THE AQUATIC PLANT COMMUNITY OF PEPPERMILL LAKE, ADAMS COUNTY, WISCONSIN 2001-2016

Presented by Reesa Evans
Certified Lake Manager, Lake Specialist
Adams County Land & Water Conservation Department
P.O. Box 287, Friendship, WI 53934
608-339-4268

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I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Peppermill Lake was conducted during the summer of 2016 by the Adams County Land and Water Conservation Department and a volunteer from the Peppermill Lake District. The survey used the Point Intercept Method currently required by the Wisconsin Department of Natural Resources.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation in the lake and the ability of the vegetation to characterize the water quality (Dennison et al., 1993).

Ecological Role: All other life in the lake depends on the plant life - the beginning of the food chain. Aquatic plants and algae provide food and oxygen for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants provide habitat, improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et al., 1993).

The present study will provide ongoing information that is important for effective management of the lake, including fish habitat improvement, protection of sensitive habitat, aquatic plant management and water quality protection. It will also allow tracking of any significant changes in the aquatic plant community that may indicate changes in the lake's overall health, as well as permit evaluation of the management strategies set out in the approved lake management plan.

Background and History: Peppermill Lake is located in the Town of Jackson in Adams County. The impoundment is 65 surface acres in size. Maximum depth is 14 feet, with an average depth of about 5 feet. During the summer of 2016 when this aquatic plant survey was conducted, the lake was at slightly higher level than usual due to frequent rains in the spring and summer. There is a boat launch open to the public owned by the Town of Jackson. By the boat ramp is the Peppermill Dam, owned and managed by the Adams County Land & Water Conservatism Department. The Peppermill Lake District completed a lake management plan that was approved by the Wisconsin Department of Natural Resources. This plan is reviewed annually for needed updates.

Residential development around the lake is found along most of the lakeshore, except the northwest end, which is in conservancy. There are no known endangered or threatened aquatic or terrestrial resources in or directly around the lake. There are no identified archeological or historical sites in either the surface or ground watersheds. Although much of the shore is inhabited, most of the buildings around Peppermill Lake are back from the shore, leaving landward near-shore areas usually covered with native vegetation.

A fish inventory in October 2006 revealed that the following fish were found in the lake: northern pike; largemouth bass; bluegill; pumpkinseed; yellow perch; black crappi*)*; bullhead; white sucker; and rock bass. In 2009, Peppermill Lake suffered a winter fish kill, likely due a failed aerator. After investigation by the Wisconsin Department of Natural Resources (WDNR), it was determined that the fish population was likely to recover on its own without any additional fish stocking. There have been no significant fish kills since the aerator pumps were replaced.

Soils directly around Peppermill Lake tend to be sand or loamy sand of less than 12% slope, except for some eroded silt loam with 12% to 29% slope at the far eastern end of the lake. Those in the surface and ground watersheds are also sands and loamy sands. Such soils tend to be excessively-drained, with infiltration of water being rapid to very rapid, and permeability also high. Such soils also usually have low water-holding and low organic matter content, thus making them difficult to establish vegetation on. These soils tend to be easily eroded by both water and wind.

Historically, efforts at controlling aquatic plant growth have included both chemical treatments and mechanical harvesting. Chemical treatment records go back to 1999. However, no chemical treatment has been done in Peppermill Lake for at least five years, as the population of Eurasian Watermilfoil diminished after several years of regular chemical treatment. The lake is evaluated each spring and fall for any re-establishment of Eurasian Watermilfoil. One other invasive aquatic plant has been found in Peppermill Lake, but has remained in low frequency occurrence: Reed Canarygrass (*Phalarais arundinacea*).

Mechanical harvesting is done one to three times per summer, depending on aquatic plant growth, and is confined to making sure that navigational channels are open throughout the lake. This keeps *Chara* mounds and water lilies from blocking navigation through the lake.

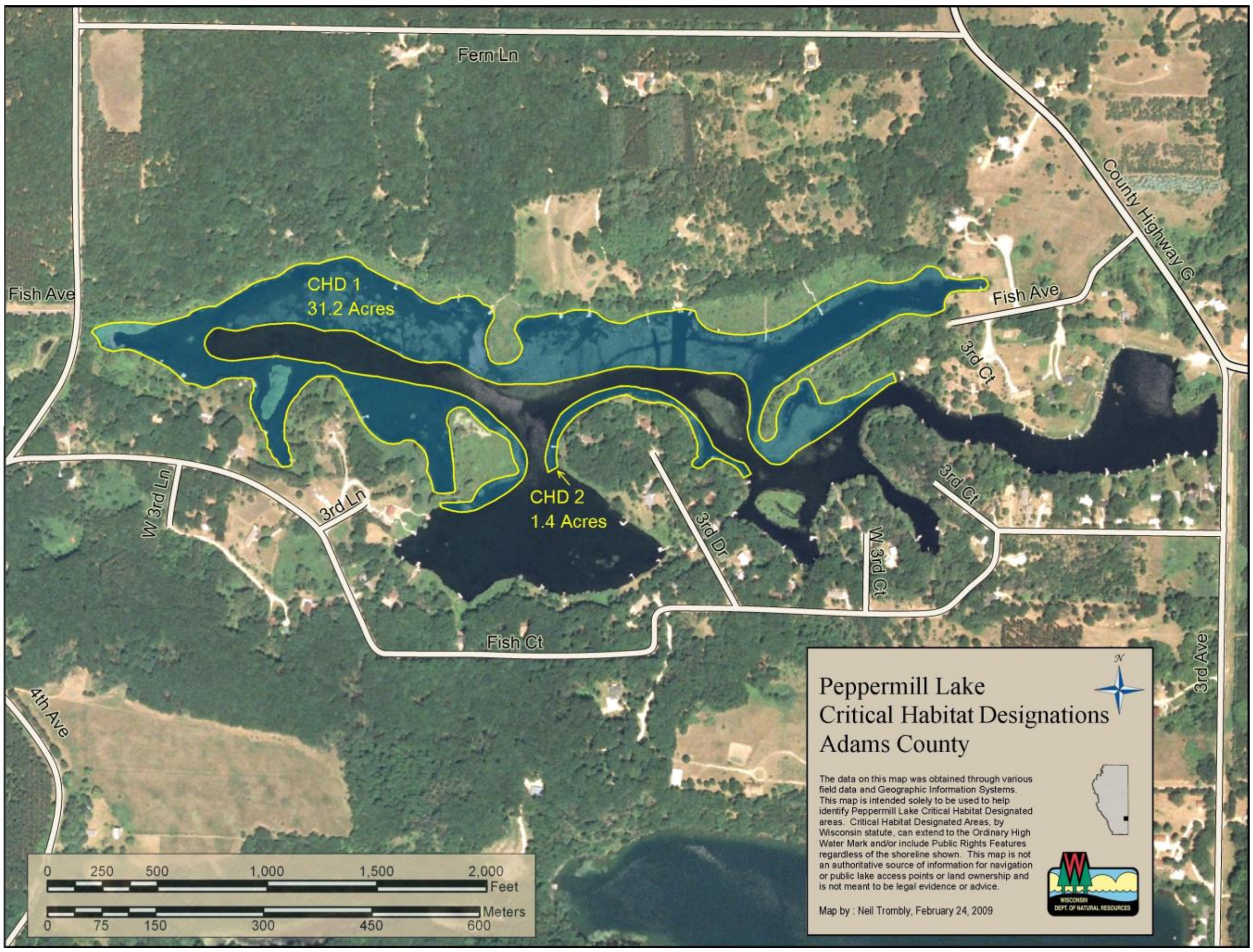
Hand harvesting of invasives like Eurasian watermilfoil is difficult in Peppermill Lake due to its very mucky bottom. The depth of the muck makes wading in to pull a plant fully impossible. Deep muck and thick water lilies make handpulling from a boat in the lake also unproductive.

Two areas in Peppermill Lake have been designated as “critical habitat”. Designation of critical habitat areas within lakes provides a holistic approach for assessing the ecosystem and for protecting those areas in and near a lake that are important for preserving the qualities of the lake. Wisconsin Rule 107.05(3)(i)(I) defines these areas as: “areas of aquatic vegetation identified by the department as offering critical or unique fish & wildlife habitat or offering water quality or erosion control benefits to the body of water.” Thus, these sites are essential to support the wildlife and fish communities. They also provide mechanisms for protecting water quality within the lake, often containing high-quality plant beds. Finally, sensitive areas often can provide the peace, serenity and beauty that draw many people to lakes in the first place.

<u>Area CH1</u> extends along approximately 7000 feet of the shoreline of about 2/3 of the northern shore of the lake and the southwest shore of the lake. Native vegetation is abundant in this area, including trees, shrubs and herbaceous species. Shrub-carr is found along part of the shore. Large woody cover is common for habitat. With minimal human disturbance along this shoreline, the area has natural scenic beauty and it provides quality habitat for many types of wildlife. Ten types of emergent aquatic plants were found in this area. Emergents provide important fish habitat and spawning areas, as well as food and cover for wildlife. Two species of free-floating plants were also present. These provide cover for fish and invertebrates and are

eaten by fish and waterfowl. Three types of rooted, floating-leaf plants were also found here. Rooted floating-leaf vegetation provides cover and dampens waves, protecting the shore. A variety of twelve submergent aquatics characterized this area. A diverse submergent community provides many benefits. The only invasive plant found in this area was Eurasian Watermilfoil.

