

Manitowish Waters Chain of Lakes
Vilas County, Wisconsin
Aquatic Plant Management Plan
January 2026



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- A. Meeting Presentation Materials
- B. Stakeholder Survey Response Charts and Comments
- C. 2023-2025 EWM Management & Monitoring Summary Materials
- D. WDNR APM Strategic Analysis & Herbicide Fact Sheet
- E. Agency and Public Comments on Official First Draft

1.0 INTRODUCTION

The Manitowish Waters Chain of Lakes consists of 10 lakes with three additional lakes located below the Rest Lake Dam (Figure 1.0-1). The waterbodies total over 4,200 acres located in and just east of the Town of Manitowish Waters in Vilas County. The chain is fed by a series of streams, including Papoose Creek, Rice Creek, Island Creek, the Manitowish River and Trout River. Downstream of the Rest Lake Dam, the Manitowish River runs into Iron County where it becomes one of two main tributaries that feed into the 13,500+ acre Turtle Flambeau Flowage.

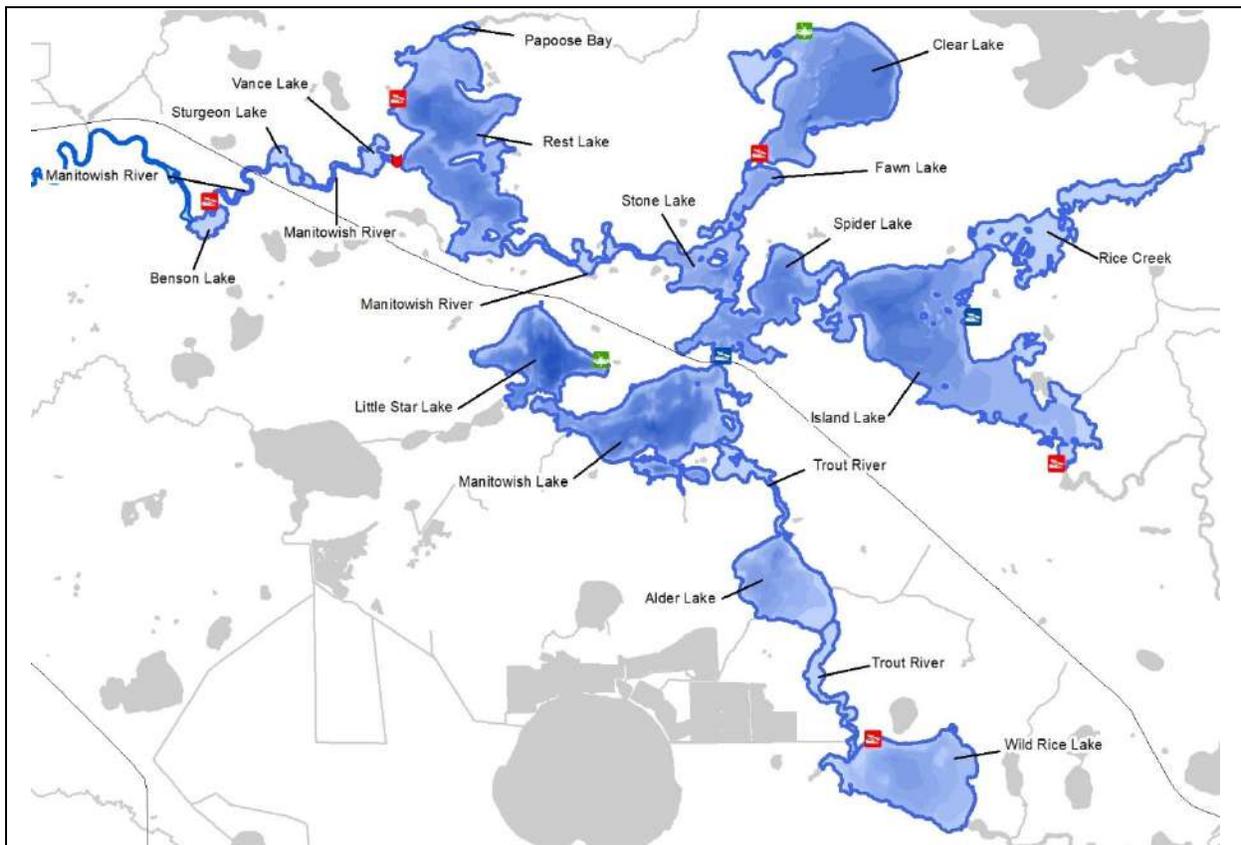


Figure 1.0-1. Manitowish Waters Chain of Lakes.

The chain's 2019 management plan called for continued water quality monitoring, consistent monitoring of AIS, and periodic vegetation monitoring. During 2023, Eurasian watermilfoil was confirmed within the Manitowish Waters Chain of Lakes for the first time. This prompted a rapid response by Manitowish Waters Lake Association (MWLA), NLDC (North Lakeland Discovery Center), WDNR, and other project partners to determine EWM's footprint within the system, conduct a series of informational meetings and educational outreach, and initiate aggressive manual removal efforts.

NLDC was awarded a WDNR Planning grant in February 2025 that includes funding to update MWLA's Aquatic Plant Management Plan, specifically aspects relating to EWM management. While this project will result in the creation of MWLA's EWM management plan for the entire Manitowish Waters Chain of Lakes, the MWLA continues to implement other AIS related management goals and actions from the 2019 comprehensive management plan.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were informed about the project and its results and 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. 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. This information is communicated through meetings, the completion of a stakeholder survey questionnaire, and communications provided by the MWLA. The highlights of this component are described below.

EWM Informational Meeting

On March 20, 2025, Todd Hanke met with stakeholders at the NLDC main building to provide general information about EWM to the attendees. Topics of discussion included EWM biology, overview of the EWM population in the Chain, EWM management techniques, and development of a management plan. Presentation slides from this meeting are contained within Appendix A.

Strategic Planning Meeting

The planning participants were supplied with the draft report sections prior to the meeting. This meeting occurred on August 9, 2025, at NLDC. The objective of the planning meeting was to fortify a solid understanding of the aquatic plants and EWM population within the Chain and to outline management goals and actions that make up the framework of the implementation plan. Todd Hanke, an aquatic ecologist with Onterra, met with available members of the planning group for approximately three hours. The discussion included an overview of the aquatic plant monitoring data that has been collected including point-intercept surveys and community mapping surveys, a review of a sub-set of the stakeholder survey questionnaire results, and extended discussion took place regarding EWM monitoring and management strategies. Chastin Harlow also attended the meeting and provided input from the WDNR's perspective.

2.1 Management Plan Review and Adoption Process

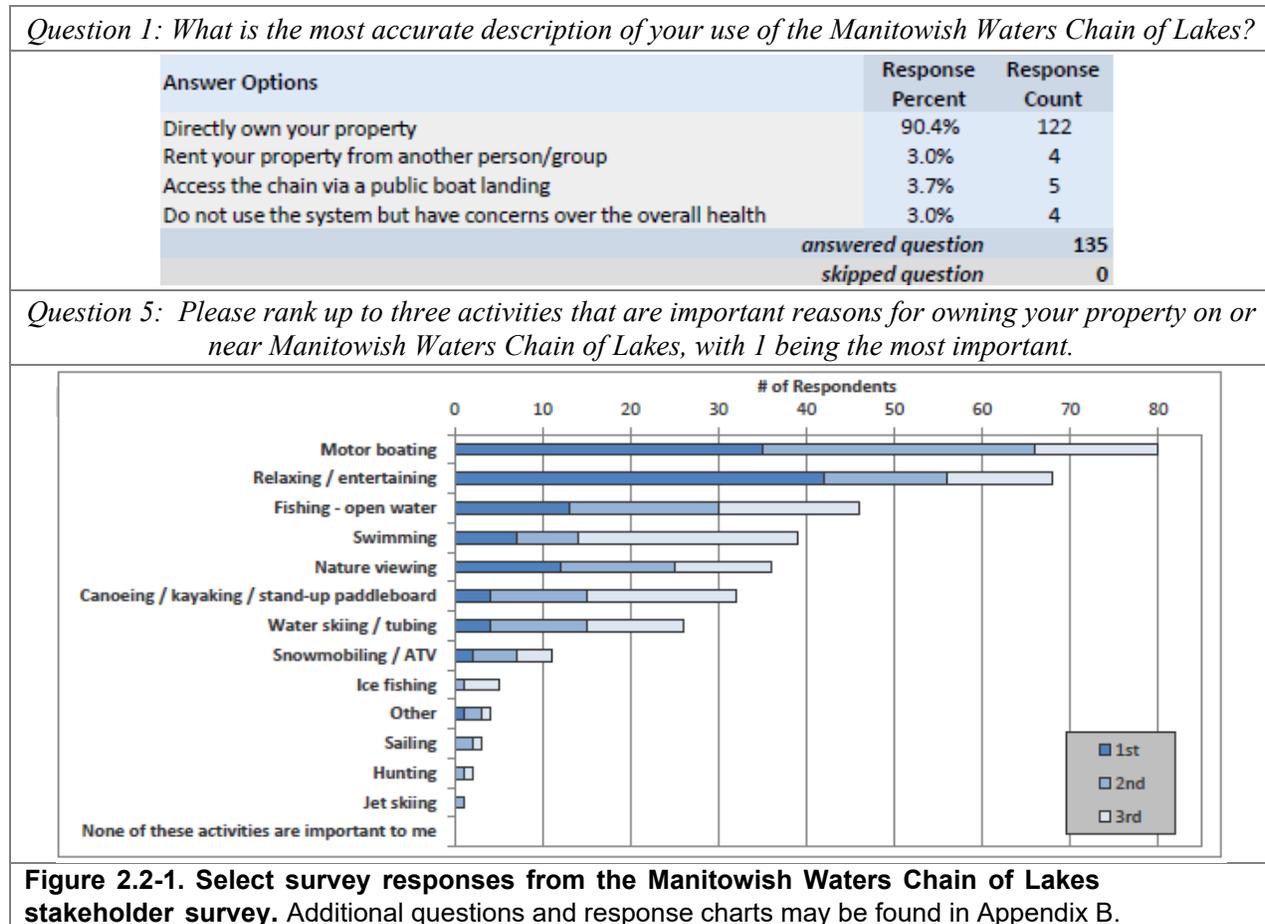
An Official First Draft of the APM Plan document was provided to WDNR for agency review in August 2025. Coinciding with the WDNR review of the draft plan, the draft was made available via the MWLA's outreach and communication avenues for public comment for at least 21 days. A summary of the public and WDNR/agency comments that were received are included within Appendix E.

Agency comments that were received include those from Chastin Harlow (WDNR Water Resources Management Specialist) in October 2025 and Jamie Vandenberg (WDNR AIS Biologist) in November 2025 (Appendix E). The draft plan was updated with results of the summer 2025 EWM monitoring surveys as well as items stemming from the WDNR comments. The final version of the plan was compiled and issued to WDNR and MWLA in January 2026.

2.2 Riparian Stakeholder Survey

As a part of this project, an opportunity to fill out the stakeholder survey was advertised to Manitowish Waters Chain of Lakes Association members and riparian property owners around Manitowish Waters Chain of Lakes. A weblink to access the survey was posted at multiple public access locations around the system and in public spaces in the local area. A link to the survey was also posted on the MWLA website. The survey was designed by Onterra staff and the MWLA EWM committee and reviewed by a WDNR social scientist. During June-July 2025, the survey was posted online through Survey Monkey for survey-takers to answer electronically. 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. As of the survey close date of July 21, 2025, 135 survey responses were received.

Over 90% of survey respondents directly owned property on the Manitowish Waters Chain of Lakes. Motor boating was the activity that had the highest response when asked to rank important reasons for owning property on the Chain, with relaxing/entertaining, and open water fishing also ranking high among respondents (Figure 2.3-1).



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 Manitowish Waters Chain of Lakes between 2005-2025. 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 in 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 Manitowish Waters Chain of Lakes. 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

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all 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

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

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.

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. 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 a lake to be compared to other lakes within the region and state.

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

Manitowish Waters Chain of Lakes 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.

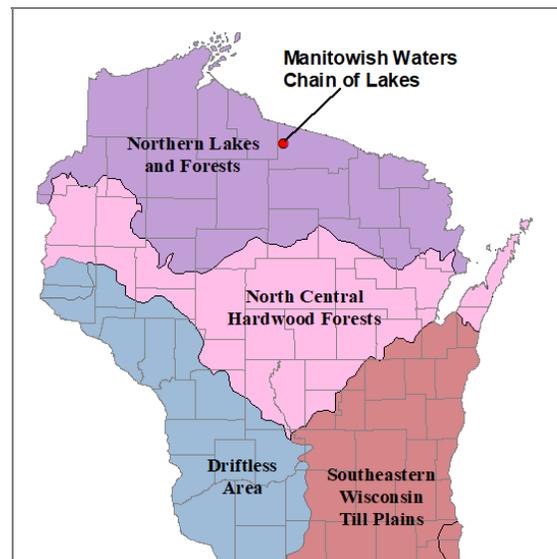


Figure 3.1-1. Location of Manitowish Waters Chain of Lakes within the ecoregions of Wisconsin. After (Nichols, 1999).

3.2 Aquatic Plant Survey Results

Whole-lake point-intercept surveys have been completed on all the lakes comprising the Manitowish Waters Chain of Lakes over the course of time dating back to 2006 (Figure 3.2-1). The details specific aquatic plant studies that have taken place over time are compiled within numerous reports authored by Onterra or NLDC, often as a deliverable for a prior grant funded project. Data specifically from the point-intercept surveys can be viewed on the WDNR's aquatic plant explorer webpage <https://dnr-wisconsin.shinyapps.io/AquaticPlantExplorer/>. Any report that was generated as a part of a grant-funded project is available through the WDNR.

Table 3.2-1. Point-Intercept Surveys Completed on Manitowish Waters Chain of Lakes.

Lake	Point-Intercept Surveys
Alder	2014 (Onterra), 2024 (Onterra)
Benson	2017 (Onterra), 2026*
Clear	2013 (Onterra), 2023 (Onterra)
Fawn	2013 (Onterra), 2023 (Onterra)
Island	2011 (WDNR), 2022 (Onterra)
Little Star	2016 (Onterra), 2025 (NLDC)
Manitowish	2016 (Onterra), 2025 (Onterra)
Rest	2008 (WDNR) 2012 (Onterra), 2022 (Onterra)
Rice Creek	2012 (WDNR), 2023 (Onterra)
Spider	2012 (Onterra), 2022 (Onterra)
Stone	2017 (Onterra), 2026*
Sturgeon	2006 (WDNR) 2017 (Onterra), 2026*
Vance	2017 (Onterra), 2026*
Wild Rice	2008 (WDNR), 2014 (Onterra), 2024 (NLDC)

* anticipated surveys in 2026.

The 2019 comprehensive management plan document compiled the chain-wide species list based on various surveys that had occurred up to that point in time and found there to be over 100 different aquatic plant species within the lakes or around their immediate shores (Onterra, December 2019). This highlights the highly diverse system capable of supporting a wide variety of native plant species. Of these species, approximately 50 are of a submergent or free-floating growth form, while the remaining species are emergent species or those growing on the margins of the lakes including various sedges and grasses.

Amongst the most common species throughout the system are coontail (*Ceratophyllum demersum*), muskgrasses (*Chara* spp.), common waterweed (*Elodea canadensis*), northern watermilfoil (*Myriophyllum sibiricum*), slender naiad (*Najas flexilis*), wild celery (*Valisneria americana*), and many pondweeds such as flat-stem pondweed (*Potamogeton zosteriformis*) (Photograph 3.2-5). All these particular species are known within each of the 14 main lakes in the system.

Submergent non-native species have been documented on Manitowish Waters Chain of Lakes in the past including Eurasian watermilfoil, curly-leaf pondweed, while pale yellow iris, purple

loosestrife, common forget-me-not, reed canary grass, and giant reed have all been identified around the shoreline of the system. Due to their ecological, economical, and sociological significance, the non-native plants and their management in Manitowish Waters Chain of Lakes are discussed in the subsequent *Non-Native Aquatic Plants in Manitowish Waters Chain of Lakes* subsection (3.3).



Photograph 3.2-1. Common submergent aquatic plant species within Manitowish Waters Chain of Lakes. Clockwise from top left – muskgrasses, coontail, common waterweed, flat-stem pondweed, slender naiad, wild celery.

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 do not include incidental species. Figure 3.2-1 displays the average FQI value from each lake in the chain and indicates that the values range from 23.0-40.7. Most of the lakes have an average FQI that is above the ecoregion and state median values. This demonstrates the generally high quality of the aquatic plant population in the Chain.

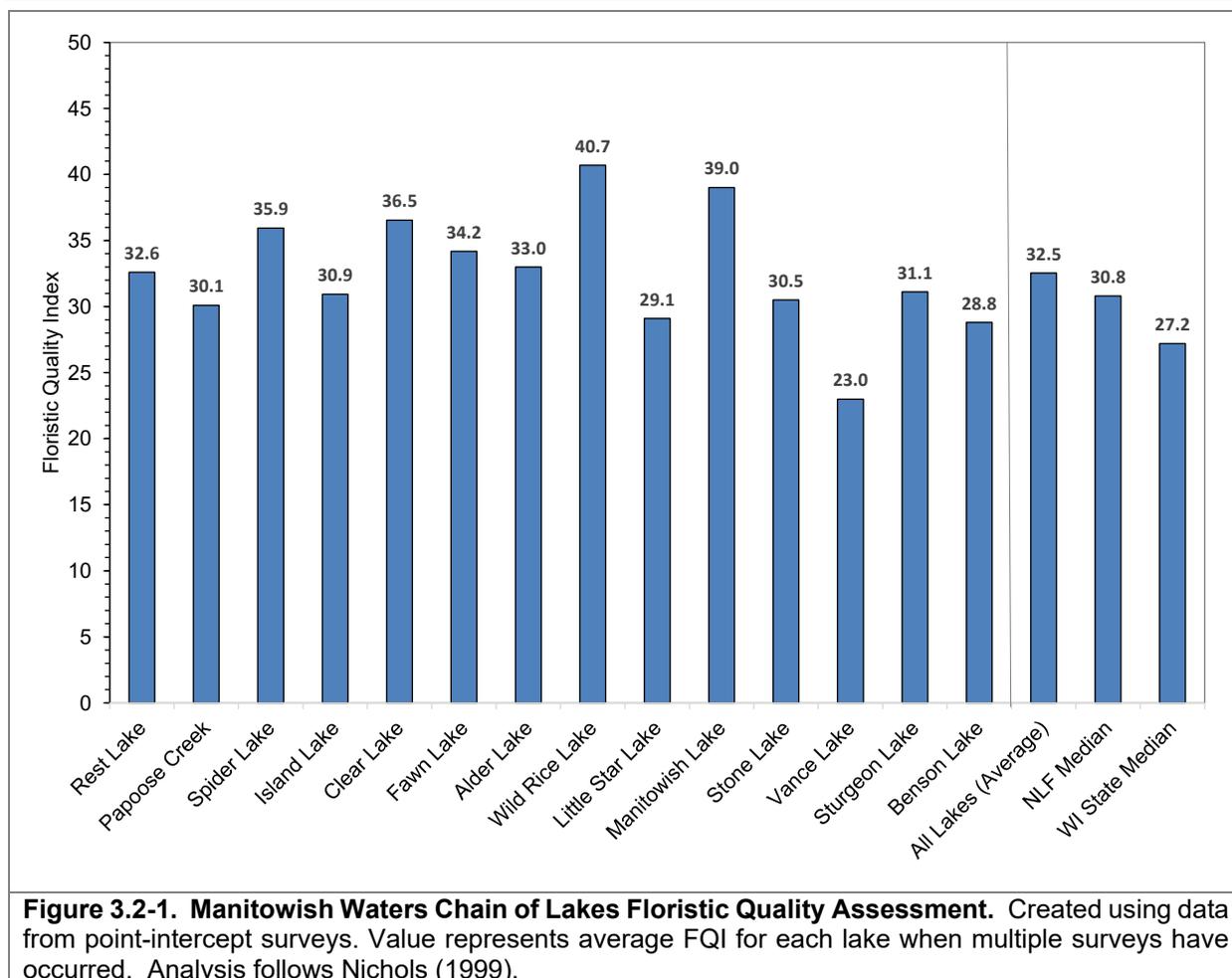


Figure 3.2-2 investigates the average number of native plant species at each littoral point-intercept sampling location for each lake in the system. These data indicate the Fawn Lake, Wild Rice Lake, and Papoose creek had the highest number of native species per sampling point, while Vance Lake, Rest Lake, and Island Lake had the fewest.

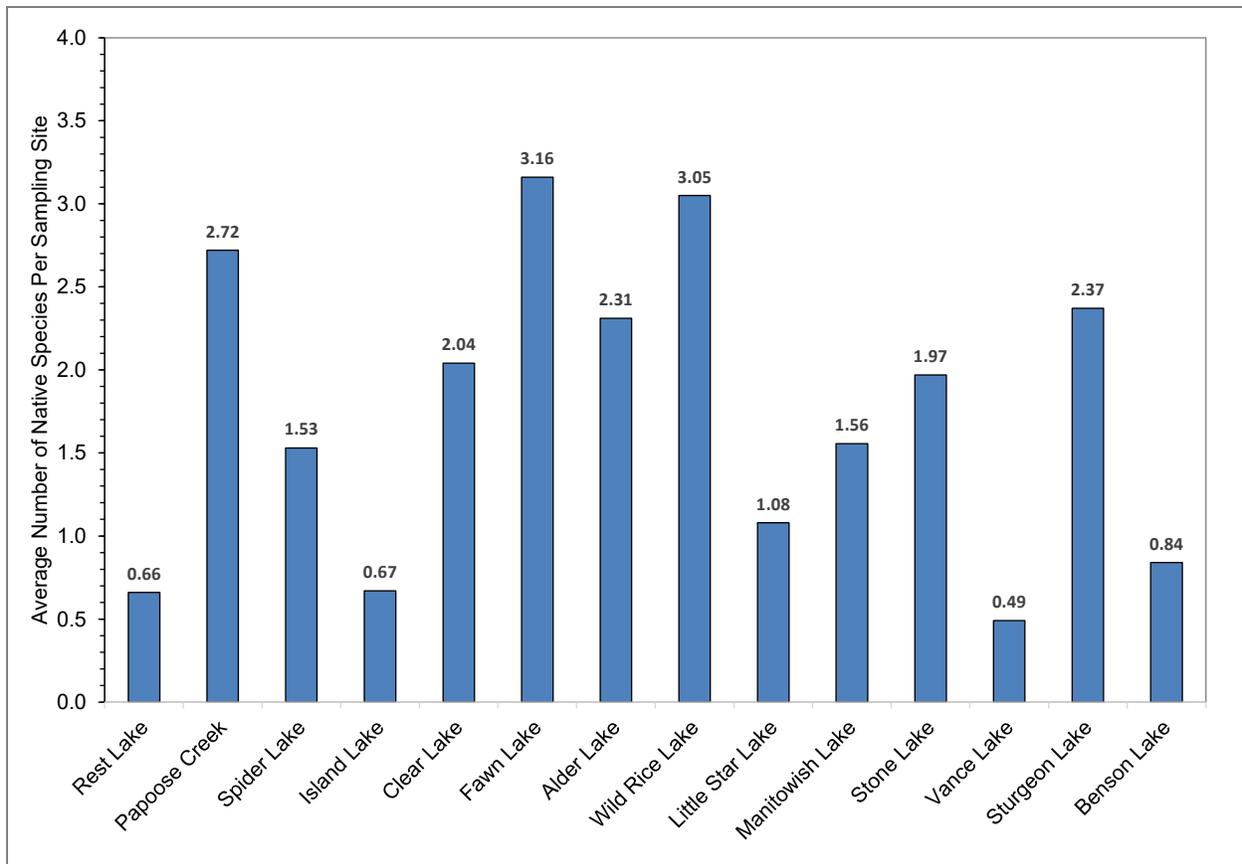


Figure 3.2-2. Average number of native aquatic plant species per littoral sampling site. Data compiled from whole-lake point-intercept surveys.

Manitowish Lake 2025 Point-Intercept Survey Results

Figure 3.2-3 displays the littoral frequency of occurrence of aquatic plants from the 2025 point-intercept survey on Manitowish Lake. Littoral frequency of occurrence is used to describe how often each species occurred in the points that are within the maximum depth of plant growth (littoral zone) and is displayed as a percentage. A total of 33 native aquatic plant species were documented in Manitowish Lake during the 2025 point-intercept survey. Of these 33 species, fern-leaf pondweed (*Potamogeton robbinsii*), slender naiad (*Najas flexilis*), wild celery (*Vallisneria americana*), and muskgrasses (*Chara spp.*) were the most frequently encountered. Eurasian watermilfoil exhibited an occurrence of 2.3%.

The 2025 point-intercept survey on Manitowish Lake yielded EWM on 11 survey points and Figure 3.2-4 displays the spatial locations where these occurrences were in the 2025 survey along with four additional sites where EWM was visually observed during the survey but not physically on the survey rake. Sample sites that contained EWM spanned depths between 3-12 feet. In at least some of the deeper growing sample sites where EWM was present on the point-intercept survey, the plants were not visible from the surface.

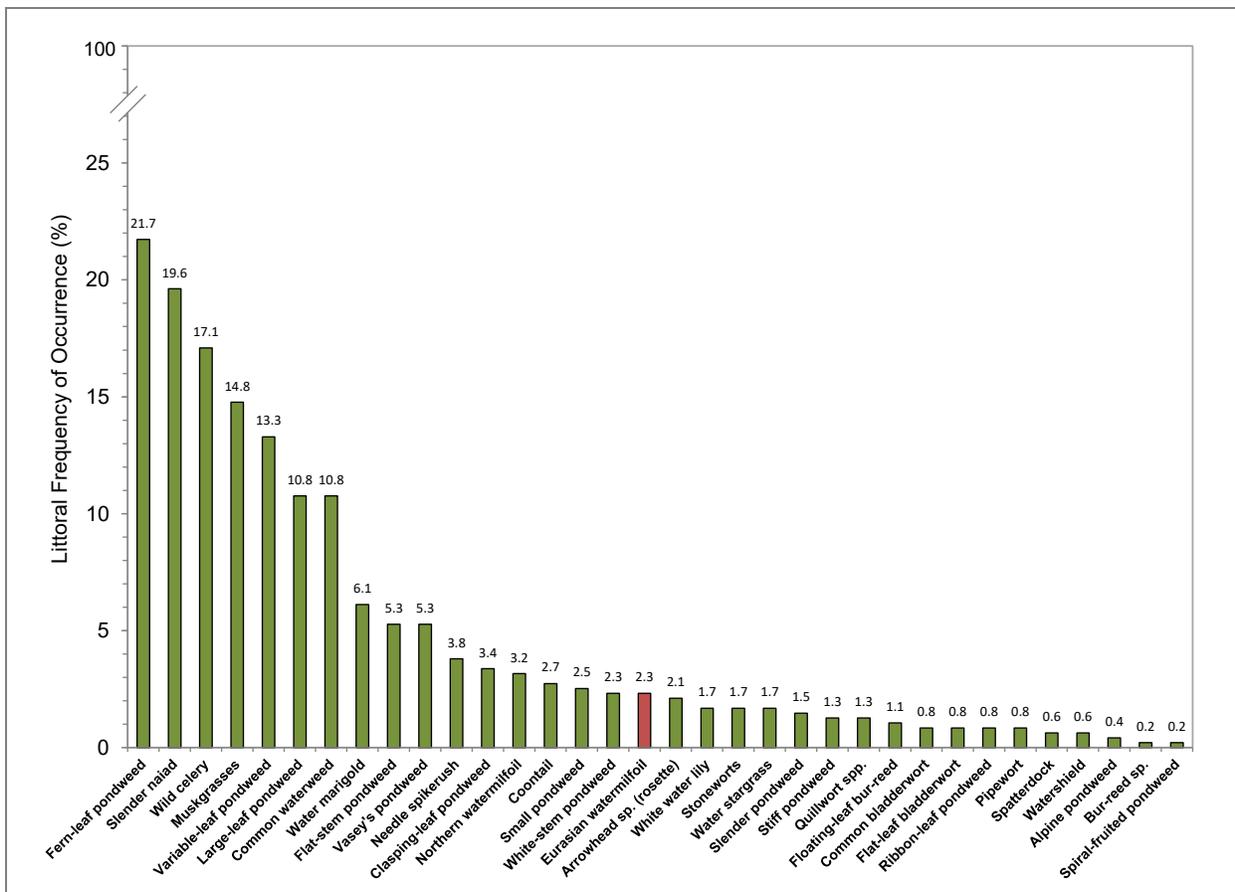


Figure 3.2-3. Littoral frequency of occurrence of aquatic plant species in Manitowish Lake in 2025. Data from 2025 point-intercept survey.

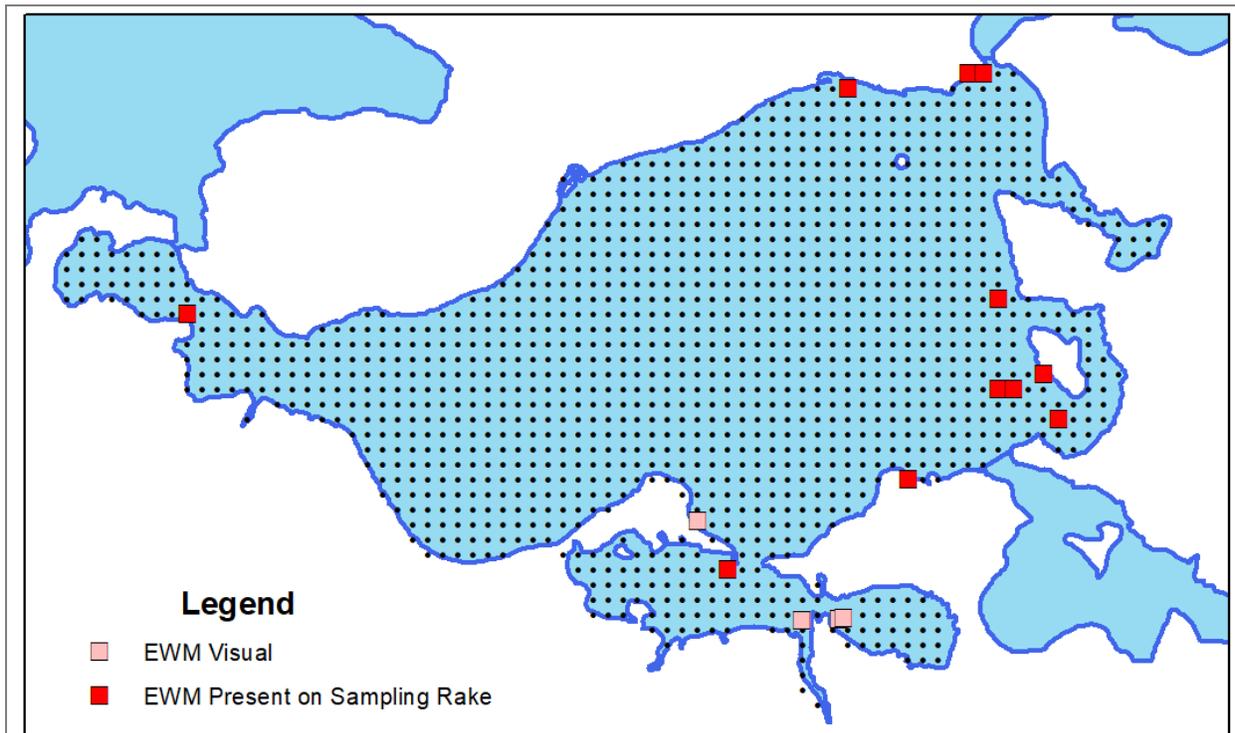


Figure 3.2-4. Manitowish Lake July 2025 Point-Intercept Survey – EWM Locations.

3.3 Non-native Aquatic Plants in Manitowish Waters Chain of Lakes

Eurasian watermilfoil (Myriophyllum spicatum)

One of the submersed non-native aquatic plants known to be present within Manitowish Waters Chain of Lakes 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 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.

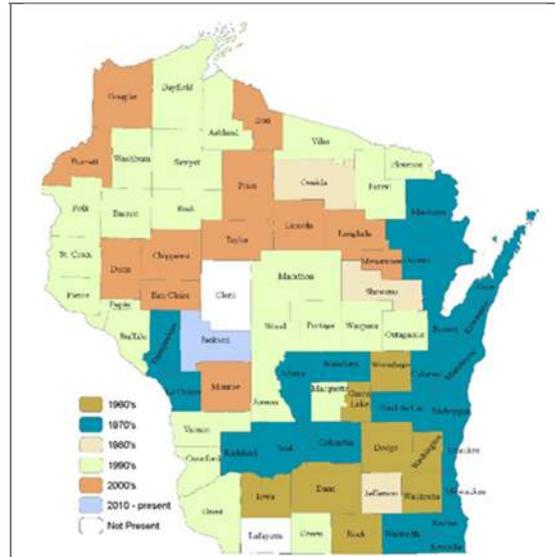


Figure 3.3-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2022.

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 on 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.

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 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



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

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 must 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.

For established populations, 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.

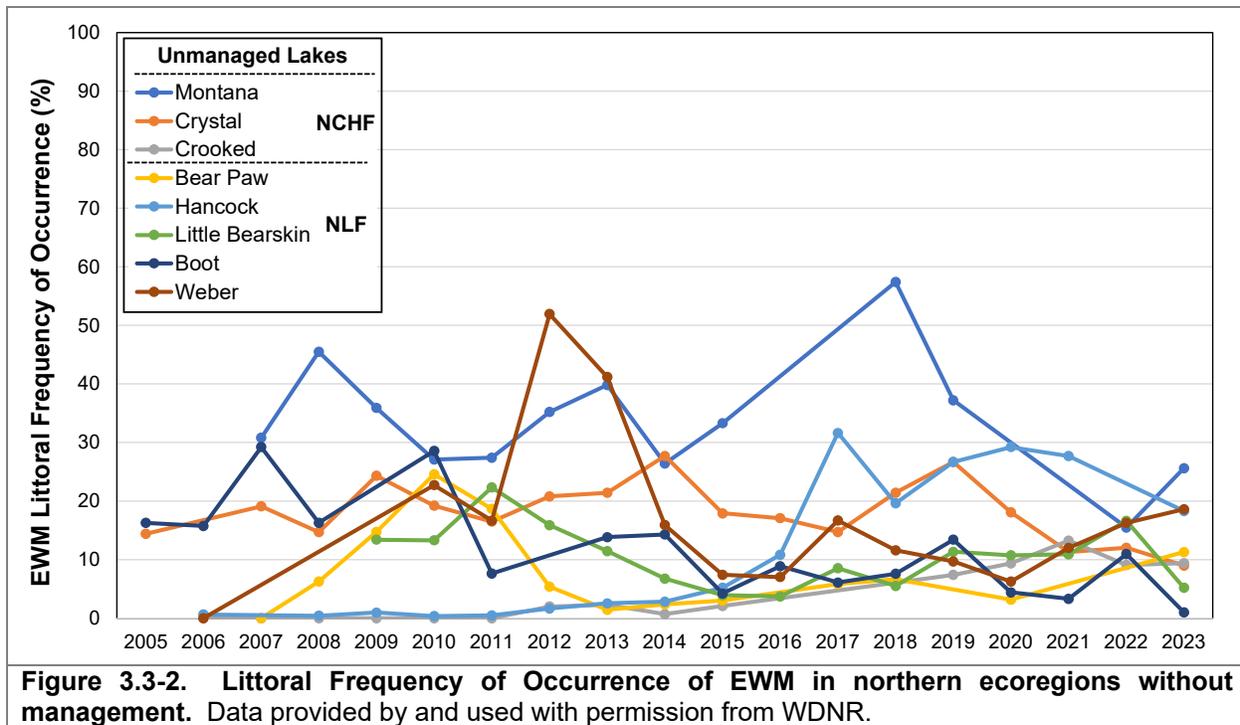


Figure 3.3-2. Littoral Frequency of Occurrence of EWM in northern ecoregions without management. Data provided by and used with permission from WDNR.

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.

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 to 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.



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

EWM population of Manitowish Waters Chain of Lakes

Point-intercept survey data can be useful for tracking EWM populations over time, but the survey methodology often does not capture EWM when the population is very low within a given lake, much like the case on several waterbodies on the Manitowish Chain. The 2025 point-intercept survey on Manitowish Lake is the only point-intercept survey to date throughout the Chain where EWM was physically sampled on the survey rake. The EWM population in the Manitowish Waters Chain of Lakes is not prevalent in most waterbodies and has only been documented on the point-intercept survey within Manitowish Lake as of 2025. While EWM is known to be present in several other waterbodies, all previous point-intercept surveys around the system have not yielded EWM on the survey rake and thus the frequency of occurrence of EWM in these lakes is 0%.

The EWM population in the Manitowish Waters Chain of Lakes has been monitored since discovery through a combination of meander surveys led by the NLDC Woods & Waters team and by professional ecologists from Onterra. Rooted EWM plants have been confirmed within Manitowish Lake, Spider Lake, Stone Lake, Little Star Lake, Fawn Lake, and Sturgeon Lake in addition to within stretches of the Trout River and Manitowish River (Figure 3.3-3). Maps depicting the EWM population identified during 2023-2024 by NLDC are contained in Appendix C. The NLDC monitoring efforts included surveying all lakes in the Chain where no EWM was known to be present, and surveying lakes with isolated few EWM plants on one or more occasions during the growing season. Results of NLDC monitoring are shared with Onterra ecologists, in particular for any waterbodies that Onterra also has EWM mapping surveys scheduled for the same season.

Map 1 displays the results of Onterra's August 2024 late-season EWM mapping survey of Manitowish Lake and the Trout River between Alder and Manitowish Lakes. This survey indicated a widespread EWM population within the Trout River section and most of the known population in Manitowish Lake being in the southeastern part of the lake. In total, approximately 14 acres of colonized EWM was delineated within the Trout River section, of which most were described as either *highly scattered* or *scattered* densities. Local accounts suggested that the densities of EWM

in this site may have increased during 2024 in the later part of the growing season after the mapping survey was completed. The population in Manitowish Lake was largely concentrated in the southeastern part of the lake and was comprised mostly of *single plants* or *clumps of plants* along with two *highly scattered* colonies that totaled under one acre in size.

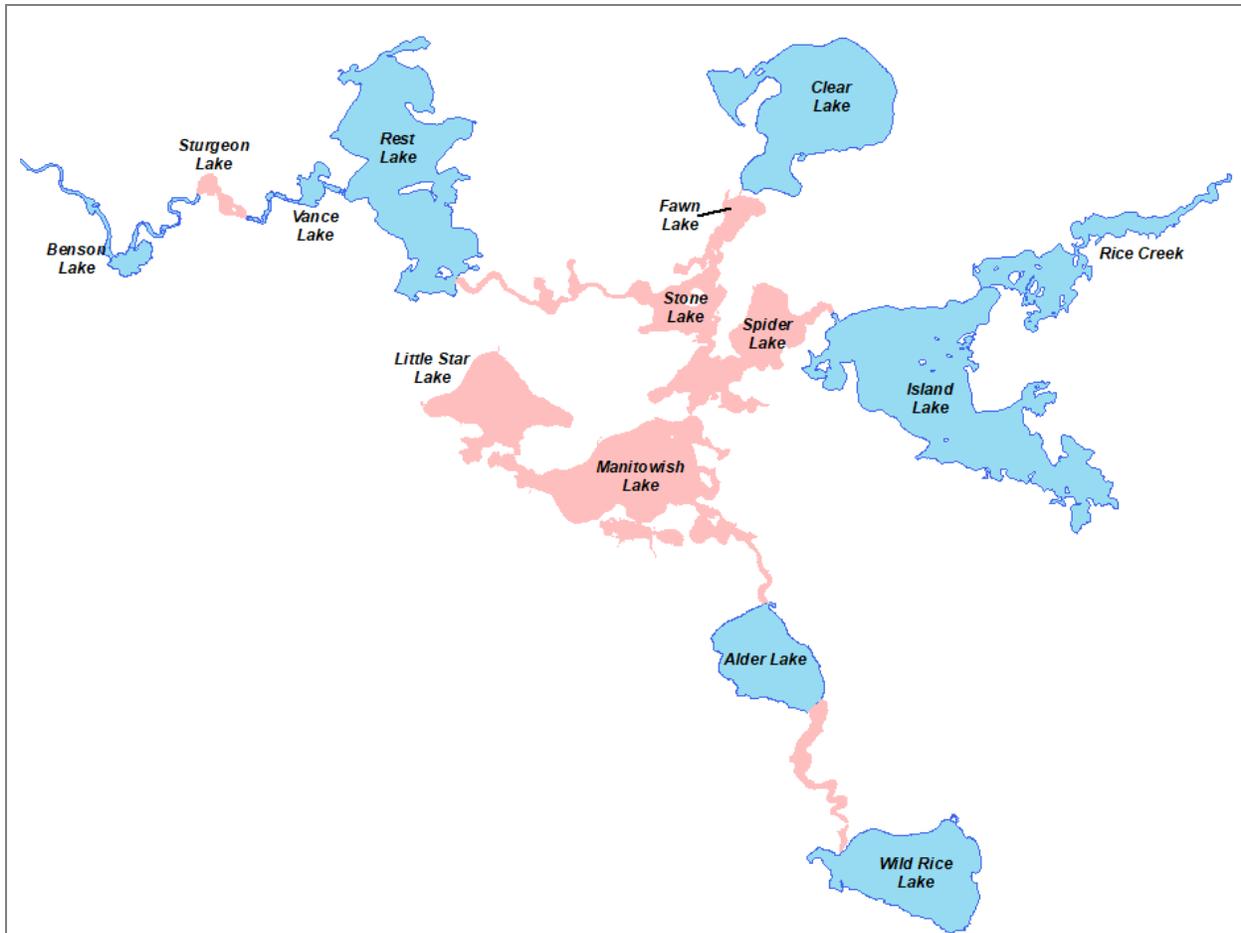


Figure 3.3-3. Known EWM Distribution within Manitowish Waters Chain of Lake as of July 2025. Lakes shaded red have confirmed EWM populations.

