DRAFT

Delavan Lake

Walworth County, Wisconsin

Aquatic Plant Management Plan

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OFFICIAL FIRST DRAFT

for public & agency comment

Created by: Eddie Heath, Ryan Flynn, Todd Hanke, and Tim Hoyman
Onterra, LLC
De Pere, WI

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1.0 INTRODUCTION

Delavan Lake in Walworth County is an approximately 1,950-acre drainage lake primarily fed by Jackson Creek and drained through Swan Creek (Figure 1.0-1). The outlet dam was constructed in the mid-1930s and is believed to augment water levels by about 8 feet. Delavan Lake has a maximum depth of slightly over 50 feet, with a mean depth of 21 feet. Approximately 24 native aquatic plant species have been confirmed growing within the ordinary high water mark of Delavan Lake during 2012, 2015, 2020, and 2024 point-intercept aquatic plant surveys. Delavan Lake is known to contain a number of non-native aquatic plants and animals, as shown on Table 1.0-1.

Table 1.0-1. Non-native species confirmed from Delavan Lake. Extracted from: https://apps.dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=793600&page=invasive

Species Name	WDNR Status	Year Found
Banded Mystery Snail	Verified and Vouchered	2012
Curly-Leaf Pondweed	Verified and Vouchered	1975
Eurasian Watermilfoil	Verified and Vouchered	1995
Hybrid Eurasian Watermilfoil	Verified	2014
Non-native *Nymphaea* species	Verified	2010
Pennywort	Verified and Vouchered	2010
Phragmites (non-native)	Verified	2014
Purple Loosestrife	Verified and Vouchered	2014
Sacred Lotus	No Longer Observed	2010
Zebra Mussel	Verified and Vouchered	1999

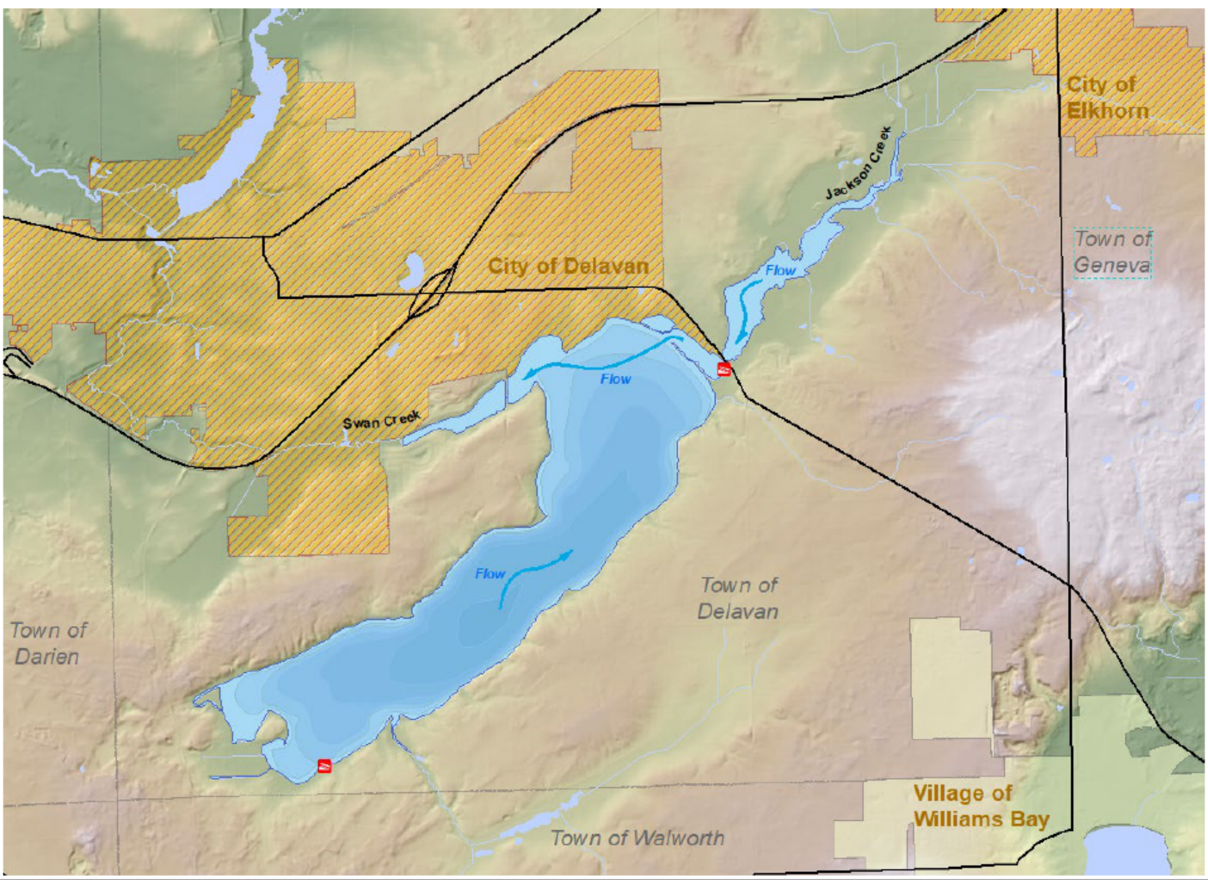


Figure 1.0-1. Delavan Lake, Walworth County.

The northern portion of Delavan Lake abuts the City of Delavan with approximately 8,505 residents per the 2020 census. Delavan Lake is a popular attraction for recreational users, including boating, fishing, and leisure activities. The primary bat launch is at the Town of Delavan Community Park, often referred to as the "Town Park." Watercraft inspections conducted as part of the WDNR's Clean Boats Clean Waters (CBCW) program occur at the town park, staffed by the Town of Delavan Parks and Recreation Department. The launch is also equipped with brooms and disposal locations to assist with removal of hitchhiking plants and animals (Photograph 1.0-1).

Photograph 1.0-1. Boat Cleaning Station at town park.

In the 1970's, Delavan Lake was rated as having amongst the worst water quality in Wisconsin, with large nutrient sources coming from Jackson Creek. Common carp and big mouth buffalo were common fish at that time. In 1981, the Delvan Lake Sanitary District (DLSD) of the Towns of Delavan and Walworth was formed as one of the first of many nutrient mitigation strategies implemented for the betterment of Delavan Lake. With the efforts of the Delavan Lake Improvement Association (DLIA) and public and private partnerships, including the Unites States Geological Survey (USGS), many subsequent studies and improvement projects have been conducted to date. This included upstream sewage treatment and effluent diversion, hydraulic modifications, fisheries manipulations, alum treatment, wetland/sedimentation basin construction, timed drawdowns, watershed management, and maintenance activities. The goal of these water improvement projects was to reduce nutrients (primarily phosphorus) which would reduce free-floating algae (as measured by chlorophyll-a) and increase water clarity (as measured by Secchi depth).

A presentation by Dale Robertson (USGS) in April 2024 at a DLIA meeting, documented how the water quality of Delavan Lake has greatly improved over the past four decades. The projects are meeting their predefined goals for chlorophyll-a and Secchi depth, but total phosphorus levels are still exceeding targets. As foretold in early studies, an increase in water clarity would likely result in a high biomass of submerged aquatic plants in Delavan Lake, likely to levels that would require management measures to allow navigation and recreation to occur.

Aquatic plant management activities were originally operated by the Town of Delvan until 1997 when the DLSD was given this responsibility on behalf of the Town. The DLSD's primary responsivity is to operate the mechanical harvesting program, but the DLSD is also involved in other aquatic plant management activities such as nuisance herbicide management and aquatic invasive species management.

The DLSD has sought to update their Aquatic Plant Management (APM) Plan at roughly 5-year intervals to allow the WDNR to issue multi-year mechanical harvesting permits under WI administrative code NR109. The previous APM Plan for Delavan Lake was completed in July 2022.

2.0 AQUATIC PLANTS

2.1 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.

Point-Intercept Survey

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 Delavan Lake in 2012, 2015, 2020, and 2024 (Map 1). The point-intercept grid has sampling locations spaced at 68-meters apart, with 1,699 total sampling points. 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 the aquatic plant species, both native and non-native, that were located during the surveys completed in Delavan Lake during 2024. The list also contains each species' scientific name, common name, status in Wisconsin, and coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

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

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

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

Floristic Quality Assessment

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

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

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

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Delavan Lake falls within the Southeastern Wisconsin Till Plains (SEWTP) *ecoregion* (Figure 2.1-1), 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.

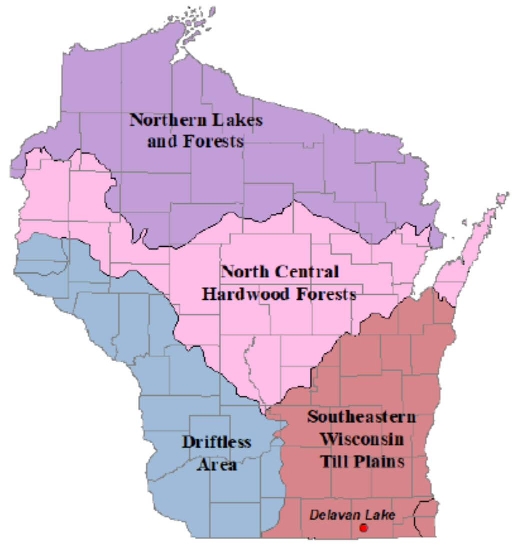


Figure 2.1-1. Location of Lake Delavan within the ecoregions of Wisconsin. After (Nichols 1999).

Species Diversity

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from Delavan Lake is compared to data collected by Onterra and the WDNR Science Services on lakes within the SWETP Ecoregion and lakes throughout Wisconsin.

2.2 Delavan Lake Aquatic Plant Survey Results

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

Point-intercept surveys were conducted in 2012 by WDNR Science Services, 2015 by the DLSD, 2020 by the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and 2024 by Onterra (Map 1). The protocol of this survey is implemented by the WDNR and allows for this data to be comparable even though it has historically been conducted by different entities.

This report will highlight the 2024 point-intercept survey results and will integrate comparisons to the previous surveys as applicable. The WDNR has developed a web-based viewer that has the capability of showing the point-intercept survey results on an individual species level, which can be accessed here:

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

During the four point-intercept surveys that have occurred on Delavan Lake, 27 aquatic plant species have been documented growing in Delavan Lake (Table 2.2-1). This table is organized by growth form which separates out species based on whether they are emergent species, floating-leaf, submergent, or free-floating species. Species with an "X" on the table indicates the species was physically encountered on the rake during the point-intercept survey. Other species that were observed but were not sampled on the survey rake are referred to as incidentals and are listed with an "I" on Table 2.2-1. Often these species are found growing on the shoreline or in shallow areas of the lake where they are more visible.

