Tomahawk Lake System

Comprehensive Lake Management Plan

Oneida County, Wisconsin

July 2015

Sponsored By

Prepared By

Ecological Integrity Services
Growth Strategies

Funded By
Tomahawk Lake Association, Inc.
Wisconsin Department of Natural Resources (Grant LPL-1554-14)

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Executive Summary

This is a comprehensive lake management plan (CLMP) for the Tomahawk Lake System including Tomahawk, Little Tomahawk, Mud, and Inkwell Lakes, Paddle Pond, and the Tomahawk Thoroughfare in Oneida County, Wisconsin. The CLMP was first developed in 2009. A plan update is required to continue lake association eligibility for WDNR grants and to guide ongoing lake management activities. The plan will guide the Tomahawk Lake Association and the Wisconsin Department of Natural Resources (WDNR) in management for the Tomahawk Lake System over the next five years (from 2016 through 2020).

The plan includes data about the plant community, watershed, and water quality of the Tomahawk Lake System. It also presents a strategy for lake management actions to achieve the lake management plan goals.

This plan is guided by public input, scientific data, and requirements from the Wisconsin Department of Natural Resources (WDNR). The plan is required by WDNR regulations for certain aquatic plant management activities and to obtain grants that fund aquatic invasive species and other lake management activities. WDNR guidelines determine the required plan contents and necessary public input.

Vision

The Tomahawk Lake System is a place where water quality, wildlife habitat, natural beauty, recreational opportunities, and peace and tranquility are maintained and improved for present and future generations to enjoy.

Goals

Goal 1 Maintain a diverse, native aquatic plant community.

Goal 2 Preserve the quality of Tomahawk Lake System waters.

Goal 3 Balance recreational use with preservation of the natural lake environment.

Goal 4 Engage the lake community in lake and watershed stewardship practices.

Goal 5 Partner with area organizations, government agencies, and local businesses to support the goals of the lake management plan.

Guiding Principles

Cooperation and Leadership
The plan will be implemented with purposeful leadership and cooperation between private citizens and public officials.

Inclusiveness and Transparency
Plan implementation will be inclusive of local businesses, property owners, visitors and government agencies, and every effort will be made to solicit input and feedback wherever possible.

Protect Lake Character
We value the natural, social, and historic character of the Tomahawk Lake System.

Focus the Plan on End Results
Plan implementation strategies will focus on desired end results. The means used to achieve those results will vary. Results will be measured and reported.

Implementation Approach
Implementation will favor education, communication, cooperation, and direct action over legislation or regulations.

Reliable Funding
Provide for funding to support the implementation and periodic updates to the Tomahawk Lake System Comprehensive Lake Management Plan.

Organizational Capacity Building
Effective governance and management are integral to the sustainability and long-term effectiveness of the Tomahawk Lake Association Board to serve the Tomahawk Lake System community. The TLA Board monitors their activities to ensure they are providing the services which are valued by the TLS community and consistent with the Comprehensive Lake Management Plan vision statement. The board actively recruits and mentors new board members, provides board training, and encourages interest in lake issues and volunteerism through education, information, and social programming. To insure the continued viability of the Tomahawk Lake Association, the TLA Board is planning to partner with the Wisconsin Lakes Partnership to review options for organizational capacity building and associated actions items. Areas of focus will be communication, leadership, information and education, and financial security.

Public Input

Seven steering committee meetings were held to guide the development of the Tomahawk Lake Comprehensive Lake Management Plan (CLMP). Results of a Lake User Survey influenced selection of management goals and objectives and the actions chosen to reach them. A plan review public meeting will be held Saturday, June 13 beginning at 9:30 a.m. at the Minocqua Chamber of Commerce meeting room.

The Tomahawk Lake System

The Tomahawk Lake System is located in Oneida County, Wisconsin in the towns of Minocqua, Hazelhurst, Lake Tomahawk, and Woodruff. It includes Tomahawk, Little Tomahawk, Mud, and Inkwell Lakes, Paddle Pond, and the Tomahawk Thoroughfare to the Thoroughfare Road Bridge. The lakes have excellent water quality which is influenced by the watershed or land area which drains to the lakes. The emphasis of this plan is to preserve the excellent water quality present here. Areas of residential and commercial development have the potential to negatively impact water quality when runoff of stormwater carries pollutants such as nutrients and sediment to the lakes.

Aquatic Habitats

Lake shorelines and shallows are critical to sustain fish and wildlife that live in and near the lake. A shoreline inventory provided information about vegetative cover, slopes, hard surface, erosion and woody debris in the water – all important factors that influence habitat and stormwater runoff from waterfront property. The plan includes a discussion of the many Functions and Values of Native Aquatic Plants and the Tomahawk Lake System Fish Community.

A detailed plant survey provided extensive information about the Tomahawk Lake System Plant Community.

- The diversity of plants in Tomahawk Lake is very high. Fifty-nine different species were sampled on the rake. The littoral zone depth (where plants grow) extended to 26.2 feet.
- The diversity of aquatic plants is also high in Little Tomahawk Lake. There were 34 species of aquatic plants sampled and one additional species viewed near a sample point. Plants were sampled to a maximum depth of 22.8 feet.
- The Tomahawk Thoroughfare had 30 species of plants sampled and four more species viewed.
- Mud Lake also had quite high plant diversity, especially considering its small size. There were 26 species of plants sampled and two more species viewed. Plants grew to at a depth of 20 feet.
- Plant growth and plant diversity in Paddle Pond is very limited. This lake had very dark, tannic stained water, which reduces light penetration and likely limits plant growth.
- Inkwell Lake is a small lake adjacent to Tomahawk Lake with access only by foot. There was only one site with vegetation and very limited plant growth observed.

Invasive Species of the Tomahawk Lake System include Curly Leaf Pondweed, Purple Loosestrife, Yellow Flag Iris, Narrow-Leafed Cattail, and Eurasian Water Milfoil. Eurasian water milfoil (EWM) has been managed in the Tomahawk Lake System for several years.

Available Aquatic Plant Management methods are described in the plan along with existing Tomahawk Lake Association management strategies. Eurasian water milfoil was discovered on Tomahawk Lake in August of 2003, and control efforts began in 2005. The TLA management structure and communications program support Eurasian water milfoil control efforts. TLA management efforts include a Clean Boats Clean Waters (CBCW) Program, Purple Loosestrife Management, and Eurasian Water Milfoil Management. Eurasian water milfoil has been controlled using both EWM Herbicide Treatments and hand removal with the Hydraulic Conveyor System.

This plan investigates additional Lake Management Options including Involvement in Planning and Zoning, habitat mapping and preservation, and Shoreland Restoration Programming.

With careful consideration, the Steering Committee developed a CLMP Implementation Strategy, which is presented in detail and outlines objectives and actions for each of five plan goals. A TLA CLMP Work Plan details how actions will be implemented listing timeline, committee and board assignments, resources needed, and partners for each action. The TLA board will update the work plan in planning for the following year's annual budget.

Introduction

This is a comprehensive lake management plan (CLMP) for the Tomahawk Lake System including Tomahawk, Little Tomahawk, Mud, and Inkwell Lakes, Paddle Pond, and the Tomahawk Thoroughfare in Oneida County, Wisconsin. The CLMP was first developed in 2009. A plan update is required to continue lake association eligibility for WDNR grants and to guide ongoing lake management activities. The plan will guide the Tomahawk Lake Association and the Wisconsin Department of Natural Resources (WDNR) in management for the Tomahawk Lake System over the next five years (from 2016 through 2020).

The Tomahawk Lake Association was formed in 2005 first as the Tomahawk Lake Property Owners Association. The organization was formed to raise funds and address the concern of invasive Eurasian water milfoil found in Tomahawk Lake.

The plan is sponsored by and developed for the Tomahawk Lake Association with input from a steering committee and plan advisors from the Wisconsin Department of Natural Resources and Oneida County. Consultant Harmony Environmental facilitated plan discussions and wrote plan content. Subconsultant Ecological Integrity Services conducted plant, shoreline, and watershed inventories and developed water quality models. Subconsultant, Growth Strategies administered the lake user survey and reported survey results.

The plan includes data about the plant community, watershed, and water quality of the Tomahawk Lake System. The plan presents a strategy for lake management actions to achieve the lake management plan goals.

Tomahawk Lake Comprehensive Lake Management Plan Goals

Goal 1 Maintain a diverse, native aquatic plant community.

Goal 2 Preserve the quality of Tomahawk Lake System waters.

Goal 3 Balance recreational uses important to lake residents and visitors with preservation of the natural lake environment.

Goal 4 Engage the lake community in lake and watershed stewardship practices.

Goal 5 Partner with area organizations, government agencies, and local businesses to support the goals of the lake management plan.

This plan is guided by public input, scientific data, and requirements from the Wisconsin Department of Natural Resources (WDNR). The plan is required by WDNR regulations for certain aquatic plant management activities and to obtain grants that fund aquatic invasive species and other lake management activities. WDNR guidelines determine the required plan contents and necessary public input.

The WDNR's aquatic plant management planning guidelines and Northern Region Aquatic Plant Management Strategy (Summer 2007) framed the development of the plan. (See Appendix F for a copy of this strategy.) WDNR sampling protocol and plant survey methods were also utilized in plan development. The plan is also structured to meet requirements of NR 191.45 (2). The Tomahawk Lake Association CLMP Steering Committee worked within these limits and guidelines to develop the management strategy for the Tomahawk Lake System.

More information about managing aquatic plants in Wisconsin is available from www.uwsp.edu/cnr/uwexlakes/ecology/apmguide.asp.

Public Input for Plan Development

Seven steering committee meetings were held to guide the development of the Tomahawk Lake Comprehensive Lake Management Plan (CLMP). The group met to learn about aquatic plant management planning requirements; the condition of the Tomahawk Lake system shoreline, watershed, water quality, and aquatic plants; aquatic plant management to date; and aquatic plant and lake management options available.

The steering committee expressed a variety of concerns that are reflected in the goals and objectives for lake management in this plan. The committee also guided implementation strategies in the plan. Committee input is summarized in the meeting notes included as Appendix A.

Following steering committee review, the draft plan update was made available to lake residents and other interested parties. Residents were made aware of the availability of the draft with a notice published in the Lakeland Times and on Facebook. The plan was available for review between June 10 and June 30, 2015 on the Tomahawk Lake Association web site (http://tomahawklake.org) and at the Minocqua Public Library during regular business hours. A plan review public meeting was held Saturday, June 13 beginning at 9:30 a.m. at the Minocqua Chamber of Commerce meeting room. Following questions and feedback at the public meeting, no public comments were received.

Lake User Survey

The Tomahawk Lake Association lake user survey was completed in the fall of 2014. Results of the survey are reported in Appendix B. Surveys were administered on the web using email notification when possible. Remaining and follow-up surveys were sent via US Mail. Web responses were made using Survey Monkey online tools. Mail responses were also entered into this on-line system.

Survey response and distribution is as follows:

Number of people invited to submit surveys: 515

Surveys received through 12/10/14: 216

- Surveys returned via US Mail: 105
- Survey responses submitted online: 111
- Response rate: 42%

According to DNR Sociologist, Jordan Petchenik, because the survey response rate is below 60% "the results should not be interpreted as a statistical representation of the lake user (or homeowner) population. Results may, however, indicate possible tendencies and preferences of the population but should not be interpreted as statistically sound."

Survey results related to specific resource concerns and management actions are included throughout this plan in related sections.

Overall concerns related to the Tomahawk Lake System were captured in the following question: *Using the following scale, please indicate your level of concern for the listed item's impact on the Tomahawk Lake System*. Results are shown in Figure 1 below. Categories with most "very concerned" ratings were aquatic invasive species and water quality followed by protection of wildlife habitat and shoreline erosion.

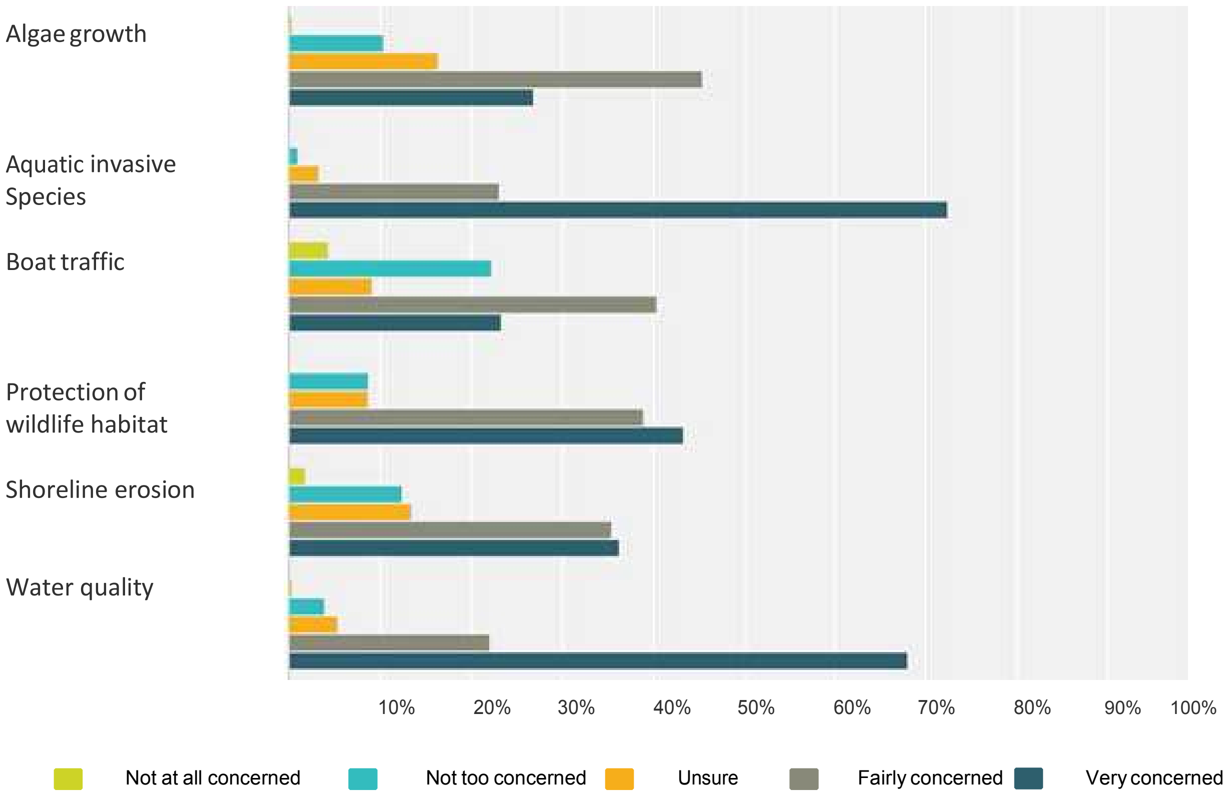


Figure 1.Concerns Related to the Tomahawk Lake System

Tomahawk Lake System

The Tomahawk Lake System is located in Oneida County, Wisconsin in the towns of Minocqua, Hazelhurst, Lake Tomahawk, and Woodruff. The Tomahawk Lake System includes Tomahawk, Little Tomahawk, Mud, and Inkwell Lakes, Paddle Pond, and the Tomahawk Thoroughfare. Information about the lakes is reported in Table 1 below. A map of the lakes is included as Figure 2. The lakes are part of the Minocqua Chain which also includes Mid, Minocqua, and Kawaguesaga downstream of the Tomahawk Lake System. Water levels are controlled by a dam on Lake Kawaguesaga operated by the Wisconsin Valley Improvement Company. (Kubisiak J. , 2011)

Tomahawk Lake is a 3,462 acre lake with a maximum depth of 84 feet and over 30 miles of shoreline. The Tomahawk Thoroughfare drains Tomahawk Lake and leads to Mid Lake, Lake Minocqua, and Lake Kawaguesaga which together form the headwaters of the Tomahawk River. The Thoroughfare is bordered by extensive wetlands. Paddle Pond is surrounded by bog and is accessible by water from the north end of Kemp's Bay where the UW Kemp Natural Resources Station is located. Inkwell Lake is located on the eastern shore of the central basin of Tomahawk Lake. It is surrounded by state forest land and is within a 20 foot portage of Tomahawk Lake. A short channel in the southeast corner of the eastern basin of Tomahawk Lake leads to Little Tomahawk Lake and Mud Lake. Mud Lake is connected to Little Tomahawk Lake by a beaver channel branching from the south. (Greedy, 2013)

Table 1. Tomahawk Lake System Lakes Information

Lake	Type	Lake Acres	Trophic State	Watershed/ Lake Ratio	Max Depth (ft.)	Mean Depth (ft.)
Tomahawk Lake	Drainage	3,462	Oligotrophic	0.99:1	84	33
Little Tomahawk Lake	Spring	163	Oligotrophic	1.8:1	48	28
Mud Lake	Flowage	41	Mesotrophic		26	13
Inkwell Lake	Seepage	13	Mesotrophic		32	
Paddle Pond	Not classified by DNR	NA	NA	NA	NA	NA
Tomahawk Thoroughfare	Connection to Lake Minocqua	NA	NA	NA	NA	NA

From WDNR 2014
NA= Information Not Available

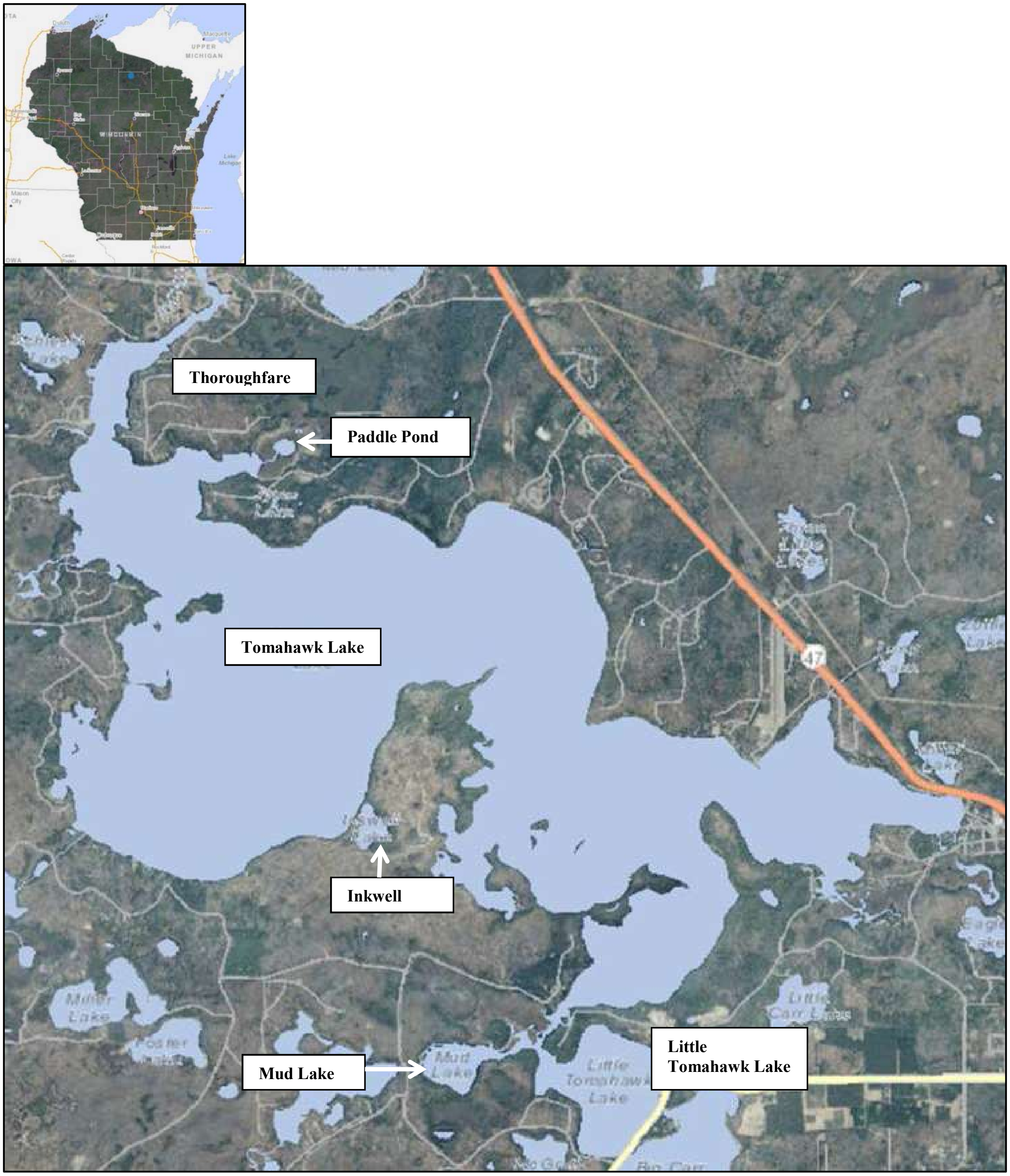


Figure 2. Map of Tomahawk Lake System

Water Quality

Outstanding Resource Water Designation[2]

Both Tomahawk Lake and Little Tomahawk Lake are designated as Outstanding Resource Waters (ORW). Waters designated as ORW or ERW (Exceptional Resource Waters) are surface waters which provide outstanding recreational opportunities, support valuable fisheries and wildlife habitat, have good water quality, and are not significantly impacted by human activities. The state of Wisconsin assigns ORW and ERW status to waters that warrant additional protection from the effects of pollution. These designations are intended to meet federal Clean Water Act obligations requiring Wisconsin to adopt an "antidegradation" policy that is designed to prevent any lowering of water quality – especially in those waters having significant ecological or cultural value.

ORWs receive the state's highest protection standards, with ERWs a close second. ORWs and ERWs share many of the same environmental and ecological characteristics. They differ in the types of discharges each receives, and the level of protection established for the waterway after it is designated.

ORWs typically do not have any point sources discharging pollutants directly to the water (for instance, no industrial sources or municipal sewage treatment plants), though they may receive runoff from nonpoint sources. New discharges may be permitted only if their effluent quality is equal to or better than the background water quality of that waterway at all times—no increases of pollutant levels are allowed.

Of Wisconsin's 15,000 lakes and impoundments, 103 are designated as ORW—fewer than 1%. Waters currently designated as ORWs and ERWs are listed in Wisconsin's Administrative Code in chapters NR 102.10 (ORWs) and NR 102.11 (ERWs).

Trophic State

Trophic state describes the productivity of a lake. The least productive or nutrient-rich lakes are oligotrophic lakes. The most productive lakes are referred to as eutrophic. Those in the middle are called mesotrophic. More productive lakes have more nutrients available for algae growth. If a watershed with little runoff and phosphorus sources surrounds a lake, the water will tend to have low phosphorus levels. This will result in limited plant and algae growth, causing it to be classified as an oligotrophic lake. As shown in Table 1 above, Tomahawk Lake System lakes are oligotrohpic, mesotrophic, or unclassified. Trophic state results are available for Tomahawk Lake based on secchi depth, phosphorus and/or chlorophyll, from 1972 through 2014 (although results are not recorded each year) as shown in Figure 3.

[2] http://dnr.wi.gov/topic/SurfaceWater/orwerw.html

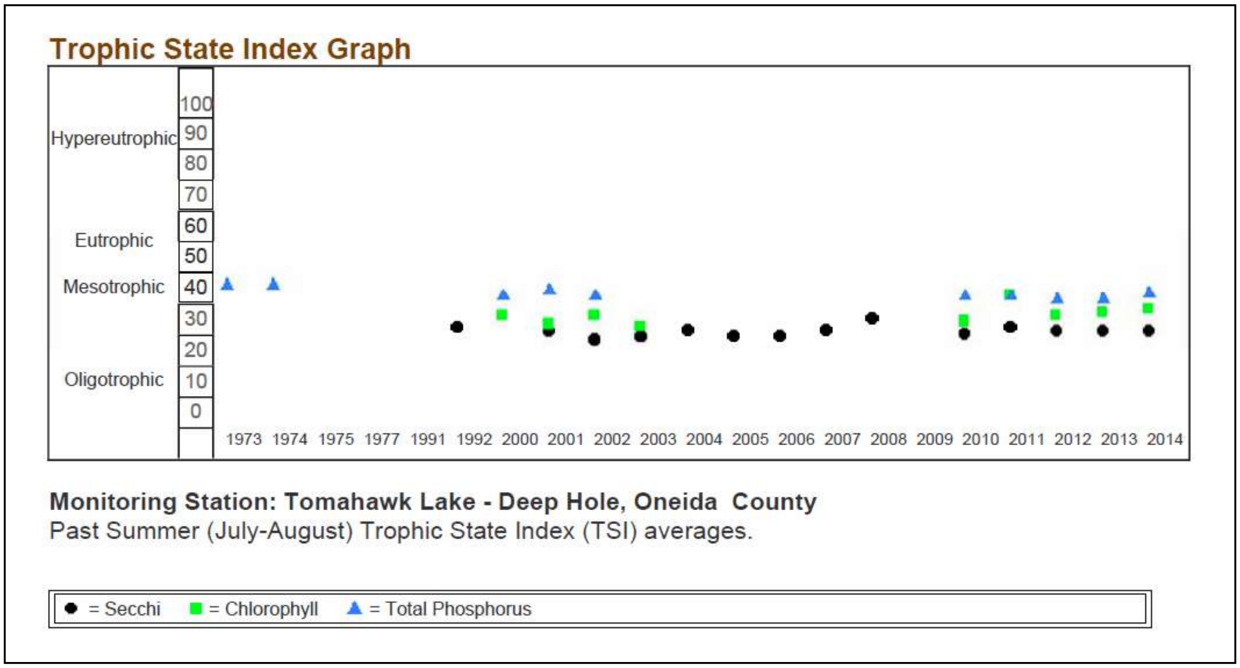


Figure 3. Trophic State Index Graph for Tomahawk Lake

Citizen Lake Monitoring Results[3]

Secchi depths are the most commonly collected and available self-help lake monitoring data. Secchi depths measure water clarity. The secchi depth reported is the depth at which the black and white secchi disk is no longer visible when it is lowered into the water. Greater secchi depths occur with greater water clarity. Tomahawk Lake had excellent water clarity in 2014 with secchi depths ranging from 15.5 to 19 feet. The Trophic State Index Graph illustrates that clear water is generally present in Tomahawk Lake. Other Tomahawk Lake System lakes are not currently included in the Citizen Lake Monitoring program.

Lake Stratification

Dissolved oxygen (DO) and temperature profiles were completed at each meter in 2010 and 2011 as illustrated in Figure 4 and Figure 5. The near bottom goes anoxic (DO< 1mg/L) as early as July. With low oxygen levels, lake sediments tend to release phosphorus, a phenomenon known as internal loading. The temperature profile indicates the lake is stratified in this deep hole. Due to stratification, phosphorus released from the sediments is generally contained in lower lake layer (the hypolimnion) until fall turnover.

[3] Wisconsin Department of Natural Resources Citizen Lake Monitoring results (http://dnr.wi.gov/lakes/CLMN). In 2015, reported by Jim Thompson, citizen lake monitor.

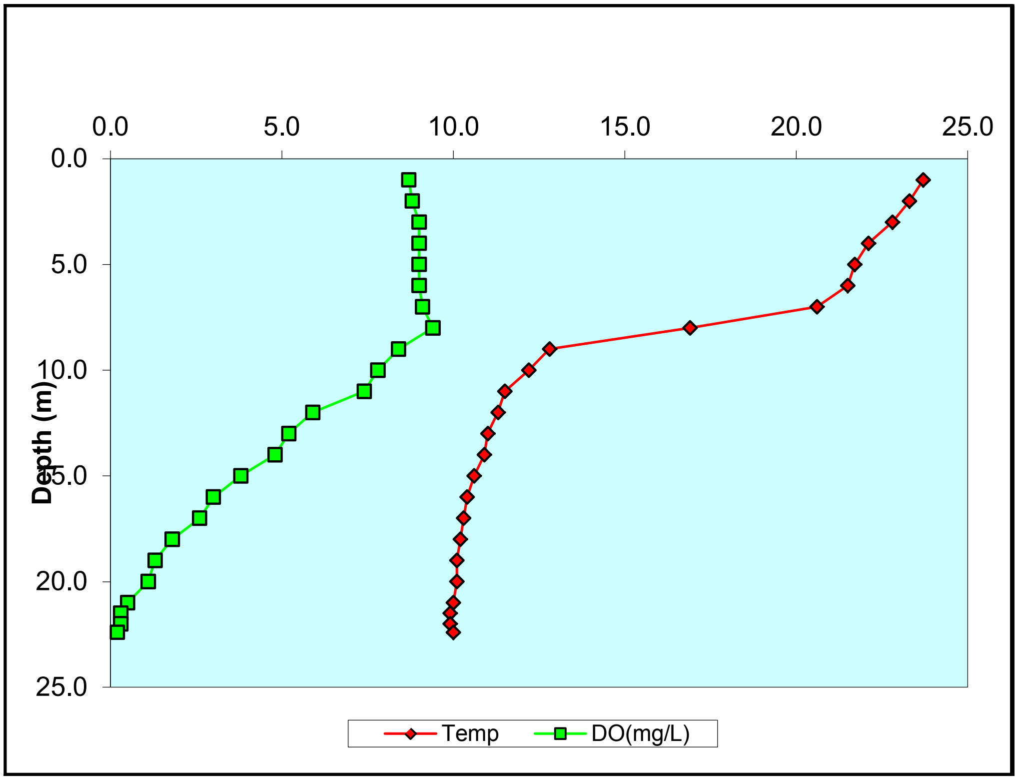


Figure 4. DO/Temperature Profile for Tomahawk Lake August 4, 2010

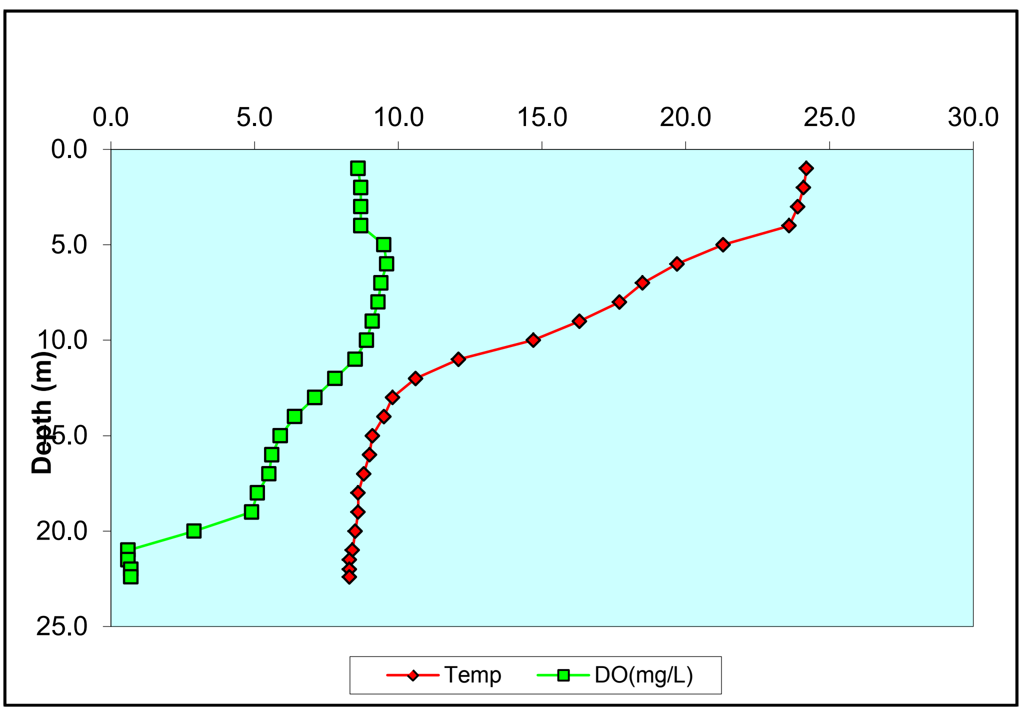


Figure 5. DO/Temperature Profile for Tomahawk Lake July 11, 2011

Watershed

A watershed is the land area that drains to a body of water. The immediate watershed of each water body in the Tomahawk Lake System is outlined in Figure 6. Land uses within the watersheds are also illustrated in Figure 6. Previous watershed delineation included a much larger watershed with some areas that drain to separate wetlands and/or ponds and flow only indirectly to project lakes.

Oneida County provided GIS maps of land use for this analysis. Only minor adjustments were made to land use categories. Volunteer ground-checking or truthing was used to adjust some areas from "residential" to "high-density residential." High-density residential areas have small lots with large areas of buildings and other hard surfaces. "Outdoor recreation" included boat landings. Lastly, some "open area" designation was changed to "wetland" following ground truthing and review of aerial photos. Forested wetlands were left in the forest classification.

Land use is itemized for Tomahawk Lake in Table 2 and Figure 7. The Tomahawk Lake watershed is largely forested, but residential land use also makes up a significant percentage of land use. Other lake watersheds in the Tomahawk Lake System are also mostly forested.

Table 2. Tomahawk Lake Watershed Land Use

Land Use Type	Area (acres)	% of Total
Forest	2,965.0	86.62
Residential	247.0	7.22
High-Density Residential	96.4	2.82
Commercial	46.8	1.37
Open	32.0	0.94
Wetland	17.0	0.50
Outdoor Recreation	12.9	0.38
Utility	5.9	0.17
Total	**3,423**	100

Table 3. Tomahawk Lake System Watershed Land Use Other Lakes

Land use	Thoroughfare	Little Tomahawk	Mud	Inkwell	Paddle
Forest	76.20%	91.10%	100%	100%	0
Residential	7.10%	8.90%	0	0	0
High-Density Residential	5.60%	0	0	0	0
Recreation (Landings)	0.25%	0	0	0	0
Wetland	10.10%	0	0	0	100%
Commercial	0.75%	0	0	0	0

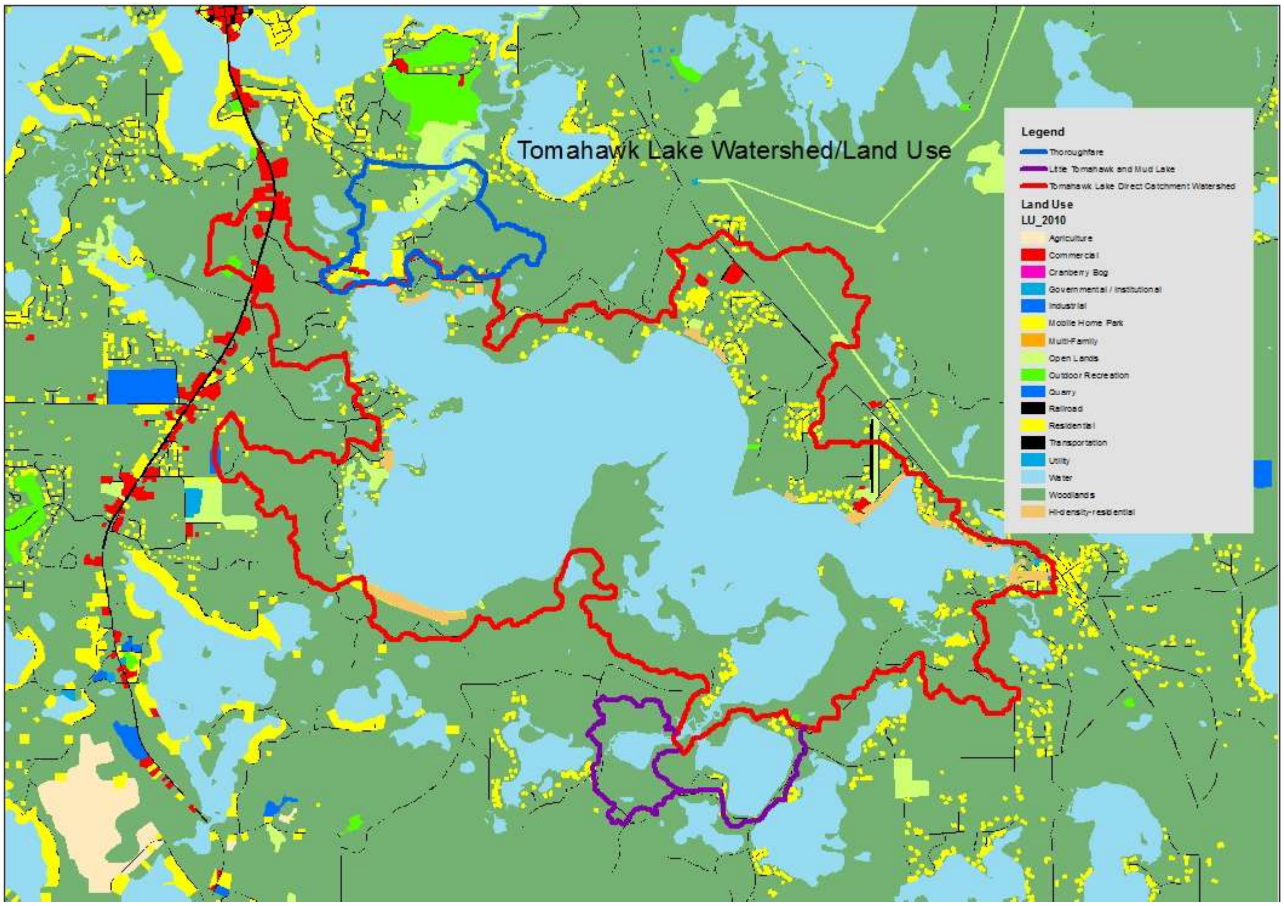


Figure 6. Tomahawk Lake System Watersheds and Land Use

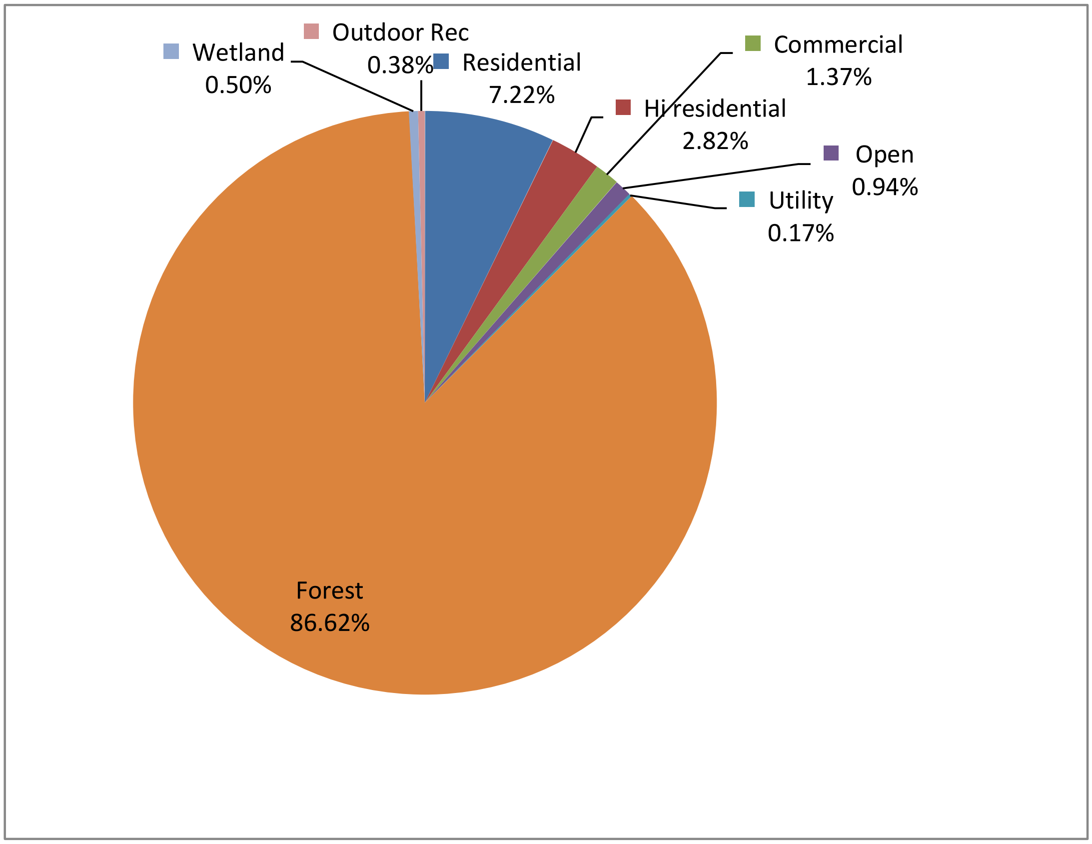


Figure 7. Tomahawk Lake Watershed Land Use

Watershed and Water Quality

The watershed for Tomahawk Lake is small relative to the lake itself. The watershed to lake area ratio is 0.99:1. A small watershed tends to reduce the nutrient load of the lake because there is a lower volume of runoff.