During mid-June 2025, Onterra field crews mapped EWM within the waterbodies that were included in the scope of the CLP monitoring project. While conducting the CLP meander survey, crews also recorded any EWM occurrences they encountered, the results of which are displayed on Map 2. Several *single plant* occurrences were marked within southern portions of Spider Lake, and one plant was marked near the border of Stone Lake and Fawn Lake. The survey crews did not encounter EWM within Rest Lake, Island Lake, or Rice Creek during this visit. The Trout River was not surveyed by Onterra during this visit.

Late-season EWM mapping surveys were conducted by Onterra on known EWM lakes on September 2, 4, & 16, 2025. All previously mapped EWM occurrences were loaded onto the on-board field survey maps allowed for known sites to be thoroughly investigated. During this visit, Onterra field survey crews covered the entire littoral area of Manitowish Lake, all of the Lower Trout River section, and most of the Upper Trout River section. Focused surveys were completed within Spider Lake, Stone Lake, and Fawn Lake and were limited to sites where NLDC had marked

EWM previously. The results of the surveys are described below and are displayed on maps 3–7. Additionally, the most recent EWM mapping survey results can be viewed on an interactive webpage built specifically as a part of this APM project located on the MWLA website <https://mwllakes.com/>

Lower Trout River (Map 3): The population within the Lower Trout River was greater than the population mapped during 2024 and included a variety of density ratings. EWM was present essentially throughout this section of the system.

Upper Trout River (Map 4): A dense area was mapped along a portion of the eastern shoreline of this section of the Trout River, and many single plants and clumps of plants were marked around the surveyed area.

Manitowish Lake (Map 5): The largest colonies were near the island on the southeast end of the lake, but these were not particularly dense. Isolated plants were spotted around many other areas of the lake, and a few more colonies were delineated on the western end of the lake near the connection to Little Star Lake.

Spider Lake (Map 6): This focused survey included the southern end of the lake where field crews encountered colonized EWM mapped as either highly scattered or scattered densities. A few isolated singles were marked in small bays on the northern shoreline, but the survey area did not include other littoral areas around the lake.

Stone Lake (Map 6): A handful of single plants and clumps of plants were marked on the eastern side of the lake in the focus areas provided by NLDC.

Fawn Lake (Map 7): Several single plants and clump of plants were marked in the northeast end of the lake in focus areas, while the rest of the lake was not surveyed by Onterra during this trip.

Little Star Lake: No map is included for this since this lake was not a part of the Onterra Late-Season EWM mapping surveys, but Onterra marked a few occurrences of EWM within Little Star Lake while on the lake for a survey as a part of a separate project.

Manitowish Waters Chain of Lakes Historic EWM Management

Since Eurasian watermilfoil's discovery, hand harvesting and DASH (Diver Assisted Suction Harvesting) has been the only form of management. In some lakes in Wisconsin, this method can slow the spread and decrease the population of EWM throughout the lake with some lakes even being able to use this control method as a long-term control solution.

During 2024, APM, LLC, a firm that offers hand harvesting and DASH harvesting services, conducted approximately 18 days of DASH and nine days of manual removal efforts within Manitowish Lake and Spider Lake targeting EWM. These efforts spanned between July 9 and September 19 and resulted in a reported harvest of 1,224 cubic feet of EWM. Professional harvesting activities took place in southern portions of Spider Lake, known EWM sites in Manitowish Lake, and within the Trout River section spanning between Manitowish Lake and Alder Lake. Divers indicated an increased EWM density present in many work areas compared to

densities documented on the previous mapping survey earlier that season. Additional details of the harvest efforts are available in Appendix C.

NLDC staff also conducted EWM removal efforts during the 2024 season, with activities focused on identifying and harvesting low-density or isolated EWM occurrences.

The 2025 management strategy was developed during a series of meetings and discussions during the winter/spring of 2025 and resulted in a plan to conduct a substantial hand harvesting/DASH effort. A local fundraising effort contributed substantial funds to apply to the 2025 harvesting activities. Contracted DASH efforts were focused on the largest known colonies within the Alder Lake channel and portions of Manitowish Lake, while NLDC staff would target isolated occurrences around other areas of the Chain.

Professional harvesting activities spanned from June 16 – September 1, 2025, with 42 total contracted days of efforts. Approximately 2,532 cubic feet of EWM were harvested over the course of the season by divers from APM, LLC. Most efforts focused on EWM present in the Lower Trout River, while some efforts took place within Manitowish Lake as well. A summary of the professional manual removal efforts is available within Appendix C.

Staff from the NLDC reported 167 hours of EWM hand pulling time during 2025. These efforts were conducted in known EWM areas outside of where contracted DASH activities from APM, LLC were occurring.

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 MWLA to review and consider when creating their updated APM Plan.

During a planning meeting for this project, Onterra outlined three broad EWM population management perspectives for consideration, including a generic potential action plan for each (Figure 3.3-4). As these management perspectives apply to the Manitowish Waters Chain, each waterbody within the Chain may be employing a different management perspective based on the current EWM population in the lake. It may make sense for certain waterbodies in the Chain to hand pull the entire known EWM population while this technique may not be applicable to another part of the system which may be entertaining various management techniques or even not managing EWM at all. Onterra extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* to serve as an objective baseline for the MWLA to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Manitowish Waters Chain of Lakes ecosystem. These chapters are included as Appendix D. The MWLA 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)**
 - May utilize 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 3.3-4. 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.

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. Due to the scale of the EWM population, large-scale management approaches—such as herbicide treatments—may be considered; however, these methods would require a thorough risk assessment given their broader potential environmental impacts. 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.

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 are 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. Targeted small-scale management approaches (manual removal/DASH) are the most likely to be approved, but they may only offer limited results. Although herbicide treatment and mechanical harvesting may be more effective for restoring navigation, their greater potential for environmental impact makes them more difficult to obtain approval for.

Aquatic Plant Management Best Management Practices

Many times, an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of several techniques that can be utilized to manage invasive species such as Eurasian watermilfoil for example. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. Unfortunately, there are no “silver bullets” that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity.

Manual Removal (Hand-Harvesting & DASH)

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources, or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however, Wisconsin law states that all plant fragments must be removed.



Photograph 3.3-4. Manual Removal with DASH. Photo credit Aquatic Plant Management, LLC.

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.

Manual removal or hand-harvesting of aquatic invasive species has gained favor in recent years as an alternative to herbicide control programs. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process.

Contracting aquatic invasive species removal by third-party firm can cost approximately \$1,500+ per day for traditional hand-harvesting methods whereas the costs can be closer to \$2,500 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants, much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In



Photograph 3.3-5. Mechanical harvester.

In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

A mechanical harvesting strategy on the Manitowish Waters Chain of Lakes would likely be designed with the intention of providing nuisance relief in the form of cutting navigation lanes through dense aquatic plants in high-use areas such as riparian piers or high traffic corridors. Multiple (usually 2-3) cutting events during the growing season may be required to maintain navigation lanes. A WDNR permit (NR 109) is required when conducting mechanical harvesting operations with permits often issued as either 1-year permit or a 5-year permit. Mechanical harvesting permits often have conditions limiting the depth at which the harvesting may occur which is typically three feet to avoid disturbing the bottom sediments or risking the harvester becoming grounded in shallow water.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian watermilfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown potential in reducing Eurasian watermilfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian watermilfoil. Milfoil weevils are not currently available for purchase. Some lake groups have investigated rearing weevils on their own. Groups may measure weevil population density in the lake or document weevil herbivory impacts to EWM. Expectations of this management technique may be to damage EWM plants or potentially suppress their biomass. A manual that is authored

by Golden Sands RC&D, and is referenced by WDNR, explains weevil biocontrol considerations for Wisconsin Lakes (Golden Sands, 2017).

Herbicide Treatment

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers. Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is more prevalent. Resource managers employ strategic management techniques towards aquatic invasive species, with the objective of reducing the target plant's population



Photograph 3.3-6. Liquid herbicide application.
Photo credit: Amy Kay, Clarke.

over time; and an overarching goal of attaining long-term ecological restoration. For submergent vegetation, this largely consists of implementing control strategies early in the growing season; either as spatially targeted, small-scale spot treatments or low-dose, large-scale (whole lake) treatments. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb herbicide.

While there are approximately 300 herbicides registered for terrestrial use in the United States, only 13 active ingredients can be applied into or near aquatic systems. All aquatic herbicides must be applied in accordance with the product's US Environmental Protection Agency (EPA) approved label. There are numerous formulations and brands of aquatic herbicides, and an extensive list can be found in Appendix F of (Gettys, 2009).

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if, "you are standing in socks and they get wet." In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high-water mark require herbicides specifically labeled by the United States Environmental Protection Agency.

Aquatic herbicides can be classified in many ways. The arguably clearest division amongst aquatic herbicides is their general mode of action and fall into two basic categories:

1. Contact herbicides act by causing extensive cellular damage but usually do not affect the areas that are not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

Both types are commonly used in Wisconsin with varying degrees of success. In northern Wisconsin, use of contact herbicides for EWM management is generally not supported or permitted by WDNR as these tend to be non-selective herbicides that impact many native species while only resulting in seasonal sub-lethal impacts to EWM. The use of herbicides is potentially hazardous to both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to reduce herbicide concentration within aquatic systems. Understanding concentration and exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of an ongoing cooperative research project between the Wisconsin Department of Natural Resources, US Army Corps of Engineers Research and Development Center, and private consultants (including Onterra). This research couples quantitative aquatic plant monitoring with field-collected herbicide concentration data to evaluate efficacy and selectivity of control strategies implemented on a subset of Wisconsin lakes and flowages. Based on their preliminary findings, lake managers have adopted two main treatment strategies: 1) whole-lake treatments, and 2) spot treatments.

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 effects 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. More recent spot treatment strategies have embraced alternate herbicides or herbicide combinations thought to be more effective in short CET scenarios.

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 of success in a spot-treatment design scenario compared to offshore sites.

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. Barrier curtain construction and placement is the responsibility of the lake group, requiring advance planning efforts and a formidable volunteer base.

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. Systemic herbicides including 2,4-D, fluridone, and florypyrauxifen-benzyl are most commonly utilized in whole-lake treatment designs, and each active ingredient comes with its own risk assessment and use requirements.

Herbicide control strategies may be applicable on the Manitowish Waters Chain of Lakes in the future. Further information is included below for the MWLA to review as a part of building an understanding of current BMP's for EWM management in Wisconsin.

ProcellaCOR

ProcellaCOR™ has been the state's most popular herbicide for EWM management in recent years, and its use is consistent with current BMP's for EWM management in Wisconsin. The active ingredient florypyrauxifen-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 several Wisconsin lakes and is also being studied in barrier curtain treatment scenarios. Onterra has monitored approximately 100 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 in Appendix D.

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.

The active ingredient of ProcellaCOR™, florypyrauxifen-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 florypyrauxifen-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 florypyrauxifen-benzyl is florypyrauxifen 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. Florypyrauxifen acid has been shown to persist in the lake longer than the active ingredient, with some 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 ProcettaCOR™ treatments indicates that EWM control has been high with almost no EWM being located in treated areas during monitoring completed later in the same season as treatment. Some treated sites have shown EWM population recovery two-years after treatment, while most other sites have demonstrated three years or more of continued EWM reductions to-date. For many ProcettaCOR™ 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.

Native aquatic plant monitoring data indicates that northern watermilfoil is highly susceptible to ProcettaCOR™. Other species that have shown a degree of susceptibility to this chemical include water marigold, coontail, and potentially water stargrass. 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 show signs of herbicidal stress such as leaf twisting (epinasty) but typically rebound a few weeks after treatment including in intentional whole-lake treatment scenarios. Monitoring data indicates that ProcettaCOR™ is more selective than 2,4-D, or other contact herbicides towards native plant species at current use rates.

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 has 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 ProcettaCOR™ 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 ProcettaCOR™ 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.

Northern wild rice (*Zizania sp.*)

Northern wild rice is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers and possesses great cultural significance to the Chippewa Tribal Communities. In addition, northern wild rice provides several valuable ecological services which include food and habitat sources for wildlife, soil stabilization, and nutrient uptake. Preliminary research suggests ProcettaCOR may be impactful to wild rice species. Recent WDNR policy precludes the use of ProcettaCOR if calculations indicate the potential for any detectable levels of herbicide to come into contact with wild rice populations. Populations of wild rice documented by Onterra during emergent/floating-leaf community mapping surveys are displayed in pink on Figure 3.3-5.

Professional floating-leaf & emergent species community mapping surveys have taken place on all lakes on the chain and the most recently available data for communities with a wild rice presence is displayed in Figure 3.3-5. The largest wild rice communities have been documented in Rice Creek, southern portions of Island Lake, Wild Rice Lake, northern portions of Rest Lake, and within the Trout River between Alder and Wild Rice Lakes. Rice was not observed during the community mapping surveys in the stretch of the Trout River between Alder and Manitowish Lake.

Populations of wild rice have also been documented by GLIFWC within the Manitowish Waters Chain of Lakes and include the section of the Trout River between where the highest EWM population in the system is currently found <https://maps.glifwc.org/>. The following narrative text is copied from GLIFWC's wild rice inventory by waterbody in the Manitowish Waters Chain.

Rest Lake: *The northwest bay is one of 2 primary rice beds associated with Rest Lake (see Papoose Creek for the other bed). Lack of development around this bay has left this bed intact. Currently, some modification of the operation of the Rest Lake Dam is being considered for the benefit of sturgeon spawning in the Manitowish River downstream. Thus watch status should be medium-high if any modifications are made until it is shown there are no negative impacts.*

Papoose Creek: *Papoose Creek, on the northeast part of Rest Lake, is one of 2 primary rice beds associated with Rest Lake (see Rest Lake for the other rice bed). Extensive mechanical removal of rice by riparian landowners on Papoose Creek has taken place almost annually in the area where it widens just before entering Rest Lake. This has created the patchwork of open channels, but rice has continued to persist where not actively removed.*

Rice Creek: *As the name suggests, Rice Creek supports significant amounts of rice. The section between Round Lake and Big Lake supports substantial beds, and included along this section is the small, Unnamed (Duck) Lake. Rice is also abundant on the section between CTY K and the unnamed water above Island Lake. Watch status for both areas is low because of site familiarity.*

The DNR Surface Water Viewer identifies the transition between Rice Creek and Island Lake as an unnamed waterbody. While this area is important to harvesters, harvest from this area is reported by survey respondents as being from Rice Creek or Island Lake. Although the harvest at this site is not date-regulated, it is part of the area that has been posted in recent years with a request for voluntary compliance. Watch status is low.

Island Lake: *Island Lake is part of a chain of waters in Vilas County with a strong presence of rice. Going from north to south, it consists of Rice Creek (the portion south of CTH K); a section considered an unnamed water on the DNR Surface water viewer (with WBIC 5505819) but commonly considered a widening of Rice Creek; Island Lake itself; and the Manitowish River (the portion south of Island Lake). The largest beds on Island Lake proper are in the large shallow area on the southeast end of the lake adjacent to where the Manitowish River enters. Rice along most of this entire chain is influenced by the Rest Lake Dam, the operation of which is currently under review. This entire chain is also important to harvesters. Watch status of these waters is high given the high likelihood that the operation of the Rest Lake Dam may change. Island Lake was added to the list of date-regulated waters in July of 2022.*

Wild Rice Lake: *The best rice beds on Wild Rice Lake are found in the vicinity of the Trout River inlet and outlet; little if any rice is known to exist on other parts of the lake. The name suggests*

rice may have once been more plentiful, but GLIFWC is unfamiliar with any distribution other than as described above. It may be that some beds were lost when water levels were raised downstream with the Rest Lake Dam. Watch status is low because of site familiarity.

Trout River: *Rice is found in many sections of the Trout River, including the area above Wild Rice Lake, between Wild Rice and Alder Lakes, and between Alder and Manitowish Lakes. The exact locations of smaller beds are not well documented, but this system appears to hold rice in most areas with suitable habitat. Many of the best beds are within the Lac du Flambeau Reservation, and are protected and managed by the Tribe. Watch status is medium-low, but some additional information on distribution, especially below Manitowish Lake, would be useful.*

Manitowish River: *Rice beds exist in several sections of the Manitowish River in Iron and Vilas counties. In Iron County the full extent of rice still needs better documentation, but rice is known to occur in some abundance in scattered patches from the Vilas County line to the HWY 47 Bridge. It likely also occurs in patches of suitable habitat in the more remote sections downstream to the junction with the Flambeau River. The bands of rice on this river are often fairly narrow and do not show up well in air photos. Watch status is medium in Iron County because proposed changes to the operation of the Rest Lake Dam may impact the abundance of rice (see IRON 7. Manitowish River). In Vilas County the most significant beds occur between the tributary from Little Rice Lake upstream to the area below the Fish Trap dam, and on the section south of Island Lake. These sections receive more harvesting pressure than most river sites in the state. Small patches of rice likely exist in other areas, including the last river mile before the Iron County line. Watch status is low in Vilas County because of site familiarity (see VILAS 20. Manitowish River).*

All other waterbodies on the Manitowish Waters Chain not listed above, do not have a narrative description in the wild rice inventory and include Alder Lake, Manitowish Lake, Little Star Lake, Spider Lake, Stone Lake, Fawn Lake, and Clear Lake. It is unknown to what extent wild rice may have been present around the Chain prior to monitoring in recent decades.

If the EWM population expands throughout areas of the Chain in the years to come, particularly if nuisance conditions are occurring, and the site is not located in an area with wild rice presence, an herbicide spot-treatment management strategy may be given consideration. Calculations may be necessary to estimate the potential whole-lake concentrations within a waterbody to gauge whether detectable levels of herbicide may be present in a lake or lake that is downstream from a treated area. This topic is elaborated on within section 5.0 below.

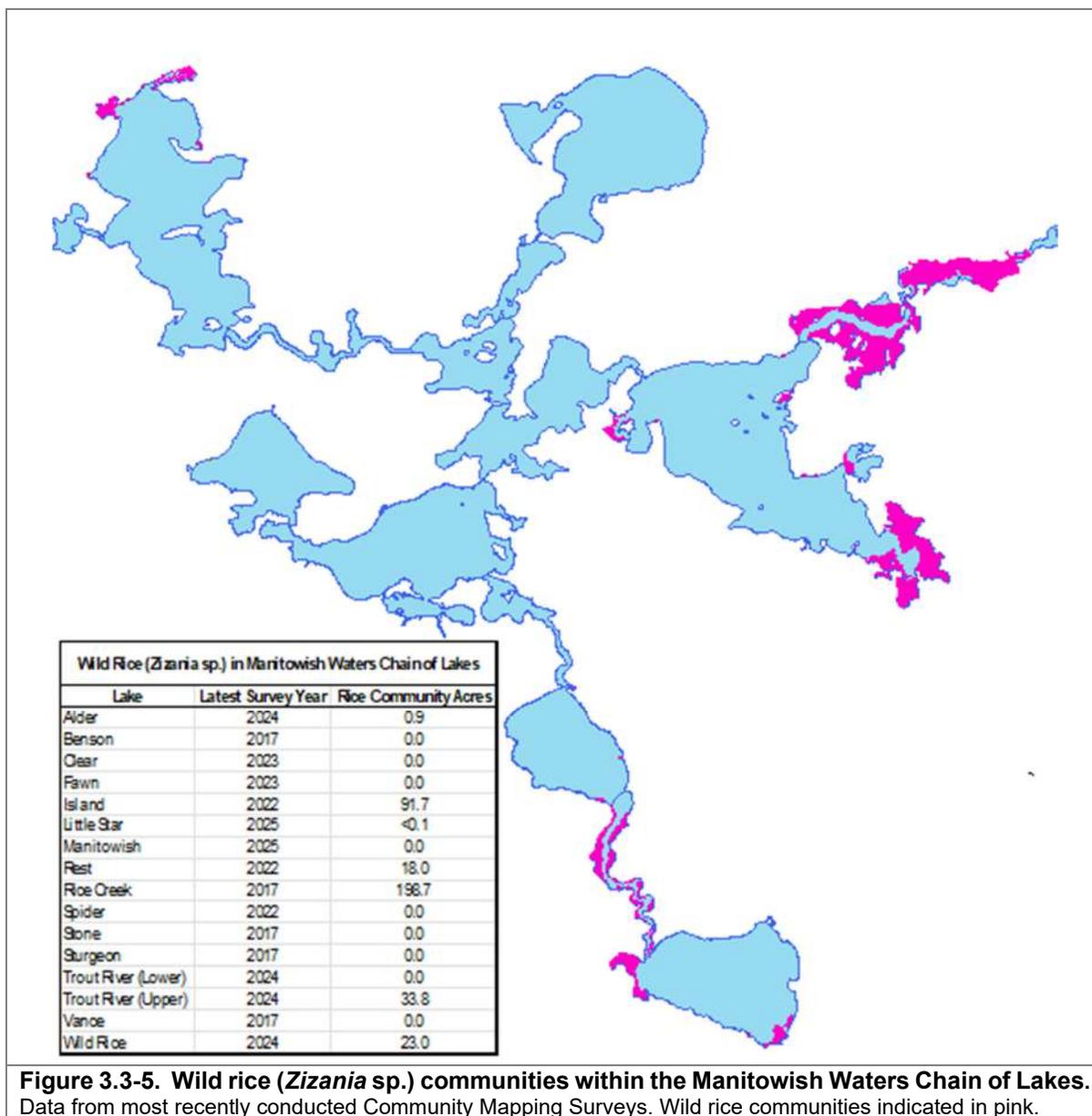


Figure 3.3-5. Wild rice (*Zizania* sp.) communities within the Manitowish Waters Chain of Lakes. Data from most recently conducted Community Mapping Surveys. Wild rice communities indicated in pink.

Stakeholder Survey Responses to Eurasian Watermilfoil Management

A high proportion of survey respondents believed AIS are a moderate or significant problem within the Manitowish Waters Chain of Lakes (Figure 3.3-6).

Question 15: In your opinion, how much of a problem do you believe aquatic invasive species are within the Manitowish Waters Chain of Lakes?

Answer Options	No problem	Mild problem	Moderate problem	Significant problem	Unsure; Need more info	Rating Average	Response Count
	0	8	35	78	3	3.49	124
							answered question
							skipped question

Figure 3.3-6. Select survey responses from the Manitowish Waters Chain of Lakes stakeholder survey. Additional questions and response charts can be found in Appendix B.

In an effort to understand how EWM impacts stakeholders, the stakeholder survey asked if the Eurasian watermilfoil population ever had a negative impact on your enjoyment of the Manitowish Waters Chain of Lakes. Overall, most respondents indicated EWM has not had a negative impact on various activities (Figure 3.3-7). This is expected due to the current footprint of the EWM population being limited to a few areas in the system.

The activities that had the most responses indicating negative impacts were for motor boating and aesthetics (Figure 3.3-7). Areas in the system where EWM is most likely to be causing impacts for any of the listed lake uses include the Trout River between Alder and Manitowish Lake and isolated sections of Manitowish Lake where the largest concentrations of EWM reside.

Question 16: Has the Eurasian watermilfoil population ever had a negative impact on your enjoyment of Manitowish Waters Chain of Lakes?

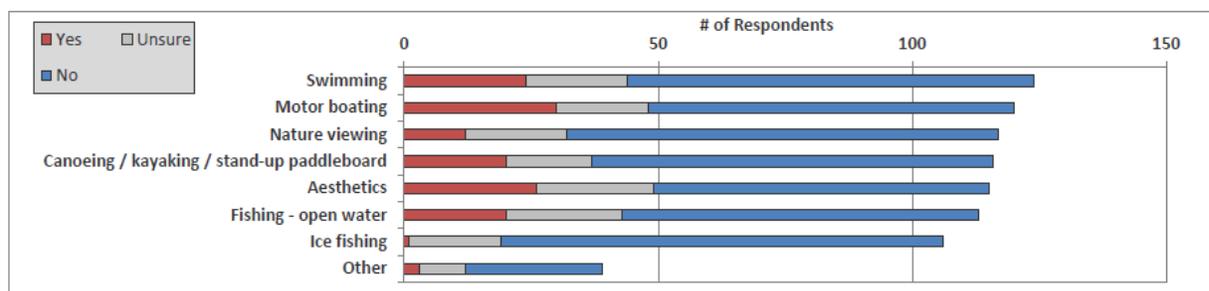


Figure 3.3-7. Select survey responses from the Manitowish Waters Chain of Lakes stakeholder survey. Additional questions and response charts may be found in Appendix B.

Stakeholders were asked to indicate their level of support or opposition to the future use of multiple AIS control techniques within Question # 17. Respondents indicated high levels of support to hand harvesting/DASH with 92% choosing either completely support or moderately support (Figure 3.3-8).

Mechanical harvesting was supported by 72% of respondents (pooled as completely support or moderately support), while 8% was opposed (pooled as completely opposed or moderately opposed). A sizable group of respondents (14%) were unsure/need more information.

Question 17: What is your level of support or opposition for the use of the following Eurasian watermilfoil management techniques in Manitowish Waters Chain of Lakes?

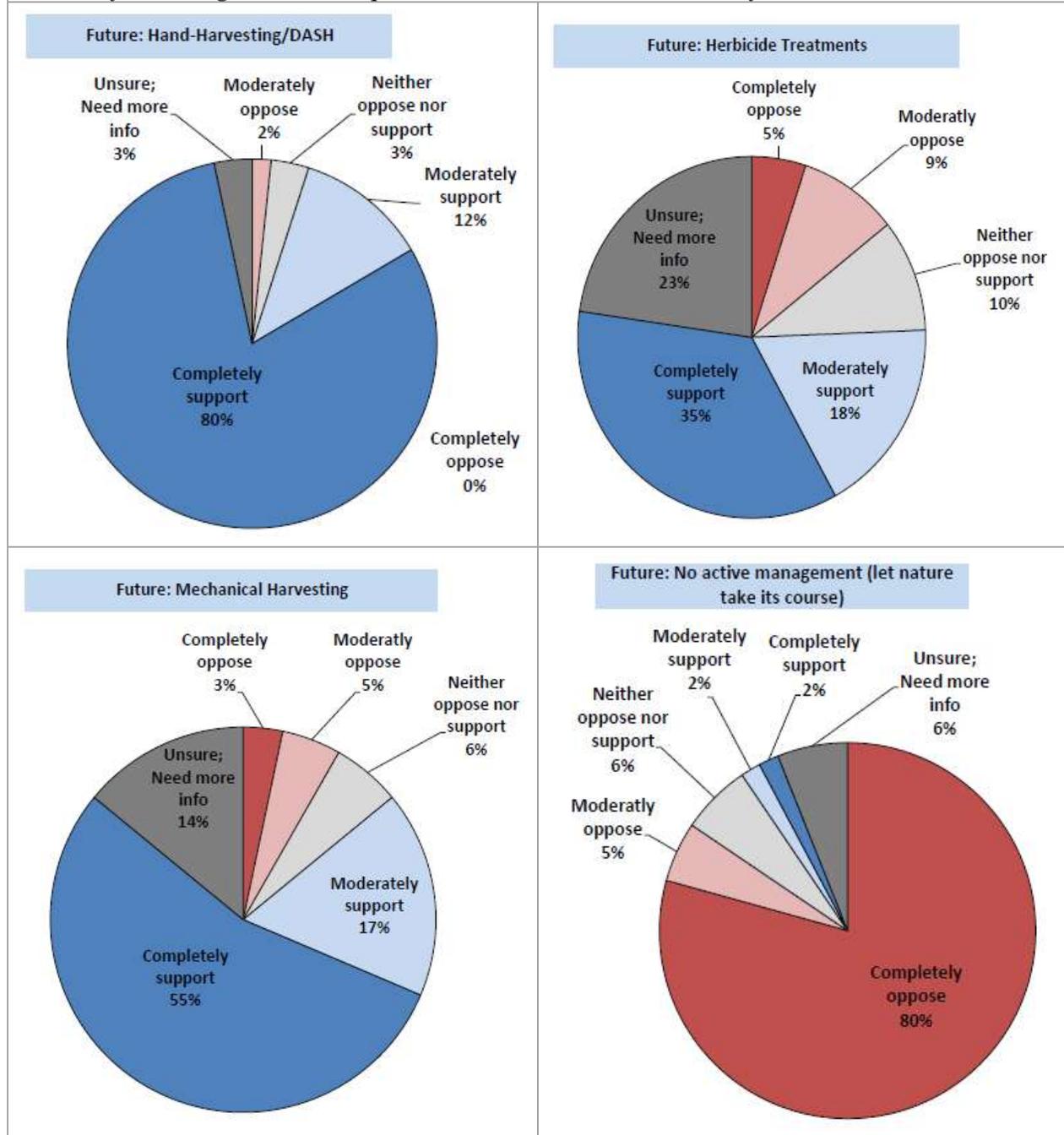


Figure 3.3-8. Select survey responses from the Manitowish Waters Chain of Lakes stakeholder survey. Additional questions and response charts may be found in Appendix B.

A total of 53% of respondents supported the future use of herbicides (pooled as either completely support or moderately support), while 14% were opposed (pooled completely opposed or moderately opposed). A significant proportion (23%) of respondents selected unsure/need more information, while another 10% were neutral.

The option of no active management (let nature take its course) received a high level of opposition from respondents with 85% indicating completely opposed or moderately opposed. Just 4% of respondents supported this strategy.

While stakeholders favored manual removal, they also expressed concerns about the effectiveness of the strategy as well as the costs of the technique being too high (Figure 3.3-9). 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 3.3-9). Some level of concern was indicated for the use of mechanical harvesting including ineffectiveness of strategy, costs, and impacts to native plant or animal species.

Question 18: What concerns, if any, do you have for the appropriate and responsible potential future use of aquatic herbicides, hand harvesting/DASH (Diver Assisted Suction Harvesting) and/or mechanical harvesting to target Eurasian watermilfoil in the Manitowish Waters Chain of Lakes?

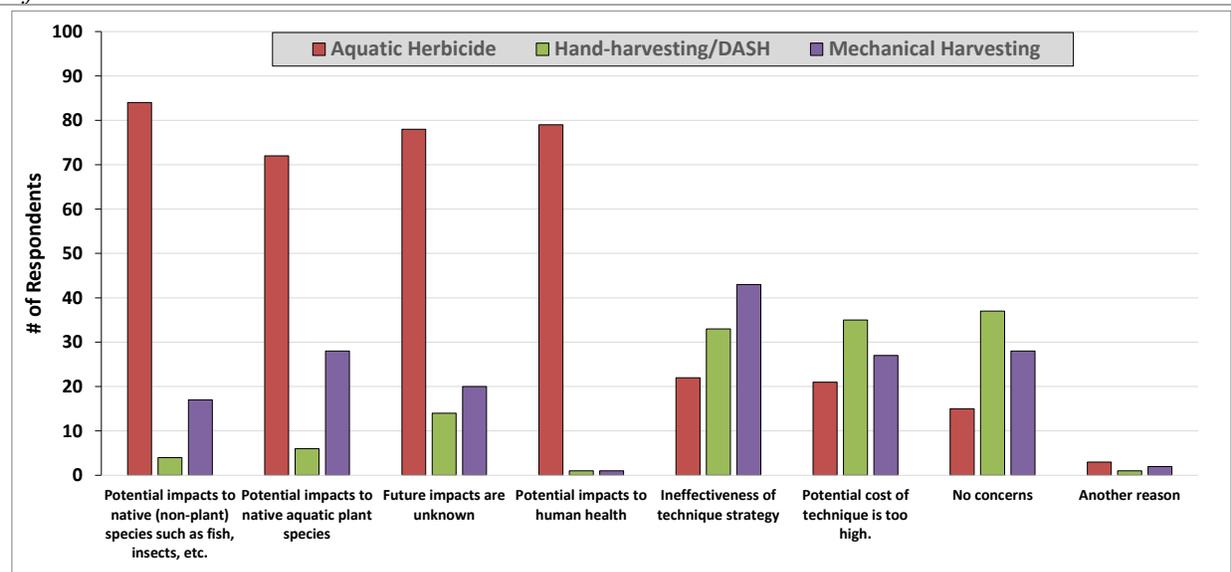


Figure 3.3-9. Select survey responses from the Manitowish Waters Chain of Lakes stakeholder survey. Additional questions and response charts may be found in Appendix B.

Curly Leaf Pondweed (*Potamogeton crispus*)

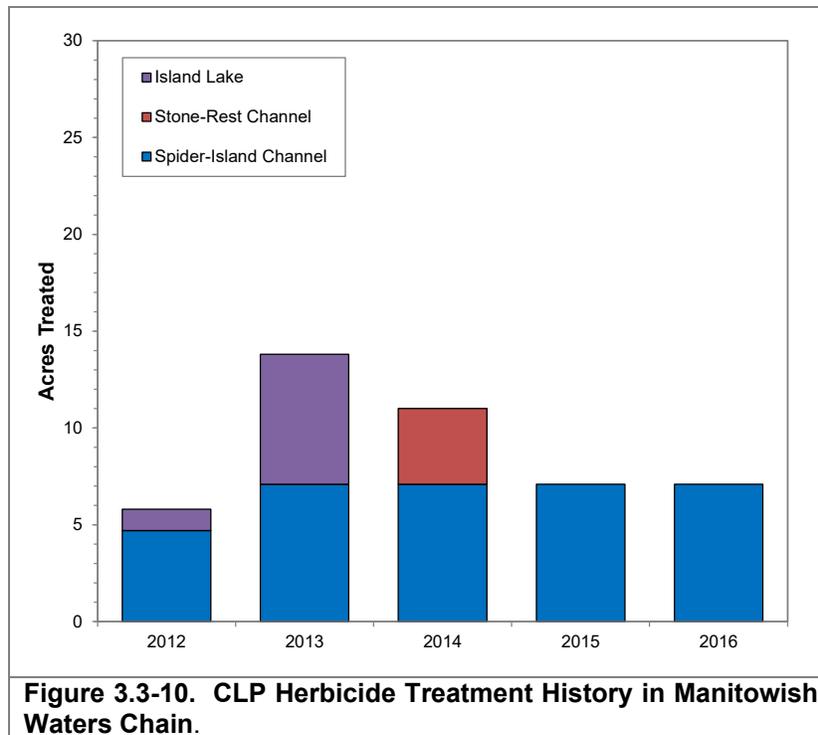
Curly-leaf pondweed (*Potamogeton crispus*; CLP) is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. The plants begin growing almost immediately after, if not immediately before, ice-out 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.



Photograph 3.3-4. Curly-leaf pondweed (*Potamogeton crispus*). Photo credit Onterra.

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.

CLP has been monitored and managed within the Manitowish Waters Chain of Lakes since discovery in 2010. CLP has been identified within several lakes in the Chain including Rest, Stone, Spider, Fawn, Alder, Vance, and Island Lakes as well as within Rice Creek. Early populations were managed through a combination of manual removal efforts and herbicide treatments. Herbicide treatments occurred between 2012-2016 targeting colonized CLP populations within Island Lake, the channel connecting Spider & Island Lakes, and with the Manitowish River between Stone and Rest Lakes (Figure 3.3-10). These treatments were considered successful at the time with reduced CLP populations in the target areas. Herbicide management of CLP has not occurred in the system since 2016 as the population was relatively sparse and manageable through hand harvesting efforts. A significant CLP population was present within Rice Creek during several years of monitoring, but this site was not managed and has since shown a highly variable CLP population including little to no plants in recent years.



Since 2017, the sole method of CLP management has been through manual removal efforts. Contracted professional harvesting has occurred each year since 2014 targeting CLP in the system, with recent years focused upon targeting a growing colony within Fawn Lake (Table 3.3-1). NLDC staff also conducts CLP harvesting around the Chain with most efforts targeted at relatively small or isolated occurrences.

In recent years, monitoring of the CLP population has been accomplished by a combination of Onterra ecologists or NLDC conducting early season mapping surveys. Onterra has surveyed known CLP lakes including Rest, Fawn, Stone, Spider, Island, and Rice Creek, while NLDC surveyed the remaining water bodies. Data from the early season mapping surveys is used to guide subsequent harvesting efforts and to assess the management strategy. Onterra’s most recent CLP monitoring survey results from June 2025 are displayed on Map 3. Aside from a 1.6-acre colony in Fawn Lake, and a relatively small *scattered* density colony in Island Lake, the CLP population in the system was modest in 2025 and consisted mostly of individual plants or *clumps of plants*.

Year	Lakes Harvested	Diver Hours	CLP Harvest (cubic feet)
2014	Island, Stone	14	3
2015	Island	24	2
2016	Island	29	11
2017	Spider, Rest	24	13.4
2018	Spider, Fawn, Rest, Stone	24	10
2019	Fawn	19.7	158
2020	Fawn	13.3	10.5
2021	Fawn	12.4	94
2022	Fawn, Rest	11.9	23
2023	Fawn, Rest	11.8	12.5
2024	Fawn	13.2	65.5
2025	Fawn	12.3	227
Total		209	630

Table 3.3-1. CLP DASH History in Manitowish Waters Chain 2017-2025. Data compiled from Aquatic Plant Management, LLC Harvest Reports.

The MWLA continues to implement its CLP monitoring and management strategy consistent with their 2019 comprehensive management plan. Aspects of CLP management were not considered for modifications as a part of the 2025 APM Plan update. A separate project commencing in 2026 will work towards updating MWLA's CLP management plan.

4.0 SUMMARY & CONCLUSIONS

The studies that took place as a part of this project focused on evaluating the Eurasian watermilfoil population within the Manitowish Waters Chain of Lakes. As of this writing, EWM is concentrated in a few areas within the Chain with several isolated occurrences around the rest of the system.

The MWLA, in partnership with NLDC and others, has developed an aquatic plant management plan specifically to address the Eurasian watermilfoil population in the Chain. The Plan that was developed was a result of many conversations between MWLA, NLDC, WDNR, and other partners. Section 5.0 contains the management actions that were developed following a Planning meeting in early-August 2025, which also considered input received from the stakeholder survey questionnaire (Appendix B).

The MWLA's plan focuses upon monitoring EWM throughout the Chain and conducting an integrated pest management approach to management that considers multiple techniques depending on the size and location of the EWM population.

The Comprehensive Lake Management Plan for the Manitowish Waters Chain of Lakes was finalized in 2019 and continues to be implemented by MWLA and other facilitators. The 2019 Plan was created prior to the discovery of Eurasian watermilfoil in the system, and this project serves to update the aquatic plant management aspects of the Plan, particularly for EWM.

5.0 IMPLEMENTATION PLAN

The Comprehensive Lake Management Plan for the Manitowish Waters Chain of Lakes was finalized in December 2019. The objective of the 2025 Aquatic Plant Management Planning (APM Plan) project was to update the goals and actions of the aquatic plant management portion of the 2019 Plan to address the Eurasian watermilfoil population specifically. The MWLA, in partnership with NLDC, and TAISP continues to follow the remaining goals outlined in the 2019 *Plan* for which the aquatic plant management related goals and actions are compiled within the table below.

Goal 4: Control Existing and Prevent Further Aquatic Invasive Species Establishment within the Manitowish Waters Chain of Lakes.	
Action:	Conduct curly-leaf pondweed Population Control on the Manitowish Waters Chain of Lakes using Hand-Harvesting and Herbicide Spot Treatments
Action:	Continue control and monitoring efforts on other aquatic invasive species that pose a threat to the Manitowish Waters Chain of Lakes.
Action:	Investigate feasibility of alternative aquatic invasive species control methodologies for applicability to the Manitowish Waters Chain of Lakes.