Figure 1: Critical Habitat Map for Peppermill Lake



<u>Area CH2</u> runs along about 800 feet of shore along the middle south part of the lake. Much of the shore is wooded. This area has more cultivated lawn and some hard structure that is absent in CH1. Shallow marsh covers part of the shore. Large

woody cover is abundant here for habitat. No threatened or endangered species were found in this area. Eurasian watermilfoil was found in this area. Only two types of emergents were found here. Two floating-leaf rooted plants were present. Two free-floating plants were also at this site. The remaining aquatic plants were five submergent species.

Figure 2: Fish & Wildlife Uses of Aquatic Plants

	Fish	Water Fowl	Shore Birds	Upland Birds	Muskrat	Beaver	Deer
Carex spp		F	F,I	-			
Chara	F,S	F,I,C					
Lemna minor	F,I,C,S	F	F		F	F	
Myriophyllum spp	F,I,C,S	F,I	F		F		
Najas spp	F,C,I	F	F	F	F		
Nuphar variegataa	F,I,C,S	F	F		F	F	F
Nymphaea odoratoa	F,I,C,S	F	F		F	F	
Potamogeton spp	F,I,C.S	F,I	F		F	F	F
Scirpus spp	F,C,I	F,C	F,C,N	F	F	F	F
Spirodela polyrhiza	F,I,C,S	F	F		F	F	
Sparganium spp	F,I,C,S	F,C,N	F,C,N		F		F

F = Food; I = Shelters Invertebrates; C = Cover; S = Spawning; N = Nesting

II. METHODS

Field Methods

The 2016 survey used the Point Intercept Method. This method involves calculating the surface area of a lake and dividing it (using a formula developed by the WDNR) into a grid of several points, always placed at the same interval from the next one(s). These points are related to a particular latitude and longitude reading. At each geographic point, the depth is noted and one rake is taken, with a score given between 1 and 3 to each species on the rake.

A rating of 1 = a small amount present on the rake;
A rating of 2 = moderate amount present on the rake;
A rating of 3 = large amount present on the rake.

A visual inspection was done between points to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording plants found. Some near shore sites were added to the original grid to be sure shallow water vegetation was adequately evaluated.

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites). Relative frequency was calculated (number of occurrences of a species/sum of all species occurrences) .The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites). Relative density was calculated (sum of a species density/sum of all plant densities). "Mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred). The relative frequency and relative density of each species were summed to obtain a dominance value for each species. Species diversity was measured by Simpson's Diversity Index.

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols (Nichols et al., 2000) was applied to Peppermill Lake results. Measures for each of seven categories that characterize a plant community are converted to values between 0 and 10 and summed to measure the quality of the plant community.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for all species found in the lake. The Floristic Quality Index is calculated from the Coefficient of Conservatism (Nichols, 1998) and is a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae, water clarity and water hardness) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also impact the aquatic plant community.

WATER QUALITY - The trophic state of a lake is a classification of its water quality. Phosphorus concentration, chlorophyll concentration and water clarity data are collected and combined to determine the trophic state.

- Eutrophic lakes are high in nutrients and support a large biomass. They are sometimes dominates by blue-green algae, with algae scums common. Plant growth is abundant, and rough fish like carp and gizzard shad can be expected.
- Oligotrophic lakes are low in nutrients and support limited plant and algae growth. Small populations of game fish are likely. They often have clear deep water which may have oxygen depletion in lower depths.
- Mesotrophic lakes have intermediate levels of nutrients and biomass with

occasional algae blooms. Water is moderately clear with a varied plant community and mixed fishery.

Peppermill Lake has water quality records for a number of years. Water clarity, total phosphorus, and chlorophyll-a readings go back to 1992. After a gap of several years, regular collection began again in 1999 and has continued through 2016. There are 4 monitoring sites for collection: the deep hole, funded by the WDNR, and 3 additional sites funded by the Peppermill Lake District.

Phosphorus

Phosphorus is a limiting nutrient in many Wisconsin lakes, including Peppermill Lake. Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth. Starting from 1990, the average growing season (May through September) for total phosphorus levels is 32.6 micrograms/liter, which is in the "fair" category. Total phosphorus level have increased in the last 10 years, resulting in an average of 38.4 micrograms/liter.

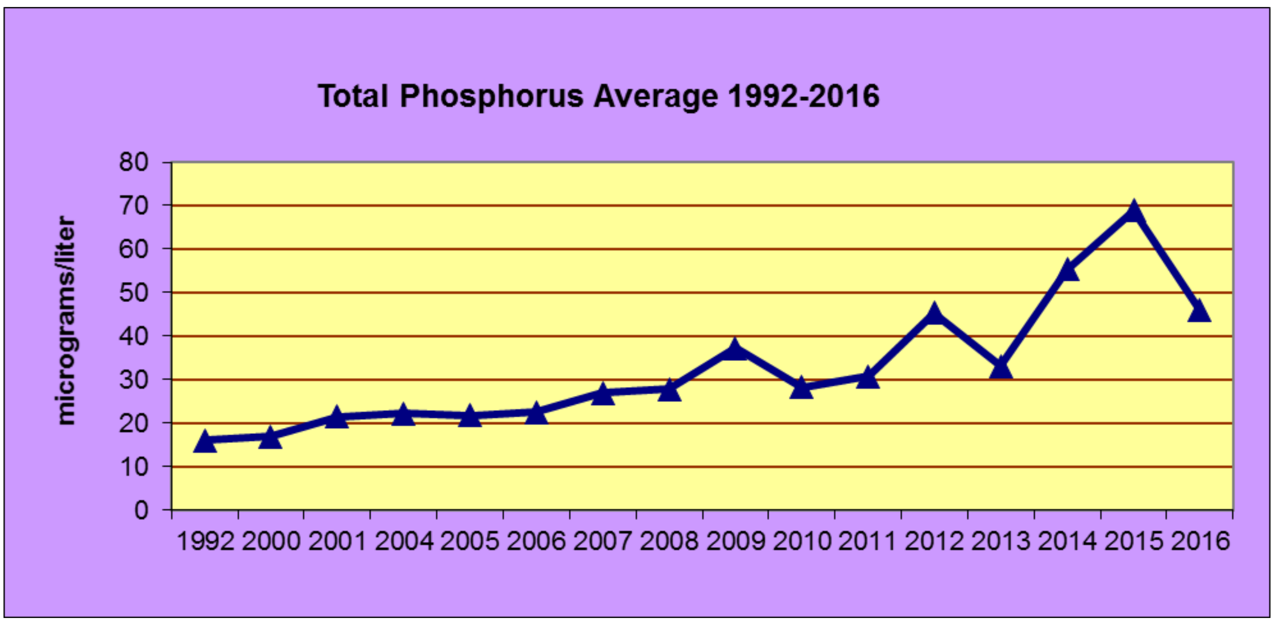
Figure 3: Trophic Status of Peppermill Lake

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.
Oligotrophic	Excellent	<1	<1	> 19
	Very Good	1-10	1-5	**8-19**
Mesotrophic	Good	10-30	5-10	6-8
	Fair	**30-50**	**10-15**	5-6
Eutrophic	Poor	50-150	15-30	3-4
Peppermill Lake Growing Season 2006-2016		**38.4**	**13.7**	**8.3**

Algae/Chlorophyll-a

Chlorophyll-a concentrations provide a measure of the amount of algae in lake water, although not the species. Algae are natural and essential in lakes, but high algae populations can increase turbidity and reduce the light available for plant growth. The 1992-2016 mean summer chlorophyll-a concentration in Peppermill Lake was 10.6 micrograms/liter, in the "fair" range for chlorophyll-a levels. If one only looks at the last 10 years, the chlorophyll-a levels appear to be rising, because the average jumps up to 13.7 micrograms/liter.

Figure 4: Average Total Phosphorus Levels in Peppermill Lake 1992-2016



Water Clarity

Water clarity is a critical factor for aquatic plants, because they need more than 2% surface illumination, or they won't survive (Chambers and Kalff, 1985; Duarte et al., 1986; Kampa, 1994). Water clarity is reduced by turbidity (suspended materials like algae and silt) and dissolved organic chemicals that color the water. Water clarity is measured with a Secchi disc. The 1992-2012 average summer Secchi disc clarity in Peppermill Lake was 8.9 feet. This falls in the "very good" category. The average for the last 10 years is down slightly to 8.3 feet, still in the 'very good' category.

