Eastern Marathon County Lakes Study

Lost Lake

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University of Wisconsin-Stevens Point

University of Wisconsin
Stevens Point

PRIMARY AUTHORS

Authors listed are from the UW-Stevens Point unless otherwise noted.

Algae
Bob Bell

Aquatic Plants
Jen McNelly

Cultural Survey
Kristin Floress

Fisheries
Ron Crunkilton, Justin Sipiorski and Christine Koeller (Graduate Student)

Sediment Core
Samantha Kaplan
Paul Garrison (Wisconsin Department of Natural Resources)

Shoreland Assessments and Build Out
Dan McFarlane

Water Quality and Watersheds
Nancy Turyk, Paul McGinley, Danielle Rupp and Ryan Haney

Zooplankton
Chris Hartleb

UW-Stevens Point Students
Melis Arik, Nicki Feiten, Sarah Hull, Chase Kasmerchak, Justin Nachtigal, Matt Pamperin, Scott Pero, Megan Radske, Anthony Recht, Cory Stoughtenger, Hayley Templar, Garret Thiltgen

Editor: Jeri McGinley

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Drs. Bob Bell, Ron Crunkilton, Kristin Floress, Chris Hartleb, Samantha Kaplan, Paul McGinley, Justin Sipiorski

UW-Stevens Point Water and Environmental Analysis Lab

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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 developing watersheds.

Eleven lakes in eastern Marathon County were selected for this study, which focused on obtaining a better understanding of the current conditions of the lakes' water quality, fisheries, habitat, and aquatic ecosystems. This information will help lake users, residents and municipalities by identifying ways to improve existing problems and make informed decisions to preserve and protect the lake from future issues. Data collected between fall 2010 and fall 2012 focused on fisheries, water quality, groundwater, algae, zooplankton, lake histories, shoreline habitats, watersheds, and resident and lake user opinions. This report contains the results of these studies for Lost 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 LOST 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. Lost Lake is located in the township of Elderon, east of County Highway Y, north of Highway 11, and south of Hatley. One public boat launch is located on the southeastern side of the lake. Lost Lake is a 43 acre seepage lake with surface runoff and groundwater contributing most of its water. The maximum depth in Lost Lake is 28 feet; the lakebed has a moderate slope (Figure 1). Lost Lake has a water residence time of approximately 3 years and 4 months. The residence time helps determine the potential impacts of nutrients entering the lake and the length of time pollutants may stay in the lake. The lake's bottom sediments are mostly muck with rock on the eastern third of the lake.

