Anvil Lake

Vilas County, Wisconsin

Aquatic Plant Management Plan

November 2024

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This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

Anvil Lake Planning Committee

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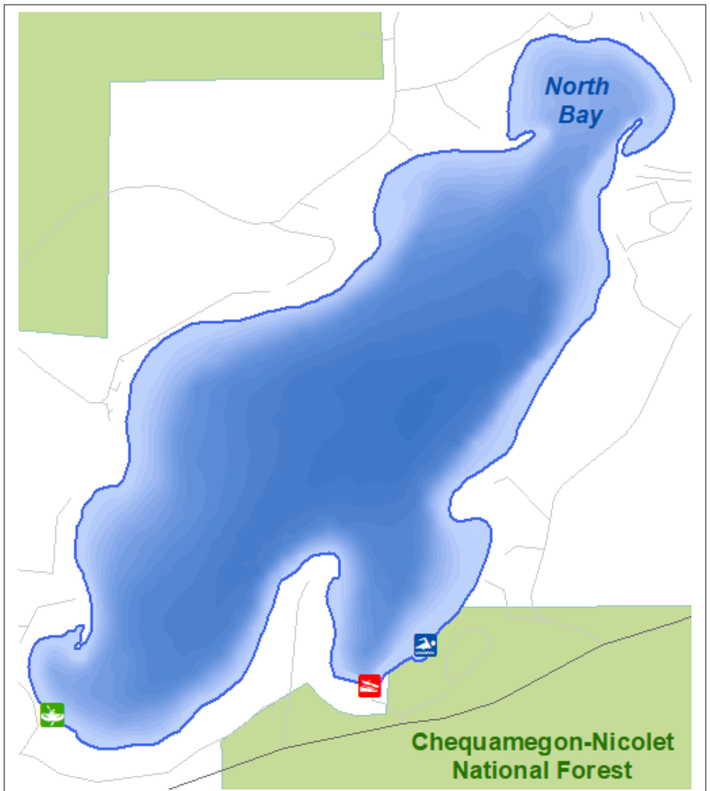


Figure 1.0-1. Anvil Lake, Vilas County, WI.

Anvil Lake, Vilas County, is an approximate 392-acre mesotrophic seepage lake with a maximum depth of 35 feet estimated during 2020 (Figure 1.0-1). The lake harbors a high-quality native aquatic plant community with approximately 39 native species, 24 of which have a coefficient of conservatism of 7 or higher. Anvil lake also contains a population of Vasey's pondweed (*Potamogeton vaseyi*), a native aquatic plant listed as special concern in Wisconsin due to its relative rarity. The lake maintains high water clarity, with an average summer Secchi disk depth of 12 feet.

The non-native, invasive aquatic plant Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was discovered in Anvil Lake in the summer of 2012 by Great Lakes Indian Fish and Wildlife Commission (GLIFWC) staff. After being made aware of GLIFWC's discovery, the Wisconsin Department of Natural Resources (WDNR) completed a whole-lake aquatic plant point-intercept survey that same summer which confirmed additional occurrences of EWM within the lake's approximate 25-acre northern bay (North Bay). The Anvil Lake Association (ALA) contracted with Onterra, to map the EWM population in the lake in August of 2012 which determined the population was mainly isolated to the North Bay and largely comprised of single-plant occurrences. Curly-leaf pondweed (*Potamogeton crispus*, CLP) was discovered in 2013, however, its population has never impacted recreational activities and has appeared to integrate itself within the rest of the aquatic plant community.

The ALA was awarded a WDNR AIS-Established Population Control grant in February 2020 that includes funding to carry out the active management and associated monitoring from 2020-2022 (ACEI-241-20). The project includes funds for the ALA to implement an Integrated Pest Management (IPM) strategy that includes a robust hand harvesting effort to follow up the herbicide treatment in 2020.

In March of 2023, the project scope was revised and approved by the WDNR to include integrated pest management (IPM) for EWM, monitoring surveys for 2023-24, a stakeholder survey, as well as an Aquatic Plant Management Implementation Plan in 2023. This report discusses the management and monitoring activities that took place during the fourth year of this project (2023). This report also serves as an updated Aquatic Plant Management Plan for the ALA which is included in section 5.0. The APM Plan update incorporates changes in best management practices for aquatic plant management, sentiments gleaned from the 2023 riparian stakeholder survey, and knowledge gained from the ALA's experience in managing AIS since the ALA's Comprehensive Management Plan was finalized in January 2018.

1.1 Water Levels

Like many other seepage lakes in Wisconsin, Anvil Lake experiences more dramatic fluctuations in water levels through time when compared to lakes that receive surface water inflow and outflow (drainage lakes). There is a long, mostly continuous, record of lake levels for Anvil Lake spanning from 1936 to present. Some of the lowest water levels on record occurred approximately from 2004-2015. From 2015-2020, water levels rose relatively rapidly and by 2019 were closer to the historical average depths observed during the first 50 years of available data. Record rainfall in many parts of Wisconsin in recent years contributed to the relatively rapid increase in water depth in Anvil Lake. All told, the water levels rose approximately 5.5 feet between 2015 and 2020 (Figure 1.1-1). The lake level in 2020 was at the highest it had been in a period of 34 years dating back to 1986 and was less than two feet below the highest ever documented levels recorded in 1943-44. Water levels remained high in the first half of 2023 with snow melt and spring rain before gradually beginning to decrease by approximately one foot between June and December 2023. Water levels have been declining gradually since May 2021.

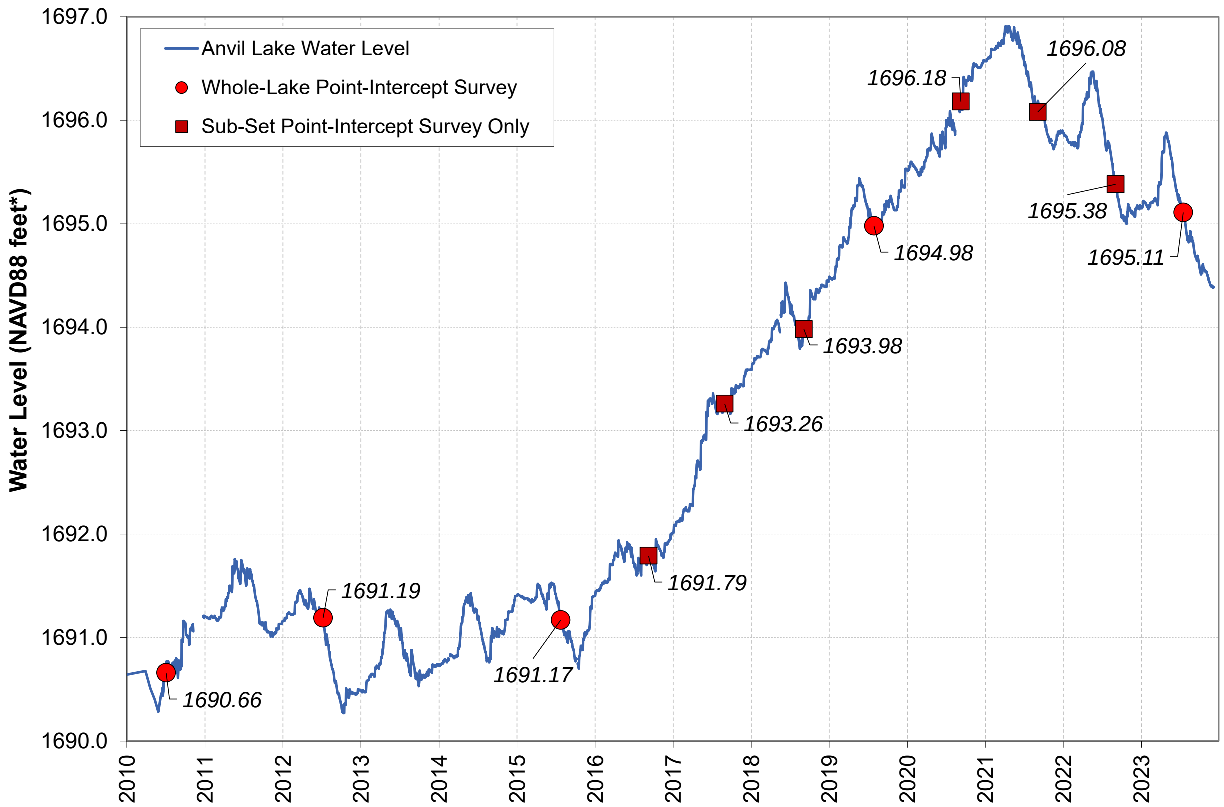


Figure 1.1-1. Anvil Lake water levels from 1936 through December 17, 2023. Created using online data from USGS Gage 05390500 with additional data and benchmarks provided by Dale Robertson, USGS).

The impact that the rising water levels may impose on the aquatic plant communities in Anvil Lake are difficult to determine. Certainly, some species are well adapted to fluctuating water levels, whereas other species may struggle to adapt and survive in deeper waters. The littoral zone in

Anvil Lake has changed in recent years as areas that were previously near the deepest limits of plant growth prior to 2015 may have become too deep for aquatic plants to obtain sufficient light to persist. Additionally, exposed lakebed that were present around much of Anvil Lake during periods of low lake levels, are now underwater again and results in “new” littoral areas for plants to establish. Pioneer species, which can include invasive plants such as EWM, are often at an advantage in establishing newly available habitat (i.e. empty niches) in lakes. Much of the EWM population outside of North Bay in Anvil Lake has historically been located in the deeper extents of the littoral area of the lake. As water levels increased, these plants may struggle to receive sufficient sunlight to survive. Figure 1.1-1 displays the timing of aquatic plant surveys dating back to 2010 in relation to water levels in Anvil Lake at that point in time.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and communications provided by the ALA board to the membership. The highlights of this component are described below.

2.1 Strategic Planning Meetings

Two meetings were used to gather comments, create management goals and actions and to deliver study results. The planning participants were supplied with the draft report sections prior to the meeting. The objective of the first meeting was to fortify a solid understanding of their lake among the members. The second committee meeting focused on the development of management goals and actions that make up the framework of the implementation plan.

ALA Board Meeting I

The first planning meeting took place on March 27, 2024 between seven members of the ALA Board and Todd Hanke, an aquatic ecologist/planner from Onterra. During this approximately 2.5-hour meeting, information covering lake management planning, study results from aquatic plant surveys on Anvil Lake, and a review of EWM management perspectives and current best management practices was discussed. Many questions about the study results and EWM management were answered during the meeting. Materials presented during this meeting are included within Appendix A.

ALA Board Meeting II

A second meeting occurred on April 17, 2024 between ALA Board members and Todd Hanke from Onterra to discuss the development of the ALA's Aquatic Plant Management Plan. This 2.5-hour long meeting focused largely on the topic of Eurasian watermilfoil management and included discussion of recent management activities, a review of related stakeholder survey results and the levels of support for various management techniques. Additional discussion including topics of AIS prevention, monitoring, role of hand harvesting/DASH, and the use of aquatic herbicides.

2.2 Management Plan Review and Adoption Process

The ALA Board members approved the Implementation Plan in mid-July 2024 and an Official First Draft of the entire APM Plan Update document was provided to WDNR for agency review in late-July 2024. Coinciding with the WDNR review of the draft plan, the draft was made available via the ALA's outreach and communication avenues for public comment for at least 21 days. Public comments and WDNR/agency comments that were received are included within

Appendix F. The final Aquatic Plant Management Plan was compiled in November 2024 and issued to WDNR and ALA.

Agency comments that were received include those by WDNR fisheries biologist Eric Wegleitner and water resource management specialist Ty Krajewski. Comments stated a conservative approach to herbicide use is favored from agency fisheries perspectives given the uncertainty surrounding potential for impacts to certain fish species such as walleye. The ALA acknowledges agency support for a conservative approach to herbicide use in the lake and considers this factor in planning EWM management actions.

Public comments that were received included two responses voicing opposition to use of herbicides while another comment indicated support for their use in Anvil Lake (Appendix F).

2.3 Riparian Stakeholder Survey

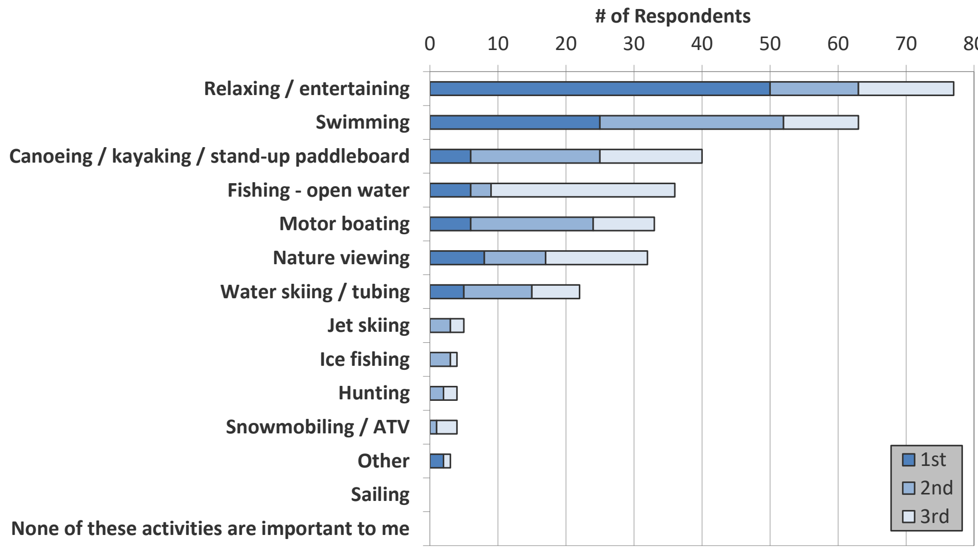
As a part of this project, a stakeholder survey was distributed to Anvil Lake Association members and riparian property owners around Anvil Lake. The survey was designed by Onterra staff and the ALA planning committee and reviewed by a WDNR social scientist. During late-spring to early summer 2023, 33-question survey was posted online through Survey Monkey for survey-takers to answer electronically. If requested, an eight-page hard copy was sent with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by an ALA volunteer for analysis. Sixty-three percent of the surveys were returned. Since over a 60% response rate was achieved, the results of the survey can be used to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the stakeholder survey, much was learned about the people who use and care for Anvil Lake. 49% of respondents indicated that they visit the lake on the weekend, vacation and/or as a holiday residence, while 25% are year-round residents, 21% are seasonal residents, and 5% utilize their property as a rental or resort. 77% of respondents have owned their property for over 11 years, and 51% have owned their property for over 25 years.

A concern of stakeholders noted throughout the stakeholder survey (see Question 16 and survey comments – Appendix B) were current aquatic invasive species within Anvil Lake specifically Eurasian watermilfoil. This topic is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Other main topics of concern by stakeholders include water quality degradation, introduction of new aquatic invasive species, and excessive watercraft traffic (Figure 2.3-1).

Question 8: Please rank up to three activities that are important reasons for owning your property on or near Anvil Lake, with 1 being the most important.



Question 16: From the list below, please rank your top three concerns regarding Anvil Lake, with 1 being your greatest concern.

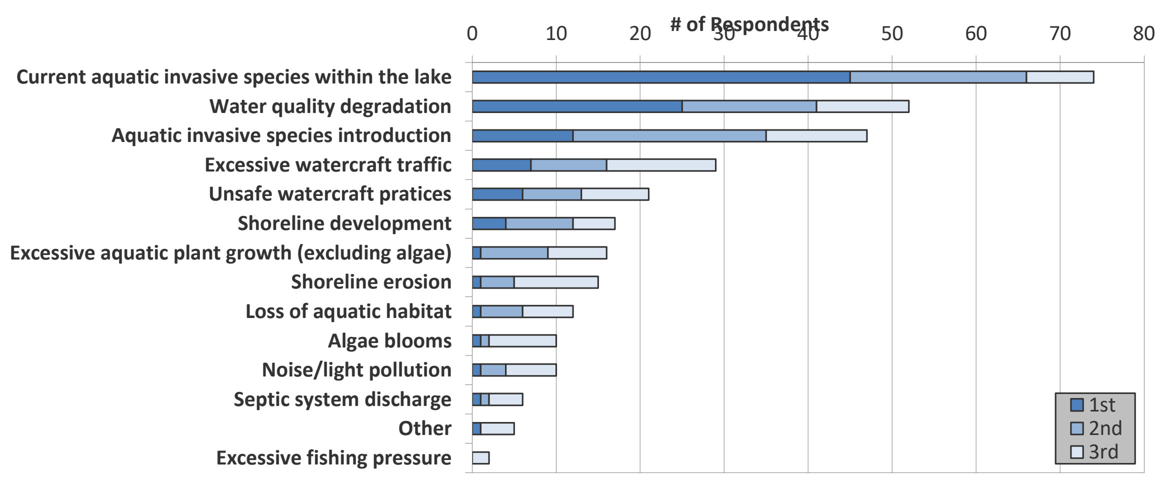


Figure 2.3-1. Select survey responses from the Anvil Lake stakeholder survey. Additional questions and response charts may be found in Appendix B.

3.0 AQUATIC PLANTS

3.1 Primer on Aquatic Plant Data Analysis & Interpretation

Native aquatic plants are an important element in every healthy aquatic ecosystem, providing food and habitat to wildlife, improving water quality, and stabilizing bottom sediments. Because most aquatic plants are rooted in place and are unable to relocate in wake of environmental alterations, they are often the first community to indicate that changes may be occurring within the system. Aquatic plant communities can respond in a variety of ways; there may be increases or declines in the occurrences of some species, or a complete loss. Or, certain growth forms, such as emergent and floating-leaf communities may disappear from certain areas of the waterbody. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide relevant information for making management decisions.

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell, et al., 2010) have been conducted on Anvil Lake in 2010, 2012, 2015, 2019, and 2023. At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance on the sampling rake was recorded.

A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 15 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 15 feet. Depth information was collected using graduated marks on the pole of the rake (at depths < 15 ft) or using an onboard sonar unit (at depths > 15 feet). Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately "feel" the bottom with this sampling device. At each point that is sampled the surveyor records a total rake fullness (TRF) value ranging from 0-3 as a somewhat subjective indication of plant biomass. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that have been located during the surveys completed in Anvil Lake. The list also contains each species' scientific name, common name, status in Wisconsin, and coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Littoral Zone is the area of a lake where sunlight is able to penetrate down to the sediment and support aquatic plant growth.

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept surveys that have been completed; plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys (equation shown below). This assessment allows the aquatic plant community of Anvil Lake to be compared to other lakes within the region and state.

$$\text{FQI} = \text{Average Coefficient of Conservatism} * \sqrt{\text{Number of Native Species}}$$

Anvil Lake falls within the Northern Lakes and Forests (NLF) *ecoregion* (Figure 3.1-1), and the floristic quality of its aquatic plant community will be compared to other lakes within this ecoregion as well as the entire State of Wisconsin. Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems within the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Ecoregional and state-wide medians were calculated from whole-lake point-intercept surveys conducted on 392 lakes throughout Wisconsin by Onterra and WDNR ecologists.

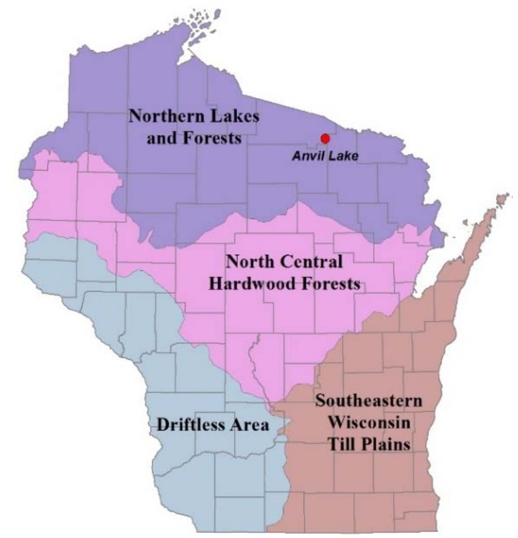


Figure 3.1-1. Location of Anvil Lake within the ecoregions of Wisconsin. After (Nichols, 1999).

Species Diversity

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

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. Some managers believe a lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan, Davis, Jordan, & Forester, 2018).

The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from Anvil Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forests (lakes only, does not include flowages) Ecoregion and on 392 lakes throughout Wisconsin.

3.2 Anvil Lake Aquatic Plant Survey Results

Whole-lake point-intercept surveys have been completed on Anvil Lake in 2010, 2012, 2015, 2019, and 2023. This report will highlight the 2023 point-intercept survey results and will integrate comparisons to the previous point-intercept surveys throughout the section. Appendix C contains a table with the occurrence of all aquatic plants from each whole-lake point-intercept survey.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations can be driven by a combination of natural factors including variations in temperature, ice and snow cover (winter light availability), nutrient availability, water levels and flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006). Adding to the complexity of factors which affect aquatic plant community dynamics, human-related disturbances such as the application of herbicides for non-native plant management, mechanical harvesting, watercraft use, and pollution runoff also affect aquatic plant community composition (Asplund and Cook 1997); (Lacoul and Freedman 2006).

In addition to the point intercept surveys, one community mapping survey was completed as a part of the Comprehensive Management Plan project in 2016. Table 3.2-1 displays the 42 species that have been documented during all surveys on Anvil Lake. Table 3.2-1 is organized by growth form which separates out species based on whether they are emergent species, floating-leaf species, submergent species, or free-floating species. Species with an "X" on the table indicates the species was physically encountered on the rake during the point-intercept survey. Examples of other species that were observed, but were not sampled on the survey rake are referred to as incidentals and are listed with an "I" on table 3.2-1. Often times, many of the incidentally encountered species were those that were identified during the emergent and floating-leaf community mapping survey which are typically found growing on the shoreline or in shallow areas of the lake.

A total of 23 aquatic plant species were documented in Anvil Lake during the 2023 point-intercept survey. Of these 23 species, muskgrasses (*Chara* spp.), stoneworts (*Nitella* spp.), and wild celery (*Vallisneria americana*) were the most frequently encountered (Figure 3.2-1). Two non-native species have been documented on Anvil Lake in the past including Eurasian watermilfoil and curly-leaf pondweed. Due to their ecological, economical, and sociological significance, the non-native plants and their management in Anvil Lake they are discussed in the subsequent *Non-Native Aquatic Plants in Anvil Lake* subsection (3.3).

Table 3.2-1. Aquatic plant species located on Anvil Lake.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010	2012	2015	2019	2023
Emergent	*Carex lasiocarpa*	Narrow-leaved woolly sedge	Native	9			I		
	Carex utriculata	Common yellow lake sedge	Native	7			I		
	Eleocharis palustris	Creeping spikerush	Native	6		X	X	X	
	Iris versicolor	Northern blue flag	Native	5			I		
	Juncus effusus	Soft rush	Native	4			I		
	Pontederia cordata	Pickerelweed	Native	9		X	I		
	Sagittaria latifolia	Common arrowhead	Native	3			I		
	Schoenoplectus acutus	Hardstem bulrush	Native	5			I		
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4		X	I		X
	Scirpus cyperinus	Wool grass	Native	4			I		
	Sparganium androcladum	Shining bur-reed	Native	8			X		
	Sparganium eurycarpum	Common bur-reed	Native	5			X		
	Typha spp.	Cattail spp.	Unknown (Sterile)	N/A		X	I		
FL	*Nuphar variegata*	Spatterdock	Native	6			I	X	X
	Nymphaea odorata	White water lily	Native	6			I		
	Persicaria amphibia	Water smartweed	Native	5			I		
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9	X		I	X	X
Submergent	*Chara spp.*	Muskgrasses	Native	7	X	X	X	X	X
	Elatine minima	Waterwort	Native	9	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X		X	X
	Elodea nuttallii	Slender waterweed	Native	7	X	X	X	X	
	Eriocaulon aquaticum	Pipewort	Native	9			X	X	
	Isoetes spp.	Quillwort spp.	Native	8	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A		X	X	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10	X	X	X	X	X
	Najas flexilis	Slender naiad	Native	6				X	X
	Najas gracillima	Northern naiad	Native - Special Concern	7	X			X	
	Nitella spp.	Stoneworts	Native	7	X	X	X	X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X	X	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7	X		X	X	X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A			X		
	Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	X	X	X	X	X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7			X	X	X
	Potamogeton pusillus	Small pondweed	Native	7		X			X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8	X		X	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8				X	X
	Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	X		X	X	X
	Ranunculus flammula	Creeping spearwort	Native	9			X	X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	Native	5	X	X	X	X	X
	Juncus pelocarpus	Brown-fruited rush	Native	8	X	X	X	X	X
FF	*Riccia sp.*	Riccia sp.	Native	7		X			

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; F/L = Floating-leaf & Emergent; S/E = Submergent and/or Emergent; FF = Free-floating

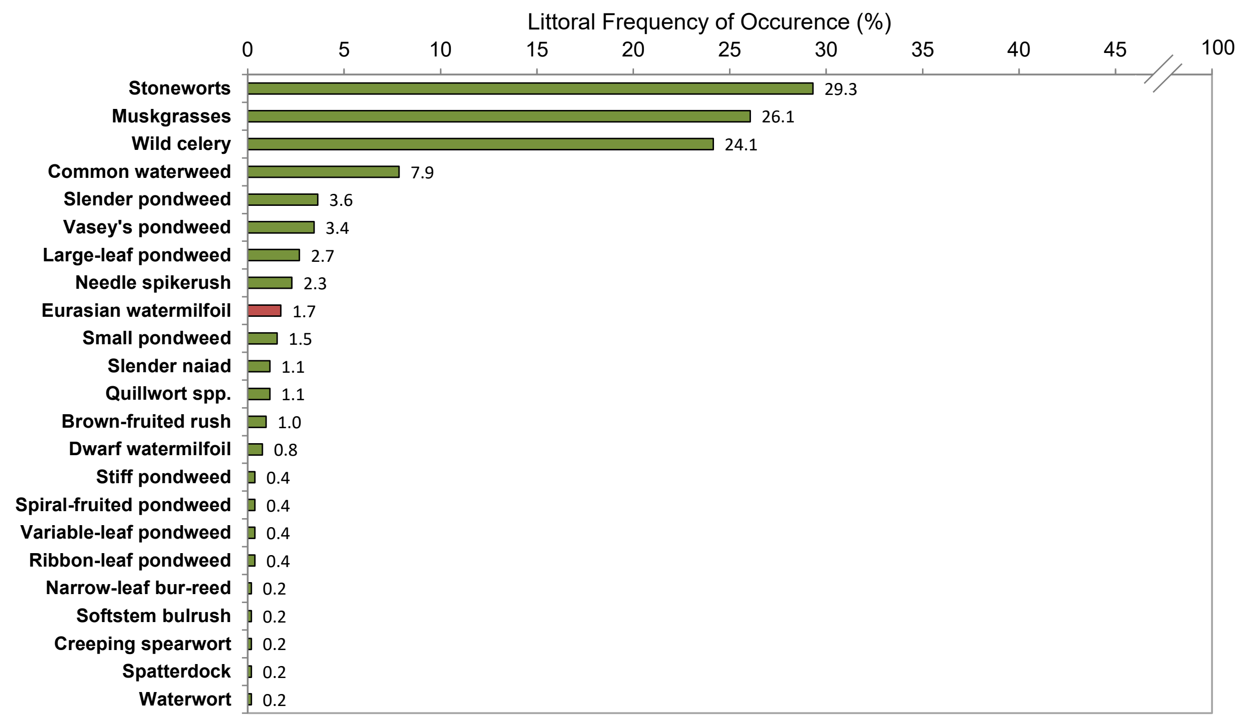


Figure 3.2-1. Littoral Frequency of Occurrence of Aquatic Plants in Anvil Lake from 2023 Point-Intercept Survey.

During the 2023 point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 75% of the point-intercept locations contained sand sediments, 21% contained soft organic, and 4% contained rock (Figure 3.2-2). Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

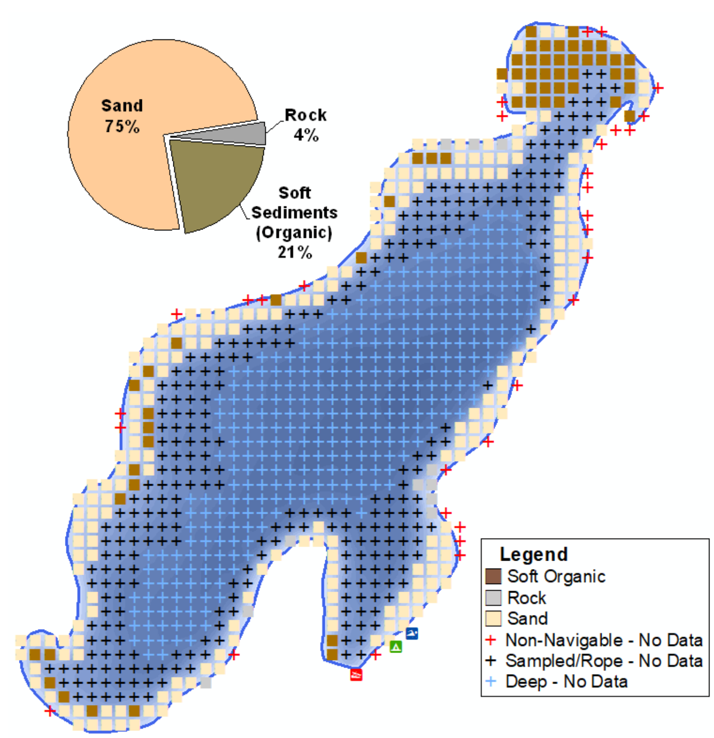


Figure 3.2-2. Anvil Lake spatial distribution of substrate hardness. Created using data from 2023 point-intercept survey.

The recorded maximum depth of aquatic plant growth has remained between 24 and 28 feet over the survey period with 2023 being 25 feet. Aquatic plant occurrence is low in deeper depths, but changes in Anvil Lake's water clarity and water levels will be the driving factor influencing the maximum depth of plant growth.

Of the 522 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2023, approximately 70% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2023 indicates that 48% of the 522 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 12% had a TRF rating of 2, and 9% had a TRF rating of 3 (Figure 3.2-3). The TRF data indicates that where aquatic plants are present in Anvil Lake, they are at a moderate abundance.

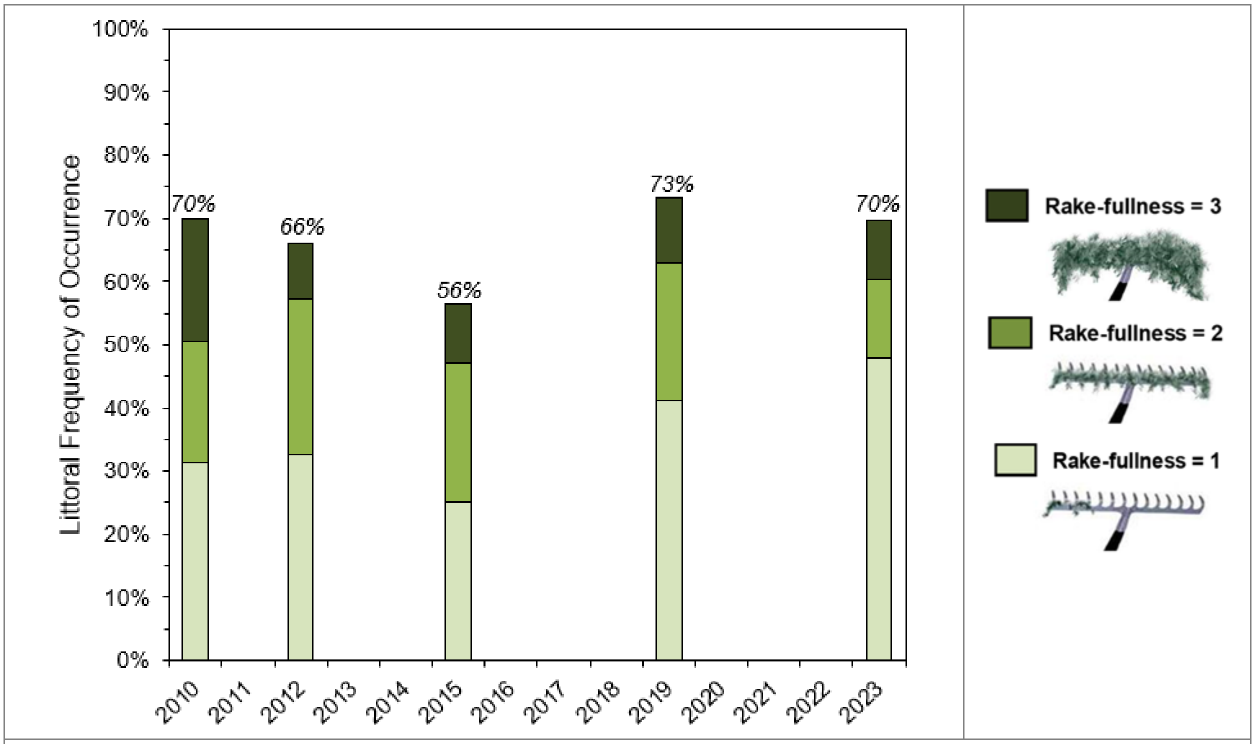


Figure 3.2-3. Aquatic vegetation total rake fullness (TRF) ratings within littoral areas.

Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. Figure 3.2-3 shows the littoral frequency of occurrence (LFOO) of aquatic plants from the 2010, 2012, 2015, 2019, and 2023 point-intercept surveys. These data indicate that charophytes, wild celery, and common & slender waterweeds are the most frequent native aquatic plant species found in Anvil Lake during the surveys (Figure 3.2-3). In the field, it is often difficult to distinguish between certain species of aquatic plants that are very similar morphologically, especially when flowering/fruiting material is not present. Due to this, the littoral occurrences of the following morphologically-similar species were combined for this analysis: muskgrasses (*Chara* spp.) and stoneworts (*Nitella* spp.) which will be referred together as charophytes, small pondweed (*Potamogeton pusillus*) and slender pondweed (*P. berchtoldii*), as well as common waterweed (*Elodea canadensis*) and slender waterweed (*E. nuttallii*).

Muskgrasses are a genus of macroalgae of which there are seven species in Wisconsin (Figure 3.2-4). Dominance of the aquatic plant community by muskgrasses is common in hardwater lakes, and these macroalgae have been found to more competitive against vascular plants (e.g.

pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002); (Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002).

Nitella species, or stoneworts as they may be called, are another type of macro-algae rather than a vascular plant. Whorls of forked branches are attached to the "stems" of the plant, which are long, slender, smooth-textured algae. Since they lack roots, stoneworts remove nutrients directly from the water. Stonewort plants also have branches which are usually translucent green. In Anvil Lake, charophytes were abundant across littoral depths of 3 to 25 feet with a littoral frequency of occurrence of 54.2% in 2023. Charophytes have consistently been the most frequently encountered species in all past point-intercept surveys in Anvil Lake with occurrences ranging from 44.8% to 56.6% (Figure 3.2-4).

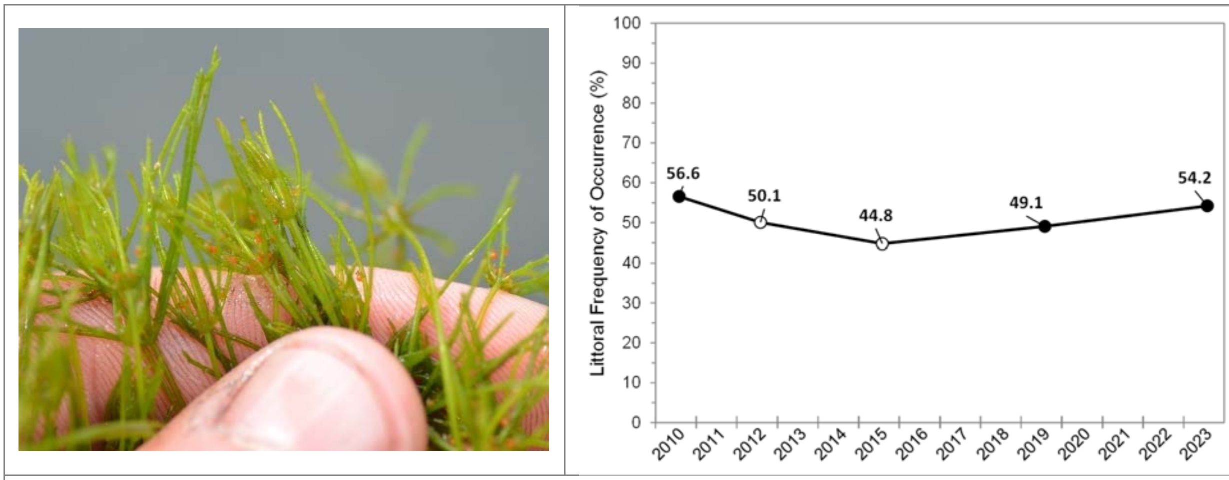


Figure 3.2-4. Littoral frequency of occurrence of charophyte species (*Chara* spp. & *Nitella* spp.). Photo credit Onterra.

Wild celery produces long, ribbon-like leaves which emerge from a basal rosette, and it prefers to grow over harder substrates and is tolerant of low-light conditions. Its long leaves provide valuable structural habitat for the aquatic community while its network of roots and rhizomes help to stabilize bottom sediments. In mid- to late-summer, wild celery often produces abundant fruit which are important food sources for wildlife including migratory waterfowl. In Anvil Lake, wild celery was abundant across littoral depths of 3 to 16 feet with a littoral frequency of occurrence of 24.1% in 2023. The occurrence of wild celery has fluctuated between 21.3%-30.3% in all surveys.

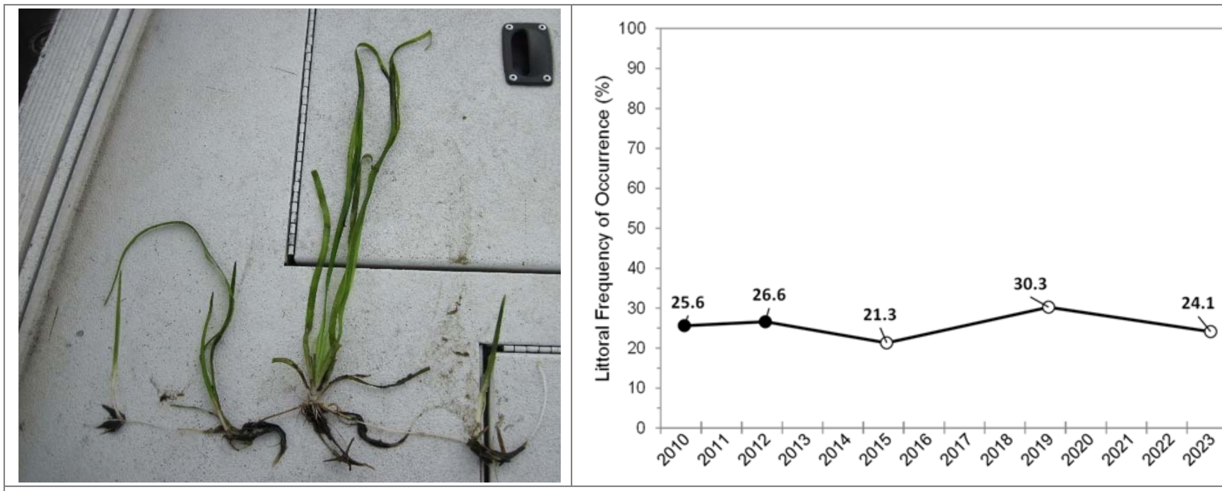


Figure 3.2-5. Littoral frequency of occurrence of wild celery (Vallisneria americana). Photo credit Onterra.

Common and slender waterweed can be found in waterbodies across Wisconsin, are tolerant of high-nutrient, low-light conditions, and can grow to nuisance levels under ideal conditions. Common waterweed has blade-like leaves in whorls of three produced on long, slender stems. Like other submersed aquatic plants, common waterweed helps to stabilize bottom sediments and provides structural habitat and food for wildlife. In Anvil Lake, common and slender waterweed was present within littoral depths of 3 to 16 feet with a littoral frequency of occurrence of 7.9% in 2023. The occurrence of common and slender waterweed has shown statistically valid decreases during the past two surveys with the 2023 occurrence the lowest of any past surveys (Figure 3.2-6).

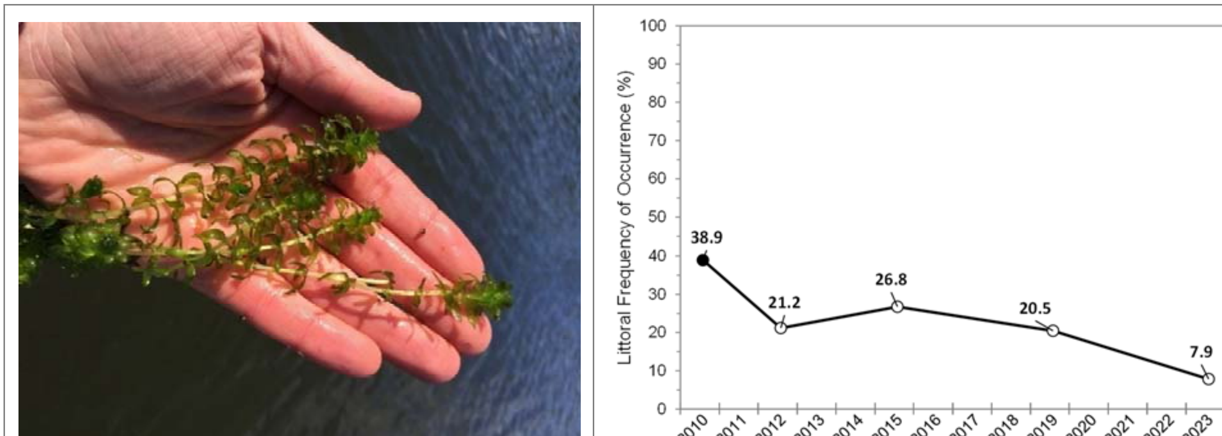


Figure 3.2-6. Littoral frequency of occurrence of waterweeds (*Elodea* spp.). Photo credit Onterra.

Since each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For example, while charophytes were found at 54.2% of the littoral sampling locations in Anvil Lake in 2023, its relative frequency of occurrence is 50.7% (Figure 3.2-7). Explained another way, if 100 plants were randomly sampled from Anvil Lake, 51 of them would be charophytes. Figure 3.2-12 displays the relative frequency of occurrence of aquatic plant species from each of the point-intercept surveys in Anvil Lake.

Looking at relative frequency of occurrence (Figure 3.2-7), the top four species comprise approximately 52% of the plant community in Anvil Lake. This is consistent with previous years and also indicates the lake is not over populated with any particular species with a wide distribution.

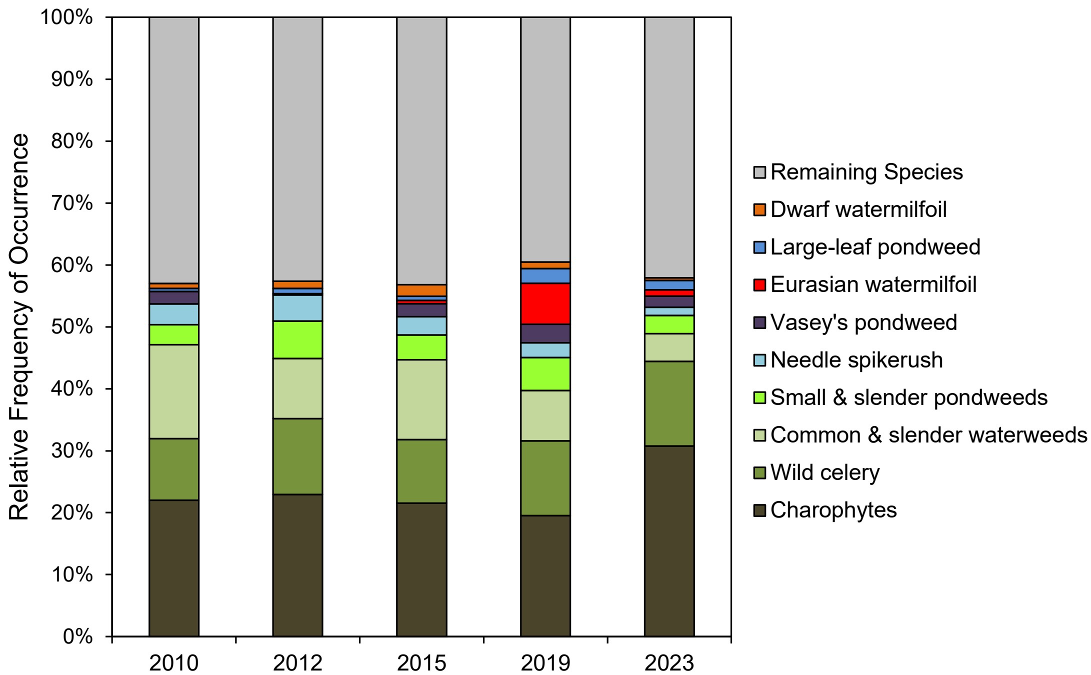


Figure 3.2-7. Relative frequency of occurrence of aquatic plants.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. Anvil Lake's native aquatic plant species richness in 2023 was above the median value for lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and above lakes throughout Wisconsin (Figure 3.2-8).

The average conservatism of the 22 native aquatic plants recorded on the rake in 2023 was 7.2, falling above the median value (6.7) for lakes within the NLFL ecoregion and above the median value (6.3) for lakes throughout Wisconsin (Figure 3.2-8). This indicates that Anvil Lake has an above average number of native aquatic plant species with high conservatism values when compared to the majority of lakes within the NLFL ecoregion.

Using Anvil Lake's 2023 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 33.8, which is above the median values for lakes within the NLFL ecoregion and the state. This indicates that Anvil Lake's aquatic plant community is of high quality in terms of species richness and community composition than the majority of lakes within the ecoregion and the state.

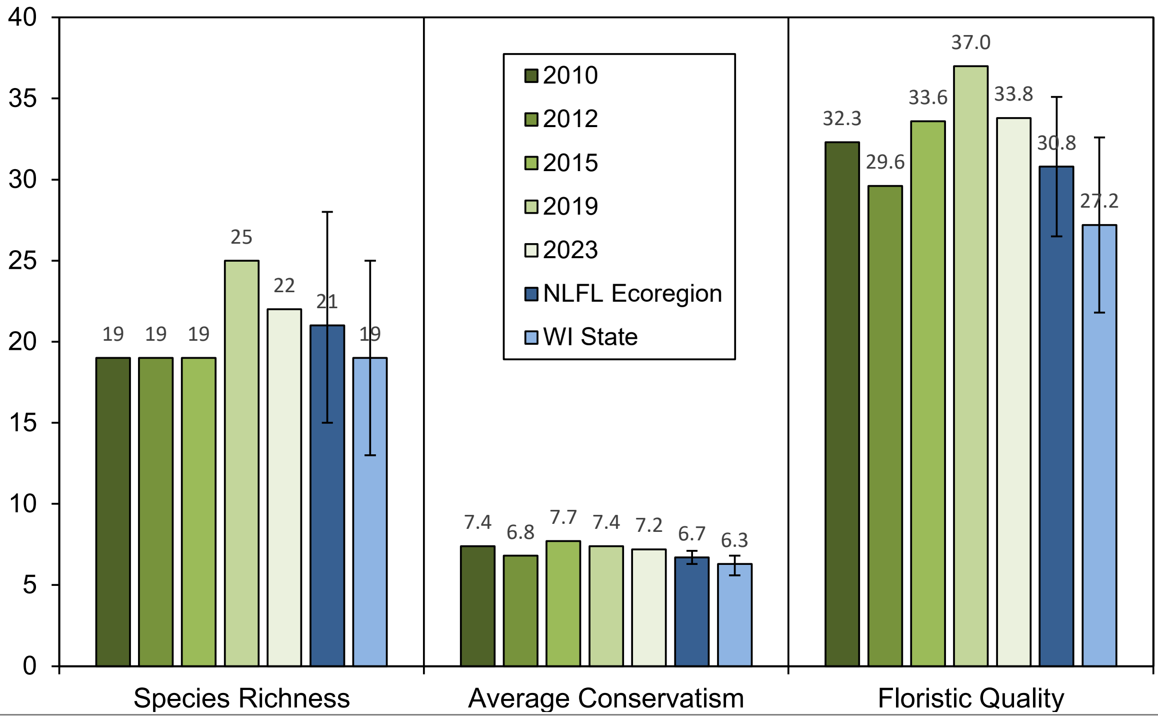


Figure 3.2-8. Floristic Quality Analysis. Analysis follows (Nichols, 1999).

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Anvil Lake's diversity values rank. Using data collected by Onterra, quartiles were calculated for lakes within the NLFL Ecoregion (Figure 3.2-9). Using the data collected from the whole-lake point-intercept surveys, Anvil Lake's aquatic plant species diversity has often fallen at or below the lower quartile level with the exception of during 2013 which was equal to the median value of 0.88. In 2023, the Simpson's diversity value was at 0.81.

Figure 3.2-10 investigates the average number of native plant species at each littoral point-intercept sampling location. The 2023 survey indicated 1.07 native species per littoral sampling site which the same value that was recorded from the 2012 survey. The largest value for this metric in any survey was 1.91 in 2010.

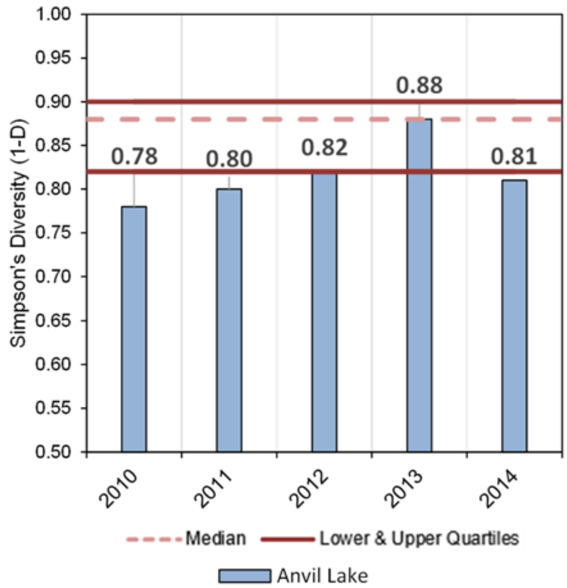
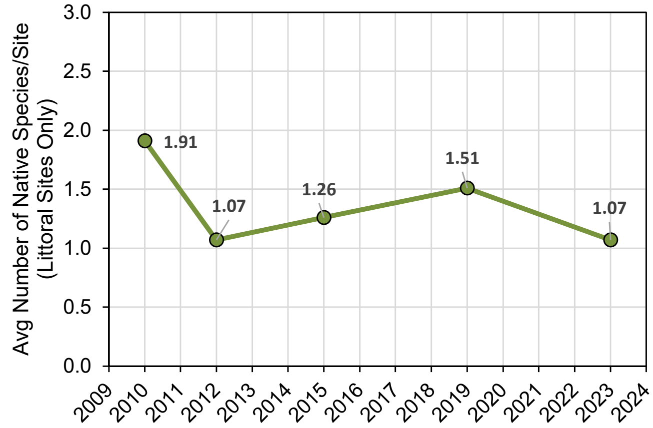
	

Figure 3.2-9. Simpson's Diversity Index.	**Figure 3.2-10. Average number of native aquatic plant species per littoral sampling site.**

3.3 Non-native Aquatic Plants in Anvil Lake

Eurasian watermilfoil (Myriophyllum spicatum)

One of the submersed non-native aquatic plants known to be present within Anvil Lake is Eurasian watermilfoil (*Myriophyllum spicatum*). Eurasian watermilfoil (EWM) is an invasive species, native to Europe, Asia and North Africa, that has spread to most counties in Wisconsin (Figure 3.3-1). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, EWM has two other competitive advantages over native aquatic plants: 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it sometimes does not stop growing like most native plants and instead continues to grow along the surface creating a canopy that blocks light from reaching native plants.

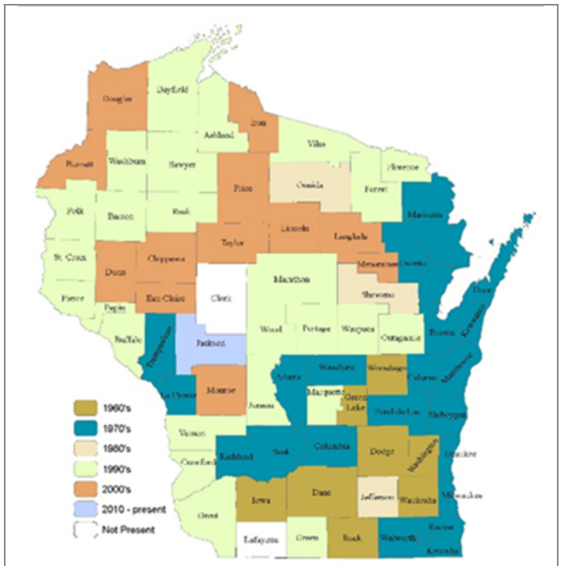


Figure 3.3-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2022 mapped by Onterra.

Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating. However, in some lakes, EWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

Fragmentation

It is true that EWM fragments transferred from one lake to another is the cause of essentially every new EWM population. It is also true that EWM fragments are the vector of population spread within a lake. Everyone has been conditioned that EWM fragments are bad. But in reality, it is much more complex.