Figure 5: Average Chlorophyll-a Levels in Peppermill Lake 1992-2016

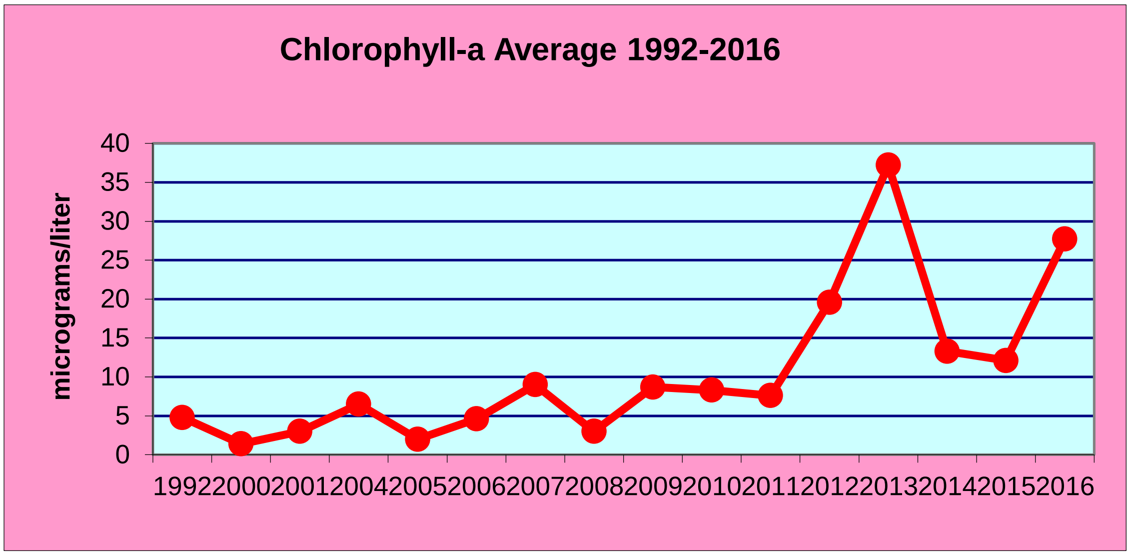
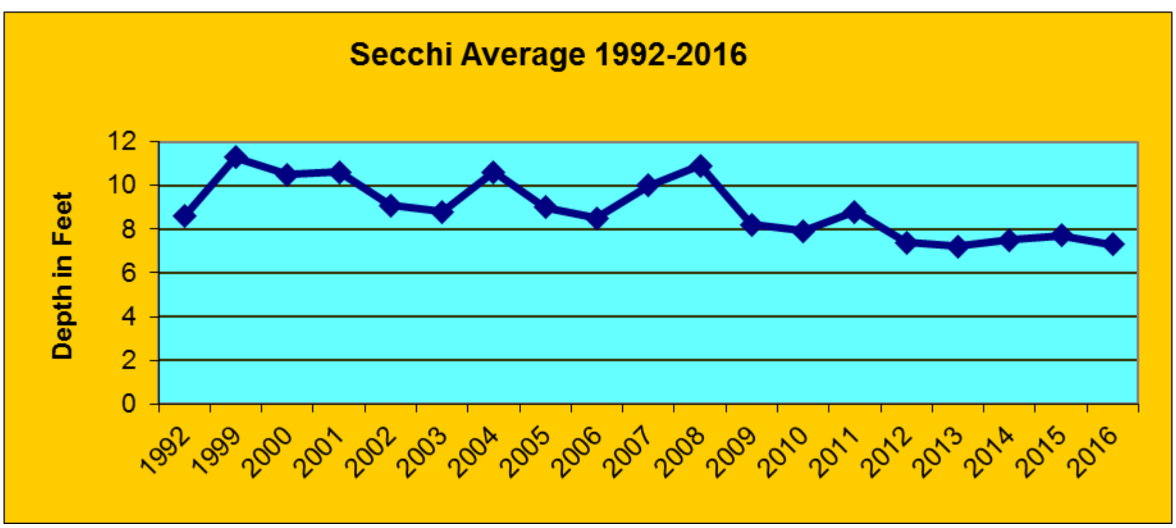


Figure 6: Peppermill Average Growing Season Secchi Depth 1992-2016



Overall Water Quality

The combination of phosphorus and chlorophyll-a concentrations and water clarity indicate that Peppermill Lake is a borderline oligotrophic/mesotrophic impoundment with good-to-very good water quality and clarity. This trophic state should favor only moderate plant growth and occasional localized summer algal blooms.

Hardness

The hardness or mineral content of lake water also influences aquatic plant growth. The 1999-2006 hardness values in Peppermill Lake ranged from of 185 to 212 milligrams/liter $CaCO_3$, with an average of 198.7 micrograms/liter $CaCO_3$. This is very hard water. Hard water lakes tend to support more plant growth than soft water lakes (B.Shaw et al., p.13). While marl (calcium carbonate) in a lake precipitates and falls to the lake bottom, some of the marl in hard water lakes often coats the external surfaces of submersed plants (C.E.Boyd, p. 112). There are marl pockets in some areas of the sediments in Peppermill Lake. Marl formations absorb phosphorus, reducing its overall concentration and decreasing algal growth (B. Shaw et al, p. 7). Such coating can be found on some of the plants in Peppermill Lake.

LAKE MORPHOMETRY - The morphometry of a lake is an important factor in determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel, 1985).

Peppermill Lake is a man-made lake with a middle "channel" area and several lobes around the lake. There are few steep slopes; instead, the littoral area tends to be the entire lake, with gradual slopes. These gradual slopes provide a stable rooting base and a broad area of shallow water that can be reached by the sun. These factors favor aquatic plant growth, which may account for the aquatic vegetation rate for Peppermill Lake at 100% for all of the recorded aquatic plant surveys.

INFLUENCE OF SEDIMENT COMPOSITION

Some plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility and texture of the sediment will determine the type and abundance of plant species that can survive in a location. The availability of mineral nutrients for growth is highest in sediments of intermediate density, such as silt, so these sediments are considered most favorable for plant growth (Barko and Smart, 1986). Mineral availability in sediments such as sand is often considerably reduced. The most common sediment in Peppermill Lake was muck, or a mixture of muck and another substance, covering nearly 60% of the lake's bottom. Muck soil has a nutrient-rich content, "perfect" for growing plants (Thompson, 2010).

SHORELINE LAND USE

Land use can strongly impact the aquatic plant community and therefore the entire aquatic community. Land use in both rural and urban settings can directly impact the plant community through increased erosion and sedimentation and increased run-off of nutrients, fertilizers and toxics applied to the land.

Native herbaceous cover is the most frequently occurring shoreline on Peppermill Lake. Shrubs and trees are also common. Woody debris by the shore is abundant in the lake. Cultivated lawn and hard structure (boat docks, patios, retaining walls, etc.) are less frequently occurring than on any other man-made lakes in Adams County.

MACROPHYTE DATA

SPECIES PRESENT

In the 2016 survey, 43 species of aquatics were found. Of these, 41 were native: 15 emergent species, 3 free-floating species, 4 rooted floating-leaf plants, and 22 submergents. Two two invasive aquatic plants were found: the emergent Reed Canarygrass (*Phalaris arundinacea*) and the submergent Eurasian Watermilfoil (*Myriophyllum spicatum*).

Figure 7: Species Found in Peppermill Lake 2016

Scientific Name	Common Name	Type
Aquatic Moss	-	-
Alisma spp	Plantain	Emergent
Bidens beckii	Water Marigold	Emergent
Carex spp	Sedge	Emergent
Carex comosa	Bristly Sedge	Emergent
Ceratophyllum demersum	Coontail	Submergent
Chara spp	Muskgrass	Submergent
Chelone glabra	Turtlehead	Emergent
Cicuta bulbifera	Bulb-Bearing Water Hemlock	Emergent
Cyperus odoratus	Flat Shining Sedge	Emergent
Eleocharis erythropoda	Bald Spikerush	Emergent
Elodea canadensis	Common Waterweed	Submergent
Impatiens capensis	Jewelweed	Emergent
Iris versicolor	Blue-Flag Iris	Emergent
Lemna minor	Lesser Duckweed	Free-Floating
Lycopus uniflorus	Northern Bugleweed	Emergent
Lycnothamnus barbatus	Bearded Stonewort	Submergent
Myriophyllym heterophyllum	Variable-Leaf Milfoil	Submergent
Myriophyllum sibiricum	Northern Milfoil	Submergent
Myriophyllum spicatum	Eurasian Watermilfoil	Submergent
Myriophyllum verticillatum	Whorled Milfoil	Submergent
Najas flexlis	Slender Naiad	Submergent
Nuphar variegata	Yellow Pond Lily	Floating-Leaf
Nymphaea odoratus	White Water Lily	Floating-Leaf
Phalaris arundinacea	Reed Canarygrass	Emergent
Polygonum amphibium	Water Smartweed	Floating-Leaf
Potamogeton amplifolius	Large-Leaf Pondweed	Submergent
Potamogeton gramineus	Variable Pondweed	Submergent