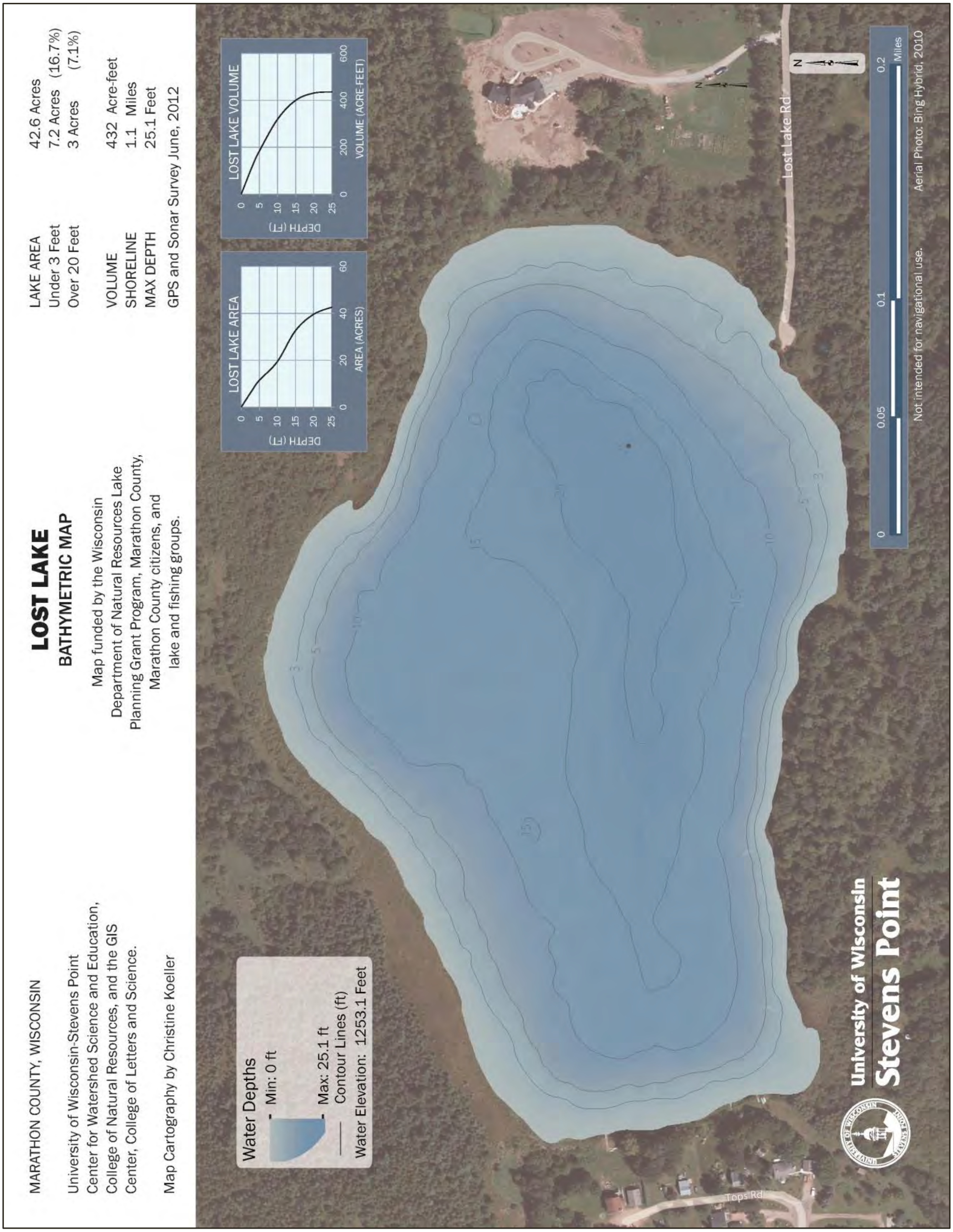


FIGURE 1. CONTOUR MAP OF THE LOST LAKE LAKEBED.

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

The water quality in Lost 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 man-made 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 Lost 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 Lost Lake is called a surface watershed. Groundwater also feeds Lost 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 carrying 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 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 Lost Lake is approximately 1,195 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 Lost Lake's shoreland include includes forests, wetlands, and residential development on the western end.

