.1.2. 2020 Post-Treatment Surveys

In 2020, EOR staff will work with the MLA to complete a second, peak biomass, focused meander AIS survey in late June or early July (within 2-4 weeks of implementation of prescribed treatment) to assess initial treatment effectiveness. Results from this survey will be used to determine if additional treatment efforts are warranted and if necessary to prioritize and target remaining EWM stands not adequately controlled through the DASH treatment (see Section 5 for complete details highlighting 2019 Management approach).

It should be noted that the ultimate success/failure of any treatment approach (hand-harvesting, DASH, herbicide, etc.) cannot always be readily determined immediately following the recommended treatment. As was seen in 2018, hand-removal efforts while initially successful in reducing EWM abundance were largely undetectable by late-fall. As such, the DNR recommends waiting a full-year following treatment (vs. within the year of treatment), to conduct comprehensive post-treatment surveys.

4.1.3. ProcellaCOR Treatment

EOR will work with the MLA to conduct a post-treatment point intercept study of both treated and non-treated areas to evaluate the reduction in EWM abundance/biomass (effectiveness) that occurs as a result of the treatment. Additionally, EOR will use results from the post-treatment point intercept study to evaluate the frequency of native plant species occurring in both treated and non-treated areas of the lake from which an evaluation can be made as to any potential positive or negative impacts resulting from the treatment. Finally, EOR will also work with SePRO to collect post treatment herbicide concentration samples in order to learn more about dissipation rates specific to Muskellunge Lake. This information will be used to inform future management efforts.

5. APPENDIX A: 2020 DASH IMAGES

Figure 5-1. Aquatic Plant Management, LLC Getting Ready to Launch – June 5th, 2019

Figure 5-2. Aquatic Plant Management, LLC Getting Ready to Dive – June 5th, 2019

Figure 5-3. Aquatic Plant Management, LLC Conducting DASH on Center Bar – June 5th, 2019

Figure 5-4. Aquatic Plant Management, LLC Conducting DASH on Center Bar – June 5th, 2019

Figure 5-5. Transition from Treated to Non-Treated Areas – August 29th, 2019

Figure 5-6. Transition from Treated to Non-Treated Areas – August 29th, 2019

Figure 5-7. MLA Volunteer helping with Biomass Evaluation Data Collection – August 29th, 2019

Figure 5-8. Dense EWM Growing to Surface in Non-Treated Portions of Center Bar.