Phosphorus is the nutrient that most influences algae growth in the Tomahawk Lake System because it is the limited ingredient for algae growth. A phosphorus limited lake has a nitrogen to phosphorus (N:P) ratio of at least 10 to 1. A Tomahawk Lake water sample taken in August 2014 indicated a total nitrogen value of 0.391 mg/L (391 μg/L). This corresponded to a N:P ratio of 38:1, reinforcing that Tomahawk Lake is phosphorus limited.

Phosphorus is found dissolved in runoff water and carried in soil particles that erode from bare soil. Phosphorus runoff from the watershed is determined by how land is used in the watershed along with watershed soils and topography. When a watershed is maintained in natural vegetation, there is less runoff of pollutants that impact the lakes. Agricultural, commercial, and residential lands tend to contribute greater amounts of phosphorus in runoff. Soil erosion is reduced when there is good vegetative cover. Water flow is slowed by tall vegetation, and forest groundcovers and fallen leaves allow runoff water to soak into the ground. In summary, anything that reduces soil erosion and/or the amount of runoff water flowing from a portion of the watershed reduces pollution to the lake.

Forested areas have less runoff and less phosphorus concentration in runoff due to tree cover breaking raindrops, more infiltration of water into the soil, and less erosion. High density residential areas along lakes have greater phosphorus loads since more runoff is generated from hard surfaces and lawns and much less water tends to be infiltrated into the soil.

Watershed land use and activities can influence water quality and lake sediment characteristics in localized areas. Excess erosion, for example, could lead to an accumulation of nutrient-rich sediment which may be more likely to support invasive aquatic plant growth (Wang, 2008) (Brenkert & Amundsen).

Lake Modeling Results

Phosphorus loading to Tomahawk Lake was estimated using WILMS. This model is used to estimate water and phosphorus budgets of Wisconsin lakes. As Table 4 shows, the highest contributor of phosphorus is precipitation at 64 percent. This is followed by forested areas, high density residential/commercial, and residential. High density residential contributes the most phosphorus per acre. The septic system load is a rough estimate based upon the number of residential buildings on the lake. It is common for septic systems to be about 4-5 percent of the total phosphorus load. If, in fact, many of the septic systems are newer in the Tomahawk Lake System, this estimate may be high. Actual water quality data from 2013 and 2014 were used to calibrate or check the WILMS model, and a good match resulted.

Table 4. Phosphorus Loading by Land Use: WILMS Model

Land use	***Likely Load Estimate from WILMS (kg/year)***	***% of Total Phosphorus Load***	***Kg/acre***
Forest	108	15.7	0.04
High density residential/commercial	31	4.5	0.32
Commercial	15	2.2	0.32
Residential	40	5.8	0.16
Open	3	0.4	0.09
Outdoor recreational	2	0.3	0.16
Utility	1	0.1	0.17
Wetland	1	0.1	0.06
Septic systems	30	4.35	n/a
Aerial deposition (precipitation)	420	61.1	0.12
Overall Loading by Land Use	651	94.55	0.098

Table 5. Phosphorus Loading from Other Sources: WILMS Model

Other sources	***Likely Load (kg/year)***	***% of Total Phosphorus Load***
Little Tomahawk Lake Outflow	8.9	1.3
Mud Lake	6.2	0.9
Internal from anoxia sediment	22	3.2
Total Phosphorus Load All	688.1	100.0

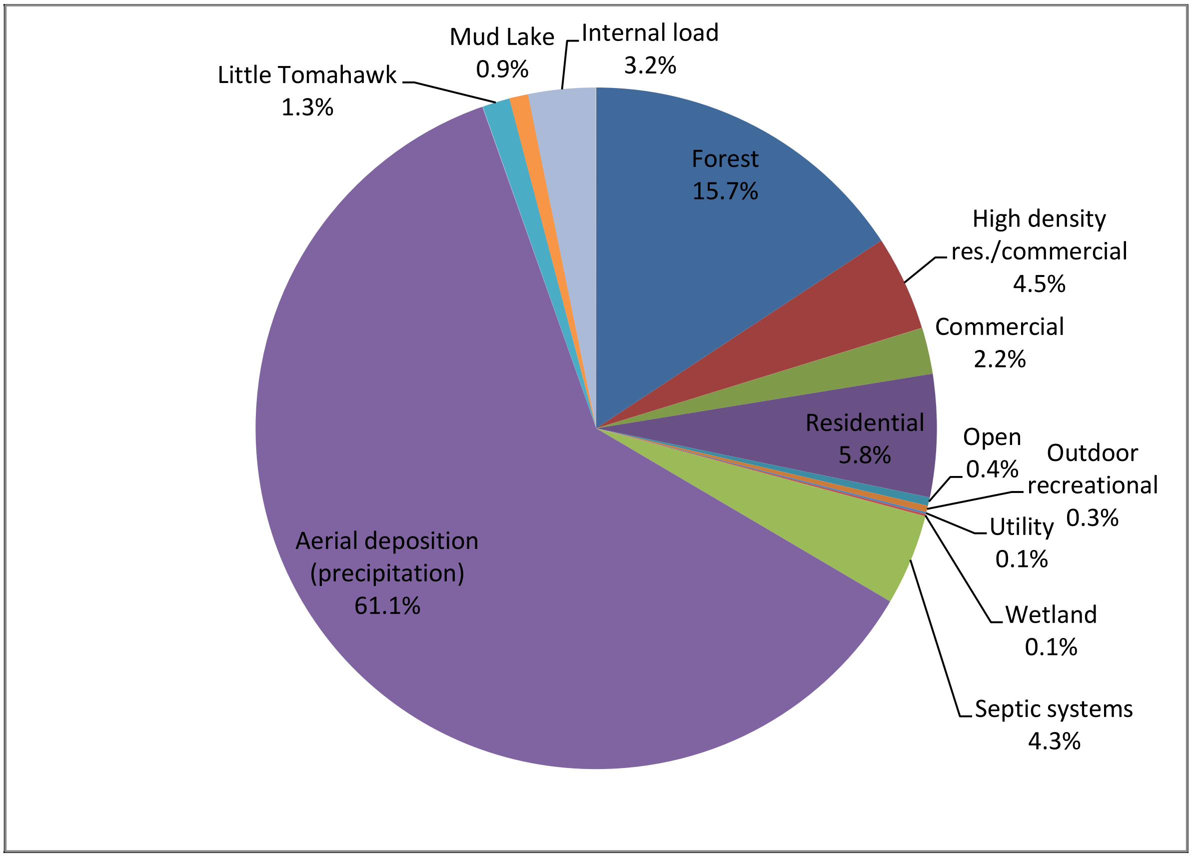


Figure 8. Tomahawk Lake Phosphorus Load by Source

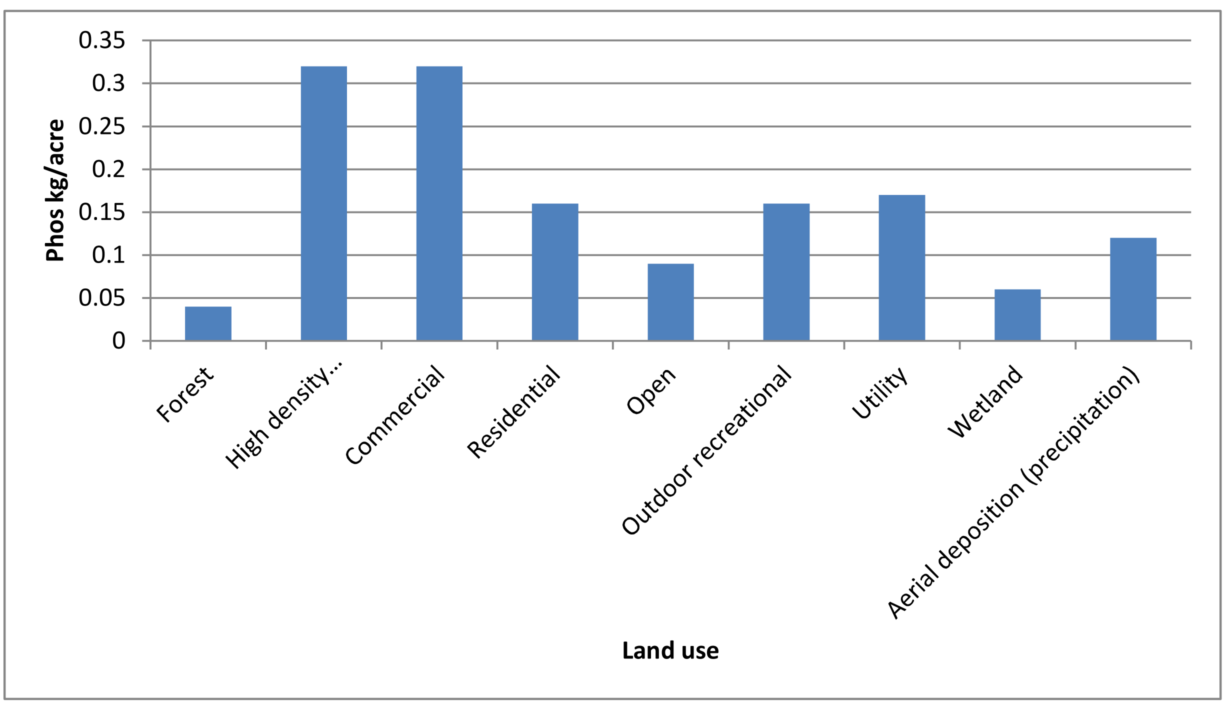


Figure 9. Tomahawk Lake Phosphorus Load kg/acre

Water Quality Trends

The following graphs summarize historical phosphorus, chlorophyll-a, and secchi disk citizen monitoring data from 2000 through 2014. A trend line is added to illustrate potential trends in each graph. Secchi depth and chlorophyll-a data show trend lines that are basically flat, indicating no change or trend in the readings.

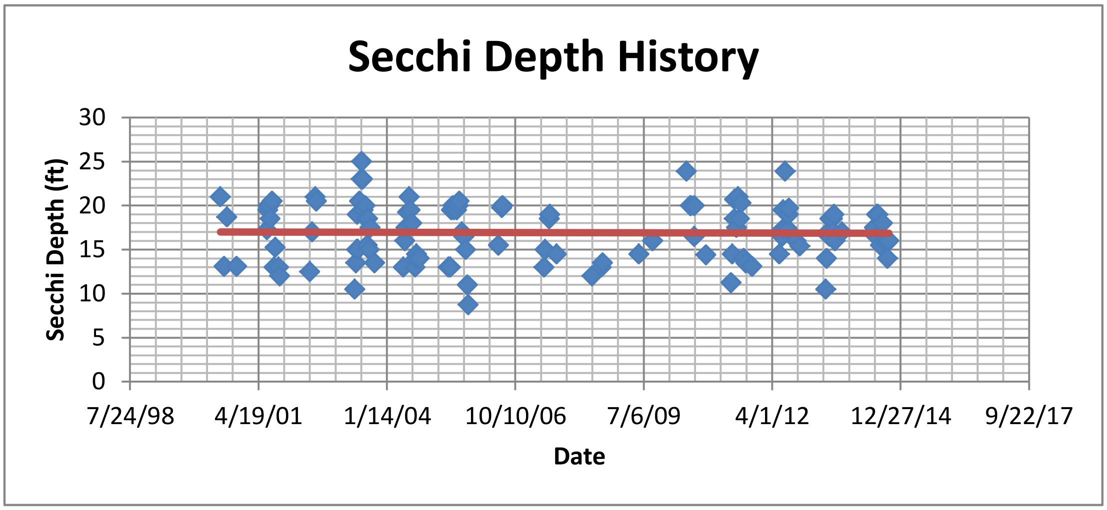


Figure 10. Tomahawk Lake Secchi Depth 2000-2014

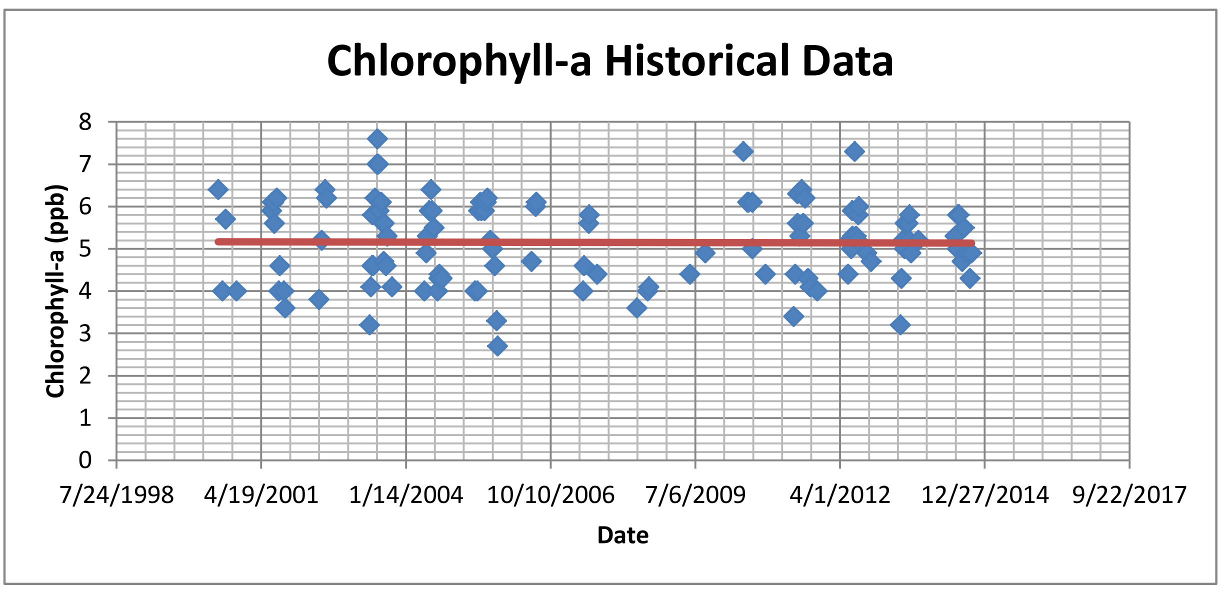


Figure 11. Tomahawk Lake Chlorophyll-a 2000-2014

Total phosphorus data was not collected (or at least not reported in DNR database) from 2003 until 2009. The scatter plot data from 2000-2002 appear to have a slightly higher total phosphorus compared to the scatter plot data from 2010-2014. The trend line shows a slight decline, however the R^2 value of 0.19 indicates that it is a very weak correlation. It is valid to state that the phosphorus values do not appear to be changing.

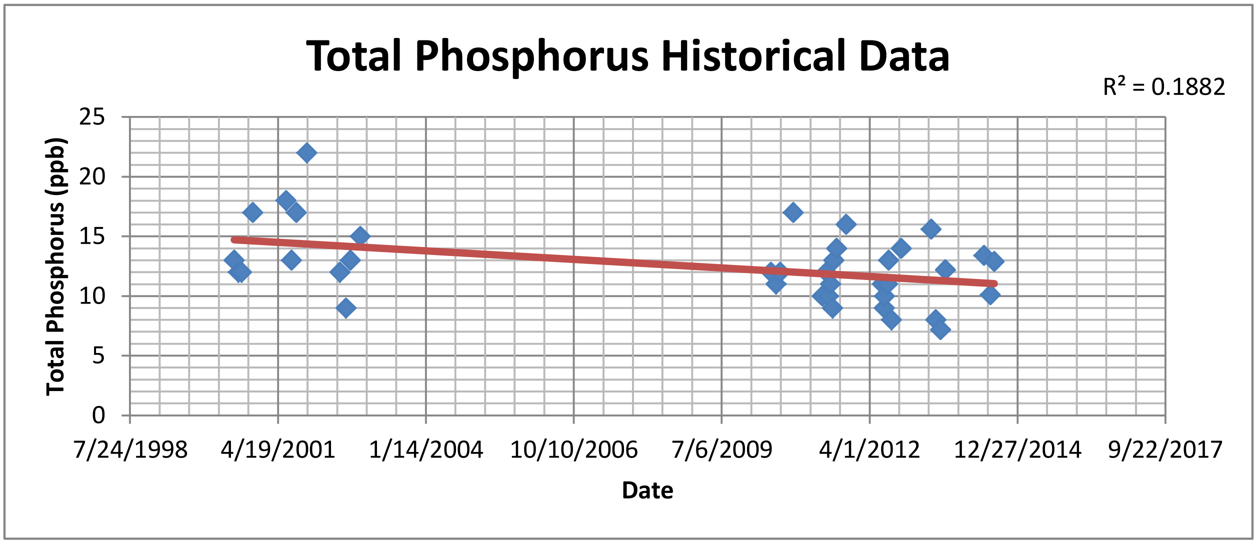


Figure 12. Tomahawk Lake Total Phosphorus 2000-2014

Watershed/Water Quality Practice Recommendations

Because Tomahawk Lake System water quality is excellent, activities should focus on avoiding degradation. High density residential land uses provide the best opportunity to maintain water quality because they have high potential loading of nutrients and sediment. Practices such as rain gardens, shoreline buffers, and other methods to capture and infiltrate runoff can be used to protect lake water quality.

Water quality can also be protected by ensuring that if residential or commercial development occurs on the lakeshore and in the watershed, it is done in a manner that limits runoff to the lakes.

Aquatic Habitats

Lake Use

Tomahawk Lake has three major public boat landings with extensive transient fishing traffic drawn to the lake by its trophy muskellunge fishery and burgeoning smallmouth and largemouth bass populations. Figure 13 illustrates the public access points for Tomahawk Lake and the Thoroughfare.

Shorelines and Shallows

Natural shorelines benefit waterfront owners in significant ways by absorbing and filtering runoff thereby maintaining water quality, controlling flood waters, stabilizing shorelines, providing habitat on the shore and in the water, and establishing a natural green screen. (UWEX, 2014)

The area where the water meets the land is critically important to fish and wildlife. In Wisconsin, 80% of endangered or threatened species spend all or part of their lives in shoreland areas. Important habitat elements in the water include emergent, floating, and submerged aquatic plants and woody debris. On the land, bird diversity and abundance is directly related to shoreland trees, shrubs, and groundcovers. Amphibians benefit from wet areas and gentle slopes next to the water. (UWEX, Protecting Our Living Shores, 2014)

Woody cover in lakes, provided by fallen trees and branches, are used by fish, birds, and turtles. In Wisconsin lakes, over 15 different fish species may inhabit a single downed tree at a time. Smallmouth bass construct their spawning beds next to large rocks or woody cover. Studies of northern Wisconsin shorelines find this cover decreases with residential development. (UWEX, Protecting Our Living Shores, 2014)

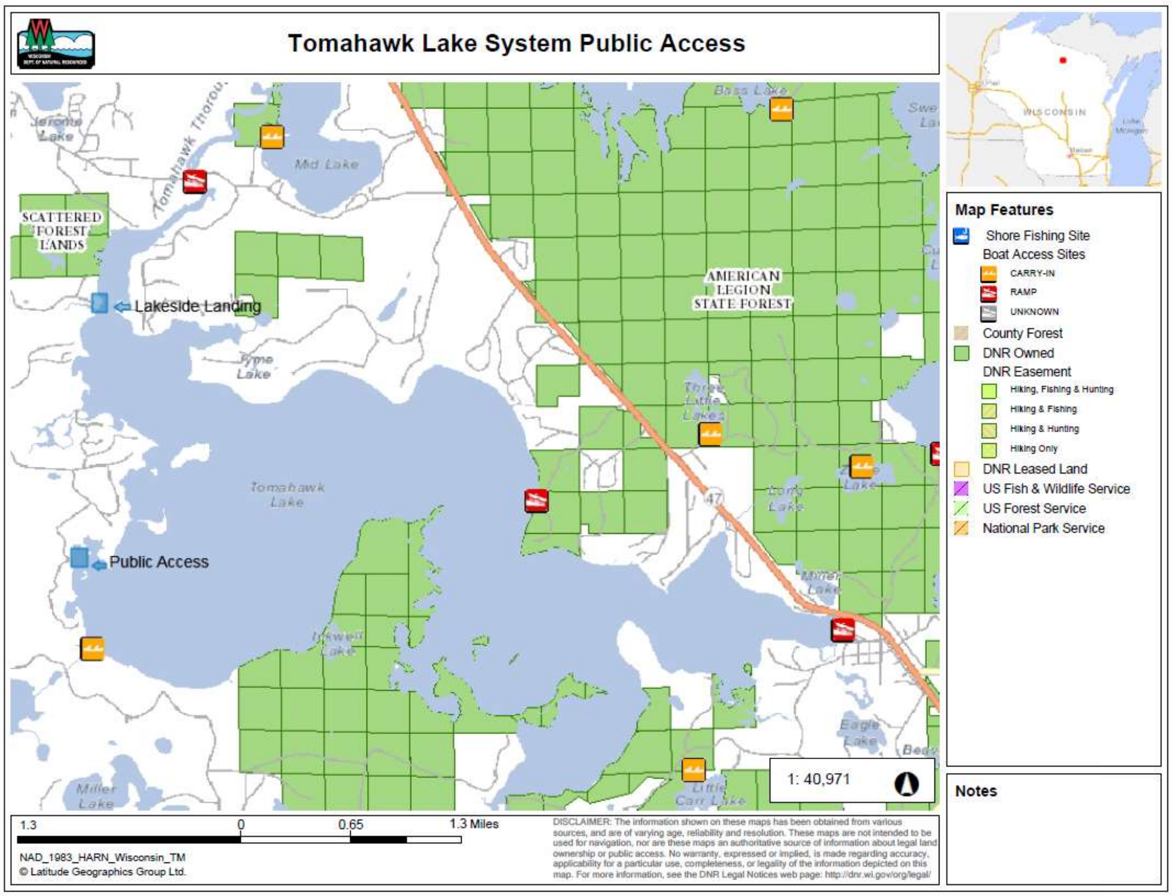


Figure 13. Tomahawk Lake and Thoroughfare Public Access Points

The TLA public survey results acknowledge the importance of shoreline habitat to respondents. Over 65% of respondents acknowledge a negative impact from removing near shore emergent vegetation (25% large negative impact and 40% small negative impact). About 60% responded that removing upland shoreline vegetation had a negative impact on the lake (25% large negative impact, 36% small negative impact). Only 36% agreed that removing shoreline woody debris negatively impacted the lake.

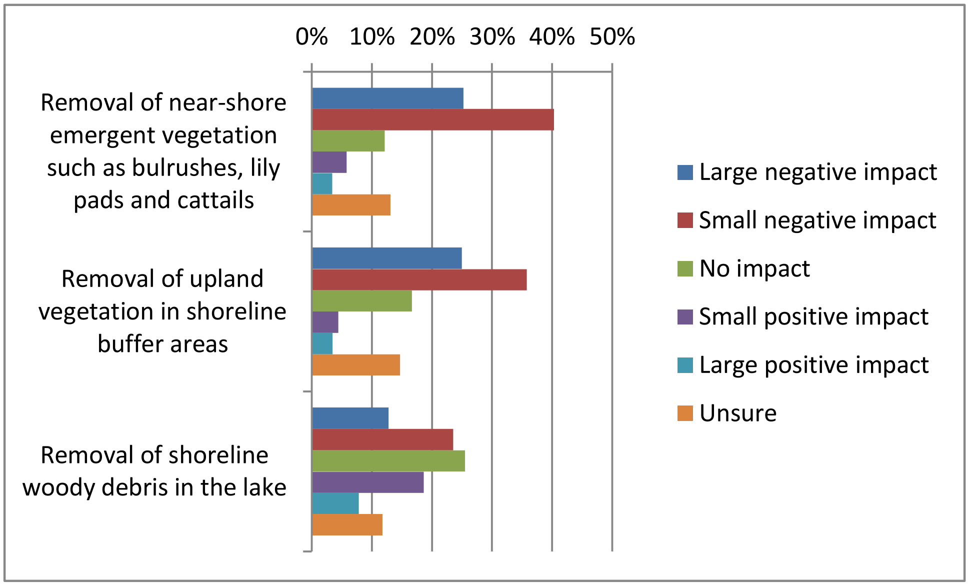


Figure 14. Perceived Impacts Related to Shoreline Alterations

Shoreline Inventory

Ecological Integrity Services conducted the shoreline inventory on developed areas only of the Tomahawk Lake and Little Tomahawk Lake shorelines in July 2014. Developed areas were delineated on a 2013 aerial photo of the lake. For Tomahawk Lake, there were 432 segments totaling 79,013 feet (51.5% of total shoreline). On 49% of the shoreline (74,315 feet) no development was observed. For Little Tomahawk Lake, there were 41 shoreline segments totaling 7,133 feet (59.4% of the total shoreline). On 40.6% of the shoreline (4,882 feet) no development was observed.

Within the developed areas, 200 foot segments were defined by a beginning GPS coordinate and an ending GPS coordinate. The area beginning at the ordinary high water mark and extending 35 feet inland was estimated and rated for several characteristics for each shoreline segment. More detail regarding survey methods is included in the shoreline inventory report.

In all areas of the lake (developed and undeveloped), locations with evident erosion concerns and coarse woody habitat were marked with GPS coordinates and mapped. Shoreline inventory maps provide detailed results including maps and tables which display ranking for each category for each shoreline segment. Example photographs of coarse woody habitat and shoreline erosion are included in Figure 15 . How the shoreline inventory information is used will depend upon objectives and actions chosen for shoreline management.

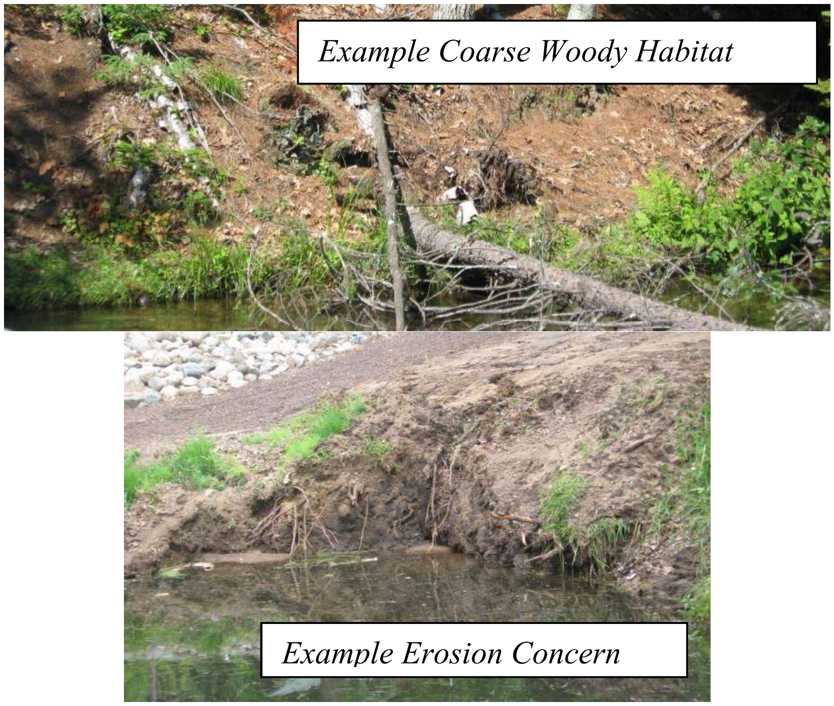


Figure 15. Photographs of Example Coarse Woody Habitat and Erosion Concerns

Table 6. Shoreline Lake Rating Criteria Descriptions

	1	2	3	4	5
Tree Canopy Cover	100 %	75%	50%	25%	<25%
Shrub Canopy Cover	100 %	75%	50%	25%	<25%
Hard Surface Area	<5%	5-10%	11-15%	16-20%	>20%
Native or Naturalized Ground Cover	100 %	75%	50%	25%	<25%
Percent Slope	0-1%	2-5%	6-9%	10-19%	>20%

Table 7. Summary Shoreline Inventory Rankings

Lake Rating: 1 to 5	Mean Tree Canopy Cover	Mean Shrub Canopy Cover	Mean Hard Surfaces Area	Mean Natural Ground Cover	Mean Percent Slope	Mean Rating (all categories)
Tomahawk	1.89	4.14	1.81	2.23	3.29	2.67
Little Tomahawk	1.38	4.35	1.38	1.55	4.38	2.61

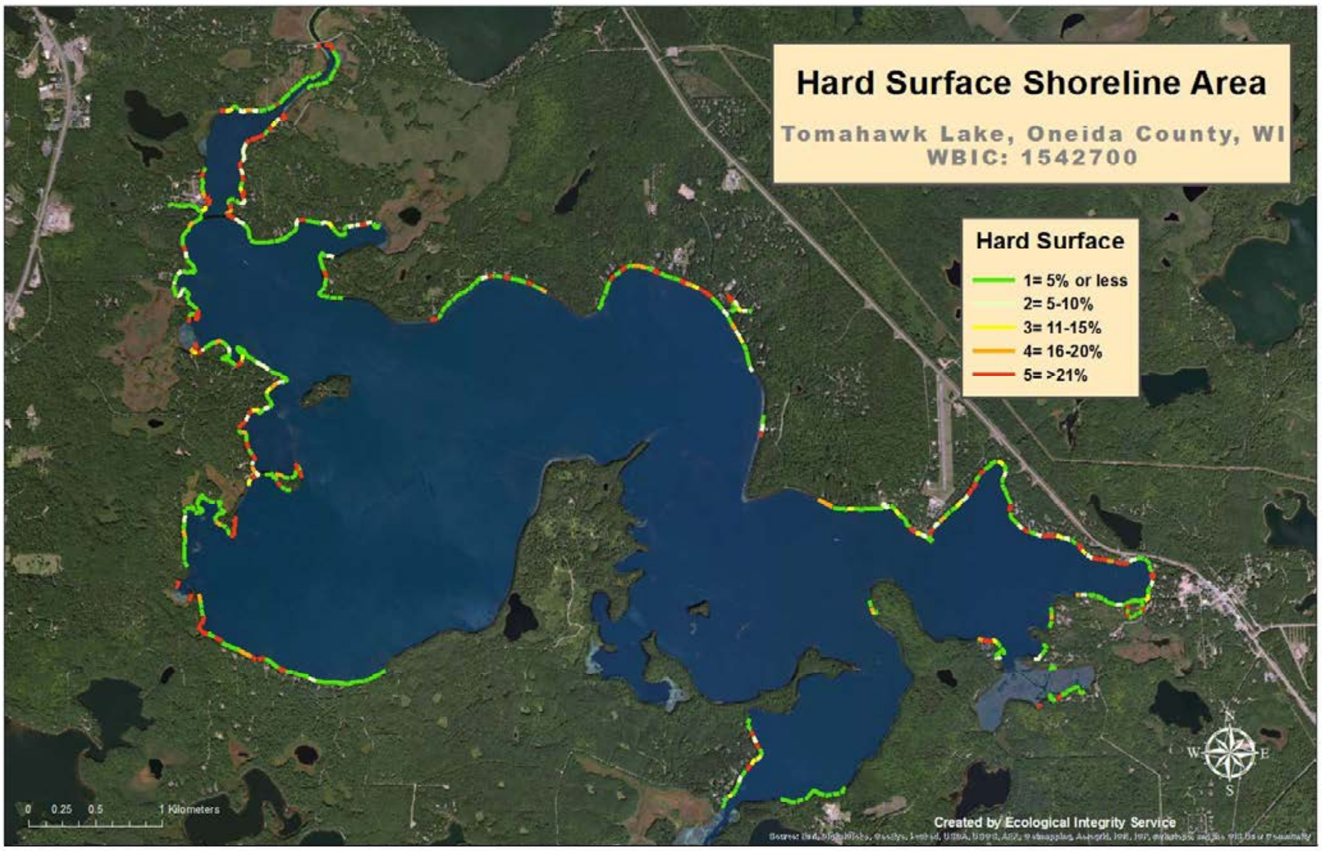


Figure 16. Tomahawk Lake Shoreline Hard Surface Ratings

Figure 17. Tomahawk Lake Shoreline Inventory Overall Shoreline Rating

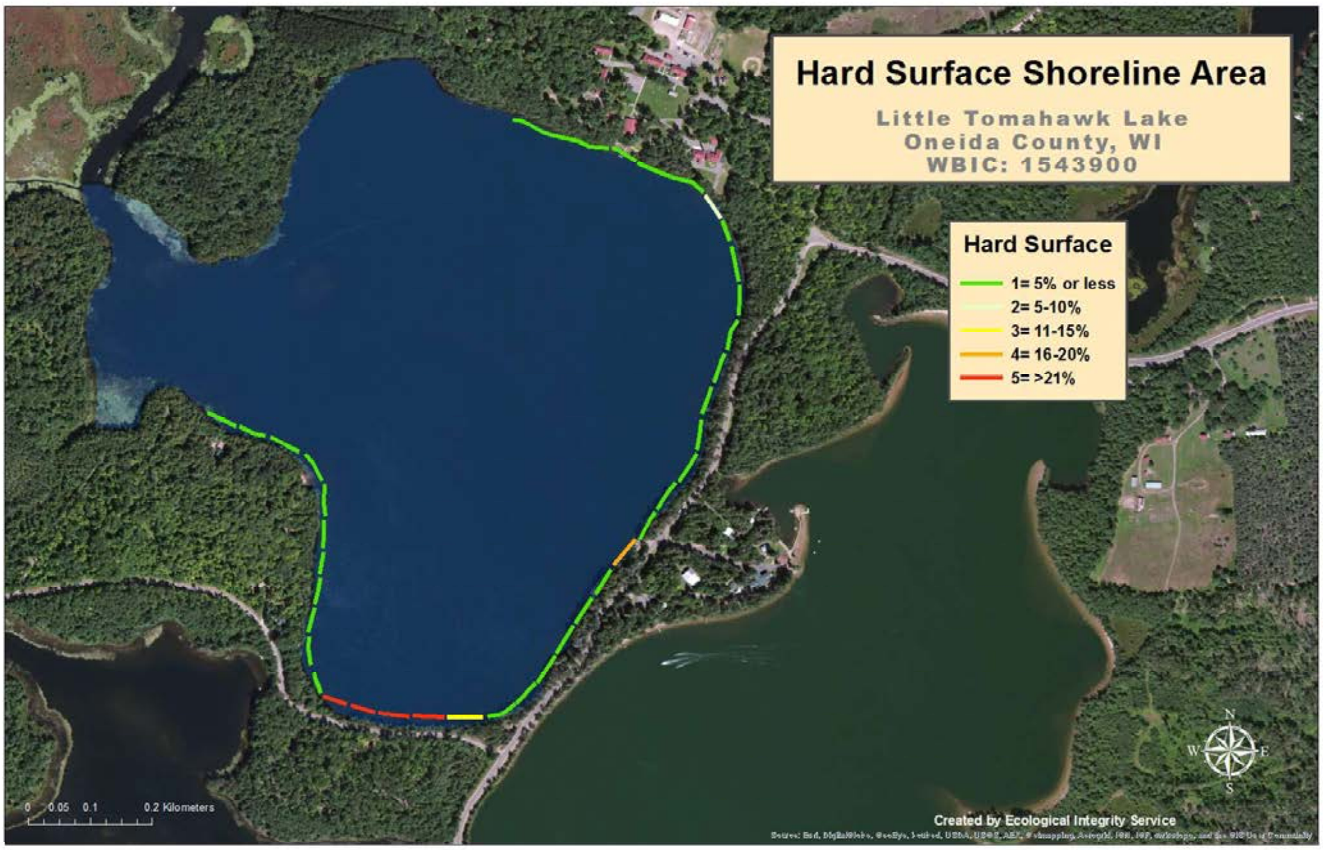


Figure 18. Little Tomahawk Lake Shoreline Hard Surface Ratings

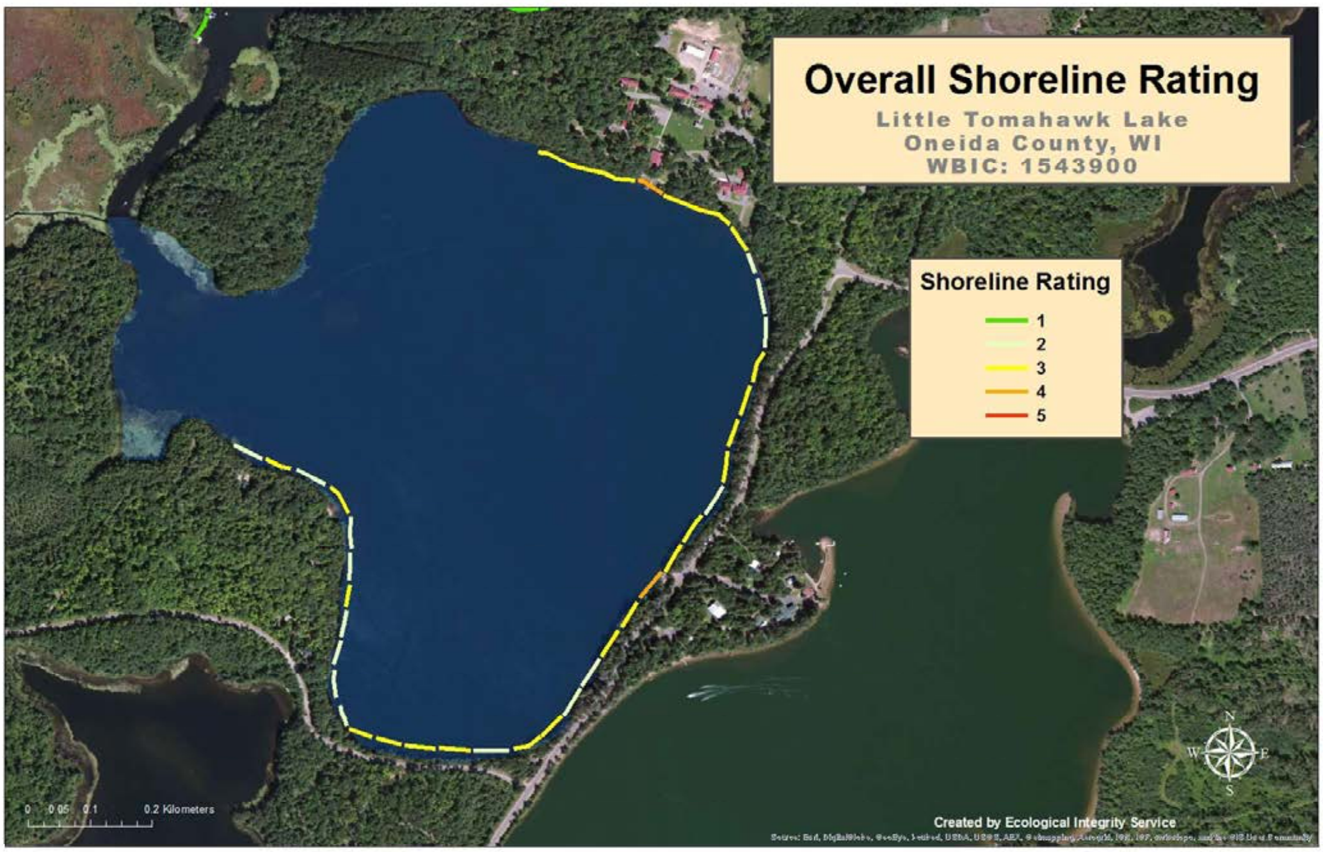


Figure 19. Little Tomahawk Shoreline Inventory Overall Shoreline Ranking

Critical Habitat Areas

The Department of Natural Resources transitioned from sensitive area designations to designations of *critical habitat areas* that include both *sensitive areas* and *public rights features*. S*ensitive areas* offer critical or unique fish and wildlife habitat, including seasonal or lifestage requirements, or offer water quality or erosion control benefits to the area (Administrative code 107.05(3)(1)(1)). Wisconsin Department of Natural Resources is given the authority for the identification and protection of sensitive areas of the lake in this code. *Public rights features* are areas that fulfill the right of the public for navigation, quality and quantity of water, fishing, swimming, or natural scenic beauty. Protecting these *critical habitat areas* requires the protection of shoreline and in-lake habitat. A *critical habitat area* designation provides a framework for management decisions that impact the ecosystem of the lake.

