Tomahawk Lake System

(Tomahawk, Little Tomahawk, Mud, Inkwell, Paddle Pond, Tomahawk Thoroughfare)

Oneida County, Wisconsin

Aquatic Plant Management Plan

December 2022

Sponsored by:

Tomahawk Lake Association

WDNR Surface Water Grant Program

(AEPP-629-21, AEPP-640-21, AEPP-641-21)

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Onterra, LLC
Lake Management Planning

Tomahawk Lake System

Oneida County, Wisconsin

Aquatic Plant Management Plan

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Funded by: Tomahawk Lake Association
Wisconsin Dept. of Natural Resources (AEPP-629-21, AEPP-640-21, AEPP-641-21)

Acknowledgements

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

Tomahawk Lake Planning Committee

Jim Kavemeier - Chair	Jon Hunt	Keith Pagel
Noah Lottig – TLA President	Donna Kempf	Julia Swaney Schilling
Tom Anderson	Pete Lasier	Paul Shain
Art Sonneland		

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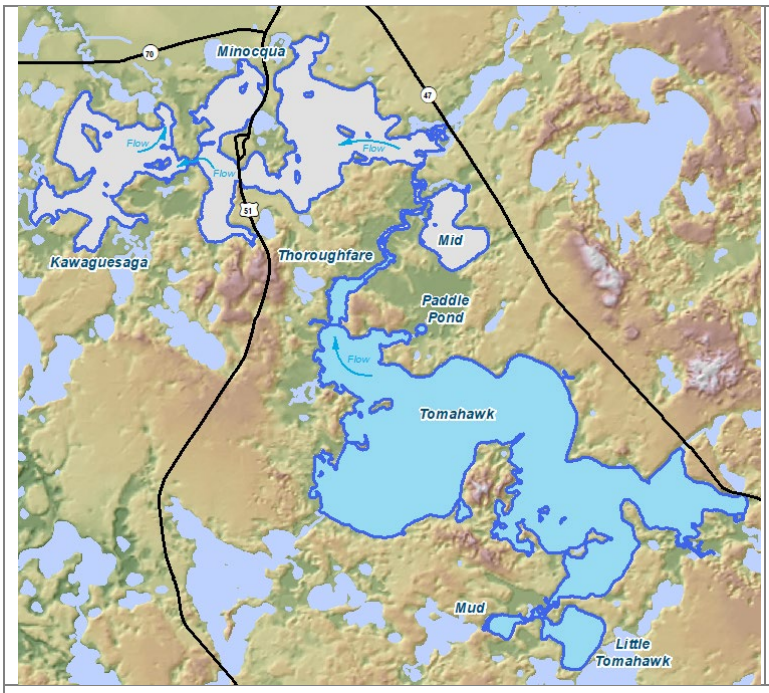
1.0 INTRODUCTION

Often referred to as the Minocqua Chain of Lakes, the Tomahawk Lake System is part of a contiguous waterbody that spans over 6,000 acres. The Minocqua Chain is managed by three separate entities: the Minocqua-Kawaguesaga Lake Protection Association (MKLPA), the Mid Lake Protection and Management District (MLPMD), and the Tomahawk Lake Association (TLA) (Figure 1.0-1).



	Acres	Management Group
Tomahawk	3,462	TLA
Little Tomahawk	163	
Mud	41	
Inkwell	13	
Paddle Pond	5	
Thoroughfare	79	
	36	MKLPA
Minocqua	1,339	
Kawaguesaga	700	
Mid Lake	225	MLPRD
	6,063	

Figure 1.0-1. Minocqua Chain, Oneida County, WI. Tomahawk Lake System managed by the TLA shown in blue.

The Tomahawk Lake System is a drainage system in Oneida County and are designated as a Statewide AIS Source Water (Map 1). Tomahawk Lake and Little Tomahawk Lake are designated as Outstanding Resource Waters (ORW) by the Wisconsin Department of Natural Resources (WDNR). Over 900 waterfront parcels exist on these lakes, paying taxes on around 225 million dollars of property. Further, the system is an integral part of Oneida County's tourist trade.

The TLA has received numerous grants from the WDNR, mainly aimed at managing aquatic invasive species (AIS) in the system (Table 1.0-1).

A Comprehensive Lake Management Plan (CLMP) for the Tomahawk Lake System was approved by the WDNR in 2016. The CLMP utilized point-intercept aquatic plant data from 2014 to characterize the aquatic plant population of the system.

The CLMP indicated that the main lakes of the system (Tomahawk and Little Tomahawk Lakes) were oligotrophic, meaning that they had overall low productivity and high water clarity. The limiting nutrient in the system was determined to be phosphorus, meaning that increases in phosphorus will increase aquatic plant and algae growth. The watershed or drainage area for the system is relatively small, with the CLMP indicating that one acre of land drains to every acre of the lake. This makes the role of the watershed is extremely important, as shifts from forest and

wetlands towards agriculture and human development can greatly increase the amount of phosphorus that enters into the system.

Table 1.0-1. TLA Grants from WDNR.

Grant Number	Project Name	Amount
AIRR-0003-05	EWM Rapid Response	$4,000.00
LPL-1109-07	Mgmt Plan (Phase I)	$7,800.00
LPL-1110-07	Mgmt Plan (Phase II)	$10,000.00
LPL-1152-07	Mgmt Plan (Phase III)	$10,000.00
SPL-137-07	Mgmt Plan (additonal waterbodies)	$3,000.00
AIRR-026-07	EWM Rapid Response: APM Plans	$10,000.00
AIRR-045-08	EWM Rapid Response; Strategy #1	$9,622.50
AIRR-046-08	EWM Rapid Response; Strategy #2	$10,000.00
ACEI-051-08	HCS Demo Project (2008)	$45,033.50
ACEI-063-09	AIS Control Project (2009-2011)	$149,701.00
ACEI-093-11	AIS Control Project (2011-2012)	$173,333.00
ACEI-130-13	AIS Control Project (2013-2014)	$173,333.00
LPL-1553-14	Comp Lake Mgmt Plan (Phase I)	$24,332.00
LPL-1554-14	Comp Lake Mgmt Plan (Phase 2)	$16,692.00
ACEI-166-15	AIS Control Project (2015)	$79,505.25
ACEI-185-16	AIS Control Project (2016)	$82,733.70
ACEI-198-17	AIS Control Project (2017)	$25,000.00
ACEI-215-18	AIS Control Project (2018)	$23,277.30
AEPP-548-18	AIS Monitoring, Mapping, Planning (2018)	$24,400.00
LPL-1688-19	Shoreland Restoration & Mapping	$8,723.40
AEPP-577-19	AIS Monitoring, Mapping, Planning (2019)	$20,119.64
AEPP-629-21	APM Plan Update (EWM Mapping Phase)	$9,483.85
AEPP-640-21	APM Plan Update (PI Survey Phase)	$9,406.80
AEPP-641-21	APM Plan Update (Mgmt Planning Phase)	$8,649.70
		$938,146.64

Commencing in 2020, the TLA sponsored a Lake Protection Grant (LPL-1688-19) to hire Nova Ecological Services to determine critical habitat areas on the lake, monitor shorelands, and create a comprehensive lake habitat and use map that will be used to educate landowners and identify areas for shoreland restoration and/or habitat protection and improvement. The APM Plan update project took these data and created an interactive web map portal to allow easier access of these data by riparians:

https://onterra.maps.arcgis.com/apps/webappviewer/index.html?id=dcf3981f1cc8408ba2adf2a4027a28e3

This project serves to update the Aquatic Plant Management aspects of the TLA's Plan by gathering and analyzing historical and current ecological data, identifying threats, determine the goals and values of stakeholders, present feasible management actions, and increase the lake group's capacity to implement the management plan. Fieldwork for this effort was conducted during the summer of 2021, with planning discussions and public outreach occurring during the winter and spring of 2022.

2.0 STAKEHOLDER PARTICIPATION

The overarching goal of every Onterra-led planning project is to create a realistic and implementable plan that will meet the needs of the lake group while keeping the lake as healthy as possible. To meet this goal, Onterra ecologists complete specific ecosystem studies on the waterbody to develop a full understanding of the lake. Onterra shares those results and our conclusions with the lake group as a whole, but also with a project-specific group called the planning committee. The planning committee is comprised of lake group members and at times, people from outside of the lake group. The planning committee acts as a focus group for the development of the management plan and is Onterra's primary point-of-contact during the project. The members of the planning committee develop a deep understanding of their lake as a part of their involvement in the process, which allows them to make good management decisions during the development of the plan and extends the life of the plan due to the core group's enhanced knowledge of the ecosystem.

The planners educate the planning committee 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 planning committee educate the planners by describing how they and their constituents would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter. The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

2.1 Strategic Planning Committee Meetings

Planning Committee Meeting I

On March 8, 2022, Eddie Heath of Onterra met virtually with the TLA Planning Committee for nearly 4 hours. Also in attendance were Scott Van Egeren and Ty Krajewski (WDNR), Adam Ray (GLIFWC), and Celeste Hockings (Lac du Flambeau Tribe). In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. Study components mainly including aquatic plant inventories and aquatic invasive plant study results. Topics of AIS management philosophies, aquatic herbicide research, best management practices, and integrated pest management were highlighted.

Planning Committee Meeting II

On April 12, 2022, Eddie Heath of Onterra met virtually with the TLA Planning Committee for over 3 hours. The focus of this meeting was to develop management goals and associated management actions to serve as the Implementation Plan Section (6.0). EWM management and alternatives analysis proceeded pointed discussion related to management goals and which actions could realistically lead to stated goals.

Planning Committee Meeting III

Based upon the discussion from previous planning meetings, a draft Implementation Plan Section (5.0) was created by Onterra and sent to the planning committee. Written comments were provided

back to Onterra, included multiple back-and-forth email correspondence on the topic of developing a trial herbicide treatment program. In addition, the TLA Planning Committee met virtually on May 4, 2022 for over 2 hours methodically going through each management action contained within the draft Implementation Plan Section (5.0).

The TLA requested more information on EWM herbicide management and monitoring programs, as well as discussion on a relatively newer herbicide, ProcellaCOR. On May 17, 2022, Eddie Heath of Onterra met virtually with the TLA Planning Committee for approximately 2 hours going through the most recent and relevant data on these subjects.

2.2 Management Plan Review and Adoption Process

On June 9, 2022, an early draft of the complete Aquatic Plant Management Plan was provided to the TLA Planning Committee and TLA Board of Directors for review. Comments were aggregated by the TLA Planning Committee Chair and provided to Onterra. These comments were addressed to result in the Official First Draft.

On June 17, 2022, the Official First Draft of the TLA's Aquatic Plant Management Plan for Tomahawk Lake was supplied to WDNR (lakes and fisheries programs), Oneida County, Great Lakes Indian Fish and Wildlife Commission, and Lac du Flambeau Tribe to solicit comments. At that time the Official First Draft was posted to the TLA website for public review, with outreach efforts requesting riparians to provide comments. The posting remained active until being replaced with the finalized version (in access of 21-day public comment period required). Comments were directed to be sent to lakehealth@tomahawklake.org.

During the TLA's annual meeting held at the Kemp Natural Resources Station on June 18, 2022, Eddie Heath of Onterra presented draft Implementation Plan developed by the TLA Planning Committee, supporting information the TLA Planning Committee used to arrive at this plan, and answered questions from the audience. Forty-one individuals were present at the meeting, with an additional 26 people viewing the live-stream via the TLA's Zoom Link. This meeting further alerted the TLA and Tomahawk Lake riparians of the draft Plan's existence on the web (onscreen QR code during presentation) and the fact that written comments are welcomed at this time.

While many questions were addressed at the Wrap-Up Meeting from attendees, no written comments were received from the general public nor entities other than the WDNR Lakes program. Scott Van Egeren provided comment related to grant applicability on 10/19/2022. Scott Van Egeren provided additional comment on 12/14/2022 as it relates to technical merit and that the materials meet the deliverables described in the three WDNR Surface Water Planning Grants that provided cost-share funding for this project. Applicable comments have been addressed within the Comment-Response Document included as Appendix E.

2.3 Riparian Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners and Tomahawk Lake Association (TLA) members. The survey was designed by Onterra staff and the TLA planning committee. The stakeholder survey design also considered questions asked during a 2014 stakeholder survey effort, allowing for comparisons of response data over time. The final

stakeholder survey was reviewed and approved by a WDNR social scientist to ensure that the questions were not misleading or biased.

During the winter of 2021-2022, the 10-page, 42-question survey was posted onto an online platform (Survey Monkey) for property owners to answer electronically. A postcard was sent to the sample population inviting their participation in the survey. The postcard included a unique code to ensure only one survey could be completed per household. The postcard also had an option for the stakeholder to request a paper copy to be sent directly to them, along with a self-addressed stamped envelope for returning the survey anonymously. A reminder postcard with much of the same information on the first postcard was sent out a couple weeks later. After receiving a low response rate, an extra reminder postcard and e-mail was sent out in January 2022 and the survey closing date was extended for another few weeks.

Of the 446 surveys distributed, 184 (41%) of the surveys were completed. In instances where stakeholder survey response rates are 60% or above, the results can generally be interpreted as being a statistical representation of the population. While the survey response rate may not be sufficient to be a statistical representation of the TLA/Tomahawk Lake riparians, the TLA believe the sentiments of the respondents is sufficient to provide an indication of riparian preferences and concerns. Said another way, these are the best quantitative data the TLA has to help understand stakeholder's opinions and will couple the results with other communications to determine which management actions to pursue moving forward.

The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people who use and care for the Tomahawk Lake system. Approximately 66% of respondents have owned their lake property for over 10 years (Figure 2.3-1).

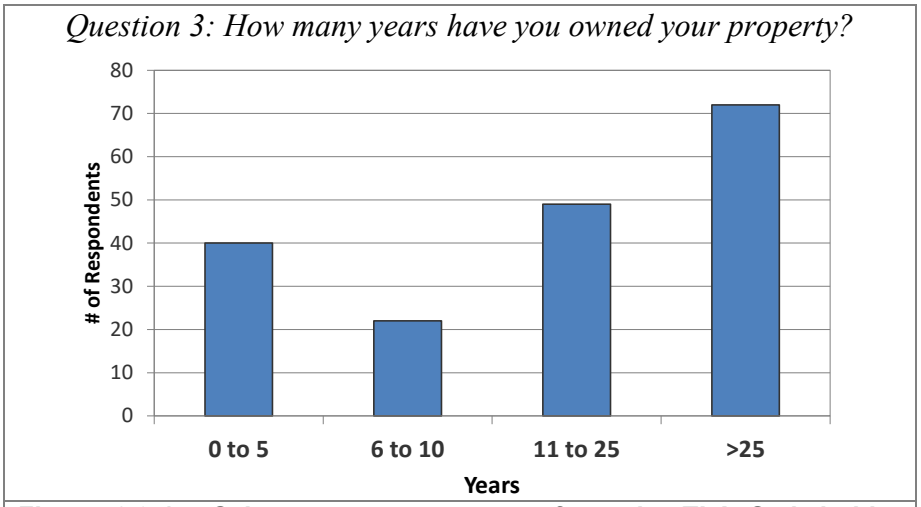
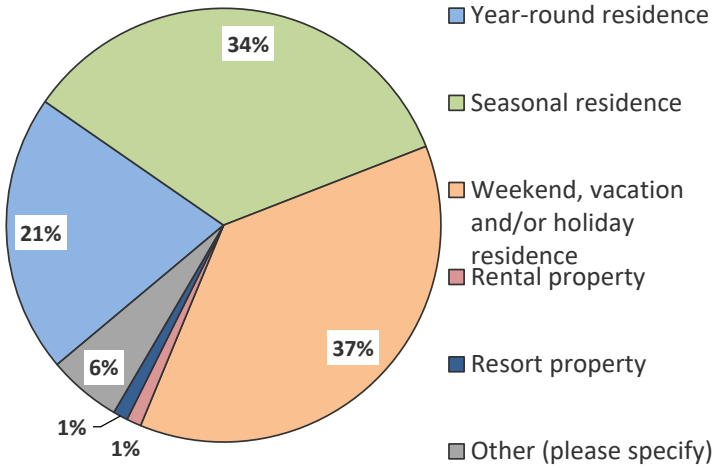


Figure 2.3-1. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Approximately 21% of stakeholder respondents live on the system year-round, while 34% use their property as a seasonal residence, 37% use it as a vacation home, and the remaining 8% have other uses (Figure 2.3-2, left). Approximately 81% of respondents use their property for 210 days or less a year (Figure 2.3-2, right).

Question 4: How is your property on or near the lake used?



Question 5: How many days each year is your property used by you or others?

Category (# of days)	Responses	%
0 to 30	12	7%
31 to 90	60	33%
91 to 120	42	23%
121 to 210	34	19%
211 to 300	9	5%
301 to 365	26	14%

Figure 2.3-2. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Relaxing/entertaining was the highest ranked activities when riparians were asked why they own property on the Tomahawk Lake system (Figure 2.3-3). Riparian respondents also ranked *boating, fishing,* and *nature viewing* as top reasons they choose to be on the system.

Question 9: Please rank up to three activities that are important reasons for owning or renting your property on or near the Tomahawk Lake system.

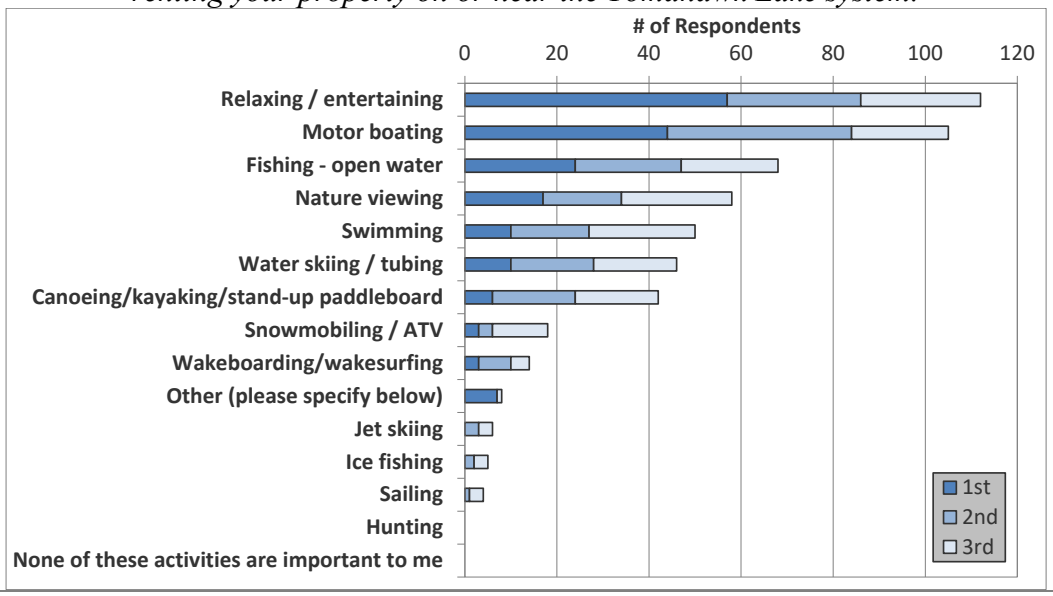


Figure 2.3-3. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Even though silent sports such as *canoeing/kayaking/paddle boarding* were ranked by respondents as the 7th highest activity on the Chain (Figure 2.3-3), 67% of respondents indicated they use that type of watercraft on the lakes (Figure 2.3-4). Approximately 63% of survey respondents indicated they use a pontoon boat and 71% indicated that they use a motor boat with greater than 25 hp motor.

Question 14: What types of watercraft do you currently use on the Tomahawk Lake system?

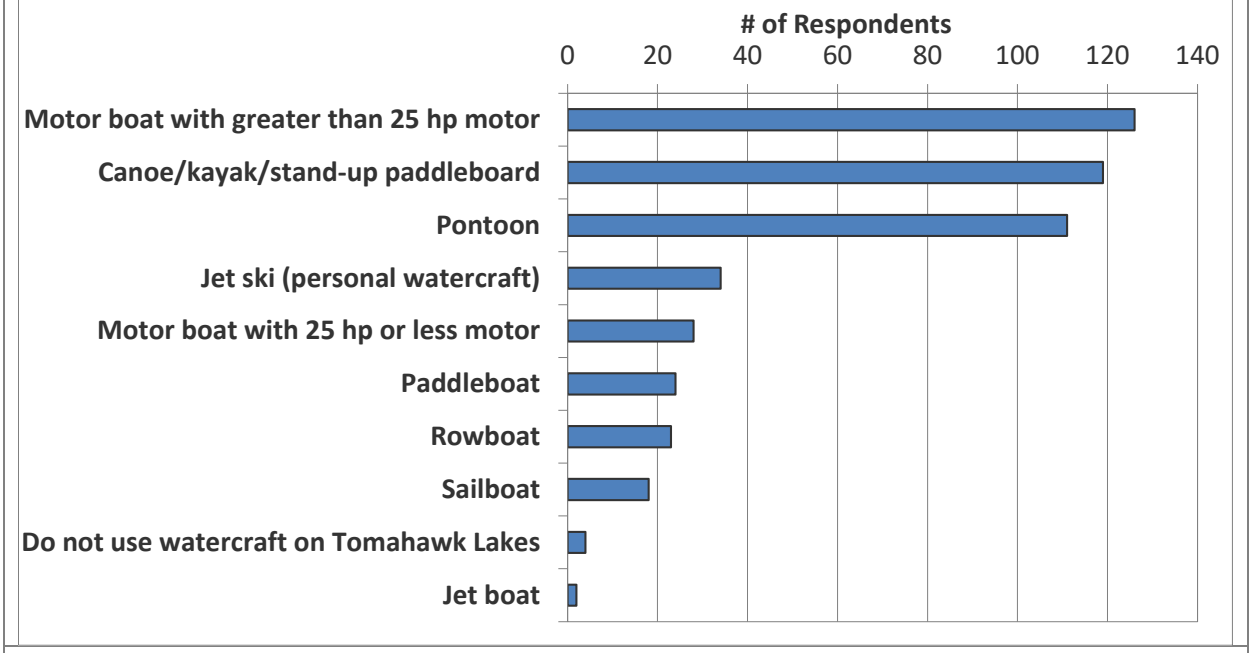


Figure 2.3-4. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.0 AQUATIC PLANTS

3.1 Primer on Aquatic Plant Data Analysis & Interpretation

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

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) have been conducted on the majority of the waterbodies within the Tomahawk Lake system in 2007, 2014, and 2021. Table 3.1-1 displays the point-intercept survey spacing and total number of sampling points for each of the waterbodies within the system. 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.

Table 3.1-1. Tomahawk Lake System point-intercept resolutions.

Lake	Distance Between Sampling Points (meters)	Number of Sampling Locations
Tomahawk Lake	58	4149
Little Tomahawk Lake	35	536
Tomahawk Thoroughfare	58	134
Mud Lake	35	89
Paddle Pond	25	27
Inkwell Lake	35	43

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

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in the Tomahawk Lake system during 2021. 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 the Tomahawk Lake system to be compared to other lakes within the region and state.

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

The Tomahawk Lake system 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.

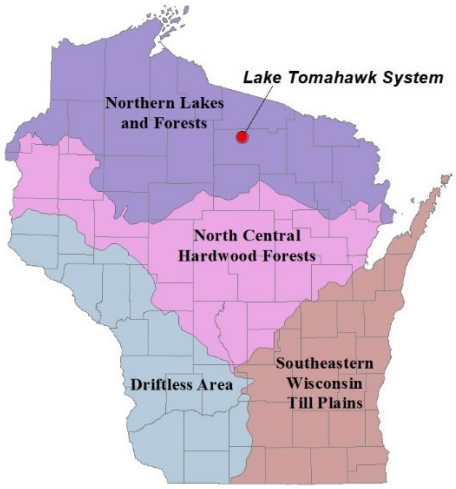


Figure 3.1-1. Location of Tomahawk Lake System within the ecoregions of Wisconsin. After Nichols 1999.

Species Diversity

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

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. Some managers believe a lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan 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 the Tomahawk Lake System is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forests (lakes only, does not include flowages) Ecoregion and on 392 lakes throughout Wisconsin.

3.2 Tomahawk Lake System Aquatic Plant Survey Results

Whole-lake point-intercept surveys have been completed on the Tomahawk Lake System in 2005, 2007, 2014, and 2021. Little Tomahawk Lake was the only waterbody sampled during 2005, whereas the remaining lakes in the system were first sampled in 2007. All lakes in the system were surveyed in 2014 as a component of a lake management planning effort. Each lake was sampled once again in 2021 as a part of this project that will result in an update to the lake management plan. This report will highlight the 2021 point-intercept survey results from each of the waterbodies in the system and will integrate comparisons to the previous surveys throughout the section. Since minimal aquatic plants are present within Paddle Pond and Inkwell Lake, these waterbodies are excluded from some of the subsequent figures and analysis.

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

A total of 62 aquatic plant species were recorded in the Tomahawk Lake System during the 2021 point-intercept survey. Of these 62 species, common waterweed (*Elodea canadensis*), fern pondweed (*Potamogeton robbinsii*), coontail (*Ceratophyllum demersum*), and slender/southern naiads (*Najas flexilis & Najas guadalupensis*), were the most frequently encountered (Photo 3.2-1 and 3.2-2). Five non-native species were documented during the 2021 survey including Eurasian watermilfoil, curly-leaf pondweed, pale-yellow iris, purple loosestrife, and flowering rush. Because of their ecological, economical, and sociological significance, the non-native plants and their management in the Tomahawk Lake System is discussed in the subsequent *Non-Native Aquatic Plants in Tomahawk Lake System* subsection (3.3).

Table 3.2-1 displays all of the 62 species that were documented during the 2021 point-intercept survey on the Tomahawk Lake System. The table excludes Paddle Pond and Inkwell Lake due to these waterbodies containing almost no vegetation in 2021. Table 3.2-1 is organized by growth form which separates out species based on whether they are emergent species, floating-leaf species, submergent species, or free-floating species. Species with an "X" on the table indicate that the species was physically encountered on the survey rake during the point-intercept survey. Additional species are known to be present within the lake, however this table only accounts for those that were sampled on the survey rake and does not account for species that were only visually

observed. Examples of other species that are known to be present in the waterbodies, but were not sampled on the survey rake often include species growing on the shoreline of the lake such as purple loosestrife, iris species, or flowering rush. Species that are present in low amounts in the system can also sometimes not be detected by the point-intercept survey methodology.

Table 3.2-1. Aquatic plant species located in 2021 point-intercept surveys in the Lake Tomahawk System. Table excludes Inkwell Lake and Paddle Pond which have minimal vegetation present.

Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	Growth Form	Tomahawk 2021	Little Tomahawk 2021	Thoroughfare 2021	Mud 2021
Eleocharis palustris	Creeping spikerush	Native	6	E			X	
Pontederia cordata	Pickerelweed	Native	9	E	X	X	X	
Brasenia schreberi	Watershield	Native	7	FL	X	X	X	X
Nuphar variegata	Spatterdock	Native	6	FL	X		X	X
Nymphaea odorata	White water lily	Native	6	FL	X	X	X	X
Sparganium angustifolium	Narrow-leaf bur-reed	Native	9	FL		X		
Sparganium fluctuans	Floating-leaf bur-reed	Native	10	FL	X			
Bidens beckii	Water marigold	Native	8	S	X	X	X	X
Ceratophyllum demersum	Coontail	Native	3	S	X	X	X	X
Ceratophyllum echinatum	Spiny hornwort	Native	10	S			X	
Chara spp.	Muskgrasses	Native	7	S	X	X	X	X
Elatine minima	Waterwort	Native	9	S	X			
Elodea canadensis	Common waterweed	Native	3	S	X	X	X	X
Elodea nuttallii	Slender waterweed	Native	7	S	X		X	
Heteranthera dubia	Water stargrass	Native	6	S	X	X	X	
Isoetes spp.	Quillwort spp.	Native	8	S	X			
Lobelia dortmanna	Water lobelia	Native	10	S	X			
Myriophyllum alterniflorum	Alternate-flowered watermilfoil	Native	10	S	X			
Myriophyllum sibiricum	Northern watermilfoil	Native	7	S	X	X	X	X
Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	S	X	X	X	
Myriophyllum tenellum	Dwarf watermilfoil	Native	10	S	X	X		
Najas flexilis	Slender naiad	Native	6	S	X	X	X	
Najas guadalupensis	Southern naiad	Native	7	S	X	X	X	X
Nitella spp.	Stoneworts	Native	7	S	X		X	
Potamogeton alpinus	Alpine pondweed	Native	9	S			X	
Potamogeton amplifolius	Large-leaf pondweed	Native	7	S	X	X	X	X
Potamogeton berchtoldii	Slender pondweed	Native	7	S	X			
Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	S			X	
Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	S			X	
Potamogeton foliosus	Leafy pondweed	Native	6	S	X	X	X	
Potamogeton friesii	Fries' pondweed	Native	8	S	X	X		X
Potamogeton gramineus	Variable-leaf pondweed	Native	7	S	X	X	X	
Potamogeton hybrid 1	Pondweed Hybrid 1	Native	N/A	S	X			
Potamogeton illinoensis	Illinois pondweed	Native	6	S	X	X	X	
Potamogeton natans	Floating-leaf pondweed	Native	5	S	X		X	
Potamogeton praelongus	White-stem pondweed	Native	8	S	X	X	X	
Potamogeton pusillus	Small pondweed	Native	7	S	X	X	X	
Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	S	X	X	X	
Potamogeton robbinsii	Fern-leaf pondweed	Native	8	S	X	X	X	X
Potamogeton spirillus	Spiral-fruited pondweed	Native	8	S	X			
Potamogeton strictifolius	Stiff pondweed	Native	8	S	X			X
Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	S			X	
Potamogeton zosteriformis	Flat-stem pondweed	Native	6	S	X	X	X	X
Ranunculus aquatilis	White water crowfoot	Native	8	S	X	X	X	
Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A	S	X	X		
Stuckenia pectinata	Sago pondweed	Native	3	S	X	X	X	
Utricularia intermedia	Flat-leaf bladderwort	Native	9	S				X
Utricularia minor	Small bladderwort	Native	10	S			X	X
Utricularia purpurea	Large purple bladderwort	Native	9	S	X	X		X
Utricularia vulgaris	Common bladderwort	Native	7	S	X		X	X
Vallisneria americana	Wild celery	Native	6	S	X	X	X	
Eleocharis acicularis	Needle spikerush	Native	5	S/E	X	X	X	
Juncus pelocarpus	Brown-fruited rush	Native	8	S/E	X			
Sagittaria cristata	Crested arrowhead	Native	9	S/E	X			
Schoenoplectus subterminalis	Water bulrush	Native	9	S/E	X			
Lemna minor	Lesser duckweed	Native	5	FF	X			
Lemna trisulca	Forked duckweed	Native	6	FF	X	X	X	
Spirodela polyrhiza	Greater duckweed	Native	5	FF	X		X	

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; FF = Free Floating; S= Submergent; E = Emergent
X = Located on rake during point-intercept survey

Common waterweed was the most frequently encountered aquatic plant in Tomahawk Lake, the Tomahawk Thoroughfare, Little Tomahawk Lake, and Mud Lake (Figure 3.2-1). Common waterweed can be found in waterbodies across Wisconsin, is tolerant of high-nutrient, low-light

conditions, and can grow to nuisance levels under ideal conditions. Common waterweed has blade-like leaves in whorls of three produced on long, slender stems. Like other submersed aquatic plants, common waterweed helps to stabilize bottom sediments and provides structural habitat and food for wildlife.

Coontail was another of the most frequently encountered aquatic plants in the Tomahawk Lake System in 2021 (Figure 3.2-1). As its name indicates, the shape of this plant resembles the tail of a racoon. Coontail possess whorls of leaves which fork into two to three segments, and provides ample surface area for the growth of periphyton and habitat for invertebrates. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives most of its nutrients directly from the water (Gross et al. 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in eutrophic waterbodies with higher nutrients and low water clarity. Coontail has the capacity to form dense beds that can float and mat on the water's surface.

Fern pondweed was one of the most abundant aquatic plant in the Tomahawk Lake System. As its name indicates, this plant resembles a terrestrial fern frond in appearance and is often a dominant species in plant communities of northern Wisconsin lakes (Photograph 3.2-1). Fern pondweed is generally found growing in thick beds over soft substrates where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. In the Lake Tomahawk System, fern pondweed was most often growing in water depths of approximately 7-13 feet.

