AQUATIC PLANT MANAGEMENT PLAN UPDATE

Teal Lake

Lost Land Lake

Ghost Lake

Teal, Lost Land and Ghost Lakes
Improvement Association, Inc.
Hayward, WI

May 2017

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Acknowledgments

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QLA President Bob Dale appointed this committee of volunteers; he and Secretary Shari Peterson, and particularly QLA Treasurer Gayle Little provided helpful information on several occasions to facilitate completion of this plan.

Alex Smith (WDNR Water Resources Management Specialist) offered valuable insights and guidance.

All members of the Teal, Lost Land, and Ghost Lakes Improvement Association, Inc. owe these AIS Committee and QLA Board members a debt of gratitude for volunteering their time and talent to this project. This document will provide valuable guidance to the conservation (wise use and management) of "The Quiet Lakes" for years to come.

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Executive Summary

With approval by the Board of Directors of the Teal, Lost Land and Ghost Lakes Improvement Association, Inc. (popularly referred to as the "Quiet Lakes Association" or QLA), the Aquatic Invasive Species (AIS) Committee has updated a Plan that was last revised in December, 2012. Despite several years of WDNR-funded boat-landing inspection, an invasive aquatic plant, Hybrid Eurasian Water Milfoil (HEWM), was discovered in Lost Land Lake during a 2013 survey by the Great Lakes Indian Fish and Wildlife Commission. This was a big concern, because HEWM can dominate and displace native plants, eventually leading to impairment of habitat for fish, wildlife, and associated recreational activities. Since then, HEWM has spread within Lost Land Lake despite an attempt at chemical control in 2015. Our main purpose in updating this plan is to document the expanding distribution of HEWM and outline options for minimizing its impact and preventing its spread to Teal Lake, the Teal River Flowage, Ghost Lake, and other waters.

The point-intercept aquatic plant survey conducted under contract by Flambeau Engineering, LLC in July/August 2016 revealed a healthy, species-rich community of native plants in each lake. No aquatic invasive species (AIS) were detected in Teal or Ghost lakes; but HEWM was mapped in several bays of Lost Land Lake. The 2016 survey did not extend into the Teal River Flowage downstream of the Teal Lake outlet. Based on our fall/winter 2016/2017 review of Flambeau Engineering's summer 2016 survey data, the AIS Committee recommends the following plan elements to the QLA Board of Directors in order to guide our management efforts:

Goal: To prevent establishment of any new aquatic invasive species in the Quiet Lakes, and to reduce the occurrence of Hybrid Eurasian Water Milfoil (HEWM) in Lost Land Lake, thus minimizing adverse impacts on native aquatic plants, other aquatic organisms, and human values such as aesthetics, recreation, and real estate.

We will have achieved this goal if the next point-intercept aquatic plant survey conducted two years after the onset of mechanical harvest (probably 2020-2022) and every four years thereafter reveals the following objectives have been met:

Objective 1: No new aquatic invasive species (AIS) in any of our lakes

Objective 2: Maintain a Simpson Diversity Index (SDI) ≥ 0.90 and a Floristic Quality Index (FQI) ≥ 30 in Teal and Lost Land lakes (see definitions on page 19, Appendix)

Objective 3: No spread of HEWM from Lost Land Lake to connected waters (Teal Lake and Teal River Flowage) or other area waters (including Ghost Lake)

Objective 4: Reduced frequency (fewer sites) and coverage (area per site) of dense beds of HEWM in Lost Land Lake

Proposed Strategies: We recommend mechanical removal of HEWM in late spring (and perhaps early fall) when this invasive plant is taller than most native plants and is therefore vulnerable to selective mechanical removal without major impact to native plants. Stopgap chemical control of HEWM is recommended for spring of 2017 in order to minimize spread until harvest equipment can be purchased (or contracted for hire) and placed into operation starting in 2018. In addition to control operations, we recommend an aggressive, web-based campaign aimed at informing lake users about the presence of HEWM in Lost Land Lake, and about steps everyone can take to avoid spreading HEWM and other aquatic invasive species in connected waters (Teal Lake and the Teal River Flowage), Ghost Lake, and other area waters.

Introduction – Physiography, Trophic Status, and Public Use

The "Teal, Lost Land and Ghost Lakes Improvement Association, Inc." (popularly referred to as the "Quiet Lakes Association" or QLA) seeks to promote healthy ecosystems, aesthetic qualities, and compatible recreational uses in the connected waters of Teal Lake, Lost Land Lake, and the Teal River Flowage, as well as nearby Ghost Lake. Collectively, these waters are known as the "Quiet Lakes" due to a Spider Lake Township ordinance that limits watercraft speed to a maximum of 10 mph. The Quiet Lakes are located in Sawyer County north of U.S. Highway 77 approximately 20 miles east of Hayward, Wisconsin.

Extensive background information about each waterbody within the purview of this Plan can be found at the following website managed by the Wisconsin Department of Natural Resources:

http://dnr.wi.gov/lakes/lakepages/Results.aspx?location=58&page=ANY&letter=ANY

By entering the lake name in a search box, or by clicking on the underlined link to the lake in an alphabetized list, users can access information that provides an overview, map, facts and figures, and more. Readers are referred to the WDNR website for general background information which will be summarized only briefly in this document.

Lost Land Lake

Lost Land Lake is a 1,264-acre drainage lake with a maximum depth of approximately 21 feet, a mean depth of 12 feet, and an estimated volume of 15,210 acre-feet. On the west side of Landing Camp Bay, the Wisconsin Department of Natural Resources (WDNR) maintains a public access with concrete boat ramp, courtesy dock, and parking space for 6-8 vehicles with trailers. From 2012 through 2014, the QLA hired summertime monitors with grant funding from WDNR in an attempt to minimize the risk of aquatic invasive species transport to and from Lost Land Lake via this sole point of public access. However, this "Clean Boats, Clean Waters" project was discontinued after the 2013 introduction and subsequent spread of HEWM had been well documented. This decision was based on a QLA Board decision in 2015, reaffirmed by consensus view of the AIS Committee in 2016, that a relatively low proportion of users accessed the system from the public boat landing in comparison with users originating from private residences and three of the five most active resorts which have private boat landings and have worked with the QLA Board on this issue.

Citizen volunteers worked in cooperation with WDNR to record observations and collect surface water samples for laboratory analysis at a site known as the "deep hole" in Lost Land Lake from 1993 through 2012. QLA Vice-President Norm Bratteig assumed these duties from George Pagnucco in 1999 and continued through 2012, with help from Paul Wiklund during 2009-2011. Between 1993 and 2012, Carlson's Trophic State Index (TSI; Carlson 1977) has ranged between 45 and 60 (excluding one outlier), allowing us to classify Lost Land Lake as slightly eutrophic. (A "mesotrophic" lake of mid-range productivity would exhibit a TSI ranging between 40 and 50.) There was no detectable upward or downward trend in TSI regardless of the metric used to calculate it during the 20-year monitoring period (http://dnr.wi.gov/lakes/clmn/reports/tsigraph.aspx?stationid=583056).

The slightly eutrophic status of Lost Land Lake was consistently predicted by all three metrics used to calculate TSI. During the last 10 years of monitoring (2003 through 2012), the average annual July-August ranges for these metrics were 5.9 to 6.6 feet for Secchi disk transparency (depth at which a black-and-white disk disappears from view at the surface), 17.0 to 21.0 micrograms per liter for total phosphorus concentration (the limiting nutrient for planktonic algae production), and 10.0 to 15.6 micrograms per liter for chlorophyll *a* concentration (direct indicator of ongoing production by planktonic algae).

During the only three-year period (2009-2011) when both water temperature and dissolved oxygen concentration were measured in 3-foot increments from the surface to the bottom of the 20-foot "deep hole" site, Lost Land Lake exhibited no July-August thermocline (depth zone of rapid temperature change). Relatively warm water (low- to mid-70s F) occurred from the surface to the bottom due to thorough mixing of the shallow lake basin by wind and wave action. Dissolved oxygen profiles sometimes revealed a pronounced July-August oxycline (depth zone of rapid change in dissolved oxygen concentration) in the deepest layers sampled, with levels too low for normal fish activity (less than 3 milligrams per liter) measured at depths greater than 15-18 feet. But just as frequently, there was no oxycline at all, reflecting a very thorough mixing of the entire lake from top to bottom.