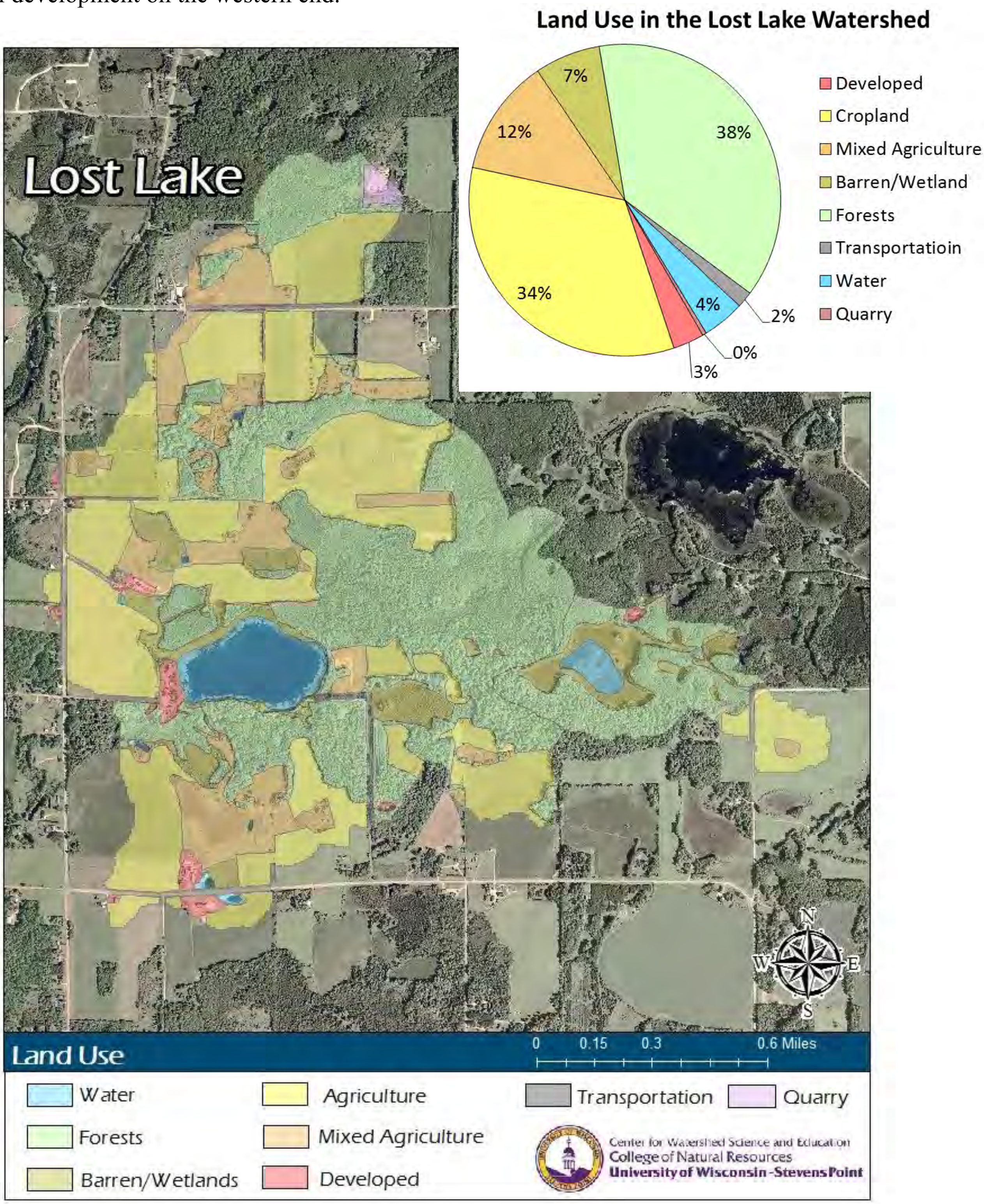
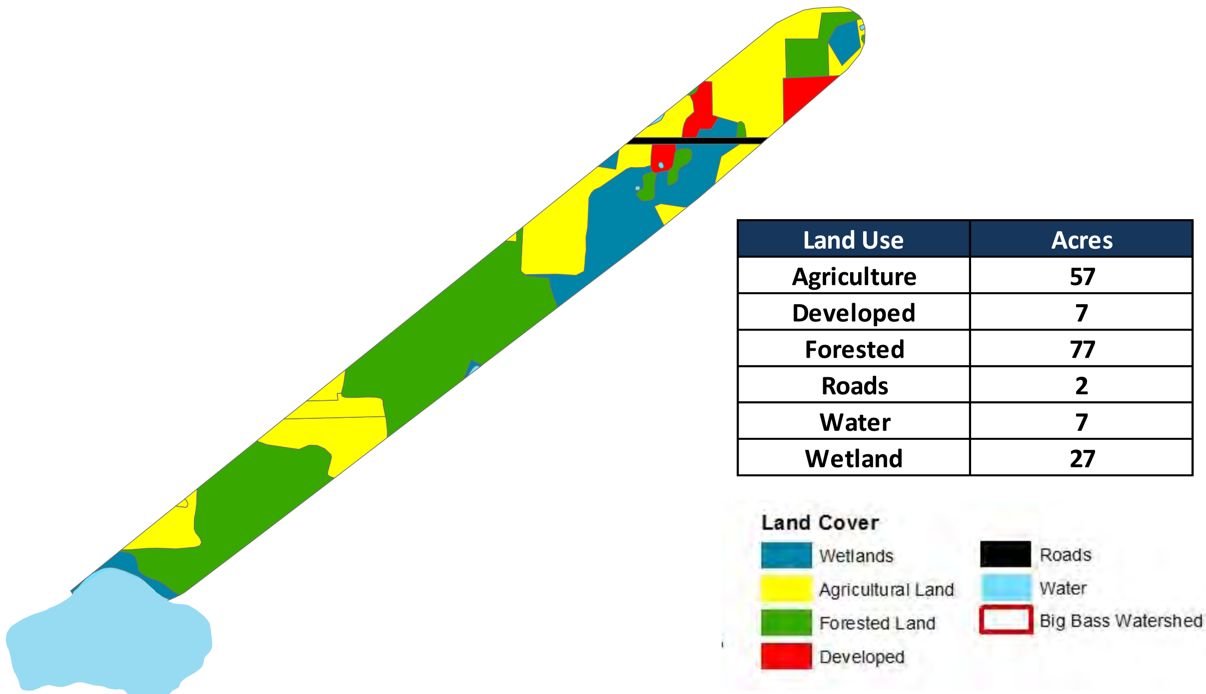


FIGURE 2. LAND USE IN THE LOST LAKE SURFACE WATERSHED.

The groundwater watershed is the area where precipitation soaks into the ground and travels below ground towards the lake. Lost Lake's groundwater watershed is approximately 177 acres (Figure 3). The primary land uses in the Lost 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 and forests are adjacent to Lost Lake where the groundwater enters.