In 2024, 24 species were located on the rake sampler and one species was located incidentally. Three species not previously documented from Delavan Lake were located in 2024, including slender waterweed, slender naiad, and greater duckweed. All three of these new occurrences were vouchered with the Robert Freckmann herbarium at UW-Stevens Point.

Two submergent non-native species, Eurasian watermilfoil (EWM) and curly-leaf pondweed, were located in 2024 and have been documented from earlier surveys. No new non-native submergent species were discovered during the survey. More discussion on non-native aquatic plants in Delavan Lake is found in Section 2.3.

Table 2.2-1. Aquatic plant species located on Delavan Lake.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2012	2015	2020	2024
E	*Hydrocotyle ranunculoides*	Floating pennywort	Non-Native - Invasive	N/A				I
	Zizania aquatica	Southern wild rice	Native	8				X
FL	*Nymphaea odorata*	White water lily	Native	6	X	X	X	X
Submergent	*Ceratophyllum demersum*	Coontail	Native	3	X	X	X	X
	Chara spp.	Muskgrasses	Native	7	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X	X	X
	Elodea nuttallii	Slender waterweed	Native	7				X
	Heteranthera dubia	Water stargrass	Native	6	X	X	X	X
	Myriophyllum sibiricum	Northern watermilfoil	Native	7		X		X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X	X
	Najas flexilis	Slender naiad	Native	6				X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X	X	X	X
	Potamogeton friesii	Fries' pondweed	Native	8	X	X	X	X
	Potamogeton illinoensis	Illinois pondweed	Native	6		X		
	Potamogeton natans	Floating-leaf pondweed	Native	5		I		X
	Potamogeton nodosus	Long-leaf pondweed	Native	5	X	X	X	X
	Potamogeton praelongus	White-stem pondweed	Native	8				X
	Potamogeton pusillus	Small pondweed	Native	7		X		X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5				X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X		
	Ranunculus aquatilis	White water crowfoot	Native	8	X			X
	Stuckenia pectinata	Sago pondweed	Native	3	X	X	X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X
	-							
FF	*Lemna minor*	Lesser duckweed	Native	5	X	X	X	X
	Lemna trisulca	Forked duckweed	Native	6	X	X	X	X
	Spirodela polyrhiza	Greater duckweed	Native	5				X
	Wolffia spp.	Watermeal spp.	Native	N/A	X	X	X	X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
E = Emergent; FL = Floating-leaf; FF = Free-floating

Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. An important component of the point-intercept survey is defining the littoral zone, or the zone at which aquatic plants can grow. The maximum depth of plant growth is typically influenced by water clarity and/or water levels although concerns about watercraft traffic and large wake-creating boats have also been suggested as possible influencers. Point-intercept aquatic plant surveys conducted since 2012 have documented a decline in the maximum depth of aquatic plants over time (Figure 2.2-1). Data provided by Dale Robertson (USGS) indicates summer water clarity has been relatively stable over this period of study, although early-season (i.e. May) clarity has been more variable. Water

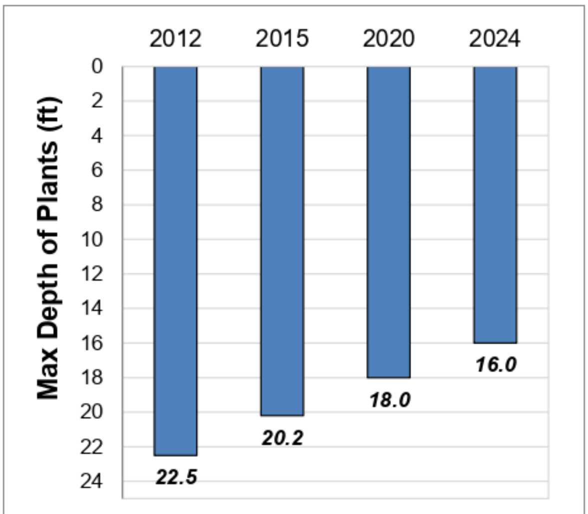


Figure 2.2-1. Maximum depth of plants in available point-intercept surveys.

levels have also fluctuated over this period of study, but it is doubtful the changes were of a magnitude to cause a 5.5 foot difference in the maximum depth of plants over the past 12 years.

Figure 2.2-2 takes a closer look at the depth aquatic plants were found in the point-intercept aquatic plant surveys conducted between 2012 to 2024. No aquatic plants were sampled on point-intercept locations deeper than 21 feet in 2020 or 2024, whereas a small number were documented in earlier surveys. Similarly, only two point-intercept locations contained aquatic plants between 16-20 feet in 2024 (both at 16 feet deep), with greater amounts in previous surveys.

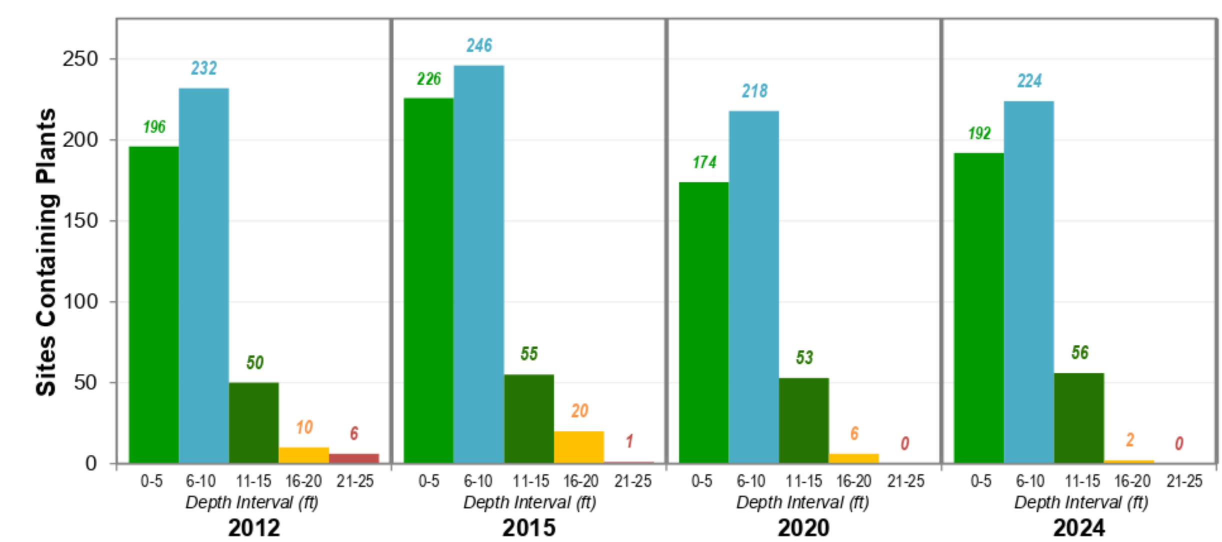


Figure 2.2-2. Aquatic plant growing depths from available point-intercept surveys.

Due to the configurations of the contours on Delavan Lake, the difference observed in maximum depth of aquatic plants does not have a great impact on the number of sampling points considered to be available for aquatic plants each year. This is because there is only a narrow area of the lake that is between 17-23 feet deep. The number of littoral sampling points that are less than or equal to the maximum depth of plants is shown on Map 2 and has varied from 645 in 2012, 623 in 2015, 599 in 2020, and 572 in 2020.

In 2024, 83% of the 572 sampling points within the lake that are 16 feet deep or less contained aquatic plants (Figure 2.2-3). These data are similar to previous years, where between 75% and 88% of any given year's littoral zone contained aquatic plant growth.

Total rake fullness (TRF) values from the available point-intercept survey are also displayed on Figure 2.2-3. These data represent the aquatic plant biomass at each sampling location and does not differentiate between native or non-native vegetation. With a higher proportion of TRF=3 locations being found in 2024 compared to earlier surveys; this suggests that denser aquatic plant growth was observed in 2024. Map 3 shows a comparison of the TRF locations from the four available point-intercept surveys.

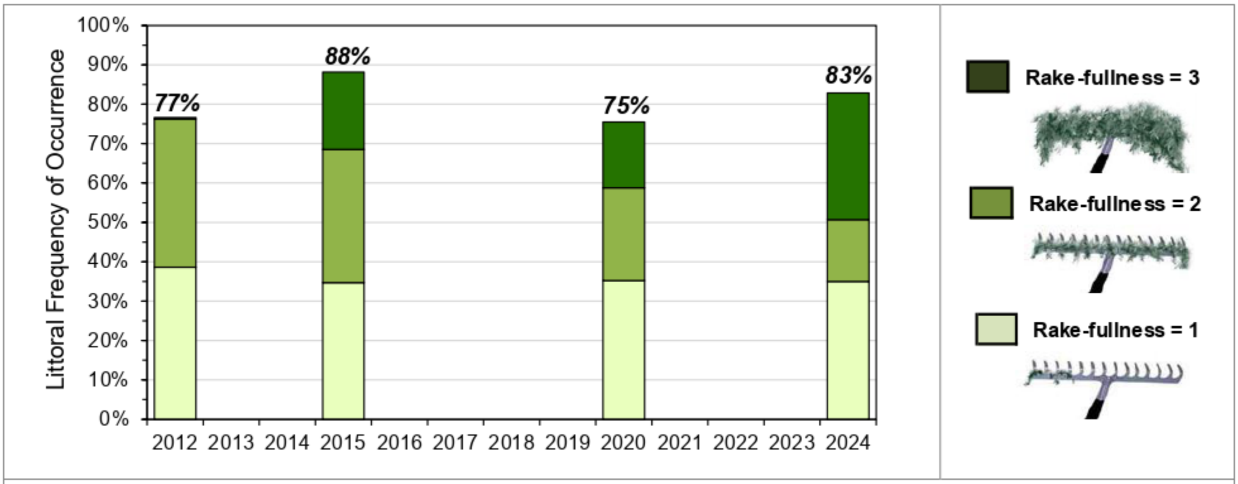


Figure 2.2-3. Aquatic vegetation TRF ratings. Data collected from point intercept surveys.

Of the 24 aquatic plant species that were sampled during the 2024 point-intercept survey in Delavan Lake, coontail, wild celery, and Eurasian watermilfoil (EWM) were the most frequently encountered species within the lake (Figure 2.2-4). A total of 13 aquatic plant species exhibited a littoral frequency of occurrence of at least 1.0% in Delavan Lake in the 2024 survey. The occurrence of all species from each of the point-intercept surveys is included in Appendix A and Appendix B shows the distribution of the top eight native plants and the two non-native submergent plants from Delavan Lake from the 2024 point-intercept survey. Figures 2.2-5 to 2.2-10 investigate common aquatic plant population trends in Delavan Lake.