Critical habitat or sensitive areas have not been designated for the Tomahawk Lake System. DNR staff initiated development a draft map of potential sensitive areas, but this map was not completed or reviewed publically. Without official critical habitat area designation, DNR has no ability to enforce special conditions for these sites. Critical habitat designation is not currently staffed as a DNR priority.

The habitat elements noted in critical habitat designation could be considered for TLA management efforts. They include:

- Large woody cover
- Plant beds of submerged, floating and emergent aquatic vegetation
- Shoreland vegetation
- Shoreline bank characteristics
- Shoreland wetlands
- Fish spawning areas such as gravel beds for walleye (Cunningham, 2008)

Tomahawk Lake is designated as a priority navigable water as a musky area.

Inkwell Lake is designated as a priority navigable water because it is <50 acres.

Little Tomahawk Lake is designated as a priority navigable water as a musky area and walleye area.

Floating and Emergent Vegetation

Floating and emergent aquatic vegetation was mapped as part of the aquatic plant point intercept survey. Floating vegetation has leaves which float on the surface. Emergent vegetation has leaves which extend above the water's surface. Mapping methods are explained in the discussion of plant survey results. Floating and emergent vegetation were found at designated sample points on all surveyed lakes. Maps of these locations follow.

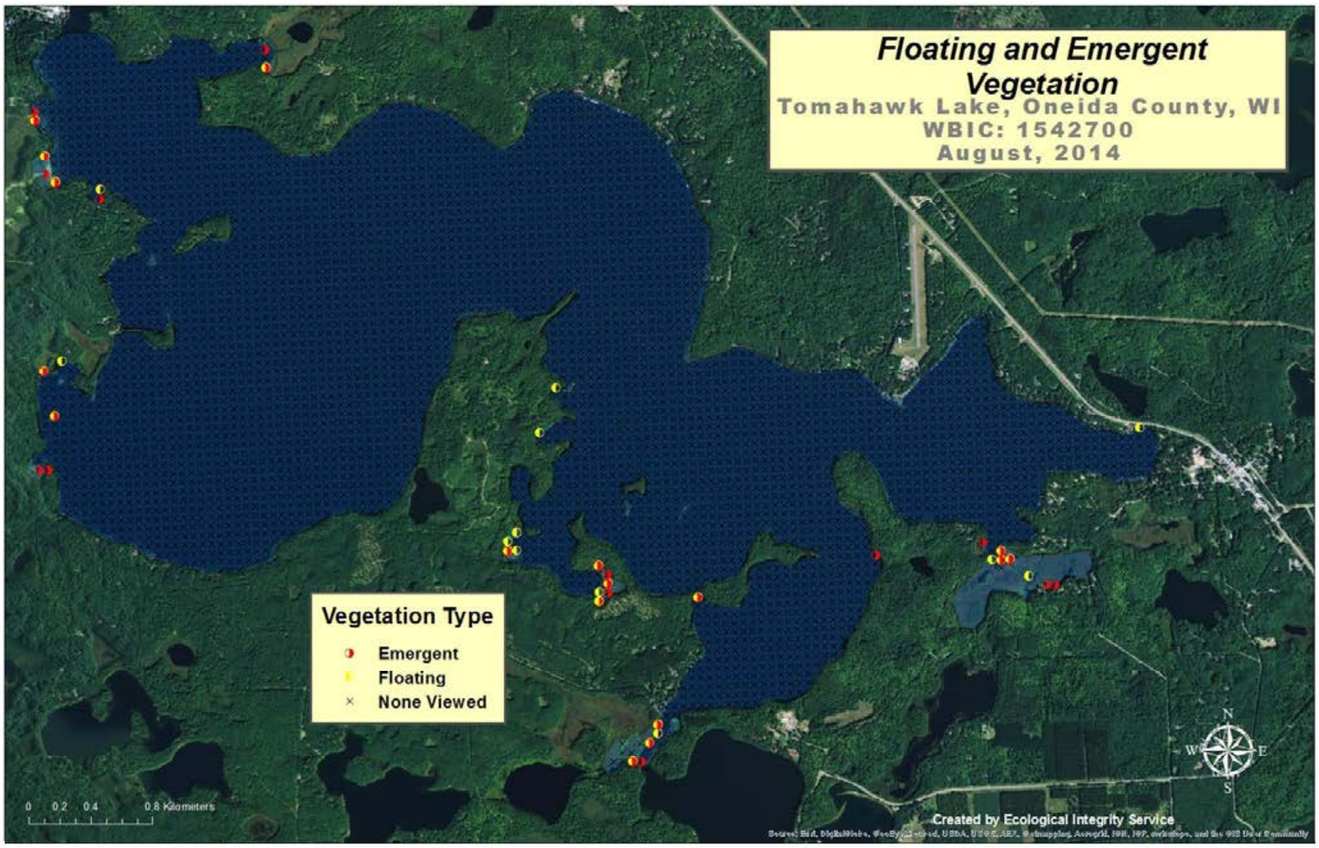
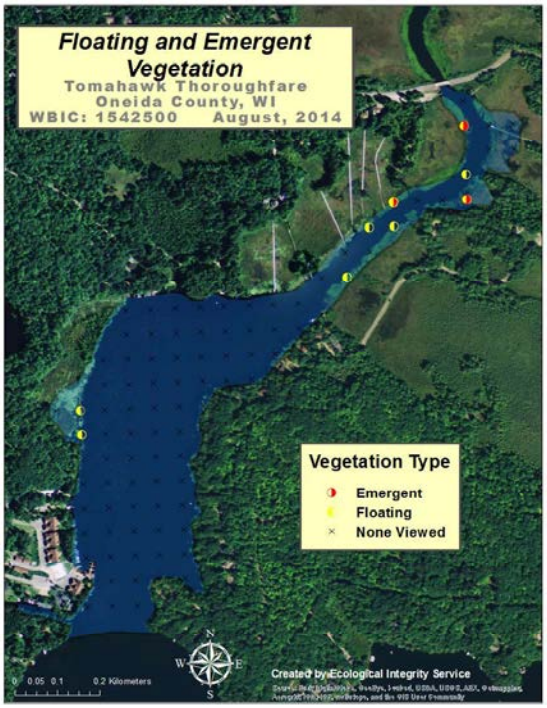


Figure 20. Floating and Emergent Vegetation Tomahawk Lake



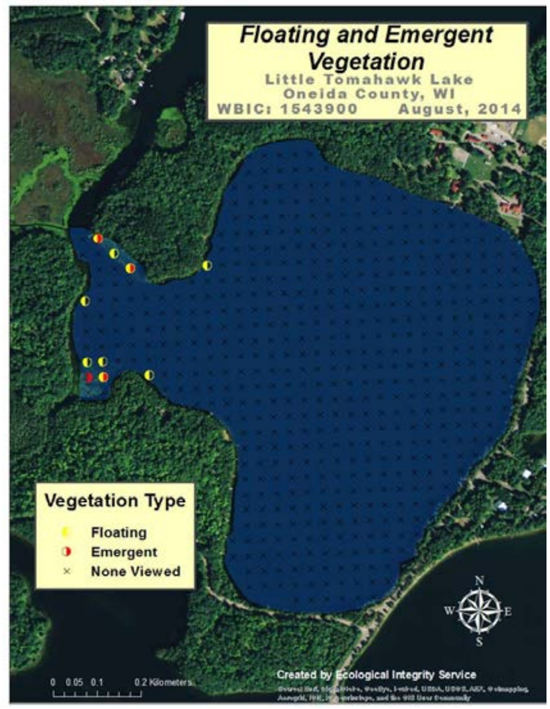


Figure 21. Floating and Emergent Vegetation Tomahawk Thoroughfare and Little Tomahawk Lake

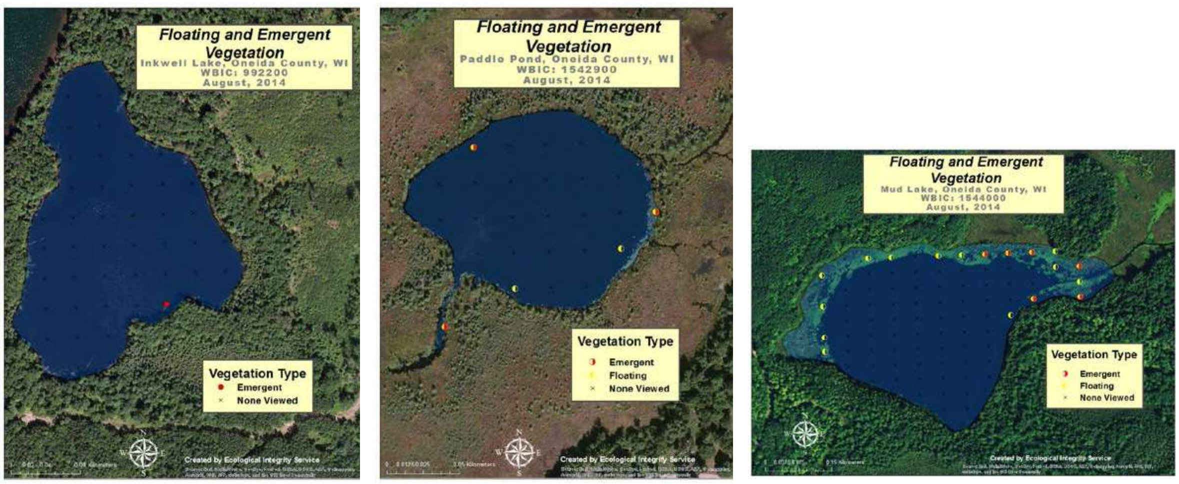


Figure 22. Floating and Emergent Vegetation Inkwell Lake, Paddle Pond, and Mud Lake

Functions and Values of Native Aquatic Plants

Naturally occurring native plants provide a diversity of habitat, help maintain water quality, sustain the fishing quality for which the Tomahawk Lake System is known, and support common lakeshore wildlife from loons to frogs.

Water Quality

Aquatic plants can improve water quality by absorbing phosphorus, nitrogen, and other nutrients from the water that could otherwise fuel nuisance algae growth. Some plants can even filter and break down pollutants. Plant roots and underground stems help to prevent resuspension of sediments from the lake bottom. Stands of emergent plants (with stems that protrude above the water surface) and floating plants help to blunt wave action and prevent erosion at the shoreline.

Fishing

Habitat created by aquatic plants provides food and shelter for both young and adult fish. Invertebrates living on or beneath plants are a primary food source for fish. Other fish such as bluegills graze directly on the plants themselves. Plant beds provide important spawning habitat for many fish species.

Waterfowl

Plants offer food, shelter, and nesting material. Birds eat both the invertebrates that live on plants and the plants themselves.[4]

Protection against Invasive Species

Non-native invasive species threaten native plants in Northern Wisconsin. The most common are Eurasian water milfoil (EWM) and curly leaf pondweed (CLP). These species are described as opportunistic invaders. This means that these "invaders" benefit where an opening occurs from removal of plants. Without competition from other plants, invasive species may successfully become established in a lake. Removal of native vegetation not only diminishes the natural qualities of a lake, it may increase the risk that an invasive species can successfully invade onto the site where native plants have been removed. This concept is easily observed on land where bared soil is quickly taken over by weeds that establish themselves as new occupants of the site. While not a providing a guarantee against invasive plants, protecting and allowing the native plants to remain may reduce the success of a new invasive species becoming established in a lake or continued spread of Eurasian water milfoil. Invasive species can change many of the natural features of a lake and often lead to expensive annual control plans. Native vegetation may cause localized concerns to some users, but as a natural feature of lakes, they generally do not cause harm.[5]

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[4] Above paragraphs summarized from Through the Looking Glass. Borman etal. 1997.

[5] Taken from Aquatic Plant Management Strategy. DNR Northern Region. Summer 2007.

Fish Community

Common fish species of the Tomahawk Lake System are listed in the WDNR web pages[6] as summarized below. A comprehensive fisheries survey of the Minocqua Chain (which includes Little Tomahawk, Mud, Minocqua and Kawaguesaga Lakes) lists black crappie, bluegill, pumpkinseed, rock bass and yellow perch as panfish present (Kubisiak, 2011). The report further stated that game species were of good size and appeared to be in excellent condition with bass the predominant gamefish. WDNR fisheries manager, Kubisiak recommends that the lakes be managed for walleye, muskellunge, bass, and panfish.

Table 8. Sport Fish of the Tomahawk Lake System

	Tomahawk Lake	**Little Tomahawk**	**Mud Lake**	**Inkwell Lake**
Muskellunge	Common	Common	Present	
Panfish	Common	Present	Present	Present
Smallmouth bass	Common	Common		
Walleye	Common	Common		
Largemouth bass	Present	Common	Common	Common
Northern pike	Present	Present	Present	

Walleye

WDNR conducted several surveys to assess the walleye population in Tomahawk Lake. Walleye ranged from 1.3 to 3.7 fish per acre. Tomahawk Lake is supported by walleye stocking. Although there is good spawning gravel present, natural recruitment (reproduction and initial survival) by walleye is low in Tomahawk Lake. Similar sized stocked lakes predict 1.2 fish per acre, and naturally reproducing lakes predict 3.2 per acre. Current walleye populations are low compared with historic values, and the WDNR recommends continued supplemental stocking.

<u>The Minocqua Chain Walleye Project</u>

The Minocqua Chain Walleye Project was initiated because of concerns regarding low walleye populations in the entire Minocqua Chain of Lakes (which includes Tomahawk Lake). This cooperative project between the WDNR, Headwaters Basin Chapter of Walleyes for Tomorrow, Lac du Flambeau Band of Lake Superior Chippewa Indians, and the Great Lakes Indian Fish and Wildlife Commission seeks to restore self-sustaining walleye populations with a density goal of at least two adult fish per acre in Tomahawk Lake. Stocking will continue under this project. The main impact to anglers is that walleye will be catch and release on the Minocqua Chain from 2015-2020. Walleye fishing regulations after 2020 will depend on the response of the fishery. To reduce competition from bass, minimum length requirements for bass were removed in 2011.

[6] http://dnr.wi.gov/lakes/LakePages

Table 9. Tomahawk Lake Walleye Population Estimates

Year	Fish/Acre
1986	3.7
1987	1.9
1992	2.5
1998	2.5
2009	1.3

Table 10. Walleye Stocking Tomahawk Lake

Year	Fry	Small Fingerling	Large Fingerling (DNR)	Fingerling (private funds)
1995	2,500,000	85,902		
1996	1,000,000	100,000 (1.5")		
1997	3,000,000			
1998	5,300,000	339,206 (1.3")		
1999	4,700,000			
2000	6,500,000 (0.3")	311,889 (1.7 and 2.3")		1,500 (4-6")
2001		330,000 (1.3")		800 (8")
2004		169,676 (1.3")		
2006		118,700 (1.3")		
2007	1,660,000 (0.3")			
2008		118,404 (1.6")		
2012			16,954 (7.9")	
2014			34,603 (7.2")	

Largemouth and Smallmouth Bass

Remaining fish data are reported for the entire Minocqua Chain in the 2009 fisheries survey. It reports both largemouth and smallmouth bass in good numbers of fish up to 16 or 17 inches with low numbers of larger fish. The longest smallmouth bass sampled (19.7 inches) was from Tomahawk Lake.

Muskellunge

Tomahawk Lake was the only lake in the Minocqua Chain that yielded a high enough capture for a population estimate. The result was a low density of one fish per acre. The largest fish was a 50.5 inch, 35.1 pound female from Tomahawk Lake. Large fingerling muskellunge were stocked in the Minocqua Chain as recently as 2001. However, the age class of fish captured suggests there is little natural reproduction. Muskellunge stocking resumed in 2011.

Table 11. Muskellunge Stocking Tomahawk Lake

Year	Fry	Large Fingerling
1995	225,000	
1996	82,400	
1997	334,000	1,500
1998	56,750	
1999	42,100 (0.5")	1,000 (12.1")
2001		850 (12")
2011		3,390(9.3")
2014		3,435 (11.3")

Fishing Activity

A 2009-10 WDNR creel survey reports fishing effort and results by species for the season. Selected results from that creel survey are included in Table 12. Tomahawk Lake Creel Survey Results 2009-10 below. Methods are described in the report. (Tobias, 2010)

Table 12. Tomahawk Lake Creel Survey Results 2009-10

Species	Hours of Effort	Total Catch	Total Harvest	Harvest Rate (Hours/Fish)	Mean Length Harvested (in.)
Walleye	24,878	419	254	129.9	21.8
Northern Pike	4,957	819	176	37.5	25.5
Muskellunge	10,384	182	0		
Small Bass	37,682	51,334	1,084	40.0	14.3
Largemouth Bass	31,385	22,815	533	122.0	14.0
Yellow Perch	24,667	20,503	5,539	5.0	8.1
Bluegilll	31,159	61,608	13,866	2.3	7.1
Pumpkinseed	5,137	6,283	1,830	3.3	7.1
Rock Bass	5,818	40,946	5,642	1.2	7.9
Black Crappie	27,906	11,721	7,849	3.6	10.5

Public Opinion Survey Results

Fishing is a popular activity in the Tomahawk Lake System with 78% of lake user survey respondents indicating they had fished in the lakes within the last three years. When Tomahawk Lake System respondents were asked to rank the top three lake activities most enjoyed, open water fishing was selected second most commonly, just after pleasure boating. Having a diverse high quality fishery was ranked as very important by 67% of respondents and fairly important by 21%. The most important fish species was clearly walleye as shown in Figure 23.

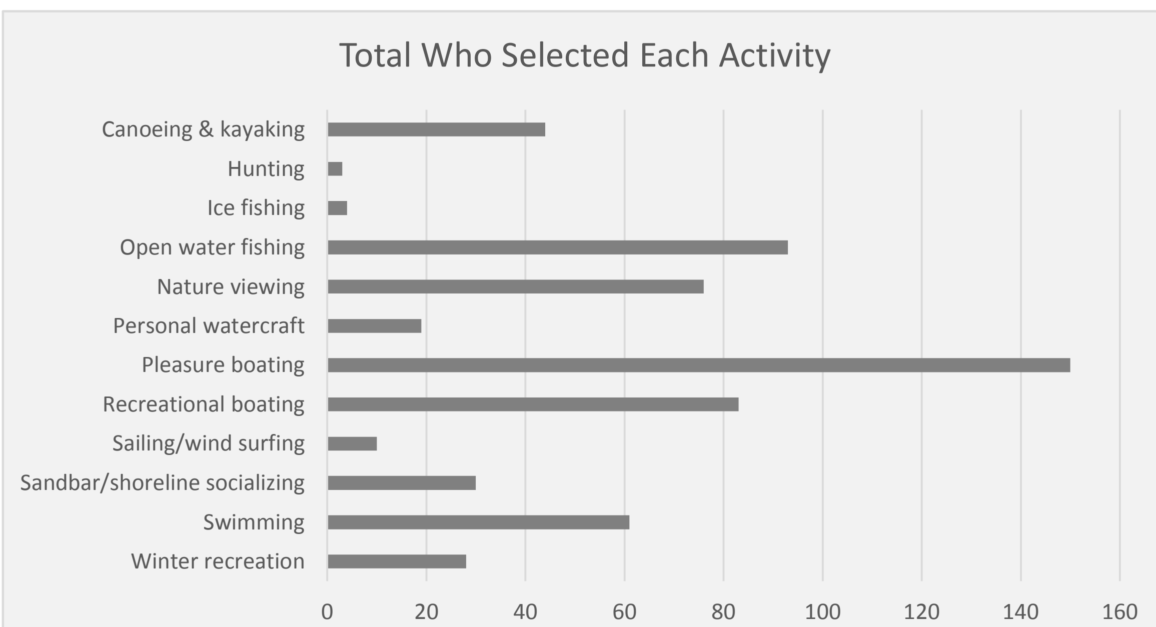

Figure 23. Rank the three activities you and/or your family most enjoy.

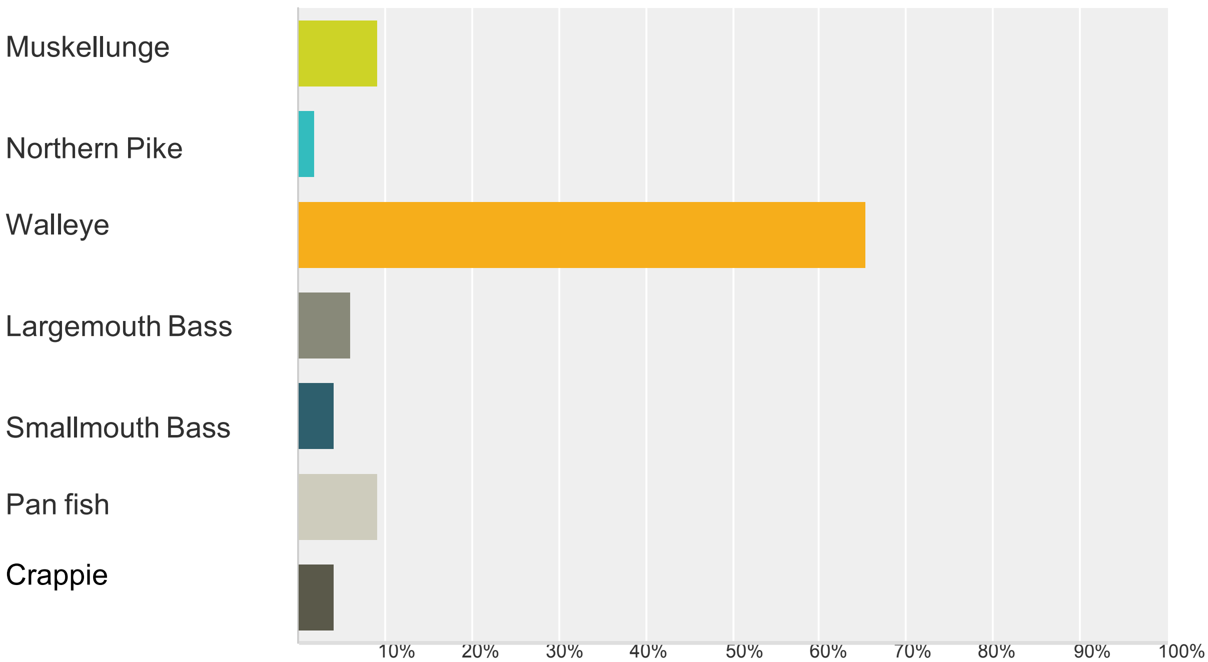

Figure 24. What is the most important fish species for you?

Fishery Management Recommendations

At a recent meeting with WDNR Fisheries staff, CLMP Steering Committee members inquired about the role for the Tomahawk Lake Association related to fisheries management.[7] Fisheries management is clearly a WDNR-led activity. Recommended involvement included:

- Providing input to DNR for proposed fish management
- Consider installing fish habitat structures in the lake.

Fish habitat, which might include half logs or trees (fish sticks) anchored to lake sediments or attached to the shoreline, require WDNR permits. The Shoreline Inventory provides specific locations of existing woody fish habitat on Tomahawk and Little Tomahawk Lakes.

[7] WDNR/TLA Meeting 1/22/15.

Plant Community

Ecological Integrity Service conducted a point intercept aquatic macrophyte survey in June and August 2014 to evaluate the plant community in the Tomahawk Lake System. Plant surveys were completed for project lakes according to standard WDNR protocol. Plant survey methods are found in Appendix C. The full survey report is available as a separate document and summarized in following sections.

The survey used sample point grids generated by the Wisconsin Department of Natural Resources. At each sample point where plants are likely to grow, a rake was used to collect plant samples. The samples were evaluated for plant density for each species with rake density ratings as described in Table 13 and illustrated in Figure 25 below. These rankings are reported as plant density (1 to 3) in several figures that follow.

Table 13. Aquatic Plant Survey Rake Density Ratings

Rake density rating	Criteria for rake density rating
1	Plant present, occupies less than ½ of tine space
2	Plant present, occupies more than ½ tine space
3	Plant present, occupies all or more than tine space
v	Plant not sampled but observed within 6 feet of boat

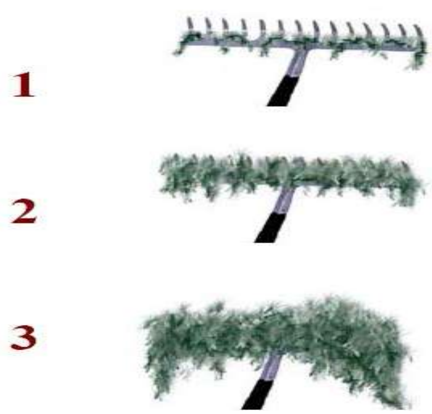

Figure 25. Illustration of Rake Plant Density

Aquatic Plant Survey Results Tomahawk Lake

Tomahawk Lake had 4,149 sample points in the survey grid, with 1,321 points within the defined littoral depth. The littoral zone depth (where plants grow) extended to 26.2 feet. Of the littoral points, 820 (62.07%) had vegetation present as shown in Table 14.

The density of plants was relatively low except for bays in the northwest, south central, and eastern portion of the lake near the landing (Figure 27).

Table 14. Tomahawk Lake 2014 Macrophyte Survey Statistic Summary

Tomahawk Lake Survey Stats	
Total number of sample sites in survey	4,149
Total number of sites with vegetation	820
Total number of sites shallower than maximum depth of plants	1321
Frequency of occurrence at sites shallower than maximum depth of plants	62.07%
Simpson Diversity Index	0.94
Maximum depth of plants (ft)	26.20
Mean depth of plants (ft)	8.88
Average number of all species per site (shallower than max depth)	1.63
Average number of all species per site (veg. sites only)	2.64
Average number of native species per site (shallower than max depth)	1.60
Average number of native species per site (veg. sites only)	2.61
Species Richness	59
Species Richness (including visuals)	65

The diversity of plants in Tomahawk Lake is very high. Fifty-nine different species were sampled on the rake. This high diversity is supported by a very high Simpson's diversity index of 0.94. Table 15 lists the species sampled and viewed and their frequency statistics.

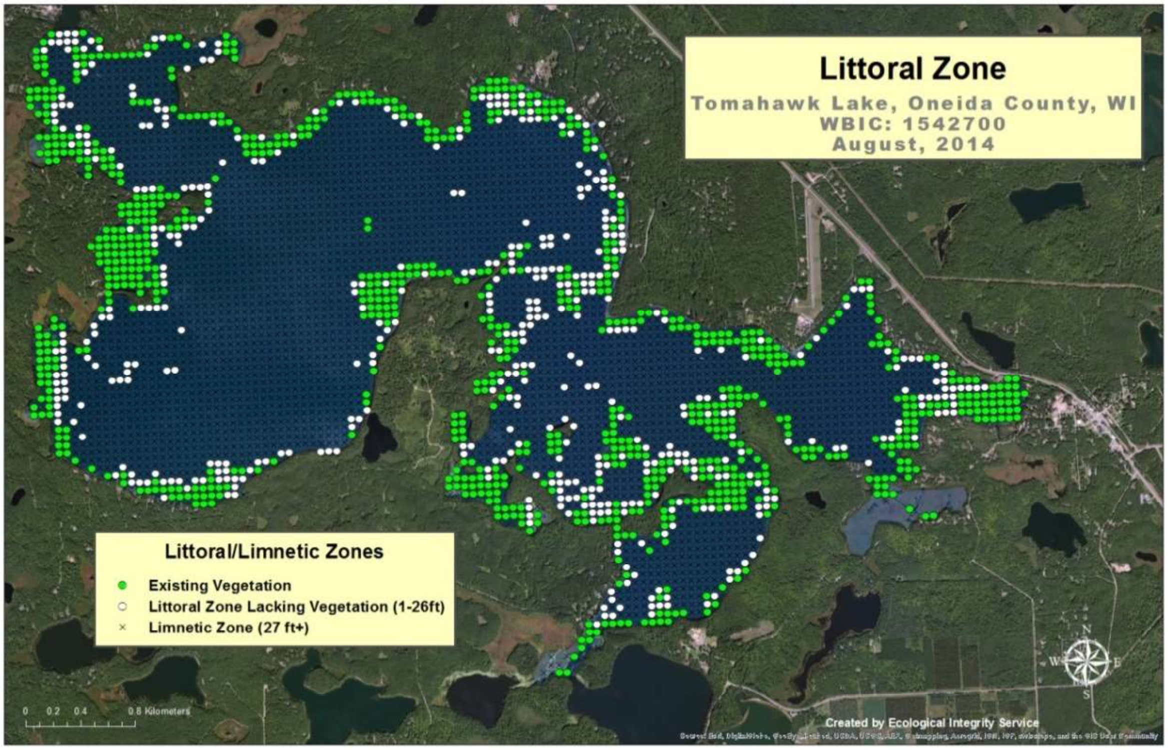

Figure 26. Tomahawk Lake Littoral Zone August 2014

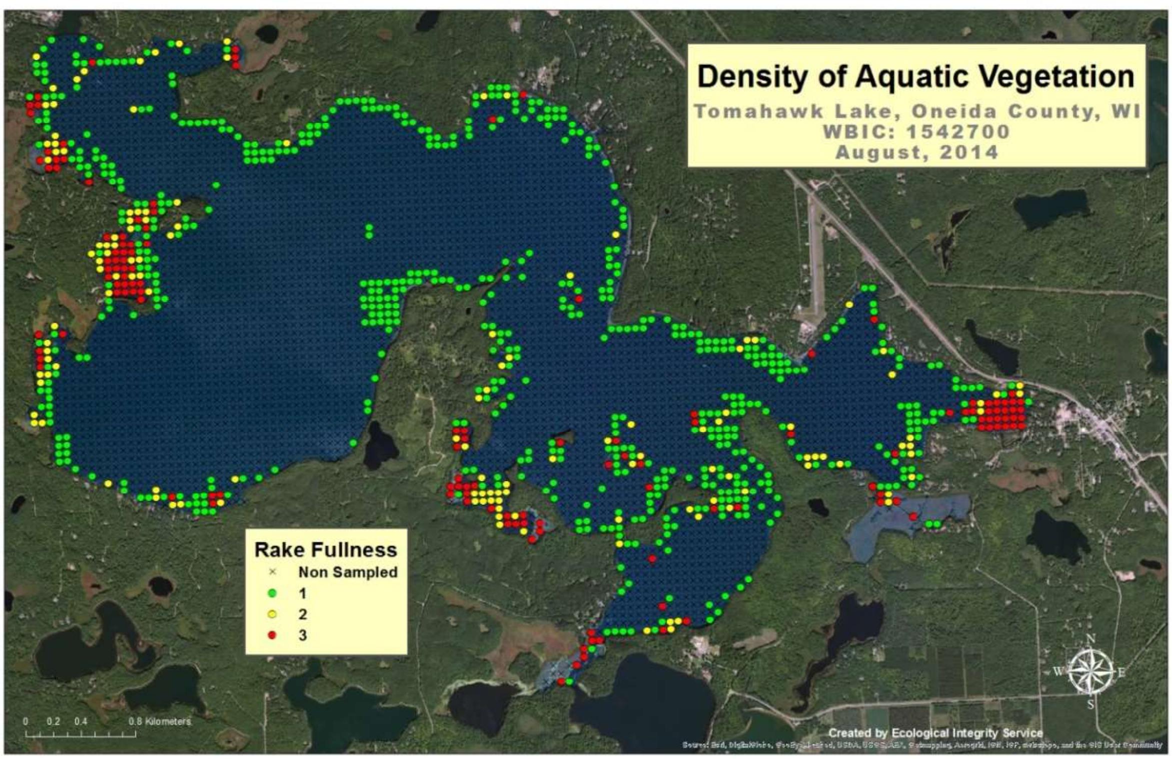

Figure 27. Tomahawk Lake Rake Fullness Density August 2014

Table 15. Tomahawk Lake Plant Species

Tomahawk Lake Species[8]	Vegetated Frequency	Littoral Freq.	Rel. Freq.	# sampled	Mean Density	Viewed
Najas flexilis, Slender naiad	30.87	19.34	11.1	230	1.03	1
Potamogeton robbinsii, Fern pondweed	28.19	17.66	10.71	210	1.52	1
Ceratophyllum demersum, Coontail	23.36	14.63	8.87	174	1.17	
Elodea canadensis, Common waterweed	21.61	13.54	8.21	161	1.14	1
Myriophyllum sibiricum, Northern water-milfoil	19.19	12.03	7.29	143	1.02	9
Potamogeton gramineus, Variable pondweed	18.66	11.69	7.09	139	1.00	8
Potamogeton pusillus, Small pondweed	15.84	9.92	6.02	118	1.01	
Najas guadalupensis, Southern naiad	10.07	6.31	3.82	75	1.27	
Potamogeton zosteriformis, Flat-stem pondweed	9.53	5.97	3.62	71	1.00	
Potamogeton richardsonii, Clasping-leaf pondweed	9.26	5.80	3.52	69	1.01	4
Potamogeton amplifolius, Large-leaf pondweed	7.79	4.88	2.96	58	1.03	4
Vallisneria americana, Wild celery	6.71	4.21	2.55	54	1.00	1
Bidens beckii , Water marigold	6.46	4.01	2.45	48	1.06	
Elodea nuttallii, Slender waterweed	6.31	3.95	2.40	47	1.06	
Potamogeton praelongus, White-stem pondweed	5.10	3.20	1.94	38	1.00	1
Chara sp., Muskgrasses	4.70	2.94	1.78	35	1.00	
Myriophyllum spicatum, Eurasian water milfoil	4.51	2.79	1.68	33	1.30	4
Ranunculus aquatilis, White water crowfoot	3.49	2.19	1.33	26	1.00	
Eleocharis acicularis, Needle spikerush	2.95	1.85	1.12	22	1.00	
Nitella sp., Nitella	2.82	1.77	1.07	21	1.00	
Heteranthera dubia, Water star-grass	2.68	1.68	1.02	20	1.00	
Nymphaea odorata, White water lily	2.55	1.60	0.97	19	1.00	5
Potamogeton illinoensis, Illinois pondweed	2.07	1.29	0.80	17	1.00	3
Potamogeton spirillus, Spiral-fruited pondweed	1.88	1.18	0.71	14	1.00	1
Brasenia schreberi, Watershield	1.61	1.01	0.61	12	1.00	2
Lemna trisulca, Forked duckweed	1.48	0.93	0.56	11	1.00	
Sagittaria cristata, Crested arrowhead	1.48	0.93	0.56	11	1.00	
Potamogeton friesii, Fries' pondweed	1.34	0.84	0.51	10	1.20	
Utricularia vulgaris, Common bladderwort	1.21	0.76	0.46	9	1.00	
Nuphar variegata, Spatterdock	1.07	0.67	0.41	8	1.00	1
Juncus pelocarpus f. submersus, Brown-fruited rush	0.94	0.59	0.36	7	1.14	
Myriophyllum tenellum, Dwarf water-milfoil	0.94	0.59	0.36	7	1.00	
Pontederia cordata, Pickerelweed	0.94	0.59	0.36	7	1.00	4
Elatine minima, Waterwort	0.81	0.50	0.31	6	1.00	1

[8] Species verified by Robert Freckmann Herbarium, UW-Stevens Point through submitted voucher specimens.