Land Use	Acres
Agriculture	57
Developed	7
Forested	77
Roads	2
Water	7
Wetland	27

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

Locally, groundwater enters some parts of the Lost Lake lakebed (inflow), has no connection to the lake in other parts, and exits the lake in other sections (outflow). Near shore, mini-wells were installed in the lakebed approximately every 200 feet around the perimeter of Lost Lake (Figure 4). Most of the groundwater entered the lake on the eastern and western sides (green triangles). Groundwater outflow was observed on the eastern end of the lake (red marker), and areas with no connection between groundwater and the lake were observed sporadically around the rest of the lake (white circles). Additional groundwater may enter Lost Lake in areas 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 Lost Lake.

The more 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 impacts the temperature and chemistry of the groundwater. Groundwater temperatures are constant year round, so groundwater feeding LostLake will help to keep the lake water cooler during the summer months.

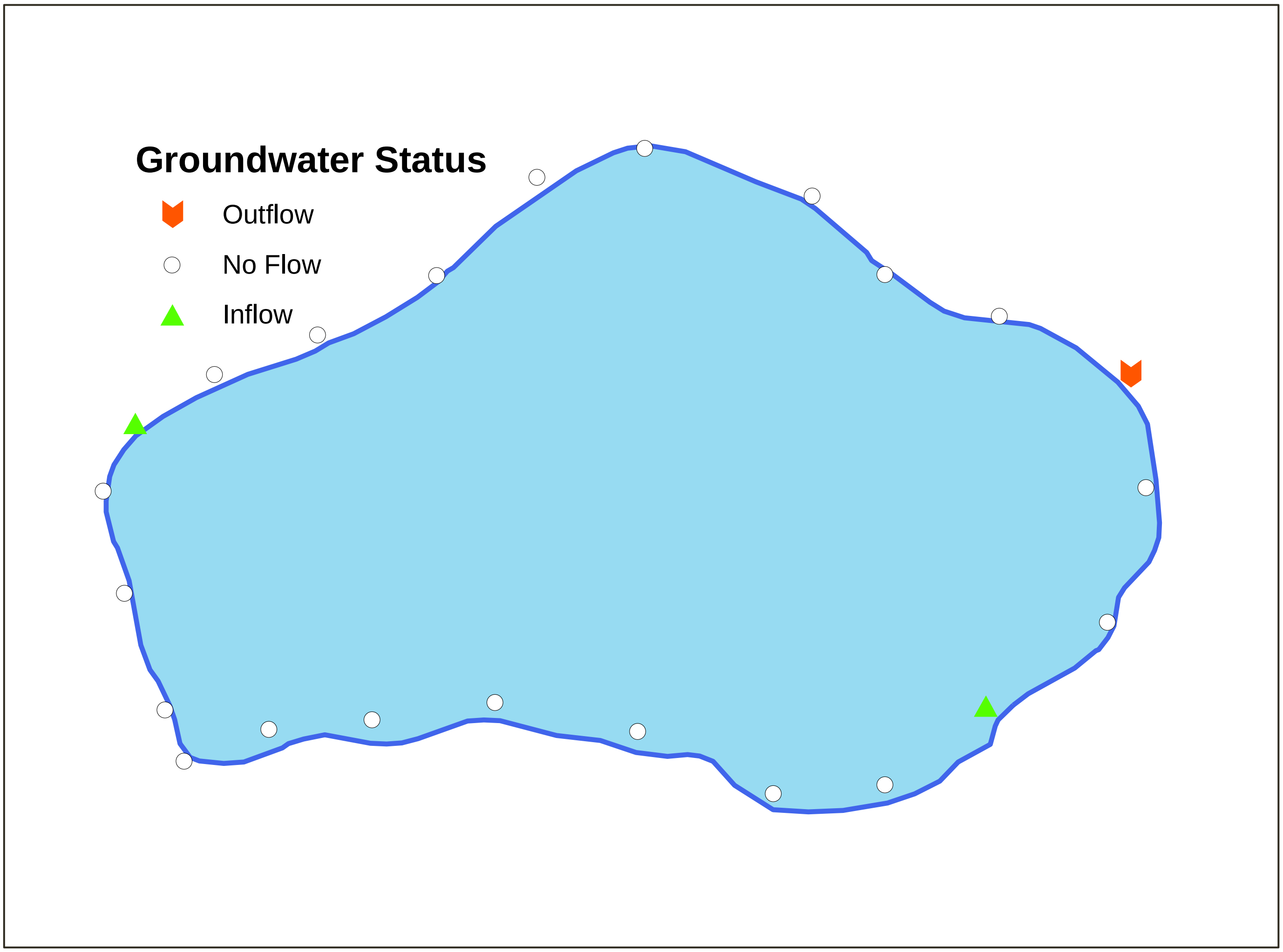
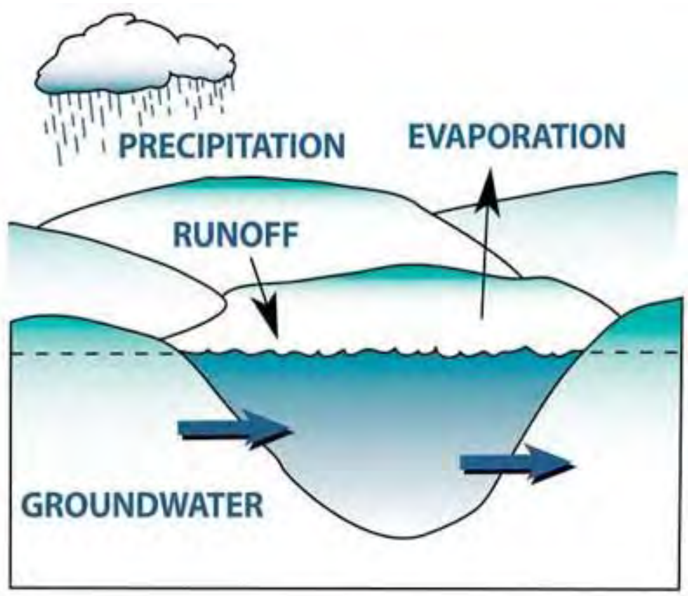