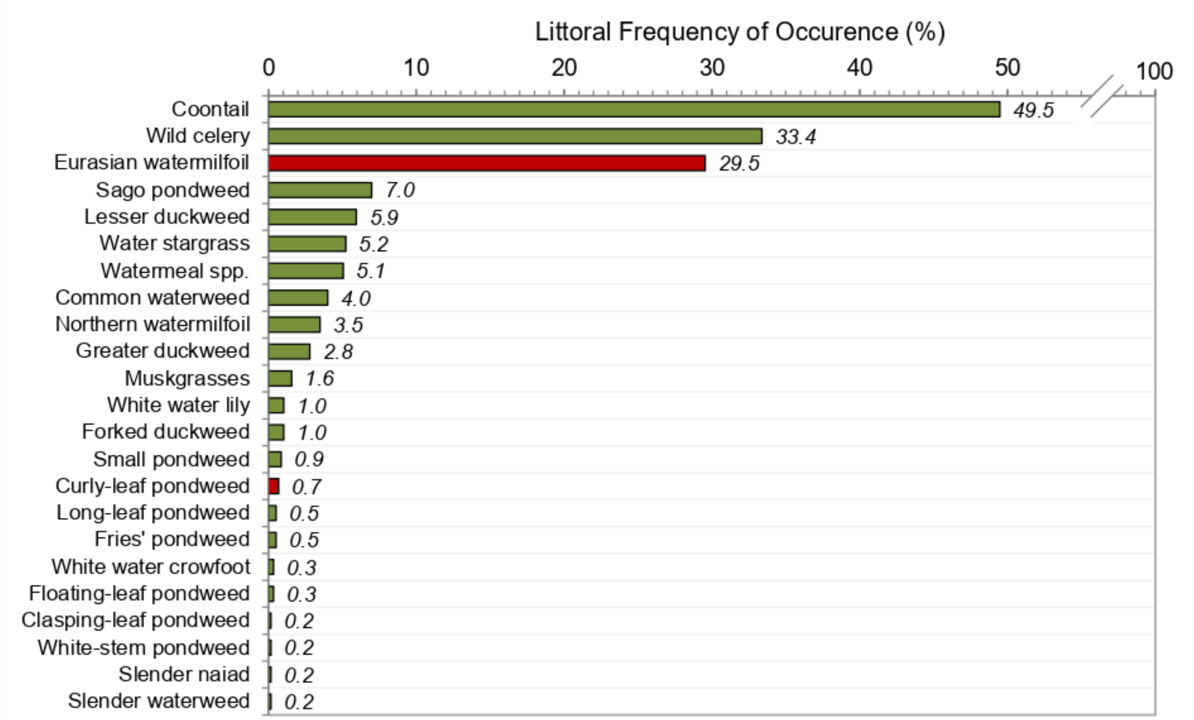


Figure 2.2-4. Delavan Lake 2024 aquatic plant littoral frequency of occurrence. Created using data from July 23-24, 2024 point-intercept survey.

Coontail was the most common aquatic plant located during the 2024 point-intercept survey of Delavan Lake. Coontail is unique in the fact that it does not produce true roots. Because it lacks true roots, this species derives all its nutrients directly from the water (Gross et al. 2003). This ability in combination with a tolerance for low-light conditions allows this species to become more abundant in productive waterbodies with higher nutrients and lower water clarity. Even though statistically valid population differences were confirmed between years, coontail population trends have been stable over the period of study (Figure 2.2-5).

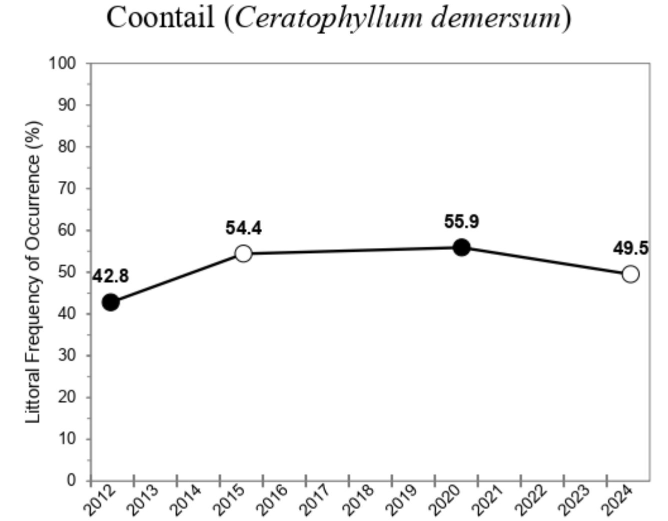


Figure 2.2-5. Littoral frequency of occurrence of coontail. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 2.2-1. Coontail. Photo credit Onterra.

Wild celery was the second-most common aquatic plant from the 2024 point-intercept survey. Wild celery contains a basal rosette, which means that the long, grass-like leaves extend in a circular fashion from the base of the plant located at the sediment-water interface. To keep the leaves standing in the water column, lacunar cells in the leaves trap air and gasses making them more buoyant. Towards the late-summer when water celery is at its peak growth stage, it is easily uprooted by wind and wave activity. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife. Wild celery populations have had statistically valid population increases every year, with almost a 600% population increase being observed since 2012.

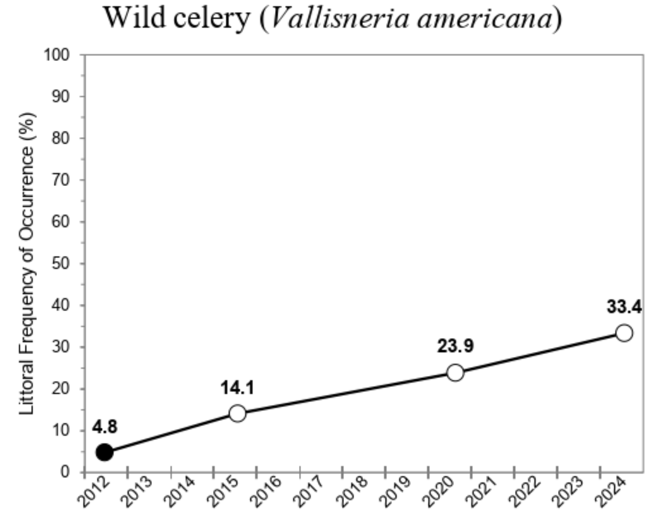


Figure 2.2-6. Littoral frequency of occurrence of wild celery. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 2.2-2. Wild celery. Photo credit Onterra.

Sago pondweed was the third-most common native aquatic plant from the 2024 point-intercept survey. Sago pondweed is a disturbance-tolerant species, closely related to the genus of pondweeds (*Potamogeton* spp.). Sago pondweed populations have been relatively stable in most surveys on Delavan Lake, although a large population spike was observed in 2015 (Figure 2.2-7). 2024 marks the lowest population of sago pondweed over the four years of study, possibly indicating more stability (less disturbance) in the ecosystem over time.

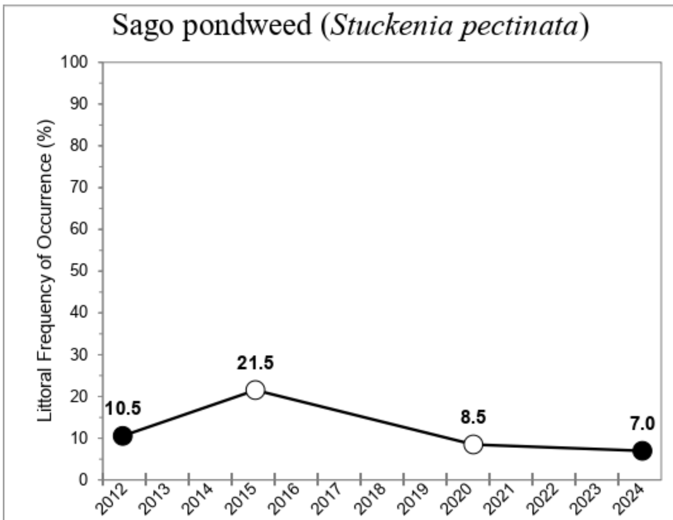


Figure 2.2-7. Littoral frequency of occurrence of sago pondweed. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 2.2-3. Sago pondweed. Photo credit Onterra.

Water stargrass was the fifth most common native aquatic plant from the 2024 point-intercept survey. This plant superficially looks similar to many narrow-leaved pondweed species, but lacks a midvein on the leaves. Water stargrass is more closely related to pickerelweed, a shoreland emergent plant found in Wisconsin lakes and rivers. Water stargrass populations increased during 2015 and 2020, but decreased in population during 2024 to levels similar to 2012 (Figure 2.2-8).

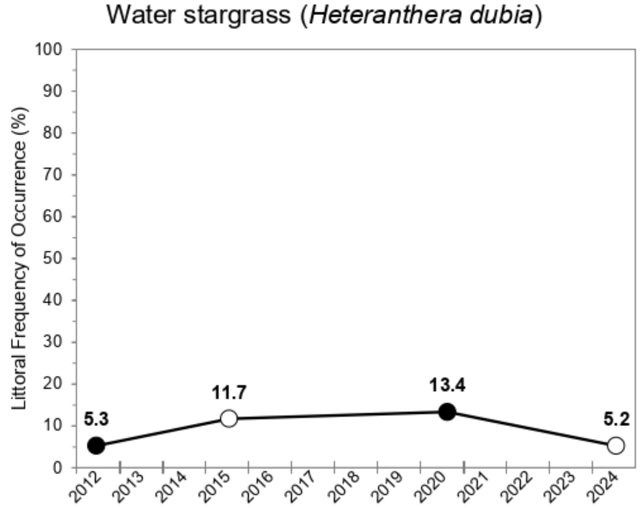


Figure 2.2-8. Littoral frequency of occurrence of water stargrass. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 2.2-4. Water stargrass. Photo credit Onterra.

Common waterweed was the seventh most common native aquatic plant found during the 2024 point-intercept survey. Like coontail, common waterweed obtains the majority of its nutrients directly from the water. While common waterweed can be found growing in many of Wisconsin's waterbodies, excessive growth of common waterweed is often observed in waterbodies with higher nutrients. Common waterweed populations increased in 2015, with populations gradually reducing to roughly 2012 levels during 2024 (Figure 2.2-9). Morphologically similar, slender waterweed was also documented (and vouchered) for the first time during the 2024 survey.

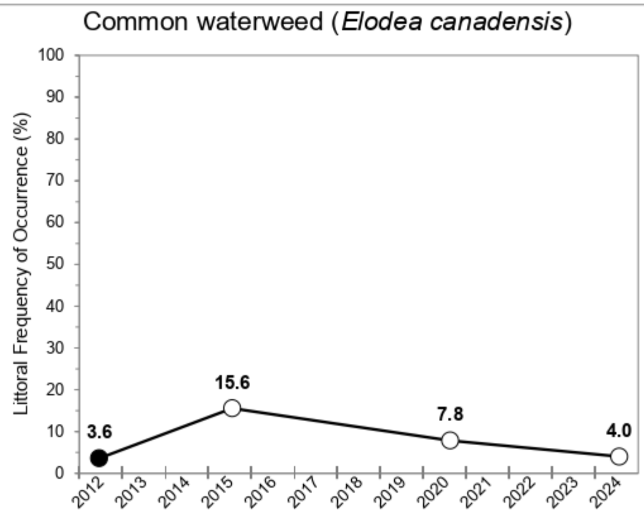


Figure 2.2-9. Littoral frequency of occurrence of common waterweed. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 2.2-5. Common waterweed. Photo credit: Onterra.

