Eastern Marathon County Lakes Study

Mission Lake

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EASTERN MARATHON COUNTY LAKES STUDY BACKGROUND

Lakes and rivers contribute to the way of life in Marathon County. Locals and tourists alike enjoy fishing, swimming, boating, wildlife viewing, and the peaceful nature of the lakes. Healthy lakes add value to our communities by providing places to relax and recreate, and by stimulating tourism. Just like other infrastructure in our communities, lakes require attention and management to remain healthy in our developed watersheds.

Eleven lakes in eastern Marathon County were selected for this study which was aimed at obtaining a better understanding of the current conditions of the lakes' water quality, fisheries, habitat, and aquatic ecosystems. This information will help lake users and municipalities by identifying how to improve existing problems and make informed decisions to preserve and protect the lake from future issues. Data collected in studies completed between fall 2010 and fall 2012 focused on the fisheries, water quality, groundwater, algae, zooplankton, lake history, shoreline habitat, watersheds, and residents' opinions. This report contains the results of the study for Mission Lake.

A resident survey was sent to all properties in the watersheds of the eastern Marathon County lakes. The majority of survey respondents expressed the importance of the lakes in their lives. The lakes provide special places for their families; many of their important family memories are tied to the lakes. The lakes seem to bring out the best in the respondents by providing environments where people can feel they are truly themselves and places where they can do what they most enjoy. The majority of respondents felt a sense of stewardship towards the lakes.

ABOUT MISSION LAKE

To understand a lake and its potential for water quality, fish and wildlife, and recreational opportunities, we need to understand its physical characteristics and setting within the surrounding landscape. Mission Lake is located in the township of Reid, northeast of Bevent. One public boat launch located on its northwestern side. Mission Lake is a 112 acre seepage lake with surface runoff and groundwater contributing most of its water. The maximum depth in Mission Lake is 26.6 feet; the lakebed has a moderate to steep slope (Figure 1). Its bottom sediments are mostly muck.

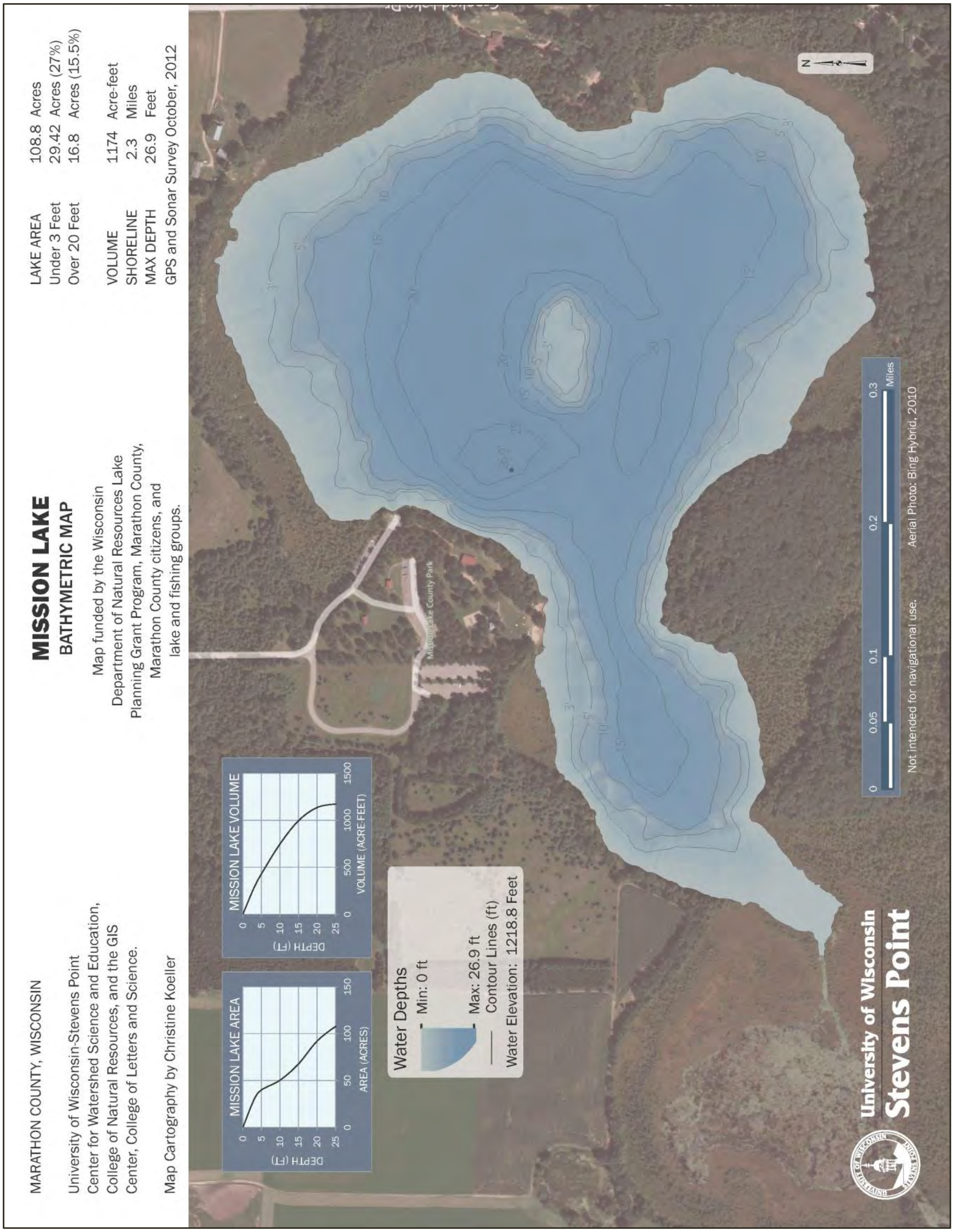


FIGURE 1. CONTOUR MAP OF THE MISSION LAKE LAKEBED.

WHERE IS THE WATER COMING FROM? - WATERSHEDS AND LAND USE

The water quality in Mission Lake is a reflection of the land that drains to it. The water quality, the amount of algae and aquatic plants, the fishery and other animals in the lake are all affected by natural and manmade characteristics. The amount of land that drains to the lake, hilliness of the landscape, types of soil, extent of wetlands, and the type of lake are all natural characteristics that affect a lake. Within its watershed, alterations to the landscape, the types of land use, and the land management practices also affect the lake.

It is important to understand where Mission Lake's water originates in order to understand the lake's health. During snowmelt or a rainstorm, water moves across the surface of the landscape (runoff) towards lower elevations such as lakes, streams and wetlands. The land area that contributes runoff to Mission Lake is called a surface watershed. Groundwater also feeds Mission Lake; its land area (groundwater watershed) is different from the surface watershed.

The capacity of the landscape to shed or hold water and contribute or filter particles determines the amount of erosion that may occur, the amount of groundwater feeding a lake, and ultimately, the lake's water quality and quantity. Essentially, landscapes with a greater capacity to hold water during rain events and snowmelt help to slow the delivery of the water to the lake. Less runoff is desirable because it allows more water to recharge the groundwater which feeds the lake year round, even during dry periods or when the lake is covered with ice.

Land use and land management practices within a lake's watershed can affect both its water quantity and quality. While forests and grasslands allow a fair amount of precipitation to soak into the ground, resulting in more groundwater and better water quality, other types of land uses may result in increased runoff, less groundwater recharge, and may be sources of pollutants that can impact the lake and its inhabitants. Areas of land with exposed soil can produce soil erosion. Soil entering the lake can make the water cloudy, plug up fish spawning beds, and contains nutrients that increase the growth of algae and aquatic plants. Development often results in changes to natural drainage patterns, alterations in vegetation on the landscape, and may be a source of pollutants. Impervious (hard) surfaces such as roads, rooftops, and compacted soil prevent rainfall from soaking into the ground, which may result in more runoff that carries pollutants to the lake. Wastewater, animal waste, and fertilizers used on lawns, gardens, and agricultural fields can contribute nutrients that enhance the growth of algae and aquatic plants in our lakes.

A variety of land management practices can be put in place to help reduce impacts to our lakes. Some practices are designed to reduce runoff. These include protecting/restoring wetlands, installing rain gardens, swales and rain barrels, and routing drainage from roads and parking lots away from the lake. Some practices are used to help reduce nutrients moving across the landscape towards the lake. Examples include manure management practices, eliminating/reducing the use of fertilizers, increasing the distance between the lake and a septic drainfield, protecting/restoring native vegetation in the shoreland, and using erosion control practices. Marathon County staff and other professionals can work with landowners to determine which practices are best suited to a particular property.

The surface watershed for Mission Lake is approximately 1,577 acres (Figure 2). The dominant land uses in the watershed are agriculture and forests. The lands closest to the lake often have the greatest impact on water quality and habitat; land uses near Mission Lake's shoreland include wetlands, forests, and recreation.

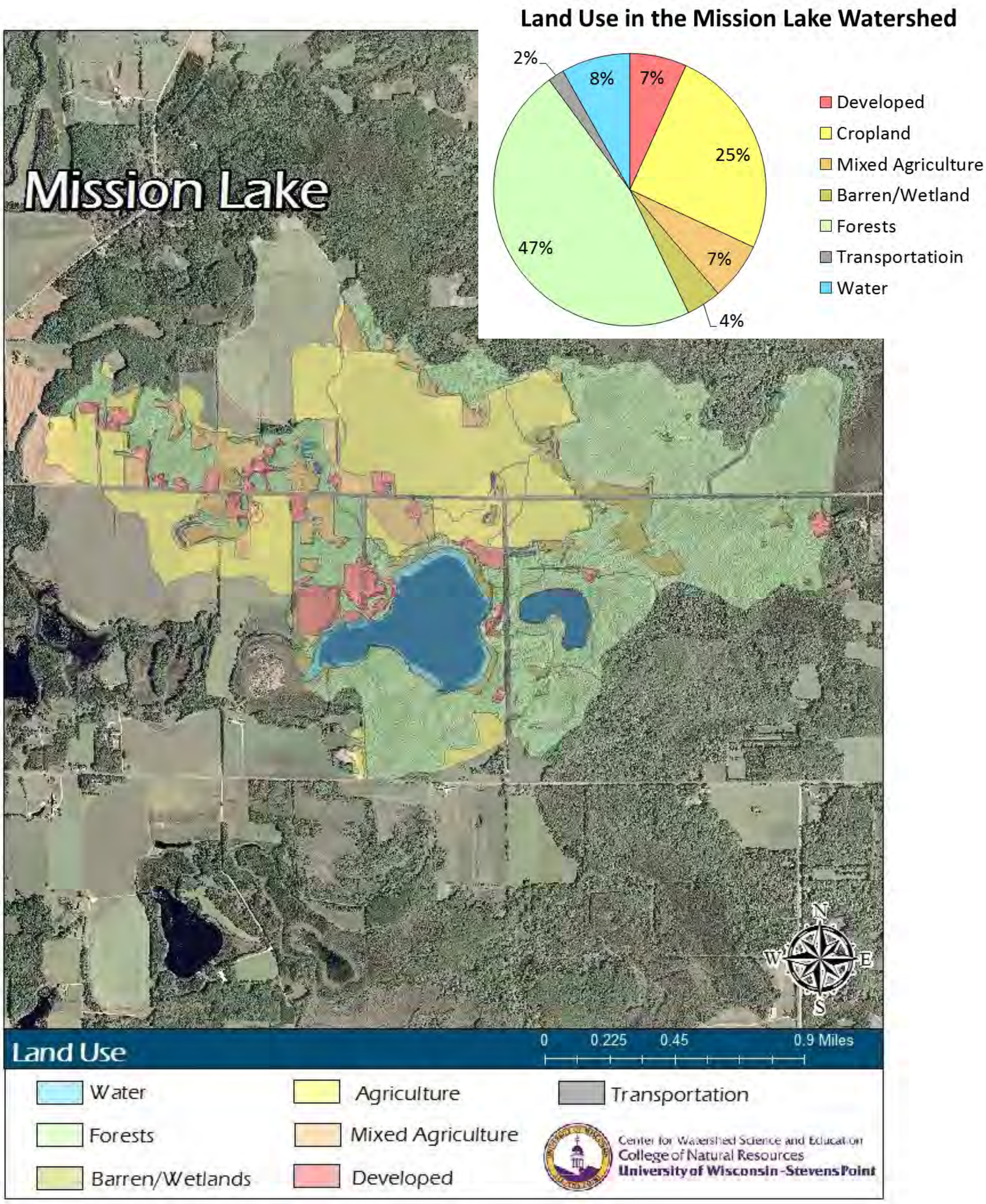
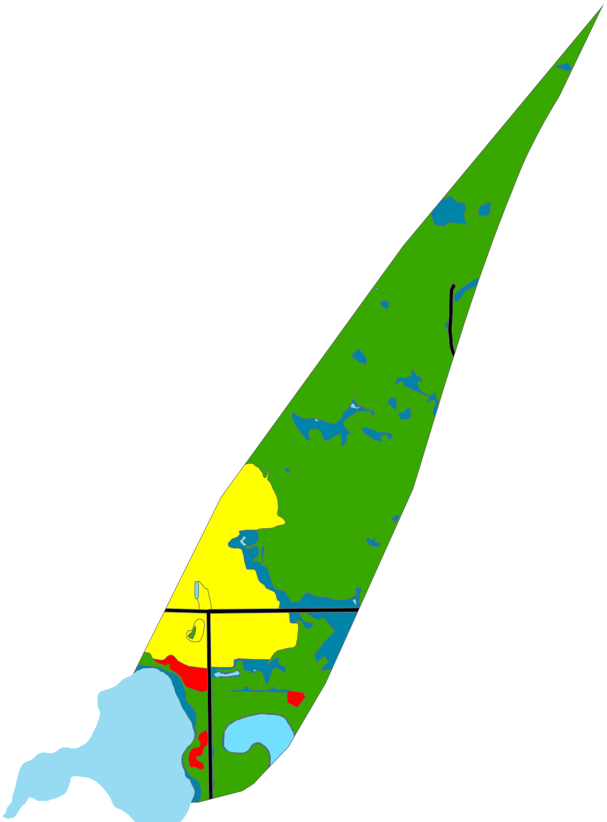


FIGURE 2. LAND USE IN THE MISSION LAKE SURFACE WATERSHED.