The Implementation Plan presented below was created through the collaborative efforts of various local groups, agencies, resource managers, and project partners. 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 stakeholders as portrayed by the members of the Board of Directors and stakeholder survey respondents. The Implementation Plan is a living document in that it will be under periodic review and adjustment depending on the condition of the lakes, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

As a part of the 2024-2025 Aquatic Plant Management Plan update project, the MWLA specifically considered updates to Management Goal #4 from the Comprehensive Plan (Table 5.0-1). During the summer 2025 planning meeting, additional actions were outlined specific to Eurasian watermilfoil. The following actions listed below are added to the Manitowish Waters Chain of Lakes Management Goal #4.

The EWM specific management goal outlined here, paired with the other management goals and general nutrient management goals from the Comprehensive Management Plan (2019), form the MWLA's Integrated Pest Management strategy on the Manitowish Waters Chain of Lakes. Integrated Pest Management (IPM) is an approach to manage an issue that utilizes a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately. Often, the goals and actions developed during an APM plan project are considered shorter-term management goals (~ 5 years) compared to longer-term management goals that may be incorporated into a Comprehensive Lake Management Plan. The MWLA continues to implement goals and actions listed under the 2019 Comp Plan that include IPM activities including monitoring native aquatic plants through periodic point-intercept surveys and floating-leaf/emergent plant community mapping surveys.

Management Action:	Monitor the Eurasian watermilfoil population
Timeframe:	Annually

Facilitator:	MWLA, NLDC
Description:	<p><u>Professional monitoring:</u> Since discovery, the EWM population in the system has been monitored by NLDC staff and by Onterra. At current population levels, the point-intercept survey does not provide sufficient detail of the EWM footprint in the system for use in guiding management, therefore, EWM mapping surveys will be the primary means of monitoring EWM in the lake. Each of the waterbodies in the Chain would be surveyed at least once each season to search for and map EWM.</p> <p>Eurasian watermilfoil mapping surveys will be conducted by NLDC each year as staffing and resources are available. The NLDC would search for and map EWM occurrences through multiple rounds of monitoring during the early and mid-summer. The focus of these surveys will be to identify pioneering EWM populations in the Chain and to monitor sites with modest EWM populations that are being managed through a NLDC- led manual removal strategy at the time. Lakes not known to harbor EWM would be monitored by NLDC staff.</p> <p>Professional late-season EWM mapping surveys would also occur on select waterbodies during the growing season, with the primary intent of monitoring known EWM populations that are being managed by contracted DASH efforts, or other techniques requiring WDNR permitting such as mechanical harvesting or herbicide treatments.</p> <p>As the name implies, the Late-Season EWM Mapping Survey is a professionally contracted survey completed towards the end of the growing season when EWM is at its anticipated peak growth stage, allowing for a true assessment of the extent of the population within the lake. For the Manitowish Waters Chain of Lakes, this survey would likely take place in August or September, dependent on the growing conditions of the particular year and occurring after all management activities have ceased. This survey would include a complete meander survey of the lake’s littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred).</p> <p>An EWM mapping strategy for each season will be developed annually to account for changing conditions and other ongoing projects on the Chain. Communications between MWLA, NLDC, and other partners will ensure this monitoring is completed as planned.</p> <p><u>Volunteer monitoring:</u> The MWLA will promote volunteer monitoring for EWM to supplement professional surveying. MWLA will connect membership with resources including identification aids for EWM. Members will be encouraged to monitor their shoreline areas for suspected EWM and report any suspected EWM occurrences to the MWLA Board for follow-up. An organized volunteer-based monitoring effort may evolve over time on the Chain depending on volunteer availability and need.</p>

Management Action:	Conduct Integrated Pest Management program for EWM
Timeframe:	Ongoing
Potential Grant:	WDNR AIS Established Population Control (EPC) Grant WDNR Early Detection & Response (EDR) Grant
Facilitator:	MWLA Board
Description:	<p>The objective of this action is to minimize the negative attributes that EWM causes on the Manitowish Waters Chain of Lakes by maintaining navigation, recreational use, and aesthetics. Further, this action also supports the MWLA's overarching goal to protect and enhance the ecology of the Manitowish Waters Chain (Comp Plan Goal #6) in maintaining a healthy aquatic plant community. MWLA 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.</p> <p>Concern exists amongst the local stakeholders regarding the potential for EWM to cause impacts on recreational use of the waterbody in the future. In an effort to inhibit EWM from establishing in new areas around the Chain and to maintain known EWM populations at low levels, the MWLA and local partners will invest significant efforts towards monitoring and managing EWM through a population management strategy. This strategy perspective essentially includes all known EWM in the Chain for active management.</p> <p><u>Manual Removal</u></p> <p>Hand harvesting (including the use of DASH) will be the default management technique throughout the Chain and this technique received high levels of support from the stakeholder survey respondents (Appendix A, Question # 17). All known EWM occurrences around the Chain will be given consideration for management through a manual removal strategy. Organized manual removal efforts will be undertaken by NLDC staff, with potential for additional efforts by MWLA volunteers. As has been the case for the past few summers, manual removal efforts will primarily target low-density EWM occurrences around the Chain (single plants, clumps of plants), while larger colonies would be targeted for removal by contracted professionals.</p> <p><u>Diver Assisted Suction Harvesting (DASH)</u></p> <p>MWLA will also consider the use of DASH methodology when the EWM population lends well to its use. This technique will be given consideration for use targeting EWM populations that are of a size or density that exceeds the NLDC staff's capacity to manage with manual removal techniques. At some population level, the use of DASH to manage EWM is scale limited, particularly when the size of the colony is multiple acres in size. In these situations, the use of DASH would shift</p>

to a nuisance relief perspective rather than solely population management. This management strategy is in place in the Trout River during 2025 such that DASH operations are seeking to suppress the EWM population densities to low levels through removal of high amounts of biomass, while acknowledging that it is not feasible for all EWM occurrences in the site to be targeted for removal.

The NLDC also owns a DASH boat that is expected to be operational in 2026. This vessel will be used to supplement the NLDC hand pulling efforts and professional DASH activities. The NLDC's DASH unit would target EWM occurrences that are too large or too deep to efficiently hand pull. The NLDC DASH boat will be a contracted service and operated by NLDC staff.

A substantial DASH effort was undertaken during 2024-2025 targeting the largest known EWM concentrations in the Chain. MWLA has gained valuable insights as to the capabilities of this technique in managing EWM as well as the limitations and costs to implement. The MWLA will use its knowledge and experience gained from monitoring these activities to apply when considering its future use as a management tool in the Chain.

EWM mapping surveys would be used to guide the hand harvesting efforts with the most recent data available. If DASH is to be used, a permit application to WDNR including a map of the areas to be harvested will be submitted as early in the calendar year as practical.

Mechanical Harvesting

A theoretical scenario in which a mechanical harvesting strategy may be applicable for EWM management was discussed during the planning meeting 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.

The current EWM population level in the Manitowish Waters Chain of Lakes does not warrant management with mechanical cutting. This management technique would be something that the MWLA would investigate in the future, particularly 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.

Any future mechanical harvesting operations would have the following guidelines:

- Harvesting locations are limited to areas on the permit map.
- The harvester would not be permitted in waters less than 3-feet to minimize sediment disturbance.
- Cut no more than half the water depth.
- Harvesting operations shall not disturb spawning or nesting fish. Harvesting shall be done in a manner to minimize accidental capture of fish. An attempt would be made to return all gamefish, panfish, amphibians, and turtles to the water immediately.
- Submerged plants, specifically EWM, would be the target for this permit. Removal of emergent (e.g. bulrushes) and floating-leaf (e.g. water lilies) species need to be avoided because of their ecological value and niche occupation.
- A reasonable effort must be made to capture all aquatic plant fragments during operation. The WDNR may consider allowing “floaters” to be picked up even if they occur outside the areas delineated on the permit map.

Reports summarizing harvesting activities shall be given to the WDNR by November 30, each harvesting season. The report shall include a map showing the areas harvested, the total amount of plant material removed from each site, and amount of effort (time) spent at each site. The report shall also include a summary of the composition and quantity of plants removed by species (rough percent of each species from each operation).

Herbicide Treatment

Considerations for conducting an herbicide treatment would be made utilizing the current understanding of best management practices for this technique.

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. Any herbicide spot-treatments on the Manitowish Waters Chain of Lakes would consider herbicides thought to be effective under short exposure situations. At the time of this writing, floryprauxifen-

benzyl (ProcellaCOR™) is an example of an herbicide with reported short exposure time requirements that are commonly 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.

MWLA understands that an herbicide treatment will not eradicate EWM from the site but would ideally result in multiple years of a reduced population that could potentially be extended longer through follow-up management efforts such as hand harvesting.

The stakeholder questionnaire indicated 53% support for herbicide treatment as a future EWM management technique in the Manitowish Waters Chain of Lakes (pooled as either highly support or moderately support). 14% of respondents were not supportive of herbicide use (pooled as either completely opposed or moderately opposed). 23% of respondents selected unsure; need more information, while 10% were neutral (Question #17, Appendix A).

The MWLA would use the following trigger to initiate discussion for considering herbicide treatment:

- A) *Strategy targets colonized areas of EWM where a sufficiently large treatment area can be constructed to achieve concentration and exposure times that would be expected to result in EWM mortality.*
- B) *Herbicide exposure to wild rice populations is not expected.*
- C) *Recreational use impairment is occurring.*

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 of success in a spot-treatment design scenario compared to offshore sites. Dominant or greater density ratings from an EWM mapping survey are approximately indicative of conditions in which recreational use of the lake is impacted. Recent regulatory interpretations of NR 107 have often required navigational impairment conditions to be present when considering issuance of herbicide permits.

MWLA acknowledges that there may be a concern with the use of herbicides within lakes in the ceded territory including the lakes of the Manitowish Waters Chain of Lakes. Further, MWLA is aware of current WDNR policy that prohibits the use of aquatic herbicides when wild rice populations are expected to be exposed to detectable levels of

herbicide. The known distribution of wild rice within the Manitowish Waters Chain is well documented and indicates that certain areas of the Chain do not currently harbor this species. Therefore, MWLA believes that herbicide spot-treatments could be considered in the future in select areas of the Chain without concern for exposure to wild rice populations.

If the conditions listed above are met and the MWLA 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 Control and Monitoring Plan would include applicable risk assessment materials for the MWLA 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 the entire lake, monitoring would occur on a whole lake 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. 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 MWLA believes important information would be gained from the effort.

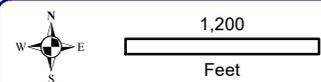
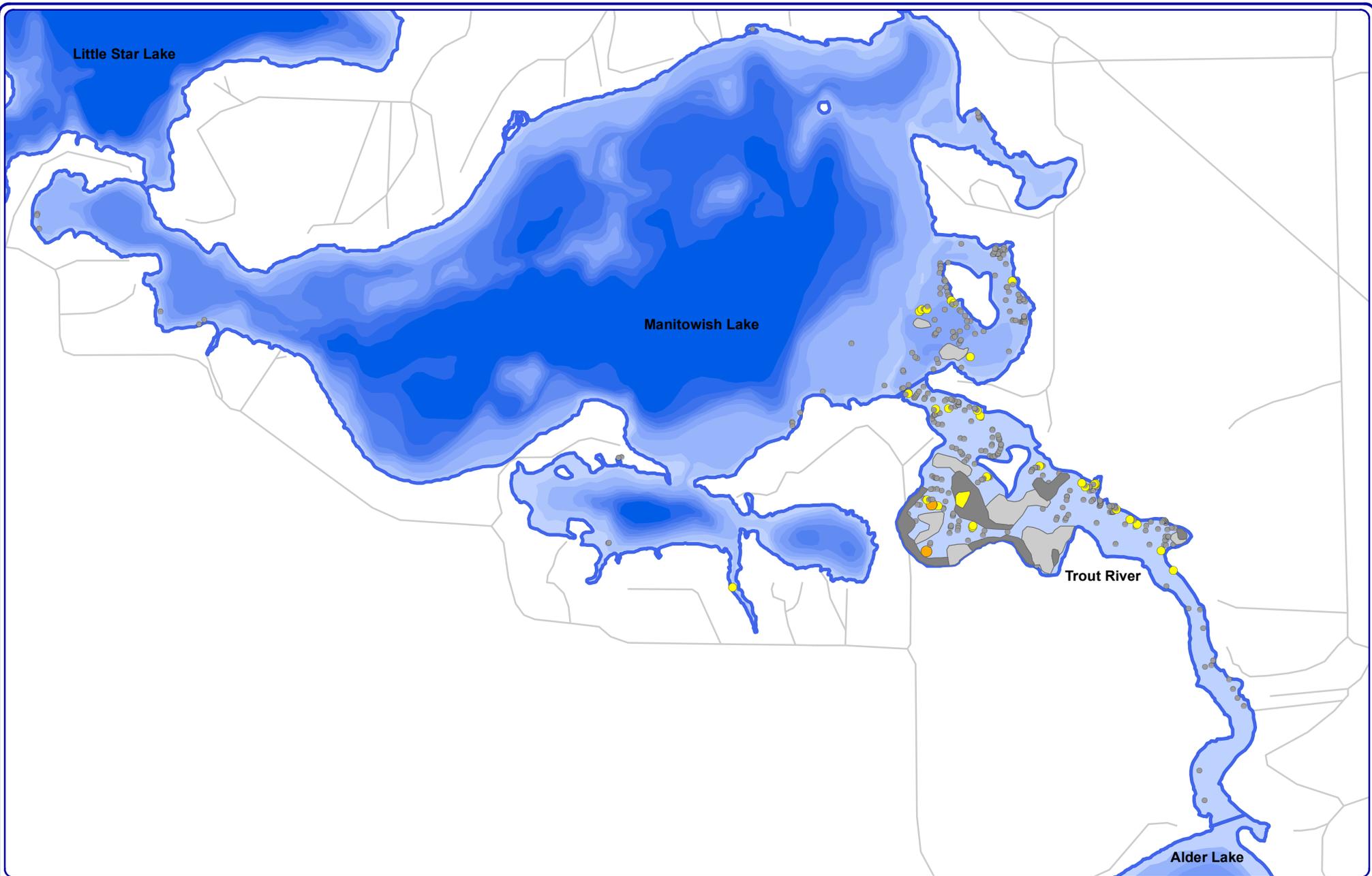
An herbicide applicator firm would be selected, and a permit application would be submitted to the WDNR as early in the calendar year as practical, allowing interested parties sufficient time to review the control plan as well as review the permit application.

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

	<p>season (typically in June), after active growth tissue is confirmed on the target plants. To address potential fisheries concerns, treatment timing would occur after walleye have progressed past their 30 days post hatch life stage. Operationally, this factor results in treatment timing around mid-June in northern Wisconsin Lakes.</p> <p>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.</p> <p>A minimum indication of meeting herbicide treatment success criteria would be such that little to no EWM would persist in treated areas during the year of treatment, with minimal sign of recovery during the year after treatment as well. After herbicide treatment, the MWLA intends to complete an IPM strategy that may include hand harvesting and/or DASH to attempt to extend the longevity of control and delay the need for the future use of another herbicide treatment in the site.</p>
<p>Action Steps:</p>	
<p>1.</p>	<p>Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.</p>
<p>2.</p>	<p>Initiate control and monitoring plan.</p>
<p>3.</p>	<p>Update management plan to reflect changes in control needs and those of the lake ecosystem.</p>

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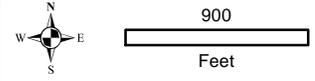
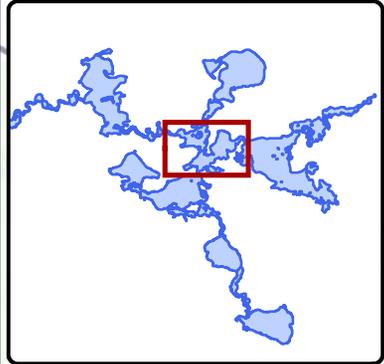
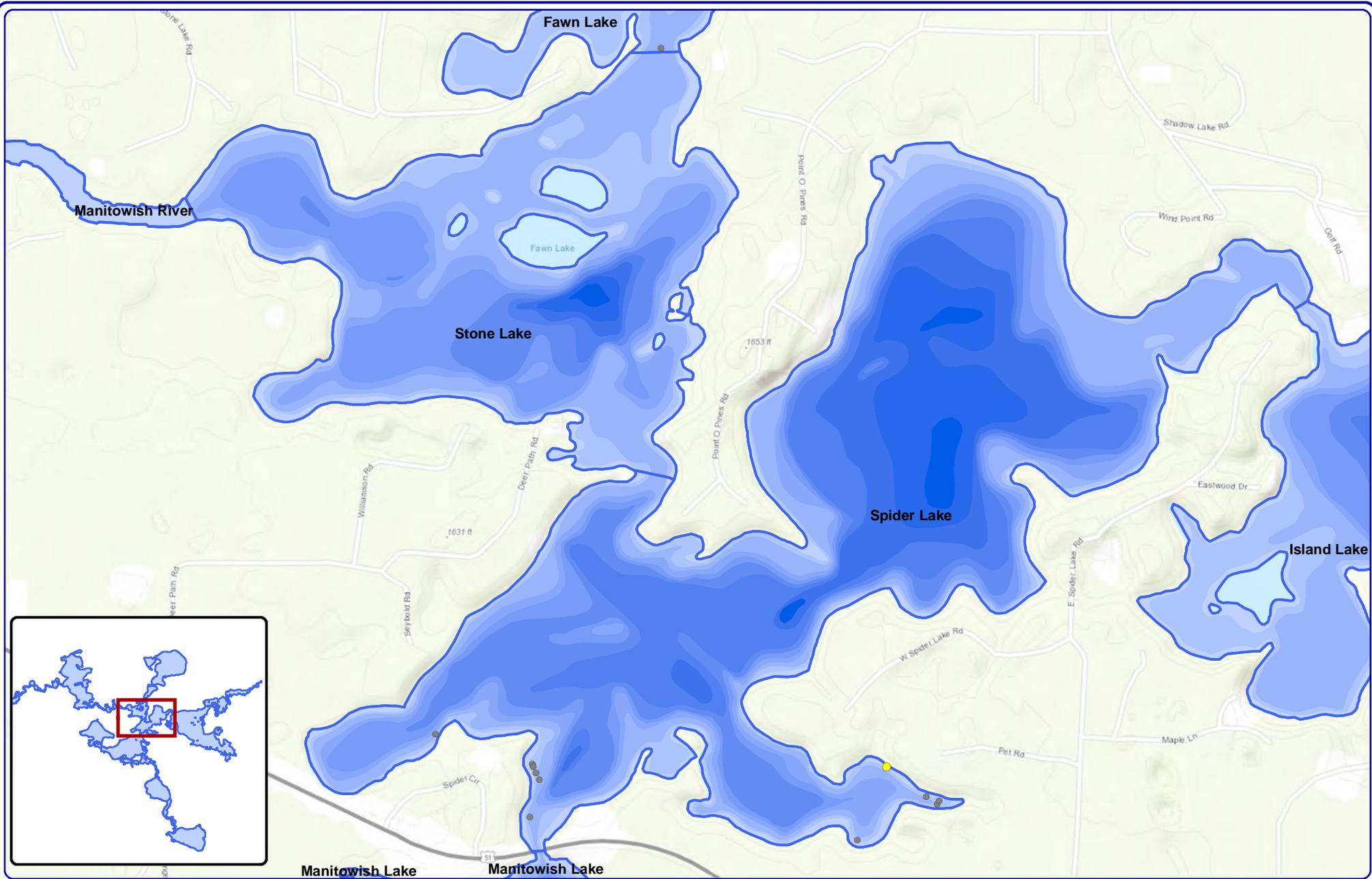
Onterra LLC
 Lake Management Planning
 815 Prosper Road
 De Pere, WI 54115
 920.338.8860
 www.onterra-eco.com

Sources:
 Roads and Hydro: WDNR
 Bathymetry: digitized by Onterra
 Aquatic Plants: Onterra, 2024
 Map Date: 8-19-24 TWH



- Legend**
EWM Survey: August 14, 2024
- | | |
|------------------------|----------------------|
| Highly Scattered | Single or Few Plants |
| Scattered | Clumps of Plants |
| Dominant | Small Plant Colony |
| Highly Dominant (None) | |
| Surface Matting (None) | |

Manitowish Chain Lakes
 Vilas County, Wisconsin
2024 Late-Season
Eurasian Watermilfoil
Survey Results



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 Basemap: ESRI
 Bathymetry: WDNR - digitized by Onterra
 Aquatic Plants: Onterra, 2025
 Map Date: 7-8-2025 TWH



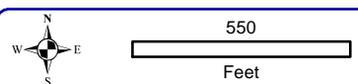
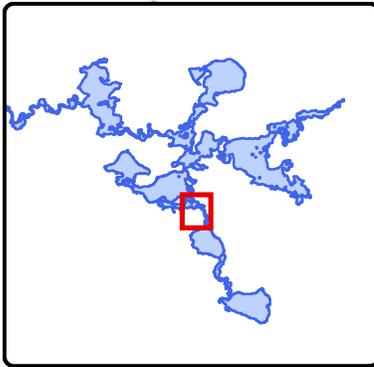
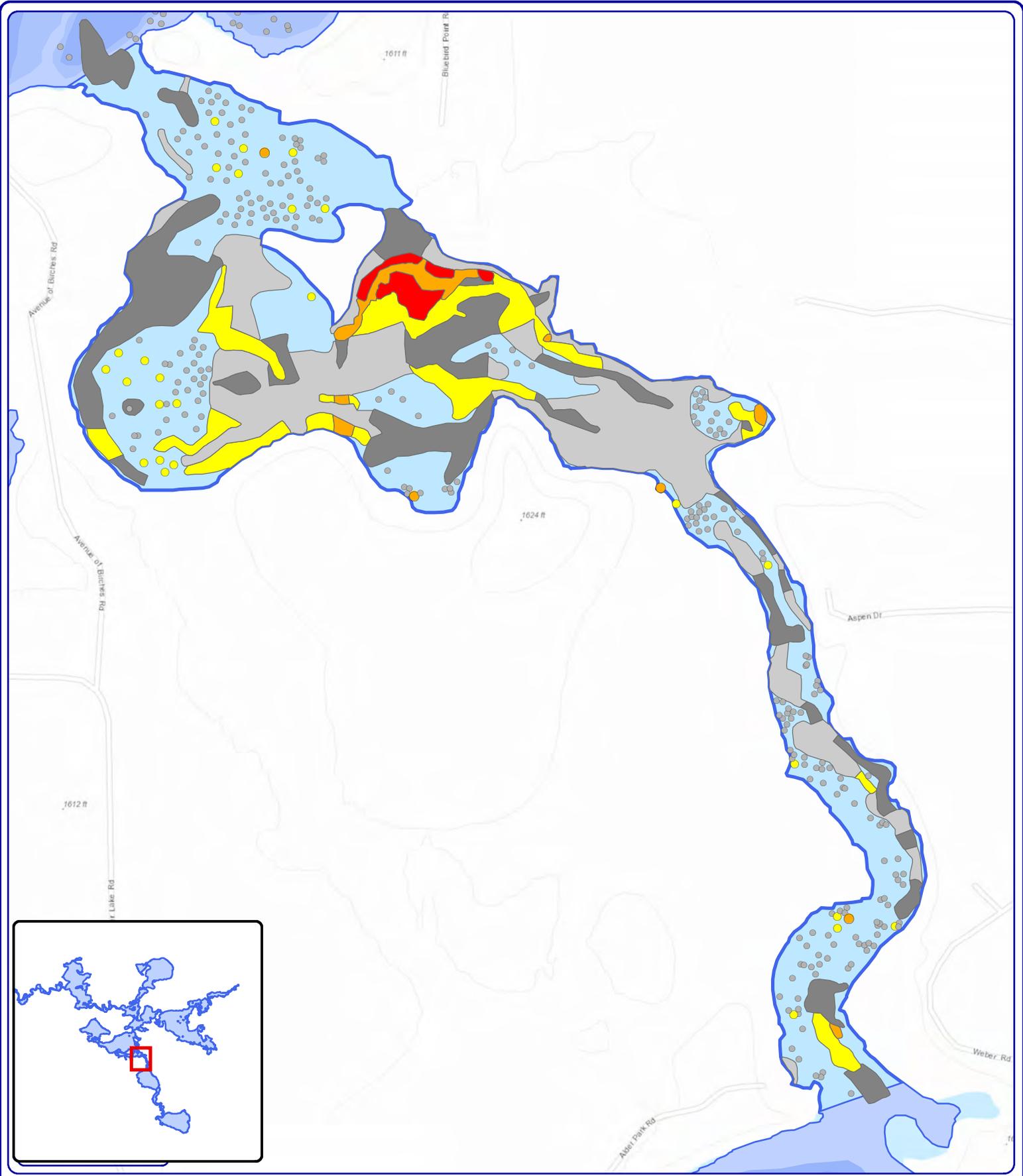
Project Location in Wisconsin

Legend

- AIS Survey: June 18, 23-24, 2025
- Single or Few Plants
 - Clump of Plants
 - Small Plant Colony (none)

Manitowish Chain
 Vilas County, Wisconsin

**June 2025
 Eurasian Watermilfoil
 Survey Results**

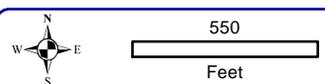
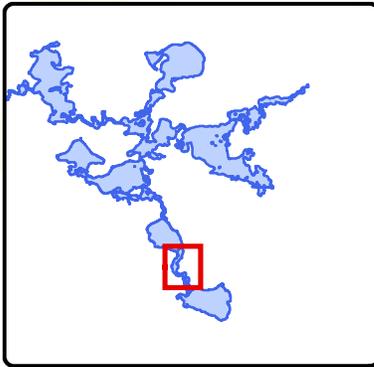
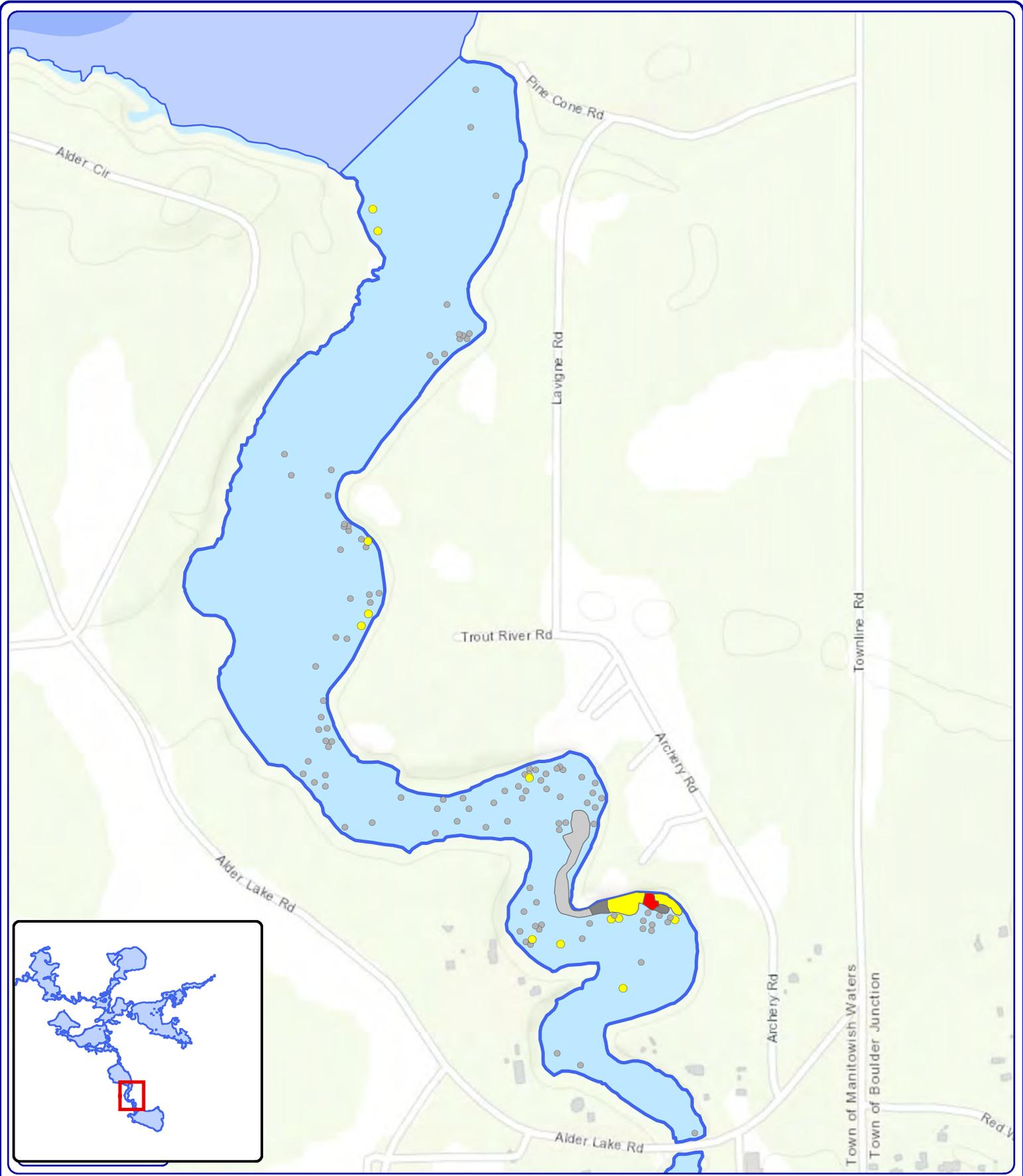


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Sources
 Bathymetry and Hydro: WDNR, Digitized by Onterra
 Aquatic Plant Survey: Onterra, 2025
 Orthophotography: NAIP, 2022
 Map Date: October 7, 2025 - LLC

- Legend**
EWM Survey: September 2 & 16, 2025)
- Highly Scattered
 - Scattered
 - Dominant
 - Highly Dominant
 - Surface Matting
 - Single or Few Plants
 - Clumps of Plants
 - Small Plant Colony

Map 3
 Lower Trout River
 Vilas County, Wisconsin
Late-Season 2025
Eurasian Watermilfoil
Survey Results

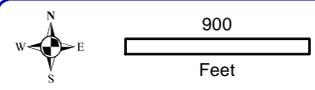
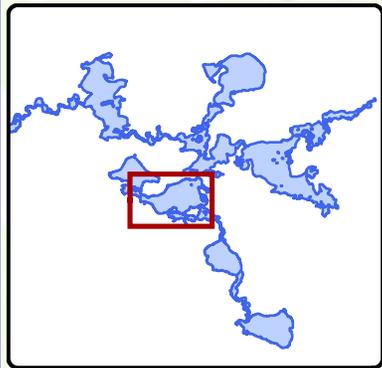
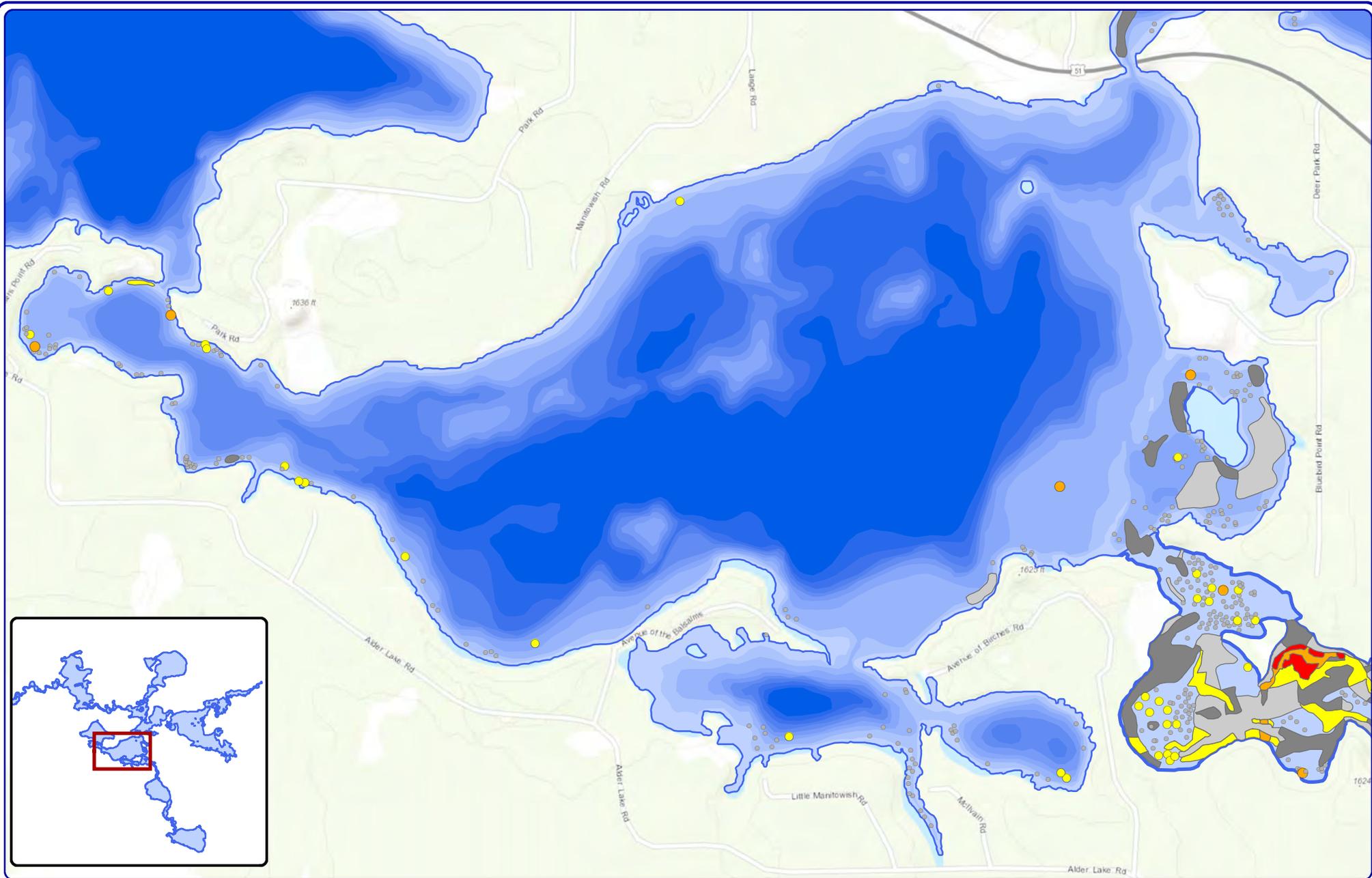


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Sources
 Bathymetry and Hydro: WDNR, Digitized by Onterra
 Aquatic Plant Survey: Onterra, 2025
 Orthophotography: NAIP, 2022
 Map Date: October 7, 2025 - LLC

- Legend**
EWM Survey: September 2 & 16, 2025)
- Highly Scattered
 - Scattered
 - Dominant
 - Highly Dominant
 - Surface Matting
 - Single or Few Plants
 - Clumps of Plants
 - Small Plant Colony

Map 4
 Upper Trout River
 Vilas County, Wisconsin
Late-Season 2025
Eurasian Watermilfoil
Survey Results



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Sources:
 Hydro and Bathy: WDNR, Digitized by Onterra
 Orthophoto: NAIP, 2022
 Aquatic Plant Survey: Onterra, 2025
 Map Date: October 7, 2025 - LLC



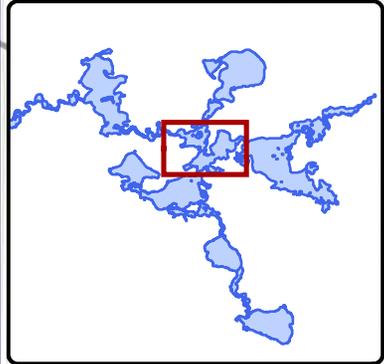
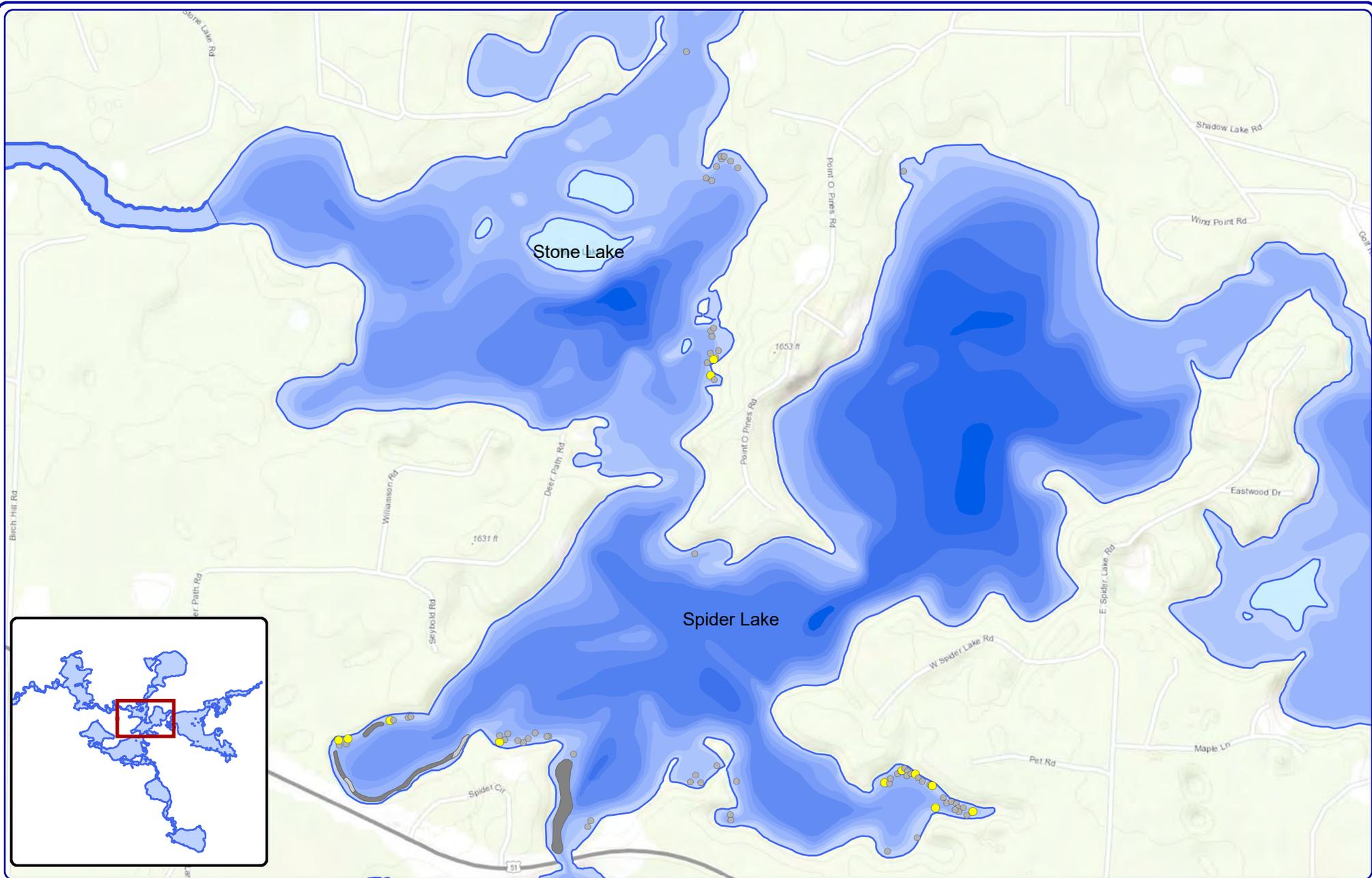
Project Location in Wisconsin

Legend

EWM Survey: September 2 & 16, 2025

- | | | | |
|--|------------------------|--|----------------------|
| | Highly Scattered | | Single or Few Plants |
| | Scattered | | Clump of Plants |
| | Dominant (none) | | Small Plant Colony |
| | Highly Dominant (none) | | |
| | Surface Matting (none) | | |

Map 5
 Manitowish Lake
 Vilas County, Wisconsin
Late-Season 2025
Eurasian Watermilfoil
Survey Results



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Sources:
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 Orthophoto: NAIP, 2022
 Aquatic Plant Survey: Onterra, 2025
 Map Date: October 7, 2025 - LLC