Large populations of free-floating vegetation collectively called "duckweeds" have been historically documented in parts of Delavan Lake, particularly mixed inside of water lilies and other shallow water areas. The free-floating plants are made up largely of lesser duckweed (*Lemna minor* & *L. turionifera*) and watermeal species (*Wolffia* spp.); with lesser amounts of forked duckweed (*Lemna trisulca*) and greater duckweed (*Spirodela polyrhiza*). These species can vary in abundance at any given time and are influenced by flow or wind driven water movement since they are not rooted in the sediment.

Unlike other duckweeds that are almost always found floating at the water's surface, forked duckweed is found throughout the water column including covering the sediment. Forked duckweed populations were highest in 2012, being located at almost 60% of littoral sampling locations (Figure 2.2-10). The population of forked duckweed has drastically declined, only being found in 1% of littoral sampling locations in 2024.

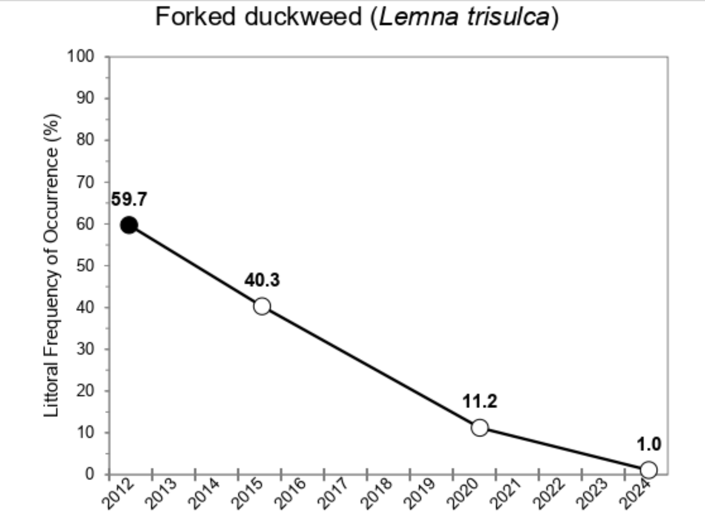


Figure 2.2-10. Littoral frequency of occurrence of forked duckweed. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 2.2-6. Forked duckweed. Photo credit: Onterra.

Since each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). Figure 2.2-12 displays the relative frequency of occurrence of aquatic plant species from each of the point-intercept surveys in Delavan Lake. Over time, approximately 50% of the overall plant population was comprised of coontail and EWM. In 2012, a large additional proportion of the overall plant population was comprised of forked duckweed. By 2024, the forked duckweed population was essentially replaced by a water celery. In all surveys, three to four species comprised about three quarters of the overall plant population.

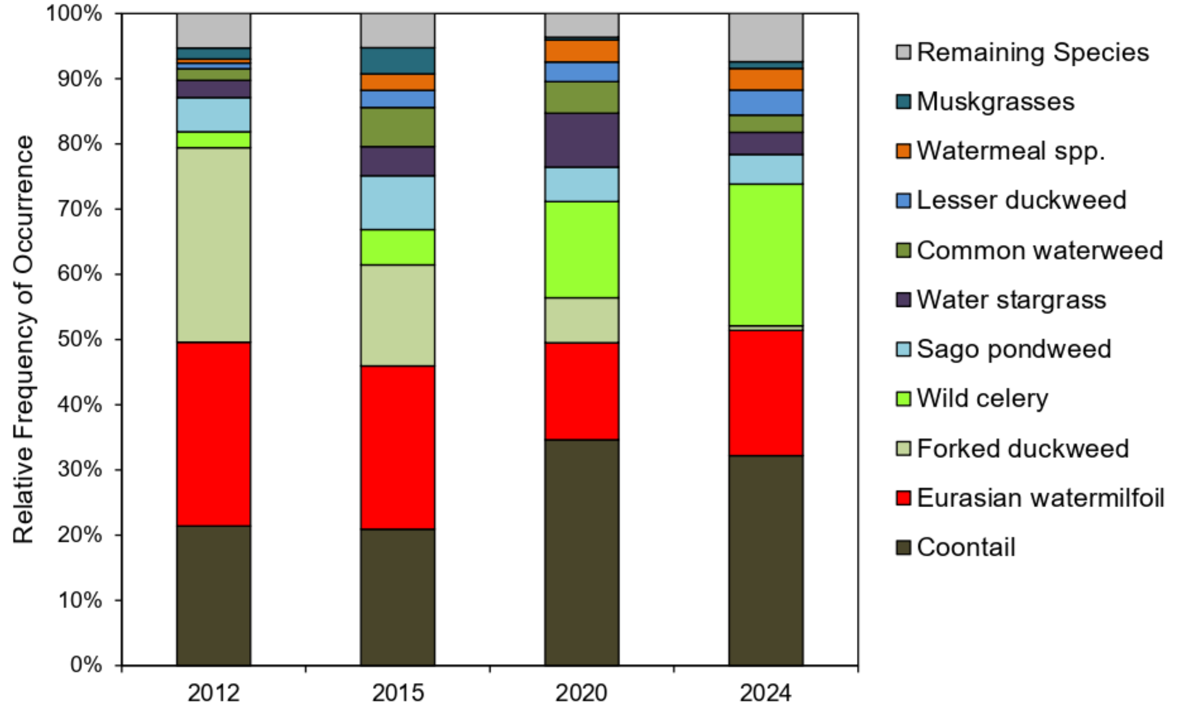


Figure 2.2-11. Relative frequency of occurrence of aquatic plants in Delavan Lake.

Lakes with diverse aquatic plant communities are thought to have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Since Delavan Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community. And as investigated by the relative frequency metric, Delavan Lake was highly dominated by 3-4 plant species.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Delavan Lake's diversity values rank. Using data collected by Onterra, quartiles were calculated for lakes within the SWTP Ecoregion (Figure 2.2-12). Using the data collected from the whole-lake point-intercept surveys, Delavan Lake's aquatic plant species diversity has varied slightly over time but continues to be similar to the median (50th percentile) for lakes in this ecoregion. The domination of a few species results reduces the diversity metric, which otherwise would be higher to a large number of native species being documented in the system.

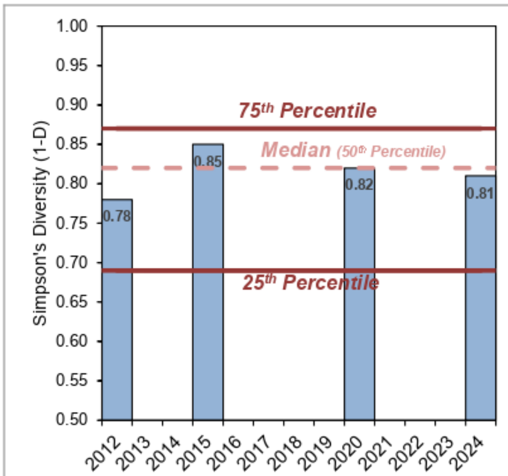


Figure 2.2-12. Delavan Lake Simpson's Diversity Index.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. Delavan Lake's native aquatic plant species richness (i.e. number of species) in 2024 was above the 75th percentile for lake in the Southeastern Wisconsin Till Plain Lakes (SWTP) ecoregion and slightly above the median (50th percentile) for lakes across all of WI. The average conservativism values were at or below the ecoregion and state medians, indicating the plants present are more indicative of a disturbed system. When these metrics are combined, the floristic quality value of Delavan Lake in 2024 was very good compared to other lakes in its ecoregion, but average compared to lakes across the state.

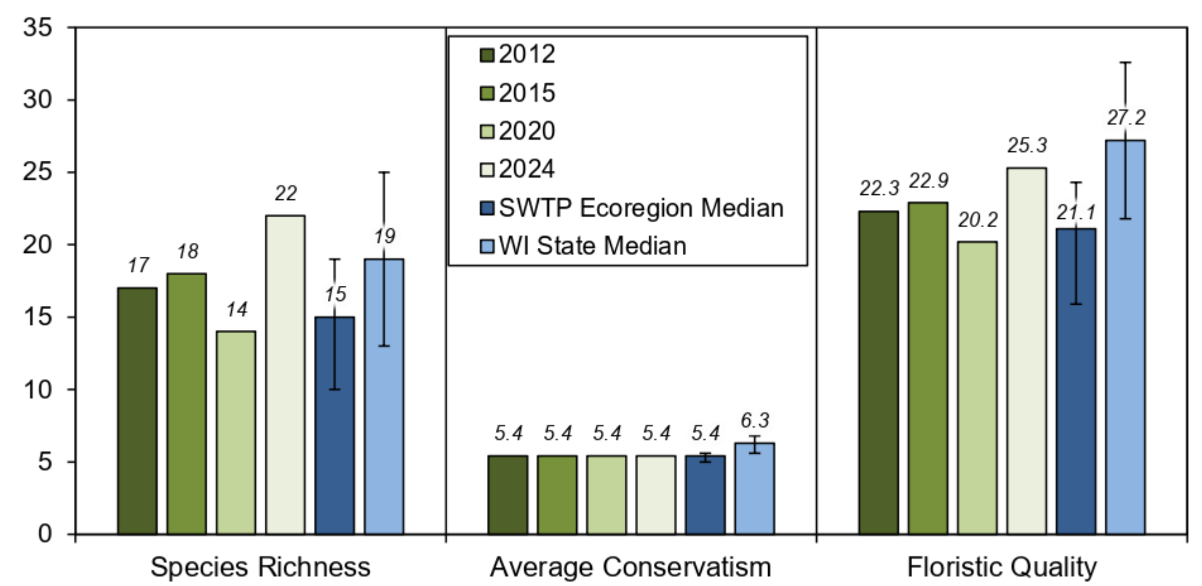


Figure 2.2-13. Delavan Lake Floristic Quality Analysis. Analysis follows (Nichols 1999). Error bars on comparables represent upper (75th) and lower (25th) quartiles.

Figure 2.2-14 shows the average of native species per sampling location from each survey. This metric was highest in 2015 at an average of 1.9 native species per sampling location. All other surveys indicated roughly 1.2-1.4 native species per point. Map 4 shows the number of native species at each sampling point during the 2024 point-intercept survey. Most of the littoral areas in the main basin contain one species per point, with a greater number of species being located on points within the Jackson Creek inlet, Swan Creek outlet, and the southwestern bay of the lake. These areas of higher native plant diversity roughly correspond with sensitive area designations on Delavan Lake.