The groundwater watershed is the area where precipitation soaks into the ground and travels below ground towards the lake. Mission Lake's groundwater watershed is approximately 368 acres (Figure 3). The primary land uses in the Mission Lake groundwater watershed are forests and agriculture. In general, the land adjacent to the lake where most of the groundwater is entering has the greatest immediate impact on water quality. Wetlands, forests, and developed land are adjacent to Mission Lake where the groundwater enters.



Land Use	Acres
Agriculture	84
Developed	14
Forested	241
Roads	5
Water	19
Wetland	5

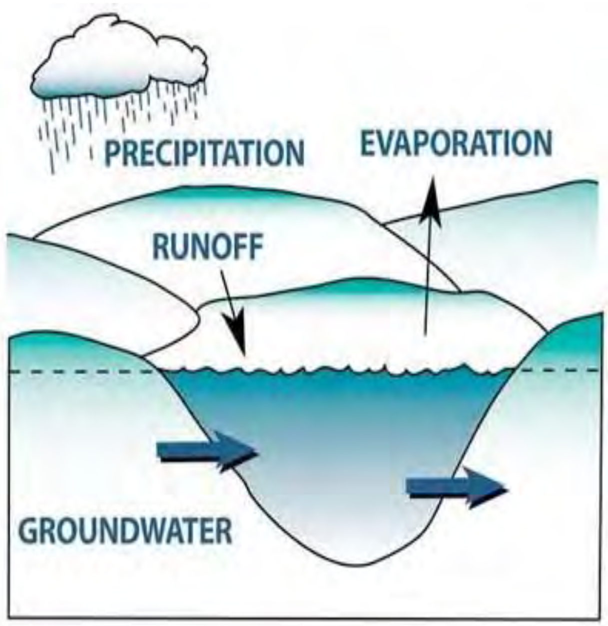
FIGURE 3. LAND USE IN THE MISSION LAKE GROUNDWATER WATERSHED.

Near shore, mini-wells were installed in the lakebed approximately every 200 feet around the perimeter of Mission Lake (Figure 4). In many lakes, this type of survey can help to identify the location of groundwater inflow or outflow. In Mission Lake, no connection between groundwater (inflow and/or outflow) and the lake was observed during this survey (gray circles). Groundwater may be entering the adjacent wetlands or in parts of the lakebed that were deeper than the groundwater survey. It should be noted that the survey was conducted in 2011, which was a dry year with lower than normal groundwater levels. These conditions would result in less groundwater entering Mission Lake.

The more the lake water interacts with groundwater (inflow and outflow), the more influence the geology has on the lake. The duration of time the water remains below ground plays a role on the temperature and chemistry of the groundwater. Groundwater temperatures remain constant year round, so groundwater feeding Mission Lake will help to keep the lake water cooler during the summer months.

FIGURE 4. GROUNDWATER INFLOW AND OUTFLOW AROUND MISSION LAKE, 2011.

Lake water quality is a result of many factors including underlying geology, climate and land use practices. Assessing lake water quality allows us to evaluate current lake health, changes from the past, and what is needed to achieve a more desirable state (or preserve an existing state) for aesthetics, recreation, wildlife and the fishery. During this study, water quality in Mission Lake was assessed by measuring different characteristics including temperature, dissolved oxygen, water clarity, water chemistry, and the algal community.



The source of a lake's water supply is important in determining its water quality and in choosing management practices to preserve or influence that quality. Mission Lake is classified as a seepage lake. Water enters and leaves the lake primarily through groundwater, and to a lesser extent, enters via surface runoff and direct precipitation (Figure 5). Seepage lakes have higher concentrations of minerals such as calcium and magnesium, which are picked up by groundwater moving through soil and rock. They also generally have longer retention times (length of time water remains in the lake), which affects contact time with nutrients that feed the growth of algae and aquatic plants. Seepage lakes are also vulnerable to contamination moving towards the lake in the groundwater. Examples for Mission Lake may include septic systems, agriculture, and road salt.

FIGURE 5. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN A SEEPAGE LAKE.

The geologic composition that lies beneath a lake has the ability to influence the temperature, pH, minerals, and other properties in a lake. As groundwater moves through the soil, some substances are filtered out, but other materials dissolve into the groundwater (Shaw et al., 2000). Minerals such as calcium and magnesium in the soil around Mission Lake dissolve, making the water hard. The average hardness for Mission Lake during the 2010-2012 sampling period was 66 mg/L, which is considered moderately hard (Table 1). Hard water provides the calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 67 mg/L; higher alkalinity in inland lakes can support higher species productivity. Hardness and alkalinity also play roles in the types of aquatic plants that are found in a lake (Wetzel, 2001).

TABLE 1. MINERALS AND PHYSICAL MEASUREMENTS IN MISSION LAKE, 2010-2012.

Mission Lake	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as CaCO3)	Color SU	Turbidity (NTU)
Average	67	15.4	7.3	66	51.6	3.2

Chloride concentrations, and to lesser degrees sodium and potassium concentrations, are commonly used as indicators impacts from human activity. The presence of these compounds in the lake at elevated levels indicates the movement of pollutants from the landscape to the lake.

Over the monitoring period, concentrations of potassium were slightly elevated, but chloride and sodium were low (Table 2). These concentrations are not harmful to aquatic organisms, but indicated that pollutants are entering the lake. Sources of potassium include animal waste, septic systems, and some fertilizers. Atrazine (DACT), an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L) in the samples that were analyzed from Mission Lake.

TABLE 2. MISSION LAKE AVERAGE WATER CHEMISTRY, 2010-2012.

Mission Lake	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium		1.3		<.75	0.75 - 1.5	>1.5
Chloride	2.9			<3	3.0 - 10.0	>10
Sodium	1.3			<2	2.0 - 4.0	>4

Dissolved oxygen is an important measure in aquatic ecosystems because a majority of organisms in the water depend upon oxygen to survive. Oxygen is dissolved into the water from contact with the air, which is increased by wind and wave action. When sunlight enters the water, algae and aquatic plants also produce oxygen; however, the decomposition of aquatic plants and algae by bacteria after they die reduces oxygen in the lake. Some forms of iron and other metals carried by groundwater can also consume oxygen when they reach the lake.

In a lake, the water temperature changes throughout the year and may vary with depth. During winter and summer when some lakes stratify (layer), the amount of dissolved oxygen is often lower towards the bottom of the lake. Dissolved oxygen concentrations below 5 mg/L can stress some species of cold water fish, and over time reduce habitat for sensitive cold water species of fish and other critters.

Water temperature and dissolved oxygen were measured in Mission Lake from the surface to the bottom at the time of sample collection during the 2010-2012 study. The temperature in Mission Lake follows a classic pattern for deeper lakes in Wisconsin. The lake water mixes thoroughly in spring and summer and stratifies during the summer and winter (Figure 6). As would be expected, late winter profiles (February 2011 and February 2012) showed colder (freezing) temperatures near the surface with slight gradual warming with depth. Spring (April 2011 and April 2012) and fall (October 2011) data showed nearly uniform temperature with depth. June to September data from both years shows a classic profile of thermal stratification with warmer temperatures near the surface and the coolest temperatures towards the lake bottom. Temperatures in Mission Lake ranged from 1°C (34°F) at the surface in February 2012 to 28°C (82°F) at the surface in July 2012.

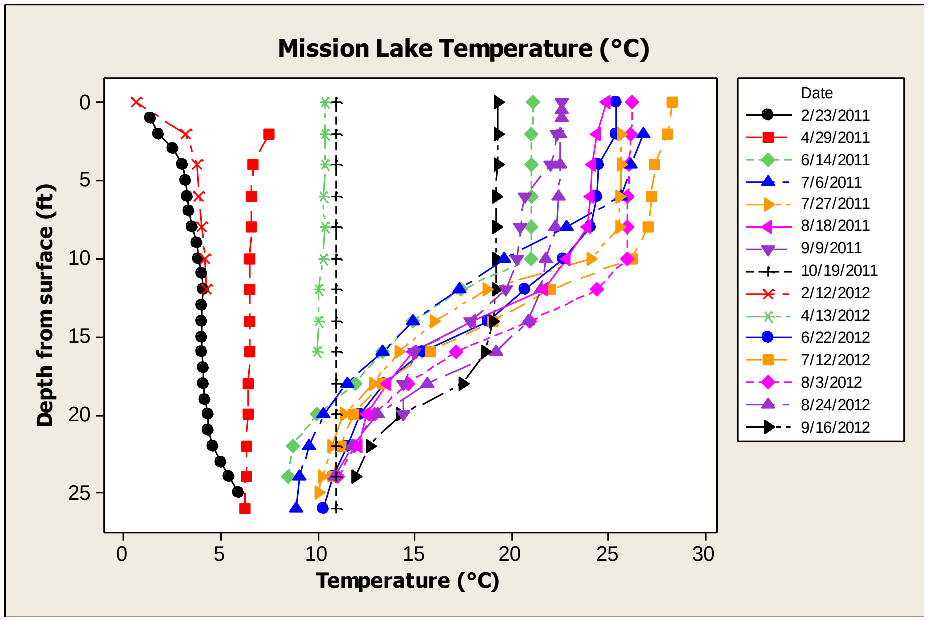


FIGURE 6. TEMPERATURE PROFILES IN MISSION LAKE, 2011-2012.

Dissolved oxygen concentrations in Mission Lake were always plentiful in at least the upper 9 feet of water (Figure 7). Like temperature, dissolved oxygen was mixed from the surface to the bottom during spring and fall. With ice cover during the winter, dissolved oxygen was sufficient in the upper 9 feet of water; below that depth, concentrations were not sufficient to support many fish. Dissolved oxygen was replenished throughout the lake in the spring, and during the summer the lake once again stratified. Algal blooms produced periodic spikes in dissolved oxygen concentrations at depths typically below 10 feet. This was particularly noticeable in the measurements taken in June and July 2012.

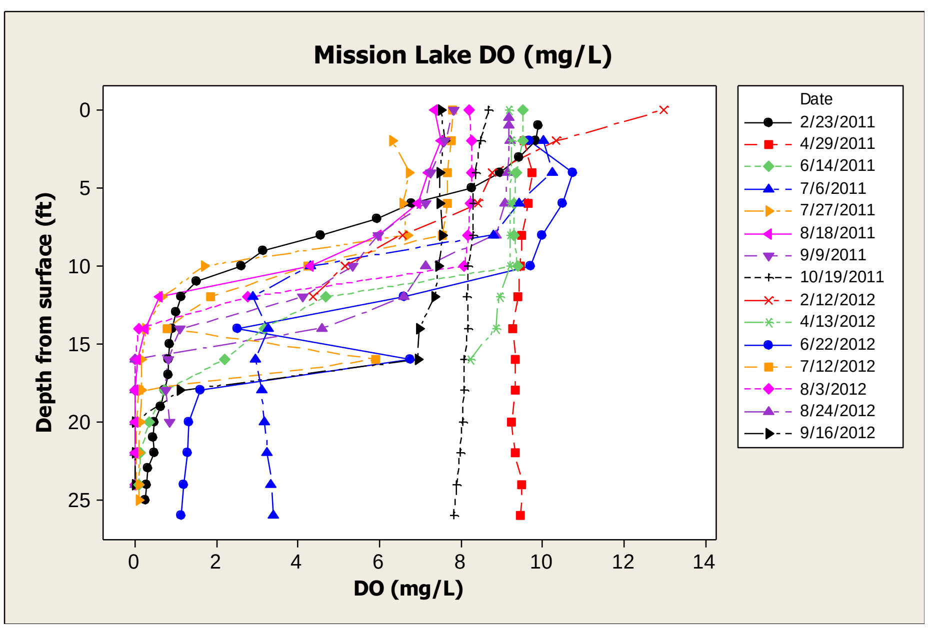
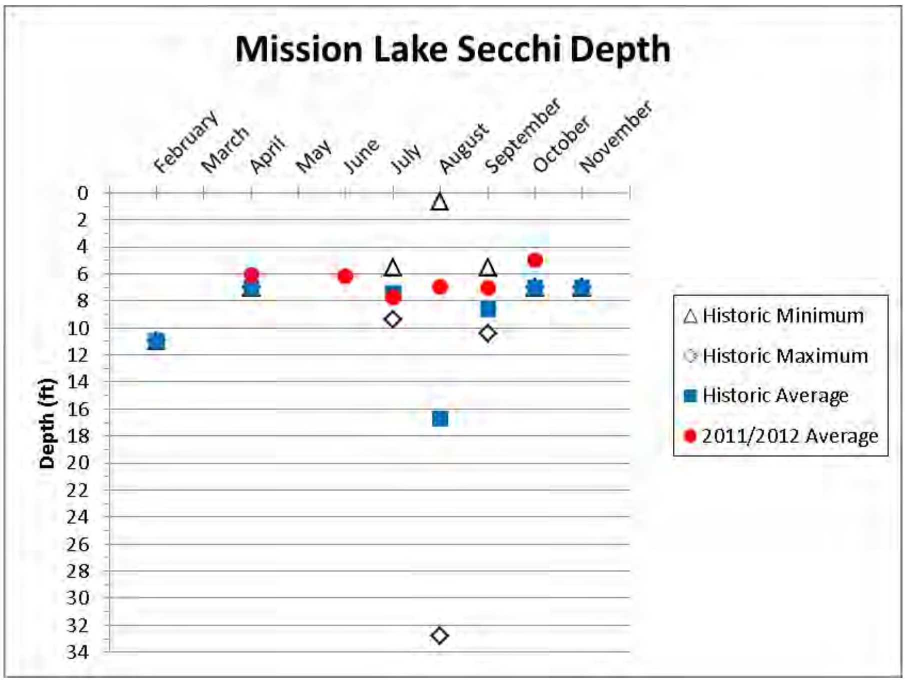


FIGURE 7. DISSOLVED OXYGEN PROFILES IN MISSION LAKE, 2011-2012.

Water clarity is a measure of the depth that light can penetrate into the water. It is an aesthetic measure and is also related to the depth that rooted aquatic plants can grow due to penetration of sunlight. Water clarity is affected by water color, turbidity (suspended sediment), and algae (chlorophyll *a*), so it is normal for water clarity to change throughout the year and from year to year.