Tomahawk Lake Species[8]	Vegetated Frequency	Littoral Freq.	Rel. Freq.	# sampled	Mean Density	Viewed
Isoetes echinospora, Spiny spored-quillwort	0.81	0.50	0.31	6	1.00	
Myriophyllum alterniflorum, Alternate-flowered water-milfoil	0.81	0.50	0.31	6	1.00	
Typha latifolia, Broad-leaved cattail	0.67	0.42	0.25	5	1.80	1
Potamogeton foliosus, Leafy pondweed	0.54	0.34	0.20	4	1.00	
Potamogeton strictifolius, Stiff pondweed	0.40	0.25	0.15	3	1.00	
Lythrum salicaria, Purple loosestrife	0.40	0.25	0.15	3	1.00	2
Myriophyllum verticillatum, Whorled water-milfoil	0.27	0.17	0.10	2	1.00	
Potamogeton epihydrus, Ribbon-leaf pondweed	0.27	0.17	0.10	2	1.00	
Potamogeton natans, Floating-leaf pondweed	0.27	0.17	0.10	2	1.00	2
Sparganium angustifolium, Narrow-leaved bur-reed	0.27	0.17	0.10	2	1.00	1
Stuckenia filiformis, Fine-leaved pondweed	0.27	0.17	0.10	2	1.00	
Typha angustifolia, Narrow-leaved cattail	0.27	0.17	0.10	2	1.00	
Utricularia intermedia, Flat-leaf bladderwort	0.27	0.17	0.10	2	1.00	
Decodon verticillatus, Swamp loosestrife	0.12	0.08	0.05	1	1.00	3
Eleocharis palustris, Creeping spikerush	0.12	0.08	0.05	1	1.00	
Myriophyllum farwellii, Farwell's water-milfoil	0.12	0.08	0.05	1	1.00	1
Potamogeton alpinus, Alpine pondweed	0.12	0.08	0.05	1	1.00	
Potamogeton obtusifolius, Blunt-leaf pondweed	0.12	0.08	0.05	1	1.00	
Potamogeton perfoliatus, Perfoliate pondweed	0.12	0.08	0.05	1	1.00	
Sagittaria latifolia, Common arrowhead	0.12	0.08	0.05	1	1.00	
Sagittaria rigida, stiff arrowhead	0.12	0.08	0.05	1	1.00	
Sagittaria cuneata, Arum-leaved arrowhead	0.12	0.08	0.05	1	1.00	
Schoenoplectus subterminalis-water bulrush	0.12	0.08	0.05	1	1.00	
Sparganium emersum, Short-stemmed bur-reed	0.12	0.08	0.05	1	1.00	2
Sparganium eurycarpum, Common bur-reed	0.12	0.08	0.05	1	1.00	
Aquatic moss	2.15	1.35	n/a	16	1.00	
Filamentous algae	3.49	2.19	n/a	26	1.00	
Calla palustris, Wild calla	viewed	only				1
Carex hystericina, Bottle brush sedge	viewed	only				1
Dulichium arundinaceum, Three-way sedge	viewed	only				1
Lemna minor, Small duckweed	viewed	only				1
Schoenoplectus tabernaemontani, Softstem bulrush	viewed	only				1
Spirodela polyrhiza, Large duckweed	viewed	only				1

Table 16. Tomahawk Lake Shoreline Species Observed

Polygonium amphibium, Water smartweed
Juncus effusus, Soft rush
Iris pseudacorus , Yellow iris
Carex utriculatum, Sedge
Scirpus cyperinus , Woolgrass

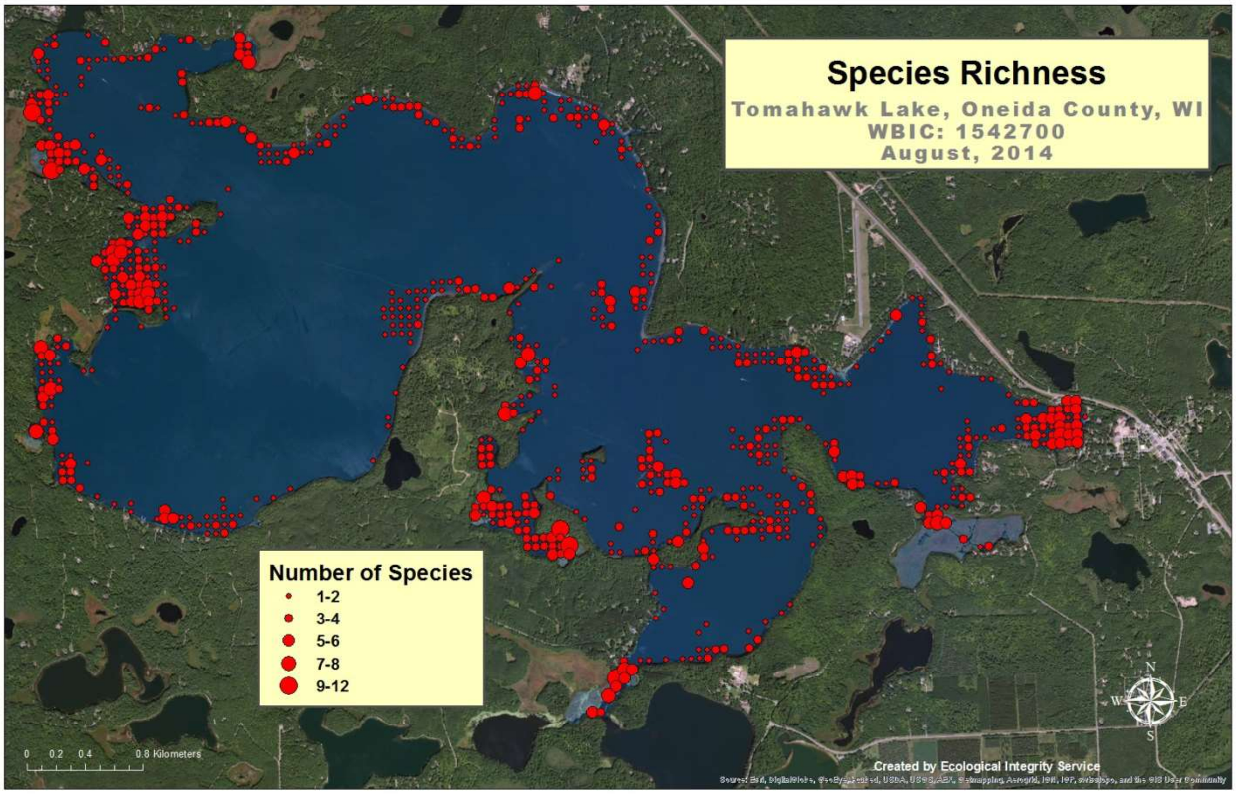

Figure 28. Tomahawk Lake Species Richness August 2014

As Figure 28 shows, most of the diversity of plants in Tomahawk Lake is located in the bays. The eastern-most bay (near the landing) and the western bays contain the most diversity of plants per sample. The area leading into Little Tomahawk as well as the south-central bay also has very high diversity.

The most common aquatic plants sampled were *Najas flexilis* (slender naiad), *Potamogeton robbinsii* (fern pondweed) and *Ceratophyllum demersum* (coontail).

Slender naiad is a common native plant in Wisconsin lakes. This plant is often associated with sandy and rocky substrate, which would account for its high frequency in Tomahawk Lake. Slender naiad grows annually from seed only, which could cause great variation in growth from year to year. Waterfowl rely heavily on slender naiad, and it also provides good habitat for fish.

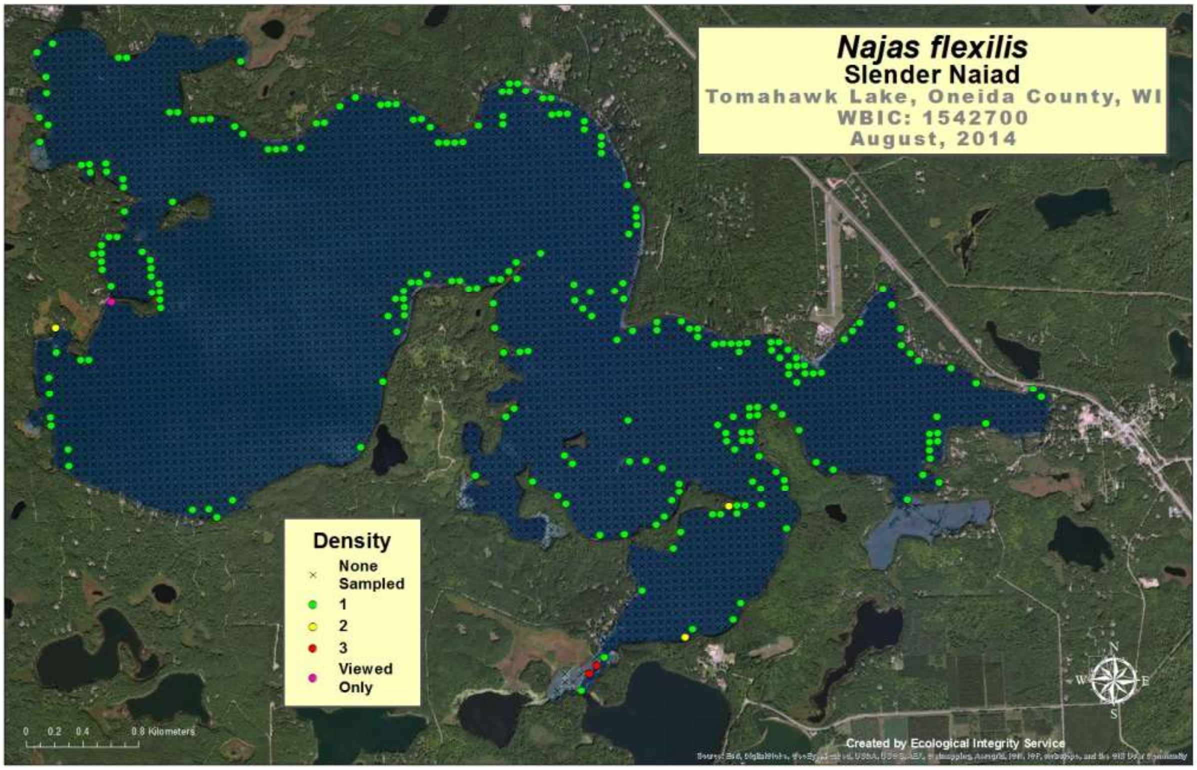

Figure 29. Slender Naiad Distribution Tomahawk Lake

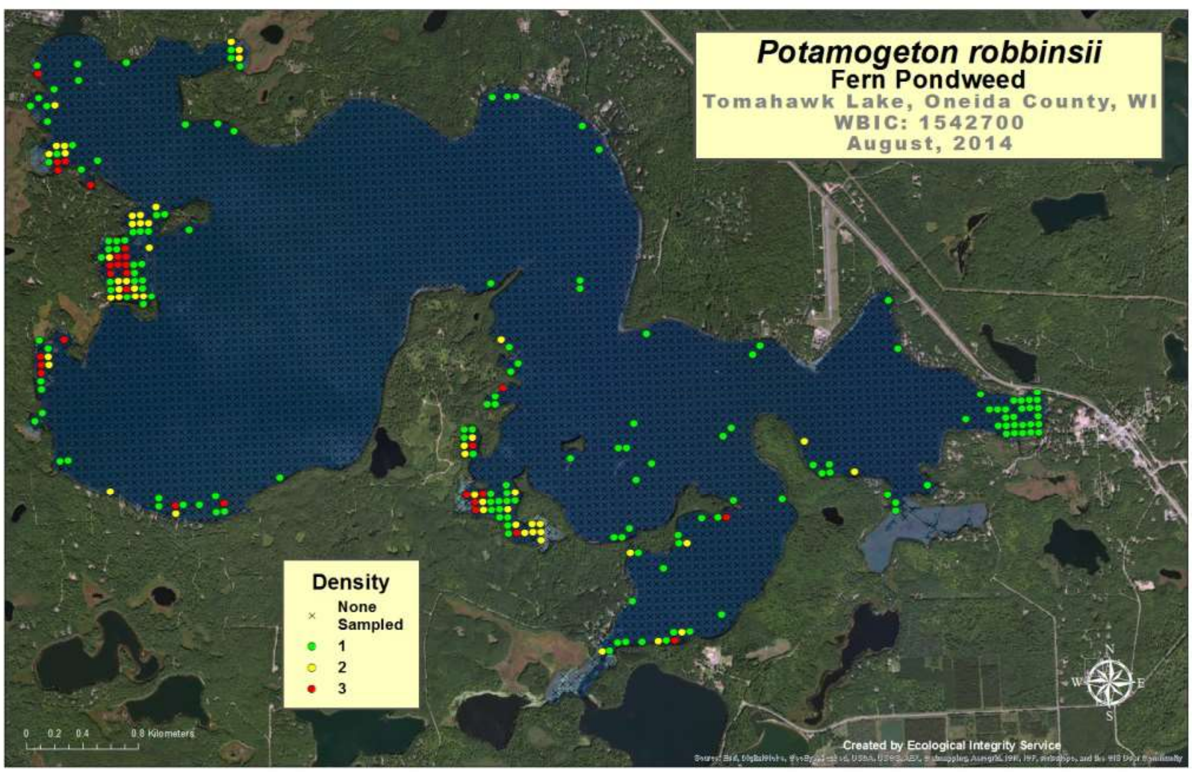

Figure 30. Fern Pondweed Distribution Tomahawk Lake

Fern pondweed is a very common plant in Wisconsin. This plant can thrive in deeper water than many other plants, and can provide critical oxygen in the lake because it overwinters. The plant sprouts in spring from rhizomes and winter buds. Fern pondweed provides excellent habitat for invertebrates and fish.

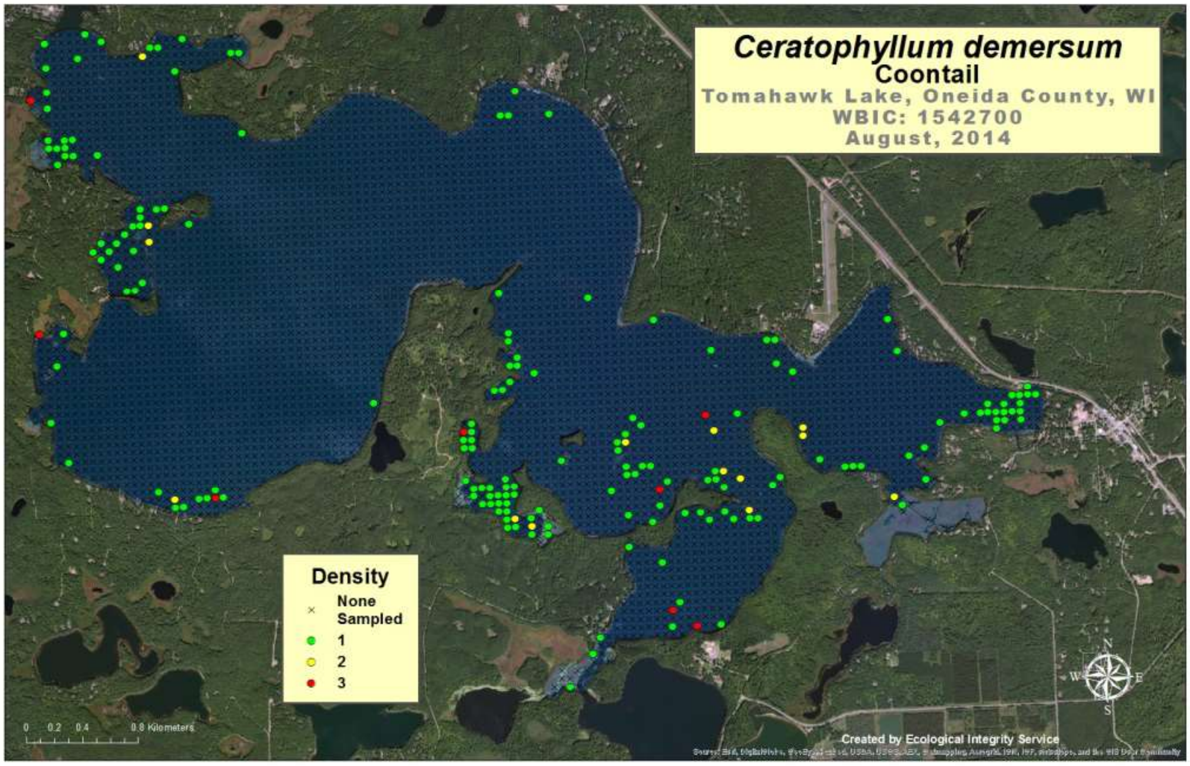

Figure 31. Coontail Distribution Tomahawk Lake

Coontail often dominates in many high-nutrient Wisconsin lakes, although it does not in Tomahawk Lake. Coontail can be very important for oxygen in lakes as it can grow in deep water and low light conditions. It often overwinters, providing key habitat and oxygen in the winter. The plant mainly spreads through stem fragmentation and is not rooted. The whorled, fine leaves provide excellent habitat for invertebrates, thus providing good forage for fish. Many waterfowl feed on the fruit and foliage.

There were two Wisconsin special concern species sampled in Tomahawk Lake: *Myriophyllum farwelli*-Farwell's watermilfoil and *Potamogeton perfoliatus*-Perfoliate pondweed.

Table 17. Tomahawk Lake Species of Special Concern

Myriophyllum farwellii, Farwell's water-milfoil
**Potamogeton perfoliatus*, Perfoliate pondweed
**Dr. Freckmann of the Freckmann Herbarium(UW-Stevens Point) stated not 100% verified. He feels fruiting/flowers are needed to identify for certain. He does agree the plant has many characteristics of P. perfoliatus.*

Southern Naiad

Southern naiad (*Najas guadalupensis*) has been identified as a potential nuisance in Tomahawk Lake and the Thoroughfare. While it is a plant native to Wisconsin, it can have nuisance growth characteristics when it tops out on the surface. A map of Southern naiad growth is included as Figure 32.

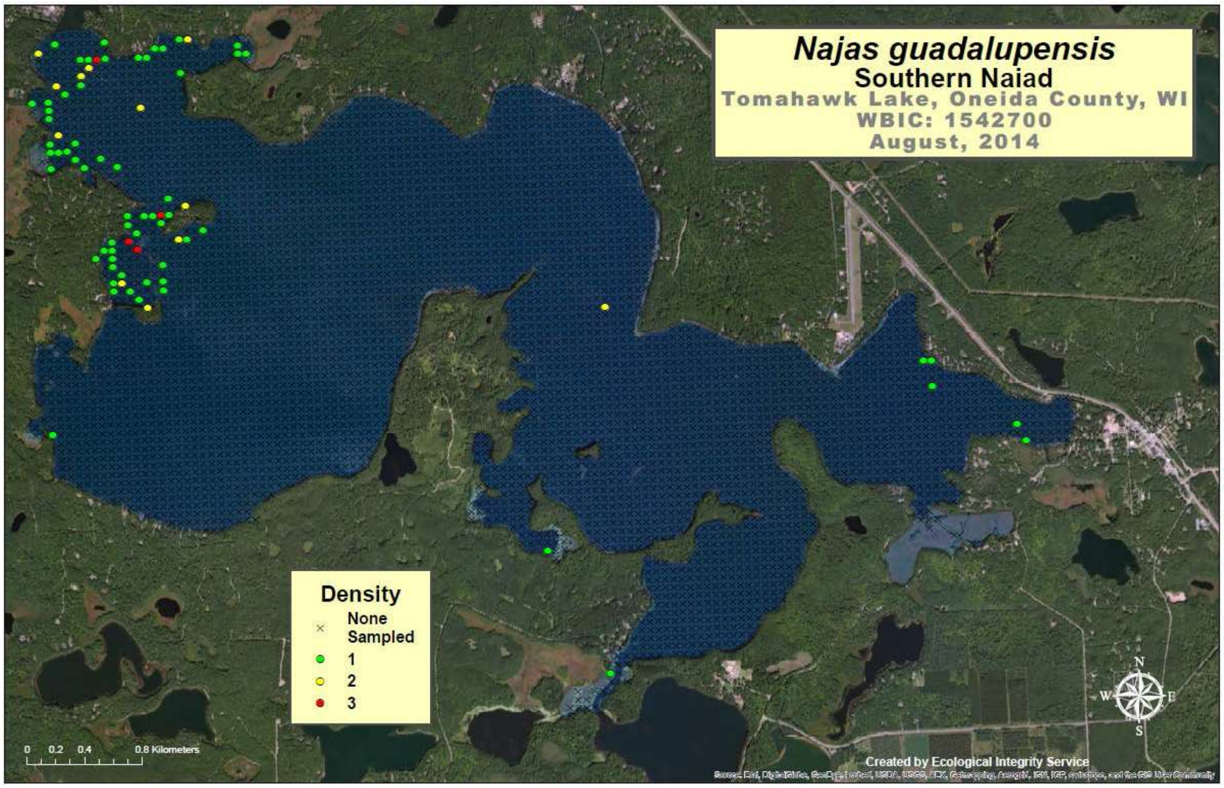

Figure 32. Southern Naiad Tomahawk Lake 2014

According to the AIS Control Grant Activity Reports in 2014, a Southern naiad monitoring protocol is in place for Thoroughfare Bay. Data is collected from 63 sites in the study area. The protocol includes recording water depths, water temperatures, plant development, and plant species present. Data was collected each 30-45 days for 6 months and will continue in 2015.

Floristic Quality Index

Evaluation of the plant community can indicate changes in habitat and water quality from human development using a tool known as the Floristic Quality Index (FQI). This index uses the number of species sampled on the rake (N) and a conservatism value (C) given to some species. The greater the conservatism value (ranges from 1-10), the less tolerant the plant is to changes in habitat disturbances. The habitat changes are compared to characteristics in the lake prior to human disturbances.

Dr. Stanley Nichols of UW-Extension surveyed numerous lakes in various eco-regions around Wisconsin. He then calculated the median number of species, median conservatism value, and the median FQI for each eco-region. (Nichols, 1999)

The Floristic Quality Index (FQI) for Tomahawk Lake is exceptionally high at 50.21. This compares to the median for other lakes evaluated within the ecoregion of 24.3.

Table 18.Tomahawk Lake and Eco-region FQI

Tomahawk Lake FQI	Tomahawk	Eco-region Median
N	54	13
mean C	6.83	6.7
FQI	50.21	24.3

Aquatic Plant Survey Results Little Tomahawk Lake

Little Tomahawk Lake had 536 sample points in the survey grid, with 131 within the defined littoral depth. Plants were sampled to a maximum depth of 22.8 feet. Of littoral zone points, 98 (74.81%) had vegetation sampled. Figure 33 shows the defined littoral zone and plant rake density at each sample point.

Table 19. Little Tomahawk Lake 2014 Macrophyte Survey Statistic Summary

Little Tomahawk Lake Survey Stats	
Number of sample sites in survey	536
Total number of sites with vegetation	98
Total number of sites shallower than maximum depth of plants	131
Frequency of occurrence at sites shallower than maximum depth of plants	74.81%
Simpson Diversity Index	0.93
Maximum depth of plants (ft)	22.80
Mean depth of plants (ft)	9.17
Average number of all species per site (shallower than max depth)	2.58
Average number of all species per site (veg. sites only)	3.45
Average number of native species per site (shallower than max depth)	2.55
Average number of native species per site (veg. sites only)	3.41
Species Richness	34
Species Richness (including visuals)	35

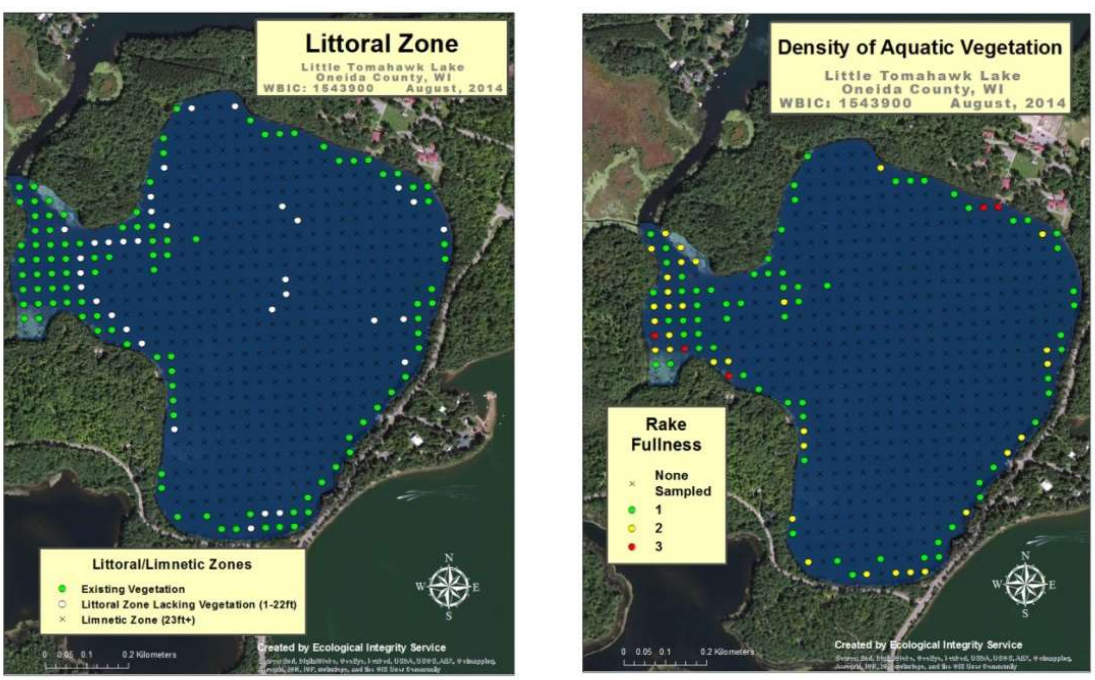

Figure 33. Little Tomahawk Lake Littoral Zone and Rake Fullness Density

Table 20. Little Tomahawk Lake Plant Species

Little Tomahawk Species	Vegetated Frequency	Littoral Frequency	Rel. Freq.	# Sampled	Mean Density	Viewed
Najas flexilis, Slender naiad	44.90	33.59	13.0	44	1.02	
Potamogeton gramineus, Variable pondweed	41.84	31.30	12.13	41	1.07	
Myriophyllum sibiricum, Northern water-milfoil	36.73	27.48	10.65	36	1.00	1
Potamogeton robbinsii, Fern pondweed	22.45	16.79	6.51	22	1.00	
Potamogeton pusillus, Small pondweed	20.41	15.27	5.92	20	1.00	
Elodea canadensis, Common waterweed	19.39	14.50	5.62	19	1.05	
Heteranthera dubia, Water star-grass	19.39	14.50	5.62	19	1.05	
Vallisneria americana, Wild celery	18.37	13.74	5.33	18	1.00	
Potamogeton zosteriformis, Flat-stem pondweed	16.33	12.21	4.73	16	1.00	
Bidens beckii, Water marigold	12.24	9.16	3.55	12	1.00	
Potamogeton richardsonii, Clasping-leaf pondweed	11.22	8.40	3.25	11	1.00	
Potamogeton strictifolius, Stiff pondweed	9.18	6.87	2.66	9	1.00	
Ceratophyllum demersum, Coontail	8.16	6.11	2.37	8	1.13	
Potamogeton amplifolius, Large-leaf pondweed	8.16	6.11	2.37	8	1.00	1
Potamogeton praelongus, White-stem pondweed	8.16	6.11	2.37	8	1.00	
Brasenia schreberi, Watershield	7.14	5.34	2.07	7	1.00	
Chara sp., Muskgrasses	4.08	3.05	1.18	4	1.00	
Myriophyllum spicatum, Eurasian watermilfoil	4.08	3.05	1.18	4	1.00	
Nitella sp., Nitella	3.06	2.29	0.89	3	1.00	
Pontederia cordata, Pickerelweed	3.06	2.29	0.89	3	1.00	1
Potamogeton friesii, Fries' pondweed	3.06	2.29	0.89	3	1.00	
Potamogeton natans, Floating-leaf pondweed	3.06	2.29	0.89	3	1.00	1
Sagittaria cristata, Crested arrowhead	3.06	2.29	0.89	3	1.00	
Najas guadalupensis, Southern naiad	2.04	1.53	0.59	2	1.50	
Nuphar variegata, Spatterdock	2.04	1.53	0.59	2	1.00	3
Potamogeton illinoensis, Illinois pondweed	2.04	1.53	0.59	2	1.00	1
Ranunculus aquatilis, White water crowfoot	2.04	1.53	0.59	2	1.00	
Sparganium augustifolium, Narrow-leaved bur-reed	2.04	1.53	0.59	2	1.00	
Utricularia vulgaris, Common bladderwort	2.04	1.53	0.59	2	1.00	
Isoetes echinospora, Spiney-spored quillwort	1.02	0.76	0.30	1	1.00	
Juncus pelocarpus f. submersus, Brown-fruited rush	1.02	0.76	0.30	1	1.00	
Myriophyllum alterniflorum, Alternate-flowered water-milfoil	1.02	0.76	0.30	1	1.00	
Stuckenia pectinata, Sago pondweed	1.02	0.76	0.30	1	1.00	
Utricularia purpurea, Large purple bladderwort	1.02	0.76	0.30	1	1.00	
Aquatic moss	2.04	1.53	n/a	2	1.50	
Filamentous algae	9.18	6.87	n/a	9	1.00	
Nymphaea odorata, White water lily	viewed	only				3

Table 21. Little Tomahawk Lake Shoreline Species Observed

Sagittaria rigida, Sessile fruited arrowhead
Elatine minima, Waterwort
Eleocharis acicularis, Needle spikerush
Typha latifolia, Broad-leaf cattail
Typha augustifolia, Narrow-leaf cattail
Schoenoplectus tabernaemontani, Softstem bulrush

The diversity of aquatic plants is high in Little Tomahawk Lake. There were 34 species of aquatic plants sampled and one additional species viewed near a sample point. Of these 35 species, 34 were native and one was the non-native Eurasian water milfoil. The western bay shows the highest diversity per sample point and the most plant growth, as shown in Figure 34.

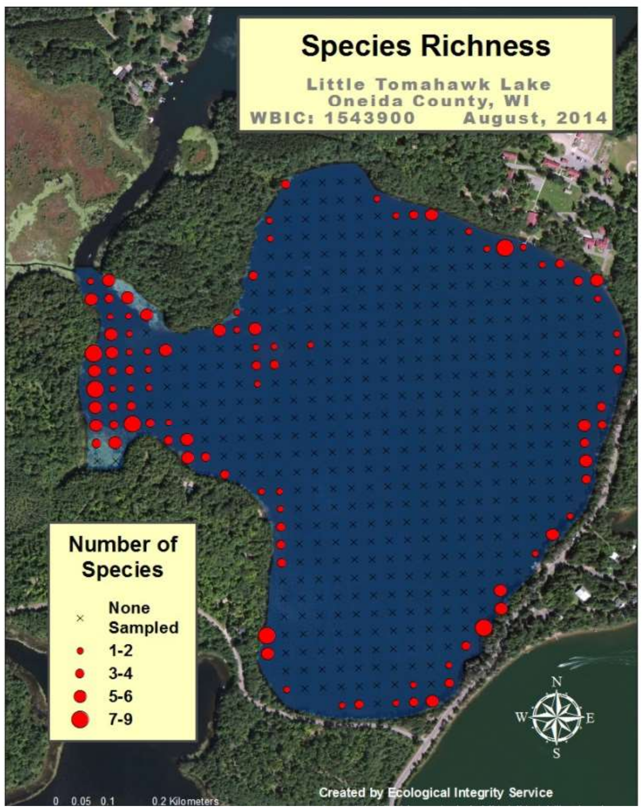

Figure 34. Little Tomahawk Lake Species Richness August 2014

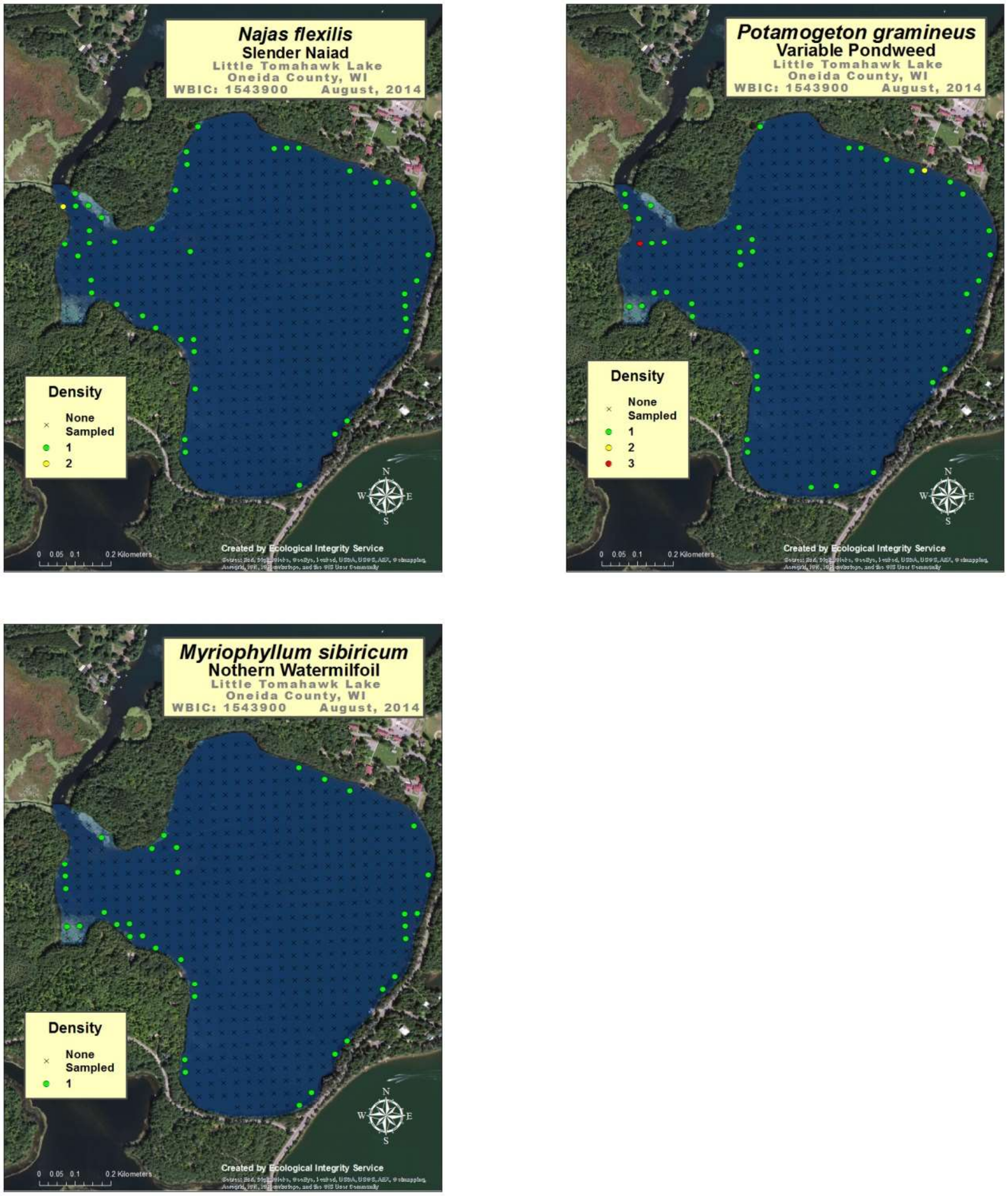

Figure 35. Most Common Sampled Plants Little Tomahawk Lake August 2014

The most common plants sampled in Little Tomahawk Lake were *Najas flexilis* (Slender naiad), *Potamogeton gramineus* (Variable pondweed), and *Myriophyllum sibiricum* (Northern watermilfoil) (Figure 35). Slender naiad is a common native plant in Wisconsin lakes. This plant is often associated with sandy and rocky substrate, which would account for its high frequency in Little Tomahawk Lake. Slender naiad grows annually from seed only, which could cause great variation in growth from year to year. Waterfowl rely on slender naiad, and it also provides good habitat for fish.

Variable pondweed is variable in appearance depending on where it grows. It can be very difficult to distinguish from Illinois pondweed (*Potamogeton illinoensis*) when it grows with larger leaves. Variable pondweed is common and widespread in Wisconsin. It tends to grow in firm sediments ranging from one meter to several meters deep. It dies in the fall and returns in the spring from rhizomes and winter buds. Waterfowl graze on the fruits and tubers. The denser growth of the smaller leaves can provide excellent habitat for invertebrates and forage areas for fish.

Northern watermilfoil is closely related to the invasive plant Eurasian watermilfoil (EWM), and these two plants thrive in similar habitat. It is important to maintain a dense population of northern watermilfoil because that density can limit EWM growth. Northern watermilfoil provides excellent habitat for invertebrates with its branched, fine leaflets. This leads to excellent foraging for various species of fish feeding on the invertebrates. Northern watermilfoil is common throughout Wisconsin. It prefers clear water and can become limited with reduced water clarity. It returns from winter dormancy from winter buds and root stalks, with limited seed reproduction.

The FQI for Little Tomahawk Lake was substantially higher than the eco-region median. This shows the plant community is healthy and robust, with many species, including some that are quite sensitive to habitat changes.