FIGURE 4. LOST LAKE GROUNDWATER INFLOW AND OUTFLOW, 2011.

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 Lost 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. Lost 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 generally have a longer retention time (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 Lost 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). If the soil around the lake is sandy and composed primarily of insoluble minerals, hardness and alkalinity will be low. This is the case in many parts of Wisconsin where the groundwater moves through glacial deposits containing little limestone.

The average hardness for Lost Lake during the 2010-2012 sampling period was 38 mg/L, which is considered soft (Table 1). Soft water does not always provide the calcium necessary for building bones and shells for animals in the lake and may be limited in its ability to buffer the effects of acid rain. The average alkalinity was 42 mg/L, which is considered low. Lower alkalinity in inland lakes is less supportive of species productivity and can help to buffer the effects of acid rain. 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 LOST LAKE, 2010-2012.

Lost Lake	Alkalinity (mg/L)	Calcium (mg/L)	Mg (mg/L)	Hardness (mg/L as CaCO3)	Color SU	Turbidity (NTU)
Average	42	9.3	4.5	38	104	2.5

Chloride concentrations, and to lesser degrees sodium and potassium concentrations, are commonly used as indicators of impacts from human activity. The presence of these compounds at elevated levels in the lake indicates the movement of pollutants from the landscape to the lake. Over the monitoring period, Lost Lake had low average chloride and sodium concentrations, and potassium was slightly elevated (Table 2). These concentrations are not harmful to aquatic organisms, but indicated that pollutants were entering the lake. Atrazine (DACT), an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L) in the two samples that were analyzed from Lost Lake.

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

Lost Lake	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium		1.5		<.75	0.75 - 1.5	>1.5
Chloride	1.2			<3	3.0 - 10.0	>10
Sodium	0.5			<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 algae and plants 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.

Water temperature in a lake changes throughout the year and may vary with depth. During winter and summer when 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 can reduce habitat for sensitive cold water species of fish and other critters.

Water temperature and dissolved oxygen were measured in Lost Lake from the surface to the bottom at the time of sample collection during the 2010-2012 study (Figure 6). The temperatures in Lost Lake exhibited a classic pattern for many deeper lakes in Wisconsin. The water in the lake mixes from top to bottom in the spring and fall and stratifies during the summer and winter. Late winter temperatures in February 2011 and February 2012 were near freezing at the surface and gradually warmed with depth. Thermal stratification was well developed in Lost Lake by mid-June, with temperatures very consistent between the two years (2011 and 2012). Temperatures began to fall at around 6 feet in depth, dropping from an average 21C (70°F) to around 10C (50°F) at about 15 feet in depth.