Common waterweed	Coontail	Fern pondweed
		

Photograph 3.2-1. Common aquatic plant species found within the Tomahawk Lake System during the 2021 point-intercept surveys. Photograph credit Onterra.

Slender naiad is one of five naiad species that can be found in Wisconsin and is also the most common. Slender naiad is an annual, meaning it reproduces via seed each year. Ongoing monitoring of aquatic plant communities in Wisconsin is indicating that the occurrence of this species can be highly variable from year to year, likely due to changes in suitability for seed germination. The numerous seeds produced by slender naiad have been shown to be an important food source for wildlife, including migratory waterfowl.

Photograph 3.2-2. Slender naiad *Najas flexilis,* left frame*)* and Southern naiad (*N. guadalupensis,* right frame), two morphologically similar species commonly found within the Tomahawk Lake System. Photograph credit Onterra.

Though southern naiad is native to North America, it has been observed to be exhibiting aggressive growth in some northern Wisconsin lakes in recent years. In Big Sand Lake, Vilas County, southern naiad increased in occurrence to become one of the most abundant plant species in the lake between 2006 and 2016, increasing in littoral occurrence from <5% to 37%, respectively (Onterra 2017). It has since declined somewhat to a littoral occurrence of 27%, but remains one of the most abundant plants in the lake. Similarly, downstream from Big Sand Lake in Long Lake, southern naiad was first recorded in 2012 with a littoral occurrence of 1%. By 2017, it had become the most frequently encountered plant in the lake with a littoral occurrence of 29%. In nearby Mid Lake, southern naiad was one of the most commonly encountered species with littoral occurrences between 53-58% from 2013-2015 before populations dramatically declined in recent years with the latest survey in 2020 indicating an occurrence of just 5.5%.

The rapid population growth of southern naiad in some northern Wisconsin lakes has some ecologists questioning whether this species was historically present in these waterbodies or if it represents a recent introduction, likely via watercraft. While closely related to slender naiad, southern naiad is often perennial and lacking fruit (Les et al. 2010). Emerging research is indicating that hybrids between southern naiad subspecies exist and are often observed growing aggressively and reaching nuisance levels in certain lakes. Slender and southern naiad are morphologically similar, and distinguishing between them in the field is often difficult. Therefore, within the following analysis, the occurrences of slender and southern naiad are combined for analysis purposes when appropriate.

Past reports have referenced a focused study in 2014-2015 within the Thoroughfare or the Thoroughfare Bay of Tomahawk Lake that investigated the population of southern naiad specifically as this species causes nuisance conditions at times.

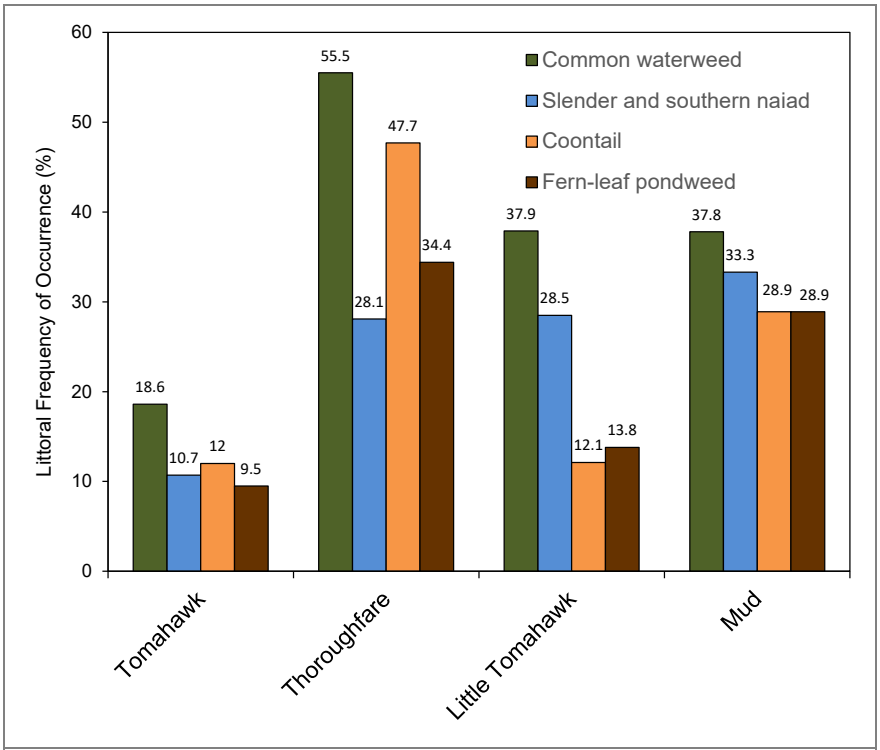


Figure 3.2-1. Frequency of occurrence at littoral depths for common native aquatic plant species within Tomahawk Lake, Tomahawk Thoroughfare, Little Tomahawk Lake, and Mud Lake within the Tomahawk Lake System. Created using data from July 2021 aquatic plant point-intercept survey. Inkwell Lake and Paddle Pond excluded from this analysis.

Vasey's pondweed was located at three sampling locations within the Tomahawk Thoroughfare during the 2021 survey (Photograph 3.2-3). Vasey's pondweed is listed as special concern by the WDNR Natural Heritage Inventory Program due to "a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Wisconsin Natural Heritage Program 2016). Vasey's pondweed requires high-quality conditions to survive, and its presence in these lakes is indicative of high-quality environmental conditions.

Photograph 3.2-3. Vasey's pondweed, a native plant species listed as special concern in Wisconsin. Photograph credit Onterra.

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. The native aquatic plant species located on the rake during the point-intercept surveys in 2021 and their conservatism values were used to calculate the FQI for each waterbody within the system.

Using the species richness and average conservatism to calculate the Floristic Quality Index for the Tomahawk Lake System reveals exceptionally high values for Tomahawk Lake, the

Thoroughfare, and Little Tomahawk Lake (Figure 3.2-2). The FQI of Mud Lake of 29.7 is slightly below the ecoregion median and slightly above the state median. A comparison of these metrics to previous surveys on a lake-by-lake basis are discussed below within each waterbody's individual report section.

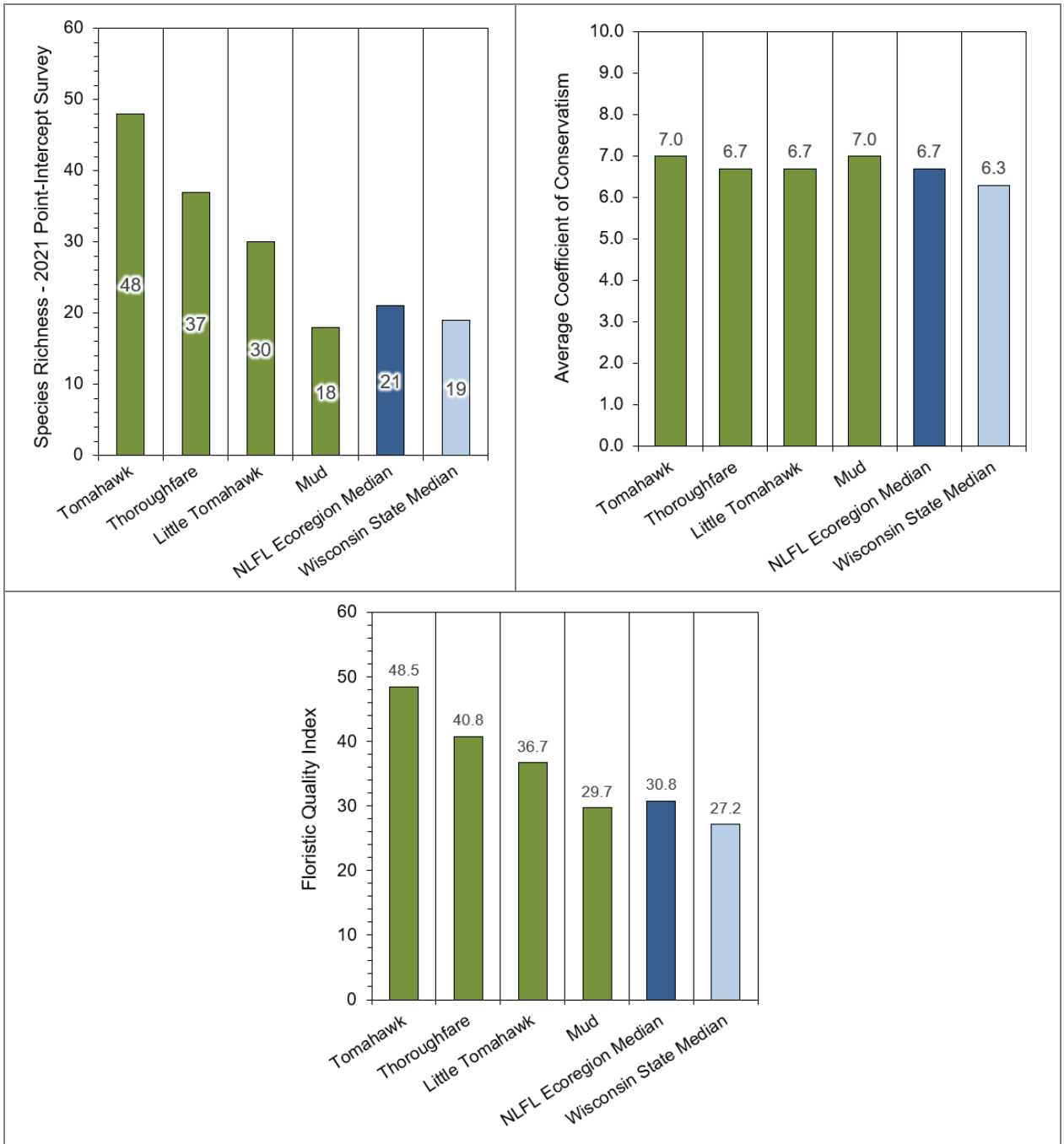


Figure 3.2-2. Species richness (upper left frame) average coefficient of conservatism (upper right frame) and floristic quality index (FQI) in the Tomahawk Lake System. Created using data from July 2021 point-intercept surveys.

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 the Tomahawk Lake System's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.2-3). Using the data collected from the whole-lake point-intercept surveys, each of the four main component waterbodies of the Tomahawk Lake System have aquatic plant species diversity values that are above the 75th percentile for lakes in the NLFL ecoregion.

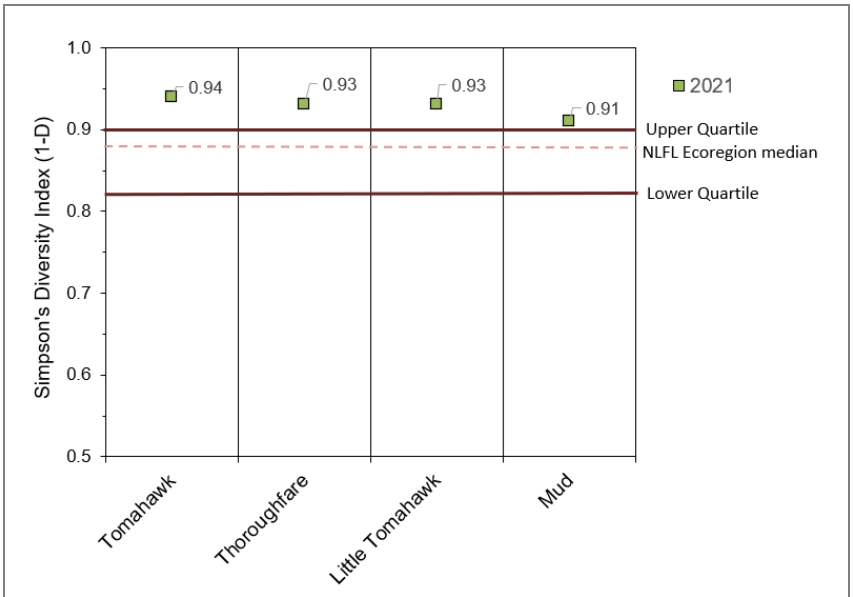


Figure 3.2-3. Simpson's Diversity Index for the Tomahawk Lake System from the 2021 point-intercept surveys.

The WDNR has a process by which Critical Habitat Designations are determined based on meeting criteria including public rights features such as wildlife or fish habitat, physical features that ensure the protection of water quality, stretches of predominantly natural shorelines, or navigational thoroughfares or if they have designated Sensitive Areas. In recent years, the WDNR has lacked the resources to evaluate Critical Habitat Areas around the state. One of the Tomahawk Lake System's previous projects included a survey of the shoreland areas around the lakes and a determination of critical habitat areas (Nova Ecological Services, 2020). Although these areas have not been officially designated as critical habitat areas by the WDNR, similar elements were evaluated during the shoreland survey to identify sites on the system that offer these valuable characteristics. More information on Critical Habitat and Shoreland Assessment can be found here:

https://www.tomahawklake.org/comprehensive-lake-management-plan/

An evaluation of the species richness recorded in the 2021 point-intercept surveys on the Tomahawk Lake System identifies areas in the system that have diverse aquatic plant communities. Map 2 displays the species richness values from each of the 2021 point-intercept survey locations in relation to locations identified by Nova Ecological Services as advisory Critical Habitat designations. The Tomahawk Thoroughfare area is an example of where high species richness is present within site TL-1 from the 2020 shoreland survey. This site was chosen as a critical habitat area in part due to its diverse aquatic plant community.

Tomahawk Lake

The Tomahawk Lake portion of the Lake Tomahawk System makes up the majority of the water in the project waters at approximately 3,492 acres. Total rake fullness values from the 2021 point-intercept survey are displayed on Figure 3.2-4. These data represent the aquatic plant biomass at each sampling location and does not differentiate between native or non-native vegetation. Some of the greatest amount of plant biomass in the 2021 survey was found in a few locations along the western shoreline of the lake, and the far eastern end of the lake. Extensive beds of Eurasian watermilfoil in these locations contribute to the plant biomass.

A total of 48 native aquatic plant species were sampled during the 2021 point-intercept survey in Tomahawk Lake with common waterweed (18.6%), coontail (12.0%), and variable-leaf pondweed (10.7%), being the most commonly encountered native species (Figure 3.2-5). Eurasian watermilfoil was the second-most frequently encountered species within the lake with an occurrence of 17.4%. A total of 18 native aquatic plant species exhibited a littoral frequency of occurrence of at least 2% in Tomahawk Lake in the 2021 survey, while another 30 species were present in lesser amounts and not displayed on Figure 3.2-5.

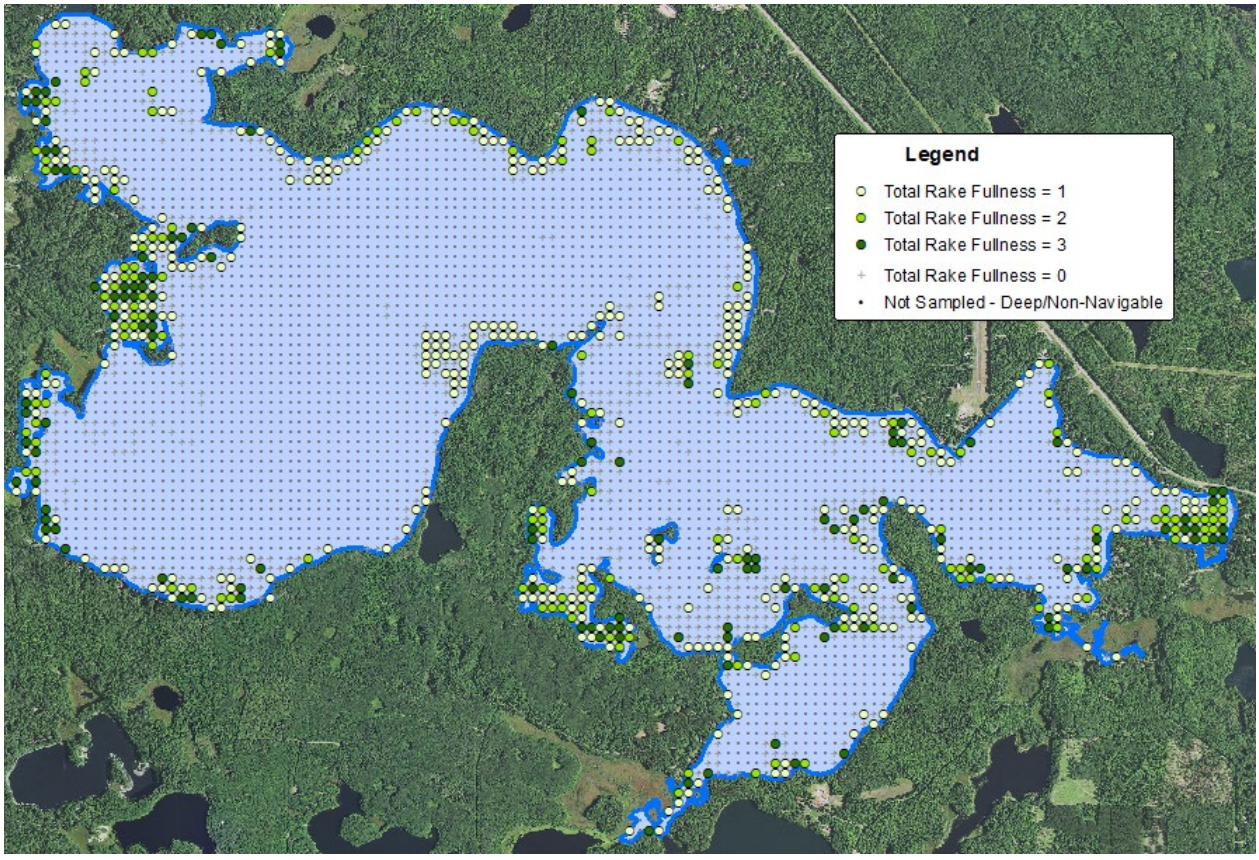


Figure 3.2-4. Tomahawk Lake aquatic plant total rake fullness (TRF) ratings. Created using data from July 2021 point-intercept survey.

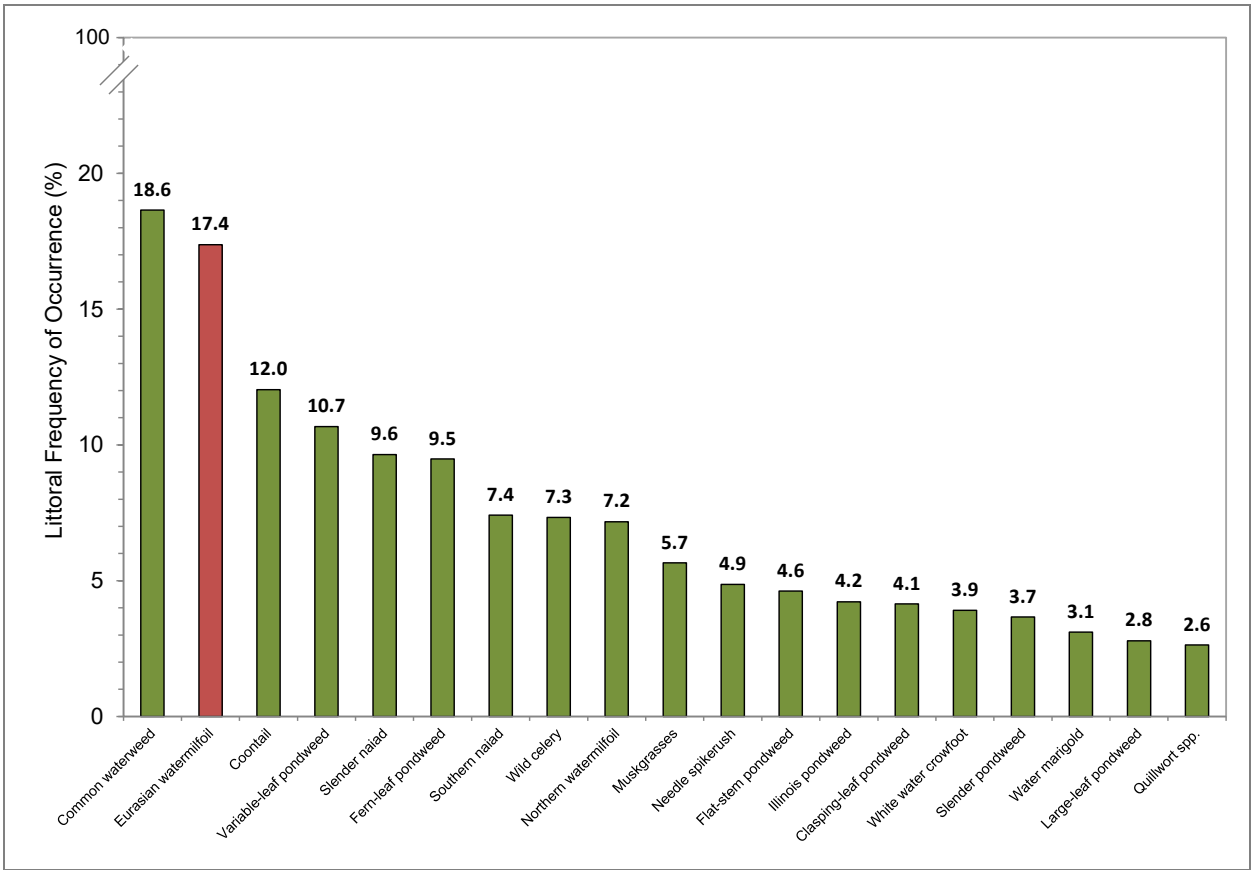


Figure 3.2-5. Tomahawk Lake aquatic plant littoral frequency of occurrence. Created using data from July 2021 point-intercept survey. Only species with an occurrence >2% are displayed.

Point-intercept surveys have also taken place in Tomahawk Lake during 2007 and 2014 and these data are comparable to the 2021 survey. A comparison of these surveys allows for detecting changes in the aquatic plant community over time. The average number of native species per sampling location within the littoral zone of the lake was greatest in 2005 at 3.04 species per sampling point. The 2021 survey found 1.38 species per site which was slightly lower than the 1.61 species documented in the 2014 survey and 1.45 species per site in 2007 (Figure 3.2-6).

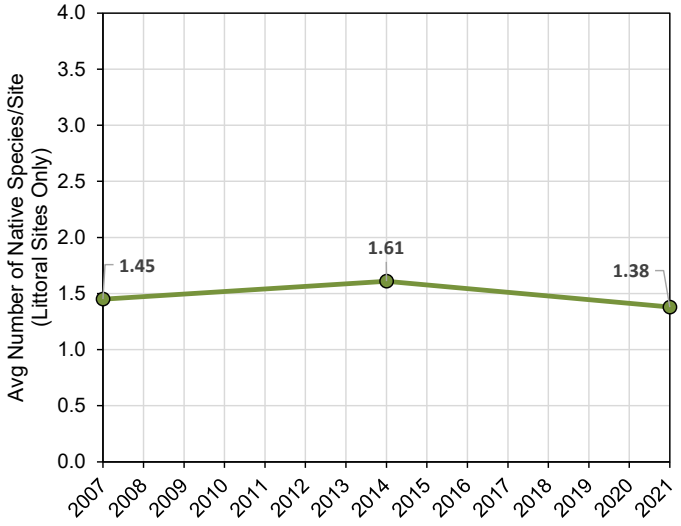


Figure 3.2-6. Average number of native aquatic plant species within the littoral areas of Tomahawk Lake within the Tomahawk Lake System from 2007, 2014, and 2021 point-intercept surveys.

Figure 3.2-7 compares the littoral frequency of select occurrence of aquatic plant species in Tomahawk

Lake from each of the three point-intercept surveys. A statistically valid change in occurrence from one survey to the next is indicated with a red asterisk on the figure.

Many species saw statistically valid changes in occurrence between the 2014 and 2021 surveys. Three native species saw valid increases in occurrence including common waterweed, wild celery, and muskgrasses while eight native species exhibited statistically valid decreases in occurrence from 2014 to 2021 including fern pondweed, slender naiad, coontail, northern watermilfoil, slender/small pondweed, flat-stem pondweed, large-leaf pondweed, and clasping-leaf pondweed. The occurrence of EWM increased dramatically from 2.8% occurrence in 2014 to 17.4% in 2021.

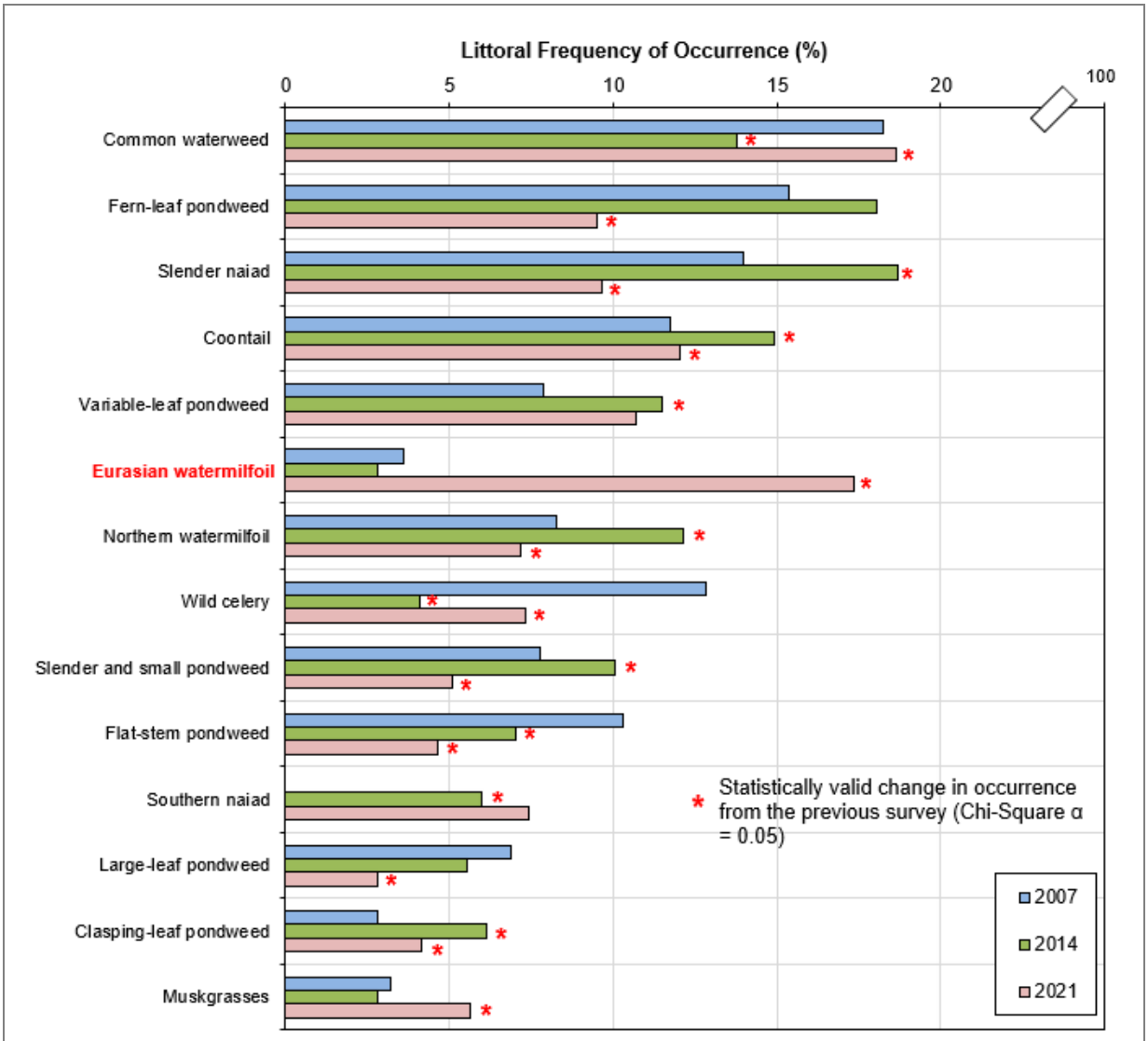


Figure 3.2-7. Tomahawk Lake littoral frequency of occurrence from 2007, 2014, and 2021 point-intercept surveys. Includes all aquatic plant species, both native and non-native.

One way to visualize the diversity of a lake's plant community is to examine the relative frequency of occurrence of aquatic plant species (Figure 3.2-8). Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. Figure 3.2-8 displays the relative frequency of occurrence of aquatic plant species from each of

the three point-intercept surveys in Tomahawk Lake. These data indicate that some species such as fern pondweed and slender naiad comprised higher portion of the relative frequency in 2007 and 2014 as compared to 2021. Southern naiad was not sampled in the 2007 survey and has expanded to account for 4.8% of the relative frequency in 2021. Eurasian watermilfoil comprised 2.4% of the relative frequency in 2007 and 1.7% in 2014 before expanding in 2021 to 11.2%.

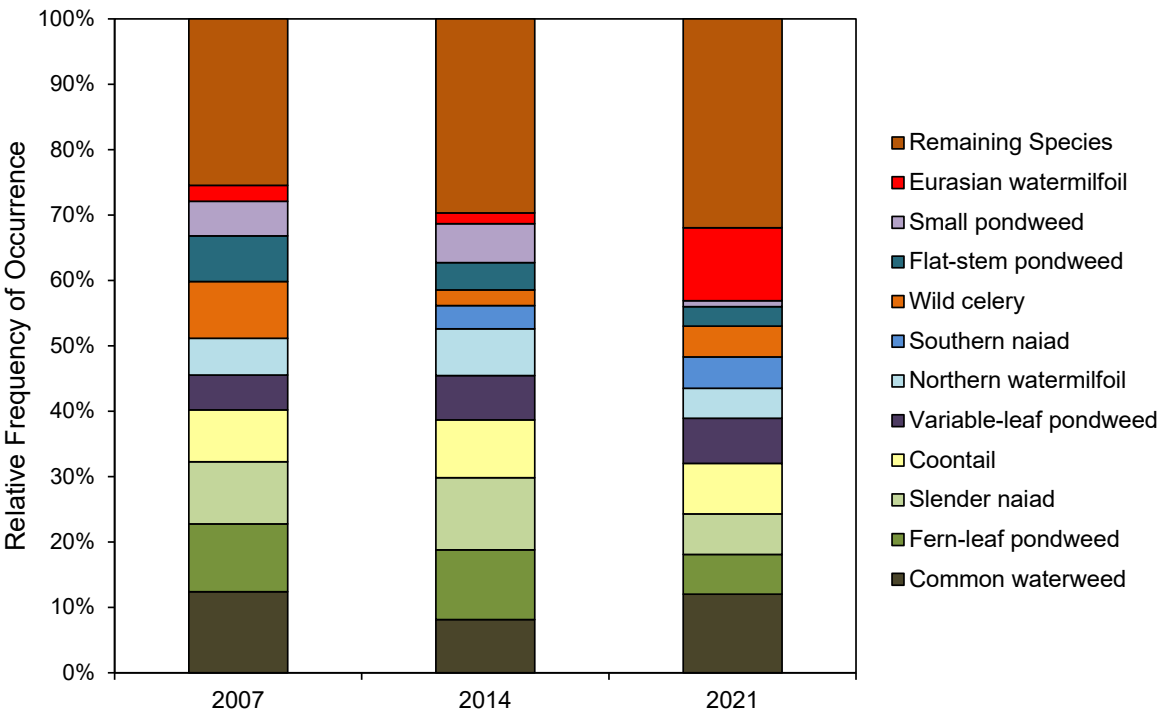


Figure 3.2-8. Relative frequency of occurrence of aquatic vegetation in Tomahawk Lake. Created using data from 2007, 2014, and 2021 point-intercept surveys.

A comparison of the species richness, average conservatism, and floristic quality from each of the three point-intercept surveys in Tomahawk Lake is displayed on Figure 3.2-9. In the 2021 point-intercept survey, the total richness was 48 compared to 47 in 2014 and 31 in 2007. Average conservatism values increased from 6.1 in 2014 to 7.0 in 2021. The floristic quality in Tomahawk Lake was 48.5 in 2021 which is higher than the 2007 and 2014 surveys and well above the ecoregion and state median values.