In Mission Lake, the color index was moderate (Table 1). Brown staining from tannins in surrounding wetlands and forest is the natural source of the slightly elevated color index. The variability in water clarity throughout the year in Mission Lake was primarily due to fluctuating algae concentrations and re-suspended sediment following storms. The water clarity in Mission Lake was considered fair. The average water clarity measurements in Mission Lake during the study were poorest in October and best in July (Figure 8). Water clarity data was submitted sporadically between 1999 and 2007. When compared with this historic data, the average water clarity measured during the study was poorer in August.



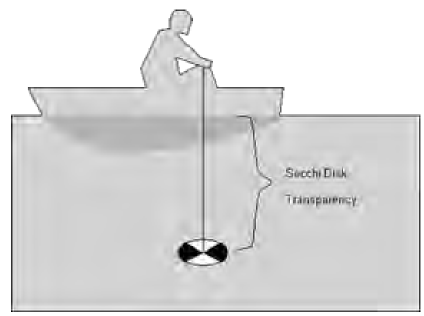


FIGURE 8. AVERAGE MONTHLY WATER CLARITY IN MISSION LAKE, 2010-2012 AND HISTORIC.

Nutrients (phosphorus and nitrogen) are used by algae and aquatic plants for growth much like houseplants or crops. Phosphorus is present naturally throughout the watershed in soil, plants, animals and wetlands. Common sources from human activities include soil erosion, animal waste, fertilizers and septic systems.

The most common mechanism for the transport of phosphorus from the land to the water is through surface runoff, but it can also travel to the lake in groundwater. Once in a lake, a portion of the phosphorus becomes part of the aquatic system in the form of plant tissue, animal tissue and sediment. The phosphorus continues to cycle within the lake for many years.

Total phosphorus concentrations in Mission Lake ranged from a high of 61 ug/L in February 2012 to a low of 8 ug/L in August 2012 (Table 3). The summer median total phosphorus was 30 ug/L and 16 ug/L in 2011 and 2012, respectively. The median concentration in 2012 was above Wisconsin's phosphorus standard of 20 ug/l for deep seepage lakes.

During the study, inorganic nitrogen concentrations in samples collected during the spring in Mission Lake were 0.12 mg/L in 2011 and 0.43 mg/L in 2012. Concentrations above 0.3 mg/L are sufficient to enhance algal blooms throughout the summer (Shaw et al., 2000). Inorganic nitrogen typically moves to lakes with groundwater and sources include fertilizers, animal waste, and septic systems.

TABLE 3. SUMMARY OF SEASONAL NUTRIENTS IN MISSION LAKE, 2010-2012.

Mission Lake	Total Phosphorus (µg/L)			Dissolved Reactive Phosphorus (µg/L)			Total Nitrogen (mg/L)			Inorganic Nitrogen (mg/L)			Organic Nitrogen (mg/L)		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Fall	17	25	30	1	1	1	0.88	1.18	1.48	0.09	0.36	0.62	0.79	0.83	0.86
Spring	31	42	53	5	8	10	1.10	1.13	1.16	0.12	0.28	0.43	0.73	0.86	0.98
Summer	8	23	41												
Winter	17	39	61	1	2	3	1.04	1.12	1.20	0.22	0.31	0.40	0.64	0.81	0.98

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Mission Lake. Land use in the surface watershed was evaluated and used to populate the Wisconsin Lakes Modeling Suite (WILMS) model. In general, each type of land use contributes different amounts of phosphorus in runoff and through groundwater. The types of land management practices that are used and the distance from the lake also affect the contributions to the lake from a parcel of land. While forests comprised the greatest amount of land in the watershed, modeling results indicated agriculture had the greatest percentage of phosphorus contributions from the watershed to Mission Lake (Figure 9). The phosphorus contributions by land use category, called phosphorus export coefficients, are shown in Table 4. The phosphorus export coefficients have been obtained from studies throughout Wisconsin (Panuska and Lillie, 1995).

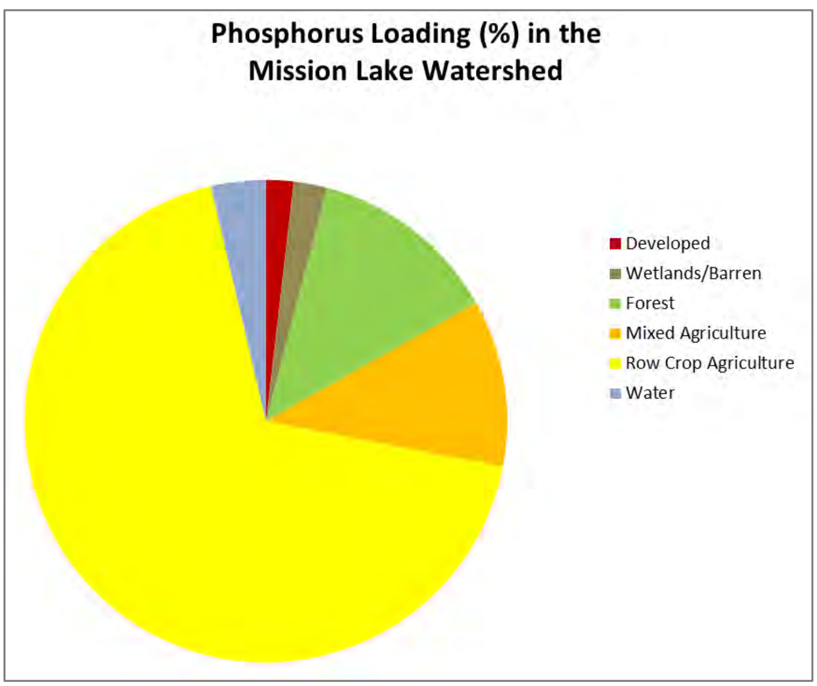


FIGURE 9. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE MISSION LAKE WATERSHED.

TABLE 4. MODELING DATA USED TO ESTIMATE PHOSPHORUS INPUTS FROM LAND USES IN THE MISSION LAKE WATERSHED (LOW AND MOST LIKELY COEFFICIENTS USED TO CALCULATE RANGE IN POUNDS).

Mission Lake Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.10	46	**15**	10-29	**4**
Developed	0.04	35	**11**	5-10	**2**
Wetland/Barren	0.09	7	**2**	6-18	**2**
Forest	0.04	210	**69**	25-34	**13**
Mixed Agriculture	0.27	2	**1**	30-76	**11**
Row Crop Agriculture	0.45	6	**2**	180-361	**68**
*Values are not exact due to rounding and conversion					

Chlorophyll *a* is an indirect measurement of algae in the water. Concentrations greater than 20 ug/L are frequently perceived as a nuisance. Chlorophyll *a* concentrations in Mission Lake were quite variable throughout the monitoring season, ranging from a high of 19 ug/L in July 2011 to a low of 1 ug/L in August 2012, with an average summer concentration of 14.7 ug/L and 2.8 ug/L in 2011 and 2012, respectively.

Algae are microscopic, photosynthetic organisms that are important food items in all aquatic ecosystems. Different algal groups increase or decrease during the year and they can be used to analyze a lake's water quality because there are more varieties of algae than fish or aquatic plants. Conclusions can be drawn about water temperature, nutrient availability, and overall water quality of a lake using algal populations.

In Marathon County lakes, there are three dominant groups of algae: blue-green algae (Cyanobacteria), green algae (Chlorophyta), and diatoms (Bacillariophyceae). During both 2011 and 2012, the algal community in Mission Lake was characteristic of a lake tending towards eutrophic status. This is evident from the early and persistent presence of the blue-green algae, and their tendency to dominate as the seasons developed. The heavy, early-season green algal populations of 2011 waned as the season ran on, but they stayed high during 2012. Conversely, diatom populations bloomed in late 2011, but 2012 diatom abundance dropped relative to 2011 (Figure 10).

Disrupted and variable algal populations lacking discernible patterns are typical of eutrophic bodies of water. The high internal nutrient load can be resuspended with surface weather events (storms, winds), and utilized serially by various algal species as water temperature changes. Heavy growth by the three dominant algal groups leads to poor water clarity and further accelerates a decline into a more eutrophic state.

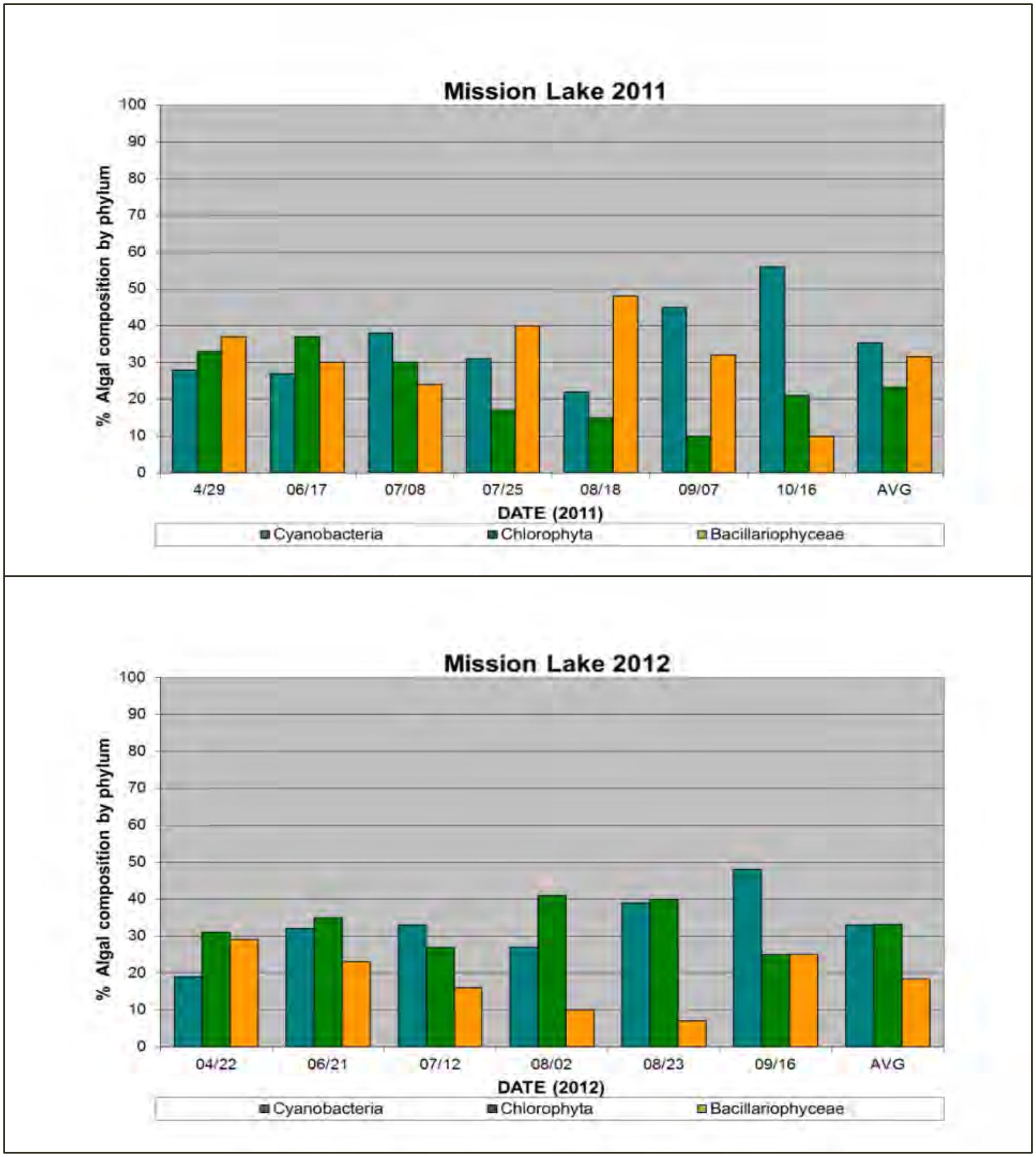


FIGURE 10. PERCENT ALGAL COMPOSITION IN MISSION LAKE, 2011-2012.

SHORELAND HEALTH

Shoreland vegetation is critical to a healthy lake's ecosystem. It provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and many small and large mammals. It also helps to improve the quality of the runoff that is flowing across the landscape towards that lake. Healthy natural vegetation includes a mix of layers such as tall grasses/forbs, shrubs, and trees.

The addition of manmade features near the shoreland area can lead to more impervious surfaces. Runoff from driveways, rooftops, and buildings carries pollutants and sediments into the nearby lake. Minimizing the presence of impervious surfaces in the shoreland area can help reduce the amount of phosphorous and sediment transported to the lake. Overdeveloped shorelines cannot support the fish, wildlife and clean water that may have attracted people to the lake in the first place. Rip-rap, seawalls and docks also contribute to an unhealthy shoreline. While it might seem that one lot's development may not have a quantifiable impact on the lake's water quality, the collective effect of many properties can be significant.

The results of the shoreline survey conducted on the eastern Marathon County lakes will serve as a tool for citizens and the Marathon County staff to identify locations of shoreland areas in need of restoration, as well as recognize natural shorelands for protection. In addition, this information will provide a baseline database from which to measure and monitor success.

MISSION LAKE SHORELAND SURVEY RESULTS

The survey collected data on the vegetation present around the lake's shoreland and identified buildings at or near the water's edge. This information can be used to assess lakeshore development's potential impact on in-lake and shoreland habitat, which may affect fish spawning grounds, shoreland wildlife habitats, and shoreline beauty.

In 2011, shoreland vegetation was recorded by mapping and estimating the depth of three categories of vegetation and the length of shoreline. Researchers in a boat navigated the shoreline and recorded the classifications of vegetation observed from the lake. The three rings surrounding Mission Lake in Figure 12 depict the depth of vegetation along Mission Lake's shore. The first ring represents the depth inland where plants occur that are 0.5 to 3 feet tall (native grasses/forbs). The second ring represents plants ranging from 3 to 15 feet tall (shrubs). The outermost ring represents all plants taller than 15 feet (trees). A greater vegetative shoreland "buffer" provides more habitat, protection from soil erosion, and improved water quality of runoff. A healthy vegetative "buffer" extends at least 35 feet inland from the water's edge and includes a mixture of grasses, forbs, shrubs and trees.

Mission Lake has 3.1 miles of shoreline. The lake's shoreland vegetation was primarily in a natural state. Grasses and forbs were the most prominent vegetative layer due to the abundance of wetlands adjacent to Mission Lake (Figure 11). The lack of shrubs and trees is the result of dense grasses, forbs, and wetland areas rather than human disturbances. Although Mission Lake's shoreland is in good shape now, changes can easily occur as development takes place. In order to minimize impacts from current and future development, prospective developers should have the information needed to make good decisions, and zoning should be in place to achieve habitat, water quality, and aesthetic goals for Mission Lake.