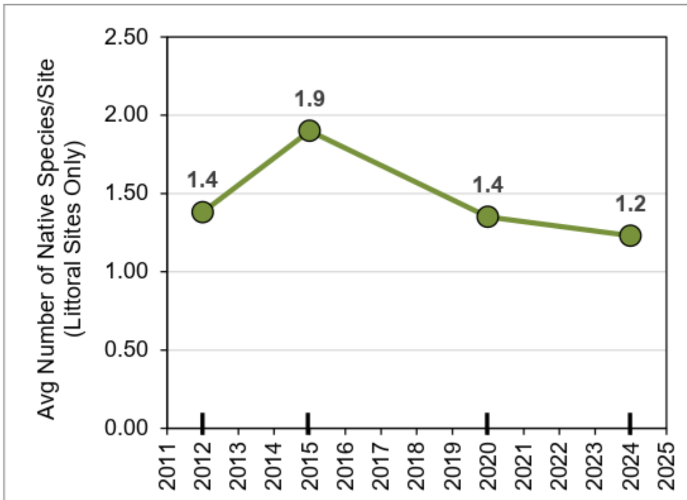


Figure 2.2-14. Delavan Lake average native species per sampling location.

While the name has changed from *sensitive area designations* to *critical habitat designation*, the goal remains to ensure important areas of the waterbody are protected from human activity and disturbances. These areas are designated through a formal process by the WNDR, and give regulators stronger ability to deny certain permits that may threatened the intrinsic value of these areas. For Delavan Lake, the areas chosen have been found to contain the mechanisms that protect the water quality of Delavan Lake, harbor high quality aquatic plant communities, and other essential habitat to support wildlife and fish life cycles. There are five sensitive areas identified on Delavan Lake and its estuaries (Map 4, inset) which all together total 207.8 acres. More details on the sensitive area designations can be found interactively online:

https://apps.dnr.wi.gov/lakes/criticalhabitat/Project.aspx?project=10177986

2.3 Delavan Lake Non-Native Plant Species

Non-native plant species are those that have natural habitats in other parts of the world, but when they arrive in a new environment, lack the mechanisms they have evolved with that keeps their populations balanced. Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. As outlined within the Introduction Section (1.0), seven non-native plant species are known to exist within or along the margins of Delavan Lake. Two of these species are wetland plants located outside the typical high-water mark, purple loosestrife and giant reed (*Phragmites australis*). The other plant species are found within the boundaries of Delavan Lake, each being discussed in a sperate sub-section below.

Curly-leaf pondweed

Curly-leaf pondweed (CLP) is a non-native, invasive submersed aquatic plant native to Eurasia (Photograph 2.3-1). 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 (saw-like). The plants are often brownish/green in color. Delavan Lake has a number of native pondweed species, some of which are similar in appearance to and may be mistaken for CLP

CLP is typically at peak growth early in the growing season, often naturally sensing (die-back) by the Independence Day Holiday. The advanced growth in spring gives the plant a significant head start over 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 (James et al. 2002). However, in many lakes, CLP appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced each year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Normally a control strategy for an established CLP population includes multiple years (5 or more) of controlling the same area to deplete the existing turion bank within the sediment with herbicide application. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species. Properly timed mechanical harvesting may reduce the rate of turion replacement into the sediment each year, but may be insignificant to having a meaningful impact on the overall population.

CLP was first officially documented from Delavan Lake in 1975, but may have existed earlier as it was present in many other nearby systems much earlier. For example, CLP was first confirmed from Geneva Lake in 1939. Mid-summer point-intercept surveys occur after much of the CLP has already senesced for the season, so it often under-represents what the population was earlier in the season. That being said, it can be helpful to understand trends. On Delavan Lake, CLP has been relatively spare during the mid-summer point-intercept surveys, recording its lowest population during late-July 2024 (Figure 2.3-1). The distribution of CLP during the 2024 point-intercept survey is displayed in Appendix B.

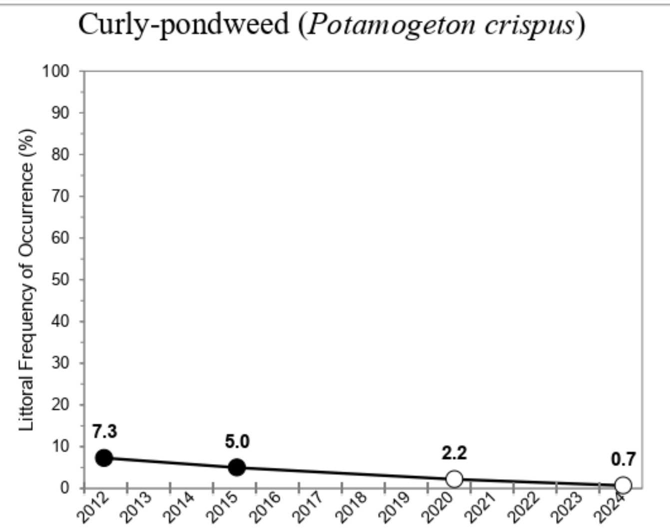


Figure 2.3-1. Littoral frequency of occurrence of CLP. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 2.3-1. Curly-leaf pondweed. Photo credit Onterra.

Eurasian Watermilfoil

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties. Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, EWM has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it sometimes does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating. However, in some lakes, EWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

EWM was officially documented in Delavan Lake in 1995. Subsequent genetic analysis has indicated that Delavan Lake contains populations of both pure-strain EWM and populations of hybrid EWM (*Myriophyllum spicatum x sibiricum*, HWM). HWM can grow faster, become more invasive, and be less susceptible to chemical control strategies than pure-strain EWM. Unless specifically indicated, this report will use "EWM" when discussing the invasive milfoil (EWM and HWM) population of Delavan Lake.

EWM populations were fairly extensive in Delavan Lake in 2012 and 2015, with well over 50% of the littoral zone containing EWM. EWM populations reduced in 2020, and continued to be below 30% within the 2024 point-intercept survey. The distribution of EWM during the 2024 point-intercept survey is displayed in Appendix A.

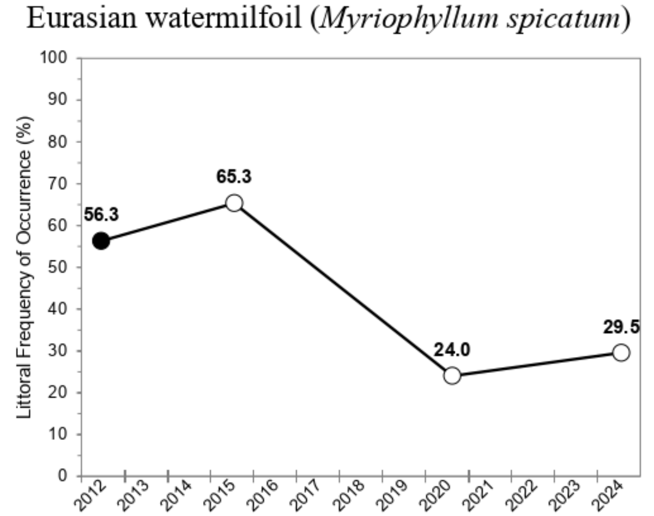


Figure 2.3-2. Delavan Lake EWM littoral frequency of occurrence. Open circles on represent a statistically valid change from previous survey.

Photograph 2.3-2. Eurasian watermilfoil. Photo credit Onterra.

Floating Pennywort

Floating pennywort (*Hydrocotyle ranunculoides*) populations have been reported from Delavan Lake since 2010 (Photograph 2.3-3). This species has shown rapid growth in some systems, reported to do best in slow-flowing waters. It can create dense interwoven mats at the water's surface. Floating pennywort has only been documented from one other location within Wisconsin, the Horicon Marsh.

Photograph 2.3-3. Floating pennywort. Photo credit Onterra.

In Delavan Lake, floating-pennywort has been documented in the Jackson Creek inlet, the Swan Creek outlet, and the southwestern bay of the lake.

During late-August 2024, Onterra documented floating pennywort in the locations shown on Figure 2.3-3. The DLSD has experimented with some limited herbicide application and timed drawdowns to reduce the pennywort populations on the lake.

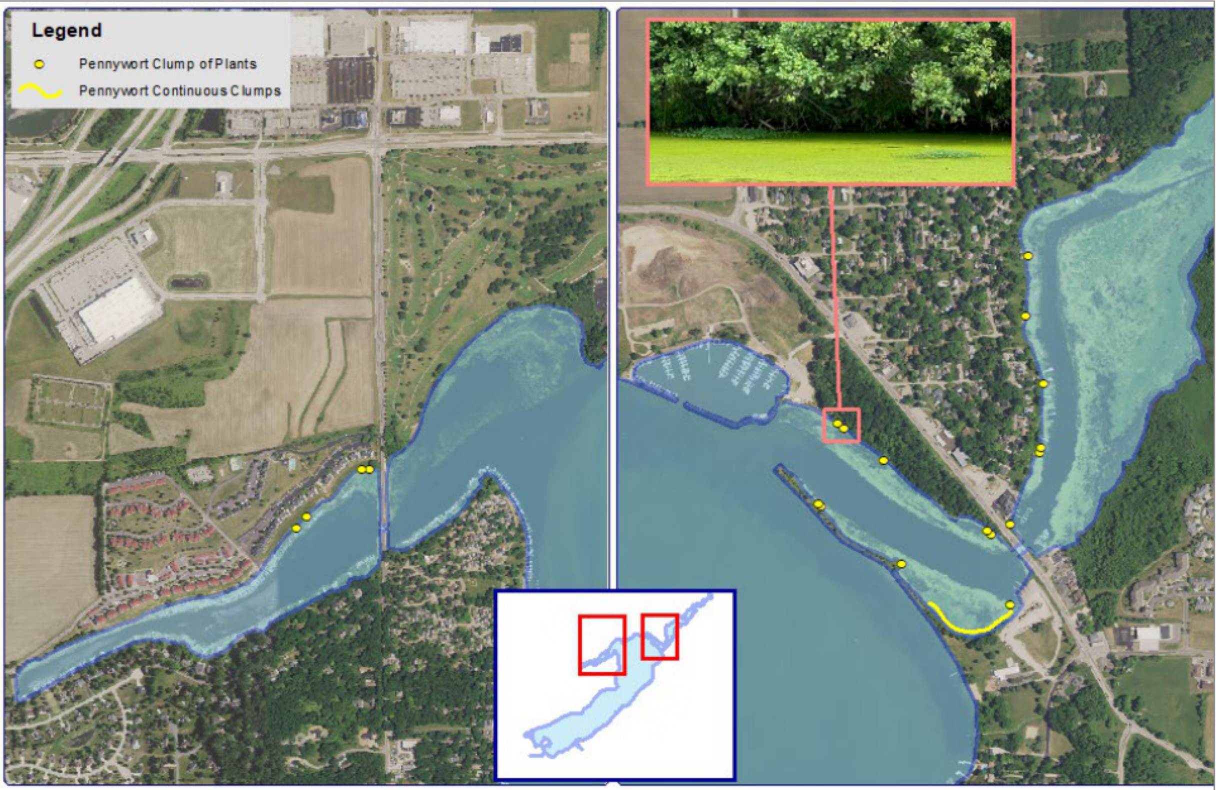


Figure 2.3-3. 2024 Floating pennywort locations. Mapped by Onterra, 8/29/2024

Sacred Lotus

In 2010, sacred lotus (*Nelumbo nucifera*) or similar horticultural variety/hybrid of lotus was located in the northwestern outlet bay of Delavan Lake (Figure 2.3-4). Sacred lotus typically has pink flowers and the plants from Delavan Lake were confirmed as having white flowers, more similar to native lotus plants. If resurgent lotus is located in this area in the future, it is recommended to collect vegetative matter to confirm species/hybrid via genetic testing.