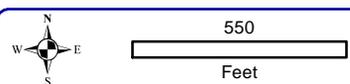
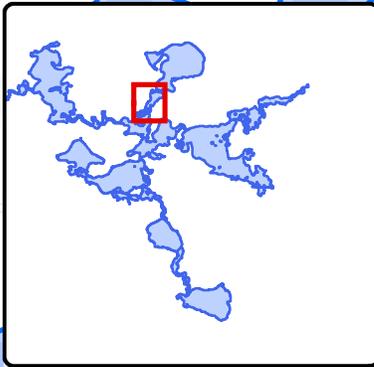
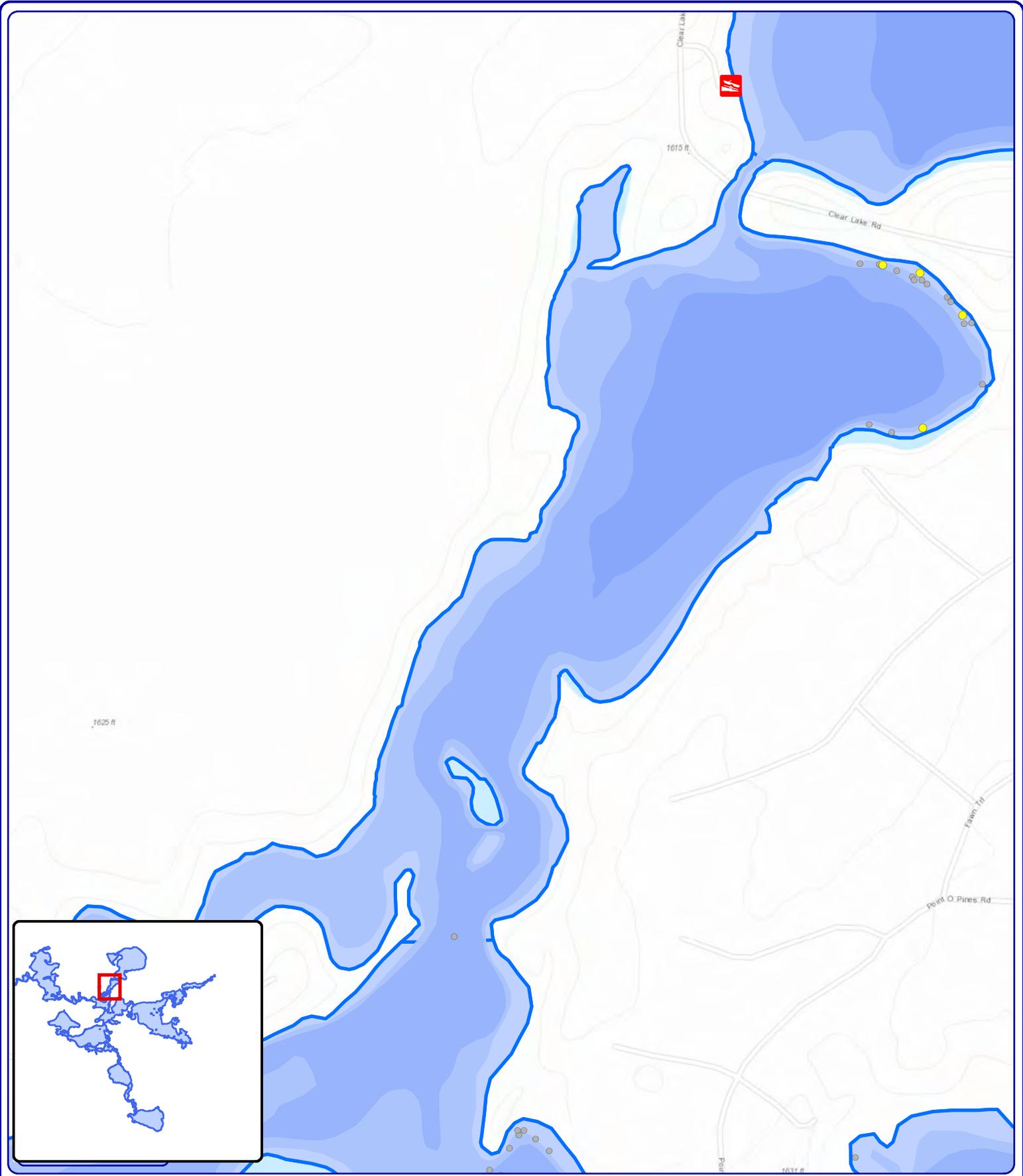
Project Location in Wisconsin

Legend

EWM Survey: September 2 & 16, 2025

- | | | | |
|--|------------------------|--|----------------------|
| | Highly Scattered | | Single or Few Plants |
| | Scattered | | Clump of Plants |
| | Dominant (none) | | Small Plant Colony |
| | Highly Dominant (none) | | |
| | Surface Matting (none) | | |

Map 6
Spider & Stone Lake
 Vilas County, Wisconsin
Late-Season 2025
Eurasian Watermilfoil
Survey Results

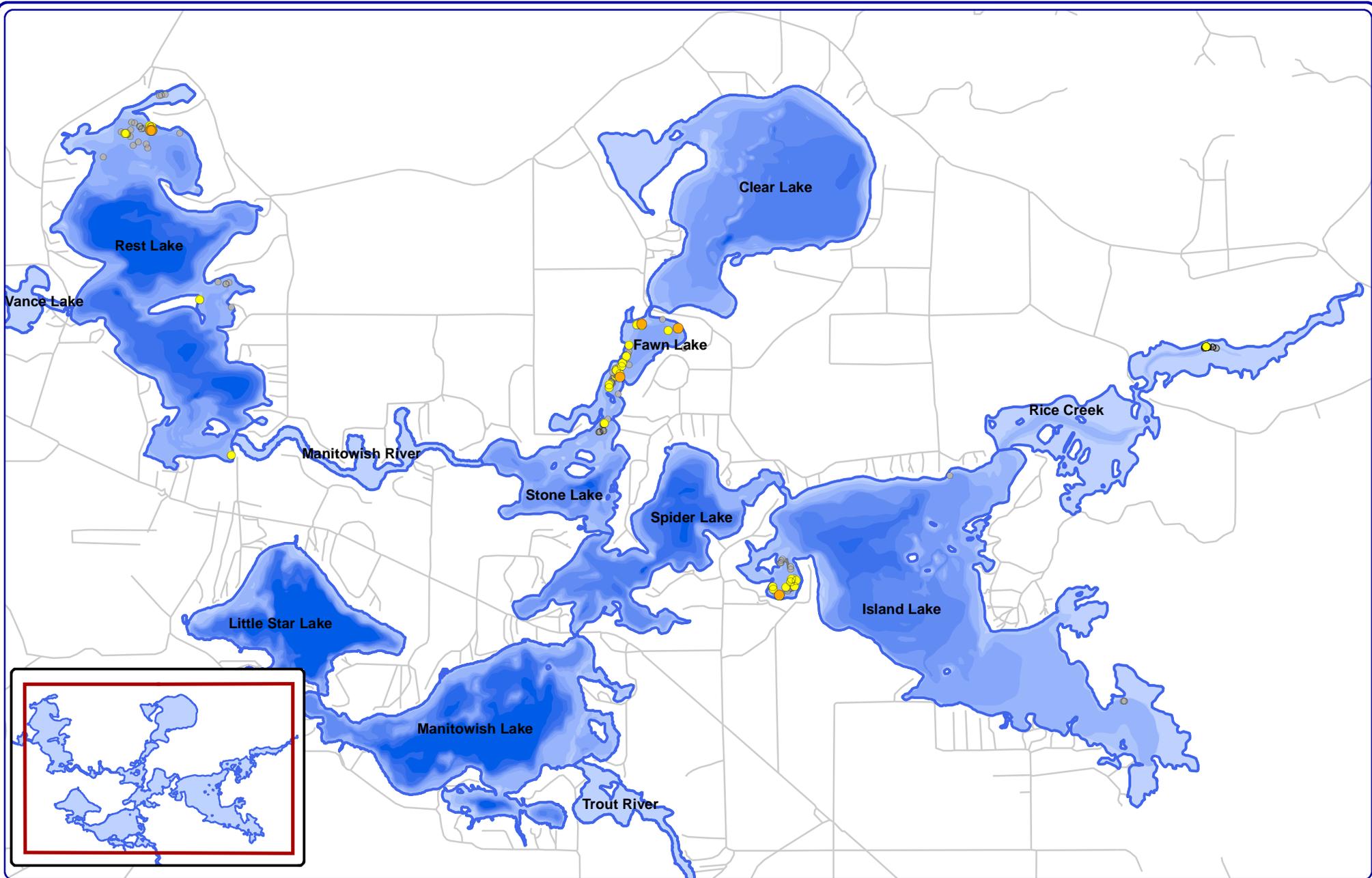


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Sources
 Bathy and Hydro: WDNR, Digitized by Onterra
 Aquatic Plant Survey: Onterra, 2025
 Orthophotography: NAIP, 2022
 Map Date: October 7, 2025 - LLC

- Legend**
EWM Survey: September 2 & 16, 2025)
- Highly Scattered
 - Scattered
 - Dominant
 - Highly Dominant
 - Surface Matting
 - Single or Few Plants
 - Clumps of Plants
 - Small Plant Colony

Map 7
Fawn Lake
 Vilas County, Wisconsin
Late-Season 2025
Eurasian Watermilfoil
Survey Results



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Sources:
 Roads and Hydro: WDNR
 Bathymetry: WDNR - digitized by Onterra
 Aquatic Plants: Onterra, 2025
 Map Date: 7-8-2025 TWH



Project Location in Wisconsin

Legend

CLP Survey: June 18, 23-25, 2025

- | | | | |
|--|------------------------|--|----------------------|
| | Highly Scattered | | Single or Few Plants |
| | Scattered | | Clump of Plants |
| | Dominant | | Small Plant Colony |
| | Highly Dominant | | |
| | Surface Matting (none) | | |

Map 8
Manitowish Chain
 Vilas County, Wisconsin
June 2025
Curly-leaf Pondweed
Survey Results

A

APPENDIX A

Planning Meeting Presentation Materials



Meeting Objective

- Provide attendees with essential EWM information.

Presentation Outline

- Introduction to Onterra
- EWM Biology
- Manitowish Chain EWM Population
- EWM Management Options
- Development of a Management Plan



Onterra, LLC

- Founded in 2005
- Head Quarters in De Pere, WI
- Staff
 - Three full-time ecologists
 - One part-time paleoecologist
 - Four full-time field technicians
 - Four summer interns
- Services
 - Science and planning
- Philosophy
 - Promote realistic planning
 - Assist, not direct



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Non-Native Aquatic Plants

Eurasian Watermilfoil

- **First officially documented in summer of 2023 (NLDC)**
- **Known within Manitowish Lake, Spider Lake, Lower Trout River (Between Alder & Manitowish Lakes), Little Star Lake, Stone Lake, Fawn Lake**






EWM Impacts

- Can be problematic in some lakes, and not in others
- Often causes localized impacts to navigation, recreation, and aesthetics
- Except in the most extreme cases, EWM is unlikely to displace native plants, at least in short term
- The addition of EWM can change the “aquascape” of density and location of plant biomass within the water column, possible fisheries shifts



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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

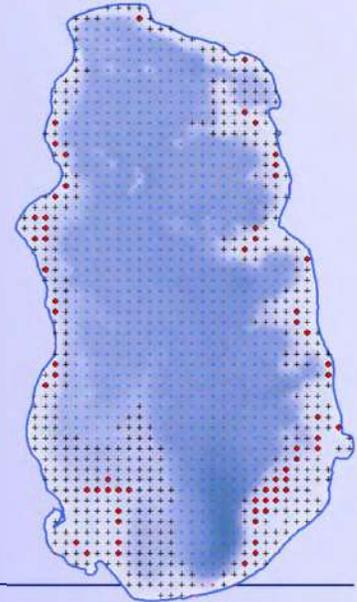
- Mechanical breakage
- Low energy storage
- Lower viability

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Types of Aquatic Plant Surveys

Quantitative

- Point-Intercept Survey
 - Numeric & systematic
 - Applied at various scales
- How frequent a plant is found within the *plant-growing zone* of a lake
- ≤ Max Depth of Plants



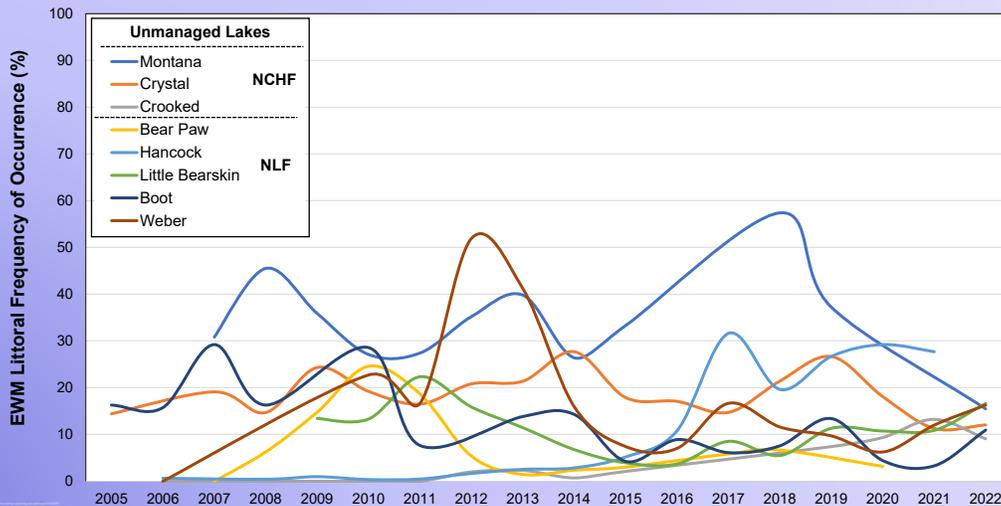
Metonga (N-704):
 470 Littoral Points

$$\frac{65}{470} = 13.8\%$$

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WDNR EWM Long-Term Monitoring Trends

Unmanaged



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Types of Aquatic Plant Surveys

Quantitative

- Point-Intercept Survey



Qualitative

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



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Professional AIS Mapping



Point-Based Mapping

- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

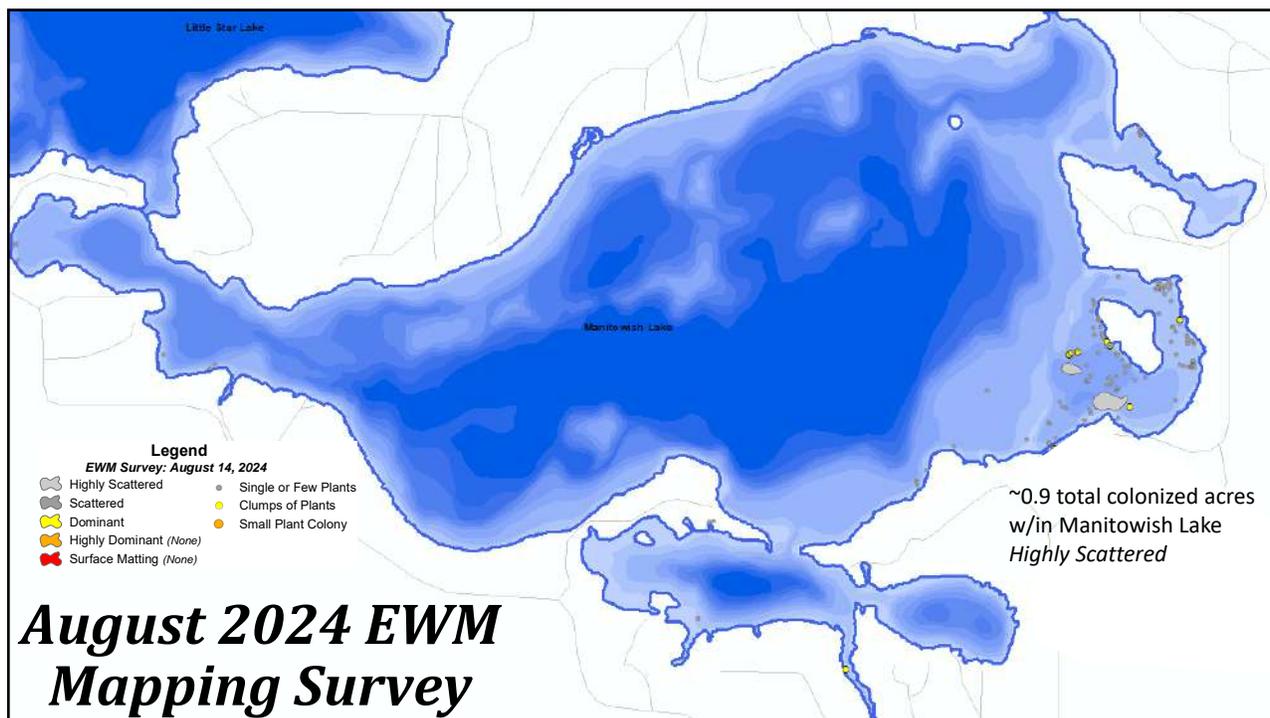
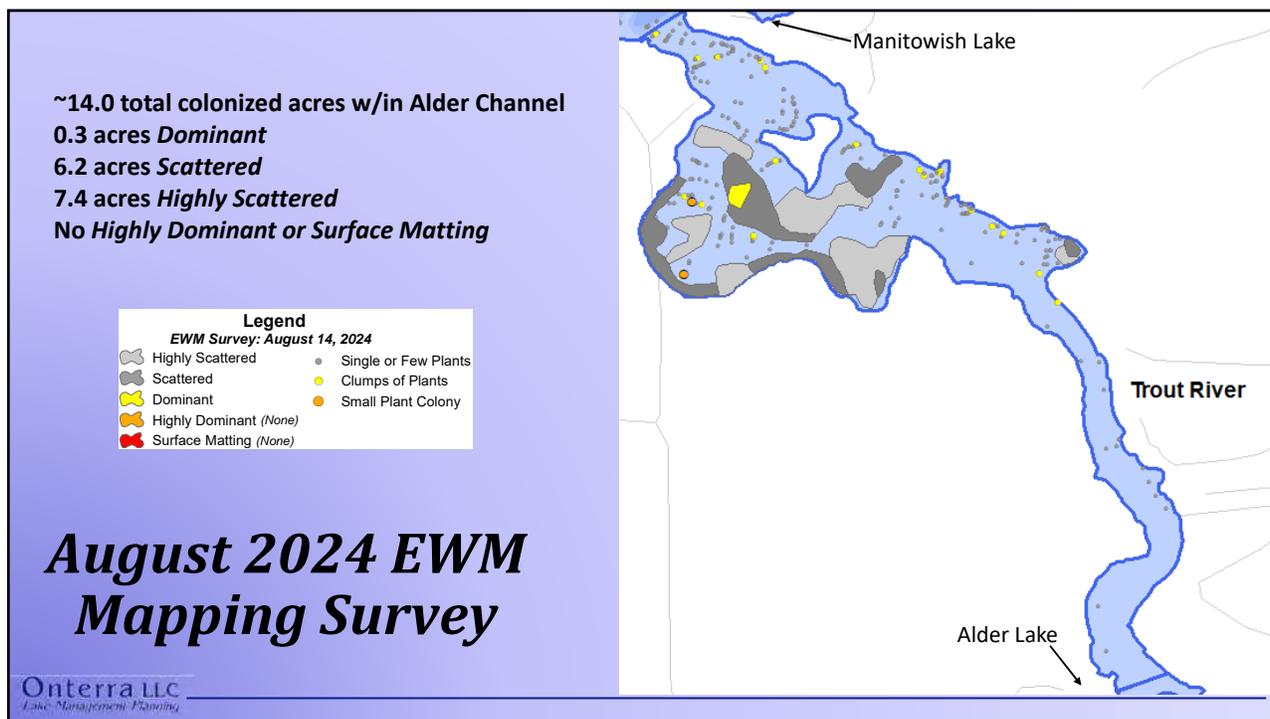


Polygon-Based Mapping

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting

Impact Use

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EWM Management Perspectives

1. No Coordinated Active Management (Let Nature Take its Course)

- Group does not organize or fund control 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
- May not be consistent with regulatory framework

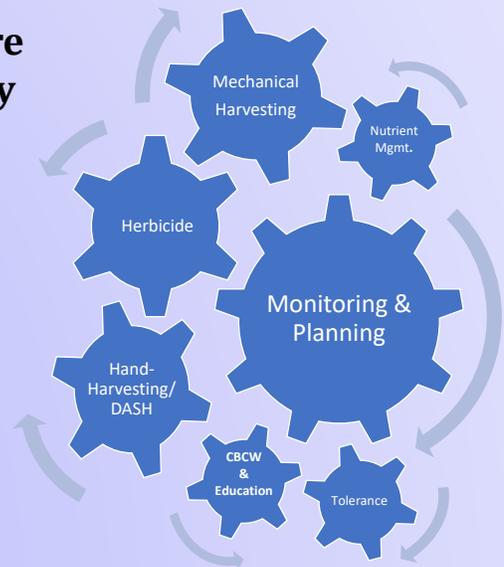
3. Minimize navigation and recreation impediment (Nuisance Control)

- Hand-harvesting alone is not able to accomplish this goal during high populations of EWM, herbicides and/or mechanical harvester would be required

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Integrated Pest Management (IPM)

Using a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately



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Hand-Harvesting

- Goal – to manage the **EWM population** or **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**
- **Diver-Assisted Suction Harvest (DASH) can increase efficacy**
- **Scale limitations, not for large or dense areas (typically an acre or less)**
- **Success expectation – population reduction in YOT, not elimination**
- **Limitations**
 - Density of EWM & native plants, clarity of water
 - Sediment type, Obstructions



Photo Credit: Aquatic Plant Management, LLC

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Utility of Hand Harvesting based on EWM Population

EWM Population

Realistic Strategy or Goal (Site by Site or Lake-wide Population)

High, very dense, established population

Seasonal Nuisance Relief

Moderate, expanding, forming colonies, rebounding population

Reduce population & Inhibit Expansion

Low, not established, isolated occurrences, new introductions

Locally Eradicate

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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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Lake Management Planning

Biological Control - Weevils

- **Goal – Let nature takes its course but impact EWM plant health & suppress biomass**
- **Largely unproven, not a common EWM control technique**
- **Feed on stems, impact buoyancy/carb reserves for overwintering, reduce competitive advantage**
- **Weevils are native to Wisconsin, already in many lakes, programs aimed at increasing their density through stocking**
- **Habitat requirements – leaf litter, natural shores**
- **WDNR AIS-Control grants - eligible for supplies, -weevils not available for purchase**



Photo Credit:
University of Minnesota

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Herbicide Treatment

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



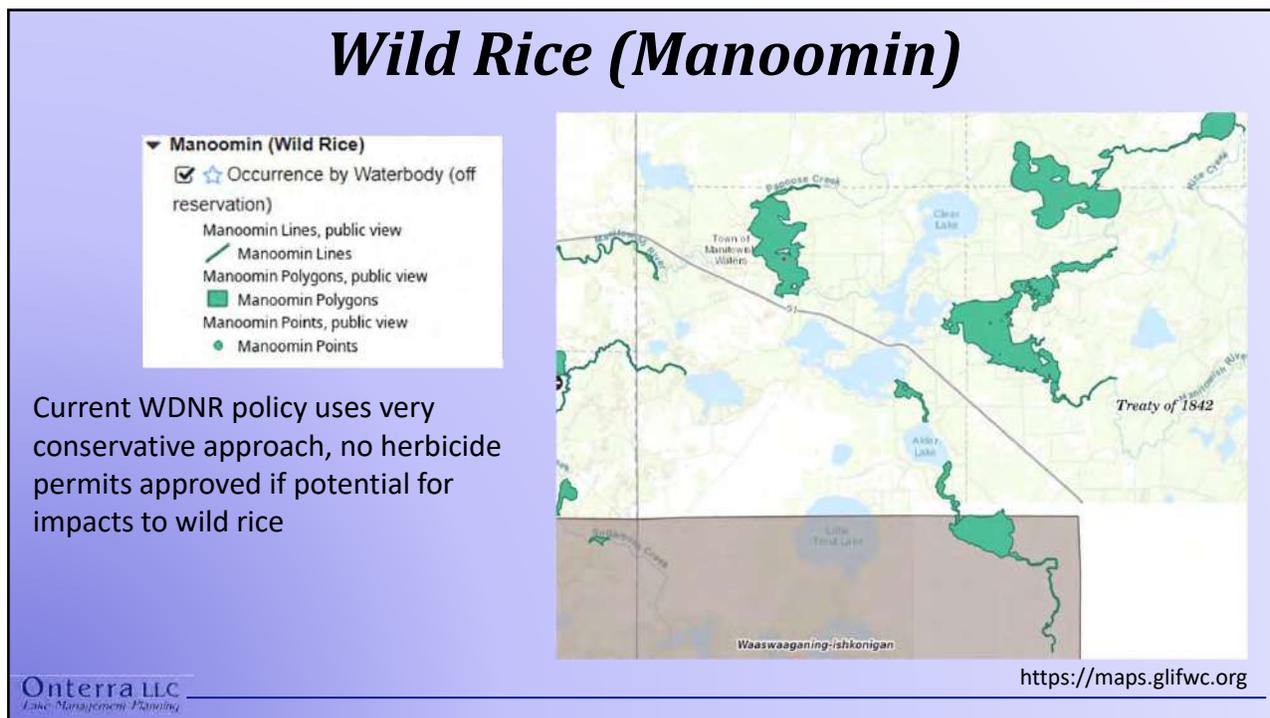
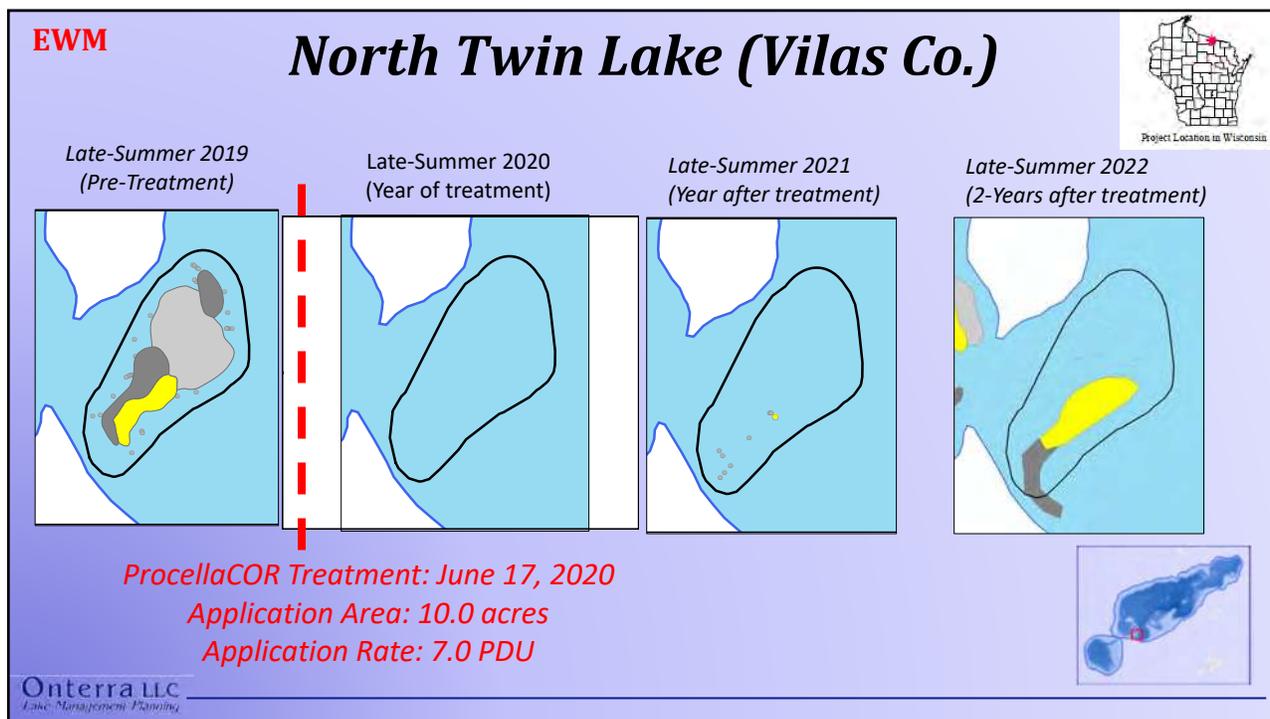
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Florpyrauxifen-benzyl (ProcellaCOR™)

- 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 – days to weeks)
- Acid metabolite has activity as an herbicide (much longer environmental fate – weeks to months)
- 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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Management Plan and Grants

- WDNR recommends lake groups conducting active plant management update aspects of the plan every 5 years (*APM Plan*)
 - Focuses largely on aquatic plants within a lake
 - Whole-lake point-intercept survey needs to have been completed within last 5 years
 - Particularly for grants/permits related to aquatic plant management (AIS control grants, NR107, NR109)
 - Annual AIS Control Plan within an AIS Grant needs to be supported by Plan
- Annual AIS Control Plan ← EDR Projects often rely on annual plans for a few years, before creating a formal Comp/APM Plan
 - Consistent with the framework outlined in APM Plan
 - Includes specific plans, delineated prioritized areas and quantity of effort
- 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.

Primary Objectives for 2025

Continued Monitoring and Hand-Harvesting

- 2024 monitoring data will be used for 2025 prioritization of harvest areas
- Alter current monitoring schedule
 - *NLDC monitors chain throughout early and mid summer*
 - *Onterra completes focused surveys in Sept. based upon NLDC findings*

Develop Focused Aquatic Plant Management Plan

- This will assure eligibility for 2025 AIS-Control Grant application
- Informational meeting with MWLA Board in early 2025
 - *AIS management perspectives*
 - *AIS management tools (hand-harvesting, mechanical harvesting, herbicides)*
 - *Determine goals/actions for 2025 and Focused APM Plan*
- Stakeholder Survey (spring/summer 2025)
- 21-Day Public Comment Period/Official First Draft to WDNR (summer)
- Refine Focused APM Plan based upon survey and comments (late-summer)

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Thank You

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1

Meeting Objective

- Discuss recent EWM monitoring & management activities
- Review Stakeholder Survey Results
- Outline MWLA’s EWM APM Plan (Goals, Actions)

Presentation Outline

- EWM Biology
- Manitowish Chain EWM Population
- EWM Management Options
- Development of a Management Plan



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2

Non-Native Aquatic Plants

Eurasian Watermilfoil

- First officially documented in summer of 2023 (NLDC)
- Known within Manitowish Lake, Spider Lake, Lower Trout River (Between Alder & Manitowish Lakes), Little Star Lake, Stone Lake, Fawn Lake





3

EWM Impacts

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- The addition of EWM can change the “aquascape” of density and location of plant biomass within the water column, possible fisheries shifts



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4

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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5

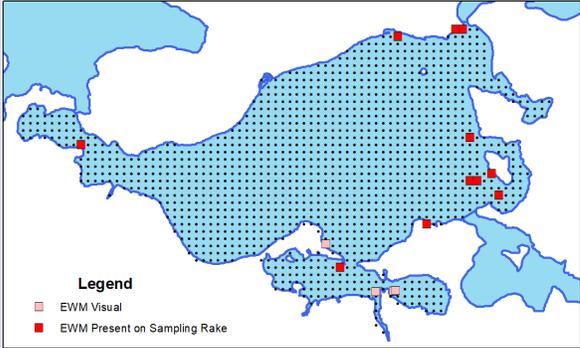
Aquatic Plant Surveys – Point-Intercept

Quantitative

- Point-Intercept Survey
 - Numeric & systematic
 - Applied at various scales
- How frequent a plant is found within the *plant-growing zone* of a lake
- ≤ Max Depth of Plants

Manitowish (N=1,315):
474 Littoral Points

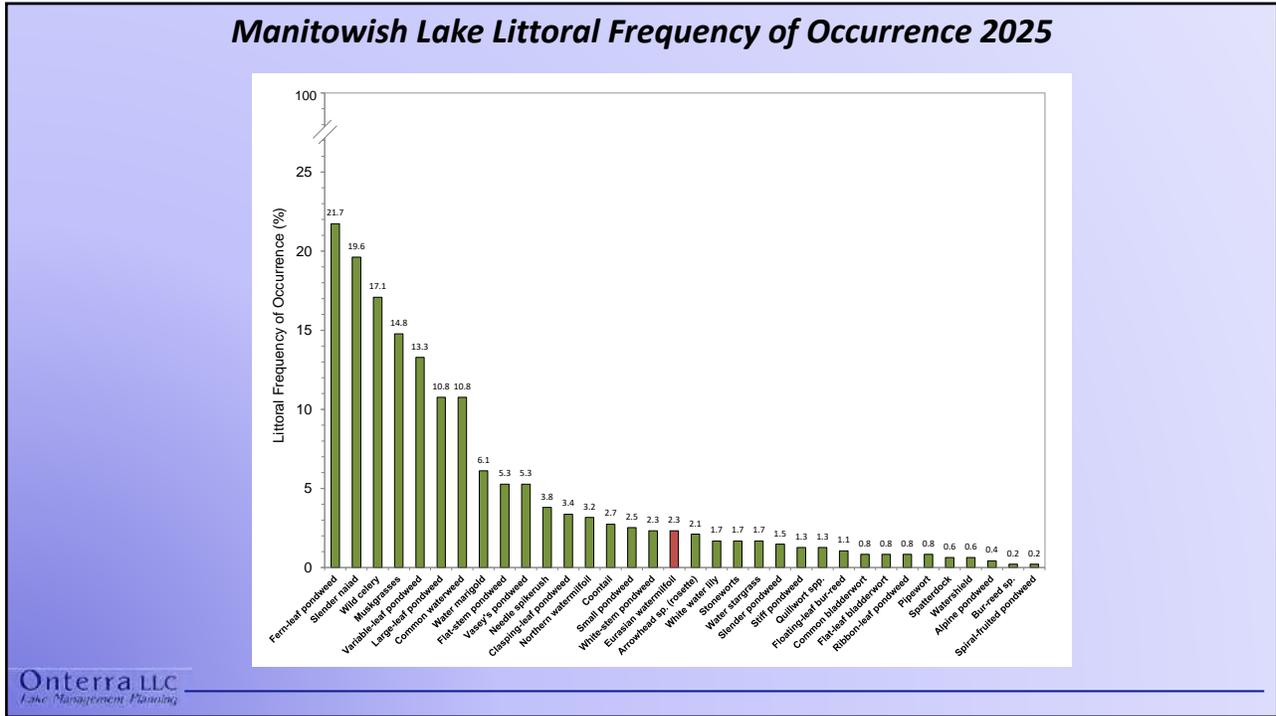
$$\frac{11}{474} = 2.3\%$$

Legend
■ EWM Visual
■ EWM Present on Sampling Rake

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6



7

Manitowish Waters Chain Point-Intercept Surveys

<https://dnr-wisconsin.shinyapps.io/AquaticPlantExplorer/>



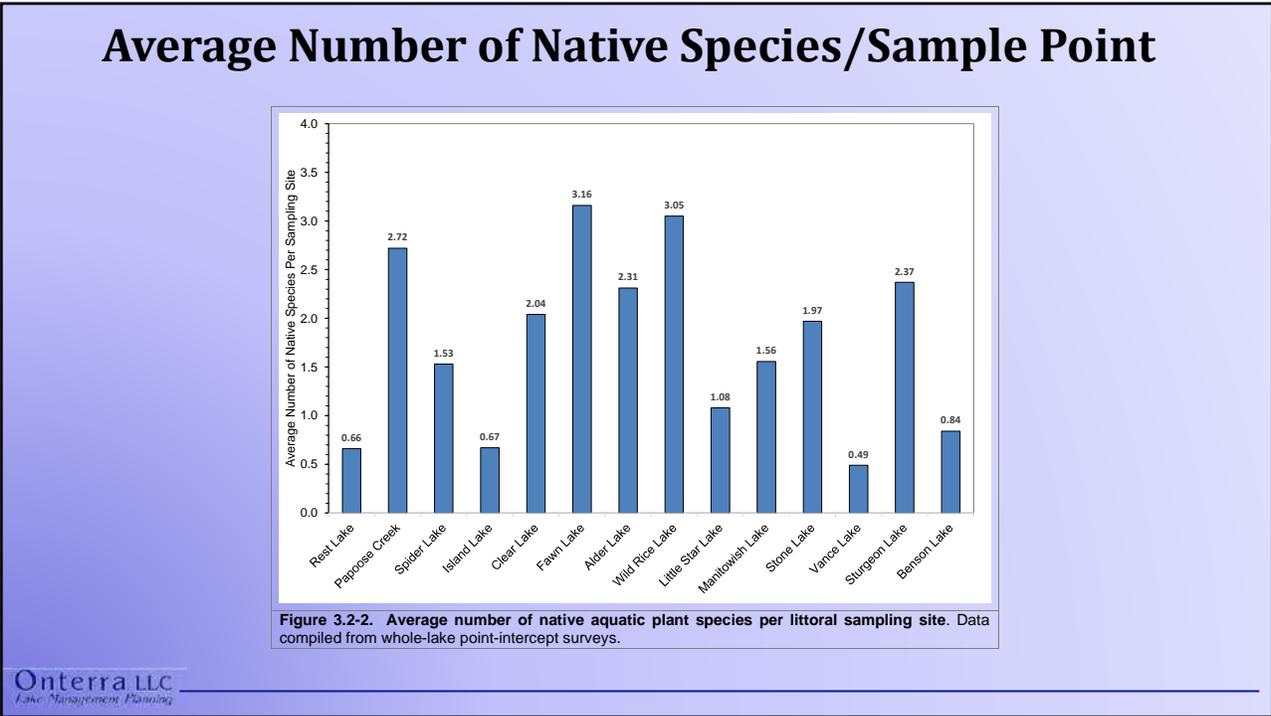

Lake	Point-Intercept Surveys
Alder	2014 (Onterra), 2024 (Onterra)
Benson	2017 (Onterra), 2026*
Clear	2013 (Onterra), 2023 (Onterra)
Fawn	2013 (Onterra), 2023 (Onterra)
Island	2011 (WDNR), 2022 (Onterra)
Little Star	2016 (Onterra), 2025 (NLDC)
Manitowish	2016 (Onterra), 2025 (Onterra)
Rest	2008 (WDNR) 2012 (Onterra), 2022 (Onterra)
Rice Creek	2012 (WDNR), 2023 (Onterra)
Spider	2012 (Onterra), 2022 (Onterra)
Stone	2017 (Onterra), 2026*
Sturgeon	2006 (WDNR) 2017 (Onterra), 2026*
Vance	2017 (Onterra), 2026*
Wild Rice	2008 (WDNR), 2014 (Onterra), 2024 (NLDC)

* anticipated surveys in 2026.