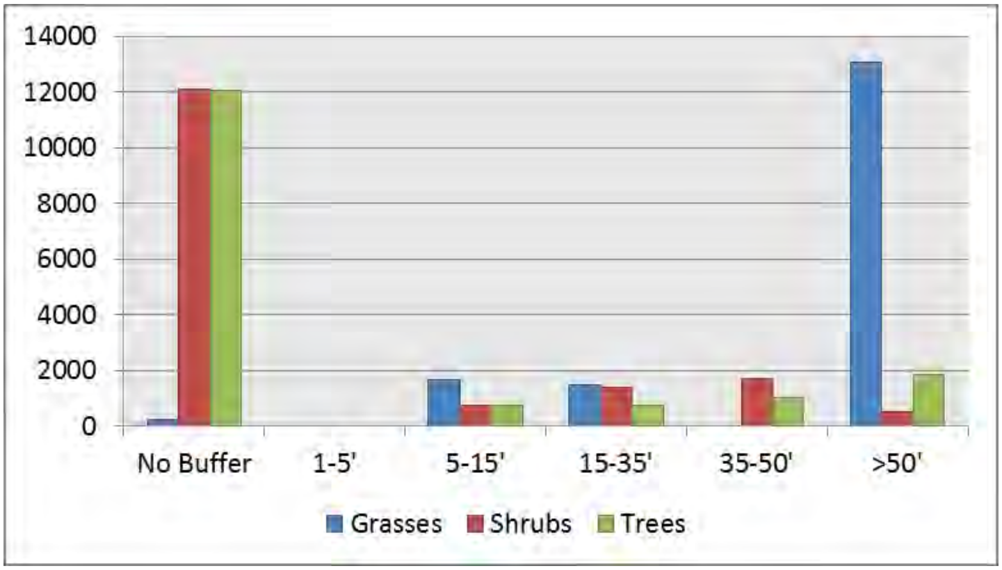


FIGURE 11. LINEAR FEET OF SHORELAND VEGETATION BY BUFFER DEPTH AROUND MISSION LAKE, 2011.

On the same day the vegetation surveys were conducted, an assessment of disturbances was conducted around Mission Lake. Surveyors paddled along the shoreline and documented artificial beaches, docks, rip-rap, seawalls, erosion, and any structures built near the water's edge (Table 5 and Figure 13). Structures such as seawalls, rip-rap (rocked shoreline), and artificial beaches often result in habitat loss. Docks and artificial beaches can result in altered in-lake habitat, with denuded lakebeds that provide opportunities for invasive species to become established and reduce habitat important to fish and other lake inhabitants. Erosion can contribute sediment to the lake, altering spawning habitat and carrying nutrients into the lake. Unmanaged runoff from the rooftops of structures located near shore can also contribute more sediment to the lake. Alone, each manmade feature may not pose a problem for a lake, but on developed lakes, the collective impact of manmade disturbances can be a problem for lake habitat and water quality.

TABLE 5. DISTURBANCES LOCATED ON MISSION LAKE, 2011.

Disturbance	No. of Occurrences
Artificial Beach	1
Dock	5
Riprap	0
Seawall	0
Erosion	1
Structures w/in 35'	1
Structures 35-75'	0

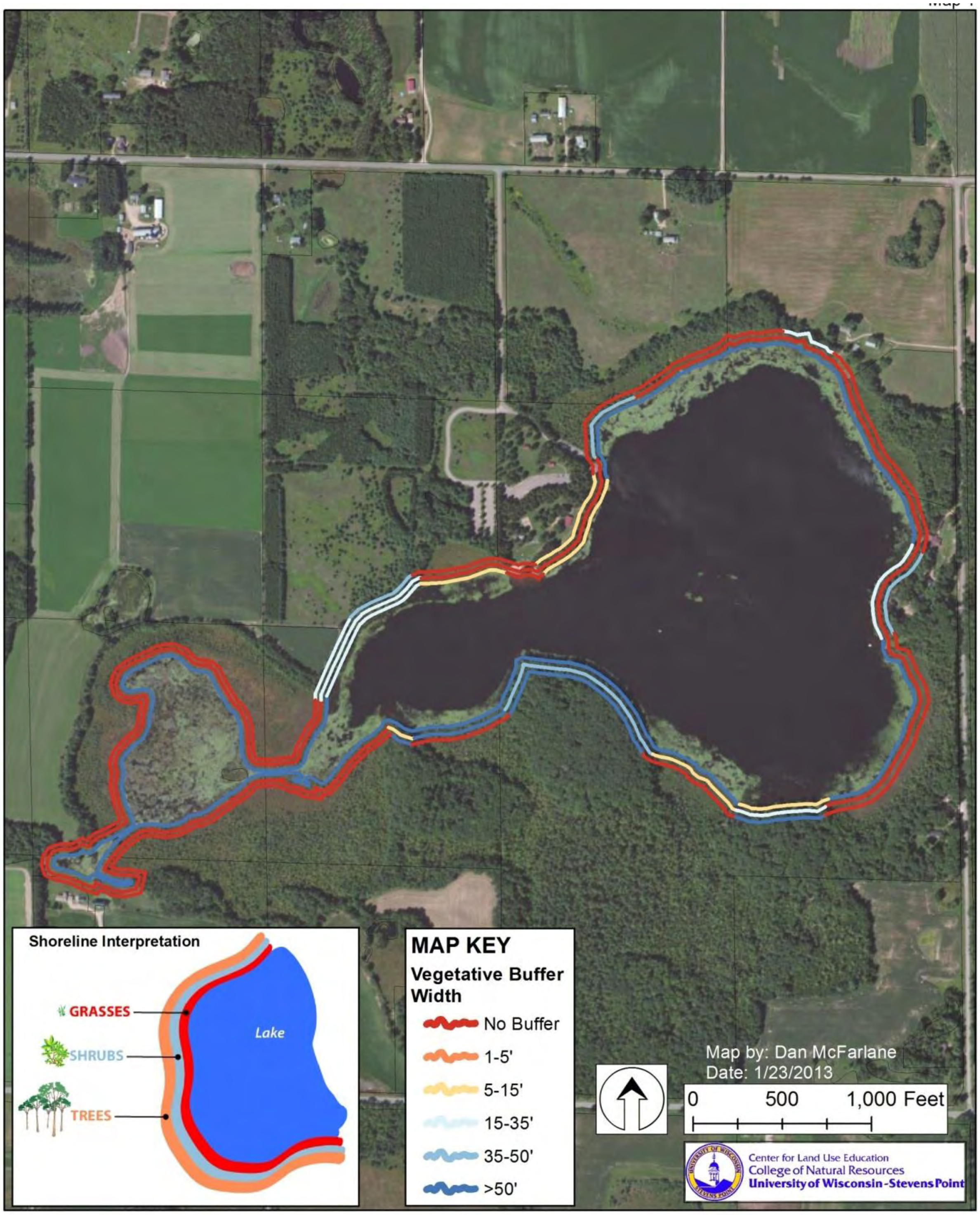


FIGURE 12. SHORELAND VEGETATION SURVEY OF MISSION LAKE, 2011.

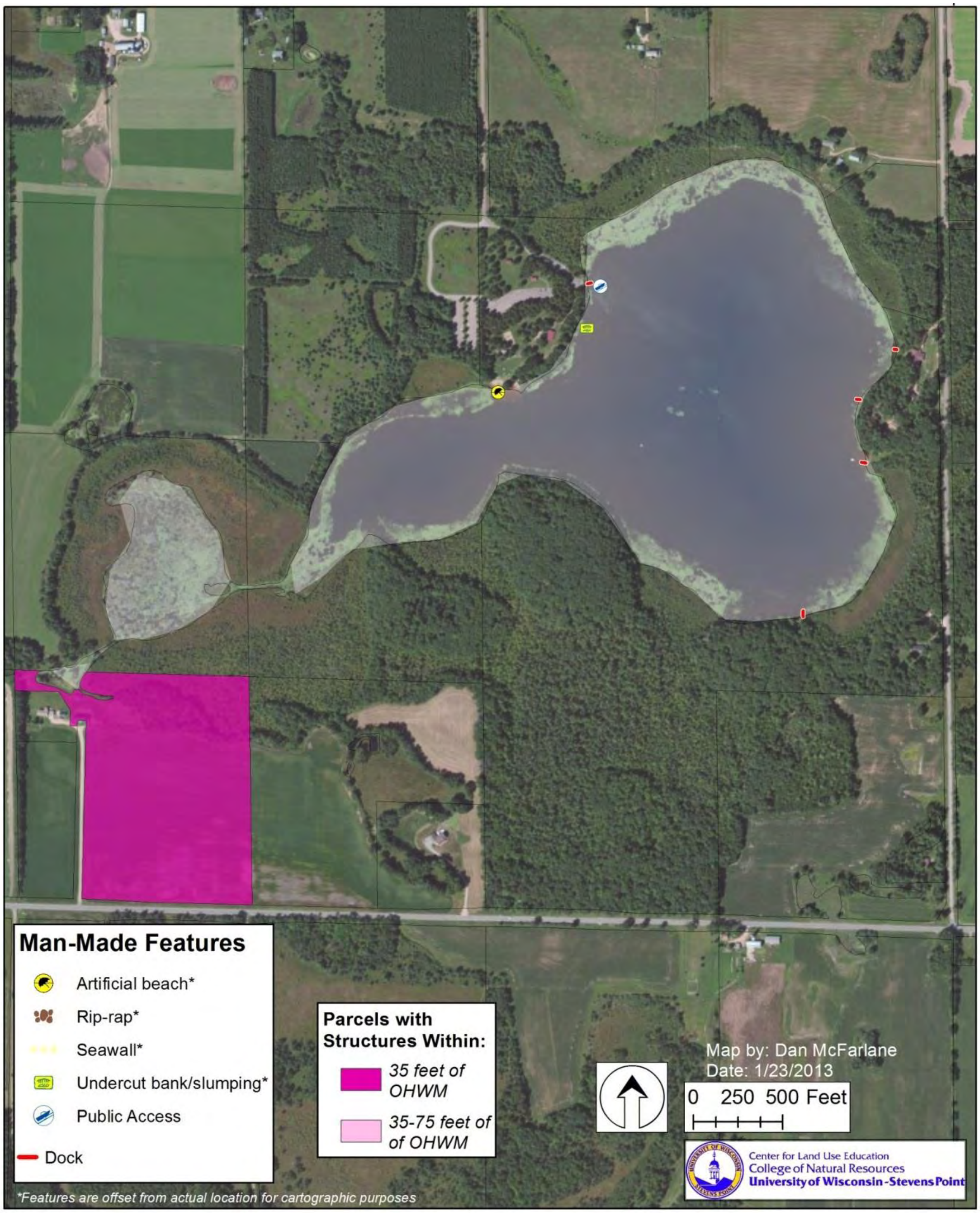


FIGURE 13. SHORELAND DISTURBANCE SURVEY OF MISSION LAKE, 2011.

A sustainable fishery is one that is in balance with the lake's natural ability to support the fish community, and is adaptable to fishing practices that do not cause declines in fish populations. A healthy fish community has a balance between predator and prey species, and each fish species has different needs to be met in order to flourish, including adequate food sources, habitat, appropriate nesting substrate, and water quality.

People are also an important part of a sustainable fishery, as they can both remove fish and add fish. The numbers and sizes of fish taken out of the lake can influence the entire ecosystem, so it is important to adhere to appropriate fishing regulations to help maintain a healthy balance of prey and predatory species, and to adjust the regulations as the fish community changes and adapts. If stocking does occur, choosing the wrong fish species for a lake's conditions will result in a less sustainable fishery and may require outside inputs such as aeration or further stocking. Each fish species has different water quality requirements, with preferred tolerance ranges for dissolved oxygen, pH, water clarity, temperature, and hardness. A few predatory species such as largemouth bass prefer good water clarity to effectively hunt prey; other species such as walleye prefer more turbid waters. Even within a species, water quality preferences may vary during different stages of reproduction.

Mission Lake supports a warm water fish community. In 2012, 20 fish species were sampled and identified. Surveys have been conducted periodically by professionals from the Wisconsin Department of Natural Resources. Twenty-two fish species have been recorded in Mission Lake since 1950 (Table 6). Although most species identified in 2012 had been previously reported, blackchin shiner (*Notropis heterodon*), blacknose shiner (*Notropis heterolepis*), bluegill (*Lepomis macrochirus*) x pumpkinseed (*Lepomis gibbosus*) hybrid, green sunfish (*Lepomis cyanellus*), and warmouth (*Lepomis gulosus*) were newly documented. Species documented previously but not detected during the 2012 survey included emerald shiner (*Notropis atherinoides*) and walleye (*Sander vitreus*). Bluegill were most abundant during both the fyke netting and shocking surveys in 2012, with a maximum size of 6.5 inches (Table 7and Table 8). Although infrequently encountered, muskellunge (*Esox masquinongy*) and northern pike (*Esox lucius*) were sampled in Mission Lake, with muskellunge reaching 33.3 inches and northern pike reaching 30 inches. White sucker (*Catostomus commersoni*), yellow bullhead (*Ameiurus natalis*), central mudminnow (*Umbra lima*), and bluegill x pumpkinseed hybrid were also infrequently encountered. Five rusty crayfish (Orconectes rusticus), a non-native and potentially invasive species, were captured during the sampling period.

Wisconsin Department of Natural Resources records have documentation for previous management in Mission Lake (also known as Crooked Lake). In 1970, a permit was submitted to dredge an area (presently the beach area of Mission Lake County Park) and install sand to create a beach. A 1971-1972 fisheries report indicated that panfish, particularly black crappie, were stunted. In 2004, professionals from the Wisconsin Department of Natural Resources identified sensitive areas along Mission Lake's shoreline that were valuable and worth protecting, including naturally forested and vegetated areas. Trees and vegetation protect water quality and prevent shoreline erosion. Fish stocking records for Mission Lake dated back to 1938 in Wisconsin Department of Natural Resources files (Table 9). Prior to 1960, efforts were focused largely on stocking northern pike and largemouth bass. After 1960, muskellunge fingerlings were the sole focus of stocking in Mission Lake. An 11.7 inch individual was sampled during the fyke net survey in 2012. It is unclear whether this young individual is the product of stocking or natural reproduction.