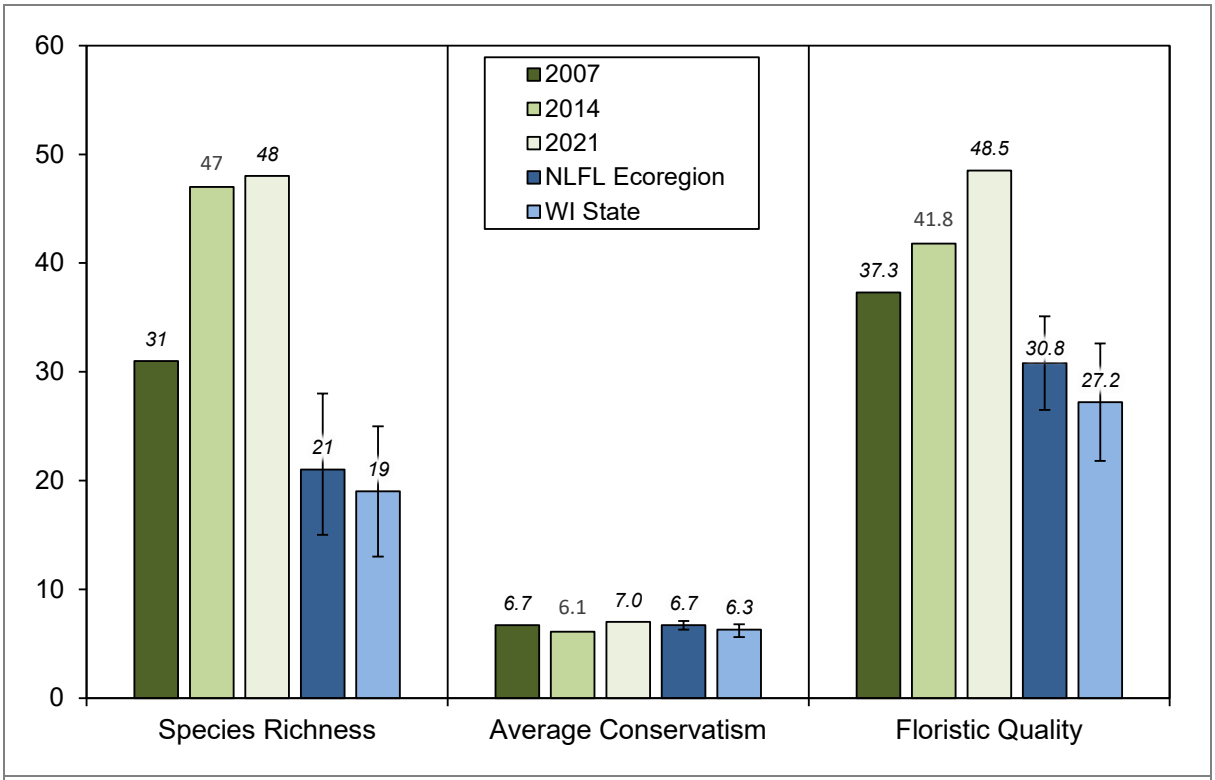


Figure 3.2-9. Tomahawk Lake Floristic Quality Index. Analysis follows (Nichols 1999).

Little Tomahawk Lake

Little Tomahawk Lake is a 163-acre basin that connects to Tomahawk Lake via a narrow channel on the southern end of the lake. Much of the Little Tomahawk Lake shoreline is surrounded by the American Legion State Forest. Of the 536 sampling points in Little Tomahawk Lake, 91 of them contained aquatic plants in the 2021 point-intercept survey (Figure 3.2-10 -inset). The maximum depth of vegetation growth in the 2021 survey was 18 feet.

A total of 30 native aquatic plant species were sampled during the 2021 point-intercept survey in Little Tomahawk Lake with common waterweed (37.9%) variable-leaf pondweed (23.3%), slender naiad (19.0%), and small pondweed (19.0%) and southern naiad (33.3%) being the most commonly encountered species (Figure 3.2-10). Eurasian watermilfoil was the second-most frequently encountered species within the lake with an occurrence of 30.2%.

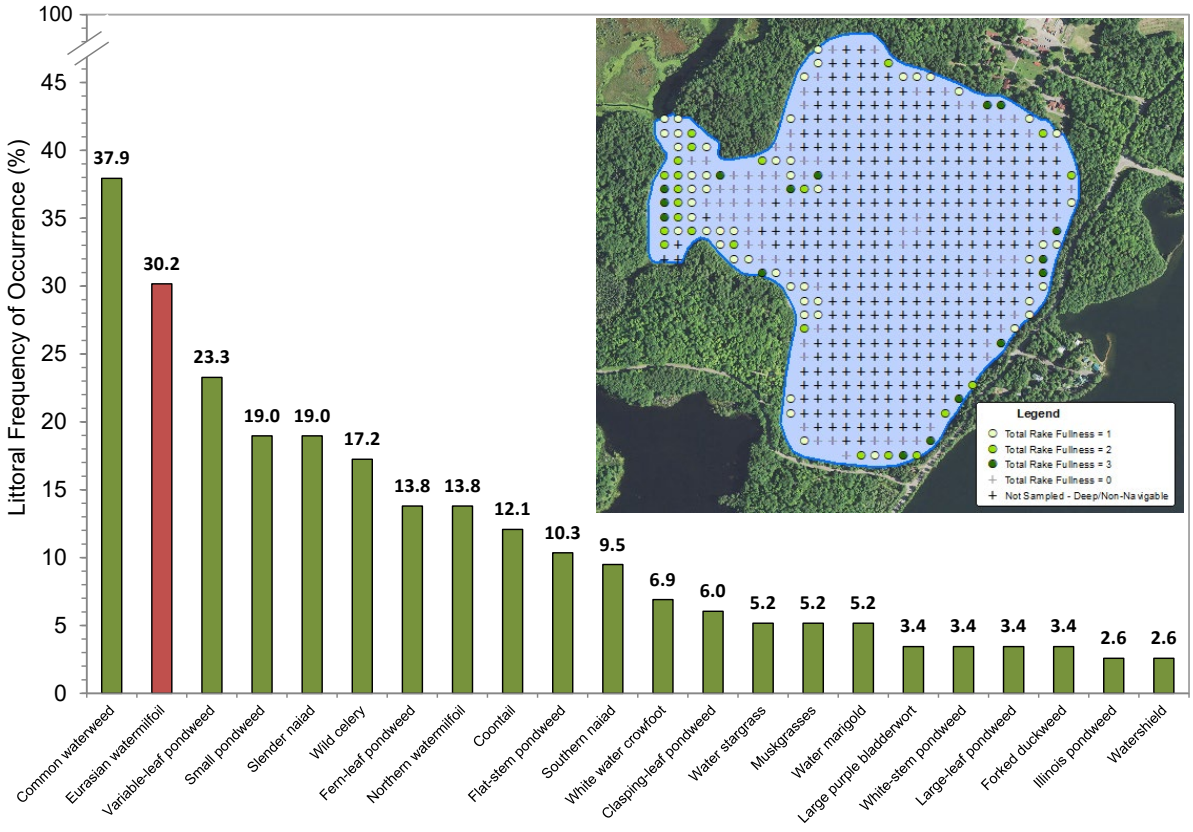


Figure 3.2-10. Little Tomahawk Lake aquatic plant littoral frequency of occurrence, vegetation distribution, and total rake fullness (TRF) ratings. Created using data from July 2021 point-intercept survey. Only species with an occurrence >2% are displayed.

Point-intercept surveys have also taken place in Little Tomahawk Lake during 2005 and 2014 and these data are comparable to the 2021 survey. A comparison of these surveys allows for detecting changes in the aquatic plant community over time. The average number of native species per sampling location within the littoral zone of the lake was greatest in 2005 at 3.04 species per sampling point. The 2021 survey found 2.65 species per site which was slightly above the 2.58 species documented in the 2014 survey (Figure 3.2-11).

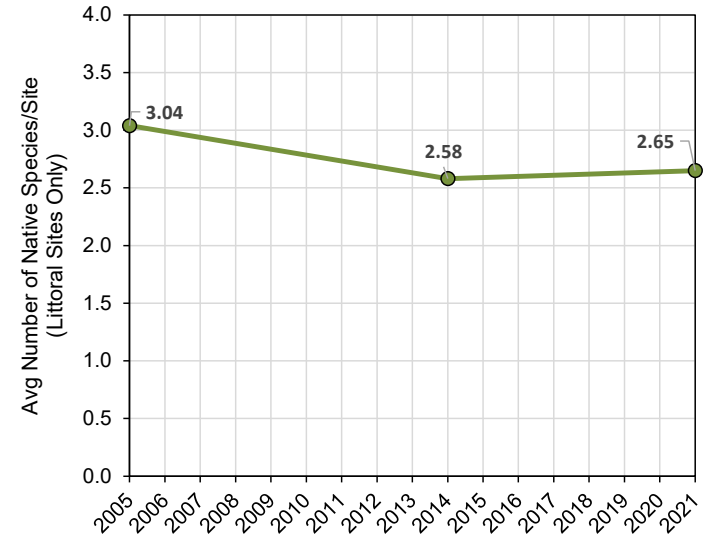


Figure 3.2-11. Average number of native aquatic plant species within the littoral areas of Little Tomahawk Lake within the Tomahawk Lake System from 2005, 2014, and 2021 point-intercept surveys.

Figure 3.2-12 displays the littoral frequency of occurrence of aquatic plant species in Little Tomahawk Lake from each of the three point-

intercept surveys. A statistically valid change in occurrence from one survey to the next is indicated with a red asterisk on the figure.

Four species exhibited a statistically valid decrease in occurrence between the 2014 and 2021 surveys including slender naiad, northern watermilfoil, water stargrass, and stiff pondweed. Four other species exhibited a statistically valid increase between the two survey and include common waterweed, southern naiad, white water crowfoot, and Eurasian watermilfoil.

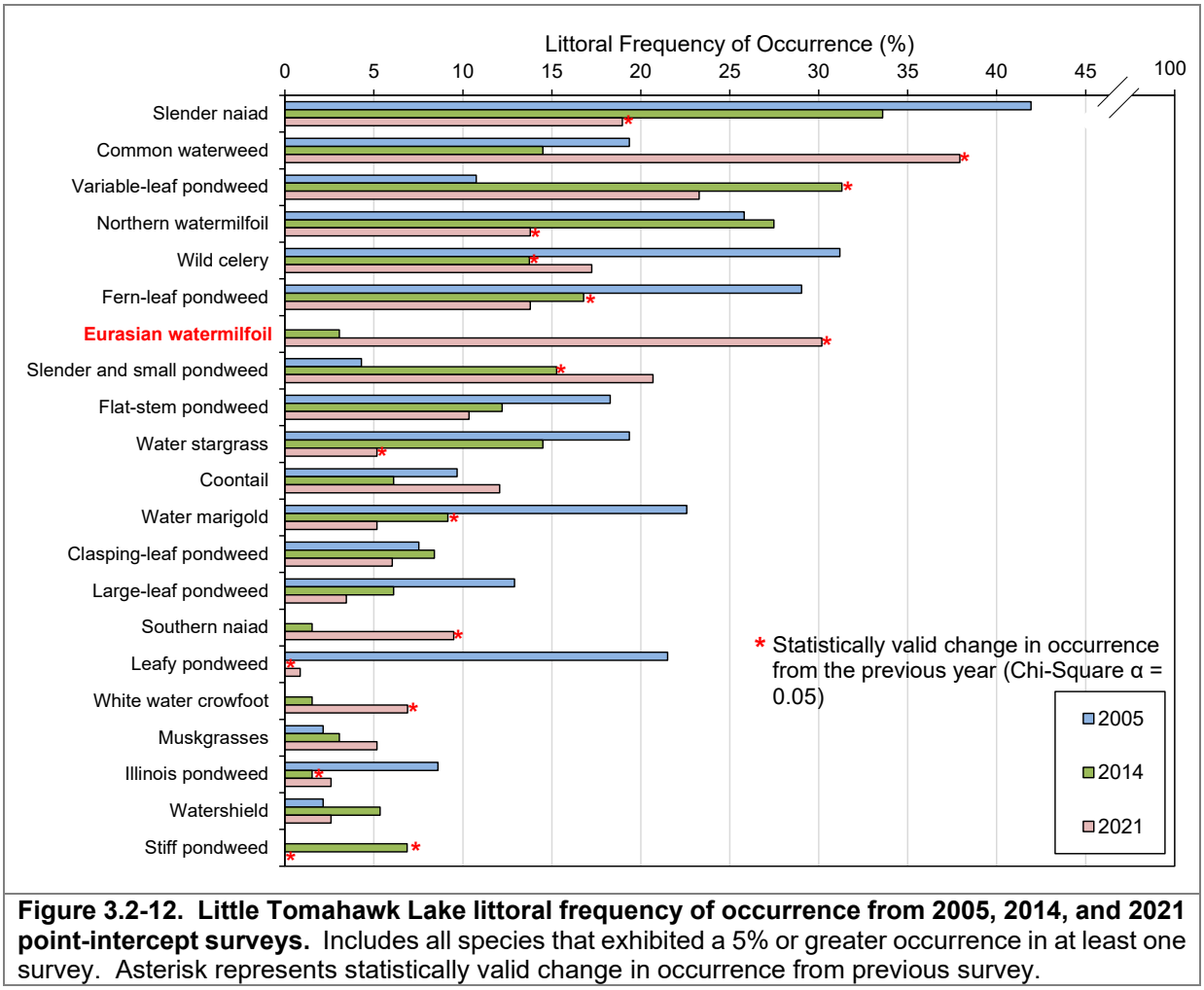


Figure 3.2-12. Little Tomahawk Lake littoral frequency of occurrence from 2005, 2014, and 2021 point-intercept surveys. Includes all species that exhibited a 5% or greater occurrence in at least one survey. Asterisk represents statistically valid change in occurrence from previous survey.

Figure 3.2-13 displays the relative frequency of occurrence of aquatic plant species from each of the three point-intercept surveys. These data show fairly consistent relative frequency values for the most common species in the lake including slender naiad, common waterweed, variable-leaf pondweed, northern watermilfoil, wild celery, and fern pondweed. These six species comprise approximately half of the aquatic plant population in Little Tomahawk Lake. Eurasian watermilfoil was not sampled during the 2005 survey and increased to 1.2% in 2014 and increased further to 11.2% relative frequency in 2021.

A comparison of the species richness, average conservatism, and floristic quality from each of the three point-intercept surveys in Little Tomahawk Lake is displayed on Figure 3.2-14. In the 2021 point-intercept survey, the total richness was 30 compared to 34 in 2014 and 28 in 2005. Average

conservatism values increased from 6.2 in 2005 to 6.6 in 2014 and 6.7 in 2021. The floristic quality in Little Tomahawk Lake was 36.7 in 2021, and has been above the ecoregion and state median value in each of the three surveys.

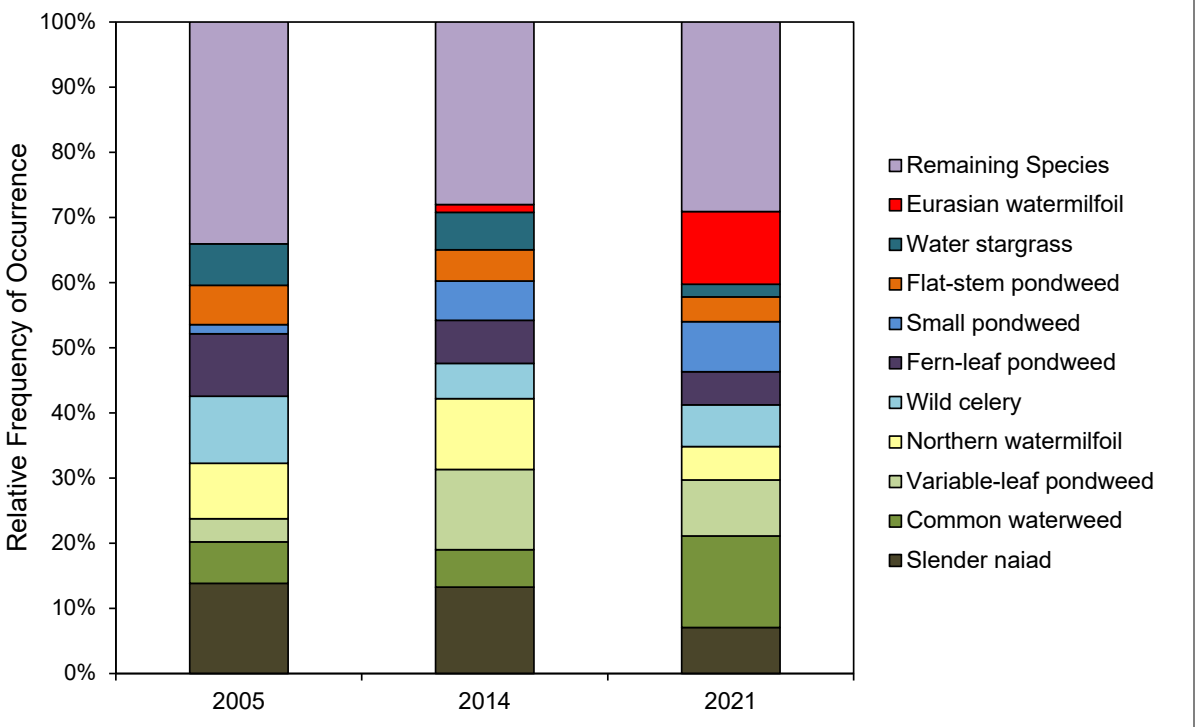


Figure 3.2-13. Relative frequency of occurrence of aquatic vegetation in Little Tomahawk Lake. Created using data from 2005, 2014, and 2021 point-intercept surveys.

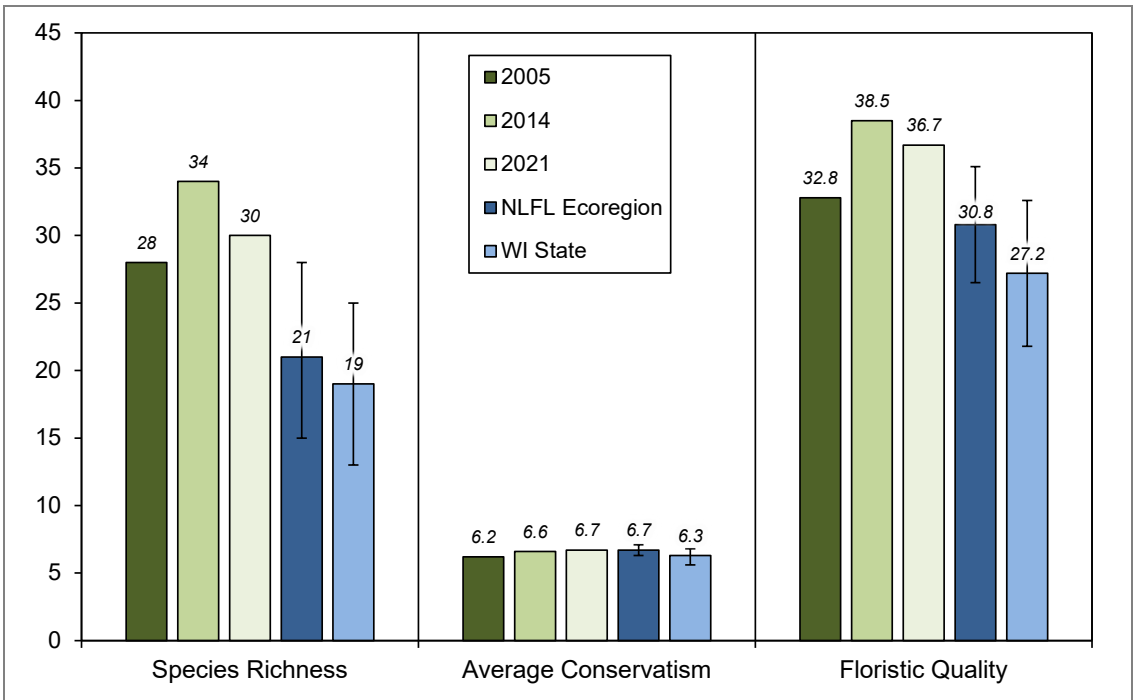


Figure 3.2-14. Little Tomahawk Lake Floristic Quality Index. Analysis follows (Nichols 1999).

Tomahawk Thoroughfare

The Tomahawk Thoroughfare includes the river channel that connects the Tomahawk Lake System to the Minocqua Chain to the north. Of the 134 sampling points in the Thoroughfare, 121 of them contained aquatic plants in the 2021 point-intercept survey (Figure 3.2-15 -inset). Nearly all of the sampling locations within the Thoroughfare contained were within the littoral zone and contained vegetation.

A total of 39 aquatic plant species were sampled during the 2021 point-intercept survey in the Thoroughfare including two non-native species and one special concern native species. Common waterweed (55.5%) and coontail (47.7%) were the most frequently encountered native species in the Thoroughfare (Figure 3.2-11). Fern pondweed (34.4%), and forked duckweed (32.8%) were the third and fourth most common species respectively. Eurasian watermilfoil exhibited an occurrence of 24.2%, making it the sixth most frequently encountered species in the Thoroughfare. CLP was present at 4.7% of the sampling locations within the Thoroughfare in the 2021 survey.

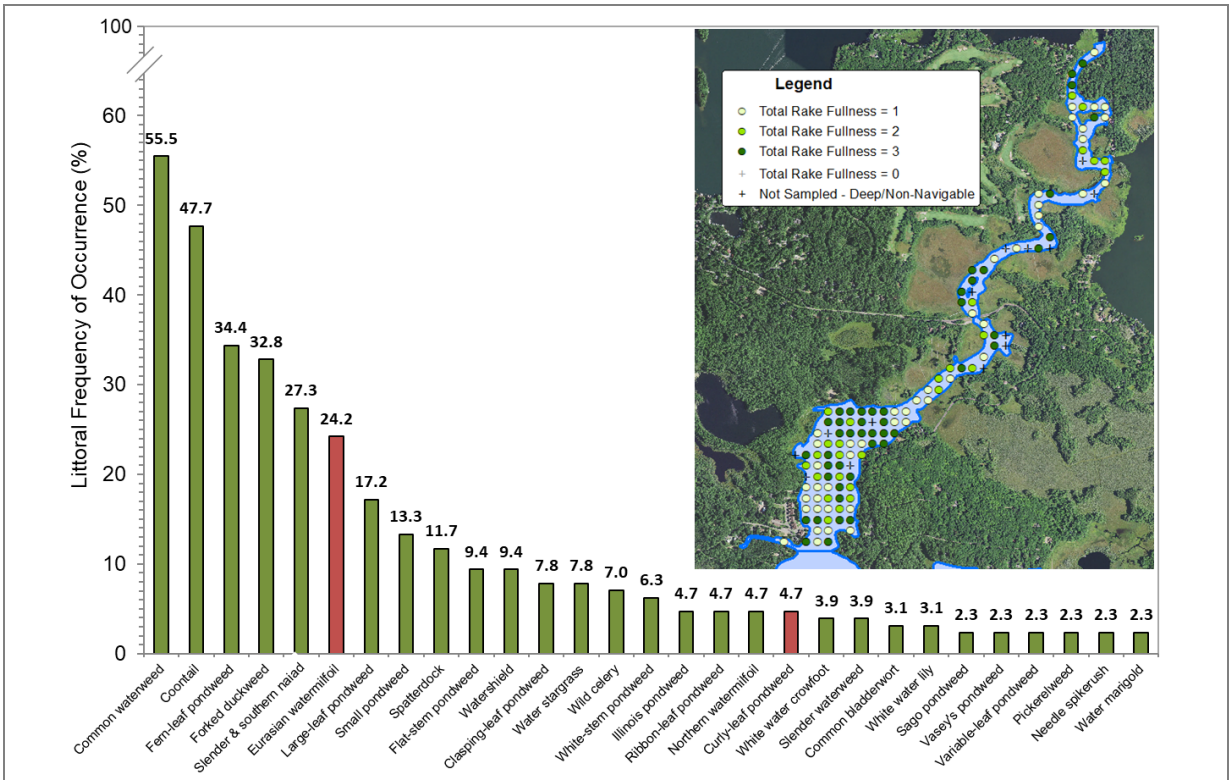


Figure 3.2-15. Tomahawk Thoroughfare aquatic plant littoral frequency of occurrence, vegetation distribution, and total rake fullness (TRF) ratings. Created using data from July 2021 point-intercept survey. Only species with an occurrence >2% are displayed.

The first point-intercept survey within the Tomahawk Thoroughfare was completed in 2007 and included the entire river channel between Tomahawk Lake and the Minocqua Chain. A subsequent survey in 2014 only included sampling locations from Tomahawk Lake to the Thoroughfare Road bridge which resulted in a much smaller sampling size. The 2021 point-intercept survey included the entire length of the Thoroughfare channel similar to the 2007 survey, therefore, only the 2007 and 2021 surveys will be compared in the following analysis. A comparison of these surveys allows for detecting changes in the aquatic plant community over time.

The average number of native species per sampling location within the littoral zone of The Thoroughfare was 3.39 in 2021 compared to 3.57 in 2007 (Figure 3.2-16). Figure 3.2-17 compares the littoral frequency of occurrence of aquatic plant species in The Thoroughfare from the 2007 and 2021 point-intercept surveys. A statistically valid change in occurrence from one survey to the next is indicated with a red asterisk on the figure. Species that exhibited a statistically valid increase in occurrence between 2007 and 2021 include common waterweed, coontail, forked duckweed, Eurasian watermilfoil, aquatic moss, the combined occurrences of small and slender pondweed, and water stargrass. Wild celery, flat-stem pondweed, white-stem pondweed, northern watermilfoil, water marigold, white water lily, and common bladderwort all exhibited a statistically valid decrease in occurrence between the two surveys. The remaining species did not show a statistically valid change in occurrence between 2007 and 2021.

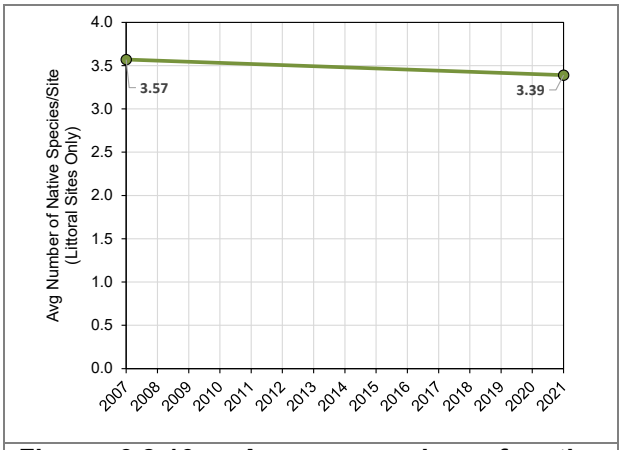


Figure 3.2-16. Average number of native aquatic plant species within the littoral areas of Tomahawk Thoroughfare within the Tomahawk Lake System from 2007 and 2021 point-intercept surveys.

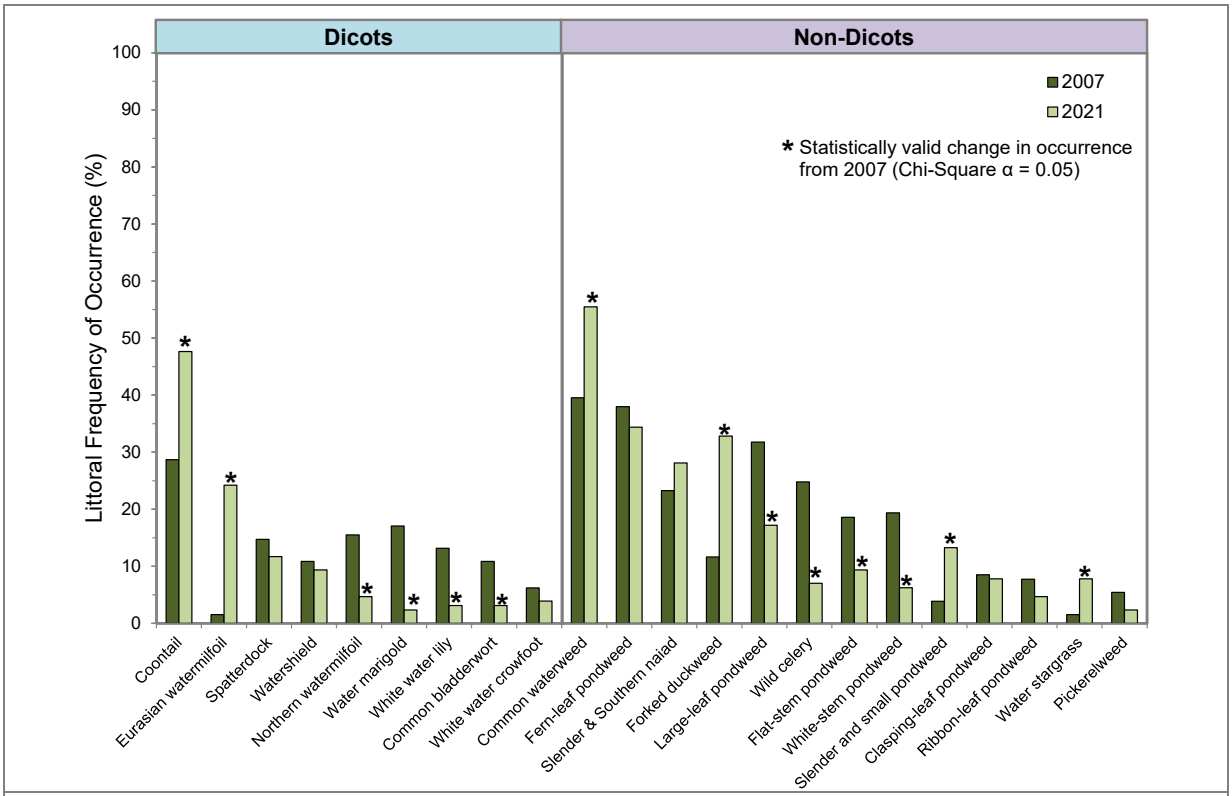


Figure 3.2-17. Tomahawk Thoroughfare littoral frequency of occurrence from 2007 and 2021 point-intercept surveys. Includes all species that exhibited a 5% or greater occurrence in at least one survey. Asterisk represents statistically valid change in occurrence from previous survey.

Figure 3.2-18 compares the relative frequency of occurrence of aquatic plant species from each of the point-intercept surveys. These data show that common waterweed, coontail, fern pondweed, slender and southern naiad, and forked duckweed comprise nearly half of the aquatic plant population in 2021. These same species comprised a smaller proportion of the relative frequency in 2007. The relative frequency of large-leaf pondweed has decreased between the two surveys while forked duckweed, and Eurasian watermilfoil have expanded to comprise a greater proportion of the plant community by 2021.

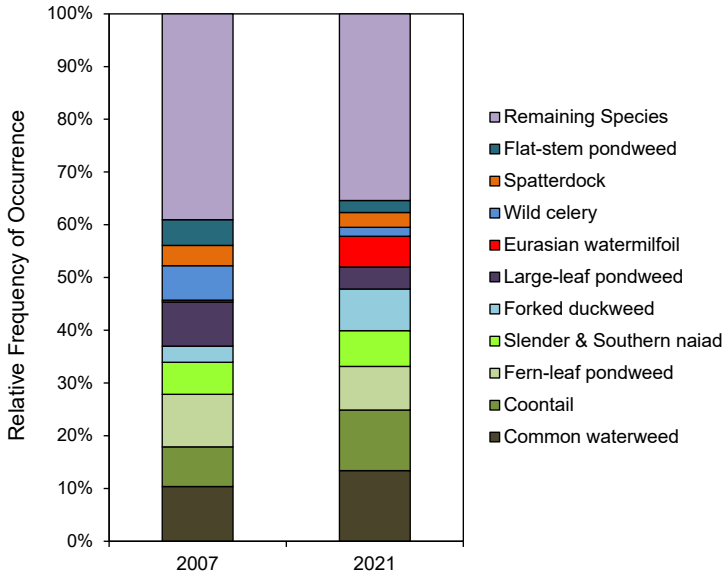


Figure 3.2-18. Relative frequency of occurrence of aquatic vegetation in the Tomahawk Thoroughfare. Created using data from 2007 and 2021 point-intercept surveys.

A comparison of the species richness, average conservatism, and floristic quality from the point-intercept surveys in the Thoroughfare is displayed on Figure 3.2-19. The species richness was 37 in the 2021 survey compared to 25 in 2007. Average conservatism values from each year were similar between 6.6 and 6.7. When combined to calculate the floristic quality, the 2021 survey results in a much higher value (40.8) than the 2007 survey (33.0) largely due to the higher species richness in 2021. The floristic quality of the Thoroughfare is well above the ecoregion and state median values.