Potamogeton illinoensis	Illinois Pondweed	Submergent
Potamogeton natans	Floating-Leaf Pondweed	Submergent
Potamogeton praelongus	White-Stemmed Pondweed	Submergent
Potamogeton pusillus	Small Pondweed	Submergent
Potamogeton zosteriformis	Flat-Stemmed Pondweed	Submergent
Ranunculus aquatilis	White Water Crowfoot	Submergent
Schoenoplectus tabernaemontani	Soft-Stemmed Bulrush	Emergent
Solanum dulcamara	Bittersweet Nightshade	Emergent
Spirodela polyrhiza	Greater Duckweed	Free-Floating
Stuckenia pectinata	Sago Pondweed	Submergent
Typha spp	Cattail	Emergent
Utriicularia gemniscapa	Twin-Stemmed Bladderwort	Submergent
Utricularia gibba	Creeping Bladderwort	Submergent
Utricularia minor	Lesser Bladderwort	Submergent
Utricularia vulgaris	Greater Bladderwort	Submergent
Wolffia columbiana	Watermeal	Free-Floating
Zosterella dubia	Water Stargrass	Submergent

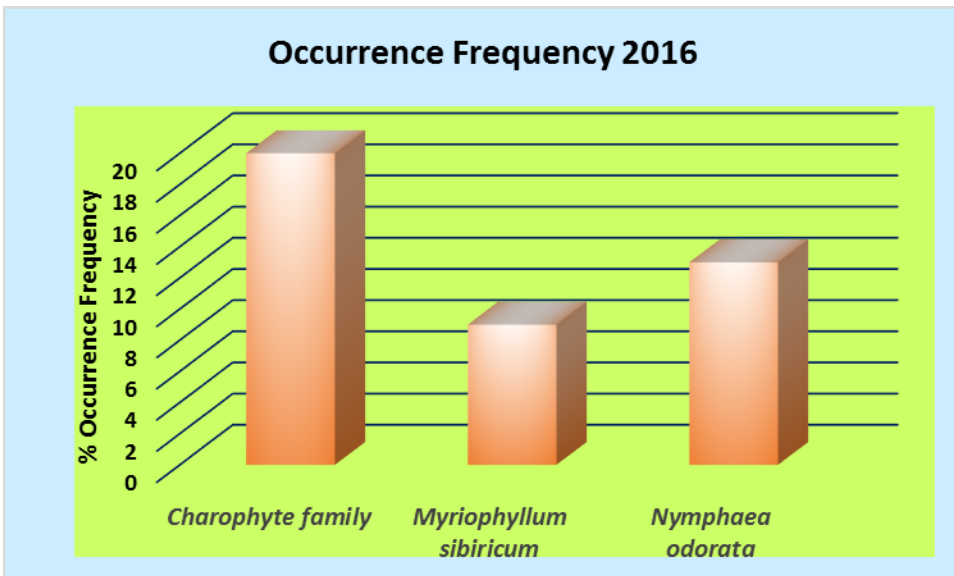
FREQUENCY OF OCCURRENCE

In 2016, members of the *Charophyte* family were the most frequently-occurring aquatic species. These species play multiple roles in an aquatic ecosystem as part of the food web, in providing habitat, and in increasing water quality. Almost all groups in an aquatic food web benefit from the presence of *Charophytes* This vegetation is especially important in the winter when it provides habitat for the invertebrates that support good fisheries.

Besides providing habitat for important invertebrates and food for fish and wildlife, *Charophytes* also serve as protection and cover for young fish. They are important in the predator-prey ratio. Their presence has even been known to inhibit the survival of mosquito larvae.

Perhaps the most important role in an aquatic ecosystem that *Charophytes* serve is in water quality. These plant-like algae naturally filter the water and play an important part in nutrient cycling. They hold massive amounts of phosphorus, thus serving as a phosphorus sink. This results in reducing and/or and blocking the availability of phosphorus for other less desirable algae and aquatic vegetation. In hard water systems, like those in Adams County, the calcification on *Charophytes* ties up even more phosphorus.

Figure 8: Most Frequently-Occurring Species in Peppermill Lake 2016



They deliver oxygen to sediments, enhancing the nitrogen cycle and preventing iron-bound phosphorus from being released into the water column. Besides holding phosphorus, they also hold a lot of nitrogen, which is the second most influential factor in the presence of nuisance aquatic plant and excessive algae production.

Charophytes are known to play important roles in forming habitat and shaping an aquatic environment, influencing both abiotic (pH, water clarity) and biologic (structure of phytoplankton) factors. Studies have shown that *Charophytes* restrict the resuspension of sediments up to 100 times more than other aquatic vegetation.

The most frequently-occurring aquatic plants in the 2016 survey were Northern Milfoil, a submergent, and White Water Lily, a rooted floating-leaf plant. Both of these are native plants found in many of the lakes in Adams County.

As is common in the Adams County lakes, submergent plants were the most frequently-occurring aquatic type in Peppermill Lake in 2016, comprising over 63% of the aquatic community.

DENSITY

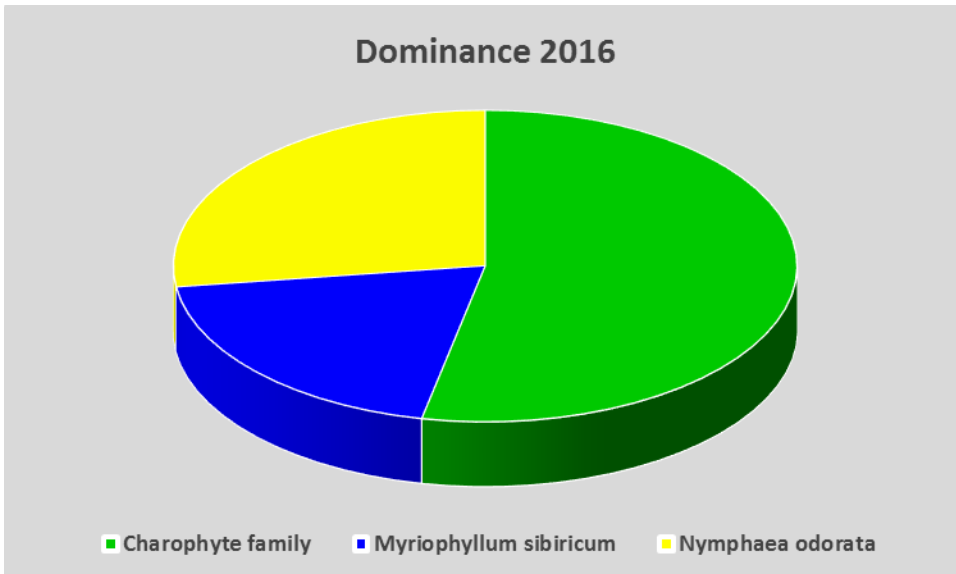
Besides the frequency at which particular species occurs, the density of growth for each plant type is also evaluated. Some plants occur mostly in beds of growth with their own kind—those would have a considerably higher growth density where present than in the lake overall. In other instances, a specie is found scattered throughout the lake, mixed with other species. The most densely-growing aquatic species in the lake overall in 2016 were the *Charophyte* species.

The most densely-growing aquatic plant was White Water Lily. In some area of Peppermill Lake, this plant is so dense that travel through the beds is nearly impossible, especially in boggy areas.

DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community. Based on the Dominance Value, members of the *Charophyte* family were the dominant aquatic species in Peppermill Lake in 2016.

Figure 9: Dominance in 2016 in Peppermill Lake

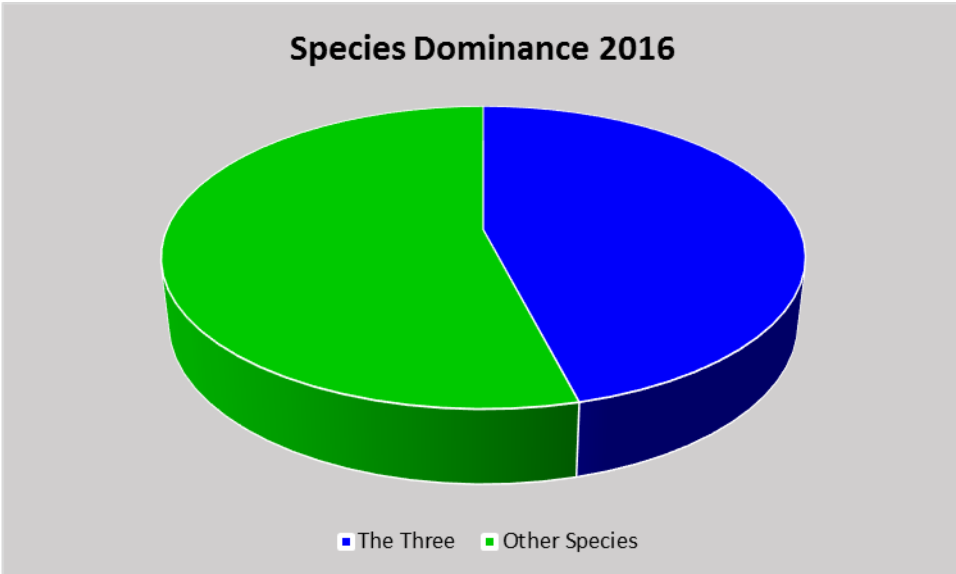


If they are combined with the two dominant aquatic plant species--White Water Lily and Northern Milfoil, they comprise 46% of the aquatic community for 2016.