Table 22. Little Tomahawk FQI Data and Ecoregion Comparison

Little Tomahawk FQI	Little Tomahawk	Eco-region median
N	32	13
mean C	6.78	6.7
FQI	38.36	24.3

Aquatic Plant Survey Results Tomahawk Thoroughfare

There were 92 sample points in the Tomahawk Thoroughfare. This is less than in past surveys, as the management responsibility for Tomahawk Lake was determined to end at the bridge crossing over the Thoroughfare since the last survey. Of the 92 sample points, there were plants at 89 of these locations, resulting in plant coverage of 96.7%. Plants grew to the maximum sampling depth of 12.5 feet.

Table 23. Tomahawk Thoroughfare Macrophyte Survey Stats Summary

Tomahawk Thoroughfare Survey Stats	
Total number of sites sampled	92
Total number of sites with vegetation	89
Total number of sites shallower than maximum depth of plants	92
Frequency of occurrence at sites shallower than maximum depth of plants	96.7%
Simpson Diversity Index	0.88
Maximum depth of plants (ft)	12.50
Mean depth of plants (ft)	5.84
Average number of all species per site (shallower than max depth)	3.35
Average number of all species per site (veg. sites only)	3.54
Average number of native species per site (shallower than max depth)	3.20
Average number of native species per site (veg. sites only)	3.38
Species Richness	30
Species Richness (including visuals)	34

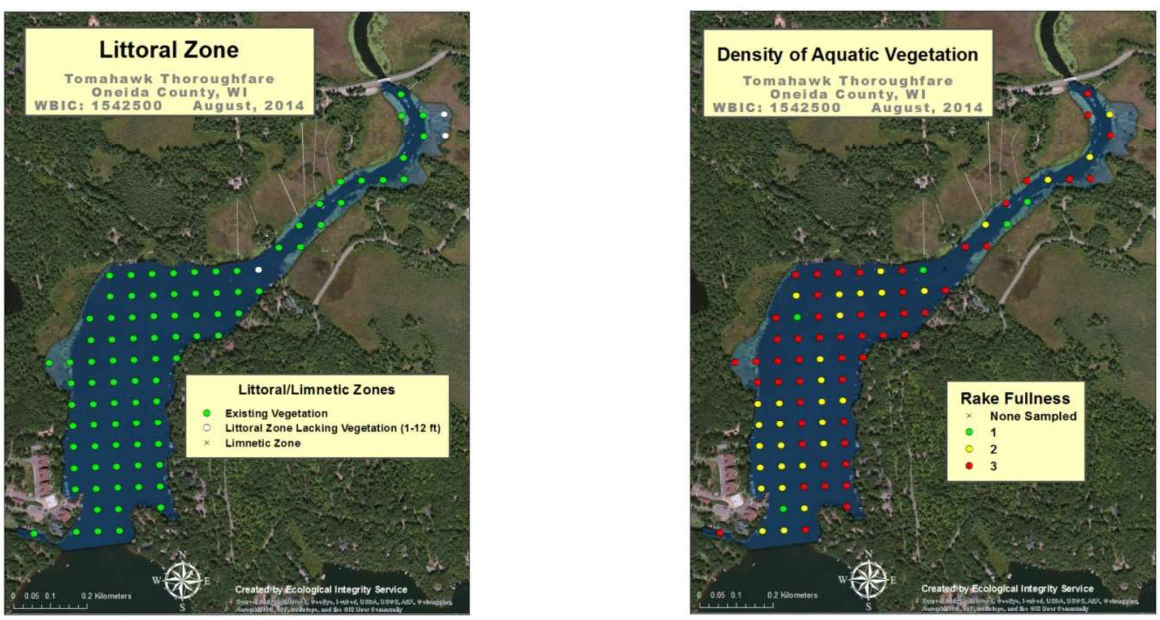

Figure 36. Thoroughfare Littoral Zone and Rake Fullness Density August 2014

Table 24. Tomahawk Thoroughfare Plant Species

Tomahawk Thoroughfare Species	Vegetated Freq.	Littoral Freq.	Rel. Freq.	# Sampled	Mean Density	Viewed
Najas guadalupensis, Southern naiad	80.46	76.09	22.73	70	1.93	
Potamogeton robbinsii, Fern pondweed	57.47	54.35	16.23	50	1.16	
Ceratophyllum demersum, Coontail	43.68	41.30	12.34	38	1.13	
Elodea canadensis, Common waterweed	42.53	40.22	12.01	37	1.14	
Potamogeton zosteriformis, Flat-stem pondweed	27.59	26.09	7.79	24	1.00	
Myriophyllum spicatum, Eurasian water milfoil	13.79	13.04	3.90	12	1.17	1
Potamogeton amplifolius, Large-leaf pondweed	10.34	9.78	2.92	9	1.00	
Lemna trisulca, Forked duckweed	9.20	8.70	2.60	8	1.00	
Potamogeton praelongus, White-stem pondweed	9.20	8.70	2.60	8	1.00	
Brasenia schreberi, Watershield	8.05	7.61	2.27	7	1.00	
Nymphaea odorata, White water lily	8.05	7.61	2.27	7	1.00	
Nuphar variegata, Spatterdock	4.60	4.35	1.30	4	1.00	2
Potamogeton richardsonii, Clasping-leaf pondweed	4.60	4.35	1.30	4	1.00	
Elodea nuttallii, Slender waterweed	3.45	3.26	0.97	3	1.00	
Pontederia cordata, Pickerelweed	3.45	3.26	0.97	3	1.00	
Potamogeton gramineus, Variable pondweed	3.45	3.26	0.97	3	1.00	
Potamogeton pusillus, Small pondweed	3.45	3.26	0.97	3	1.00	
Utricularia vulgaris, Common bladderwort	3.45	3.26	0.97	3	1.00	
Potamogeton crispus, Curly leaf pondweed	2.30	2.17	0.65	2	1.00	
Potamogeton epihydrus, Ribbon-leaf pondweed	2.30	2.17	0.65	2	1.50	
Ranunculus aquatilis, White water crowfoot	2.30	2.17	0.65	2	1.00	
Bidens beckii, Water marigold	1.15	1.09	0.32	1	1.00	
Decodon verticillatus, Swamp loosestrife	1.15	1.09	0.32	1	1.00	
Heteranthera dubia, Water star-grass	1.15	1.09	0.32	1	1.00	
Lemna minor, Small duckweed	1.15	1.09	0.32	1	1.00	
Myriophyllum sibiricum, Northern water-milfoil	1.15	1.09	0.32	1	1.00	
Nitella sp., Nitella	1.15	1.09	0.32	1	1.00	
Sagittaria cristata, Crested arrowhead	1.15	1.09	0.32	1	1.00	
Spirodela polyrhiza, Large duckweed	1.15	1.09	0.32	1	1.00	
Vallisneria americana, Wild celery	1.15	1.09	0.32	1	1.00	
Aquatic moss	3.45	3.26	n/a	3	1.67	
Myriophyllum verticillatum, Whorled water-milfoil	Viewed	only				1
Potamogeton illinoensis, Illinois pondweed	Viewed	only				1
Sparganium eurycarpum, Common bur-reed	Viewed	only				1
Utricularia minor, Small bladderwort	Viewed	only				1

Table 25. Tomahawk Thoroughfare Shoreline Survey Species

Iris pseudacorus , Yellow flag iris
Lythrum salicaria, Purple loosestrife

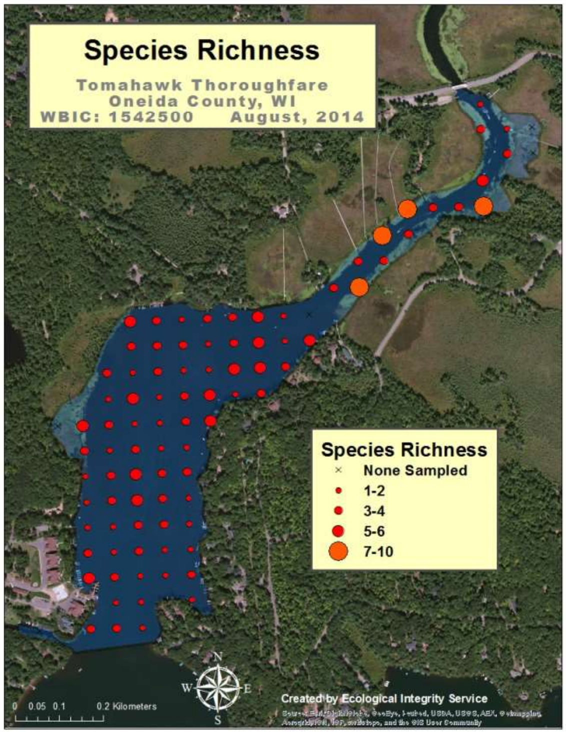

Figure 37. Tomahawk Thorough Species Richness August 2014

The diversity of aquatic plants in the Tomahawk Thoroughfare is quite high. There were 30 species of plants sampled and four more species viewed out of only 92 sample points. This Simpson's diversity index is fairly high at 0.88. The highest diversity of plants per sample point is in the narrow portion of the thoroughfare as approaching the bridge. The lower diversity in the wider portion is likely due to the extensive growth of southern naiad, which blankets the lake bottom.

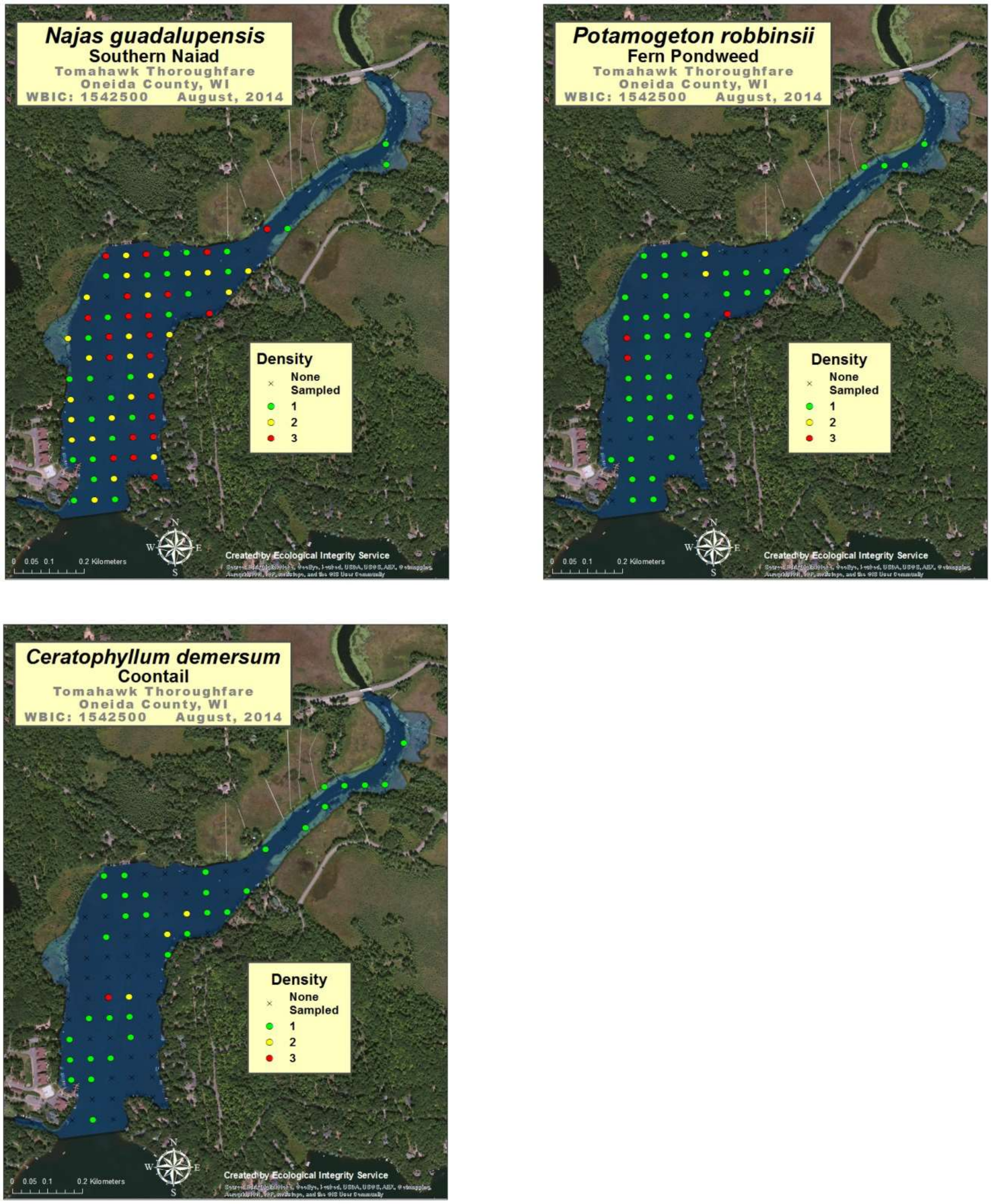

Figure 38. Tomahawk Thoroughfare Most Common Sampled Plants August 2014

The most common plants sampled in the Tomahawk Thoroughfare were *Najas gaudalupensis* (southern naiad), *Potamogeton robbinsii* (fern pondweed), and *Ceratophyllum demersum* (coontail).

Southern naiad was not identified in the Thoroughfare in 2007. It is possible that southern naiad was present but misidentified in 2007. For example, *Najas flexilis* (slender naiad) was identified in the Thoroughfare in 2007 but not in 2014.

Southern naiad has become quite dense, especially in the wider portion of the Thoroughfare where it enters Tomahawk Lake. The plant blankets the lake bottom and may be affecting the diversity of plants by overcrowding other species. Southern naiad is widely distributed in Wisconsin, but tends to be less common in northern lakes. There were no observed nuisance issues contributed by southern naiad in August 2014. However, it did top out on the surface in 2013.

Table 26. Tomahawk Thoroughfare FQI Data

Tomahawk Thoroughfare FQI	Thorough-fare	Eco-region median
N	26	23.5
mean C	6.38	6.2
FQI	32.56	28.3

The FQI for the Tomahawk Thoroughfare was 32.56 in 2014. This is higher than the eco-region median for other lakes sampled. This shows the plant community is healthy and robust, with little effect from human disturbance.

Aquatic Plant Survey Results Mud Lake

There were 89 sample points in the Mud Lake survey with 47 points less than the maximum depth of plants (20 feet). Forty of 47 sample points had plant growth – an 85.11% littoral zone plant coverage. The eastern and western near-shore areas had high density plant growth.

Table 27. Mud Lake Macrophyte Survey Stats Summary

Mud Lake Survey Statistics	
Number of sample sites in survey	89
Total number of sites with vegetation	40
Total number of sites shallower than maximum depth of plants	47
Frequency of occurrence at sites shallower than maximum depth of plants	85.11%
Simpson Diversity Index	0.93
Maximum depth of plants (ft)	20.0
Mean depth of plants (ft)	5.35
Average number of all species per site (shallower than max depth)	2.81
Average number of all species per site (veg. sites only)	3.3
Average number of native species per site (shallower than max depth)	2.81
Average number of native species per site (veg. sites only)	3.3
Species Richness	26
Species Richness (including visuals)	28

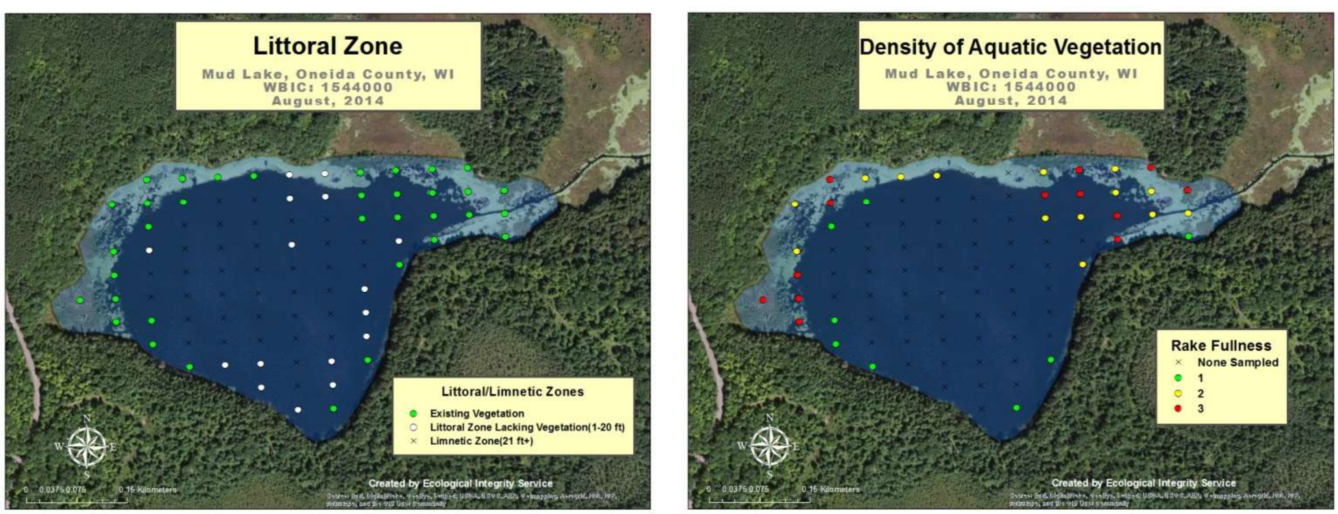

Figure 39. Mud Lake Littoral Zone and Rake Fullness Density August 2014

Table 28. Mud Lake Plant Species

Mud Lake Species	Vegetated Freq	Littoral Freq	Rel. Freq	# Sampled	Mean Density
Potamogeton robbinsii, Fern pondweed	47.5	40.43	14.39	19	1.58
Brasenia schreberi, Watershield	30	25.53	9.09	12	1.17
Utricularia purpurea, Large purple bladderwort	30	25.53	9.09	12	1.08
Nymphaea odorata, White water lily	27.5	23.40	8.33	11	1.00
Nuphar variegata, Spatterdock	25	21.28	7.58	10	1.00
Ceratophyllum demersum, Coontail	22.5	19.15	6.82	9	1.22
Elodea canadensis, Common waterweed	22.5	19.15	6.82	9	1.00
Potamogeton friesii, Fries' pondweed	15	12.77	4.55	6	1.00
Potamogeton zosteriformis, Flat-stem pondweed	15	12.77	4.55	6	1.00
Myriophyllum verticillatum, Whorled water-milfoil	12.5	10.64	3.79	5	1.20
Najas guadalupensis, Southern naiad	12.5	10.64	3.79	5	2.00
Utricularia vulgaris, Common bladderwort	10	8.51	3.03	4	1.00
Chara sp., Muskgrasses	7.5	6.38	2.27	3	1.00
Sparganium natans, Small bur-reed	7.5	6.38	2.27	3	1.00
Utricularia intermedia, Flat-leaf bladderwort	7.5	6.38	2.27	3	1.00
Pontederia cordata, Pickerelweed	5	4.26	1.52	2	1.00
Potamogeton natans, Floating-leaf pondweed	5	4.26	1.52	2	1.00
Potamogeton pusillus, Small pondweed	5	4.26	1.52	2	1.00
Schoenoplectus subterminalis, Water bulrush	5	4.26	1.52	2	1.00
Eleocharis palustris, Creeping spikerush	2.5	2.13	0.76	1	1.00
Myriophyllum sibiricum, Northern water-milfoil	2.5	2.13	0.76	1	1.00
Najas flexilis, Slender naiad	2.5	2.13	0.76	1	1.00
Potamogeton amplifolius, Large-leaf pondweed	2.5	2.13	0.76	1	1.00
Typha latifolia, Broad-leaved cattail	2.5	2.13	0.76	1	1.00
Utricularia minor, Small bladderwort	2.5	2.13	0.76	1	1.00
Vallisneria americana, Wild celery	2.5	2.13	0.76	1	1.00
Decodon verticillatus, Swamp loosestrife	Viewed	only			1.00
Potamogeton gramineus, Variable pondweed	Viewed	only			1.00

Table 29. Mud Lake Shoreline Survey Species

Carex hystericina, Bottle sedge
Schoenoplectus tabernaemontani, Softstem bulrush
Dulichium arundinaceum, Three-way sedge
Sparganium augustifolium, Narrow bur-reed
Sagittaria latifolia, Common arrowhead
Juncus effusus, Soft rush
Typha augustifolia, Narrow-leaf cattail

The diversity of aquatic plants in Mud Lake is high, especially considering its small size. There were 26 species of plants sampled and two more species viewed. The highest diversity occurs in the eastern portion of the lake near the channel leading to Tomahawk Lake.

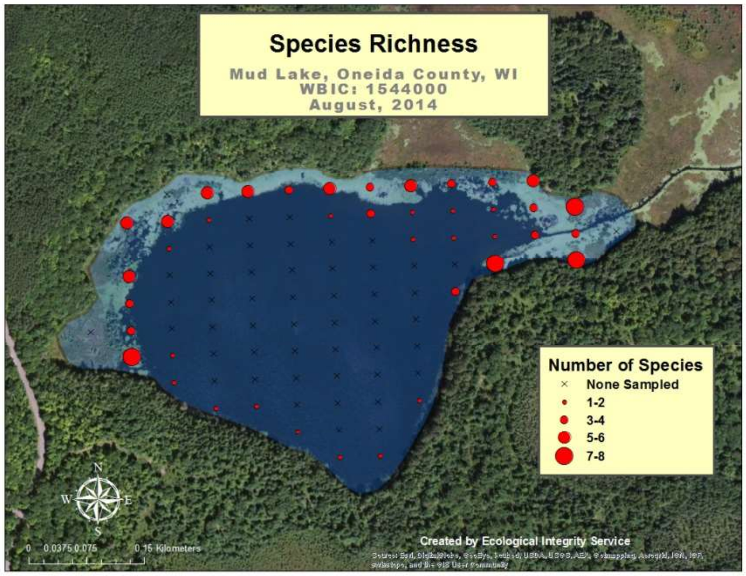

Figure 40. Mud Lake Species Richness August 2014

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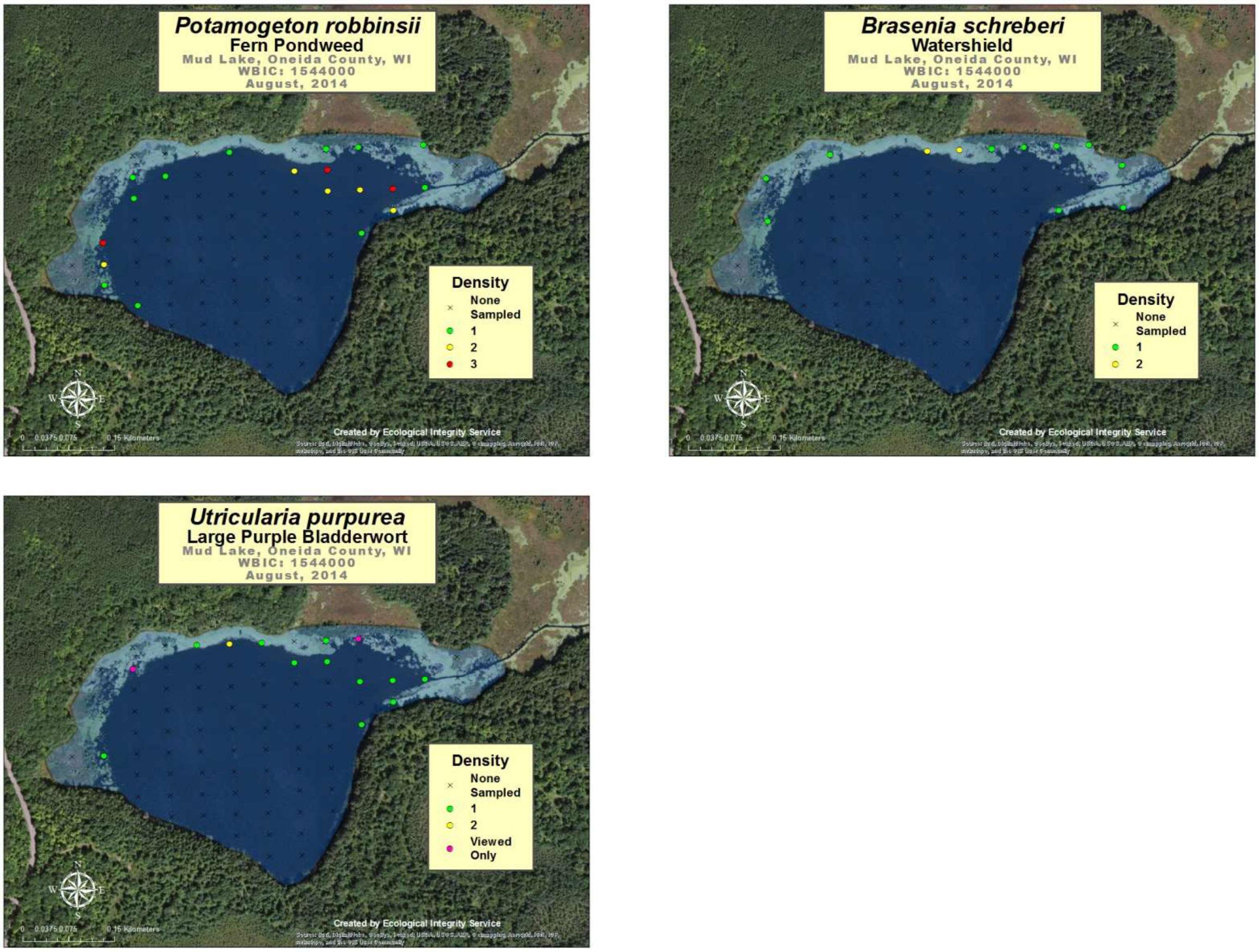

Figure 41. Mud Lake Most Common Sampled Plants August 2014

The most common plants sampled in Mud Lake were *Potamogeton robbinsii* (fern pondweed), *Brasenia schreberi* (watershield) and *Utricularia purpurea* (large purple bladderwort).

Fern pondweed is a very common plant in Wisconsin. This plant can thrive in deeper water than many other plants, and can overwinter, providing important oxygen for the lake. The plant sprouts in spring from rhizomes and winter buds. Fern pondweed provides excellent habitat for invertebrates and fish.

Watershield is a common aquatic plant in northern Wisconsin. It is often associated with high organic content sediment in water depth up to two meters. The shoots develop from rhizomes or seeds in the spring, with round floating leaves at the surface. Waterfowl feed on the seeds, leaves, stems, and buds of watershield. The floating leaves provide shade and cover for invertebrates and fish.

Large purple bladderwort was found in scattered locations. It is often associated with low pH (acidic) lakes and can grow in shallow depths to depths of several meters. Plants grow in the spring from stems and winter buds. Large purple bladderwort can grow in large masses that provide great habitat for invertebrates and foraging for fish.

The FQI for Mud Lake was higher than the eco-region median in 2014 with a value of 34.12. This shows the plant community is healthy and does not appear to be affected by human activity.

Table 30. Mud Lake FQI Data with Ecoregion Comparison

Mud Lake FQI	Mud	Eco-region median
N	26	23.5
mean C	6.69	6.2
FQI	34.12	28.3

Aquatic Plant Survey Results Paddle Pond

There were 27 sample points in Paddle Pond. There were only two locations where plants were sampled, which limited the depth of plants and therefore the sites shallower than plants. This resulted in 40% of the defined littoral zone with plants. Plant growth and plant diversity in Paddle Pond is very limited. The only place plants were prevalent was in the channel leading into Paddle Pond. This lake had very dark, tannic stained water, which reduces light penetration and likely limits plant growth.

Table 31. Paddle Pond Plant Species

Species	Vegetated Frequency	Littoral Freq.	Rel. Freq.	# Sampled	Mean Den.	Viewed
Brasenia schreberi, Watershield	100	40	28.6	2	1	
Ceratophyllum demersum, Coontail	50	20	14.3	1	2	1
Lemna minor, Small duckweed	50	20	14.3	1	1	
Nuphar variegata, Spatterdock	50	20	14.3	1	1	
Nymphaea odorata, White water lily	50	20	14.3	1	1	2
Typha latifolia, Broad-leaved cattail	50	20	14.3	1	1	
Dulichium arundinaceum, Three-way sedge	Viewed	only				1
Eleocharis palustris, Creeping spikerush	Viewed	only				2
Potamogeton natans, Floating-leaf pondweed	Viewed	only				1
Sagittaria latifolia, Common arrowhead	Viewed	only				1

Table 32. Paddle Pond Shoreline Survey Species List

Comarum palustre, Marsh cinquefoil
Rumex orbiculatus, Water dock

The Simpson's diversity index was a relatively low value of 0.82. The lack of species richness is reflected in a FQI much less than the eco-region median.

Table 33. Paddle Pond FQI Data

Paddle Pond FQI	Paddle Pond	Eco-region Median
N	6	13
mean C	4.33	6.7
FQI	10.61	24.3

Aquatic Plant Survey Results Inkwell Lake

Inkwell Lake is a small lake adjacent to Tomahawk Lake with access only by foot. There was only one site with vegetation and very limited plant growth observed. The maximum depth of plants was 5.7 feet, with only 33.33% of the defined littoral zone with plant growth. Plant coverage in the entire lake is minimal (2.33%).

Table 34. Inkwell Lake Macrophyte Survey Stats Summary

Stats	
Number of sample sites in survey	43
Total number of sites with vegetation	1
Total number of sites shallower than maximum depth of plants	3
Frequency of occurrence at sites shallower than maximum depth of plants	33.33%
Simpson Diversity Index	0.00
Maximum depth of plants (ft)	5.70
Mean depth of plants (ft)	5.70
Average number of all species per site (shallower than max depth)	0.33
Average number of all species per site (veg. sites only)	1.00
Average number of native species per site (shallower than max depth)	0.33
Average number of native species per site (veg. sites only)	1.00
Species Richness	1
Species Richness (including visuals)	2

Table 35. Inkwell Lake Plant Species

Species	Vegetated Frequency	Littoral Freq.	Rel Freq.	# Sampled	Mean Den.	Viewed
Isoetes echinospora, Spiny spored-quillwort	50	33.33	100	1	1	
Sparganium angustifolium, Narrow-leaved bur-reed						1

Table 36. Inkwell Lake Shoreline Survey Species

Nymphaea odorata, White water lily
Nuphar variegata, Spatterdock
Sparganium eurycarpum, Common bur-reed
Euriocaulon aquaticum, Pipewort

The FQI was substantially below the eco-region median. It is evident the plant habitat in Inkwell Lake is marginal. Plant surveyors did not speculate reasons for low plant presence and diversity.

Table 37. Inkwell Lake FQI Data

Inkwell Lake FQI	Inkwell	Eco-region Median
N	1	13
mean C	8	6.7
FQI	8	24.3

Invasive Species of the Tomahawk Lake System

Invasive plant descriptions and control methods are included in Appendix D.

Curly Leaf Pondweed

Curly leaf pondweed (CLP) was found only in the Thoroughfare, where it was not sampled in 2007. The plant was sampled in only two locations and observed in a couple of other locations between sample points. Curly leaf pondweed is present in Minocqua Lake, and this is likely how it spread into the Thoroughfare.

The Wisconsin Department of Natural Resources web site lists curly leaf pondweed present in Tomahawk Lake. However, no details are provided as to when or where the plant was discovered. TLA Executive Director, Ned Greedy reports finding and removing a few plants in Thoroughfare Bay in 2014. He also stated that this species has not acted invasively in the Tomahawk Lake System.

Recommendations
Continue monitoring for this plant throughout the Tomahawk Lake System.

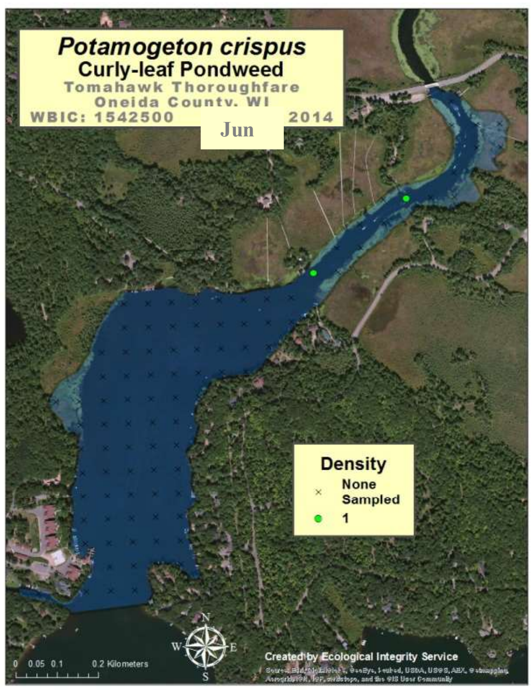

Figure 42. Curly leaf pondweed on Tomahawk Thoroughfare June 2014

Purple Loosestrife

Lythrum salicaria (purple loosestrife) was sampled in three locations and viewed in two other locations on Tomahawk Lake (Figure 43). There were also several wetland areas that had purple loosestrife growing in varying degrees of density.

Purple loosestrife was not sampled, but was observed in much of the wetland areas adjacent to the shoreline of the Thoroughfare in 2014. The density of purple loosestrife is quite thick in many locations along the shoreline and deeper into the wetland areas.

Noah Lottig mapped purple loosestrife for the Tomahawk Lake Association in 2012, and that map is included as Figure 44. The 2012 map shows additional locations where purple loosestrife was found.

Recommendations
Areas of purple loosestrife along Tomahawk Lake and the Tomahawk Thoroughfare should be monitored and mapped. Continued control efforts are recommended to prevent the spread of this invasive plant.

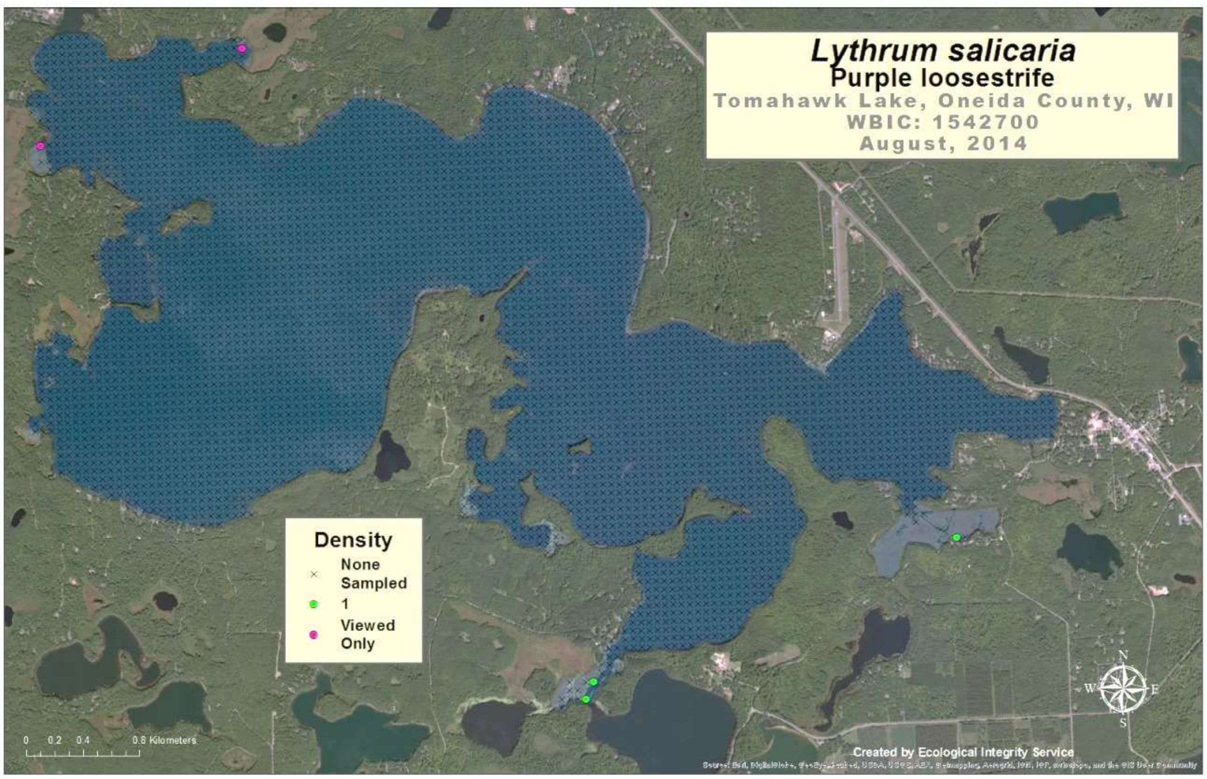

Figure 43. Tomahawk Lake Purple Loosestrife August 2014

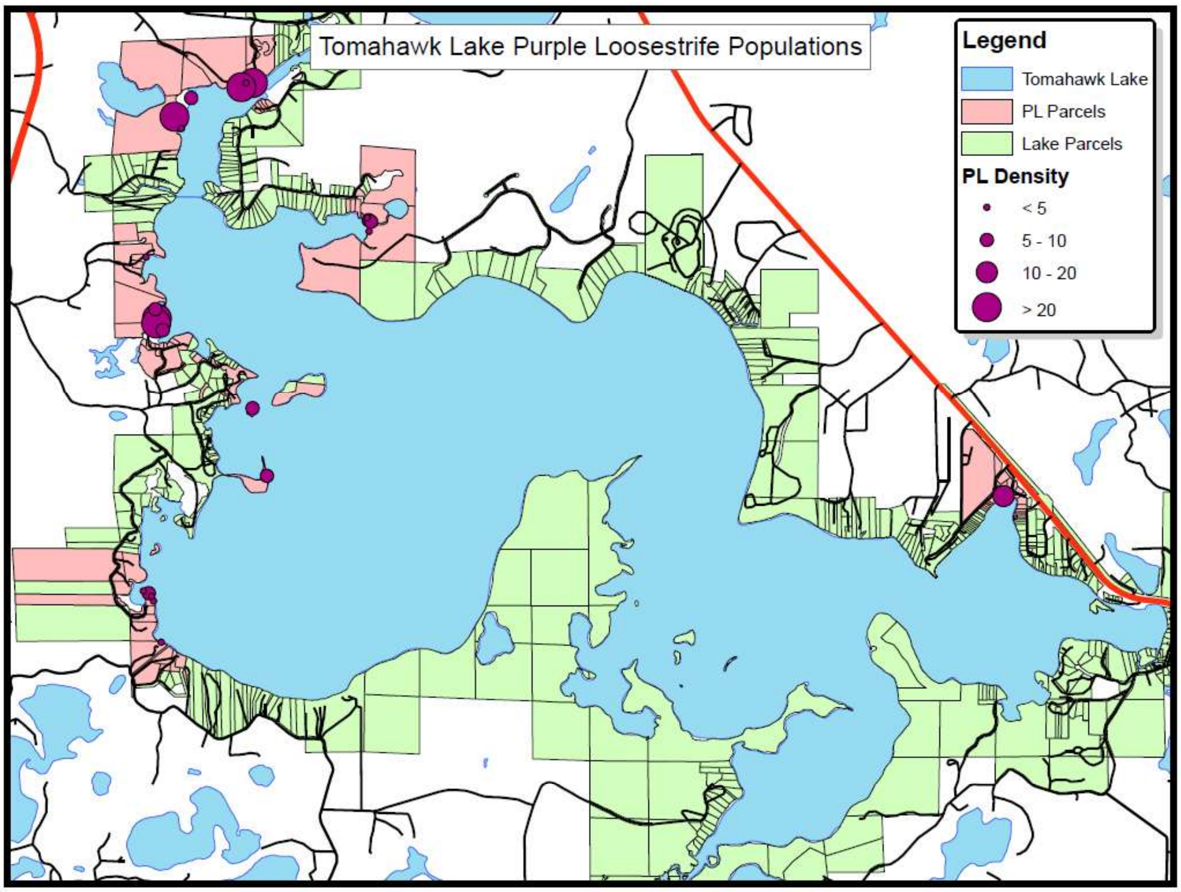

Figure 44. Tomahawk Lake Purple Loosestrife 2012

Yellow Flag Iris

Iris pseudacorus (yellow flag iris) was observed along the shoreline of Tomahawk Lake and the Tomahawk Thoroughfare in many locations during the early June AIS survey. Since this plant was only present on or near shore, none was sampled in the point intercept survey. However, since the plant was fairly widespread, the locations were recorded and mapped. The most extensive yellow flag iris was located in the Thoroughfare.