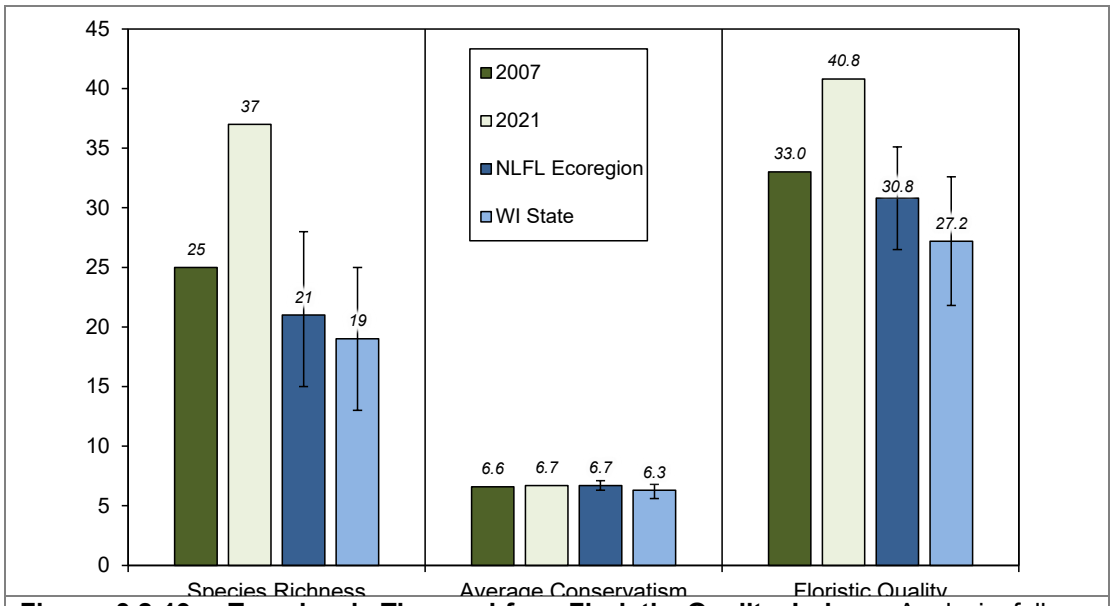


Figure 3.2-19. Tomahawk Thoroughfare Floristic Quality Index. Analysis follows (Nichols 1999).

Mud Lake

Mud Lake is a 41-acre basin that connects to Tomahawk Lake via a narrow channel on the southern end of the lake. Mud Lake is entirely surrounded by the American Legion State Forest and has a shoreline that is in a totally natural and undisturbed state. Of the 89 sampling points in Mud Lake, 40 of them contained aquatic plants in the 2021 point-intercept survey (Figure 3.2-20 -inset). The sampling points in the center of the basin were deeper than 15 feet and beyond the maximum depth of vegetation growth.

A total of 18 native aquatic plant species were sampled during the 2021 point-intercept survey in Mud Lake with common waterweed (37.8%) and southern naiad (33.3%) being the most commonly encountered species (Figure 3.2-20). Fern pondweed (28.9%), coontail (28.9%), muskgrasses (24.4%), and watershield (20.0%) were the next most frequently encountered species with each exhibiting at least a 20% occurrence. No non-native species were identified during the point-intercept survey in Mud Lake; however, a clump of EWM and another single EWM plant was mapped on the southwest part of the lake during a late-summer EWM 2021 mapping survey (Section 3.3).

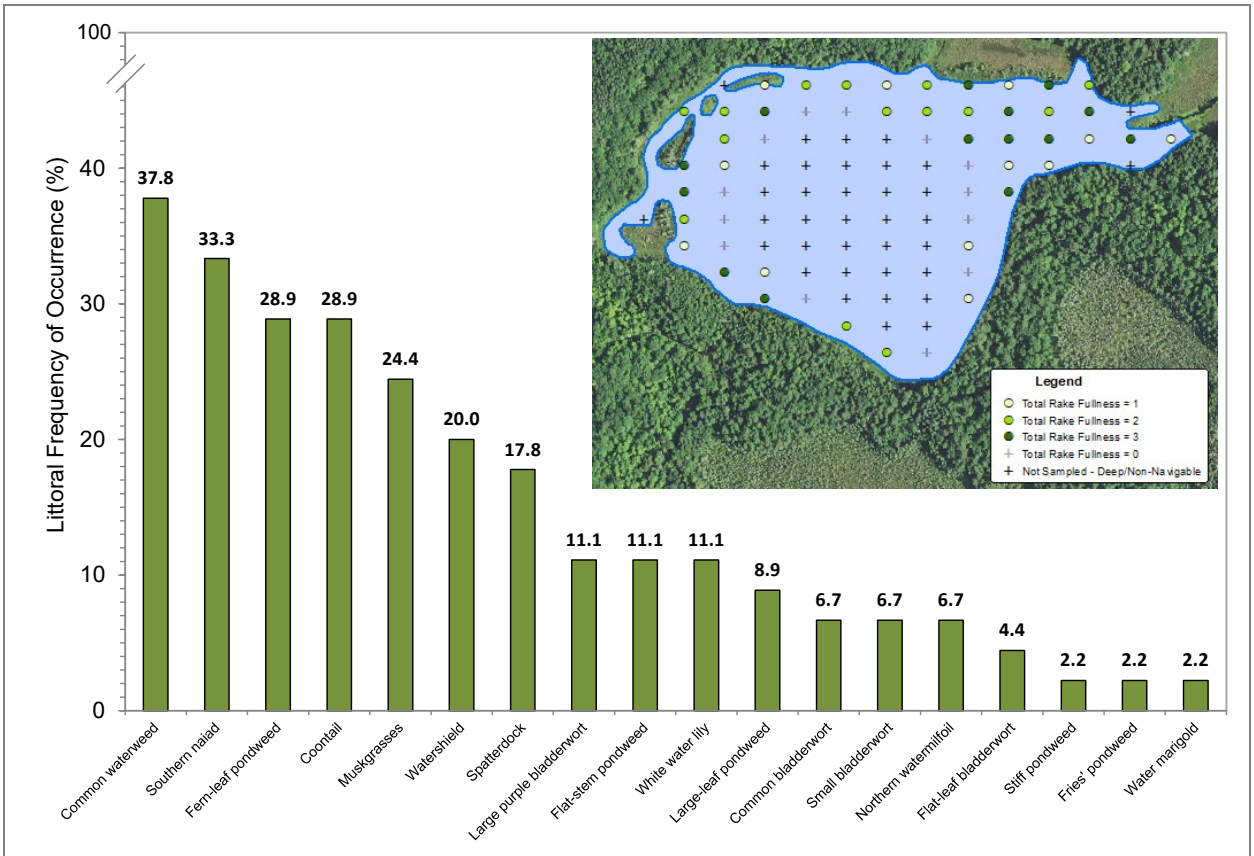


Figure 3.2-20. Mud Lake aquatic plant littoral frequency of occurrence, vegetation distribution, and total rake fullness (TRF) ratings. Created using data from July 2021 point-intercept survey.

Point-intercept surveys have also taken place in Mud Lake during 2007 and 2014 and these data are comparable to the 2021 survey. A comparison of these surveys allows for detecting changes in the aquatic plant community over time. The average number of native species per sampling location within the littoral zone of the lake have been fairly consistent over time demonstrated by the 2.64 species/sampling site in 2021 compared to 2.81 in 2014 and 2.69 in the 2007 survey (Figure 3.2-21).

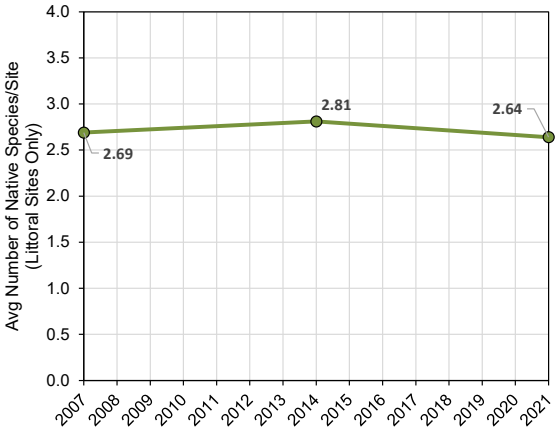


Figure 3.2-21. Average number of native aquatic plant species within the littoral areas of Mud Lake within the Tomahawk Lake System from 2007, 2014, and 2021 point-intercept surveys.

Figure 3.2-22 displays the littoral frequency of occurrence of aquatic plant species in Mud Lake from each of the three point-intercept surveys. A statistically valid change in occurrence from one survey to the next is indicated with a red asterisk on the figure. Species that exhibited a statistically valid increase in occurrence between 2014 and 2021 include common waterweed, southern naiad, and muskgrasses; whereas, whorled watermilfoil was the only species to exhibit a statistically valid decrease in occurrence during the same time period. The remaining species did not show a statistically valid change in occurrence between 2014 and 2021.

Figure 3.2-23 displays the relative frequency of occurrence of aquatic plant species from each of the three point-intercept surveys. These data show that common waterweed, fern pondweed, and coontail have consistently represented a large proportion of the relative frequency of species within Mud Lake. The relative frequency of the combined occurrences of the floating-leaf species including white water lily, watershield, and spatterdock appear to be consistent between the three surveys. Two species that were not identified during the first survey in 2007 but were present in 2014 and 2021 include large purple bladderwort and southern naiad.

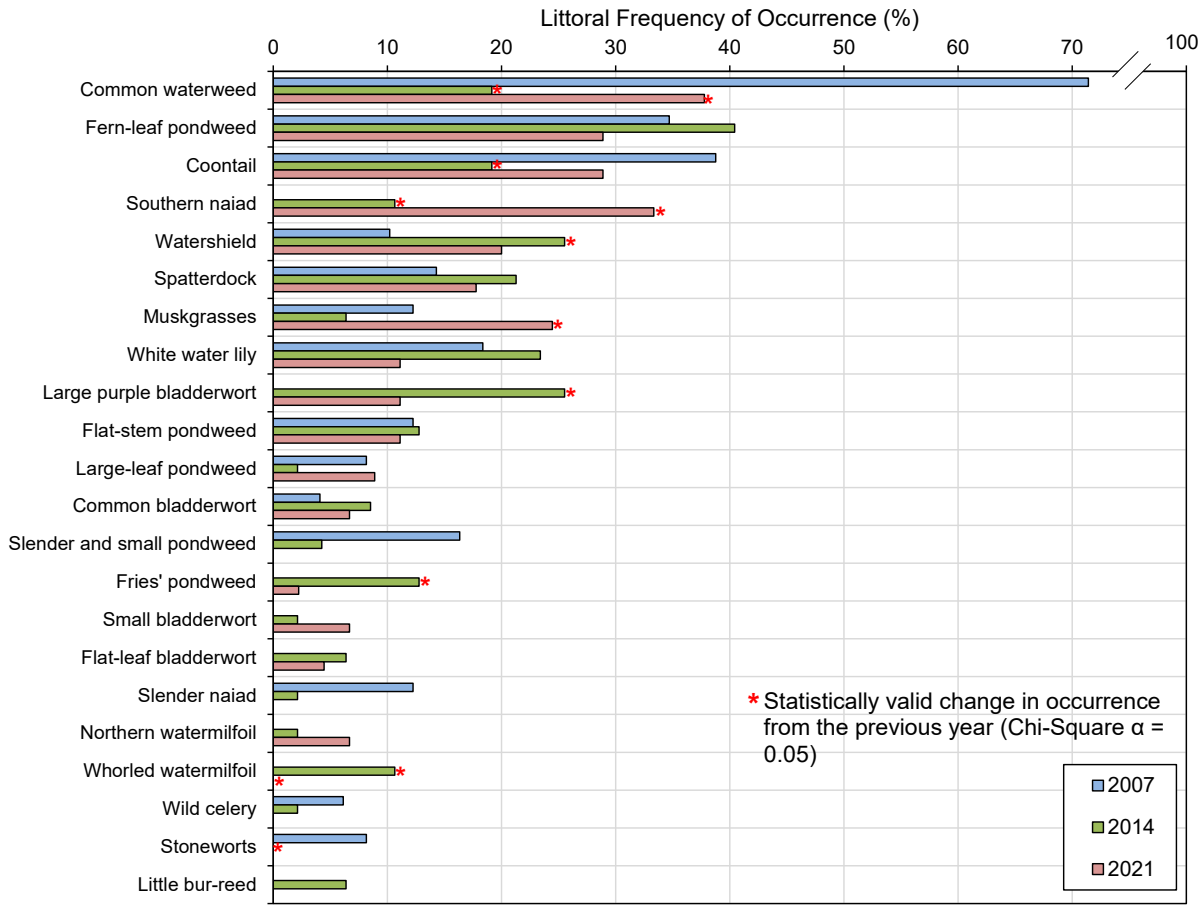


Figure 3.2-22. Mud littoral frequency of occurrence from 2007, 2014, and 2021 point-intercept surveys. Includes all species that exhibited a 5% or greater occurrence in at least one survey. Asterisk represents statistically valid change in occurrence from previous survey.

A comparison of the species richness, average conservatism, and floristic quality from each of the three point-intercept surveys in Mud Lake is displayed on Figure 3.2-24. The species richness was 18 in 2021, compared to 24 in 2014 and 15 in 2007. Average conservatism values have increased slightly from one survey to the next with a 7.0 average in the 2021 survey. The floristic quality was 29.7 in 2021, which is slightly below the value from the 2014 survey and is near the ecoregion and state median values.

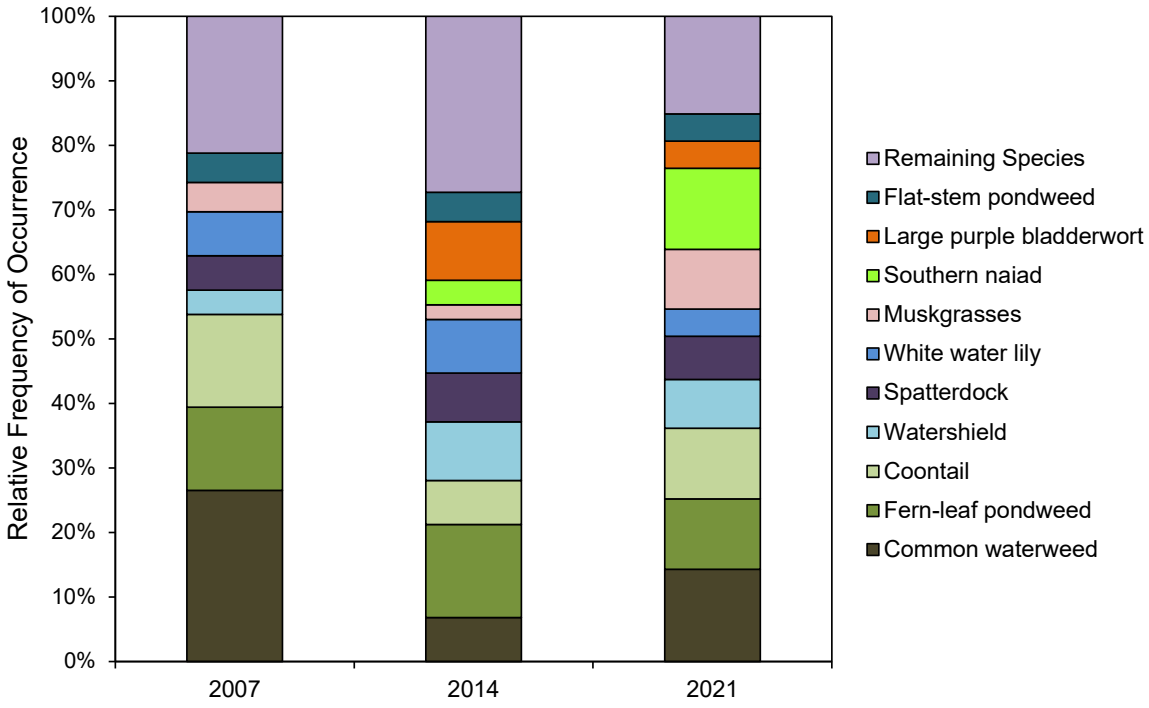


Figure 3.2-23. Relative frequency of occurrence of aquatic vegetation in Mud Lake. Created using data from 2007, 2014, and 2021 point-intercept surveys.

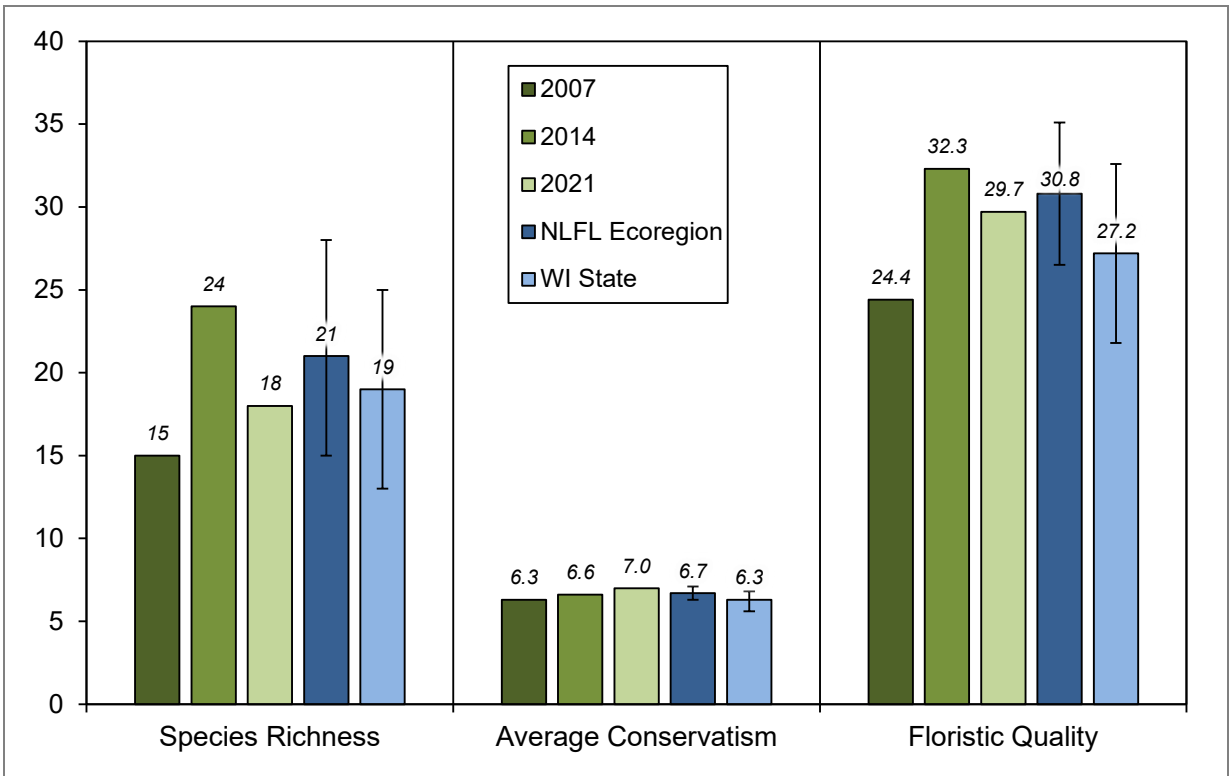


Figure 3.2-24. Mud Lake Floristic Quality Index. Analysis follows (Nichols 1999).

Inkwell Lake & Paddle Pond

Inkwell Lake is a small water body that is adjacent to Tomahawk Lake and was only accessible by portaging over land. Of the 43 sampling locations that were visited during the 2021 point-intercept survey in Inkwell Lake, just one point had spatterdock present on the survey rake while the remaining points had no vegetation (Figure 3.2-25). Species that were observed incidentally during 2021 within Inkwell Lake include: narrow-leaf bur-reed, water arum, three-way sedge, and quillwort. Past studies have also documented minimal aquatic plant growth in Inkwell Lake. Additional species that have been documented in the past include white water lily, common bur-reed, and pipewort. The dark and stained water within Inkwell Lake combined with relatively deep water depths limits the littoral growing zone of this waterbody to a very narrow range.

Paddle Pond is a small basin that is nearly completely surrounded by wetland habitat and connects to Tomahawk Lake through a narrow channel just east of the Thoroughfare. No vegetation was present at any of the 26 sampling locations that were visited during the 2021 point-intercept survey in Paddle Pond (Figure 2.3-26). The dark-stained water in Paddle Pond likely constricts the littoral zone to a narrow area as the water depths dropped off quickly from the wetland edges. Although not physically sampled on any of the point-intercept survey locations (0% occurrence), Eurasian watermilfoil was confirmed and mapped within Paddle Pond during surveys conducted during 2021.

Past studies in Paddle Pond have documented sparse submersed aquatic plant growth. Species that were documented in the past include watershield, coontail, small duckweed, spatterdock, white water lily, broad-leaf cattail, three-way sedge, creeping spikerush, floating-leaf pondweed, and common arrowhead. Most of these species are floating-leaf or emergent plant species which are typically under-represented by the point-intercept survey methodology.

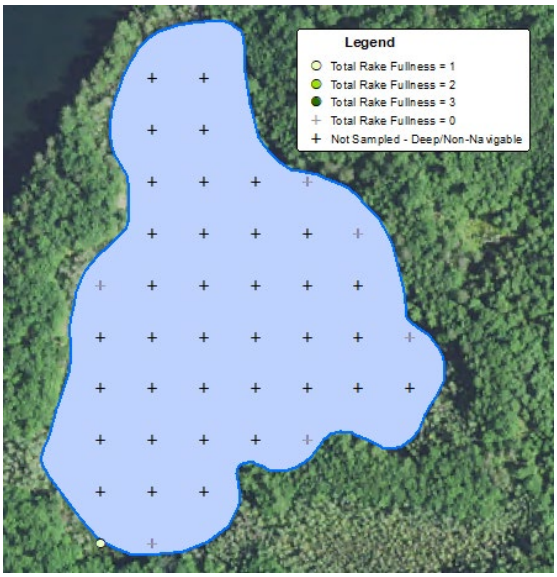


Figure 3.2-25. Inkwell Lake aquatic plant total rake fullness (TRF) ratings. Created using data from July 2021 point-intercept survey.

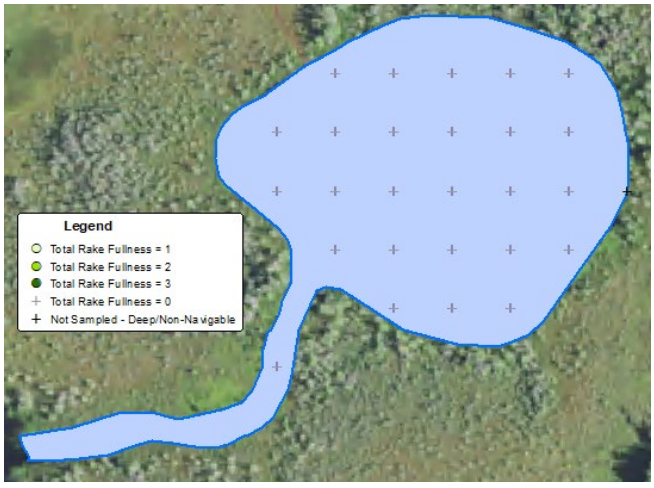


Figure 3.2-26. Paddle Pond aquatic plant total rake fullness (TRF) ratings. Created using data from July 2021 point-intercept survey.

3.3 Non-native Aquatic Plants in the Tomahawk Lake System

Eurasian watermilfoil (Myriophyllum spicatum)

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

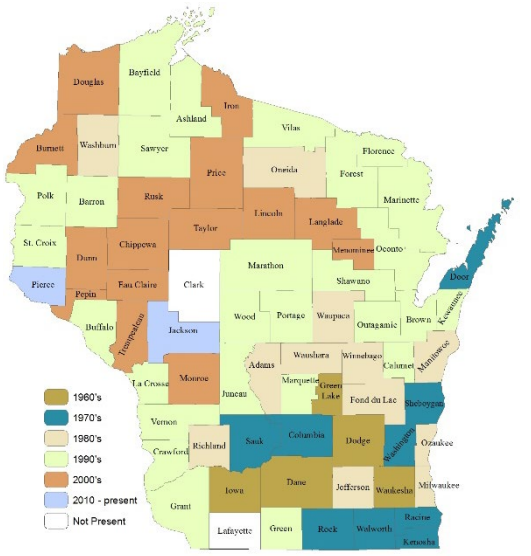


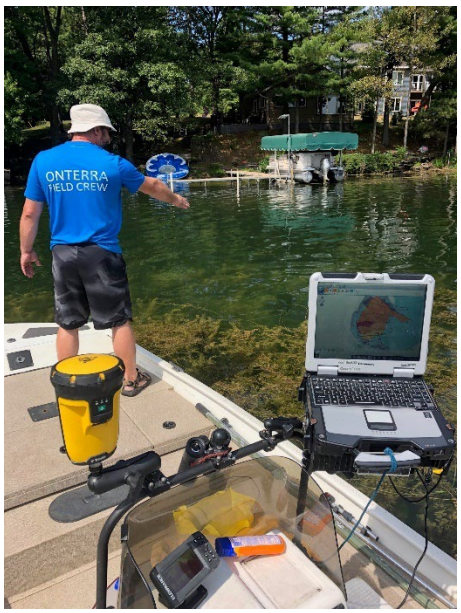
Figure 3.3-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

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

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.

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. These types of sub-sample point-intercept survey have also been applied on the Tomahawk Lake System in the past.

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. During the EWM mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat (Photograph 3.3-1). Field crews supplemented the visual survey by deploying a submersible camera along with periodically doing rake tows. The EWM population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.



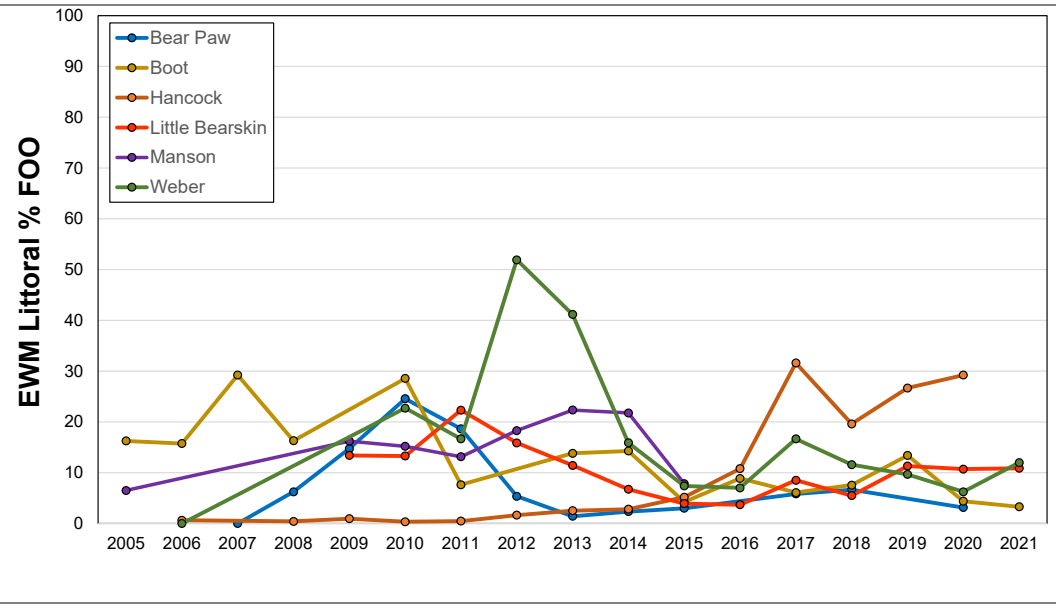
Photograph 3.3-1. EWM mapping survey. Photo credit Onterra.

Overall, each survey has its strengths and weaknesses, which is why both are utilized in different ways as part of this project.

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 (Figure 3.3-2). The upper frame of Figure 3.3-2 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected *unmanaged lakes* were moved into the *managed* category as the EWM populations were targeted for control by the local lake organization as populations increased.



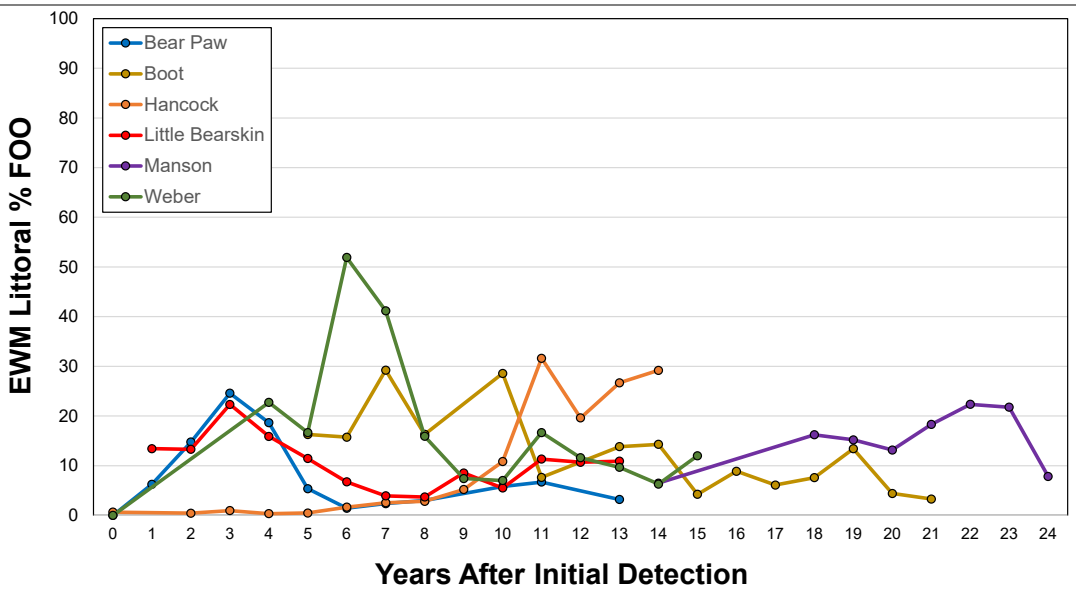


Figure 3.3-2. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from WDNR.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. 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.

EWM population of the Tomahawk Lake System

Using data from the point-intercept surveys that have been completed over the years, the littoral frequency of occurrence of EWM can be compared for each of the lakes (Figure 3.3-3). The frequency of occurrence of EWM saw a statistically valid increase in occurrence 2021 compared

to the previous survey in Little Tomahawk Lake, Tomahawk Lake, and the Thoroughfare. No EWM has been sampled in Mud Lake in any of the three point-intercept surveys to date.

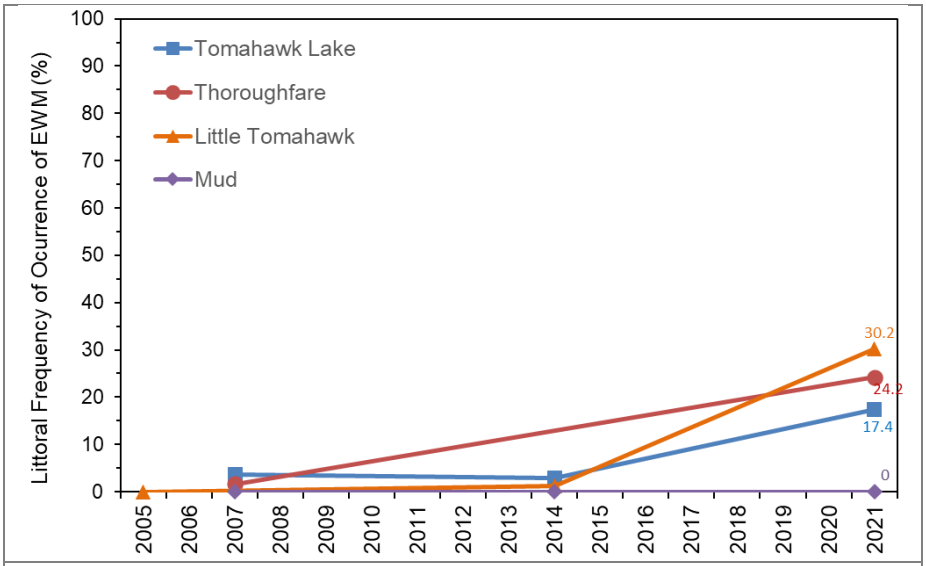


Figure 3.3-3. EWM littoral frequency of occurrence within the Tomahawk Lake System. Data from available point-intercept surveys.