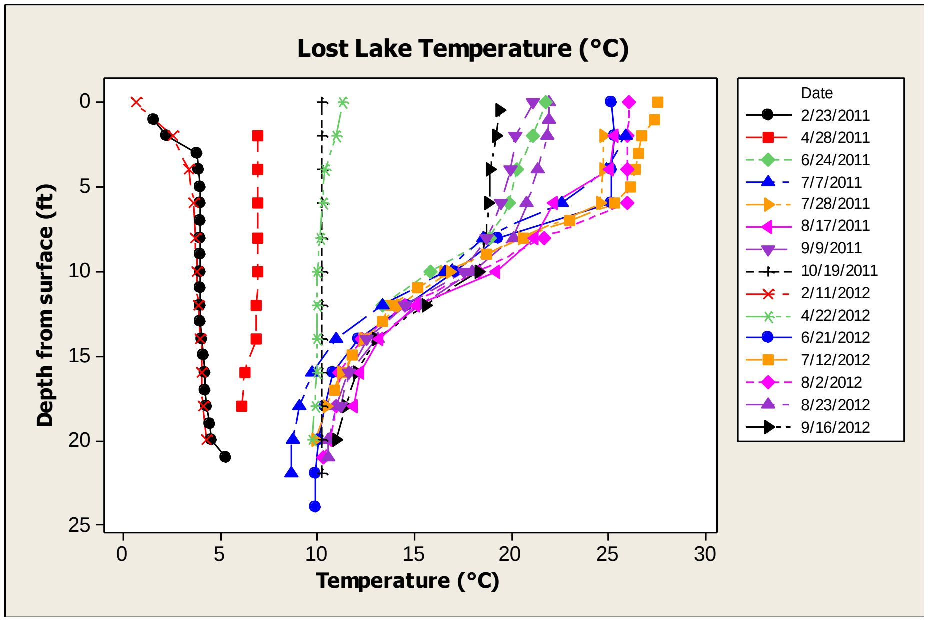


FIGURE 6. TEMPERATURE PROFILES IN LOST LAKE, 2011-2012.

Like the temperature profiles, dissolved oxygen data shows that Lost Lake experiences thorough mixing at spring and fall overturn, occurring in mid-April and mid-October, respectively (Figure 7). Dissolved oxygen concentrations of 7 to 8 mg/L are replenished throughout the lake during these times. Over winter and during summer stratification, however, much of the lake is lacking sufficient oxygen to maintain fisheries. A partial winter fish kill may have occurred in late winter 2011 as dissolved oxygen concentrations, even near the surface, remained below 4 mg/L. In contrast, winter 2012 maintained dissolved oxygen concentrations above 5 mg/L in the upper 12 feet of the lake. Oxygen is quickly consumed early in the growing season where by June, as little as the top 7 or 8 feet of water contains sufficient concentrations to maintain fisheries. Lake water commonly loses oxygen by 8 to 10 feet in depth.

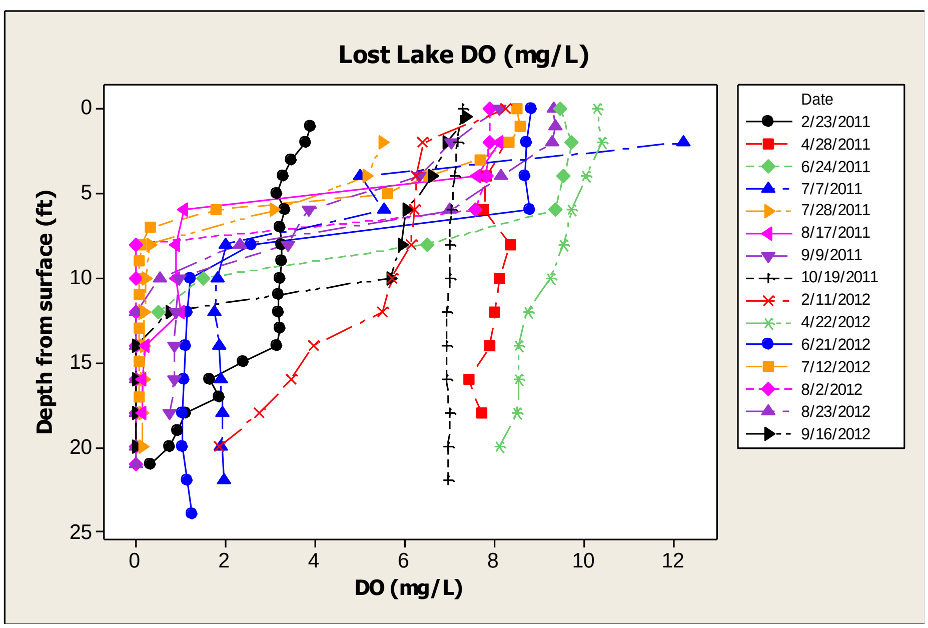


FIGURE 7. DISSOLVED OXYGEN PROFILES IN LOST LAKE, 2011-2012.

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. Water clarity is affected by water color, turbidity (suspended sediment), and algae, so it is normal for water clarity to change throughout the year and from year to year.

In Lost Lake, the color was highly stained (Table 1). Staining from tannins in the surrounding wetlands and forest are the natural source of the elevated color. While brown coloring affects the depth that light can penetrate, the maximum water clarity measurement in Lost Lake was 7.7 feet in late September 2004. This depth can be used as a reference for comparison. Fluctuations throughout the summer are typical as algae populations and sedimentation increase and decrease.