Teal Lake and Teal River Flowage

Lost Land Lake flows into Teal Lake via a shallow, mile-long navigable thoroughfare fringed with dense growths of native aquatic plants. Teal Lake is a 1,024-acre drainage lake with a maximum depth of approximately 31 feet, a mean depth of 15 feet, and an estimated volume of 15,400 acre-feet. The only convenient public boater access to Teal Lake is via the mile-long thoroughfare from Lost Land Lake. The Teal River flows south from the outlet of Teal Lake and under the Highway 77 bridge where it becomes the upper end of the 66-acre Teal River Flowage.

This long, narrow impoundment was created by a 3-foot rock roller dam built during the logging era and maintained to this day by the QLA under agreement with the U.S. Forest Service. This dam has no engineered water control structure; the elevation of the rocks regulates water levels in Teal and Lost Land lakes which drain into the Teal River Flowage. The U.S. Forest Service maintains a little-used sand/gravel boat launching area with space for one or two vehicles with trailers to park on National Forest property just upstream of the rock roller dam – accessible by gravel road off Sawyer County Road S. The weedy, muck-bottomed Flowage has a maximum depth of 9 feet and a mean depth of 3 feet, making it vulnerable to invasion by HEWM and other invasive plants. There has been no water quality monitoring on the Teal River Flowage.

Among the 15,000 lakes and impoundments in Wisconsin, Teal Lake is one of only 103 to have "Outstanding Resource Water" (ORW) status under NR 102.10, Wisconsin Administrative Code. An ORW is a lake, stream, or flowage having excellent water quality, high recreational and aesthetic value, and high quality fishing. ORWs are free from point-source pollution. As a citizen volunteer working in cooperation with WDNR, QLA Past-President Jack Wellauer has recorded observations and collected surface water samples for laboratory analysis from the "deep hole" on Teal Lake since 2002 when he assumed the volunteer duties begun by Mary Witt in 1992. Between 1992 and 2016, Carlson's Trophic State Index (TSI; Carlson 1977) has ranged between 45 and 60, allowing us to classify Teal Lake as slightly eutrophic. (A "mesotrophic" lake of mid-range productivity would exhibit a TSI ranging between 40 and 50.) There has been no detectable upward or downward trend in TSI regardless of the metric used to calculate it during the past 24 years at Teal Lake (http://dnr.wi.gov/lakes/clmn/reports/tsigraph.aspx?stationid=583055).

The slightly eutrophic status of Teal Lake was consistently predicted by all three metrics used to calculate TSI. Over the past 10 years (2007 through 2016), the average annual July-August ranges for these metrics were 4.7 to 8.6 feet for Secchi disk transparency (depth at which a black-and-white disk disappears from view at the surface), 26.4 to 34.2 micrograms per liter for total phosphorus concentration (the limiting nutrient for planktonic algae production), and 12.7 to 21.5 micrograms per liter for chlorophyll *a* concentration (direct indicator of ongoing production by planktonic algae).

During the most recent three years (2012-2014) when water temperature and dissolved oxygen concentration were measured in 3-foot increments from the surface to the bottom of the 33-foot "deep hole" site, Teal Lake exhibited a distinct July-August thermocline (depth zone of rapid temperature change), with relatively warm water at depths less than 18-21 feet and relatively cold water at depths greater than 24-27 feet. On 8/21/12, however, the lake had undergone an anomalous "early turnover" and become almost isothermous from surface to bottom. Usually that does not happen until mid-September. Dissolved oxygen profiles revealed a pronounced July-August oxycline (depth zone of rapid change in dissolved oxygen concentration), with high levels generally occurring at depths less than 18 feet, but levels too low for normal fish activity (less than 3 milligrams per liter) measured at depths greater than 21-24 feet. These data reflect normal patterns of mid-summer stratification in a slightly eutrophic lake of moderate depth.

<u>Ghost Lake</u>

Nearby Ghost Lake (not connected to Teal or Lost Land lakes) is a 372-acre drainage lake impounded by a 15-foot dam with a maximum depth of approximately 12 feet and an estimated volume of 2,000 acre-feet. The U.S. Forest Service maintains a lightly used public access with concrete boat ramp on the east side of Ghost Lake. During 2012 and 2013, the QLA hired summertime monitors with grant funding from WDNR in an attempt to minimize the risk of aquatic invasive species transport to and from Ghost Lake and the upper end of the Teal River Flowage at Larson Road from these points of public access. However, this "Clean Boats, Clean Waters" project was discontinued in 2014 because the rare use of these points of access did not warrant the cost of monitoring them or the time required by our Treasurer to track expenses and request grant reimbursements.

Citizen volunteers worked in cooperation with WDNR to record observations and collect surface water samples for laboratory analysis at a site known as the "deep hole" in Ghost Lake from 1999 through 2001 (Candice Gryzik, Secchi disk readings only) and from 2003 through 2006 (Mary Witt and Debi Cooke). From 2003 through 2005 (the only years of monitoring total phosphorus and chlorophyll *a*), Carlson's Trophic State Index (TSI; Carlson 1977) ranged between 47 and 67, allowing us to classify Ghost Lake as eutrophic.

The eutrophic status of Ghost Lake was predicted by all three metrics used to calculate TSI. During seven years of monitoring, the average annual July-August Secchi disk transparency (depth at which a black-and-white disk disappears from view at the surface) was only 4.4 feet due to highly tannin-stained inflows from Ghost Lake's forested wetland watershed. During the only three years of nutrient and productivity monitoring (2003-2005), July-August total phosphorus concentration (the limiting nutrient for planktonic algae production) averaged 36 micrograms per liter, and July-August chlorophyll *a* concentration (direct indicator of ongoing production by planktonic algae) averaged 20 micrograms per liter.

Because of mixing by wind and wave action in this shallow lake basin, Ghost Lake does not exhibit a classic mid-summer thermocline (depth zone of rapid temperature change); but strong oxyclines (depth zones of rapid change in dissolved oxygen concentration) were observed in mid-summer of 2005 (3-6 feet) and 2006 (6-9 feet). At depths below these oxyclines, water was uninhabitable by fish (dissolved oxygen concentrations less than 0.5 milligrams per liter). Tannin-stained water limits the production of dissolved oxygen by planktonic algae to surface layers, while organically enriched sediments consume available dissolved oxygen by naturally occurring bacteria near the lake bottom.

Recreation

The Quiet Lakes offer a variety of open-water recreational activities, including:

- Paddling while viewing or photographing nature from non-motorized watercraft
- Pleasure boating using motorized watercraft under 10 mph
- Fishing for walleye, muskellunge, black crappie, bass and other species
- Swimming

All these activities can potentially fragment and ultimately spread aquatic plants, including Hybrid Eurasian Water Milfoil (HEWM), whether by paddle, propeller, fishing lure, or human appendage. The AIS Committee believes it is impractical and probably impossible to prohibit or severely restrict any of these activities in Waters of the State under regulatory conventions supported by decades of legal precedent under Wisconsin's Public Trust Doctrine. Furthermore, legal precedent related to Wisconsin riparian rights requires that the flow of water cannot be changed in any way that would be considered detrimental to the public interest. Therefore, it is the opinion of the AIS Committee that the QLA Board does not have the option to prohibit or severely restrict any of the popular recreational activities noted above for purposes of minimizing the probability of spreading aquatic invasive species anywhere in the system, including the thoroughfare between Lost Land and Teal lakes. State law currently prohibits the transportation of aquatic plant material away from a body of water in or on any vehicle, including boats towed on trailers. Any effort to remove aquatic plants, including HEWM, would require a permit from WDNR.

Lester et al. (2004) demonstrated that a Secchi disk transparency of approximately 6 feet was optimal for lakes in which walleye are preferred as the dominant sport fish. Within a tolerable range, this is exactly what we have observed during the average mid-summer monitoring season at Lost Land and Teal lakes. Walleye was the most desired fish species among 19 Quiet Lakes stakeholders who attended a 4-hour WDNR fishery visioning session at the Spider Lake Town Hall on June 3, 2006. We have no desire to change (increase or decrease) nutrient levels or other elements of water quality (such as run-off of brown, tannin-stained water from the forested watershed) that contribute to optimal water clarity for walleye at Lost Land and Teal lakes. Not only are walleyes the most desired sport fish in our lakes, but increased walleye numbers are needed to exert heavier predation on young panfish, so that surviving black crappies and bluegills have less competition for food and can grow more quickly to angler-preferred sizes for harvest.