DISTRIBUTION

Aquatic plants were found throughout Peppermill Lake in all the recorded surveys. Although plants were found all through the lake, not all plant types or species were found everywhere.

Figure 10: Species Dominance in 2016 in Peppermill Lake



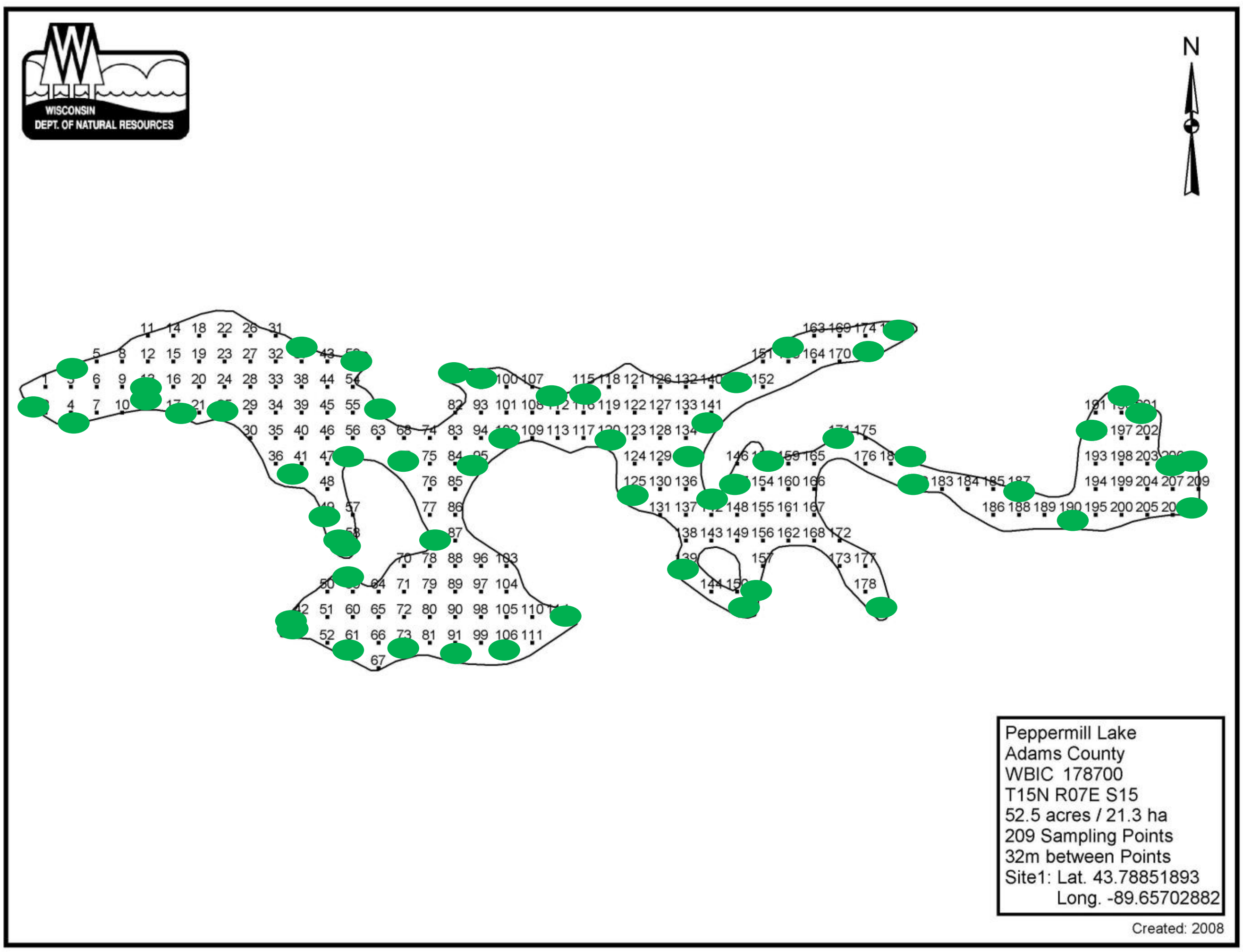
Eurasian Watermilfoil was consistently found in Peppermill Lake for many years. After several years of chemical treatment, it seemed to disappear from the lake for a while. The lake has been monitored every year spring and fall by Adams County Land & Water Conservation Department and Peppermill Lake volunteers for any recurrence. In the last several surveys, it has only been found as isolated plants. Spring and fall monitoring will continue for the near future.

In 2007, a survey was done to look for the native weevil known to damage Eurasian watermilfoil, *Euhrychiopsis lecontei*, in Peppermill Lake. 14% of the milfoil collected showed significant damage to stems that could be attributed to weevil presence. Although the Peppermill Lake District has expressed some interest in raising the weevils to increase the numbers present, the current protocol is extremely labor-intensive. So far, there are insufficient volunteers available to engage in a rearing project. Research funded by the WDNR is ongoing, hoping to find a less labor-intensive way of raising these biological controls.

Figure 11: Milfoil Weevil

Eurasian Watermilfoil

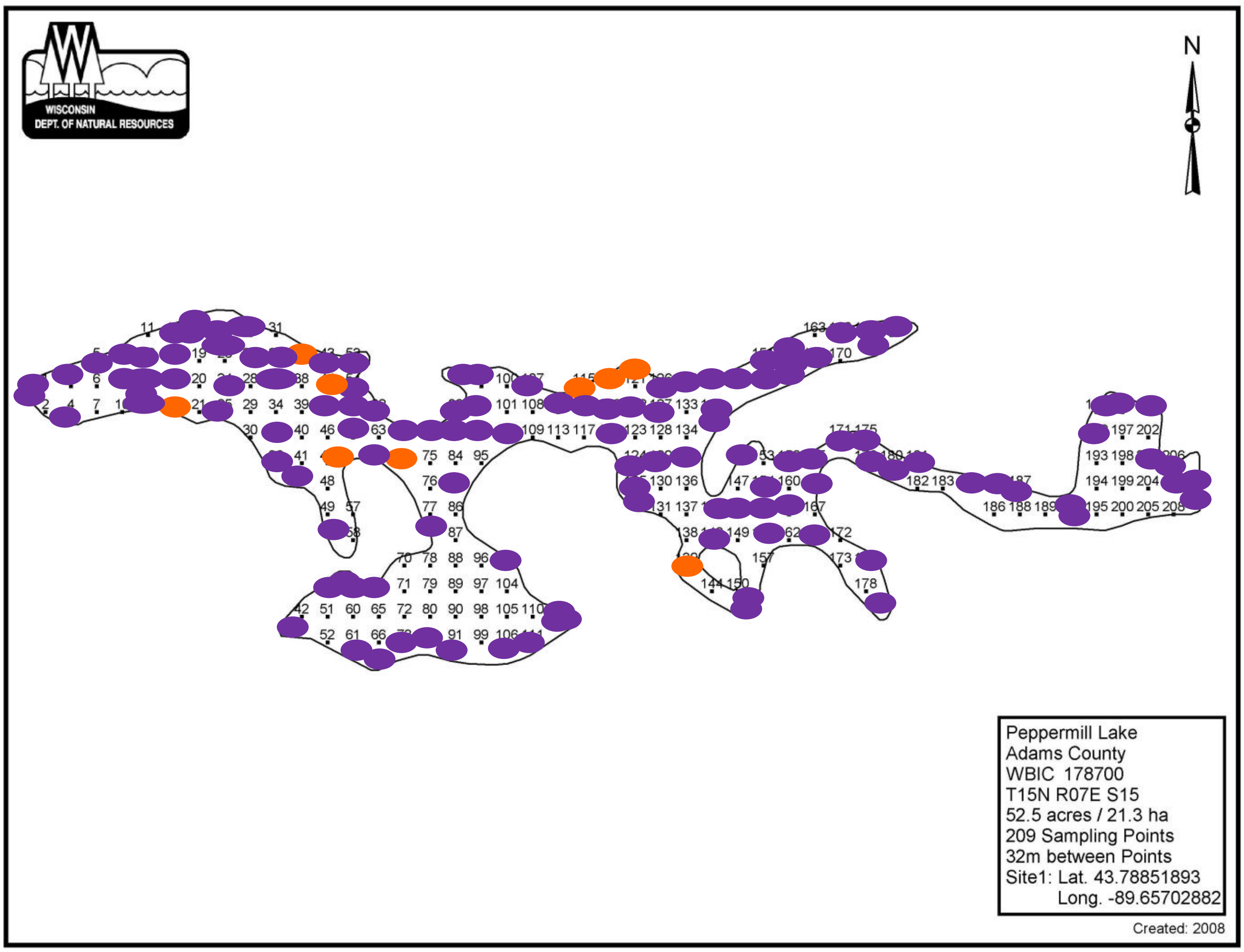
Figure 12: Distribution of Emergent Plants 2016



The Peppermill Lake District has actively pursued hand-pulling Eurasian Watermilfoil in areas that can be reached by wading or snorkeling without sinking in muck. This has focused on the removal of individual plants or small isolated populations and continues each year. In the 2006 transect survey, Eurasian Watermilfoil comprised 10% of the aquatic community. By 2012, it had decreased to 3%. In 2016, it was only 1% of the total aquatic community.