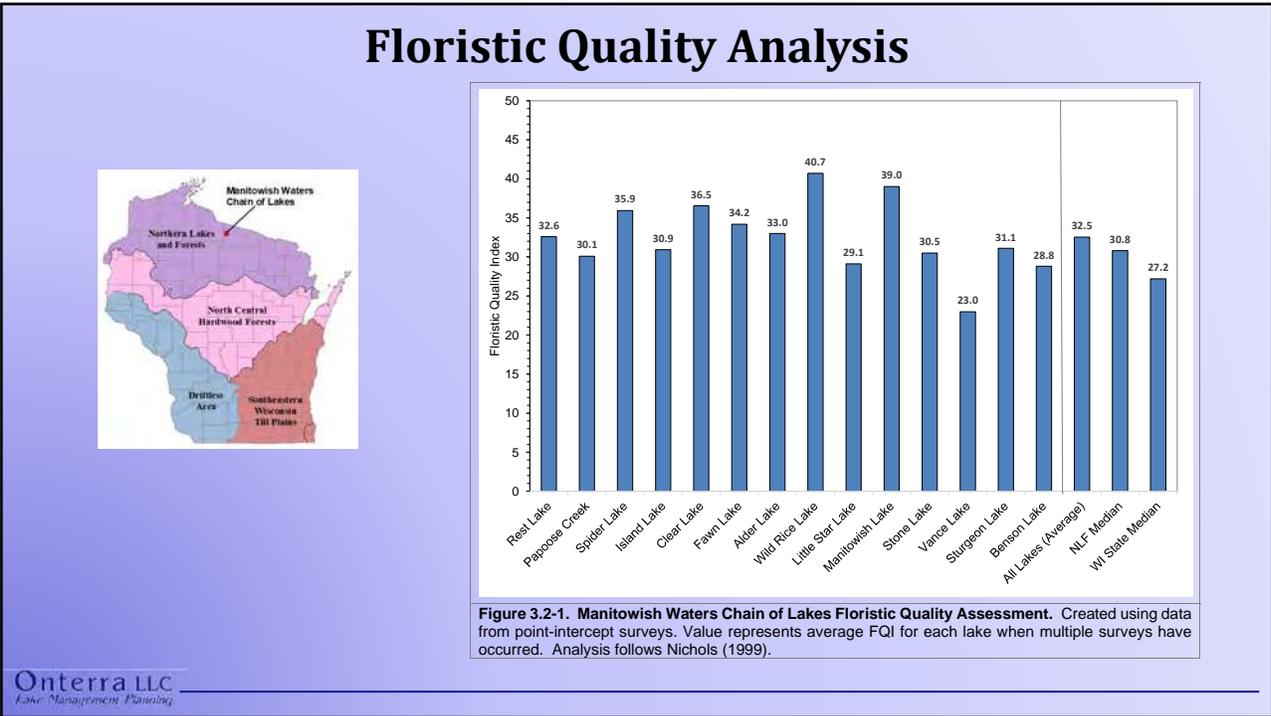



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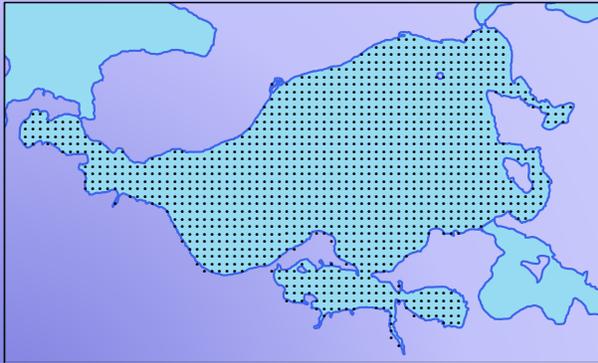


10

Types of Aquatic Plant Surveys

Quantitative

- Point-Intercept Survey



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Qualitative

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



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Professional AIS Mapping



Point-Based Mapping

- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

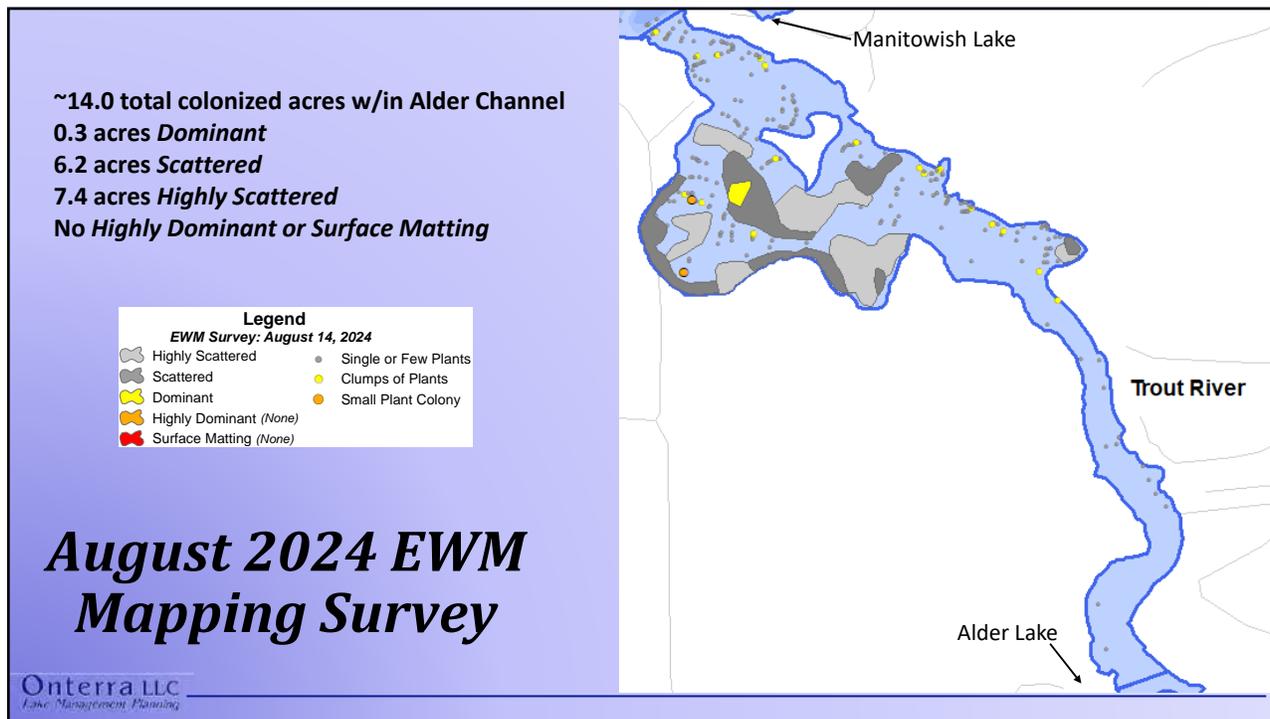


Polygon-Based Mapping

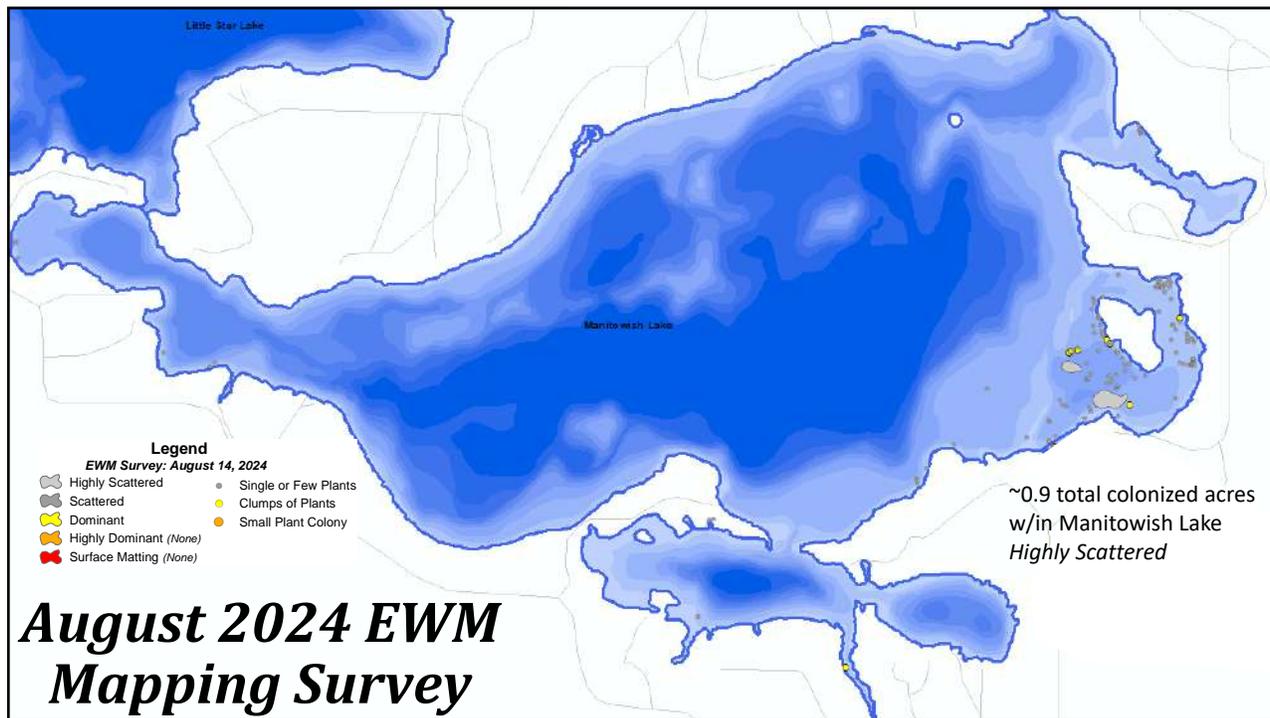
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting

Impact Use

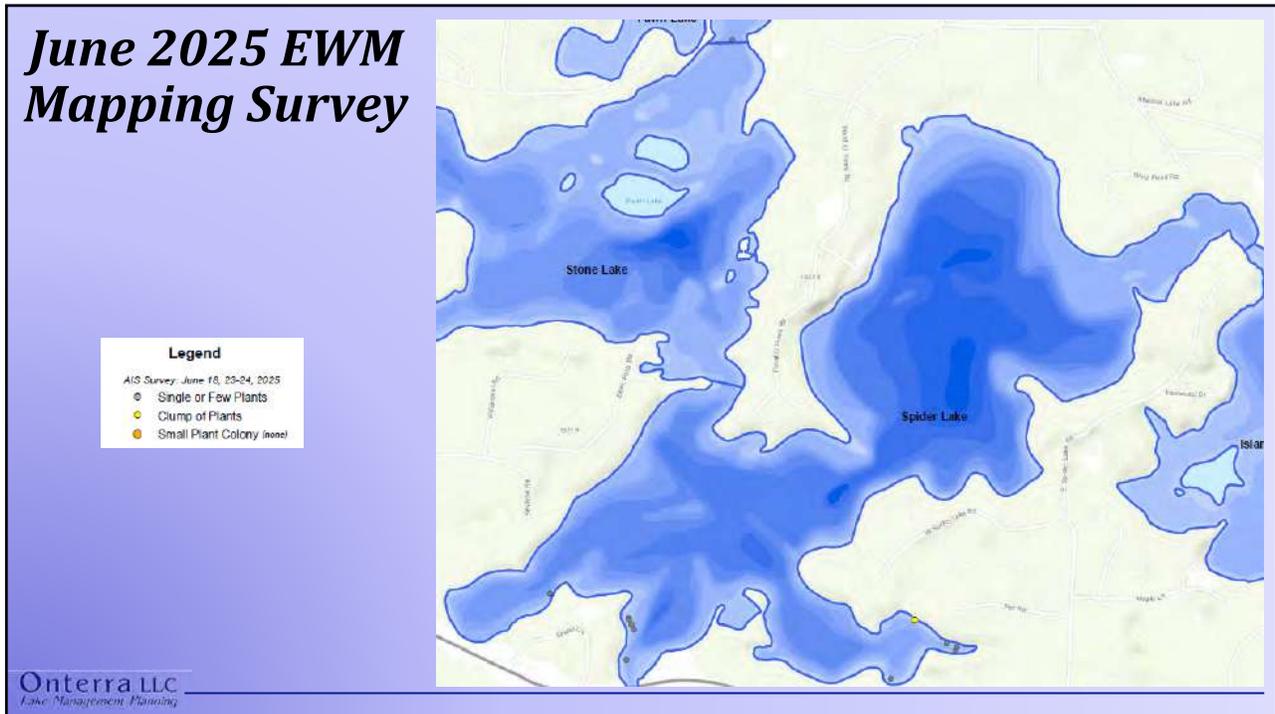
12



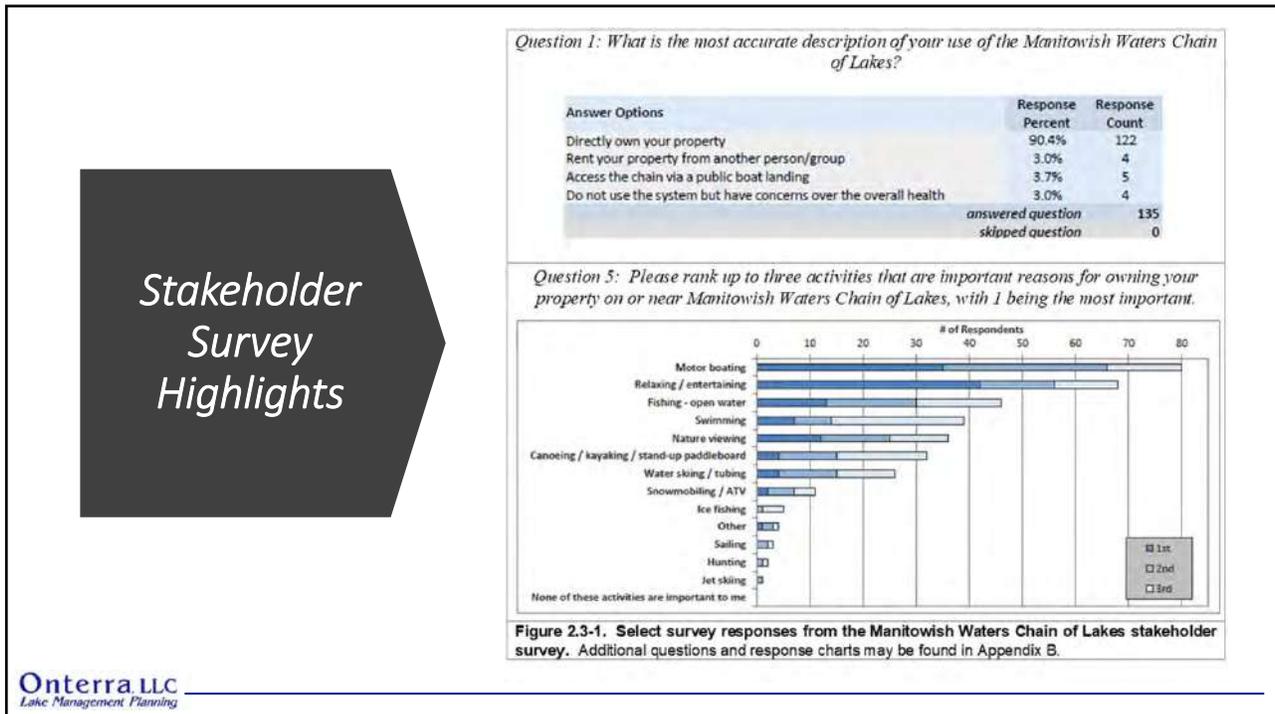
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15



16

Stakeholder Survey Highlights

Question 15: In your opinion, how much of a problem do you believe aquatic invasive species are within the Manitowish Waters Chain of Lakes?

Answer Options	No problem	Mild problem	Moderate problem	Significant problem	Unsure: Need more info	Rating Average	Response Count
	0	8	35	78	3	3.49	124
							11

answered question 124
skipped question 11

Figure 3.3-6. Select survey responses from the Manitowish Waters Chain of Lakes stakeholder survey. Additional questions and response charts may be found in Appendix B.

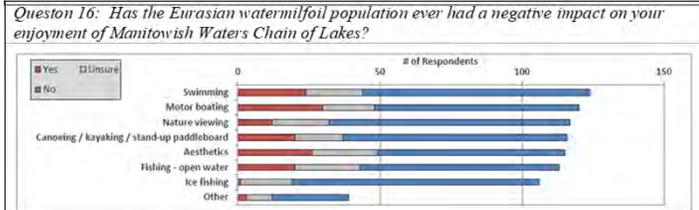
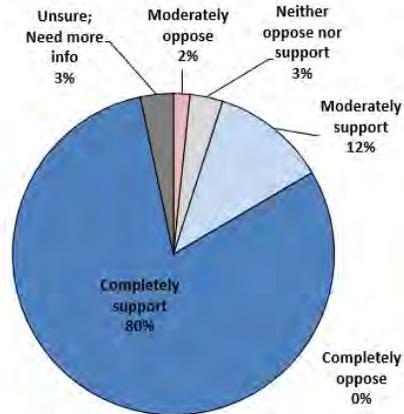


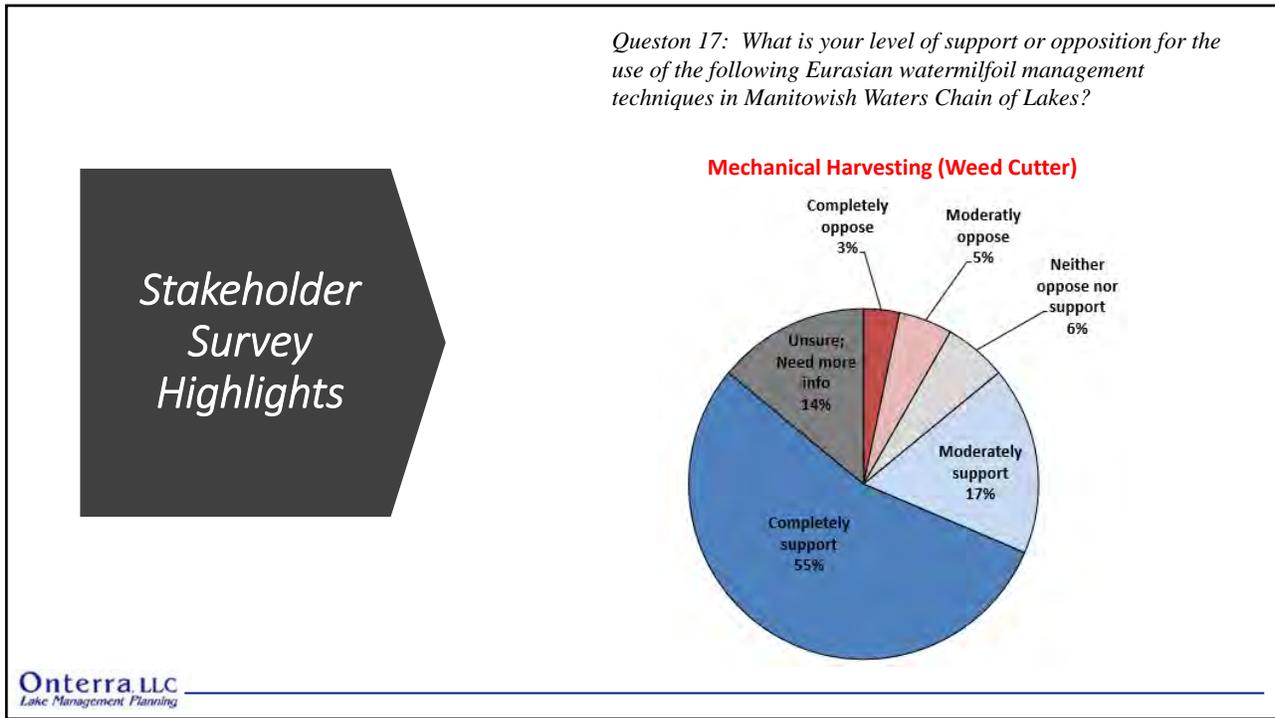
Figure 3.3-7. Select survey responses from the Manitowish Waters Chain of Lakes stakeholder survey. Additional questions and response charts may be found in Appendix B.

Stakeholder Survey Highlights

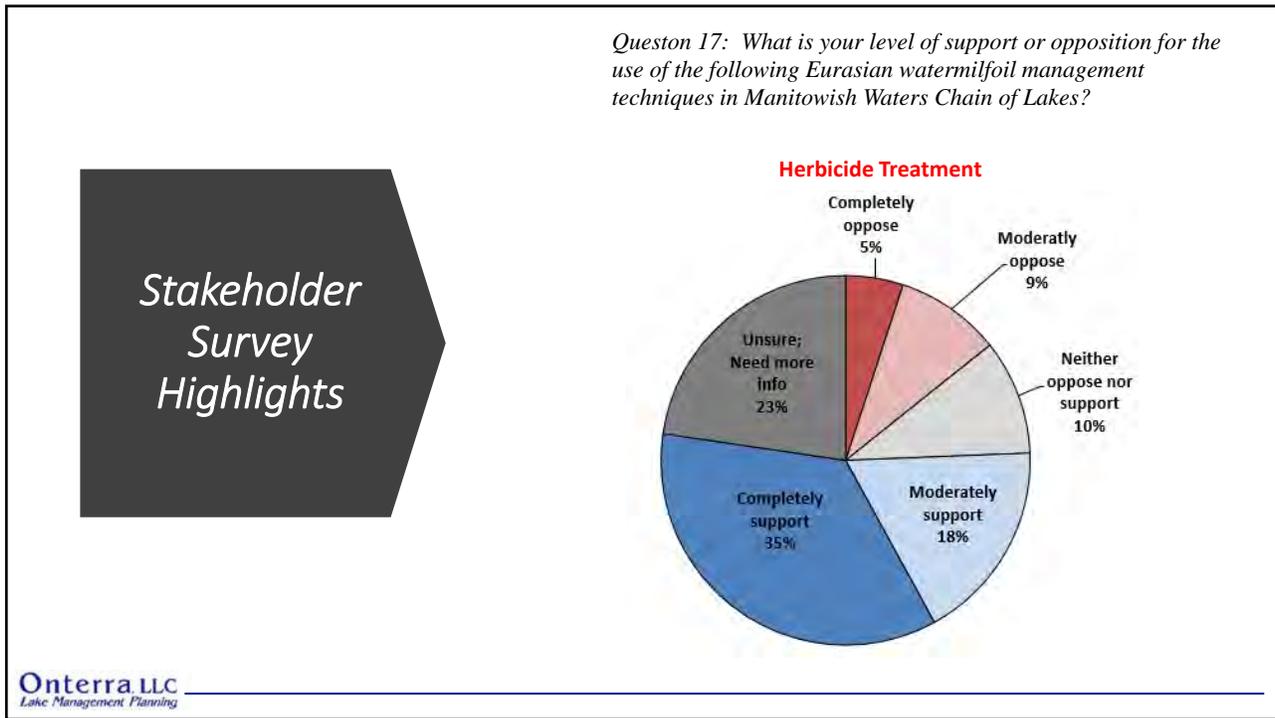
Question 17: What is your level of support or opposition for the use of the following Eurasian watermilfoil management techniques in Manitowish Waters Chain of Lakes?

Hand Harvesting/Diver Assisted Suction Harvest

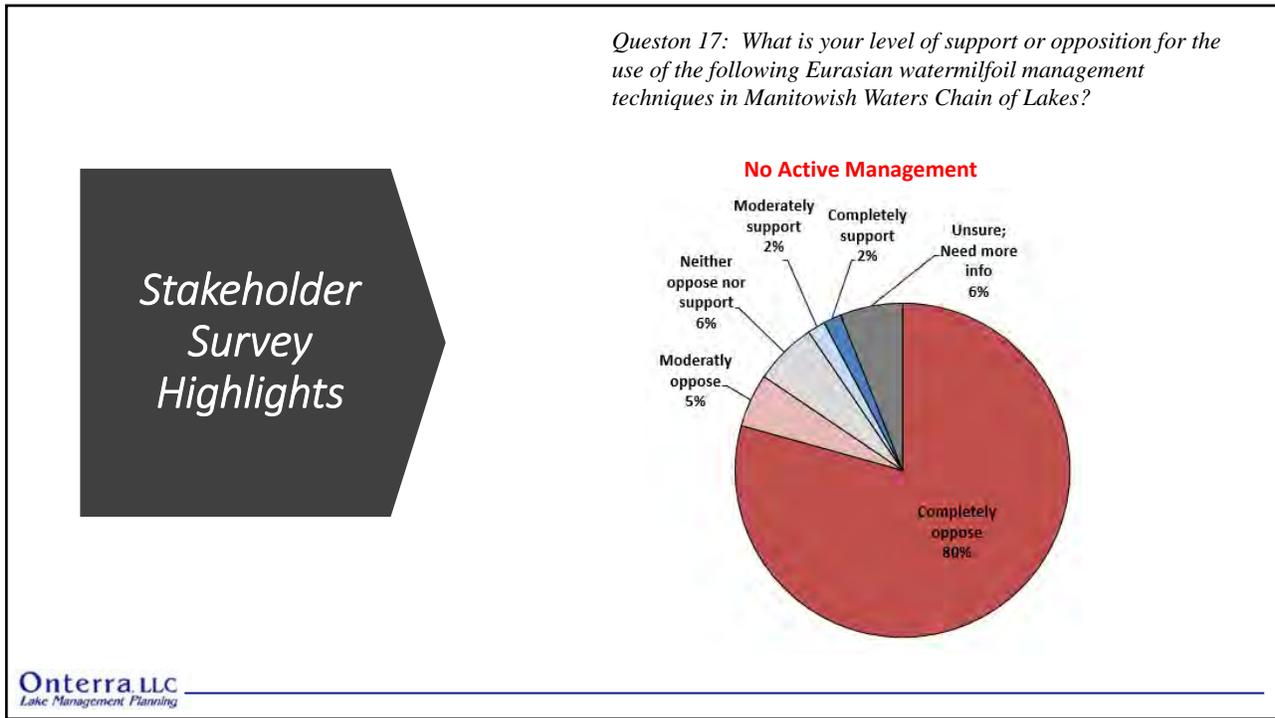




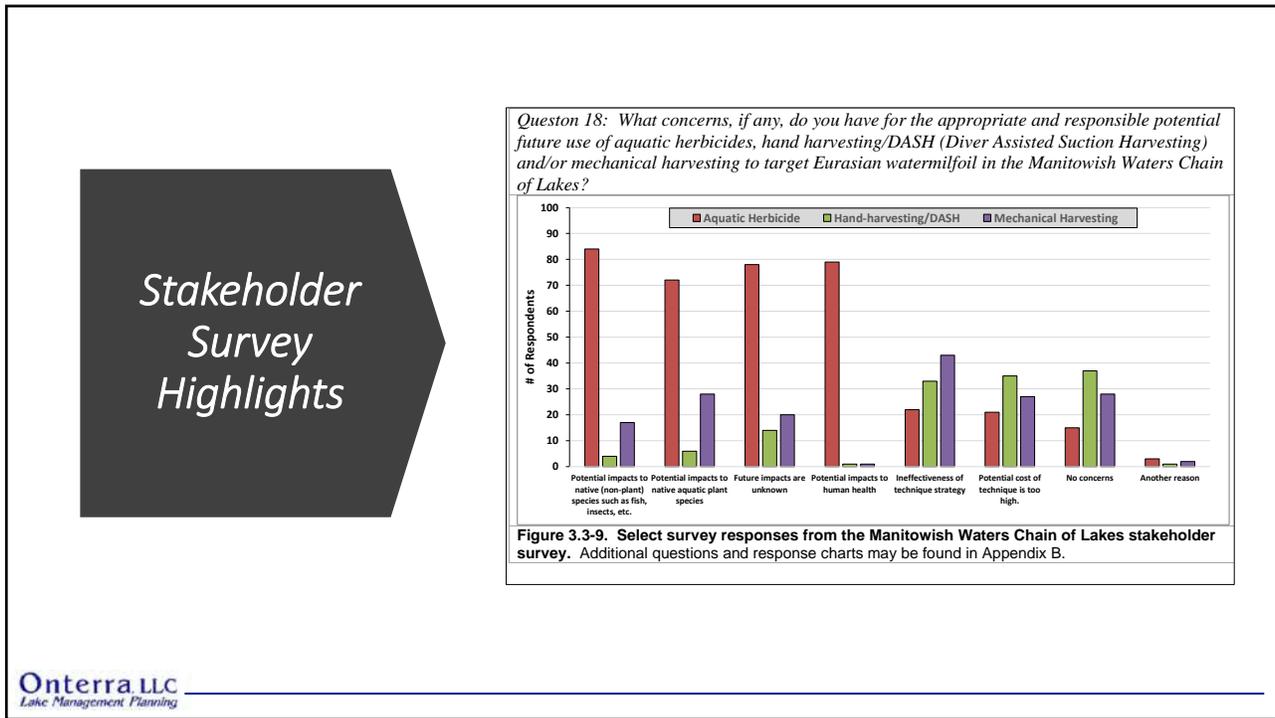
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20



21



22

EWM Management Perspectives

1. No Coordinated Active Management (Let Nature Take its Course)

- Group does not organize or fund control 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
- May not be consistent with regulatory framework

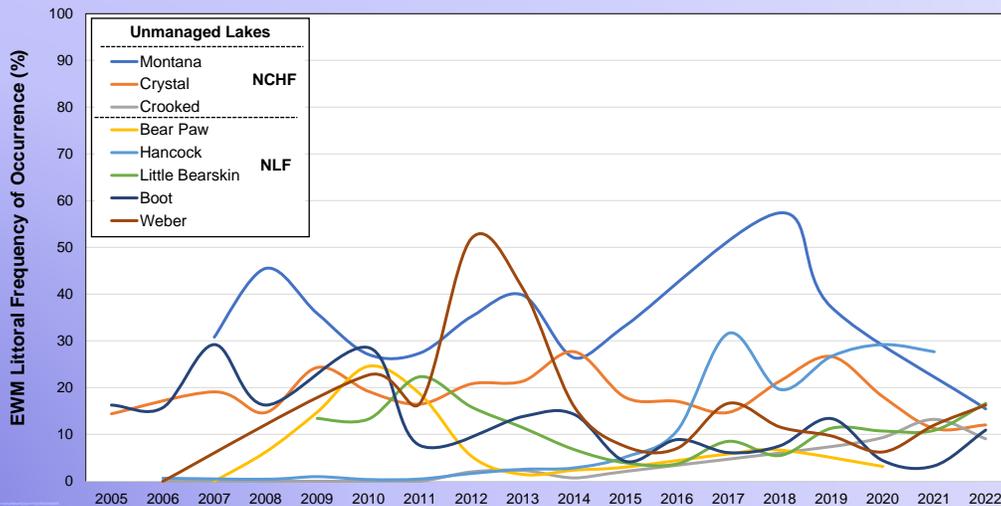
3. Minimize navigation and recreation impediment (Nuisance Control)

- Hand-harvesting alone is not able to accomplish this goal during high populations of EWM, herbicides and/or mechanical harvester would be required

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WDNR EWM Long-Term Monitoring Trends Unmanaged

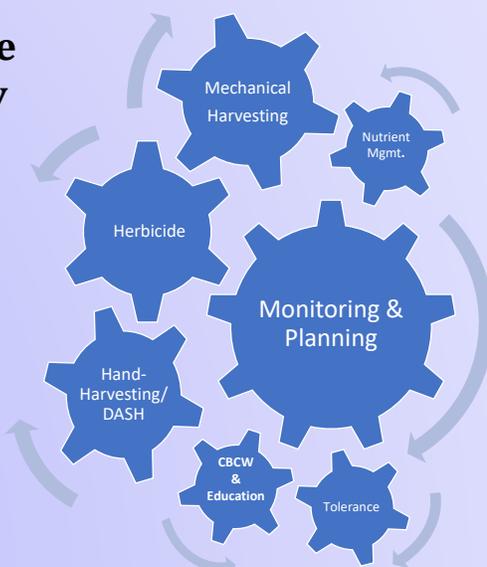


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Integrated Pest Management (IPM)

Using a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately




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Hand-Harvesting

- **Goal** – to manage the **EWM population** or **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**
- **Diver-Assisted Suction Harvest (DASH) can increase efficacy**
- **Scale limitations, not for large or dense areas (typically an acre or less)**
- **Success expectation – population reduction in YOT, not elimination**
- **Limitations**
 - Density of EWM & native plants, clarity of water
 - Sediment type, Obstructions



Photo Credit: Aquatic Plant Management, LLC

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<u>Utility of Hand Harvesting based on EWM Population</u>	
<u>EWM Population</u>	<u>Realistic Strategy or Goal</u> (Site by Site or Lake-wide Population)
High, very dense, established population	Seasonal Nuisance Relief
Moderate, expanding, forming colonies, rebounding population	Reduce population & Inhibit Expansion
Low, not established, isolated occurrences, new introductions	Locally Eradicate

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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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Biological Control - Weevils

- **Goal – Let nature takes its course but impact EWM plant health & suppress biomass**
- **Largely unproven, not a common EWM control technique**
- **Feed on stems, impact buoyancy/carb reserves for overwintering, reduce competitive advantage**
- **Weevils are native to Wisconsin, already in many lakes, programs aimed at increasing their density through stocking**
- **Habitat requirements – leaf litter, natural shores**
- **WDNR AIS-Control grants - eligible for supplies, -weevils not available for purchase**



Photo Credit:
University of Minnesota

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Herbicide Treatment

- **Goal – multi-year EWM population control**
- **Meet concentration & exposure times (CETs) for mortality**
 - Small (< 5 acres) spot treatments are often ineffective
 - Broad areas more effective
 - Protected areas more effective
 - Whole-lake/basin scale concepts
- **Introduces greater need for risk assessment discussion**
 - Impacts to native plants, particularly native watermilfoils and other sensitive species
 - 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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Herbicide Treatment on Lake Metonga



- Tracer Dye (Rhodamine WT)
- A-15 (south) ~ 3 acres
- B-15 (north) ~ 5 acres



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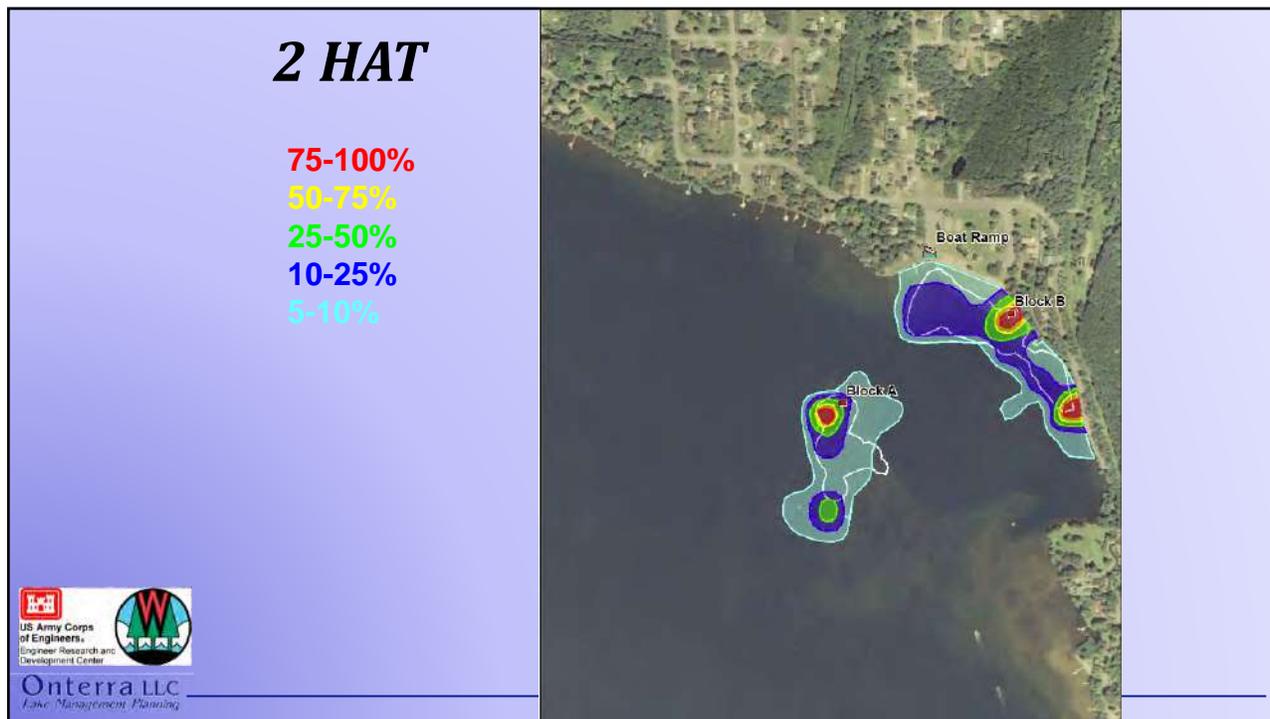
1 HAT

- 75-100%
- 50-75%
- 25-50%
- 10-25%
- 5-10%

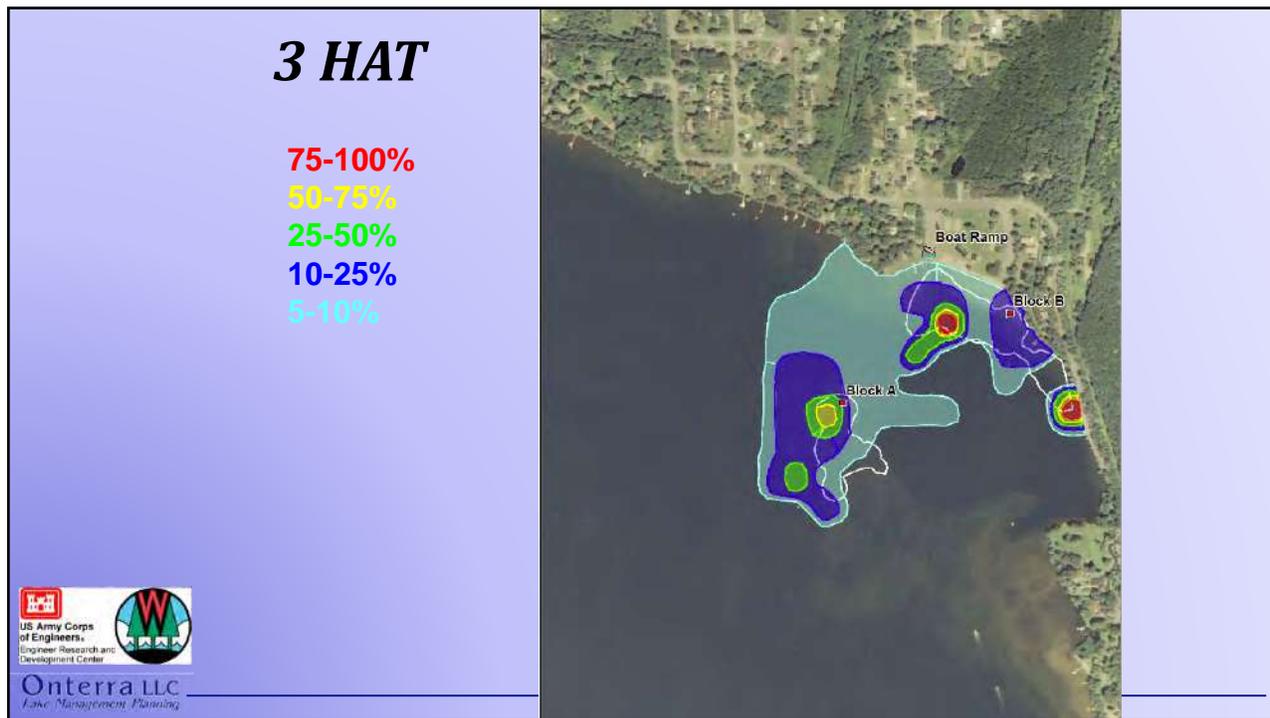


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33



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5 HAT

75-100%

50-75%

25-50%

10-25%

5-10%

2,4-D CET needed for EWM control based upon published studies:

sustained 4.0 ppm for 12 hours

sustained 2.0 ppm for 24 hours

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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 – days to weeks)
- Acid metabolite has activity as an herbicide (much longer environmental fate – weeks to months)
- 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™ 2019-2024 Field Trials

- Onterra has monitored ~100 treatments
- Nearly all show high level of initial control with little to no EWM/HWM extending through year-after-treatment
- Dissipation & mixing resulting in off-target impacts on many projects
- Slightly reduced efficacy and dissipation in high pH lakes, SE WI lakes
- Native plant impacts largely confined to northern watermilfoil (highly impacted), coontail, and water stargrass (moderately impacted)
- Preliminary research suggests wild rice sensitivity in early life stages

Designing and Monitoring Florypyrauxifen benzyl (ProcellaCOR™) Treatment Strategies in Wisconsin Lakes

Midwest Aquatic Plant Management Society
March 14, 2023

Todd Hanke
Eddie Heath, Tim Hoyman
Onterra, LLC

Summarizing Monitoring Results for Florypyrauxifen-benzyl (ProcellaCOR) Treatments in Wisconsin Lakes

UMISC – November 13, 2024

Todd Hanke
Onterra, LLC

A Review of Two Decades of Invasive Watermilfoil Management on Wisconsin Lakes

MAPMS – February 25, 2025

Eddie Heath,
Todd Hanke, Tim Hoyman
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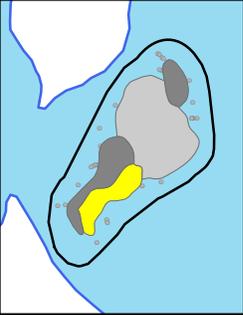
EWM

North Twin Lake (Vilas Co.)