Aquatic Plant Management (APM) Plan

Goal

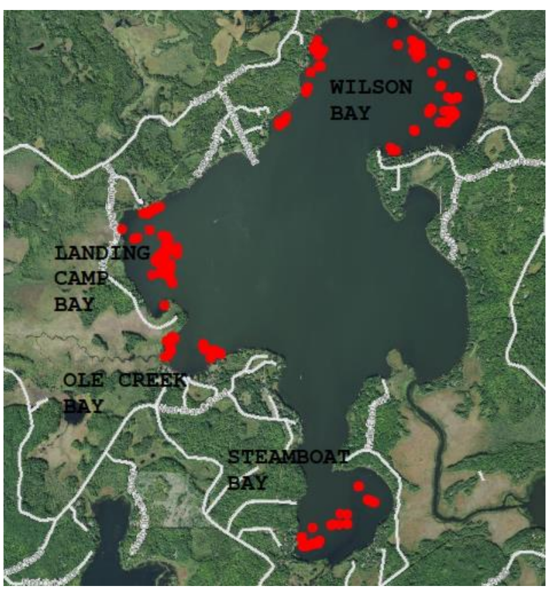
To prevent establishment of any new aquatic invasive species in the Quiet Lakes and to reduce the occurrence of Hybrid Eurasian Water Milfoil (HEWM) in Lost Land Lake, thus minimizing adverse impacts on native aquatic plants, other aquatic organisms, and human values such as aesthetics, recreation, and real estate.

Current Status

Point-intercept surveys conducted by Flambeau Engineering in summer 2016 revealed that Teal, Lost Land, and Ghost lakes had healthy communities of native aquatic plants. (See Appendix A for a detailed report of survey methods and results.) Taxonomic richness was high – 28 species at Teal, 29 at Lost Land, and 18 at Ghost (darker-stained water, fewer species). Mean Simpson Diversity (SDI ≥ 0.90) and Floristic Quality (FQI ≥ 30) indices were relatively high at both Teal and Lost Land based on 2012 and 2016 surveys. Native plants provide excellent habitat and food for aquatic invertebrates, fish, mammals, and migratory waterfowl. Stands of native vegetation were dense enough in some areas of Lost Land Lake to potentially affect fishing and other recreational activities, but native plants rarely attained levels that would impede navigation.

The 2016 point-intercept surveys revealed no evidence of invasive plant species in Teal or Ghost lakes. But several established stands of Hybrid Eurasian Water Milfoil (HEWM – a cross between the invasive Eurasian water milfoil and our native northern water milfoil) were mapped in four bays of Lost Land Lake (Wilson, Landing Camp, Ole Creek and Steamboat; Figure 1). After a marginally effective attempt at treatment with 2,4-D in Wilson Bay in 2015, WDNR Water Resources Management Specialist Alex Smith estimated approximately 21 acres of "topped out" HEWM when he inspected Lost Land Lake on 6/23/16. Identification of the hybrid form had been confirmed in October of 2014 when a representative of Project AquaGen at Grand Valley State University in Michigan (a state-of-the-art genetic testing facility) informed Alex Smith that two of three samples collected from Lost Land Lake were hybrids. In general, HEWM is known to be more difficult to control than purebred EWM by using traditional chemical treatment methods.

Figure 1. Hybrid Eurasian Water Milfoil (HEWM) in Lost Land Lake, Summer 2016.



Objectives

We will have achieved our goal if the next point-intercept aquatic plant survey conducted two years after the onset of mechanical harvest (probably 2020-2022) and every four years thereafter reveals the following objectives have been met:

Objective 1: No new aquatic invasive species (AIS) in any of our lakes

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Objective 3: No spread of HEWM from Lost Land Lake to connected waters (Teal Lake and Teal River Flowage) or other area waters (including Ghost Lake)

Objective 4: Reduced frequency (fewer sites) and coverage (area per site) of dense beds of HEWM in Lost Land Lake

General Strategy and Specific Actions

In late spring of 2017, we will implement a temporary, stopgap strategy to contain HEWM in Lost Land Lake by chemically treating the most prominent beds where HEWM is rapidly outpacing the growth and development of native plants. During summer/fall 2017, we will apply for public agency grants and raise private matching funds to enable us to initiate a long-term mechanical control strategy starting in spring of 2018, supported by an aggressive, web-based informational campaign. We believe the best way to maintain ecosystem integrity – the infrastructure upon which our quality of life depends – is to approach this problem in public-private partnership, using the best available science and technology for analysis, execution, and communication.

2017 Chemical Treatment at Lost Land Lake – A Bridge to Mechanical Control

1. Upon Plan approval by the QLA Board, the AIS Committee will apply to WDNR for a permit to chemically treat submersed plants growing in approximately 9.9 acres of Lost Land Lake identified as areas of densest HEWM growth during the summer 2016 survey. Flambeau Engineering has provided maps with GPS-referenced polygons that identify all proposed treatment areas. Our intent with this chemical treatment will be to interrupt the development of HEWM sufficiently to prevent it from "topping out" (developing a dense canopy at the water surface) later in the summer when it would become highly vulnerable to fragmentation and could spread to new sites. We view this one-time chemical application as a "bridge tactic" to keep the HEWM problem manageable until we are fully prepared to implement a more promising, affordable, and environmentally sound mechanical control strategy beginning in spring of 2018.

2. We will contract with a Certified Pesticide Applicator for the application of Reward herbicide in late spring after water temperature warms to at least 50F to a depth of 8 feet and HEWM achieves a height visible from, but not reaching, the water surface. Reward is a liquid-formulation, broad-spectrum herbicide with 37.3% Diquat Dibromide [6,7-dihydrodipyrido (1 ,2-a:2', 1 '-c) pyrazinediium dibromide] as its active ingredient. Current prices at amazon.com suggest this product can be purchased for less than $105 per gallon with free shipping. If we purchase 20 gallons to treat 9.9 acres at the maximum label rate of 2.0 gallons/acre, the herbicide should cost ~ $2,100.

3. At least one week prior to treatment with Reward herbicide, we will place a Public Notice in the Sawyer County Record and send postcards by mail to all addresses in our database to advise that livestock (and presumably pets) should not drink from the lake for at least one day following application, and that lake water should not be used to irrigate landscape plants (including turf grass) for 3 days or garden crops for 5 days following treatment. No other use restrictions are recommended in the product label. Diquat is a relatively safe chemical that vacates the water column within 24 hours, at which time it becomes tightly bound to sediment particles and loses all effect as a contact herbicide. Recipients of this information will be encouraged to visit our new website for more details.

4. In late summer, volunteer members of the AIS Committee will visually inspect sites of the spring 2017 application of Reward herbicide (Diquat) in order to subjectively document post-application response by HEWM and native plants – all of which should be affected by this non-selective, contact herbicide. A written update will be shared with all partners and QLA members on our new website; and updated GPS data will be used to guide future mechanical control efforts in remaining HEWM beds beginning in 2018.

2017 Website Development and Fund Raising

1. We must create an Association website that enables vital communication about the status of ongoing HEWM control efforts and other matters of interest to QLA members. We hope to have this site functional in time to advise stakeholders about the spring 2017 application of Reward herbicide (Diquat) prior to date of treatment, and also to provide anyone with Internet access an opportunity to review this Plan prior to our annual summer meeting, where we will be asking for private matching-fund donations to execute our strategies. An informed membership is more likely to be a supportive membership.

2. To initiate the website, we propose to contact Tim Gavigan (608-206-5348), webmaster at www.oldcabin.net, to arrange for him to custom-build ($100) and host ($11/month) the site, with a pass-through charge of $17/year for domain registration and renewal. As of 1/18/17, the domain name www.quietlakes.org was available. Mr. Gavigan's service would include guidance and posting privileges for members of the AIS Committee and QLA Board who are approved to add/delete site content. An AIS Committee member has volunteered first-year funding to initiate the site.