Photograph 3.3-1. EWM fragment with adventitious roots. Photo credit Onterra.

There are two types of EWM fragments, auto-fragments and allo-fragments. Auto-fragmentation is the purposeful fragmentation of EWM for the purposes of asexual reproduction. This plant has evolved a mechanism to increase its population in this manner. The parent plant actually sends carbohydrate reserves to the growing tip (apical meristem) before the fragment separates. Also, before separation, the fragment will start growing root-like structures (adventitious roots, Photograph 3.3-1). Applying an analogy, that plant has packed its bags and is ready to endure floating around in the lake for a few days and then trying to grow in new place in the lake. This naturally happens in all lakes. Onterra's experience is that there are two main events – once in late-spring and again towards the end of the growing season. Allo-fragments are those fragments that break off by mechanical breakage by boats, wind, mechanical harvesting, etc. These fragments have a smaller chance of producing a new plant – continuing with the analogy, because they did not get to pack their bags and have to try to make it with what they have on hand.

For a new infestation, lake managers are concerned with all types of fragments. But for an established population with auto fragmentations occurring naturally, a few additional allo-fragments are insignificant to worry about from a population management perspective. However, fragments of any plant species can be unwelcomed by riparians when they accumulate on their shoreline.

Frankly, for established populations like those that exist on the Anvil Lake, lake managers are not really concerned with EWM fragments at all (either kind). The footprint of EWM is everywhere conducive for the plant under the current environmental conditions. If it is not growing in a part of the lake, it is not because it has never been exposed to that area. It is because the conditions are not favorable at this time. Conditions change from year to year and the footprint and density of EWM will also, even if unmanaged.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are clearest for unmanaged lakes in the Northern Lakes and Forests Ecoregion (NLF) and the North Central Hardwood Forests Ecoregion (NCHF) (Figure 3.3-2).

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years (Figure 3.3-2). Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Regional climatic factors also seem to be a driver in EWM populations, as many EWM populations declined in 2015 even though the lakes were at vastly different points in time following initial detection within the lake. 2019 also experienced record rainfall which may have had an impact on the EWM population indirectly through a decrease in water clarity.

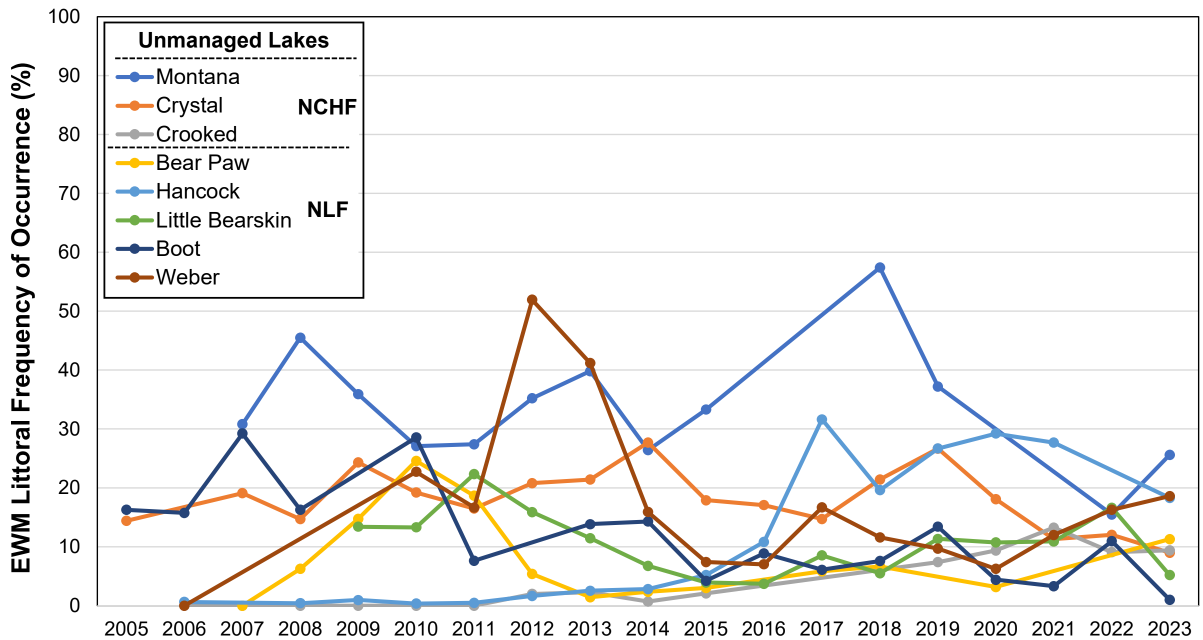


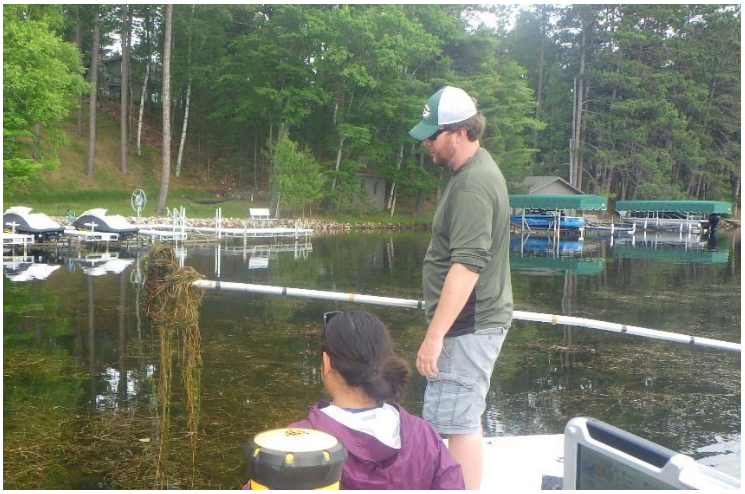
Figure 3.3-2. Littoral Frequency of Occurrence of EWM in northern ecoregions without management. Data provided by and used with permission from WDNR.

Monitoring Surveys

It is important to note that two types of surveys are discussed in the subsequent materials: 1) whole lake point-intercept surveys and 2) EWM mapping survey. Overall, each survey has its strengths and weaknesses, which is why both are utilized in different ways as part of this project.

The point-intercept survey provides a standardized way to gain quantitative information about a lake's aquatic plant population through visiting predetermined locations and using a rake sampler to identify all the plants at each location. The point-intercept survey can be applied at various scales. Most commonly, the point-intercept survey is applied at the whole-lake scale to provide a lake-wide assessment of the overall plant community. More focused point-intercept surveys, called sub-sample point-intercept surveys, may be conducted over specific areas to monitor an active management strategy such as herbicide treatments or mechanical harvesting. Sub-sample point-intercept survey have also been applied on Anvil Lake in the past to study the aquatic plant population dynamics in North Bay during a period of active plant management.

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake. EWM grows high in the water column, which can cause recreation and navigation impediments. This factor allows it to typically be mapped through surface observation. During the EWM mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat (Photograph 3.3-3). Field crews supplemented the visual survey by deploying a submersible camera along with periodically doing rake tows. The EWM population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.



Photograph 3.3-2. Point-intercept survey on a WI lake. Photo credit Onterra.

Photo 3.3-3. EWM mapping survey on a Wisconsin lake. Photo credit Onterra.

EWM population of Anvil Lake

Using data collected from the point-intercept surveys, the littoral frequency of occurrence (LFOO) of EWM can be compared for Anvil Lake. EWM exhibited a statistically valid increase in littoral occurrence from 1.2% in 2015 to 16.6% in 2019. The 2023 survey point-intercept survey indicates an occurrence of 1.7%.

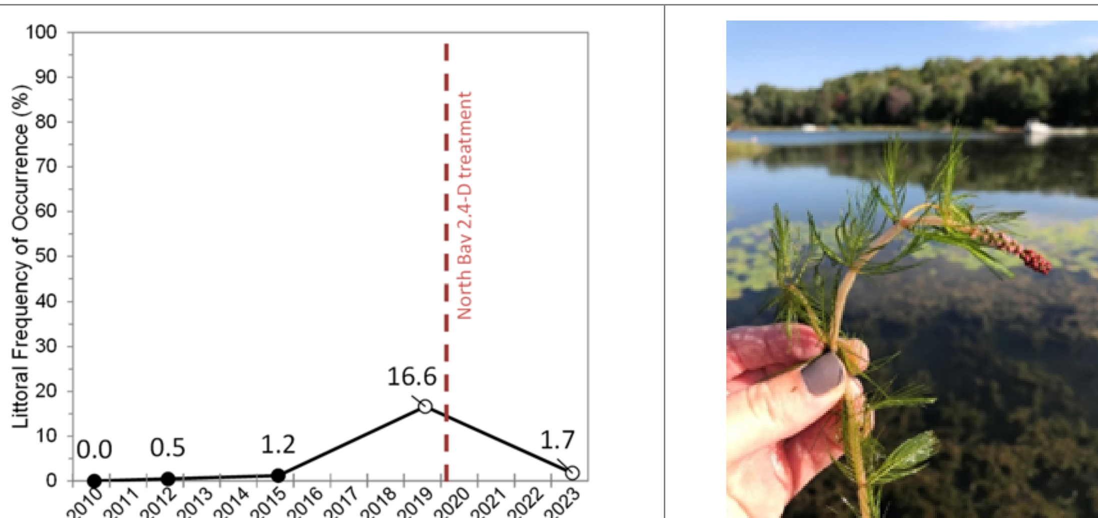


Figure 3.3-3. EWM Littoral Frequency of Occurrence from Anvil Lake whole-lake point-intercept surveys.

The EWM population in Anvil Lake has been monitored since 2012 through the completion of annual Late-Summer EWM Mapping Surveys by Onterra ecologists allowing for a good historical record of the EWM population dynamics. The figure clearly shows the expanding EWM footprint from 2014-2019 with nearly 66 acres delineated in 2019. The total acreage was reduced to less than 1 acre in 2020 and 2021 following a 2,4-D herbicide treatment in spring 2020. The population has increased incrementally since 2020 with a total of 11.3 acres of colonized EWM was mapped throughout the lake in 2023 (Figure 3.3-4). It is important to note that the acreage only accounts for EWM occurrences that were mapped with area-based (polygons) mapping methodologies. Many additional EWM occurrences were mapped with point-based methodologies throughout the system and are described as either single or few plants, clumps of plants, or small plant colonies. Any EWM mapped with point-based methods do not contribute to the acreages displayed on Figure 3.3-4.

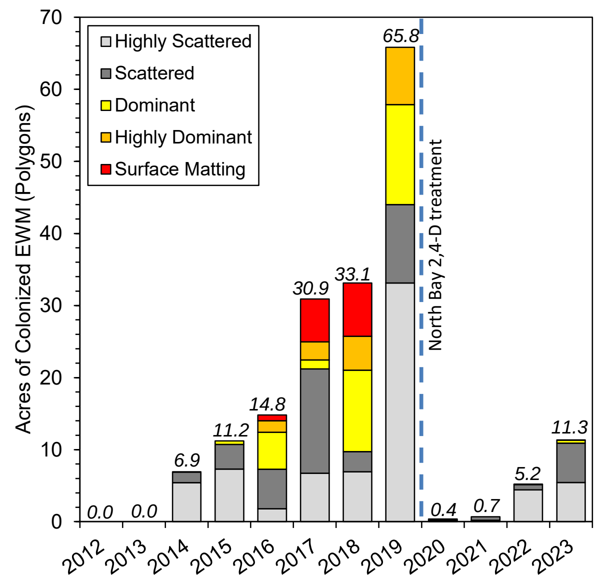


Figure 3.3-4. Acres of colonized EWM (polygons) from 2012-2023 in Anvil Lake.

The EWM population in Anvil Lake was greatly reduced between 2019-2020 as a result of an herbicide treatment targeting most of the dense areas of the lake in North Bay and compounded by a rapidly increasing water levels due to record rainfall in the region. The EWM population has gradually expanded since 2020 and has begun to populate many littoral areas around the lake (Map 2). Water levels have declined during this timeframe as well which may be favoring EWM growth in deeper areas of the littoral zone that now receive more sunlight than during high water levels.

The most recent EWM mapping survey completed in September 2023 indicated colonized EWM expanding within parts of North Bay as well as colonized areas forming in the southern end of the lake as well as in the bay nearest the public boat landing (Map #). Another *dominant* density colony was mapped along the northern shoreline in the center portion of the site. Many more *single plants*, *clumps of plants*, and *small plant colonies* were identified in littoral areas around the entire lake.

Anvil Lake Historic EWM Management

Since Eurasian watermilfoil's discovery, hand harvesting and DASH (Diver Assisted Suction Harvesting) has been the primary form of management (Table 3.3-5) while a 2,4-D herbicide treatment also took place in 2020 targeting the population in the North Bay. In many Wisconsin lakes, this method is able to slow the spread and decrease the population of EWM throughout the lake with some even being able use this control method as a long-term control solution.

The ALA conducted annual hand harvesting efforts from 2012-2019. The ALA funded the construction of their own DASH unit in 2017 for more effective and cost-efficient removal of

EWM in Anvil Lake. As the EWM population expanded in the lake during this time, the ALA's strategy shifted from attempting to manage the entire population to managing for nuisance relief with targeted hand harvesting efforts in prioritized areas of the lake. The EWM population expanded to form large surface matted areas within much of North Bay by 2017-2019 which prompted the ALA to pursue the use of herbicides to manage EWM in 2020.

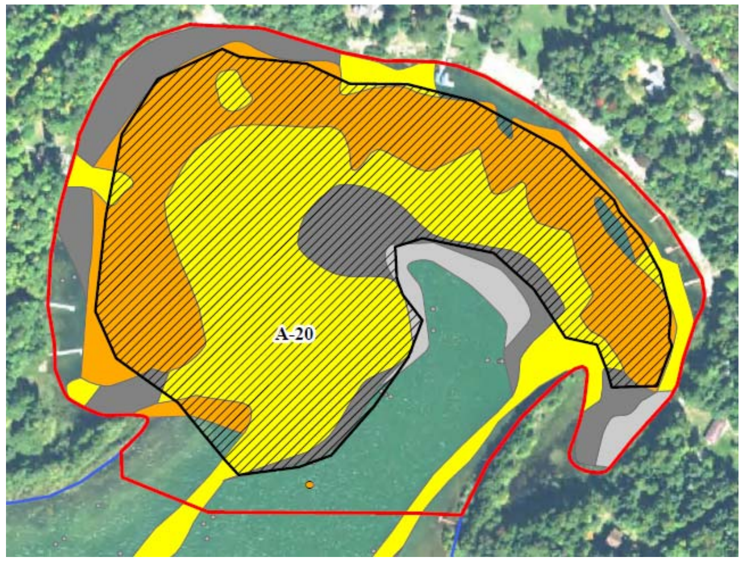


Figure 3.3-5. Anvil Lake 2020 herbicide treatment site in North Bay. Herbicide application area in black hashed area. 2019 (pretreatment) EWM population displayed**.**

Figure 3.3-5 reflects the final 2020 herbicide treatment strategy using liquid 2,4-D with an application rate of 1.05 ppm ae over 17.0 acres within North Bay. Herbicide was anticipated to mix within the North Bay to reach a bay-wide concentration of 0.600 ppm which was expected to have impacts on EWM throughout that area of potential impact (red outline on Figure 3.3-5). The herbicide application was completed on June 4, 2020. Monitoring conducted during 2020 indicated a large reduction in the EWM population within the targeted area of North Bay. Comparative pre- and post-treatment monitoring surveys indicated that the 2020 herbicide treatment resulted in a high level of control during the *year of treatment*.

The herbicide concentration monitoring data indicated the 2,4-D concentrations were below target levels in all samples collected within North Bay after treatment. Herbicide concentrations measured at the deep hole location following treatment were consistent with predicted estimates. The lake-wide 2,4-D concentrations observed in Anvil Lake were nearly ten times lower than typical whole-lake treatment concentrations.

It is suspected that the active management was a significant driver in the reductions of EWM and some native aquatic plants in the studied areas surrounding the time of the herbicide treatment; however, environmental factors such as water levels likely also contributed. It is suspected that environmental conditions in Anvil Lake in 2020 were not favorable for EWM growth, in particular, areas where EWM was growing towards the deeper extents of the littoral zone.

The ALA was awarded a WDNR AIS-Established Population Control grant in February 2020 that included funding to carry out the active hand harvesting management and associated monitoring from 2020-2023 (ACEI-241-20). The project included funds for the ALA to implement an Integrated Pest Management (IPM) strategy that included a robust hand harvesting effort to follow up the herbicide treatment in 2020.

Table 3.3-1 summarizes the hand harvesting efforts over the past four years in Anvil Lake. Since 2020, over 650 hours of dive time has resulted in a harvest of approximately 14,400 pounds of EWM from Anvil Lake. The lowest yield of EWM during this timeframe was during 2021 when only sparse EWM plants were known within the lake and divers harvested 56 pounds of plants. In contrast, during 2023, the ALA's paid divers in combination with efforts from a contracted professional firm accounted for over 9,000 pounds of EWM harvest.

Year	Diver Hours	EWM Harvest (lbs)
2020	152	4800
2021	106	56
2022	111.5	538
2023	288	9010
Total	**657.5**	**14404**

Table 3.3-1. 2020-2023 Hand Harvesting/DASH Effort Summary on Anvil Lake. Data compiled from ALA harvest reports.

Much of the 2023 hand harvesting efforts were focused within the North Bay, with additional visits to other areas around the lake. Additional details of the 2023 hand harvesting efforts are included within Appendix D. The late-summer 2023 EWM mapping survey indicated that the EWM population increased in Anvil Lake since the previous summer including within North Bay. The expectation of the 2023 harvesting operations in 2023 were not to reduce the population, but rather to attempt to suppress it to density levels that did not interfere with recreational use of the area. This objective appears to have been met for 2023 with minimal areas in the bay comprised of *dominant* or greater density designations.

The ALA has gained valuable experience relating to managing EWM in Anvil Lake with a coordinated hand harvesting approach following an herbicide treatment. The ALA has gained further understanding of the expectations and potential limitations associated with this management technique.

The North Bay of Anvil Lake has historically harbored the largest and most dense EWM colonies within the lake as this area of the lake seems to be conducive to its growth. Since the 2020 herbicide treatment in North Bay, the EWM population has incrementally increased each year with large colonized areas becoming more apparent in 2022 and 2023 (Figure 3.3-6). The ALA's coordinated hand harvesting management strategy during this time has likely slowed the rate of expansion in this area of the lake, but has not been able to result in maintaining or reducing the population.

With the current population in the North Bay, it is unclear whether a similar goal can be attained through a hand harvesting strategy in 2024. The population may be trending to the level that harvesting lanes for navigation purposes may be more feasible that attempting to target all areas of EWM in the Bay. The ALA will consider management options for North Bay in 2024 and beyond as a part of this Aquatic Plant Management Plan Update project.

The population around the rest of Anvil Lake outside of North Bay is at relatively modest levels that are not currently causing issues with recreational use. The ALA will consider hand harvesting in select areas around the lake in an effort to suppress the population from expanding into larger colonized areas, but may also entertain the option of not managing EWM at its current population level.

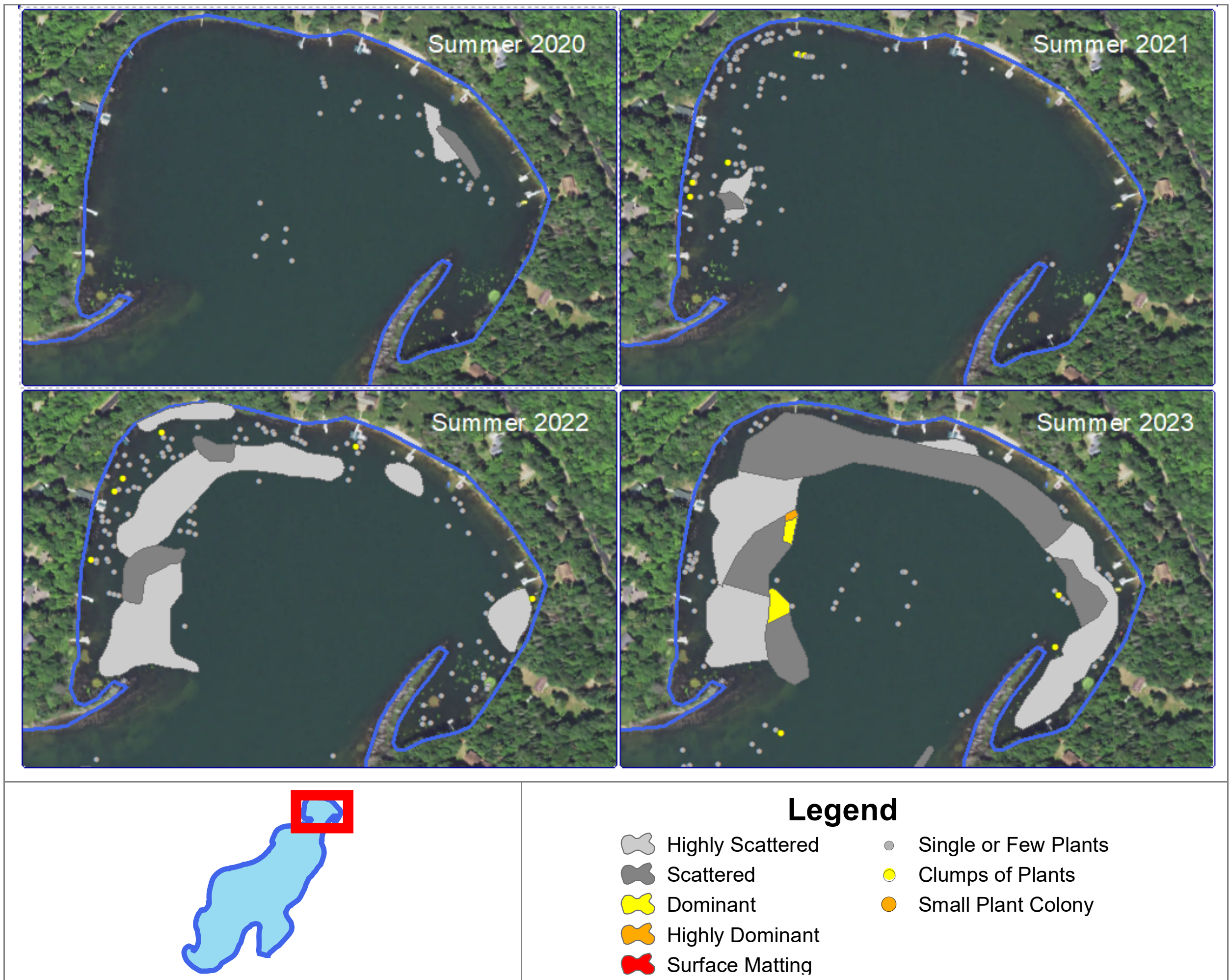


Figure 3.3-6. North Bay 2020-2023 EWM progression

Future AIS Management Philosophy

The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. One of the primary purposes of completing an APM Update is to ensure that the group's goals and actions align with what is considered to be the current BMP for AIS management. Materials included within the text below serve to provide an overview of current BMP's for EWM management for the ALA to review and consider when creating their updated APM Plan.

During the upcoming Planning Committee meetings, Onterra will outline three broad EWM population management perspectives for consideration, including a generic potential action plan for each (Figure 3.3-7). Onterra has extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* to serve as an objective baseline for the ALA to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Anvil Lake ecosystem. These chapters are included as Appendix E. The ALA Planning Committee will also review these management perspectives in the context of perceived riparian stakeholder support, which is discussed in the subsequent sub-section.

1. **No Coordinated Active Management**
   (Let Nature Take its Course)
   - Focus on education of manual removal methods for property owners
   - Lake organization does not oppose contracted efforts, but does not organize or pay for them
2. **Reduce EWM Population on a lake-wide level**
   (Lake-Wide Population Management)
   - Would likely rely on herbicide treatment strategies (risk assessment)
   - Will not eradicate EWM
   - Set triggers (thresholds) of implementation and tolerance
3. **Minimize navigation and recreation impediment**
   (Nuisance Control)
   - Hand-harvesting alone is not likely able to accomplish this goal and herbicides or a mechanical harvester may be required

Figure 3.3-7. Potential EWM Management Perspectives

Let Nature Take its Course: In some instances, the EWM population of a lake may plateau or reduce without conducting active management, as shown in the WDNR Long-Term EWM Trends Monitoring Research Project on Figure 3.3-2. Some lake groups decide to periodically monitor the EWM population, typically through a semi-annual point-intercept survey, but do not coordinate active management (e.g., hand-harvesting or herbicide treatments). This requires that the riparians tolerate the conditions caused by the EWM, acknowledging that some years may be problematic to recreation, navigation, and aesthetics. Individual riparians may choose to hand-remove the EWM within their recreational footprint, but most often the lake group chooses not to assist financially or with securing permits. In some instances, the lake group may select this management goal, but also set an EWM population threshold or management *trigger* where they would revisit their management strategy if the population reached that level. Said another way, the lake group would let nature take its course up until populations reached a certain lake-wide level or site-specific density threshold. At that time, the lake group would investigate whether active management measures may be justified.

Even with hand-harvesting activities during 2023 on Anvil Lake, the EWM population was anticipated to increase. Typically, during the third summer following an herbicide treatment, the EWM population becomes a little more noticeable to lake users, with some areas approaching levels that may be impactful to navigation and recreation. After a year or two of conducting hand-harvesting, some lake groups transition to a “Let Nature Take its Course” goal by not actively managing the EWM population. The lake group may target specific areas with management to alleviate the nuisance conditions, but not attempt to manage the population as a whole. Once the EWM population approaches pretreatment levels, the lake group often considers another herbicide treatment to reset the population to a lower level that may once again be scale appropriate for management with manual removal techniques.

Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with EWM populations, that may be to manage the EWM population at a reduced level with the perceived goal to allow the system to function as it had prior to EWM establishment. It must also be acknowledged that some lake managers and natural resource regulators question whether that is an achievable goal as management actions have unintended collateral impacts.

In early EWM infestations when the extent of the populations is relatively small or contained to one or a few locations, the entire population may be targeted through hand-harvesting or spot treatments. On more advanced or established populations, this may be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies. In areas of the state that contain highly established and prevalent EWM populations, lake-wide population management is often considered too aggressive by local WDNR regulators. In these instances, the nuisance conditions are targeted for management and other areas are tolerated or avoided. In Anvil Lake, a whole-lake herbicide treatment would likely be the only technique that could seek to manage the entire lake-wide population.

Nuisance Control: The concept of ecosystem services is that the natural world provides a multitude of services to humans, such as the production of food and water (provisioning), control of climate and disease (regulating), nutrient cycles and pollination (supporting), and spiritual and recreational benefits (cultural). Some lake groups acknowledge that the most pressing issues with the EWM population on their lake is the reduced recreation, navigation, and aesthetics compared to before EWM became established in their lake. Particularly on lakes with large EWM populations that may be impractical or unpopular to target on a lake-wide basis, the lake group would coordinate (secure permits and financially support the effort) a strategy to improve these cultural ecosystem services.

There has been a change in preferred strategy amongst many lake managers and regulators when it comes to established EWM population in recent years. Instead of chasing the entire EWM population with management, perhaps focusing on the areas that are causing the largest impacts can be more economical and cause less ecological stress. The majority of EWM management in Wisconsin would be considered nuisance management, where dense areas that are causing navigation or recreation issues are prioritized for management and dense areas not meeting these criteria being left unmanaged. Mechanical harvesting and herbicide spot treatments are most typically employed to reach nuisance management goals, although hand-harvesting/DASH is sometimes employed to target small footprints.

A mechanical harvesting management strategy may be applicable to managing EWM in Anvil Lake, including in North Bay where EWM has shown the potential to reach surface matting conditions that inhibit recreational uses in the bay. A mechanical harvesting strategy in North Bay would likely involve cutting access lanes to many or all of the riparian docks in the bay along with the creation of common use lanes extending out from the bay into deeper waters in the main body of the lake. It is expected that two or three cutting events would need to take place each year in order to maintain navigability in the bay when EWM is at high density levels. This type of nuisance relief strategy has been used in the North Bay in the past with the use of DASH attempting to create navigation lanes in the years prior to the 2,4-D treatment. DASH or a mechanical harvester may be able to achieve the objective a nuisance relief goal in North Bay, but with potentially differing levels of costs and effectiveness.

Spot vs Whole-Lake or Whole-Basin Herbicide Treatment Approaches

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant affects outside of that area. Spot treatments typically rely on a short exposure time to cause mortality as the herbicide dissipates out of the spots rapidly. Historically, spot treatments were conducted largely with 2,4-D. Studies have confirmed that it is extremely rare that 2,4-D concentrations are maintained within most spot treatments long enough to cause EWM mortality.

Whole-lake or whole-basin treatments are a collective of spot-treatments around that lake that are expected to mix into a uniform lake-wide concentration that is sufficient to impact EWM. During 2010-2020, whole-lake and whole-basin herbicide treatments gained popularity, as it was easier to predict EWM control goals and understand levels of collateral native plant impacts. The 2020 2,4-D treatment was designed as a “basin-wide” treatment with the intention of controlling EWM throughout the North Bay of Anvil Lake.

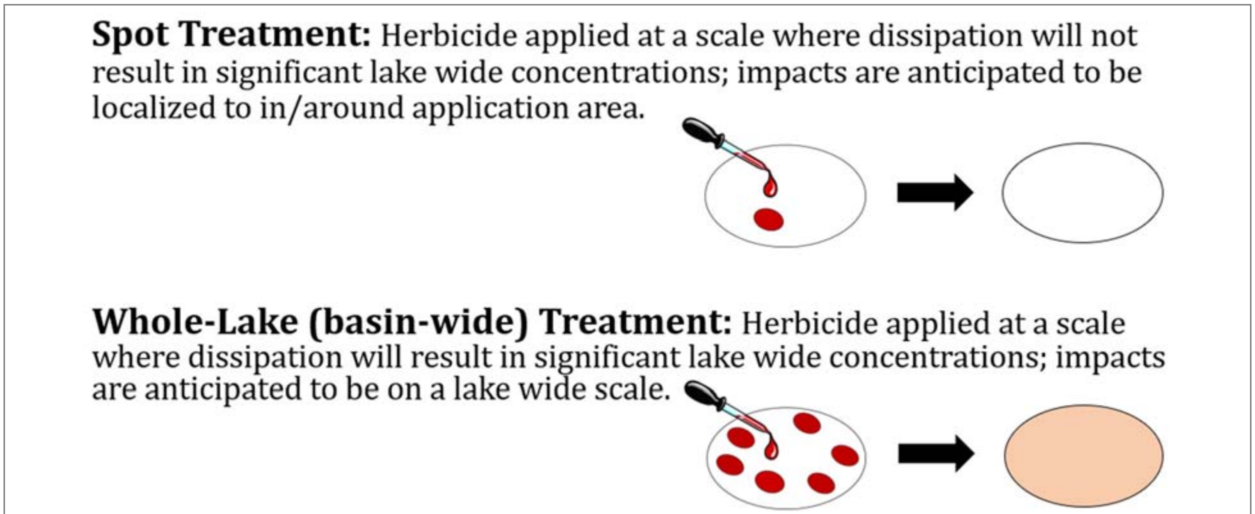


Figure 3.3-8. Ecological definitions of herbicide treatment. Graphics created in conjunction with WDNR.

ProcellaCOR

ProcellaCOR™ has been the state’s most popular herbicide for EWM management in recent years. The active ingredient florpyrauxifen-benzyl is sold exclusively by SePRO under the tradename ProcellaCOR™. This herbicide has largely been used in spot treatment scenarios, but has recently been adopted as a whole-lake treatment option on a number of Wisconsin lakes. Onterra has monitored over 50 ProcellaCOR™ treatments in Wisconsin since 2019 with data analysis related to herbicide concentration monitoring and native aquatic plant impacts being investigated in the majority of treatments. Analysis of these data have allowed lake managers to better understand the ways in which the herbicide dissipates or mixes within a lake in the hours and days after application. Additionally, aquatic plant monitoring data provides insights as to which native species are typically impacted with ProcellaCOR™ treatments. The WDNR’s fact sheet on this chemistry can be found here:

https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305

Lake managers continue to learn how to successfully implement this form of treatment after being registered for use in Wisconsin only a few years ago. ProcellaCOR™ is in a new class of synthetic auxin mimic herbicides (arylpicolinates) with reportedly short concentration and exposure time (CET) requirements compared to other systemic herbicides. Auxin-mimic herbicides are translocated throughout the plant and suppress growth regulation hormones, so the plant grows uncontrollably at the cellular level which causes mortality.

Traditional auxin-mimic herbicides used to manage EWM, like 2,4-D and triclopyr, require longer exposure times that can be achieved by most spot treatments. Uptake rates of ProcellaCOR™ into EWM were two times greater than reported for triclopyr (Haug, 2018) (Vassios, Nissen, Koschnick, & Hielman, 2017). The active ingredient of ProcellaCOR™, florpyrauxifen-benzyl, is primarily degraded by photolysis (light exposure), with some microbial degradation. The active ingredient is relatively short-lived in the environment, with half-lives of 4-6 days in aerobic environments and 2 days in anerobic environments (WSDE 2017). Onterra's experience monitoring herbicide concentrations following ProcellaCOR treatments in Wisconsin confirms the active ingredient typically is below detectable levels within a week after treatment, sometimes slightly longer in whole-lake use patterns. Preliminary research suggests that florpyrauxifen-benzyl may have a different or quicker breakdown pattern in waters with high pH and high biomass of aquatic plants.

The primary breakdown product of florpyrauxifen-benzyl is florpyrauxifen acid. This chemical metabolite is reported to have activity as an herbicide on aquatic plants, albeit to a lower degree than the active ingredient. Within Onterra's case studies, the acid metabolite is detected during early monitoring periods (ie. hours after treatment), increasing in concentration after days to weeks as the active ingredient is converted into this form. Florpyrauxifen acid has been shown to persist in the lake longer than the active ingredient, with some of Onterra case studies confirming florpyrauxifen acid for at least 70 days after treatment, particularly in whole-lake treatment scenarios. The persistence of the acid metabolite is also a concern for agency regulators, particularly as it relates to toxicology.

Onterra's experience monitoring ProcellaCOR™ treatments indicates that EWM control has been high with almost no EWM being located during the summer post treatment surveys. Some treated sites have shown EWM population recovery two-years after treatment, while most other sites have demonstrated three years and counting of continued EWM reductions to-date. For many ProcellaCOR™ treatments that Onterra monitored in Wisconsin to date, EWM impacts were observed extending outside of the application area and into a basin or semi-defined mixing area called an Area of Potential Impact (AOPI).

Native aquatic plant monitoring data indicates that northern watermilfoil is highly susceptible to ProcellaCOR™ with frequency of occurrences typically reduced to 0% in the year of treatment with little to no sign of recovery during the year after treatment. Other species that have shown a degree of susceptibility to this chemical include water marigold, coontail, and potentially water stargrass. In many of the treatments that Onterra has monitored, coontail occurrence has been reduced by approximately 50% during the year of treatment, but is not typically reduced to 0%.

Pondweed species appear to be largely unaffected by this herbicide, with some lakes having large increases in species, such as clasping-leaf pondweed, during the years following treatment. Onterra's experience is that adjacent populations of floating-leaf species (i.e. water lilies) may initially shows signs of herbicidal stress such as leaf twisting (epinasty), but typically rebound a few weeks after treatment including in intentional whole-lake treatment scenarios.

Registration of aquatic herbicides by the US Environmental Protection Agency (EPA) is conducted at short exposure and high concentration scenarios. As the use of aquatic herbicides in whole-lake or whole-basin scenarios have become more common, research on environmental toxicity for long exposure and low concentrations scenarios has followed. Research conducted by UW-Madison researchers have confirmed impacts of 2,4-D in long-exposure situations when exposure overlapped with specific early life stages of some fish species (Dehnert G. K., Freitas, Sharma, Barry, & Karasov, 2020), with the first 14 days post hatch being the most sensitive stage (Dehnert G. K., Freitas, DeQuattro, Barry, & Karasov, 2018). Specifically, walleye are one of the fish species shown to be impacted by 2,4-D when early life states are exposed to long exposures. While published data is not currently available on ProcellaCOR™ impacts to early life stages of fishes, the potential for similar sensitivity is high considering its similar auxin-mimic hormone mode of action. Therefore, Onterra recommends all ProcellaCOR™ treatments occur after sensitive fish species of concern, like walleye, have outgrown their most-sensitive life stage to auxin herbicide exposure (first 14 days after hatching). Operationally for walleye, herbicide application would need to be delayed until approximately mid-June of a given year.

Herbicide Resistance

While understood in terrestrial herbicide applications for years, herbicide resistance is an emerging topic amongst aquatic herbicide applicators, lake management planners, regulators, and researchers. Herbicide resistance is when a population of a given species develops reduced susceptibility to an herbicide over time, such that an herbicide use pattern that once was effective no longer produces the same level of effect. This occurs in a population when some of the targeted plants have an innate tolerance to the herbicide and some do not. Following an herbicide treatment, the more tolerant strains will rebound whereas the more sensitive strains will be controlled. Thus, the plants that re-populate the lake will be those that are more tolerant to that herbicide resulting in a more tolerant population over time.

Repetitive treatments with the same herbicide mode-of-action may cause a shift towards increased herbicide tolerance in the population. Rotating herbicide use-patterns can help avoid population-level herbicide tolerance evolution from occurring. Although in the same herbicide class as 2,4-D, ProcellaCOR is thought to be unique enough that given the past use of 2,4-D on Anvil Lake, a ProcellaCOR application would not be more likely to drive herbicide resistance within the lake.

Stakeholder Survey Responses to Eurasian Watermilfoil Management

In an effort to understand how EWM impacts stakeholders, the 2023 stakeholder survey asked if the Eurasian watermilfoil population ever had a negative impact on your enjoyment of the Anvil Lake. The category with the highest number of respondents indicating *Yes* was aesthetics and swimming (Figure 3.3-9).

Queston 24: Has the Eurasian watermilfoil population ever had a negative impact on your enjoyment of Anvil Lake?

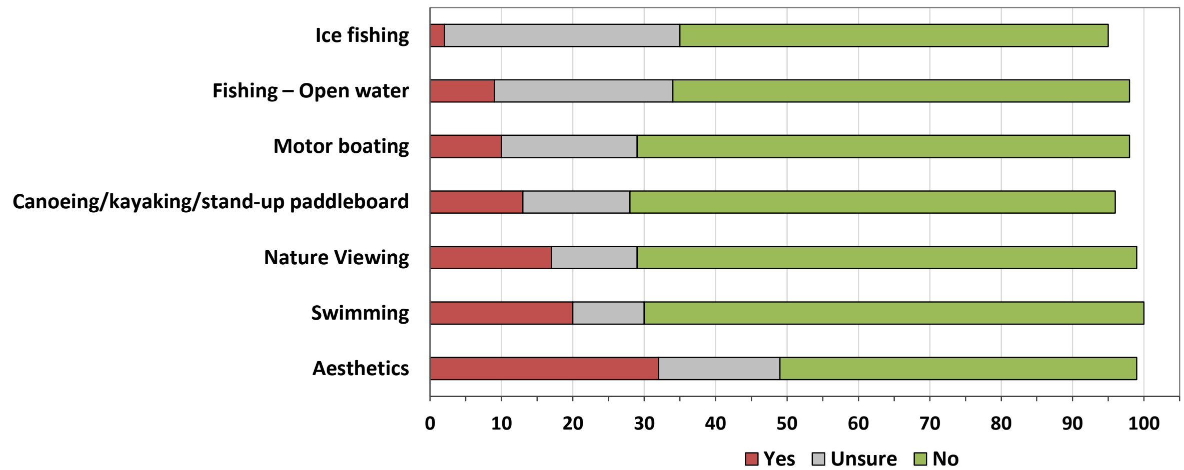


Figure 3.3-9. Select survey responses from the ALA stakeholder survey. Additional questions and response charts may be found in Appendix B.

In 2023, riparian property owners and ALA members were asked about a number of management techniques for managing non-native aquatic plants. Figure 3.3-10 highlights the support or opposition for a variety of management techniques for Eurasian watermilfoil. The majority of stakeholders strongly support hand-removal by divers or property owners while most oppose the strategy of not managing Eurasian watermilfoil. Herbicide use saw mixed levels of support with slightly more support for its use if a barrier curtain was used.

Some lake groups have attempted to "contain" the herbicide in place with the use of barrier curtains, allowable to be in place for up to 72 hours after the treatment is conducted (other restrictions and safety measures apply). Typically, areas already somewhat contained by a bay or shoreline were chosen to minimize the amount of curtain material needed.

The majority of research trials that have taken place in Wisconsin utilized an economical-priced herbicide like 2,4-D to determine if the herbicide can be held in place long enough to be effective. Recently, some lake groups are considering barrier curtains to contain the herbicide to limit non-target collateral impacts to native plants. Barrier curtain construction and placement is the responsibility of the lake group, requiring advance planning efforts and a formidable volunteer base. In 2023, riparians were asked whether they would support an "herbicide use with a barrier curtain to help contain the chemical within the treatment area (newer technique)" (Appendix B, Question 28). This increased support (pooled *highly supportive* and *somewhat supportive)* for herbicide treatment to approximately 66% compared to 53% without a curtain as shown in Figure 3.3-10.

Queston 26: Eurasian watermilfoil can be controlled using many techniques. What is your level of support for the use of the following Eurasian watermilfoil management techniques in Anvil Lake?

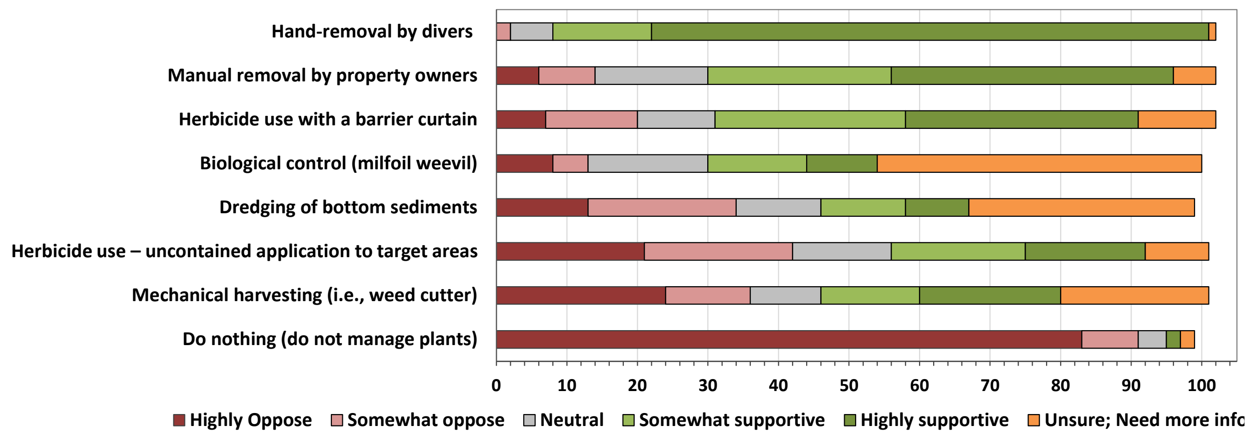


Figure 3.3-10. Select survey responses from the ALA stakeholder survey. Additional questions and response charts may be found in Appendix B.

While stakeholders favored hand-removal, they also expressed concerns for the effectiveness of the strategy (Figure 3.3-11). The largest number of concerns however were indicated under the use of aquatic herbicides. Of these, the top concerns included potential impacts to native plant and non-plant species, potential impacts to human health, and future impacts are unknown (Figure 3.3-11). The top concern regarding mechanical harvesting was ineffectiveness of technique strategy.

Queston 27: What concerns, if any, do you have for the future use of aquatic herbicides, hand harvesting and/or mechanical harvesting to target Eurasian watermilfoil in Anvil Lake?

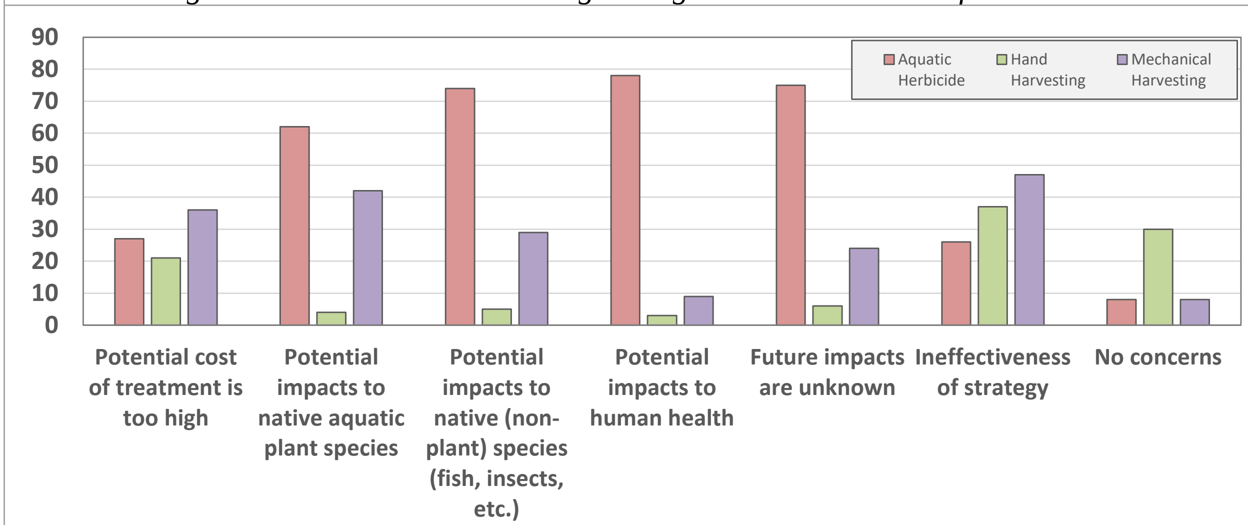


Figure 3.3-11. Select survey responses from the ALA stakeholder survey. Additional questions and response charts may be found in Appendix B.

Curly Leaf Pondweed (Potamogeton crispus)

Curly-leaf pondweed (*Potamogeton crispus*; CLP) is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. The plants begin growing almost immediately after, if not immediately before, ice-out and by early-summer they reach their peak growth. As they are growing, each plant produces numerous turions (asexual reproductive structures) which break away from the plant and settle to the bottom following the plant's senescence. The deposited turions lie dormant until autumn when they sprout to produce small winter foliage, and they remain in this state until spring foliage is produced. The advanced growth in spring gives the plant a significant jump on native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition. However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance.

Like our native pondweeds, CLP produces alternating leaves along a long, slender stem. The leaves are linear in shape with a blunt tip, and the margins are wavy and conspicuously serrated (Photograph 3.3-4). The plants are often brownish/green in color.

Photograph 3.3-4. A single curly-leaf pondweed turion sprouting several new plants (left) and a fully grown plant specimen (right). Photo credit Onterra.

Curly-leaf pondweed was first encountered in Anvil Lake during a July 2013 survey by Onterra. This lone occurrence consisting of a few plants were identified and removed by ALA members during the summer of 2013. Several low density CLP occurrences were located in the northern bay during 2014. Subsequent surveys have shown the CLP population integrates itself well within the native aquatic plant community with no instances of nuisance conditions developing.

An early season AIS survey was completed on Anvil Lake on June 19, 2023 which corresponds with the approximate time of the growing season when CLP is expected to be near its maximum growth potential for the season. A full visual meander of the entire littoral area of the lake was completed during this visit including the selective use of submersible cameras. No CLP was observed anywhere in the lake during this visit. CLP populations in any given year can be highly variable based on regional climactic factors such as duration of ice and snow cover, water clarity, or water temperatures. While no CLP was located in Anvil Lake during 2023, viable turions are very likely present within the substrate and conditions in the lake during 2023 were likely not conducive to turion propagation. CLP persists in the lake at modest levels that were below detection levels in 2023.

The ALA's 2018 Comprehensive Management Plan included a management action to monitor the CLP population in the lake. As a part of the ALA's Updated Aquatic Plant Management Plan, this action will be revisited. CLP has not shown invasive growth in Anvil Lake to-date; however, this species has the potential to do so and continued monitoring will be helpful in understanding if this species is increasing within the lake such that management actions would be considered in the future.

4.0 SUMMARY & CONCLUSIONS

Monitoring studies completed during 2023 shows a high quality aquatic plant population based on floristic quality index metrics and comparison to other lakes in the ecoregion and state. A comparison of point-intercept surveys shows variability in occurrence for some species with no obvious concerning trends apparent.

Since the EWM population was greatly reduced following a 2020 2,4-D treatment in the lake, the ALA has implemented an aggressive hand harvesting/DASH program that has served to slow the rebound or re-establishment of EWM in the lake over the past several years. The EWM population has gradually increased each year since 2020 and by 2024 has reached a population that exceeds the ability of hand harvesting to be an effective population management technique.

Building off the recent management experience and the information gathered during the Onterra studies completed in 2023, the ALA has developed an aquatic plant management plan for Anvil Lake that serves to address the concerns of stakeholders around the lake. As is outlined in the subsequent Implementation Plan Section (5.0), the ALA has developed an Integrated Pest Management Strategy for Eurasian watermilfoil management. This includes the ALA's intention to pursue herbicide treatment as soon as 2025, with continued hand harvesting and Diver Assisted Suction Harvesting efforts.

Discussion during the planning meetings for this project included extended conversation about management techniques for meeting EWM control goals in Anvil Lake. The ALA understands that EWM eradication is not attainable, and have reviewed different management perspectives. The ALA intends to conduct an integrated pest management approach to EWM in the future and will use an adaptive approach to manage the species in the long term.

The ALA has also outlined goals to ensure their management plan is up to date and to conduct basic aquatic plant monitoring activities going forward.

5.0 AQUATIC PLANT IMPLEMENTATION PLAN SECTION

The ALA's Comprehensive Management Plan (January 2018) remains in place and the Implementation Plan outlined below updates certain aspects of that Plan, particularly Management Goal #2 which is related to managing AIS in Anvil Lake. The other management goals within the ALA's 2018 Plan remain in place and include goals relating to increasing ALA's capacity, protecting and restoring the lake shoreline and fisheries, and maintaining current water quality conditions.

The Implementation Plan presented below was created through the collaborative efforts of the ALA Board of Directors and ecologist/planners from Onterra. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Anvil Lake stakeholders as portrayed by the returned stakeholder survey and communications with ALA Board members. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Ensure the Anvil Lake Association has a Functioning and Up-to-Date Management Plan

Management Action:	Periodically update lake management plan
Timeframe:	Periodic
Facilitator:	Board of Directors
Description:	The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. ***Comprehensive Management Plan*** The WDNR recommends *Comprehensive Lake Management Plans* generally get updated every 10 years. Implementation projects require a completion date of "no more than 10 years prior to the year in which an implementation grant application is submitted. The department may determine a longer lifespan is appropriate if the applicant can demonstrate a plan has been actively implemented and updated during its lifespan." This allows a review of the available data from the lake, as well as to consider changing BMPs for water quality, watershed, and shoreland management. The ALA's previous *Comprehensive Lake Management Plan* was finalized in January 2018. ***Aquatic Plant Management Plan*** BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. To be eligible to apply for grants that provide cost share for AIS control and monitoring, "a current plan must have a completion date of no more than 5 years prior to

	submittal of the recommendation for approval. The department may determine that a longer lifespan is appropriate for a given management plan if the applicant can demonstrate it has been actively implemented and updated during its lifespan. However, a [whole-lake] point-intercept survey of the aquatic plant community conducted within five years of the year an applicant applies for a grant is required." It is important to work with the regional WDNR Lakes Biologist to understand what is required at this time, as it is more subjective in comparison to the requirements of a *Comprehensive Lake Management Plan* as it relates to the specific management actions being considered. Some regional biologists require additional aspects in within an Aquatic Plant Management Plan update, such as a riparian stakeholder survey, a review of available water quality data for example. The ALA conducted an official update to their aquatic plant management plan as part of this project which will be finalized during 2024. ***<u>Annual Control & Monitoring Plan</u>*** It is important to note that the comprehensive management plan or aquatic plant management plan provides a framework to guide the management action, but does not include the specific control plan for a given year. A written control plan, consistent with the *Management Plan*, would be produced prior to the action outlining the management and monitoring strategy. The control plan is useful for WDNR and tribal regulators when considering approval of the action, as well as to convey the control plan to ALA members for their understanding. Annual AIS control and monitoring plans have been issued for the ALA each year for over a decade which includes an evaluation of the past years' management and monitoring activities as well as outlines the strategy for the following year. These reports are typically issued during January-March which allows for sufficient time to analyze results from the previous year, develop a strategy for the following season, engage and communicate with ALA leadership and WDNR regulators, and seek any permits that may be required to carry out the upcoming management activities.

<u>Management Action:</u>	Conduct periodic riparian stakeholder surveys
Timeframe:	Periodic: every 5 years, corresponding with management plan updates
Facilitator:	Board of Directors
Description:	Formal riparian stakeholder user surveys have been performed by the association in 2019 and 2024. Approximately once every 5-6 years, potentially at the time of a Plan update or prior to a large management effort, an updated stakeholder survey would be distributed to the Anvil Lake riparians and ALA members. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be

	critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2024, with modified or additional questions as appropriate. The survey would again need to receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.