The EWM population in the Tomahawk Lake System was mapped during an August 3-5, 2021 survey by Onterra ecologists. A total of 169.4 acres of colonized EWM was mapped throughout the system of which 14 acres was matting on the surface, 67.9 acres was of a highly dominant density, and another 43.3 acres was described as dominant density (Figure 3.3-4). Lower density colonies include those mapped as highly scattered (1.6 acres) or scattered density (42.7) acres. It is important to note that Figure 3.3-4 displays only those EWM occurrences that were mapped with area-based (polygons) mapping methodologies. Many additional EWM occurrences were mapped with point-based methodologies throughout the system and are described as either single or few plants, clumps of plants, or small plant colonies. Any EWM mapped with point-based methods do not contribute to the acreages displayed on Figure 3.3-4.

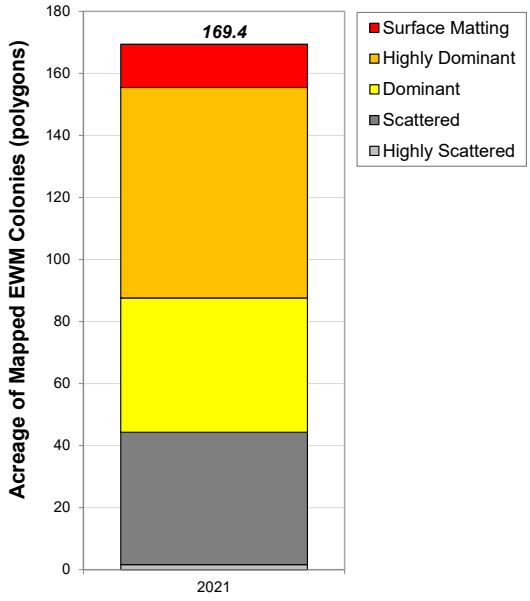


Figure 3.3-4. Tomahawk Lake System acreage of colonized EWM (polygons) from 2021. Created using data from Onterra 2021 late-summer EWM mapping survey.

Most of the EWM population was found to be growing between approximately 7-14 feet of water; however, EWM was recorded out to a depth of 22 feet on the point intercept survey in Tomahawk Lake. The results of the mapping survey are displayed on Maps 3-9. Large and dense colonies of EWM were mapped in many areas around off shore areas of Tomahawk Lake and Little

Tomahawk Lake, and throughout much of the lower sections of the Tomahawk Thoroughfare. A modest EWM population was mapped within Paddle Pond and Mud Lake during the survey. No EWM was observed in Inkwell Lake during the 2021 studies.

In an effort to increase the flow of information between lake stakeholders and project planners, the TLA has piloted an interactive web map application for the system, allowing users to see the late-season EWM mapping survey and management areas as they relate to their property or favorite recreation and fishing spots. Various layers can be turned on and off, and some layers can be selected and a pop-up window will provide additional information. This platform allows a better understanding of the EWM population dynamics and management strategies over time. To directly access this interactive map:

https://onterra.maps.arcgis.com/apps/webappviewer/index.html?id=5ce67c25fc7049c7bf75f4b06e113050

Tomahawk Lake Historic EWM Management

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. During the early days of management on the system, the BMP for managing EWM was through 2,4-D spot treatments (Figure 3.3-5). Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant affects outside of that area. Spot treatments typically rely on a short exposure time to cause mortality as the herbicide dissipates out of the spots rapidly. Due to the size and shape of Lake Tomahawk, essentially all previous herbicide applications have been spot treatments.

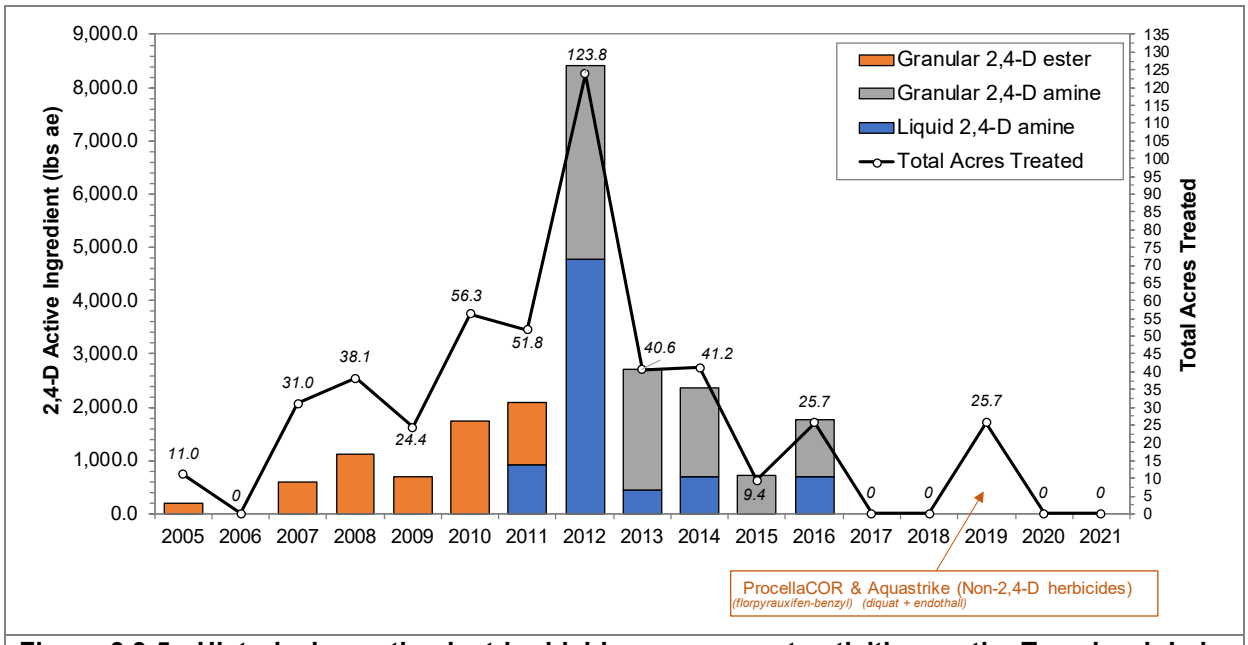


Figure 3.3-5. Historical aquatic plant herbicide management activities on the Tomahawk Lake System.

At the start of the timeframe, the TLA initiated granular 2,4-D spot treatments (Figure 3.3-5). Emerging research demonstrated that liquid treatments provided more consistent results at a

fraction of the cost of granular products, which prompted the TLA to move towards liquid herbicides starting in 2011, especially in contained bays. With today's understanding, it is likely that semi-protected bays are able to hold concentrations longer than exposed parts of the system which lead to more efficacious treatments.

EWM population rebound was often observed occurring as soon as the *year after treatment*. Areas were requiring treatment on an every-other-year basis as new areas were emerging around the chain. This program was analogous to playing the Whac-A-Mole™ arcade game, constantly responding to the same areas over time. As can be observed on Map 10, many application areas were targeted for multiple years over this period. Much of the acreage only targeted in a single year appears to be a result of expanded buffers on areas targeted multiple times, potentially as a results as expanded EWM colonies or larger application areas in an effort to improve effectiveness. This *seasonal control* no longer meets lake managers and regulator's expectations of longevity following treatment, as the sustainability of the strategy in regards to financial and ecological costs is questioned. When engaged in this form of management, ceasing treatment for a year or two typically results in all areas returning to pretreatment levels.

While understood in terrestrial herbicide applications for years, tolerance evolution is an emerging topic amongst aquatic herbicide applicators, lake management planners, regulators, and researchers. Herbicide resistance is when a population of a given species develops reduced susceptibility to an herbicide over time, such that an herbicide use pattern that once was effective no longer produces the same level of effect. This occurs in a population when some of the targeted plants have an innate tolerance to the herbicide and some do not. Following an herbicide treatment, the more tolerant strains will rebound whereas the more sensitive strains will be controlled. Thus, the plants that re-populate the lake will be those that are more tolerant to that herbicide resulting in a more tolerant population over time. Onterra maintains concern for future use of 2,4-D in the Tomahawk Lake system; the extensive use of this product may have created herbicide resistance and therefore herbicide rotation away from this herbicide is recommended.

No herbicide treatment occurred during 2017-2018 as the TLA moved away from 2,4-D spot treatments. In 2019, a trial set of treatments using Aquastrike (2,4-D & endothall) and ProcellaCOR (florpyrauxifen-benzyl) occurred. These herbicides are thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides (e.g. 2,4-D, triclopyr). These treatments failed to meet expectations of success.

ProcellaCOR™ (florpyrauxifen-benzyl) is a relatively new herbicide that has shown some promise in spot treatments in Wisconsin Lakes. The manufacturer is currently working towards new formulations and guidance for whole-lake use patterns. ProcellaCOR™ is in a new class of synthetic auxin mimic herbicides (arylpicolinates) with short concentration and exposure time (CET) requirements compared to other systemic herbicides. Uptake rates of ProcellaCOR™ into EWM were two times greater than reported for triclopyr (Haug 2018) (Vassios et al. 2017). ProcellaCOR™ is primarily degraded by photolysis (light exposure), with some microbial degradation. The herbicide 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). The product has a high affinity for binding to organic materials (i.e., high KOC).

Onterra's experience monitoring over three dozen ProcellaCOR™ treatments within the state during this same time period indicates that EWM control has been high with almost no EWM

being located during the summer post treatment surveys in most treatments. Within these treatments, native plant impacts have been almost exclusive contained to sensitive dicot species such as northern watermilfoil and water marigold. It is unclear why the 2019 ProcellaCOR treatment on Lake Tomahawk was not successful, but may be related to the relatively low application rate employed. ProcellaCOR™ has been used on the downstream Minocqua Chain from 2019-2021 with a high degree of EWM control. The WDNR's fact sheet on this chemistry can be found here:

https://dnr.wi.gov/water/wsSWIMSDocument.ashx?documentSeqNo=164039981

In 2009, the TLA created a Hydraulic Conveyor System (HCS) which now falls into what is commonly called Diver Assisted Suction Harvesting (DASH, see discussion in section 3.1). The HCS system has been operated every year since. Table 3.3-1 shows the effort of HCS hand-removal activities from 2010-2020.

Table 3.3-1. Historical HCS removal activities on the Tomahawk Lake System.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of Sites	101	89	81	106	149	114	102	85	124	128	77
Seasonal drained weight	18,301	22,507	17,699	20,311	20,679	24,765	26,653	44,375	41,538	36,457	26,082
Impacted Area (sq ft)	21,555	64,243	30,401	34,250	62,090	65,225	84,040	65,522	59,940	78,375	22,550
Impacted Area (acres)	0.49	1.47	0.70	0.79	1.43	1.50	1.93	1.50	1.38	1.80	0.52
EWM Selectivity	92.0%	92.7%	91.8%	93.6%	93.2%	93.2%	94.0%	95.7%	95.1%	93.2%	97.0%

In the face of data and changing BMPs, the association has been eager to pivot toward more widely accepted EWM management directions. The TLA's 2016 CLMP has a goal to "maintain a diverse native plant community," which is not likely being accomplished with herbicide treatments causing impact to non-target aquatic plants and not providing more than seasonal control. During the spring of 2019, the TLA applied for a WDNR permit to conduct a mechanical harvesting trial in select parts of the system including Thoroughfare. The 2019 season was met with mechanical failures such that the TLA opted to rerun the trial again in 2020.

Figure 3.3-5. 2020 trial mechanical harvesting location. Location approximate.

During 2020, two days of mechanical harvesting were conducted on July 16-17 on roughly 19 acres (Figure 3.3-5). This location was revisited 52 days later on September 7 for assessment. The results indicate that EWM growth had largely returned to the surface by this time, so any improvement in navigation or recreation in this area was less than 52 days. The TLA now knows that 2 days is an insufficient amount of mechanical harvesting to sufficiently target an area of this size and with the amount of EWM biomass.

The TLA Board opted for an expanded mechanical harvesting program in 2021, where 33 days of harvesting occurred over approximately 80 acres of the lake (Map 11). Please note that not all

areas shown on Map 4 were able to be targeted or completely targeted during this effort. This effort was more successful than attempts made in 2019 and 2020.

During the later-summer of 2021, the TLA worked with the local WDNR biologist (Scott Van Egeren) and Onterra to develop an adaptive management strategy that may be worthy of WDNR Control Grant funding. The TLA secured the maximum WDNR grant award allowed ($150,000) to fund a trial mechanical harvesting project in 2022 and 2023. Slightly larger equipment is being proposed as part of the 2022-2023 effort in which around 125-acres is preliminarily estimated to be targeted and monitored. Professional monitoring will consist of pre- and post-harvesting monitoring of the aquatic plant community through a sub-sample point-intercept survey. A professional EWM mapping survey will also occur in 2023 to compare with the 2021 survey. Volunteer-based monitoring will aim to monitor the longevity of relief provided by mechanical harvesting by measuring measure the distance from the top of the EWM plants to the surface of the lake at designated intervals following the mechanical harvesting activities.

Tomahawk Lake Future EWM Management Discussions

During the upcoming Planning Committee meetings, Onterra will outline three broad EWM population management perspectives for consideration, including a generic potential action plan for each (Figure 3.3-6). Onterra has extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* to serve as an objective baseline for the TLA to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Tomahawk Lake ecosystem. These chapters are included as Appendix D. The TLA Planning Committee will also review these management perspectives in the context of perceived riparian stakeholder support, which is discussed in the subsequent sub-section.

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

Figure 3.3-6. 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 3.3-1. 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 (only necessary if Diver Assisted Suction Harvest [DASH] is used). 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 populations, the entire population may be targeted through hand-harvesting or spot treatments. On more advanced or established populations, this may be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies. In areas of the state that contain highly established and prevalent EWM populations, lake-wide population management is often considered too aggressive by local WDNR regulators. In these instances, the nuisance conditions are targeted for management and other areas are tolerated or avoided.

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

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

On some lakes, traditional mechanical harvesters may be too large, too cumbersome, or too expensive to mobilize to be practical. Sometimes referred to as an "eco-harvester," Silver Mist Aquatic Services of Waupaca, WI has developed a small, dual-paddlewheel propelled, mechanical

harvester that utilizes an expanded metal barrel to pull aquatic plants out of the water. This unit transforms into an offloading conveyor, reducing the need for additional equipment to perform that duty. The manufacturer claims it can be used in water as shallow as 10 inches; however, that is likely a minimum requirement for operation, but not for effective, ecologically-sound operation. The WDNR typically restricts mechanical harvesting in less than 3 feet of water to minimize sediment disruption. Still, it is likely that the harvester can be used in shallower areas than a conventional mechanical harvester. This method of harvesting reportedly operates by pulling aquatic plants from the sediments; as opposed to cutting, as utilized in conventional mechanical harvesting. In operation, the plants are largely not being pulled up by the roots, but the plant stems are snapped at a location below the rotating barrel. The WDNR has limited the use of this method statewide because the feel that cutting is less environmentally harmful that pulling (or tearing) the plants out of the sediment.

Stakeholder Survey Responses to Eurasian Watermilfoil Management

As discussed in Section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. The return rate of the 2022 survey was 41% and the response rate of an earlier 2014 survey was 42%. Because the response rate was below 60% in both instances, it is important to reiterate that the stakeholder survey results need to be understood in the context of the respondents to the survey, not to the overall population sampled.

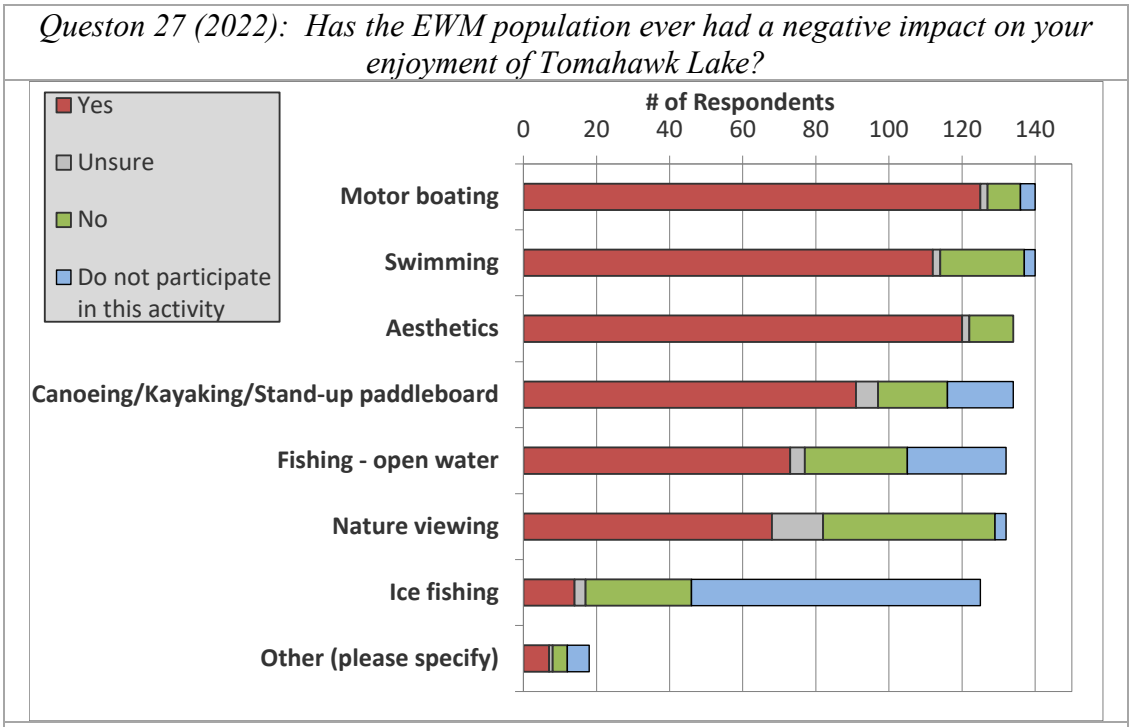


Figure 3.3-7. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

In an effort to understand how EWM impacts stakeholders, the 2022 stakeholder survey asked if the Eurasian watermilfoil population ever had a negative impact on your enjoyment of the Tomahawk Lake system. The category with the highest number of respondents indicating *Yes* was motor boating (Figure 3.3-7 - above). This was ranked as the second-highest reason for owning or renting property on the system (Section 2.3, Figure 2.3-3). Stakeholder respondents also

indicated that swimming, aesthetics, and silent sports were also negatively impacted by EWM in Tomahawk Lake.

In both 2014 and 2022, riparian and TLA members were asked about a number of management techniques for managing non-native aquatic plants. It is important to note that these questions were worded a little differently between surveys, and the 2022 survey provided more response options. To assist with understanding the comparisons, the responses of *highly supportive* and *somewhat supportive* from the 2022 survey were combined together under "Support", and the *somewhat unsupportive* and *not supportive* responses were combined together under "Oppose". Figure 3.3-8 highlights the responses for a typical herbicide treatment. The level of support amongst stakeholder respondents has shifted, with stronger support for herbicide management in 2014 compared to 2022.

Question 18 (2014): Please indicate your support or opposition for the following invasive aquatic plant management control techniques (aquatic herbicides) by the Tomahawk Lake Association.

Queston 28 (2022): What is your level of support for the use of the following Eurasian watermilfoil management techniques (herbicide use - uncontained application to target areas) in the Tomahawk Lake system?

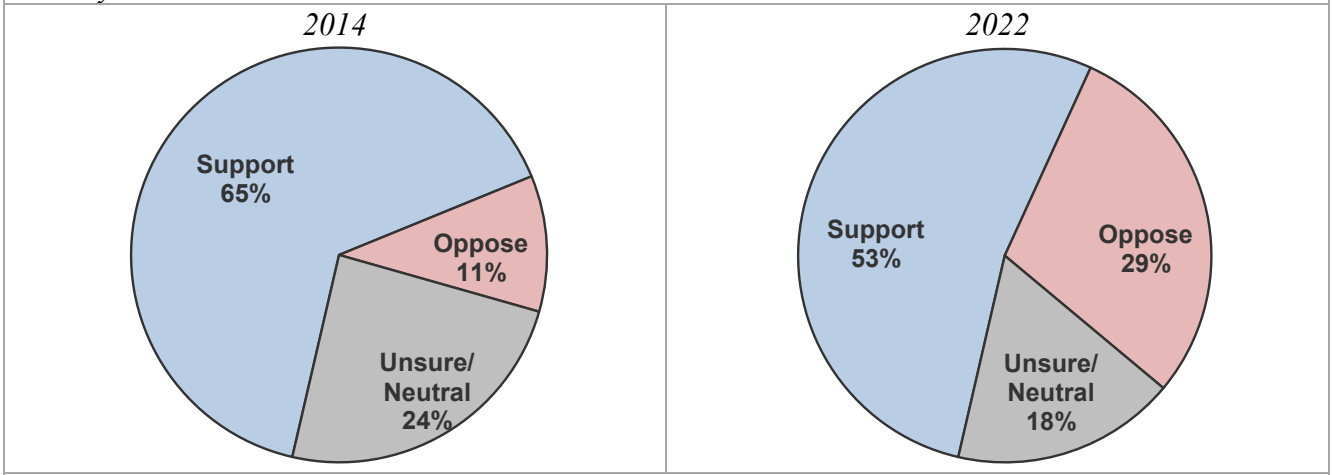


Figure 3.3-8. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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 (Photograph 3.3-2).

The majority of research trials that have taken place in Wisconsin utilized an economical-priced herbicide like 2,4-D to determine if the herbicide can be held in place long enough to be effective. Recently, some lake groups are considering barrier curtains to contain the herbicide to limit non-target collateral impacts to native plants. Barrier curtain construction and placement is the responsibility of the lake group, requiring advance planning efforts and a formidable volunteer base. In 2021, riparians were asked whether they would support an "herbicide use with a barrier curtain to help contain the chemical within the treatment area (newer technique)" (Appendix B, Question 28). This increased support (pooled *highly supportive* and *somewhat supportive)* for

herbicide treatment to approximately 66% compared to 53% without a curtain as shown in Figure 3.3-8.

Photograph 3.3-2. Herbicide enclosure on an Oconto County Lake. Photo credit Archibald Lake Association.

Within the 2022 survey, stakeholders were also asked about their level of support for hand-harvesting including HCS (hydraulic conveyor system) (Figure 3.3-9). Respondents largely favored this management technique for the control of EWM. This level of support is similar to the results of the 2014 stakeholder survey (85% support). The 2022 respondents indicated concern for HCS/hand-harvesting due to high cost and ineffectiveness of the technique (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 3.3-10). The top concern regarding mechanical harvesting was ineffectiveness of technique strategy.

Queston 28 (2022): What is your level of support for the use of hand-removal by divers/ HCS to manage Eurasian watermilfoil in the Tomahawk Lake system?

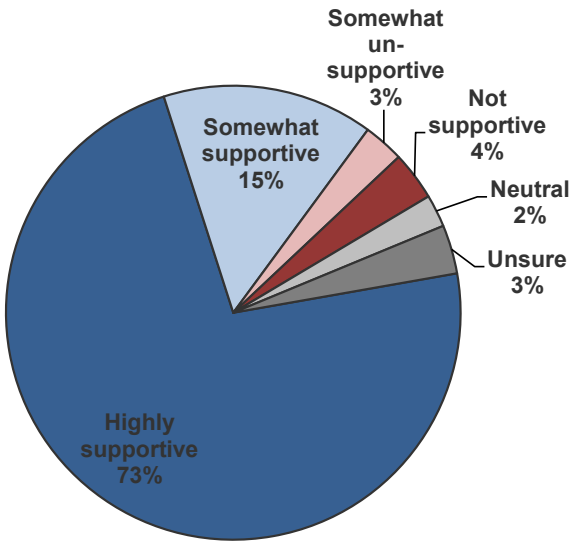


Figure 3.3-9. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B

Queston 29 (2022): What concerns, if any, do you have for the future use of aquatic herbicides, HCS/hand-harvesting, and/or mechanical harvesting to target Eurasian watermilfoil in the Tomahawk Lake system?

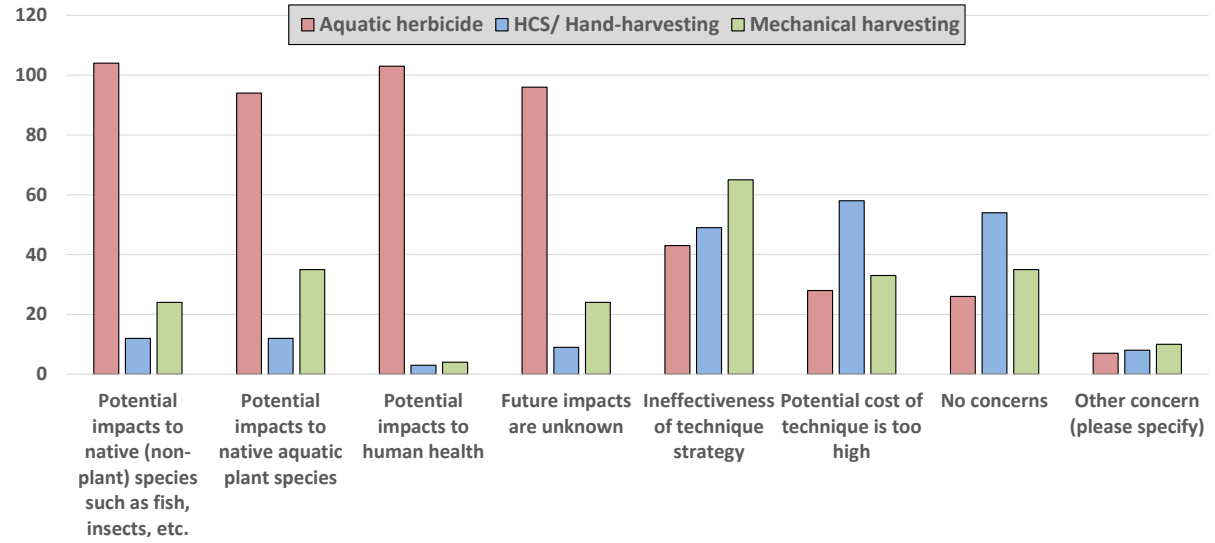


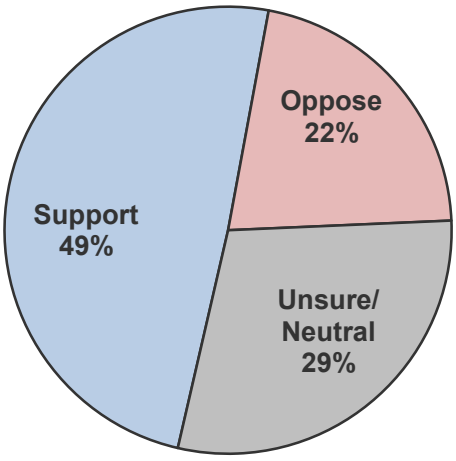
Figure 3.3-10. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

The 2014 stakeholder survey indicated that 49% of respondents favored the use of mechanical harvesting to manage invasive aquatic plants like EWM (Figure 3.3-11). As discussed above, mechanical harvesting was piloted during the summer of 2021. Respondents to the 2022 stakeholder survey indicated 67% support for this management technique.

Question 18 (2014): Please indicate your support or opposition for the following invasive aquatic plant management control techniques (mechanical mowing and harvesting) by the Tomahawk Lake Association.

Queston 28 (2022): What is your level of support for the use of the following Eurasian watermilfoil management techniques (mechanical harvesting [i.e. weed cutter]) in the Tomahawk Lake system?

2014



2021

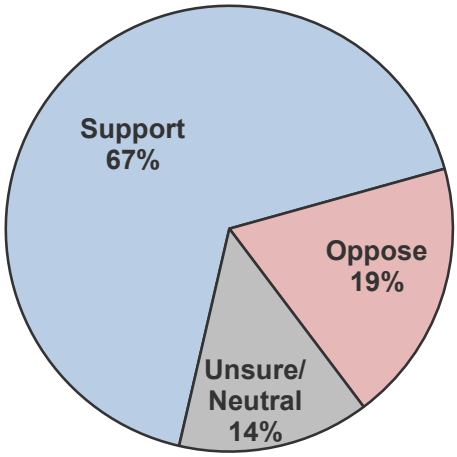


Figure 3.3-11. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

The 2022 stakeholder survey attempted to understand the riparian perceptions of success from the mechanical harvesting effort (Figure 3.3-12). The respondents that had mechanical harvesting in front of their property generically suggest that there was a shift in EWM density from *surface matting* to *dense, but below the surface*. In a subsequent question, approximately 23% of these respondents indicated that the outcome *greatly improved usability*, 52% indicated that it *slightly improved usability,* and 21% indicated that the conditions largely *remained the same* (Appendix B, Question 34).

*Question 32 (2022): What was the density of the Eurasian watermilfoil **prior** to the harvesting in front of your property?*

*Question 33 (2022): What was the density of the Eurasian watermilfoil **after** being harvesting in front of your property?*

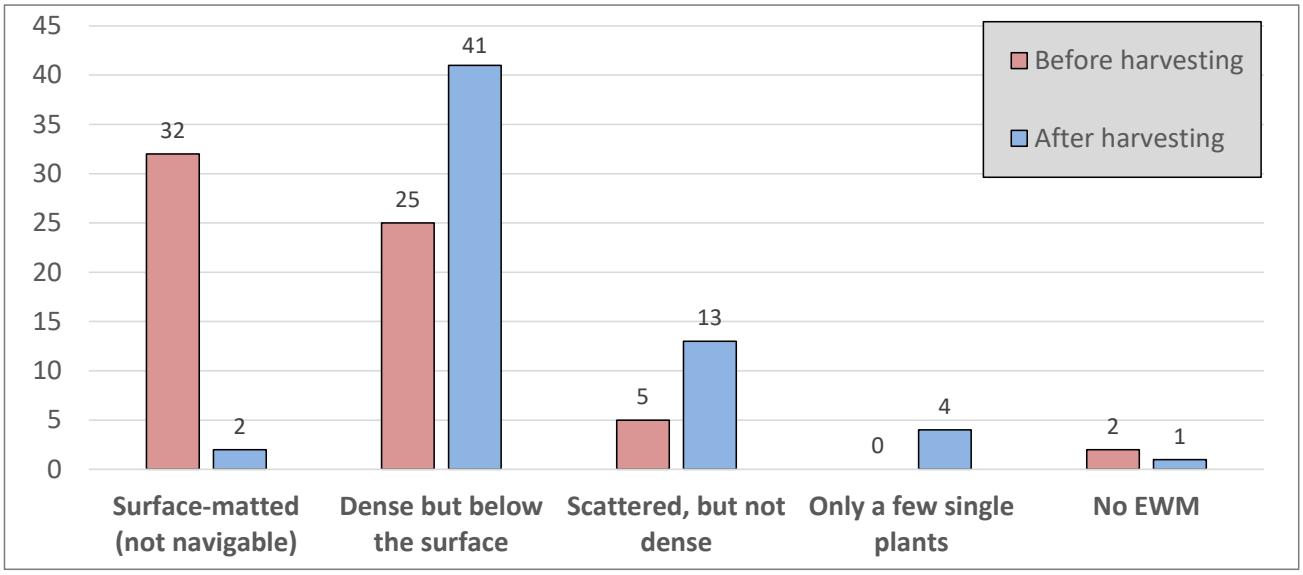


Figure 3.3-12. Select survey responses from the TLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Tomahawk Lake Prevention & Containment

The Tomahawk Lake System is an extremely popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of a watercraft inspection program is not only be to prevent additional invasive species from entering the system through its public access locations, but also to prevent the infestation of other waterways with invasive species that originated in the system. The goal is typically to cover the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread.

The TLA utilizes WDNR grant funding to sponsor watercraft inspections through the WDNR's Clean Boats Clean Waters (CBCW) program at two public boat launches (Lake Tomahawk Park Boat Launch and the lake access at Indian Mounds Campground). CBCW inspection is provided on Fridays, Saturdays, Sundays, and holidays. The TLA's Clean Boats Clean Waters program has been well organized, with numerous watercraft inspections occurring annually (Table 3.3-2

showing recent history). The Minocqua-Kawaguesaga Lakes Protection Association and the Mid Lake protection and Management District also conduct CBCW efforts on other landings on the greater Minocqua Chain of Lakes.

Table 3.3-2. Watercraft inspections conducted on Tomahawk Lake 2015-2020.
Data from WDNR, SWIMS.