Recommendations
Consider a management plan for yellow flag iris control. An initial management plan could simply be to provide information to landowners to discourage the growth and spread of this invasive plant.

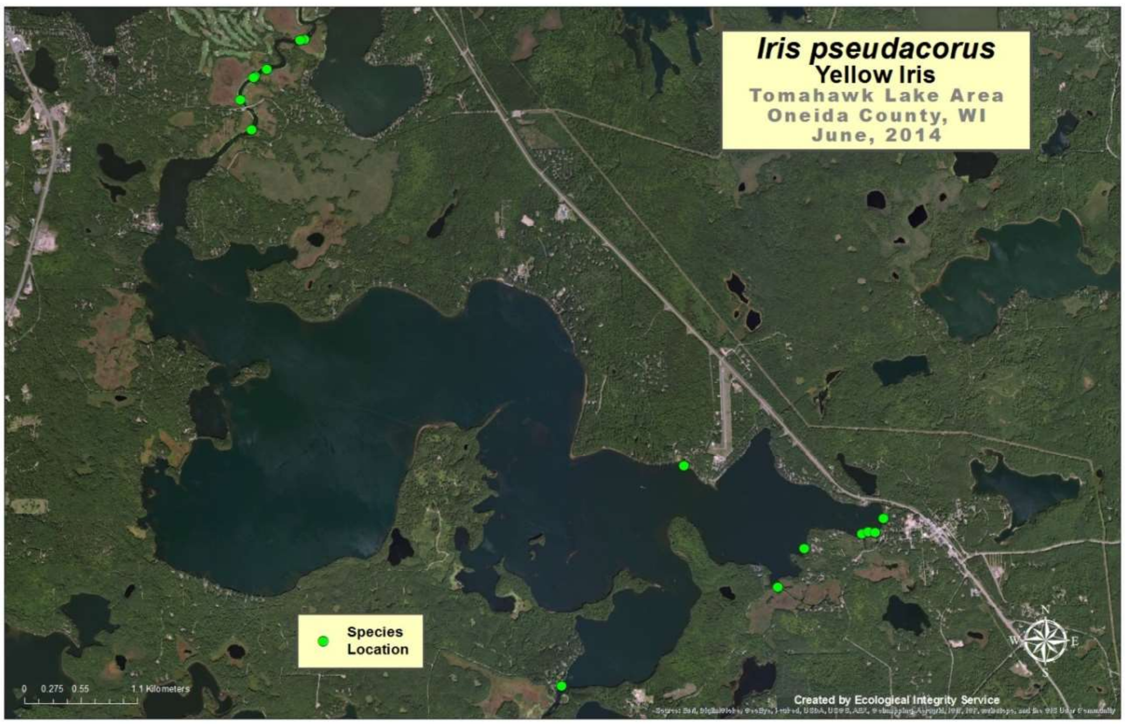

Figure 45. Yellow Flag Iris, Tomahawk Lake and Tomahawk Thoroughfare August 2014

Narrow-Leafed Cattail

Typha augustifolia (Narrow-leaved cattail) is considered a restricted, potentially invasive species by the state of Wisconsin. Narrow-leaved cattail was sampled in two locations in Tomahawk Lake. The shoreline of the western-most bay of Little Tomahawk Lake had extensive emergent plants.

This plant has a tolerance for deeper water and can compete with the native broad-leaved cattail. The degree at which narrow-leaved cattail dominates the native cattail is not very well established. It is common for narrow leaf cattail to hybridize with the native broad-leaved cattail, and the hybrid is considered to demonstrate more aggressive invasive characteristics.

Recommendations
Monitor cattail beds to evaluate if they become more dominated by narrow-leaf cattail.

Figure 46. Narrow-leaved Cattail Tomahawk Lake 2014

Eurasian Water Milfoil

Myriophyllum spicatum (Eurasian water milfoil or EWM), has been managed in the Tomahawk Lake System for several years. In Tomahawk Lake, plant surveyors found EWM at 33 sample locations and viewed it at four (Figure 47) in 2014. EWM was observed in other locations, but was not mapped. Herbicide control and some hydraulic conveyor assisted hand pulling preceded the August 2014 plant survey.

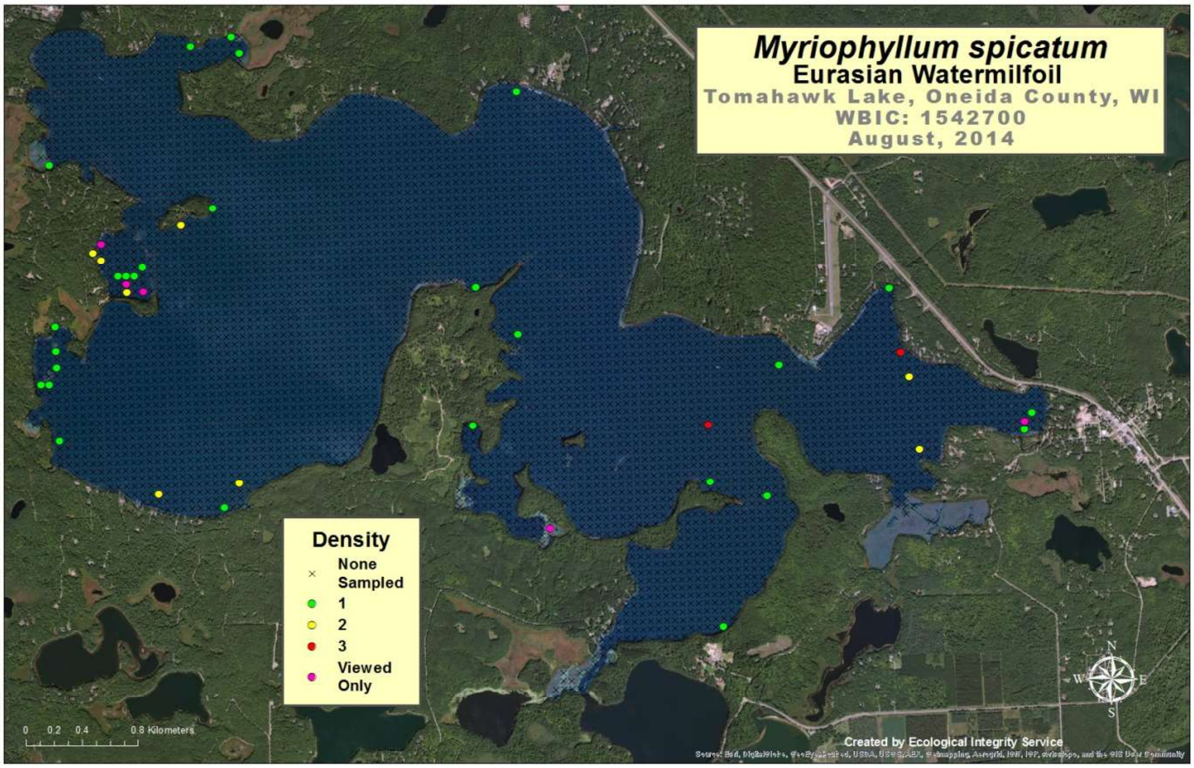

Figure 47. Eurasian Watermilfoil Distribution Tomahawk Lake August 2014

EWM was the only invasive species found in Little Tomahawk Lake. It was sampled at four locations, but other areas between sample points had some small, but relatively dense beds (Figure 47).

EWM has been in the thoroughfare for several years and is being actively managed. EWM was sampled in 12 locations with one dense area surveyed.

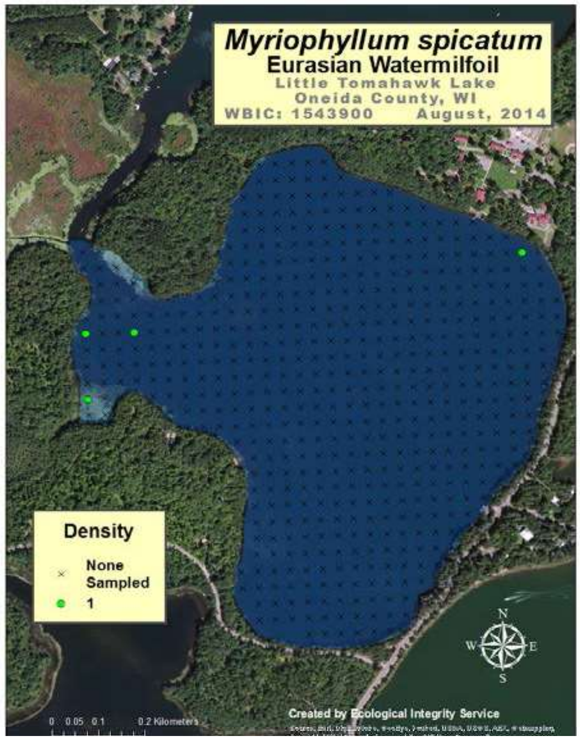

Figure 48. Eurasian Watermilfoil Distribution Little Tomahawk Lake August 2014

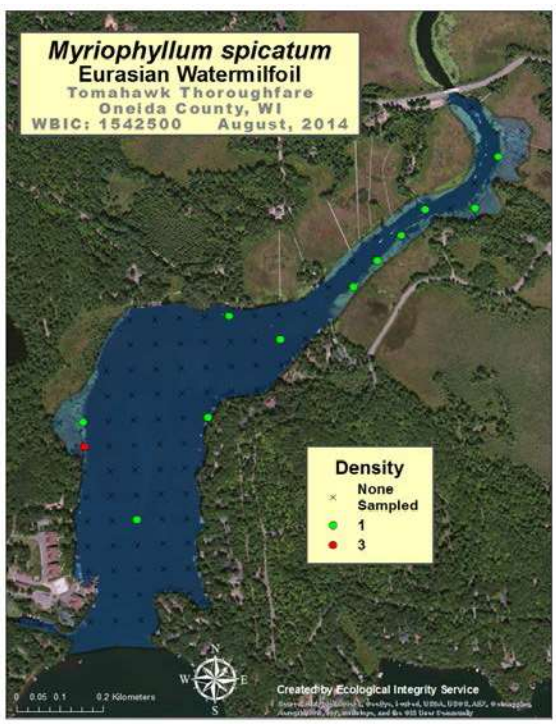

Figure 49. Eurasian Watermilfoil Distribution Tomahawk Thoroughfare August 2014

Plant Survey Comparison 2014 to 2007

A detailed comparison of plant survey results for each lake is found in the plant survey report. The results are summarized for each lake below.

Tomahawk Lake Comparison

Table 38. Tomahawk Lake Statistics Summary Comparison 2007 to 2014

Statistic	2007	2014
% of littoral zone with plants	57.33	62.07
Species richness	38	59
Simpson's diversity index	0.93	0.94
Maximum depth with plants	26.0	26.2
FQI	41.16	50.21

Fourteen aquatic plant species had a significant frequency increase from 2007 to 2014. Northern water milfoil is one of the species that increased. An increase in northern milfoil during Eurasian water milfoil management is a desirable outcome. Native milfoils are especially worth noting, as they can potentially help keep the invasive milfoil contained and are sensitive to the same reduction methods.

Increases demonstrated in the pondweeds could be because of misidentification in the 2007 plant survey.

Southern naiad demonstrated significant increases. This plant was not sampled in 2007, and has become quite dense near the Tomahawk Thoroughfare. Southern naiad is also dense in neighboring Minocqua Lake. Southern naiad is a native plant.

Plants that decreased from 2007 to 2014 included *Elodea Canadensis* (common waterweed), *Potamogeton zosteriformis (*flat-stem pondweed), *Potamogeton amplifolius* (large-leaf pondweed,) and *Vallisneria Americana* (wild celery). All of these species are very common native plants found in many Wisconsin lakes. The cause of these decreases is unknown. Since they are quite widespread, it is unlikely due to sampling variation. It could be due to seasonal variation and misidentification in 2007.

Little Tomahawk Lake Comparison

Table 39. Little Tomahawk Lake Survey Stats Summary Comparison 2007 and 2014

Statistic	2007	2014
% of Littoral zone with plants	92.47	74.81
Species Richness	28	34
Simpson's diversity index	0.93	0.93
Maximum depth with plants	15.0	22.8
FQI	32.14	38.31

The species richness and the FQI in Little Tomahawk Lake increased from 2007 to 2014. A significant increase occurred in three native species and in one invasive species (Eurasian water milfoil). EWM was not sampled in Little Tomahawk Lake in 2007.

There was only one species with a significant decrease, *Potamogeton foliosus (*leafy pondweed). There was an increase in two other small pondweeds, so this may be due to field misidentification in 2007. All small pondweeds were identified using magnification in the field in 2014.

The reduction in the percentage of the littoral zone with plants is likely due to the increase in maximum depth of plants which went from 15 to 22.8 feet. With this increase in depth, more points were added in deeper water where fewer plants grow.

Tomahawk Thoroughfare Comparison

Table 40. Tomahawk Thoroughfare stats Summary Comparison 2007 to 2014

Statistic	2007	2014*
% of Littoral zone with plants	99.2	96.7
Species Richness	26	30
Simpson's diversity index	0.94	0.88
Maximum depth with plants	13.0	12.0
FQI	32.46	32.56
****Fewer points were sampled in 2014 as management for Tomahawk Lake only goes to the first bridge.***		

The Tomahawk Lake Association and Minocqua Lake/Kawaguesaga Lake Protection Association agreed to divide the Thoroughfare management responsibilities at the bridge. This resulted in fewer sample points for the Thoroughfare in 2014 compared to 2007. As a result, the frequency reductions could be partly due to reduced sampling. The most common plant sampled in 2014 was southern naiad. Southern naiad was very dense, and this could be lowering the frequency/density of other species by crowding them out.

There was an increase in Eurasian water milfoil from 2007 to 2014. EWM was sampled at two points in 2007 while it was sampled in 12 points in 2014. *Potamogeton crispus* (curly leaf pondweed) is another invasive species that was not sampled in 2007 and was sampled (two locations) in 2014. Southern naiad was the most common plant in 2014 but not found in the

Thoroughfare in 2007. It is possible that the southern naiad was present but misidentified in 2007. For example, *Najas flexilis* was identified in the Thoroughfare in 2007 but not in 2014.

Mud Lake Comparison

Table 41. Mud Lake Stat Summary Comparison 2007 to 2014

Statistic	2007	2014
% of Littoral zone with plants	93.88	85.11
Species richness	15	26
Simpson's diversity index	0.87	0.93
Maximum depth with plants	17.0	20.0
FQI	23.25	34.12

Plant diversity increased in Mud Lake from 2007 to 2014. The species richness went from 15 to 26. One of the more significant increases was the presence of *Utricularia pupurea* (large purple bladderwort). This was not sampled in 2007, but was sampled in 12 locations in 2014.

A major reduction occurred with *Elodea Canadensi (*common waterweed). It went from 35 sampled in 2007 to only 9 sampled in 2014. The cause of this reduction is unknown but is quite significant. There is no development on Mud Lake and there have been no management practices occurring. It is therefore likely seasonal and sampling variation.

Paddle Pond and Inkwell Lake Comparison

Table 42. Paddle Pond Statistics Summary Comparison 2007 to 2014

Statistic	2007	2014
% of Littoral zone with plants	40.0	40.0
Species richness	2	6
Simpson's diversity index	0.47	0.82
Maximum depth with plants	12.0	9.2
FQI	3.0	10.61

Table 43. Inkwell Lake Statistics Summary Comparison 2007 to 2014

Statistic	2007	2014
% of Littoral zone with plants	0	33.33
Species richness	0	1
Simpson's diversity index	0.00	0.00
Maximum depth with plants	n/a	5.7
FQI	11.5 (0)	8.0

Paddle Pond and Inkwell Lake both had very little plant growth in 2007 and 2014. Paddle Pond is a bog lake that has very dark, tannic water. Inkwell also seems to lack adequate aquatic plant habitat as the plant growth is very limited. Plant surveyors did not speculate reasons for low plant presence and diversity in Inkwell Lake. In both lakes, there were no significant changes that are cause for discussion or concern.

Aquatic Plant Management

This section reviews the potential management methods available, existing management activities, and presents aquatic plant management goals and strategies for the Tomahawk Lake System.

Discussion of Management Methods

Techniques to control the growth and distribution of aquatic plants are discussed in following text. The application, location, timing, and combination of techniques must be considered carefully.

Permitting Requirements

The Department of Natural Resources regulates the removal of aquatic plants when chemicals are used, when plants are removed mechanically, and when plants are removed manually from an area greater than 30 feet in width along the shore. The requirements for chemical plant removal are described in Administrative Rule NR 107 – Aquatic Plant Management. A permit is required for any aquatic chemical application in Wisconsin. This includes granular herbicides available through mail order and internet purchase. A Department of Agriculture, Trade, and Consumer Protection pesticide applicator certification (aquatic nuisance control category) is required to apply liquid chemicals in the water.

The requirements for manual and mechanical plant removal are described in NR 109 – Aquatic Plants: Introduction, Manual Removal & Mechanical Control Regulations. A permit is required for manual and mechanical removal except for when a riparian (waterfront) landowner manually removes or gives permission to someone to manually remove plants (with the exception of wild rice) from his/her shoreline limited to a 30-foot corridor. A riparian landowner may also manually remove the invasive plants Eurasian water milfoil, curly leaf pondweed, and purple loosestrife along his or her shoreline without a permit. Manual removal means the control of aquatic plants by hand or hand–held devices without the use or aid of external or auxiliary power.[9]

Manual Removal[10]

Manual removal involving hand pulling, cutting, or raking plants will effectively remove plants from small areas. It is likely that plant removal will need to be repeated during the growing season. The best timing for hand removal of herbaceous plant species is after flowering but before seedhead production. For plants that possess rhizomatous (underground stem) growth, pulling roots is not generally recommended since it may stimulate new shoot production. Hand pulling is a strategy recommended for rapid response to a Eurasian water milfoil establishment and for private landowners who wish to remove small areas of curly leaf pondweed growth. Raking is recommended to clear nuisance growth in riparian area corridors up to 30 feet wide.

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[9] More information regarding DNR permit requirements and aquatic plant management contacts is found on the DNR web site www.dnr.wi.gov.

[10] Information from APIS (Aquatic Plant Information System) U.S. Army Corps of Engineers. 2005.

Mechanical Control

Larger-scale control efforts require more mechanization. Mechanical cutting, mechanical harvesting, diver-operated suction harvesting, and rotovating (tilling) are the most common forms of mechanical control available. Department of Natural Resources permits under Chapter NR 109 are required for mechanical plant removal.

Aquatic plant harvesters are floating machines that cut and remove vegetation from the water. The cutter head uses sickles similar to those found on farm equipment, and generally cut to depths from one to six feet. A conveyor belt on the cutter head brings the clippings onboard the machine for storage. A harvester can also be used to gather dislodged, free-floating plant fragments such as from coontail or wild celery. Once full, the harvester travels to shore to discharge the load of weeds off of the vessel.

The size, and consequently the harvesting capabilities of these machines vary greatly. As they move, harvesters cut a swath of aquatic plants that is between 4 and 20 feet wide, and can be up to 10 feet deep. The on-board storage capacity of a harvester ranges from 100 to 1,000 cubic feet (by volume) or 1 to 8 tons (by weight).

In some cases, the plants are transported to shore by the harvester itself for disposal, while in other cases, a barge is used to store and transport the plants in order to increase the efficiency of the cutting process. The plants are deposited on shore, where they can be transported to a local farm to be used as compost (the nutrient content of composted aquatic plants is comparable to that of cow manure) or to an upland landfill for proper disposal. Most harvesters can cut between 2 and 8 acres of aquatic vegetation per day, and the average lifetime of a mechanical harvester is 10 years.

Mechanical harvesting of aquatic plants presents both positive and negative consequences to any lake. Its results—open water and accessible boat lanes—are immediate and can be enjoyed without the restrictions on lake use which follow herbicide treatments. In addition to the human use benefits, the clearing of thick aquatic plant beds may also increase the growth and survival of some fish. By eliminating the upper canopy, harvesting reduces the shading caused by aquatic plants. The nutrients stored in the plants are also removed from the lake, and the sedimentation that would normally occur as a result of the decaying of this plant matter is prevented. Additionally, repeated treatments may result in thinner, more scattered growth.

Aside from the obvious effort and expense of harvesting aquatic plants, there are many environmentally-detrimental consequences to consider. The removal of aquatic species during harvesting is non-selective. Native and invasive species alike are removed from the target area. This loss of plants results in a subsequent loss of the functions they perform, including sediment stabilization and wave absorption. Sediment suspension and shoreline erosion may therefore increase. Other organisms such as fish, reptiles, and insects are often displaced or removed from the lake in the harvesting process. This may have adverse effects on these organisms' populations as well as the lake ecosystem as a whole.

While the results of harvesting aquatic plants may be short term, the negative consequences are not so short lived. Much like mowing a lawn, harvesting must be conducted numerous times throughout the growing season. Although the harvester collects most of the plants that it cuts, some plant fragments inevitably persist in the water. This may allow the invasive plant species to propagate and colonize in new, previously unaffected areas of the lake. Harvesting may also result in re-suspension of contaminated sediments and the excess nutrients they contain.

Disposal sites are a key component when considering the mechanical harvesting of aquatic plants. The sites must be on shore and upland to make sure the plants and their reproductive structures do not make their way back into the lake or to other lakes. The number of available disposal sites and their distance from the targeted harvesting areas will determine the efficiency of the operation, in terms of time as well as cost.

Timing is also important. The ideal time to harvest, in order to maximize the efficiency of the harvester, is just before the aquatic plants break the surface of the lake. For curly leaf pondweed, it should also be before the plants form turions (reproductive structures) to avoid spreading the turions within the lake. If the harvesting is conducted too early, the plants will not be close enough to the surface, and the cutting will not do much damage to them. If too late, turions may have formed and may be spread, and there may be too much plant matter on the surface of the lake for the harvester to cut effectively.

If the harvesting work is contracted, the equipment should be inspected before and after it enters the lake. Since contracted machines travel from lake to lake, they may carry plant fragments with them, and facilitate the spread of aquatic invasive species from one body of water to another. One must also consider prevailing winds, since cut vegetation can be blown into open areas of the lake or along shorelines.

The 2007/08 Aquatic Plant Management Committee discussed harvesting as an option for clearing navigation channels. However, native plant growth has not reached a threshold where management has been necessary. Harvesting is not a proven successful method for CLP management. Harvesting is not recommended for native plant management at this time because of the lack of demand and likely small acreage of navigation impairment.

Diver dredging operations use pump systems to collect plant and root biomass. The pumps are mounted on a barge or pontoon boat. The dredge hoses are from 3 to 5 inches in diameter and are handled by one diver. The hoses normally extend about 50 feet in front of the vessel. Diver dredging is especially effective against pioneering establishment of submersed invasive plant species. When a weed is discovered in a pioneering state, this methodology should be considered. To be effective, the entire plant including the subsurface portions should be removed.

Plant fragments can be formed from this type of operation. Fragmentation is not as great a problem when infestations are small. Diver dredging operations may need to be repeated to be effective. When applied toward a pioneering infestation, control can be complete. However, periodic inspections of the lake should be performed to ensure that all the plants have been found and collected.

Lake substrates can play an important part in the effectiveness of a diver dredging operation. Soft substrates are very easy to work in. Divers can remove the plant and root crowns with little problem. Hard substrates, however, pose more of a problem. Divers may need hand tools to help dig the root crowns out of hardened sediment.

Mechanically Assisted Manual Harvesting - Hydraulic Conveyor System[11]
The TLA Hydraulic Conveyor System (HCS) is an automated system that removes, filters, and bags harvested EWM after it has been hand harvested from the lake bed by divers. The system includes a floating chassis, a "jet pump" water system, a three tiered separation system, and a Hookah diver air supply system. Because of the mechanical elements of the system, a WDNR aquatic plant management harvesting permit is required.

Use of the TLA HCS began in the summer of 2007. A second generation HCS began operation in 2011. Capital costs for the system are just over $25,000 and annual operating costs are about $31,000.

Figure 50. TLA Hydraulic Conveyor System (Greedy)

Rotovation involves using large underwater rototillers to remove plant roots and other plant tissue. Rotovators can reach bottom sediments to depths of 20 feet. Rotovating may significantly affect non-target organisms and water quality as bottom sediments are disturbed. However, the

[11] From a Lakes Convention presentation, TLA Hydraulic Conveyor System. Ned Greedy, 2014.

suspended sediments and resulting turbidity produced by rotovation settles fairly rapidly once the tiller has passed. Tilling sediments that are contaminated could possibly release toxins to the water column. If there is any potential of contaminated sediments in the area, further investigation should be performed to determine potential impacts from this type of treatment. Tillers do not operate effectively in areas with many underwater obstructions such as trees and stumps. If operations are releasing large amounts of plant material, harvesting equipment should be on hand to collect this material and transport it to shore for disposal.

Biological Control[12]

Biological control is the purposeful introduction of parasites, predators, and/or pathogenic microorganisms to reduce or suppress populations of plant or animal pests. Biological control counteracts the problems that occur when a species is introduced into a new region of the world without a complex or assemblage of organisms that feed directly upon it, attack its seeds or progeny through predation or parasitism, or cause severe or debilitating diseases. With the introduction of native pests to the target invasive organism, the exotic invasive species may be maintained at lower densities.

There are advantages and disadvantages to the use of biological control as part of an overall aquatic plant management program. Advantages include longer-term control relative to other technologies, lower overall costs, as well as plant-specific control. On the other hand, there are several disadvantages to consider, including very long control times of years instead of weeks, lack of available agents for particular target species, and relatively narrow environmental conditions for success.

While this theory has worked in practice for control of some nonnative aquatic plants, results have been varied (Madsen, 2000). Beetles are commonly used to control purple loosestrife populations in Wisconsin with good success. Weevils are used as an experimental control for Eurasian water milfoil once the plant is established. Tilapia and carp are used to control the growth of filamentous algae in ponds. Grass carp, an herbivorous fish, is sometimes used to feed on pest plant populations. Grass carp introduction is not allowed in Wisconsin.

[12] Information from APIS (Aquatic Plant Information System) U.S. Army Corps of Engineers. 2005 except as otherwise noted.

Eurasian Water Milfoil Biocontrol
According to the company which provides the weevils for Eurasian Water Milfoil biocontrol, it is an effective management option. *The milfoil weevil (Euhrychiopsis lecontel) is native to North America and has been augmented in many inland lakes and rivers to suppress the growth of Eurasian Water Milfoil. This weevil damages the plant in multiple ways. The most significant impact is caused by the weevil larva as it damages the growing tip and burrows through the stem. Nutrient flow in the plant is disrupted and the stem loses buoyance, collapsing in the water column.* (EnviroScience, 2011) EnviroScience is no longer raising weevils because it is not cost effective.[13]

The Minocqua and Kawaguesaga Lakes Protection Association experimented with a weevil program for six areas infested with Eurasian Water Milfoil beginning in 2008. The weevils showed little effect on EWM growth when monitored in 2010. Herbicide treatment began in one of the six beds because of concern for EWM expansion. In 2011 the weevil augmentation results were showing some positive results with small decreases in both frequency and in density. However, a second bed was switched to herbicide treatment for 2012 because of expansion of EWM growth. Then in 2012, both frequency and density were back to levels seen in 2010 (density) and prior to 2010 (frequency). Beginning in 2012, any bed that met the criteria for herbicide treatment was treated and reliance on the weevil program was essentially discontinued. (Schieffer, 2012).

The results report for Minocqua and Kawaguesaga Lakes are consistent with DNR research that indicates weevils are not an effective solution in Northern Wisconsin.[14] A weevil biocontrol program for EWM is not recommended for the Tomahawk Lake System.

Purple Loosestrife Biocontrol[15]
Biocontrol may be the most viable long term control method for purple loosestrife control.
The DNR and University of Wisconsin-Extension (UWEX), along with hundreds of citizen cooperators, have been introducing natural insect enemies of purple loosestrife, from its home in Europe to infested wetlands in the state since 1994. Careful research has shown that these insects are dependent on purple loosestrife and are not a threat to other plants. Insect releases monitored in Wisconsin and elsewhere have shown that these insects can effectively decrease purple loosestrife's size and seed output, thus letting native plants reduce its numbers naturally through enhanced competition.

A suite of four different insect species has been released as biological control organisms for purple loosestrife in North America and Wisconsin. Two leaf beetle species called "Cella" beetles that feed primarily on shoots and leaves were the first control insects to be released in Wisconsin, and are the insects available from DNR for citizens to propagate and release into their local wetlands. A root-mining weevil species and a type of flower-eating weevil have also been released and are slowly spreading naturally. The Purple Loosestrife Biocontrol Program offers cooperative support, including free equipment and starter beetles from DNR and UWEX, to all state citizens who wish to use these insects to reduce their local purple loosestrife.

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13 Susan Knight, Personal Communication with Noah Lottig.
14 Susan Knight, Personal Communication with Noah Lottig.
15 http://dnr.wi.gov/topic/Invasives/loosestrife.html

The length of time required for effective biological control of purple loosestrife in any particular wetland ranges from one to several years depending on such factors as site size and loosestrife densities. The process offers effective and environmentally sound control of the plant, not elimination, in most cases. It is also typically best done in some combination with occasional use of more traditional control methods such as digging and herbicide use. Biocontrol with beetles is recommended for the Tomahawk Lake Systems if concerns regarding flooding of plants can be alleviated.

Re-vegetation with Native Plants
Another aspect to biological control is native aquatic plant restoration. The rationale for re-vegetation is that restoring a native plant community should be the end goal of most aquatic plant management programs (Nichols 1991; Smart and Doyle 1995). However, in communities that have only recently been invaded by nonnative species, a propagule (seed) bank probably exists that will restore the community after nonnative plants are controlled (Madsen, Getsinger, and Turner, 1994). Re-vegetation following plant removal is probably not necessary on the Tomahawk Lake System because a healthy, diverse native plant population is present.

Physical Control[16]

In physical management, the environment of the plants is manipulated, which in turn acts upon the plants. Several physical techniques are commonly used: dredging, drawdown, benthic (lake bottom) barriers, and shading or light attenuation. Because they involve placing a structure on the bed of a lake and/or affect lake water level, a Chapter 30 or 31 WDNR permit would be required.

Dredging removes accumulated bottom sediments that support plant growth. Dredging is usually not performed solely for aquatic plant management but to restore lakes that have been filled in with sediments, have excess nutrients, need deepening, or require removal of toxic substances (Peterson 1982). Lakes that are very shallow due to sedimentation tend to have excess plant growth. Dredging can form an area of the lake too deep for plants to grow, thus creating an area for open water use (Nichols 1984). By opening more diverse habitats and creating depth gradients, dredging may also create more diversity in the plant community (Nichols 1984). Results of dredging can be very long term. However, due to the cost, environmental impacts, and the problem of disposal, dredging should not be performed for aquatic plant management alone. It is best used as a lake remediation technique.

Dredging is not suggested for Tomahawk Lakes as part of the aquatic plant management plan.

Drawdown, or significantly decreasing lake water levels, can be used to control nuisance plant populations. With drawdown, the water body has water removed to a given depth. It is best if this depth includes the entire depth range of the target species. Drawdowns need to be at least one month long to ensure thorough drying and effective removal of target plants (Cooke 1980a). In northern areas, a drawdown in the winter that will ensure freezing of sediments is also effective. Although drawdown may be effective for control of hydrilla for one to two years (Ludlow 1995),

[16] Information from APIS (Aquatic Plant Information System) U.S. Army Corps of Engineers. 2005.

it is most commonly applied to Eurasian water milfoil (Geiger 1983; Siver et al. 1986) and other milfoils or submersed evergreen perennials (Tarver 1980). Drawdown requires a mechanism to lower water levels.

Although drawdown is inexpensive and has long-term effects (2 or more years), it also has significant environmental effects and may interfere with use and intended function (e.g., power generation or drinking water supply) of the water body during the drawdown period. Lastly, species respond in very different manners to drawdown and often not in a consistent fashion (Cooke 1980a). Drawdowns may provide an opportunity for the spread of highly weedy species, particularly annuals. Drawdown is not a feasible option for Tomahawk Lakes.

Benthic Barriers, or other bottom-covering approaches, are another physical management technique. The basic idea is that the plants are covered over with a layer of a growth-inhibiting substance. Many materials have been used, including sheets or screens of organic, inorganic, and synthetic materials; sediments such as dredge sediment, sand, silt or clay; fly ash; and combinations of the above (Cooke 1980b; Nichols 1974; Perkins 1984; Truelson 1984). The problem with using sediments is that new plants establish on top of the added layer (Engel and Nichols 1984). The problem with synthetic sheeting is that the gasses evolved from decomposition of plants and sediment decomposition collect under and lift the barrier (Gunnison and Barko 1992). Benthic barriers will typically kill plants under them within 1 to 2 months, after which they may be removed (Engel 1984). Sheet color is relatively unimportant; opaque (particularly black) barriers work best, but even clear plastic barriers will work effectively (Carter et al. 1994). Sites from which barriers are removed will be rapidly re-colonized (Eichler et al. 1995). Synthetic barriers, if left in place for multi-year control, will eventually become sediment-covered and will allow colonization by plants. Benthic barriers may be best suited to small, high-intensity use areas such as docks, boat launch areas, and swimming areas. However, benthic barriers are too expensive to use over widespread areas, and they heavily affect benthic communities by removing fish and invertebrate habitat. A Department of Natural Resources permit would be required for a benthic barrier and are not recommended for the Tomahawk Lake System.

Shading or light attenuation reduces the light plants need to grow. Shading has been achieved by fertilization to produce algal growth, by application of natural or synthetic dyes, shading fabric, or covers, and by establishing shade trees (Dawson 1981, 1986; Dawson and Hallows 1983; Dawson and Kern-Hansen 1978; Jorga et al. 1982; Martin and Martin 1992; Nichols 1974). During natural or cultural eutrophication, algae growth alone can shade aquatic plants (Jones et al. 1983). Although light manipulation techniques may be useful for narrow streams or small ponds, in general, these techniques are of only limited applicability. Physical control is not currently proposed for management of aquatic plants in Tomahawk Lakes.

Herbicide and Algaecide Treatments

Herbicides are chemicals used to kill plant tissue. Currently, no product can be labeled for aquatic use if it poses more than a one in a million chance of causing significant damage to human health, the environment, or wildlife resources. In addition, it may not show evidence of biomagnification, bioavailability, or persistence in the environment (Joyce, 1991). Thus, there are a limited number of active ingredients that are assured to be safe for aquatic use (Madsen, 2000).

An important caveat is that these products are considered safe when used according to the label. The U.S. Environmental Protection Agency (EPA)-approved label gives guidelines protecting the health of the environment, the humans using that environment, and the applicators of the herbicide. Wisconsin Department of Natural Resources permits under Chapter NR 107 are required for herbicide application. **Aquatic herbicides must be applied only by licensed applicators.**

General descriptions of herbicide classes are included below.[17]

Contact Herbicides
Contact herbicides act quickly and are generally lethal to all plant cells that they contact. Because of this rapid action, or other physiological reasons, they do not move extensively within the plant and are effective only where they contact plants. They are generally more effective on annuals (plants that complete their life cycle in a single year). Perennial plants (plants that persist from year to year) can be defoliated by contact herbicides, but they quickly resprout from unaffected plant parts. Submersed aquatic plants that are in contact with sufficient concentrations of the herbicide in the water for long enough periods of time are affected, but regrowth occurs from unaffected plant parts, especially plant parts that are protected beneath the sediment. Because the entire plant is not killed by contact herbicides, retreatment is necessary, sometimes two or three times per year. **Endothall, diquat,** and **copper** are contact aquatic herbicides.

Systemic Herbicides
Systemic herbicides are absorbed into the living portion of the plant and move within the plant. Different systemic herbicides are absorbed to varying degrees by different plant parts. Systemic herbicides that are absorbed by plant roots are referred to as soil active herbicides, and those that are absorbed by leaves are referred to as foliar active herbicides. **2,4-D, dichlobenil, fluridone, and glyphosate** are systemic aquatic herbicides. When applied correctly, systemic herbicides act slowly in comparison to contact herbicides. They must move to the part of the plant where their site of action is. Systemic herbicides are generally more effective for controlling perennial and woody plants than contact herbicides. Systemic herbicides also generally have more selectivity than contact herbicides.