Management Goal 2: Monitor Aquatic Vegetation in Anvil Lake

Management Action:	Monitor the Eurasian watermilfoil population
Timeframe:	Annually, during late-summer
Facilitator:	Board of Directors
Description:	As the name implies, the Late-Season EWM Mapping Survey is a professionally contracted survey completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For Anvil Lake, this survey would likely take place in August or September, dependent on the growing conditions of the particular year. This survey would include a complete or focused meander survey of the lake's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). Late Season EWM Mapping Surveys have been conducted annually since 2012 with consistent methodology being used. These data allow lake stakeholders to understand annual EWM populations in response to natural variation and directed management activities. The mapping data that is provided from this survey is instrumental in monitoring active EWM management activities and in developing a management strategy for the following year. When the late-summer EWM mapping survey is not already covered within a grant funding project, the ALA would pay out-of-pocket for this monitoring to ensure the continuity of this dataset.

Management Action:	Monitor the curly-leaf pondweed population
Timeframe:	annually
Facilitator:	Board of Directors
Description:	Since CLP was discovered in Anvil Lake, it has largely integrated into the aquatic plant community and has not expanded to high population levels. Professional monitoring during 2023 did not identify any CLP in the lake during the time of the

	growing season when the population would be expected to be at its greatest growth potential. The ALA will conduct a volunteer-based CLP monitoring effort. This will include trained volunteers with confident identification skills searching the lake during early-summer (May-June) and noting where the species is present. The volunteer CLP monitoring results will be shared with the ALA Board and with ALA membership. Divers that are in the water as a part of the EWM harvesting activities will also be able to provide information about whether CLP is present in the work areas. While CLP is not currently being managed on Anvil Lake, the ALA will encourage its removal from the lake by individual property owners and anyone that encounters it. The ALA will seek a professional CLP monitoring survey in the event that the local volunteer monitoring efforts are indicating an expanding population to the point that management may be warranted. Future aquatic plant management plan update projects will provide an opportunity to conduct a professional monitoring survey as a part of a larger project that may be a part of a grant funded project. Professional CLP monitoring would include a full meander survey of all littoral areas of the lake by ecologists with the use of GPS guidance. The survey would occur during early-summer (late-May through June) to coincide with the expected peak growth stage of this species.

Management Action:	Coordinate periodic point-intercept aquatic plant surveys
Timeframe:	Periodic: at least once every 5 years; Timing: during July-August
Facilitator:	Board of Directors
Description:	The point-intercept aquatic plant monitoring methodology as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) has been used on Anvil Lake in the past. Whole-lake point-intercept surveys have occurred in 2010, 2012, 2015, 2019, and 2023. The ALA will ensure the point-intercept survey is conducted at least once every five years. This will allow a continued understanding of the submergent aquatic plant community dynamics within the lake. The WDNR indicates that repeating a point-intercept survey every five years will generally suffice to meet WDNR planning requirements and grant eligibility requirements. If large-scale aquatic plant management is taking place, more frequent monitoring may be required.

Management Action:	Consider periodic community mapping (floating-leaf and emergent) surveys
Timeframe:	Periodic: every 10 years or when prompted

Facilitator:	Board of directors
Description:	In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Anvil Lake, a community mapping survey would be conducted approximately every 10 years. This survey would delineate the margins of floating-leaf (e.g., water lilies) and emergent (e.g., cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. This survey was completed on Anvil Lake in 2015. A replication of the community mapping survey will be considered in future management plan update projects, unless prompted sooner if changes are believed to be occurring to these communities.

Management Goal 3: Prevent Establishment of New Aquatic Invasive Species

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at Anvil Lake public access location
Timeframe:	Ongoing
Facilitator:	Environment & Education Committee
Description:	The intent of this program is not only to prevent additional invasive species from entering Anvil Lake through its public access location, but also to prevent the infestation of other waterways with invasive species that originated in Anvil Lake. This program will help to prevent other AIS from entering Anvil Lake including species such as spiny waterflea, starry stonewort, and zebra mussels. The ALA utilizes WDNR grant funding to sponsor watercraft inspections through the WDNR's Clean Boats Clean Waters (CBCW) program at the public boat launch. CBCW inspection is provided primarily on Fridays, Saturdays, Sundays, and holidays, with additional weekdays monitored at times as well. The ALA Clean Boats Clean Waters program has been well organized, with numerous watercraft inspections occurring annually. Monitoring summary information data is entered into the WDNR's Surface Water Integrated Monitoring System database (SWIMS). The ALA will continue to seek cost share assistance through the WDNR's Clean Boats Clean Waters program. Signage is in place at the public boat landing that encourages the removal of aquatic hitchhikers from vessels entering the lake which is a prevention item that supplements the ALA's CBCW program.

Management Goal 4: Promote Education of Aquatic Invasive Species & Aquatic Invasive Species Management

Management Action:	Convey updated aquatic invasive species information and messaging to ALA members and Anvil Lake riparians
Timeframe:	Ongoing
Facilitator:	ALA Board
Description:	Emerging science and new information is continually coming out of the aquatic plant management field, impacting management philosophies and what is considered the Best Management Practices (BMP). The ALA understands the importance of keeping the Anvil Lake riparians informed of this rapidly changing landscape. To accomplish this educational objective, the ALA plans to highlight key topics from the plan and share educational materials on the subjects over time. This management goal builds on an action within Management Goal 1 within the ALA's existing Management Plan to promote lake protection and good stewardship through stakeholder education. Educational outreach occurs through email updates to membership, in-person meetings, and the ALA's others communication avenues. The ALA has identified the following list to serve as a basis for their education and outreach in regards to EWM management: • EWM herbicide resistance • Unrealistic expectations (e.g. eradication) • Role of native aquatic plants • Human tolerance to EWM conditions • Role of Diver Assisted Suction Harvesting in EWM management • EWM fragmentation as a natural means of propagation

Management Goal 5: Actively manage Eurasian watermilfoil to ensure recreational use of the lake is maintained

Management Action:	Conduct Integrated Pest Management Program towards EWM
Timeframe:	Ongoing
Facilitator:	Board of Directors

Description:	The long-term objective of this action is to minimize the negative attributes that EWM causes on Anvil Lake by maintaining navigation, recreational use, and aesthetics. The ALA has outlined an Integrated Pest Management (IPM) approach toward managing EWM in order to reach the intended goal. Each of the potential management strategies are discussed below. This action serves to minimize the negative impacts EWM is causing in the lake and to attempt to contain the population to fewer areas of the lake while inhibiting new areas from becoming established.

Stakeholders were asked to provide an indication of their level of support for various EWM management techniques within the stakeholder survey. The survey responses are also factored into the ALA's management strategies outlined below. Respondents' answers for the various techniques are summarized in the figure below:

Question 33. As the EWM population rebounds from previous management activities, the Anvil Lake Association will begin assessing future management techniques for the EWM population. What is your level of support or opposition for the future use of the following EWM management techniques in Anvil Lake?

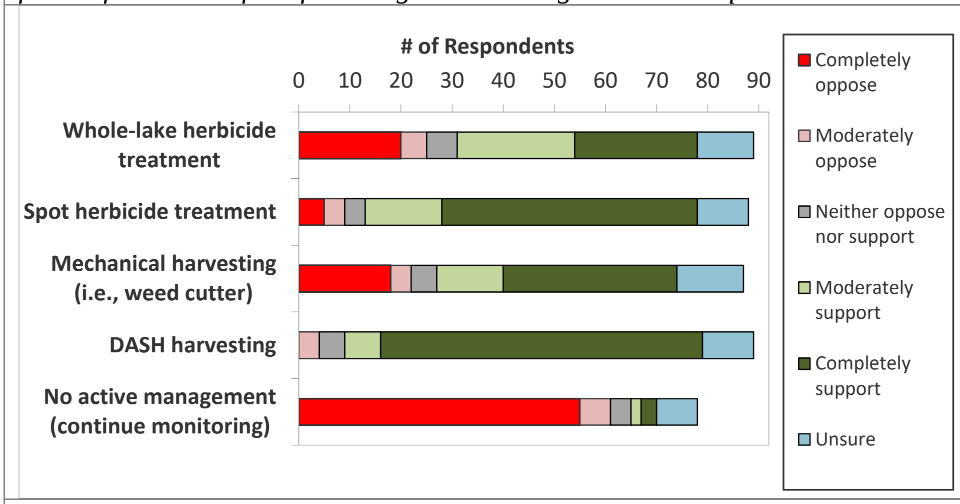


Figure 5.0-1. Survey responses from Question #33 from the ALA stakeholder survey. Additional questions and response charts may be found in Appendix B.

Volunteer hand harvesting

The ALA will inform property owners of options available to them for improving recreational use of their individual frontage. Each riparian owner can legally harvest any aquatic plants in a 30' wide area of one's frontage directly adjacent to one's pier without a permit. Simply wading into the lake and removing aquatic plant vegetation by hand or with the aid of a rake or other hand-held accessories can be helpful in managing aquatic plants on a small and individual property-based scale. Non-native species including EWM can be hand removed anywhere in the lake without a permit and therefore is not limited to the 30' corridor zone. A WDNR permit is required if an area larger than the 30' corridor is being harvested or if a mechanical assistance mechanism, like DASH (Diver Assisted Suction Harvesting), is being used. Individual property owners may seek a WDNR permit to utilize DASH to manage aquatic plants in their frontage zone. One or two days of harvesting each year would likely provide seasonal relief from dense aquatic plants in an area being used for recreational purposes.

Some professional firms offer services to remove aquatic vegetation from within the riparian property owner's 30' frontage zone, though it is more economical to solicit these efforts from local sources if available.

Contracted Hand harvesting/Diver Assisted Suction Harvest

The ALA owns and maintains their own DASH vessel for which they have hired qualified divers each year to operate since 2017. Volunteers and divers also hand harvest in shallow areas of the lake. DASH has been the primary tool that the ALA has employed in recent years for EWM management and is a highly supported EWM management technique for future management (Figure 5.0-1).

During periods of low EWM populations in the lake, such as after the 2020 herbicide treatment, DASH functions as a population management tool such that all known EWM is targeted for removal during the season. As the size of the EWM population increases, the utility of a hand harvesting strategy becomes scale limited, and can be cost prohibitive. When the EWM population expands to a size that DASH cannot realistically target all occurrences, the utility of this technique shifts to a nuisance control type of strategy. In these scenarios, the use of DASH is prioritized to ensure recreational use of the lake with efforts focused in high-use areas of the lake or sites where recreational use is being impacted. A nuisance relief type strategy may include harvesting high amounts of EWM biomass in an effort to suppress the population for the season to lower densities.

One of the most-commonly employed uses of a hand harvesting strategy in lakes with an established EWM population is to target remnant or resurgent plants in the years after herbicide management occurs. The smaller EWM population expected after herbicide management is typically of a more feasible scale for a hand harvesting approach to be an effective method of management. The goal of using this type of integrated pest management approach is to delay the need for future herbicide management and slow the inevitable resurgence of the EWM population in the lake. This has been the ALA's strategy since the 2020 2,4-D treatment lowered the population substantially and the EWM has gradually increased over time.

The ALA will consider conducting hand harvesting, including the use of DASH, to target EWM in the years following herbicide treatments and when EWM management is desired but other management actions such as herbicide treatments are not taking place. The ALA will consider supplementing the ALA DASH operations with contracted hand harvesting/DASH efforts depending on the current EWM population and available resources.

EWM mapping surveys would be used to guide the hand harvesting efforts when these data are available. Typically, a late-summer EWM mapping survey will guide the following years' harvesting activities, but in some cases, the ALA may seek an early-season mapping survey to identify new occurrences or to refine the harvesting strategy for the season. When DASH is to be used, the ALA will submit a permit application to WDNR including a map of the areas to be harvested.

Mechanical Harvesting
A theoretical mechanical harvesting strategy was discussed during the planning meetings for this project. This type of management technique has the potential to serve as a long-term aquatic plant management tool for lakes where impacts to recreational use are taking place, either through native and/or non-native aquatic plant species alike. The use of a mechanical harvester would likely involve cutting lanes from high-use areas of the lake such as from pierheads out to deeper waters, or in other high use areas of the lake. This technique would be much more efficient than DASH in terms of accomplishing the creation of recreational use lanes. Cutting operations on one or two occasions during the growing season would likely be sufficient in achieving the seasonal relief from nuisance level plant growth and this type of program may require annual implementation to meet management goals. A WDNR permit would be required to conduct mechanical harvesting with clearly delineated harvesting areas displayed on a map. A disposal location for the harvested plant materials would be determined as a part of a mechanical harvesting plan.

This management technique would be something that the ALA would investigate in future APM updates, particularly if grant funding is possible, if nuisance level growth of aquatic plants occurs on a regular basis, and if the use of herbicide to mitigate the EWM population is not permitted or otherwise taking place. Mechanical harvesting as a tool for future EWM management in Anvil Lake received mixed levels of support with more respondents supportive than opposed (Figure 5.0-1).

Herbicide Treatment
Considerations for conducting an herbicide treatment would be made utilizing the current understanding of best management practices for this technique. The ALA acknowledges that WDNR fisheries managers prefer a conservative approach to use of herbicides in the lake and that Tribal interests are generally opposed to any use of herbicides in ceded territory.

While some herbicide spot treatments show promise, the unpredictability of spot treatments state-wide has resulted in less favorability of this strategy with some WDNR regulators and lake managers. This is particularly true in areas of increased water exchange via flow, exposed and offshore EWM colonies, or when traditional weak-acid herbicides like 2,4-D are used. Any herbicide spot-treatments on Anvil Lake would consider herbicides thought to be effective under short exposure situations. At the time of this writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike™) are examples of herbicides with reported short exposure time requirements that are employed for spot treatments

	of invasive watermilfoil control in Wisconsin. Advancements in research into new herbicides and use patterns will need to be integrated into future management strategies, including effectiveness, native plant selectivity, and environmental risk profile. Any herbicide treatment design for Anvil Lake will also consider the potential for meaningful basin-wide or whole-lake concentrations and may include intentional whole-lake dosing calculations. The ALA understands that even a whole-lake herbicide treatment will not eradicate EWM from the lake, but would ideally result in several years (3-5 years or longer) of a reduced population that could potentially be extended longer through follow-up management efforts such as hand harvesting. When asked to state their level of support for the future use of herbicide use to manage EWM, 65 of 88 respondents (74%) indicated either *completely support*, or *moderately support* herbicide spot treatments with nine respondents (10%) opposed (pooled as either *completely oppose* or *moderately oppose*) (Question #33, Appendix B). Support for a whole-lake herbicide treatment strategy was slightly lower than for a spot-treatment, but saw a larger proportion of support (53%, pooled as either *completely support* or *moderately support*) versus opposition (28%, pooled as *completely oppose* and *moderately oppose*). The ALA would use the following trigger to initiate discussion for considering herbicide treatment: *colonized areas of EWM where a sufficiently large treatment area can be constructed to hold concentration and exposure times that would be expected to result in EWM mortality (preference to dominant or greater density EWM populations)* In practice, spot-treatments require a minimum size of approximately 5 acres to be able to hold concentration exposure times long enough to achieve EWM mortality. Sites that are somewhat protected from dissipation, such as being located in a bay of a lake, and sites that are broader in shape rather than narrow, would have a greater likelihood for success in a spot-treatment design scenario compared to offshore sites. When an EWM mapping survey indicates dominant or greater densities, impacts to recreational use of the lake becomes apparent. Anvil Lake has experienced extensive surface matting conditions in the North Bay in the past, and the ALA intends to consider herbicide before conditions reach those levels again. If the trigger is met and the ALA is considering herbicide treatment, early consultation with WDNR would occur along with the following set of bullet points: • Create a Control and Monitoring Plan. The Control and Monitoring Plan would likely be created based on the results of a late-summer EWM mapping survey or in combination with the results of a whole-lake point-

intercept survey. These data would be used to create a specific EWM control strategy for the following year including information such as the herbicide to be used, dosing strategy, targeted areas, and an accompanying monitoring strategy. The annual Control and Monitoring Plan would include applicable risk assessment materials for the ALA to review. This might include a summary of available research, toxicity, selectivity, etc.

- Monitoring for EWM efficacy at the scale of likely impact. If the treatment is a true spot treatment, the application area should be monitored. If the Area of Potential Impact (AOPI) is larger, such as a bay of the lake or the entire lake, monitoring would occur on that level.
- EWM control efficacy would occur by comparing annual late-summer EWM mapping surveys.
- If grant funds are being used or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with the *Draft Aquatic Plant Treatment Evaluation Protocol (October 1, 2016).* This generally consists of collecting quantitative point-intercept the *late-summer prior to treatment* (pre) and the summer following the treatment (post) at the scale of AOPI.
- Herbicide concentration monitoring may also occur surrounding the treatment if grant funds are being used or the ALA believes important information would be gained from the effort.

An herbicide applicator firm would be selected and a permit application would be applied to the WDNR as early in the calendar year as practical, allowing interested parties sufficient time to review the control plan as well as review the permit application.

Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would occur. This would consist of the herbicide treatment occurring towards the beginning of the growing season (typically in June), after active growth tissue is confirmed on the target plants. A focused pretreatment survey would take place approximately a week or so prior to treatment. This site visit would evaluate the growth stage of the EWM (and native plants) and confirm the proposed treatment area extents and water depths. This information would be used to finalize and confirm the treatment specifics and dictate approximate ideal treatment timing. Additional aspects of the treatment may also be investigated, depending on the use pattern being considered, such as the role of stratification.

In order to meet herbicide spot-treatment control expectations, little to no EWM would be expected to persist in treated areas during the year of treatment, with minimal sign of recovery during the year after treatment as well. Basin-wide or whole-lake treatment strategies would be expected to result in 3-5+ years of reduced EWM populations.

	Short-Term EWM Control Plan (2024): The ALA intends to continue an active EWM management effort in 2024 with a combination of volunteer and paid hand harvesting efforts including the use of the ALA's DASH vessel. The EWM population has trended higher in recent years in Anvil Lake and further population expansion is expected during 2024. A short winter and early spring season during 2023-2024 has resulted in favorable growing conditions for EWM in many lakes in the region, and Anvil Lake may experience a similar fate in 2024. The 2024 EWM management strategy will approximately mirror the 2023 plan during which substantial amounts of EWM biomass will be harvested, largely from North Bay, and other known populations around the lake will also be targeted. This strategy will serve to suppress the EWM population during 2024, however even with substantial effort, the lake-wide population is likely to expand. In the event that the population in North Bay reaches levels that impact navigation through a large area of the bay, the DASH strategy will attempt to create navigation lanes from riparian docks out to deeper waters. If EWM densities increase during 2024, as early reports suggest it has, the ALA's trigger for considering herbicide use as described above will likely be met. With the completion of this Aquatic Plant Management Plan, the ALA will be eligible to apply for WDNR AIS Control Grants. The ALA applied for a WDNR grant in the fall 2024 cycle that would provide funding assistance for the ALA to enact management and monitoring activities in 2025-2026. The ALA understands that the WDNR AIS grant program is highly competitive and they will consider the possibility of funding their EWM management activities without the aid of state funding. The current grant funded project included funding assistance for the completion of a late-summer EWM mapping survey during 2024. This survey will guide the development of the 2025 EWM management strategy.

6.0 LITERATURE CITED

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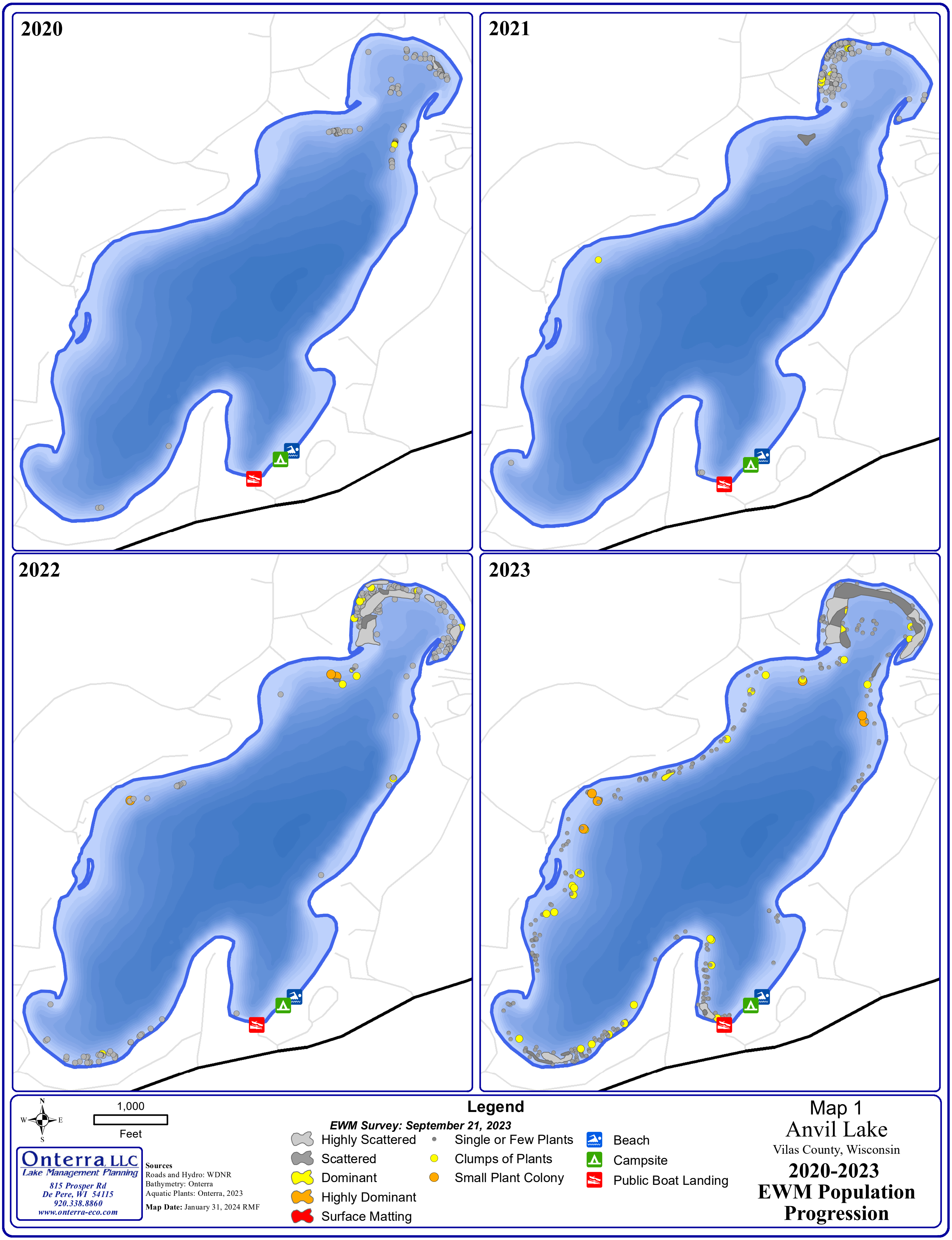
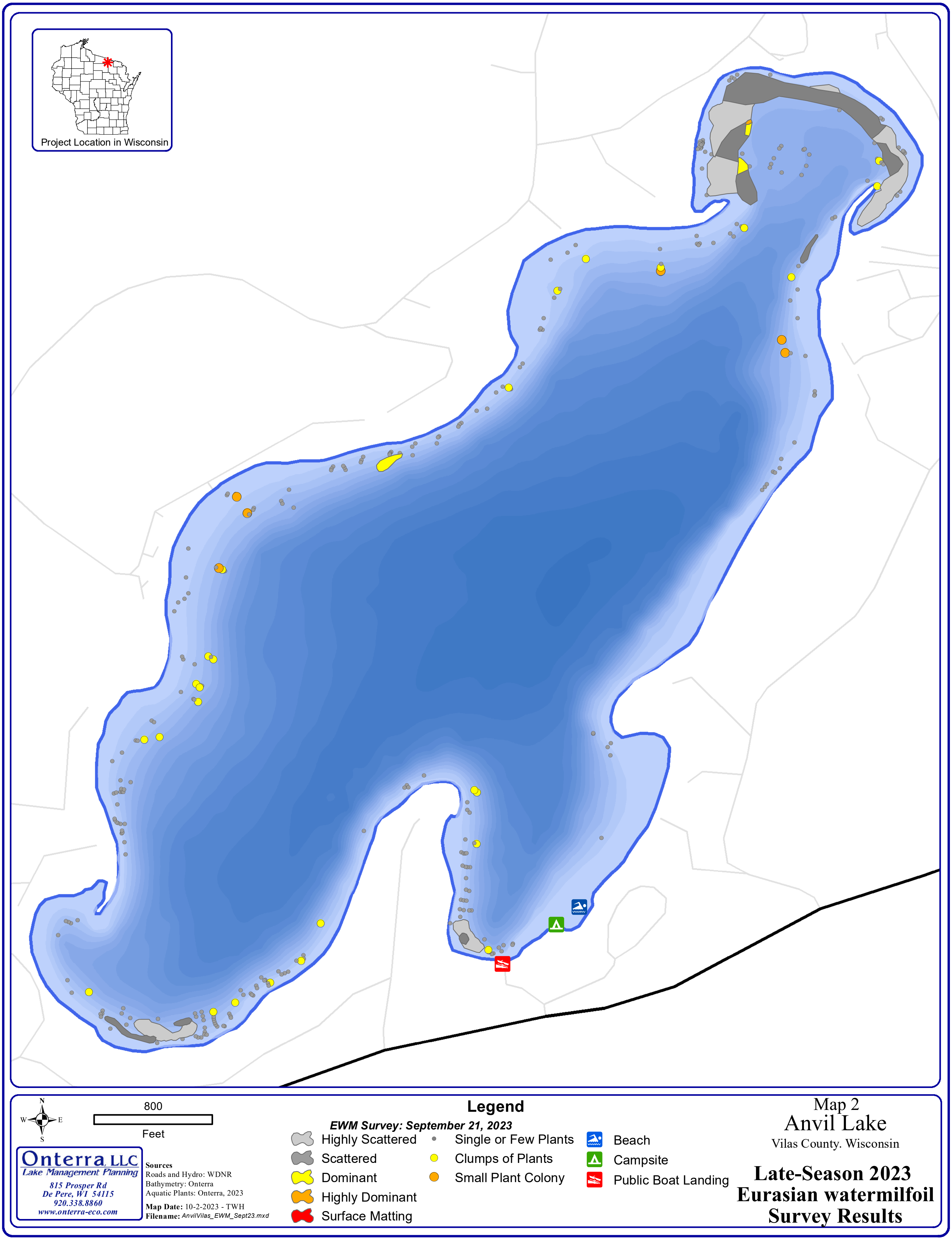

2020
2021
2022
2023
N
W
E
S
1,000
Feet
Onterra, LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2023
Map Date: January 31, 2024 RMF
Legend
EWM Survey: September 21, 2023
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony
Beach
Campsite
Public Boat Landing
Map 1
Anvil Lake
Vilas County, Wisconsin
2020-2023
EWM Population
Progression



Project Location in Wisconsin
N
W
E
S
800
Feet
Legend
EWM Survey: September 21, 2023
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony
Beach
Campsite
Public Boat Landing
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Sources
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2023
Map Date: 10-2-2023 - TWH
Filename: AnvilVilas_EWM_Sept23.mxd
Map 2
Anvil Lake
Vilas County. Wisconsin
Late-Season 2023
Eurasian watermilfoil
Survey Results

A

APPENDIX A

Public Participation Materials

Management Planning Meeting I Presentation Materials


Anvil Lake Association
Aquatic Plant Management Plan
Planning Meeting I
March 27, 2024
Todd Hanke
Onterra LLC
Lake Management Planning


Presentation Outline
• Introduction to Onterra
• Lake Management Planning
• Point-Intercept Survey Results
• EWM Population Monitoring
• EWM Management
• Development of an EWM Management Plan
Onterra LLC
Lake Management Planning


Onterra, LLC
• Founded in 2005, HQ in De Pere, WI
• Staff
• Three aquatic ecologists
• One paleoecologist
• Four full-time field technicians
• Four summer interns
• Services
• Science and planning
• Philosophy
• Promote realistic planning
• Assist, not direct
Onterra LLC
Current Projects
ICE AGE TRAIL
Onterra LLC
Lake Management Planning


Lake Management Planning

What is a Lake Management Plan?

- Many organizations may have "plans" for managing Anvil Lake and its watershed
- The ALA's *Comprehensive Management Plan* for managing Anvil Lake was finalized in January 2019
  - Based upon ALA capacity
  - Addressing your concerns
  - Complimentary to other *Plans*
- Long-term & useable plan (~10 years)
- Living plan subject to revision over time (APM Updates)

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Lake Management Planning

Management Plan and Grants

- WDNR recommends ***Comprehensive Management Plans*** generally get updated every 10 years
  - Aquatic Plant Management (APM) Plan is one component of a Comprehensive Plan, along with water quality, watershed, shoreland, fisheries, etc.
  - Particularly for grants/permits related to water quality/watershed improvements
- WDNR recommends lakes conducting active plant management update aspects of the plan every 5 years (***APM Plan***)
  - Particularly for grants/permits related to aquatic plant management (AIS control grants, NR107, NR109)
  - Updates management goals and actions to be consistent with changing BMP's, incorporates knowledge gained from past APM activities on the lake
  - Management action in AIS Grant needs to be supported by Plan
- Annual AIS Control Plan
  - Consistent with the framework outlined in APM Plan
  - Includes specific plans, delineated prioritized areas and description of monitoring components

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Management Planning Timeline

2023				2024				2025			
Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter

Field Data Collection
EWM Mapping
PI Survey

Data Analysis & Reporting
Stakeholder Survey

Planning Committee Mtgs
Present Findings
Develop Goals
Construct Imp. Plan

Plan Approval
Public Input
Agency Review
Adoption

Potential AIS Control Grant Application
Sept 15 pre-app
Nov 15 final app

Grant Awards

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Aquatic Plant Management Plan Outline

Plan Mtg I

- 1.0 Introduction
  - 1.1 Water levels
- 2.0 Stakeholder Participation
- 3.0 Aquatic Plants
  - 3.1 Primer
  - 3.2 Aquatic Plant Survey Results
  - 3.3 AIS in Anvil Lake
- 4.0 Summary & Conclusions
- 5.0 Implementation Plan
- 6.0 Literature Cited

Plan Meeting II

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Lake Management Planning

APM Plan Update – Data Collection

- 2023 ALA & Riparian Survey (Fall 2023)
  - 148 Sent, 93 returned = 63%
  - Included questions on EWM & EWM management options
- 2023 Whole-Lake Point-Intercept Survey
- 2023 Late-Season EWM Mapping Survey
  - Completed during Late-August/September when EWM is at peak growth stage (9/21/2023)

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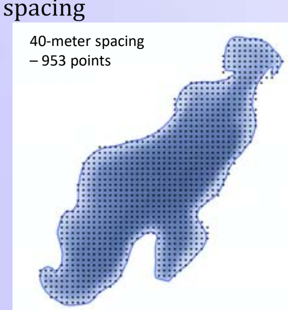
Whole-Lake Point-Intercept Surveys

- Systematic approach to collecting aquatic plant information from a waterbody
- Using established protocol, WDNR dictates grid spacing
  - Snapshot of current plant community
  - Trend analysis
  - Allows comparisons between lakes



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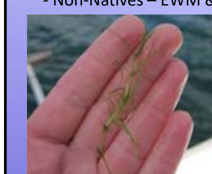
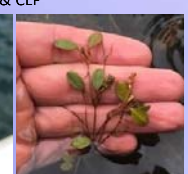
Species List

-39 unique native species

-2 classified as Special Concern in Wisconsin Natural Heritage Inventory (Northern naiad, Vasey's pondweed)

- Non-Natives – EWM & CLP





Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010	2012	2015	2019	2023
Emergent	*Carex lasiocarpa*	Narrow-leaved woolly sedge	Native	9			I		
	Carex utriculata	Common yellow lake sedge	Native	7			I		
	Eleocharis palustris	Creeping spikerush	Native	6		X	X	X	
	Iris versicolor	Northern blue flag	Native	5			I		
	Juncus effusus	Soft rush	Native	4			I		
	Pontederia cordata	Pickerelweed	Native	9		X	I		
	Sagittaria latifolia	Common arrowhead	Native	3			I		
	Schoenoplectus acutus	Hardstem bulrush	Native	5			I		
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4		X	I		X
	Scirpus cyperinus	Wool grass	Native	4			I		
	Sparganium androcladum	Shining bur-reed	Native	8			X		
	Sparganium eurycarpum	Common bur-reed	Native	5			X		
	Typha spp.	Cattail spp.	Unknown (Sterile)	N/A		X	I		
FL	*Nuphar variegata*	Spatterdock	Native	6			I	X	X
	Nymphaea odorata	White water lily	Native	6			I		
	Persicaria amphibia	Water smartweed	Native	5			I		
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9	X		I	X	X
Submergent	*Chara spp.*	Muskgrasses	Native	7	X	X	X	X	X
	Elatine minima	Waterwort	Native	9	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X		X	X
	Elodea nuttallii	Slender waterweed	Native	7	X	X	X	X	
	Eriocaulon aquaticum	Pipewort	Native	9			X	X	
	Isoetes spp.	Quillwort spp.	Native	8	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A		X	X	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10	X	X	X	X	X
	Najas flexilis	Slender naiad	Native	6				X	X
	Najas gracillima	Northern naiad	Native - Special Concern	7	X			X	
	Nitella spp.	Stoneworts	Native	7	X	X	X	X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X	X	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7	X		X	X	X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A			X		
	Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	X	X	X	X	X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7			X	X	X
	Potamogeton pusillus	Small pondweed	Native	7		X			X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8	X		X	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8				X	X
	Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	X		X	X	X
	Ranunculus flammula	Creeping spearwort	Native	9			X	X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	Native	5	X	X	X	X	X
	Juncus pelocarpus	Brown-fruited rush	Native	8	X	X	X	X	X
FF	*Riccia sp.*	Riccia sp.	Native	7		X			

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; F/L = Floating-leaf & Emergent; S/E = Submergent and/or Emergent; FF = Free-floating

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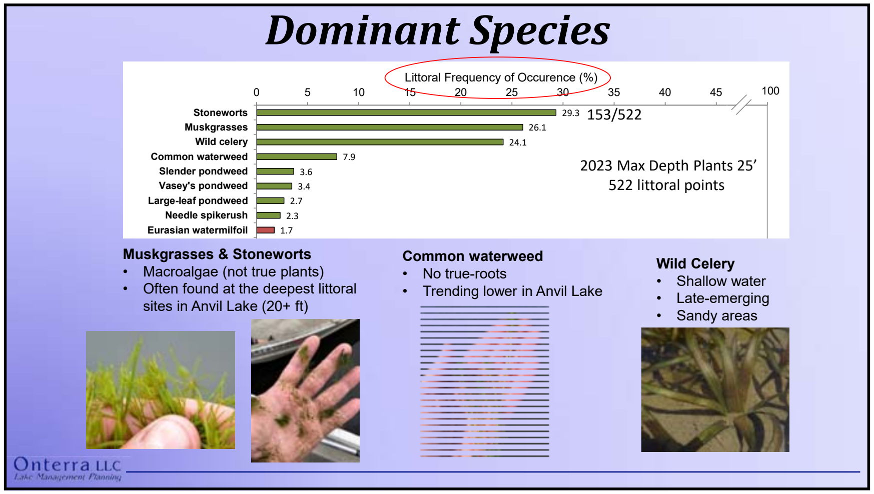
Dominant Species
Littoral Frequency of Occurence (%)
0 5 10 15 20 25 30 35 40 45 100
Stonewort 29.3
Muskgrasses 26.1
Wild celery 24.1
Common waterweed 7.9
Slender pondweed 3.6
Vasey's pondweed 3.4
Large-leaf pondweed 2.7
Needle spikerush 2.3
Eurasian watermilfoil 1.7
153/522
2023 Max Depth Plants 25'
522 littoral points
Muskgrasses & Stoneworts
• Macroalgae (not true plants)
• Often found at the deepest littoral sites in Anvil Lake (20+ ft)
Common waterweed
• No true-roots
• Trending lower in Anvil Lake
Wild Celery
• Shallow water
• Late-emerging
• Sandy areas
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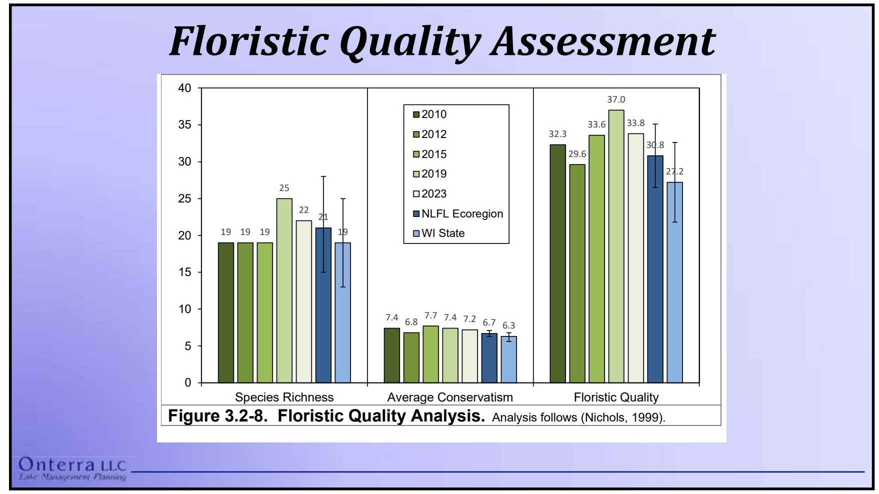
Floristic Quality Assessment
40 35 30 25 20 15 10 5 0
2010
2012
2015
2019
2023
NLFL Ecoregion
WI State
19 19 19 25 22 21 19
7.4 6.8 7.7 7.4 7.2 6.7 6.3
32.3 29.6 33.6 37.0 33.8 30.8 27.2
Species Richness
Average Conservatism
Floristic Quality
Figure 3.2-8. Floristic Quality Analysis. Analysis follows (Nichols, 1999).
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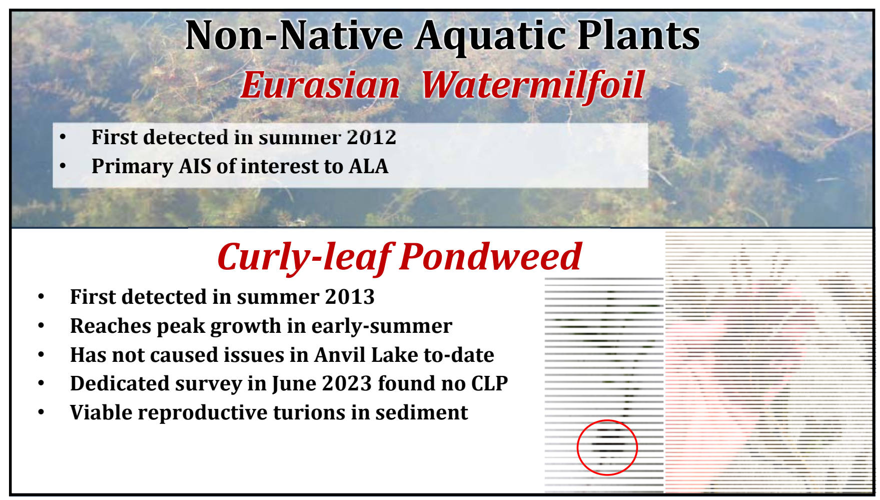
Lake Management Planning


AIS Population Monitoring


Non-Native Aquatic Plants
Eurasian Watermilfoil
• First detected in summer 2012
• Primary AIS of interest to ALA
Curly-leaf Pondweed
• First detected in summer 2013
• Reaches peak growth in early-summer
• Has not caused issues in Anvil Lake to-date
• Dedicated survey in June 2023 found no CLP
• Viable reproductive turions in sediment

EWM Propagation

- **Produces seed, but low viability**
- **Spread primarily through fragments, a vegetative clone**
- **Ability to manage spread from fragments is overstated**

Auto-fragment
- Purposefully produced
- High energy storage
- Higher viability

Allo-fragment
- Mechanical breakage
- Low energy storage
- Lower viability

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Types of Aquatic Plant Surveys

Quantitative
- Point-Intercept Survey
  - Numeric & systematic
  - Applied at various scales

Qualitative
- EWM Mapping Surveys
  - Fine-scale location accuracy
  - Subjective designations

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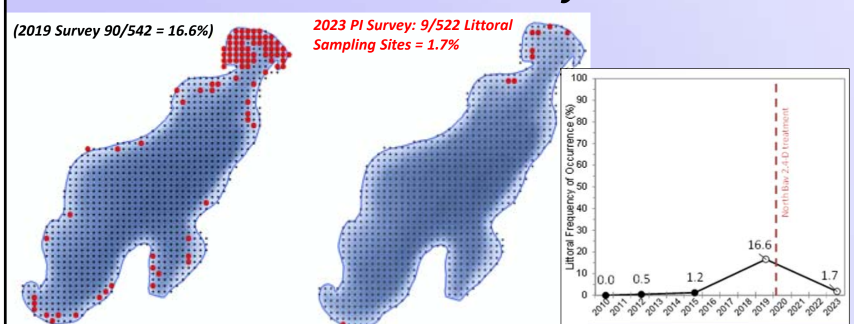
EWM In PI Surveys



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Professional AIS Mapping

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

Polygon-Based Mapping
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting

True Colonies

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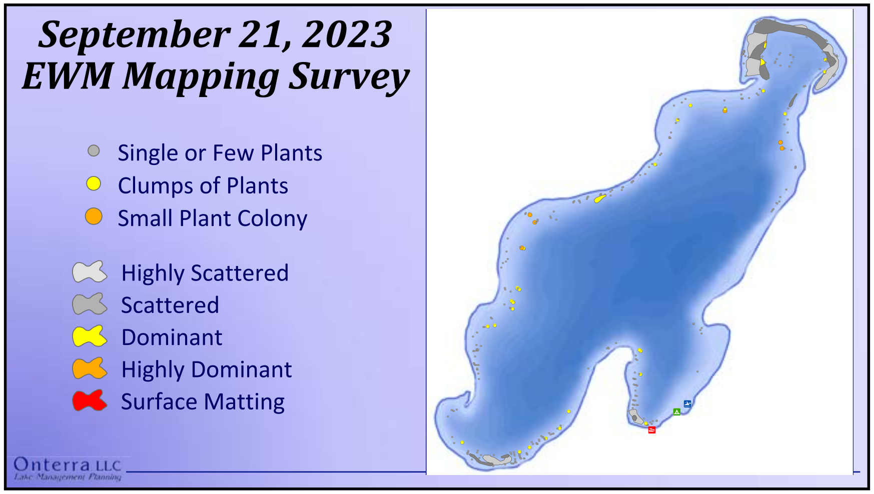
September 21, 2023
EWM Mapping Survey
Single or Few Plants
Clumps of Plants
Small Plant Colony
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
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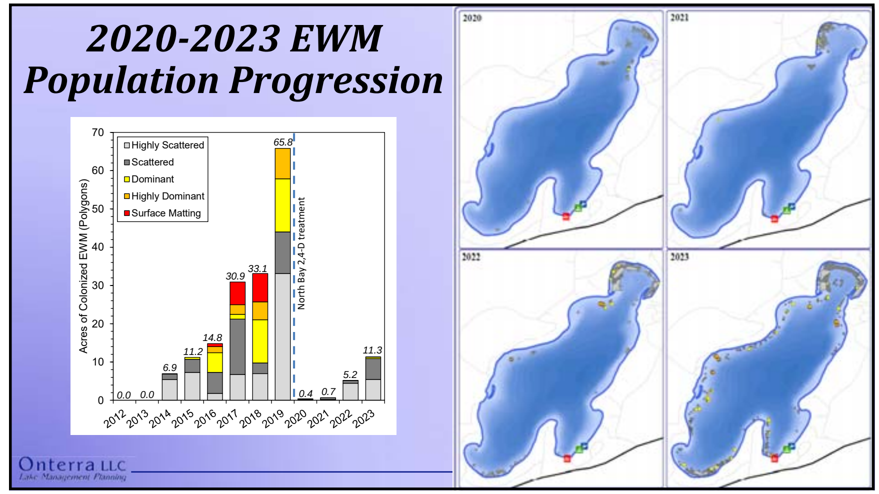
2020-2023 EWM
Population Progression
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Acres of Colonized EWM (Polygons)
North Bay 2,4-D treatment
0.0
0.0
6.9
11.2
14.8
30.9
33.1
65.8
0.4
0.7
5.2
11.3
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2020
2021
2022
2023
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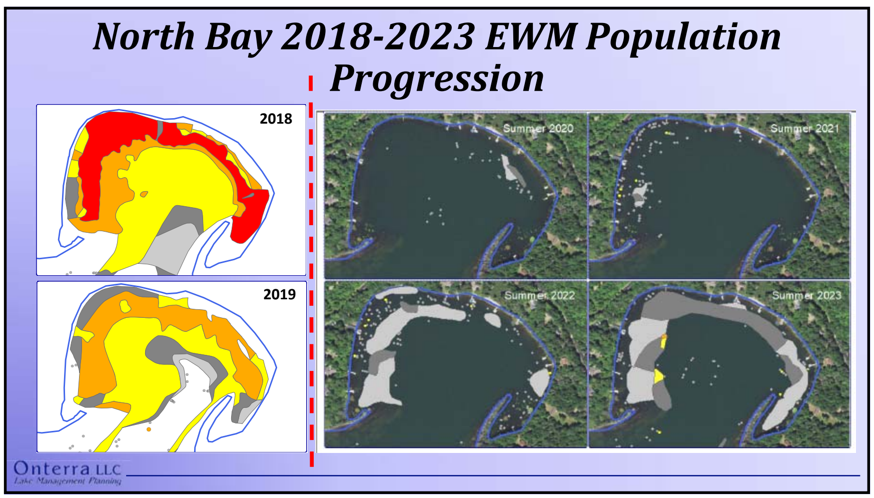
North Bay 2018-2023 EWM Population
Progression
2018
2019
Summer 2020
Summer 2021
Summer 2022
Summer 2023
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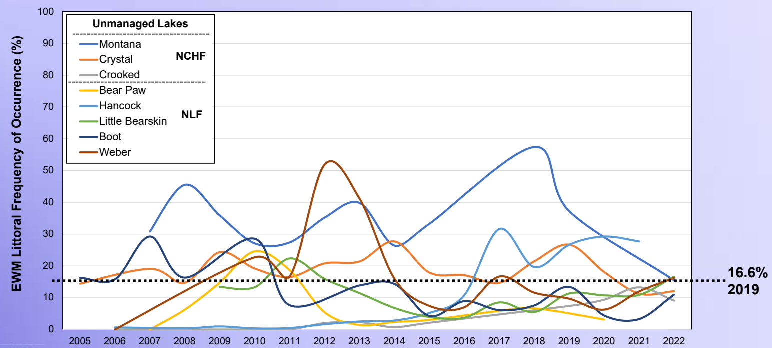
EWM Management

WDNR EWM Long-Term Monitoring Trends

Unmanaged



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EWM Management Perspectives

1. **No Coordinated Active Management (Let Nature Take its Course)**
   - Group does not organize or fund nuisance manual removal efforts
2. **Reduce AIS Population on a lake-wide level (Population Management – "Control")**
   - Will not *eradicate* EWM
   - Early populations may be targeted with manual removal efforts, established populations may need to entertain herbicide treatment (risk assessment)
   - Set triggers (thresholds) of implementation and tolerance
3. **Minimize navigation and recreation impediment (Nuisance Control)**
   - Often accomplished through mechanical harvesting or herbicide treatment, limited applicability for hand harvesting
   - Prioritize areas based on human use & HWM density

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Manual Removal – *Hand Harvesting & DASH*

- **Goal – to manage the EWM population or nuisance control**

EWM population	Nuisance control
Initial populations Low density & isolated occurrences Follow-up after treatments	In riparian footprint Navigation lanes or small areas

- **Removal of entire root material required for mortality**
- **Scale limitations, not for large or dense areas**
- **Diver-Assisted Suction Harvest (DASH) can increase efficiency**
- **Limitations**
  - –Density of EWM & native plants
  - –Clarity of water
  - –Sediment type
  - –Obstructions


Photo credit ALA

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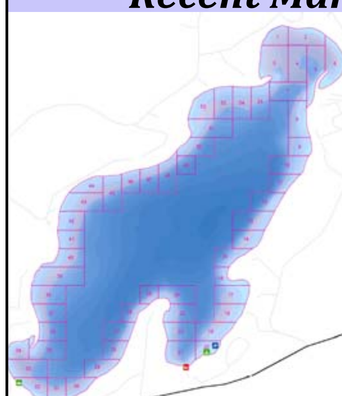
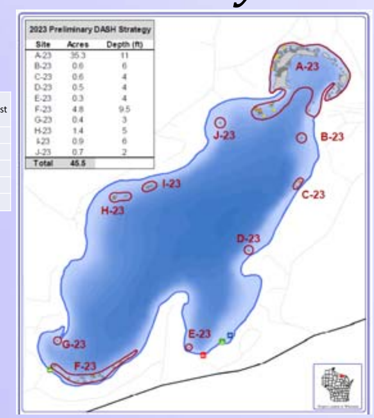
Recent Manual Removal History



Year	Diver Hours	EWM Harvest (lbs)
2020	152	4800
2021	106	56
2022	111.5	538
2023	288	9010
Total	657.5	14404



2023 Preliminary DASH Strategy		
Site	Acres	Depth (ft)
A-23	35.3	11
B-23	0.6	6
C-23	0.6	4
D-23	0.5	4
E-23	0.3	4
F-23	4.8	9.5
G-23	0.4	3
H-23	1.4	5
I-23	0.9	6
J-23	0.7	2
Total	45.5	

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Mechanical Harvesting

- **Goal – to restore aspects of use and aesthetics**
- **Cuts and removes EWM biomass; does not cause mortality**
- **Suitable for large and dense EWM**
- **Applied as clear-cutting or confined to lanes**
- **Concern for spread of EWM is overstated**
- **Risk of bi-catch**
  - –Native plants
  - –Fish & amphibians
  - –Insects, small animals


Photo Credit: Aquatic Plant Management, LLC

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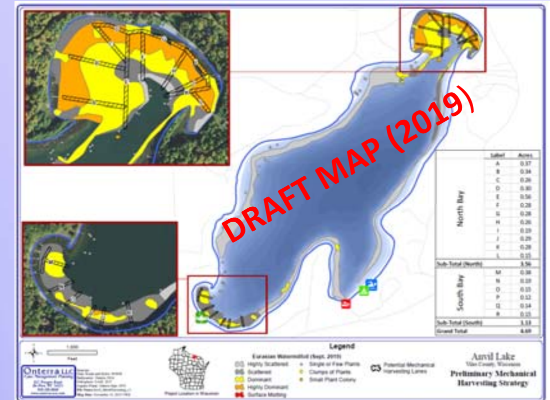
Mechanical Harvesting

- **Could be a nuisance relief strategy in North Bay or other areas in the lake when EWM at high density levels.**
- **Likely applied in the form of cutting lanes to docks, common use lanes for navigability. Requires WDNR permit.**
- **Contracted services or locally owned and operated**
- **Favored by regional WDNR, Tribal interests over herbicide use**
- **Low likelihood for WDNR AIS-Control Grants**



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Herbicide Treatment

- **Goal – multi-year EWM population control**
- **Meet concentration & exposure times (CETs) for mortality**
  - –Spot vs whole-lake/basin treatments
  - –Small (< 5 acres) spot treatments are often ineffective
  - –Protected areas more effective
- **Introduces greater need for risk assessment discussion**
  - –Impacts to native plants, particularly native watermilfoils and select dicots
  - –Potential impacts to early life stages of select fish species (i.e. walleye)
  - –Unknown impacts


Photo Credit: Schmidt's Aquatic, LLC

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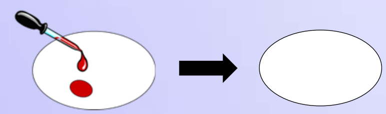
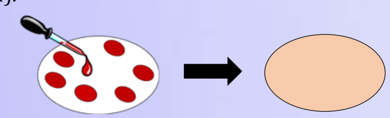
Ecological Definitions of Herbicide Treatment

Spot Treatment: Herbicide applied at a scale where dissipation will not result in significant lake wide concentrations; impacts are anticipated to be localized to in/around application area.



Whole-Lake (basin-wide) Treatment: Herbicide applied at a scale where dissipation will result in significant lake wide concentrations; impacts are anticipated to be within a defined Area of Potential Impact (AOPI).