Herbicide management actions taken at that time seem to be highly effective at reducing this population as no lotus species were located during a late-August 2024 survey of this area. This segment of shoreline consists of almost-continuous piers paralleling shore, so the near-shore area required searching with binoculars from a little distance. The area is also completely covered by white-water lily, so there is potential that small populations of lotus or individual lotus floating-leaves may have escaped detection. That being said, the survey crew felt confident that they did not miss any lotus flowers or larger aggregations of vegetative lotus growth.

2010 (Before Herbicide Treatment)	2024 (None Detected)
	

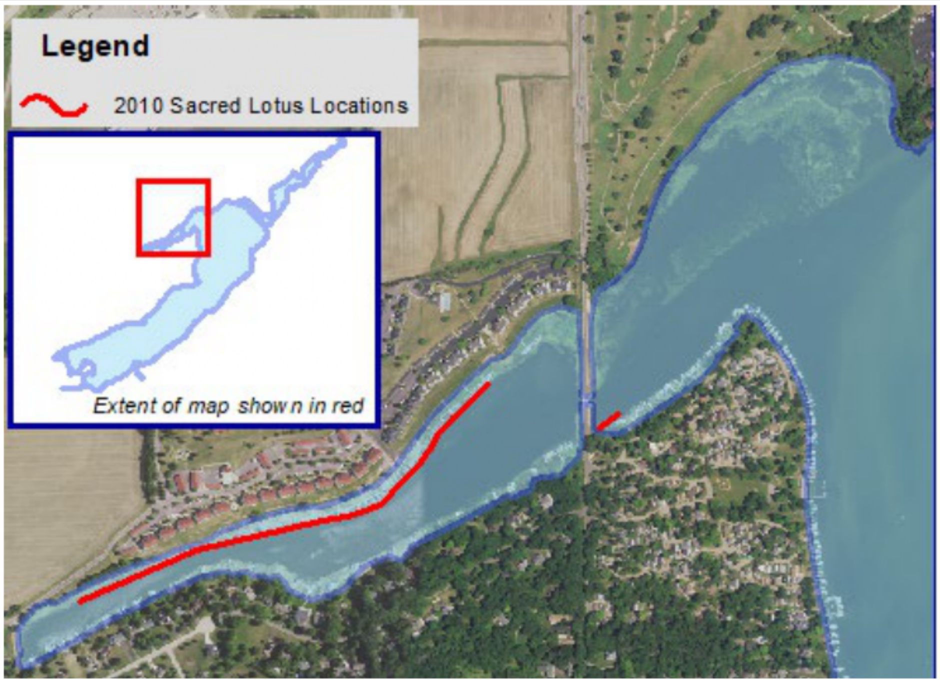


Figure 2.3-4. Sacred lotus or similar lotus hybrid survey locations. 2010 picture provided by WDNR, 2024 picture by Onterra.

Yellow Floating Heart (not found in Delavan Lake)

Yellow floating heart (*Nymphoides peltata*) is a non-native water lily species that has been found in a few Wisconsin locations, likely has a horticultural escape. In 2008, yellow floating heart was found in two small condo retention ponds very close to the lake (Figure 2.3-5). Follow-up removal activities occurred as a part of WDNR AIS-Early Detection & Response Grant. A late-August 2024 survey of the Swan Creek outlet and the two stormwater ponds did not yield any findings of yellow floating heart.

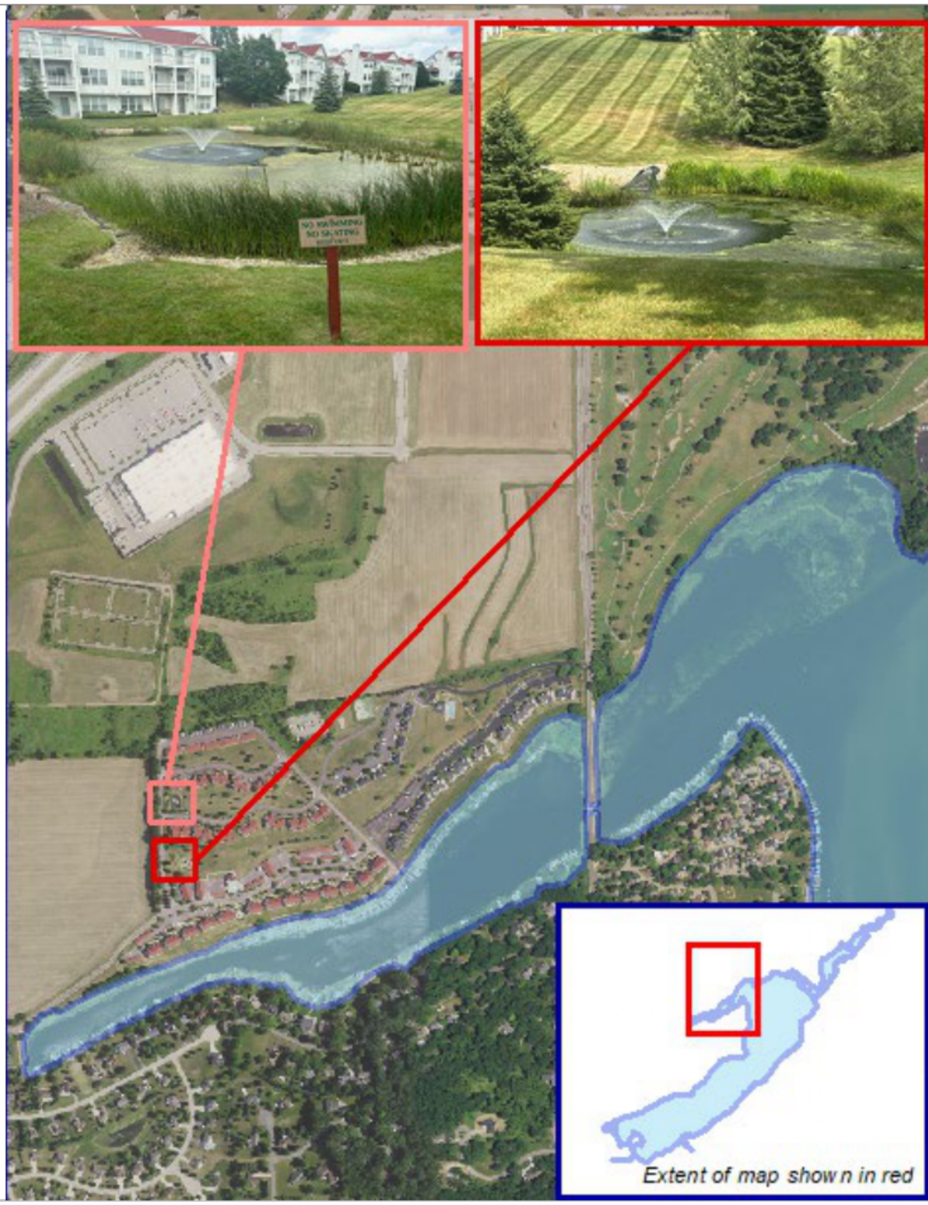
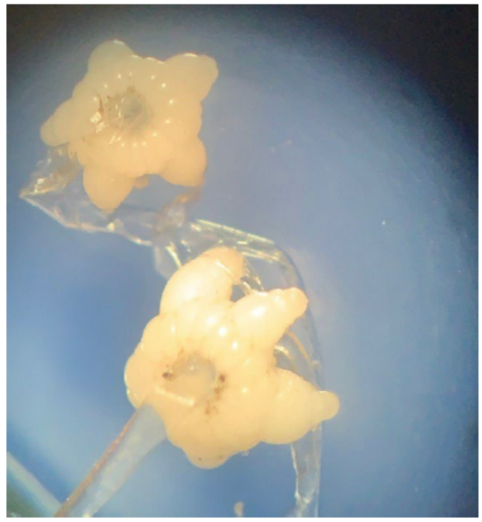


Figure 2.3-5. Yellow floating heart survey locations. Pictures within insets courtesy of Onterra.

Starry Stonewort (not found in Delavan Lake)

Starry stonewort (*Nitellopsis obtusa*; SSW) is a non-native, invasive macroalgae that was first observed in the United States in 1978 within the St. Lawrence River. The species has a distinct star-shaped reproductive structure called a bulbil which forms during late-summer or fall and is deposited into the lake sediments (Photograph 2.3-3). Interestingly, this species receives special protections in its native range due to low population numbers. Starry stonewort was discovered in a southeastern Wisconsin lake in 2014, and has now been verified within 21 inland lakes within eight counties. Starry stonewort was also found in Sturgeon Bay in 2016 and subsequent investigations indicate this species is present in coastal areas of Lake Michigan and Green Bay, so it may be more widespread in Lake Michigan than documented.



Photograph 2.3-3 Starry stonewort. Non-native, invasive macroalgae. Photo credit Onterra.

Like other non-native species, SSW has been shown to dominate aquatic plant communities, in some cases growing to nuisance levels and hindering recreation. However, this species does not act invasively in all situations. Preliminary data from surveys in Wisconsin indicate that frequency can vary across lakes, with some lakes experiencing rapid increase in SSW frequency after discovery, while other lakes have seen a much slower rate of expansion. To date, there have not been any effective chemical management strategies for SSW. Copper-based algaecides can temporarily suppress SSW populations, but have been ineffective at long-term population control. While control methods attempted to date in Wisconsin have demonstrated a lack of control efficacy, the WDNR and other lake managers are working towards developing and testing new management strategies.

While not known from Delvan Lake, nearby waters including Geneva Lake hold populations of this non-native macroalgae (*Nitellopsis obtusa*). Biomass of this species increases later in the season and is more likely to be detected at that time, so a sub-set of the point-intercept survey locations near the main boat landing were sampled during a late-August survey (Figure 2.3-6). At each location, field crews conducted at least two rake samples. Starry stonewort was not located during this late-August survey, nor was in encountered during the mid-July whole-lake point-intercept survey.