Indian Mounds Campground						
	2015	**2016**	**2017**	**2018**	**2019**	**2020**
Boats Inspected	132	347	453	785	816	759
Hours Spent	36	229	350	182	268	181
Boats Inspected/Hrs Spent	0.27	0.66	0.77	0.23	0.33	0.24

Coffen Ln off Hwy 47						
	2015	**2016**	**2017**	**2018**	**2019**	**2020**
Boats Inspected	1,783	1,971	1,734	1,900	1,883	2,021
Hours Spent	304	322	319	332	340	356
Boats Inspected/Hrs Spent	0.17	0.16	0.18	0.17	0.18	0.18

Based upon modeling by the University of Wisconsin Center for Limnology, Tomahawk Lake is one of the state's top 300 AIS Prevention Priority Waterbodies. This means that Tomahawk Lake has a high number of boats arriving from lakes that have AIS (receiving) and a high number of boats moving from Tomahawk Lake to uninvaded waters (sending). Therefore, the WDNR encourages additional supplemental prevention efforts above just watercraft inspections, offering additional grant funds for these activities for applicable lakes. Supplemental prevention efforts such as decontamination stations (e.g., pressure washer) and remote video surveillance (e.g., I-Lids™) could be funded through this program.

Curly-leaf Pondweed (Potamogeton crispus)

Curly-leaf pondweed (CLP) is a non-native, invasive submersed aquatic plant native to Eurasia. This species has been verified within Tomahawk Lake and is present within the Tomahawk Thoroughfare connecting the Tomahawk Lake System with the Minocqua Chain to the north. A substantial population of CLP has also been historically present in nearby Mid Lake for many years. During the July 2021 point-intercept surveys conducted on the Tomahawk Lake System, CLP was present on six sampling locations within the Tomahawk Thoroughfare (4.7% occurrence) and observed to be present near several additional sampling locations.

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. The Tomahawk Lake System has a number of native pondweed species, some of which are similar in appearance to and may be mistaken for CLP (Figure 3.3-13).

Figure 3.3-13. Curly-leaf pondweed and native pondweed 'look-a-likes' found in Tomahawk Lake System. Photo credit Onterra.

Like some of Wisconsin's native pondweeds, CLP's primary method of propagation is through the production of numerous asexual reproductive structures called turions. Once mature, these turions break free from the parent plant and may float for some time before settling and overwintering on the lake bottom. Once favorable growing conditions return (i.e., spring), new plants emerge and grow from these turions (Photograph 3.3-3). Many of the turions produced by CLP begin to sprout in the fall and overwinter as small plants under the ice. Immediately following ice-out, these plants grow rapidly giving them a competitive advantage over native vegetation. Curly-leaf pondweed typically reaches its peak biomass by mid-June, and following the production of turions, most of the CLP will naturally senesce (die back) by mid-July. Although some CLP was present during the July 2021 point-intercept survey within the Tomahawk Thoroughfare, part of the population had likely already senesced by the time of the survey.

Photograph 3.3-3. A single curly-leaf pondweed turion sprouting several new plants. Photo credit Onterra.

If the CLP population is large enough, the natural senescence and the resulting decaying of plant material can release sufficient nutrients into the water to cause mid-summer algal blooms. In some lakes, CLP can reach growth levels which interfere with navigation and recreational activities. However, in other lakes, CLP appears to integrate itself into the plant community and does not grow to levels which inhibit recreation or have apparent negative impacts to the lake's ecology. Because CLP naturally senesces in early summer, surveys are completed early in the growing season in an effort to capture the full extent of the population.

Because a portion of the CLP turions produced each year do not sprout and lie dormant in the sediment to sprout in subsequent years, chemical management of CLP typically includes numerous, repeat annual herbicide applications completed a few weeks following ice-out. The goal of the herbicide treatment is to kill the CLP plants before they are able to produce turions. Following multiple years of herbicide application, the turion supply in the sediment becomes exhausted and the CLP population decreases significantly to levels that may be better managed with finer-scale strategies such as manual removal. 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.

Early-season herbicide treatments, particularly low-concentration whole-lake or whole-basin treatments, have shown large reductions in CLP biomass and decreased recurrence of CLP populations after multiple consecutive treatments (Skogerboe et al. 2008). Johnson et al. (2012) investigated nine midwestern lakes that received five consecutive annual large-scale endothall treatments to control CLP. The greatest reductions in CLP frequency, biomass, and turions was observed in the first two years of the control program, but continued reductions were observed following all five years of the project. The authors noted that they saw no clear indication of the number of consecutive treatments needed to achieve long-term control, with viable turions (represented through sprouting) persisting greater than five years (Johnson et al. 2012).

Five consecutive years of large-scale CLP treatment also occurred on Half Moon Lake (Eau Claire County, WI). Following the five-year control strategy, CLP occurrence was documented to quickly rebound to pretreatment levels, with the authors indicating that "the turion bank in the sediment was still viable after five consecutive years of control" (James 2017). It is unclear how the ongoing internal phosphorus management activities (alum treatments) and subsequent changes in water quality may be impacting turion sprouting and corresponding CLP populations. Half Moon Lake has entered into another five-year CLP control program, which will result in large-scale endothall treatments occurring in ten out of eleven years. From the existing scientific literature, it is unclear how many consecutive years of directed herbicide treatments are needed in a given waterbody to exhaust the base of turions present to meet management goals.

Pale-yellow Iris (Iris pseudacorus)

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers (Photograph 3.3-4). Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species.

Photograph 3.3-4. The non-native wetland plant, pale-yellow iris. Clump of the non-native pale-yellow iris mixed with the native blue-flag iris (left) and large, contiguous colony of pale-yellow iris on the shores of Tomahawk Thoroughfare (right). Photo credit Onterra.

Pale-yellow iris is typically in flower during the second half of June. The foliage of pale-yellow iris and northern blue flag iris (valuable native species) is too similar to make a definitive identification based off of this alone. Positive ID really needs to come from the flowers or the seed pods, which come after the flower is pollinated. Control of pale-yellow iris includes digging and removing the entire plant, cutting leaves below the water's surface, cutting flowers before they can go to seed, and herbicide applications for larger colonies.

Pale-yellow iris was verified in the WDNR records in Tomahawk Lake in 2012 and a significant population is known to be present along the shores of the Tomahawk Thoroughfare.

Purple Loosestrife (Lythrum salicaria)

Like pale-yellow iris, purple loosestrife is a perennial, herbaceous wetland plant native to Europe and was likely brought over to North America as a garden ornamental (Photograph 3.3-5). This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to nearly the entire state. Purple loosestrife largely spreads by seed, but can also spread from root or stem fragments.

The Tomahawk Lake Association initiated a purple loosestrife management program in 2012. This initially consisted of removing flowering heads from areas in Tomahawk Lake and the Thoroughfare. In 2013, *Galerucella* beetles were released in the Thoroughfare, but high water was thought to limit the success of these activities. Purple loosestrife locations were assessed in 2020 and locations are shown in Figure 3.3-14.

Photograph 3.3-5. The non-native wetland plant, purple loosestrife. Photo credit Onterra.

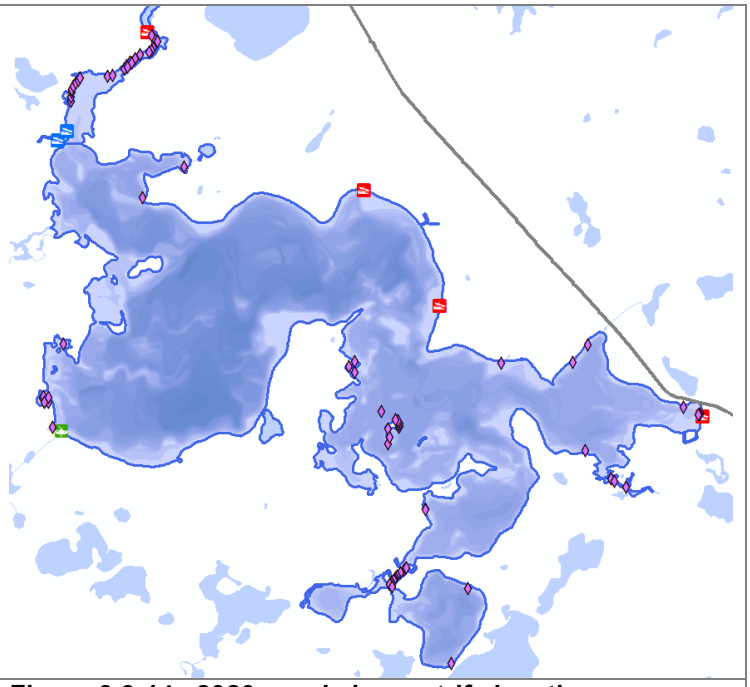
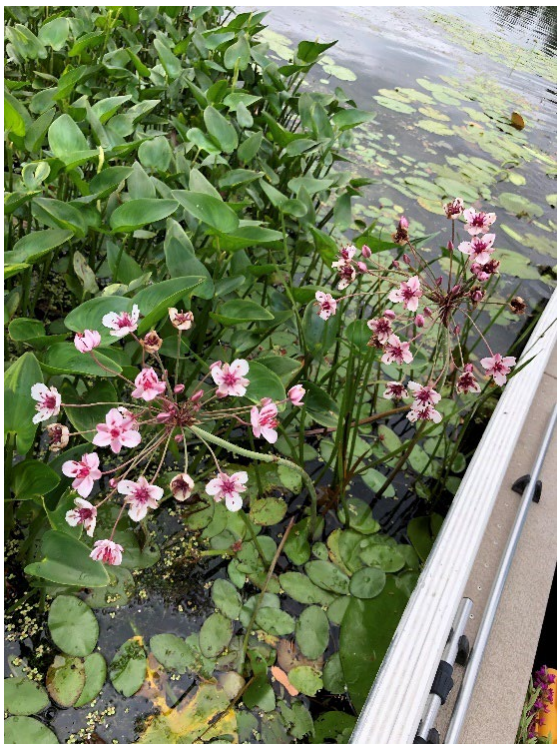


Figure 3.3-14. 2020 purple loosestrife locations.

Flowering Rush (Butomus umbellatus)

Flowering rush an invasive wetland/aquatic plant that is native to Europe (Photograph 3.3-6). This perennial plant flowers in late summer to early fall. It ranges in size from 1-5 feet, generally growing it shallow water, though it can be found growing submersed up 10 feet deep. Like other non-native invasive plants, flowering rush displaces native aquatic and wetland plants and can alter ecosystem functions.

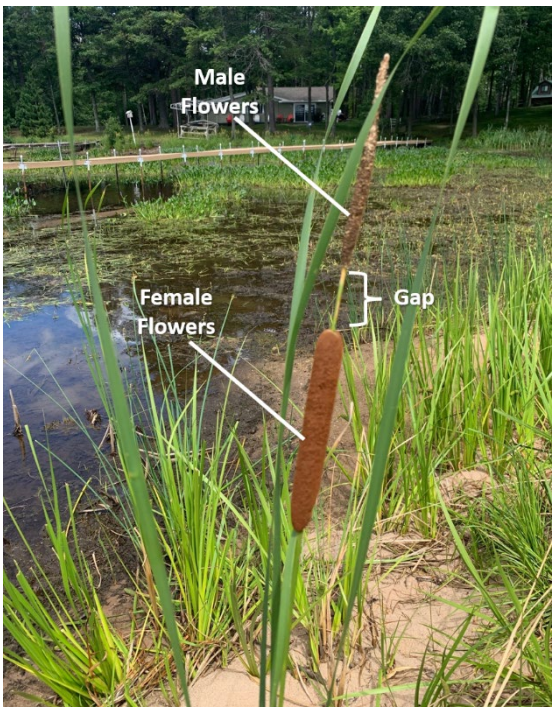
Flowering rush populations have been known from nearby Lake Minocqua since 1985 and Kawaguesaga Lake since 2010. Flowering rush was also documented in Mid Lake for the first time in 2019. Herbicides have been used to control larger populations of flowering rush on Wisconsin lakes, while smaller populations are recommended for manual hand-removal for control.



Photograph 3.3-6. Flowering rush in the Thoroughfare. Photo credit – Onterra.

Narrow-leaf Cattail (Typha angustifolia)

Two species of cattail can be found in Wisconsin, broad-leaved cattail (*Typha latifolia*) and narrow-leaved cattail (*Typha angustifolia*). Broad-leaved cattail is considered to be indigenous to North America while narrow-leaved cattail is believed to have been introduced from Europe and is considered to be ecologically invasive. While there are certain characteristics that differentiate these two species, hybridization between them (*T. x glauca*) is believed to be common, making positive identification without DNA analysis difficult (Photograph 3.3-7). Both species have been identified from the Tomahawk System



Photograph 3.3-7. Cattail identification aid. Narrow-leaved cattail shown, as there is a defined gap between male and female flowers. Broad-leaved cattail would have no gap between male and female flowers. Photo credit Onterra.

4.0 SUMMARY & CONCLUSIONS

The design of this project was intended to fulfill two main objectives;

1) Collect detailed information regarding the aquatic plant community of the Tomahawk Lake System, with additional emphasis on Eurasian watermilfoil.
2) Collect sociological information from Tomahawk Lake riparian stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

These objectives were fulfilled during the project and have led to a good understanding of the Tomahawk Lake aquatic plant community, the folks that care about the lakes, and what steps can be taken by the TLA to protect the system's ecological integrity and support the public's use of the waterbody.

Native aquatic vegetation are the foundation of the lake ecosystem. Overall vegetation studies (point-intercept surveys) have taken place in three intervals on the Tomahawk Lake System: 2005/2007, 2014, and 2021. These data reveal changes in species abundance that have occurred over this time period. The overall aquatic plant community continues to be healthy and diverse.

During the 2021 surveys, over 62 species were located during the point-intercept surveys on the Tomahawk System. Vasey's pondweed, a species is listed as special concern by the WDNR Natural Heritage Inventory Program due was located in the Tomahawk Thoroughfare during these surveys. Two submergent non-native species were located, Eurasian watermilfoil (EWM) and curly-leaf pondweed (CLP). Three non-native emergent species were located, pale-yellow iris, purple loosestrife, narrow-leaf cattail, and flowering rush.

The TLA, in conjunction with WDNR grants, have invested a large amount of money managing the EWM population of Tomahawk Lake. Active management activities have included herbicide treatment, hand-harvesting (including with diver-assisted suction harvesting), and mechanical harvesting. As a part of this project, the TLA Planning spent a great deal of time discussing all the alternative management actions, their associated risks, and what are the current Best Management Practices (BMPs).

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. The herbicide strategies employed in the past on the Tomahawk System were considered the *Best Management Practices (BMPs*) of the time. However, some of these management actions have gone out of favor as new research and information has become available.

At the start of this timeframe, the TLA initiated small granular 2,4-D spot treatments. Emerging research demonstrated that liquid 2,4-D treatments provided more consistent results at a fraction of the cost of granular products, which prompted the TLA to move towards liquid herbicides. The exposed and offshore locations of many of the EWM colonies on the Tomahawk Lake system still proved difficult for 2,4-D to reach sufficient exposure times. New herbicide chemistries, such as ProcellaCOR™, have recently been found to be effective in spot treatment scenarios, particularly

when they employed in partially contained bays. While a single trial ProcellaCOR™ in 2019 proved ineffective on Tomahawk Lake, advancements in knowledge of how to employ this chemical suggest that it may be effective in certain scenarios on Tomahawk Lake. And while its toxicological rating may suggest it is safer than many other herbicides, it is not without risk. The TLA Planning Committee discussed these risks and was particularly concerned with the unknown long term risks of herbicides in general.

The TLA Planning Committee has devised an Integrated Pest Management (IPM) Program for managing the EWM population on Tomahawk Lake. An IPM Program is an approach to manage a species that utilizes a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately. Because most of the lake is not conducive to herbicide management, the TLA will primarily use mechanical harvesting to minimize the nuisance conditions caused by the EWM population. The TLA was awarded a WDNR grant to implement mechanical harvesting at a high effort in 2022-2023 and monitor its impacts. If this effort proves to meet the needs of Tomahawk Lake system riparians, this program may be made self-sustainable through future fundraising efforts.

The TLA also intends to use herbicide management in areas that are less compatible with mechanical harvesting, such as shallow back bays that contain obstacles such as woody habitat or docks. These are also situations where the herbicide treatment will be more effective. This will allow the mechanical harvesting effort to focus on other parts of the system. The TLA intends to apply for a WDNR grant during the upcoming cycle to cost share the trial herbicide treatment and monitoring program.

The TLA will also promote contracted hand-harvesting with Diver Assisted Suction Harvesting (DASH). Removing EWM in navigation lanes through hand-harvesting, likely with DASH, can be an effective nuisance mitigation technique. The TLA would help connect the benefiting riparian with a contracted firm, and assist with the permitting. The cost of the activity would be responsibility of the benefitting riparian.

Through the process of this aquatic plant management planning effort, the TLA has learned much about their system, both in terms of its positive and negative attributes. The TLA continues to be tasked with properly maintaining and caring for this resource. It is particularly important to protect high quality aspects of the Tomahawk Lake ecosystem such as the nearshore areas of the lake. The TLA will continue to make shoreland protection and enhancement a high priority.

5.0 AQUATIC PLANT IMPLEMENTATION PLAN SECTION

The TLA's *Comprehensive Lake Management Plan* for Tomahawk Lake was finalized and approved by the WDNR in 2016. This *Plan* can be found on the WDNR website located here:

https://dnr.wi.gov/lakes/grants/project.aspx?project=99223410

The Implementation Plan Strategy Section of the *2016 CLMP* (pg 105) includes the following strategic management directions along with specific management actions developed to help reach the objectives.

1. Maintain a diverse, native aquatic plant community.
2. Preserve the quality of Tomahawk Lake System waters
3. Balance recreational use with preservation of the natural lake environment
4. Engage the lake community in lake and watershed stewardship practices
5. Partner with area organizations, government agencies, and local businesses to support the goals of the lake management plan

Figure 6.0-1. TLA management goals from 2016 CLMP. From *Tomahawk Lake Comprehensive Lake Management Plan* (September 2016)

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. The following Implementation plan updates the TLA's *Comprehensive Management Plan* for Tomahawk Lake as it applies to aquatic plant management (APM). During this process, the TLA revisits their Aquatic Plant Management Plan based on the lessons learned during the project and current BMPs for aquatic plant management.

The APM-related Implementation Plan provided here outlines separate management goals and actions that together form the TLA's Integrated Pest Management strategy. Integrated Pest Management (IPM) is an approach to manage a species that utilizes a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately. This long-term vision considers all available control practices such as:

Prevention	Pesticide application
Biological control	Water level manipulation
Biomanipulation	Mechanical removal
Nutrient management	Feasibility planning
Habitat manipulation	Population monitoring
Substantial modification of cultural practices	

The Implementation Plan presented below was created through the collaborative efforts of the TLA Planning Committee and ecologist/planners from Onterra. The Implementation Plan represents the path TLA will follow in order to meet their lake management goals. 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 Tomahawk Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members. 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, level of volunteer involvement, and needs of the stakeholders.

The management actions below are assigned to either the TLA Board of Directors or the Environment & Education Committee. Each entity will access whether the actions may be better facilitated by a sub-committee or an individual director/coordinator. Each entity will also be responsible for creating their overall work plan, which will provide additional clarity on prioritization and allocation of resources (i.e. time and funding).

Management Goal 1: Ensure the TLA has a Functioning and Up-to-Date Management Plan

Management Action:	Periodically update lake management plan
Timeframe:	Periodic
Facilitator:	Board of Directors
Description:	The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. ***Comprehensive Management Plan*** The WDNR recommends *Comprehensive Lake Management Plans* generally get updated every 10 years. Implementation projects require a completion data of "no more than 10 years prior to the year in which an implementation grant application is submitted. The department may determine a longer lifespan is appropriate if the applicant can demonstrate a plan has been actively implemented and updated during its lifespan." This allows a review of the available data from the lake, as well as to consider changing BMPs for water quality, watershed, and shoreland management. The TLA's previous *Comprehensive Lake Management Plan* was completed in 2016. ***Aquatic Plant Management Plan*** BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. To be eligible to apply for grants that provide cost share for AIS control and monitoring, "a current plan 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." It is important to work with the regional WDNR Lakes Biologist to understand what is required at this time, as it is more subjective in comparison to the requirements of a *Comprehensive Lake Management Plan* as it relates to

	the specific management actions being considered. The TLA conducted an official update to their aquatic plant management plan as part of this project. ***Annual Control & Monitoring Plan*** It is important to note that the management plan provides a framework to guide the management action, but does not include the specific control plan for a given year. A written control plan, consistent with the *Management Plan*, would be produced prior to the action outlining the management and monitoring strategy. The control plan is useful for WDNR and tribal regulators when considering approval of the action, as well as to convey the control plan to TLA members for their understanding.
Action Steps:	
	See description above.

Management Action:	Conduct periodic riparian stakeholder surveys
Timeframe:	Periodic: every 5 years, corresponding with management plan updates
Facilitator:	Board of Directors
Description:	Formal riparian stakeholder user surveys have been performed by the association in 2014 and 2022. Approximately once every 5-6 years, potentially at the time of a Plan update or prior to a large management effort, an updated stakeholder survey would be distributed to the Tomahawk Lake riparians and TLA members. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the chain and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2021, with modified or additional questions as appropriate. The survey would again need to receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

Management Goal 2: Monitor Aquatic Vegetation on Tomahawk Lake

Management Action:	Periodically monitor the Eurasian watermilfoil population
Timeframe:	Periodic: every 2-3 years; Timing: during latter part of growing season
Facilitator:	Board of Directors
Description:	As the name implies, the Late-Season EWM Mapping Survey is a professionally contracted survey completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For the Tomahawk Lake, this survey would likely take place in mid-August to the end of September, dependent on the growing conditions of the particular year. This survey would include a complete or focused meander survey of the system's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). Late Season EWM Mapping Surveys have been conducted regularly for decades, with modified methodology being used in 2021 upon the initial hiring of Onterra. These data allow lake stakeholders to understand annual EWM populations in response to natural variation and directed management activities. The costs of this survey would be eligible for a Surface Water Grant, which has an application deadline of November 15 of each year, with intent materials being due 60 days prior (September 15).

Management Action:	Coordinate periodic point-intercept aquatic plant surveys
Timeframe:	Periodic: every 5 years; Timing: during July-August
Facilitator:	Board of Directors
Description:	The point-intercept aquatic plant monitoring methodology as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) has been used on the Tomahawk Lake System in the past. Whole-lake point-intercept surveys have occurred in 2005, 2007, 2014, and 2021. Little Tomahawk Lake was the only waterbody sampled during 2005, whereas the remaining lakes in the system were first sampled in 2007. All lakes in the system were surveyed in 2014 as a component of a lake management planning effort. Each lake was sampled once again in 2021 as a part of this project that will result in an update to the lake management plan. 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 TLA will ensure the point-intercept surveys is conducted at least once every five years. The WDNR indicates that repeating a point-intercept survey every five years will generally suffice to meet WDNR planning requirements unless large-scale aquatic plant management is taking place and more frequent monitoring is requested for the specifically targeted areas. The costs of this survey would be eligible for a Surface Water Grant, which has an application deadline of November 15 of each year, with intent materials being due 60 days prior (September 15).

Management Action:	Periodically monitor the non-native emergent plant population
Timeframe:	Periodic: every 5 years
Facilitator:	Board of directors
Description:	The Tomahawk Lake system includes several non-native emergent plant species including pale-yellow iris, purple loosestrife, narrow-leaved cattail, and flowering rush. Over the years, professional and volunteer-based surveys have occurred on the system. The TLA will consider conducting periodic system-wide surveys of these non-native species, potentially once every five years. Having an understanding of these species' populations and population trends is important to determine if management is warranted. The TLA will continue to educate property owners on the importance of native vegetation and shoreline health, as well as preferred management methods for these species. The costs of this survey would be eligible for a Surface Water Grant, which has an application deadline of November 15 of each year, with intent materials being due 60 days prior (September 15).

Management Action:	Consider periodic community mapping (floating-leaf and emergent) surveys
Timeframe:	Periodic: every 10 years or when prompted
Facilitator:	Board of directors
Description:	This survey would delineate the margins of floating-leaf (e.g., water lilies) and emergent (e.g., cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. This baseline survey has never been conducted on the Tomahawk system, but would tie in with the TLA's efforts on shoreline condition and established Critical Habitat Areas.

	The costs of this survey would be eligible for a Surface Water Grant, which has an application deadline of November 15 of each year, with intent materials being due 60 days prior (September 15).

Management Goal 3: Prevent Establishment of New Aquatic Invasive Species

Management Action:	Monitor Tomahawk Lake entry points for aquatic invasive species
Timeframe:	Ongoing
Facilitator:	Environment & Education Committee
Description:	The intent of this program is not only be to prevent additional invasive species from entering the Tomahawk Lake through its public access locations, but also to prevent the infestation of other waterways with invasive species that originated in Tomahawk Lake. The TLA utilizes WDNR grant funding to sponsor watercraft inspections through the WDNR's Clean Boats Clean Waters (CBCW) program at two public boat launches (Lake Tomahawk Park Boat Launch and the lake access at Indian Mounds Campground). CBCW inspection is provided on Fridays, Saturdays, Sundays, and holidays. The TLA's Clean Boats Clean Waters program has been well organized, with numerous watercraft inspections occurring annually. The Minocqua-Kawaguesaga Lakes Protection Association and the Mid Lake protection and Management District also conduct CBCW efforts on other landings on the greater Minocqua Chain of Lakes. The TLA will reach out to these entities at the beginning of each season to ensure all landings are covered and that consistent messaging strategies are applied. Table 5.0-1 lists some of the known aquatic invasive species (AIS) that the TLA should be aware of.

Table 5.0-1. Notable AIS of Concern to the TLA.

Category	Common Name	Scientific Name	Nearest Lake with confirmed AIS	AIS Distance to Tomahawk (mi)	NR 40 Classification	Concern level	Notes
Invertebrates	Spiny waterflea	*Bythotrephes longimanus*	Trout Lake (Vilas Co)	13	Prohibited	High	Suitable (DNR)
	Zebra mussel	*Dreissena polymorpha*	Lake Metonga (Forest Co)	40	Restricted	Low	Unsuitable (DNR)
Fish	Rainbow smelt	*Osmerus mordax*	Fence Lake (Vilas Co)	11	Restricted	High	Suitable (DNR)
Plants	Starry stonewort	*Nitellopsis obtusa*	Pine Lake (Shawano Co)	94	Prohibited	Moderate	-
	Phragmites	*Phragmites australis*	Tomahawk River (Oneida Co)	5	Prohibited/Restricted	High	-
	Reed mannagrass	*Glyceria maxima*	Sureshot Lake (Oneida Co)	4	Prohibited/Restricted	High	-

The TLA will continue to seek cost share assistance through the WDNR's streamline Clean Boats Clean Waters (CBCW) program:

https://dnr.wi.gov/Aid/documents/SurfaceWater/CleanBoatsCleanWatersFactSheet.pdf

Management Action:	Investigate supplemental aquatic invasive species prevention and containment methods.
Timeframe:	Ongoing
Facilitator:	Environment & Education Committee
Description:	Based upon modeling by the University of Wisconsin Center for Limnology, Tomahawk Lake, Minocqua Lake, Kawaguesaga Lake, and the Tomahawk Thoroughfare are all on the list of the state's top 300 AIS Prevention Priority Waterbodies. This means that these lakes have a high number of boats arriving from lakes that have AIS (receiving) and a high number of boats moving from the system to uninvaded waters (sending). Therefore, the WDNR encourages additional supplemental prevention efforts above just watercraft inspections, offering additional grant funds for these activities for applicable lakes. Supplemental prevention efforts such as decontamination stations (e.g., pressure washer), water-less cleaning stations (e.g. CD3 systems), and remote video surveillance (e.g., I-Lids™) could be partially funded through this program. The TLA will strive to have updated signage at all landings promoting CBCW messaging. They will also consider supplemental prevention efforts as described above.

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

Management Action:	Convey updated aquatic invasive species information and messaging to TLA members and Tomahawk Lake riparians
Timeframe:	Ongoing
Facilitator:	Environment and Education Committee
Description:	Emerging science and new information is continually coming out of the aquatic plant management field, impacting management philosophies and what is considered the Best Management Practices (BMP). The TLA understands the importance of keeping the Tomahawk Lake riparians informed of this rapidly changing landscape. The two key concepts below represent some of the largest knowledge disparities in EWM management held by many lake residents in Wisconsin. **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. Autofragmentation is the purposeful fragmentation of EWM for the purposes of asexual reproduction. This plant has evolved a mechanism to increase its population in this manner. The parent plant actually sends carbohydrate reserves to the growing tip (apical meristem) before the fragment separates. Also, before separation, the fragment will start growing root-like structures (adventitious roots). Applying an analogy, that plant has packed its bags and is ready to endure floating around in the lake for a few days and then trying to grow in new place in the lake. This naturally happens in all lakes. Onterra's experience is that there are two main events – once in late-spring and again towards the end of the growing season. Alloframents are those fragments that break off by mechanical breakage by boats, wind, mechanical harvesting, etc. These fragments have a smaller chance of producing a new plant – continuing with the analogy, because they did not get to pack their bags and have to try to make it with what they have on hand.

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

Frankly, for established populations like those that exist on the Tomahawk Lake System. 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 Tomahawk Lake system, 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.

Population Management of Established EWM Populations

As discussed within the Eurasian Watermilfoil sub-section (4.3), there are differing management philosophies and approaches to invasive aquatic plant species. Where EWM populations already have an established footprint in a lake and are already present in most nearby waterbodies, it may not be practical to manage for an overall lowered population goal. This is especially true for large systems like Tomahawk Lake. The ecosystem stress that is imparted on these systems during large-scale management activities is arguably greater than what EWM is imparting on the system if left unchecked. In these instances, areas are not targeted for management until documented ecological impairment or recreation impediment occurs. Therefore, prioritized areas may be targeted for management and other areas are tolerated or avoided.

To accomplish this educational objective, the TLA plans to highlight key topics from the plan and share educational materials on the subjects over time. The TLA

	believes that creating smaller modules of information and spreading out the delivery over time will be an effective educational initiative. In addition to these primary changes in EWM management, the TLA has identified the following list to serve as a basis for their education and outreach in regards to EWM management: • Conservation ethics • EWM hybridity • EWM herbicide resistance • Unrealistic expectations (e.g. eradication) • Silver-bullet strategies • Role of native aquatic plants • Importance of nutrient management • Safety concerns related to dense EWM • Human tolerance to EWM conditions (surface-matting)

Management Goal 5: Actively manage EWM to keep the population from negatively impacting recreation, navigation, and aesthetics

Management Action:	Conduct Integrated Pest Management Program towards EWM
Timeframe:	Ongoing
Facilitator:	Board of Directors
Description:	The objective of this action will be to minimize the periodic nuisance conditions that EWM causes on Tomahawk Lake by restoring navigation, recreation, and aesthetics. In order to reach this objective, the TLA has developed a multi-pronged approach as part of this Integrated Pest Management (IPM) Program. Each management technique described below is discussed in regards to site selection and corresponding monitoring strategy. Each management technique will be considered in context of any adjacent Critical Habitat Areas. Specifically, the TLA will evaluate the potential of each activity to disrupt the virtue driving the rationale for being identified as a critical habitat area. For example, if the area was designated as a Critical Habitat Area for having a valuable littoral aquatic plant community, using a non-selective herbicide near that site would not be compatible with maintaining the areas integrity. The following bullets are a general guide to the IPM Program: • ***Mechanical Harvesting*** will be the primary EWM management tool. Much of the EWM footprint of EWM in the Tomahawk Lake System is in offshore and exposed areas where herbicide treatment is not likely to be effective. Previous trials have faced implementation obstacles, such that 2021 was the only year where mechanical harvesting was implemented to a level worthy of serving as a trial. Building off what was learned in previous attempts, a more robust trial mechanical harvesting program will

occur in 2022-2023 to continue to learn how to best implement this tool and develop success expectations.

- ***Herbicide Treatment*** will be integrated into the IPM Program after trials document its effectiveness. The first trial will occur in spring 2023. Herbicide treatment is likely to be confined to protected bays of the lake where the likelihood of success is higher. These areas may also be less compatible with mechanical harvesting, as they contain shallow water and/or docks and other obstacles.
- ***Hand-Harvesting*** using HCS/DASH will be applied by requesting riparians at a local scale. The costs of the action will be the responsibility of the requesting riparian, with assistance on permitting from the TLA.

The WDNR has indicated they support the least impactful method that is feasible to alleviate an aquatic plant issue. The Lac du Flambeau Tribal Natural Resource Department maintains opposition to herbicide treatment on any lake within ceded territory for concerns of impacts to sensitive wild rice populations as well as potential impacts to fisheries.