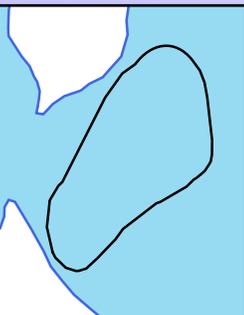


Project Location in Wisconsin

Late-Summer 2019
(Pre-Treatment)



Late-Summer 2020
(Year of treatment)



Late-Summer 2021
(Year after treatment)



Late-Summer 2022
(2-Years after treatment)



ProcellaCOR Treatment: June 17, 2020
Application Area: 10.0 acres
Application Rate: 7.0 PDU



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Wild Rice (Manoomin)

Manoomin (Wild Rice)

- Occurrence by Waterbody (off reservation)
- Manoomin Lines, public view
- Manoomin Lines
- Manoomin Polygons, public view
- Manoomin Polygons
- Manoomin Points, public view
- Manoomin Points

Current WDNR policy uses very conservative approach, no herbicide permits approved if potential for impacts to wild rice

<https://maps.glifwc.org>

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Wild Rice (*Zizania sp.*)

Wild Rice (<i>Zizania sp.</i>) in Manitowish Waters Chain of Lakes		
Lake	Latest Survey Year	Rice Community Acres
Alder	2024	0.9
Benson	2017	0.0
Clear	2023	0.0
Fawn	2023	0.0
Island	2022	91.7
Little Star	2016	<0.1
Manitowish	2016	0.0
Rest	2022	18.0
Rice Creek	2017	198.7
Spider	2022	0.0
Stone	2017	0.0
Sturgeon	2017	0.0
Trout River (Lower)	2024	0.0
Trout River (Upper)	2024	33.8
Vance	2017	0.0
Wild Rice	2024	23.0

Mapping data from Onterra emergent and floating-leaf community mapping surveys.
- Was not documented in lower Trout River section

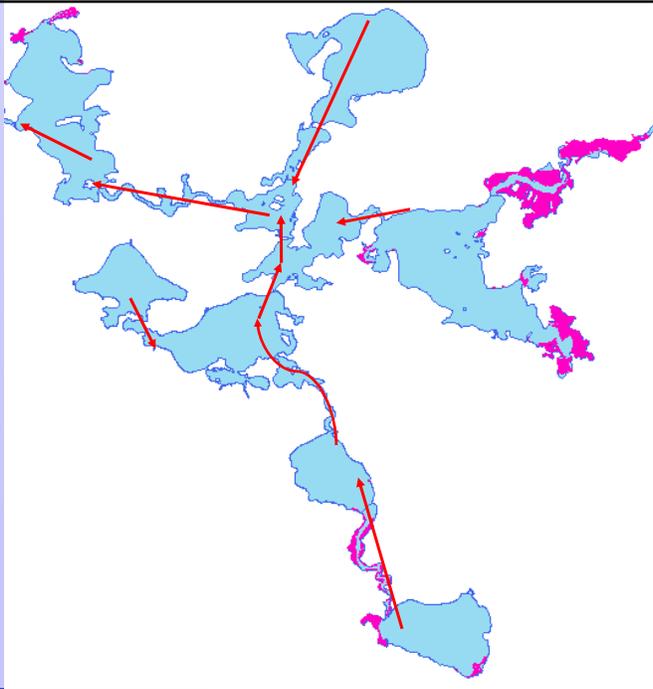
Rice is found in many sections of the Trout River, including the area above Wild Rice Lake, between Wild Rice and Alder Lakes, and between Alder and Manitowish Lakes. The exact locations of smaller beds are not well documented, but this system appears to hold rice in most areas with suitable habitat. Many of the best beds are within the Lac du Flambeau Reservation, and are protected and managed by the Tribe. Watch status is medium-low, but some additional information on distribution, especially below Manitowish Lake, would be useful. (GLIFWC)

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Theoretical Herbicide Treatment Scenarios

- A) No rice impacts or exposure expected
- B) Dense EWM impacting recreational use (ie. Dominant or greater density ratings)
- C) Size/Location of site conducive to herbicide use, expected to meet CET's to reach EWM mortality



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The image shows a map of the Manitowish Chain lakes system. The lakes are colored in light blue, and the surrounding land is white. Red arrows point to various locations across the chain, indicating theoretical herbicide treatment scenarios. The arrows originate from the central part of the chain and point towards the northern and southern ends, as well as to specific smaller lakes and inlets.

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Interim 2025 EWM Strategy

Continued Monitoring and Hand-Harvesting

- 2024 monitoring data used for 2025 prioritization of harvest areas
- Contract with professional hand harvesting (DASH) firm (APM, LLC) to target largest EWM areas (Lower Trout River, select sites in Manitowish Lake).
- NLDC Staff monitors chain early & mid summer and harvests isolated and low-density EWM occurrences as they encounter them.
- Onterra completes late-season EWM mapping surveys in late-August/September to assess 2025 management sites and document peak growth stage of EWM.

Implementation Plan Development

Primary Objective: Create implementation plan framework

Steps to Achieve Objective:

1. Discuss challenges facing the lake and the lake group
2. Convert challenges to management goals
3. Create management actions to meet management goals
4. Determine timeframes and facilitators to carry out actions

2019 Comprehensive Lake Management Plan

Management Goal #4: Control Existing and Prevent Further Aquatic Invasive Species Establishment within the Manitowish Waters Chain of Lakes.

Action: Conduct CLP population control on MWCL using hand harvesting and herbicide spot treatments.

Action: Continue control and monitoring efforts on other AIS that pose a threat to the MWCL. (*Description is specific to purple loosestrife, Phragmites, Paly yellow iris, Japanese knotweed, & spiny waterflea*).

Action: Investigate feasibility of alternative AIS control methodologies for applicability to the MWCL.

Planning Timeline

- Conduct Planning Meeting
- Onterra write Draft Implementation Plan & send to committee for review
- Committee review Draft Implementation Plan & provide comments
- Committee accepts Implementation Plan
- Onterra compile full Official First Draft (Report Sections + Implementation Plan)
- Send OFD to WDNR, other agencies or partners for review (OFD issue by Aug 21)
- MWLA complete 21-day public comment period (complete before Sept 15.)
- -----
- Agency Comments & Public comments integrated into final Plan

Thank You

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B

APPENDIX B

Stakeholder Survey Responses

Manitowish Waters Chain of Lakes - Anonymous Stakeholder Survey

Surveys Distributed: NA
Surveys Returned: 135
Response Rate: NA

Manitowish Waters Chain of Lakes Usage

1. What is the most accurate description of your use of the Manitowish Waters Chain of Lakes?

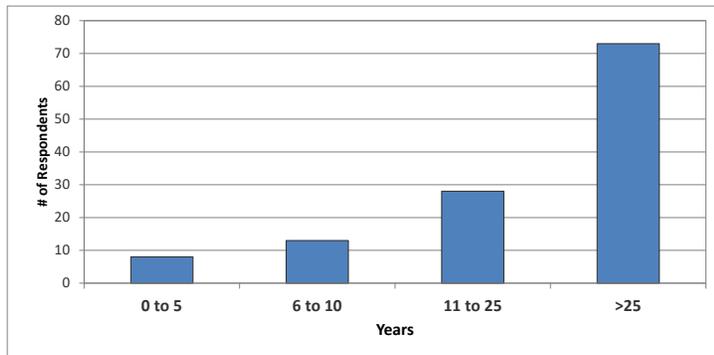
Answer Options	Response Percent	Response Count
Directly own your property	90.4%	122
Rent your property from another person/group	3.0%	4
Access the chain via a public boat landing	3.7%	5
Do not use the system but have concerns over the overall health	3.0%	4
answered question		135
skipped question		0

The following questions pertain specifically to those that own or rent property to others directly on the Manitowish Waters Chain of Lakes.

2. How many years have you owned or rented your property on or near the Manitowish Waters Chain of Lakes?

Answer Options	Response Count
	122
answered question	122
skipped question	13

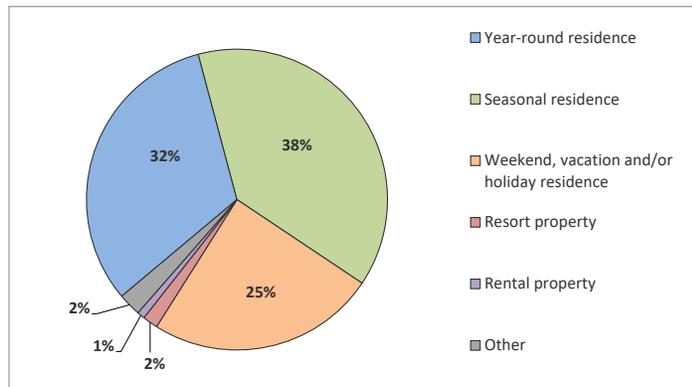
Category (# of years)	Responses	% Response
0 to 5	8	7%
6 to 10	13	11%
11 to 25	28	23%
>25	73	60%



3. How is your property on or near the Manitowish Waters Chain of Lakes used?

Answer Options	Response Percent	Response Count
Year-round residence	32.0%	39
Seasonal residence	38.5%	47
Weekend, vacation and/or holiday residence	24.6%	30
Resort property	1.6%	2
Rental property	0.8%	1
Other	2.5%	3
answered question		122
skipped question		13

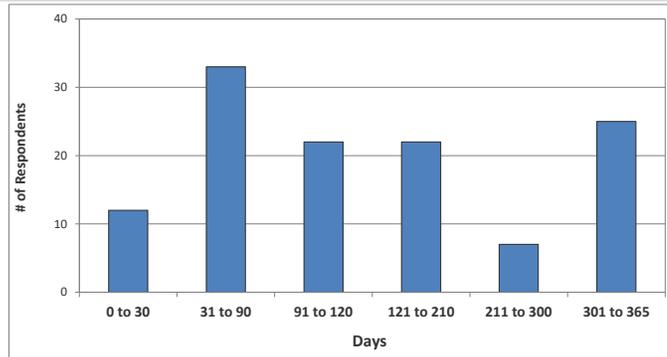
Number	"Other" responses
1	10 months of the year
2	Vacations, short periodic stints, year round
3	This is our legal residence and we are here at least 6 months a year



4. Considering the past three years, how many days each year is your property on the Manitowish Waters Chain of Lakes used by you or others?

		Response Count
<i>answered question</i>		121
<i>skipped question</i>		14

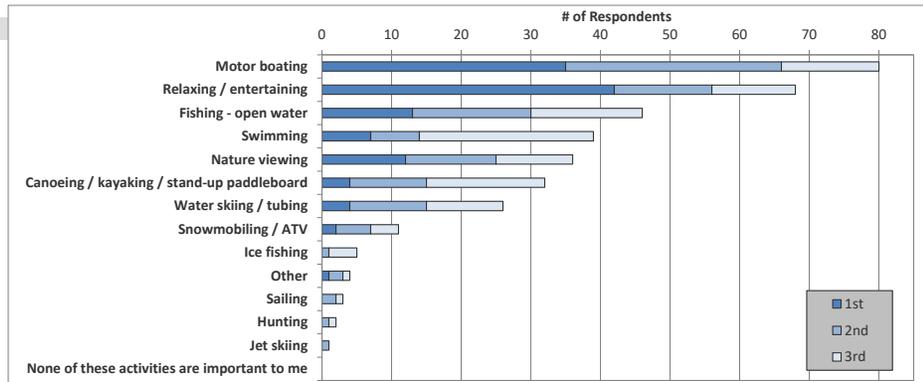
Category (# of days)	Responses	%
0 to 30	12	10%
31 to 90	33	27%
91 to 120	22	18%
121 to 210	22	18%
211 to 300	7	6%
301 to 365	25	21%



5. Please rank up to three activities that are important reasons for owning your property on or near the Manitowish Waters Chain of Lakes, with 1 being the most important.

Answer Options	1st	2nd	3rd	Rating Average	Response Count
Motor boating	35	31	14	1.74	80
Relaxing / entertaining	42	14	12	1.56	68
Fishing - open water	13	17	16	2.07	46
Swimming	7	7	25	2.46	39
Nature viewing	12	13	11	1.97	36
Canoeing / kayaking / stand-up paddleboard	4	11	17	2.41	32
Water skiing / tubing	4	11	11	2.27	26
Snowmobiling / ATV	2	5	4	2.18	11
Ice fishing	0	1	4	2.8	5
Other	1	2	1	2	4
Sailing	0	2	1	2.33	3
Hunting	0	1	1	2.5	2
Jet skiing	0	1	0	2	1
None of these activities are important to me	0	0	0	0	0
<i>answered question</i>					121
<i>skipped question</i>					14

Number	"Other" responses
1	Wake surfing
2	All but "none of these activities are important to me"
3	Wake surfing
4	Pontoon boating
5	Sitting on the dock
6	Skating & cross country skiing

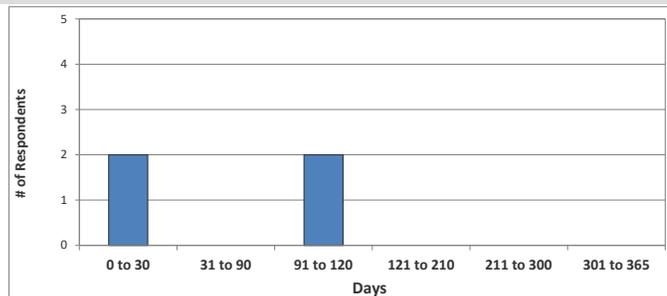


The following questions pertain specifically to those that rent property from another person or group on the Manitowish Waters Chain of Lakes.

6. Considering the past three years, how many days each year have you recreated on the Manitowish Waters Chain of Lakes?

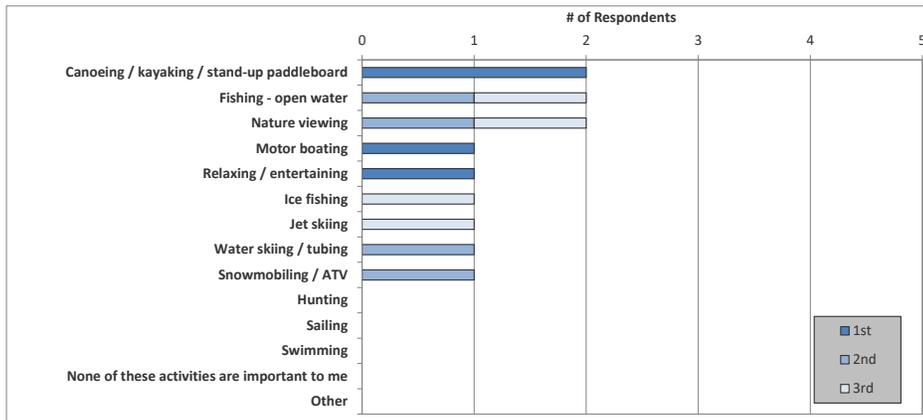
		Response Count
<i>answered question</i>		4
<i>skipped question</i>		131

Category (# of days)	Responses	%
0 to 30	2	2%
31 to 90	0	0%
91 to 120	2	2%
121 to 210	0	0%
211 to 300	0	0%
301 to 365	0	0%



7. Please rank up to three activities that are important to you as a renter on the Manitowish Waters Chain of Lakes, with 1 being the most important.

Answer Options	1st	2nd	3rd	Rating	Response
Canoeing / kayaking / stand-up paddleboard	2	0	0	1	2
Fishing - open water	0	1	1	2.5	2
Nature viewing	0	1	1	2.5	2
Motor boating	1	0	0	1	1
Relaxing / entertaining	1	0	0	1	1
Ice fishing	0	0	1	3	1
Jet skiing	0	0	1	3	1
Water skiing / tubing	0	1	0	2	1
Snowmobiling / ATV	0	1	0	2	1
Hunting	0	0	0	0	0
Sailing	0	0	0	0	0
Swimming	0	0	0	0	0
None of these activities are important to me	0	0	0	0	0
Other	0	0	0	0	0
<i>answered question</i>					
<i>skipped question</i>					

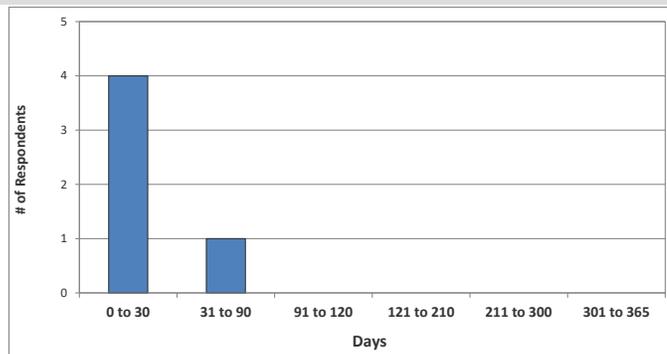


The following questions pertain specifically to those that access the Manitowish Waters Chain of Lakes through a public boat launch but do not own or rent property on the Manitowish Waters Chain of Lakes.

8. Considering the past three years, how many days each year have you used a public boat launch to access the Manitowish Waters Chain of Lakes?

Category	Responses	%
0 to 30	4	3%
31 to 90	1	1%
91 to 120	0	0%
121 to 210	0	0%
211 to 300	0	0%
301 to 365	0	0%

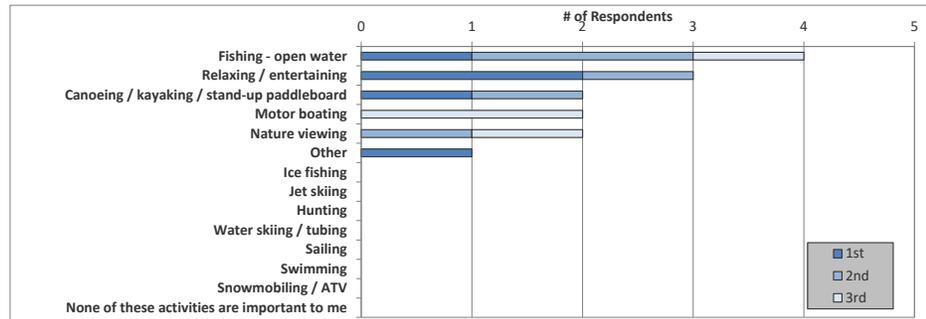
	Response Count
<i>answered question</i>	5
<i>skipped question</i>	130



9. Please rank up to three activities that are important to you as a user of the Manitowish Waters Chain of Lakes, with 1 being the most important.

Answer Options	1st	2nd	3rd	Rating	Response
Fishing - open water	1	2	1	2	4
Relaxing / entertaining	2	1	0	1.33	3
Canoeing / kayaking / stand-up paddleboard	1	1	0	1.5	2
Motor boating	0	0	2	3	2
Nature viewing	0	1	1	2.5	2
Other	1	0	0	1	1
Ice fishing	0	0	0	0	0
Jet skiing	0	0	0	0	0
Hunting	0	0	0	0	0
Water skiing / tubing	0	0	0	0	0
Sailing	0	0	0	0	0
Swimming	0	0	0	0	0
Snowmobiling / ATV	0	0	0	0	0
None of these activities are important to me	0	0	0	0	0
answered question					5
skipped question					130

Number "Other" responses
1 Wild rice harvesting



The following questions pertain to all people who utilize the Manitowish Waters Chain of Lakes by any means and/or those who simply are concerned about the future well-being of the chain

10. Do you have a watercraft that you use on waters other than the Manitowish Waters Chain of Lakes?

Answer Options	Response	Response
	Percent	Count
Yes	53.7%	72
No	46.3%	62
answered question		134
skipped question		1

11. What is your typical cleaning routine after using your watercraft on waters other than the Manitowish Waters Chain of Lakes?

Answer Options	Response	Response
Remove aquatic hitch-hikers (ex. - plant material, clams, mussels)	43.7%	31
Other	43.7%	31
Rinse boat	32.4%	23
Air dry boat for 5 or more days	32.4%	23
Drain bilge	29.6%	21
Power wash boat	7.0%	5
Do not clean boat	5.6%	4
Apply bleach	4.2%	3
answered question		71
skipped question		64

Number "Other" responses

- | | |
|---|---|
| 1 Don't take boats off the chain | 17 Only use on Manitowish Waters Chain |
| 2 Do not use in other waters. | 18 Do not use outside of Manitowish Chain |
| 3 Never leaves the chain | 19 wash the bow every couple years of speedboat- nothing under pontoons |
| 4 boats are never used outside the MW Chain | 20 Boat in beginning of summer. Out october |
| 5 ? my boat doesn't leave the chain | 21 I use it and put it back on the Shore station |
| 6 No bilge. | 22 I only use kayaks. |
| 7 We don't take boats off the chain. | 23 Do not use boats on other bodies of water |
| 8 Towel dry | 24 don't take our boat to other lakes. stays on the lift |
| 9 our boats never leave the chain | 25 When it is not air dried for five days, I bleach it. |
| 10 Boat only on Manitowish Waters chain | 26 My boats never leave the chain |
| 11 Doesn't leave the chain, but will a lot moving forward | 27 Dock at my house |
| 12 The boat never leaves the Manitowish Chain, except for winter storage, where it is cleaned and winterized. | 28 Boats go in in the spring and out in the fall never clean them only man to wish waters water usage |
| 13 We never take our boats off the chain. | 29 Never leave chain |
| 14 Rarely take our boat off of the chain | 30 Other boat not used on chlN |
| 15 Do not use on any other waters | 31 Only use boat on the Manitowish chain. |
| 16 do not bring boat onto chain for use | |

12. Before reading the statement above, had you ever heard of aquatic invasive species?

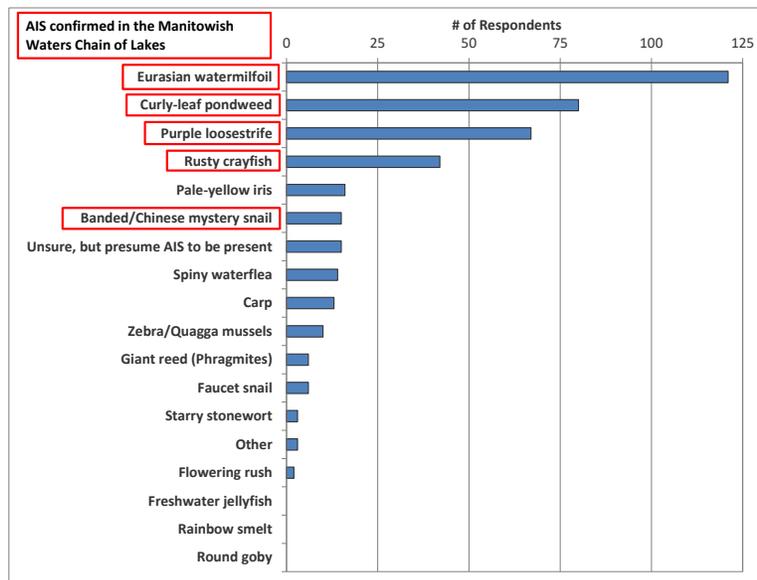
Answer Options	Response Percent	Response Count
Yes	99.3%	133
No	0.7%	1
answered question		134
skipped question		1

13. Do you believe aquatic invasive species are present within the Manitowish Waters Chain of Lakes?

Answer Options	Response Percent	Response Count
Yes	97.0%	129
I think so but am not certain	0.0%	0
No	3.0%	4
answered question		133
skipped question		2

14. Which aquatic invasive species do you believe are present in or immediately around the Manitowish Waters Chain of Lakes?

Answer Options	Response Percent	Response Count
Eurasian watermilfoil	96.8%	121
Curly-leaf pondweed	64.0%	80
Purple loosestrife	53.6%	67
Rusty crayfish	1400.0%	42
Pale-yellow iris	160.0%	16
Banded/Chinese mystery snail	#DIV/0!	15
Unsure, but presume AIS to be present	107.1%	15
Spiny waterflea	700.0%	14
Carp	433.3%	13
Zebra/Quagga mussels	#DIV/0!	10
Giant reed (Phragmites)	#DIV/0!	6
Faucet snail	#DIV/0!	6
Starry stonewort	#DIV/0!	3
Other	#DIV/0!	3
Flowering rush	#VALUE!	2
Freshwater jellyfish	#DIV/0!	0
Rainbow smelt	#DIV/0!	0
Round goby	#DIV/0!	0
answered question		125
skipped question		10



Number "Other" responses

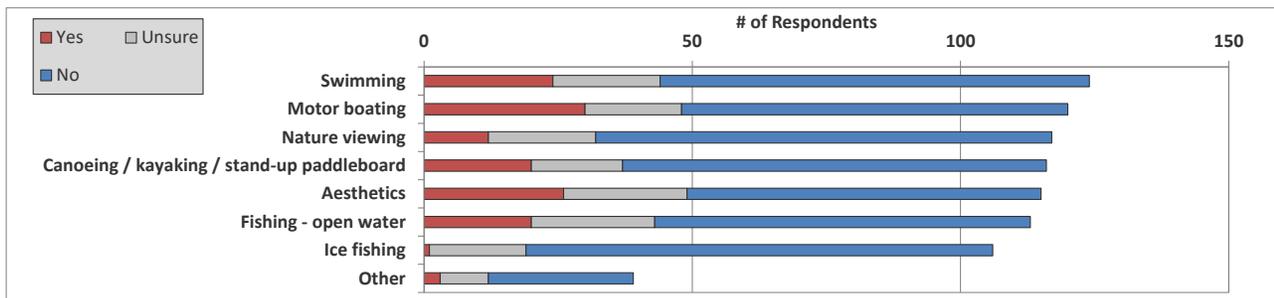
- 1 Haven't seen it, just read about it
- 2 Blue green algae
- 3 The most amount of weeds on Clear Lake in the 23 years of owning our property.

15. In your opinion, how much of a problem do you believe aquatic invasive species are within the Manitowish Waters Chain of Lakes?

Answer Options	No problem	Mild problem	Moderate problem	Significant problem	Unsure; Need more info	Rating Average	Response Count
	0	8	35	78	3	3.49	124
answered question							124
skipped question							11

16. Has the Eurasian watermilfoil population ever had a negative impact on your enjoyment of the Manitowish Waters Chain of Lakes?

Answer Options	Yes	Unsure	No	Response
Swimming	24	20	80	123
Motor boating	30	18	72	120
Nature viewing	12	20	85	117
Canoeing / kayaking / stand-up paddleboard	20	17	79	116
Aesthetics	26	23	66	115
Fishing - open water	20	23	70	113
Ice fishing	1	18	87	105
Other	3	9	27	39
answered question				125
skipped question				10

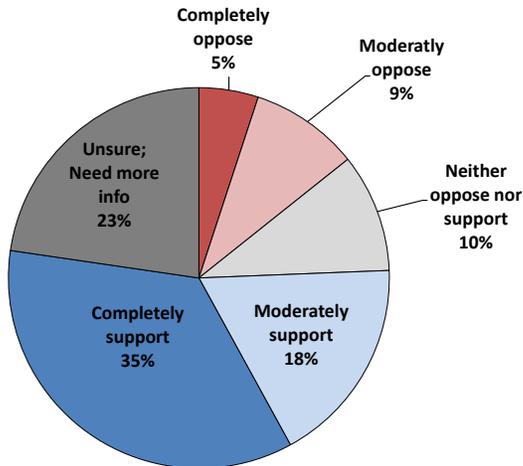


Number	"Other" responses
1	We have found it twice off our dock. 2024 and 2025.
2	Eurasian watermilfoil has not been a problem YET.
3	Not sure
4	Blue green algae, great concern for swimming and boating and unattractive look.
5	As far as I know, I haven't been to eurasian milfoil areas on the chain.. I've seen it elsewhere an it changes the ecological function, and aesthetic character of a lake.
6	Causes me to have to sanitize my boat extra well if I move to another body of water
7	You should have N/A as an answer. I don't ice fish, for example.
8	The weeds are becoming a problem.

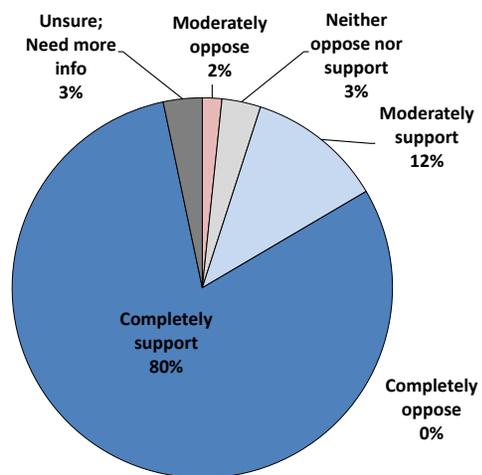
17. What is your level of support or opposition for the appropriate and responsible potential future use of herbicide treatments, hand-harvesting/DASH (Diver Assisted Suction Harvesting), and/or mechanical harvesting to target Eurasian watermilfoil in the Manitowish Waters Chain of Lakes?

Answer Options	Completely oppose	Moderately oppose	Neither oppose nor support	Moderately support	Completely support	Unsure: Need more info	Response Count
Herbicide treatments	6	11	12	21	42	27	119
Hand-harvesting/DASH	0	2	4	14	97	4	121
Mechanical Harvesting (Weed Cutter)	4	6	7	21	66	17	121
No active management (let nature take its course)	92	6	7	2	2	7	116
<i>answered question</i>							121
<i>skipped question</i>							14

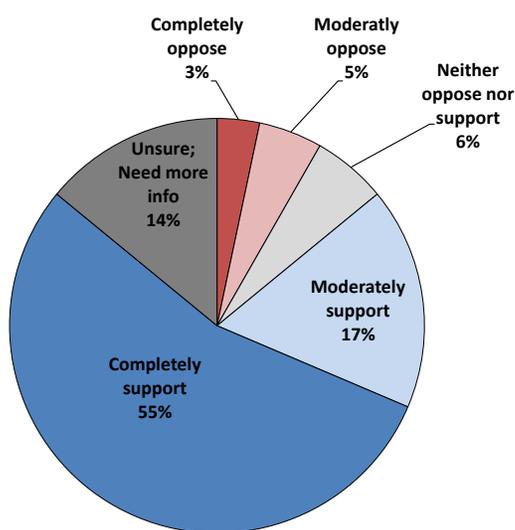
Future: Herbicide Treatments



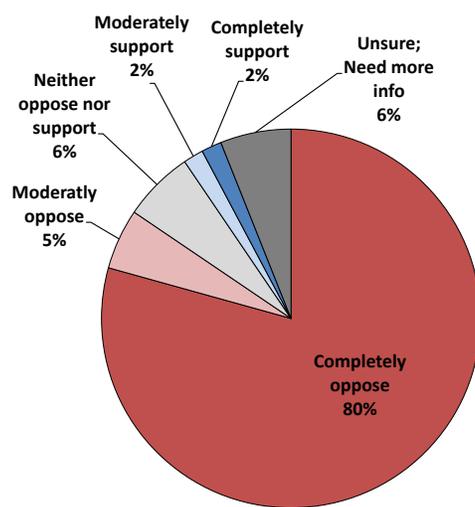
Future: Hand-Harvesting/DASH



Future: Mechanical Harvesting



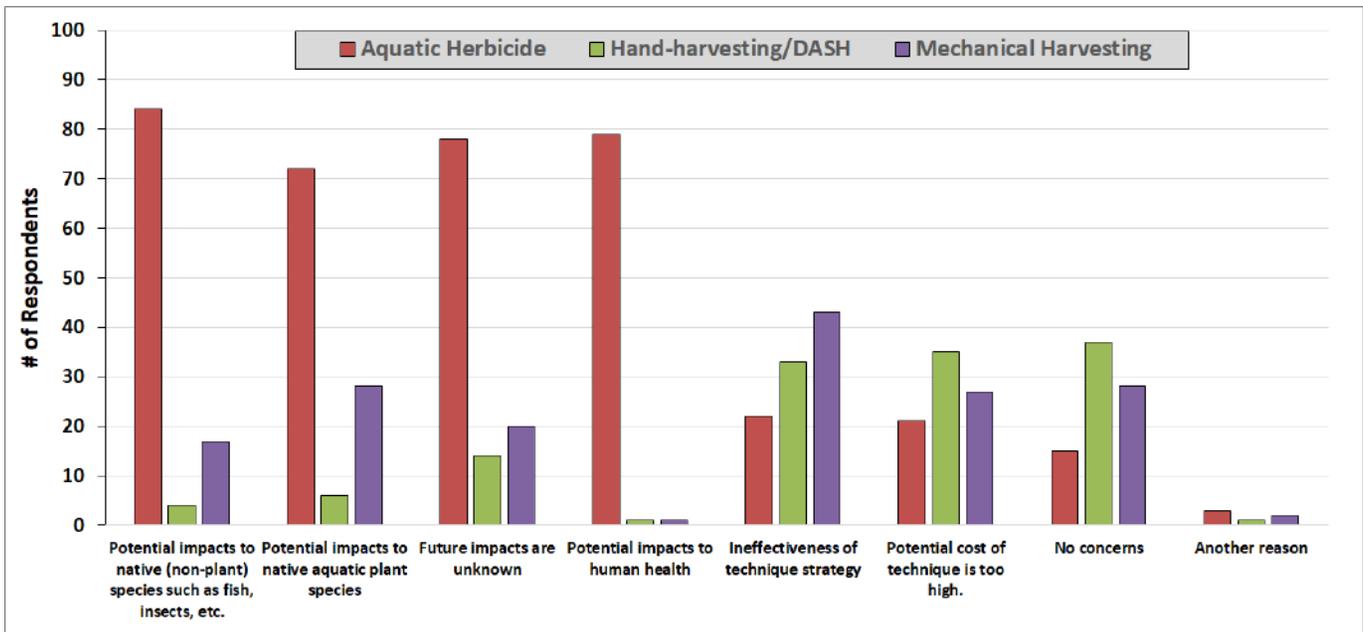
Future: No active management (let nature take its course)



18. What concerns, if any, do you have for the appropriate and responsible potential future use of aquatic herbicides, hand harvesting/DASH (Diver Assisted Suction Harvesting) and/or mechanical harvesting to target Eurasian watermilfoil in the Manitowish Waters Chain of Lakes?

Answer Options	Aquatic Herbicide	Hand-harvesting /DASH	Mechanical Harvesting	Response Count
Potential impacts to native (non-plant) species such as fish, insects, etc.	84	4	17	87
Potential impacts to native aquatic plant species	72	6	28	83
Future impacts are unknown	78	14	20	83
Potential impacts to human health	79	1	1	79
Ineffectiveness of technique strategy	22	33	43	61
Potential cost of technique is too high.	21	35	27	49
No concerns	15	37	28	43
Another reason	3	1	2	4
			<i>answered question</i>	111
			<i>skipped question</i>	24

- Number "Other" responses**
- 1 Won't mechanical spread the milfoil?
 - 2 We're not well versed, but think EWM will take over if not taken care of.
 - 3 Ne more knowledge in this area
 - 4 I do not know enough information about aquatic herbicide to answer these questions
 - 5 I am not knowledgeable about the above concerns
 - 6 dumb question! every thing should be used to fight the weeds
 - 7 Aquatic herbicides have been used many places effectively



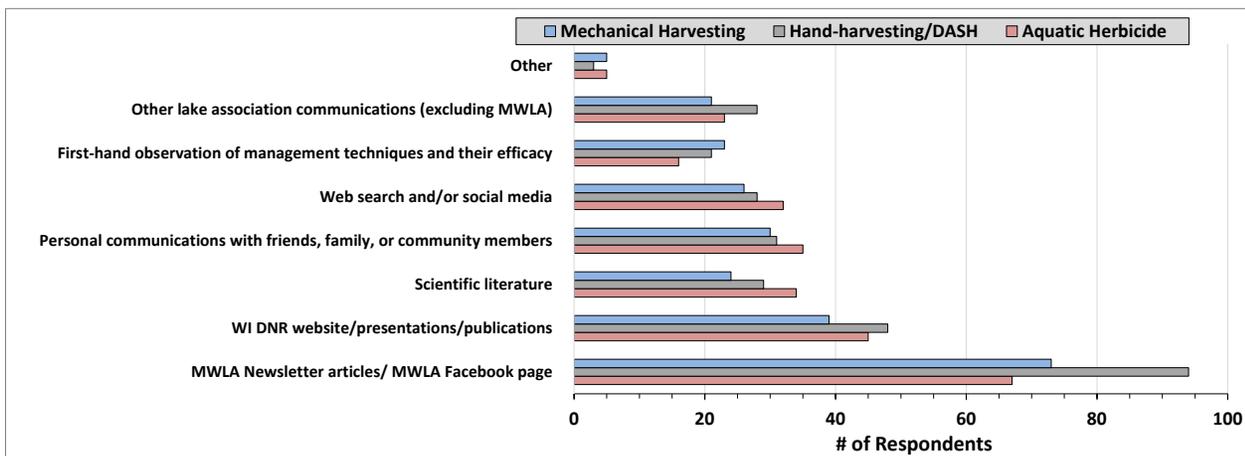
19. From what source(s) do you draw the majority of your information for each of the three listed aquatic plant management techniques?

Answer Options	Aquatic Herbicide	Hand-harvesting /DASH	Mechanical Harvesting	Response Count
MWLA Newsletter articles/ MWLA Facebook page	67	94	73	95
WI DNR website/presentations/publications	45	48	39	56
Scientific literature	34	29	24	41
Personal communications with friends, family, or community members	35	31	30	41
Web search and/or social media	32	28	26	36
First-hand observation of management techniques and their efficacy	16	21	23	34
Other lake association communications (excluding MWLA)	23	28	21	31
Other	5	3	5	7
	answered question			112
	skipped question			23

Number "Other" responses

- 1 Need more info
- 2 I am not learning about this matter
- 3 I live in Madison and have seen what this stuff will do to a lake. it's bad!
- 4 N. Lakeland Discovery Center, Woods and water program.

There appears to be no place for general comments on this survey, so I will put them here. I think a mini presentation taken to every sort of get-together in the area, regardless of the organization, with Jessie from the NLDC giving the talk she did at the end of the presentation which was held at the Lion's pavilion with the people from Madison... I think all that was not very useful, but Jessie's talk at the end about "here's where it was in 2023 and here it was in 2024, and it could get a lot worse," and then show a couple images where the weeds have completely covered lakes in other parts of the state... That is all you'd need. Just a short little presentation like that... this would have the most impact. It SCARED the heck out of me, and created urgency like nothing else I'd heard before on this topic. And maybe ask every organization in MW... "Can we come do a ten minute presentation at the beginning of one of your meetings"? And either have Jessie do it in person, or have her prerecord it, and then have a Save Our Lakes person go and show it to the group.



20. Have you ever attended a locally offered free aquatic invasive species identification training session?

Answer Options	Response Percent	Response Count
Yes, more than 2 years ago	16.7%	20
Yes, 1-2 years ago	6.7%	8
Yes, within the past year	18.3%	22
No, I have never attended	58.3%	70
	answered question	120
	skipped question	15

21. What would be your level of interest in attending a locally offered free aquatic invasive species identification training session offered within the next 12 months?

Answer Options	Response	Response
	Percent	Count
High interest	36.7%	44
Moderate interest	42.5%	51
Low interest	13.3%	16
No interest	7.5%	9
answered question		120
skipped question		15

22. Do you feel you know where you can access local information for the Manitowish Waters Chain of Lakes on current Eurasian watermilfoil status and management methods?

Answer Options	Response	Response
	Percent	Count
Yes	83.5%	101
No	5.0%	6
Unsure; Need more info	11.6%	14
answered question		121
skipped question		14

23. Do you feel that sources of local information (local newspaper, lake association website/postings, etc.) on current Eurasian watermilfoil status and management methods on the Manitowish Waters Chain of Lakes are helpful in your understanding of the impact this aquatic plant is having on our waters?

Answer Options	Response	Response
	Percent	Count
Yes	88.4%	107
No	3.3%	4
Unsure; Need more info	8.3%	10
answered question		121
skipped question		14

24. Would you utilize an online interactive map on the MWLA website for accessing information on the location of and control methods being used to control Eurasian watermilfoil in the Manitowish Chain?

Answer Options	Response	Response
	Percent	Count
Yes	95.0%	115
No	1.7%	2
Unsure; Need more info	3.3%	4
answered question		121
skipped question		14

C

APPENDIX C

2023-2024 EWM Monitoring & Management Materials



Manitowish Chain EWM Removal Report 2024

PO Box 1134 Minocqua, WI 54548



Manitowish Chain EWM Removal Summary

Dive Background: In June, July and August, Aquatic Plant Management LLC (APM) conducted ~18 days of Diver Assisted Suction Harvesting and ~9 days of Hand Harvesting for Eurasian Watermilfoil (EWM) on Manitowish Chain on Manitowish Lake and Spider Lake in Vilas County, WI. The team focused their efforts at many sites as prioritized by the North Lakeland Discovery Center. In total APM was able to remove **1,224.0 cubic feet of EWM** from Manitowish Chain.