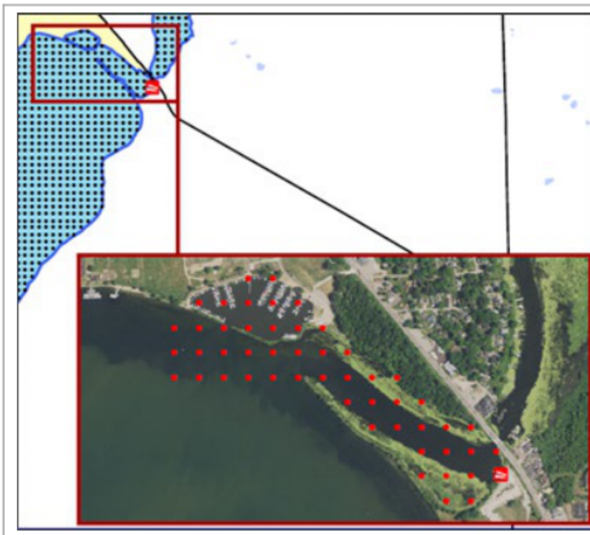


Figure 2.3-4. Late-season subset point-intercept sample locations.

2.4 Nuisance Aquatic Plant Management

Historic aquatic plant management has occurred on Delavan Lake since at least the 1950s, originally relying on sodium arsenate until 1969, switching to copper- and diquat-based herbicides/algaecides.

More recently, the DLSD has been conducting a nuisance control strategy towards aquatic plants utilizing aquatic herbicides and mechanical harvesting. The goal of these activities has been solely to provide increased navigational abilities within select areas of the system. Herbicide treatments are reserved for channels and near-shore areas that the mechanical harvesters are unable to operate within (Map 10).

The DLSD primarily relies on the use of four mechanical harvesters and a high-speed transport barge to cut and remove aquatic plants from the system. The DLSD employs two full-time and numerous seasonal and part-time staff to operate its mechanical harvesting program, outlined on Maps 6-9. Delavan Lake is divided into 12 harvesting areas to assist with tracking and reporting efforts. Additional harvesting operations may occur in Harvest Zone 11, conducted by Lake Lawn Resort. The DLSD primarily offloads cut aquatic plants at the Town Park Landing, but also uses the Blue Gill Road Landing when water levels permit.

The DLSD also operates a pier pick-up service, where riparians place plant materials at the ends of docks and the DLSD staff picks up at a scheduled interval after being notified by phone.

Figure 2.4-1 shows the amount of mechanical harvesting that has occurred since 1997, with the average being 3,743 cubic yards of harvested material occurring annually. Mechanical harvest removals have increased since 2021, with 2024 removing the most amount of aquatic plant material at 8,028 cubic feet.

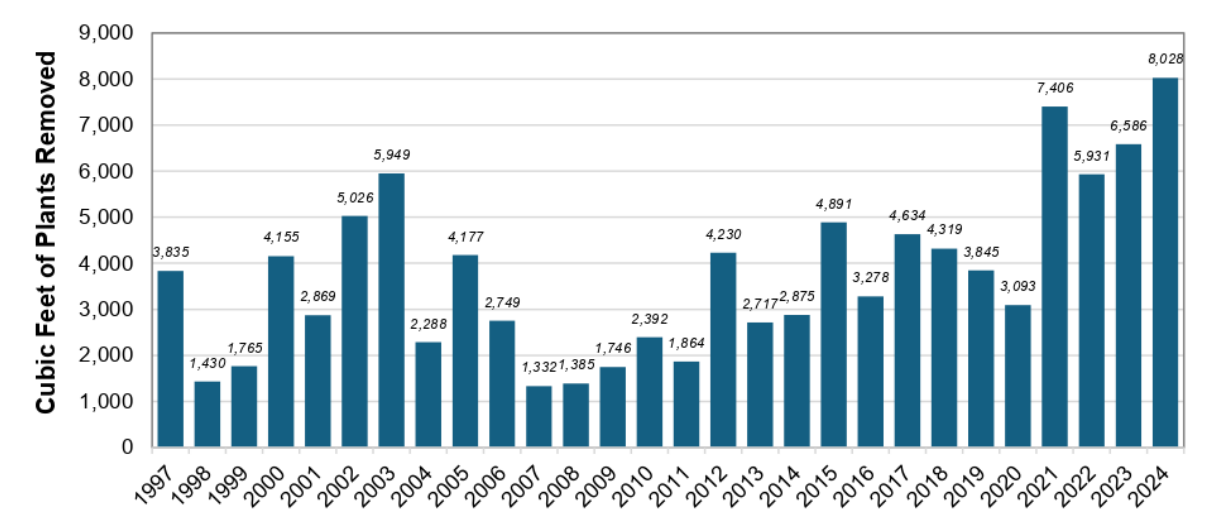


Figure 2.4-1. Mechanical harvesting history on Delavan Lake.

Mechanical harvesting largely targets Eurasian watermilfoil, with an abundance of late-season wild celery removal occurring. Figure 2.4-2 outlines the species composition of the 2024 mechanical harvesting activities.

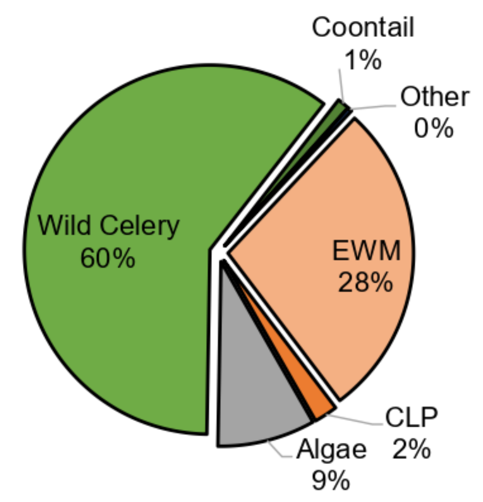


Figure 2.4-2. 2024 Estimated volume of plants by species.

When plants are removed from a lake as part of a mechanical harvesting program, nutrients are also removed. The nutrient composition of extracted plants varies greatly by species, but also can vary by productivity of the lake and time of year. The DLSD estimates that a cubic yard of wet harvested material weights approximately 900 lbs, with quite a bit of variability based upon species composition. Combining the mass of plant material removed annually with phosphorus content coefficients of harvested material from three different literature examples (models), a potential range of phosphorus removal from mechanical harvesting can be calculated (Figure 2.4-3).

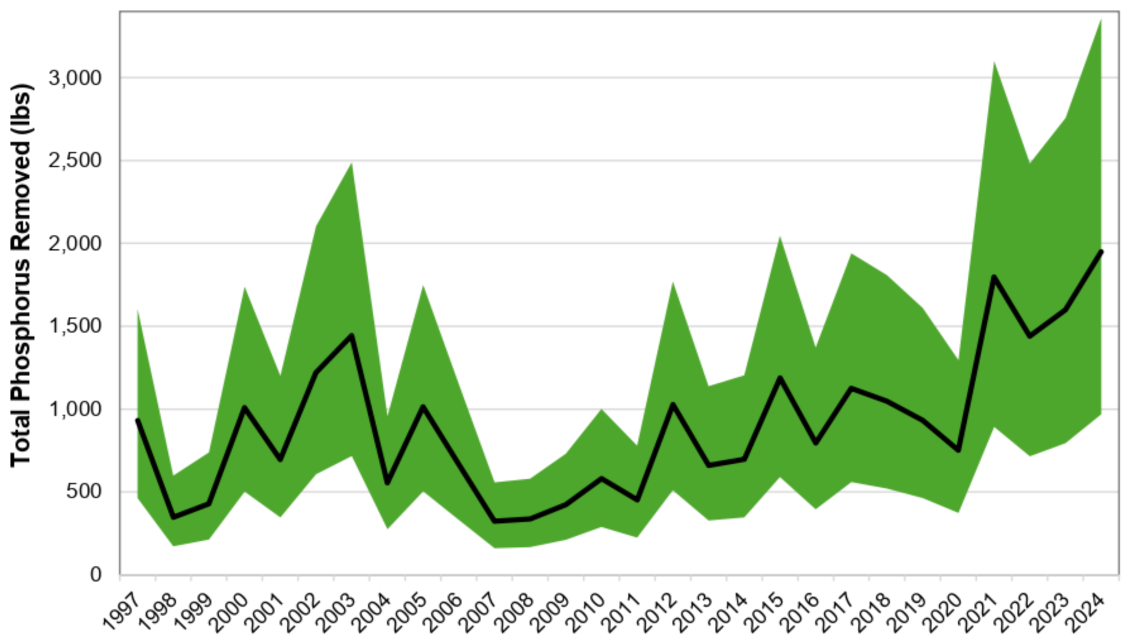


Figure 2.4-3. Potential phosphorus removed by mechanical harvesting. Total phosphorus content in vegetated material using a 2009 study on Pewaukee Lake, WI (Ebeling et al. 2011), a 1991 study on Whitewater-Rice Lakes, WI (Goddard and Field 1994), and Lake Sallie, MN (Peterson et al. 1974).

Based upon this modeling exercise, an average of about 1,570 lbs of phosphorus are removed from Delavan Lake annually, with a high of almost 2,000 lbs of phosphorus being removed in 2024. It is important to note that the source of phosphorus in aquatic plants comes from a combination of 1) uptake from the water column and 2) root-mined from the sediments, depending on the type of plants removed. Phosphorus from rooted plants like EWM and water celery largely originate from legacy phosphorus in the sediment, whereas the phosphorus of free-floating plants like duckweeds is derived from the water column. Therefore, the phosphorus removed from mechanical harvesting originates from a combination of watershed loading and internal legacy nutrient sources. However, all lakes act as nutrient sinks as a part of their aging process (eutrophication), so that cumulation must be compared to the massive and unknown amount of phosphorus that has accumulated in the lake since its creation 12,000 years ago.

3.0 SUMMARY & CONCLUSIONS

This project was conducted to create an updated Aquatic Plant Management (APM) Plan for the DLSD by gathering and analyzing historical and current ecological data, identifying threats, evaluating feasible management actions, and increasing the lake group's capacity to implement the management plan. The following five-page Implementation Plan Section is the actual "plan" part of this document, precisely outlining the DLSD's management goals and associated actions they will take to reach those goals.

Specifically, the DLSD pursued an update to their APM Plan as it relates to the continuation of their mechanical harvesting program. The aquatic plant community of Delavan Lake continues to be in a good condition, with increases in beneficial plants like wild celery being documented, and stability in non-native plants like EWM. The DLSD continues to increase their capacity to manage nuisance aquatic plants on Delavan Lake. A review of their mechanical harvesting program yield no significant changes needed. A series of updated mechanical harvesting maps created by this planning project will serve as a useful tool in permitting and documenting activities.