3. In late spring of 2017 members of the AIS Committee will schedule a tour with Kristina Olson, President of the Chetek Lakes Protection Association, in order to witness a demonstration of their new Eco-Harvester mechanical weed puller in the Chetek Chain of Lakes in Barron County. If Committee members are convinced of the effectiveness and economy of this new weed removal technology, fund-raising can begin.

4. At the summer 2017 QLA annual meeting, members of the AIS Committee will present this plan to members in attendance and ask for their support (strategic and financial) to transition to the proposed mechanical control strategy by spring of 2018. After presentation and discussion, the AIS Committee will initiate a pledge drive (that will continue online at our new website) aimed at securing sufficient private commitment to match the anticipated agency grants required to purchase a mechanical harvester before spring of 2018. The website will be updated regularly with news about private pledge totals and progress in applying for agency grants and purchasing needed equipment.

2018 and Beyond – A New Era of Mechanical Control

Anyone may access detailed information on the design features, operation, advantages, and costs of the Eco-Harvester aquatic plant harvesting machine (manufactured and sold by Lake Weeders Digest LLC of New Hope, Minnesota) by visiting the product webpage at http://www.lakeweedharvester.com/eco-harvester/. We will share a link to this site on our new QLA website in order to help members and visitors understand our strategy.

We think it is particularly important to note one critical advantage of Eco-Harvester over other mechanical harvesters for purposes of controlling HEWM: Unlike traditional harvesters that cut plants at some preset height above the lake bottom (leaving a rooted fragment intact to resume growth and sprout new stems), Eco-Harvester's roller-drum can be set to operate at a height calculated to selectively pull taller plants (like HEWM) by the roots, removing the entire plant and leaving only shorter, mostly native plants intact. Pulling rather than cutting, combined with a shallow paddle-wheel propulsion system, allows Eco-Harvester to minimize plant fragmentation – the primary mechanism by which HEWM spreads to new areas. Any minor fragmentation of HEWM during Eco-Harvester operation can be remedied by operating the machine in "skimmer" mode to quickly clean up miscellaneous floating fragments after a bed has been harvested. This seems to be an excellent new technology for controlling HEWM while minimizing impacts to beds of valuable native plants like large-leaf pondweed that are frequently invaded by HEWM.

Execution of this strategic action depends on two major assumptions: 1) We assume the AIS Committee (and ultimately the QLA Board) will be convinced by the spring 2017 demonstration that mechanical control by Eco-Harvester is the preferred method for controlling HEWM in Lost Land Lake; and 2) We assume we can raise sufficient private funds during fall/winter 2017/2018 to match anticipated agency grants for equipment purchase and operation of an Eco-Harvester. We strongly suspect we will have to purchase, register, insure, operate, maintain, and store our own Eco-Harvester (and custom hauling trailer) in order to guarantee its availability for use during the limited, difficult-to-predict time periods in spring (and hopefully fall) when it can be used to maximum effect in pulling taller stems of HEWM without also removing shorter native plants. We note the remote possibility that a local entrepreneur could purchase an Eco-Harvester and be available to contract for HEWM removal services exactly where and when needed (with top scheduling priority given to Lost Land Lake), thus sparing QLA the cost of ownership. But currently we are unaware of any professional lake management service that operates the Eco-Harvester or can guarantee selective mechanical removal of HEWM exactly where and when needed on Lost Land Lake. Therefore, the remainder of this Plan will assume Eco-Harvester ownership and self-management is our only viable option, which we hope to begin executing in spring of 2018.

Eco-Harvester Cost Projections and Funding Sources

The 2017 Eco-Harvester will list for $67,000, including custom haul trailer. If we make a 30% down payment ($20,100) by December 31, 2017, we can probably have a unit built and delivered to us by Weeders Digest LLC in time for use in spring of 2018. If we succeed in obtaining a WDNR Recreational Boating grant (application deadline February 1, 2018) after being encouraged to apply by WDNR Lakes Grants Coordinator Alex Smith, 50% ($33,500) of our cost for this equipment could be reimbursed upon delivery.

In spring of 2017, WDNR constructed a new webpage (http://dnr.wi.gov/aid/surfacewater.html) to help partners understand and apply for various grants aimed at conserving surface water resources. Among these grants, the "AIS Established Population Control Grant" (authorized under NR 198.40 of the Wisconsin Administrative Code) would be the most appropriate source for us to request additional funds needed to operate and maintain an Eco-Harvester. These grants "are intended to assist applicants in eradicating or substantially reducing established populations of Aquatic Invasive Species (AIS) to protect and restore native species communities." Maximum grant funding is 75% of total project cost up to $200,000. The application deadline is February 1 each year.

We also recommend applying to the U.S. Forest Service for funding to operate the Eco-Harvester under the Secure Rural Schools and Community Self-Determination Act of 2008 (Public Law 110-343) – a program designed to help local communities pay for projects in or near National Forest lands that do not contribute to the local tax base. Title II funds under this Act may be used for projects that improve the maintenance of existing infrastructure, enhance forest ecosystems, and restore and improve land health and water quality. Projects must be on national forests or directly benefit national forest lands and may include, but are not limited to, the following: 1) watershed restoration and maintenance; 2) restoration, maintenance and improvement of wildlife and fish habitat; 3) control of noxious and exotic weeds; and 4) re-establishment of native species. We believe these criteria place us in a competitive position for these funds, given that two "Quiet Lakes" boat landings (Teal River Flowage and Ghost Lake) are on the Chequamegon National Forest, and the U.S. Forest Service has an interest in preventing HEWM from spreading between our lakes and to other lakes nearby that lie entirely within the boundary of the National Forest. In 2017, 12 of 17 proposed projects were recommended by the RAC to receive $252,000 in available funding – approximately 60% of the total amount requested under Title II, with an average of $21,000 in funding to recommended projects. Future Congressional authorization of Title II funding is uncertain, but we should monitor budgetary developments and be prepared to submit a Title II proposal in the next cycle (Federal fiscal year 10/1/2017 – 9/30/2018) if authorization is continued and Chequamegon National Forest staff are able to solicit new project proposals. Funds could be used to operate the harvester, but we will still need membership support for the initial purchase of equipment.

Operational expenses and additional equipment to execute a mechanical control strategy include:

- vehicle registration for the Eco-Harvester and trailer;
- liability and accident insurance;
- onboard depth sounder with integrated GPS to ensure accurate location of HEWM beds and recorded documentation of areas harvested;
- dockage fee during operating seasons (unless a QLA member is willing to donate secure docking space on the water with electricity available to charge batteries);
- off-season storage of Eco-Harvester (unless a QLA member or local business operator can donate secure indoor space);
- fuel containers, fuel, oil, and routine generator maintenance;
- operation of Eco-Harvester by hired contractor and/or volunteers; and
- $5,000 for a dump trailer that can be towed to and from a boat ramp by a volunteer to haul away and dispose of HEWM off-loaded by the Eco-Harvester conveyor system.

We cannot provide an estimated total of these operating costs until we have had an opportunity to solicit volunteer labor or contributions that could significantly reduce costs to our Association.

Public Awareness

In addition to control operations, we recommend an aggressive web-based informational campaign aimed at informing lake users about the presence of HEWM in Lost Land Lake, and about steps everyone can take to avoid spreading HEWM and other aquatic invasive species in connected waters (Teal Lake and the Teal River Flowage), Ghost Lake, and other area waters. This effort will include, but is not necessarily limited to, the following actions:

1) Create and routinely update a page on our new website that visitors can use to access this APM Plan, view updates on AIS fund-raising and expenses, read brief updates and view photos of ongoing control efforts, and learn about progress toward achieving Plan objectives. This page will include links to established websites that include valuable tips on identifying and preventing the spread of HEWM and other aquatic invasive species. And because aquatic plant communities ultimately influence the character and quality of fish communities, WDNR fish survey reports and fishery management plans will be linked to our website. We want everyone to understand how aquatic plants affect the quality of fishing, which is vital to our quality of life and the economic viability of our resort operators.

2) In cooperation with the Quiet Lakes Resort Association and U.S. Forest Service, update and improve AIS prevention signage at public boat landings (including the Teal River Flowage where no signage exists currently) at approximately a dozen private points of boater access located on Lost Land, Teal, and Ghost lakes. We believe our conscientious resort owners will be our best emissaries for AIS control in the future.