Dive Results by Day

Date	Weather Conditions	Water Temp (F)	Underwater Dive Time (hrs)	AIS Removed (cubic ft)
7/9/2024	Sunny	71	6.1	81.0
7/10/2024	Partly Cloudy	71	5.5	157.5
7/11/2024	Sunny	71	6.2	118.5
7/14/2024	Sunny	71	6.2	75.0
7/16/2024	Cloudy	67	6.8	60.0
7/17/2024	Periods of rain	68	7.7	31.0
7/18/2024	Partly Cloudy	72	8.2	61.0
7/19/2024	Sunny	69	8.2	48.0
8/9/2024	Cloudy	68	5.6	6.0
8/19/2024	Sunny	72	11.9	70.0
8/20/2024	Sunny	72	12.2	98.5
8/21/2024	Sunny	71	6.3	30.5
8/22/2024	Partly Cloudy	72	12.3	146.0
8/23/2024	Cloudy	69	10.8	72.0
8/26/2024	Partly Cloudy	75	6.8	31.0
8/30/2024	Partly Cloudy	74	6.8	35.5
9/4/2024	Sunny	73	6.8	62.5
9/9/2024	Sunny	73	5.0	6.0
9/12/2024	Sunny	73	5.8	6.0
9/13/2024	Partly Cloudy	73	5.3	16.0
9/18/2024	Sunny	73	5.1	5.0
9/19/2024	Cloudy	72	4.5	7.0
Grand Total			159.7	1224.0

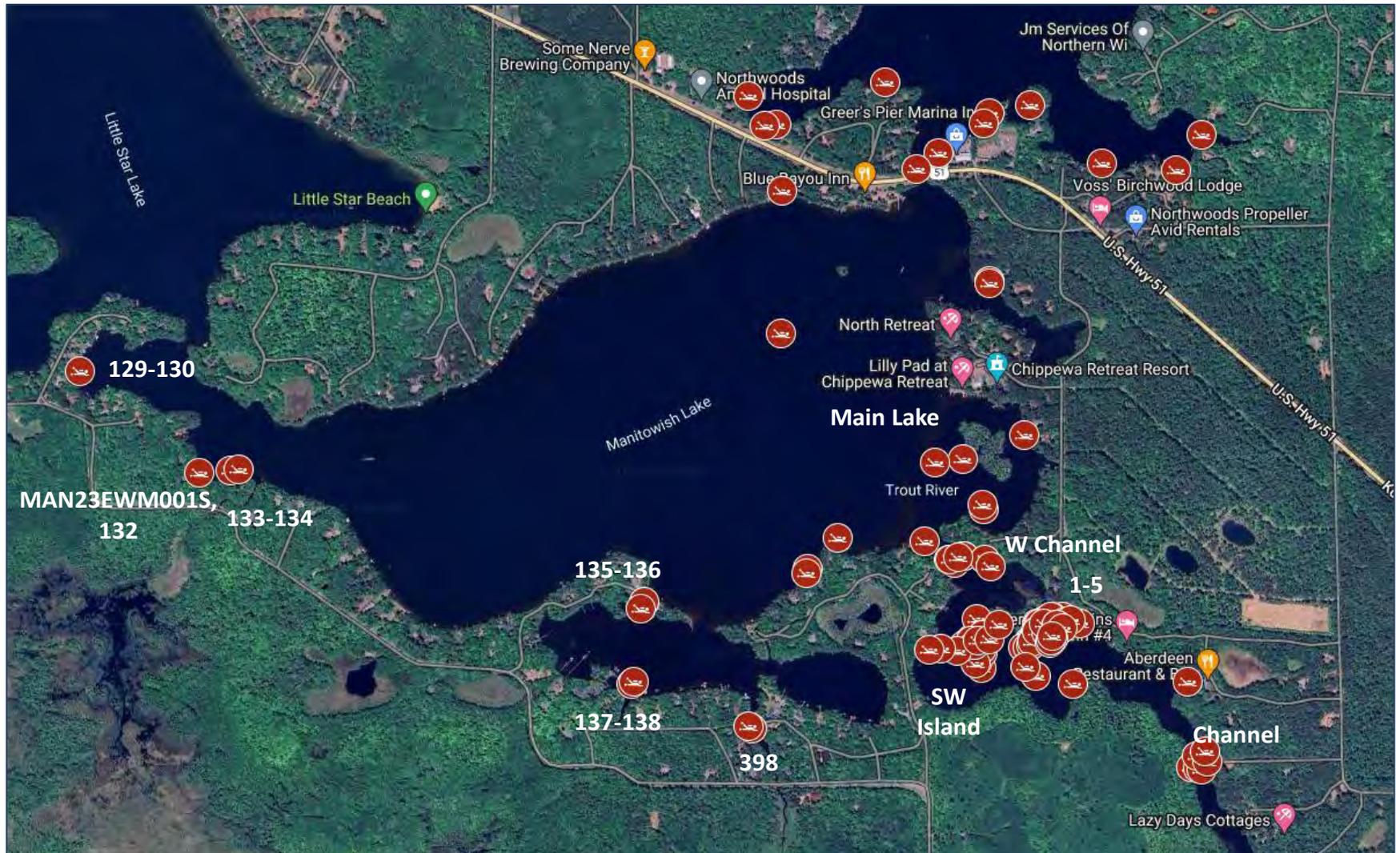


Dive Results by Site

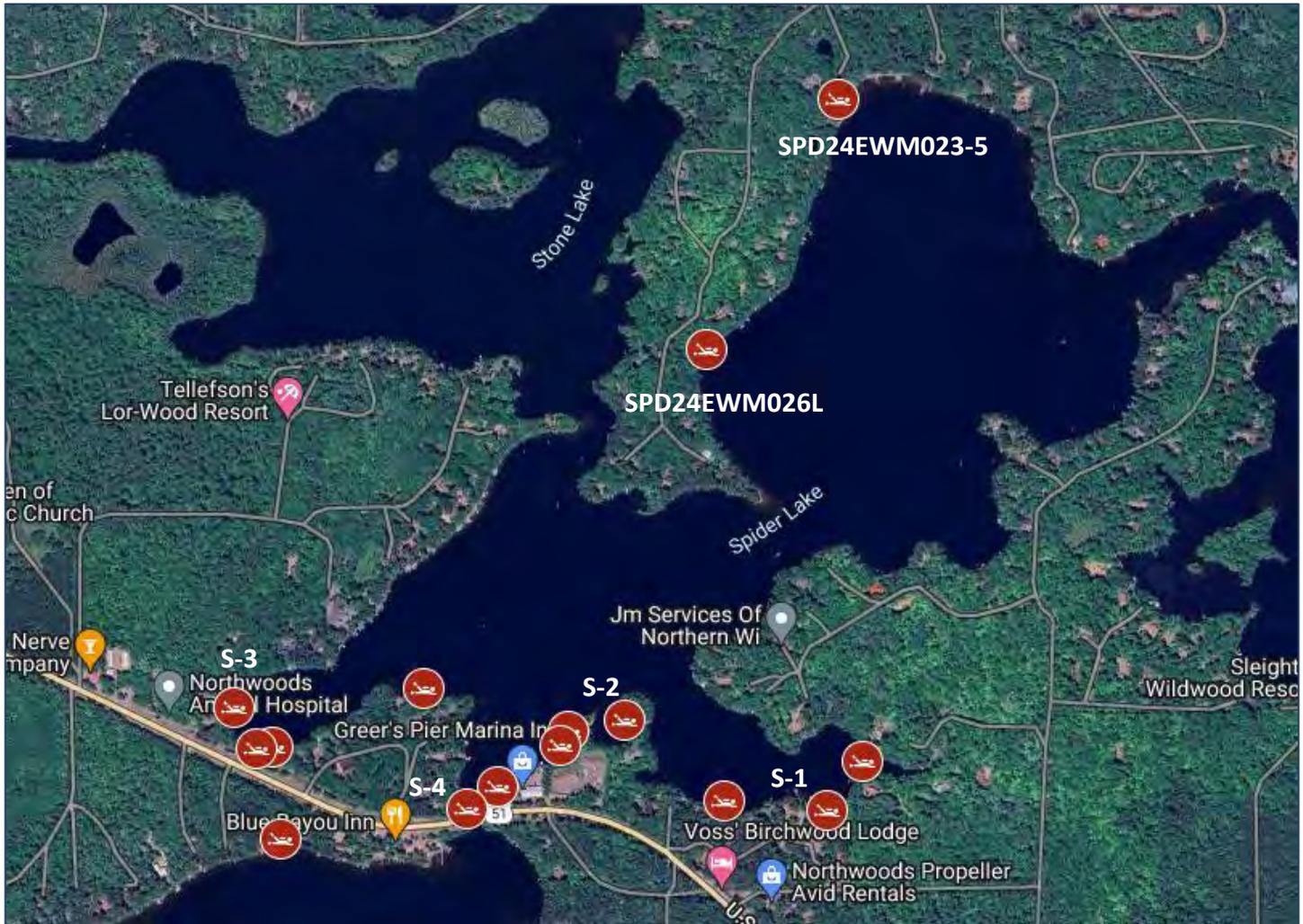
Lake	Dive Location	Avg. Depth	# of Dives	Underwater Dive Time	AIS Removed (cubic feet)
Manitowish	1	6.4	7	10.8	128.0
	2	5.8	12	19.4	217.5
	3	6.9	4	7.1	127.0
	4	6.5	10	17.9	179.5
	5	5.9	8	14.6	106.0
	398	3.5	2	1.7	1.0
	129, 130	3.5	1	0.5	0.5
	133, 134	7.3	2	1.5	2.0
	135, 136	3.8	3	1.4	1.5
	137, 138	3.5	2	1.8	1.5
	Channel	5.7	9	9.2	12.5
	Main Lake	5.3	12	11.8	39.0
	MAN23EWM001S, 132	5.5	1	1.9	1.5
	S Island	5.0	2	3.3	35.0
	S Point	4.5	1	1.3	7.0
SW of Island	5.9	22	33.7	281.5	
W Channel	7.1	9	11.6	70.0	
Manitowish Total		5.8	107	149.4	1211.0
Spider	S-1	8.7	3	2.7	2.0
	S-2	6.5	3	0.8	1.0
	S-3	7.6	4	4.3	7.5
	S-4	5.5	2	1.8	1.5
	SPD24EWM023-5	5.0	1	0.6	0.5
	SPD24EWM026L	5.0	1	0.2	0.5
Spider Total		6.9	14	10.3	13.0
Grand Total		6.0	121	159.7	1224.0

Dive Highlights and Recommendations: The dive team started their work near the island (sites 1-5) coming out of the trout river, where they removed 758 cubic feet of EWM. Southwest of the island also had significant EWM as well as the channel leading to the main lake. In the main portion of the lake and at sites in the SW portion had 44 cubic feet removed of the total 1,211 on Manitowish Lake. All in all, there was significantly more EWM than originally identified on the map provided to the dive team. Spider lake had 13 cubic feet of EWM removed from 6 different focus areas. Overall, Manitowish Chain 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 Manitowish Chain.

Map of Manitowish Lake Dive Sites



Map of Spider Lake Dive Sites





Detailed Diving Activities | July

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
7/9/2024	1	46.10241	-89.82731	3.08	18.0	Clumps	5.0	Coontail	0.5	Organic/Sand
7/9/2024	1	46.10241	-89.82731	0.75	14.0	Clumps	10.0	Coontail	1.0	Organic
7/9/2024	2	46.10279	-89.82704	2.25	49.0	Scattered	7.0	Coontail	5.0	Organic
7/10/2024	1	46.10222	-89.82757	1.25	21.0	Scattered	5.5	Coontail	1.0	Organic
7/10/2024	1	46.10223	-89.82739	0.50	14.0	Scattered	5.5	Coontail	2.0	Organic
7/10/2024	2	46.10285	-89.82703	1.17	52.5	Highly Dominant	7.0	Coontail	1.0	Organic
7/10/2024	3	46.10292	-89.82677	2.17	56.0	Highly Dominant	7.0	Coontail	3.0	Organic
7/10/2024	3	46.10294	-89.82675	0.42	14.0	Highly Dominant	7.0	Coontail	0.5	Organic
7/11/2024	4	46.10293	-89.82632	3.33	52.5	Dominant	7.0	Coontail	1.0	Organic/Sand
7/11/2024	5	46.10286	-89.82581	1.92	45.5	Dominant	5.5	Grasses	1.0	Organic
7/11/2024	4	46.10293	-89.82645	0.92	20.5	Dominant	7.0	Coontail	0.5	Organic
7/14/2024	1	46.10229	-89.82726	1.25	15.0	Clumps	6.0	Coontail	3.0	Organic
7/14/2024	2	46.10280	-89.82704	1.25	9.0	Clumps	7.0	Coontail	2.0	Organic
7/14/2024	2	46.10285	-89.82698	1.08	16.5	Clumps	6.5	Coontail	4.0	Organic
7/14/2024	4	46.10280	-89.82647	1.58	13.5	Clumps	7.5	Coontail	3.0	Organic
7/14/2024	4	46.10279	-89.82631	1.00	21.0	Clumps	7.5	Coontail	6.0	Organic
7/16/2024	1	46.10242	-89.82724	1.25	15.0	Clumps	6.0	Grasses	3.0	Organic
7/16/2024	2	46.10263	-89.82709	2.17	15.0	Clumps	5.0	Grasses	3.0	Organic
7/16/2024	5	46.10301	-89.82609	1.17	15.0	Clumps	5.0	Grasses	3.0	Organic
7/16/2024	4	46.10301	-89.82649	2.17	15.0	Clumps	7.0	Grasses	3.0	Organic
7/17/2024	1	46.10236	-89.82723	2.75	31.0	Single or Few	6.5	Elodea	2.0	Organic
7/17/2024	2	46.10264	-89.82703	1.50	0.0	Single or Few	6.0	Elodea	0.0	Organic
7/17/2024	5	46.10291	-89.82603	1.33	0.0	Single or Few	7.0	Elodea	0.0	Organic
7/17/2024	4	46.10302	-89.82652	2.08	0.0	Single or Few	5.5	Elodea	0.0	Organic
7/18/2024	5	46.10287	-89.82605	2.75	15.0	Single or Few	6.5	Northern Milfoil	0.5	Organic
7/18/2024	2	46.10260	-89.82671	3.17	13.0	Single or Few	6.5	Elodea	0.5	Organic
7/18/2024	3	46.10251	-89.82649	2.25	33.0	Clumps	7.5	Elodea	0.5	Organic
7/19/2024	5	46.10279	-89.82603	2.08	6.0	Single or Few	6.5	Grasses	0.5	Organic
7/19/2024	5	46.10286	-89.82548	1.67	12.0	Scattered	5.0	Grasses	0.5	Organic
7/19/2024	3	46.10285	-89.82678	2.25	24.0	Small Plant Colony	6.0	Elodea	0.5	Organic
7/19/2024	5	46.10294	-89.82581	2.17	6.0	Scattered	5.5	Elodea	0.5	Organic
Total	31			54.68	632.0					



Detailed Diving Activities | August

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
8/9/2024	Channel	46.09911	-89.82134	2.58	3.0	Clumps	8.0	Coontail	1.5	Organic/Sand
8/9/2024	Channel	46.09906	-89.82108	0.50	1.5	Clumps	8.0	Coontail	0.5	Organic/Sand
8/9/2024	Channel	46.09930	-89.82100	0.58	0.5	Clumps	7.0	Coontail	0.0	Organic/Sand
8/9/2024	Channel	46.09930	-89.82100	1.92	1.0	Clumps	7.0	Coontail	0.5	Organic/Sand
8/19/2024	Channel	46.09904	-89.82097	0.50	0.5	Single or Few	5.0	Coontail	0.5	Organic/Sand
8/19/2024	Channel	46.09939	-89.82111	0.42	0.5	Single or Few	5.0	Coontail	0.5	Organic/Sand
8/19/2024	Channel	46.10132	-89.82147	0.83	3.5	Clumps	3.5	Elodea	1.0	Organic
8/19/2024	4	46.10261	-89.82634	0.75	12.5	Dominant	6.5	Elodea	1.5	Organic
8/19/2024	4	46.10261	-89.82634	3.50	35.0	Dominant	6.5	Elodea	1.5	Organic
8/19/2024	Channel	46.09925	-89.82076	1.00	1.0	Highly Scattered	4.0	Northern Milfoil	0.5	Sand
8/19/2024	Channel	46.09951	-89.82083	0.83	1.0	Highly Scattered	4.0	Northern Milfoil	0.5	Sand
8/19/2024	4	46.10282	-89.82633	1.08	4.0	Clumps	4.0	Elodea	1.0	Organic
8/19/2024	4	46.10282	-89.82633	1.50	5.5	Clumps	6.0	Elodea	0.5	Organic
8/19/2024	5	46.10274	-89.82610	1.50	6.5	Clumps	6.5	Northern Milfoil	2.0	Organic
8/20/2024	SW of Island	46.10242	-89.82917	1.25	14.5	Clumps	5.5	Elodea	0.5	Organic
8/20/2024	SW of Island	46.10249	-89.82943	1.67	20.5	Small Plant Colony	5.5	Elodea	0.5	Organic
8/20/2024	SW of Island	46.10238	-89.82957	3.08	21.0	Scattered	5.5	Elodea	0.5	Organic
8/20/2024	SW of Island	46.10295	-89.82928	1.67	13.0	Scattered	5.5	Grasses	2.5	Organic
8/20/2024	SW of Island	46.10256	-89.82890	1.67	8.5	Clumps	5.5	Elodea	2.5	Organic
8/20/2024	SW of Island	46.10254	-89.82907	1.50	7.0	Clumps	5.5	Elodea	1.0	Organic
8/20/2024	SW of Island	46.10188	-89.82928	1.33	14.0	Small Plant Colony	7.5	Grasses	0.5	Organic
8/21/2024	SW of Island	46.10228	-89.82977	1.92	3.5	Scattered	6.0	Grasses	0.5	Organic
8/21/2024	SW of Island	46.10168	-89.82913	1.42	6.0	Scattered	6.0	Grasses	0.5	Organic
8/21/2024	SW of Island	46.10186	-89.82925	3.00	21.0	Clumps	6.0	Grasses	2.5	Organic
8/22/2024	SW of Island	46.10207	-89.82907	2.00	18.5	Clumps	6.0	Grasses	0.5	Organic
8/22/2024	SW of Island	46.10215	-89.82911	0.83	20.0	Clumps	6.5	Grasses	0.5	Organic
8/22/2024	SW of Island	46.10179	-89.82933	2.42	36.5	Clumps	6.0	Grasses	0.5	Organic
8/22/2024	S Point	46.10127	-89.82571	1.25	7.0	Single or Few	4.5	Grasses	0.5	Organic/Sand
8/22/2024	SW of Island	46.10241	-89.82948	1.75	22.0	Clumps	5.0	Pondweeds	8.0	Organic
8/22/2024	SW of Island	46.10227	-89.82938	1.08	20.0	Clumps	5.0	Pondweeds	4.0	Organic
8/22/2024	SW of Island	46.10227	-89.82938	0.92	7.0	Clumps	5.0	Pondweeds	3.0	Organic
8/22/2024	SW of Island	46.10213	-89.83003	0.67	5.0	Scattered	7.5	Pondweeds	1.0	Organic
8/22/2024	SW of Island	46.10218	-89.83062	0.92	6.0	Clumps	7.5	Pondweeds	1.0	Organic
8/22/2024	SW of Island	46.10215	-89.83103	0.50	4.0	Clumps	5.0	Elodea	0.5	Organic
8/23/2024	W Channel	46.10442	-89.83010	1.67	12.0	Clumps	7.0	Elodea	3.0	Organic
8/23/2024	W Channel	46.10450	-89.83030	0.50	4.0	Clumps	6.0	Grasses	1.0	Organic
8/23/2024	S Island	46.10149	-89.82708	1.50	14.0	Clumps	5.0	Northern Milfoil	3.0	Organic
8/23/2024	S Island	46.10171	-89.82747	1.83	21.0	Small Plant Colony	5.0	Northern Milfoil	3.0	Organic
8/23/2024	W Channel	46.10460	-89.82975	1.50	9.0	Scattered	7.0	Pondweeds	3.0	Organic
8/23/2024	W Channel	46.10460	-89.82975	0.75	3.0	Scattered	7.0	Pondweeds	0.5	Organic
8/23/2024	SW of Island	46.10239	-89.82923	1.00	3.0	Scattered	6.0	Pondweeds	1.0	Organic
8/23/2024	SW of Island	46.10242	-89.82883	2.00	6.0	Scattered	6.0	Pondweeds	1.5	Organic
8/26/2024	Main Lake	46.10775	-89.82754	1.17	1.5	Single or Few	2.5	Grasses	0.5	Organic
8/26/2024	Main Lake	46.10583	-89.82902	0.92	2.0	Single or Few	6.0	Grasses	0.5	Organic
8/26/2024	Main Lake	46.10593	-89.82908	0.75	3.5	Clumps	6.0	Grasses	0.5	Organic
8/26/2024	Main Lake	46.10714	-89.82978	0.58	2.5	Clumps	6.5	Grasses	0.5	Organic
8/26/2024	Main Lake	46.10704	-89.83081	1.83	10.5	Small Plant Colony	9.0	Grasses	0.5	Organic
8/26/2024	W Channel	46.10500	-89.83123	1.50	11.0	Small Plant Colony	9.0	Grasses	0.5	Organic
8/30/2024	W Channel	46.10450	-89.82897	1.58	7.5	Scattered	7.0	Grasses	0.5	Organic
8/30/2024	W Channel	46.10434	-89.82877	1.67	10.5	Clumps	7.5	Grasses	0.5	Organic
8/30/2024	W Channel	46.10452	-89.83028	1.25	5.0	Highly Scattered	6.5	Grasses	0.5	Organic
8/30/2024	W Channel	46.10458	-89.82998	1.17	8.0	Scattered	7.0	Grasses	0.5	Organic
8/30/2024	SW of Island	46.10282	-89.82845	1.08	4.5	Clumps	5.0	Grasses	0.5	Organic
Total	53			72.59	489.5					



Detailed Diving Activities | September

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
9/4/2024	2	46.10234	-89.82657	1.67	14.0	Small Plant Colony	5.0	Grasses	1.0	Organic
9/4/2024	2	46.10240	-89.82651	1.25	8.0	Small Plant Colony	5.0	Grasses	1.0	Organic
9/4/2024	2	46.10245	-89.82647	0.50	9.5	Small Plant Colony	5.0	Grasses	1.0	Organic
9/4/2024	2	46.10240	-89.82655	1.50	14.5	Small Plant Colony	5.0	Grasses	1.0	Organic
9/4/2024	2	46.10252	-89.82650	1.92	16.5	Small Plant Colony	5.0	Grasses	1.0	Organic
9/13/2024	Main Lake	46.11041	-89.83652	1.42	7.0	Surface Matting	3.0	Grasses	3.0	Organic
9/13/2024	Main Lake	46.11176	-89.82883	0.50	0.5	Single or Few	3.0	None	0.0	Organic
9/13/2024	Main Lake	46.10507	-89.83443	0.75	1.0	Scattered	7.0	None	0.0	Gravel
9/13/2024	Main Lake	46.10427	-89.83555	0.75	6.0	Clumps	7.0	None	0.0	Organic/Sand
9/13/2024	Main Lake	46.10415	-89.83561	1.00	1.0	Clumps	7.5	None	0.0	Organic/Sand
9/13/2024	Main Lake	46.11170	-89.82881	0.83	0.5	Single or Few	3.0	None	0.0	Organic
9/12/2024	133, 134	46.10683	-89.85692	0.92	0.5	Scattered	7.5	Northern Milfoil	0.5	Organic/Gravel
9/12/2024	135, 136	46.10339	-89.84159	0.58	0.5	Single or Few	4.0	None	0.0	Organic
9/12/2024	137, 138	46.10127	-89.84209	1.33	1.0	Scattered	4.0	Northern Milfoil	0.5	Organic
9/12/2024	135, 136	46.10342	-89.84161	0.42	0.5	Single or Few	4.0	None	0.0	Organic
9/12/2024	398	46.10012	-89.83762	1.25	0.5	Scattered	3.5	None	0.0	Organic/Sand
9/12/2024	Main Lake	46.11411	-89.83649	1.25	3.0	Dominant	3.0	Grasses	3.0	Organic
9/9/2024	SPD24EWM023-5	46.12800	-89.82161	0.58	0.5	Highly Scattered	5.0	Northern Milfoil	0.5	Organic/Sand
9/9/2024	SPD24EWM026L	46.12332	-89.82510	0.17	0.5	Single or Few	5.0	None	0.0	Organic/Sand
9/9/2024	135, 136	46.10324	-89.84171	0.42	0.5	Single or Few	3.5	None	0.0	Organic
9/9/2024	137, 138	46.10133	-89.84199	0.42	0.5	Scattered	3.0	None	0.0	Organic
9/9/2024	398	46.10018	-89.83773	0.42	0.5	Highly Scattered	3.5	None	0.0	Organic/Sand
9/9/2024	133, 134	46.10686	-89.85661	0.58	1.5	Clumps	7.0	None	0.0	Organic/Sand
9/9/2024	MAN23EWM001S, 132	46.10678	-89.85808	1.92	1.5	Clumps	5.5	Northern Milfoil	1.5	Sand
9/9/2024	129, 130	46.10942	-89.86248	0.50	0.5	Scattered	3.5	None	0.0	Gravel
9/18/2024	S-1	46.11559	-89.82097	0.92	1.0	Clumps	6.0	Northern Milfoil	0.5	Sand
9/18/2024	S-1	46.11466	-89.82188	0.83	0.5	Scattered	8.0	None	0.0	Organic/Sand
9/18/2024	S-1	46.11484	-89.82466	0.92	0.5	Single or Few	12.0	None	0.0	Organic/Sand
9/18/2024	S-2	46.11634	-89.82729	0.33	0.0	None	4.5	None	0.0	Organic/Sand
9/18/2024	S-3	46.11660	-89.83773	0.83	2.5	Small Plant Colony	8.0	Elodea	0.5	Organic
9/18/2024	S-3	46.11694	-89.83268	1.25	0.5	Single or Few	8.0	None	0.0	Sand
9/19/2024	S-3	46.11584	-89.83672	1.25	2.5	Small Plant Colony	7.5	Elodea	0.5	Organic/Sand
9/19/2024	S-2	46.11616	-89.82880	0.25	0.5	Clumps	8.0	None	0.0	Sand
9/19/2024	S-2	46.11588	-89.82904	0.17	0.5	Single or Few	7.0	None	0.0	Sand
9/19/2024	S-4	46.11511	-89.83068	0.83	0.5	Scattered	4.0	None	0.0	Sand
9/19/2024	S-4	46.11469	-89.83151	1.00	1.0	Scattered	7.0	None	0.0	Sand
9/19/2024	S-3	46.11582	-89.83714	1.00	2.0	Clumps	7.0	None	0.0	Organic/Sand
Total	37			32.43	102.5					



Manitowish Lake EWM Removal Report 2025

PO Box 1134 Minocqua, WI 54548



Manitowish Lake EWM Removal Summary

Dive Background: In June, July, August and September Aquatic Plant Management LLC (APM) conducted 42 days of Diver Assisted Suction Harvesting and Hand Harvesting for Eurasian Watermilfoil (EWM) on Manitowish Lake in Vilas County, WI. The team focused their efforts at eight sites as prioritized by the North Lakeland Discovery Center. In total APM was able to remove **~2.5K cubic feet of EWM** from Manitowish Lake.

Dive Results by Day

Week	Water Temp (F)	Underwater Dive Time (hrs)	AIS Removed (cubic ft)
06/16/25	65	5.9	25.0
06/23/25	72	32.6	191.0
06/30/25	72	37.7	656.0
07/07/25	71	6.3	41.5
07/14/25	71	31.9	357.0
07/28/25	74	67.0	728.0
08/11/25	72	43.7	169.9
08/18/25	72	12.7	101.5
08/25/25	69	13.0	144.0
09/01/25	65	12.1	119.0
Grand Total		262.7	2532.9

Dive Results by Site

Dive Location	Avg. Water Depth	# of Dives	Underwater Dive Time	AIS Removed (cubic feet)
Aberdeen	5.0	3	4.0	9.5
Channel	7.9	10	16.7	100.0
TR1	8.0	2	3.2	43.0
TR2	5.1	4	12.4	133.0
TR3	6.2	11	29.2	273.8
Trout River	6.6	79	147.0	1837.0
W Island	8.2	12	13.6	52.0
W Manitowish	7.9	14	36.7	84.6
Grand Total	6.9	135	262.7	2532.9

Dive Highlights and Recommendations: The dive team started along the western portion of the island before moving up into the Trout River area. At times, the team would focus on select areas within the Trout River as identified by the NLDC and Trout Station. Towards the end of the season, the team also spent time on the western part of Manitowish lake where there were more pioneering colonies. The EWM infestation is very established, especially in the Trout River area, and the lake should consider all management techniques for future years. Overall, Manitowish 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 Manitowish Lake.

Map of Manitowish Lake Dive Sites





Detailed Diving Activities | June

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
6/16/2025	W Island	46.10719	-89.82980	1.00	2.5	Scattered	8.0	Grasses	0.5	Organic
6/16/2025	W Island	46.10719	-89.82980	0.83	1.0	Scattered	8.0	Grasses	0.5	Organic
6/16/2025	W Island	46.10711	-89.83072	1.33	5.5	Scattered	8.0	Grasses	1.5	Organic
6/16/2025	W Island	46.10711	-89.83072	0.33	1.5	Scattered	8.0	Grasses	0.5	Organic
6/16/2025	W Island	46.10666	-89.83085	0.83	5.0	Scattered	8.0	Grasses	1.0	Organic
6/16/2025	W Island	46.10683	-89.83066	0.92	4.5	Scattered	8.0	Grasses	1.0	Organic
6/16/2025	W Island	46.10584	-89.82903	0.67	5.0	Clumps	7.0	Grasses	0.5	Organic
6/23/2025	W Island	46.10704	-89.83059	1.75	3.5	Clumps	8.0	Pondweeds	0.0	Organic
6/23/2025	Channel	46.10494	-89.83128	1.58	7.0	Clumps	8.0	Pondweeds	0.5	Organic/Sand
6/23/2025	Channel	46.10494	-89.83128	1.75	4.5	Clumps	8.0	Pondweeds	0.5	Organic/Sand
6/23/2025	Channel	46.10453	-89.83029	1.33	9.0	Dominant	8.0	Pondweeds	0.5	Organic
6/24/2025	Channel	46.10453	-89.83029	2.58	11.0	Dominant	8.0	Pondweeds	0.5	Organic
6/24/2025	Channel	46.10458	-89.82982	0.83	11.0	Dominant	8.0	Grasses	1.0	Organic/Sand
6/24/2025	Channel	46.10458	-89.82982	2.17	21.0	Dominant	8.0	Grasses	1.0	Organic/Sand
6/24/2025	Channel	46.10451	-89.82879	1.00	6.0	Dominant	8.0	Grasses	0.5	Organic/Sand
6/25/2025	Channel	46.10451	-89.82879	2.50	14.0	Dominant	8.0	Grasses	1.0	Organic/Sand
6/25/2025	Channel	46.10451	-89.82879	2.00	12.0	Dominant	8.0	Grasses	1.0	Organic/Sand
6/25/2025	Channel	46.10439	-89.82868	1.00	4.5	Scattered	6.5	Grasses	0.5	Organic/Sand
6/25/2025	Trout River	46.10228	-89.83061	1.67	7.5	Clumps	8.0	Grasses	0.5	Organic
6/25/2025	Trout River	46.10217	-89.83042	1.17	6.5	Clumps	8.0	Grasses	0.5	Organic
6/26/2025	Trout River	46.10217	-89.83042	1.58	3.5	Scattered	8.0	Grasses	0.5	Organic
6/26/2025	Trout River	46.10197	-89.83025	1.67	9.5	Clumps	8.5	Charophytes	0.5	Organic
6/26/2025	Trout River	46.10197	-89.83025	1.08	3.0	Clumps	8.5	Charophytes	0.5	Organic
6/26/2025	Trout River	46.10180	-89.83024	1.00	6.0	Clumps	8.5	None	0.0	Organic
6/26/2025	Trout River	46.10165	-89.83004	0.75	2.0	Clumps	8.5	Grasses	0.5	Organic
6/26/2025	Trout River	46.10262	-89.82855	2.08	15.0	Clumps	5.0	Elodea	0.5	Organic
6/27/2025	Trout River	46.10230	-89.82932	1.33	14.0	Clumps	7.0	Grasses	1.0	Organic
6/27/2025	Trout River	46.10213	-89.82926	1.75	20.5	Small Plant Colony	7.0	Elodea	1.0	Organic
6/30/2025	Trout River	46.10252	-89.82907	2.25	41.0	Dominant	5.5	Elodea	10.0	Organic
6/30/2025	Trout River	46.10252	-89.82907	0.83	12.0	Dominant	5.5	Elodea	2.5	Organic
6/30/2025	Trout River	46.10252	-89.82907	1.33	26.0	Dominant	6.5	Elodea	6.5	Organic
6/30/2025	Trout River	46.10249	-89.82907	1.75	29.0	Dominant	6.5	Elodea	7.0	Organic
Total	32			44.64	324.0					



Detailed Diving Activities | July 1-15

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
7/1/2025	Trout River	46.10245	-89.82918	1.83	38.0	Dominant	7.0	Elodea	10.0	Organic
7/1/2025	Trout River	46.10245	-89.82918	2.50	40.0	Dominant	7.0	Elodea	12.0	Organic
7/1/2025	Trout River	46.10149	-89.82904	0.83	6.0	Clumps	5.5	Elodea	0.5	Organic
7/1/2025	Trout River	46.10149	-89.82904	0.92	9.0	Clumps	5.5	Elodea	1.0	Organic
7/1/2025	Trout River	46.10219	-89.82936	1.42	48.0	Dominant	6.0	Elodea	10.0	Organic
7/1/2025	Trout River	46.10213	-89.82941	3.50	39.0	Highly Dominant	6.5	Elodea	12.0	Organic
7/1/2025	Trout River	46.10209	-89.82937	2.25	39.0	Highly Dominant	6.5	Elodea	12.0	Organic
7/1/2025	Trout River	46.10224	-89.82973	0.50	12.0	Highly Dominant	6.0	Elodea	3.0	Organic
7/2/2025	Trout River	46.10323	-89.82948	1.83	27.0	Scattered	4.5	Elodea	5.0	Organic
7/2/2025	Trout River	46.10285	-89.82937	0.50	13.0	Scattered	4.5	Elodea	1.5	Organic
7/2/2025	Trout River	46.10228	-89.82941	3.50	63.0	Highly Dominant	6.0	Elodea	14.0	Organic
7/2/2025	Trout River	46.10234	-89.82941	2.75	36.0	Highly Dominant	6.5	Elodea	13.5	Organic
7/3/2025	Trout River	46.10224	-89.82976	3.00	27.0	Dominant	6.0	Elodea	9.0	Organic
7/3/2025	Trout River	46.10178	-89.82948	2.00	33.0	Dominant	6.0	Elodea	12.0	Organic
7/3/2025	Trout River	46.10237	-89.82963	1.92	46.0	Highly Dominant	7.0	Elodea	7.0	Organic
7/3/2025	Trout River	46.10240	-89.82959	2.25	72.0	Highly Dominant	6.5	Elodea	12.0	Organic
7/11/2025	Trout River	46.10278	-89.82963	3.50	7.0	Highly Dominant	5.0	Elodea	0.5	Organic
7/11/2025	Trout River	46.10278	-89.82993	1.08	15.5	Clumps	6.0	Pondweeds	8.5	Organic
7/11/2025	Trout River	46.10253	-89.82993	0.75	9.0	Clumps	6.5	Pondweeds	5.5	Organic
7/11/2025	Trout River	46.10151	-89.82950	0.92	10.0	Clumps	7.5	Pondweeds	5.5	Organic
7/14/2025	Trout River	46.10279	-89.82925	3.83	30.0	Clumps	6.0	Elodea	14.0	Organic
7/14/2025	Trout River	46.10279	-89.82925	1.00	20.0	Clumps	6.0	Elodea	14.0	Organic
7/14/2025	Trout River	46.10254	-89.82937	2.00	37.5	Clumps	5.5	Elodea	14.0	Organic
7/15/2025	Trout River	46.10272	-89.82924	4.00	33.0	Highly Dominant	6.0	Elodea	14.0	Organic
7/15/2025	Trout River	46.10219	-89.82963	2.00	18.0	Clumps	4.5	Elodea	7.0	Organic
7/15/2025	Trout River	46.10218	-89.82950	1.25	10.5	Clumps	6.0	Elodea	2.5	Organic
Total	26			51.83	738.5					



Detailed Diving Activities | July 1-15

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
7/16/2025	Trout River	46.10292	-89.82957	1.67	36.0	Small Plant Colony	7.0	Elodea	14.0	Organic
7/16/2025	Trout River	46.10292	-89.82957	1.75	12.0	Small Plant Colony	7.0	Elodea	6.0	Organic
7/16/2025	Trout River	46.10279	-89.82986	2.00	28.5	Small Plant Colony	6.5	Elodea	14.0	Organic
7/16/2025	W Island	46.10721	-89.83021	2.08	11.5	Clumps	10.0	Northern Milfoil	4.5	Organic
7/17/2025	W Island	46.10725	-89.83018	1.67	6.5	Single or Few	8.0	Elodea	3.5	Organic
7/17/2025	W Island	46.10704	-89.83010	1.58	4.5	Single or Few	8.0	Elodea	0.0	Organic
7/17/2025	W Island	46.10687	-89.82977	0.58	1.0	Clumps	9.0	Elodea	0.5	Organic
7/17/2025	Trout River	46.10288	-89.82959	1.17	0.5	Clumps	8.5	Elodea	14.0	Organic
7/17/2025	Trout River	46.10268	-89.82926	1.42	15.0	Clumps	5.5	Elodea	8.5	Organic
7/18/2025	Trout River	46.10225	-89.82904	1.58	54.0	Surface Matting	5.5	Elodea	14.0	Organic
7/18/2025	Trout River	46.10225	-89.82904	2.33	38.5	Highly Dominant	6.5	Elodea	14.0	Organic
7/28/2025	Trout River	46.10148	-89.83005	1.50	12.0	Small Plant Colony	7.0	Elodea	0.5	Organic
7/28/2025	Trout River	46.10158	-89.83013	0.58	3.5	Small Plant Colony	7.0	Elodea	0.5	Organic
7/28/2025	Trout River	46.10160	-89.83002	1.17	18.0	Small Plant Colony	7.0	Elodea	0.5	Organic
7/28/2025	Trout River	46.10170	-89.83025	2.00	19.5	Small Plant Colony	8.0	Elodea	0.5	Organic
7/28/2025	Trout River	46.10175	-89.83028	1.50	14.5	Small Plant Colony	8.0	Elodea	0.5	Organic
7/28/2025	Aberdeen	46.10035	-89.82166	2.25	2.5	Clumps	4.0	Elodea	0.1	Organic/Sand
7/28/2025	Aberdeen	46.10089	-89.82227	1.00	1.0	Scattered	3.0	Elodea	0.1	Organic/Sand
7/28/2025	Aberdeen	46.10146	-89.82287	0.75	6.0	Scattered	8.0	Elodea	0.1	Organic/Sand
7/28/2025	Trout River	46.10187	-89.83073	2.17	18.0	Small Plant Colony	10.0	Elodea	0.3	Organic/Sand
7/29/2025	Trout River	46.10152	-89.83046	3.67	42.0	Small Plant Colony	9.0	Elodea	1.0	Organic
7/29/2025	Trout River	46.10171	-89.83098	1.08	10.5	Clumps	5.0	Elodea	1.0	Organic
7/29/2025	Trout River	46.10172	-89.83110	0.58	10.0	Clumps	4.5	Elodea	1.0	Organic
7/29/2025	Trout River	46.10165	-89.83111	1.33	7.0	Clumps	3.0	Elodea	0.5	Organic
7/30/2025	Trout River	46.10136	-89.83023	2.42	15.0	Small Plant Colony	7.0	Elodea	0.5	Organic
7/30/2025	Trout River	46.10210	-89.83033	0.92	13.5	Small Plant Colony	7.0	Elodea	0.5	Organic
7/30/2025	Trout River	46.10197	-89.83029	1.00	3.5	Small Plant Colony	6.0	Elodea	0.5	Organic
7/30/2025	Trout River	46.10180	-89.83007	0.50	3.5	Small Plant Colony	6.0	Elodea	0.5	Organic
7/30/2025	Trout River	46.10186	-89.82896	1.83	33.0	Small Plant Colony	5.0	Elodea	1.0	Organic
7/30/2025	Trout River	46.10098	-89.83067	1.08	7.0	Scattered	4.0	Elodea	5.0	Organic
7/30/2025	Trout River	46.10169	-89.82994	1.50	10.5	Clumps	7.0	Elodea	5.0	Organic
7/30/2025	Trout River	46.10207	-89.82964	0.58	3.5	Scattered	6.0	None	0.0	Organic
7/30/2025	Trout River	46.10207	-89.82964	3.33	52.5	Highly Dominant	8.0	None	0.0	Organic
7/31/2025	Trout River	46.10237	-89.82927	3.92	50.0	Surface Matting	6.0	Elodea	1.5	Organic
7/31/2025	Trout River	46.10237	-89.82927	2.75	44.0	Surface Matting	6.0	Elodea	2.0	Organic
7/31/2025	Trout River	46.10199	-89.82880	3.67	86.0	Surface Matting	8.0	Elodea	10.0	Organic
7/31/2025	Trout River	46.10212	-89.82884	3.42	54.0	Surface Matting	8.0	Elodea	2.5	Organic
Total	37			64.33	748.5					