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Florpyrauxifen-benzyl (ProcellaCOR™)

- New class of synthetic auxin hormone mimics
  - Much different binding affinity than other auxins
  - Use at PPB rate vs PPM
- Shorter contact exposure time (CET) requirement
- Short environmental fate of active ingredient (mainly photolysis)
- Acid metabolite has activity as an herbicide (longer environmental fate)
- Detailed information on field applications is limited (first in 2019 in WI)
- *Practically nontoxic* to freshwater fish and invertebrates, birds, bees, reptiles, amphibians and mammals

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ProcellaCOR Monitoring

Onterra has compiled and presented data relating to native aquatic plant response, longevity of EWM control, & herbicide concentration monitoring
-Risk Assessment would occur if being considered for use in Anvil Lake
-limited toxicology studies exist to date

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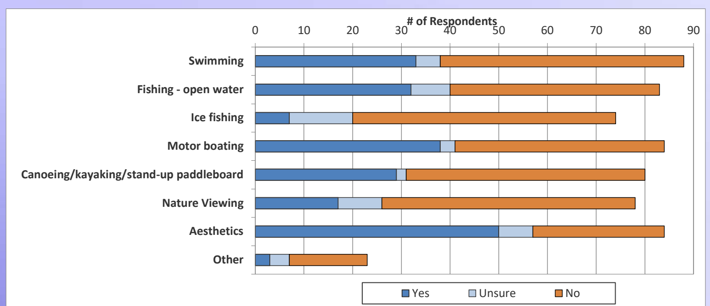
Stakeholder Perceptions of EWM Management

30. Has the Eurasian watermilfoil population ever had a negative impact on your enjoyment of Anvil Lake?



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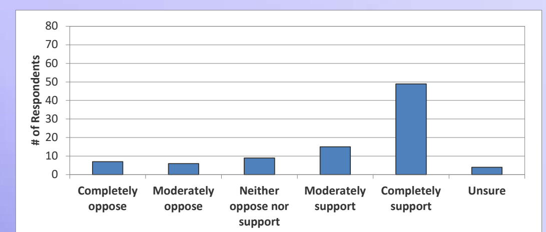
Stakeholder Perceptions of EWM Management

31. In 2020, a spatially targeted 2,4-D herbicide treatment was conducted within the North Bay of Anvil Lake to treat EWM. What was your level of support or opposition for the use of aquatic herbicides to treat EWM in the North Bay in 2020?



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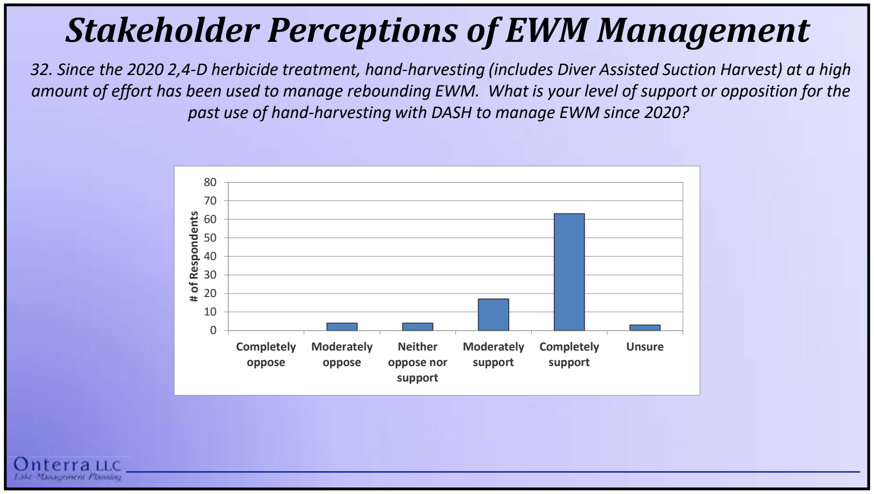
Stakeholder Perceptions of EWM Management
32. Since the 2020 2,4-D herbicide treatment, hand-harvesting (includes Diver Assisted Suction Harvest) at a high amount of effort has been used to manage rebounding EWM. What is your level of support or opposition for the past use of hand-harvesting with DASH to manage EWM since 2020?
# of Respondents
0
10
20
30
40
50
60
70
80
Completely oppose
Moderately oppose
Neither oppose nor support
Moderately support
Completely support
Unsure
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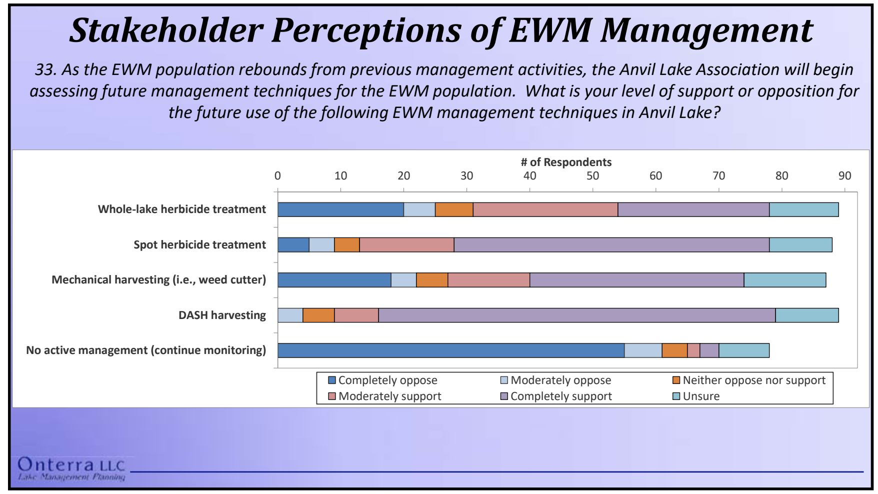
Stakeholder Perceptions of EWM Management
33. As the EWM population rebounds from previous management activities, the Anvil Lake Association will begin assessing future management techniques for the EWM population. What is your level of support or opposition for the future use of the following EWM management techniques in Anvil Lake?
# of Respondents
0
10
20
30
40
50
60
70
80
90
Whole-lake herbicide treatment
Spot herbicide treatment
Mechanical harvesting (i.e., weed cutter)
DASH harvesting
No active management (continue monitoring)
Completely oppose
Moderately oppose
Neither oppose nor support
Moderately support
Completely support
Unsure
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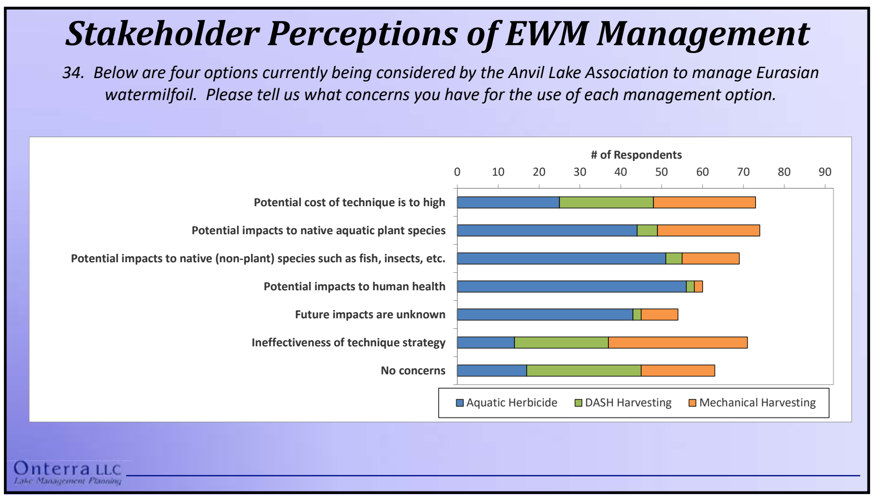
Stakeholder Perceptions of EWM Management
34. Below are four options currently being considered by the Anvil Lake Association to manage Eurasian watermilfoil. Please tell us what concerns you have for the use of each management option.
# of Respondents
0
10
20
30
40
50
60
70
80
90
Potential cost of technique is to high
Potential impacts to native aquatic plant species
Potential impacts to native (non-plant) species such as fish, insects, etc.
Potential impacts to human health
Future impacts are unknown
Ineffectiveness of technique strategy
No concerns
Aquatic Herbicide
DASH Harvesting
Mechanical Harvesting
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Development of an EWM Management Plan

ALA 2019 Comp Management Plan

Management Goal #2: ***Manage the Existing Aquatic Invasive Species Population in Anvil Lake***

Action: Three Year Trial DASH EWM Control Strategy in North Bay

Action: Keep Isolated EWM Populations from Expanding in areas Outside of North Bay

Action: Monitor CLP Population within Anvil Lake

Action: Continue Clean Boat Clean Waters Watercraft Inspections at Anvil Lake Public Access Location

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Planning Meeting II *(April 2024)*

Primary Objective: Create implementation plan framework

- Primarily focus on EWM Management
- Aquatic plant monitoring

Assignment for Planning Meeting II

1. Create list aquatic plant issues that this plan should address
2. First focus on the goal, not the action needed to reach the goal
3. Review stakeholder survey results
4. Send potential report section edits and questions to ALA rep (Amy?) (aggregate/filter>>Todd)

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Thank You

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B

APPENDIX B

Stakeholder Survey Response Charts and Comments

Anvil Lake - Anonymous Stakeholder Survey

Surveys Distributed: *148*
Surveys Returned: *93*
Response Rate: *63%*

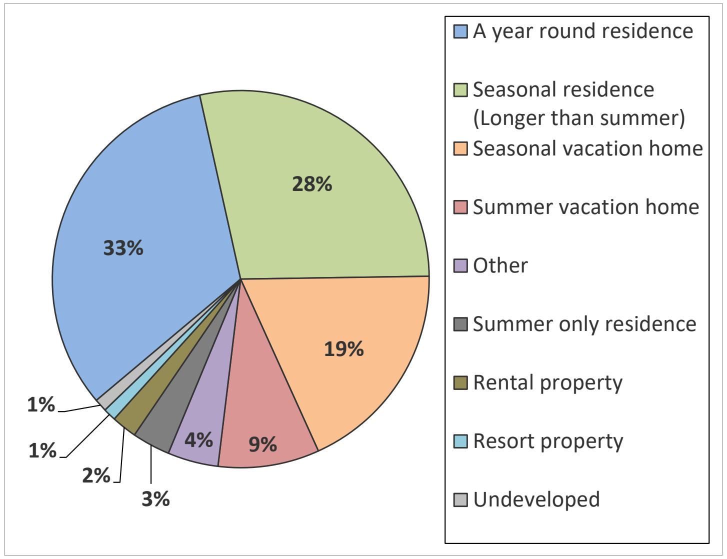
Anvil Lake Property

1. Is your property on the lake or off the lake?

Answer Options	Response Percent	Response Count
On the lake	94.6%	87
Off the lake	5.4%	5
	answered question	**92**
	skipped question	**1**

2. How is your property on or near Anvil Lake utilized?

Answer Options	Response Percent	Response Count
A year round residence	32.6%	30
Seasonal residence (Longer than summer)	28.3%	26
Seasonal vacation home	18.5%	17
Summer vacation home	8.7%	8
Other	4.4%	4
Summer only residence	3.3%	3
Rental property	2.2%	2
Resort property	1.1%	1
Undeveloped	1.1%	1
	answered question	**92**
	skipped question	**1**



Number	"Other" responses
1	Property is used occasionally in both the summer and winter
2	year round vacation
3	year round vacation property
4	Seasonal residence 50% of the year

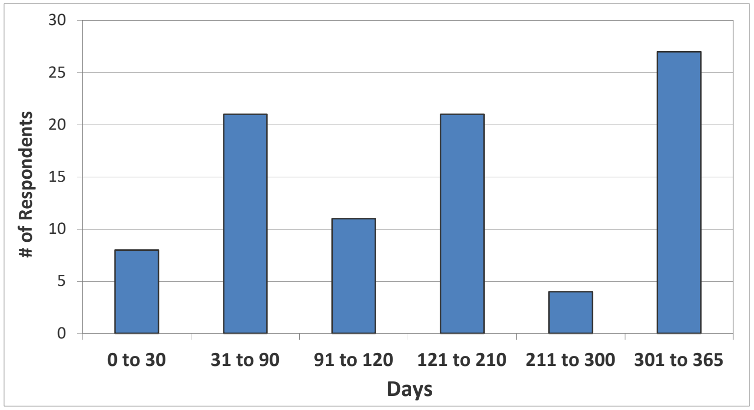
3. Even if renting is not the primary use of your property, have you rented out your property at all in the last year?

Answer Options	Response Percent	Response Count
Yes	8.7%	8
No	91.3%	84
	answered question	92
	skipped question	1

4. Considering the past three years, how many days each year is your property used by you or others?

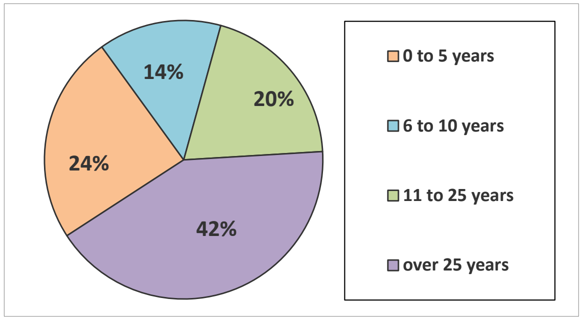
	Response Count
answered question	92
skipped question	1

Category (# of days)	Responses	%
0 to 30	8	9%
31 to 90	21	23%
91 to 120	11	12%
121 to 210	21	23%
211 to 300	4	4%
301 to 365	27	29%



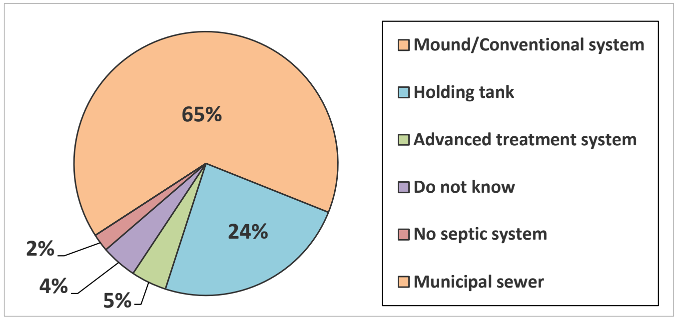
5. How many years have you owned or rented your property on or near Anvil Lake?

Answer Options	Response Percent	Response Count
0 to 5 years	24.2%	22
6 to 10 years	14.3%	13
11 to 25 years	19.8%	18
over 25 years	41.8%	38
	answered question	91
	skipped question	2



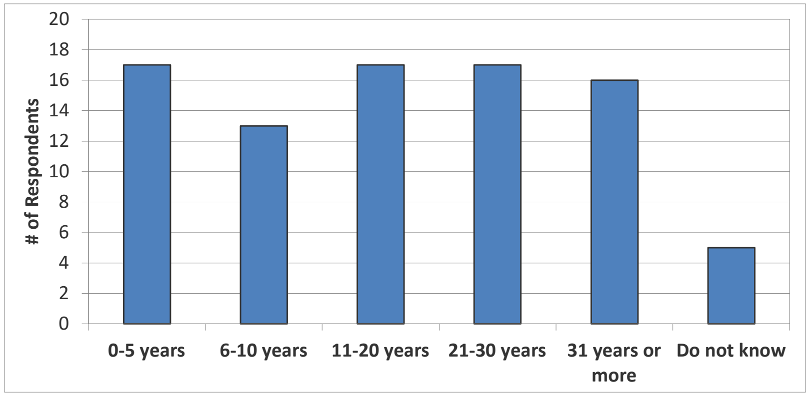
6. What type of septic system does your property utilize?

Answer Options	Response Percent	Response Count
Mound/Conventional system	65.2%	60
Holding tank	23.9%	22
Advanced treatment system	4.4%	4
Do not know	4.4%	4
No septic system	2.2%	2
Municipal sewer	0.0%	0
answered question		92
skipped question		1



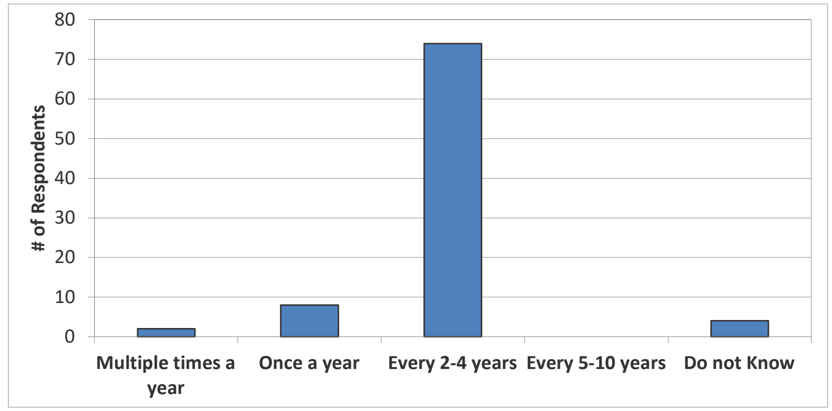
7. How old is the current septic system installed on your property?

Answer Options	Response Percent	Response Count
0-5 years	20.0%	17
6-10 years	15.3%	13
11-20 years	20.0%	17
21-30 years	20.0%	17
31 years or more	18.8%	16
Do not know	5.9%	5
answered question		85
skipped question		8



8. How often is the septic system on your property pumped?

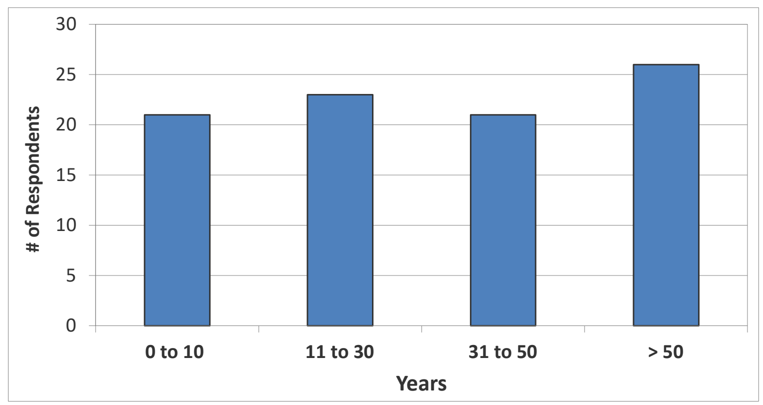
Answer Options	Response Percent	Response Count
Multiple times a year	2.3%	2
Once a year	9.1%	8
Every 2-4 years	84.1%	74
Every 5-10 years	0.0%	0
Do not Know	4.6%	4
answered question		88
skipped question		5



Recreational Activity on Anvil Lake

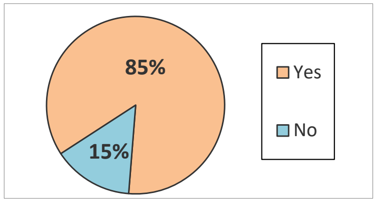
9. How many years ago did you first visit Anvil Lake?

Answer Options	Response Percent	Response Count
0 to 10 years ago	23.1%	21
11 to 30 years ago	25.3%	23
31 to 50 years ago	23.1%	21
More than 50 years ago	28.6%	26
answered question		91
skipped question		2



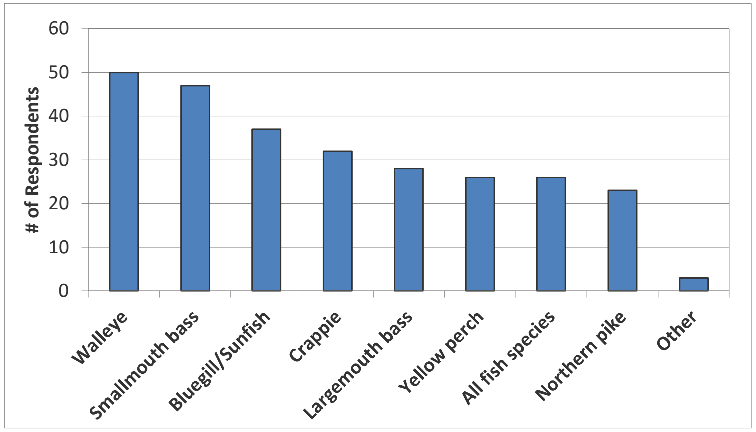
10. Have you or your family personally fished on Anvil Lake in the past three years?

Answer Options	Response Percent	Response Count
Yes	85.4%	76
No	14.6%	13
	answered question	**89**
	skipped question	**4**



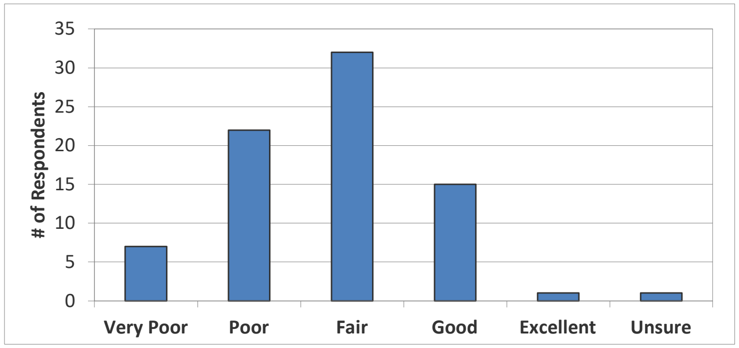
11. What species of fish do you try to catch on Anvil Lake?

Answer Options	Response Percent	Response Count
Walleye	64.1%	50
Smallmouth bass	60.3%	47
Bluegill/Sunfish	47.4%	37
Crappie	41.0%	32
Largemouth bass	35.9%	28
Yellow perch	33.3%	26
All fish species	33.3%	26
Northern pike	29.5%	23
Other	3.9%	3
	answered question	**78**
	skipped question	**15**

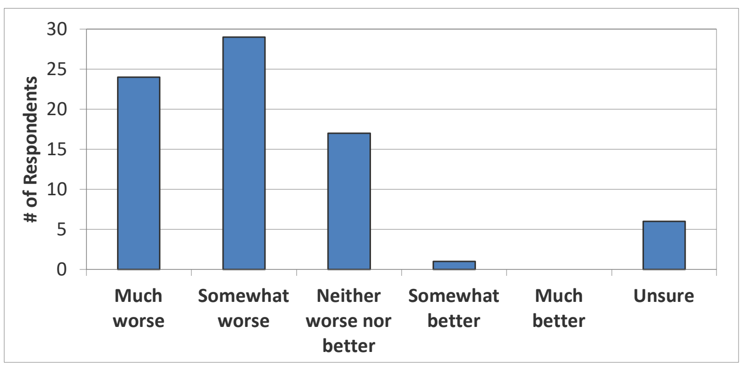


Number	"Other" responses
1	Not sure Grandson is the fisher
2	panfish have declined, abundance of small pike
3	Rock bass

12. How would you describe the current quality of fishing on Anvil Lake?						
Answer Options	**Very Poor**	**Poor**	**Fair**	**Good**	**Excellent**	**Unsure**
	7	22	32	15	1	1
					answered question	**78**
					skipped question	**15**

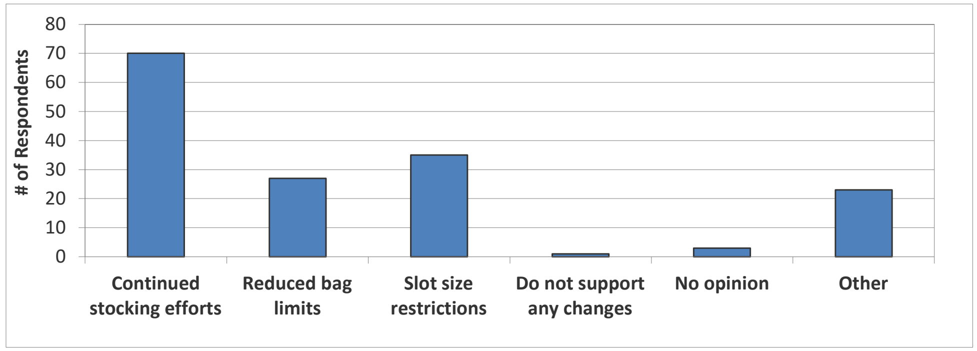


13. How has the quality of fishing changed on Anvil Lake since you have started fishing the lake?						
Answer Options	**Much worse**	**Somewhat worse**	**Neither worse nor better**	**Somewhat better**	**Much better**	**Unsure**
	24	29	17	1	0	6
					answered question	**77**
					skipped question	**16**



14. The Anvil Lake Association, similar to other lake groups in northern Wisconsin, is particularly concerned about declining walleye populations in Anvil Lake. In recent years, several regulations have been changed in northern Wisconsin in an attempt to protect young walleye.What changes, if any, do you support regarding walleye management in Anvil Lake?

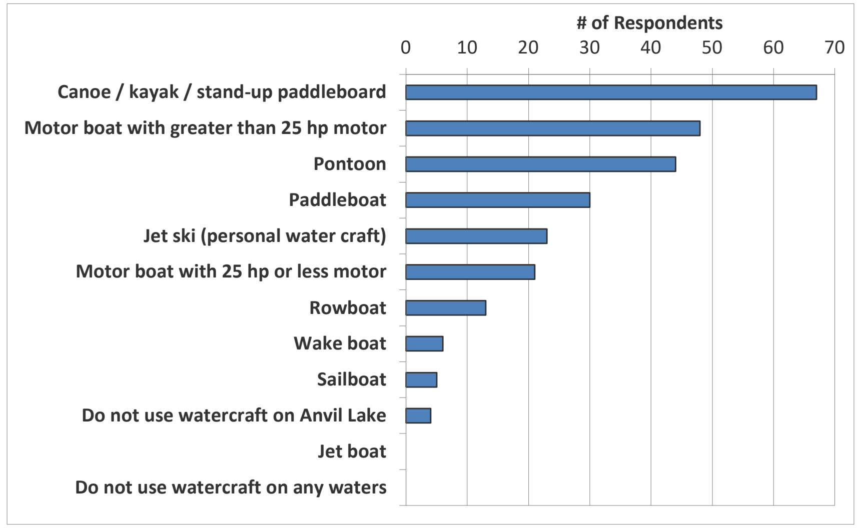
Answer Options	Response Percent	Response Count
Continued stocking efforts	89.7%	70
Reduced bag limits	34.6%	27
Slot size restrictions	44.9%	35
Do not support any changes	1.3%	1
No opinion	3.9%	3
Other	29.5%	23
answered question		78
skipped question		15



Number	"Other" responses
1	Reduce Northern and Largemouth Bass numbers in Anvil
2	Stop spearing!
3	Eradicate the northern population
4	Reduced spear fishing
5	eliminate the right to spear the lake by indians, only for larger lakes
6	The state of Wisconsin needs to readdress spearing
7	Eliminate spearing
8	No chemical poisoning damaging fish fry
9	all fishermen should be under the same rules on same lake
10	Northern Pike should not have been placed in the lake by an individual
11	Reduce Northern and Largemouth Bass numbers in Anvil
12	Reduced spearing
13	Strong monitoring of spear fishing
14	Get rid of fish eating walleye minnows
15	Stop spearing in spring if so use old traditional methods
16	1. Catch and release only 2. Obtain agreement with tribes not to spear walleyes until populations reach DNR's desired numbers
17	reduce largemouth bass population
18	Not have the Indians spear or go over their limits
19	Ban Spearing
20	Negotiate tribal member harvest to zero, or they should be responsible for rearing a substantial number for restocking efforts.
21	Have someone from DNR out there to observe and count fish the fFirst Nation are catching and accounting for their use.
22	Stop spear fishing by tribes
23	Ban spearing

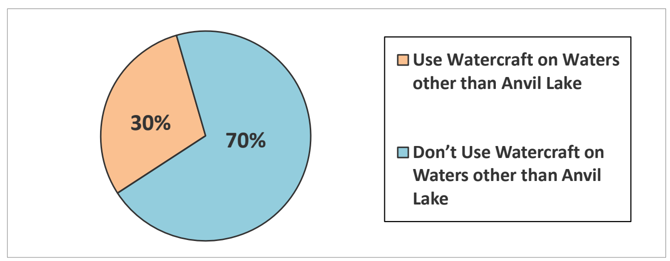
15. What types of watercraft do you currently use on Anvil Lake?

Answer Options	Response Percent	Response Count
Canoe / kayak / stand-up paddleboard	73.6%	67
Motor boat with greater than 25 hp motor	52.8%	48
Pontoon	48.4%	44
Paddleboat	33.0%	30
Jet ski (personal water craft)	25.3%	23
Motor boat with 25 hp or less motor	23.1%	21
Rowboat	14.3%	13
Wake boat	6.6%	6
Sailboat	5.5%	5
Do not use watercraft on Anvil Lake	4.4%	4
Jet boat	0.0%	0
Do not use watercraft on any waters	0.0%	0
	answered question	**91**
	skipped question	**2**



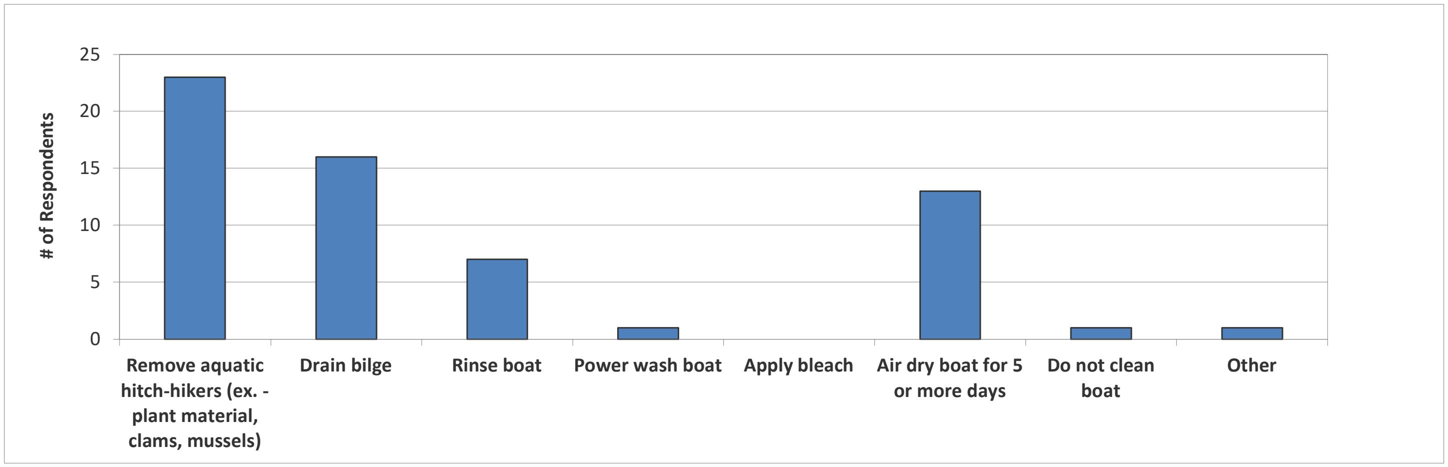
16. Do you use your watercraft on waters other than Anvil Lake?

Answer	Response	Response
Yes	29.7%	27
No	70.3%	64
Other	0.0%	0
	answered question	**91**
	skipped question	**2**



17. What is your typical cleaning routine after using your watercraft on waters other than Anvil Lake?

Answer Options	Response	Response
Remove aquatic hitch-hikers (ex. - plant material, clams, mussels)	88.5%	23
Drain bilge	61.5%	16
Rinse boat	26.9%	7
Power wash boat	3.9%	1
Apply bleach	0.0%	0
Air dry boat for 5 or more days	50.0%	13
Do not clean boat	3.9%	1
Other	3.9%	1
	answered question	**26**
	skipped question	**67**



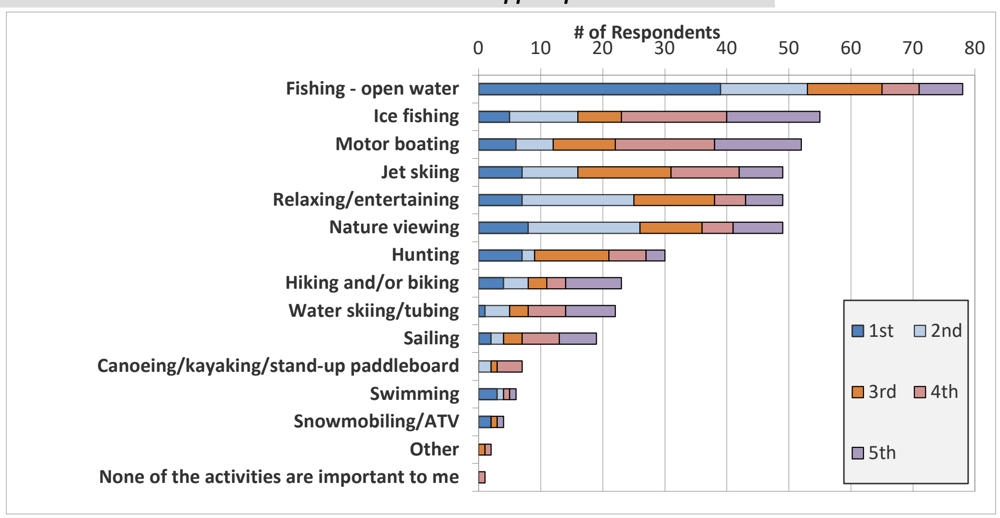
Number	"Other" responses
1	boat & kayaks only used on Anvil

Anvil Lake Current and Historic Condition, Health and Management

18. Please rank up to five activities that are important reasons for owning your property on or near Anvil Lake, with the 1st being the most important activity.

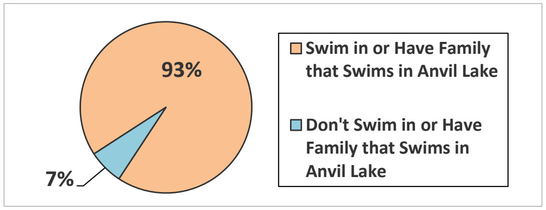
Answer Options	1st	2nd	3rd	4th	5th	Total
Fishing - open water	39	14	12	6	7	78
Ice fishing	5	11	7	17	15	55
Motor boating	6	6	10	16	14	52
Jet skiing	7	9	15	11	7	49
Relaxing/entertaining	7	18	13	5	6	49
Nature viewing	8	18	10	5	8	49
Hunting	7	2	12	6	3	30
Hiking and/or biking	4	4	3	3	9	23
Water skiing/tubing	1	4	3	6	8	22
Sailing	2	2	3	6	6	19
Canoeing/kayaking/stand-up paddleboard	0	2	1	4	0	7
Swimming	3	1	0	1	1	6
Snowmobiling/ATV	2	0	1	0	1	4
Other	0	0	1	1	0	2
None of the activities are important to me	0	0	0	1	0	1
					answered question	**91**
					skipped question	**2**

Number	"Other" responses
1	Bicycling
2	#6- kayaking, canoeing
3	Living the up north/ lake lifestyle
4	ATV/UTV
5	Cocktail cruising, wake surfing, waterskiing
6	#1 BEING WITH FAMILY WHO ALSO OWN ON ANVIL LAKE



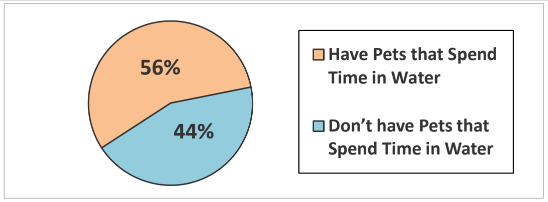
19. During a typical summer, do you or your family ever swim in Anvil lake?

Answer Options	Response Percent	Response Count
Yes	93.4%	85
No	6.6%	6
answered question		91
skipped question		2

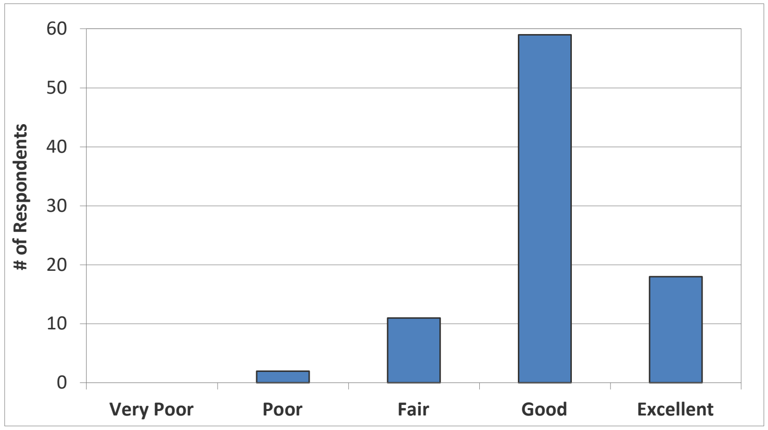


20. Do you have pets that spend time in the water of Anvil Lake?

Answer Options	Response Percent	Response Count
Yes	56.0%	51
No	44.0%	40
answered question		91
skipped question		2

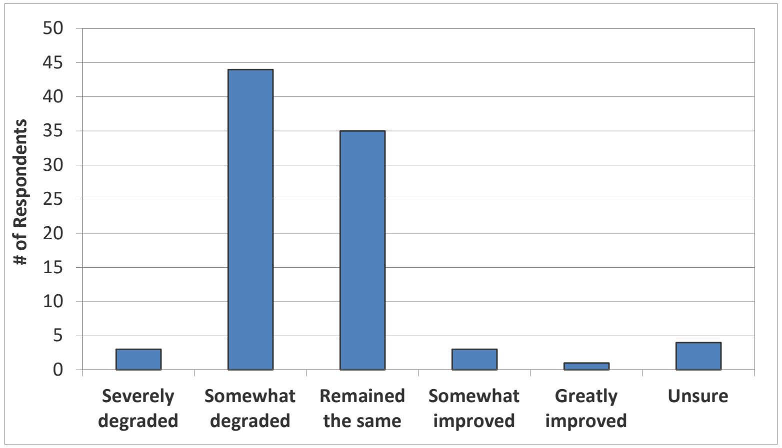


21. How would you describe the current water quality of Anvil Lake?						
Answer Options	**Very Poor**	**Poor**	**Fair**	**Good**	**Excellent**	**Unsure**
	0	2	11	59	18	1
					answered question	***91***
					skipped question	***2***



22. How has the overall water quality changed in Anvil Lake since you first visited the lake?

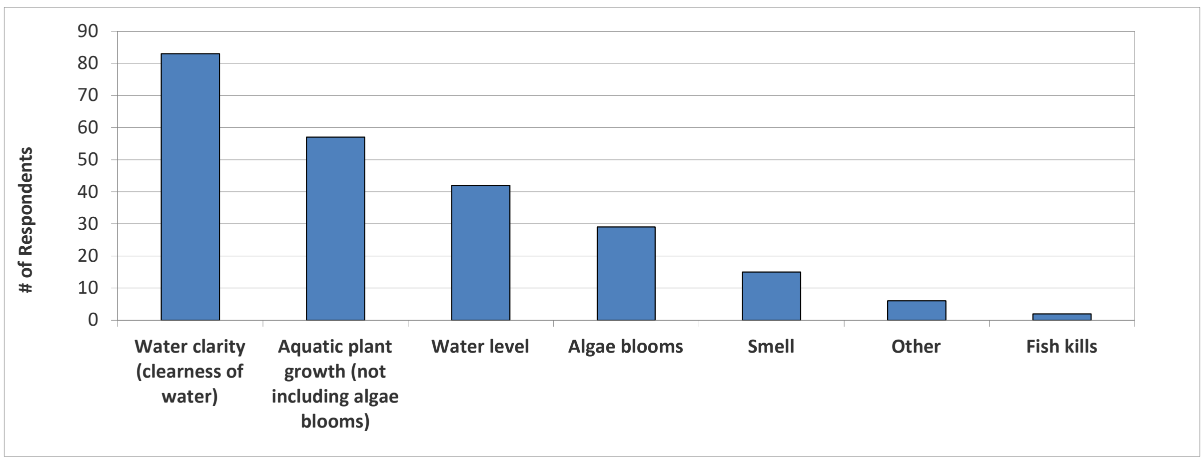
Answer Options	Severely degraded	Somewhat degraded	Remained the same	Somewhat improved	Greatly improved	Unsure
	3	44	35	3	1	4
					answered question	**90**
					skipped question	**3**



23. Considering how you answered the questions above, what do you think of when describing water quality?

Answer Options	Response Percent	Response Count
Water clarity (clearness of water)	93.3%	83
Aquatic plant growth (not including algae blooms)	64.0%	57
Water level	47.2%	42
Algae blooms	32.6%	29
Smell	16.9%	15
Other	6.7%	6
Fish kills	2.3%	2
	answered question	**89**
	skipped question	**4**

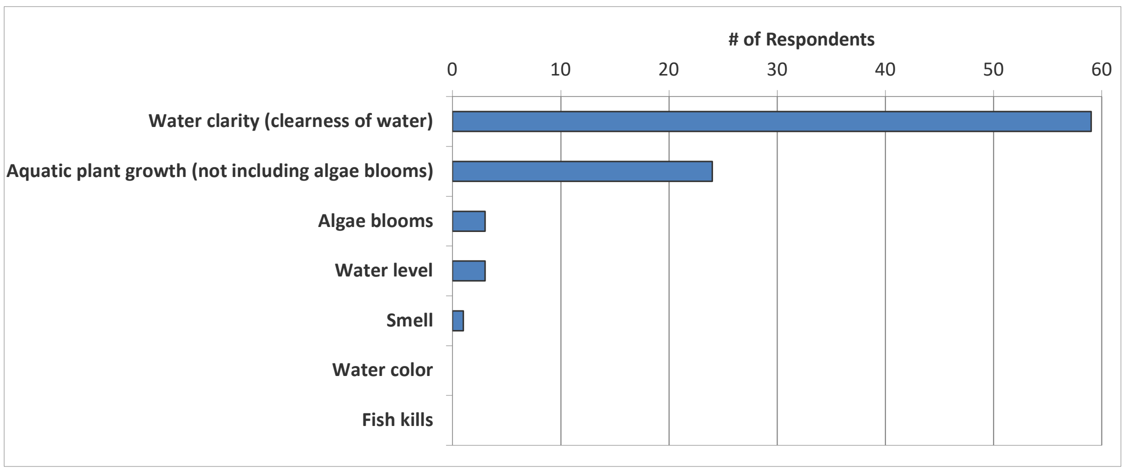
Number	"Other" responses
1	loss of frogs and crawdads compared to past years
2	Blue color of water
3	Loss of clams, crawfish and snails
4	Blue color of water
5	Increase in manicured lawns and fertilization without vegetative barrier
6	Noticed fishing for walleye (bottom dwellers) I've encountered algae strands in deep water that I never encountered prior to the herbicide treatment in 2020



24. Based on your answer above, Which of the following would you say is the single most important aspect when considering water quality?

Answer Options	Response Percent	Response Count
Water clarity (clearness of water)	64.8%	59
Aquatic plant growth (not including algae blooms)	26.4%	24
Water color	0.0%	0
Algae blooms	3.3%	3
Smell	1.1%	1
Water level	3.3%	3
Fish kills	0.0%	0
Smell	1.1%	1
	answered question	**91**
	skipped question	**2**

Number	"Other" responses
1	I can't decide between clarity and plant growth

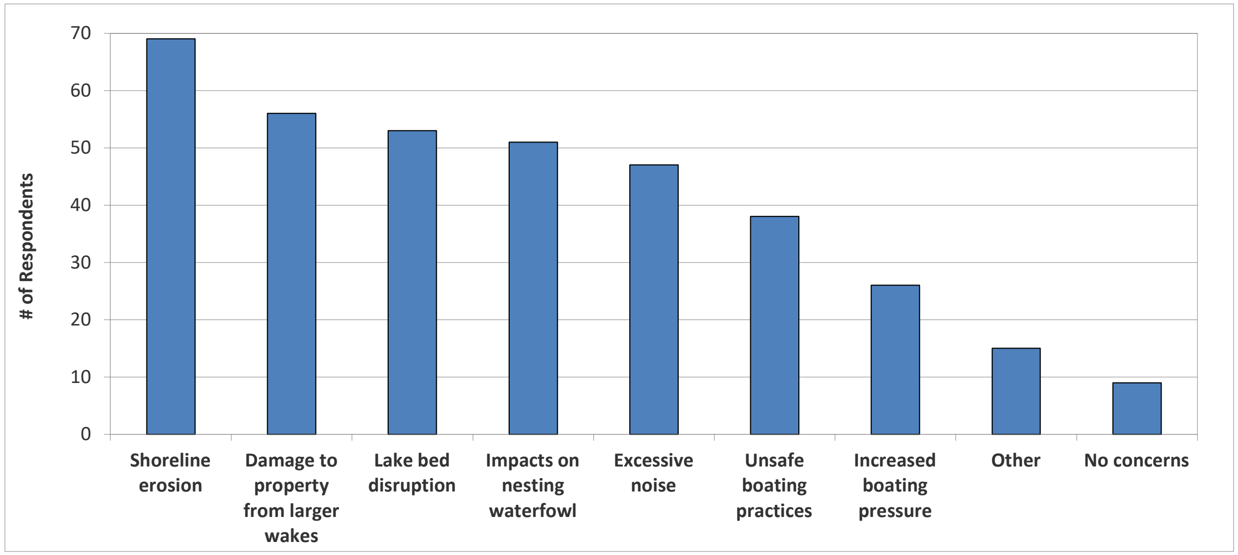


25. What concerns, if any, do you have about the effects of wake surf boats on Anvil Lake?

Answer Options	Response Percent	Response Count
Shoreline erosion	75.8%	69
Damage to property from larger wakes	61.5%	56
Lake bed disruption	58.2%	53
Impacts on nesting waterfowl	56.0%	51
Excessive noise	51.7%	47
Unsafe boating practices	41.8%	38
Increased boating pressure	28.6%	26
Other	16.5%	15
No concerns	9.9%	9
	answered question	**91**
	skipped question	**2**

Number	"Other" responses
1	Safety of people swimming, boating, canoe/kayaking. Spread of Aquatic Invasive species/plant growth.
2	Impacts on other water activities from big waves
3	Hazard to other water sports from excessive wake
4	wake boats should only be used on larger lakes hopefully the state will regulate this for larger lakes of at least 1000 acres.
5	People skiing at night with large lights, we have seen this just this past summer
6	Piers are impacted to the point of being unsafe. Our pier collapsed when someone walked on it. Luckily not hurt.
7	It’s not just wake boats but all boats that play loud music
8	Threat of new invasive species from bilge water
9	I am not real familiar but I believe if used respectfully to others I shouldn't complain
10	Limit future number of wake surf boats on the lake.
11	Safety of people swimming, boating, canoe/kayaking. Spread of Aquatic Invasive species/plant growth.
12	Big wakes impact row boats
13	surf boat wakes do not significantly dissipate on small lakes like Anvil before they hit shore. Similar to a tsunami, waves build as water depths become shallower. If tsunami warnings are posted thousands of miles from the point of the disturbance does limiting wake boats to operate in the center of Anvil Lake offer much relief from shoreline erosion?
14	OCCASIONAL BAD ACTORS - RENTERS
15	It’s all about them. Music etc.. no consideration for anyone else

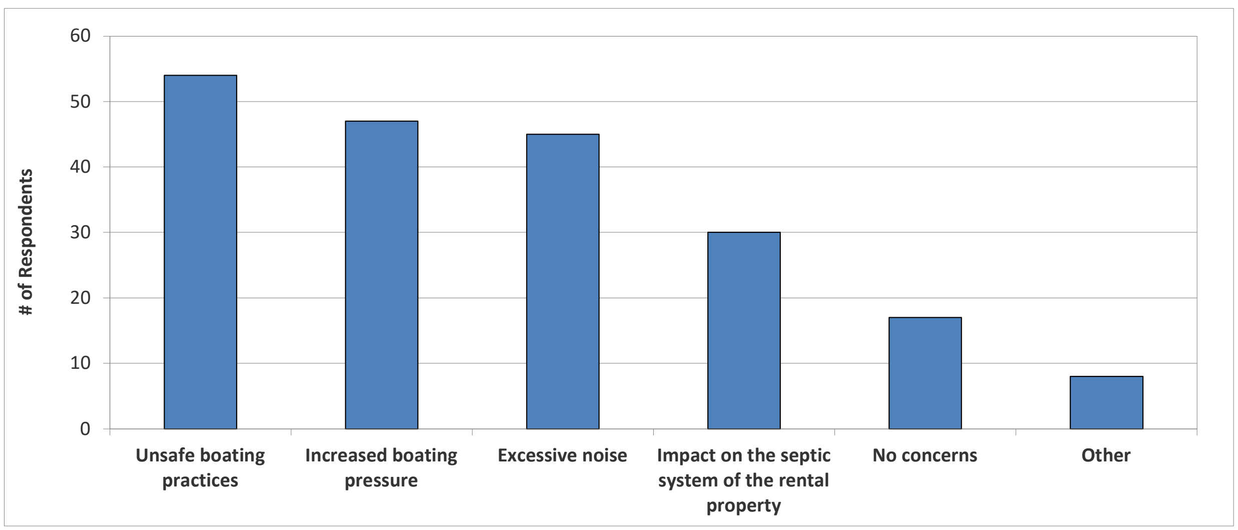
Question 25 continued



26. What concerns, if any, do you have regarding short-term rentals on Anvil Lake?

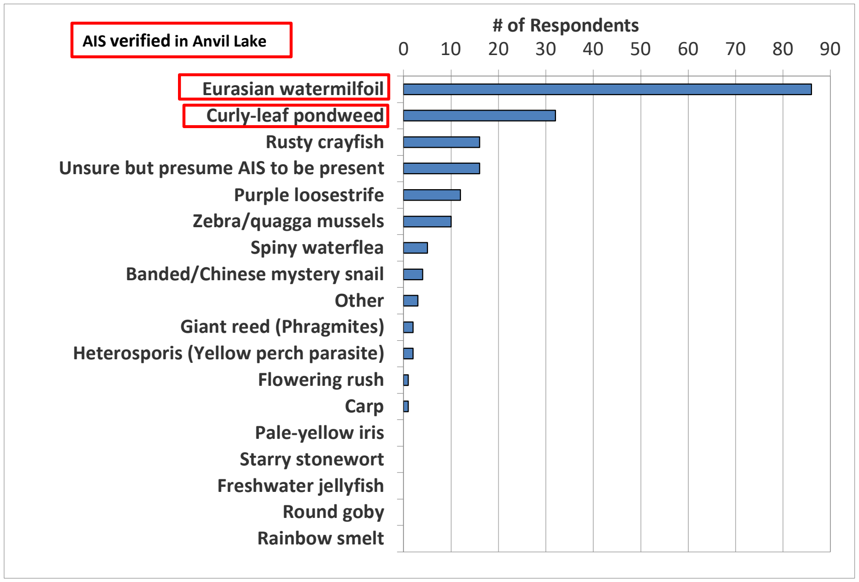
Answer Options	Response Percent	Response Count
Excessive noise	49.5%	45
Unsafe boating practices	59.3%	54
Increased boating pressure	51.7%	47
Impact on the septic system of the rental property	33.0%	30
No concerns	18.7%	17
Other	8.8%	8
	answered question	**91**
	skipped question	**2**

Number	"Other" responses
1	Should not be allowed if renting less then one month.
2	Increased road traffic
3	Decreased respect for the property/community
4	Just ensure that people are respectful of others.
5	Lack of concern for wild life
6	Concerned renters aren't fully aware of county rules and lake association guidelines
7	General disregard for the courtesy code
8	no concern for others when operation wake boats or jet skis



27. Which aquatic invasive species do you believe are in Anvil Lake?

Answer Options	Response Percent	Response Count
Eurasian watermilfoil	94.5%	86
Curly-leaf pondweed	35.2%	32
Rusty crayfish	17.6%	16
Unsure but presume AIS to be present	17.6%	16
Purple loosestrife	13.2%	12
Zebra/quagga mussels	11.0%	10
Spiny waterflea	5.5%	5
Banded/Chinese mystery snail	4.4%	4
Other	3.3%	3
Giant reed (Phragmites)	2.2%	2
Heterosporis (Yellow perch parasite)	2.2%	2
Flowering rush	1.1%	1
Carp	1.1%	1
Pale-yellow iris	0.0%	0
Starry stonewort	0.0%	0
Freshwater jellyfish	0.0%	0
Round goby	0.0%	0
Rainbow smelt	0.0%	0
	answered question	**91**
	skipped question	**2**

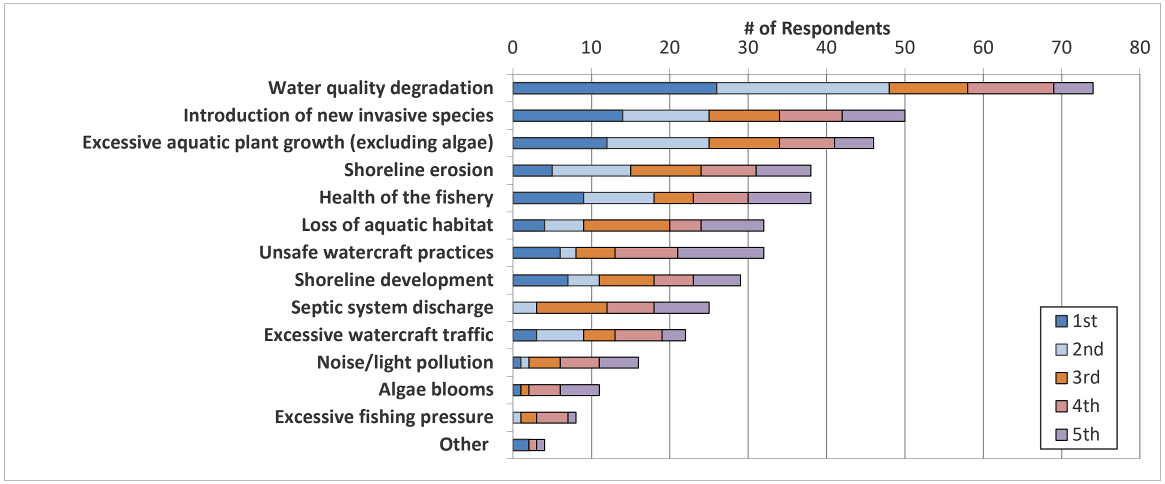


Number	"Other" responses
1	Nonnative thistles and cattails
2	Don’t know much about this topic.
3	Haven’t been educated on others

28. From the list below, please rank your top five concerns regarding Anvil Lake, with the 1st being your greatest concern.						
Answer Options	**1st**	**2nd**	**3rd**	**4th**	**5th**	**Total**
Water quality degradation	26	22	10	11	5	74
Introduction of new invasive species	14	11	9	8	8	50
Excessive aquatic plant growth (excluding algae)	12	13	9	7	5	46
Shoreline erosion	5	10	9	7	7	38
Health of the fishery	9	9	5	7	8	38
Loss of aquatic habitat	4	5	11	4	8	32
Unsafe watercraft practices	6	2	5	8	11	32
Shoreline development	7	4	7	5	6	29
Septic system discharge	0	3	9	6	7	25
Excessive watercraft traffic	3	6	4	6	3	22
Noise/light pollution	1	1	4	5	5	16
Algae blooms	1	0	1	4	5	11
Excessive fishing pressure	0	1	2	4	1	8
Other	2	0	0	1	1	4
					answered question	**91**
					skipped question	**2**

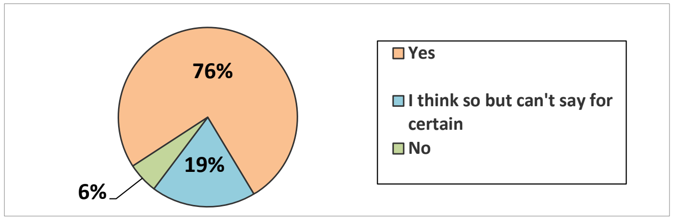
Number	"Other" responses
1	Invasive species currently present in the lake
2	#1 Wake/Surf Boat Use on Lake. #2 Spead of Eurasian Milfoil in Anvil
3	Existing and threat of new invasive species
4	Wakeboats
5	#1 Wake/Surf Boat Use on Lake. #2 Spead of Eurasian Milfoil in Anvil
6	I’m not interested in answering

Question 28 continued



29. Do you believe you are able to identify Eurasian watermilfoil from Anvil Lake?

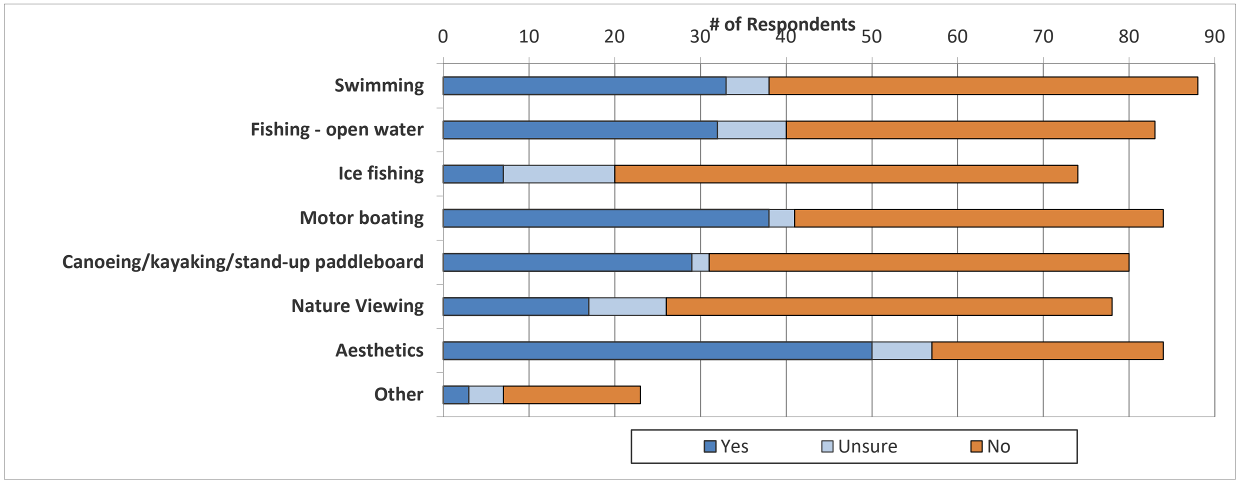
Answer Options	Response Percent	Response Count
Yes	75.6%	68
I think so but can't say for certain	18.9%	17
No	5.6%	5
	answered question	**90**
	skipped question	**3**



30. Has the Eurasian watermilfoil population ever had a negative impact on your enjoyment of Anvil Lake?

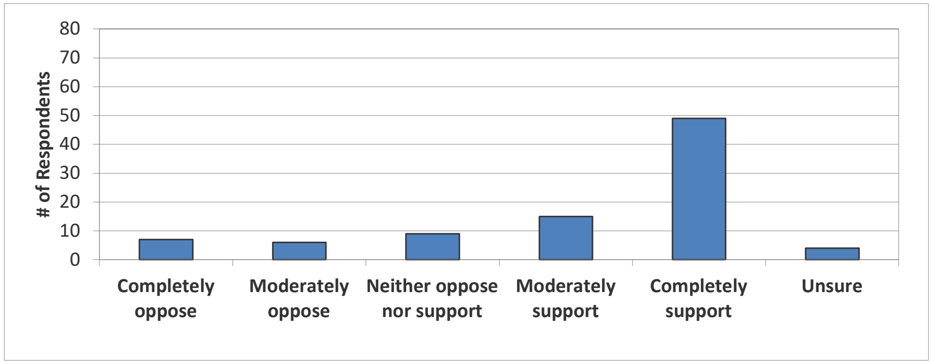
Answer Options	Yes	Unsure	No	Total
Swimming	33	5	50	88
Fishing - open water	32	8	43	83
Ice fishing	7	13	54	74
Motor boating	38	3	43	84
Canoeing/kayaking/stand-up paddleboard	29	2	49	80
Nature Viewing	17	9	52	78
Aesthetics	50	7	27	84
Other	3	4	16	23
			answered question	**91**
			skipped question	**2**

Number	"Other" responses
1	Volunteer time and money spent on EWM management
2	Milfoil itself hasn't had a negative impact for us on any of the above, but chemical treatment has stopped us from swimming and eating fish from the lake.
3	lakes aquatic health

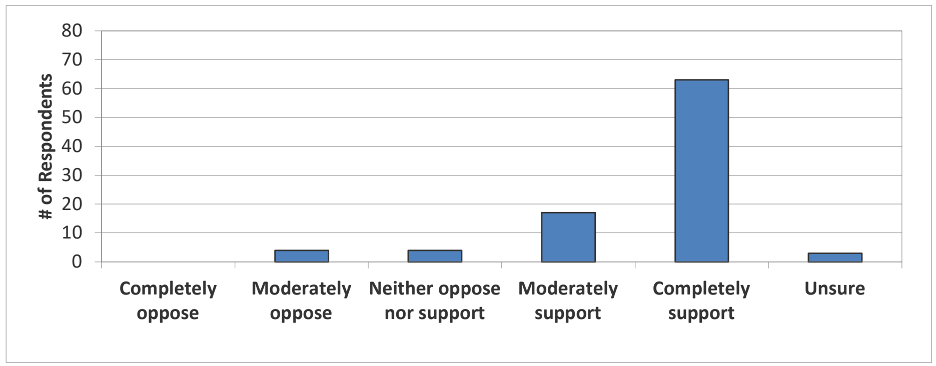


31. In 2020, a spatially targeted 2,4-D herbicide treatment was conducted within the North Bay of Anvil Lake to treat EWM. What was your level of support or opposition for the use of aquatic herbicides to treat EWM in the North Bay in 2020?