Broad Spectrum Herbicides
Broad spectrum (sometimes referred to as nonselective) herbicides are those that are used to control all or most vegetation. This type of herbicide is often used for total vegetation control in areas such as equipment yards and substations where bare ground is preferred. **Glyphosate** is an example of a broad spectrum aquatic herbicide. **Diquat, endothall, and fluridone** are used as broad spectrum aquatic herbicides, but they can also be used selectively under certain circumstances.

[17] This discussion is taken directly from: Managing Lakes and Reservoirs. North American Lake Management Society.

Selective Herbicides
Selective herbicides are those that are used to control certain plants but not others. Herbicide selectivity is based upon the relative susceptibility or response of a plant to an herbicide. Many related physical and biological factors can contribute to a plant's susceptibility to an herbicide. Physical factors that contribute to selectivity include herbicide placement, formulation, timing, and rate of application. Biological factors that affect herbicide selectivity include physiological factors, morphological factors, and stage of plant growth.

Environmental Considerations
Aquatic communities consist of aquatic plants including macrophytes (large plants) and phytoplankton (free floating algae), invertebrate animals (such as insects and clams), fish, birds, and mammals (such as muskrats and otters). All of these organisms are interrelated in the community. Organisms in the community require a certain set of physical and chemical conditions to exist such as nutrient requirements, oxygen, light, and space. Aquatic weed control operations can affect one or more of the organisms in the community that can, in turn, affect other organisms. Or, weed control operations can affect water chemistry that, in turn, affects organisms.

General descriptions of the breakdown of commonly used aquatic herbicides are included below.[18] Chemicals commonly used in Wisconsin lakes are listed and described in Table 44 below.

Table 44. Herbicides Used to Manage Aquatic Plants in Wisconsin

Brand Name(s)	Chemical	Target Plants
Captain, Nautique, Cutrine Plus	Copper compounds	Free floating and filamentous algae, also coontail, curly leaf pondweed, water celery, pondweeds
Aquathol K, Hydrothal	Endothall	Curly leaf pondweed also other submergent plants: coontail, milfoil, pondweed, water celery
Reward	Diquat	Pondweeds, coontail, Eurasian water milfoil
Aquakleen, Navigate	2,4-D	Eurasian and other milfoils

Copper[19]
Copper is an essential trace element that tends to accumulate in sediments and can be toxic to aquatic life at elevated concentrations (United States Environmental Protection Agency, June 2008).

18 These descriptions are taken from Hoyer/Canfield: Aquatic Plant Management. North American Lake Management Society. 1997.
19 Copper background information is from the Long Lake Management Plan prepared by the Polk County Land and Water Resources Department March 2013.

A study completed by MacDonald et al. (2000) developed consensus based numerical sediment quality guidelines for metals in freshwater ecosystems. This study provides guidelines for metals in freshwater ecosystems that reflect threshold effect concentrations (TECs, below which harmful effects are unlikely to be observed) and probable effect concentrations (PECs, above which harmful effects are likely to be observed). The consensus based TEC for copper is 31.6 mg/kg and the consensus based PEC for copper is 149 mg/kg.

2,4-D

2,4-D photodegrades on leaf surfaces after applied to leaves and is broken down by microbial degradation in water and sediments. Complete decomposition usually takes about 3 weeks in water and can be as short as 1 week. 2,4-D breaks down into naturally occurring compounds.

Diquat

When applied to enclosed ponds for submersed weed control, diquat is rarely found longer than 10 days after application and is often below detection 3 days after application. The most important reason for the rapid disappearance of diquat from water is that it is rapidly taken up by aquatic vegetation and bound tightly to particles in the water and bottom sediments. When bound to certain types of clay particles, diquat is not biologically available. When diquat is bound to organic matter, it can be slowly degraded by microorganisms. When diquat is applied foliarly, it is degraded to some extent on the leaf surfaces by photodegradation. Because it is bound in the plant tissue, a proportion is probably degraded by microorganisms as the plant tissue decays.

Endothall

Like 2,4-D, endothall is rapidly and completely broken down into naturally occurring compounds by microorganisms. The by-products of endothall dissipation are carbon dioxide and water. Complete breakdown usually occurs in about 2 weeks in water and 1 week in bottom sediments.

Fluridone

Dissipation of fluridone from water occurs mainly by photodegradation. Metabolism by tolerant organisms and microbial breakdown also occurs. Microbial breakdown is probably the most important method of breakdown in bottom sediments. The rate of breakdown of fluridone is variable and may be related to time of application. Applications made in the fall or winter when the sun's rays are less direct and days are shorter result in longer half-lives. Fluridone usually disappears from pondwater after about 3 months but can remain up to 9 months. It may remain in bottom sediment between 4 months and 1 year.

Glyphosate

Glyphosate is not applied directly to water for weed control. However, when it does enter the water, it is bound tightly to dissolved and suspended particles and to bottom sediments and becomes inactive. Glyphosate is broken down into carbon dioxide, water, nitrogen, and phosphorus over a period of several months.

Algaecide Treatments for Filamentous Algae

Copper-based compounds are generally used to treat filamentous algae. Common chemicals used are copper sulfate and Cutrine Plus, a chelated copper algaecide.

Herbicide Use to Manage Invasive Species

Curly Leaf Pondweed
The Army Corps of Engineers Aquatic Plant Information System (APIS) identifies three herbicides for control of curly leaf pondweed: diquat, endothall, and fluridone. Fluridone requires exposure of 30 to 60 days making it infeasible to target a discreet area in a lake system. The other herbicides act more rapidly. Herbicide labels provide water use restriction following treatment. Diquat (Reward) has the following use restrictions: drinking water 1-3 days, swimming and fish consumption 0 days. Endothall (Aquathol K) has the following use restrictions: drinking water 7 – 25 days, swimming 0 days, fish consumption 3 days.

Early season herbicide treatment:[20]
Studies have demonstrated that curly leaf can be controlled with Aquathol K (a formulation of endothall) in 50 - 60 degree F water, and treatments of curly leaf this early in its life cycle can prevent turion formation. Since curly leaf pondweed is actively growing at these low water temperatures and many native aquatic plants are yet dormant, this early season treatment selectively targets curly leaf pondweed.

Because the dosage is at lower rates than dosage recommended on the label, a greater herbicide residence time is necessary. To prevent drift of herbicide and allow greater contact time, application in shallow bays is likely to be most effective. Herbicide applied to a narrow band of vegetation along the shoreline is likely to drift, rapidly decrease in concentration, and be rendered ineffective.[21]

Eurasian Water Milfoil
The Army Corps of Engineers Aquatic Plant Information System (APIS) identifies the following herbicides for control of Eurasian water milfoil: complexed copper, 2,4-D, diquat, endothall, fluridone, and triclopyr. Early season treatment of Eurasian water milfoil is also recommended by the Department of Natural Resources to limit the impact on native aquatic plant populations. Herbicide has been used to control Eurasian water milfoil in the Tomahawk Lake system since 2005.

Native Plant Aquatic Plant Management
According to a 2009 report, WDNR issued permits for aquatic herbicide treatments in the years 1967, 1968, 1981, 1988, 2005, 2007 and 2008. Treatments issued at least prior to 2004 most likely targeted native plants because Eurasian water milfoil was not confirmed on Tomahawk Lake until 2004. (Northern Environmental, 2009)

The WDNR Northern Region released an Aquatic Plant Management Strategy in the summer of 2007 to protect the important functions aquatic plants provide in lakes. As part of this strategy, the WDNR prohibited management of native aquatic plants in front of individual lake properties

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[20] Research in Minnesota on Control of Curly Leaf Pondweed. Minnesota Wendy Crowell, Minnesota Department of Natural Resources. Spring 2002.
[21] Personal communication, Frank Koshere. March 2005.

after 2008 unless management is designated in an approved aquatic plant management plan.[22] Permits for waterfront corridors were issued in 2008 only for formerly permitted sites where impairment of navigation and/or nuisance conditions were demonstrated. Because of the importance of the native plant population for habitat, protection against erosion, and as a guard against invasive species infestation, plant removal with herbicides as an option for individual property owners is carefully reviewed. The WDNR has not allowed removal after January 1, 2009 unless the "impairment of navigation" and/or "nuisance" conditions are clearly documented.

The WDNR recommends (and may require) that residents who wish to maintain an opening for boating and swimming use rakes or other hand methods.

[22] Aquatic Plant Management Strategy. DNR Northern Region. Summer 2007.

Current Aquatic Plant Management Activities[23]

Tomahawk Lake System Aquatic Invasive Species (AIS) Management includes resident education, the Clean Boats Clean Waters Program, invasive species monitoring, and purple loosestrife and Eurasian water milfoil control.

AIS Education Opportunities
The TLA hosts an impressive list of educational activities (from the 2015 AIS Control Grant Application) including:

- Town meetings
- TLA spring and fall newsletters
- TLA website: TomahawkLake.org
- TLA Facebook page
- Monthly email blasts
- Annual volunteer appreciation newspaper advertisement
- TLA social events and informational meetings
- Web based course for shoreline owners

Clean Boats Clean Waters (CBCW) Program
Clean Boats Clean Waters educators provide boaters with information on the threat posed by Eurasian Milfoil and other invasive species. They offer tips on how to keep boats, trailers, and equipment free of aquatic hitchhikers. Educational information includes a current map of EWM infestation so boaters are aware of areas to avoid. CBCW staff and volunteers also collect information on boater behavior, concerns, and knowledge of existing local and state laws related to anti-AIS measures.

The Tomahawk Lake Association's (TLA) Clean Boats, Clean Waters Program has had several successful years, educating boaters on the need to be good stewards of the lake. In addition to performing watercraft inspections at the two largest boat ramps, ramp attendants present AIS educational material to boaters. The program is staffed by both paid staff and volunteers. Paid staff covered two boat landings (Tomahawk Lake and Thoroughfare Landings) each weekend (Friday afternoon, Saturday and Sunday) for 16 weeks during recent summers. A grant proposal for the coming year seeks funding to cover a third landing. Volunteers cover the landings as available during the week.

Table 45. Recent Clean Boats Clean Waters Program Statistics

Year	2112	2013	2014
Boats Inspected	2307	2329	2547
People Contacted	6713	6680	10,884
Inspection Hours	472	651	910
Boaters Aware of Laws	97%	99%	95%

[23] Unless otherwise noted, the information in this section is taken from TLA grant applications and reports prepared by Edward Greedy, TLA Executive Director.

Purple Loosestrife Management
Dr. Noah Lottig, TLA Board of Directors Environmental and Education Committee Chair, guided the development and implementation of a purple loosestrife management program. Purple loosestrife GPS mapping occurred in the summers of 2012 and 2013. TLA control of purple loosestrife began in 2012 with a clip and bag program. For this program, volunteers remove flower heads to prevent seed formation and spreading. The TLA does not currently use herbicides for purple loosestrife control.

A beetle biocontrol program was piloted in wetlands surrounding the Thoroughfare in 2013. However, the beetles were lost when plants were inundated with high water. The beetle program was suspended as a result but will restart when conditions are suitable for beetle growth. Lower water levels are expected in the future. In 2013 and 2014 late spring snow conditions in southern Wisconsin precluded lowering Northern Wisconsin River reservoirs (including the Tomahawk Lake System). As a result, opening season water levels were extremely high.

Educational materials, including a direct mail and email packet, are proposed for 2015 to target owners where purple loosestrife is present and to solicit volunteer participation in the control program.

Eurasian Water Milfoil Management
Eurasian water milfoil was discovered on Tomahawk Lake in August of 2003. Control efforts began in 2005. The TLA EWM management program includes a two-tiered approach with both herbicide treatment and diver hand pulling with the Hydraulic Conveyor System (HCS).

Monitoring
Volunteer EWM Sentinels (17 teams with two or more volunteers each) map EWM locations and look for other AIS twice each year. The Sentinels record GPS coordinates where EWM is found. The HCS team uses this data to identify areas for diver removal and areas for potential polygon mapping for herbicide treatment. The Sentinels are trained each spring prior to survey periods.

The TLA Executive Director (ED) performs professional pre and post monitoring surveys and mapping. Pre and post monitoring is according to standard WDNR methods which record both EWM and native plant rake density at pre-determined sampling points within treatment polygons. The ED selects areas for chemical treatment for the following year and maps these polygons in late summer. This information is used in the annual aquatic plant management herbicide permit application.

EWM Herbicide Treatments
The TLA uses early season 2,4-D herbicide treatment in either liquid form (at 4 ppm) or granular form (at 3 ppm) to control Eurasian water milfoil. The liquid formulation is used in areas less subject to drift such as protected bays with high banks. The granular form is used in all other areas.

The 2009 Comprehensive Lake Management Plan set a EWM reduction goal of 80% from fall 2008 baseline conditions through 2013. Acres of EWM beds treated are summarized in Table 46 below. The planned reduction goals have not been achieved - largely because of new areas of EWM infestation. Treatment areas from 2009 through 2014 are shown in Figure 51.

Table 46. Tomahawk Lake EWM Acreage and Treatments 2006-2014

Year (late summer mapping)	Mapped Acres	Treated Acres following year (buffered or modified)	Reduction Within Beds after treatment	comments
2006	31	NA[24]	NA	
2007	33	34 +7	44%[25]	Baseline- 26 acres- 2,4-D, 7 acres HCS[26]
2008	15	NA	NA	
2009	**50**	NA	NA	CLMP implementation
2010	44	52	35% (increase)	
2011	127	124	67%	
2012	39	41	67%	
2013	**41**	41	71%	Year 5 of plan
2014	10	NA		

EWM Polygon Delineation

Criteria for EWM polygons/areas suitable for herbicide treatment are not clearly defined. Instead, beds are selected each year based on such factors as:

- EWM frequency per unit area
- Estimated stem density (visual)
- Rake density
- Native species presence and distribution
- Bed history
- Depth of EWM below surface

The minimum bed size is generally at least 4,400 square feet.

Frequency of EWM within Littoral Zone

DNR internal discussion (tentative) might consider <10% frequency of occurrence of EWM within the littoral zone to be a reasonable maintenance level. This statistic is not regularly measured for Tomahawk Lake. In the 2014 PI survey, EWM had a littoral zone frequency of 2.79% and a vegetated sample point frequency of 4.5%. However, this was following herbicide treatment of 41 acres and HCS operation. The littoral zone of Tomahawk Lake is about 1,100 acres. Forty-one acres is another 3.7% of the littoral zone.

[24] NA = Not Available
[25] Chemical and hand pulling results. Chemical results alone showed 50% reduction.
[26] Hydraulic Conveyor System

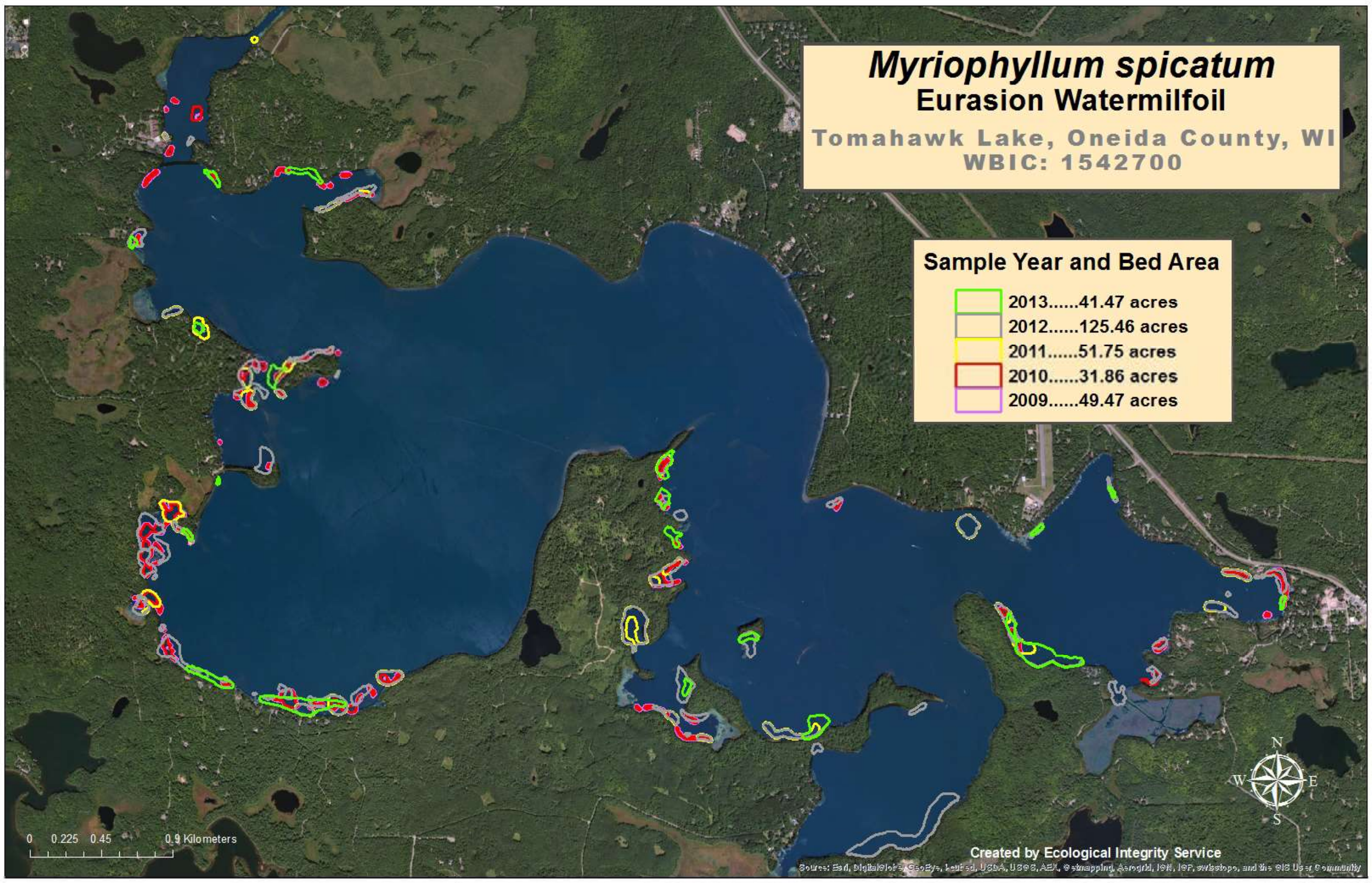

Figure 51. Eurasian Water Milfoil Treatment 2009-2013

Hydraulic Conveyor System

The Hydraulic Conveyor System (HCS) allows for highly selective mechanical harvesting of EWM in areas where chemical herbicide applications are not possible or appropriate. HCS use began in 2008.

Selected HCS harvesting areas include but are not limited to:

1. Small pioneering stands of EWM
2. Areas too small for chemical application (<4,400 ft^2)
3. Areas where EWM is mixed with native aquatic plants
4. Shallow aquatic habitats (<2 feet)
5. High traffic areas where fragmentation and spread is likely – near docks and boat houses (Greedy, 2013)

A mechanical harvesting permit is submitted for HCS operation each fall. The permit designates high risk basins or areas where HCS operations may occur. These areas are illustrated for 2014 in Figure 52. The TLA hires two certified divers to operate the HCS during the growing season from the end of May to early September. Harvest totals are included in Table 47.

Table 47. TLA Hydraulic Conveyor System Annual Harvest Totals

Year	Weight Harvested (pounds)	Area Harvested (square feet)	Sites Harvested
2009	18,725	28,435	88
2010	18,301	21,555	101
2011	22,507	64,243	89
2012	17,699	30,400	81
2013	20,311	34,250	106
2014	20,679	62,090	149

Herbicide Concentration Dispersion

The TLA participated in the Army Corps of Engineers/WDNR herbicide concentration study from 2009 through 2012. In 2011 herbicide concentrations were sampled at sites treated with liquid (three sites) and granular (three sites) formulations of 2,4-D. Initial treatment concentrations were higher for liquid (2,000 *u*g/L) than for granular (1,400 *u*g/L) applications. However, even with an initial rise in concentration, granular treatment areas had lower concentrations than sites where liquid 2,4-D was used until about 72 hours after treatment.

No data regarding efficacy of EWM control was presented with the data.

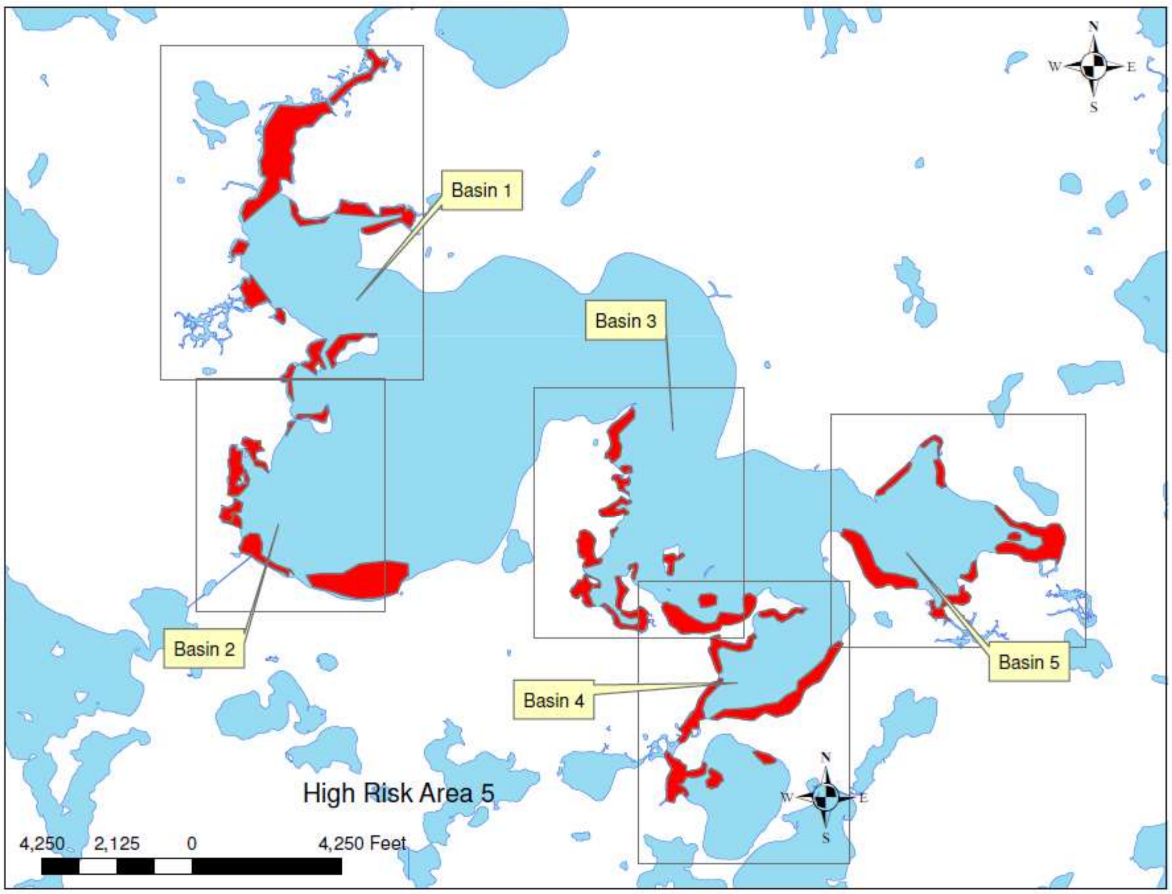

Figure 52. Tomahawk Lake System High Risk EWM Areas 2014

Past Grant Funding

The Tomahawk Lake Association has a successful track record in obtaining Wisconsin Department of Natural Resource grant support for aquatic invasive species planning and implementation. Table 48 summarizes the grants awarded.

Table 48. WNDR Grants Supporting Tomahawk Lake System AIS Management

Grant No	Grant Name	Amount	Begin Date	End Date
	TL Rapid Response		2005	
	Lake Tom Management Plan – Phase 1		2006	
	Lake Tom Management Plan – Phase 2		2007	
	Lake Tom Management Plan – Phase 3		2007	
AIRR-026-07	APM Plans	$10,000	3/23/07	12/31/07
SPL-137-07	Waterbody Surveys	$3,000	4/01/07	12/31/08
AIRR-045-08	Prevention and Control Strategy 1	$9,622.50	9/06/07	12/31/08
AIRR-046-08	Prevention and Control Strategy 2	$10,000	9/06/07	12/31/08
ACEI-051-08	EWM Hydraulic Conveyor Demo Project	$45,033.50	4/01/08	12/31/08
ACEI-063-09	AIS Control Project	$149,701	4/01/09	12/31/11
ACEI-093-11	AIS Control Project	$173,333	4/01/11	6/30/13
ACEI-130-13	AIS Control Project	$173,333	4/01/13	6/30/15
LPL-1553-14	CLMP Phase 1	$24,332	4/01/14	12/31/15
LPL-1554-14	CLMP Phase 2	$16,692	4/01/14	12/31/15
ACEI-166-15	AIS Control Project	$79,505.25	4/01/15	12/31/15

TLA Management Structure

The Tomahawk Lake Association (TLA) is a 501(C) (3) tax exempt organization with a volunteer board. TLA members pay annual dues to subscribe. In 2013 the TLA had 225 members.

The TLA hires an executive director to manage several aspects of the aquatic plant management program including the following tasks:

- Grant writing and management
- Aquatic plant management permit requests and management
- Pre and post herbicide treatment monitoring
- Coordinate Hydraulic Conveyor employees

TLA Communications[27]

The Tomahawk Lake Association (TLA) uses a variety of methods to reach lake residents and the surrounding community. Each is listed and briefly described below.

Spring and Fall Newsletters
A full color, semi-annual newsletter which includes lake news, water quality and invasive species control results, upcoming events, and who's who among other topics.

Website: Tomahawklake.org
A basic informational website introduces the viewer to the TLA.

Tomahawk Lake Facebook Page (closed group)
Facebook members can post messages, photos, news, poems, and essays.

TLA E-blasts
E-blasts come out monthly providing event and other information. Maintaining an accurate, up-to-date email list is a constant challenge.

Lakeland Times Volunteer and Donors Appreciation Full Page Advertisement
Recognizes members and friends who provide volunteer and financial support to TLA

TLA Social/Fundraising Events
Wine & Cheese Tasting, Hermit Island Swim Challenge, Skates, Snowshoes & Skis, Beef a Rama Blast.

Public Meetings
Comprehensive Lake Planning meeting
Township Board meetings aimed at updating & gaining support

AIS Education
Clean Boats Clean Waters – boat ramp education
Aquatic Invasive Species web courses

Face to Face
Pier to Pier – informational visits with lake shore neighbors
Neighborhood get-togethers hosted by TLA members
Lake fairs
Science presentations

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[27] Provided by Ned Greedy, 2/11/15.

Lake Management Options

Involvement in Planning and Zoning
Understanding of state and local regulations and planning activities can help the Tomahawk Lake Association protect lake water quality. Involvement in planning activities can help to ensure that land uses that protect the lake are in place in the watershed. Plans might be developed at the town, county, or state level. As concerns are identified, board members may attend related meetings and hearings to express concerns and gather information.

Comprehensive Land Use Planning
The Oneida County Comprehensive Land Use Plan was adopted in 2013. The plan includes an analysis of demographics, natural resources, housing, utilities, economics, intergovernmental cooperation, and land use.

Selected natural resource goals, objectives and policies include the following (items selected are most relevant to the comprehensive lake management plan):

Goal. Balance natural resource protection with economic development.
Policies:
1. Conserve and enhance shoreland areas by minimizing impacts from land disturbing activities.
2. Slow the spread of invasive species.
3. Examine the impacts of metallic mining on the County's natural resources

Goal. Reduce contamination of surface and groundwater resources.
Objectives:
1. Promote development that minimizes surface and groundwater impacts from on-site septic systems and other sources.
2. Conserve and enhance surface water, groundwater, and shoreline quality.

Goal. Encourage and support the conservation of natural areas that minimize flooding, such as grasslands, wetland and woodlands.
Objective. Increase and improve wildlife habitat.
Policy. Encourage the development of natural area network connecting open areas, wetlands, and woodlands.

The Town of Lake Tomahawk adopted its own comprehensive plan in 2013.

Oneida County Zoning and Shoreland Protection Ordinance (Chapter 9)

The goal of the ordinance is to promote the following specific purposes (among others):

- Prevent and control water pollution by regulating septic systems and other wastewater disposal.
- Protect spawning grounds, fish and aquatic life by preserving wetlands and fish and aquatic habitat; regulating pollution sources; and controlling shoreline alterations, dredging and lagooning.
- Control building sites, placement of structures and land use with special requirements in shoreland areas.
- Preserve shore cover and natural beauty by restricting removal of natural shore cover; preventing shoreline encroachment by structures; controlling shoreland excavation and other earth moving activities; and regulating the placement of boat houses and other structures.

Zoning provisions apply within all unincorporated areas within towns in the Tomahawk Lake System watershed including the Towns of Minocqua, Hazelhurst, Lake Tomahawk, and Woodruff. Land use regulations in the zoning ordinance include building height requirements, lot sizes, permitted uses by zoning district, and setbacks among other provisions.

Shoreland protection provisions apply within 1,000 feet of the ordinary high water mark of navigable lakes, ponds, and flowages and 300 feet of the ordinary high water mark of rivers and streams or the landward side of floodplains. Shoreland provisions include requirements for wetlands, lot size, set backs, shoreland vegetation protection area, shoreland alterations, and structures.

Oneida County Land and Water Resources Management Plan

The Oneida County Land and Water Resources Management Plan (2012-2016) was developed to assist in managing and protecting land and water resources throughout Oneida County. Several of the plan goals are relevant to this comprehensive lake management plan.

Goals, objectives and actions are listed in priority order below.

Goal 1: Slow the spread of invasive species.

☐ Seek DNR grants and other sources of funding to assist with prevention, education and control of non-native aquatic invasive species

☐ Distribute educational materials for general public regarding non-native terrestrial invasive species

Goal 2: Protect shoreland areas.

☐ Provide technical assistance to landowners with mitigation requirements

☐ Work with Planning & Zoning to develop at least one shoreland zoning fact sheet, and publish online to encourage compliance with the non-agricultural performance standards and prohibitions

Goal 3: Restore shorelands.

☐ Seek state funding to provide cost sharing to at least six riparian landowners

☐ Provide technical expertise to implement at least six shoreland projects on a minimum of 1000 feet of shoreline

☐ Work with Oneida County Lakes and Rivers Association and at least three lake associations/districts to provide and develop educational information. Submit related articles for newsletter

Goal 4: Reduce sources of nonpoint source water pollution.

☐ Develop a fact sheet regarding construction site erosion control

☐ Create a list of agriculture producers in the county

☐ Develop rotational grazing plans for farmers in the county

☐ Provide guidance and/or technical assistance to local units of government on storm water management

☐ Distribute existing publications and provide information to local media

Goal 5: Educate public about groundwater quality.

☐ Work with lake associations to require replacement of failing septic systems

☐ Inventory all on-site septic systems regardless of age to ensure proper maintenance

☐ Educate local units of government on the importance of protecting wetlands within their community

Goal 6: Protect lake ecosystems from recreational pressure degradation.

☐ Work with Oneida County Lakes and Rivers Association, at least three lake associations/districts, and at least 300 lake users to identify environmentally sensitive areas on lakes

Land Preservation

Land preservation involves purchasing land or putting land in conservation easements to preserve natural areas or to ensure that conservation practices will remain in place. A conservation easement is a voluntary legal agreement that restricts some land uses to protect important conservation values.

There are two conservancy organizations in the Tomahawk Lake System area. The Northwoods Land Trust protects land in a seven county area in the Northwoods of Wisconsin. It is based in Eagle River. Contact Executive Director, Bryan Pierce, pierce@northwoodslandtrust.org, 715-479-2490.

The Lakeland Conservancy is a tax exempt organization formed to preserve properties in Vilas and Oneida Counties. It holds conservation easements on forestland owned by the Pottawattomie Colony west of Tomahawk Lake. Contact: Tuck Mallery, 2299 River Forest Lane, Mosinee, WI 54455.

Shoreland Restoration Programming[27]

Restoration of natural shorelands is included in many lake management plans to meet goals of restoring habitat next to the water and reducing runoff of nutrients and sediment from waterfront properties. A range of management activities are available to encourage natural shoreland restoration including the following:

- Information and Education
- Demonstration Projects
- Recognition
- Technical and Design Assistance
- Incentives such as Cost Sharing Installation

Information and Education

Providing information and education to lake residents is an important component of any lake management program. There is an abundance of printed and web information to help explain lake ecology and management methods. The University of Wisconsin Extension (http://learningstore.uwex.edu) and the Wisconsin Department of Natural Resources (http://dnr.wi.gov/lakes/publications) have many resources available. Lake organizations also develop informational materials specific to their lake and management program.

A variety of methods are available to distribute information:

- Packets of information for new homeowners
- Brochures and guidebooks
- Web sites
- Newsletters
- Newspapers
- Workshops and training sessions

Distributing information can certainly increase knowledge. A key consideration is that people often understand lake concerns, but still do not make desired behavioral changes. It is important to identify specific targeted behaviors and the barriers to those behavioral changes, then to design programs to overcome these barriers. For example, concerns about native vegetation blocking views to water where children are swimming can be a barrier to shoreland restoration. To address this concern, information about shoreland restoration can emphasize planting lower growing plants and maintaining viewing corridors so the waterfront is still visible.

[27] Shoreland restoration programming examples provided were developed by Harmony Environmental in cooperation with the lake or government organizations and consulting partners. Unless specifically mentioned, the examples are from Polk County, Wisconsin. For more information contact: Cheryl Clemens harmonyenv@amerytel.net.

The lake user survey results can help to develop targeted educational messages. Only about 25% of survey respondents report a large negative impact from the removal of near shore emergent vegetation or upland vegetation. A small negative impact is reported by 35-40% of respondents. So, negative impacts from removing near-shore and upland vegetation are reported by 60-65% of survey respondents.

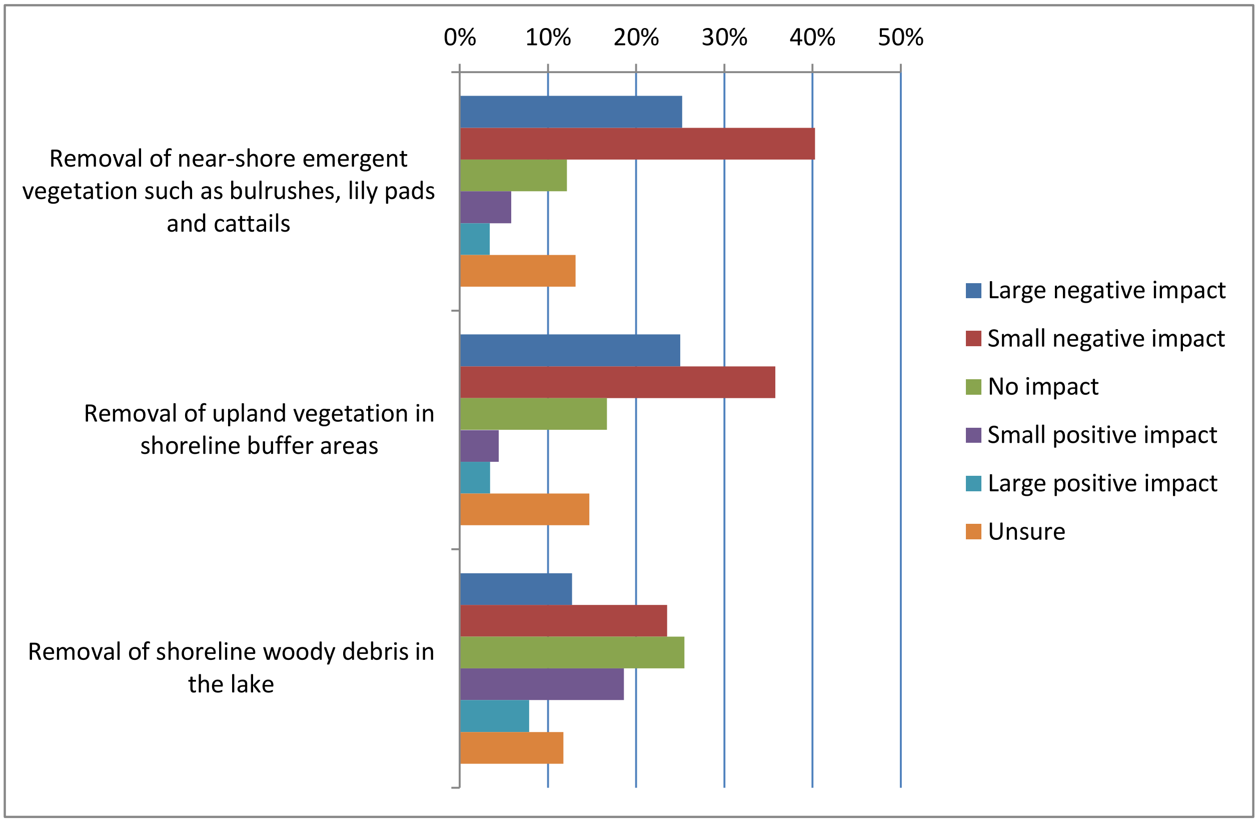


Figure 53. Survey results: What impact do you believe these practices have on the water quality of the Tomahawk Lake System?

Figure 55. Shoreland Buffer in Burnett County

Figure 54. Example Shoreland Buffer Diagram

DEFINITIONS

Natural shoreland restoration, shoreland habitat restoration, and shoreland/shoreline buffer restoration are frequently used interchangeably. They all refer to restoring the natural characteristics of the area near the water by planting native vegetation or allowing it to grow. Shoreland habitat restoration is the term used in state standards for restoring native vegetation. Shoreland buffers or vegetation protection areas are the terms used in county shoreland ordinances to refer to areas required to remain in native vegetation or to be restored to native vegetation. Shoreland buffers generally extend from the ordinary high water mark inland at least 35 feet nearly the entire length of the shoreline. They allow for an opening or view corridor for access and views to the lake. An example shoreland buffer diagram is shown in Figure 54. Standards for shoreland buffers vary by county and are explained in county shoreland ordinances.