Figure 13: Distribution of Free-Floating and Rooted Floating-Leaf Plants 2016

Both Free-Floating & Floating-Leaf **Floating-Leaf Only**



Reed Canarygrass, the other invasive found at Peppermill Lake, has never comprised a large part of the aquatic community. Although it has been found for many years at Peppermill Lake, it continues to be found in low frequency of occurrence and low density of growth, comprising about 2% of the aquatic plant community.

Figure 14: Location of Invasives 2016

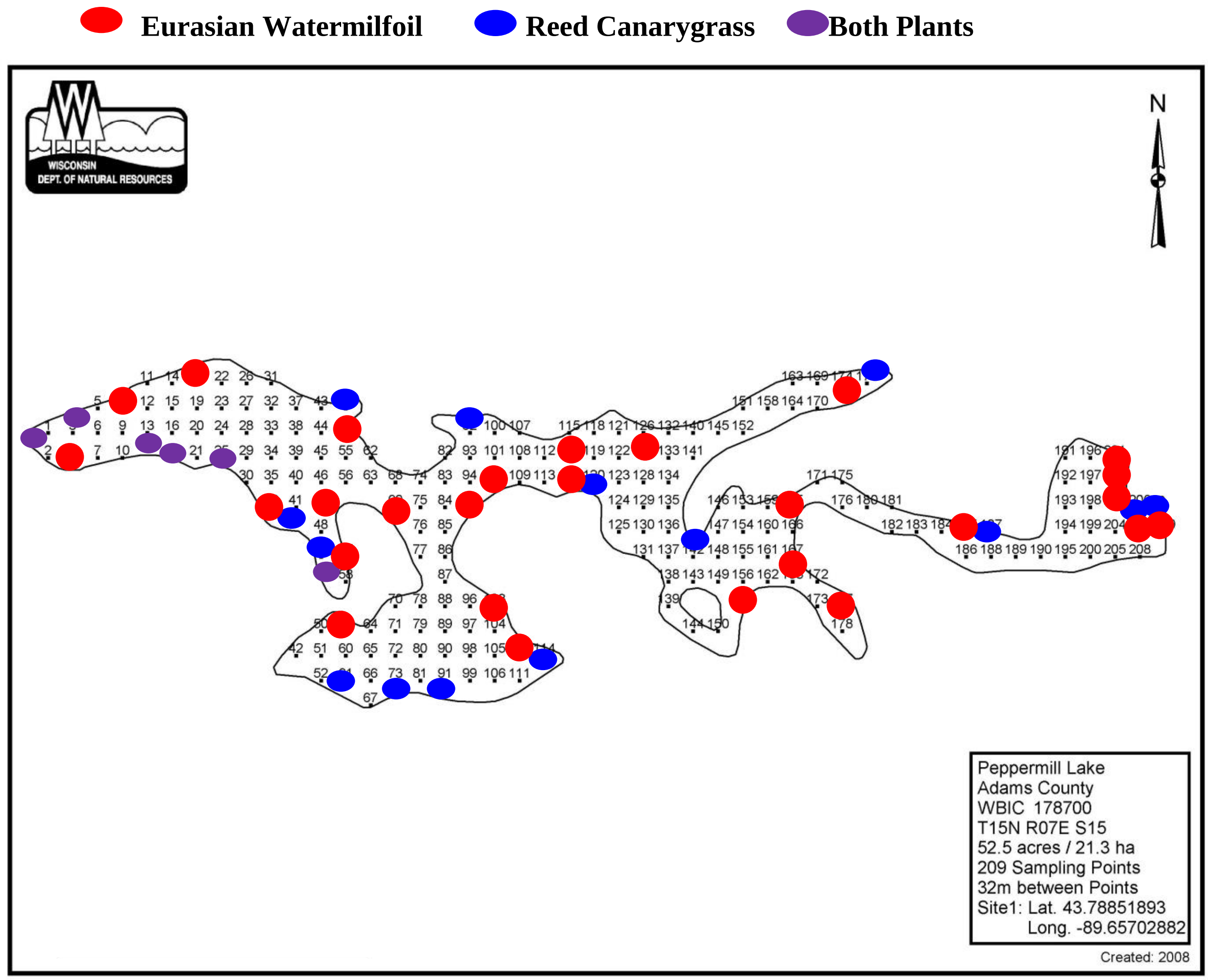


Figure 15: Reed Canarygrass

THE COMMUNITY

The Simpson's Diversity Index (SI) for the 2016 survey was .92. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This score places Peppermill Lake in the upper quartile for diversity for all the lakes in Wisconsin and for the North Central Hardwoods Region.

Species richness is the number of species in a given area. When looking at aquatic survey results, higher species richness usually indicates a higher quality aquatic plant community. The 2012 PI species richness was 3.24. The score for 2016 was 3.98.

The Average Coefficient of Conservation and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance. A coefficient of conservation is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservationism is the mean of the coefficients for the species found in the lake. The Average Coefficient of Conservatism for Peppermill Lake in 2016 was 5.7. This figure would put Peppermill Lake in the median of lakes in Wisconsin and in median range for the North Central Hardwoods Region.

The coefficient of conservatism is used to calculate the Floristic Quality Index (FQI), a measure of a plant community's closeness to an undisturbed condition. The Floristic Quality Index is also a tool that can be used to identify areas of high conservation value, monitor sites over time, assess the anthropogenic (human-caused) impacts affecting an area and measure the ecological condition of an area (M. Bourdaghs et al, 2006).

The FQI for the 2016 PI survey was 36.21. This score places Peppermill Lake in the highest quartile for Wisconsin lakes and the North Central Hardwood Region lakes. These figures indicate that the plant community in Peppermill Lake is closer to an undisturbed condition than the average lake in Wisconsin and within the group of lakes in the region closest to an undisturbed condition.

Figure 16: Floristic Quality and Coefficient of Conservatism of Peppermill Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡
Wisconsin Lakes	5.5, 6.0, 6.9 *	16.9, 22.2, 27.5
NCHR	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4
Peppermill Lake 2012	5.7	36.21

***** - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.

† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

‡ - lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

These results may at first seem contradictory, with one score in the median range and one in the highest quartile. However, the Average Coefficient of Conservatism doesn't include considering the frequency or density of the species involved, unlike the FQI.

Disturbances can be of many types:

1) Physical disturbances to the plant beds from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2) Indirect disturbances that impact water clarity and stress species that are more sensitive: resuspension of sediments, sedimentation from erosion, or increased algae growth due to nutrient inputs.
3) Biological disturbances like the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by a fish or wildlife population.

The major disturbances in Peppermill Lake are likely:

1) the introduction of non-native aquatic plant species;

2) damage by motor boats in the shallow water areas.

The Aquatic Macrophyte Community Index (AMCI) for Peppermill Lake was 51 in 2016. This value is in the average for lakes in the North Central Hardwoods Region (48 to 57) and Wisconsin (45 to 57) and indicate that the aquatic plant community in Peppermill Lake is of at least average quality.

In spring 2016, the Wisconsin Department of Natural Resources released a proposed protocol for shoreland habitat assessment that could be used on both lakes and streams. There are three phases outlined: photographing every waterfront parcel with overlap, thus preserving a visual representation of the entire shore in 2016; assessing each parcels for a number of items, including buffer presence & description, runoff issues, and near-shore vegetation; and locating large woody debris in the water near the shore, known to be an important habitat component (Gregory et al, 2003).

Woody debris often improves fish habitat quality by creating pools and providing cover. It also increases the retention of organic matter and nutrients and helps create islands and new channels that provide additional refuge and habitat, especially for rearing juvenile fish. Removing wood can lead to habitat declines such as the loss of spawning gravel and pools for rearing. Wood also helps stabilize shorelines and provides vital habitat for many creatures. It serves as a refuge for juvenile and adult fish, creates diversity of habitat, provides food and habitat for aquatic insects & wildlife, and serves as a corridor for wildlife movement.

The protocol requires verifying the location of woody debris by GPS. Qualifying woody debris has to be at least 4 inches in diameter and at least 5 feet long. The map below shows the location of woody debris found in 2016. Note that at some sites, there may be several qualifying pieces at the same GPS point.

In addition, woody debris helps stabilize shores and prevent erosion, as well as serving to intercept runoff from the land, thus helping water quality. Preserving and even increasing the amounts of large woody debris along shorelines is important for keeping aquatic areas healthy.

Peppermill Lake has a large amount of woody debris, sufficient for serving all the potential functions of such habitat structures.

COMPARISON TO PRIOR RESULTS

In 2006, 31 aquatic species were found in Peppermill Lake, using the transect method. In 2012, the transect survey method found 41 species and the PI survey yielded 51 species. During the summer of 2012, the lake level of Peppermill Lake was reduced, down in depth due to the hot dry weather and drought. Despite this variance in water level, the aquatic plant community found in the 2012 transect community was much the same as that in the 2006 survey, with a small change in percentages between emergent, rooted floating-leaf, and submergent species. By 2016, 43 species were located and identified. The results of the 2016 survey, done using the PI method, will be compared to the 2012 PI survey.