3) Provide updates of recent progress and upcoming plans pertaining to AIS control by making brief presentations at annual summer meetings of the QLA general membership.

4) Pending successful fund-raising efforts and effective use of Eco-Harvester as a mechanical control strategy for HEWM, representatives of the AIS Committee will take advantage of opportunities to attend conferences or meetings (e.g., Annual Meeting of the Sawyer County Lakes Forum) where we can share our experience with other local/regional entities struggling to conserve their lake ecosystems.

Alternatives Analysis

Other methods for achieving APM Plan objectives were reviewed and discussed by the AIS Committee during fall/winter 2016/2017. Flambeau Engineering, LLC brought to our attention several alternatives, including annual chemical treatments and high-frequency monitoring of boat ramps and aquatic plant communities. In the end, we chose to recommend an innovative new mechanical control strategy augmented by increased public awareness efforts – strategies we believe to be practical, affordable, effective, and environmentally acceptable. Here we provide a brief list of alternate strategies and reasons they were not selected:

- We considered mechanical harvesters other than Eco-Harvester, but most models cut weeds rather than pulling them, leaving live stems rooted in the sediment to resume growth, and creating floating fragments to drift away and take root elsewhere. (Each leaf node can sprout new roots.) The "dynamic flow intake" of Eco-Harvester is 95% efficient in pulling weeds. This machine is one-third the price of comparable harvesters and can be operated by a single worker or volunteer.

- Dredging was discussed also. Besides throwing out the baby (desirable native plants) with the bath water (nuisance HEWM), the expense of removing, transporting, and disposing of all plants and thousands of tons of contaminated sediment would be highly prohibitive. WDNR probably would not permit dredging on such a large scale due to legitimate concerns about re-suspension and biological uptake of mercury currently trapped in the sediments. Environmental scientists have proven that decades of electrical power generation at coal-fired power plants near the Twin Cities produced atmospheric plumes containing mercury that reached our downwind wetlands and lakes in the form of precipitation and runoff. If left sequestered deep in the sediments, much of this mercury may never again enter the aquatic food chain and become biomagnified as it passes in ever-greater concentration from algae to zooplankton to small fish to large fish. But a major disturbance of the sediments could reactivate enough mercury in its biologically available form (methyl mercury) to exacerbate an already significant human health problem with mercury contamination in the edible muscle tissues of older, larger specimens of piscivorous fish species such as muskellunge, northern pike, walleye, and largemouth bass. In summary, dredging is not a viable option for HEWM control in the Quiet Lakes.

- We evaluated other mechanical removal strategies that do not involve heavy machinery. Diver-assisted suction harvesting (DASH) was considered, but this method is economical only in small, isolated areas of infestation. The widespread distribution and high density of HEWM in many areas of Lost Land Lake already exceed the scale of problem addressable by DASH. It is also doubtful that our tannin-stained waters would be clear enough to allow accurate identification and selective removal of HEWM by divers.

- We also evaluated biological control methods, such as the culture and release of milfoil weevils *(Euhrychiopsis lecontei)* that live on the upper portion of milfoil plants, laying eggs on milfoil meristems and feeding on stems and leaves. They cause damage by burrowing through the stem and consuming vascular tissue. Even though they produce 3-5 generations per summer, milfoil weevil populations have been strongly suppressed in lakes with abundant sunfish (Ward and Newman 2006). In a WDNR electrofishing survey conducted at Lost Land Lake on May 21, 2010, bluegills 3 inches and longer were captured at an exceptionally high rate of 400 fish per mile of shoreline. The size distribution of those fish (only 1% ≥ 7 inches and none ≥ 8 inches) reflected slow growth rate due to high competition for food in an over-crowded population. We have seen no evidence of significant change in the bluegill population since 2010. The AIS Committee concluded that milfoil weevils have no chance of reaching densities sufficient to control HEWM amid so many hungry bluegills in Lost Land Lake.

- Finally, we evaluated several chemical control options in addition to the one-time treatment with Reward herbicide (Diquat) planned for spring of 2017. EPA-registered chemicals considered for use on a recurrent basis included 2,4-D, Fluridone, and Triclopyr. Applied carefully in early spring, liquid formulations of 2,4-D have been shown to selectively kill actively growing EWM before many native plant species begin growing and become vulnerable. However, HEWM has shown some resistance to 2,4-D, which must be maintained at an effective concentration in the treatment area for several days of "contact time" in order to achieve desired results. HEWM in Lost Land Lake occurs in numerous small, dense beds generally less than an acre in area. Rapid diffusion of 2,4-D into adjacent untreated waters, aided by wind-driven currents, can reduce treatment area contact time significantly. Given that even semi-discrete areas such as Wilson Bay would have to be treated in their entirety to achieve desired results, the $600/acre price tag to apply 2,4-D effectively is deemed cost-prohibitive, especially on a recurrent basis.

  Fluridone is 1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone. Sold as Sonar* A.S. (41.7% fluridone) by the SePRO Corporation, this herbicide is applied as a whole-lake treatment that kills submersed aquatic plants at concentrations of 10-90 parts per billion. A study of 8 small lakes (most 135-250 acres) in Michigan found that low-dose treatments (5 parts per billion) selectively killed most Eurasian water milfoil (not the hybrid) 8-12 weeks post-application in 3 of 4 treatment lakes, with significant residual control the following year (Madsen et al. 2002). These low-dose treatments did not alter native plant species diversity or cover during the year following treatment. However, because Fluridone has an extremely long contact period (45-60 days), a second "booster" application was required to maintain the concentration needed to selectively kill EWM. Treating the entire volume of Lost Land Lake even once at a Fluridone concentration of only 5 parts per billion would require approximately 50 gallons of Sonar (0.04 gallon per surface acre in a 1264-acre lake with mean depth of 12 feet). The cost of this product usually exceeds $2,000/gallon, so a single-dose application would cost at least $100,000 (not including contract labor to apply).

Treating an entire lake with Sonar twice per season, even at a reduced dosage, would be far too expensive for practical consideration in controlling HEWM at Lost Land Lake. Triclopyr, another aquatic herbicide that may be useful in selectively killing EWM, is even more expensive than Fluridone. None of the selective herbicides we considered can be used for spot-treatment for reasons explained earlier for 2,4-D. In summary, we found no spot-treatment or whole-lake herbicide control options that are both effective and affordable on a long-term basis.

Monitoring

In order to determine whether our mechanical control and public awareness strategies are effective, we must monitor the aquatic plant community periodically. The AIS Committee recommends a repeat of the 2016 point-intercept survey two years after the onset of mechanical control (probably 2020-2022) and every four years thereafter, adding the Teal River Flowage, which is an integral part of the system that has not been sampled previously. We do not see value in vigorous monitoring any earlier than 2020 because the planned 2017 chemical treatment is a one-time action (no need to evaluate if no intent to repeat). And we believe mechanical control (hopefully starting in 2018) must be conducted for at least two years before any significant change in the plant community (for better or worse) can be expected or measured. Nichols (1997) estimated how much quantitative change would be required to conclude that changes in key metrics are statistically significant. In Wisconsin aquatic plant communities, changes (up or down) exceeding 2.5 feet in maximum depth of plant growth, 13% in proportion of open (unvegetated) area, and 0.04 in SDI would be deemed significant because these changes would be more than expected from seasonal and sampling variability alone. Our three-year window (2020-2022) for next evaluation allows for the possibility of delayed onset of mechanical control (if fund-raising, permitting, or start-up logistics take longer than expected), and also for the possibility that agency grants to share the cost of monitoring may not be available as soon as desired.

Other citizen monitoring activities (public boat ramp use, water quality, etc.) were considered, but we opted not to recommend participation at this time. Our current goal is ambitious, and the time and effort required to achieve it substantial. As volunteers, we will do well to execute this Plan without the distractions (coordination, hiring, training, oversight, and grant administration) and additional expenses associated with activities that have either failed to date (e.g., three years of boat ramp monitoring that did not prevent HEWM from invading Lost Land Lake) or will offer little insight into the efficacy of our mechanical control and public awareness strategies (e.g., water quality monitoring). Past and current water quality conditions have resulted in healthy aquatic plant communities in all our lakes. The only negative change has been the appearance of invasive HEWM. Within the scope of this APM Plan, we propose to remain laser-focused on our goal to prevent establishment of any new aquatic invasive species in the Quiet Lakes and to reduce the occurrence of Hybrid Eurasian Water Milfoil (HEWM) in Lost Land Lake.