TABLE 6. FISH SPECIES IN MISSION LAKE, 2012 SURVEY AND HISTORICAL WISCONSIN DEPARTMENT OF NATURAL RESOURCES RECORDS.

Species	1950	1961	1967	1971	1983	1985	2003	2004	2012
Black Crappie	x	x	x	x	x	x	x	x	x
Blackchin Shiner									x
Blacknose Shiner									x
Bluegill	x	x	x	x	x	x	x	x	x
Bluegill x Pumpkinseed hybrid									x
Bullhead	x	x	x		x	x			
Common Shiner				x					x
Emerald Shiner				x					
Green Sunfish									x
Golden Shiner				x					x
Iowa Darter							x		x
Johnny Darter				x					x
Least Darter									x
Largemouth Bass	x	x	x	x	x	x	x	x	x
Central Mudminnow				x			x		x
Muskellunge			x	x	x	x	x	x	x
Northern Pike	x	x	x	x		x		x	x
Pumpkinseed	x	x	x	x	x	x	x	x	x
Walleye					x	x			
Warmouth									x
White Sucker		x		x		x	x		x
Yellow Bullhead								x	x
Yellow Perch			x	x	x	x	x	x	x

TABLE 7. TOTAL CATCH AND LENGTHS (MIN/MAX/AVERAGE) OF FISH SPECIES IN MISSION LAKE DURING THE 2012 FYKE NET AND SEINING SURVEYS.

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	0.8	7.0	4.4	566
Yellow Perch	3.0	8.1	5.1	184
Black Crappie	1.2	13.5	8.3	129
Pumpkinseed	4.1	4.1	4.1	44
Blackchin Shiner	0.9	1.7	1.3	35
Green Sunfish	1.9	7.0	5.0	27
Golden Shiner	1.5	7.7	4.0	13
Iowa Darter	1.5	2.4	1.9	12
Warmouth	4.5	7.4	6.4	11
Least Darter	0.9	1.2	1.1	8
Largemouth Bass	14.6	18.2	15.8	7
Yellow Bullhead	6.7	10.2	9.1	7
Blacknose Shiner	1.0	2.0	1.5	3
Northern Pike	13.1	26.4	18.7	3
Johnny Darter	2.1	2.1	2.1	2
Muskellunge	11.7	33.3	22.5	2
White Sucker	6.9	16.2	11.6	2
Bluegill x Pumpkinseed hybrid	7.2	7.2	7.2	1
Common Shiner	1.5	1.5	1.5	1

TABLE 8. TOTAL CATCH AND LENGTHS (MIN/MAX/AVERAGE) OF SPECIES IN MISSION LAKE DURING THE 2012 BOOM SHOCKING SURVEY.

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	1.1	16.5	4.8	151
Pumpkinseed	3.8	8	5.8	41
Black Crappie	3.3	13.6	7.8	36
Golden shiner	3.2	7.4	5.0	24
Largemouth Bass	4.1	15.4	9.7	21
Warmouth	5	6.8	5.7	10
Yellow Perch	4.4	6.2	5.2	8
Northern Pike	14.8	30	20.9	5
Muskellunge	30.1	30.1	30.1	1
Yellow Bullhead	9	9	9.0	1
Mudminnow	1.7	1.7	1.7	1

TABLE 9. WISCONSIN DEPARTMENT OF NATURAL RESOURCES FISH STOCKING SUMMARY FOR MISSION LAKE, INCLUDING SPECIES, AGE CLASS, NUMBER STOCKED, AND AVERAGE LENGTH IN INCHES.

Year	Species	Age Class	Number Fish Stocked	Avg Fish Length (in)	Year	Species	Age Class	Number Fish Stocked	Avg Fish Length (in)
1939	Largemouth Bass	Fingerling	5000		1965	Muskellunge	Fingerling	100	
1941	Northern Pike	Adult	48		1968	Muskellunge	Fingerling	100	
1942	Northern Pike	Fry	50000		1969	Muskellunge	Fingerling	100	
1943	Largemouth Bass	Fingerling	400		1970	Muskellunge	Fingerling	200	
1943	Northern Pike	Fry	24000		1972	Muskellunge	Fingerling	200	13
1944	Northern Pike	Fry	10000		1975	Muskellunge	Fingerling	200	11
1946	Northern Pike	Fry	30000		1976	Muskellunge	Fingerling	200	11
1949	Northern Pike	Fry	60000		1977	Muskellunge	Fingerling	700	10
1950	Northern Pike	Fingerling	200		1978	Muskellunge	Fingerling	200	8
1950	Northern Pike	Adult	54		1979	Muskellunge	Fingerling	200	8
1951	Northern Pike	Fry	47355		1980	Muskellunge	Fingerling	200	10
1951	Northern Pike	Adult	150		1982	Muskellunge	Fingerling	200	11
1952	Northern Pike	Adult	50		1985	Muskellunge	Fingerling	200	9
1953	Northern Pike	Adult	24		1987	Muskellunge	Fingerling	400	12
1954	Northern Pike	Adult	24		1987	Muskellunge	Fingerling	200	12
1955	Northern Pike	Adult	240		1991	Muskellunge	Fingerling	200	12
1956	Northern Pike	Adult	240		1993	Muskellunge	Fingerling	200	11
1962	Muskellunge	Fingerling	600		1997	Muskellunge	Fingerling	100	12
1963	Muskellunge	Fingerling	50		2003	Muskellunge	Fingerling	200	11
1964	Muskellunge	Fingerling	400		2007	Muskellunge	Fingerling	133	12
1965	Muskellunge	Fingerling	1000		2011	Muskellunge	Fingerling	100	9

BOTTOM SUBSTRATE AND COARSE WOODY HABITAT

To successfully sustain a healthy fish community, a lake must have the habitat to support it. Habitat needs of fish include aquatic plants (not too many and not too few) and woody structure such as logs, fallen trees, and stumps. Woody structure provides cover for fish to hide, as well as habitat for invertebrates that are food for many fish species. Invertebrates, zooplankton and algae are the main food sources for many fish. These organisms often live on or around aquatic plants or woody structure. Many fish use floating vegetation such as lily pads or near-shore emergent vegetation such as bulrush for spawning habitat. Cobble and gravel substrates also provide excellent spawning beds for numerous species. Many young fish prefer to dwell in adjacent wetlands that provide plenty of food, cover, and fewer large predators.

Bottom substrate and woody habitat were examined with side-scan sonar from the shoreline lakeward for a distance of 90 feet. Substrate distribution in Mission Lake primarily consisted of a soft bottom (muck, 89.3%) (Figure 14). In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build nests on softer substrates. Depressions are deepened until small amounts of coarser substrate, mostly fragments of snail shells, accumulate in the bottom of the nests. In areas of soft substrate, largemouth bass are also reported to nest on woody habitat swept clear of sediments. The presence of young bass and abundant sunfish indicated successful reproduction was occurring in Mission Lake. Sand substrate was mostly present along the southern and eastern shorelines (10.5%). Sand can be important habitat for reproduction of non-game minnow. Gravel areas are utilized by many fish for spawning habitat, including sunfish (bluegill, pumpkinseed, black bass), where males will construct nests and guard their young. Yellow perch and walleye utilize near-shore cobble in oxygen-rich environments for spawning activity; parents do not offer parental care.

Bulrush beds were present near the outlet of Mission Lake. Northern pike, which do not offer parental care, utilize areas with emergent and floating-leaf vegetation in shallow or flooded areas for spawning. Black crappie utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young. Sampling indicated successful reproduction of northern pike may be occurring, although more intense population sampling over several seasons would be required to determine the reproductive success of this species.

Coarse woody habitat (CWH), including downed trees and logs, are present in Mission Lake (Figure 14); however it is mostly limited to the southern and eastern shorelines. This structure is utilized by young prey fish and other aquatic organisms for spawning, foraging, and protective cover. The fish community would benefit from the addition of CWH in areas where it is sparse.

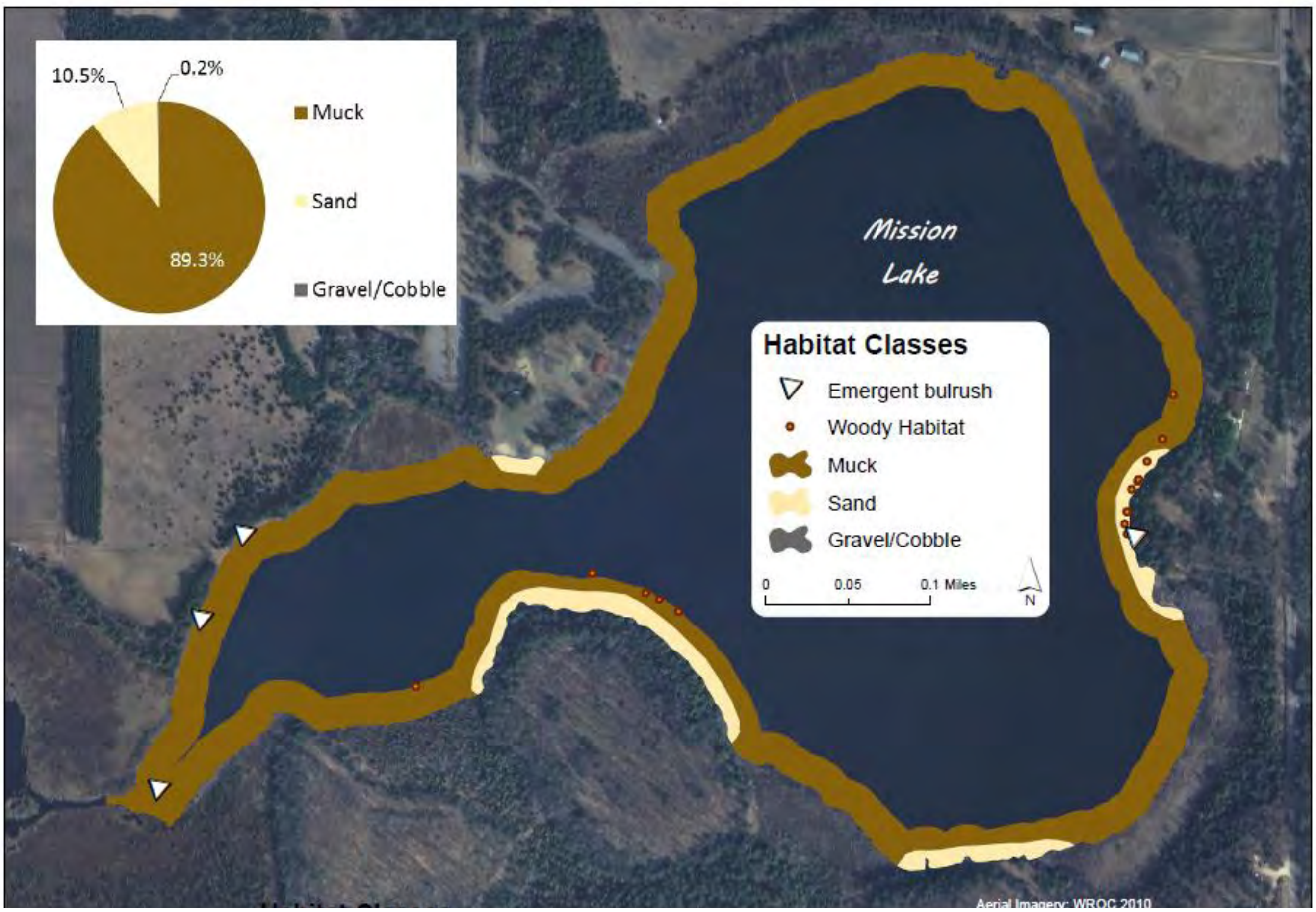
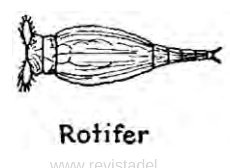


FIGURE 14. DISTRIBUTION OF SUBSTRATE AND COARSE WOODY HABITAT IN MISSION LAKE, 2012.

Zooplankton are microscopic invertebrate animals that swim or drift in water. They are the primary consumers at the base of the food chain in our lakes and are an important food for many fish. Most zooplankton are filter feeders, using their appendages to strain bacteria and algae from water, so they help to keep algae populations under control. While zooplankton can reproduce rapidly, with populations capable of doubling in a few days, they live short lives. Food (bacteria and algae), temperature, and water chemistry are important in determining the types of zooplankton that can live in a particular lake. Fish predation can also have a profound impact on zooplankton abundance and community composition.

While the semi-transparency and small size (0.01 – 4.0 mm) of zooplankton are effective deterrents to fish predation, it is the timing of zooplankton abundance that frequently determines the success of a lake's larval fish community. The abundance and slow-moving nature of zooplankton make them the primary food of young fish (fry). The interdependence of algae, zooplankton, and young fish as predators and prey forms the primary food web in most lakes. Some of the non-native and invasive zooplankton species are much larger in size than native zooplankton. The non-native zooplankton can disturb the fishery in a lake because they are often too large to fit in the mouth of young fish.

In Marathon County lakes, three dominant groups of zooplankton were observed – **Rotifers** (microscopic wheel organisms), **Cladocerans** (water fleas), and **Copepods**. The various zooplankton groups and species within these groups wax and wane during the ice-free season as algae, temperature and fish predation change.

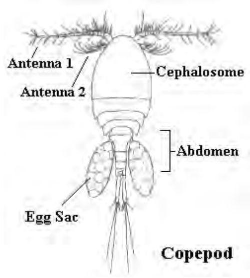


Rotifers are small invertebrate animals with simple body designs. They are usually not found uniformly throughout lakes, but congregate in areas of high food abundance (bacteria, algae, and other rotifers). Generally, a lake's trophic status influences, or can be predicted by, the abundance and diversity of rotifers. Eutrophic lakes show greater abundance and diversity of rotifers than oligotrophic systems.

Cladocerans, commonly called water fleas, are a widespread group occurring in all but a few of the most extreme freshwater habitats. Cladoceran richness in a lake depends on several factors such as water chemistry, lake size, productivity, the number of adjacent lakes, and biological interactions.

Cladoceran populations usually peak in early summer and fall immediately after algal population peaks, since algae are the preferred food of cladocerans. It is the cladocerans that are responsible for increasing water clarity in mid-summer by filtering algae that cause summertime blooms.