Figure 17: Distribution of Woody Debris in Peppermill Lake 2016

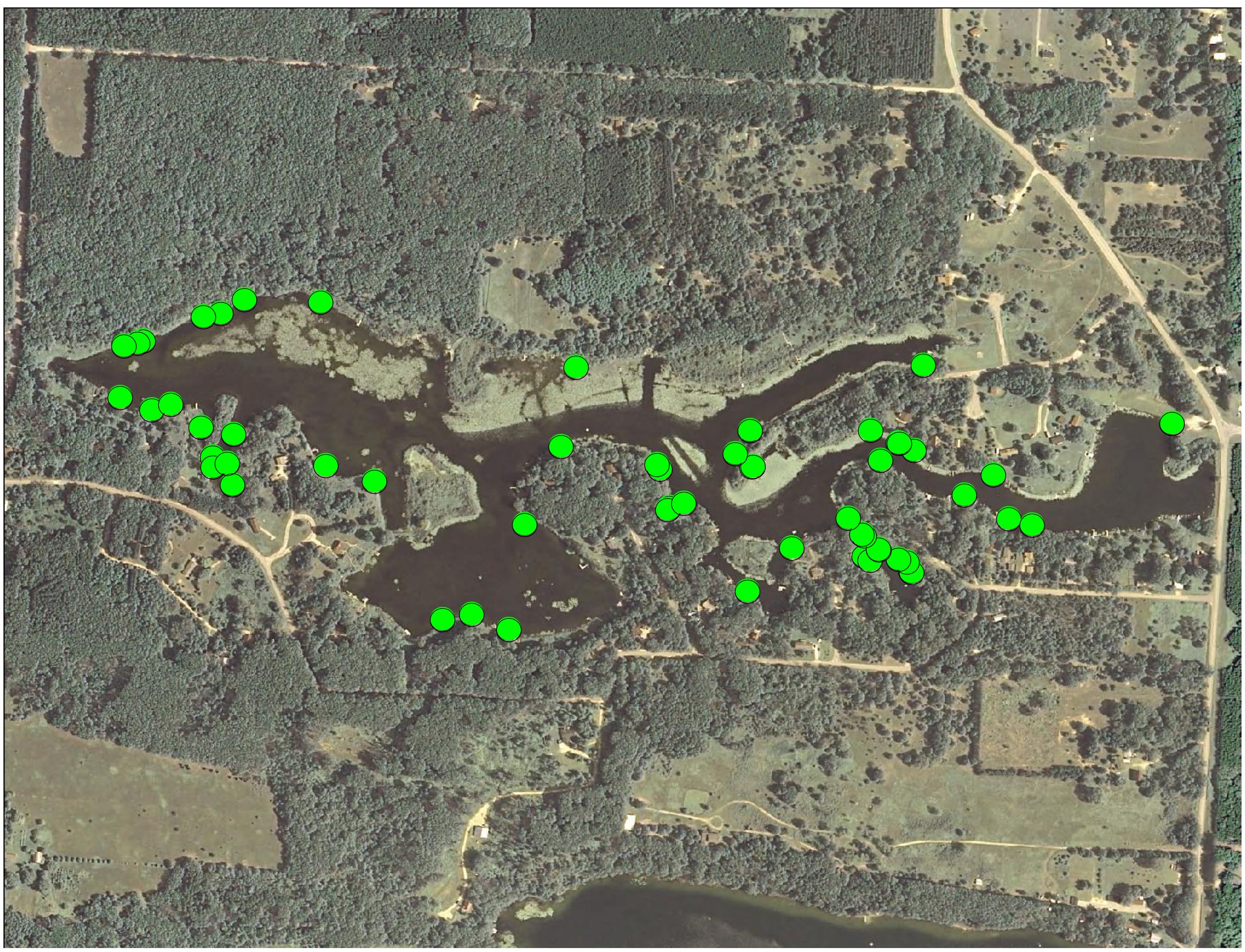


Figure 18: Plant List 2001-2016

Scientific Name	Common Name	2001(t)	2006(t)	2012(t)	2012(pi)	2016(pi)
Acorus americana	Sweet Flag		x		x	
Alisma spp	Plantain					x
Angelica atropurpurea	Angelica				x	
Ascelpias incarnata	Swamp Milkweed		x	x	x	
Bidens beckii	Swamp Marigold					x
Bidens frondosus	Common Beggar's Tick				x	
Bromus ciliatus	Fringed Brome				x	
Calamagrostis canadensis	Canada Blue-Joint Grass			x	x	
Carex spp	Sedge		x	x	x	x
Carex aquatilis	Lake Sedge			x		
Carex comosa	Porcupine Sedge		x		x	x
Carex prairea	Prairie Sedge				x	
Cornus stolonifera	Buttonbush				x	
Ceratophyllum demersum	Coontail	x	x	x	x	x
Chara spp	Muskgrass	x	x	x	x	x
Chelone glabra	Turtlehead			x		x
Cicuta bulbifera	Bulb-Bearing Water Hemlock	x	x	x	x	x
Cornus stolonifera	Red-Osier Dogwood	x	x	x	x	
Cyperus odoratus	Fragrant Flat Sedge					x
Eleocharis erythropoda	Bald Spikerush				x	x
Elodea canadensis	Common Waterweed	x	x	x	x	x
Eupatorium maculatum	Joe Pye Week			x	x	x
Eupatorium perfoliatum	Boneset			x	x	
Galium asperellum	Rough Bedstraw				x	
Impatiens capensis	Jewelweed		x	x	x	
Iris versicolor	Blue-Flag Iris			x	x	x
Leersia oryzoides	Rice-Cut Grass		x			
Lemna minor	Lesser Duckweed	x	x	x	x	x
Lycopus uniflorus	Northern Bugleweed			x	x	x
Lycnothamnus barbatus	Bearded Stonewort					x
Myriophyllym heterophyllum	Various-Leaved Milfoil		x	x	x	x
Myriophyllum sibiricum	Northern Milfoil	x	x	x	x	x
Myriophyllum spicatum	Eurasian Watermilfoil	x	x	x	x	x
Myriophyllum verticillatum	Whorled Watermilfoil			x	x	x
Najas flexilis	Bushy Pondweed	x	x	x	x	x
Nuphar variegata	Yellow Pond Lily	x	x	x	x	x
Nymphaea odorata	White Water Lilly	x	x	x	x	x
Onoclea sensibilis	Sensitive Fern		x		x	
Phalaris arundinacea	Reed Canarygrass		x	x	x	x
Physiocoarpus opulifolis	Common Ninebark		x			
Polygoncum amphibium	Water Smartweed		x		x	x
Potamogeton amplifolious	Large-Leaf Pondweed	x	x	x	x	x
Potamogeton foliosus	Leafy Pondweed		x	x	x	
Potamogeton friesii	Fries's Pondweed		x	x	x	
Potamogeton gramineus	Variable-Leaf Pondweed					x

Potamogeton illinoensis	Illinois Pondweed	x	x	x	x	x
Potamgeton natans	Floating-Leaf Pondweed		x	x	x	x
Potamogeton praelongus	White-Stemmed Pondweed			x	x	x
Potamogeton pusillus	Small Pondweed					x
Potamogeton richardsonii	Clasping-Leaf Pondweed	x			x	
Potamogeton zosteriformis	Flat-Stemmed Pondweed		x		x	x
Ranunculus aquatilis	White-Stemmed Pondweed					x
Rumex spp	Dock		x			
Sagittaria spp	Arrowhead		x	x	x	
Salix spp	Willow			x	x	
Schoenoeplectus tabernaemontani	Soft-Stemmed Bulrush	z	x	x	x	x
Scutellaria laterifolia	Mad-Dog Skullcap		x			
Scirpus cyperinus	Woolgrass				x	
Sium suave	Hemlock Water Parsnip				x	
Solanum dulcamara	Bittersweet Nightshade			x		x
Sparganium eurycarpum	Common Bur Weed		x	x	x	
Spirodela polyrhiza	Greater Duckweed		x	x	x	x
Stuckenia pectinata	Sago Pondweed	x	x	x	x	x
Typha spp	Cattails	x		x	x	x
Utricularia gemniscapa	Twin-Stemmed Bladderwort				x	x
Utricularia gibba	Creeping Bladderwort				x	x
Utricularia minor	Lesser Bladderwort					x
Utricularia vulgaris	Greater Bladderwort	x	x		x	x
Zosterella dubia	Water Stargrass		x		x	x

The aquatic communities of 2012 and 2016 were compared by calculating coefficients of similarity (developed by Jaccard in 1901), using both actual frequency of occurrence and relative frequency of occurrence. Using the actual frequency of occurrence, the communities were 82.8% similar. Using relative species, they were 87.6% similar. These figures suggest that the aquatic plant community at Peppermill Lake has remained relatively stable in the last fifteen-plus years, despite some variances in species occurrence or density.