Answer Options	Response Percent	Response Count
Completely oppose	7.8%	7
Moderately oppose	6.7%	6
Neither oppose nor support	10.0%	9
Moderately support	16.7%	15
Completely support	54.4%	49
Unsure	4.4%	4
	answered question	**90**
	skipped question	**3**

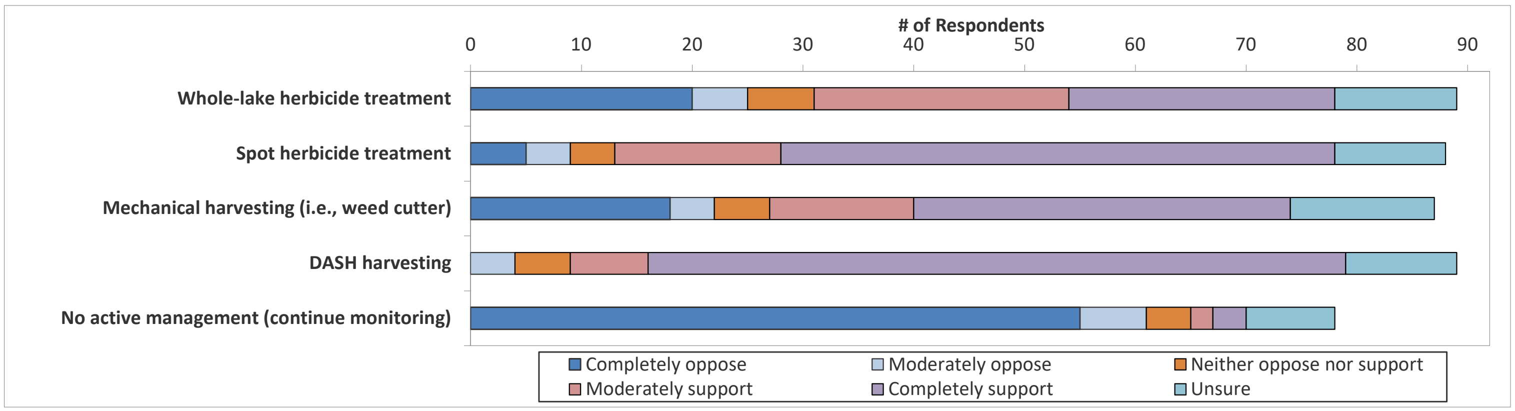


32. Since the 2020 2,4-D herbicide treatment, hand-harvesting (includes Diver Assisted Suction Harvest) at a high amount of effort has been used to manage rebounding EWM. What is your level of support or opposition for the past use of hand-harvesting with DASH to manage EWM since 2020?		
Answer Options	**Response Percent**	**Response Count**
Completely oppose	0.0%	0
Moderately oppose	4.4%	4
Neither oppose nor support	4.4%	4
Moderately support	18.7%	17
Completely support	69.2%	63
Unsure	3.3%	3
answered question		**91**
skipped question		**2**



33. As the EWM population rebounds from previous management activities, the Anvil Lake Association will begin assessing future management techniques for the EWM population. What is your level of support or opposition for the future use of the following EWM management techniques in Anvil Lake?

Answer	Completely oppose	Moderately oppose	Neither oppose nor support	Moderately support	Completely support	Unsure	Total
Whole-lake herbicide treatment	20	5	6	23	24	11	89
Spot herbicide treatment	5	4	4	15	50	10	88
Mechanical harvesting (i.e., weed cutter)	18	4	5	13	34	13	87
DASH harvesting	0	4	5	7	63	10	89
No active management (continue monitoring)	55	6	4	2	3	8	78
						answered question	**89**
						skipped question	**4**

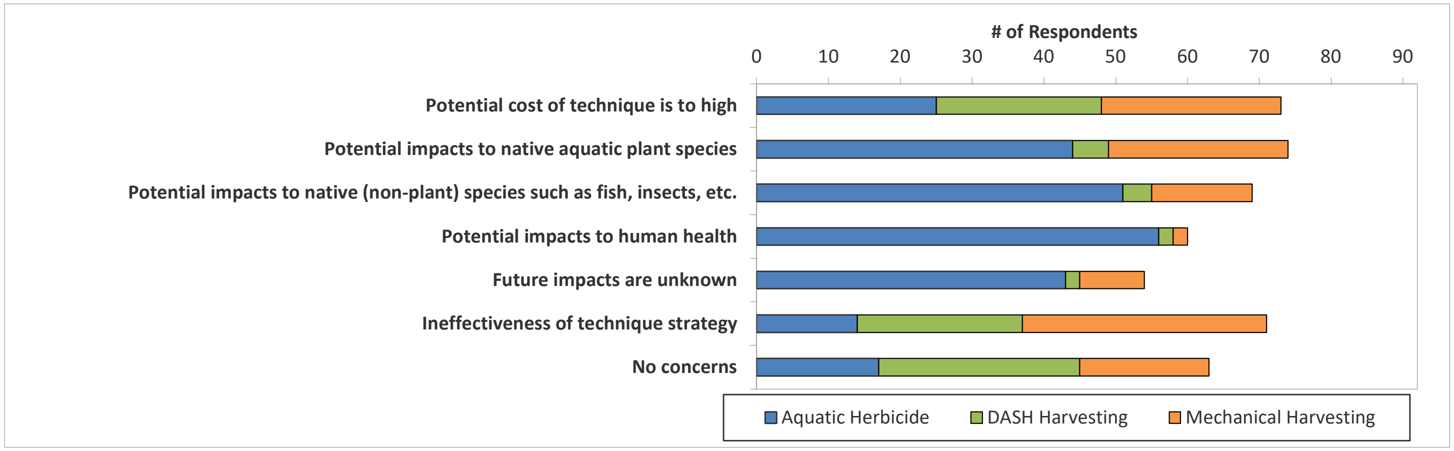


34. Below are four options currently being considered by the Anvil Lake Association to manage Eurasian watermilfoil. Please tell us what concerns you have for the use of each management option.

Answer Options	Aquatic Herbicide	DASH Harvesting	Mechanical Harvesting	Total
Potential cost of technique is to high	25	23	25	46
Potential impacts to native aquatic plant species	44	5	25	60
Potential impacts to native (non-plant) species such as fish, insects, etc.	51	4	14	57
Potential impacts to human health	56	2	2	58
Future impacts are unknown	43	2	9	45
Ineffectiveness of technique strategy	14	23	34	46
No concerns	17	28	18	40
			answered question	**86**
			skipped question	**7**

Number	"Other" responses
1	Potential impacts to Pets(Dog)--Aquatic Herbicide. No Concerns with DASH Harvesting, however, if Wake/Surf Boats are allowed on Anvil they can spread aquatic Invasive species and could defeat the purpose of DASH Harvesting or use of Herbicide.
2	Do what ever necessary at any cost
3	You only gave us three options, but no management is another option - which we fully support to allow the natural lake system to rebalance to a new equillibrium.
4	Use safe monitored approach.
5	Potential impacts to Pets(Dog)--Aquatic Herbicide. No Concerns with DASH Harvesting, however, if Wake/Surf Boats are allowed on Anvil they can spread aquatic Invasive species and could defeat the purpose of DASH Harvesting or use of Herbicide.
6	DASH method I feel actually helped spread the milfoil to other parts of the lake as any part of the plant that floats away can start to grow where it lands
7	Not sure about any of the above
8	I’m concerned with some of the questions in this survey
9	Not educated enough to answer

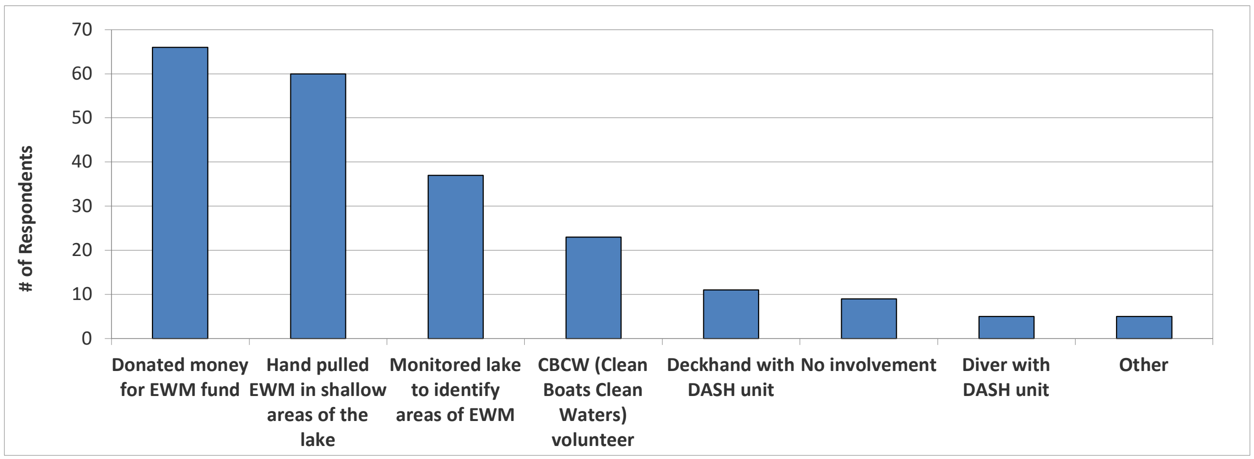
Question 34 continued



35. What involvement have you or your family had with Eurasian watermilfoil (EWM) removal from Anvil Lake?

Answer Options	Response Percent	Response Count
Donated money for EWM fund	73.3%	66
Hand pulled EWM in shallow areas of the lake	66.7%	60
Monitored lake to identify areas of EWM	41.1%	37
CBCW (Clean Boats Clean Waters) volunteer	25.6%	23
Deckhand with DASH unit	12.2%	11
No involvement	10.0%	9
Diver with DASH unit	5.6%	5
Other	5.6%	5
answered question		**90**
skipped question		**3**

Number	"Other" responses
1	I have volunteered to work on dash but never get any call
2	Managed the DASH
3	Diver without DASH unit
4	Removed any that floated to dock or grows near dock in shallow water
5	I THINK WE DONATED AND WILL DO SO IN FUTURE



36. Before receiving this mailing, had you ever heard of the Anvil Lake Association?

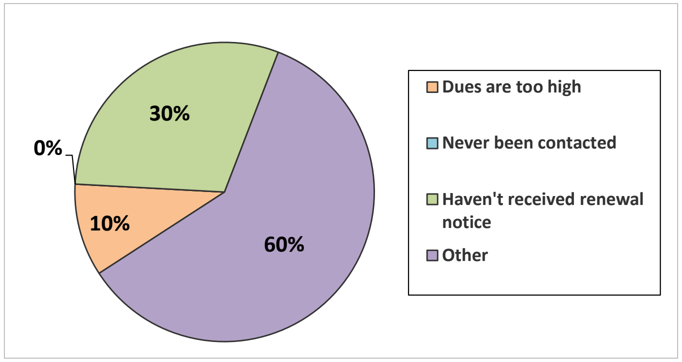
Answer Options	Response Percent	Response Count
Yes	100.0%	90
No	0.0%	0
	answered question	90
	skipped question	3

37. What is your membership status with the Anvil Lake Association?

Answer Options	Response Percent	Response Count
Current member	85.4%	76
Former member	7.9%	7
Never been a member	6.7%	6
	answered question	89
	skipped question	4

38. If you are not a current member please indicate the reason below.

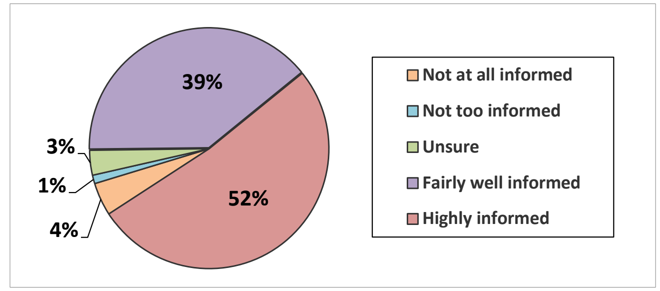
Answer Options	Response Percent	Response Count
Dues are too high	10.0%	1
Never been contacted	0.0%	0
Haven't received renewal notice	30.0%	3
Other	60.0%	6
	answered question	10
	skipped question	83



Number	"Other" responses
1	Am a member
2	Current member
3	N/A
4	Our opposition to chemical treatment is too high to continue to support the lake association.
5	My concerns were not addressed in a respectful manner
6	not interested anymore

39. How informed has (or had) the Anvil Lake Association kept you regarding issues with Anvil Lake and its management?

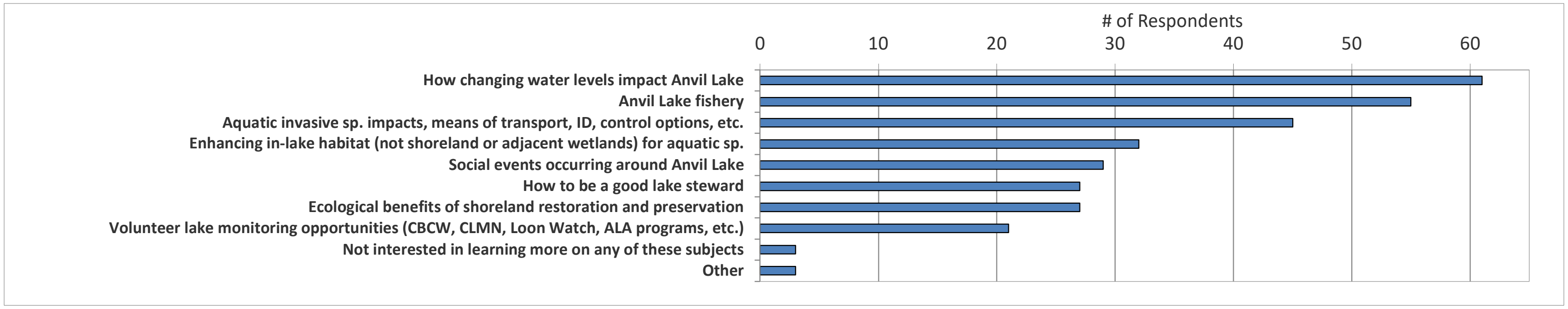
Answer Options	Response Percent	Response Count
Not at all informed	4.5%	4
Not too informed	1.1%	1
Unsure	3.4%	3
Fairly well informed	39.3%	35
Highly informed	51.7%	46
	answered question	89
	skipped question	4



40. Stakeholder education is an important component of every lake management planning effort. Which of these subjects would you like to learn more about?

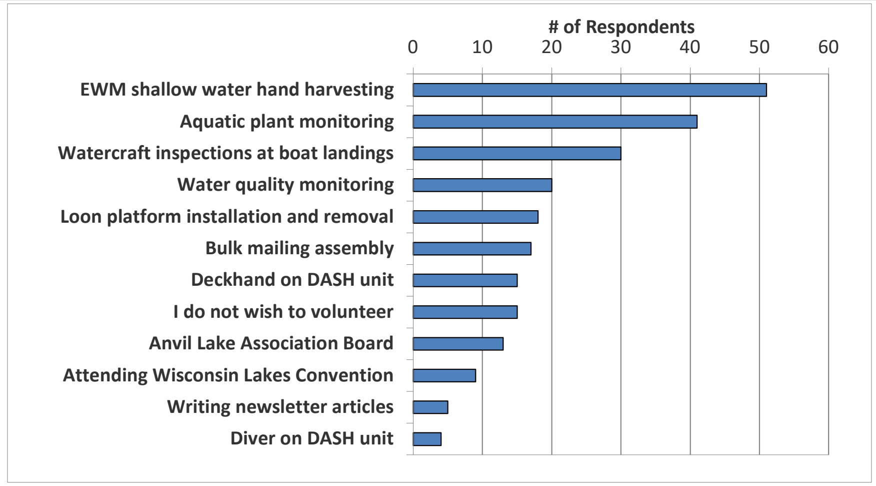
Answer Options	Response Percent	Response Count
Aquatic invasive species impacts, means of transport, identification, control options, etc.	52%	45
How to be a good lake steward	31%	27
How changing water levels impact Anvil Lake	70%	61
Social events occurring around Anvil Lake	33%	29
Enhancing in-lake habitat (not shoreland or adjacent wetlands) for aquatic species	37%	32
Ecological benefits of shoreland restoration and preservation	31%	27
Anvil Lake fishery	63%	55
Volunteer lake monitoring opportunities (Clean Boats Clean Waters, Citizens Lake Monitoring Network, Loon Watch, Anvil Lake Association programs, etc.)	24%	21
Not interested in learning more on any of these subjects	3%	3
Other	3%	3
answered question		**87**
skipped question		**6**

Number	"Other" responses
1	Only at the lake 2-3 weeks per year in the summer
2	The ALA communicates & informs very well
3	We feel that we're well informed already. ALA does a great job messaging on the above topic.



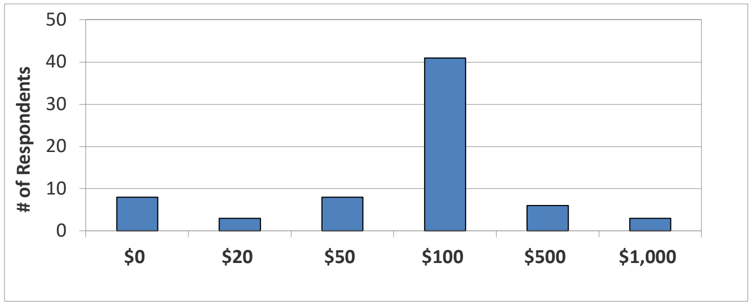
41. Please note that because this survey is anonymous, your answer to this question will not be regarded as a commitment to participate, but instead will be used to gauge potential participation of stakeholders in the Anvil Lake Association. The effective management of your lake will require the cooperative efforts of numerous volunteers.

Answer Options	Response Percent	Response Count
EWM shallow water hand harvesting	59%	51
Aquatic plant monitoring	48%	41
Watercraft inspections at boat landings	35%	30
Water quality monitoring	23%	20
Loon platform installation and removal	21%	18
Bulk mailing assembly	20%	17
Deckhand on DASH unit	17%	15
I do not wish to volunteer	17%	15
Anvil Lake Association Board	15%	13
Attending Wisconsin Lakes Convention	10%	9
Writing newsletter articles	6%	5
Diver on DASH unit	5%	4
	answered question	**86**
	skipped question	**7**



42. What would you be willing to contribute (in addition to annual membership dues) to support management of non-native species in Anvil Lake?

Answer Options	Response Percent	Response Count
$0	11.6%	8
$20	4.4%	3
$50	11.6%	8
$100	59.4%	41
$500	8.7%	6
$1,000	4.4%	3
	answered question	**68**
	skipped question	**24**



Number	"Other" responses
1	$200
2	Or more depending on the plan
3	$200-$300
4	I don’t live on anvil-normally treated as an outsider because I don’t have a home on the lake and I use the public launch. I am left with the feeling that I am being contacted because you need more members and funding.
5	We will consider future contributions if chemical treatment is no longer applied.
6	$200
7	200
8	200 ok
9	$250.00
10	$200
11	200
12	depends on what it is
13	$75
14	200.00
15	250
16	Need to understand the plans and associated cost.
17	$200
18	$250
19	I think we already paid $200 maybe?
20	$150.00

43. Please feel free to provide written comments concerning Anvil Lake, its current and/or historic condition and its management.

Answer Options	Response Count
	36
answered question	**36**
skipped question	**56**

Number	Response Text
1	Erratic driving of singular craft into the bay area. High speed and dangerous to people swimming. It's the jet skis that are the worst.
2	I believe I submitted a previous Stakeholder Survey approx a month ago. Never received confirmation it was received. Please disregard this response if our other survery was received. Wake Boating Is a Huge Issue to us. After much research we believe Anvil is too small a lake to allow Wake Boating. Current guidelines do not go far enough to protect our shoreline and at times our Grandchilden swimming as well as our Dogs.
3	Thanks for all the help!
4	Great Lake, great president of out association.ט
5	Sincere thanks to all involved in the management of the EWM situation on the lake. This invasive weed is by far and away the most serious problem faced by the lake and threatens everyone's use and enjoyment of the lake. It is extremely important that this EWM situation be treated effectively and aggressively.
6	Thank you for all your work!
7	We can be inside with all windows closed and still hear the wake boats across the lake with stereos blaring. Echoes across the lake and should not even be occurring in the night hours. We often wonder if these are actual land owners or someone just renting a property for the weekend.
8	See previous comment
9	Keep up the fine job
10	The Anvil Lake Association Board needs to base their management of Eurasian watermilfoil on the scientific information presented previously by the UW-Madison professor regarding the extremely negative impacts of even low levels of chemical treatment of milfoil on fish fry and on the potential impacts on human health, especially on a lake with such a long flushing rate.
11	We think the Anvil Lake Board is doing a great job with the Milfoil problem. We would like to see more residents under the age of 50 being involved with the lake.
12	my personal opinion is that the shorelines have become over developed
13	Wakeboats must be outlawed. Anvil lake is too small to handle that wave action. The east shore gets pounded and majority of wakeboats are located in areas protected in bays where the boats don't go. Perhaps if they saw what happens on the east shoreline while they were operating they would agree they should be banned.
14	When I was a kid, you could go anytime of the day and catch your limit of 5 walleye. With Indian spear fishing taking 'spawning' walleyes out of the lake, I have not caught a walleye in years! When I was a kid there were lots of crayfish in the lake, now there is not. I heard in Europe, they put crayfish in the lakes and milfoil was dramatically lowered, as they eat the weeds?
15	In my life long use of Anvil Lake, it's sad to see the decline of shellfish in the lake. Also, it's not unusual for oily films to come our way on the lake surface. This year I noticed a lot of sand wash away from our beach leaving more stones than sand along the shore. 👎

16	thank you ALA board! We are hoping to increase herbicide treatments to control EWM. Consider increasing knowledge for residents regarding septic sytems and lawn fertilizers to invasive species management. We have lived on several lakes in addition to Anvil and find herbicides to be the only option as increased pressure affects lake use/ management.
17	2021 high lake level was still 3 or so inches below the high lake level of 1973. Water clarity in 2023 was the best it has for at least 20-25 years. The biggest environmental threats to the lake are more from fertilizers and chemicals lawns treatments and the mosquito pest control. Wake surf boats pose a minimal disturbance concerning to overall environmental problems on the lake from concerned shoreline ALA members. Thanks to all the people that help to work and control the milfoil problem-appreciate it!!!
18	Please address the use of wake boats on Anvil Lake. I feel the lake is too small and shallow to support the use of this type of water craft. I do not feel safe swimming or kayaking as the waves are too big to navigate and visibility is not good.
19	Herbicide treatment should be high on list of EWM options. More than enough evidence that it works and presents no danger to the lake. We can't let the lake be ruined by this invasive species.
20	We have a very strong concern for wake boats: too much wake for Anvil, too much
21	It was truly unfortunate that in 2022 there were problems with the Dash Unit Oshkosh students. I feel that harvesting failures contributed to increased EWM in growth in 2023.
22	ALA is a great association. I wish we could eliminate Wake Boats
23	Our Anvil Lake Association Board does an excellent job being on top of concerns and works tirelessly for the betterment of Anvil and its property owners.
24	none
25	Please keep up an active Anvil Lake HOA!!!
26	Consider restoring fish cribs....concerned on how various fish species were introduced to the lake which eliminated others......enjoy the lake and your land....
27	Wake Boats are a huge concern especially with lowering water levels. Also troubling to see shoreline being cleared and turned into non-natural beaches. Septic should all be being inspected.
28	I am thankful for the interest shown by our association for managing our lake. Thank you.
29	ALA board is doing a good job managing lake issues. I wouldn't be opposed to a catch and release of all fish species for a year or two and when fish can once again be harvested that there are strict limits.
30	Part of Lake management needs to be a discussion about fetalizer and yard waste. Given our location we cab see the lovey green results of spring and fall fertalizer application. This is not healthy for the lake. We chose to live in the woods. This should not include a suburban lawn. It would be good to see encouraged use of native plants for landscaping.
31	Keep up the great work, sorry we are not there enough to participate more
32	Need more support and respect for all property owners within the Anvil Lake watershed.
33	ALA IS BLESSED WITH GREAT MANAGEMENT!!
34	It seems an awful lot of time and money is spent on hand and DASH boat harvesting and the battle to control the Milfoil is being lost. Preference is to get right to the heart of the matter and address the problem with cautious herbicide treatments.
35	I wholeheartedly support the management efforts put forth by the elected officers and board members over the years.
36	I appreciate the efforts that ALA go through to keep our lake in great condition. I'm a big fan of the DASH harvesting for invasive weeds - I see only benefits from this activity. I also hope that the walleye fishery can someday rebound to the point where we can catch some.

C

APPENDIX C

Point-Intercept Survey – Aquatic Plant Littoral Frequency Matrix

Anvil Lake Point-Intercept
Survey Matrix

Scientific Name	Common Name	LFOO (%)				
		2010	2012	2015	2019	2023
Chara spp. & Nitella Spp.	Charophytes	56.6	50.1	44.8	49.1	54.2
Nitella spp.	Stoneworts	55.4	47.7	6.0	37.3	29.3
Vallisneria americana	Wild celery	25.6	26.6	21.3	30.3	24.1
Elodea canadensis & E. nuttallii	Common & slender waterweeds	38.9	21.2	26.8	20.5	7.9
Chara spp.	Muskgrasses	1.7	2.9	38.9	13.5	26.1
Elodea canadensis	Common waterweed	35.6	9.5	0.0	20.3	7.9
Potamogeton pusillus & P. berchtoldii	Small & slender pondweeds	8.3	13.2	8.3	13.5	5.2
Elodea nuttallii	Slender waterweed	4.2	11.8	26.8	0.2	0.0
Potamogeton berchtoldii	Slender pondweed	8.3	0.0	8.3	13.5	3.6
Eleocharis acicularis	Needle spikerush	8.7	9.2	6.1	5.9	2.3
Potamogeton vaseyi	Vasey's pondweed	5.2	0.0	4.4	7.6	3.3
Myriophyllum spicatum	Eurasian watermilfoil	0.0	0.5	1.2	16.6	1.7
Potamogeton pusillus	Small pondweed	0.0	13.2	0.0	0.0	1.5
Potamogeton amplifolius	Large-leaf pondweed	1.3	1.8	1.3	5.9	2.7
Myriophyllum tenellum	Dwarf watermilfoil	2.0	2.6	3.8	2.8	0.8
Juncus pelocarpus	Brown-fruited rush	0.2	1.7	2.0	3.3	1.0
Elatine minima	Waterwort	1.2	1.7	2.5	1.7	0.2
Potamogeton epihydrus	Ribbon-leaf pondweed	0.5	1.2	1.6	2.2	0.4
Isoetes spp.	Quillwort spp.	1.5	1.4	1.1	0.2	1.1
Potamogeton spirillus	Spiral-fruited pondweed	0.8	0.0	0.4	1.8	0.4
Eleocharis palustris	Creeping spikerush	0.0	0.5	0.5	1.7	0.0
Najas flexilis	Slender naiad	0.0	0.0	0.0	0.6	1.1
Ranunculus flammula	Creeping spearwort	0.0	0.0	0.1	0.9	0.2
Sparganium angustifolium	Narrow-leaf bur-reed	0.7	0.0	0.0	0.2	0.2
Potamogeton strictifolius	Stiff pondweed	0.0	0.0	0.0	0.4	0.4
Potamogeton gramineus	Variable-leaf pondweed	0.0	0.0	0.1	0.2	0.4
Potamogeton crispus	Curly-leaf pondweed	0.0	0.0	0.8	0.0	0.0
Pontederia cordata	Pickerelweed	0.0	0.8	0.0	0.0	0.0
Fissidens spp. & Fontinalis spp.	Aquatic Moss	0.0	0.0	0.0	0.9	0.0
Najas gracillima	Northern naiad	0.5	0.0	0.0	0.2	0.0
Sparganium androcladum	Shining bur-reed	0.0	0.0	0.4	0.0	0.0
Schoenoplectus tabernaemontani	Softstem bulrush	0.0	0.2	0.0	0.0	0.2
Riccia sp.	Riccia sp.	0.0	0.5	0.0	0.0	0.0
Nuphar variegata	Spatterdock	0.0	0.0	0.0	0.2	0.2
Eriocaulon aquaticum	Pipewort	0.0	0.0	0.1	0.2	0.0
Typha spp.	Cattail spp.	0.0	0.2	0.0	0.0	0.0
Sparganium eurycarpum	Common bur-reed	0.0	0.0	0.1	0.0	0.0

D

APPENDIX D

Anvil Lake 2023 EWM Management Summary

- ALA DASH Summary
- ALA Diver Logs
- APM, LLC DASH Summary Report

2023 Eurasian Watermilfoil Harvest Report

Anvil Lake Association

Submitted to:

The Anvil Lake Association and the Wisconsin Department of Natural Resources

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Ty Krajewski: Ty.Krajewski@wisconsin.gov

Submitted by: Amy Kuhns, ALA president

Feb 1, 2024

Introduction:

The Anvil Lake Association has been hand harvesting EWM in Anvil Lake since it was discovered in the summer of 2012. The ALA funded the construction of their own Diver Assisted Suction Harvesting-DASH unit in 2017 for more effective and cost efficient removal of EWM in Anvil Lake. This past summer was the seventh year of EWM harvesting with the DASH unit in Anvil Lake. Divers and volunteers also hand harvest EWM without the DASH unit in more shallow areas of the littoral zone and in areas of more scattered EWM growth. A permit was granted to the ALA in 2020 for an herbicide treatment with 2,4-D in the north bay of Anvil Lake. The permit granted to the ALA in 2023 by the Wisconsin Department of Natural Resources allowed for DASH unit EWM hand harvesting in up to 45 acres of Anvil Lake with varying amounts of EWM.

Dive Methods:

The ALA contracted in 2023 with four divers and five deckhands to harvest EWM with the DASH unit. The divers typically worked in four hour shifts assisted by a deckhand on the DASH unit. The diver removed EWM plants and their root balls from the lake bed by hand and fed the harvested EWM into the open end of the suction hose by their side. The suction hose carries the harvested EWM up to the deck of the DASH unit, where it is deposited into large mesh bags. The mesh bags allow the water to filter back into the lake, while retaining the harvested EWM. The DASH unit is designed to allow the other end of the suction hose to pivot between two adjacent bagging stands on the deck. The deckhand is responsible for monitoring the DASH unit equipment and replacing the mesh bags once they are filled with EWM. The deckhand also skims floating pieces of EWM around the DASH unit that surface during the harvesting process. After the dive shift has ended, a sample bag is used to estimate the percentage of EWM harvested. The bags of harvested EWM are removed from the DASH unit, weighed and emptied. The harvested EWM is periodically moved onto a trailer and taken to the Town of Washington transfer station, the designated disposal site.

The ALA also contracted in 2023 with a professional company, Aquatic Plant Management, for additional EWM harvesting with their DASH unit and crew.

A volunteer diver utilized a portable hookah system to hand harvest additional scattered EWM into mesh bags. The diver would surface with the harvested EWM which was transferred into a boat to be transported back to shore.

DASH unit deckhands and volunteers also hand harvested EWM in shallower areas of the littoral zone. They would free dive with mask and snorkel or wade along the shoreline to locate and remove EWM plants.

Harvest Summary:

Since the herbicide treatment of the north bay of Anvil Lake in 2020, EWM has been gradually re-emerging in the bay, with more accelerated regrowth in the past two years. After several years of higher water levels in the lake that seemed to inhibit EWM growth in the other areas of the lake, the past two years have seen more gradual regrowth of EWM in the littoral zone outside of the north bay. Harvesting EWM from the re-emerging colonies in the north bay continued to be the priority for the DASH units utilized in 2023.

EWM dive harvesting efforts for 2023 began on June 14th. The first week primarily focused on training the novice divers and deckhands for the ALA DASH unit. Once properly trained, the part time divers were then scheduled to work two four hour dive shifts, four to five days a week, depending on weather and other work commitments. EWM dive harvesting continued through July and August, with two final dives in September.

The repairs and maintenance of the DASH unit that took place in the spring resulted in the DASH unit operating well through the summer, without significant shut down time for mechanical issues. Unfortunately, two of the novice divers needed to transition to deckhands and shallow water hand harvesters. The decreased visibility in sediment laden waters while dive harvesting with the DASH unit created anxiety with these divers.

The ALA was fortunate to hire a new diver with extensive experience in EWM dive harvesting in another lake. This diver also led the training sessions in June and provided valuable insights with the ALA dive harvesting logistics. The remaining novice diver adapted quickly to the challenges of EWM dive harvesting. He was responsible through the summer for DASH unit maintenance, purchase of supplies and gas, and EWM transport to the transfer station. He also put in the pier for the DASH unit and took it out at the end of the season.

Our two remaining divers were able to fill in for a number of the shifts that were originally assigned to the novice divers unable to continue dive harvesting. A total of 63 dive shifts were completed with the ALA DASH unit in 2023, with 234 hours of paid EWM dive harvesting efforts. Dive harvesting sites prioritized the north bay, but also included a number of shifts in areas of EWM re-emerging in other areas of the lake. Paid shallow water hand harvesting in the north bay without the DASH unit accounted for another 18.5 hours of EWM removal.

Aquatic Plant Management conducted five eight hour days of EWM hand harvesting with their own DASH unit and crew from July 17th through July 21st. Their DASH unit completed a total of 35.5 hours of EWM dive harvesting. The APM divers harvested EWM from the large colony of scattered EWM in the western part of the north bay.

The total amount of EWM harvested with the ALA DASH unit and paid shallow water hand harvesting was 6,230 pounds. The Aquatic Plant Management DASH unit crew harvested a total of 185.5 cubic feet of EWM, which is equivalent to 2,780 pounds of EWM. The combined total of EWM harvested in 2023 from Anvil Lake was 9,010 pounds of EWM.

Divers reported that the EWM harvested in the north bay was in scattered to highly scattered colonies and also more scattered individual EWM plants and clumps of plants. Native aquatic vegetation was also growing well in the north bay. In other areas of the lake, they report that the EWM was very scattered in the littoral zone, with a small re-emerging colony in the southwest bay of the lake.

The Onterra late season EWM survey was conducted on September 21st. The survey found that the colony of scattered to highly scattered EWM in the north bay continues to increase in size, despite the significant amount of EWM harvested in 2023. A smaller colony of highly scattered EWM is continuing to re-emerge in the boat landing bay and the southwest bay of Anvil Lake. One small colony of dominant EWM was located along the northwest shoreline of the lake. An increased number of isolated EWM plants were identified in other areas of the lake compared to 2022. Onterra reports that 2023 was unfortunately a favorable year for EWM growth in many of the lakes in the Northwoods.

ALA DASH Sign In Log 2023

Date	Deck Hand	Diver	Paid Hours	Donated Hours	Other
6/14/23	Gaby, Haven, Jonah Lillyann, Rachel	Ally, Cal, Cedric, Sarah	3.5		(Training)
6/19/23	Gaby	Cal, Sarah	4		
6/20/23		Cedric, Sarah	4		
6/20/23	Jonah	Ally, Sarah	3		
6/21/23	Jonah	Cedric	4		
6/22/23	Haven	Cal, Sarah	4		
6/22/23	Gaby	Ally, Sarah	4		
6/26/23	Cal + Sarah	Cal + Sarah	5		
6/27/23	Rachel	Sarah	4		
6/27/23	Sarah	Cal	4		
6/28/23	Haven	Ally + Sarah	4		
6/28/23	Jonah	Cedric + Sarah	5.5		
6/29/23	Lilyann, Sarah, ~~[illegible]~~	Sarah, Cal	3.5		
6/30/23	Jonah	Cedric	1		boat maintenance
~~6/30/23~~	~~Rachel~~	~~Cal~~	~~1.75~~		~~pressure tank not giving enough air to dive~~

ALA DASH Sign In Log 2023

Date	Deck Hand	Diver	Paid Hours	Donated Hours	Other
7/13/23	Rachel	Cal	4		
7/6/23	Jonah	Cal	4.5		
7/6/23	Jonah	Sarah	4		Randy?
7/6/23	Gaby	Sarah	4		overflow, clog, broke scale
7/7/23	Haven	Cal	4		
7/10/23	Lilyann Ogden	Cal	4.5		
7/11/23	Rachel L.	Cal	2		coffe bags overflow
7/14/23	Jonah	Cedric	4	0	
7/1[illegible]	Haven	Cedric	4		
7/17	Lilyann	Sarah	3.75	0	shake coffee bags to drain water
7/[illegible]	Ally	Sarah	1		moving milfoil bags
7/17	Ally	Sarah	3		
7/18	Gaby	Cal	4		...lost an anchor
7/19	Jonah	Cal	4.25		...Found the anchor
7/20	Rachel	Cal	3.50	0	

ALA DASH Sign In Log 2023

Date	Deck Hand	Diver	Paid Hours	Donated Hours	Other
7/24	Lilyann Ogden	Cal	4hrs	X	
7/25	Haven	Cal	4hrs		
7/25	~~Haven~~ Ally	Cal	2hrs		
7/25	Ally	Sarah	2hrs		
7/25	Lilyann	Sarah	1.5hrs	X	started tightening gear
7/26	Ally	Cal	3		
〃	Haven	Cal	3.5		found some Mardi Gras beads + a painted rock
7/26	Rachel	Cedric	3.5		Shore waded
7/27	Ally	Cal	4		
7/28	Gaby	Cedric	3		shore waded
7/31	Rachel	Cal	4		
7/31	Lilyann	Cal	2		
7/31	Lilyann	Sarah	2.5		
-/31	Jonah	Sarah	4		
8/1	Lilyann	Sarah	3		

Replaced ~~Hose~~ Hose #3

ALA DASH Sign In Log 2023

Date	Deck Hand	Diver	Paid Hours	Donated Hours	Other
8/1	Gaby	Sarah	4.25		
8/1	Rachel		2		Shore waded
8/3	Ally	Sarah	3.5		
8/7	Gaby	Sarah	2.25		
8/7	Gaby	Cal	2.25		
8/7	Ally	Cal	4		
8/8	Ally		2.5		hand pulled
8/9	Ally	Cal	4		
8/10	Rachel	Cal	4		
8/10	Lilyann	Cal	2		
8/10	~~Sarah~~ Lilyann	Sarah	2.		
8/13	Haven	Cal	4		
8/10	Haven	Sarah	4		
8/12	Gaby, Jonah		4		hand harvesting
8/14	Ally	Cal	4		

ALA DASH Sign In Log 2023

Date	Deck Hand	Diver	Paid Hours	Donated Hours	Other
8/14	Haven	Cal	~~4~~ 2	0	
8/14	Haven	Sarah	2	0	
8/14	Jonah	Sarah	3		
8/15	Ally	Cal	4		
8/16	Haven	Cal	4	0	
8/16	Jonah, Gaby		4		hand harvesting
8/21	Haven	cal	4	0	
8/21	Haven	Sarah	4.25	0	
8/21	Gaby	Cal	4		
8/23	Gaby	Cal	4		total 11 bags & 380 lbs
8/25	Jonah	Cal	4		
8/28		Sarah + Cal	4.75		
9/5		Sarah + Cal	5.75		
9/22		"	4		Last Day ♡

Date	Location Number on Grid map	Dive Time (Hrs)	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity, + (GPS coordinates)
6/19/23	SW 2	1hr 5min	14lbs	1	99%	14lbs	78°, light breeze, no waves, 8ft 45.95N, 89.05W
6/20/23	NW 6	[illegible]					82, light breeze, [illegible], 45.57 N, 89.03 W
6/21/23	SW 2	45 min			99%		80, light breeze, no waves, 5 ft
6/21/23	SW 30	20 min	0 lbs	0	0	0	[illegible] breeze, no waves, 8 ft
6/22/23	NE 3	45 min	33 34	2	99%	67lbs	73, lite breeze, no waves, 12ft good vis 45.95N, 89.06W
6/22/23	NE 3	35 min	35 30 29	3	99%	94 lbs	" "
6/22/23	NE 3	35 min	28lbs	1	99%	28lbs	" "
6/26/23	NE 3	30 m	35 lbs	1	99%	35lbs	60°, light wind, 13ft rainy/cloudy 45.95,
"	Middle 1	40 min	36 31 33	3	99	100lbs	" , low vis
"	NE 3	34	38 32 25	2 1/2	"	95	"
6/27/23	central 3	31	30 34 10	2 1/2	99%	74lbs	62, light breeze, no waves, 12ft 45.95, 89.06
" "	" "	40	33, 33, 32 32 22	4 1/2	99%	152lbs	
" "	" "	57	23, 33, 33 33, 31, 29	5 1/2	99%	182	
6/28/23	Central 3	20	32, 33, 10	2	99%	75lbs	58, light wind, 45°57.101 N 089°03.421 W
6/28/23	central 3		28	3/4	99%	28.	45.57, 89.03

found rocks fish cribs

89.06

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location Grid number	Dive Time (Hrs)	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity GPS Coordinates
6/29/23	NE 3.	40min	20, 30 31, 32	4	99%	123lbs.	light breeze 13ft 45.57, 89.03
6/29/23	NE 3.	20min	2, 32, 32 35	$3\frac{1}{4}$	99%.	120lbs	light breeze, 13ft 45.57, 89.03
7/3/23	SW 3	20min	22	1	98%	22 lbs	light breeze, 10ft, Clear 45.95 89.06
7/3/23	SW 3	10 min	26	3/4	99%	26 lbs	light breeze 9ft, clear 45.95 89.06
7/6/23	SW 3	45 min	44, 48 5	2 1/2	99%	97	light breeze 9ft, medium vis.
7/6/23	SW 3.	78 min	30, 30, 30 30, 31, 32, 16	5 1/2	98%	199lbs	68, light wind, 10ft 45.57, 89.03
7/6/23	SE1	60 min	21, 57, 60	3	98%	138lbs	69, light wind 12ft bad vis 45.57, 89.03
7/7/23	NE 3	45min	27, 30, 31, 34	3 1/2	96%	122lbs	58, 4 mph wind, 7ft, med clarity 45.95, 89.06
7/7/23	NE 3	35min	~~27~~, 22 36	1 3/4	99%.	58 lbs	62, 4 mph wind, 7ft, med clarity, 45.95, 89.06
7/7/23	NW 1	40min	32, 30, 31	3 1/2	99%.	93lbs	65, 5 mph wind, 12ft, mucky 45.95, 89.05
7/9/23	NW 2	35min	35lbs	1	99%	35	71, 12 mph wind, very mucky 45.95, 89.05 6ft
~~7/9/23~~	~~NW 2~~	~~15min~~			~~99%.~~		~~75, 12 mph, very mucky, 45.95, 89.05, 6ft~~
7/10/23	NW3	20min	15 lbs	1/2	99%.	15lbs	67, 5mph wind, 8ft, mucky, No clarity 45.57.120 089.03.437.
7/10/23	NW 1	25min	30 17	1 1/2	99%.	47	73, 5mph wind, mucky, Med clarity, 8ft 45.57.199 089.03.406
7/10/23	NW 2	30 min	40, 30 20	2 1/2	99%.	90	70, 5 mph wind, mucky, med clarity, 12ft 45.57.199 089.03.343

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location	Dive Time ~~(Hrs)~~ (min)	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity
	Grid number	30		2	89		GPS Coordinates
7/10/23	NW 3	[illegible]	30,35	[illegible]	99%	[illegible]	76, 4 mph wind, 9ft, mid clarity, mucky 49.97.087, 089.03.435
7/10/23	NW 2	40	34 6lbs	15	99%	6lbs	79° 11mph wind, 8 ft, med clarity 45.95, 89.06
7/11/23	SW 2	~~28~~ 40	28, 35, 33	3	99%		68° slight wind 16ft
7/11/23	Central 2	40	29, 30, 38	3			45.95274N, 89.05477W
7/11/23	Central 2	25	40, 28, 32	3		300lbs	
7/12/23	SW 2	25 min	30 70	2	99%	100	630 light breeze No waves 45.95 89.06 mid clarity 12'
7/14/23	NW 2	35 min					45.57087 89.034 windy
7/17	NW 6	39 min	14, 16	1	97%	30lbs	49.57.067 089.03.165 67° strong wind, 8ft, mid clarity, mucky
7/17/23	Central 2	40 min	28, 14	2	99%	42	45.95253 89.05477W 68 mild wind
7/18	NW 2	40+20	35, 31, 34	3	"	100	66°F, 5mph wind, 12-15ft, murky
7/18	43	42	22	1	"	22	66°F 5mph 7ft, clear
7/19	NW 2	2H	31 35 30 24 30 30 38	6.5	98%	218	windy and rainy 72°F, mucky,
7/20	NE 2	45 min	30 20	2	99%	50	6ft no wind dark 60° 45.95 89.05
7/20	NW 2	30+20 50 min	33	1/2	98%	33	8 ft light breeze mucky 45.15 89.05 60°
7/24	NW 6	40 min	24, 43	2	98%	55	5-8ft, No wind 73° Mucky, 49.57.070 089.03.158