1. **Mechanical Harvesting** The TLA have determined an appropriate logistical path for using mechanical harvesting methods as their primary technique to reach their EWM management objectives. The TLA has recently secured the maximum WDNR grant award allowed ($150,000) to fund a trial mechanical harvesting project in 2022 and 2023. For this 2-year project, the TLA will be contracting a local firm to conduct the mechanical harvesting operation. This firm has newer and slightly larger equipment than used in past years, which around 125-acres is preliminarily estimated to be targeted and monitored.

   Areas targeted for mechanical harvesting include areas within high riparian footprint and areas of local importance for recreation. A map of the proposed mechanical harvesting areas for a given year will be created during the late-winter, with attention to the development of prioritization and efficiency strategy. Areas considered for mechanical harvesting would be evaluated in the context of any adjacent critical habitat areas.

   During this 2-year trial program, professional monitoring will consist of pre- and post-harvesting monitoring of the aquatic plant community through a sub-sample point-intercept survey. A professional EWM mapping survey will also occur in 2023 to compare with the 2021 survey. Volunteer-based monitoring will aim to monitor the longevity of relief provided by mechanical harvesting by measuring measure the distance from the top of the EWM plants to the surface of the lake at designated intervals following the mechanical harvesting activities. After the 2-year trial program, the TLA will objectively review the results of the program to potentially drive a modified management action in future years.

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.
- No harvesting shall occur before June 1 to avoid impacting valuable muskellunge spawning habitat for the chain.
- 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, are the target for this permit. Removal of emergent (e.g. bulrushes) and floating-leaf (e.g. water lilies) species needs to be avoided because of their ecological value and niche occupation.
- Aquatic plants that are cut must be removed from the water.
- 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).

2. **Herbicide Spot Treatment** While some herbicide treatments have provided successful results, the unpredictability of spot treatments state-wide has resulted in less favorability of this strategy with WDNR regulators and lake managers. This is particularly true in areas of increased water exchange via flow, exposed and offshore EWM colonies, or when traditional weak-acid herbicides like 2,4-D are used.

   In accordance with the APM plan TLA will pursue a trial herbicide treatment in areas where this plant is impacting navigation, recreation, and aesthetics. The TLA would like to use herbicide management as part of their Integrated Pest Management strategy for sites conducive to holding effective herbicide concentrations and exposure times, such as protected and confined areas of the system. Further, high-use areas that may be less compatible with mechanical harvesting would be prioritized. Examples of sites difficult for mechanical harvesting include areas that are mostly shallow water (i.e. less than 5 feet deep), have high frequency of docks and other obstacles, are located far from off-loading locations, and have history of quick EWM regrowth following harvesting. Areas considered for herbicide treatment would be evaluated in the context of any adjacent critical habitat areas.

   Onterra maintains concern for future use of 2,4-D in the Tomahawk Lake system; the extensive use of this product may have created herbicide

resistance and therefore herbicide rotation away from this herbicide is recommended. Concerns for fisheries impacts also accompany this herbicide.

A trial treatment using ProcellaCOR™ (florpyrauxifen-benzyl) in 2019 failed to meet expectations of success even though this chemistry has been highly effective on other regional waterbodies including the downstream Minocqua-Kawaguesaga Lakes. At this time, Onterra believes future ProcellaCOR™ treatments are still the most likely to be effective in the Tomahawk system as other herbicides have not been able to hold sufficient concentrations and exposure times to yield multiyear EWM population reductions. Treatment efficacy could be improved by attention to precise volume calculations, implementing higher dosing strategies, and consideration of potential mixing concentrations within an Area of Potential Impact (AOPI), such as a protected bay of the lake.

The TLA and current lake management consultant have been investigating the potential for herbicide treatments with barrier curtains to target smaller areas of EWM (i.e. less than 5 acres) or more exposed areas within a lake. Along with a few other stipulations, the WDNR does not require any additional permits (aside from normal NR 107 Herbicide Treatment Permit) to implement a barrier curtain so long as access is not denied to any part of the system and the curtain is in place for no more than 96 hours. Barrier curtain construction and placement is the responsibility of the lake group, requiring advance planning efforts and a formidable volunteer base. The TLA will consider advancements in research into new herbicides and use patterns, including barrier curtains, as annual EWM control plans are developed.

If the TLA decides to pursue future herbicide management towards EWM, the following set of bullet points would occur:

- Early consultation with WDNR would occur.
- The preceding annual *EWM Control & Monitoring Report* would outline the precise control and monitoring strategy.
- Give consideration to pretreatment invasive watermilfoil genetic testing (i.e., fingerprinting)
- EWM efficacy would occur by comparing annual late-summer EWM mapping surveys. This monitoring should take place at least at the scale of likely impact. If the treatment is a true spot treatment, the application area should be monitored. If the Area of Potential Impact (AOPI) is larger, such as a basin or an entire lake, that AOPI should be monitored.
- If grant funds are being used, large areas are being targeted, and/or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with the *Draft Aquatic Plant Treatment Evaluation Protocol (October 1, 2016):*
  https://dnrx.wisconsin.gov/swims/downloadDocument.do?id=158140137

This generally consists of collecting quantitative point-intercept data the *late-summer prior to treatment* (pre) and the summers following the treatment (*year of treatment and year after treatment*) at the scale of AOPI. While the logistical challenges of collecting data during the *year prior to treatment* have resulted in some managers opting for pretreatment data collection during the late-spring of the *year of treatment*, the WDNR strongly prefers following the timing outlined in the protocol referenced above as pre and post data collected at the same time of the year is the most comparable.

- Herbicide concentration monitoring may also occur surrounding the treatment if grant funds are being used or the TLA believes important information would be gained from the effort.
- An herbicide applicator firm would be selected in late-winter and a permit application would be applied to the WDNR as early in the calendar year as possible, allowing interested parties sufficient time to review the control plan outlined within the annual report as well as review the permit application.
- Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would likely occur. This would consist of the herbicide treatment occurring towards the beginning of the growing season (typically in early-June), active growth tissue is confirmed on the target plants, and is after Native American open-water spear harvest has concluded. 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) as well as to confirm the proposed treatment area extents and water depths. This information would be used to finalize the permit, potentially with adjustments 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.

Short-Term EWM Control Plan:

The TLA maintains hesitancy for moving forward with a wide-scale herbicide management strategy at this time. The TLA feels strongly that herbicide effectiveness needs to be demonstrated on their system before being incorporated into their overall Integrated Pest Management Program.

Following the management plan outlined above, the TLA aims to conduct a set of trial ProcellaCOR™ treatments in 2023 and seek AIS Control Grant funding to offset the costs of the management and monitoring. This grant program has an application deadline of November 15 of each year, with intent materials being due 60 days prior (September 15).

3. **Hand-Harvesting (includes HCS/DASH)** In 2009, the TLA created a Hydraulic Conveyor System (HCS) which now falls into what is commonly called Diver Assisted Suction Harvesting (DASH). The HCS system has

	been operated annually as part of their EWM population management program. Hand-harvesting can also be a useful tool for nuisance mitigation. Removing EWM in navigation lanes through hand-harvesting, likely with DASH/HCS, can accomplish this goal. Each riparian owner can legally hand-remove EWM and native plant species in a 30-foot-wide area of one's frontage directly adjacent to their pier without a permit. EWM can be hand-removed outside of the 30-foot-wide area without a permit. A permit is required if an area larger than the 30-foot corridor is being hand-removed or if a mechanical assistance mechanism, like DASH, is being used. The TLA supports riparians manually removing EWM within a 30-foot-wide lane extending from their dock out to deeper water, especially if they are willing to leave native plants intact within this footprint. The TLA also supports riparians contracting with a hand-harvesting firm to conduct DASH efforts in these areas. In the future, the TLA will assist with permitting in these scenarios, but all costs are incurred by the benefitting riparian. Contracted hand-harvesting operations with DASH would adhere to the following bullet points in addition to WDNR permit conditions: • Requesting riparians need a WDNR permit if DASH/HCS methods are being used. The TLA may be willing to assist with WDNR permitting. • The TLA requests the requesting riparian and/or the contracted hand-harvesting firm provide information on the harvesting activity (i.e. location, amount of effort) following implementation to assist with the TLA's tracking of the EWM population. • The TLA prefers native plants are not disturbed during this process.

Management Goal 6: Promote Lake Stewardship and Conservation Ethics to TLA Members and Tomahawk Lake Riparians

Management Action:	Educate stakeholders on the importance of shoreland condition and shoreland restoration and protection
Timeframe:	Ongoing
Facilitator:	Environment and Education Committee
Description:	The intrinsic value of natural shorelands is found in numerous forms. Vegetated shorelands prevent polluted runoff from entering lakes by filtering this water or allowing it to slow to the point where particulates settle. Nutrient management can be an important component of aquatic invasive species management, as issues caused by plants like EWM can be exacerbated in high nutrient situations. The roots of shoreland plants stabilize the soil, thereby

	preventing shoreland erosion. Shorelands also provide habitat for both aquatic and terrestrial animal species. Many species rely on natural shorelands for all or part of their life cycle as a source of food, cover from predators, and as a place to raise their young. Shorelands and the nearby shallow waters serve as spawning grounds for fish and nesting sites for birds. Thus, both the removal of vegetation and the inclusion of development reduces many forms of habitat for wildlife. Overall lake stewardship and conservation ethics are important qualities that the TLA will continue to promote. The TLA has created a Lake Steward Pledge, with defined action steps to help riparians understand the concept: *https://www.tomahawklake.org/steward/take-the-pledge-become-a-lake-steward/* The TLA sponsored a WDNR Lake Protection Grant (LPL-1688-19) to hire Nova Ecological Services in 2020 to determine critical habitat areas on the lake, monitor shorelands, and create a comprehensive lake habitat and use map that will be used to educate landowners and identify areas for shoreland restoration and/or habitat protection and improvement. The APM Plan update project took these data and created an interactive web map portal to allow easier access of these data by riparians: *https://onterra.maps.arcgis.com/apps/webappviewer/index.html?id=dcf3981f1cc8408ba2adf2a4027a28e3* The *Environment and Education Committee* would continue to provide education on the importance of shoreland condition and the resources that are available (planning and funding). As is discussed in the next management action, partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative. The *Environment and Education Committee* would also strive to initiate Healthy Lakes shoreline restoration projects to serve as demonstration sites, being publicized to lake users so they may want to follow suit on their properties.

Management Action:	Facilitate connecting riparians with Healthy Lakes & River Grants
Timeframe:	Ongoing
Facilitator:	Environment and Education Committee
Description:	Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program, now called the Healthy Lakes and Rivers Grant program, provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality: • Rain Garden

	• Rock Infiltration • Diversion • Native Plantings • Fish Sticks The cost share allows $1,000 per practice, up to $25,000 per annual grant application. More details and resources for the program can be found at: https://healthylakeswi.com The TLA will continue to focus specific education on the importance of shoreland condition and the resources that are available (planning and funding). Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative but needs to be applied for by a qualified lake group such as the TLA, not an individual riparian. The TLA would assist with the grant application, but all direct and indirect costs would be the responsibility of the benefiting riparian. If shoreline property erosion issues are larger than can be addressed through the Healthy Lakes grant program, the TLA would consider the possibility of WDNR Surface Water Grants or potential cost-share funding available through Oneida County The above Healthy Lakes practices are important and applicable to all riparian properties except the addition of fish sticks. Fish stick projects need to be implemented in accordance to approved technical requirements from the local WDNR fisheries biologist and complies with local shoreland zoning ordinances. It's important to reiterated the importance of working with the local WDNR fisheries biologist (Nathan Lederman - Nathaniel.Lederman@wi.gov) prior to implementing fish stick projects to ensure the activity will be beneficial for the fish species being managed for.

Management Action:	Promote long-term protections for private property on the Tomahawk Lake System
Timeframe:	Ongoing
Facilitator:	Environment and Education Committee
Description:	As shown on Map 1, a large portion of the land adjacent to the Tomahawk Lake System is part of the American Legion State Forest. Additional lands are also owned by the various townships or the UW Regents (Kemp Natural Resource Station). The TLA will continue to promote the direct preservation of land through implementation of conservation easements or land trusts. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Oneida County Land & Water Conservation Department. Several websites of interest include:

	• Conservation easements or land trusts: *www.northwoodslandtrust.org* • UW-Extension Shoreland Restoration: *https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/ecology/shoreland/default.aspx* • WDNR Shoreland Zoning website: *http://dnr.wi.gov/topic/ShorelandZoning/* WDNR land acquisition grants are available to pay for the costs of property purchases and conservation easements. Scott Van Egeren (WDNR lakes biologist) or Jill Sunderland (WDNR environmental grants specialist) can be contacted with questions about this specific grant program.

6.0 LITERATURE CITED

Becker, G.C. 1983. *Fishes of Wisconsin.* London, England: The University of Wisconsin Press, 1983.

Coops, H. 2002. Ecology of charophytes; an introduction. *Aquatic Botany*, 2002: 72(3-4): 205-208.

Dehnert, G. K., M. B. Freitas, Z. A. DeQuattro, T. Barry, and W. H. Karasov. 2018. Effects of Low, Subchronic Exposure of 2,4-Dichlorophenoxyacetic Acid (2,4-D) and Commercial 2,4-D Formulations of Early Life Stages of Fathead minnows (Pimephales promelas). *Environmental Toxicology and Chemistry*, 2018: 37(10):25502559.

Dehnert, Gavin K., Mariella B. Freitas, Prashant P. Sharma, Terence P. Barry, and William H. Karasov. 2020. Impacts of subchronic exposure to a commercial 2,4-D herbicide on developmental stages of multiple freshwater fish species. Edited by Jim Lazorchak. *Chemosphere*, 2020: 11.

Dequattro, Z. A., and W. H. Karasov. 2015. Impacts of 2,4-dichlorophenoxyacetic acid aquatic herbicide formulations on reproduction and development of the fathead minnow (pimephales promelas). *Environmental Toxicology and Chemistry*, 2015: 35(6):153-169.

GLIFWC. 2017. *Great Lakes Indian Fish and Wildlife Service Interactive Mapping Website.* 2017. http://maps.glifwc.org.

Glomski, L M, and M D Nehterland. 2010. Response of Eurasian and Hybrid Watermilfoil to Low Use Rates and Extended Exposures of 2,4-D and Tricoplyr. *Journal of Aquatic Plant Management* (Journal of Aquatic plant Management), 2010: 48:12-14.

Gross, E. M., D. Erhard, and E. Ivanyi. 2003. Allelopathic activity of Ceratophyllum demersum L. and Najas marina spp. intermedia (Wolfgang) Casper. *Hydrobiologia*, 2003: 506:583.

Haug, E J. 2018. *Monoecious Hydrilla and Crested Floating Heart Biology, and the Response of Aquatic Plant Species to Florpyrauxifen-benzyl Herbicide.* Dissertation, North Carolina State University, 2018.

Hauxwell, J., et al. 2010. *Recommended baseline monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications.* PUB-SS-1068, Madison, WI: Wisconsin Department of Natural Resources, 2010.

Johnson, J. A., A. R. Jones, and R. M. Newman. 2012. Effects of repeated early season herbicide treatments of curly-leaf pondweed on native macrophyte assemblages in Minnesota Lakes. *Lake and Reservoir Management*, 2012: 28(4):364-374.

Lacoul, P., and B. Freedman. 2006. Environmental influences on aquatic plants in freshwater ecosystems. *Environmental reviews*, 2006: 14(2):89-136.

LaRue, E.A., M.P. Zuellig, M.D. Netherland, M.A. Heilman, and R.A. Thum. 2012. Hybrid watermilfoil lineages are more invasive and less sensitive to commonly used herbicide than their exotic parent (Eurasian watermilfoil). *Evolutionary Applications* 6 (2012): 462-471.

Luehring, Mark. Pike L Chain Walleye and Bass Population Estimate Summary. 2020.

Moody, M L, and D H Les. 2007. Geographic distribution and genotypic composition of invasive hybrid watermilfoil (Myriophyllum spicatum x M. sibiricum) populations in North America. *Biological Invasions*, 2007: 9:559-570.

Muthukrishnan, R., A. S. Davis, N. R. Jordan, and J. D. Forester. 2018. Invasion complexity at large spatial scales is an emergent property of interactions among landscape characteristics and invader traits. *PLOS ONE.* 2018. https://doi.org/10.1371/journal.pone.0195892 (accessed 2018).

Nault. 2016. The science behind the "so-called" super weed. *Wisconsin Natural Resources*, 2016: 10-12.

Nault, M. E., et al. 2018. Evolution of large-scale low-concentration 2,4-D treatments for Eurasian and hybrid watermilfoil control across multiple Wisconsin lakes. *Lake and Reservoir Management*, 2018: 34(2):115-129.

Netherland, M.D. 2009. Chapter 11, "Chemical Control of Aquatic Weeds.". In *Biology and Control of Aquatic Plants: A Best Management Handbook*, by W.T. Haller, & M. Bellaud (eds.) L.A. Gettys, 65-77. Marietta, GA.: Aquatic Ecosystem Restoration Foundation, 2009.

Neuswanger, D., and M. A. Bozek. 2004. *Preliminary assessment of Effects of Rock Habitat Projects on Walleye Reproduction in 20 Northern Wisconsin Lakes.* A Summary of Case Histories, Wisconsin Department of Natural Resources, 2004.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. *Journal of Lake and Reservoir Management*, 1999: 15(2): 133-141.

Poovey, A G, J G Slade, and M D Netherland. 2007. Susceptibility of Eurasian Watermilfoil (Myriophyllum spicatum) and a Milfoil Hybrid (M. spicatum x M. sibiricum) to Tricoplyr and 2,4-D Amine. *Journal of Aquatic Plant Management*, 2007: 45:111-115.

Rypel, Andrew, et al. 2019. Flexible Classification of Wisconsin Lakes for Improved Fisheries Conservation and Management. *Fisheries Magazine* 44, no. 5 (2019): 225-238.

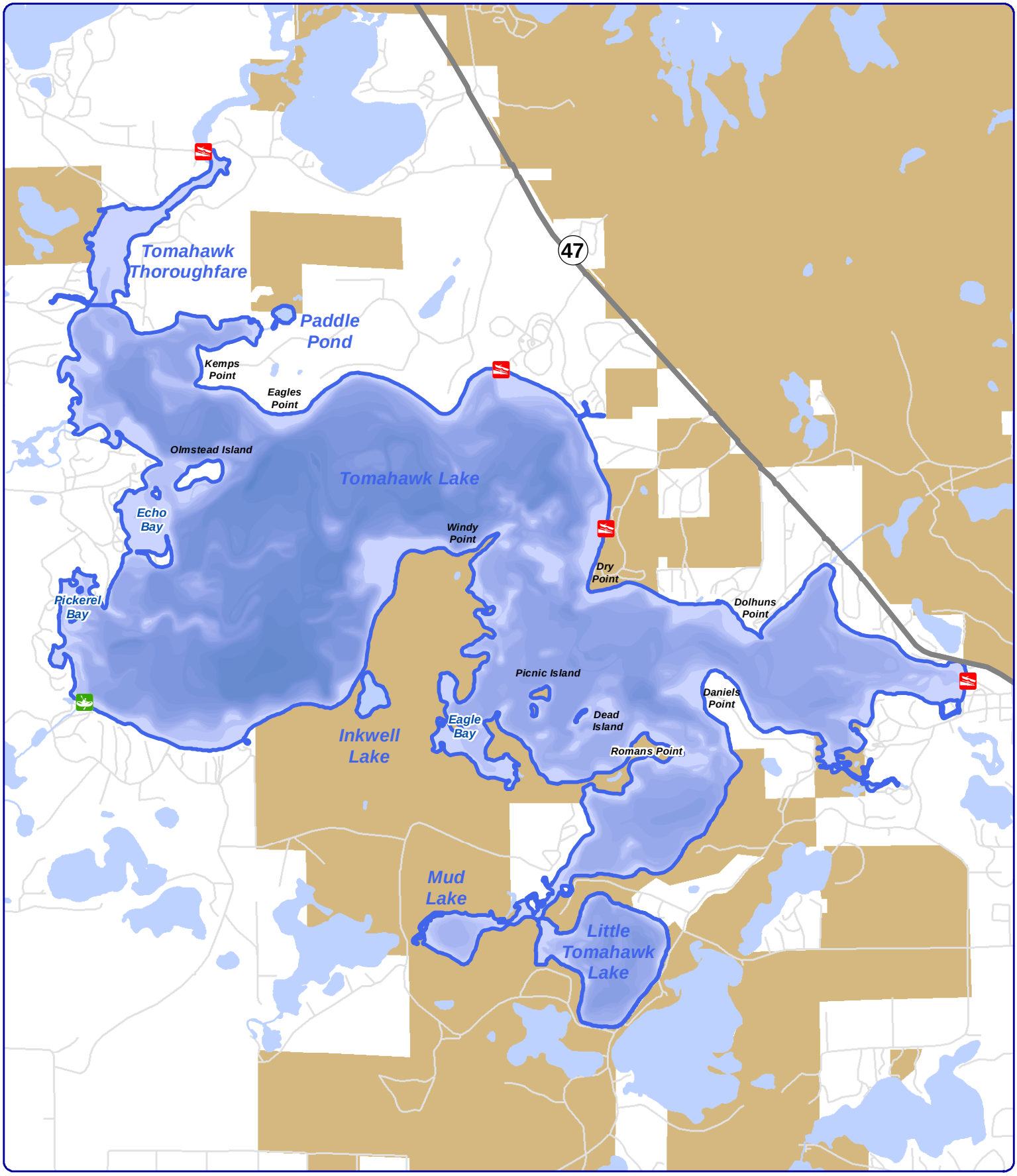
Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In *Encyclopedia of Inland Waters*, by Gene E. Likens, 1: 60-69. Oxford: Elsevier, 2009.

Skogerboe, J.G., A. Poovey, K.D. Getsinger, W. Crowell, and Macbeth E. 2008. Early-season, low-dose applications of endothall to selectively control curlyleaf pondweed in Minnesota lakes. *U.S. Army Engineer Research and Development Center*, 2008: ERDC/TN APCRP-CC-08.

Vassios, J D, S J Nissen, T J Koschnick, and M A Hielman. 2017. Fluridone, penoxsulam, and Tricoplyr absorption and translocation by Eurasian watermilfoil (Myriophyllum spicatum) and Hydrilla (Hydrilla verticillata). *Journal of Aquatic Plant Management*, 2017: 55:58-64.

Watras, C.J., et al. 2013. Decadal oscillation of lakes and aquifers in the upper Great Lakes region of North America: Hydroclimate implications. *Geophysical Research Letters* 41, no. 2 (2013): pp. 456-462.

Wills, T. C., M. T. Bremigan, and D. B. Haynes. 2004. Variable Effects of Habitat Enhancement Structures across Species Habitats in Michigan Reservoirs. *American Fisheries Society*, 2004: 133:399-411.



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Sources:
Hydro, Roads, Public Lands: WDNR
Map Date: October 22, 2020 - EJH

Project Location in Wisconsin

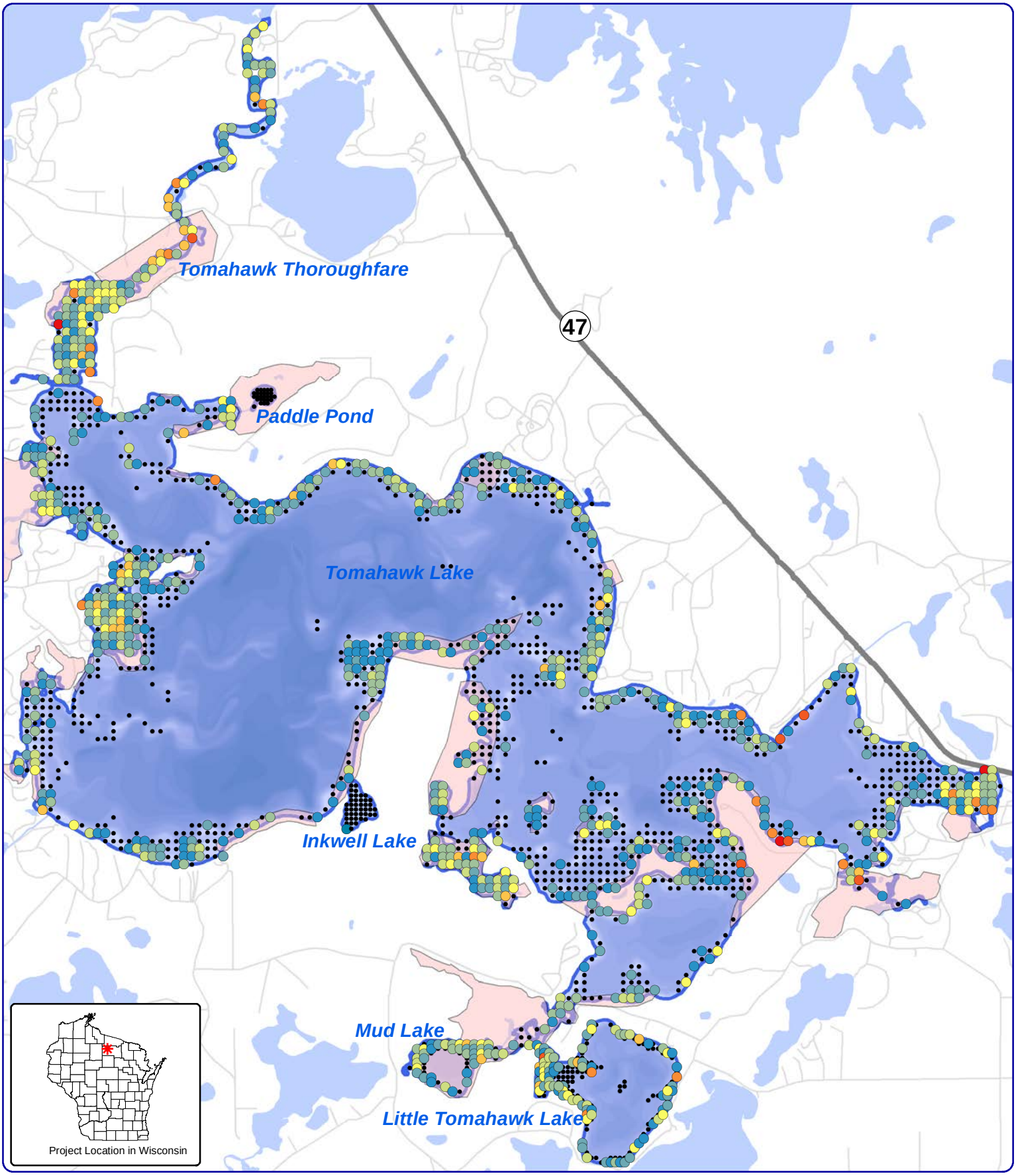
Legend

- Project Boundaries
- American Legion State Forest
- Boat Landing
- Carry-In

Map 1

Tomahawk System
Oneida County, Wisconsin

Project Location & Boundaries



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Sources:
Hydro, Roads, Public Lands: WDNR
Aquatic Plants: Onterra, 2021
Map Date: November 17, 2021 - TWH

Legend

Number of Native Species per Littoral Sampling Site

0 1 2 3 4 5 6 7 8 9

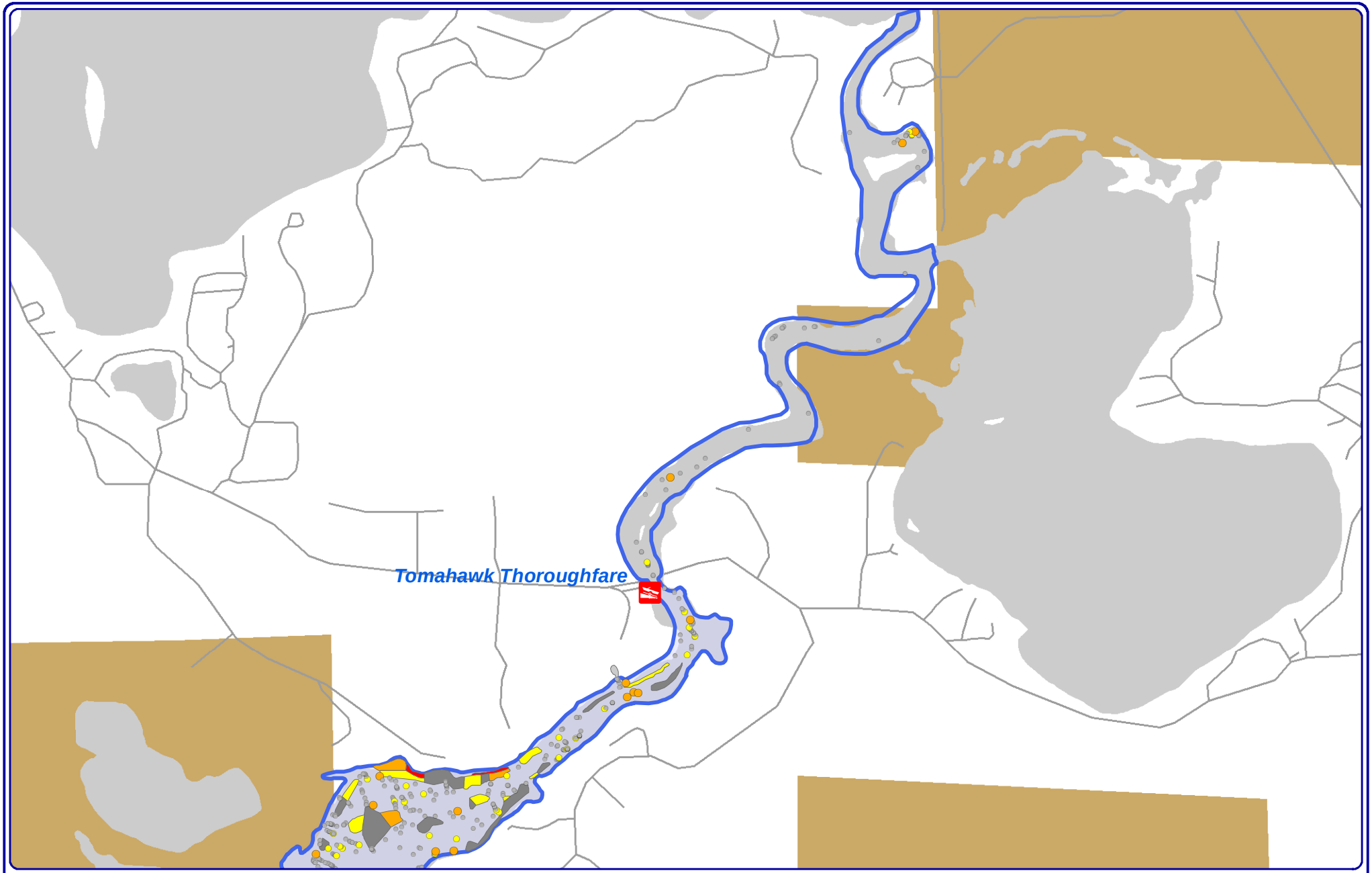
Critical Habitat Areas

Map 1

Tomahawk System

Oneida County, Wisconsin

2021 PI Survey: Native Species Richness



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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plants: Onterra, 2021
Orthophtography: NAIP, 2020
Map Date: August 27, 2021 TWH