Many cladocerans exhibit a behavior called diel vertical migration, swimming to deep water during the day and rising to the surface at night. This is a response to avoid heavy fish predation and can result in lower than expected cladoceran numbers during daytime collections.



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Copepods, like cladocerans, can fluctuate in abundance and composition due to food limitation, temperature and predation within a lake. They can occur in high densities and populations can double in 1 to 2 weeks. There is a documented positive relationship between copepod numbers and increased **eutrophy**; as lakes become more nutrient rich copepod numbers increase. Also, like cladocerans, native copepods are a favorite prey for young fish.

The zooplankton community of Mission Lake was highly diverse (Table 10 and Table 11). Zooplankton were classified based on two general size categories: nano-plankton (80 *u*m or less) or net plankton (210 *u*m or less).

The dominant groups of nano-plankton were the rotifers and copepods, with copepod, cladoceran, and rotifer subdominants.

- There were 1,354 individuals counted during this period:
    - 782 rotifers, 83 cladocerans, and 491 copepods.

The dominant group of net plankton were cladocerans and copepods, with copepod and rotifer subdominants.

- There were 1,446 individuals counted during this period:
    - 68 rotifers, 593 cladocerans, and 785 copepods.

In the nano-plankton, copepods were abundant in 3 of 12 sampling periods. Only in the fall did the rotifers represent the most dominant type of nano-plankton in Mission Lake. The cladocerans were the dominant net plankton in summer. Otherwise, the copepods were abundant fall through early spring in net plankton samples, but faded from the abundance list during summer. Rotifers appeared in summer and fall.

The zooplankton community presented a picture of a lake transitioning to eutrophic when considered relative to the algal, phosphorus, and nitrogen values for Mission Lake. The seven genera of rotifers, four genera of cladocerans, and eight genera of copepods identified during the sample periods were relatively common but diverse. None of those that reached numerical dominance in the sample counts were associated as invasive or exotic. A stable, little-changing zooplankton community dominated by copepods in both the nano and net-plankton suggests that Mission Lake is fairly eutrophic.

TABLE 10. MOST COMMON (NANO) ZOOPLANKTON BY DATE IN MISSION LAKE, APRIL 2011 TO MARCH 2012.

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 29	Copepod	*Diacyclops nanus*	Copepod	Nauplii	Rotifer	*Keratella longispina*
June 14	Copepod	Nauplii	Rotifer	*Polyarthra dolichoptera*	Cladoceran	*Daphnia retrocurva*
October 19	Rotifer	*Syncheata oblonga*	Rotifer	*Keratella cochlearis*	Copepod	*Diacyclops nanus*
March 4	Copepod	Nauplii	Copepod	*Eucyclops speratus*	Rotifer	*Filinia terminalis*

TABLE 11. MOST COMMON (NET) ZOOPLANKTON BY DATE IN MISSION LAKE, APRIL 2011 TO MARCH 2012.

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 29	Copepod	*Diacyclops nanus*	Copepod	Cyclopoid copepodite		
June 14	Cladoceran	*Daphnia retrocurva*	Cladoceran	*Bosmina longirostris*	Cladoceran	*Daphnia pulex*
October 19	Cladoceran	*Daphnia retrocurva*	Copepod	*Diacyclops nanus*	Copepod	*Epischura lacustris*
March 4	Copepod	*Eucyclops speratus*	Copepod	*Limnocalanus macrurus*	Copepod	*Diacyclops nanus*

AQUATIC PLANTS

Aquatic plants are the forested landscape within a lake. They provide food and habitat for a wide range of species including fish, waterfowl, turtles, amphibians, as well as invertebrates and other aquatic animals. They improve water quality by releasing oxygen into the water and utilizing nutrients that would otherwise be used by algae. A healthy lake typically has a variety of aquatic plant species which creates diversity that makes the aquatic plant community more resilient and can help to prevent the establishment of non-native aquatic species.

During the 2012 aquatic plant survey of Mission Lake, 31 species of aquatic plants were found (Table 12), with the greatest diversity of species occurring around the shoreline (Figure 15). Mission Lake had the most aquatic plant species in the Eastern Marathon County Lakes Study. Fifty-seven percent (118 of 206) of the sampled sites had vegetative growth. The average depth of the sampled sites was 10 feet and the maximum depth with vegetation was16 feet.

The dominant plant species in the survey was slender naiad (*Najas flexilis*), followed by white water lily (*Nymphaea odorata*) and muskgrass (*Chara* spp.). The stems, leaves, and seeds of slender naiad are important food sources for waterfowl and marsh birds. This common aquatic species provides habitat for fish as well. The seeds of the white water lily also provide food to waterfowl. The broad, floating leaves of this aquatic species offer shade and shelter to fish. Muskgrass is a favorite food source for a wide variety of waterfowl. Beds of muskgrass offer cover and food for fish, especially young trout, largemouth bass, and smallmouth bass (Borman et al., 2001).

The Floristic Quality Index (FQI) evaluates the closeness of a plant community to undisturbed conditions. Each plant is assigned a coefficient of conservatism (C value) that reflects its sensitivity to disturbance. These numbers are used to calculate the FQI. C values range from 0 to 10, with higher values designating species that are less tolerant of disturbance. The FQI for Mission Lake was 33.1, which was well above average and the highest ranked lake in the Eastern Marathon County Lakes Study.

Of the aquatic plant species within Mission Lake, six had a C value of eight or greater (Table 12), tying Mission Lake with Rice Lake for fourth out of the eleven lakes within the Eastern Marathon County Lakes Study. The high quality species in Mission Lake included pickerelweed (*Pontederia cordata*), spiny-spored quillwort (*Isoetes echinospora*), brown fruited rush (*Juncus pelocarpus*), Fries' pondweed (*Potamogeton friesii*), blunt-leaf pondweed (*Potamogeton obtusifolius*), and whitewater crowfoot (*Ranunculus aquatilis*). No species of special concern in Wisconsin were found in Mission Lake.

The Simpson Diversity Index (SDI) quantifies biodiversity based on a formula that uses the number of species surveyed and the number of individuals per site. The SDI uses a decimal scale of zero to one with values closer to one representing higher amounts of biodiversity. Mission Lake had an SDI value of 0.90. This represents above-average biodiversity when compared to all the lakes in the Eastern Marathon County Lakes Study.

During the 2012 aquatic plant survey, one non-native species, Eurasian water-milfoil (*Myriophyllum spicatum*), EWM, occupied a sparse patch at one location in Mission Lake. This aquatic invasive plant species begins its growth early in the spring and can quickly out-compete native species. EWM is effective at distributing its population in a lake. It has two mechanisms to create new plants: plant fragments broken off a parent plant that float to a new destination and take root, and seeds. The presence of EWM in Mission Lake highlights the lake's vulnerability to infection by other aquatic invasive species.

A strategy should be developed to prevent the introduction of aquatic invasive species along with a monitoring strategy that is designed to identify AIS before it becomes established.

Overall, the aquatic plant community in Mission Lake can be characterized as having an excellent variety of high quality species. The habitat, food source, and water quality benefits of this diverse plant community, as well as the control and removal of Eurasian water milfoil, should be focal points in future lake management strategies.

TABLE 12. AQUATIC PLANTS IDENTIFIED IN MISSION LAKE, 2012 SURVEY.

Common Name	Scientific Name	Coefficient of Conservatism Value (C Value)
Emergent Species		
Robbins' spikerush	*Eleocharis robbinsii*	
common arrowhead	*Sagittaria latifolia*	3
pickerelweed	*Pontederia cordata*	8
broad leaved cattail	*Typha latifolia*	1
hardstem bulrush	*Schoenoplectus acutus*	6
softstem bulrush	*Schoenoplectus tabernaemontani*	4
Floating Leaf Species		
watershield	*Brasenia schreberi*	6
large duckweed	*Spirodela polyrhiza*	5
spatterdock	*Nuphar variegata*	6
white water lily	*Nymphaea odorata*	6
floating-leaf pondweed	Potamogeton natans	5
Submergent Species		
coontail	*Ceratophyllum demersum*	3
muskgrass	*Chara*	7
common waterweed	*Elodea canadensis*	3
water star-grass	*Heteranthera dubia*	6
spiny-spored quillwort	*Isoetes echinospora*	8
brown fruited rush	*Juncus pelocarpus f. submersus*	8
northern water-milfoil	*Myriophyllum sibiricum*	6
Eurasian water-milfoil	*Myriophyllum spicatum*	0
slender naiad	*Najas flexilis*	6
Nitella	*Nitella*	7
Fries' pondweed	*Potamogeton friesii*	8
variable pondweed	*Potamogeton gramineus*	7
Illinois pondweed	*Potamogeton illinoensis*	6
blunt-leaf pondweed	*Potamogeton obtusifolius*	9
clasping-leaf pondweed	*Potamogeton richardsonii*	5
flat-stem pondweed	*Potamogeton zosteriformis*	6
whitewater crowfoot	*Ranunculus aquatilis*	8

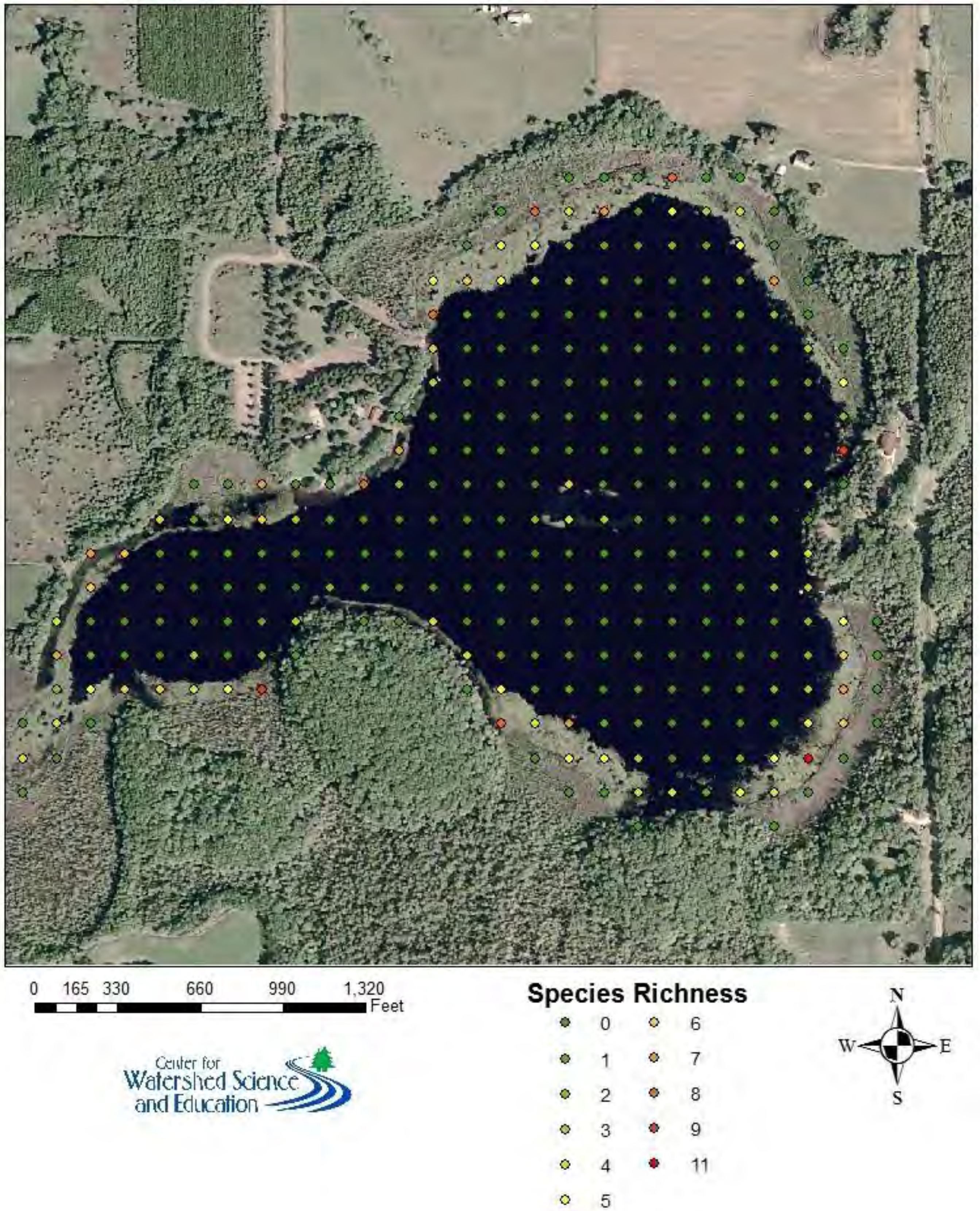


FIGURE 15. SPECIES RICHNESS AT SAMPLE SITES ON MISSION LAKE, 2012,

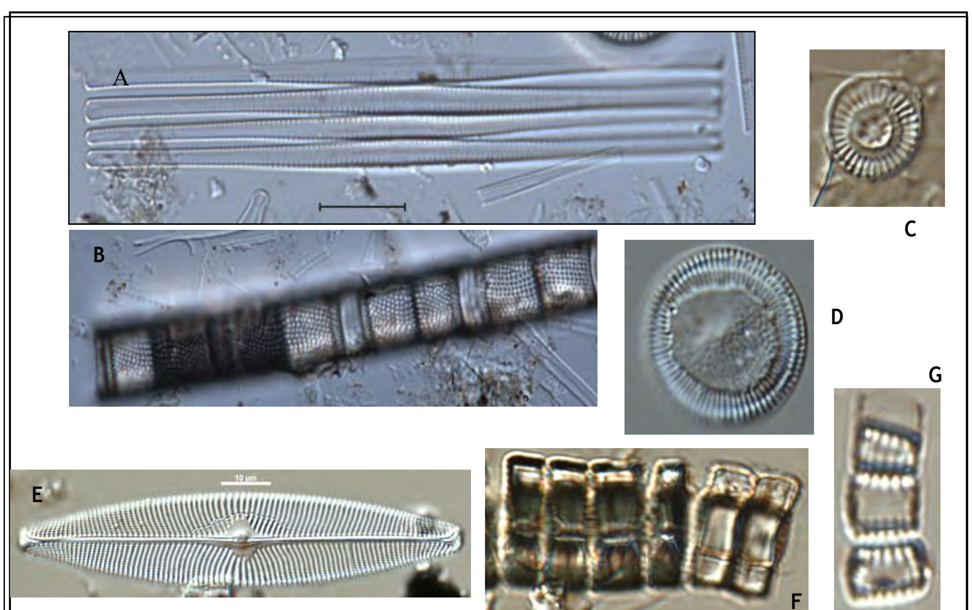
SEDIMENT CORE

Questions often arise concerning how a lake's water quality has changed over time related to changes in land use in the watershed, the abundance and diversity of its aquatic plant communities, and the state of its shoreland vegetation. The analysis of a lake's sediment core is an effective means to reconstruct some of the changes that have occurred over time. Lakes act as sediment traps for particles that are either delivered to the lake from the surrounding landscape, the atmosphere, or occur in the lake itself. The chemical composition of the sediment can help decipher the composition of a lake's former environment. Lake sediment also contains remains such as diatom skeletons, cell walls of algal species, and the partially preserved remains of aquatic plants. By examining remains contained in the sediment, changes in a lake's ecosystem can be inferred.