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location Grid Number	Dive Time (Hrs)	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity GPS Coordinates
7/24	NW6	35	28.12	1½	98%	40	5-8ft, No wind, 73°F, Murky 45.57.071, 089.03.156
7/24	~~NW~~ SW55	20	12	½	98%	12	5-8ft, little wind, current, 78°, Murky 45.56.989 08903.307'
7/25	SE 15	35	20	1	99%	20	71°, little wind, murky, 7ft 45.56, 089.03
7/25	SE 2	40	27.27	2	99%.	54	73, little wind, murky, 12ft 45.95, 89.05
7/25	NW 6	25	40	1	99%	40	75, little wind, murky, 15ft 45.95, 89.05
7/25	SW 3	30	50	1 ~~[illegible]~~	99	50	75 light wind
7/25	SW3	30	15	½	99	15	75 light wind
7/25	NC4	~~2ma~~ 15	~~15~~ 0	~~½~~ 0	99	~~15~~ 0	75
7/25	NE6	20	-	1	99	45	75 45.95187 N 89.05268 W 5'7"
7/25	central 3	10	-	½	99%	4/	76, calm 45.57, 89.03
7/26	central 6	45	32"	1	~~78~~ 90%.	32	81, some wind/waves, 8ft, ok clarity 45.95, 89.053
7/26	central 6	35	20	1/2	95%.	20	81, light wind ~~[illegible]~~ 4ft, bad vis 45.95, 89.053
7/26	NW 2	15	10	1/4	95%	10	82, light wind, 4ft, 45.953, 89.056'
7/26	NW 1	3½	18	1/4	99%	18	82, No wind, 4ft Shoreline Murky
7/27	NC 2	30	—	1/2	99	—	Rain light wind

great vis!! :)

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location Grid Number	Dive Time ~~(Hrs)~~ min	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity GPS Coordinates
7/27	NC 2	20	—	1/2	99%	—	rain light wind
7/27	NC 2	20	—	1/2	99	—	
7/27	E 6	15	—	1/4	99	—	
7/27	NE 6	15	—	1/4	99	~90	
7/28	NE 1		total 22		99		steady wind. 60 - 70°F, small waves
7/28	NW 2				99		
7/31	NE 54	20	5,10	3/4	10	15	58° No wind, no waves, 12' Hazy sky, Dark water 45.95 89.05
7/31	W 6	28	26,3	1	10	29	58° No wind, no waves 15' Dark water 45.95 89.05
7/31	W 6	15	11	1/2	90	11	58° light wind, no waves, 15' Mucky 45.95 89.05
7/31	N 2	40	10,19	1 1/2	90	30	60° light wind, no waves 15' mucky 45.95 89.05
7/31	SW 3	30	10	1	98%	10	78° light wind, little waves MUCKY N 45.57092 W0890342 4
7/31		20	5	$\frac{1}{2}$	98%	5	78°. shallow, light wind N 15
7/31	43	15 min	3	1/8	99%	3	45.57, 89.04, shallow, calm 5 ft
7/31	central 3	10	6	1/3	98%	6	45.57, 89.03 8 ft
8/1	central 3	/	/	/	/	/	45.57, 89.03 suction hose not working

pump troubles

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location Grid Number	Dive Time (~~Hrs~~) (min)	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity GPS Coordinates
8/1	North 2.	40 min	27 21	2.	90%	48	45.57, 89.03, calm breeze, 4ft
8/1	3 (middle)	35 min	31	1	90%	31	45.57, 89.03 light breeze 7ft
8/2	SW ~~#~~1	25 min	26	1	85%	26	light breeze / waves, 72°, 8ft, bad clarity 45.9524, 89.057
8/2	NW 1	20 min	30	1	85%	30	light breeze / waves, 73°, 8ft, bad clar 45.9524, 89.057
8/2	N 2	35 min	24, 29, 36	3	96%	89	breeze, some waves, 75°, 7-15ft, bad cla- 45.95, 89.057
8/7	SW 2	35 min	28	1	90%	28	light breeze, 11 ft 45.57, 89.03
8/7	2 (middle)	30 min	30	1	95%	30	20 ft. very light breeze no waves
8/7	NE 1	35	30 30 25	2.5	90%	85	45.57, 89.03 " [illegible]
8/7	SE 1	35	32	1	90%	32	cloudy 45.57 89.03
8/7	M 3	30	33	1	90%	33	cloudy
8/7	N 7	35	29	1	90%	29	cloudy light wind 45.95 89.05
8/8	3	1.5 hr	–	1/4	100%	–	near [illegible]
8/9	NW 2	30	18	1	98%	18	cloudy, [illegible] 45.95 28 N, 89.05453 W
8/9	~~B~~W2	35	28, 26	2	90%	54	45.95239 N, 89.05506 W
8/9	NW 2	35	27	1 3/4	90%	27	45.95259, 89.05540 W

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location Grid Number	Dive Time ~~(Hrs)~~ min	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity GPS Coordinates
8/9	NE 1	20	30	1	90%	30	45.95259 N 89.05540 W
8/10	W 55	45	21 26 22 25	4	90	94	62° light wind, no waves, 17' Clear 45.95 89.06
8/10	W 55	20	10	1/2	90	10	63° windy choppy 18' clear 45.95 89.06
8/10	W 55	20	—	—	—	—	63° light wind choppy 19' clear 45.95 89.06 anchor rescue mission
8/10	NW 3 SW 3	2 hrs	5	1/4	99	5	70° windy no waves 2' dark shoreline 3 on grid
8/10	NW 49	20	10	1/2	98	10	70° Windy N 45 56.967 W 089 03.371
8/10	NW 50	30 min	24 24	2	98	48	72° N 45° 56.977 W 089 03.490
8/10	SW 1	25 min	28	1	90	28	light wind, 8ft, 76, good vis 45.95224, 89.05711
8/10	SW 1	10 min	24	1	90	24	
8/12	2,3,4		10	1	100%	10	windy found milfoil in neither 31, 32, 33
8/14	49/50	20	—	1/2	90%	—	cold, light rain, overcast 45.94563 N, 89.04734 W
8/14	49/50	20	22, 25	1 1/2	90%	47	cold light rain overcast 45.94563 N 89.04734 W
8/14	50	40	15, 28, 26, 28, 34	5	90%	135	45.94543 89.04432 W
8/14	NE 45	45	27, 32, 25, 30, 35, 14	7	90%	190	45.94536 N 89.07119 W
8/14	S 44	30	24, 18	2	80%	42	62, med wind, 10ft, 45.56705 N 89.04221 W

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location Grid Number	Dive Time (Hrs)	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity GPS Coordinates
8/14	S44	15					windy, 61°, 10ft, OK clear 45.54705 N, 89.04221 W
8/14	5	40	6	.5	98%	6	65, 74 45.57, 89.03
8/15	N45	25	27,	1	99	27	sunny, calm, 10ft clear 45.94615 N, 89.06444 W
8/15	C50	20	30	1	95%	30	10ft 45.94615 N, 89.06444 W
8/15	C55	30	29, 27	2	95%	56	8-10ft 45.94615 N, 89.06444 W
8/15	E54	45	26, 28, 30 27, 31, 27, 29	7	95%	195	8-10ft light wind 45.94963 N, 89.05866 W
8/16	NE54	46	25, 26	2	95%.	51	65°, 7 mph wind. 12ft, good vis 45.56976, 89.03507
8/16	NE54	45	26, 26	2	90%.	52	↓ ↓
8/16	N3	20					13ft ↓ ↓ 45.95168, 89.05646
8/16	E21	3hrs	6, 6	NA	99%.	12	windy. 4-5ft. 45.56236, 89.13881
8/21	C30	25min	30, 20	2	98%	50	64, no wind, 6ft, good clar 45.93563, 89.07079
8/21	C1	28min	25, 28	2	90%.	53	↓ ↓ 45.95265, 89.05599
8/21	C30	30min	15	1	90%.	15	45.9355 N, 89.07083 W
8/21	C45	30min		1/2	90%	43	dark 45.56228, 89.03876
8/21	NW1	35min		2/3	90%.		45.56227, 89.03876

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

Date	Location Grid number	Dive Time (Hrs)	EWM Weight (lbs)	Total Bags Harvested	% milfoil Harvest Sample	Total Harvest (lbs)	Local Conditions Temperature, Wind, Waves, Depth, Water Clarity GPS coordinates
8/21	NW1	25min		2/3	90%		11
8/23	NE 3	30min	27	1	95%	27	humid, warm, no wave
8/23	SW 3	40min	29, 29 28, 28, 27	5 } total 11	90%	141	45.56987, 89.03439
8/23	N 7	25min	30, 34	2	90%	64	45.56982, 89.03444
8/23	W 55	35min	30 34 30	3	90%	94	45.56955, 89.03522
8/24	NW8	35 min	25	1/2	90%	26	45.56970, 08903529
8/24	SW2	30 min	32	1	95%	32	45.5649 8384 053
8/24	NW1	45 min	98	3	90%	98	4556921 3748
8/28	central 3	30 min	23	1	98%	23	45.57, 89.03 13ft 100ft off dock next to jacks
8/28	21	45min	5	.33	99%	5	45.56, 89.04 free diving along shoreline
9/5	43	35min	26, 21	2	99%	47	45.57, 89.04 9ft very windy/wavy
11	30	40	20	1	11	20	hot, windy, medium-vis., 7ft
9/22	29	40	21, 30, 15	2.5	11	66	nice + sunny, slight breeze, 11ft good vis.
9/22	NW2	20min	25	.5	99%	25	45.57, 89.03 (Margie's) Last Dive ♡

N45°56.185'
W089°04.265
N45°56.140'
W089°04.260'

NOTE: The Outboard and Water Pump Both use Regular Gasoline. No Oil Mix

AQUATIC PLANT MANAGEMENT

EST. 2013

Anvil Lake EWM Removal Report 2023

PO Box 1134 Minocqua, WI 54548

Anvil Lake EWM Removal Summary 2023

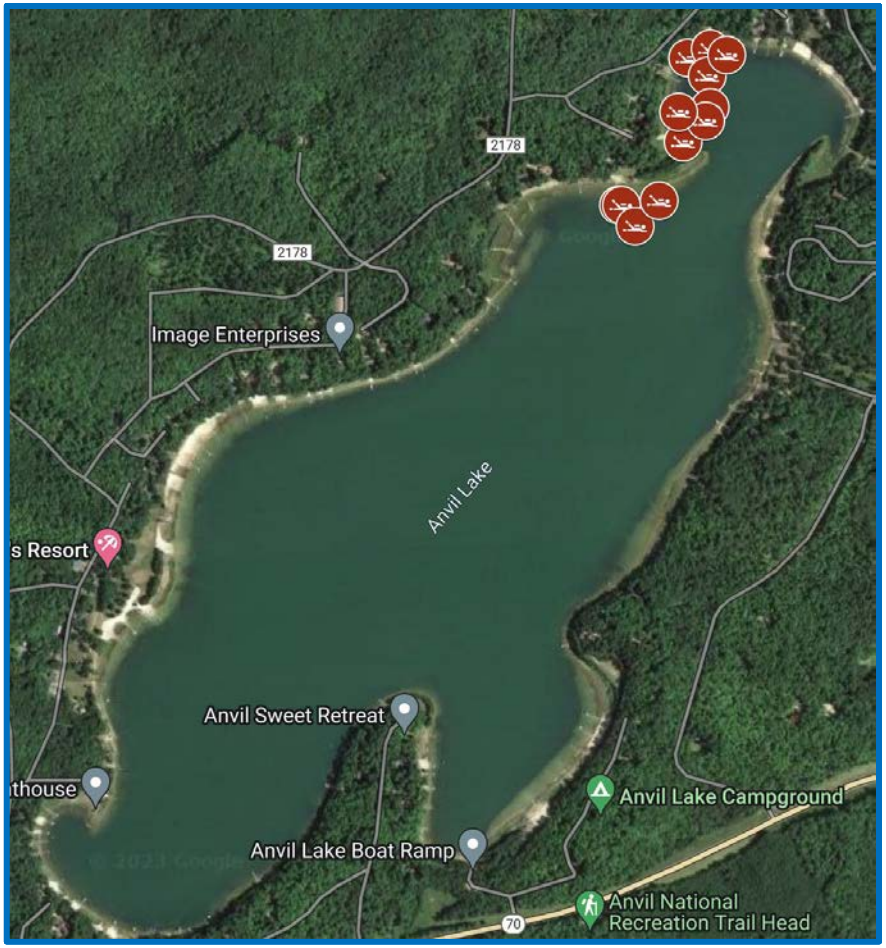
Dive Background: In July Aquatic Plant Management LLC (APM) conducted five (5) days of Diver Assisted Suction Harvesting (DASH) for Eurasian Watermilfoil (EWM) on Anvil Lake in Vilas County, WI. The team focused their efforts at 1 site as prioritized by the Anvil Lake Association and Onterra LLC. In total APM was able to remove **185.5 cubic feet of EWM** from Anvil Lake.

Date	Weather Conditions	Water Temp (F)	Underwater Dive Time (hrs)	AIS Removed (cubic ft)
7/17/2023	Partly Cloudy	69	7.1	14.0
7/18/2023	Partly Cloudy	67	7.0	28.0
7/19/2023	Thunderstorms	67	7.0	48.5
7/20/2023	Cloudy	72	7.1	35.5
7/21/2023	Periods of rain	72	7.1	59.5
Grand Total			**35.3**	**185.5**

Dive Location	Avg. Water Depth	# of Dives	Underwater Dive Time	AIS Removed (cubic feet)
A-22	8.4	12	35.3	185.5
Grand Total	**8.4**	**12**	**35.3**	**185.5**

Dive Highlights and Recommendations: The team spent their time focusing on EWM in the northeast section of the lake. The team started harvesting at the south end of the EWM colony along the west side of the north bay. They then worked their way towards the north end of the colony, picking up on progress that the in-house Anvil Lake team had already completed. Overall, Anvil Lake should continue to take an Integrated Pest Management (IPM) approach and evaluate different strategies to manage the EWM population on the lake. Continued monitoring and management efforts are important to prevent the spread of EWM throughout Anvil Lake.

Map of Anvil Lake Dive Sites



Detailed Diving Activities

Date	Dive Location	Latitude	Longitude	Underwater Dive Time (hrs)	AIS Removed (cubic ft)	AIS Density	Avg Water Depth (ft)	Native Species	Native By-Catch	Substrate Type
7/17/2023	A-22	45.95088	-89.05727	4.17	7.0	Single or Few	6.0	Grasses	0.0	Organic
7/17/2023	A-22	45.95255	-89.05717	2.92	7.0	Single or Few	6.0	Grasses	0.0	Organic
7/18/2023	A-22	45.95274	-89.05650	4.75	19.0	Clumps	7.0	Grasses	0.5	Organic
7/18/2023	A-22	45.95218	-89.05658	2.25	9.0	Clumps	7.0	Grasses	0.5	Organic
7/19/2023	A-22	45.95158	-89.05649	3.75	22.5	Single or Few	9.0	Grasses	0.5	Organic/Sand
7/19/2023	A-22	45.95130	-89.05664	3.25	26.0	Clumps	9.0	Grasses	0.5	Organic
7/20/2023	A-22	45.95149	-89.05739	2.08	8.0	Single or Few	8.0	Grasses	0.5	Organic/Sand
7/20/2023	A-22	45.95262	-89.05605	1.33	7.5	Single or Few	8.0	Grasses	0.5	Organic/Sand
7/20/2023	A-22	45.94964	-89.05913	3.67	20.0	Small Plant Colony	11.0	Grasses	0.5	Organic/Sand
7/21/2023	A-22	45.94962	-89.05905	3.50	38.5	Small Plant Colony	10.0	Grasses	0.5	Organic/Sand
7/21/2023	A-22	45.94920	-89.05867	1.00	7.0	Clumps	10.0	Grasses	0.5	Organic/Sand
7/21/2023	A-22	45.94973	-89.05798	2.58	14.0	Clumps	10.0	Grasses	0.5	Organic/Sand
Total	**12**			**35.25**	**185.5**					

E

APPENDIX E

Strategic Analysis of Aquatic Plant Management in Wisconsin (June 2019). Extracted Supplemental Chapters:

- 3.3 Herbicide Treatment
- 3.4 Physical Removal
- 3.5 Biological Control

In 2016-2019, the WDNR conducted a Strategy Analysis of Aquatic Plant Management in Wisconsin, which will serve as a reference document to mold future policies and approaches. The strategy the WDNR is following is outlined on the WDNR's APM Strategic Analysis Webpage:

https://dnr.wi.gov/topic/eia/apmsa.html

Below is a table of contents for the extracted materials for use in risk assessment of the discussed management tools within this project. Please refer to the WDNR's full text document cited above for Literature Cited.

Extracted Table of Contents

S.3.3. Herbicide Treatment

Herbicides are the most commonly employed method for controlling aquatic plants in Wisconsin. They are extremely useful tools for accomplishing aquatic plant management (APM) goals, like controlling invasive species, providing waterbody access, and ecosystem restoration. This Chapter includes basic information about herbicides and herbicide formulations, how herbicides are assessed for ecological and human health risks and registered for use, and some important considerations for the use of herbicides in aquatic environments.

A pesticide is a substance used to either directly kill pests or to prevent or reduce pest damage; herbicides are pesticides that are used to kill plants. Only a certain component of a pesticide product is intended to have pesticidal effects and this is called the active ingredient. The active ingredient is listed near the top of the first page on an herbicide product label. Any product claiming to have pesticidal properties must be registered with the U.S. EPA and regulated as a pesticide.

Inert ingredients often make up the majority of a pesticide formulation and are not intended to have pesticidal activity, although they may enhance the pesticidal activity of the active ingredient. These ingredients, such as carriers and solvents, are often added to the active ingredient by manufacturers, or by an herbicide applicator during use, in order to allow mixing of the active ingredient into water, make it more chemically stable, or aid in storage and transport. Manufacturers are not required to identify the specific inert ingredients on the pesticide label. In addition to inert ingredients included in manufactured pesticide formulations, adjuvants are inert ingredient products that may be added to pesticide formulations before they are applied to modify the properties or enhance pesticide performance. Adjuvants are typically not intended to have pesticidal properties and are not regulated as pesticides under the Federal Insecticide, Fungicide and Rodenticide Act. However, research has shown that inert ingredients can increase the efficacy and toxicity of pesticides especially if the appropriate label uses aren't followed (Mesnage et al. 2013; Defarge et al. 2016).

The combination of active ingredients and inert ingredients is what makes up a pesticide formulation. There are often many formulations of each active ingredient and pesticide manufacturers typically give a unique product or trade name to each specific formulation of an active ingredient. For instance, "Sculpin G" is a solid, granular 2,4-D amine product, while "DMA IV" is a liquid amine 2,4-D product, and the inert ingredients in these formulations are different, but both have the same active ingredient. Care should always be taken to read the herbicide product label as this will give information about which pests and ecosystems the product is allowed to be used for. Some formulations (i.e., non-aquatic formulations of glyphosate such as "Roundup") are not allowed for aquatic use and could lead to environmental degradation even if used on shorelines near the water. There are some studies which indicate that the combination of two chemicals (e.g., 2,4-D and endothall) applied together produces synergistic efficacy results that are greater than if each product was applied alone (Skogerboe et al. 2012). Conversely, there are studies which indicate the combination of two chemicals (i.e. diquat and penxosulam) which result in an antagonistic response between the herbicides, and resulted in reduced efficacy than when applying penoxsulam alone (Wersal and Madsen 2010b).

The U.S. EPA is responsible for registering pesticide products before they may be sold. In order to have their product registered, pesticide manufacturers must submit toxicity test data to the EPA that shows that the intended pesticide use(s) will not create unreasonable risks. "Unreasonable" in this context means that the risks of use outweigh the potential benefits. Once registered, the EPA must re-evaluate each pesticide and new information related to its use every 15 years. The current cycle of registration review will end in 2022, with a new cycle and review schedule starting then. In addition, EPA may decide to only register certain uses of any given pesticide product and can also require that only trained personnel can apply a pesticide before the risks outweigh the benefits. Products requiring training before application are called Restricted Use Pesticides.

As part of their risk assessments, EPA reviews information related to pesticide toxicity. Following laboratory testing, ecotoxicity rankings are given for different organismal groups based on the dosage that would cause harmful ecological effects (e.g., death, reduction in growth, reproductive impairment, and others). For example, the ecotoxicity ranking for 2,4-D ranges from "practically non-toxic" to "slightly toxic" for freshwater invertebrates, meaning tests have shown that doses of >100 ppm and 10-100 ppm are needed to cause 50% mortality or immobilization in the test population, respectively. Different dose ranges and indicators of "harm" are used to assess toxicity depending on the organisms being tested. More information can be found on the EPA's website.

Beyond selecting herbicide formulations approved for use in aquatic environments, there are additional factors to consider supporting appropriate and effective herbicide use in those environments. Herbicide treatments are often used in terrestrial restorations, so they are also often requested in the management and restoration of aquatic plant communities. However, unlike applications in a terrestrial environment, the fluid environment of freshwater systems presents a set of unique challenges. Some general best practices for addressing challenges associated with herbicide dilution, migration, persistence, and non-target impacts are described in Chapter 7.4. More detailed documentation of these challenges is described below and in discussions on individual herbicides in Supplemental Chapter S.3.3 (Herbicide Treatment).

As described in Chapter 7.4, when herbicide is applied to waters, it can quickly migrate offsite and dilute to below the target concentrations needed to provide control (Hoeppel and Westerdal 1983; Madsen et al. 2015; Nault et al. 2015). Successful plant control with herbicide is dependent on concentration exposure time (CET) relationships. In order to examine actual observed CET relationships following herbicide applications in Wisconsin lakes, a study of herbicide CET and Eurasian watermilfoil (*Myriophyllum spicatum*) control efficacy was conducted on 98 small-scale (0.1-10 acres) 2,4-D treatment areas across 22 lakes. In the vast majority of cases, initial observed 2,4-D concentrations within treatment areas were far below the applied target concentration, and then dropped below detectable limits within a few hours after treatment (Nault et al. 2015). These results indicate the rapid dissipation of herbicide off of the small treatment areas resulted in water column concentrations which were much lower than those recommended by previous laboratory CET studies for effective Eurasian watermilfoil control. Concentrations in protected treatment areas (e.g., bays, channels) were initially higher than those in areas more exposed to wind and waves, although concentrations quickly dissipated to below detectable limits within hours after treatment regardless of spatial location. Beyond confining small-scale treatments to protected areas, utilizing or integrating faster-acting herbicides with shorter CET requirements may also help to compensate for reductions in plant control due to dissipation (Madsen et al. 2015). The use of chemical curtains or adjuvants (weighting or sticking agents) may also help to maintain adequate CET, however more research is needed in this area.

This rapid dissipation of herbicide off of treatment areas is important for resource managers to consider in planning, as treating numerous targeted areas at a 'localized' scale may actually result in low-concentrations capable of having lakewide impacts as the herbicide dissipates off of the individual treatment sites. In general, if the percentage of treated areas to overall lake surface area is >5% and targeted areas are treated at relatively high 2,4-D concentrations (e.g., 2.0-4.0 ppm), then anticipated lakewide concentrations after dissipation should be calculated to determine the likelihood of lakewide effects (Nault et al. 2018).

Aquatic-use herbicides are commercially available in both liquid and granular forms. Successful target species control has been reported with both granular and liquid formulations. While there has been a commonly held belief that granular products are able to 'hold' the herbicide on site for longer periods of time, actual field comparisons between granular and liquid 2,4-D forms revealed that they dissipated similarly when applied at small-scale sites (Nault et al. 2015). In fact, liquid 2,4-D had higher initial observed water column concentrations than the granular form, but in the majority of cases concentrations of both forms decreased rapidly to below detection limits within several hours after treatment Nault et al. 2015). Likewise, according to United Phosphorus, Inc. (UPI), the sole manufacturer of endothall, the granular formulation of endothall does not hold the product in a specific area significantly longer than the liquid form (Jacob Meganck [UPI], *personal communication*).

In addition, the stratification of water and the formation of a thermal density gradient can confine the majority of applied herbicides in the upper, warmer water layer of deep lakes. In some instances, the entire lake water volume is used to calculate how much active ingredient should be applied to achieve a specific lakewide target concentration. However, if the volume of the entire lake is used to calculate application rates for stratified lakes, but the chemical only readily mixes into the upper water layer, the achieved lakewide concentration is likely to be much higher than the target concentration, potentially resulting in unanticipated adverse ecological impacts.

Because herbicides cannot be applied directly to specific submersed target plants, the dissipation of herbicide over the treatment area can lead to direct contact with non-target plants and animals. No herbicide is completely selective (i.e., effective specifically on only a single target species). Some plant species may be more susceptible to a given herbicide than others, highlighting the importance of choosing the appropriate herbicide, or other non-chemical management approach, to minimize potential non-target effects of treatment. There are many herbicides and plant species for which the CET relationship that would negatively affect the plant is unknown. This is particularly important in the case of rare, special concern, or threatened and endangered species. Additionally, loss of habitat following any herbicide treatment or other management technique may cause indirect reductions in populations of invertebrates or other organisms. Some organisms will only recolonize the managed areas as aquatic plants become re-established.

Below are reviews for the most commonly used herbicides for APM in Wisconsin. Much of the information here was pulled directly from DNR's APM factsheets (http://dnr.wi.gov/lakes/plants/factsheets/), which were compiled in 2012 using U.S. EPA herbicide product labels, U.S. Army Corps of Engineers reports, and communications with natural resource agencies in other northern, lake-rich states. These have been supplemented with more recent information from primary research publications.

Each pesticide has at least one mode of action which is the specific mechanism by which the active ingredient exerts a toxic effect. For example, some herbicides inhibit production of the pigments needed for photosynthesis while others mimic plant growth hormones and cause uncontrolled and unsustainable growth. Herbicides are often classified as either systemic or contact in mode of action, although some herbicides are able to function under various modes of action depending on environmental variables such as water temperature. Systemic pesticides are those that are absorbed by organisms and can be moved or translocated within the organism. Contact pesticides are those that exert toxic effects on the part(s) of an organism that they come in contact with. The amount of exposure time needed to kill an organism is based on the specific mode of action and the concentration of any given pesticide. In the descriptions below herbicides are generally categorized into which environment (above or below water) they are primarily used and a relative assessment of how quickly they impact plants. Herbicides can be applied in many ways. In lakes, they are usually applied to the water's surface (or below the water's surface) through controlled release by equipment including spreaders, sprayers, and underwater hoses. In wetland environments, spraying by helicopter, backpack sprayer, or application by cut-stem dabbing, wicking, injection, or basal bark application are also used.

S.3.3.1. Submersed or Floating, Relatively Fast-Acting Herbicides

Diquat

Registration and Formulations

Diquat (or diquat dibromide) initially received Federal registration for control of submersed and floating aquatic plants in 1962. It was initially registered with the U.S. EPA in 1986, evaluated for reregistration in 1995, and is currently under registration review. A registration review decision was expected in 2015 but has not been released (EPA Diquat Plan 2011). The active ingredient is 6,7-dihydrodipyrido[1,2-α:2',1'-c] pyrazinediium dibromide, and is commercially sold as liquid formulations for aquatic use.

Mode of Action and Degradation

Diquat is a fast-acting herbicide that works through contact with plant foliage by disrupting electron flow in photosystem I of the photosynthetic reaction, ultimately causing the destruction of cell membranes (Hess 2000; WSSA 2007). Plant tissues in contact with diquat become impacted within several hours after application, and within one to three days the plant tissue will become necrotic. Diquat is considered a non-selective herbicide and will rapidly kill a wide variety of plants on contact. Because diquat is a fast-acting herbicide, it is oftentimes used for managing plants growing in areas where water exchange is anticipated to limit herbicide exposure times, such as small-scale treatments.

Due to rapid vegetation decomposition after treatment, only partial treatments of a waterbody should be conducted to minimize dissolved oxygen depletion and associated negative impacts on fish and other aquatic organisms. Untreated areas can be treated with diquat 14 days after the first application.

Diquat is strongly attracted to silt and clay particles in the water and may not be very effective under highly turbid water conditions or where plants are covered with silt (Clayton and Matheson 2010).

The half-life of diquat in water generally ranges from a few hours to two days depending on water quality and other environmental conditions. Diquat has been detected in the water column from less than a day up towards 38 DAT, and remains in the water column longer when treating waterbodies with sandy sediments with lower organic matter and clay content (Coats et al. 1964; Grzenda et al. 1966; Yeo 1967; Sewell et al. 1970; Langeland and Warner 1986; Langeland et al. 1994; Poovey and Getsinger 2002; Parsons et al. 2007; Gorzerino et al. 2009; Robb et al. 2014). One study reported that diquat is chemically stable within a pH range of 3 to 8 (Florêncio et al. 2004). Due to the tendency of diquat to be rapidly adsorbed to suspended clays and particulates, long exposure periods are oftentimes not possible to achieve in the field. Studies conducted by Wersal et al. (2010a) did not observe differences in target species efficacy between daytime versus night-time applications of diquat. While large-scale diquat treatments are typically not implemented, a study by Parsons et al. (2007), observed declines in both dissolved oxygen and water clarity following the herbicide treatment.

Diquat binds indefinitely to organic matter, allowing it to accumulate and persist in the sediments over time (Frank and Comes 1967; Simsiman and Chesters 1976). It has been reported to have a very long-lived half-life (1000 days) in sediment because of extremely tight soil sorption, as well as an extremely low rate of degradation after association with sediment (Wauchope et al. 1992; Peterson et al. 1994). Both photolysis and microbial degradation are thought to play minor roles in degradation (Smith and Grove 1969; Emmett 2002). Diquat is not known to leach into groundwater due to its very high affinity to bind to soils.

One study reported that combinations of diquat and penoxsulam resulted in an antagonistic response between the herbicides when applied to water hyacinth (*Eichhornia crassipes*) and resulted in reduced efficacy than when applying penoxsulam alone. The antagonistic response is likely due to the rapid cell destruction by diquat that limits the translocation and efficacy of the slower acting enzyme inhibiting herbicides (Wersal and Madsen 2010b).

Toxicology

There are no restrictions on swimming or eating fish from waterbodies treated with diquat. Depending on the concentration applied, there is a 1-3 day waiting period after treatment for drinking water. However, in one study, diquat persisted in the water at levels above the EPA drinking water standard for at least 3 DAT, suggesting that the current 3-day drinking water restriction may not be sufficient under all application scenarios (Parsons et al. 2007). Water treated with diquat should not be used for pet or livestock drinking water for one day following treatment. The irrigation restriction for food crops is five days, and for ornamental plants or lawn/turf, it varies from one to three days depending on the concentration used. A study by Mudge et al. (2007)

on the effects of diquat on five popular ornamental plant species (begonia, dianthus, impatiens, petunia, and snapdragon) found minimal risks associated with irrigating these species with water treated with diquat up to the maximum use rate of 0.37 ppm.

Ethylene dibromide (EDB) is a trace contaminant in diquat products which originates from the manufacturing process. EDB is a documented carcinogen, and the EPA has evaluated the health risk of its presence in formulated diquat products. The maximum level of EDB in diquat dibromide is 0.01 ppm (10 ppb). EBD degrades over time, and it does not persist as an impurity.

Diquat does not have any apparent short-term effects on most aquatic organisms that have been tested at label application rates (EPA Diquat RED 1995). Diquat is not known to bioconcentrate in fish tissues. A study using field scenarios and well as computer modelling to examine the potential ecological risks posed by diquat determined that diquat poses a minimal ecological impact to benthic invertebrates and fish (Campbell et al. 2000). Laboratory studies indicate that walleye (*Sander vitreus*) are more sensitive to diquat than some other fish species, such as smallmouth bass (*Micropterus dolomieu),* largemouth bass (*Micropterus salmoides*), and bluegills (*Lepomis macrochirus*), with individuals becoming less sensitive with age (Gilderhus 1967; Paul et al. 1994; Shaw and Hamer 1995). Maximum application rates were lowered in response to these studies, such that applying diquat at recommended label rates is not expected to result in toxic effects on fish (EPA Diquat RED 1995). Sublethal effects such as respiratory stress or reduced swimming capacity have been observed in studies where certain fish species (e.g., yellow perch (*Perca flavescens*), rainbow trout (*Oncorhynchus mykiss*), and fathead minnows (*Pimephales promelas*)) have been exposed to diquat concentrations (Bimber et al. 1976; Dodson and Mayfield 1979; de Peyster and Long 1993). Another study showed no observable effects on eastern spiny softshell turtles (*Apalone spinifera spinifera*; Paul and Simonin 2007). Reduced size and pigmentation or increased mortality have been shown in some amphibians but at above recommended label rates (Anderson and Prahlad 1976; Bimber and Mitchell 1978; Dial and Bauer-Dial 1987). Toxicity data on invertebrates are scarce and diquat is considered not toxic to most of them. While diquat is not highly toxic to most invertebrates, significant mortality has been observed in some species at concentrations below the maximum label use rate for diquat, such as the amphipod *Hyalella azteca* (Wilson and Bond 1969; Williams et al. 1984), water fleas (*Daphnia* spp.). Reductions in habitat following treatment may also contribute to reductions of *Hyalella azteca*. For more information, a thorough risk assessment for diquat was compiled by the Washington State Department of Ecology Water Quality Program (WSDE 2002). Available toxicity data for fish, invertebrates, and aquatic plants is summarized in tabular format by Campbell et al. (2000).
Species Susceptibility

Diquat has been shown to control a variety of invasive submerged and floating aquatic plants, including Eurasian watermilfoil (*Myriophyllum spicatum*), curly-leaf pondweed (*Potamogeton crispus*), parrot feather (*Myriophyllum aquaticum*), Brazilian waterweed (*Egeria densa*), water hyacinth, water lettuce (*Pistia stratiotes*), flowering rush (*Butomus umbellatus*), and giant salvinia (*Salvinia molesta*; Netherland et al. 2000; Nelson et al. 2001; Poovey et al. 2002; Langeland et al. 2002; Skogerboe et al. 2006; Martins et al. 2007, 2008; Wersal et al. 2010a; Wersal and Madsen 2010a; Wersal and Madsen 2012; Poovey et al. 2012; Madsen et al. 2016). Studies conducted on the use of diquat for hydrilla (*Hydrilla verticillata*) and fanwort (*Cabomba caroliniana*) control have resulted in mixed reports of efficacy (Van et al. 1987; Langeland et al. 2002; Glomski et al. 2005; Skogerboe et al. 2006; Bultemeier et al. 2009; Turnage et al. 2015). Non-native phragmites (*Phragmites australis* subsp. *australis*) has been shown to not be significantly reduced by diquat (Cheshier et al. 2012).

Skogerboe et al. 2006 reported on the efficacy of diquat (0.185 and 0.37 ppm) under flow-through conditions (observed half-lives of 2.5 and 4.5 hours, respectively). All diquat treatments reduced Eurasian watermilfoil biomass by 97 to 100% compared to the untreated reference, indicating that this species is highly susceptible to diquat. Netherland et al. (2000) examined the role of various water temperatures (10, 12.5, 15, 20, and 25°C) on the efficacy of diquat applications for controlling curly-leaf pondweed. Diquat was applied at rates of 0.16-0.50 ppm, with exposure times of 9-12 hours. Diquat efficacy on curly-leaf pondweed was inhibited as water temperature decreased, although treatments at all temperatures were observed to significantly reduce biomass and turion formation. While the most efficacious curly-leaf pondweed treatments were conducted at 25°C, waiting until water warms to this temperature limits the potential for reducing turion production. Diquat applied at 0.37 ppm (with a 6 to 12-hour exposure time) or at 0.19 ppm (with a 72-hour exposure time) was effective at reducing biomass of flowering rush (Poovey et al. 2012; Madsen et al. 2016).

Native species that have been shown to be affected by diquat include: American lotus (*Nelumbo lutea*), common bladderwort (*Utricularia vulgaris*), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), needle spikerush (*Eleocharis acicularis*), Illinois pondweed (*Potamogeton illinoensis*), leafy pondweed (*P. foliosus*), clasping-leaf pondweed (*P. richardsonii*), fern pondweed (*P. robbinsii*), sago pondweed (*Stuckenia pectinata*), and slender naiad (*Najas flexilis*) (Hofstra et al. 2001; Glomski et al. 2005; Skogerboe et al. 2006; Mudge 2013; Bugbee et al. 2015; Turnage et al. 2015). Diquat is particularly toxic to duckweeds (*Landoltia punctata* and *Lemna* spp.), although certain populations of dotted duckweed (*Landoltia punctata*) have developed resistance of diquat in waterbodies with a long history (20-30 years) of repeated diquat treatments (Peterson et al. 1997; Koschnick et al. 2006). Variable effects have been observed for water celery (*Vallisneria americana*), long-leaf pondweed (*Potamogeton nodosus*), and variable-leaf watermilfoil (*Myriophyllum heterophyllum*; Skogerboe et al. 2006; Glomski and Netherland 2007; Mudge 2013).

Flumioxazin

Registration and Formulations

Flumioxazin (2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-isoindole-1,3(2H)-dione) was registered with the U.S. EPA for agricultural use in 2001 and registered for aquatic use in 2010. The first registration review of flumioxazin is expected to be completed in 2017 (EPA Flumioxazin Plan 2011). Granular and liquid formulations are available for aquatic use.

Mode of Action and Degradation

The mode of action of flumioxazin is through disruption of the cell membrane by inhibiting protoporphyrinogen oxidase which blocks production of heme and chlorophyll. The efficacy of this mode of action is dependent on both light intensity and water pH (Mudge et al. 2012a; Mudge and Haller 2010; Mudge et al. 2010), with herbicide degradation increasing with pH and efficacy decreasing as light intensity declines.

Flumioxazin is broken down by water (hydrolysis), light (photolysis) and microbes. The half-life ranges from approximately 4 days at pH 5 to 18 minutes at pH 9 (EPA Flumioxazin 2003). In the majority of Wisconsin lakes half-life should be less than 1 day.

Flumioxazin degrades into APF (6-amino-7-fluro-4-(2-propynyl)-1,4,-benzoxazin-3(2H)-one) and THPA (3,4,5,6-tetrahydrophthalic acid). Flumioxazin has a low potential to leach into groundwater due to the very quick hydrolysis and photolysis. APF and THPA have a high potential to leach through soil and could be persistent.

Toxicology

Tests on warm and cold-water fishes indicate that flumioxazin is "slightly to moderately toxic" to fish on an acute basis, with possible effects on larval growth below the maximum label rate of 0.4 ppm (400 ppb). Flumioxazin is moderately to highly toxic to aquatic invertebrates, with possible impacts below the maximum label rate. The potential for bioaccumulation is low since degradation in water is so rapid. The metabolites APF and THPA have not been assessed for toxicity or bioaccumulation.

The risk of acute exposure is primarily to chemical applicators. Concentrated flumioxazin doesn't pose an inhalation risk but can cause skin and eye irritation. Recreational water users would not be exposed to concentrated flumioxazin.

Acute exposure studies show that flumioxazin is "practically non-toxic" to birds and small mammals. Chronic exposure studies indicate that flumioxazin is non-carcinogenic. However, flumioxazin may be an endocrine disrupting compound in mammals (EPA Flumioxazin 2003), as some studies on small mammals did show effects on reproduction and larval development, including reduced offspring viability, cardiac and skeletal malformations, and anemia. It does not bioaccumulate in mammals, with the majority excreted in a week.

Species Susceptibility

The maximum target concentration of flumioxazin is 0.4 ppm (400 ppb). At least one study has shown that flumioxazin (at or below the maximum label rate) will control the invasive species fanwort (*Cabomba caroliniana*), hydrilla (*Hydrilla verticillata*), Japanese stiltgrass (*Microstegium vimineum*), Eurasian watermilfoil (*Myriophyllum spicatum*), water lettuce (*Pistia stratiotes*), curly-leaf pondweed (*Potamogeton crispus*), and giant salvinia (*Salvinia molesta*), while water hyacinth (*Eichhornia crassipes*) and water pennyworts (*Hydrocotyle* spp.) do not show significant impacts (Bultemeier et al. 2009; Glomski and Netherland 2013a; Glomski and Netherland 2013b; Mudge 2013; Mudge and Netherland 2014; Mudge and Haller 2012; Mudge and Haller 2010). Flowering rush (*Butomus umbellatus*; submersed form) showed mixed success in herbicide trials

(Poovey et al. 2012; Poovey et al. 2013). Native species that were significantly impacted (in at least one study) include coontail (*Ceratophyllum demersum*), water stargrass (*Heteranthera dubia*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*), America lotus (*Nelumbo lutea*), pond-lilies (*Nuphar* spp.), white waterlily (*Nymphaea odorata*), white water crowfoot (*Ranunculus aquatilis*), and broadleaf cattail (*Typha latifolia*), while common waterweed (*Elodea canadensis*), squarestem spikerush (*Eleocharis quadrangulate*), horsetail (*Equisetum hyemale*), southern naiad (*Najas guadalupensis*), pickerelweed (*Pontederia cordata*), Illinois pondweed (*Potamogeton illinoensis*), long-leaf pondweed (*P. nodosus*), broadleaf arrowhead (*Sagittaria latifolia*), hardstem bulrush (*Schoenoplectus acutus*), common three-square bulrush (*S. pungens*), softstem bulrush (*S. tabernaemontani*), sago pondweed (*Stuckenia pectinata*), and water celery (*Vallisneria americana*) were not impacted relative to controls. Other species are likely to be susceptible, for which the effects of flumioxazin have not yet been evaluated.

Carfentrazone-ethyl

Registration and Formulations

Carfentrazone-ethyl is a contact herbicide that was registered with the EPA in 1998. The active ingredient is ethyl 2-chloro-3-[2 -chloro-4-fluoro-5-[4 -(difluoromethyl)-4,5-diydro-3-methyl-5-oxo-1H-1,2,4-trizol-1-yl)phenyl]propanoate. A liquid formulation of carfentrazone-ethyl is commercially sold for aquatic use.

Mode of Action and Degradation

Carfentrazone-ethyl controls plants through the process of membrane disruption which is initiated by the inhibition of the enzyme protoporphyrinogen oxidase, which interferes with the chlorophyll biosynthetic pathway. The herbicide is absorbed through the foliage of plants, with injury symptoms viable within a few hours after application, and necrosis and death observed in subsequent weeks.

Carfentrazone-ethyl breaks down rapidly in the environment, while its degradates are persistent in aquatic and terrestrial environments. The herbicide primarily degrades via chemical hydrolysis to carfentrazone-chloropropionic acid, which is then further degraded to carfentrazone -cinnamic, -propionic, -benzoic and 3-(hydroxymethyl)-carfentrazone-benzoic acids. Studies have shown that degradation of carfentrazone-ethyl applied to water (pH = 7-9) has a half-life range of 3.4-131 hours, with longer half-lives (>830 hours) documented in waters with lower pH (pH = 5). Extremes in environmental conditions such as temperature and pH may affect the activity of the herbicide, with herbicide symptoms being accelerated under warm conditions.

While low levels of chemical residue may occur in surface and groundwater, risk concerns to non-target organisms are not expected. If applied into water, carfentrazone-ethyl is expected to adsorb to suspended solids and sediment.

Toxicology

There is no restriction on the use of treated water for recreation (e.g., fishing and swimming). Carfentrazone-ethyl should not be applied directly to water within ¼ mile of an active potable water intake. If applied around or within potable water intakes, intakes must be turned off prior to application and remain turned off for a minimum of 24 hours following application; the intake may be turned on prior to 24 hours only if the carfentrazone-ethyl and major degradate level is determined by laboratory analysis to be below 200 ppb. Do not use water treated with carfentrazone-ethyl for irrigation in commercial nurseries or greenhouses. In scenarios where the herbicide is applied to 20% or more of the surface area, treated water should not be used for irrigation of crops until 14 days after treatment, or until the carfentrazone-ethyl and major degradate level is determined by analysis to be below 5 ppb.

In scenarios where the herbicide is applied as a spot treatment to less than 20% of the waterbody surface area, treated water may be used for irrigation by commercial turf farms and on residential turf and ornamentals without restriction. If more than 20% of the waterbody surface area is treated, water should not be used for irrigation of turf or ornamentals until 14 days after treatment, or until the carfentrazone-ethyl and major degradate level is determined by analysis to be below 5 ppb.

Carfentrazone-ethyl is listed as very toxic to certain species of algae and listed as moderately toxic to fish and aquatic animals. Treatment of dense plants beds may result in dissolved oxygen declines from plant decomposition which may lead to fish suffocation or death. To minimize impacts, applications of this herbicide should treat up to a maximum of half of the waterbody at a time and wait a minimum of 14 days before retreatment or treatment of the remaining half of the waterbody. Carfentrazone-ethyl is considered to be practically non-toxic to birds on an acute and sub-acute basis.

Carfentrazone-ethyl is harmful if swallowed and can be absorbed through the skin or inhaled. Those who mix or apply the herbicide need to protect their skin and eyes from contact with the herbicide to minimize irritation and avoid breathing the spray mist. Carfentrazone-ethyl is not carcinogenic, neurotoxic, or mutagenic and is not a developmental or reproductive toxicant.

Species Susceptibility

Carfentrazone-ethyl is used for the control of floating and emergent aquatic plants such as duckweeds (*Lemna* spp.), watermeals (*Wolffia* spp.), water lettuce (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*), and salvinia (*Salvinia* spp.). Carfentrazone-ethyl can also be used to control submersed plants such as Eurasian watermilfoil (*Myriophyllum spicatum*).

S.3.3.2. Submersed, Relatively Slow-Acting Herbicides

2,4-D

Registration and Formulations

2,4-D is an herbicide that is widely used as a household weed-killer, agricultural herbicide, and aquatic herbicide. It has been in use since 1946 and was registered with the U.S. EPA in 1986 and evaluated and reregistered in 2005. It is currently being evaluated for reregistration, and the estimated registration review decision date was in 2017 (EPA 2,4-D Plan 2013). The active ingredient is 2,4-dichloro-phenoxyacetic acid. There are two types of 2,4-D used as aquatic herbicides: dimethyl amine salt (DMA) and butoxyethyl ester (BEE). The ester formulations are toxic to fish and some important invertebrates such as water fleas (*Daphnia* spp.) and midges at application rates. 2,4-D is commercially sold as a liquid amine as well as ester and amine granular products for control of submerged, emergent, and floating-leaf vegetation. Only 2,4-D products labeled for use in aquatic environments may be used to control aquatic plants.

Mode of Action and Degradation

Although the exact mode of action of 2,4-D is not fully understood, the herbicide is traditionally believed to target broad-leaf dicotyledon species with minimal effects generally observed on numerous monocotyledon species, especially in terrestrial applications (WSSA 2007). 2,4-D is a systemic herbicide which affects plant cell growth and division. Upon application, it mimics the natural plant hormone auxin, resulting in bending and twisting of stems and petioles followed by growth inhibition, chlorosis (reduced coloration) at growing points, and necrosis or death of sensitive species (WSSA 2007). Following treatment, 2,4-D is taken up by the plant and translocated through the roots, stems and leaves, and plants begin to die within one to two weeks after application, but can take several weeks to decompose. The total length of target plant roots can be an important in determining the response of an aquatic plant to 2,4-D (Belgers et al. 2007). Treatments should be made when plants are growing. After treatment, the 2,4-D concentration in the water is reduced primarily through microbial activity, off-site movement by water, or adsorption to small particles in silty water.

Previous studies have indicated that 2,4-D degradation in water is highly variable depending on numerous factors such as microbial presence, temperature, nutrients, light, oxygen, organic content of substrate, pH, and whether or not the water has been previously exposed to 2,4-D or other phenoxyacetic acids (Howard et al. 1991). Once in contact with water, both the ester and amine formulations dissociate to the acid form of 2,4-D, with a faster dissociation to the acid form under more alkaline conditions. 2,4-D degradation products include 1,2,4-benzenetriol, 2,4-dichlorophenol, 2,4-dichloroanisole, chlorohydroquinone (CHQ), 4-chlorophenol, and volatile organics.

The half-life of 2,4-D has a wide range depending on water conditions. Half-lives have been reported to range from 12.9 to 40 days, while in anaerobic lab conditions the half-life has been measured at 333 days (EPA RED 2,4-D 2005). In large-scale low-concentration 2,4-D treatments monitored across numerous Wisconsin lakes, estimated half-lives ranged from 4-76 days, and the rate of herbicide degradation was generally observed to be slower in oligotrophic seepage lakes. Of these large-scale 2,4-D treatments, the threshold for irrigation of plants which are not labeled for direct treatment with 2,4-D (<0.1 ppm (100 ppb) by 21 DAT) was exceeded the majority of the treatments (Nault et al. 2018). Previous historical use of 2,4-D may also be an important variable to consider, as microbial communities which are responsible for the breakdown of 2,4-D may potentially exhibit changes in community composition over time with repeated use (de Lipthay et al. 2003; Macur et al. 2007). Additional detailed information on the environmental fate of 2,4-D is compiled by Walters 1999.

There have been some preliminary investigations into the concentration of primarily granular 2,4-D in water-saturated sediments, or pore-water. Initial results suggest the concentration of 2,4-D in the pore-water varies widely from site to site following a chemical treatment, although in some locations the concentration in the pore-water was observed to be 2-3 times greater than the application rate (Jim Kreitlow [DNR], *personal communication*). Further research and additional studies are needed to assess the implications of this finding for target species control and non-target impacts on a variety of organisms.

Toxicology

There are no restrictions on eating fish from treated waterbodies, human drinking water, or pet/livestock drinking water. Based upon 2,4-D ester (BEE) product labels, there is a 24-hour waiting period after treatment for swimming. Before treated water can be used for irrigation, the concentration must be below 0.1 ppm (100 ppb), or at least 21 days must pass. Adverse health effects can be produced by acute and chronic exposure to 2,4-D. Those who mix or apply 2,4-D need to protect their skin and eyes from contact with 2,4-D products to minimize irritation and avoid inhaling the spray. In its consideration of exposure risks, the EPA believes no significant risks will occur to recreational users of water treated with 2,4-D.

There are differences in toxicity of 2,4-D depending on whether the formulation is an amine (DMA) or ester (BEE), with the BEE formulation shown to be more toxic in aquatic environments. BEE formulations are considered toxic to fish and invertebrates such as water fleas and midges at operational application rates. DMA formulations are not considered toxic to fish or invertebrates at operational application rates. Available data indicate 2,4-D does not accumulate at significant levels in the tissues of fish. Although fish exposed to 2,4-D may take up very small amounts of its breakdown products to then be metabolized, the vast majority of these products are rapidly excreted in urine (Ghassemi et al. 1981).

On an acute basis, EPA assessment considers 2,4-D to be “practically non-toxic” to honeybees and tadpoles. Dietary tests (substance administered in the diet for five consecutive days) have shown 2,4-D to be “practically non-toxic” to birds, with some species being more sensitive than others (when 2,4-D was orally and directly administered to birds by capsule or gavage, the substance was “moderately toxic” to some species). For freshwater invertebrates, EPA considers 2,4-D amine to be “practically non-toxic” to “slightly toxic” (EPA RED 2,4-D 2005). Field studies on the potential impact of 2,4-D on benthic macroinvertebrate communities have generally not observed significant changes, although at least one study conducted in Wisconsin observed negative correlations in macroinvertebrate richness and abundance following treatment, and further studies are likely warranted (Stephenson and Mackie 1986; Siemering et al. 2008; Harrahy et al. 2014). Additionally, sublethal effects such as mouthpart deformities and change in sex ratio have been observed in the midge *Chironomus riparius* (Park et al. 2010).

While there is some published literature available looking at short-term acute exposure of various aquatic organisms to 2,4-D, there is limited literature is available on the effects of low-concentration chronic exposure to commercially available 2,4-D formulations (EPA RED 2,4-D 2005). The department recently funded several projects related to increasing our understanding of the potential impacts of chronic exposure to low-concentrations of 2,4-D through AIS research and development grants. One of these studies observed that fathead minnows (*Pimephales promelas*) exposed under laboratory conditions for 28 days to 0.05 ppm (50 ppb) of two different commercial formulations of 2,4-D (DMA® 4 IVM and Weedestroy® AM40) had decreases in larval survival and tubercle presence in males, suggesting that these formulations may exert some degree of chronic toxicity or endocrine-disruption which has not been previously observed when testing pure compound 2,4-D (DeQuattro and Karasov 2016). However, another follow-up study determined that fathead minnow larval survival (30 days post hatch) was decreased following exposure of eggs and larvae to pure 2,4-D, as well as to the two commercial formulations (DMA® 4 IVM and Weedestroy® AM40), and also identified a critical window of exposure for effects on survival to the period between fertilization and 14 days post hatch (Dehnert et al. 2018).

Another related follow-up laboratory study is currently being conducted to examine the effects of 2,4-D exposure on embryos and larvae of several Wisconsin native fish species. Preliminary results indicate that negative impacts of embryo survival were observed for 4 of the 9 native species tested (e.g., walleye, northern pike, white crappie, and largemouth bass), and negative impacts of larval survival were observed for 4 of 7 natives species tested (e.g., walleye, yellow perch, fathead minnows, and white suckers; Dehnert and Karasov, *in progress*).