Legend

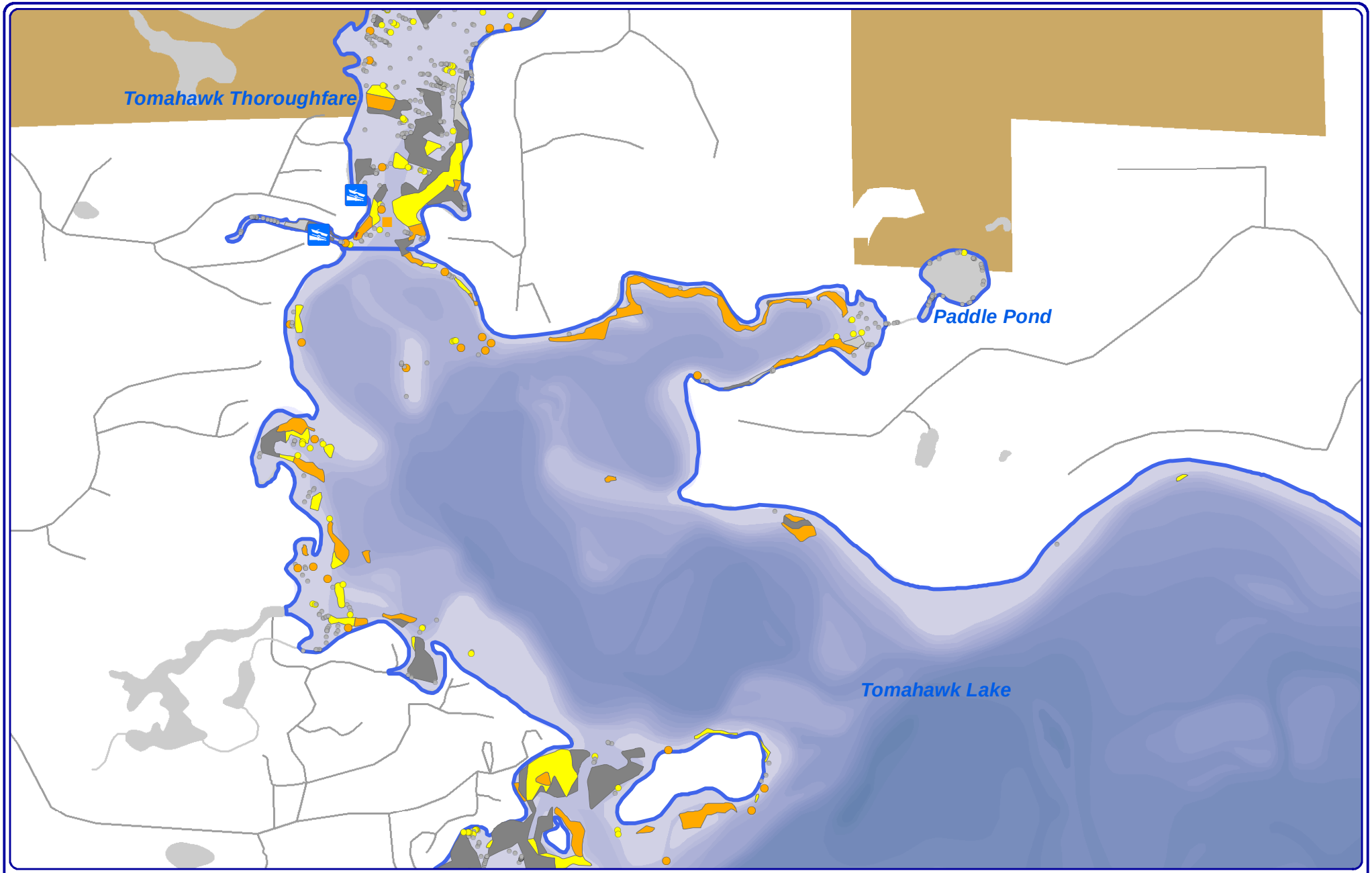
Eurasian watermilfoil (August 3-5, 2021)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

- Public Boat Landing
- Private Boat Landing
- Carry-In
- American Legion State Forest

Map 3
Tomahawk Lake
Oneida Co, Wisconsin

August 2021 EWM Survey Results



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Orthophtography: NAIP, 2020
Map Date: August 27, 2021 TWH

Legend

Eurasian watermilfoil (August 3-5, 2021)

- Highly Scattered
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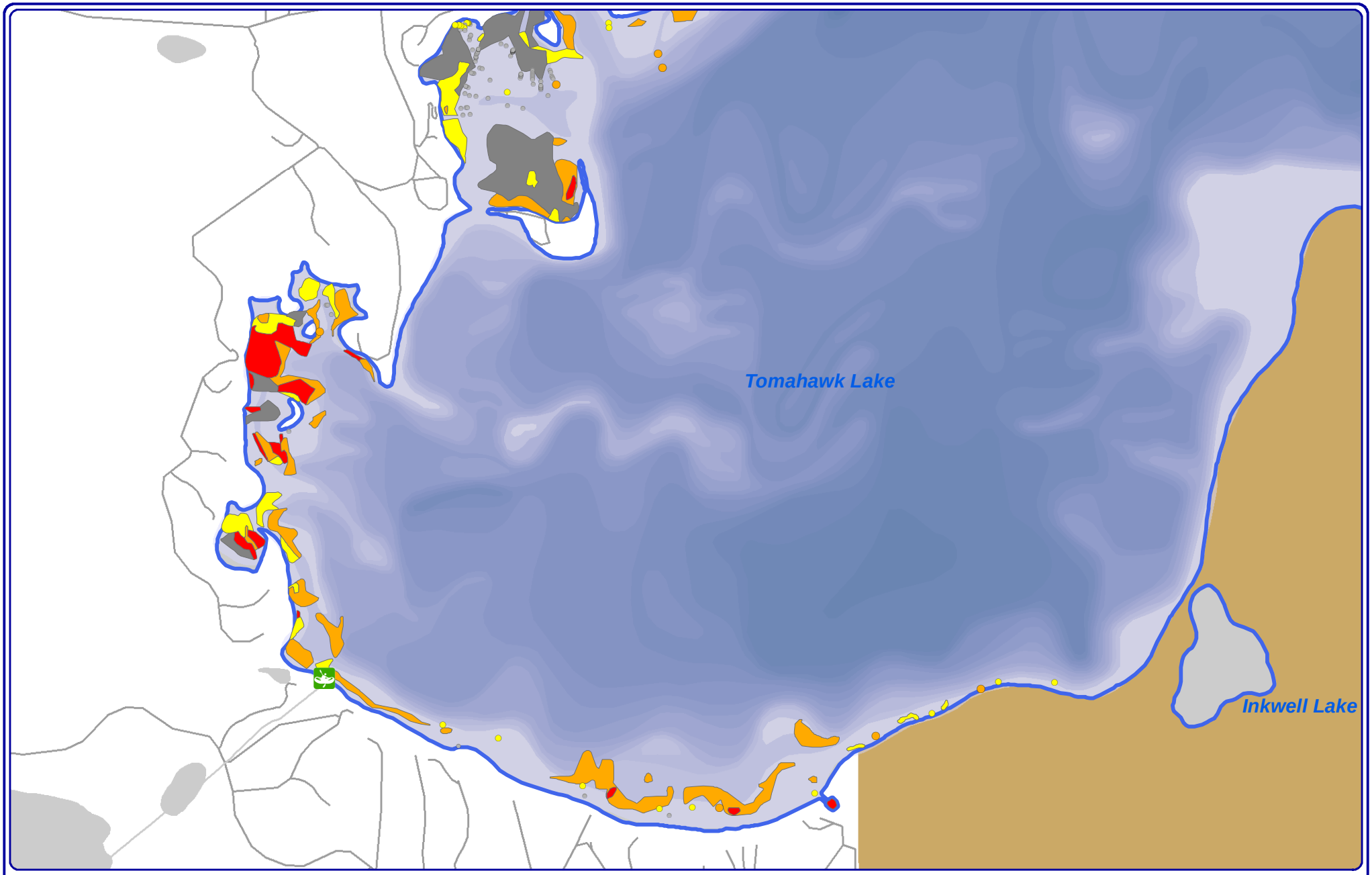
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

- Public Boat Landing
- Private Boat Landing
- Carry-In
- American Legion State Forest

Map 4
Tomahawk Lake
Oneida Co, Wisconsin

August 2021 EWM Survey Results



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Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plants: Onterra, 2021
Orthophtography: NAIP, 2020
Map Date: August 27, 2021 TWH

Legend

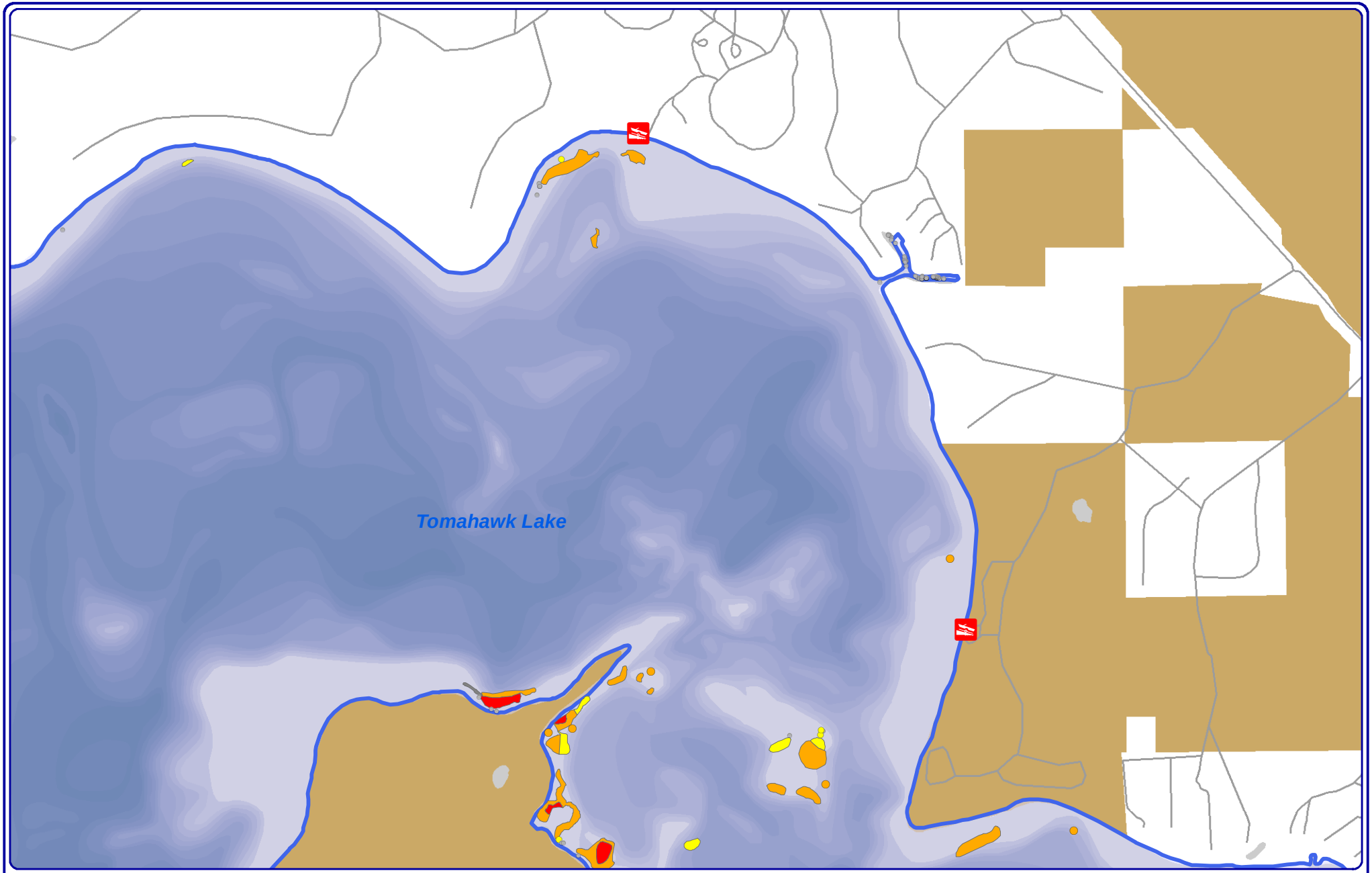
Eurasian watermilfoil (August 3-5, 2021)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

- Public Boat Landing
- Private Boat Landing
- Carry-In
- American Legion State Forest

Map 5
Tomahawk Lake
Oneida Co, Wisconsin

August 2021 EWM Survey Results



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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plants: Onterra, 2021
Orthophtography: NAIP, 2020
Map Date: August 27, 2021 TWH

Legend

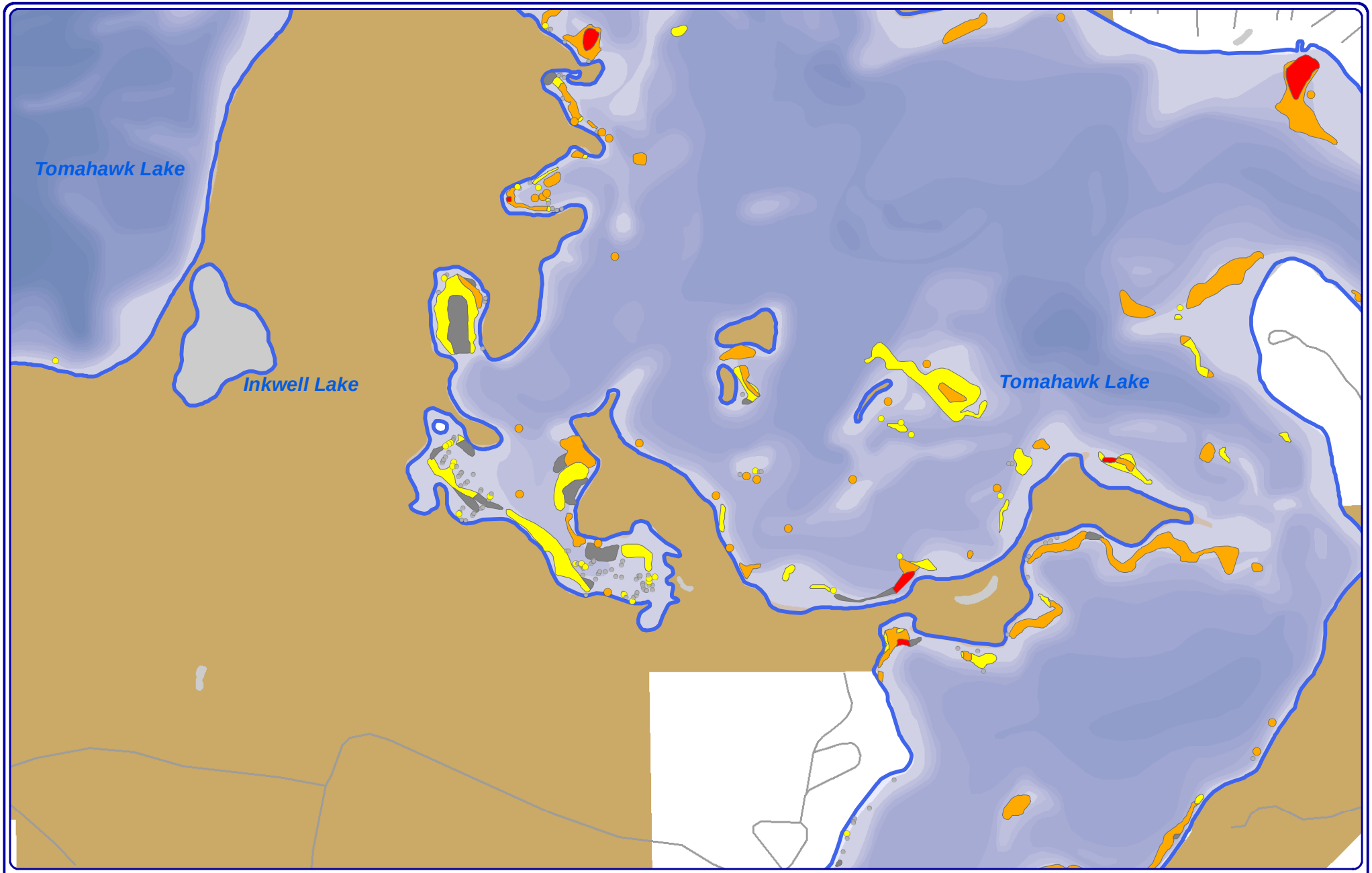
Eurasian watermilfoil (August 3-5, 2021)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

- Public Boat Landing
- Private Boat Landing
- Carry-In
- American Legion State Forest

Map 6
Tomahawk Lake
Oneida Co, Wisconsin

August 2021 EWM Survey Results



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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plants: Onterra, 2021
Orthophtography: NAIP, 2020
Map Date: August 27, 2021 TWH

Legend

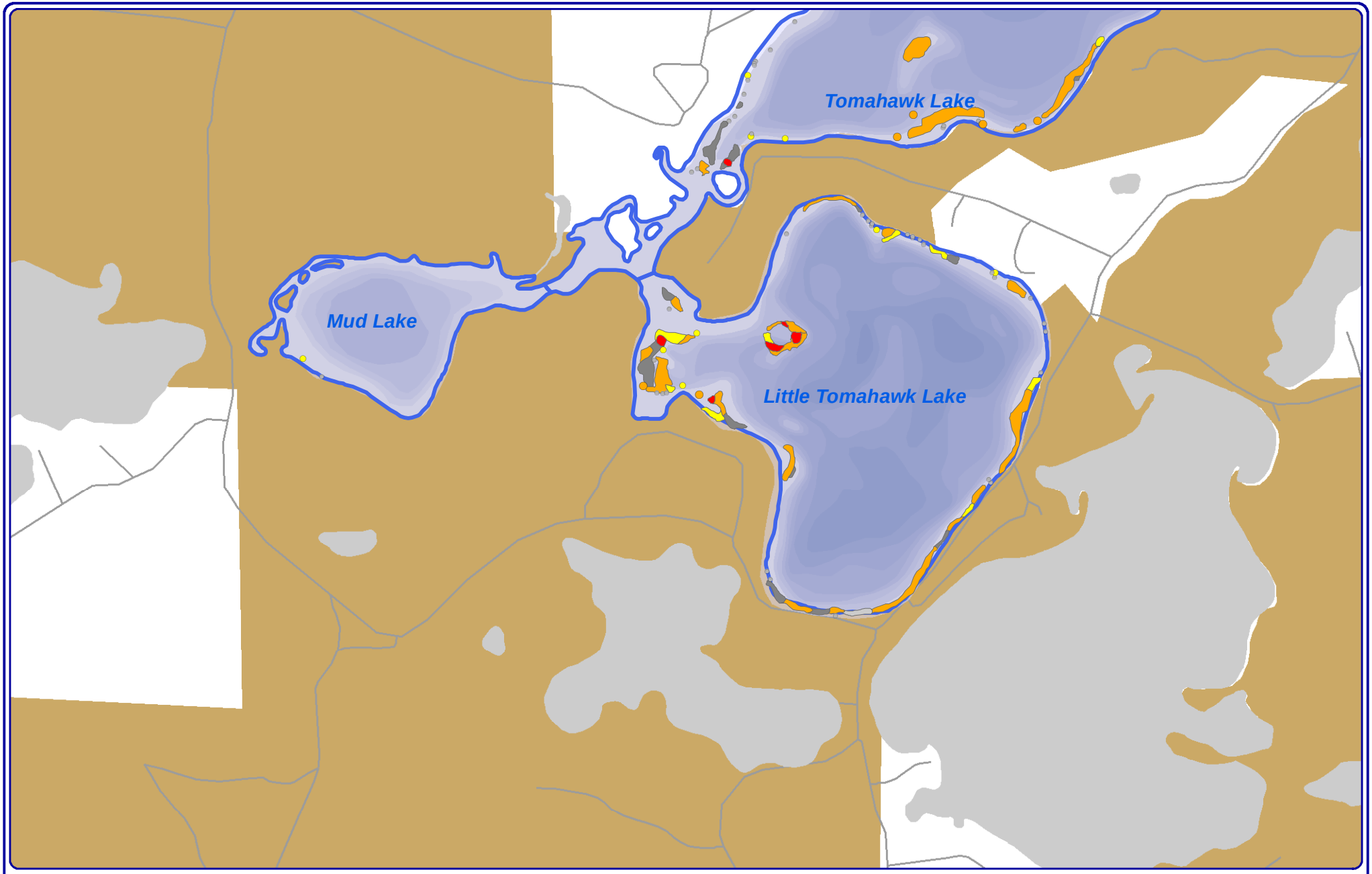
Eurasian watermilfoil (August 3-5, 2021)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

- Public Boat Landing
- Private Boat Landing
- Carry-In
- American Legion State Forest

Map 7
Tomahawk Lake
Oneida Co, Wisconsin

August 2021 EWM Survey Results



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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plants: Onterra, 2021
Orthophtography: NAIP, 2020
Map Date: August 27, 2021 TWH

Legend

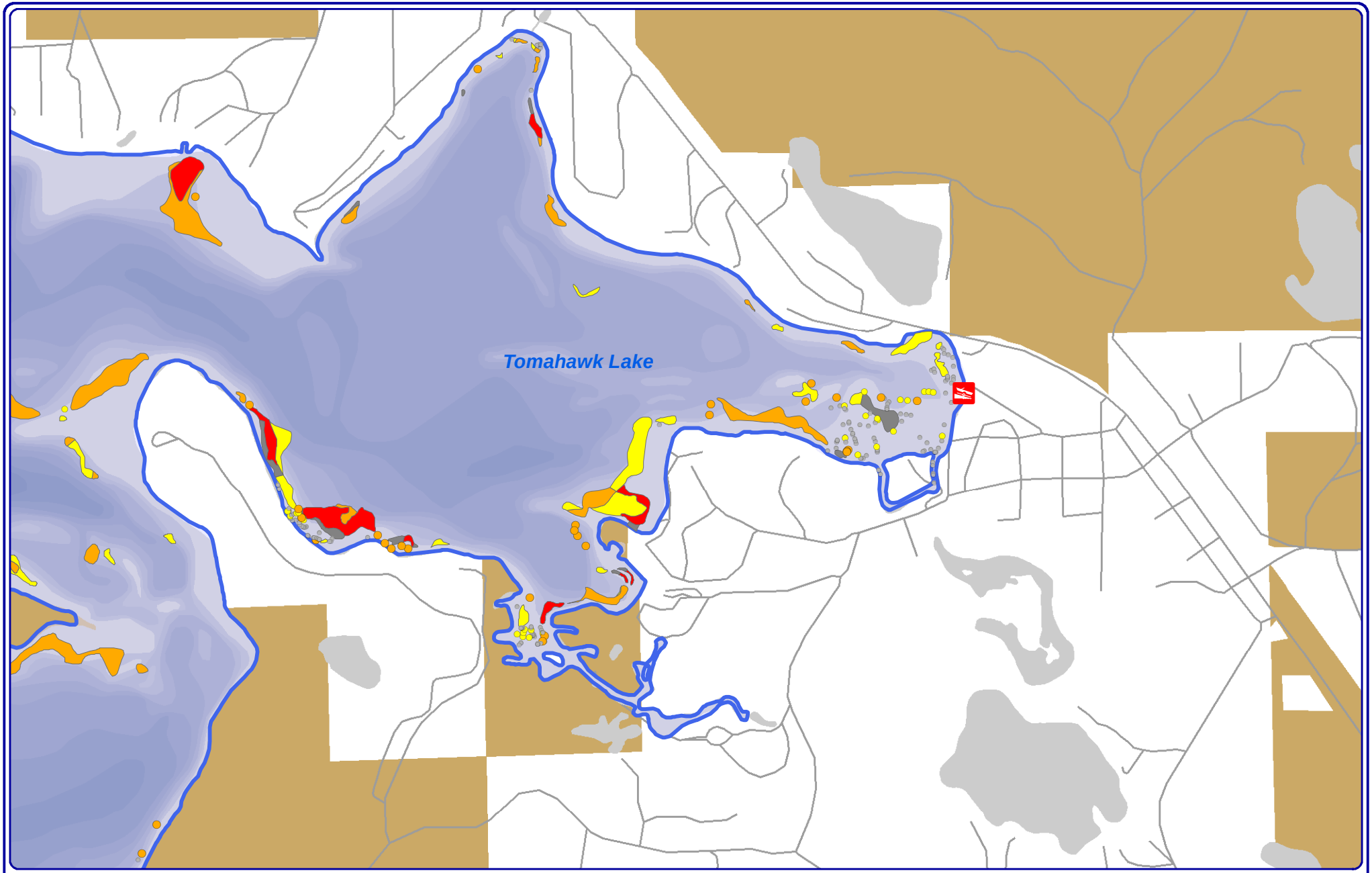
Eurasian watermilfoil (August 3-5, 2021)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

- Public Boat Landing
- Private Boat Landing
- Carry-In
- American Legion State Forest

Map 8
Tomahawk Lake
Oneida Co, Wisconsin

August 2021 EWM Survey Results



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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR
Aquatic Plants: Onterra, 2021
Orthophtography: NAIP, 2020
Map Date: August 27, 2021 TWH

Legend

Eurasian watermilfoil (August 3-5, 2021)

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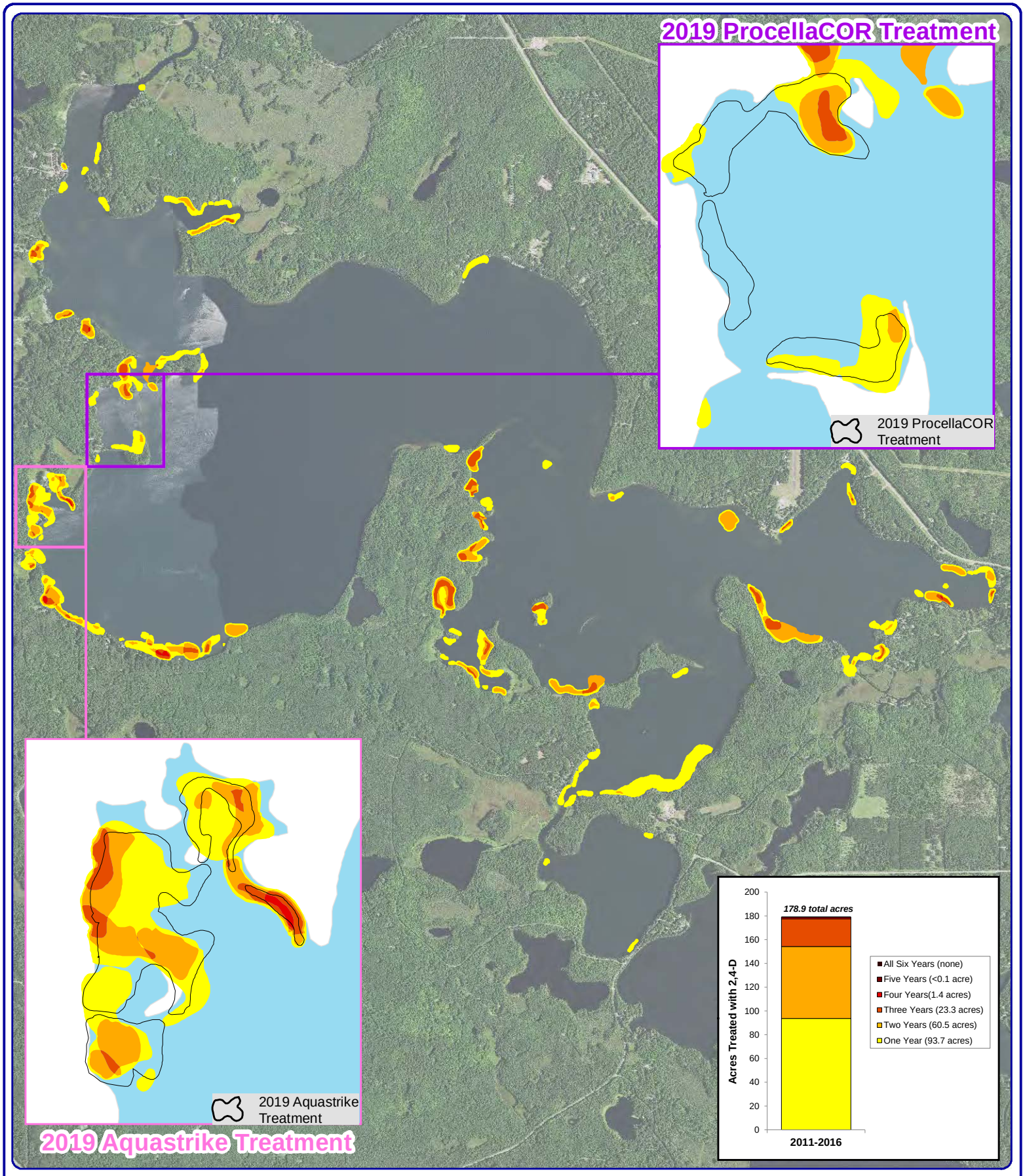
- Public Boat Landing
- Private Boat Landing
- Carry-In
- American Legion State Forest

Map 9
Tomahawk Lake
Oneida Co, Wisconsin

August 2021 EWM Survey Results



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Sources:
Hydro, Roads, Public Lands: WDNR
Treatment History: Schmidt's Aquatic, TLA
Map Date: November 11, 2021 - EJH

Legend

Years Treated with 2,4-D during 2011-2016

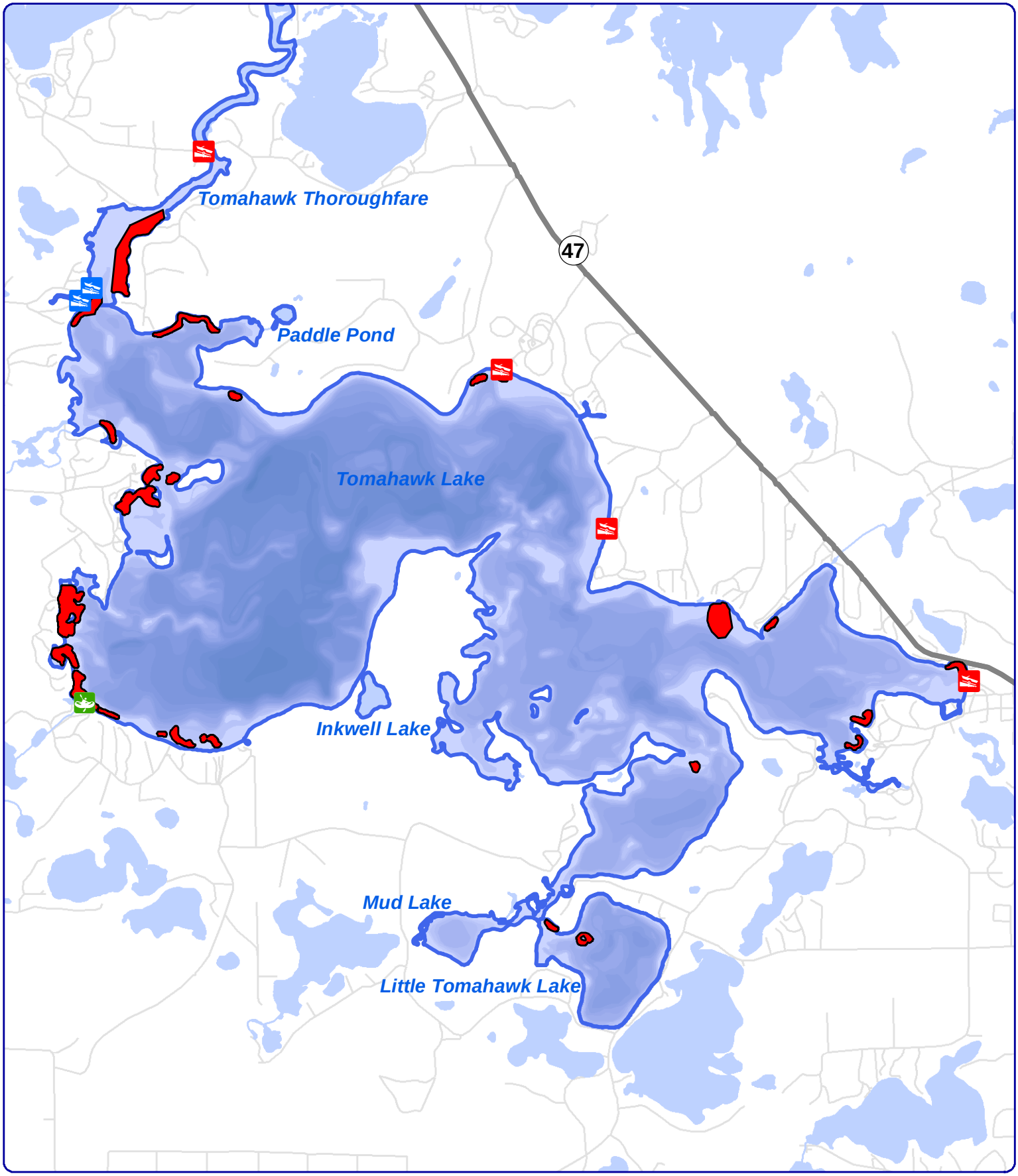
1 2 3 4 5 6

Map 10

Tomahawk System

Oneida County, Wisconsin

2011-2019 Herbicide Footprint



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Sources:
Hydro, Roads, Public Lands: WDNR
Map Date: November 1, 2021 - EJH


Project Location in Wisconsin

Legend

- Project Boundaries
- 2021 Mechanical Harvest Areas
- Public Landing
- Private Landing
- Carry-In

Map 11

Tomahawk System
Oneida County, Wisconsin

2021 Mechanical Harvest Areas