Detailed Diving Activities | August & September

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
8/1/2025	Trout River	46.10163	-89.83000	3.67	30.0	Clumps	7.0	Elodea	1.5	Organic
8/1/2025	Trout River	46.10128	-89.82892	2.75	32.5	Clumps	7.0	Elodea	1.0	Organic
8/1/2025	Trout River	46.10183	-89.82857	3.33	45.0	Surface Matting	7.0	Elodea	1.0	Organic
8/1/2025	Trout River	46.10184	-89.82847	1.00	3.5	Scattered	7.0	Elodea	0.0	Organic
8/1/2025	Trout River	46.10208	-89.82841	2.00	27.0	Small Plant Colony	7.0	Elodea	0.5	Organic
8/1/2025	Trout River	46.10224	-89.82903	2.00	12.0	Surface Matting	6.0	Elodea	3.0	Organic
8/1/2025	Trout River	46.10211	-89.82901	2.25	17.0	Clumps	7.0	Elodea	3.0	Organic
8/1/2025	Trout River	46.10211	-89.82901	1.33	1.5	Scattered	7.0	Elodea	1.5	Organic
8/1/2025	Trout River	46.10201	-89.82915	2.17	19.0	Highly Dominant	8.0	Elodea	14.0	Organic
8/11/2025	W Manitowish	46.10812	-89.85557	2.75	9.0	Dominant	10.0	Pondweeds	1.0	Gravel
8/11/2025	W Manitowish	46.10702	-89.85799	1.58	1.5	Scattered	8.0	Pondweeds	0.1	Organic/Gravel
8/11/2025	W Manitowish	46.10696	-89.85803	1.75	3.0	Scattered	9.0	Pondweeds	0.5	Organic/Gravel
8/12/2025	W Manitowish	46.10835	-89.85580	3.00	3.0	Clumps	11.0	Pondweeds	0.1	Sand
8/12/2025	W Manitowish	46.10876	-89.85692	3.00	6.0	Small Plant Colony	8.0	Elodea	0.1	Organic/Sand
8/12/2025	W Manitowish	46.10704	-89.85800	2.92	9.5	Scattered	7.5	Northern Milfoil	1.0	Sand
8/12/2025	W Manitowish	46.10714	-89.85803	3.42	10.5	Scattered	6.5	Northern Milfoil	1.0	Gravel
8/13/2025	W Manitowish	46.10887	-89.85707	3.50	12.0	Dominant	10.0	Elodea	3.0	Organic/Sand
8/13/2025	W Manitowish	46.10887	-89.85707	3.25	9.0	Scattered	10.0	Elodea	0.1	Organic/Sand
8/14/2025	W Manitowish	46.10730	-89.85822	3.00	3.0	Small Plant Colony	8.0	Pondweeds	0.1	Sand
8/14/2025	W Manitowish	46.10670	-89.85739	3.50	6.0	Scattered	7.0	Pondweeds	1.0	Organic/Sand
8/15/2025	TR1	46.10344	-89.82943	2.33	33.0	Clumps	8.0	Elodea	10.0	Organic
8/15/2025	TR1	46.10344	-89.82943	0.83	10.0	Clumps	8.0	Elodea	3.5	Organic
8/15/2025	TR2	46.10282	-89.82855	2.75	42.0	Clumps	4.5	Elodea	14.0	Organic
8/15/2025	W Manitowish	46.10670	-89.85789	1.75	1.5	Scattered	5.0	Northern Milfoil	0.1	Organic/Sand
8/15/2025	W Manitowish	46.11043	-89.86151	0.25	0.1	Single or Few	5.0	None	0.0	Organic/Sand
8/15/2025	TR3	46.10230	-89.82605	0.75	10.5	Dominant	5.0	Elodea	3.0	Organic
8/15/2025	TR3	46.10230	-89.82605	3.33	0.3	Scattered	10.0	Northern Milfoil	0.1	Organic/Sand
8/18/2025	W Manitowish	46.10748	-89.85814	3.00	10.5	Small Plant Colony	5.0	Elodea	1.0	Gravel
8/18/2025	TR2	46.10271	-89.82864	3.17	17.5	Clumps	5.0	Elodea	3.5	Sand
8/19/2025	TR2	46.10251	-89.82879	3.00	31.5	Scattered	5.5	Elodea	7.0	Organic
8/19/2025	TR2	46.10251	-89.82879	3.50	42.0	Scattered	5.5	Elodea	10.5	Organic
8/28/2025	TR3	46.10237	-89.82821	3.00	45.0	Dominant	4.5	Elodea	14.0	Organic/Sand
8/28/2025	TR3	46.10250	-89.82842	3.50	36.0	Dominant	5.0	Elodea	14.0	Organic/Sand
8/29/2025	TR3	46.10246	-89.82852	3.00	27.0	Dominant	5.0	Elodea	14.0	Organic/Sand
8/29/2025	TR3	46.10229	-89.82809	3.50	36.0	Dominant	5.0	Elodea	14.0	Organic/Sand
9/4/2025	TR3	46.10216	-89.82760	3.00	36.0	Dominant	6.0	Elodea	14.0	Organic
9/4/2025	TR3	46.10208	-89.82753	2.25	27.0	Dominant	6.5	Elodea	14.0	Organic
9/4/2025	TR3	46.10210	-89.82787	3.33	25.0	Dominant	7.5	Elodea	14.0	Organic
9/4/2025	TR3	46.10210	-89.82775	3.00	28.0	Dominant	7.5	Elodea	14.0	Organic
9/5/2025	TR3	46.10212	-89.82755	0.50	3.0	Dominant	6.5	Elodea	1.5	Organic
Total	40			101.91	721.9					

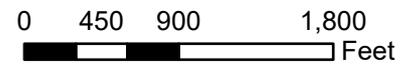


**Fawn and Stone Lakes
Early Detection Rapid
Response Survey**

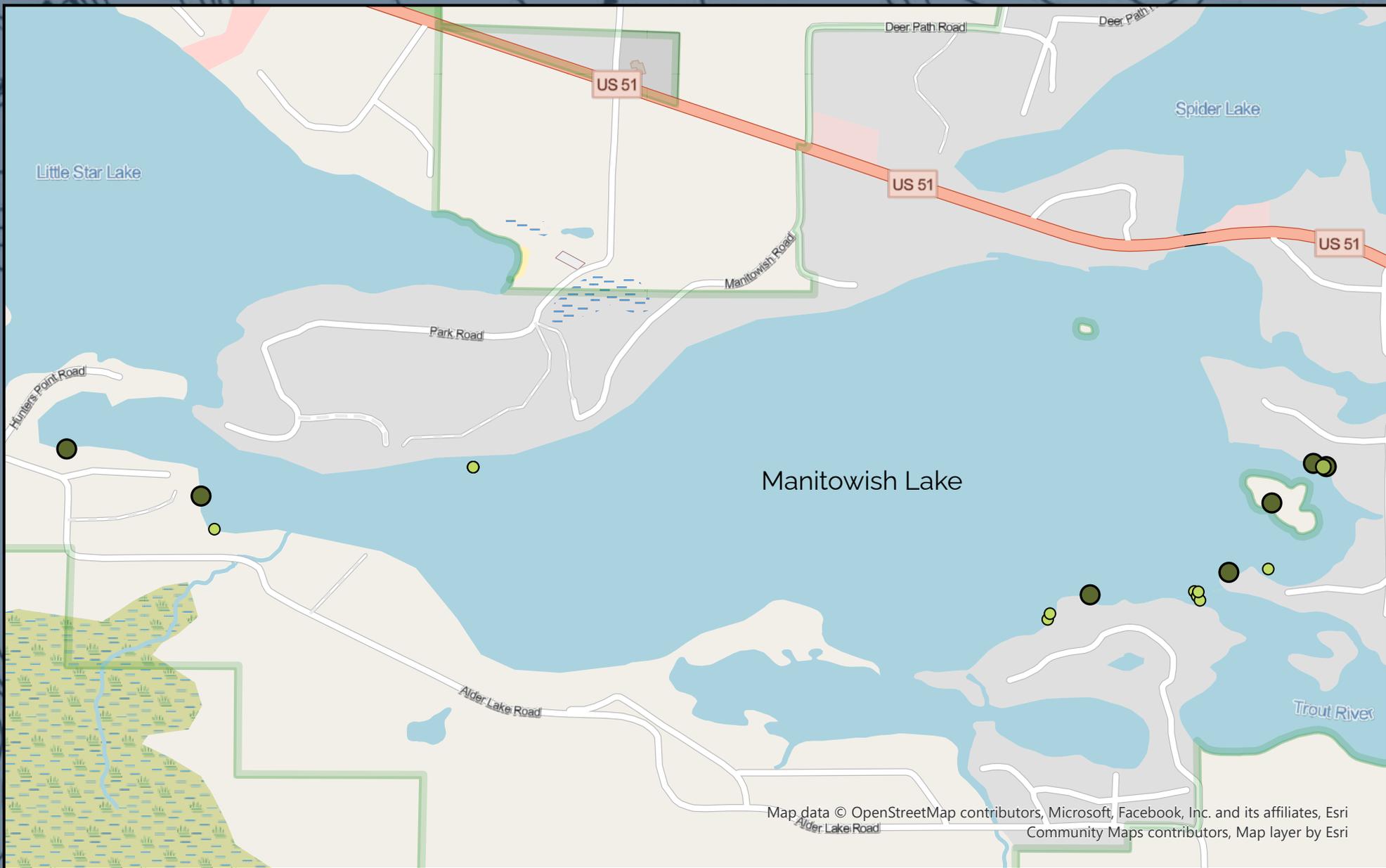
Town of Manitowish Waters
Vilas County, Wisconsin
August 29th, 2024

Legend

-  Single plant
-  Few plants
-  Large patch
-  Established colony



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 Post Office Box 237
 14006 Discovery Lane
 Manitowish Waters, WI
www.DiscoveryCenter.net

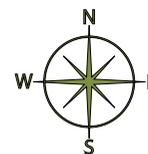


Manitowish Lake Survey
Eurasian watermilfoil
(*Myriophyllum spicatum*)

Town of Manitowish Waters
 Vilas County, Wisconsin
 June 20th, 2024

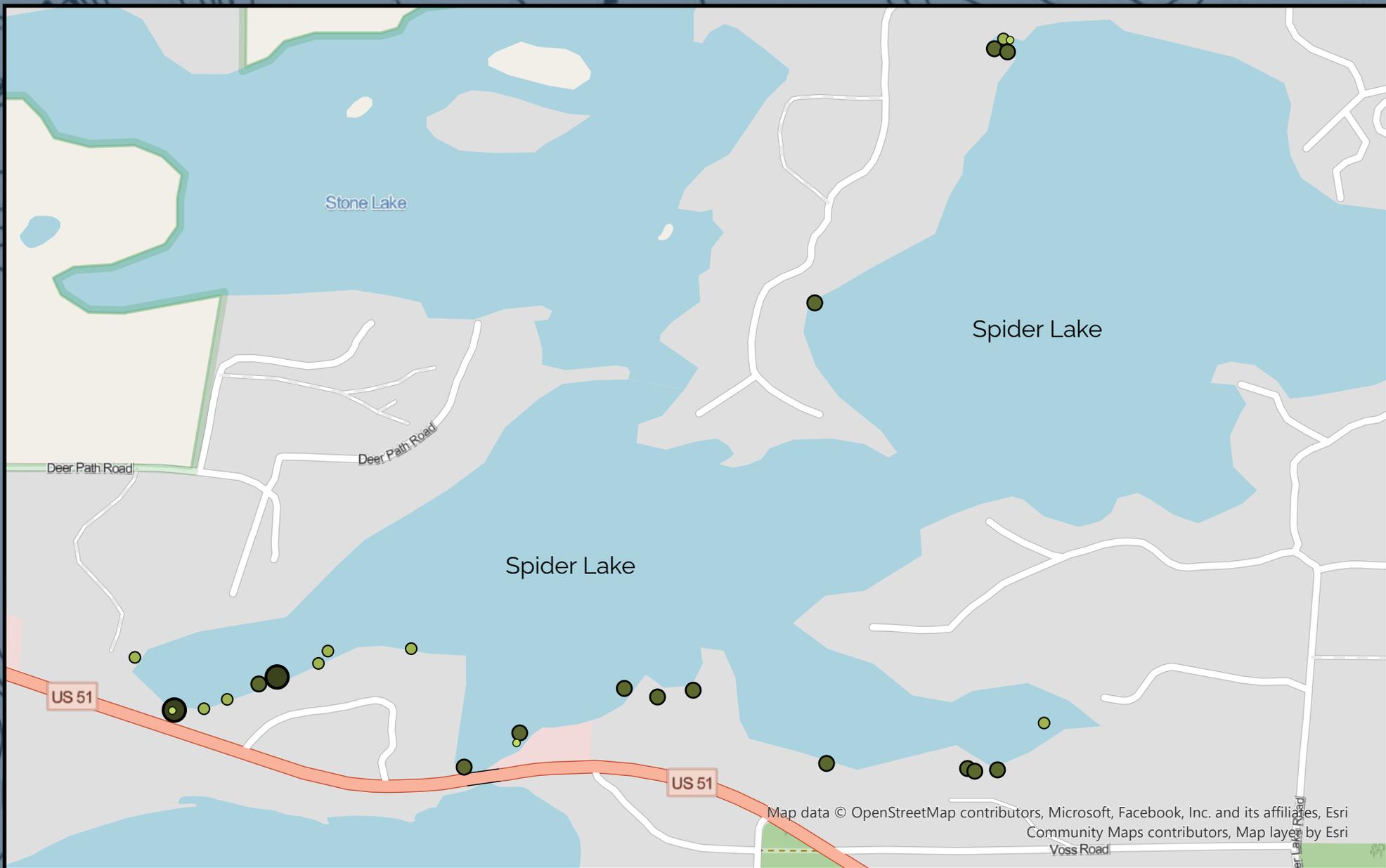
Legend

- Single plant
- Medium patch
- Large patch



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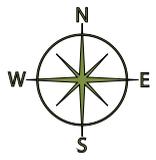


Spider Lake Survey
Eurasian watermilfoil
(*Myriophyllum spicatum*)

Town of Manitowish Waters
 Vilas County, Wisconsin
 August 20th, 2024

Legend

- Single plant
- Few plants
- Large patch
- Established colony



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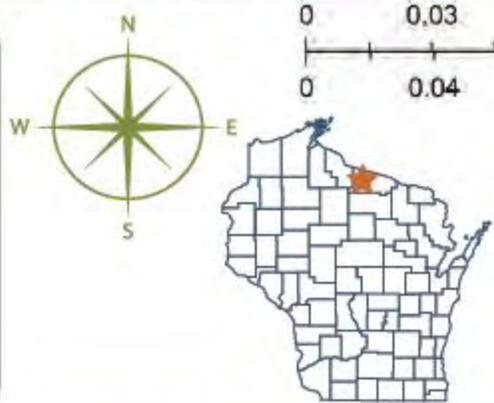


Trout River Eurasian Watermilfoil Survey August 2023

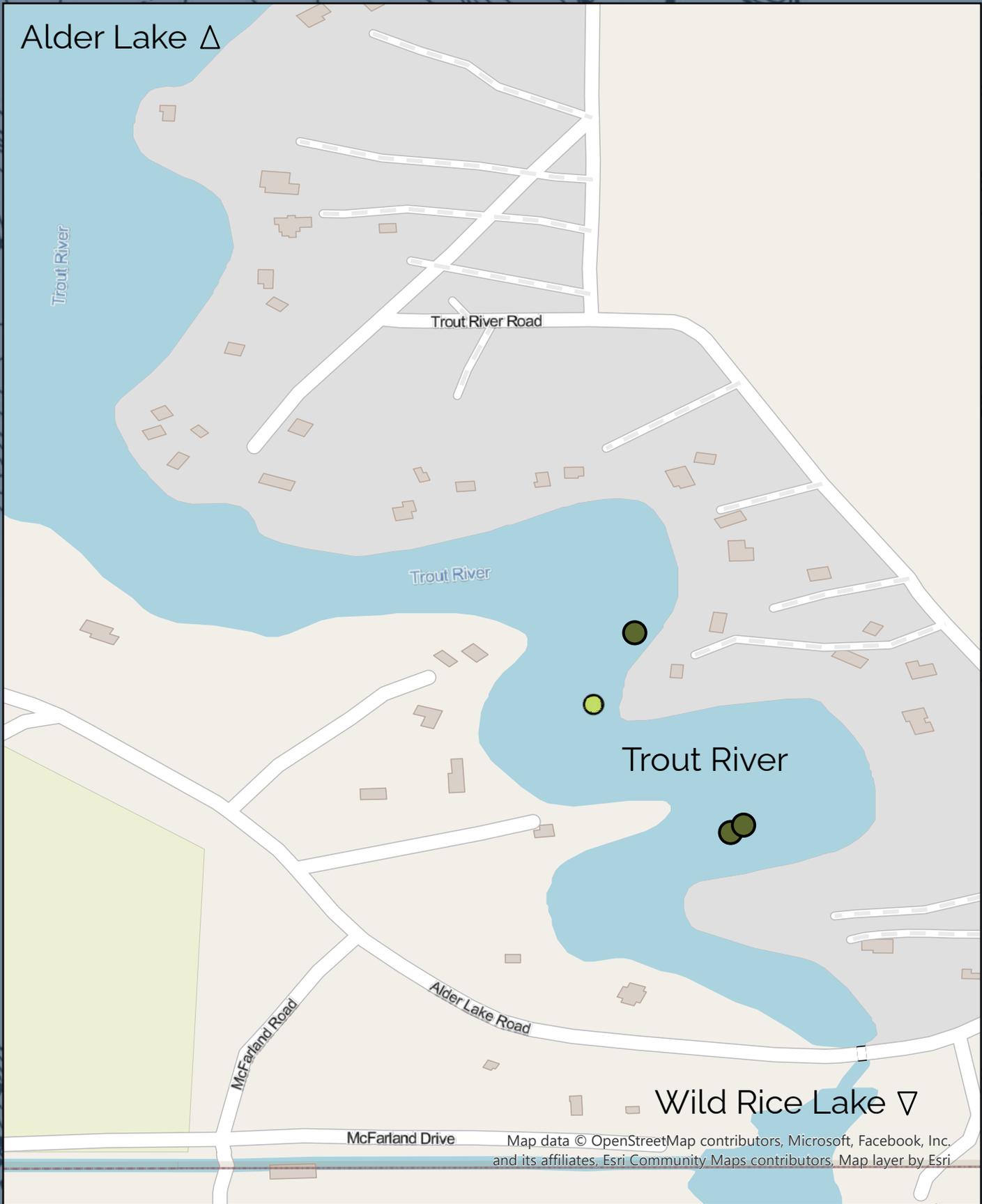
Town of Manitowish Waters
Vilas County, Wisconsin

LEGEND

-  Routed single plants of EWM
-  Established EWM colony



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**Trout River Survey
Eurasian watermilfoil
(*Myriophyllum spicatum*)**

Town of Manitowish Waters
Vilas County, Wisconsin
August 20th, 2024

Legend

- Single or Few Plants
- Large patch of plants



0 310 620 Feet

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D

APPENDIX D

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

WDNR Herbicide Fact Sheets:

- Florpyrauxifen-benzyl (ProcellaCOR)

FLORPYRAUXIFEN-BENZYL CHEMICAL FACT SHEET

Formulations

Florpyrauxifen-benzyl is a relatively new herbicide that was first registered with the U.S. EPA in 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 labeled for control of submerged, floating and emergent aquatic plants using surface, subsurface or foliar application in slow-moving and quiescent waters. Commercial formulations approved for aquatic use in Wisconsin include ProcellaCOR™*.

Aquatic Use and Considerations

Florpyrauxifen-benzyl is a systemic herbicide (i.e., it moves throughout the plant tissue). It is a WSSA Group 4 herbicide, meaning that the mechanism of action is by mimicking the plant growth hormone auxin and causing excessive elongation of plant cells, ultimately killing the plant. Affected plants may show atypical growth patterns (e.g., large and/or twisted leaves, stem elongation), and leaf and shoot tissue may become fragile. While initial effects will become apparent within a few days after treatment, it will take two to three weeks for the full plant decomposition process to occur. Florpyrauxifen-benzyl should be applied to plants that are actively growing; mature plants may require a higher concentration of herbicide and a longer contact time compared to smaller, less established plants.

It is important to note that repeated use of herbicides in the same WSSA group (i.e., with the same mechanism of action) can lead to herbicide-resistant plants, even in aquatic

environments. In order to reduce the risk of developing resistant genotypes, avoid using the same type of herbicides year after year, and utilize effective integrated pest management strategies as part of any long-term control program.

Florpyrauxifen-benzyl has relatively short contact exposure time (CET) requirements (typically 12 to 24 hours). The short CET may be advantageous for localized treatments of submersed aquatic plants, however, the target species efficacy compared to the size of the treatment area is not yet known. In some Wisconsin lakes impacts to target and non-target plants have been observed in areas beyond the targeted treatment areas, and research is ongoing to better understand the herbicide's dissipation and degradation patterns across various lake types.

Florpyrauxifen-benzyl is labeled for control of invasive Eurasian watermilfoil (*Myriophyllum spicatum*), hybrid watermilfoil (*M. spicatum x sibiricum*) and yellow floating heart (*Nymphoides peltata*)†. Native species listed on the product label as susceptible to florpyrauxifen-benzyl include coontail (*Ceratophyllum demersum*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*), watershield (*Brasenia schreberi*), pickerelweed (*Pontederia cordata*) and American lotus (*Nelumbo lutea*)†.

Preliminary results from pre- and post-treatment monitoring conducted on a subset of Wisconsin lakes observed negative impacts to dicot species such as northern watermilfoil (*Myriophyllum sibiricum*), white water crowfoot (*Ranunculus aquatilis*), water marigold (*Bidens beckii*), & coontail following treatment.

* Product names are provided solely for your reference and should not be considered exhaustive nor endorsements.

† May vary by formulation, application rate, and/or product. Every product label must be carefully reviewed and followed by the user.

Post-Treatment Water Use Restrictions

There are no drinking water or recreational use restrictions, including swimming and fishing, and no restrictions on irrigating turf. There is a short waiting period (dependent on application rate) for other non-agricultural irrigation purposes. Treated water should not be used for livestock drinking water or for agricultural irrigation without analytical monitoring to confirm dissipation[†].

Herbicide Degradation, Persistence and Trace Contaminants

Florpyrauxifen-benzyl is short-lived, with a half-life (the time it takes for half of the active ingredient to degrade) of four to six days in aerobic aquatic environments and two days in anaerobic aquatic environments.

Florpyrauxifen-benzyl in water is subject to rapid breakdown by light (photolysis), with a reported photolytic half-life of approximately two hours in surface water when exposed to sunlight. In addition, the herbicide can convert partially to an acid form via breakdown by water (hydrolysis) at high pH (greater than 9) and higher water temperatures (greater than 25°C). Microbial activity in the water and sediment can also enhance degradation.

Florpyrauxifen-benzyl breaks down into five major degradation products. These materials are generally more persistent in water than the active herbicide (with a half-life of up to three weeks), but four of the five products are minor metabolites detected at less than 5% of applied active ingredient.

Florpyrauxifen-benzyl has a high soil adsorption coefficient (KOC) and low volatility, which allows for rapid plant uptake resulting in short exposure time requirements.

Florpyrauxifen-benzyl degrades quickly (two to 15 days) in sediment. 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.

Impacts on Fish and Other Aquatic Organisms

Florpyrauxifen-benzyl is practically nontoxic to freshwater fish and invertebrates, birds, bees, reptiles, amphibians and mammals.

Florpyrauxifen-benzyl will temporarily bioaccumulate (the process by which chemicals in the environment or in a food source are taken up by plants or animals) in freshwater organisms but is expelled and/or metabolized within one to three days after exposure to high (greater than 150 parts per billion) concentrations.

Human Health

There are no risks of concern to human health since no adverse short- or long-term effects, including a lack of carcinogenicity or mutagenicity, were observed in the submitted toxicological studies for florpyrauxifen-benzyl regardless of the route of exposure. Drinking water exposures to florpyrauxifen-benzyl also do not pose a significant human health risk. Additionally, there is no hazard concern for metabolites and/or degradants of florpyrauxifen-benzyl that may be found in drinking water, plants and livestock.

For Additional Information

U.S. Environmental Protection Agency (EPA)
Office of Pesticide Programs
epa.gov/pesticides

Wisconsin Department of Agriculture, Trade,
and Consumer Protection
[datcp.wi.gov/Pages/Programs_Services/ACMOv
erview.aspx](http://datcp.wi.gov/Pages/Programs_Services/ACMOv
erview.aspx)

Wisconsin Department of Natural Resources
608-266-2621
dnr.wi.gov/lakes/plants

National Pesticide Information Center
1-800-858-7378
npic.orst.edu

Washington State Department of Ecology. 2017.
[fortress.wa.gov/ecy/publications/documents/
1710020.pdf](http://fortress.wa.gov/ecy/publications/documents/
1710020.pdf)



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

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

Diquat
Flumioxazin
Carfentrazone-ethyl

S.3.3.2. Submersed, Relatively Slow-Acting Herbicides

2,4-D
Fluridone
Endothall
Imazomox
Florpyrauxifen-benzyl

S.3.3.3. Emergent and Wetland Herbicides

Glyphosate
Imazapyr

S.3.3.4. Herbicides Used for Submersed and Emergent Plants

Triclopyr
Penoxsulam

S.3.4. Physical Removal Techniques

S.3.4.1. Manual and Mechanical Cutting

S.3.4.2. Hand Pulling and Diver-Assisted Suction Harvesting (DASH)

S.3.4.3 Benthic Barriers

S.3.4.4 Dredging

S.3.4.4 Drawdown

S.3.5. Biological Control

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, "Sculpín 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 penoxsulam) 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] pyrazinedium 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). EDB 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 *Hyaella azteca* (Wilson and Bond 1969; Williams et al. 1984), water fleas (*Daphnia* spp.). Reductions in habitat following treatment may also contribute to reductions of *Hyaella 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-fluoro-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-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-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 Liphay 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 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 native 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).

Species Susceptibility

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 hydrosols, 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 ($\geq 10\%$ 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 comprehensive 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 it 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-(methoxymethyl)-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 californiensis*) 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 at 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 degrades 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 (Netherlands 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 Netherlands 2010; Netherlands and Glomski 2014; Netherlands 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; Netherlands 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 spiralis*) 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 (Kimbél 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 (Kimbél 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 utilize 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 grow 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 ($\geq 90\%$). 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.

Ecological effects of Dredging

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 ($>5^{\circ}\text{C}$) 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 Heerd 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; Geraldine 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 californiensis*, *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 feed 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).

E

APPENDIX E

Comment Response Document for the Official First Draft

Manitowish Waters Chain of Lakes Draft Aquatic Plant Management Plan

Official First Draft: August 20, 2025

Public Comment Summary

Reviewer 1

- Concern for expanding EWM and lilly pads in Fawn Lake

Reviewer 2

- Desire for aggressive approach to EWM management including the immediate use of herbicides
- Concern about the spread of fragments due to hand pulling activities
- Concern about the effectiveness of manual removal of EWM

Reviewer 3

- Desire for cautious approach to herbicide use
- Seeking more information on costs and funding sources

Reviewer 4

- Desire for aggressive approach to EWM management including herbicides.

Reviewer 5

- Seeking clarity on decision making process for EWM management activities.
- Supports aggressive management including hand pulling and herbicides.
- Seeking more information on costs

Reviewer 6

- Supports use of herbicides.

Manitowish Waters Chain Aquatic Plant Management Plan

Official First Draft: August 20, 2025

Response Comments by Onterra in red

WDNR Comments from Chastin Harlow (Water Resource Management Specialist), 10/15/2025

Hi Todd,

Apologies for the delayed response in this review. I haven't heard back from any other internal reviewers on potential issues they found but had a few questions myself.

- It mentions that the Strategic Planning Committee "Met with available members of the planning group" (pg. 6/157). Would we want to list those members and mention that LDF did not attend? **Specific participants in the planning process are acknowledged on the cover page of the report. LDF input and participation has been sought throughout the planning process including after issuance of this draft plan. We do not feel it is necessary to include that fact in the management plan.**

- Is there a specific reason as to why the 2025 Manitowish Lake PI results are summarized whereas the Little Star PI is not? I think I remember seeing that Manitowish Lake was the only one with EWM documented during the PI survey and I think that would make sense, but I was just wanting to double check.
Yes, as of this writing, of all lakes on the system, only Manitowish Lake has ever had EWM on a point-intercept survey sampling location. The Little Star PI data will be reported on within a separate project that included that survey.

- The report is missing the LS EWM Mapping Surveys and harvesting efforts (pg. 19&20/157). I understand that the data might've not been ready when this draft was shared in August, but don't forget to include it in the final version.
The 2025 Late-season EWM mapping surveys were not completed at the time of the issuance of the Official First Draft. They have since been completed and will be included in the final draft. Professional contracting services for DASH and/or hand pulling are summarized in reporting issued by the contractors and will be included in an Appendix. NLDC-led harvesting efforts can also be summarized and included in the text when they are made available.

- Management Perspectives (pg. 21/157)
2. Reduce EWM Population on a lake-wide level : While this might be outlining perspectives, I don't agree with the idea that this "Would likely rely on herbicide treatment strategies". It's an option, but stating that it's likely to be relied upon when it's not likely to be permitted can provide a false sense of reliability for a method that should be a last resort. And, again, it still might not be permitted. However, later it mentions that the permit process would still need to be thoroughly pursued regardless, so I'm not sure what changes should be made.
The management perspectives are not specific to this Implementation Plan but rather serve as generic or broad perspectives. The description paragraph about the lake-wide population

management describes how an advanced/established population may be managed through water level drawdowns or whole-lake treatment strategies which is consistent with what is realistic. We rephrased the text to read *“may utilize herbicide treatment strategies”* rather than *likely rely on herbicide treatment strategies”*

Also added the following text under the lake-wide population management sub-heading: *Due to the scale of the EWM population, large-scale management approaches—such as herbicide treatments—may be considered; however, these methods would require a thorough risk assessment given their broader potential environmental impacts.*

Whole-lake treatments have been permitted in other lakes in Vilas County and northern Wisconsin in recent years. This is the reality of population control on an obviously established population. That reality is not included to promote the use of herbicides, but to help the MWLA and other partners realize that no amount of DASH will provide that level of control. This statement is backed by over a decade of experience monitoring active management strategies in Wisconsin.

For a newer/smaller EWM population, the entire population can sometimes be managed through hand harvesting as stated the same paragraph.

3. Minimize navigation and recreation impediment: Again, herbicides and a mechanical harvesters can be pursued. However, framing other, less intrusive options that should be exhausted first as “not likely to accomplish this goal” gives off the impression that it shouldn’t even be considered when, realistically, those control techniques are much more likely to be approved. Harvesters/herbicide should be a last resort and not framed as the inevitable management technique in the future.

This is relative to scale appropriateness. If there are nuisance conditions present that impact navigability and recreation, that typically requires very dense populations of EWM. Hand pulling/DASH can have a role in a property-by-property scale for enacting this management perspective, but on a Chain-wide level, hand pulling will not be scale appropriate and mechanical harvesting is often the next management option to consider.

The following text has been added under the Nuisance Control sub heading on page 20: *Targeted small-scale management approaches (manual removal/DASH) are the most likely to be approved, but they may only offer limited results. Although herbicide treatment and mechanical harvesting may be more effective for restoring navigation, their greater potential for environmental impact makes them more difficult to obtain approval for.*

- Lake-Wide Population Management: "This may be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies". While true, they might also be accomplished through an Integrated Pest Management Strategy that considers shoreline/watershed health, runoff concerns, native aquatic plant resiliency when left undisturbed, biocontrols, etc.
 - Comment acknowledged. Although the IPM strategies you list have their roles in the long-term, they are not typically useful tools for a group to manage EWM in

the short-term, especially for navigational impairment, for which this APM is purposed.

- Wild Rice (pg. 29/157): Says if “the site is not located in an area with Wild Rice presence, an herbicide spot-treatment management strategy might be given consideration.” Realistically, even if rice is not present at the site, the proposed management would need to demonstrate that wild rice is not being impacted in any way (especially not being accidentally exposed to lethal levels of herbicide due to currents, treatment area drifts, or other causes).
This is understood. This is accounted for in the thresholds for considering herbicide use laid out in the Implementation Plan on page 39. *Herbicide exposure to wild rice populations is not expected.* Theoretical future herbicide site selection would consider downstream rice populations and potential for detectable levels of herbicides based on volumetric calculations.
 - o Missing updated Wild Rice Population Data (all community mapping surveys according to Figure 3.3-5 occurred before 2025,) Figure 3.3-5 represents the most recent rice mapping survey, of which all occurred prior to 2025. Since that figure was made, Onterra conducted floating-leaf/emergent community mapping surveys in Little Star Lake and Manitowish Lake in 2025 as a part of a separate project. Wild rice was not observed within either Manitowish Lake or Little Star Lake during the September 2025 community mapping survey. Table embedded on Figure will be updated to list 2025 as most recent survey year for these two waterbodies.
 - o Only talks of rice in relation to impact by herbicide The 2019 Comp Plan includes extended conversation about wild rice. This report’s focus is in relation to aquatic plant management and implications of wild rice to that end. We added a few lines of text on page 26 on the importance of wild rice so the reader knows why it is important to protect.
- Stakeholder Survey (pg. 30/157)
 - o Site 14% as "sizable group" were unsure/needs more information for mechanical harvesting... Don't site the 14% opposed to herbicide as "sizable group". Again, seems like it is being framed to inevitable pursue herbicide treatment.
I don’t follow how this has anything to do with being framed to pursue herbicide treatment. The verbiage used here highlighted the fact that 14% of the respondents need more information about mechanical harvesting. Similar phrasing was used in the herbicide specific results where a “significant proportion (23%)” of respondents selected unsure/need more information. Again, pointing out that a group of respondents also need more information about this technique as well.
- NLDC harvest efforts not reported (hand harvest only This is a good point, we will contact Abby to see if the NLDC has specific data we can include in the report or an appendix.
- Section 4: Summary & Conclusions (pg.36/157)
 - o "Conducting an integrated pest management approach to management that considers multiple techniques depending on the size and location of the EWM pop."

- IPM Definition according to SWG Guidance: “Integrated Pest Management (IPM) is an **ecosystem-based** management strategy that focuses on long-term prevention and/or control of species of concern or their damage. IPM considers all the available control practices such as: prevention, biological control, biomanipulation, nutrient management, habitat manipulation, substantial modification of cultural practices, pesticide application, water level manipulation, mechanical removal, and population monitoring.
 - **The Comp Plan (2019) includes goals relating to some of these other IPM practices that are less specific to managing EWM. There are actions relating to shoreland protection, AIS prevention, and maintaining water quality conditions for example. We acknowledge that we need to include a reference to the Comp Plan and its activities that tie into an the IPM strategy on a longer term basis than this APM Plan which is purposed more for the shorter-term (~5 years). We added text stating that these long-term strategies are discussed in the Comp Plan and must be considered in the overall management strategy for EWM and other AIS.**
 - Biological control of EWM was discussed during this project and deemed not applicable to the current conditions.
 - EWM Population monitoring is in place under the first action of this Implementation Plan (pg 35-36).
 - While we understand the role that nutrient management plays in driving a lake’s productivity, it is not a practice that will meet the immediate EWM management objectives.
 - Please elaborate on how you see biomanipulation, habitat manipulation, water level manipulation, or modification of cultural practices fitting into MWLA’s EWM management strategy. Could you share examples or literature showing how these have reduced EWM populations in temperate lakes? Having that information would be a great addition to this plan and many others as well.
- Implementation Plan (pg. 37/157) : No mention of tribal input (or absence from August Strategic Planning Committee meeting). **See response to first comment.**
- IPM Plan for EWM (pg. 39-43/157)
 - Pg. 39/157: "The long-term objective of this action is to minimize the negative attributes that EWM causes..." proceeding to highlight maintaining navigation, recreational use, and aesthetics. Whereas in the “Lake-wide Population Management” perspective (pg. 21/157) it highlights the “goal to allow the system to function as it had prior to EWM establishment.” **I’m not sure what the question is here. The IPM Plan includes a long-term objective to minimize EWM’s negative impacts to navigation, recreational use, and aesthetics, while the shorter-term strategy is to consider managing all/most of the currently known EWM population to inhibit establishing in new areas. Added text to the beginning of the Implementation Plan section that re-states what the new management actions are for this APM Plan and how they tie into the Comp Plan Goal #4.**
 - Chemical Treatment Considerations (pg. 42/157)

Hi Todd,

Here are my few comments on the plan. Thanks for working with all of us partners on this project.

EWM APM plan comments

- Add sturgeon, 1 plant found rooted, it was hand pulled, in late summer 2025 during an AIS ED survey by NLDC **This has been updated in the text and on Figure 3.3-3.**
- Pg 16, 'EWM Population of Manitowish Waters Chain of Lakes'
 - This section describes the surveying conducted by Onterra, would be a good place to add the surveying that was done by NLDC such as which lakes, what time(s) of years, they made multiple passes on some of the waterbodies that had few and single plant occurrences, and had surveyed all waterbodies even those without CLP or EWM detected; hopefully NLDC can provide this info to get it included
Agreed, a few lines of text were added here to describe the basic NLDC monitoring actions.
- Pg 18. Future AIS Management Philosophy
 - 'ALA'... should this be MWLA?
 - Do ctrl+f for 'ALA', its mentioned several times **Good catch, this has been corrected to be MWLA.**
- Figure 3.3-4
 - This table eludes to the different options for 'lake' management, but I think it's worth noting either in this table and/or in the narrative follow it that because the Manitowish Chain is such a large system and includes many different lake types, EWM management will look different across those waterbodies at a given point in time. In some form, I think the point could be made that while one area of the chain may be 'letting nature take its course' because DASH is no longer a viable option and maybe they're looking at a chemical control method for that section, another area it may be very important to be hand-pulling every plant found still, ... etc. They're managing 13 lakes and 2 rivers here, it's complex. **This is a good point; I added a few lines in the paragraph directly above Figure 3.3-4.**
- Pg 19 -'Lake-Wide Population Management'...
 - 'Some believe that there is an intrinsic..'... just want to say that I really appreciate this sentence and how it is phrased. **Comment acknowledged, no changes made.**
- Pg 28 - confirm with NLDC if any rice monitoring did occur. There were some hesitations after communicating with tribal partners I think. **This was confirmed with NLDC, no rice monitoring occurred in 2025 by NLDC staff.**
- Pg 37. 'The Implementation Plan below was created through the efforts of then...'
 - Were the Town reps and LDF reps not a part of this part of the process? If I recall, they were invited to and provided input/review all along the way, even if they missed some meetings. **Yes, these folks are listed on the acknowledgements section on the cover**

page. Re-phrased the sentence on pg 37 to list various groups, agencies, resource managers, and project partners.

- Pages 36/37 Re mgmt actions
 - I think monitoring aquatic plant health/native plants should be a considered action in every EWM mgmt plan, whether it is built into one of these existing actions or stand-alone. Native plant data can also drive EWM control strategies, either allowing for or being a threshold for changing decisions/course of a certain management technique, both lake-wide or in an isolated area that control is being implemented. **Quantitative monitoring of native vegetation in the Chain is the first action listed in the 2019 Comp Plan under Goal #6. This continues to be implemented by NLDC/MWLA through ongoing point intercept surveys and floating-leaf/emergent plant community mapping surveys. I added a sentence in section 5.0 tying this in.**
 - I know it's a part of before/after herbicide treatments, but should be done at other times too such as alongside significant DASH efforts. Also extra care and consideration given to making the decision to hand pull or DASH in an area of heavy native plant growth, or if rare or special concern plants are identified in a particular area of a lake **Quantitative pre-post native aquatic plant monitoring, usually through a modified version of the point-intercept survey, rarely has utility in monitoring a hand harvesting program due to the nature of that type of management strategy where non-target impacts are limited to by-catch during the harvesting process. Usually, the scale of hand pulling effort is of too small an area to accommodate sub-point-intercept survey grid of reasonable sample size, although perhaps for this project it may make more sense in the harvest sites in the Manitowish River. No changes were made to the report, but MWLA will continue to be cognizant of native plant impacts during all management activities and how best to protect them.**
 - Conduct IPM for EWM Action-
 - Under Description, first sentence, consider rephrasing or adding language to also support ecological health of the lake/native aquatic plant communities.
 - Ie, the intended goal is not just to 'maintain navigation, recreation, and aesthetics', but to also maintain a healthy lake ecosystem and healthy aquatic plant community.... This whole document is titled 'aquatic plant management plan' and these plans often don't circle back to the higher level idea of managing the entire aquatic plant community for its health and integrity; we should be reminding readers and the lake group of this point and to not sacrifice that with tunnel vision

Good points, to tie this action into the larger goal of MWLA to protect and enhance the ecology of the MW Chain, this paragraph has been rephrased as follows:

The objective of this action is to minimize the negative attributes that EWM causes on the Manitowish Waters Chain of Lakes by maintaining navigation, recreational use, and aesthetics. Further, this action also supports the MWLA's overarching goal to protect and enhance the ecology of the Manitowish Waters Chain (Comp Plan Goal #6) in maintaining a healthy aquatic plant community. MWLA 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.