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APPENDIX. Report of the 2016 Aquatic Plant Surveys

Methods

Flambeau Engineering, LLC coordinated and conducted aquatic plant community surveys on the "Quiet Lakes" during summer of 2016 by using the point-intercept method (Madsen 1999) as outlined in "Aquatic Plant Management in Wisconsin" (WDNR 2005). WDNR research staff provided a base map with sample point locations, and they determined sample point resolution in accordance with their guidance (Table A1).

Table A1. Point-intercept aquatic plant surveys conducted by Flambeau Engineering on the "Quiet Lakes" in Sawyer County, WI during summer of 2016.

Lake	Survey Date(s)	No. Points	Resolution (m)
Teal	July 8, 2016	649	80
Lost Land	July 6 & 7, 2016	512	100
Ghost	August 2, 2016	427	60

Latitude, longitude, and sample ID numbers were assigned to each intercept point on the grid. Geographic coordinates were uploaded into a global positioning system (GPS) receiver, which was used to navigate to intercept points. At each sample site, a specialized rake on a pole was twisted on the bottom to collect plants. All collected plants were identified to the lowest practicable taxonomic level (typically species). A subjective rating of abundance ranging from 1 (lowest) to 3 (highest) was given to each species and labeled as "rake fullness" in this report. Water depth and detectable sediment types at each intercept point were recorded, as were visual observations of aquatic plants in the general area.

The point-intercept method was used to evaluate emergent, submersed, floating-leaf, and free-floating aquatic plants. Data for each sample point was entered into WDNR "Worksheets" (data-processing spreadsheet) to calculate the following metrics:

- **Taxonomic richness** – total number of taxa detected (usually species-level resolution). To put results in perspective, the average number of aquatic plant species in northern Wisconsin drainage lakes during the 1980s and 1990s was 26 (Nichols 2001).
- **Maximum depth of plant growth**
- **Community frequency of occurrence** – number of intercept points where aquatic plants were detected divided by the number of intercept points shallower than the maximum depth of plant growth
- **Mean intercept point taxonomic richness** – average number of taxa per intercept point
- **Mean intercept point native taxonomic richness** – average number of native taxa per intercept point
- **Taxonomic frequency of occurrence within vegetated areas** – number of intercept points where a particular taxon (e.g., genus, species, etc.) was detected, divided by the total number of intercept points where vegetation was present

- **Taxonomic frequency of occurrence at sites within the photic zone** – number of intercept points where a particular taxon was detected divided by the total number of intercept points which were equal to or shallower than the maximum depth of plant growth

- **Relative taxonomic frequency of occurrence** – number of intercept points where a particular taxon was detected divided by the sum of all species' occurrences

- **Mean density** – the sum of the density rankings for a particular species divided by the number of sample sites

- **Simpson Diversity Index (SDI)** – indicator of aquatic plant species diversity (species richness combined with an "evenness" of distribution among species present), calculated by the formula:

  $$SDI = 1 - \Sigma\,(\text{Relative Frequency}^2)$$

  The closer SDI is to one, the greater is the diversity within the plant community.

- **Floristic Quality Index (FQI)** – calculated by using a coefficient of conservatism (C) assigned to each native plant species in Wisconsin on a scale of 0 to 10, with 10 being assigned to species most sensitive to disturbance (Nichols 1999). Non-native plants are not assigned C-values. Conservatism is the estimated probability that a plant is likely to occur in a lake that is believed to be relatively unaltered from pre-settlement conditions. Lakes with high FQI values have high plant species richness combined with a high proportion of species that are less tolerant of human disturbance than others, reflecting healthy natural conditions. The FQI is calculated for each site as follows:

  $$FQI = \text{mean } C * \sqrt{N}$$

  where "mean C" = the average coefficient of conservatism for each species in a sample; and √N = the square root of the number of native species in that sample.

  Average FQI for drainage lakes in northern Wisconsin during the 1980s and 1990s was 32-33 (Nichols 2001).

As with other plant taxa, HEWM was recorded when encountered during the point-intercept survey; but these data were insufficient to estimate areas of dense beds of HEWM that may require treatment/removal. To provide such estimates, beds of HEWM were circumnavigated with a boat while the perimeter was recorded using GPS. Resulting polygons were mapped to determine potential treatment/removal areas. Density of HEWM beds and the occurrence of scattered plants were subjectively noted.

Results

Results of the 2016 survey are presented alongside data from the 2012 and 2006 surveys for purposes of comparison. But insufficient funding and low sample size in 2006 make it impossible to compare 2006 data with larger datasets from 2012 and 2016 in a statistically valid manner. The 2012 survey may provide a sound baseline from which to start monitoring long-term trends. Numbers were provided by Flambeau Engineering, with interpretation by APM Plan Coordinator.

Teal Lake

Of 649 target sites in 2016, 460 were visited, and 94 had aquatic plants (Table A2). Sites not visited either exceeded the maximum depth of plant growth or could not be accessed due to physical barriers. The aquatic plant community included a relatively high total of 28 species (Table A2), of which 25 were sampled by rake and 3 were recorded visually. Plants were collected to a maximum depth of 12 feet in 2016, thus defining the limit of the "photic zone" (depth of effective sunlight penetration) that year. Plants occurred at 42% of photic zone sites. A Simpson Diversity Index value of 0.91 indicated high species diversity within a healthy Teal Lake plant community (Table A2). On average, we found 2.05 species per vegetated site.

Table A2. Summary of aquatic plant community metrics based on point-intercept surveys conducted at Teal Lake in summers of 2006, 2012, and 2016.

Observed or Calculated Metrics	2016	2012	2006
Total number of sites visited	460	382	82
Total number of sites with plants	94	95	34
Total number of sites shallower than maximum depth of plants	223	193	53
Frequency of occurrence (%) of plants at sites shallower than maximum depth of plants	42	49	64
Simpson Diversity Index (SDI, where 1.0 = maximum diversity)	0.91	0.92	0.90
Maximum depth of plants (feet)	12	12	9
Number of sites sampled using rake on Rope (R)	0	0	17
Number of sites sampled using rake on Pole (P)	460	382	65
Average number of all species per site (shallower than max depth)	0.87	1.09	1.92
Average number of all species per site (vegetated sites only)	2.05	2.22	3.00
Average number of native species per site (shallower than max depth)	0.87	1.09	1.92
Average number of native species per site (vegetated sites only)	2.05	2.22	3.00
Total number of plant species sampled	25	26	16
Total number of plant species (including visuals) – Species Richness	28	33	18

Based on frequency of occurrence at vegetated sites, the three most common plant species collected at Teal Lake during the 2016 survey were wild celery (47%), large-leaf pondweed (26%), and fern pondweed (22%; Table A3). Wild celery is a particularly valuable near-shore food for ducks, geese, turtles and muskrats. Large-leaf pondweed offers preferred mid-depth habitat with optimal "plant architecture" for adult fish of several species, including muskellunge, walleye, black crappie, and yellow perch. Fern pondweed offers good habitat for fish of various species and life stages in shallow and mid-depth locations. We found no aquatic invasive plant species in Teal Lake during any of the surveys conducted in 2006, 2012, or 2016.

Table A3. Taxa collected during aquatic plant surveys at Teal Lake in 2006, 2012, and 2016. Frequency of occurrence is expressed as a percentage of all sites with plants. Rake fullness is an average of sites with plants, ranging from 1 (least abundant) to 3 (most abundant).