Five lakes in the Eastern Marathon County Lakes Study were chosen for sediment core analysis. A core of sediment was collected for analysis from Mission Lake's deepest area in 20 feet of water in November 2012. The core was approximately 36 inches in length and it is estimated that the bottom portion of this core was deposited at least 150 years ago.

BIOLOGICAL COMPONENTS IN THE SEDIMENT CORE

Aquatic organisms can be good indicators of water chemistry because they live in direct contact with the water and are strongly affected by the chemical composition of their surroundings. Most indicator groups grow rapidly and are short-lived, so the community composition responds quickly to changing environmental conditions. Diatoms, a type of algae, are especially useful because they are usually abundant, are ecologically diverse, and their ecological tolerances are well known. In addition, the cell walls of diatoms are comprised of silica, which enables them to be highly resistant to degradation and therefore, well-preserved in sediments (Figure 16).



THE FIRST FOUR DIATOMS, FRAGILARIA CROTONENSIS (A), AULACOSEIRA AMBIGUA (B), DISCOTELLA STELLIGERA (C), AND CYCLOTELLA MICHIGANIANA (D) TYPICALLY ARE FOUND IN OPEN WATER ENVIRONMENTS. STAUROSIRA CONSTRUENS (F) AND STAUROSIRA CONSTRUENS VAR. VENTER (G) ARE COMMONLY FOUND ATTACHED TO SUBSTRATES SUCH AS AQUATIC PLANTS, OTHER FILAMENTOUS ALGAE OR GROWING ON THE SEDIMENTS AND ARE OFTEN ASSOCIATED WITH HIGHER NUTRIENT CONCENTRATIONS. NAVICULA VULPINA (E) GROWS ON AQUATIC PLANTS AND IS USUALLY FOUND IN LOW NUTRIENT ENVIRONMENTS.

FIGURE 16. PHOTOMICROGRAPHS OF THE COMMON DIATOMS FOUND IN MARATHON COUNTY LAKE SEDIMENT CORES.

Figure 2. Photomicrographs of the common diatoms found in the sediment cores. The first four diatoms (A) *Fragilaria crotonensis*, (B) *Aulacoseira ambigua*, (C) *Discotella stelligera, and (D) Cyclotella michiganiana* typically are found in open water environments. *Staurosira construens* ((F) and *Staurosira construens* var. *venter (G)* is commonly found attached to substrates such as aquatic plants, other filamentous algae or grow on the sediments and are often associated with higher nutrient concentrations. *Navicula vulpina* (E) grows on aquatic plants and is usually found in low nutrient environments.

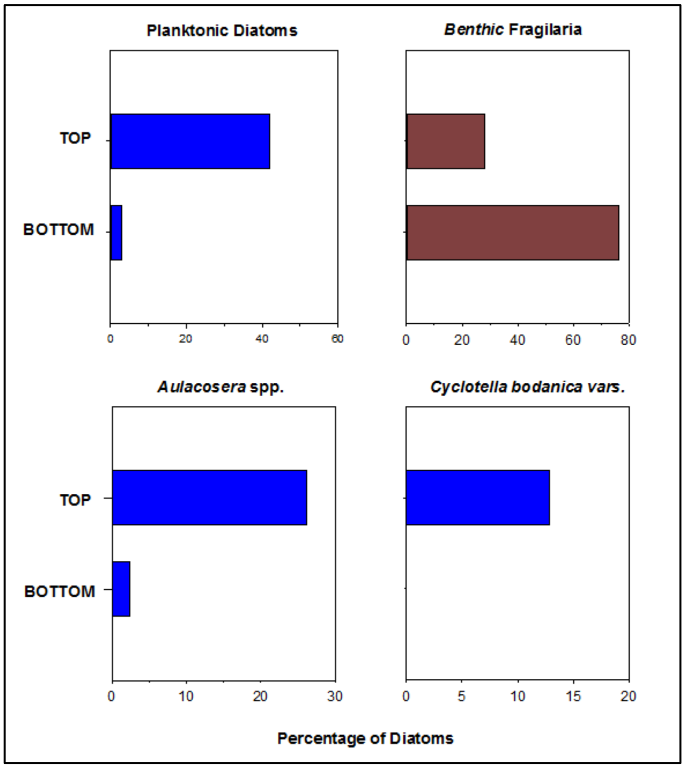


FIGURE 17. ABUNDANCE OF IMPORTANT DIATOMS FOUND AT THE TOP AND BOTTOM OF THE SEDIMENT CORE FROM MISSION LAKE, 2012.

The diatom community was analyzed in top and bottom samples of the Mission Lake sediment core (Figure 17). The bottom of the core was dominated by *S. pinnata* and *Staurosira construens*, which are both benthic (bottom-feeding) species of diatoms. These species are associated with sediments, submerged aquatic plants, and filamentous algae. In contrast, the top of the core was dominated by planktonic species of diatoms, which are most commonly found floating on top of open water and are associated with higher nutrient levels. Often, as nutrients increase, the water clarity decreases, which reduces the depth that light can penetrate. This decreases the area of the lakebed that could be occupied by benthic diatoms. Species richness and diversity were greater at the top of the core. This indicated that there are currently more submerged aquatic plants in Mission lake than in the past, and that lake productivity is also greater.

Relative dating techniques were used to provide a chronological control of the sedimentary record of lake events. A spike in ragweed pollen (*Ambrosia* spp.) served as a strong indicator of initial land clearance. When combined with historical maps, tax records and other documentation, an accurate date could be ascribed to the onset of these settlement activities, and related to the depth of the ragweed spike in the lake sediment.

Ragweed pollen was high throughout the core, but was remarkably high between 10-11 inches (Figure 18). Ragweed typically increases with increased logging and land clearing. Its pollen peaks when the remaining undergrowth is cleared or burned for agricultural use later on. The increase in ragweed pollen between 10-11 inches indicated an increase in agricultural expansion of the land around Mission Lake during the first two decades of the 20th century. This dramatic spike in ragweed pollen towards the top of the core indicated the land was cleared sometime long after logging.

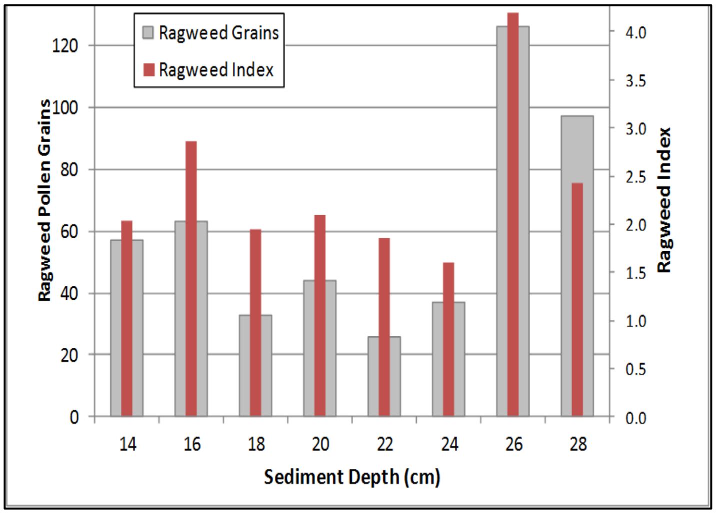
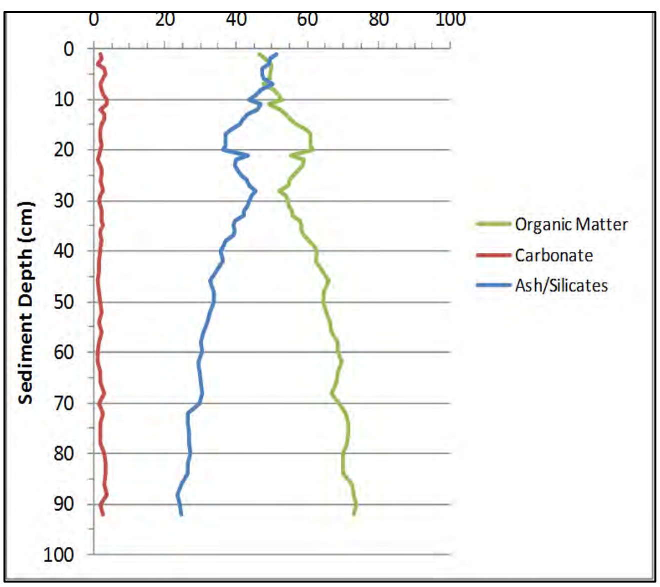


FIGURE 18. RAGWEED POLLEN IN THE MISSION LAKE SEDIMENT CORE.

PHYSICAL PROPERTIES OF SEDIMENT

Mission Lake's newly-extracted sediment appeared to be dark brown towards the bottom and graded to black towards the top of the core. However, later when it was analyzed in the lab, all the sediment appeared black, suggesting the sediment contained compounds that changed appearance when exposed to air. The dark color is likely the result of high amounts of organic matter and/or iron staining the sediment. As microbes and other organisms decompose in a lake, dissolved oxygen in the overlying water decreases and the sediment can be altered by the production of iron compounds. Although this typically occurs seasonally, it becomes more pronounced with an increase in nutrients, algae, and aquatic plants.

There were few textural changes in the Mission Lake sediment core compared to the color changes in the sediment core. The sediment was fine grained and smooth and contained varying amounts of sand throughout. Sand can be indicative of shoreland disturbance associated with erosion from land clearing and storm events. The morphology within Mission Lake allows sand to easily accumulate in the lake's deepest areas.



In order to further understand the composition of Mission Lake's sediment core, a test called loss on ignition (LOI) was conducted. To provide more specifics about the core's composition, various components of a lake's sediment core are burned off, including organic matter, marl (carbonate), and silica (sand, silt, and clay) (Figure 19). The LOI results for Mission Lake indicated that silica was abundant in the upper 7 inches of the core and again at 11 inches. The upper occurrence of increased silica was a result of shoreland disturbance such as erosion from land clearing and development around the lake in more recent years, and the lower spike of silica correlated to the logging that occurred around Mission Lake in the past.

FIGURE 19. LOSS ON IGNITION RESULTS FOR MISSION LAKE.

SEDIMENT CORE RESULTS SUMMARY

Analysis of biological components and physical properties of the sediment core from Mission Lake indicated an increase in erosion-induced processes such as land clearing, storm events, and shoreland disturbances since the time of land settlement around the lake. The analyses indicated that these activities have occurred more frequently in recent decades, but appear to have declined in recent years. There has likely been an increase in nutrient delivery, including phosphorus, to the lake over this time period and an increase in the color of the water. The shift in diatom communities and the physical properties of the sediment reflected increases in phosphorus, aquatic plants, and algae towards the top of the core. The analyses also suggested that Mission Lake has experienced an increase in phosphorus concentrations in addition to large changes in habitat during the last century.

CONCLUSIONS & RECOMMENDATIONS

Mission Lake has some outstanding natural features which qualify it as a unique lake in central Wisconsin. However, a number of measures during the study suggested that the quality of Mission Lake may be declining. The water quality, algal and zooplankton communities, and the presence of aquatic invasive species in Mission Lake all contribute to this perspective. While changes may be occurring, carefully considered and informed steps taken by the community could slow the decline or even lead to improvements in Mission Lake.

A healthy fishery is one that is in balance with the lake's natural ability to support the fish community, and is adaptable to fishing practices that do not cause declines in fish populations. A healthy fish community has a balance between predator and prey species, and each fish species has different needs to be met in order to flourish, including adequate food sources, habitat, appropriate spawning substrate, and water quality.

- Mission Lake supports a warm water fish community. In 2012, 20 fish species were sampled and identified. A total of twenty-two fish species have been recorded in Mission Lake since 1950.
- Newly reported species in the 2012 survey included blackchin shiner, blacknose shiner, bluegill x pumpkinseed hybrid, green sunfish, and warmouth.
- Species documented previously, but not detected during the 2012 survey, included the emerald shiner and walleye.
- Bluegill was the most abundant species during both the fyke netting and shocking surveys in 2012. The maximum size of bluegill captured during the survey was 6.5 inches.
- Although infrequently encountered, muskellunge and northern pike occurred in the surveys of Mission Lake. Maximum sizes of those captured were muskellunge at 33.3 inches and northern pike at 30 inches.
- Five rusty crayfish (*Orconectes rusticus*), a non-native and potentially invasive species, were captured during the sampling period.

To successfully sustain a healthy fish population, a lake must have the habitat to support it. Habitat needs of fish include healthy aquatic plants and woody structure such as logs, fallen trees, and stumps. Woody structure provides places for fish to hide, as well as habitat for invertebrates that many fish species use as food sources. Many fish use lily pads and bulrush, as well as gravel and cobble substrates, for spawning habitat.