The water clarity measured in Lost Lake was considered poor. The average water clarity measurements during the study were poorest in June and best in July (Figure 8). Past water clarity data was collected sporadically between 1999 and 2010. When compared with this historic data, the average water clarity measured during the study was slightly better in August and worse in July and September.

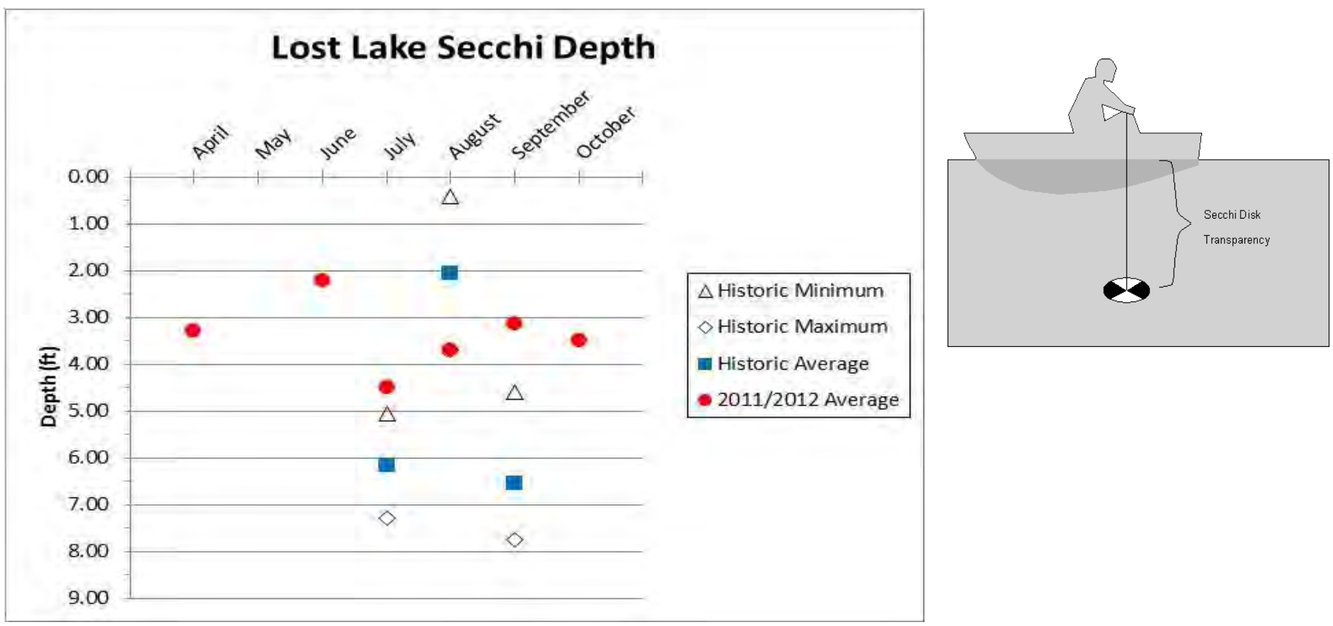


FIGURE 8. AVERAGE MONTHLY WATER CLARITY IN LOST LAKE, 2010-2012 AND HISTORIC.

Nutrients (phosphorus and nitrogen) are used by algae and aquatic plants for growth. Phosphorus is present naturally throughout the watershed in soil, plants, animals and wetlands. Additional 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 Lost Lake ranged from a high of 108 µg/L in April 2012 to a low of 35 µg/L in August 2012 (Table 3). The summer median total phosphorus was 43.5 ug/L and 39 ug/L in 2011 and 2012, respectively. This is well 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 averaged 0.67 mg/L. 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; however, ammonium (the largest form of inorganic nitrogen in Lost Lake samples) may be released from lake sediments when dissolved oxygen concentrations are low.

TABLE 3. SUMMARY OF SEASONAL NUTRIENT CONCENTRATIONS IN LOST LAKE, 2010-2012.

Lost 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	42	53	60	6	9	11	1.69	1.99	2.28	0.31	0.56	0.80	1.38	1.43	1.48
Spring	55	82	108	6	14	21	1.80	1.95	2.10	0.55	0.67	0.79	1.01	1.28	1.55
Summer	35	43	61	7	7	7									
Winter	38	48	58	15	18	21	2.31	2.32	2.33	0.97	0.97	0.97	1.34	1.35	1.36

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Lost 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 their distances 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 that agriculture had the greatest percentage (88%) of phosphorus contributions from the watershed to Lost Lake (Figure 9). The phosphorus contributions by land use category, called phosphorus export coefficients, are shown in Table 4. The phosphorus export coefficients were obtained from studies throughout Wisconsin (Panuska and Lillie, 1995).