A controlled field study was conducted on six northern Wisconsin lakes to understand the potential impacts of early season large-scale, low-dose 2,4-D on fish and zooplankton (Rydell et al. 2018). Three lakes were treated with early season low-dose liquid 2,4-D (lakewide epilimnetic target rate: 0.3 ppm (300 ppb)), while the other three lakes served as reference without treatment. Zooplankton densities were similar within lakes during the pre-treatment year and year of treatment, but different trends in several zooplankton species were observed in treatment lakes during the year following treatment. Peak abundance of larval yellow perch (*Perca flavescens*) was lower in the year following treatment, and while this finding was not statistically significant, decreased larval yellow perch abundance was not observed in reference lakes. The observed declines in larval yellow perch abundance and changes in zooplankton trends within treatment lakes in the year after treatment may be a result of changes in aquatic plant communities and not a direct effect of treatment. No significant effect was observed on peak abundance of larval largemouth bass (*Micropterus salmoides*), minnows, black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), or juvenile yellow perch. Larval black crappie showed no detectable response in growth or feeding success. Net pen trials for juvenile bluegill indicated no significant difference in survival between treatment and reference trials, indicating that no direct mortality was associated with the herbicide treatments. Detection of the level of larval fish mortality found in the lab studies would not have been possible in the field study given large variability in larval fish abundance among lakes and over time.

Concerns have been raised about exposure to 2,4-D and elevated cancer risk. Some epidemiological studies have found associations between 2,4-D and increased risk of non-Hodgkin lymphoma in high exposure populations, while other studies have shown that increased cancer risk may be caused by other factors (Hoar et al. 1986; Hardell and Eriksson 1999; Goodman et al. 2015). The EPA determined in 2005 that there is not sufficient evidence to classify 2,4-D as a human carcinogen (EPA RED 2,4-D 2005).

Another chronic health concern with 2,4-D is the potential for endocrine disruption. There is some evidence that 2,4-D may have effects on reproductive development, though other studies suggest the findings may have had other causes (Garry et al. 1996; Coady et al. 2013; Goldner et al. 2013; Neal et al. 2017). The extent and implications of this are not clear and it is an area of ongoing research.

Detailed literature reviews of 2,4-D toxicology have been compiled by Garabrant and Philbert (2002), Jervais et al. (2008), and Burns and Swaen (2012).

<u>Species Susceptibility</u>

With appropriate concentration and exposure, 2,4-D is capable of reducing abundance of the invasive plant species Eurasian watermilfoil (*Myriophyllum spicatum*), parrot feather (*M. aquaticum*), water chestnut (*Trapa natans*), water hyacinth (*Eichhornia crassipes*), and water lettuce (*Pistia stratiotes*; Elliston and Steward 1972; Westerdahl et al. 1983; Green and Westerdahl 1990; Helsel et al. 1996, Poovey and Getsinger 2007; Wersal et al. 2010b; Cason and Roost 2011; Robles et al. 2011; Mudge and Netherland 2014). Perennial pepperweed (*Lepidium latifolium)* and fanwort (*Cabomba caroliniana*) have been shown to be somewhat tolerant of 2,4-D (Bultemeier et al. 2009; Whitcraft and Grewell 2012).

Efficacy and selectivity of 2,4-D is a function of concentration and exposure time (CET) relationships, and rates of 0.5-2.0 ppm coupled with exposure times ranging from 12 to 72 hours have been effective at achieving Eurasian watermilfoil control under laboratory settings (Green and Westerdahl 1990). In addition, long exposure times (>14 days) to low-concentrations of 2,4-D (0.1-0.25 ppm) have also been documented to achieve milfoil control (Hall et al. 1982; Glomski and Netherland 2010).

According to product labels, desirable native species that may be affected include native milfoils (*Myriophyllum* spp.), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), naiads (*Najas* spp.), waterlilies (*Nymphaea* spp. and *Nuphar* spp.), bladderworts (*Utricularia* spp.), and duckweeds (*Lemna* spp.). While it may affect softstem bulrush (*Schoenoplectus tabernaemontani*), other species such as American bulrush (*Schoenoplectus americanus*) and muskgrasses (*Chara* spp.) have been shown to be somewhat tolerant of 2,4-D (Miller and Trout 1985; Glomski et al. 2009; Nault et al. 2014; Nault et al. 2018).

In large-scale, low-dose (0.073-0.5 ppm) 2,4-D treatments evaluated by Nault et al. (2018), milfoil exhibited statistically significant lakewide decreases in posttreatment frequency across 23 of the 28 (82%) of the treatments monitored. In lakes where year of treatment milfoil control was achieved, the longevity of control ranged from 2–8 years. However, it is important to note that milfoil was not 'eradicated' from any of these lakes and is still present even in those lakes which have sustained very low frequencies over time. While good year of treatment control was achieved in all lakes with pure Eurasian watermilfoil populations, significantly reduced control was observed in the majority of lakes with hybrid watermilfoil (*Myriophyllum spicatum* x *sibiricum*) populations. Eurasian watermilfoil control was correlated with the mean concentration of 2,4-D measured during the first two weeks of treatment, with increasing lakewide concentrations resulting in increased Eurasian watermilfoil control. In contrast, there was no significant relationship observed between Eurasian watermilfoil control and mean concentration of 2,4-D. In lakes where good (>60%) year of treatment control of hybrid watermilfoil was achieved, 2,4-D degradation was slow, and measured lakewide concentrations were sustained at >0.1 ppm (>100 ppb) for longer than 31 days. In addition to reduced year of treatment efficacy, the longevity of control was generally shorter in lakes that contained hybrid watermilfoil versus Eurasian watermilfoil, suggesting that hybrid watermilfoil may have the ability to rebound quicker after large-scale treatments than pure Eurasian watermilfoil populations. However, it is important to keep in mind that hybrid watermilfoil is broad term for multiple different strains, and variation in herbicide response and growth between specific genotypes of hybrid watermilfoil has been documented (Taylor et al. 2017).

In addition, the study by Nault et al. (2018) documented several native monocotyledon and dicotyledon species that exhibited significant declines posttreatment. Specifically, northern watermilfoil (*Myriophyllum sibiricum*), slender naiad (*Najas flexilis*), water marigold (*Bidens beckii*), and several thin-leaved pondweeds (*Potamogeton pusillus*, *P. strictifolius*, *P. friesii* and *P. foliosus*) showed highly significant declines in the majority of the lakes monitored. In addition, variable/Illinois pondweed (*P. gramineus*/*P. illinoensis*), flat-stem pondweed (*P. zosteriformis*), fern pondweed (*P. robbinsii*), and sago pondweed (*Stuckenia pectinata*) also declined in many lakes. Ribbon-leaf pondweed (*P. epihydrus*) and water stargrass (*Heteranthera dubia*) declined in the lakes where they were found. Mixed effects of treatment were observed with water celery (*Vallisneria americana*) and southern naiad (*Najas guadalupensis*), with some lakes showing significant declines posttreatment and other lakes showing increases.

Since milfoil hybridity is a relatively new documented phenomenon (Moody and Les 2002), many of the early lab studies examining CET for milfoil control did not determine if they were examining pure Eurasian watermilfoil or hybrid watermilfoil (*M. spicatum* x *sibiricum*) strains. More recent laboratory and mesocosm studies have shown that certain strains of hybrid watermilfoil exhibit more aggressive growth and are less affected by 2,4-D (Glomski and Netherland 2010; LaRue et al. 2013; Netherland and Willey 2017; Taylor et al. 2017), while other studies have not seen differences in overall growth patterns or treatment efficacy when compared to pure Eurasian watermilfoil (Poovey et al. 2007). Differences between Eurasian and hybrid watermilfoil control following 2,4-D applications have also been documented in the field, with lower efficacy and shorter longevity of hybrid watermilfoil control when compared to pure Eurasian watermilfoil populations (Nault et al. 2018). Field studies conducted in the Menominee River Drainage in northeastern Wisconsin and upper peninsula of Michigan observed hybrid milfoil genotypes more frequently in lakes that had previous 2,4-D treatments, suggesting possible selection of more tolerant hybrid strains over time (LaRue 2012).

Fluridone

Registration and Formulations

Fluridone is an aquatic herbicide that was initially registered with the U.S. EPA in 1986. It is currently being evaluated for reregistration. The estimated registration review decision date was in 2014 (EPA Fluridone Plan 2010). The active ingredient is (1-methyl-3-phenyl-5-[3-(trifluoromethyl) phenyl]-4(1H)-pyridinone). Fluridone is available in both liquid and slow-release granular formulations.

Mode of Action and Degradation

Fluridone's mode of action is to reduce a plant's ability to protect itself from sun damage. The herbicide prevents the plant from making a protective pigment and as a result, sunlight causes the plant's chlorophyll to break down. Treated plants will turn white or pink at the growing tips a week after exposure and will begin to die one to two months after treatment (Madsen et al. 2002). Therefore, fluridone is only effective if plants are actively growing at the time of treatment. Effective use of fluridone requires low, sustained concentrations and a relatively long contact time (e.g., 45-90 days). Due to this requirement, fluridone is usually applied to an entire waterbody or basin. Some success has been demonstrated when additional follow-up 'bump' treatments are used to maintain the low concentrations over a long enough period of time to produce control. Fluridone has also been applied to riverine systems using a drip system to maintain adequate CET.

Following treatment, the amount of fluridone in the water is reduced through dilution and water movement, uptake by plants, adsorption to the sediments, and via breakdown caused by light and microbes. Fluridone is primarily degraded through photolysis (Saunders and Mosier 1983), while depth, water clarity and light penetration can influence degradation rates (Mossler et al. 1989; West et al. 1983). There are two major degradation products from fluridone: n-methyl formamide (NMF) and 3-trifluoromethyl benzoic acid.

The half-life of fluridone can be as short as several hours, or hundreds of days, depending on conditions (West et al. 1979; West et al. 1983; Langeland and Warner 1986; Fox et al. 1991, 1996; Jacob et al. 2016). Preliminary work on a seepage lake in Waushara County, WI detected fluridone in the water nearly 400 days following an initial application that was then augmented to maintain concentrations via a 'bump' treatment at 60 and 100 days later (Onterra 2017a). Light exposure is influential in controlling degradation rate, with a half-life ranging from 15 to 36 hours when exposed to the full spectrum of natural sunlight (Mossler et al. 1989). As light wavelength increases, the half-life increases too, indicating that season and timing may affect fluridone persistence. Fluridone half-life has been shown to be only slightly dependent on fluridone concentration, oxygen concentration, and pH (Saunders and Mosier 1983). One study found that the half-life of fluridone in water was slightly lower when the herbicide was applied to the surface of the water as opposed to a sub-surface application, suggesting that degradation may also be affected by mode of application (West and Parka 1981).

The persistence of herbicide in the sediment has been reported to be much longer than in the overlying water column, with studies showing persistence ranges from 3 months to a year in

sediments (Muir et al. 1980; Muir and Grift 1982; West et al. 1983). Persistence in soil is influenced by soil chemistry (Shea and Weber 1983; Mossler et al. 1993). Fluridone concentrations measured in sediments reach a maximum in one to four weeks after treatment and decline in four months to a year depending on environmental conditions. Fluridone adsorbs to clay and soils with high organic matter, especially in pellet form, and can reduce the concentration of fluridone in the water. Adsorption to the sediments is reversible; fluridone gradually dissipates back into the water where it is subject to chemical breakdown.
Some studies have shown variable release time of the herbicide among different granular fluridone products (Mossler et al. 1993; Koschnick et al. 2003; Bultemeier and Haller 2015). In addition, pelletized formulations may be more effective in sandy hydrosoils, while aqueous suspension formulations may be more appropriate for areas with high amounts of clay or organic matter (Mossler et al. 1993)

Toxicology

Fluridone does not appear to have short-term or long-term effects on fish at approved application rates, but fish exposed to water treated with fluridone do absorb fluridone into their tissues. However, fluridone has demonstrated a very low potential for bioconcentration in fish, zooplankton, and aquatic plants (McCowen et al. 1979; West et al. 1979; Muir et al. 1980; Paul et al. 1994). Fluridone concentrations in fish decrease as the herbicide disappears from the water. Studies on the effects of fluridone on aquatic invertebrates (e.g., midge and water flea) have shown increased mortality at label application rates (Hamelink et al. 1986; Yi et al. 2011). Studies on birds indicate that fluridone would not pose an acute or chronic risk to birds. In addition, no treatment related effects were noted in mice, rats, and dogs exposed to dietary doses. No studies have been published on amphibians or reptiles. There are no restrictions on swimming, eating fish from treated waterbodies, human drinking water or pet/livestock drinking water. Depending on the type of waterbody treated and the type of plant being watered, irrigation restrictions may apply for up to 30 days. There is some evidence that the fluridone degradation product NMF causes birth defects, though NMF has only been detected in the lab and not following actual fluridone treatments in the field, including those at maximum label rate (Osborne et al. 1989; West et al. 1990).

Species Susceptibility

Because fluridone treatments are often applied at a lakewide scale and many plant species are susceptible to fluridone, careful consideration should be given to potential non-target impacts and changes in water quality in response to treatment. Sustained native plant species declines and reductions in water clarity have been observed following fluridone treatments in field applications (O'Dell et al. 1995; Valley et al. 2006; Wagner et al. 2007; Parsons et al. 2009). However, reductions in water clarity are not always observed and can be avoided (Crowell et al. 2006). Additionally, the selective activity of fluridone is primarily rate-dependent based on analysis of pigments in nine aquatic plant species (Sprecher et al. 1998b).

Fluridone is most often used for control of invasive species such as Eurasian and hybrid watermilfoil (*Myriophyllum spicatum* x *sibiricum*), Brazilian waterweed (*Egeria densa*), and hydrilla (*Hydrilla verticillata*; Schmitz et al. 1987; MacDonald et al. 1993; Netherland et al. 1993;

Netherland and Getsinger 1995a, 1995b; Cockreham and Netherland 2000; Hofstra and Clayton 2001; Madsen et al. 2002; Netherland 2015). However, fluridone tolerance has been observed in some hydrilla and hybrid watermilfoil populations (Michel et al. 2004; Arias et al. 2005; Puri et al. 2006; Slade et al. 2007; Berger et al. 2012, 2015; Thum et al. 2012; Benoit and Les 2013; Netherland and Jones 2015). Fluridone has also been shown to affect flowering rush (*Butomus umbellatus*), fanwort (*Cabomba caroliniana*), buttercups (*Ranunculus* spp.), long-leaf pondweed (*Potamogeton nodosus*), Illinois pondweed (*P. illinoensis*), leafy pondweed (*P. foliosus*), flat-stem pondweed (*P. zosteriformis*), sago pondweed (*Stuckenia pectinata*), oxygen-weed (*Lagarosiphon major*), northern watermilfoil (*Myriophyllum sibiricum*), variable-leaf watermilfoil (*M. heterophyllum*), curly-leaf pondweed (*Potamogeton crispus*), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), southern naiad (*Najas guadalupensis*), slender naiad (*N. flexilis*), white waterlily (*Nymphaea odorata*), water marigold (*Bidens beckii*), duckweed (*Lemna* spp.), and watermeal (*Wolffia columbiana*) (Wells et al. 1986; Kay 1991; Farone and McNabb 1993; Netherland et al. 1997; Koschnick et al. 2003; Crowell et al. 2006; Wagner et al. 2007; Parsons et al. 2009; Cheshier et al. 2011; Madsen et al. 2016). Muskgrasses (*Chara* spp.), water celery (*Vallisneria americana*), cattails (*Typha* spp.), and willows (*Salix* spp.) have been shown to be somewhat tolerant of fluridone (Farone and McNabb 1993; Poovey et al. 2004; Crowell et al. 2006).

Large-scale fluridone treatments that targeted Eurasian and hybrid watermilfoils have been conducted in several Wisconsin lakes. Recently, five of these waterbodies treated with low-dose fluridone (2-4 ppb) have been tracked over time to understand herbicide dissipation and degradation patterns, as well as the efficacy, selectivity, and longevity of these treatments. These field trials resulted in a pre- vs. post-treatment decrease in the number of vegetated littoral zone sampling sites, with a 9-26% decrease observed following treatment (an average decrease in vegetated littoral zone sites of 17.4% across waterbodies). In four of the five waterbodies, substantial decreases in plant biomass (≥10% reductions in average total rake fullness) was documented at sites where plants occurred in both the year of and year after treatment. Good milfoil control was achieved, and long-term monitoring is ongoing to understand the longevity of target species control over time. However, non-target native plant populations were also observed to be negatively impacted in conjunction with these treatments, and long-term monitoring is ongoing to understand their recovery over time. Exposure times in the five waterbodies monitored were found to range from 320 to 539 days before falling below detectable limits. Data from these recent projects is currently being compiled and a compressive analysis and report is anticipated in the near future.

Endothall

Registration and Formulations

Endothall was registered with the U.S. EPA for aquatic use in 1960 and reregistered in 2005 (Menninger 2012). Endothall is the common name of the active ingredient endothal acid (7-oxabicyclo[2,2,1] heptane-2,3-dicarboxylic acid). Granular and liquid formulations are currently registered by EPA and DATCP. Endothall products are used to control a wide range of terrestrial and aquatic plants. Two types of endothall are available: dipotassium salt and dimethylalkylamine salt (“mono-N,N-dimethylalkylamine salt” or “monoamine salt”). The dimethylalkylamine salt form is toxic to fish and other aquatic organisms and is faster-acting than the dipotassium salt form.

Mode of Action and Degradation

Endothall is considered a contact herbicide that inhibits respiration, prevents the production of proteins and lipids, and disrupts the cellular membrane in plants (MacDonald et al. 1993; MacDonald et al. 2001; EPA RED Endothall 2005; Bajsa et al. 2012). Although typical rates of endothall application inhibit plant respiration, higher concentrations have been shown to increase respiration (MacDonald et al. 2001). The mode of action of endothall is unlike any other commercial herbicide. For effective control, endothall should be applied when plants are actively growing, and plants begin to weaken and die within a few days after application.

Uptake of endothall is increased at higher water temperatures and higher amounts of light (Haller and Sutton 1973). Netherland et al. (2000) found that while biomass reduction of curly-leaf pondweed (*Potamogeton crispus*) was greater at higher water temperature, reductions of turion production were much greater when curly-leaf pondweed was treated a lower water temperature (18 °C vs 25 °C).

Degradation of endothall is primarily microbial (Sikka and Saxena 1973) and half-life of the dipotassium salt formulations is between 4 to 10 days (Reinert and Rodgers 1987; Reynolds 1992), although dissipation due to water movement may significantly shorten the effective half-life in some treatment scenarios. Half of the active ingredient from granular endothall formulations has been shown to be released within 1-5 hours under conditions that included water movement (Reinert et al. 1985; Bultemeier and Haller 2015). Endothall is highly water soluble and does not readily adsorb to sediments or lipids (Sprecher et al. 2002; Reinert and Rodgers 1984). Degradation from sunlight or hydrolysis is very low (Sprecher et al. 2002). The degradation rate of endothall has been shown to increase with increasing water temperature (UPI, *unpublished data*). The degradation rate is also highly variable across aquatic systems and is much slower under anaerobic conditions (Simsiman and Chesters 1975). Relative to other herbicides, endothall is unique in that is comprised of carbon, hydrogen, and oxygen with the addition of potassium and nitrogen in the dipotassium and dimethylalkylamine formulations, respectively. This allows for complete breakdown of the herbicide without additional intermediate breakdown products (Sprecher et al. 2002).

Toxicology

All endothall products have a drinking water standard of 0.1 ppm and cannot be applied within 600 feet of a potable water intake. Use restrictions for dimethylalkylamine salt formulations have additional irrigation and aquatic life restrictions.

Dipotassium salt formulations

At recommended rates, the dipotassium salt formulations appear to have few short-term behavioral or reproductive effects on bluegill (*Lepomis macrochirus*) or largemouth bass (*Micropterus salmoides;* Serns 1977; Bettolli and Clark 1992; Maceina et al. 2008). Bioaccumulation of dipotassium salt formulations by fish from water treated with the herbicide is unlikely, with studies showing less than 1% of endothall being taken up by bluegill (Sikka et al. 1975; Serns 1977). In addition, studies have shown the dipotassium salt formulation induces no significant adverse effects on aquatic invertebrates when used at label application rates (Serns 1975; Williams et al. 1984). A freshwater mussel species was found to be more sensitive to dipotassium salt endothall than other invertebrate species tested, but significant acute toxicity was still only found at concentrations well above the maximum label rate. However, as with other plant control approaches, some aquatic plant-dwelling populations of aquatic organisms may be adversely affected by application of endothall formulations due to habitat loss.

During EPA reregistration of endothall in 2005, it was required that product labels state that lower rates of endothall should be used when treating large areas, "such as coves where reduced water movement will not result in rapid dilution of the herbicide from the target treatment area or when treating entire lakes or ponds."

Dimethylalkylamine salt formulations

In contrast to the respective low to slight toxicity of the dipotassium salt formulations to fish and aquatic invertebrates, laboratory studies have shown the dimethylalkylamine formulations are toxic to fish and macroinvertebrates at concentrations above 0.3 ppm. In particular, the liquid formulation will readily kill fish present in a treatment site. Product labels for the dimethylalkylamine salt formulations recommend no treatment where fish are an important resource.

The dimethylalkylamine formulations are more active on aquatic plants than the dipotassium formulations, but also are 2-3 orders of magnitude more toxic to non-target aquatic organisms (EPA RED Endothall 2005; Keckemet 1969). The 2005 reregistration decision document limits aquatic use of the dimethylalkylamine formulations to algae, Indian swampweed (*Hygrophila polysperma*), water celery (*Vallisneria americana*), hydrilla (*Hydrilla verticillata*), fanwort (*Cabomba caroliniana*), bur reed (*Sparganium* sp.), common waterweed (*Elodea canadensis*), and Brazilian waterweed (*Egeria densa*). Coontail (*Ceratophyllum demersum*), watermilfoils (*Myriophyllum* spp.), naiads (*Najas* spp.), pondweeds (*Potamogeton* spp.), water stargrass (*Heteranthera dubia*), and horned pondweed (*Zannichellia palustris*) were to be removed from product labels (EPA RED Endothall 2005).

Species Susceptibility

According to the herbicide label, the maximum target concentration of endothall is 5000 ppb (5.0 ppm) acid equivalent (ae). Endothall is used to control a wide range of submersed species, including non-native species such as curly-leaf pondweed and Eurasian watermilfoil (*Myriophyllum spicatum*). The effects of the different formulations of endothall on various species of aquatic plants are discussed below.

Dipotassium salt formulations

At least one mesocosm or lab study has shown that endothall (at or below the maximum label rate) will control the invasive species hydrilla (Netherland et al. 1991; Wells and Clayton 1993; Hofstra and Clayton 2001; Pennington et al. 2001; Skogerboe and Getsinger 2001; Shearer and Nelson 2002; Netherland and Haller 2006; Poovey and Getsinger 2010), oxygen-weed (*Lagarosiphon major*; Wells and Clayton 1993; Hofstra and Clayton 2001), Eurasian watermilfoil (Netherland et al. 1991; Skogerboe and Getsinger 2002; Mudge and Theel 2011), water lettuce (*Pistia stratiotes*; Conant et al. 1998), curly-leaf pondweed (Yeo 1970), and giant salvinia (*Salvinia molesta*; Nelson et al. 2001). Wersal and Madsen (2010a) found that parrot feather (*Myriophyllum aquaticum*) control with endothall was less than 40% even with two days of exposure time at the maximum label rate. Endothall was shown to control the shoots of flowering rush (*Butomus umbellatus*), but control of the roots was variable (Poovey et al. 2012; Poovey et al. 2013). One study found that endothall did not significantly affect photosynthesis in fanwort with 6 days of exposure at 2.12 ppm ae (2120 ppb ae; Bultemeier et al. 2009). Large-scale, low-dose endothall treatments were found to reduce curly-leaf pondweed frequency, biomass, and turion production substantially in Minnesota lakes, particularly in the first 2-3 years of treatments (Johnson et al. 2012).

Native species that were significantly impacted (at or below the maximum endothall label rate in at least one mesocosm or lab study) include coontail (Yeo 1970; Hofstra and Clayton 2001; Hofstra et al. 2001; Skogerboe and Getsinger 2002; Wells and Clayton 1993; Mudge 2013), southern naiad (*Najas guadalupensis*; Yeo 1970; Skogerboe and Getsinger 2001), white waterlily (*Nymphaea odorata*; Skogerboe and Getsinger 2001), leafy pondweed (*Potamogeton foliosus*; Yeo 1970), Illinois pondweed (*Potamogeton illinoensis*; Skogerboe and Getsinger 2001; Shearer and Nelson 2002; Skogerboe and Getsinger 2002; Mudge 2013), long-leaf pondweed (*Potamogeton nodosus*; Yeo 1970; Skogerboe and Getsinger 2001; Shearer and Nelson 2002; Mudge 2013), small pondweed (*P. pusillus*; Yeo 1970), broadleaf arrowhead (*Sagittaria latifolia*; Skogerboe and Getsinger 2001), sago pondweed (*Stuckenia pectinata*; Yeo 1970; Sprecher et al. 1998a; Skogerboe and Getsinger 2002; Slade et al. 2008), water celery (*Vallisneria americana*; Skogerboe and Getsinger 2001; Skogerboe and Getsinger 2002; Shearer and Nelson 2002; Mudge 2013), and horned pondweed (Yeo 1970; Gyselinck and Courter 2015).

Species which were not significantly impacted or which recovered quickly include watershield (*Brasenia schreberi*; Skogerboe and Getsinger 2001), muskgrasses (*Chara* spp.; Yeo 1970; Wells and Clayton 1993; Hofstra and Clayton 2001), common waterweed (Yeo 1970; Wells and Clayton 1993; Skogerboe and Getsinger 2002), water stargrass (Skogerboe and Getsinger 2001), water net (*Hydrodictyon reticulatum*; Wells and Clayton 1993), the freshwater macroalgae *Nitella clavata* (Yeo 1970), yellow pond-lily (*Nuphar advena*; Skogerboe and Getsinger 2002), swamp smartweed (*Polygonum hydropiperoides*; Skogerboe and Getsinger 2002), pickerelweed (*Pontederia cordata*; Skogerboe and Getsinger 2001), softstem bulrush (*Schoenoplectus tabernaemontani*; Skogerboe and Getsinger 2001), and broadleaf cattail (*Typha latifolia*; Skogerboe and Getsinger 2002).

Field trials mirror the species susceptibility above and in addition show that endothall also can impact several high-value pondweed species (*Potamogeton* spp.), including large-leaf pondweed (*P. amplifolius*; Parsons et al. 2004), fern pondweed (*P. robbinsii*; Onterra 2015; Onterra 2018), white-stem pondweed (*P. praelongus*; Onterra 2018), small pondweed (Big Chetac Chain Lake Association 2016; Onterra 2018), clasping-leaf pondweed (*P. richardsonii*; Onterra 2018), and flat-stem pondweed (*P. zosteriformis*; Onterra 2017b).

Dimethylalkylamine salt formulations

The dimethylalkylamine formulations are more active on aquatic plants than the dipotassium formulations (EPA RED Endothall 2005; Keckemet 1969). At least one mesocosm study has shown that dimethylalkylamine formulation of endothall (at or below the maximum label rate) will control the invasive species fanwort (Hunt et al. 2015) and the native species common waterweed (Mudge et al. 2015), while others have shown that the dipotassium formulation does not control these species well.

Imazamox

Registration and Formulations

Imazamox is the common name of the active ingredient ammonium salt of imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethl)-3-pyridinecarboxylic acid. It was registered with U.S. EPA in 2008 and is currently under registration review with an estimated registration decision between 2019 and 2020 (EPA Imazamox Plan 2014). In aquatic environments, a liquid formulation is typically applied to submerged vegetation by broadcast spray or underwater hose application and to emergent or floating leaf vegetation by broadcast spray or foliar application. There is also a granular formulation.

Mode of Action and Degradation

Imazamox is a systemic herbicide that moves throughout the plant tissue and prevents plants from producing a necessary enzyme, acetolactate synthase (ALS), which is not found in animals. Susceptible plants will stop growing soon after treatment, but plant death and decomposition will occur over several weeks (Mudge and Netherland 2014). If used as a post-emergence herbicide, imazamox should be applied to plants that are actively growing. Resistance to ALS-inhibiting herbicides has appeared in weeds at a higher rate than other herbicide types in terrestrial environments (Tranel and Wright 2002).

Dissipation studies in lakes indicate a half-life ranging from 4 to 49 days with an average of 17 days. Herbicide breakdown does not occur readily in deep, poorly-oxygenated water where there is no light. In this part of a lake, imazamox will tend to bind to sediments rather than breaking down, with a half-life of approximately 2 years. Once in soil, leaching to groundwater is believed to be very limited. The breakdown products of imazamox are nicotinic acid and di- and tricarboxylic acids. It has been suggested that photolytic break down of imazamox is faster than other herbicides, reducing exposure times. However, short-term imazamox exposures have also been associated with extended regrowth times relative to other herbicides (Netherland 2011).

Toxicology

Treated water may be used immediately following application for fishing, swimming, cooking, bathing, and watering livestock. If water is to be used as potable water or for irrigation, the tolerance is 0.05 ppm (50 ppb), and a 24-hour irrigation restriction may apply depending on the waterbody. None of the breakdown products are herbicidal nor suggest concerns for aquatic organisms or human health.

Most concerns about adverse effects on human health involve applicator exposure. Concentrated imazamox can cause eye and skin irritation and is harmful if inhaled. Applicators should minimize exposure by wearing long-sleeved shirts and pants, rubber gloves, and shoes and socks.

Honeybees are affected at application rates so drift during application should be minimized. Laboratory tests using rainbow trout (*Oncorhynchus mykiss*), bluegill (*Lepomis macrochirus*), and water fleas (*Daphnia magna*) indicate that imazamox is not toxic to these species at label application rates.

Imazamox is rated "practically non-toxic" to fish and aquatic invertebrates and does not bioaccumulate in fish. Additional studies on birds indicate toxicity only at dosages that exceed approved application rates.

In chronic tests, imazamox was not shown to cause tumors, birth defects or reproductive toxicity in test animals. Most studies show no evidence of mutagenicity. Imazamox is not metabolized and was excreted by mammals tested. Based on its low acute toxicity to mammals, and its rapid disappearance from the water column due to light and microbial degradation and binding to soil, imazamox is not considered to pose a risk to recreational water users.

Species Susceptibility

In Wisconsin, imazamox is used for treating non-native emergent vegetation such as non-native phragmites (*Phragmites australis* subsp. *australis*) and flowering rush (*Butomus umbellatus*). Imazamox may also be used to treat the invasive curly-leaf pondweed (*Potamogeton crispus*). Desirable native species that may be affected could include other pondweed species (long-leaf pondweed (*P. nodosus*), flat-stem pondweed (*P. zosteriformis*), leafy pondweed (*P. foliosus*), Illinois pondweed (*P. illinoensis*), small pondweed (*P. pusillus*), variable-leaf pondweed (*P. gramineus*), water-thread pondweed (*P. diversifolius*), perfoliate pondweed (*P. perfoliatus*), large-leaf pondweed (*P. amplifolius*), watershield (*Brasenia schreberi*), and some bladderworts (*Utricularia* spp.). Higher rates of imazamox will control Eurasian watermilfoil (*Myriophyllum spicatum*) but would also have greater non-target impacts on native plants. Imazamox can also be used during a drawdown to prevent plant regrowth and on emergent vegetation.

At low concentrations, imazamox can cause growth regulation rather than mortality in some plant species. This has been shown for non-native phragmites and hydrilla (*Hydrilla verticillata*; Netherland 2011; Cheshier et al. 2012; Theel et al. 2012). In the case of hydrilla, some have suggested that this effect could be used to maintain habitat complexity while providing some target species control (Theel et al. 2012). Imazamox can reduce biomass of non-native phragmites though some studies found regrowth to occur, suggesting a combination of imazapyr and glyphosate to be more effective (Cheshier et al. 2012; Knezevic et al. 2013).

Some level of control of imazamox has also been reported for water hyacinth (*Eichhornia crassipes*), parrot feather (*Myriophyllum aquaticum*), Japanese stiltgrass (*Microstegium* *vimineum*), water lettuce (*Pistia stratiotes*), and southern cattail (*Typha domingensis*; Emerine et al. 2010; de Campos et al. 2012; Rodgers and Black 2012; Hall et al. 2014; Mudge and Netherland 2014). Imazamox was observed to have greater efficacy in controlling floating plants than emergents in a study of six aquatic plant species, including water hyacinth, water lettuce, parrot feather, and giant salvinia (*Salvinia molesta*; Emerine et al. 2010). Non-target effects have been observed for softstem bulrush (*Schoenoplectus tabernaemontani*), pickerelweed (*Pontederia cordata*), and the native pondweeds long-leaf pondweed, Illinois pondweed, and coontail (*Ceratophyllum demersum*; Koschnick et al. 2007; Mudge 2013). Giant salvinia, white waterlily (*Nymphaea odorata*), bog smartweed (*Polygonum setaceum*), giant bulrush (*Schoenoplectus californicus*), water celery (*Vallisneria americana*; though the root biomass of wide-leaf *Vallisneria* may be reduced), and several algal species have been found by multiple studies to be unaffected by imazamox (Netherland et al. 2009; Emerine et al. 2010; Rodgers and Black 2012; Mudge 2013; Mudge and Netherland 2014). Other species are likely to be susceptible, for which the effects of imazamox have not yet been evaluated.

Florpyrauxifen-benzyl

Registration and Formulations

Florpyrauxifen-benzyl is a relatively new herbicide, which was first registered with the U.S. EPA in September 2017. The active ingredient is 4-amino-3-chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl)-5-fluoro-pyridine-2-benzyl ester, also identified as florpyrauxifen-benzyl. Florpyrauxifen-benzyl is used for submerged, floating, and emergent aquatic plant control (e.g., ProcellaCORTM) in slow-moving and quiescent waters, as well as for broad spectrum weed control in rice (*Oryza sativa*) culture systems and other crops (e.g., RinskorTM).

Mode of Action and Degradation

Florpyrauxifen-benzyl is a member of a new class of synthetic auxins, the arylpicolinates, that differ in binding affinity compared to other currently registered synthetic auxins such as 2,4-D and triclopyr (Bell et al. 2015). Florpyrauxifen-benzyl is a systemic herbicide (Heilman et al. 2017).

Laboratory studies and preliminary field dissipation studies indicate that florpyrauxifen-benzyl in water is subject to rapid photolysis (Heilman et al. 2017). In addition, the herbicide can also convert partially via hydrolysis to an acid form at high pH (>9) and higher water temperatures (>25°C), and microbial activity in the water and sediment can also enhance degradation (Heilman et al. 2017). The acid form is noted to have reduced herbicidal activity (Netherland and Richardson 2016; Richardson et al. 2016). Under growth chamber conditions, water samples at 1 DAT found that 44-59% of the applied herbicide had converted to acid form, while sampling at 7 and 14 DAT indicated that all the herbicide had converted to acid form (Netherland and Richardson 2016). The herbicide is short-lived, with half-lives ranging from 4 to 6 days in aerobic aquatic environments, and 2 days in anaerobic aquatic environments (WSDE 2017). Degradation in surface water is accelerated when exposed to sunlight, with a reported photolytic half-life in laboratory testing of 0.07 days (WSDE 2017).

There is some anecdotal evidence that initial water temperature and/or pH may impact the efficacy of florpyrauxifen-benzyl (Beets and Netherland 2018). Florpyrauxifen-benzyl has a high soil adsorption coefficient (KOC) and low volatility, which allows for rapid plant uptake resulting in short exposure time requirements (Heilman et al. 2017). Florpyrauxifen-benzyl degrades quickly (2-15 days) in soil and sediment (Netherland et al. 2016). Few studies have yet been completed for groundwater, but based on known environmental properties, florpyrauxifen-benzyl is not expected to be associated with potential environmental impacts in groundwater (WSDE 2017).

Toxicology

No adverse human health effects were observed in toxicological studies submitted for EPA herbicide registration, regardless of the route of exposure (Heilman et al. 2017). There are no drinking water or recreational use restrictions, including swimming and fishing. There are no restrictions on irrigating turf, and a short waiting period (dependent on application rate) for other non-agricultural irrigation purposes.

Florpyrauxifen-benzyl showed a good environmental profile for use in water, and is "practically non-toxic" to birds, bees, reptiles, amphibians, and mammals (Heilman et al. 2017). No ecotoxicological effects were observed on freshwater mussel or juvenile chinook salmon (Heilman et al. 2017). Florpyrauxifen-benzyl will temporarily bioaccumulate in freshwater organisms but is rapidly depurated and/or metabolized within 1 to 3 days after exposure to high (>150 ppb) concentrations (WSDE 2017).

An LC50 value indicates the concentration of a chemical required to kill 50% of a test population of organisms. LC50 values are commonly used to describe the toxicity of a substance. Label recommendations for milfoils do not exceed 9.65 ppb and the maximum label rate for an acre-foot of water is 48.25 ppb. Acute toxicity results using rainbow trout (*Oncorhynchus mykiss*), fathead minnow (*Pimephales promelas*), and sheepshead minnows (*Cyprinodon variegatus variegatus*) indicated LC50 values of greater than 49 ppb, 41 ppb, and 40 ppb, respectively when exposed to the technical grade active ingredient (WSDE 2017). An LC50 value of greater than 1,900 ppb was reported for common carp (*Cyprinus carpio*) exposed to the ProcellaCOR end-use formulation (WSDE 2017).

Acute toxicity results for the technical grade active ingredient using water flea (*Daphnia magna*) and midge (*Chironomus* sp.) indicated LC50 values of greater than 62 ppb and 60 ppb, respectively (WSDE 2017). Comparable acute ecotoxicity testing performed on *D. magna* using the ProcellaCOR end-use formulation indicated an LC50 value of greater than 8 ppm (80,000 ppb; WSDE 2017).

The ecotoxicological no observed effect concentration (NOEC) for various organisms as reported by Netherland et al. (2016) are: fish (>515 ppb ai), water flea (*Daphnia* spp.; >21440 ppb ai), freshwater mussels (>1023 ppb ai), saltwater mysid (>362 ppb ai), saltwater oyster (>289 ppb ai), and green algae (>480 ppb ai). Additional details on currently available ecotoxicological information is compiled by WSDE (2017).

Species Susceptibility

Florpyrauxifen-benzyl is a labeled for control of invasive watermilfoils (e.g., Eurasian watermilfoil (*Myriophyllum spicatum*), hybrid watermilfoil (*M. spicatum* x *sibiricum*), parrot feather (*M. aquaticum*)), hydrilla (*Hydrilla verticillata*), and other non-native floating plants such as floating hearts (*Nymphoides* spp.), water hyacinth (*Eichhornia crassipes*), and water chestnut (*Trapa natans*; Netherland and Richardson 2016; Richardson et al. 2016). Natives species listed on the product label as susceptible to florpyrauxifen-benzyl include coontail (*Ceratophyllum demersum*; Heilman et al. 2017), watershield (*Brasenia schreberi*), and American lotus (*Nelumbo lutea*). In laboratory settings, pickerelweed (*Pontederia cordata*) vegetation has also been shown to be affected (Beets and Netherland 2018).

Based on available data, florpyrauxifen-benzyl appears to show few impacts to native aquatic plants such as aquatic grasses, bulrush (*Schoenoplectus* spp.), cattail (*Typha* spp.), pondweeds (*Potamogeton* spp.), naiads (*Najas* spp.), and water celery (*Vallisneria americana*; WSDE 2017). Laboratory and mesocosm studies also found water marigold (*Bidens beckii*), white waterlily (*Nymphaea odorata*), common waterweed (*Elodea canadensis*), water stargrass (*Heteranthera dubia*), long-leaf pondweed (*Potamogeton nodosus*), and Illinois pondweed (*P. illinoensis*) to be relatively less sensitive to florpyrauxifen-benzyl than labeled species (Netherland et al. 2016; Netherland and Richardson 2016). Non-native fanwort (*Cabomba caroliniana*) was also found to be tolerant in laboratory study (Richardson et al. 2016).

Since florpyrauxifen-benzyl is a relatively new approved herbicide, detailed information on field applications is very limited. Trials in small waterbodies have shown control of parrot feather (*Myriophyllum aquaticum*), variable-leaf watermilfoil (*M. heterophyllum*), and yellow floating heart (*Nymphoides peltata*; Heilman et al. 2017).

S.3.3.3. Emergent and Wetland Herbicides

Glyphosate

Registration and Formulations

Glyphosate is a commonly used herbicide that is utilized in both aquatic and terrestrial sites. It was first registered for use in 1974. EPA is currently re-evaluating glyphosate and the registration decision was expected in 2014 (EPA Glyphosate Plan 2009). The use of glyphosate-based herbicides in aquatic environments that are not approved for aquatic use is very unsafe and is a violation of federal and state pesticide laws. Different formulations of glyphosate are available, including isopropylamine salt of glyphosate and potassium glyphosate.

Glyphosate is effective only on plants that grow above the water and needs to be applied to plants that are actively growing. It will not be effective on plants that are submerged or have most of their foliage underwater, nor will it control regrowth from seed.

Mode of Action and Degradation

Glyphosate is a systemic herbicide that moves throughout the plant tissue and works by inhibiting an important enzyme needed for multiple plant processes, including growth. Following treatment, plants will gradually wilt, appear yellow, and will die in approximately 2 to 7 days. It may take up to 30 days for these effects to become apparent for woody species.

Application should be avoided when heavy rain is predicted within 6 hours. To avoid drift, application is not recommended when winds exceed 5 mph. In addition, excessive speed or pressure during application may allow spray to drift and must be avoided. Effectiveness of glyphosate treatments may be reduced if applied when plants are growing poorly, such as due to drought stress, disease, or insect damage. A surfactant approved for aquatic sites must be mixed with glyphosate before application.

In water, the concentration of glyphosate is reduced through dispersal by water movement, binding to the sediments, and break-down by microorganisms. The half-life of glyphosate is between 3 and 133 days, depending on water conditions. Glyphosate disperses rapidly in water so dilution occurs quickly, thus moving water will decrease concentration, but not half-life. The primary breakdown product of glyphosate is aminomethylphosphonic acid (AMPA), which is also degraded by microbes in water and soil.

Toxicology

Most aquatic forms of glyphosate have no restrictions on swimming or eating fish from treated waterbodies. However, potable water intakes within ½ mile of application must be turned off for 48 hours after treatment. Different formulations and products containing glyphosate may vary in post-treatment water use restrictions.

Most glyphosate-related health concerns for humans involve applicator exposure, exposure through drift, and the surfactant exposure. Some adverse effects from direct contact with the herbicide include temporary symptoms of dermatitis, eye ailments, headaches, dizziness, and nausea. Protective clothing (goggles, a face shield, chemical resistant gloves, aprons, and footwear) should be worn by applicators to reduce exposure. Recently it has been demonstrated that terrestrial formulations of glyphosate can have toxic effects to human embryonic cells and linked to endocrine disruption (Benachour et al. 2007; Gasnier et al. 2009).

Laboratory testing indicates that glyphosate is toxic to carp (*Cyprinus* spp.), bluegills (*Lepomis macrochirus*), rainbow trout (*Oncorhynchus mykiss*), and water fleas (*Daphnia* spp.) only at dosages well above the label application rates. Similarly, it is rated "practically non-toxic" to other aquatic species tested. Studies by other researchers examining the effects of glyphosate on important food chain organisms such as midge larvae, mayfly nymphs, and scuds have demonstrated a wide margin of safety between application rates.

EPA data suggest that toxicological effects of the AMPA compound are similar to that of glyphosate itself. Glyphosate also contains a nitrosamine (n-nitroso-glyphosate) as a contaminant at levels of 0.1 ppm or less. Tests to determine the potential health risks of nitrosamines are not required by the EPA unless the level exceeds 1.0 ppm.

Species Susceptibility

Glyphosate is only effective on actively growing plants that grow above the water's surface. It can be used to control reed canary grass (*Phalaris arundinacea*), cattails (*Typha* spp.; Linz et al. 1992; Messersmith et al. 1992), purple loosestrife (*Lythrum salicaria*), phragmites (*Phragmites australis* subsp. *australis*; Back and Holomuzki 2008; True et al. 2010; Back et al. 2012; Cheshier et al. 2012), water hyacinth (*Eichhornia crassipes*; Lopez 1993; Jadhav et al. 2008), water lettuce (*Pistia stratiotes*; Mudge and Netherland 2014), water chestnut (*Trapa natans*; Rector et al. 2015), Japanese stiltgrass (*Microstegium vimineum*; Hall et al. 2014), giant reed (*Arundo donax*; Spencer 2014), and perennial pepperweed (*Lepidium latifolium*; Boyer and Burdick 2010). Glyphosate will also reduce abundance of white waterlily (*Nymphaea odorata*) and pond-lilies (*Nuphar* spp.; Riemer and Welker 1974). Purple loosestrife biocontrol beetle (*Galerucella calmariensis*) oviposition and survival have been shown not to be affected by integrated management with glyphosate. Studies have found pickerelweed (*Pontederia cordata*) and floating marsh pennywort (*Hydrocotyle ranunculoides*) to be somewhat tolerant to glyphosate (Newman and Dawson 1999; Gettys and Sutton 2004).

Imazapyr

Registration and Formulations

Imazapyr was registered with the U.S. EPA for aquatic use in 2003 and is currently under registration review. It was estimated to have a registration review decision in 2017 (EPA Imazapyr Plan 2014). The active ingredient is isopropylamine salt of imazapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid). Imazapyr is used for control of emergent and floating-leaf vegetation. It is not recommended for control of submersed vegetation.

Mode of Action and Degradation

Imazapyr is a systemic herbicide that moves throughout the plant tissue and prevents plants from producing a necessary enzyme, acetolactate synthase (ALS), which is not found in animals. Susceptible plants will stop growing soon after treatment and become reddish at the tips of the plant. Plant death and decomposition will occur gradually over several weeks to months. Imazapyr should be applied to plants that are actively growing. If applied to mature plants, a higher concentration of herbicide and a longer contact time will be required.

Imazapyr is broken down in the water by light and has a half-life ranging from three to five days. Three degradation products are created as imazapyr breaks down: pyridine hydroxy-dicarboxylic acid, pyridine dicarboxylic acid (quinolinic acid), and nicotinic acid. These degradates persist in water for approximately the same amount of time as imazapyr (half-lives of three to eight days). In soils imazapyr is broken down by microbes, rather than light, and persists with a half-life of one to five months (Boyer and Burdick 2010). Imazapyr doesn't bind to sediments, so leaching through soil into groundwater is likely.

Toxicology

There are no restrictions on recreational use of treated water, including swimming and eating fish from treated waterbodies. If application occurs within a ½ mile of a drinking water intake, then the intake must be shut off for 48 hours following treatment. There is a 120-day irrigation restriction for treated water, but irrigation can begin sooner if the concentration falls below 0.001 ppm (1 ppb). Imazapyr degradates are no more toxic than imazapyr itself and are excreted faster than imazapyr when ingested.

Concentrated imazapyr has low acute toxicity on the skin or if ingested but is harmful if inhaled and may cause irreversible damage if it gets in the eyes. Applicators should wear chemical-resistant gloves while handling, and persons not involved in application should avoid the treatment area during treatment. Chronic toxicity tests for imazapyr indicate that it is not carcinogenic, mutagenic, or neurotoxic. It also does not cause reproductive or developmental toxicity and is not a suspected endocrine disrupter.

Imazapyr is “practically non-toxic” to fish, invertebrates, birds and mammals. Studies have also shown imazapyr to be “practically non-toxic” to “slightly toxic” to tadpoles and juvenile frogs (Trumbo and Waligora 2009; Yahnke et al. 2013). Toxicity tests have not been published on reptiles. Imazapyr does not bioaccumulate in animal tissues.

Species Susceptibility

The imazapyr herbicide label is listed to control the invasive plants phragmites (*Phragmites australis* subsp. *australis*), purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), non-native cattails (*Typha* spp.) and Japanese knotweed (*Fallopia japonica*) in Wisconsin. Native species that are also controlled include cattails (*Typha* spp.), waterlilies (*Nymphaea* sp.), pickerelweed (*Pontederia cordata*), duckweeds (*Lemna* spp.), and arrowhead (*Sagittaria* spp.).

Studies have shown imazapyr to effectively control giant reed (*Arundo donax*), water hyacinth (*Eichhornia crassipes*), manyflower marsh-pennywort (*Hydrocotyle umbellata*); yellow iris (*Iris pseudacorus*), water lettuce (*Pistia stratiotes*), perennial pepperweed (*Lepidium latifolium*), Japanese stiltgrass (*Microstegium vimineum*), parrot feather (*Myriophyllum aquaticum*), and cattails (Boyer and Burdick 2010; True et al. 2010; Back et al. 2012; Cheshier et al. 2012; Whitcraft and Grewell 2012; Hall et al. 2014; Spencer 2014; Cruz et al. 2015; DiTomaso and Kyser 2016). Giant salvinia (*Salvinia molesta*) was found to be imazapyr-tolerant (Nelson et al. 2001).

S.3.3.4. Herbicides Used for Submersed and Emergent Plants

Triclopyr

Registration and Formulations

Triclopyr was initially registered with the U.S. EPA in 1979, reregistered in 1997, and is currently under review with an estimated registration review decision in 2019 (EPA Triclopyr Plan 2014). There are two forms of triclopyr used commercially as herbicides: the triethylamine salt (TEA) and the butoxyethyl ester (BEE). BEE formulations are considered highly toxic to aquatic organisms, with observed lethal effects on fish (Kreutzweiser et al. 1994) as well as avoidance behavior and growth impairment in amphibians (Wojtaszek et al. 2005). The active ingredient triethylamine salt (3,5,6-trichloro-2-pyridinyloxyacetic acid) is the formulation registered for use in aquatic systems. It is sold both in liquid and granular forms for control of submerged, emergent, and floating-leaf vegetation. There is also a liquid premixed formulation that contains triclopyr and 2,4-D, which when combined together are reported to have synergistic impacts. Only triclopyr products labeled for use in aquatic environments may be used to control aquatic plants.

Mode of Action and Degradation

Triclopyr is a systemic plant growth regulator that is believed to selectively act on broadleaf (dicot) and woody plants. Following treatment, triclopyr is taken up through the roots, stems and leaf tissues, plant growth becomes abnormal and twisted, and plants die within one to two weeks after application (Getsinger et al. 2000). Triclopyr is somewhat persistent and can move through soil, although only mobile enough to permeate top soil layers and likely not mobile enough to potentially contaminate groundwater (Lee et al. 1986; Morris et al. 1987; Stephenson et al. 1990).

Triclopyr is broken down rapidly by light (photolysis) and microbes, while hydrolysis is not a significant route of degradation. Triclopyr photodegrades and is further metabolized to carbon dioxide, water, and various organic acids by aquatic organisms (McCall and Gavit 1986). It has been hypothesized that the major mechanism for the removal of triclopyr from the aquatic environment is microbial degradation, though the role of photolysis likely remains important in near-surface and shallow waters (Petty et al. 2001). Degradation of triclopyr by microbial action is slowed in the absence of light (Petty et al. 2003). Triclopyr is very slowly degraded under anaerobic conditions, with a reported half-life (the time it takes for half of the active ingredient to degrade) of about 3.5 years (Laskowski and Bidlack 1984). Another study of triclopyr under aerobic aquatic conditions yielded a half-life of 4.7 months (Woodburn and Cranor 1987). The initial breakdown products of triclopyr are TCP (3,5,6-trichloro-2-pyridinol) and TMP (3,5,6-trichloro-2-methoxypridine).

Several studies reported triclopyr half-lives between 0.5-7.5 days (Woodburn et al. 1993; Getsinger et al. 2000; Petty et al. 2001; Petty et al. 2003). Two large-scale, low-dose treatments were reported to have longer triclopyr half-lives from 3.7-12.1 days (Netherland and Jones 2015). Triclopyr half-lives have been shown to range from 3.4 days in plants, 2.8-5.8 days in sediment, up to 11 days in fish tissue, and 11.5 days in crayfish (Woodburn et al. 1993; Getsinger et al. 2000; Petty et al. 2003). TMP and TCP may have longer half-lives than triclopyr, with higher levels in bottom-feeding fish and the inedible parts of fish (Getsinger et al. 2000).

Toxicology

Based upon the triclopyr herbicide label, there are no restrictions on swimming, eating fish from treated waterbodies, or pet/livestock drinking water use. Before treated water can be used for irrigation, the concentration must be below 0.001 ppm (1 ppb), or at least 120 days must pass. Treated water should not be used for drinking water until concentrations of triclopyr are less than

0.4 ppm (400 ppb). There is a least one case of direct human ingestion of triclopyr TEA which resulted in metabolic acidosis and coma with cardiovascular impairment (Kyong et al. 2010).

There are substantial differences in toxicity of BEE and TEA, with the BEE shown to be more toxic in aquatic settings. BEE formulations are considered highly toxic to aquatic organisms, with observed lethal effects on fish (Kreutzweiser et al. 1994) as well as avoidance behavior and growth impairment in amphibians (Wojtaszek et al. 2005). Triclopyr TEA is "practically non-toxic" to freshwater fish and invertebrates (Mayes et al. 1984; Gersich et al. 1984). It ranges from "practically non-toxic" to "slightly toxic" to birds (EPA Triclopyr RED 1998). TCP and TMP appear to be slightly more toxic to aquatic organisms than triclopyr; however, the peak concentration of these degradates is low following treatment and depurates from organisms readily, so that they are not believed to pose a concern to aquatic organisms.