Plant Species TEAL LAKE		Frequency of Occurrence			No. Sites			Rake Fullness			No. of Visual Sitings		
Scientific Name	**Common Name**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**
Bidens beckii	Water marigold		1			1			1				
Brasenia schreberi	Watershield	5.3	2.1	3	5	2	1	1	1	1	2	6	
Ceratophyllum demersum	Coontail	9.6	9.5	32	9	9	11	1	1	1			
Chara Sp	Muskgrass	1			1			1					
Eleocharis palustris	Creeping spikerush											2	2
Elodea canadensis	Common waterweed	12.8	5.3	29	12	5	10	1.17	1.2	1			
Heteranthera dubia	Water stargrass			12			4		1	1			
Isoetes sp.	Quillwort		1			1			1				
Juncus pelocarpus	Brown-fruited rush	1			1			1					
Littorella uniflora	Littorella		2.1			2			1				
Myriophyllum sibiricum	Northern water-milfoil	7.5	3.2	18	7	3	6	1	1	1	1		
Najas flexilis	Slender naiad	10.6	14.7	24	10	14	8	1.1	1	1		1	
Nitella sp	Nitella	20.2	30.5	6	19	29	2	1.3	1.3	1			1
Nuphar variegata	Spatterdock	3.2	4.2		3	4		1	1		1	5	11
Nymphaea odorata	White water lily	1	2.1	3	1	2	1	1	1	1	3	4	6
Nymphaea tetragona	Small water lily		1			1			1				
Pontederia cordata	Pickerelweed			3			1			1	1	7	8
Potamogeton amplifolius	Large-leaf pondweed	25.5	17.9	26	24	17	9	1.1	1.1	1	12	7	1
Potamogeton epihydrus	Ribbon-leaf pondweed	1	3.2		1	3		1	1				
Potamogeton foliosus	Leafy pondweed	1	7.4		1	7		1	1			1	
Potamogeton gramineus	Variable pondweed	14.9	13.7		14	13		1	1		5	2	
Potamogeton natans	Floating-leaf pondweed	1	1		1	1		1	1				1
Potamogeton nodosus	Long-leaf pondweed		1			1			1		1	1	
Potamogeton praelongus	White-stem pondweed	4.3			4			1			2		
Potamogeton pusillus	Small pondweed	12.8			12			1					
Potamogeton richardsonii	Clasping-leaf pondweed	8.6	15.8	6	8	15	2	1.2	1.1	1	10	12	
Potamogeton robbinsii	Fern pondweed	22.4	17.9	35	21	17	12	1.3	1.1	1		1	
Potamogeton zosteriformis	Flat-stem pondweed	16	28.4	21	15	27	7	1.1	1.1	1	2	6	
Sagittaria latifolia	Common arrowhead											1	
Schoenoplectus acutus	Hardstem bulrush											1	
Schoenoplectus pungens	Three-square bulrush											1	
Schoenoplectus tabernaemontani	Softstem bulrush										1	1	
Sparganium fluctuans	Floating-leaf bur-reed	4.3	16.8		4	16		1	1		3	3	
Stuckenia pectinata	Sago pondweed			21			7			1		1	
Utricularia vulgaris	Common bladderwort	7.5	9.5		7	9		1	1			4	
Vallisneria americana	Wild celery	46.8	12.6	56	44	12	19	1.2	1.1	1	1	2	2
	Filamentous algae	20.2	10.5		19	10		1	1			2	
	Aquatic moss	5.3	17.9		5	17		1	1				

Lost Land Lake

Of 512 target sites in 2016, 234 were visited, and 180 had aquatic plants (Table A4). Sites not visited either exceeded the maximum depth of plant growth or could not be accessed due to physical barriers. The aquatic plant community included a relatively high total of 29 species (Table A4), of which 28 were sampled by rake and one was recorded visually. Plants were collected to a maximum depth of 15 feet in 2016, thus defining a photic zone 3 feet greater than in Teal Lake that year. Plants occurred at 78% of photic zone sites in Lost Land Lake compared with only 42% of photic zone sites in Teal Lake (more suitable muck substrate in Lost Land). A Simpson Diversity Index value of 0.91 indicated high species diversity within a generally healthy Lost Land Lake plant community (Table A4). On average, we found 2.21 native species per vegetated site (more than Teal despite the recent invasion of HEWM in Lost Land).

Table A4. Summary of aquatic plant community metrics based on point-intercept surveys conducted at Lost Land Lake in summers of 2006, 2012, and 2016.

Observed or Calculated Metrics	2016	2012	2006
Total number of sites visited	234	284	136
Total number of sites with plants	180	196	109
Total number of sites shallower than maximum depth of plants	232	257	132
Frequency of occurrence (%) of plants at sites shallower than maximum depth of plants	78	76	83
Simpson Diversity Index (SDI, where 1.0 = maximum diversity)	0.91	0.89	0.88
Maximum depth of plants (feet)	15	12	18
Number of sites sampled using rake on Rope (R)	0	0	29
Number of sites sampled using rake on Pole (P)	234	284	105
Average number of all species per site (shallower than max depth)	1.66	1.68	1.88
Average number of all species per site (vegetated sites only)	2.23	2.20	2.28
Average number of native species per site (shallower than max depth)	1.65	1.68	1.88
Average number of native species per site (vegetated sites only)	2.21	2.20	2.28
Total number of plant species sampled	28	22	15
Total number of plant species (including visuals) – Species Richness	29	23	18

Based on frequency of occurrence at vegetated sites, the three most common plant species collected at Lost Land Lake during the 2016 survey were fern pondweed (40%), flat-stem pondweed (38%), and common waterweed (15%; Table A5). Wild celery – a highly preferred source of food for aquatic wildlife – occurred at only 15% of vegetated sites in Lost Land Lake compared with 47% in Teal Lake. And large-leaf pondweed – a highly preferred fish habitat – occurred at only 12% of vegetated sites in Lost Land compared with 25% in Teal. Despite similar metrics for species richness and overall plant community diversity, 2016 plant species composition seemed a bit more favorable for fish and wildlife in Teal than in Lost Land.

Eurasian water milfoil (presumably the hybrid, but recorded as purebred *Myriophyllum spicatum* in Table A5) was patchy in its distribution and was therefore collected by rake at only 3 of the uniformly assigned point-intercept sites in 2016 (1.7% frequency of occurrence). HEWM was visually observed in 6 other locations near rake sample sites.

Table A5. Taxa collected during aquatic plant surveys at Lost Land Lake in 2006, 2012, and 2016. Frequency of occurrence is expressed as a percentage of all sites with plants. Rake fullness is an average of sites with plants, ranging from 1 (least abundant) to 3 (most abundant).

Plant Species		Frequency of Occurrence			No. Sites			Rake Fullness			No. of Visual Sitings		
Scientific Name	**Common Name**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**
Myriophyllum spicatum	Eurasian water milfoil	1.7			**3**			**1**			**6**		
Bidens beckii	Water marigold	1.7	0.5	1	3	1	1	1	1	1	1		4
Brasenia schreberi,	Watershield	0.6			1			1					
Ceratophyllum demersum	Coontail	13.3	22.4	40	24	44	44	1.2	1.3	1			3
Chara sp	Muskgrasses	6.1	7.6	2	11	15	2	1	1	1			1
Elodea canadensis	Common waterweed	15	17.9	28	27	35	30	1.2	1.1	1			1
Isoetes sp.	Quillwort	0.6	0.5	1	1	1	1	1	1	1			
Littorella uniflora	Littorella	1.1	0.5		2	1		1	1		1		
Myriophyllum sibiricum	Northern water-milfoil	5.6	2.5	10	10	5	11	1	1	1	4		
Najas flexilis	Slender naiad	7.2	12.2	9	13	24	10	1.15	1	1			
Nitella sp	Nitella	4.4	3.1		8	6		1	1.2				
Nuphar variegata	Spatterdock	1.1	0.5	1	2	1	1	2	1	1	7	2	
Nymphaea odorata	White water lily	1.1	0.5		2	1		2	1		3	1	
Pontederia cordata	Pickerelweed	1.1			2			2					
Potamogeton amplifolius	Large-leaf pondweed	11.7	7.6	16	21	15	17	1	1	1	25	7	
Potamogeton foliosus	Leafy pondweed	1.1	1		2	2		1	1				
Potamogeton gramineus,	Variable pondweed	12.2			22			1					
Potamogeton praelongus	White-stem pondweed	6.7	20.9	3	12	41	3	1	1	1	8	1	
Potamogeton pusillus	Small pondweed	12.2	1		22	2		1.1	1				
Potamogeton richardsonii	Clasping-leaf pondweed	13.3	19.4	10	24	38	11	1	1	1	2	1	
Potamogeton robbinsii	Fern pondweed	40	37.2	22	72	73	24	1	1.9	1			
Potamogeton vaseyi	Vasey's pondweed		5.1			10		1.8	1				
Potamogeton zosteriformis	Flat-stem pondweed	38.3	43.9	40	69	86	43	1.3	1.7	2	2		
Schoenoplectus pungens	Three-square bulrush										2	3	
Schoenoplectus tabernaemontani	Softstem bulrush	0.6	0.5		1	1		1	1				
Sparganium fluctuans	Floating-leaf bur-reed	3.3	0.5		6	1		1	1			1	
Stuckenia pectinata	Sago pondweed			35	2		38			1			
Utricularia vulgaris,	Common bladderwort	4.4			8			1			1		
Vallisneria americana	Wild celery	15	14.3	11	27	28	12	1.1	1.1	1			