Figure 19: Comparisons in Aquatic Communities Peppermill 2001-2016

Peppermill	2001(T)	2006(T)	2012(T)	2012(PI)	2016(PI)
Number of Species	19	31	39	49	43
Maximum Rooting Depth	10.0	8.0	7.5	9.5	9
% of Littoral Zone Unvegetated	0	0	0	0	0.4
%Emergents	14%	11%	26%	10%	16%
%Free-floating	8%	2%	0%	0%	5%
%Submergents	69%	72%	59%	74%	100%
%Floating-leaf	9%	15%	15%	16%	24%
Simpson's Diversity Index	0.90	0.93	0.93	0.87	0.92
Species Richness	3.50	5.05	4.70	3.24	3.98
Floristic Quality	36.02	28.28	29.52	36.81	36.21
Average Coefficient of Conservatism	4.8	5	4.8	5.3	5.7
AMCI Index	43	56	49	51	51

V. DISCUSSION

Based on water clarity, chlorophyll-a, and phosphorus data, Peppermill Lake is a borderline oligotrophic/mesotrophic lake with very good water clarity and good water quality. Adequate nutrients (including sediments), good water clarity, hard water, and the large shallow areas in the lake would favor plant growth. Fairly high traffic and a significant presence of aquatic invasive plants, especially Eurasian Watermilfoil, have disturbed the aquatic plant community in the past, although overall the aquatic plant community has remained fairly stable. When the Eurasian Watermilfoil (EWM) was significantly reduced, *Chara* (muskgrass) moved in to many of the areas formerly occupied by EWM.

V. CONCLUSIONS

Peppermill Lake is a mesotrophic/oligotrophic lake with aquatic plants all through the lake. Depths of less than 5 feet supported the most abundant aquatic plant growth. Rooted aquatic plants were found as deep as 9.0 feet. *Chara* spp. was the dominant species found in the 2016 survey. Northern Milfoil and White Water Lily, both native, were also common. All other species were found much less frequently and occurred in relatively low density of growth. No endangered or threatened species were found in Peppermill Lake in 2016.

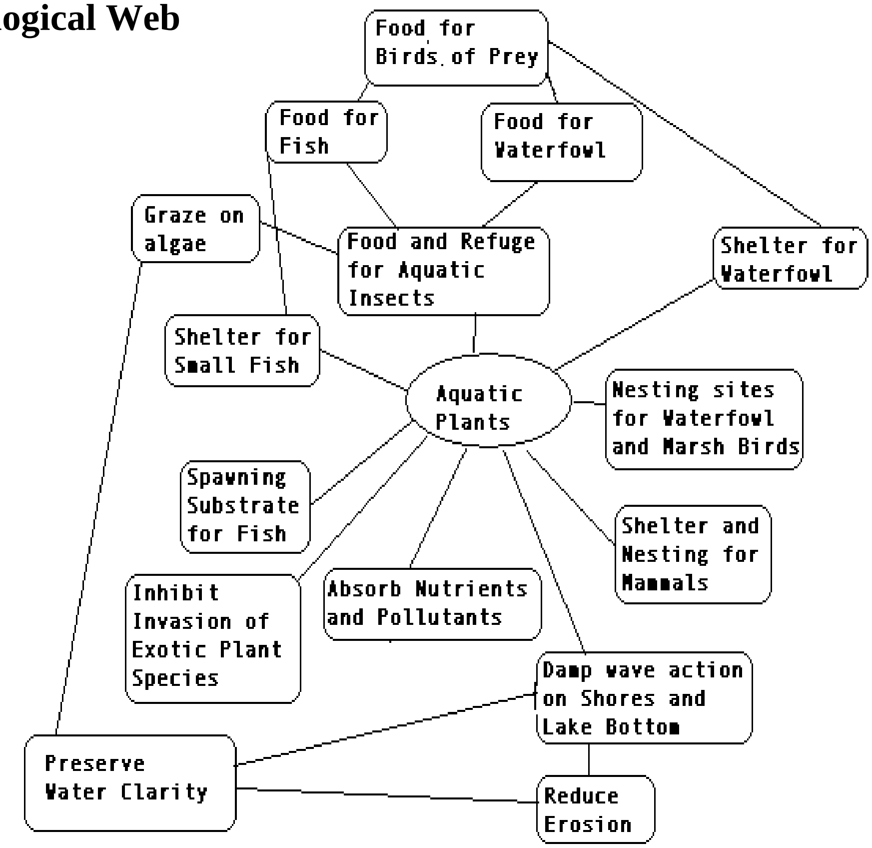
Two invasive aquatic plant species have been present in Peppermill Lake for some time. One of them, Reed Canarygrass, has continued to be present only in low numbers. However, the second, Eurasian Watermilfoil, has been a problem treated with chemicals in the past, but seems at least temporarily to be reduced in presence and occurrence, found only in scattered plants.

The Peppermill Lake aquatic plant community is characterized by at least average quality and good species diversity. Depending on the indices used, the plant community is either in the top quartile or median of lakes in the region, with an above average tolerance to disturbance.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in: 1) improving water quality; 2) providing valuable habitat resources for fish and wildlife; 3) resisting invasions of non-native species; and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity. Aquatic plant communities improve water quality in many ways (Engel, 1985):

- they trap nutrients, debris, and pollutants entering a water body;
- they absorb and break down some pollutants;
- they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
- they remove nutrients that would otherwise be available for algae blooms.

Figure 20: Aquatic Ecological Web



Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish and are an essential part of the ecological web of a lake (Figure 20).

Lakes with diverse aquatic plant beds support larger, more diverse invertebrate populations. These in turn support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of aquatic plants support 3-8 times as many invertebrates and fish as monocultural stands (Engel, 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Aquatic plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel, 1990). Peppermill Lake, with a diversity of aquatic vegetation species and varied aquatic plant structure, should support diverse invertebrate and fish populations.

MANAGEMENT RECOMMENDATIONS

1) All lake residents should practice best management on their lake properties. Peppermill Lake is borderline between oligotrophic and mesotrophic. A small increase in nutrients could push the lake into another trophic state, resulting in noticeably worse water quality. Conversely, reducing nutrients could have a noticeable favorable impact on water quality.

- Keep septic systems cleaned and in proper condition;
- Use no lawn fertilizers;
- Clean up pet wastes;
- No composting should be done near the water nor should yard wastes & clippings be allowed to enter the lake (Do not compost near the water or allow yard wastes and clippings to enter the lake).

2) Continued involvement in regular water quality monitoring (through the Citizen Lake Monitoring Program) and aquatic invasive species monitoring should occur. This is important for keeping track of changes in the lake and also for evaluating the effect of the management plan activities.

3) Peppermill Lake is heavily used by the public, especially for fishing. The Clean Boats, Clean Waters Program should continue. Small-scale grants have recently become available specifically to help with Clean Boats, Clean Waters activities. The Peppermill Lake District may want to consider applying for this grant.

4) A few years ago, a small pier was installed for fishing that could also be used to launch canoes and kayaks. However, the path to this pier is frequently so overgrown that it is impossible to reach the pier from the parking area. Perhaps a volunteer program could be set in place with regular clearing of the path, so that easier access is available.

5) With critical habitat areas designated, a map of these areas should be posted at the public access points with a sign encouraging avoidance of motorboat disturbance to these areas. Education about what these areas mean to the lake would also be a good idea. Landowners on the lake should watch for disturbance of these areas and report any violations. These areas are very important for habitat, the high value aquatic plant community, maintaining the positive water quality, and for preserving endangered and rare species.

6) The Peppermill Lake District should continue working with the Adams County Land & Water Conservation Department and the Wisconsin Department of Natural Resources in the ongoing Eurasian Watermilfoil monitoring project. Hand-pulling efforts should be continued where possible.

7) Regular monitoring for the presence of aquatic invasives should continue, especially for the presence of Eurasian Watermilfoil. Pre-and-post treatment monitoring for the presence of aquatic invasives should also be scheduled if chemical treatment begins again.

8) The Peppermill Lake District should continue to regularly review and, if necessary, update its lake management plan.

9) New WDNR rules require a contingency plan and funding description that outlines how the district would manage invasion by a new invasive and/or spread of the current invasives known. This plan needs to be developed and made a part of the Peppermill Lake Management Plan.

10) Lake residents should protect natural shoreline around Peppermill Lake and install/improve buffers practices in the few areas that don't comply with the state shoreland zoning requirements. Cost-share funds to assist in installing such practices may be available through Adams County LWCD.

11) Once the results of the 2016 shore habitat survey have been evaluated, recommendations from that survey should be followed up.

12) All lake users should protect the aquatic plant community in Peppermill Lake. The standing-water emergent community, floating-leaf community, and submergent plant community are all unique plant communities. Each of these plant communities provides their own benefits for fish and wildlife habitat and water quality protection.

13) An aquatic plant survey should be repeated in 3 to 5 years in order to continue to track any changes in the community and the lake's overall health.

14) The Peppermill Lake District should consider approaching the landowners who own the undeveloped waterfront property on the lake and see if those landowners would be interested in conservation easements. If so, the Peppermill Lake District Lake could apply for a WDNR grant to gain these easements.

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