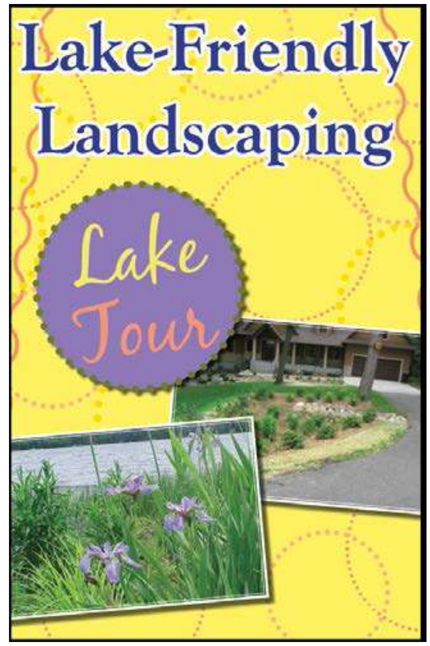
Natural shoreline restoration may also involve smaller areas of native plantings that may be less deep and cover a lower percentage of the shoreline length.

Demonstration Projects

Demonstration projects provide a location to view completed projects. They may be installed on public or private property. Burnett County has a shoreland buffer restoration site at a park in the Village of Siren. Bone Lake has demonstrations of native plantings at its North Landing. These public sites are available for viewing anytime the facilities are open.

Figure 56. Demonstration Site at Village of Siren Crooked Lake Park

Demonstrations at private property provide examples of how native plantings can work in more real-life settings. These sites can be shared with special tours, at open houses or parties, or through photos and information provided in websites, newsletters, publications, and presentations. The Balsam Lake Protection and Rehabilitation District hosted pontoon tours of demonstration sites. Homeowners who completed projects as part of the Amery Clean Lakes Project hosted parties. Both were helpful in encouraging others to participate.



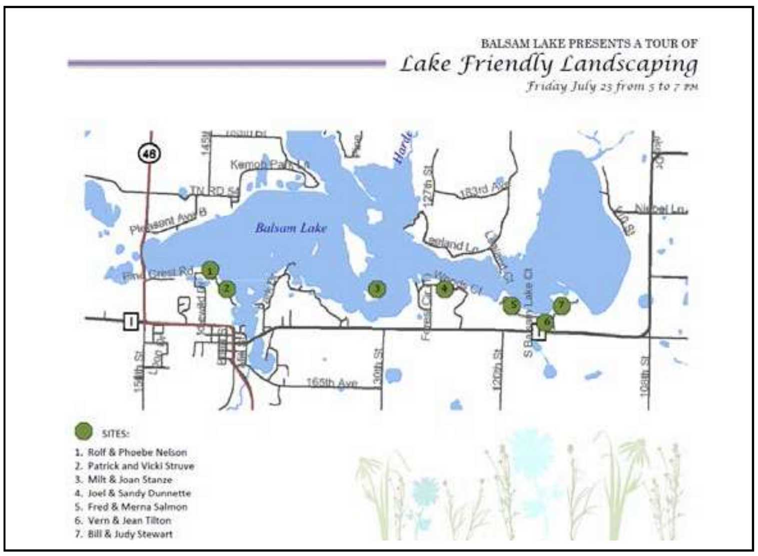


Figure 57. Pontoon Tour Promotion

Recognition

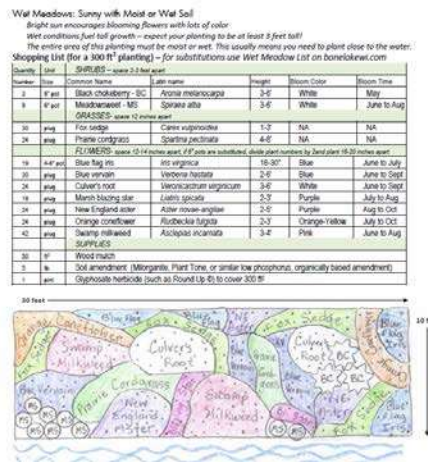
The Long Lake Protection and Rehabilitation District is installing signs to recognize owners who have installed native plantings and other projects to reduce runoff from waterfront property. Burnett County also has signs to acknowledge program participation and encourage others to join in.

Figure 58. Recognition Signs
KJE Design

Technical Assistance

Written Guidance

Some lake organizations provide technical assistance for natural shoreland restoration. For simple practices, this assistance might be in the form of a guidebook or brochure. The Bone Lake Management District promotes 10 foot by 35 foot native plantings, and encourages homeowners to prepare the site and plant on their own using simple instructions, standard designs, and shopping lists. The Burnett County program also provides a landowner guide for do-it-yourself projects. The WDNR Healthy Lakes Program provides a native planting guide with similar information.



Wet Meadows: Sunny with Moist or Wet Soil

Bright sun encourages blooming flowers with lots of color

Wet conditions fuel tall growth – expect your planting to be at least 5 feet tall!

The entire area of this planting must be moist or wet. This usually means you need to plant close to the water.

Shopping List (for a 300 ft² planting) – *for substitutions use Wet Meadow List on bonelakewi.com*

Quantity	Unit					
		SHRUBS				
Number	Size	Common Name	Latin name	Height	Bloom Color	Bloom Time
3	pot	Black chokeberry - BC	*Aronia melanocarpa*	3-6'	White	May
9	pot	Meadowsweet - MS	*Spiraea alba*	3-6'	White	June to Aug
		GRASSES				
30	plug	Fox sedge	*Carex vulpinoidea*	1-3'	NA	NA
24	plug	Prairie cordgrass	*Spartina pectinata*	4-6'	NA	NA
		FLOWERS				
19	pot	Blue flag iris	*Iris virginica*	18-30"	Blue	June to July
30	plug	Blue vervain	*Verbena hastata*	2-6'	Blue	June to Sept
24	plug	Culver's root	*Veronicastrum virginicum*	3-6'	White	June to Sept
18	plug	Marsh blazing star	*Liatris spicata*	2-3'	Purple	July to Aug
24	plug	New England aster	*Aster novae-angliae*	2-5'	Purple	Aug to Oct
24	plug	Orange coneflower	*Rudbeckia fulgida*	2-3'	Orange-Yellow	July to Oct
42	plug	Swamp milkweed	*Asclepias incarnata*	3-4'	Pink	June to Aug
		SUPPLIES				
30		Wood mulch				
5		Soil amendment (Milorganite, Plant Tone, or similar low phosphorus, organically based amendment)				
1		Glyphosate herbicide (such as Round Up ®) to cover 300 ft²				

Figure 59. Bone Lake 10X35 Guidance

Personalized Designs

Other organizations provide more personalized professional design assistance to homeowners. The Balsam Lake Protection and Rehabilitation District emphasized personalized design assistance for native plantings and other projects to reduce runoff from waterfront property. Initial consultations lasted about one hour with follow-up assistance if more detailed designs were requested. Many homeowners installed projects without any financial assistance from the lake district.

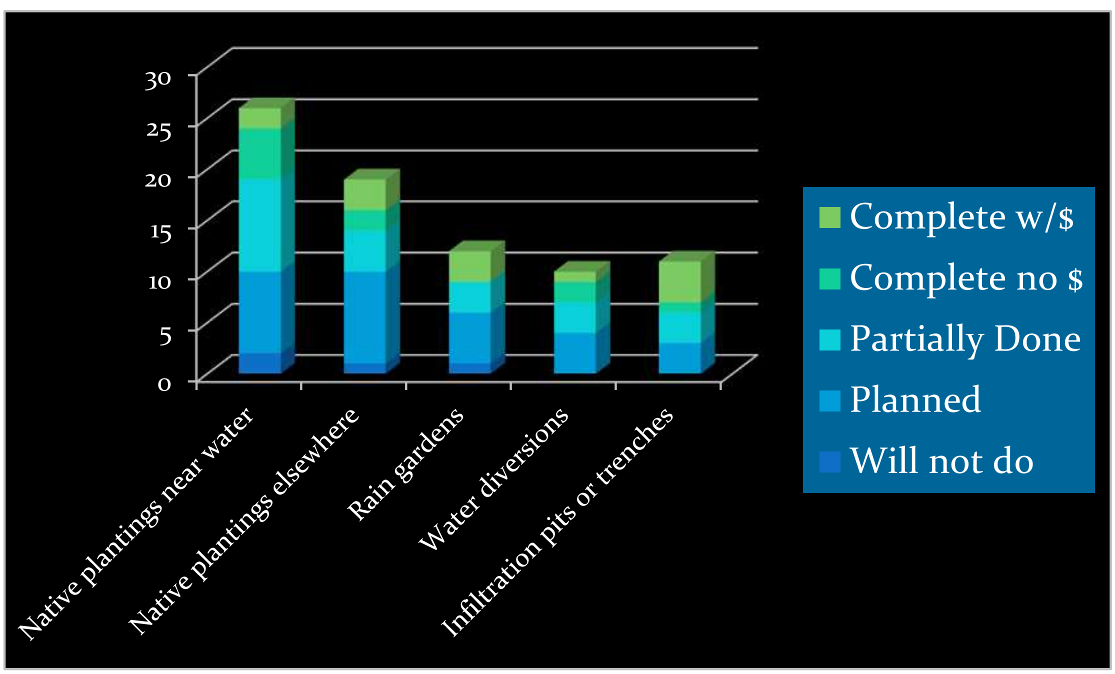


Figure 60. Installation Results with Personalized Design Assistance

Professional designs are also provided when programs provide cost sharing for installation. These designs provide the homeowner with enough information so they can install projects themselves or can put the project out to bid for landscaper installation.

Incentives

Examples of incentives include cost share payments, tax rebates, and even coupons. The Burnett County Shoreland Incentive Program uses cost sharing, an annual property tax rebate, participation shirts and hats, and shoreline signs as incentives to encourage participation. Enrollment in the program involves signing a perpetual covenant to restore and preserve a shoreland buffer on waterfront property in Burnett County. From 2000-2014 the program preserved 50 miles of shoreline on 723 parcels in Burnett County.

Cost sharing

Cost sharing is provided to encourage installation with the sponsor generally paying from 50 to 75% of the project installation cost. Some programs put caps on the maximum amount to be cost shared for each project or property. Examples are shown in Table 49. If Wisconsin DNR Lake Protection Grant funding is used, shoreland buffer cost sharing requires that plantings meet shoreland buffer standards described previously and include a perpetual covenant that is registered with the property deed.

Table 49. Shoreland Buffer Cost Sharing Examples

Program	Free Technical Assistance	Cost Share Program	Cost Share Landowner	Buffer Incentive Payments
Deer Lake Conservancy	Yes	75%	25%	No
Balsam Lake P&R District	Yes	70%	30%	No
Bone Lake Management District	Yes	75% (up to $4,500)	25%	No
Pipe Lakes P&R District	Yes	75% (up to $4,000)	25%	No
Burnett County Shoreland Incentive	Yes	70%	30%	$250 $50 annual tax rebate

Recent changes to the Lake Protection Grant program allow for smaller 350 square foot plantings through the Healthy Lakes Initiative Program with funding up to $1,000 per property and the cost share rate chosen by the grant sponsor. Property owner volunteers must be signed up for the program for lake organizations to apply for the grant. The Healthy Lakes grants provide money primary for installation. Technical assistance support is very limited. The Bone Lake Management District has paid 50 to 70% of the cost of installing 10X30 foot native plantings up to $500 for the past several years. They recently changed program standards to match the Healthy Lakes Initiative with 70% cost sharing up to $1,000 per project.

Coupons and Greenhouse Promotion

In Burnett County ten native shrubs were selected and local greenhouses were encouraged to carry them. A companion booklet provided photos and planting information. As part of a community based social marketing project sponsored by UW Extension, coupons provided a free native shrub or $7 discount toward the purchase of a shrub. While the value was equivalent, almost twice as many free coupons were used. The coupons were mailed with the county-wide *Lakelines* newsletter and promotional posters were displayed at the point of purchase. Greenhouse managers reported much greater interest in native plants as a result of the promotion. Previous coupon incentives promoted “Top Ten Native Plants” in Burnett County with similar coupons and supporting information.

Figure 61. Native Shrub Coupon and Poster Promotion

Waterfront Stormwater Practices

Waterfront stormwater practices include rock pits or trenches, rain gardens, in addition to shoreland buffers. Deer Lake, Bone Lake, Balsam Lake, and Burnett County offer programs and educational materials to encourage waterfront stormwater practices. These programs could be used as examples, and educational materials developed for these programs could be used on other lakes.

Figure 62. Rain Gardens Collect and Infiltrate Runoff Water in this Deer Lake Rain Garden (photo by Steve Palmer)

Figure 63. A Checklist for Waterfront Runoff Evaluation

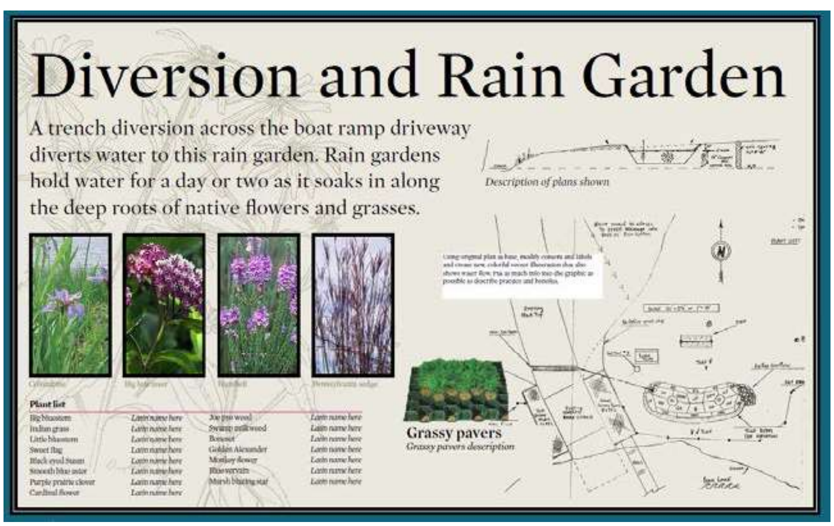


Figure 64. Waterfront Stormwater Demonstration Sign: Bone Lake North Landing by KJE Design

Choosing Management Options

To choose from the many management options that are available, it is important to do the following:

- Set clear goals and objectives
- Understand potential results
- Prioritize activities
- Consider social and political feasibility
- Investigate funding possibilities
- Seek available assistance

The goals, objectives, and action items in the work plan seek to incorporate the above considerations.

Social and political feasibility can be demonstrated, in part, by the results of the lake user survey. Providing cost sharing and technical assistance to assist waterfront owners with shoreline restoration was viewed to be fairly important by 35% of lake users and very important by 25% of lake users. Education for property owners was viewed to be fairly important by 37% of lake users and very important by 46% of lake users. Supporting zoning and land use regulations to protect water quality was also recognized as important with 22% stating it was fairly important and 49% very important.

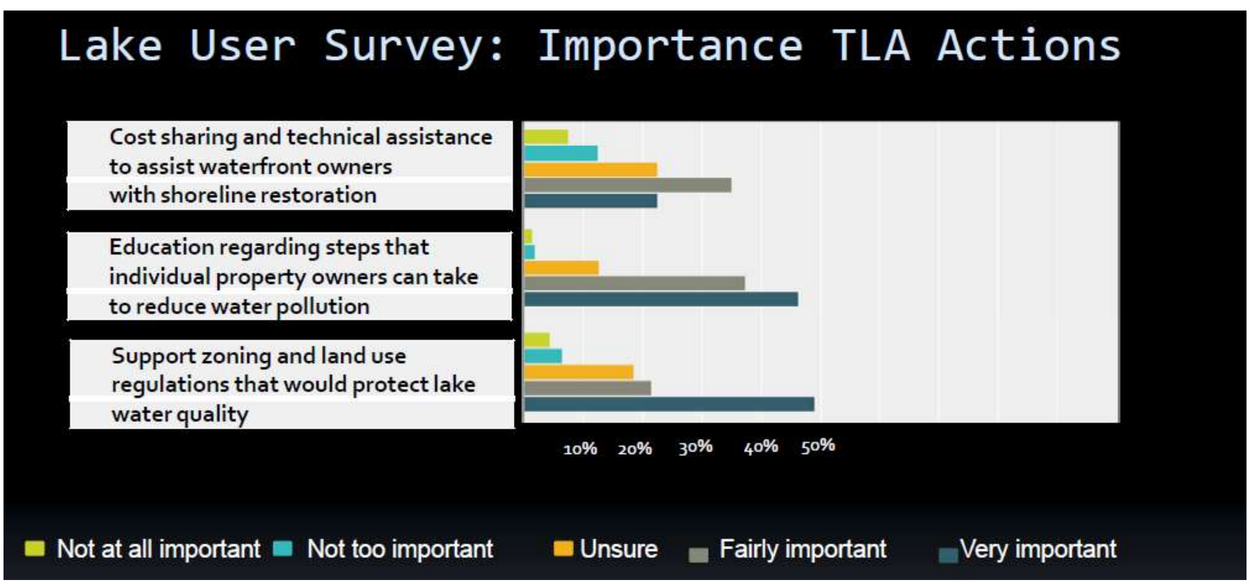


Figure 65. Lake User Survey: Importance of TLA Actions

CLMP Implementation Strategy

Plan goals, objectives, and strategies or actions are detailed below. The work plan in Appendix G details how action steps will be carried out listing timeline, board/committee assignment, resources needed, and partners. This work plan will be updated annually in October and November to keep actions and budgets current.

Goals are broad statements of direction.
Objectives are the detailed direction or desired result under each goal.
Actions are the means to reach the selected goals and objectives.

Vision

The Tomahawk Lake System is a place where water quality, wildlife habitat, natural beauty, recreational opportunities, and peace and tranquility are maintained and improved for present and future generations to enjoy.

Goals

Goal 1 Maintain a diverse, native aquatic plant community.

Goal 2 Preserve the quality of Tomahawk Lake System waters.

Goal 3 Balance recreational use with preservation of the natural lake environment.

Goal 4 Engage the lake community in lake and watershed stewardship practices.

Goal 5 Partner with area organizations, government agencies, and local businesses to support the goals of the lake management plan.

Guiding Principles

Cooperation and Leadership
The plan will be implemented with purposeful leadership and cooperation between private citizens and public officials.

Inclusiveness and Transparency
Plan implementation will be inclusive of local businesses, property owners, visitors and government agencies, and every effort will be made to solicit input and feedback wherever possible.

Protect Lake Character
We value the natural, social, and historic character of the Tomahawk Lake System.

Focus the Plan on End Results
Plan implementation strategies will focus on desired end results. The means used to achieve those results will vary. Results will be measured and reported.

Implementation Approach
Implementation will favor education, communication, cooperation, and direct action over legislation or regulations.

Reliable Funding
Provide for funding to support the implementation and periodic updates to the Tomahawk Lake System Comprehensive Lake Management Plan.

Organizational Capacity Building
Effective governance and management are integral to the sustainability and long-term effectiveness of the Tomahawk Lake Association Board to serve the Tomahawk Lake System community. The TLA Board monitors their activities to ensure they are providing the services which are valued by the TLS community and consistent with the Comprehensive Lake Management Plan vision statement. The board actively recruits and mentors new board members, provides board training, and encourages interest in lake issues and volunteerism through education, information, and social programming. To insure the continued viability of the Tomahawk Lake Association, the TLA Board is planning to partner with the Wisconsin Lakes Partnership to review options for organizational capacity building and associated actions items. Areas of focus will be communication, leadership, information and education, and financial security.

Goal 1. Maintain a diverse, native aquatic plant community.

Objective a. Avoid a trend of long-term increase in dense growth of Eurasian water milfoil.

Evaluation/Monitoring (track and report the following to analyze long-term trends)

- ✓ acres in dense beds/polygons
- ✓ frequency of occurrence of EWM within polygons (generally >50%)
- ✓ average rake fullness of EWM within polygons (generally 1 or more)

Tracking Eurasian Water Milfoil Growth
While the Eurasian water milfoil control program seeks to reduce dense growth and spread of the plant, other factors beyond control method effectiveness influence its growth. Environmental factors such as lake levels, rainfall, water clarity, snow amounts in winter, and lake water temperature can affect the growth of Eurasian water milfoil. These factors vary from year to year and are obviously outside the control of TLA program managers. Similarly, spread of EWM to other parts of the lake via plant fragmentation and drift is influenced by environmental factors outside of TLA control.

Objective b. Manage invasive species using the most appropriate, effective treatment methods.

Eurasian Water Milfoil Control

Action. Assign appropriate management method

1. Identify areas with Eurasian water milfoil growth
2. Map general locations – Sentinel volunteer program (2times/year) + lake user sightings
3. Evaluate EWM locations for appropriate treatment method
4. Assign appropriate treatment method
5. Map polygons for chemical treatment
6. Map areas for HCS management

Action. Implement Chemical Treatment

Chemical Treatment Criteria (consider all)

- Visually estimated high frequency of occurrence and high density of EWM growth
- Water depth > 2ft.
- Herbicide not readily dispersed
- > 4,400 ft2

Other considerations

- Native species presence and distribution (visually estimated high frequency of occurrence of natives, high rake density of Northern Water Milfoil or other species susceptible to 2,4-D or good competitor to EWM may discourage chemical treatment)
- Bed history
- Depth of EWM below surface (in deep water, EWM might not pose as much concern)
- Overall size and width of treatment polygon (narrow beds near drop offs are a challenge to treat)

Chemical Treatment Objective(s)

- Attain minimum 65% reduction in frequency of occurrence within herbicide treatment polygons within treatment year.
- Consider adding a qualitative site evaluation for treatment.

Qualitative Site Evaluation

Qualitative site evaluation provides another means to evaluate EWM growth. It can aid in evaluating treatment effectiveness and determining the most appropriate treatment method and timing. With qualitative evaluation, a numerical score might be assigned for a range of EWM growth observed, as in the example that follows:

1	no vegetation present
2	sparsely vegetated, EWM present
3	vegetated, EWM less than 20%
4	vegetated, EWM greater than 20%, less than 40%
5	vegetated, EWM greater than 40%, less than 60%
6	vegetated, EWM greater than 60% less than 90%
7	heavy vegetation, EWM greater than 90%, canopied.

The TLA proposed treatment areas mapping would include the qualitative site evaluation number for each polygon (or selected area). Qualitative site evaluation could be used to assign density levels of any aquatic invasive or native plant, or for an overall examination of the entire plant community with minor changes to the ranking criteria and mapping.

Chemical Treatment Process

1. Map areas for chemical treatment
2. Conduct detailed pre-treatment monitoring, measuring frequency of occurrence and rake fullness of EWM and native plants within each polygon.
3. Apply for aquatic plant management permit
4. Conduct pre- monitoring verification of proposed treatment areas
5. Implement early season herbicide treatment
6. Conduct post-treatment monitoring
7. Report chemical treatment results in Aquatic Plant Management Report

Evaluation

- ✓ Conduct pre-and post-treatment monitoring to assess within year EWM frequency of occurrence reduction.
- ✓ Compare year-to year proposed treatment acreage and pre-treatment frequency and rake fullness by polygon and overall treatment polygons.

Action. Implement Hydraulic Conveyor System (HCS)

Hydraulic Conveyor System Criteria (any of below)

- High traffic areas where fragmentation and spread is likely – near docks and boat houses (highest priority)
- Small areas of concentrated growth
- New areas of infestation (low density: few plants/m^2, few total plants)
- Areas where EWM is mixed with native aquatic plants
- Shallow water (depth <2 ft.)
- Flowing water (as in the Thoroughfare)

Hydraulic Conveyor System Process

1. Map general areas for HCS control (identified as "high risk" for the permit application)
2. Apply for aquatic plant management permit
3. Identify specific sites for HCS harvest
4. Conduct Hydraulic Conveyor System process (first Monday in June through at least Labor Day)
5. Complete Hydraulic Conveyor System Annual Report

Evaluation

✓ Track sites harvested, approximate area (square feet), EWM % harvested (compared to total plants), and pounds of EWM harvested. Divers also record GPS locations, water depth, and EWM density level.

Why is the total area harvested with the Hydraulic Conveyor System difficult to track?
At first glance area harvested might seem like an easy item to track. However, the difficulty lies in drawing the outline of the area to be measured. Once the area is determined and drawn, results are not readily comparable. The HCS tends to target small clumps of growth and sparse growth of EWM. Very sparse growth can cover quite a large area. Small clumps might also be measured separately to cover only a small area. The same amount of EWM might be harvested in each instance.

✓ Develop a meaningful method to assess overall effectiveness of Hydraulic Conveyor System harvesting (consider following methods):

- amount of EWM growth in subsequent years following previous season harvesting (stem count, or other measure) within selected, specific 10 feet square (or other area) grids
- pre and post frequency of EWM in selected priority harvest areas (fine point grid, more than one area)
- changes in number of points identified by Sentinels for HCS harvest
- number of years a previously chemically treated bed stays below herbicide treatment threshold because of hand removal employed

Action. Encourage hand-pulling of Eurasian water milfoil and avoidance of EWM beds.

Methods:
- *Web site teaching module*
- *Facebook*
- *Direct mail*
- *Seminar (notification via email blasts)*
- *Lake maps with EWM beds*

Message:
- *AIS identification and removal*
- *Encourage boaters to avoid EWM beds*

Audience:
- *Riparian owners (primary)*
- *Friends of the lake (secondary)*

Purple Loosestrife Control
Actions
Large areas
1. Release beetles to minimize purple loosestrife growth
2. Consider herbicide or other control methods if beetle release is not successful.

Isolated patches/small areas
1. Encourage landowners to control purple loosestrife by hand-pulling or cutting blossoms. Owners should contact the Oneida County Aquatic Invasive Species Coordinator for guidance on additional control measures. Provide instruction regarding control options.

Evaluation
✓ Map purple loosestrife growth (annually)

Aquatic Invasive Species Monitoring
Yellow-flag iris
Narrow-leaf cattail

Actions
1. Recruit and train volunteer "special forces" group to monitor growth of aquatic invasive species listed above.
2. Monitor growth of aquatic invasive species on monitoring list and map annually.
3. Consider control methods if monitoring indicates plants are likely to spread.
4. Additional species may be added to the list if detected in the Tomahawk Lake System and identified as a priority for monitoring.

All Aquatic Invasive Species
Action
1. Investigate new methods to effectively control AIS and implement as appropriate.

Objective c. Preserve native plant communities.

Actions

1. Minimize damage to native plant communities in AIS control efforts by using early season chemical treatment, selecting appropriate sites for chemical and HCS control, etc.

2. Monitor and track native species that are susceptible to herbicide impacts from EWM control efforts.

> *Northern water milfoil, present in Tomahawk Lake, is also susceptible to 2,4-D according to the product label. Small pondweed (P. pusillus) and slender naiad (N. flexilis) have also shown declines with some low-dose (0.2-0.5 ppm), large-scale, liquid 2,4-D treatments monitored in Wisconsin lakes (Nault et al 2014; Nault 2015). The susceptibility of these species to higher-dose (2.0-4.0 ppm) small-scale 2,4-D treatments has not yet been well studied in the field.*

3. Map areas of emergent, floating and other high quality aquatic plant communities.

> *Initial maps of emergent and floating plants were developed from the 2015 point intercept survey and are shown as Figures 20-22 in this plan.*

4. Identify and implement actions to protect emergent, floating, and other high quality aquatic plant communities.

> *Actions to protect aquatic plant communities might include no-wake zones, installation and preservation of woody habitat/fallen trees in lake, preservation of native plants by property owners, and waterfront/shoreland restoration and stormwater projects.*

Evaluation/Monitoring

- ✓ Pre and post monitoring surveys (annually)
  - Mean native richness/point (by EWM treatment polygon)
  - Overall FQI, Simpson Diversity Index
  - Indicator native species frequency of occurrence: northern water milfoil, small pondweed and slender naiad

- ✓ Point intercept surveys (every 5 years)
  Same stats as above for whole lake

Objective d. Prevent new aquatic invasive species infestation.

Actions

1. Implement an effective Clean Boats Clean Waters program at the three public landings, using paid and volunteer attendants. [*Note: consider fishing tournament schedules for CBCW staffing*.]

2. Provide AIS prevention information and plant disposal containers at private landings (Lakeside Condominium, old Camp Minocqua, and Indian Shores).

3. Identify and address likely pathways for AIS introduction: fishing tournaments, dock installation, private ramps, duck hunters, trappers, and others.

4. Train "special forces" volunteers and landowners to identify Priority Target AIS. Develop specific prevention measures as needed for these species.

   > *DEFINITION: Priority Target AIS are those most likely to threaten TLS waters such as Flowering Rush, Yellow Floating Heart, Phragmites, Zebra Mussels, and Spiny Water Flea.*

5. Prevent runoff of sediment and nutrients from near-shore areas to limit establishment of nutrient-rich sediment prone to AIS infestation over the long term (through restoration of natural shorelines and shoreland stormwater projects).

6. Implement AIS education program

   Methods:
   - *Current TLA communication tools*
   - *Signs*
   - *Place mats, grocery bags, bait container labels, book marks*

   Audience:
   - *Lake users (more specifically define via pathways identified above)*

   Messages:
   - *AIS identification and reporting*

Evaluation/Monitoring

- ✓ Invasive plant monitoring results: no new confirmed AIS
- ✓ Point intercept surveys (every 5 years)

Goal 2. Preserve the quality of Tomahawk Lake System waters.

Objective a. Support watershed land use practices which limit nutrient and soil runoff.

Objective b. Encourage the preservation, enhancement, and restoration of natural shorelines.

DEFINITION *A watershed is the land area that drains to a lake or river.*

Actions

1. Initiate demonstration projects and provide design assistance to encourage shoreland restoration and stormwater projects.

    a. Seek available technical assistance for shoreland projects from the Oneida County Land and Water Conservation Department and the Wisconsin Department of Natural Resources.
    b. Support and encourage nursery and landscaper partners in shoreland restoration and stormwater efforts. (e.g., native plant availability and promotion)

2. Participate in public dialog regarding land use policy and zoning and stormwater regulations as they potentially influence Tomahawk Lake System water quality.

3. Help to identify and implement stormwater water management projects at priority areas such as public access sites.

4. Educate and communicate why shoreland restoration and stormwater projects are important for the preservation of the Tomahawk Lake System water quality. Identify and encourage stewardship actions to preserve water quality.

    Behaviors to encourage
    - *Allow a 10 foot or deeper no-mow area along your shoreline*
    - *Consider a 350 ft^2 or larger native planting*
    - *Take advantage of available consulting and design assistance to:*
        - *complete shoreland restoration*
        - *capture stormwater runoff from your property*
    - *Consider installing a shoreland restoration or stormwater project like at our demonstration sites*
    - *Encourage growth of natural vegetation such as tag alders to prevent shoreline erosion.*

    Barriers to these behaviors
    - *Availability of local expertise*
    - *Impression of telling people what to do*
    - *False perceived connection with enforcement*
    - *Preference for manicured landscaping*

Messages to use

- *Why shoreland and stormwater practices are important. Provide specifics for each practice.*
- *Lake stewardship begins with you and how you manage your property.*
- *Preserve the natural shoreland and lake environment.*
- *We share an ethic of lake stewardship.*
- *Keep the North the North!*

Methods to address

- *Share maps from shoreline inventory*
- *Promote installed demonstration sites with U-tube video, boat tours*
- *Brochures, Web site, newsletter, Facebook page*

Evaluation

- ✓ Support and implement the WDNR Citizen Lake Monitoring (CLM) Program. Consider additional locations for CLM. – (Little Tomahawk Lake, historic monitoring sites in Tomahawk Lake bays)
- ✓ Track project participation in shoreland projects
- ✓ Track phosphorus reductions with larger stormwater projects

Goal 3. Balance recreational use with preservation of the natural lake environment.

Objective a. Promote an environment which encourages a quality Tomahawk Lake System fishery.

Action. Identify and map critical spawning and nursery areas.

> ***Critical spawning and nursery areas** include: woody cover, aquatic vegetation, gravel beds (for walleye), and shoreland wetlands. DNR fisheries biologists can provide guidance for defining these areas.*

Action. Participate in public and private dialog in support of a sustainable fishery.

Action. Encourage fisheries stewardship

Behaviors to encourage

- *Don't disturb aquatic vegetation and fallen trees in the water for fish habitat*

Barriers to these behaviors

- *People want to clean up their shorelands*

Messages to use

- *Explain why wood and plants in the water are important because they provide fish habitat.*

Methods to address

- *Develop: A new way of looking at spring clean-up – checklist.*

Evaluation

- ✓ Results of WDNR fish surveys

Objective b. Promote courteous and responsible boating and minimize recreation conflicts.

Action: Use TLA education methods to promote courteous and responsible recreational use of the lake.

Behaviors to encourage

- *Encourage responsible use of watercraft*
- *Lake users are considerate of others.*
- *Travel at slow, no- wake speed within 100 feet of shoreline – it's the law*
- *Follow boating regulations*

Barriers to these behaviors

- *People may not like to be told where and how to recreate.*

Messages to use

- *Ways to boat safely*
- *Courteous lake use*
- *Use common sense*

Methods to address

- *Web site content*
- *Links to additional web sources*
- *Eblasts*
- *Brochure*

Objective c. Preserve natural communities and scenic beauty in the Tomahawk Lake System watershed.

Action. Map critical habitats for shoreland and aquatic species.

Mapping critical shoreland and aquatic habitats can help the TLA effectively influence local land use decisions, promote lake stewardship, and partner for land preservation.

Action. Participate in public dialog and promote the identification of primary and secondary environmental corridors.

DEFINITION: Primary and Secondary Environmental Corridors

Environmental corridors are elongated areas in the landscape that encompass most of the best remaining woodland, wetlands, prairie, wildlife habitat, and surface water and attendant floodlands and shorelands, together with many related historic, scenic, and recreational sites. It is recommended that these corridors be preserved in essentially natural, open uses.

Primary environmental corridors are concentrations of significant natural resources at least 400 acres in area, at least two miles in length, and at least 200 feet in width.

Secondary environmental corridors are concentrations of significant natural resources at least 100 acres in area and at least one mile in length.

Source: A Regional Land Use Plan for Southeastern Wisconsin 2035
Planning Report No 48
Southeastern Wisconsin Regional Planning Commission

Action. Identify potential threats to mapped habitat areas and effective means for habitat protection. Facilitate collaborative preservation projects using conservation easements and fee simple ownership.

Action. Raise awareness regarding habitat areas and habitat protection.

Behaviors to encourage
- *Protection of habitats for species that people love such as loons, songbirds, eagles, owls, and frogs.*

Barriers to these behaviors
- *Residents are unaware of significant habitat areas and what to do to preserve them.*

Messages to use
- *Identify where critical habitat areas are on the lake.*

Methods to address
- *Share maps with lake residents.*

Objective d. Better define and encourage appreciation of natural scenic beauty.

Action. Encourage dialog/discussion of natural scenic beauty through activities such as photo, poetry, and/or essay contests.

Objective e. Monitor Southern Naiad growth for potential impacts on recreation and navigation.

Action. Continue monthly monitoring of Southern Naiad growth in Thoroughfare Bay.

Goal 4. Engage the lake community in lake and watershed stewardship practices.

See individual goals for targeted behaviors, identified barriers, messages and methods.

Common methods to engage the lake community
Website
Newsletter
Facebook page
Email blasts
Displays
Kiosks at public boat landings
Brochures or flyers
Shoreland management guide
Lake stewardship information for new property owners
Awards or recognition program for shoreline stewardship efforts
News releases

Goal 5. Partner with area organizations, government agencies, and local businesses to support the goals of the lake management plan.

Objective. Understand and share information and solutions regarding local lake-related issues.

Action. Meet on a regular basis with lake representatives and local government agencies.

Action. Provide local newspapers, radio stations, TV stations, and other local media with information regarding current TLA education and lake management programs.

Action. Meet with local units of government to share TLA CLMP information and project implementation.

Action. Participate in the Oneida County Lakes and Rivers Association.

Action. Participate in the AIS partnership with Oneida County and other lake groups.

TLA CLMP Work Plan

The TLA CLMP Work Plan, included as Appendix G, outlines how each action will be accomplished listing a timeline, assignments, resources needed, funding sources, and partners. The work plan will be reviewed each year and updated as needed. Actions may be modified as new information becomes available. The TLA board will approve updated implementation charts including modified management actions.

Funding Plan Implementation

The main sources of implementation funds are TLA contributions and Wisconsin Department of Natural Resources grants. Potential grant sources are listed in the TLA CLMP Implementation Chart funding source column for each action item. The WDNR Surface Water Grant Program has two major types of grants: planning and management. Planning grants are due each year by December 10. Management grants are due each year by February 1. Additional detail for the most likely grant sources for initial CLMP implementation is provided in Table 50 below.

Table 50. Wisconsin Department of Natural Resources Surface Water Grants for Plan Implementation

Grant Type	Due Date	Maximum Award	Maximum Grant DNR %
Large Scale Lake Planning	December 10	$25,000	67%
Small Scale Lake Planning	December 10	$3,000	67%
AIS Education, Planning, Prevention	December 10	$150,000 (Categories above and below $50,000)	75%
AIS Clean Boats, Clean Waters	December 10	$4,000/landing/year	75%
Lake Protection: CLMP Plan Implementation	February 1	$200,000	75%
Lake Protection: Healthy Lakes Projects	February 1	$25,000	75%
AIS Established Population Control	February 1	$150,000	75%

Fair Share Contributions

TLA established its Fair Share program to encourage and engage lake property owners in the support of TLA initiatives. Prior to Fair Share, TLA relied upon a few very generous donors, while many property owners were not engaged or even aware of the efforts of TLA to preserve and protect Tomahawk Lake. TLA initiated a marketing and communication plan to educate property owners and introduced full transparency to the budget, activities, and funding of TLA. Approximately 40% of TLA's annual budget comes from TLA members, and it was decided that the target fundraising amount should be divided up equally so everyone pays their Fair Share on an annual basis. The project has been very successful, as we have increased our membership and have been able to consistently raise the necessary funds to support the organization and its efforts.

Volunteer Hours and In-Kind Contributions

Volunteers provide significant hours that are used to match grant programs. Use of boats and equipment also provides match for WDNR grants. For example, for the 2015 Aquatic Invasive Species Control grant, a value of $56,000 or almost 25% of the program budget was contributed by volunteer and in-kind match.

Town Contributions

The Towns of Minocqua, Woodruff, Hazelhurst and Lake Tomahawk have made annual contributions toward Eurasian Water Milfoil control and aquatic invasive species prevention. Ongoing support is anticipated with the implementation of this plan.