Ghost Lake

Of 427 target sites in 2016, 258 were visited, and 103 had aquatic plants (Table A6). Sites not visited either exceeded the maximum depth of plant growth or could not be accessed due to physical barriers. The aquatic plant community included a relatively low total of 18 species (Table A6), of which 17 were sampled by rake and one was recorded visually. Plants were collected to a maximum depth of only 7 feet in 2016, reflecting Ghost Lake's limited photic zone compared with Teal and Lost Land lakes. Ghost Lake receives far more wetland drainage than either Teal or Lost Land, resulting in a high concentration of dissolved organic compounds that impart a very dark color to the water. This limits underwater light penetration and the number of plant species that can tolerate such low-light conditions. Plants occurred at 46% of photic zone sites due to favorable sediment composition. A Simpson Diversity Index value of 0.85 indicated moderate species diversity within a relatively healthy Ghost Lake plant community where we found 1.7 species per vegetated site (Table A6). SDI and species richness were considerably higher in the clearer waters of Teal and Lost Land lakes.

Table A6. Summary of aquatic plant community metrics based on point-intercept surveys conducted at Ghost Lake in summers of 2006, 2012, and 2016.

Observed or Calculated Metrics	2016	2012	2006
Total number of sites visited	258	235	114
Total number of sites with plants	103	99	85
Total number of sites shallower than maximum depth of plants	224	184	113
Frequency of occurrence (%) of plants at sites shallower than maximum depth of plants	46	54	75
Simpson Diversity Index (SDI, where 1.0 = maximum diversity)	0.85	0.78	0.92
Maximum depth of plants (feet)	7	6	11
Number of sites sampled using rake on Rope (R)	0	0	0
Number of sites sampled using rake on Pole (P)	258	242	30
Average number of all species per site (shallower than max depth)	0.76	0.88	1.50
Average number of all species per site (vegetated sites only)	1.67	1.64	2.02
Average number of native species per site (shallower than max depth)	0.76	0.88	1.34
Average number of native species per site (vegetated sites only)	1.67	1.64	2.02
Total number of plant species sampled	17	13	22
Total number of plant species (including visuals) – Species Richness	18	15	24

Based on frequency of occurrence at vegetated sites, the three most common plant species collected at Ghost Lake during the 2016 survey were fern pondweed (60%), watershield (19%), and coontail (17%; Table A7). Watershield was rare in Teal and Lost Land lakes (Tables A3 and A5). It thrives in lakes with low alkalinity and low pH, which would be expected in Ghost Lake due to its substantial wetland watershed. Watershield, with its oval leaves floating flat on the water's surface, can form a dense canopy that prevents sunlight from penetrating to the water and sediments below. In this manner, the relatively high frequency of occurrence of watershield in Ghost Lake probably contributes to lower SDI and species richness in Ghost compared with Teal and Lost Land. We found no aquatic invasive plant species in Ghost Lake during any of the surveys conducted in 2006, 2012, or 2016.

Table A7. Taxa collected during aquatic plant surveys at Ghost Lake in 2006, 2012, and 2016. Frequency of occurrence is expressed as a percentage of all sites with plants. Rake fullness is an average of sites with plants, ranging from 1 (least abundant) to 3 (most abundant).

Plant Species GHOST LAKE		Frequency of Occurrence			No. Sites			Rake Fullness			No. of Visual Sitings		
Scientific Name	**Common Name**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**	**2016**	**2012**	**2006**
Bidens beckii	Water marigold	1.94			2			1					
Brasenia schreberi	Watershield	19.42	12.1	2.3	20	12	2	1.4	1.25	2	25	7	
Carex comosa	Bottle-brush sedge			1.2			1			1			28
Ceratophyllum demersum	Coontail	16.5	31.3	18	17	31	15	1.1	1	1	9	1	17
Ceratophyllum echinatum	Spiny hornwort			3.5			3			1			15
Chara sp	Muskgrass			7			6			1			12
Elodea canadensis	Common waterweed			14			12			1			11
Myriophyllum sibiricum	Northern water-milfoil		2	6		2	5		1	1			8
Najas flexis	Slender naiad			25			21			1			7
Nitella sp	Nitella			20			17			1			5
Nuphar variegata	Spatterdock	7.8	1	2.3	8	1	2	1	1	1	13	4	5
Nymphaea odorata	White water lily	5.9	5	2.3	6	5	2	1	1	1	87	56	5
Pontederia cordata	Pickerelweed	1			1			1			10		3
Potamogeton amplifolius	Large-leaf pondweed	12.6	17.1	14	13	17	12	1.1	1.1	2	18	25	2
Potamogeton epihydrus	Ribbon-leaf pondweed	1		1.2	1		1	1		1			1
Potamogeton gramineus	Variable pondweed	1.9	5		2	5		1	1		20	1	1
Potamogeton illinoensis	Illinois pondweed		3	3.5		3	3		1	1		22	
Potamogeton natans	Floating-leaf pondweed	4.8	3	2.3	5	3		1.4	1		1		
Potamogeton praelongis	White-stem pondweed	9.7		2.35	10		2	1		1	48	4	
Potamogeton richardsonii	Clasping-leaf pondweed			8.2			7			1			
Potamogeton robbinsii	Fern pondweed	60.1	65.6	28	62	65	24	1.7	1.4	2	3	5	
Potamogeton zosteriformis	Flat-stem pondweed	9.7	5	2.3	10	5	2	1	1	1	12	5	
Schoenoplectus acutus	Harstem bulrush	1			1			1			5	2	
Sparganium fluctuans	Floating-leaf bur-reed	11.6		1.2	12		1	1.2		1	14		
Utricularia vulgaris	Common bladderwort	10.7	4		11	4		1.1	1		13		
Vallisneria americana	Wild celery	8.8	9.1	8.2	9	9	1	1	1	1	6		
	Filamentous algae			22			19						
	Aquatic moss	3.9	2		4	2		1	1				

Floristic Quality Index (FQI) – A "Quiet Lakes" Summary

Combining 2012 and 2016 survey results at Teal and Lost Land lakes, the mean FQI and its component parts (mean species richness and mean conservatism) exceeded published averages for drainage lakes and flowages in northern Wisconsin (Table A8; Nichols 1999). This indicates a high degree of aquatic plant community integrity in Teal and Lost Land, despite the recent invasion of HEWM into Lost Land. Lost Land Lake is still in good shape, provided we do not allow HEWM to expand and begin dominating the aquatic plant community. Ghost Lake exhibited lower-than-average species richness due largely to natural causes of reduced water clarity, but it demonstrated the highest conservatism (C) of the three lakes, and FQI was similar to the regional average (Table A8). In summary, the "Quiet Lakes" currently have very healthy aquatic plant communities that reflect very little human disturbance.

Table A8. Average Floristic Quality Index (FQI) metrics based on mean species richness and composition observed in 2012 and 2016 point-intercept surveys at the Quiet Lakes, in comparison with similar waters (drainage lakes and flowages in northern Wisconsin) reported by Nichols (1999).

Component Metrics	Teal Lake	Lost Land Lake	Ghost Lake	Northern Wisconsin Drainage Lakes (Nichols 1999)
Mean Species Richness	30.5	26.0	16.5	23.5
Mean C	6.4	6.4	6.8	6.2
Mean FQI	35.3	32.6	27.6	28.3