- Substrate distribution in Mission Lake primarily consisted of a soft bottom, muck (89.3%). In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build nests on softer substrates. Depressions are deepened until small amounts of coarser substrate, mostly fragments of snail shells, accumulate in the bottom of the nests. The presence of young bass and abundant sunfish indicated that successful reproduction was occurring in Mission Lake. In areas of soft substrate, largemouth bass are also reported to nest on woody habitat swept clear of sediments.
- Sand substrate was mostly present along the southern and eastern shorelines (10.5%). Sand can be important habitat for reproduction of non-game minnow.
- Bulrush beds were present near the outlet of Mission Lake.
    - Northern pike utilize areas with emergent and floating-leaf vegetation in shallow or flooded areas for spawning. Sampling indicated successful reproduction of northern

    - pike may be occurring, but more intense population sampling over several seasons would be required to determine the reproductive success of this species.
    - Black crappie utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young.
- Coarse woody habitat (CWH), including downed trees and logs, are present in Mission Lake; however, it is mostly limited to the southern and eastern shorelines.
    - This structure is utilized by young prey fish and other aquatic organisms for spawning, foraging, and protective cover.
    - The fish community would benefit from the addition of CWH in areas where it is sparse.

The interdependence of algae, zooplankton, and young fish as predators and prey form the primary food web in most lakes. Zooplankton are microscopic invertebrate animals that swim or drift in water. They are the primary consumers at the base of the food chain in our lakes and are an important food for many fish. Most zooplankton are filter feeders, using their appendages to strain bacteria and algae from water, so they help to keep algal populations under control. It is the timing of zooplankton abundance that frequently determines the success of a lake's larval fish community. The abundance and slow-moving nature of zooplankton make them the primary food of young fish (fry).

- A stable, little-changing zooplankton community dominated by copepods in both the nano and net-plankton suggested that Mission Lake is fairly eutrophic.
- The zooplankton identified during the sample periods were relatively common but diverse. None of those that reached numerical dominance in the sample counts were associated as invasive or exotic.

Aquatic plants are the forested landscape within a lake. They provide food and habitat for a wide range of species including fish, waterfowl, turtles, and amphibians, as well as invertebrates and other aquatic animals. They improve water quality by releasing oxygen into the water and utilizing nutrients that would otherwise be used by algae. A healthy lake typically has a variety of aquatic plant species which creates diversity that makes the aquatic plant community more resilient and can help to prevent the establishment of non-native aquatic species.

- During the 2012 aquatic plant survey of Mission Lake, 31 species of aquatic plants were found, with the greatest diversity of species occurring around the shoreline. Mission Lake had the most aquatic plant species in the Eastern Marathon County Lakes Study.
- The Floristic Quality Index (FQI) evaluates the closeness of a plant community to undisturbed conditions. The FQI for Mission Lake was 33.1, which is well above average compared with the other lakes in the Eastern Marathon County Lakes Study.
- Of the aquatic plant species within Mission Lake, six were considered high quality, with C values of eight or greater: pickerelweed, spiny-spored quillwort, brown fruited rush, Fries' pondweed, blunt-leaf pondweed, and whitewater crowfoot.
- No species of special concern in Wisconsin were found in Mission Lake.
- During the 2012 aquatic plant survey, one non-native species, Eurasian water-milfoil (EWM), occupied a sparse patch in Mission Lake. This aquatic invasive plant species begins its growth early in the spring and can quickly out-compete native species. EWM is effective at distributing its population in a lake. It has two mechanisms to create new plants: plant fragments broken off a parent plant that float to a new destination and take root, and seeds.

- The presence of EWM in Mission Lake highlights the lake's vulnerability to infection by other aquatic invasive species. Strategies should be developed to prevent the introduction of aquatic invasive species along with a monitoring strategy designed to identify AIS before it becomes established.
- Overall, the aquatic plant community in Mission Lake can be characterized as having an excellent variety of high quality species. The habitat, food source, and water quality benefits of this diverse plant community, as well as the control and removal of Eurasian water milfoil, should be focal points in future lake management strategies.
- The amount of disturbed lakebed from raking or pulling plants should be minimized, since these open spaces are "open real estate" for aquatic invasive plants to establish.
- Early detection of aquatic invasive species (AIS) can help to prevent their establishment should they be introduced into the lake. Boats and trailers that have visited other lakes can be a primary vector for the transport of AIS.
- Programs are available to help volunteers learn to monitor for AIS and to educate lake users at the boat launch about how they can prevent the spread of AIS.

Algae are microscopic, photosynthetic organisms that are important food items in all aquatic ecosystems. Different algal groups increase or decrease during the year and they can be used to analyze a lake's water quality because there are more varieties of algae than fish or aquatic plants. Conclusions can be drawn about water temperature, nutrient availability, and overall water quality of a lake using algal populations.

- During both 2011 and 2012, the algal community in Mission Lake was characteristic of a lake tending towards eutrophic status. This was evident from the early and persistent presence of the blue-green algae, and their tendency to dominate as the seasons developed.
- The heavy, early-season green algal populations of 2011 waned as the season ran on, but they stayed high during 2012. Conversely, diatom populations bloomed in late 2011, but 2012 diatom abundance dropped relative to 2011.
- Disrupted and variable algal populations lacking discernible patterns are typical of eutrophic bodies of water. The high internal nutrient load can be resuspended with surface weather events (storms, winds), and utilized serially by various algal species as water temperature changes.
- Heavy growth by the three dominant algal groups leads to poor water clarity and further accelerates a decline into a more eutrophic state.

Analysis of biological components and physical properties of the sediment core from Mission Lake indicated an increase in erosion-induced processes such as land clearing, storm events, and shoreland disturbances since the time of land settlement around the lake. The analyses indicated that these activities have occurred more frequently in recent decades, but appear to have declined in recent years.

- There has likely been an increase in nutrient delivery, including phosphorus, and an increase in the color of the water in Mission Lake over the most recent 150 year period.
- The shift in diatom communities and the physical properties of the sediment reflected increases in phosphorus, aquatic plants, and algae towards the top of the core.
- The analyses also suggested that Mission Lake has had large changes in habitat during the last century.

Some of the water quality analyses indicated good quality in Mission Lake. Chloride, potassium, and sodium were all low, and DACT, an agricultural herbicide, was not present in the two samples analyzed. Dissolved oxygen concentrations were plentiful in the upper 9 feet of the lake. Mission Lake is clearly a nutrient-enriched lake.

- Total phosphorus concentrations in Mission Lake were elevated. The summer median total phosphorus was 30 ug/L and 16 ug/L in 2011 and 2012, respectively. The median concentration in 2012 was above Wisconsin's phosphorus standard of 20 ug/L for deep seepage lakes.
- During the study, inorganic nitrogen concentrations in samples collected during the spring in Mission Lake were 0.12 mg/L in 2011 and 0.43 mg/L in 2012. Concentrations above 0.3 mg/L are sufficient to enhance algal blooms throughout the summer. Inorganic nitrogen typically moves to lakes with groundwater and sources include fertilizers, animal waste, and septic systems.

In general, each type of land use contributes different amounts of phosphorus, nitrogen, and pollutants in runoff and through groundwater. The types of land management practices that are used and their distances from the lake affect the contributions to the lake from a parcel of land. Mission Lake's surface and groundwater watersheds provided most of the water to the lake. Forests comprised nearly half of the 1,577 acre surface watershed, followed by agriculture which comprised about 32% of the watershed. In the groundwater watershed, forests also had the greatest percent land use (55%), followed by agriculture (23%).

- While forests comprised the greatest amount of land in the watershed, water quality modeling results indicated agriculture had the greatest percentage of phosphorus contributions from the watershed to Mission Lake.
- Over-application of chemicals and nutrients should be avoided. Landowners in the watershed should be made aware of their connection to the lake and should work to reduce their impacts through the implementation of water quality-based best management practices.
- The Marathon County Conservation Department and Natural Resources Conservation Service (NRCS) have professional staff available to assist landowners interested in learning how they can improve water quality through adjustments in land management practices.

Shoreland health is critical to a healthy lake's ecosystem. Mission Lake's shoreland was assessed for the extent of vegetation and disturbances. Shoreland vegetation provides habitat for many aquatic and terrestrial animals, including birds, frogs, turtles, and many small and large mammals. Vegetation also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs and trees extending at least 35 feet inland from the water's edge.

- Mission Lake has 3.1 miles of shoreline.
- The lake's shoreland vegetation was primarily in a natural state. Grasses and forbs were the most prominent vegetative layer due to the abundance of wetlands adjacent to Mission Lake.
- For the most part, the lack of shrubs and trees is the result of dense grasses, forbs, and wetland areas rather than human disturbances.
- Alone, each manmade disturbance may not pose a problem for a lake, but on developed lakes, the collective impact of these disturbances can be a problem for lake habitat and water quality.
    - Structures such as seawalls, rip-rap (rocked shoreline), and artificial beach result in habitat loss. Mission Lake had one artificial beach.
    - Erosion contributes sediment to the lake, which can alter spawning habitat and carry nutrients into the lake. Mission Lake had one site of erosion.

    - Unmanaged runoff from rooftops of structures contribute more runoff to the lake, often resulting in delivery of more sediment to the lake. There was one structure within 35 feet of Mission Lake's shoreline.
    - Docks result in altered in-lake habitat. Denuded lakebeds adjacent to docks provide opportunities for invasive species to become established and reduce habitat that is important to fish and other lake inhabitants. There were five docks present on Mission Lake.
- Strategies should be developed to ensure that healthy shorelands remain intact and efforts should be made to improve shorelands that have disturbance. Depending upon the source of the disturbances, erosion should be controlled, vegetation should be restored, and/or excess runoff should be minimized.
- Dissemination of relevant information to property owners is the recommended first step towards maintaining healthy shorelands.
- Although Mission Lake's shoreland is in good shape now, changes can easily occur as development takes place. Minimizing impacts to Mission Lake from future development should include planning to ensure that prospective developers have information to make good decisions and that zoning is in place to achieve habitat, water quality, and aesthetic goals.

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GLOSSARY OF TERMS

Algae: One-celled (phytoplankton) or multicellular plants either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

Atrazine: A commonly used herbicide. Transports to lakes and rivers by groundwater or runoff. Has been shown to have toxic effects on amphibians.

Blue-Green Algae: Algae that are often associated with problem blooms in lakes. Some produce chemicals toxic to other organisms, including humans. They often form floating scum as they die. Many can fix nitrogen (N2) from the air to provide their own nutrient.

Calcium (Ca++): The most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed. Reported as milligrams per liter (mg/1) as calcium carbonate (CaCO3), or milligrams per liter as calcium ion (Ca++).

Chloride (Cl-): The chloride ion (Cl-) in lake water is commonly considered an indicator of human activity. Agricultural chemicals, human and animal wastes, and road salt are the major sources of chloride in lake water.

Chlorophyll *a*: Green pigment present in all plant life and necessary for photosynthesis. The amount present in lake water depends on the amount of algae, and is therefore used as a common indicator of algae and water quality.

Clarity: See "Secchi disk."

Color: Color affects light penetration and therefore the depth at which plants can grow. A yellow-brown natural color is associated with lakes or rivers receiving wetland drainage. Measured in color units that relate to a standard. The average color value for Wisconsin lakes is 39 units, with the color of state lakes ranging from zero to 320 units.

Concentration units: Express the amount of a chemical dissolved in water. The most common ways chemical data is expressed is in milligrams per liter (mg/l) and micrograms per liter (ug/l). One milligram per liter is equal to one part per million (ppm). To convert micrograms per liter (ug/l) to milligrams per liter (mg/l), divide by 1000 (e.g. 30 ug/l = 0.03 mg/1). To convert milligrams per liter (mg/l) to micrograms per liter (ug/l), multiply by 1000 (e.g. 0.5 mg/l = 500 ug/l).

Cyanobacteria: See "Blue-Green Algae."

Dissolved oxygen: The amount of oxygen dissolved or carried in the water. Essential for a healthy aquatic ecosystem in Wisconsin lakes.

Drainage basin: The total land area that drains runoff towards a lake.

Drainage lakes: Lakes fed primarily by streams and with outlets into streams or rivers. They are more subject to surface runoff problems, but generally have shorter residence times than seepage lakes.

Emergent: A plant rooted in shallow water and having most of its vegetative growth above water.

Eutrophication: The process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Groundwater drainage lake: Often referred to as a spring-fed lake, it has large amounts of groundwater as its source and a surface outlet. Areas of high groundwater inflow may be visible as springs or sand boils. Groundwater drainage lakes often have intermediate retention times with water quality dependent on groundwater quality.

Hardness: The quantity of multivalent cations (cations with more than one +), primarily calcium (Ca^{++}) and magnesium (Mg^{++}) in the water expressed as milligrams per liter of $CaCO_3$. Amount of hardness relates to the presence of soluble minerals, especially limestone or dolomite, in the lake watershed.

Intermittent: Coming and going at intervals, not continuous.

Macrophytes: See "Rooted aquatic plants."

Marl: White to gray accumulation on lake bottoms caused by precipitation of calcium carbonate ($CaCO_3$) in hard water lakes. Marl may contain many snail and clam shells. While it gradually fills in lakes, marl also precipitates phosphorus, resulting in low algae populations and good water clarity. In the past, marl was recovered and used to lime agricultural fields.

Mesotrophic: A lake with an intermediate level of productivity. Commonly clear water lakes and ponds with beds of submerged aquatic plants and mediums levels of nutrients. See also "eutrophication".

Nitrate (NO_3^-): An inorganic form of nitrogen important for plant growth. Nitrate often contaminates groundwater when water originates from manure, fertilized fields, lawns or septic systems. In drinking water, high levels (over 10 mg/L) are dangerous to infants and expectant mothers. A concentration of nitrate-nitrogen (NO_3-N) plus ammonium-nitrogen (NH_4-N) of 0.3 mg/L in spring will support summer algae blooms if enough phosphorus is present.

Oligotrophic: Lakes with low productivity, the result of low nutrients. Often these lakes have very clear waters with lots of oxygen and little vegetative growth. See also "eutrophication".

Overturn: Fall cooling and spring warming of surface water increases density, and gradually makes lake temperatures and density uniform from top to bottom. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. Common in many lakes in Wisconsin.

Phosphorus: Key nutrient influencing plant growth in more than 80% of Wisconsin lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Rooted aquatic plants (macrophytes): Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects and provide food for many aquatic and terrestrial animals. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

Secchi disk: An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration).

Sedimentation: Materials that are deposited after settling out of the water.

Stratification: The layering of water due to differences in density. As water warms during the summer, it remains near the surface while colder water remains near the bottom. Wind mixing determines the thickness of the warm surface water layer (epilimnion), which usually extends to a depth of about 20 feet. The narrow transition zone between the epilimnion and cold bottom water (hypolimnion) is called the metalimnion. Common in many deeper lakes in Wisconsin.

Watershed: See "Drainage basin."