Species susceptibility

Triclopyr has been used to control Eurasian watermilfoil (*Myriophyllum spicatum*) and hybrid watermilfoil (*M. spicatum* x *sibiricum*) at both small- and large-scales (Netherland and Getsinger 1992; Getsinger et al. 1997; Poovey et al. 2004; Poovey et al. 2007; Nelson and Shearer 2008; Heilman et al. 2009; Glomski and Netherland 2010; Netherland and Glomski 2014; Netherland and Jones 2015). Getsinger et al. (2000) found that peak triclopyr accumulation was higher in Eurasian watermilfoil than flat-stem pondweed (*Potamogeton zosteriformis*), indicating triclopyr's affinity for Eurasian watermilfoil as a target species.

According to product labels, triclopyr is capable of controlling or affecting many emergent woody plant species, purple loosestrife (*Lythrum salicaria*), phragmites (*Phragmites australis* subsp. *australis*), American lotus (*Nelumbo lutea*), milfoils (*Myriophyllum* spp.), and many others. Triclopyr application has resulted in reduced frequency of occurrence, reduced biomass, or growth regulation for the following species: common waterweed (*Elodea canadensis*), water stargrass (*Heteranthera dubia*), white waterlily (*Nymphaea odorata*), purple loosestrife, Eurasian watermilfoil, parrot feather (*Myriophyllum aquaticum*), variable-leaf watermilfoil (*M. heterophyllum*), watercress (*Nasturtium officinale*), phragmites, flat-stem pondweed (*Potamogeton zosteriformis*), clasping-leaf pondweed (*P. richardsonii*), stiff pondweed (*P. strictifolius*), variable-leaf pondweed (*P. gramineus*), white water crowfoot (*Ranunculus aquatilis*), sago pondweed (*Stuckenia pectinata*), softstem bulrush (*Schoenoplectus tabernaemontani*), hardstem bulrush (*S. acutus*), water chestnut (*Trapa natans*), duckweeds (*Lemna* spp.), and submerged flowering rush (*Butomus umbellatus*; Cowgill et al. 1989; Gabor et al. 1995; Sprecher and Stewart 1995; Getsinger et al. 2003; Poovey et al. 2004; Hofstra et al. 2006; Poovey and Getsinger 2007; Champion et al. 2008; Derr 2008; Glomski and Nelson 2008; Glomski et al. 2009; True et al. 2010; Cheshier et al. 2012; Netherland and Jones 2015; Madsen et al. 2015; Madsen et al. 2016). Wild rice (*Zizania palustris*) biomass and height has been shown to decrease significantly following triclopyr application at 2.5 mg/L. Declines were not significant at lower concentrations (0.75 mg/L), though seedlings were more sensitive than young or mature plants (Madsen et al. 2008). American bulrush (*Schoenoplectus americanus*), spatterdock (*Nuphar variegata*), fern pondweed (*Potamogeton robbinsii*), large-leaf pondweed (*P. amplifolius*), leafy pondweed (*P. foliosus*), white-stem pondweed (*P. praelongus*), long-leaf pondweed (*P. nodosus*), Illinois pondweed (*P. illinoensis*), and water celery (*Vallisneria americana*) can be somewhat tolerant of triclopyr applications depending on waterbody characteristics and application rates (Sprecher and Stewart 1995; Glomski et al. 2009; Wersal et al. 2010b; Netherland and Glomski 2014).

Netherland and Jones (2015) evaluated the impact of large-scale, low-dose (~0.1-0.3 ppm) granular triclopyr) applications for control of non-native watermilfoil on several bays of Lake Minnetonka, Minnesota. Near complete loss of milfoil in the treated bays was observed the year of treatment, with increased milfoil frequency reported the following season. However, despite the observed increase in frequency, milfoil biomass remained a minor component of bay-wide biomass (<2%). The number of points with native plants, mean native species per point, and native species richness in the bays were not reduced following treatment. However, reductions in frequency were seen amongst individual species, including northern watermilfoil (*Myriophyllum sibiricum*), water stargrass, common waterweed, and flat-stem pondweed.

Penoxsulam

Registration and Formulations

Penoxsulam (2-(2,2-difluoroethoxy)--6-(trifluoromethyl-N-(5,8-dimethoxy[1,2,4] triazolo[1,5-c]pyrimidin-2-yl))benzenesulfonamide), also referred to as DE-638, XDE-638, XR-638 is a post-emergence, acetolactate synthase (ALS) inhibiting herbicide. It was first registered for use by the U.S. EPA in 2009. It is liquid in formulation and used for large-scale control of submerged, emergent, and floating-leaf vegetation. Information presented here can be found in the EPA pesticide fact sheet (EPA Penoxsulam 2004).

Mode of Action and Degradation

Penoxsulam is a slow-acting herbicide that is absorbed by above- and below-ground plant tissue and translocated throughout the plant. Penoxsulam interferes with plant growth by inhibiting the AHAS/ALS enzyme which in turn inhibits the production of important amino acids (Tranel and Wright 2002). Plant injury or death usually occurs between 2 and 4 weeks following application.

Penoxsulam is highly mobile but not persistent in either aquatic or terrestrial settings. However, the degradation process is complex. Two degradation pathways have been identified that result in at least 13 degradation products that persist for far longer than the original chemical. Both microbial- and photo-degradation are likely important means by which the herbicide is removed from the environment (Monika et al. 2017). It is relatively stable in water alone without sunlight, which means it may persist in light-limited areas.

The half-life for penoxsulam is between 12 and 38 days. Penoxsulam must remain in contact with plants for around 60 days. Thus, supplemental applications following initial treatment may be required to maintain adequate concentration exposure time (CET). Due to the long CET requirement, penoxsulam is likely best suited to large-scale or whole-lake applications.

Toxicology

Penoxsulam is unlikely to be toxic to animals but may be "slightly toxic" to birds that consume it. Human health studies have not revealed evidence of acute or chronic toxicity, though some indication of endocrine disruption deserves further study. However, screening-level assessments of risk have not been conducted on the major degradates which may have unknown non-target effects. Penoxsulam itself is unlikely to bioaccumulate in fish.

Species Susceptibility

Penoxsulam is used to control monocot and dicot plant species in aquatic and terrestrial environments. The herbicide is often applied at low concentrations of 0.002-0.02 ppm (2-20 ppb), but as a result long exposure times are usually required for effective target species control (Cheshier et al. 2011; Mudge et al. 2012b). For aquatic plant management applications, penoxsulam is most commonly utilized for control of hydrilla (*Hydrilla verticillata*). It has also been used for control of giant salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*), and water lettuce (*Pistia stratiotes*; Richardson and Gardner 2007; Mudge and Netherland 2014). However, the herbicide is only semi-selective; it has been implicated in injury to non-target emergent native species, including arrowheads (*Sagittaria* spp.) and spikerushes (*Eleocharis* spp.) and free-floating species like duckweed (Mudge and Netherland 2014; Cheshier et al. 2011). Penoxsulam can also be used to control milfoils such as Eurasian watermilfoil (*Myriophyllum spicatum*) and variable-leaf watermilfoil (*M. heterophyllum*; Glomski and Netherland 2008). Seedling emergence as well as vegetative vigor is impaired by penoxsulam in both dicots and monocots, so buffer zone and dissipation reduction strategies may be necessary to avoid non-target impacts (EPA Penoxsulam 2004).

When used to treat salvinia, the herbicide was found to have effects lasting through 10 weeks following treatment (Mudge et al. 2012b). The herbicide is effective at low doses, but while low-concentration applications of slow-acting herbicides like penoxsulam often result in temporary growth regulation and stunting, plants are likely to recover following treatment. Thus, complementary management strategies should be employed to discourage early regrowth (Mudge et al. 2012b). In particular, joint biological and herbicidal control with penoxsulam has shown good control of water hyacinth (Moran 2012). Alternately, a low concentration may be maintained over time by repeated low-dose applications. Studies show that maintaining a low concentration for at least 8-12 weeks provided excellent control of salvinia, and that a low dose followed by a high-dose application was even more efficacious (Mudge et al. 2012b).

S.3.4. Physical Removal Techniques

There are several management options which involve physical removal of aquatic plants, either by manual or mechanical means. Some of these include manual and mechanical cutting and hand-pulling or Diver-Assisted Suction Harvesting (DASH).

S.3.4.1. Manual and Mechanical Cutting

Manual and Mechanical Cutting

Manual and mechanical cutting involve slicing off a portion of the target plants and removing the cut portion from the waterbody. In addition to actively removing parts of the target plants, destruction of vegetative material may help prevent further plant growth by decreasing photosynthetic uptake, and preventing the formation of rhizomes, tubers, and other growth types (Dall Armellina et al. 1996a, 1996b; Fox et al. 2002). These approaches can be quick to allow recreational use of a waterbody but because the plant is still established and will continue to grow from where it was cut, it often serves to provide short-term relief (Bickel and Closs 2009; Crowell et al. 1994). A synthesis of numerous historical mechanical harvesting studies is compiled by Breck et al. 1979.

The amount of time for macrophytes to return to pre-cutting levels can vary between waterbodies and with the dominant plant species present (Kaenel et al. 1998). Some studies have suggested that annual or biannual cutting of Eurasian watermilfoil (*Myriophyllum spicatum*) may be needed, while others have shown biomass can remain low the year after cutting (Kimbel and Carpenter 1981; Painter 1988; Barton et al. 2013). Hydrilla (*Hydrilla verticillata*) has been shown to recover beyond pre-harvest levels within weeks in some cases (Serafy et al. 1994). In deeper waters, greater cutting depth may lead to increased persistence of vegetative control (Unmuth et al. 1998; Barton et al. 2013). Higher frequency of cutting, rather than the amount of plant that is cut, can result in larger reductions to propagules such as turions (Fox et al. 2002).

The timing of cutting operations, as for other management approaches, is important. For species dependent on vegetative propagules, control methods should be taken before the propagules are formed. However, for species with rhizomes, cutting too early in the season merely postpones growth while later-season cutting can better reduce plant abundance (Dall Armellina et al. 1996a, 1996b). Eurasian watermilfoil regrowth may be slower if cutting is conducted later in the summer (June or later). Cutting in the fall, rather than spring or summer, may result in the lowest amount of Eurasian watermilfoil regrowth the year after management (Kimbel and Carpenter 1981). However, managing early in the growing season may reduce non-target impacts to native plant populations when early-growing non-native plants are the dominant targets (Nichols and Shaw 1986). Depending on regrowth rate and management goals, multiple harvests per growing season may be necessary (Rawls 1975).

Vegetative fragments which are not collected after cutting can produce new localized populations, potentially leading to higher plant densities (Dall Armellina et al. 1996a). Eurasian watermilfoil and common waterweed (*Elodea canadensis*) biomass can be reduced by cutting (Abernethy et al. 1996), though Eurasian watermilfoil can maintain its growth rate following cutting by developing a more-densely branched form (Rawls 1975; Mony et al. 2011). Cutting and physical removal tend to be less expensive but require more effort than benthic barriers, so these approaches may be best used for small infestations or where non-native and native species inhabit the same stand (Bailey and Calhoun 2008).

Ecological Impacts of Manual and Mechanical Cutting

Plants accrue nutrients into their tissues, and thus plant removal may also remove nutrients from waterbodies (Boyd 1970), though this nutrient removal may not be significant among all lake types. Cutting and harvesting of aquatic plants can lead to declines in fish as well as beneficial zooplankton, macroinvertebrate, and native plant and mussel populations (Garner et al. 1996; Aldridge 2000; Torn et al. 2010; Barton et al. 2013). Many studies suggest leaving some vegetated areas undisturbed to reduce negative effects of cutting on fish and other aquatic organisms (Swales 1982; Garner et al. 1996; Unmuth et al. 1998; Aldridge 2000; Greer et al. 2012). Recovery of these populations to cutting in the long-term is understudied and poorly understood (Barton et al. 2013). Effects on water quality can be minimal but nutrient cycling may be affected in wetland systems (Dall Armellina et al. 1996a; Martin et al. 2003). Cutting can also increase algal production, and turbidity temporarily if sediments are disturbed (Wile 1978; Bailey and Calhoun 2008).

Some changes to macroinvertebrate community composition can occur as a result of cutting (Monahan and Caffrey 1996; Bickel and Closs 2009). Studies have also shown 12-85% reductions in macroinvertebrates following cutting operations in flowing systems (Dawson et al. 1991; Kaenel et al. 1998). Macroinvertebrate communities may not rebound to pre-management levels for 4-6 months and species dependent on aquatic plants as habitat (such as simuliids and chironomids) are likely to be most affected. Reserving cutting operations for summer, rather than spring, may reduce impacts to macroinvertebrate communities (Kaenel et al. 1998).

Mechanical harvesting can also incidentally remove fish and turtles inhabiting the vegetation and lead to shifts in aquatic plant community composition (Engel 1990; Booms 1999). Studies have shown mechanical harvesting can remove between 2%-32% of the fish community by fish number, with juvenile game fish and smaller species being the primary species removed (Haller et al. 1980; Mikol 1985). Haller et al. (1980) estimated a 32% reduction in the fish community at a value of $6000/hectare. However, fish numbers rebounded to similar levels as an unmanaged area within 43 days after harvesting in the Potomac River in Maryland (Serafy et al. 1994). In addition to direct impacts to fish populations, reductions in fish growth rates may correspond with declines in zooplankton populations in response to cutting (Garner et al. 1996).

S.3.4.2. Hand Pulling and Diver-Assisted Suction Harvesting

Hand-pulling and DASH involve removing rooted plants from the bottom sediment of the water body. The entire plant is removed and disposed of elsewhere. Hand-pulling can be done at shallower depths whereas DASH, in which SCUBA divers do the pulling, may be better suited for deeper aquatic plant beds. As a permit condition, DASH and hand-pulling may not result in lifting or removal of bottom sediment (i.e., dredging). Efforts should be made to preserve water clarity because turbid conditions reduce visibility for divers, slowing the removal process and making species identification difficult. When operated with the intent to distinguish between species and minimize disturbance to desirable vegetation, DASH can be selective and provide multi-year control (Boylen et al. 1996). One study found reduced cover of Eurasian watermilfoil both in the year of harvest and the following year, along with increased native plant diversity and reduced overall plant cover the year following DASH implementation (Eichler et al. 1993). However, hand harvesting or DASH may require a large time or economic investment for Eurasian watermilfoil and other aquatic vegetation control on a large-scale (Madsen et al. 1989; Kelting and Laxson 2010). Lake type, water clarity, sediment composition, underwater obstacles and presences of dense native plants, may slow DASH efforts or even prohibit the ability to utilized DASH. Costs of DASH per acre have been reported to typically range from approximately $5,060-8,100 (Cooke et al. 1993; Mattson et al. 2004). Additionally, physical removal of turions from sediments, when applicable, has been shown to greatly reduce plant abundance for multiple subsequent growing seasons (Caffrey and Monahan 2006), though this has not been implemented in Wisconsin due to the significant effort it requires.

Ecological Impacts of Hand-Pulling and DASH

Because divers are physically uprooting plants from the lake bed, hand removal may disturb benthic organisms. Additionally, DASH may also result in some accidental capture of fish and invertebrates, small amounts of sediment removal, or increased turbidity. It is possible that equipment modifications could help minimize some of these unintended effects. Because DASH is a relatively new management approach, less information is available about potential impacts than for some more established techniques like large-scale mechanical harvesting.

S.3.4.3. Benthic Barriers

Benthic barriers can be used to kill existing plants or prevent their growth from the outset. They are sometimes referred to as benthic mats, or screens, and involve placing some sort of covering over a plant bed, which provides a physical obstruction to plant growth and reduces light availability. They may be best used for dense, confined infestations or along shore or for providing boat lanes (Engel 1983; Payne et al. 1993; Bailey and Calhoun 2008). Reductions in abundance of live aquatic plants beneath the barrier may be seen within weeks (Payne et al. 1993; Carter et al. 1994). The target plant species, light availability, and sediment accumulation have been shown to influence the efficacy of benthic barriers for aquatic plant control. Effects on the target plants may be more rapid in finer sediments because anoxic conditions are reached more quickly due to higher sediment organic content and oxidization by bacteria (Carter et al. 1994). Benthic barriers may be more expensive but less time intensive than some of the physical removal approaches described above (Carter et al. 1994; Bailey and Calhoun 2008). Engel (1983) suggests that benthic barriers may be useful in situations where plants are growing too deep for other physical removal approaches or effective herbicide application. They may also improve plant control when used in combination with herbicide treatments to hold most of the herbicide to a given treatment area (Helsel et al. 1996).

There is some necessary upkeep associated with the use of benthic barriers. Some barriers can be difficult to re-use because of algae and plants that can grow on top of the barrier. Periodically removing sediment that accumulates on the barrier can help offset this (Engel 1983; Carter et al. 1994; Laitala et al. 2012). Some materials are made to be removed after the growing season, which may make cleaning and re-use easier (Engel 1983). Additionally, gases often accumulate beneath benthic barriers as a result of plant decay, which can cause them to rise off the bottom of the waterbody, requiring further maintenance (Engel 1983; Ussery et al. 1997; Bailey and Calhoun 2008). Eurasian watermilfoil (*Myriophyllum spicatum*) and other plant species have been shown to recolonize the managed area quickly following barrier removal (Eichler et al. 1995; Boylen et al. 1996), so this approach may require hand-pulling or other integrated approaches once the barrier is removed (Carter et al. 1994; Eichler et al. 1995; Bailey and Calhoun 2008). Some studies have observed low abundance of plants maintained for 1-2 months after barriers were removed (Engel 1983). Others found that combining 2,4-D treatments with benthic barriers could reduce Eurasian watermilfoil to a degree that helped native plants recolonize the target site (Helsel et al. 1996).

The material used to create benthic barriers can vary and include biodegradable jute matting, fiberglass screens, and woven polypropylene fibers (Mayer 1978; Perkins et al. 1980; Lewis et al. 1983; Hoffman et al. 2013). Some plants such as Eurasian watermilfoil and common waterweed (Elodea canadensis; Eichler et al. 1995) are able to growth through the mesh in woven barriers but this material can be effective in reducing growth on certain target plant species (Payne et al. 1993; Caffrey et al. 2010; Hoffman et al. 2013). Hofstra and Clayton (2012) suggested that less dense materials barriers may provide selective control of some species while allowing more tolerant species, such as some charophytes (*Chara* spp. and *Nitella* spp.), to grow through. More dense materials may prevent growth of a wider range of aquatic plants (Hofstra and Clayton 2012). Most materials must be well anchored to the bottom of the waterbody, which can be accomplished early in the growing season or by placing the barriers on ice before thawing of the waterbody (Engel 1983). Gas accumulation can occur in using both fibrous mesh and screen-type barriers (Engel 1983).

Eurasian watermilfoil and common waterweed have been found to be somewhat resistant to control by benthic barriers (Perkins et al. 1980; Engel 1983) while affected species include hydrilla (*Hydrilla verticillata*), curly-leaf pondweed (*Potamogeton crispus*), and coontails (*Ceratophyllum* spp.; Engel 1983; Payne et al. 1993; Carter et al. 1994). One study found that an 8-week barrier placement removed Eurasian watermilfoil while allowing native plant regrowth after the barrier was retrieved; while shorter durations were less effective in reducing Eurasian watermilfoil abundance and longer durations negatively impacted native plant regrowth (Laitala et al. 2012).

Ecological Impacts of Benthic Barriers

Macroinvertebrates will be negatively affected by benthic barriers while they are in place (Engel 1983) but have been shown to rebound to pre-management conditions shortly after removal of the barrier (Payne et al. 1993; Ussery et al. 1997). Benthic barriers may also affect spawning of some warm water fish species through direct disruption of spawning habitat (NYSFOLA 2009). Additionally, increased ammonium and decreased dissolved oxygen contents are often observed beneath benthic barriers (Carter et al. 1994; Ussery et al. 1997). These water chemistry considerations may partially explain decreases in macroinvertebrate populations (Engel 1983; Payne et al. 1993) and ammonium content is likely to increase with sediment organic content (Eakin 1992). Toxic methane gas has also been found to accumulate beneath benthic barriers (Gunnison and Barko 1992).

There may be some positive ecological aspects of benthic barriers. Barriers may reduce turbidity and nutrient release from sediments (Engel 1983). They may also provide channels that improve ease of fish foraging when other aquatic plant cover is present near the managed area. Fish may feed on the benthic organisms colonizing any sediment accumulating on top of the barrier (Payne et al. 1993). Payne et al. (1993) also suggest that, despite negative impacts in the managed area, the overall impact of benthic barriers is negligible since they typically are only utilized in small areas of the littoral zone. However, further research is needed on the effects of benthic barriers on fish and wildlife populations and their ability to rebound following barrier removal (Eichler et al. 1995).

S.3.4.4. Dredging

Dredging is a method that involves the removal of top layers of sediment and associated rooted plants, sediment-dwelling organisms, and sediment-bound nutrients. This approach is "non-selective" (USACE 2012), meaning that it offers limited control over what material is removed. In addition to being employed as an APM technique, dredging is often used to manage water flow, provide navigation channels, and reduce the chance of flooding (USACE 2012). Due to the expense of this method, APM via dredging is often an auxiliary effect of dredging performed for other purposes (Gettys et al. 2014). However, reduced sediment nutrient load and decreased light penetration due to greater depth post-dredging may result in multi-season reductions in plant biomass and density (Gettys et al. 2014).

Several studies discuss the utility of dredging for APM. Dredging may be effective in controlling species that propagate by rhizomes, by removing the rhizomes from the sediment before they have a chance to grow (Dall   Armellina et al. 1996b). Additionally, invasive phragmites has been controlled in areas where dredging increases water depth to ≥ 5-6 feet; though movement of the equipment used in dredging activities has been implicated in expanding the range of invasive phragmites (Gettys et al. 2014). In streams, dredging resulted in a significant reduction in plant biomass (≥ 90%). However, recovery of plant populations reflected the timing of management actions relative to flowering: removal prior to flowering allowed for plant population recovery within the same growing season, while removal after flowering meant populations did not rebound until the next spring (Kaenel and Uehlinger 1999). Sediment testing for chemical residue levels high enough to be considered hazardous waste (from historically used sodium arsenite, copper, chromium, and other inorganic compounds) should be conducted before dredging, to avoid stirring of toxic material into the water column. The department routinely requires sediment analysis before dredging begins and destination approval of spoils to prevent impacts from sediment leachate outside of the disposal area. Planning and testing can be an extensive component to a dredging project.

<u>Ecological effects of Dredging</u>

Repeated dredging may result in plant communities consisting of populations of fast-growing species that are capable of rebounding quickly (Sand-Jensen et al. 2000). In experimental studies, faster growing invasive plant species with a higher tolerance for disturbance were able to better recover from simulated dredging than slower growing native plant species, suggesting that post-dredging plant communities may be comprised of undesirable invasives (Stiers et al. 2011).

Macroinvertebrate biomass has been shown to decrease up to 65% following dredging, particularly among species which use plants as habitat. Species that live deeper in sediments, or those that are highly mobile, were less affected. As macroinvertebrates are valuable components of aquatic ecosystems, it is recommended that plant removal activities consider impacts on macroinvertebrates (Kaenel and Uehlinger 1999). Dredging can also result in declines to native mussel populations (Aldridge 2000).

Impacts to fish and water quality parameters have also been observed. Dredging to remove aquatic plants significantly increased both dissolved oxygen levels and the number of fish species found inhabiting farm ponds (Mitsuo et al. 2014). This increase in fish abundance may have been due to extremely high pre-dredging density of aquatic plants, which can negatively influence fish foraging success. In another study, aquatic plant removal decreased the amplitude of daily oxygen fluctuations in streams. However, post-dredging changes in metabolism were short-lived, suggesting that algae may have taken over primary productivity (Kaenel et al. 2000). Finally, several studies have also documented or suggested a reduction in sediment phosphorous levels after dredging, which may in turn reduce nutrient availability for aquatic plant growth (Van der Does et al. 1992; Kleeberg and Kohl 1999; Meijer et al. 1999; Søndergaard et al. 2001; Zuccarini et al. 2011). However, consideration must be given to factors affecting whether goals are obtainable via dredging (e.g., internal or external phosphorus inputs, water retention time, sediment characteristics, etc.).

S.3.4.5. Drawdown

Water-level drawdown is another approach for aquatic plant control as well as aquatic plant restoration. Exposure of aquatic plant vegetation, seeds, and other reproductive structures may reduce plant abundance by freezing, drying, or consolidation of sediments. This management technique is not effective for control of all aquatic plant species. Due to potential ecological impacts, it is necessary to consider other factors such as: waterfowl habitat, fisheries enhancement, release of nutrients and solids downstream, and refill and sediment consolidation potential. Often drawdowns for aquatic plant control and/or restoration can be coordinated to time with dam repair or repair of shoreline structures. A review by Cooke (1980), suggests drawdown can provide at least short-term aquatic plant control (1-2 years) when the target species is vulnerable to drawdown and where sediment can be dewatered under rigorous heat or cold for 1-2 months. Costs can be relatively low when a structure for manipulating water level is in place (otherwise high capacity pumps must be used). Conversely, costs can be high to reimburse an owner for lost power generation if the water control structure produces hydro-electric power. The aesthetic and recreational value of a waterbody may be reduced during a drawdown, as large areas of sediment are exposed prior to revegetation. Bathymetry is also important to consider, as small decreases in water level may lead to drop-offs if a basin does not have a gradual slope (Cooke 1980). The downcutting of the stream to form a new channel can also release high amounts of solids and organic matter that can impair water quality downstream. For example, in July 2005, the Waupaca Millpond, Waupaca Co. had to conduct an emergency drawdown that resulted in the river downcutting a new channel. High suspended solid concentrations and BOD resulted in decreased water clarity, sedimentation and depressed dissolved oxygen levels. A similar case occurred in 2015 with the Amherst Mill Pond, Portage Co. during a drawdown at a rate of six inches per day (Scott Provost [WDNR], *personal communication*).

Because extreme heat or cold provide optimal conditions for aquatic plant control, drawdowns are typically conducted in the summer or winter. Because of Wisconsin's cold winters, winter drawdown is likely to have several advantages when used for aquatic plant management, including avoiding many conflicts with recreational use, potential for cyanobacterial blooms, and terrestrial and emergent plant growth in sediments exposed by reduced water levels (ter Heerdt and Drost 1994; Bakker and Hilt 2016).

A synthesis of the abiotic and biotic responses to annual and novel winter water level drawdowns in littoral zones of lakes and reservoirs is summarized by Carmignani and Roy 2017. Climatic conditions also determine the capacity of a waterbody to support drawdown (Coops et al. 2003). Resources managers pursuing drawdown must carefully calculate the waterbody's water budget and the potential for increased cyanobacterial blooms in the future may reduce the number of suitable waterbodies (Callieri et al. 2014). Additionally, mild winters and groundwater seepage in some waterbodies may prevent dewatering, leading to reduced aquatic plant control (Cooke 1980). Complete freezing of sediment is more likely to control aquatic plants. Sediment exposure during warmer temperatures (>5° C) can also result in the additional benefit of oxidizing and compacting organic sediments (Scott Provost and Ted Johnson [DNR], *personal communication*). When drawdowns are conducted to improve migratory bird habitat, summer drawdowns prove to be more beneficial for species of shorebirds, as mudflats and shallow water are exposed to promote the production of and accessibility to invertebrates during late summer months that coincide with southward migration (Herwig and Gelvin-Innvaer 2015). Drawdowns conducted during mid-late summer can result in conditions that are favorable for cattails (*Typha* spp.) germination and expansion. However, cattails can be controlled if certain stressors are implemented in conjunction with a drawdown, such as cutting, burning or herbicide treatment during the peak of the growing season. The ideal situation is to cut cattail during a drawdown and flood over cut leaves when water is raised. However, this option is not always feasible due to soil conditions and equipment limitations.

Ecological Impacts of Water-level Drawdown

Artificial manipulation of water level is a major disturbance which can affect many ecological aspects of a waterbody. Because drawdown provides species-selective aquatic plant control, it can alter aquatic plant community composition and relative abundance and distribution of species (Boschilia et al. 2012; Keddy 2000). Sometimes this is the intent of the drawdown, which creates plant community characteristics that are desired for wildlife or fish habitat. Consecutive annual drawdowns may prevent the re-establishment of native aquatic plants or lead to reduced control of aquatic plant abundance as drawdown-tolerant species begin to dominate the community (Nichols 1975). Sediment exposure can also lead to colonization of emergent vegetation in the drawdown zone. In one study, four years of consecutive marsh drawdown led to dominance of invasive phragmites (*Phragmites australis subsp. australis*; ter Heerdt and Drost 1994). However, when drawdowns are conducted properly, it can provide a favorable response to native emergent plants for providing food and cover for migrating waterfowl in the fall. Population increases in emergent plant species such as bulrush (*Schoenoplectus* spp.), bur-reeds (*Sparganium* spp.), and wild rice (*Zizania palustris*) is often a goal of drawdowns, which provides a great food source for fish and wildlife, and provides important spawning and nesting habitat. Full or partial drawdowns that are conducted after wild rice production in the fall tend to favor early successional emergent germination such as wild rice and bulrush the following spring. Spring drawdowns are also possible for producing wild rice but must be done during a tight window following ice-out and slowly raised prior to the wild rice floating leaf stage.

Drawdown can also have various effects on ecosystem fauna. Drawdowns can influence the mortality, movement and behavior of native freshwater mussels (Newton et al. 2014). Although mussels can move with lowering water levels, they can be stranded and die if they are unable to move fast enough or get trapped behind logs or other obstacles (WDNR et al. 2006). Some mussels will burrow down into the mud or sand to find water but can desiccate if the water levels continue to lower (Watters et al. 2001). Maintaining a slow drawdown rate can allow mussels to respond and stranded individuals can be relocated to deeper water during the drawdown period to reduce mussel death (WDNR et al. 2006). Macroinvertebrate communities may experience reduced species diversity and abundance from changes to their environment due to drawdown and loss of habitat provided by aquatic plants (Wilcox and Meeker 1992; McEwen and Butler 2008). These effects may be reduced by considering benthic invertebrate phenology in determining optimal timing for drawdown release. Adequate moisture is required to support the emergence of many macroinvertebrate species and complete drawdown may also result in hardening of sediments which can trap some species (Coops et al. 2003). Reduced macroinvertebrate availability can have negative effects on waterfowl and game fish species which rely on macroinvertebrate food sources (Wilcox and Meeker 1992). Depending on the time of year, drawdown may also lead to decreased reproductive success of some waterfowl through nest loss, including common loon (*Gavia immer*) and red-necked grebe (*Podiceps grisegena*; Reiser 1998). However, drawdown may lead to increased production of annual plants and seed production, thereby increasing food availability for brooding and migrating waterfowl. Semi-aquatic mammals such as muskrats and beavers may also be adversely affected by water level drawdown (Smith and Peterson 1988, 1991). DNR Wildlife Management staff follow guidance to ensure drawdowns are timed with the seasons or temperature to minimize negative impacts to wildlife. Negative impacts to reptiles are possible during the spring if water is raised following a drawdown, as nests may be flooded. In the fall, negative impacts to reptiles and amphibians are possible if water is lowered when species are attempting to settle into sediments for hibernation. The impact may be reduced dissolved oxygen if they are below the water or freezing if the water is dropped below the point of hibernation (Herwig and Smith 2016a, 2016b). Surveying and relocation of stranded organisms may help to mitigate some of these impacts. In Wisconsin there are general provisions for conducting drawdowns for APM that are designed to mitigate or even eliminate potential negative impacts.

Water chemistry can also be affected by water level fluctuation. Beard (1973) describes a substantial algal bloom occurring the summer following a winter drawdown which provided successful aquatic plant control. Other studies reported reduced dissolved oxygen, severe cyanobacterial blooms with summer drawdown, or increased nutrient concentrations and reduced water clarity during summer drawdown for urban water supply (Cooke 1980; Geraldes and Boavida 2005; Bakker and Hilt 2016). Water clarity and trophic state may be improved when drawdown level is similar to a waterbody's natural water level regime (Christensen and Maki 2015).

Species Susceptibility to Water-level Drawdown

Not all plant species are susceptible to management by water level drawdown and some dry- or cold-tolerant species may benefit from it (Cooke 1980). Generally, plants and charophytes which reproduce primarily by seed benefit from drawdowns while those that reproduce vegetatively tend to be more negatively affected. Marsh vegetation can be dependent on water level fluctuation (Keddy and Reznicek 1986). Cooke (1980) provides a summary table of drawdown responses for 63 aquatic plant species. Watershield (Brasenia schreberi), fern pondweed (*Potamogeton robbinsii*), pond-lilies (*Nuphar* spp.) and watermilfoils (*Myriophyllum* spp.) tend to be controlled by drawdown. Increases in abundance associated with drawdown have often been seen for duckweed (*Lemna minor*), rice cutgrass (*Leersia oryzoides*) and slender naiad (*Najas flexilis*; Cooke 1980). One study showed drawdown reduced Eurasian watermilfoil (*Myriophyllum spicatum*) at shallow depths while another cautioned that Eurasian watermilfoil vegetative fragments may be able to grow even after complete desiccation (Siver et al. 1986; Evans et al. 2011). Similarly, a tank-simulated drawdown experiment suggested short-term summer drawdown may be effective in controlling monoecious hydrilla (*Hydrilla verticillata*; Poovey and Kay 1998). However, other studies have shown hydrilla fragments to be resistant to drying following drawdown (Doyle and Smart 2001; Silveira et al. 2009). A study on Brazilian waterweed (*Egeria densa*) showed that stems were no longer viable after 22 days of exposure due to drawdown (Dugdale et al. 2012).

Two examples of recent drawdowns in Wisconsin that were evaluated for their efficacy in controlling invasive aquatic plants occurred in Lac Sault Dore and Musser Lake, both in Price County, which were conducted in 2010 and 2013, respectively. Dam maintenance was the initial reason for these drawdowns, with the anticipated control of nuisance causing aquatic invasive species as a secondary benefit. Aquatic plant surveys showed that the drawdown in Lac Sault Dore resulted in a 99% relative reduction in the littoral cover of Eurasian watermilfoil when comparing pre- vs. post-drawdown frequencies. Native plant cover expanded following the drawdown and Eurasian watermilfoil cover has continued to remain low (82% relative reduction compared to pre-drawdown) as of 2017 (Onterra 2013). Lake-wide cover of curly-leaf pondweed in Musser Lake decreased following drawdown (63% relative reduction compared to pre-drawdown), and turion viability was also reduced. Reductions in native plant populations were observed, though population recovery could be seen in the second year following the drawdown (Onterra 2016). These examples of water-level drawdowns in Wisconsin show that they can be valuable approaches for aquatic invasive species control in some waterbodies. Water level reduction must be conducted such that a sufficient proportion of the area occupied by the target species is exposed. Numerous other single season winter drawdowns monitored in central Wisconsin by department staff show similar results (Scott Provost [DNR], *personal communication*). Careful timing and proper duration is needed to maximize control of target species and growth of favorable species.

S.3.5.Biological Control

Biological control refers to any method involving the use of one organism to control another. This method can be applied to both invasive and native plant populations, since all organisms experience growth limitation through various mechanisms (e.g., competition, parasitism, disease, predation) in their native communities. As such, when control of aquatic plants is desired it is possible that a growth limiting organism, such as a predator, exists and is suitable for this purpose.

Care must be taken to ensure that the chosen biological control method will effectively limit the target population and will not cause unintended negative effects on the ecosystem. The world is full of examples of biological control attempts gone wrong: for example, Asian lady beetles (*Harmonia axyridis*) have been introduced to control agricultural aphid pests. While the beetles have been successful in controlling aphid populations in some areas, they can also outcompete native lady beetles and be a nuisance to humans by amassing on buildings (Koch 2003). Additionally, a method of control that works in some Wisconsin lakes may not work in other parts of the state where differing water chemistry and/or biological communities may affect the success of the organism. The department recognizes the variation in control efficacy and well as potential unintentional effects of some organisms and is very cautious in allowing their use for control of aquatic plants.

Purple loosestrife beetles

The use of herbivorous insects to reduce populations of aquatic plants is another method of biocontrol. Several beetle species native to Eurasia (*Galerucella calmariensis*, *G. pusilla*, *Hylobius transversovittatus*, and *Nanophyes marmoratus*) have been well-studied and intentionally released in North America for their ability to suppress populations of the invasive wetland plant, purple loosestrife (*Lythrum salicaria*). These beetles only feed on loosestrife plants and therefore are not a threat to other wetland plant species (Kok et al. 1992; Blossey et al. 1994a, 1994b; Blossey and Schroeder 1995). The department implements a purple loosestrife biocontrol program, in which citizens rear and release beetles on purple loosestrife stands to reduce the plants' ability to overtake wetlands, lakeshores, and other riparian areas.

Beetle biocontrol can provide successful long-term control of purple loosestrife. The beetles feed on purple loosestrife foliage which in turn can reduce seed production (Katovich et al. 2001). This approach typically does not eradicate purple loosestrife but stresses loosestrife populations such that other plants are able to compete and coexist with them (Katovich et al. 1999). Depending on the composition of the plant community invaded by purple loosestrife and the presence of other non-native invasive species, further restoration efforts may be needed following biocontrol efforts to support the regrowth of beneficial native plants (McAvoy et al. 2016).

Several factors have been identified that may influence the efficacy of beetle biocontrol of purple loosestrife. Purple loosestrife beetles have for the most part been shown to be capable of successfully surviving and establishing in a variety of locations (Hight et al. 1995; McAvoy et al. 2002; Landis et al. 2003). The different species have different preferred temperatures for feeding and reproduction (McAvoy and Kok 1999; McAvoy and Kok 2004). In addition, one study suggests that the number of beetles introduced does not necessarily correlate with greater beetle colonization (Yeates et al. 2012). Disturbance, such as flooding and predation by other animals on the beetles, can also reduce desired effects on loosestrife populations (Nechols et al. 1996; Dech and Nosko 2002; Denoth and Myers 2005). Finally, one study suggests that the use of triclopyr amine for purple loosestrife control may be compatible with beetle biocontrol, although there may be negative effects on beetle egg-batch size or indirect effects if the beetle's food source is too greatly depleted (Lindgren et al. 1998). Some mosquito larvicides may harm purple loosestrife beetles (Lowe and Hershberger 2004).

Milfoil weevils

Similar to the use of beetles for biological control of purple loosestrife, the use of milfoil weevils (*Euhrychiopsis lecontei*) has been investigated in North America to control populations of non-native Eurasian and hybrid watermilfoils (*Myriophyllum spicatum* x *sibiricum*). This weevil species is native to North America and is often naturally present in waterbodies that contain native watermilfoils, such as northern watermilfoil (*M. sibiricum*). The weevils have the potential to damage Eurasian watermilfoil (*M. spicatum*) by feeding on stems and leaves and/or burrowing into stems. Weevils may reduce milfoil plant biomass, inhibit growth, and compromise buoyancy (Creed and Sheldon 1993; Creed and Sheldon 1995; Havel et al. 2017a). Damage caused to the milfoil tissue may then indirectly increase susceptibility to pathogens (Sheldon and Creed 1995).

In experiments, weevils have been shown to negatively impact Eurasian watermilfoil populations to varying degrees. Experiments by Creed and Sheldon (1994) found that plant weight was negatively affected when weevils were at densities of 1 and 2 larvae/tank, and Eurasian watermilfoil in untreated control tanks added more root biomass than those in tanks with weevils, suggesting that weevil larvae may interfere with the plant's ability to move nutrients. Similarly, experiments by Newman et al. (1996) found that weevils at densities of 6, 12, and 24 adults/tank caused significant decreases in Eurasian watermilfoil stem and root biomass, and that higher weevil densities generally produced more damage.

In natural communities, effects of weevils have been mixed, likely because waterbody characteristics may play a role in determining weevil effects on Eurasian watermilfoil populations in natural lakes. In a 56 ha (138 acre) pond in Vermont, weevil density was negatively associated with Eurasian watermilfoil biomass and distribution; Eurasian watermilfoil beds were reduced from 2.5 (6.2 acres) to 1 ha (2.5 acres) in one year, and biomass decreased by 4 to 30 times (Creed and Sheldon 1995). A survey of Wisconsin waterbodies conducted by Jester et al. (2000) revealed that most lakes containing Eurasian watermilfoil also contained weevils. Weevil abundance varied from functionally non-detectable to 2.5 weevils/stem and was positively associated with the presence of large, shallow Eurasian watermilfoil beds (compared to deep, completely submerged beds). There was no relationship between natural weevil abundance and Eurasian watermilfoil density between lakes. However, when the authors augmented natural weevil populations in plots in an attempt to achieve target densities of 1, 2, or 4/stem, they found that augmentation was associated with significant decreases in Eurasian watermilfoil biomass, stem density and length, and tips/stem (Jester et al. 2000). However, another more recent study conducted in several northern Wisconsin lakes found no effect of weevil stocking on Eurasian watermilfoil or native plant biomass (Havel et al. 2017a).

There are several factors to consider when determining whether weevils are an appropriate method of biocontrol. First, previous research has suggested that densities of at least 1.5 weevils per stem are required for control (Newman and Biesboer 2000). Adequate densities may not be achievable due to factors including natural population fluctuations, the amount of available milfoil biomass within a waterbody, the presence of insectivorous predators, such as bluegills (*Lepomis macrochirus*), and the availability of nearshore overwintering habitat (Thorstenson et al. 2013; Havel et al. 2017a). In addition, weevils fed and reproduce on native milfoil species and biocontrol efforts could potentially impact these species, although experiments conducted by Sheldon and Creed (2003) found that native milfoil weevil density was lower and weevils caused less damage than when they were found on Eurasian watermilfoil. Adult weevils spend their winters on land, so available habitat for adults must be present for a waterbody to sustain weevil populations (Reeves and Lorch 2011; Newman et al. 2001). Additionally, one study found that lakes with no Eurasian watermilfoil (despite the presence of other milfoil species) and lakes that had a recent history of herbicide treatment had lower weevil densities than similar, untreated lakes or lakes with Eurasian watermilfoil (Havel et al. 2017b).

Grass carp – not allowed in Wisconsin

The use of grass carp (*Ctenopharyngodon idella*) to control aquatic plants is not allowed in Wisconsin; they are a prohibited invasive species under ch. NR 40, Wis. Admin. Code, which makes it illegal to possess, transport, transfer, or introduce grass carp in Wisconsin.

Sterile (also known as triploid) grass carp have been used to control populations of aquatic plants with varying success (Pípalová 2002; Hanlon et al. 2000). Whether this method is effective depends on several factors. For instance, each individual fish must be tested to ensure sterility before stocking, which can be a time- and resource-consuming process. Since the sterile fish do not reproduce, it can be difficult to achieve the desired density in a given waterbody. In addition, grass carp, like many fish species, have dietary preferences for different plant species which must be considered (Pine and Anderson 1991). Further information summarizing the effects of stocking triploid grass carp can be found in Pípalová (2006), Dibble and Kovalenko (2009), and Bain (1993).

F

APPENDIX F

Comment-Response Document for the Official First Draft

Anvil Lake Aquatic Plant Management Plan

Official First Daft: July 24, 2024

Comments in red by Todd Hanke – Onterra, LLC

WDNR Comments from Eric Wegleitner (Fisheries Biologist), 8/15/2024

Todd,

As the DNR Vilas County Fisheries Biologist, I appreciate you allowing me to read and comment on the Aquatic Plant Management Plan draft for Anvil Lake. Onterra did a great job summarizing plant survey data, past management activities and gathering feedback from Anvil Lake riparian landowners through the stakeholder survey. Additionally, I liked the development of various management philosophies with discussion of pros and cons related to potential management options that may be used to address EWM within each approach. From a fisheries perspective, inclusion of information related to potential negative impacts of chemical treatments on early life stages of important gamefish species like walleye is useful for the target audience and recommendations to delay chemical use until walleye have grown through the earliest life stages is warranted.

Anvil Lake was once a thriving walleye fishery was supported by natural reproduction but in recent years we have documented little to no natural recruitment of juvenile walleye. To address this, Anvil Lake is one of the area lakes that are part of a collaborative walleye rehabilitation effort referred to as Walleye Lakes of Concern (WLOC). The main collaborators are DNR, Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and Lac du Flambeau Tribe, with additional participation from lake associations, special interest groups and the public throughout this ongoing process. The main objective is to get these lakes back to being self-sustaining walleye fisheries by restoring successful walleye natural reproduction. Here is a link where you will find the WLOC Management Plan with further background and management objectives.

https://dnr.wisconsin.gov/sites/default/files/topic/Fishing/WalleyeLakesofConcernPlan2022.pdf

We are focusing significant effort on walleye rehabilitation in Anvil Lake. While I appreciate the seemingly conservative approach to EWM management in Anvil thus far, I feel I must voice my concerns regarding use of herbicides for treating EWM given previous findings of potential negative impacts from herbicides on early life stages of walleye (Dehnert et al., 2020; Schleppenbach et al., 2022). Although newer herbicides are thought to be less harmful than the chemicals used in the past, there is little published research on the effects of these compounds on fish and aquatic organisms. Given the history of various chemicals being used relatively early after development and lags in sufficient research evaluating the impacts, I am in favor of a conservative approach when considering herbicides for aquatic plant management.

The ALA exercises caution when considering herbicide use and has a conservative approach to their use having conducted extensive manual removal efforts in the past in an effort to delay the need for herbicide use or avert their use altogether. This conservative approach is also demonstrated in that herbicides have been used on only one occasion since EWM discovery in 2012. The ALA is aligning for a potential herbicide treatment in 2025, which if implemented would be 5 years since the prior treatment.

The ALA has reviewed available research and data pertaining to use of ProcellaCOR and would consider research conducted on 2,4-D's impacts to early life stages of fish in planning the implementation of any treatments. Timing of the treatment would be planned to occur after walleye have outgrown their most sensitive life stage to auxin herbicide exposure (first 14 days post hatch).

The following sentence was added within the Implementation Plan section on page 47: *The ALA acknowledges that WDNR fisheries managers prefer a conservative approach to use of herbicides in the lake and that Tribal interests are generally opposed to any use of herbicides in ceded territory.*

I recognize it is possible that lack of effective EWM management may be detrimental to walleye rehabilitation effort too. There could be negative impacts on walleye associated with changing aquatic plant species composition and increasing aquatic plant density in Anvil Lake. For example, in some failing walleye fisheries, changes in fish species composition has been noted with increasing numbers of centrarchids, like largemouth bass, that may be associated with increases in aquatic vegetation that they are better adapted to. From this perspective, all management actions should be considered, and chemical treatment only used if other actions will be ineffective.

Based on the stakeholder survey results, the people on Anvil Lake want to fish (#1 and #2 activities) and want to fish for walleye (#1 among species they try to catch). Impacts on walleye should be considered when establishing an APM plan and discussing management actions.

Thank you again for reaching out to me for comment. If you have any questions or comments please let me know.

Thank you for your thoughtful comments on the Anvil Lake APM Plan.

Public Comments on Official First Draft - Received August 2024

Hi Amy,

We want to thank you and the Anvil Lake Planning Committee for your work on the Anvil Lake Aquatic Management Plan Draft, and for this opportunity to comment on it.

We have thoroughly reviewed the draft plan and have the following comments:

- We are in favor of continued management through hand harvesting and and DASH.
- We would also support allowing nature to take its course to determine if that would allow the EWM populations to reach an acceptable equilibrium.
- We oppose any herbicide treatment strategies. Our rationale for this opposition is outlined below.

The draft plan prepared by Onterra promotes the use of ProcellaCor, stating that it's the state's most popular herbicide for EWM treatment in recent years. Yet, the Minnesota Department of Agriculture has recently identified the active ingredient in ProcellaCor as a PFAS-containing pesticide. Even when the active ingredient in ProcellaCor degrades, the residue has been determined to be a PFAS pesticide. We already know that PFAS is a class of chemicals that can cause cancer and have contaminated drinking water supplies all across the country. Since ProcellaCor is a relatively new treatment, we think there are simply too many unknowns.

In 2020, when Onterra's plan recommended the use of 2,4-d, that pesticide was considered safe and effective. Yet, just four years later, the Wisconsin DNR asked the public during the spring natural resource hearings if the use of 2,4-d should be prohibited in all aquatic ecosystems in Wisconsin. Their rationale included the use of the pesticide was unsuccessful and expensive. Further, the agency stated that it is now documented that the 2,4-d has a detrimental effect on plant and animal communities, affects adult reproductive capabilities, egg quality degradation, larval mortality and reduced egg hatching percentages of many fish species. The results of this survey showed Wisconsin residents strongly in favor of banning the use of 2,4-d. The same is true for just Vilas County residents. This leaves us wondering what we will find out about ProcellaCor after it's been applied in a basin-wide treatment of Anvil Lake. Will Wisconsin also classify it as a "forever chemical?"

We understand that this issue is complex and there are many unknown risks and benefits no matter what we do. Even though we are affected by the presence of EWM near our dock just like many others are, we'd rather live with EWM than continue to treat it with herbicides. It seems like an endless cycle - one that will never eliminate EWM, but will expose all of us to potentially harmful chemicals.

Thank you for considering our comments.

Sincerely,

Gail Gilson Pierce and Bryan Pierce

Thank you for providing input on the Draft Anvil Lake Aquatic Plant Management Plan. Perspective is acknowledged, no changes made.

I begin by stating I am against the use of chemicals in the lake for a number of reasons. I do realize that the Board of the Anvil Lake Association has the ability, with a majority vote, to seek a permit from the DNR for chemical use despite opposition from residents. I would remind the Board that they should be the stewards of the lake and surrounding ecosystem for the immediate and future generations. As we have seen, the introduction of anything foreign to the lake ecosystem has the potential to greatly change the balance of the system. I cite the introduction of EWM and curly pondweed roughly 20 years ago as examples of how dramatically the natural balance can be upended. Another example would be the targeted chemical treatment took place on 12 acres of EWM 4.5 yers ago. In my opinion, the decaying material from this treatment caused an increase in suspended materials and later increased sediment on the lake bottom. The decaying plant material also increased the nutrients in the lake, leading to increased aquatic plant growth throughout the lake. I urge the board to use caution when looking toward a solution that will again introduce a foreign substance into the lake. As for the specifics of the plan, several things concern me. First, it appears there is a shift from chemical treatment when lake use is “inhibited or dramatically impeded,” to a chemical treatment when EWM is viewed as a “nuisance” and as a “preventative measure.” Second, the time-frame has changed from planning chemical use every 5 years to the new timeline of every 3-5 years. Third, the plan seems to acknowledge Dr. Karasov’s study and the impact on walleye, yet still discusses a early spring treatment and does not address the possibility of toxic buildup in fish tissue. Fourth, there is information on a variety of potential chemicals, and the half-life, dilution time, or whatever term is chosen varies from hours after application to up to 400 days after application. Fifth, the information states that some of the chemicals bind and settle in sediment which would lead one to conclude that it will have an impact when the lake sediment is disturbed through motorized boat use as we have seen in the past several years with larger boats on the lake. Sixth, what is viewed as safe today and introduced in a closed system has a the potential to later be found to be an adverse agent or more hazardous than originally thought. I cite Agent Orange as one example, and PFAS as another. And do find the plan/information lacking in recent information about Procellcore, which was recently found to be a "forever chemical" as a PFAS. For the above reasons I have concerns about the proposed lake management plan and urge the board to use caution in selecting the path forward.

Sincerely, Gene Welhoefer

Thank you for providing input on the Draft Anvil Lake Aquatic Plant Management Plan. Perspective is acknowledged, no changes made.

Hello Amy,

We wanted to first thank you, the ALA and others behind the scenes for helping to ensure Anvil Lake continues to be as healthy as possible. We participated in the original survey and the report is extremely thorough.

Although we have only been on Anvil Lake for the past 5 years, we have been waterfront owners for over 20+ years ourselves and grew up on the water. To share our personal experience, our previous lake home had an active monitoring and management plan, in coordination with the DNR. Every year our lake was monitored a few times and the recommended herbicide treatment was applied, sometimes more than once depending on findings. We never had to worry about invasive species getting to nuisance levels and our lake and lake habitants flourished. Things were identified early each season.

We greatly appreciate and respect all efforts thus far to help manage EWM. As the report states, by 2024 EWM "has reached a population that exceeds the ability of hand harvesting to be an effective population management technique". We know that EWM is not going away and the 2020 application had great results. We will be curious what the 2024 monitoring report shows as one can visually see the increase in EWM and in new locations. It was evident in the spring and at nuisance levels now in many areas. We have EWM in front of our property and all along our neighbors shores as well. We are hand harvesting for the first time along our shore, but they are in 8-10 feet of water which makes it difficult. The roots are pretty deep. Our elderly neighbors can not hand harvest and it is unrealistic to try and keep up. The north bay is awful. Interesting to note, on the SI side imaging of our son's fish finder, we noted something "different" in the spring compared to years past and now it obvious EWM colonies.

We fully support the ALA's decision to move forward with whole-lake herbicide treatment as planned for 2025. We also hope a more regular cadence of treatments can occur as well. We would have to learn more about mechanical harvesting (weed cutters) as mentioned in the report. Our only experience with it is having friends on other lakes who have had negative results with this method as it only gives a "haircut".

Thank much for all you and our ALA team does! Wishing you well   -The Dixons

Thank you for providing input on the Draft Anvil Lake Aquatic Plant Management Plan. Perspective is acknowledged, no changes made.