During this planning process, the DLSD also reviewed their herbicide management program. This program was also largely unchanged, but more precise maps were created during this project. Two channels off of Lake Delavan will be targeted with herbicides for nuisance management, as mechanical harvesting cannot occur in these narrow and populated areas. The DLSD intends to continue timed drawdowns as a mechanism to manage pennywort populations, but this APM Plan also includes a potential herbicide management strategy in the event that technique is considered again in the future.

The Implementation Plan Section also outlines the intervals of future aquatic plant monitoring activities and lake management planning activities.

4.0 AQUATIC PLANT IMPLEMENTATION PLAN SECTION

The Delavan Lake Improvement Association (DLIA) is currently developing a comprehensive management plan for Delavan Lake that will focus studies and planning related to enhancing and protection water quality and the watershed. Since being the responsibility was handed over by the Town of Delvan in 1997, the Delavan Lake Sanitary District's (DLSD) primary responsibility is to operate the mechanical harvesting program. The DLSD is also involved in other aquatic plant management activities, including herbicide treatments in select bays where mechanical harvesting is not feasible, and

The DLSD has sought to update their Aquatic Plant Management (APM) Plan at roughly 5-year intervals to allow the WDNR to issue multi-year mechanical harvesting permits under WI administrative code NR109. The previous APM Plan for Delavan Lake was completed in July 2022.

The goals detailed within the plan below are designed to be realistic and achievable considering the capacity of the DLSD. The DLSD will be the facilitator for all management actions. The Implementation Plan is a living document that will be under constant review and adjustment depending on the condition of the lake, availability of funds, and needs of the stakeholders.

Management Goal 1: Ensure the DLSD has a Functioning and Up-to-Date Aquatic Plant Management Plan

Management Action:	Periodically update aquatic plant management plan
Timeframe:	Continuation of current effort; periodic at roughly 5-year intervals
Description:	The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. To be eligible for multi-year mechanical harvesting permits (NR109) or APM-related WDNR surface water grants (NR193), "a current plan has a completion date of no more than 5 years prior to submittal of the recommendation for approval. The department may determine that a longer lifespan is appropriate for a given management plan if the applicant can demonstrate it has been actively implemented and updated during its lifespan. However, a [whole-lake] point-intercept survey of the aquatic plant community conducted within 5 years of the year an applicant applies for a grant is required." The DLSD will update the APM Plan at roughly 5-year intervals, unless the WDNR agrees that a slightly longer interval is appropriate. With the completion of this APM plan in 2025, the DLSD will start the roughly 2-year process of updating their APM Plan in 2029 with intended completion in 2030.

Management Action:	Participate in Wisconsin Lakes and Rivers Convention
Timeframe:	Annually or as needed
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Department of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake districts and associations. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/association. Even though the DLSD is comprised of paid professionals, periodic participation in this conference is important to stay relevant on lake-related issues, attend training sessions, and to network with other organizations and professionals dealing with similar lake management concerns.

Management Goal 2: Monitor Aquatic Vegetation on Delavan Lake

Management Action:	Coordinate periodic point-intercept aquatic plant surveys
Timeframe:	Periodic: at least once every 5 years, Timing: during July-August
Description:	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 Delavan Lake in 2012 by WDNR Science Services, 2015 by the DLSD, 2020 by the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and 2024 by Onterra. This survey provides quantitative population estimates for all aquatic plant species within the lake and is designed to allow comparisons with past surveys in Delavan Lake as well as to other waterbodies throughout the state. 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 (rake fullness) on the sampling rake is recorded. The DLSD will ensure the point-intercept surveys is conducted at least once every five years as part of an APM Planning Project to maintain eligibility for multi-year mechanical harvesting permits. The next interval for a whole-lake point-intercept survey is in 2029.

Management Action:	Periodically monitor for non-native species in Delavan Lake
Timeframe:	Periodic: annually or when prompted.
Description:	While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it is often too course to identify species at low populations, plant species located along the margins of the lake, or areas of the lake to direct management. The DLSD would periodically conduct causal visual surveys searching for species known or historically known from Delavan Lake, including floating pennywort and sacred lotus. As discussed in the following management goal, the DLSD is actively managing these populations, and the results of these investigations are required to justify the need for management. The DLSD would also periodically search for non-native species that are known from surrounding waterbodies, including yellow floating-heart and starry stonewort. If a new AIS is suspected from Delavan Lake, the location should be recorded or marked (e.g. GPS, maker buoy) and a specimen would be provided to a regional WDNR lakes biologist/specialist or other respected professional to confirm identification. If the suspected specimen is indeed a non-native species, the WDNR will properly prepare the specimen for vouchering and will fill out a formal WDNR incident form. Depending on the species identified, follow-up monitoring and/or management may be eligible for WDNR grant funding.

Management Goal 3: Manage Select Existing Aquatic Invasive Species Infestations within Delavan Lake

Management Action:	Manage pennywort and sacred lotus populations
Timeframe:	Continuation of current effort
Description:	Eurasian watermilfoil (EWM) and curly-leaf pondweed (CLP) are well established in Delavan Lake and are not targeted as part of a population management goal, where the objective is a lower population in the future. The upper biomass of these plants are targeted for nuisance mitigation measures, such as within the mechanical harvesting program. This program does not impact the overall population of these species, but does alleviate the nuisance navigation impacts they contribute to. Within this management action focused on pennywort and sacred lotus, the objective is to reduce the population of the target species over time, or at least keep the population from increasing. As discussed Section 2.3, sacred lotus (*Nelumbo nucifera*) or a similar horticultural variety/hybrid of lotus was located in 2010 within the outlet bay

	of Delavan Lake. Herbicide treatments conducted at that time appear to have extirpated this lotus species from the system. If resurgence of the population is observed, directed management (manual removal or herbicide treatment) would be conducted again to keep the population from establishing in the lake. Prior to management, the DLSD is advised to collect vegetative matter to gain a better understanding of which species/hybrid is within the lake via genetic testing. Floating pennywort (*Hydrocotyle ranunculoides*) populations have been observed on Delavan Lake since 2010. Herbicide management has provided some population control, but many areas are not responding as favorably as desired. With no clear effective herbicide treatment strategy at this time, the DLSD intends to conduct timed drawdowns as a trial to see if population reductions can be achieved through this method. The entirety of the pennywort population is very near shore and slight changes in water levels may desiccate and kill these plants. In the event that the drawdown trial is unsuccessful, the DLSD may again consider herbicide management techniques. Map 5 outlines the areas the DLSD would consider herbicide management actions based upon historical presence of pennywort. Based upon earlier surveys of the lake, the DLSD would submit a permit application for the specific areas to be targeted, hiring a licensed herbicide applicator to perform the treatment.

Management Goal 4: Maintain Navigability on Delavan Lake

Management Action:	Continue mechanical harvesting program
Timeframe:	Continuation of Current Effort
Description:	The DLSD understands the importance of aquatic vegetation within Delavan Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, caused largely by a combination of submersed aquatic invasive species (e.g. Eurasian water milfoil and curly-leaf pondweed), loosely rooted or uprooted native vegetation (e.g. coontail, & water celery), and filamentous algae. The mechanical harvesting operations are directed to avoid floating-leaf species when possible (i.e. water lilies). The DLSD supports the reasonable and environmentally sound actions to facilitate navigability on the Delavan Lake system. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than absolutely necessary. The DLSD currently performs mechanical harvesting operations as outlined on Maps 6-9. This includes a series of 50-ft wide harvest lanes, and 30-ft lanes

	harvested after fish spawning activities ceased (June 15 of each year). The DLSD also surface-cuts areas of primarily EWM, roughly from 5 feet to 20 feet of water depth on an as-needed basis.
	
	The DLSD seeks multi-year mechanical harvesting permits, which are available to applicants that have APM Plans that have been updated in the last 5 years. The current mechanical harvesting permit is for the time period of 2023-2028.
	
	The bulleted list below outlines some of the conditions the DLSD intends to follow as outlined on the WDNR permit.
	• Areas denoted as "Habitat" on Maps 6-9 should not be harvested prior to June 15. 50-foot harvesting lanes in the inlet and outlet may be harvested prior to June 15 of each year, if necessary, to facilitate boating to piers and channels.
	• Cutter bars must be kept out of the sediment. A minimum of 1 to 2 feet of aquatic plant growth must remain at the bottom of the lake in all harvested areas
	• Highlands Bay and Viewcrest Bay shall not be harvested before June 15th of each year.
	    o Navigational boating access channels (2) may be cut in Viewcrest Bay to a width of 50 feet each. The depth of the cut may not exceed a maximum of 3 feet below the surface of the water.
	    o Navigational boating access channels (3) may be cut in Highlands Bay to a width of 50 feet. The depth of the cut may not exceed a maximum of 3 feet below the surface of the water.
	• Stands of native aquatic plants such as native pondweeds and water stargrass shall not be top cut or clear cut outside of designated harvesting lanes
	• Stands of water celery shall not be clear cut outside of designated harvesting lanes. Dislodged and floating wild celery would be okay to target, specially later in the season when this naturally occurs.
	• All equipment transferred between the inlet, outlet and main basin of Delavan Lake must be sterilized after each use and must abide by all provisions of NR 40. Harvesters, conveyors and trailers must be completely pressure washed and all plant fragments removed.
	• The DLSD shall submit an annual report with a detailed map of treatment areas, total acres harvested, total time spent harvesting and aquatic plant material removed by weight (unit), volume (unit) and species – including by-catch, within 30 days of the last cutting event.
	
	Three disposal locations are currently being used for harvesting aquatic vegetation: 1) Charles G & Connie Palmer, 2) CST Holding LLC, 3) William J Henry Trust. Disposal of aquatic plant material is prohibited from occurring in a wetland.

Management Action:	Continue herbicide treatment of select channels
Timeframe:	Continuation of Current Effort
Description:	In addition to the mechanical harvesting activities outlined in the previous management action, the DLSD has implemented herbicide treatment by a contracted applicator to restore watercraft navigation patterns in three areas the mechanical harvester cannot effectively operate within (Map 10). These treatments largely target nuisance aquatic plants and filamentous algae using contact herbicides/algaecides. Decaying aquatic plants following an herbicide treatment can result in localized reductions in dissolved oxygen, especially in warmer waters. Large reductions in dissolved oxygen can cause sudden fish kills and cause harm to other important aquatic life. The early-season application timing is favored by the DLSD, as cold water can hold larger amounts of oxygen that warm water which buffers the concerns of dissolved oxygen crashes following herbicide treatments. Onterra cautions that in highly enclosed situations such as confined channels, dissolved oxygen reductions following herbicide treatment are more likely regardless of water temperature. Therefore careful herbicide treatment planning is needed to ensure adequate oxygen levels exist if such management actions are taken.

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