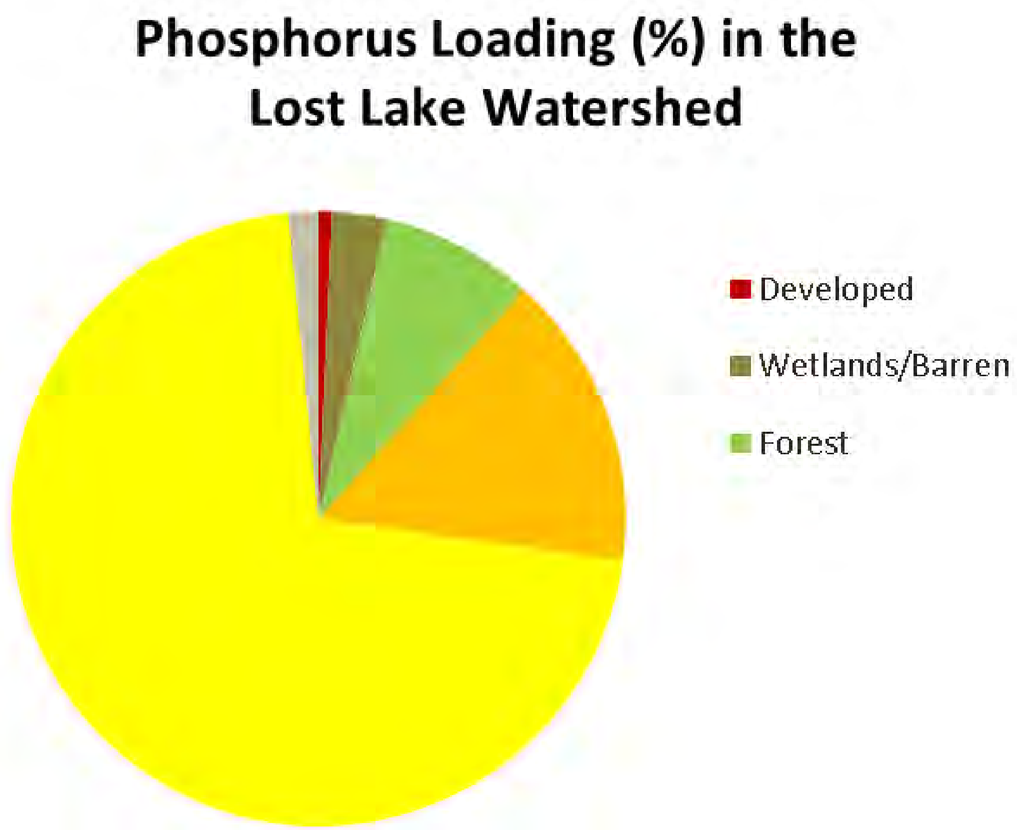


FIGURE 9. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE LOST LAKE WATERSHED.

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

Lost Lake Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.10	53	**4**	4-11	2
Developed	0.04	39	**3**	2-4	**1**
Wetland/Barren	0.09	83	**7**	7-22	**3**
Forest	0.04	460	**38**	21-37	**8**
Mixed Agriculture	0.27	148	**12**	40-106	**16**
Row Crop Agriculture	0.45	407	**34**	182-363	**72**
Quarry	0.04	5	**0**	0.2-0.4	**0**
*Values are not exact due to rounding and conversion					

Chlorophyll *a* is a measurement of algae in the water. Concentrations greater than 20 µg/L are perceived by many as problem blooms. Chlorophyll *a* concentrations in Lost Lake were generally high, ranging from a high of 66 µg/L in August 2011 to a low of 13 µg/L in September 2012.

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). Lost Lake is very eutrophic. The algal community of Lost Lake was dominated by blue-green algae. The most common species of this group are associated with nutrient-enriched water typical of eutrophic lakes. The only consistent pattern across the two years of the study was the early and consistent dominance of the blue-green algae. The large colonial and filamentous forms common in Lost Lake are difficult for zooplankton, small fish, and other creatures to eat, and grow at densities that reduce visibility in the water column. This leads to shallow water clarity values. Low visibility can become problematic for submerged aquatic plants that need penetration of sunlight to remain viable.

The green algae were minor components of the community (18%). Euglenophyta, rarely one of the most abundant phyla, was the third most common group (14%), just ahead of the diatoms (13%). The euglenoids prefer organically-enriched waters with high turbidity. The diatoms were very abundant during 2011, but nearly disappeared in 2012 with no obvious explanation. The green algae (a preferred food) were only minor components of the community (Figure 10). This variable, unpredictable, and blue-green dominated algal community, coupled with high total phosphorus values, indicated Lost Lake has reached a very eutrophic state.

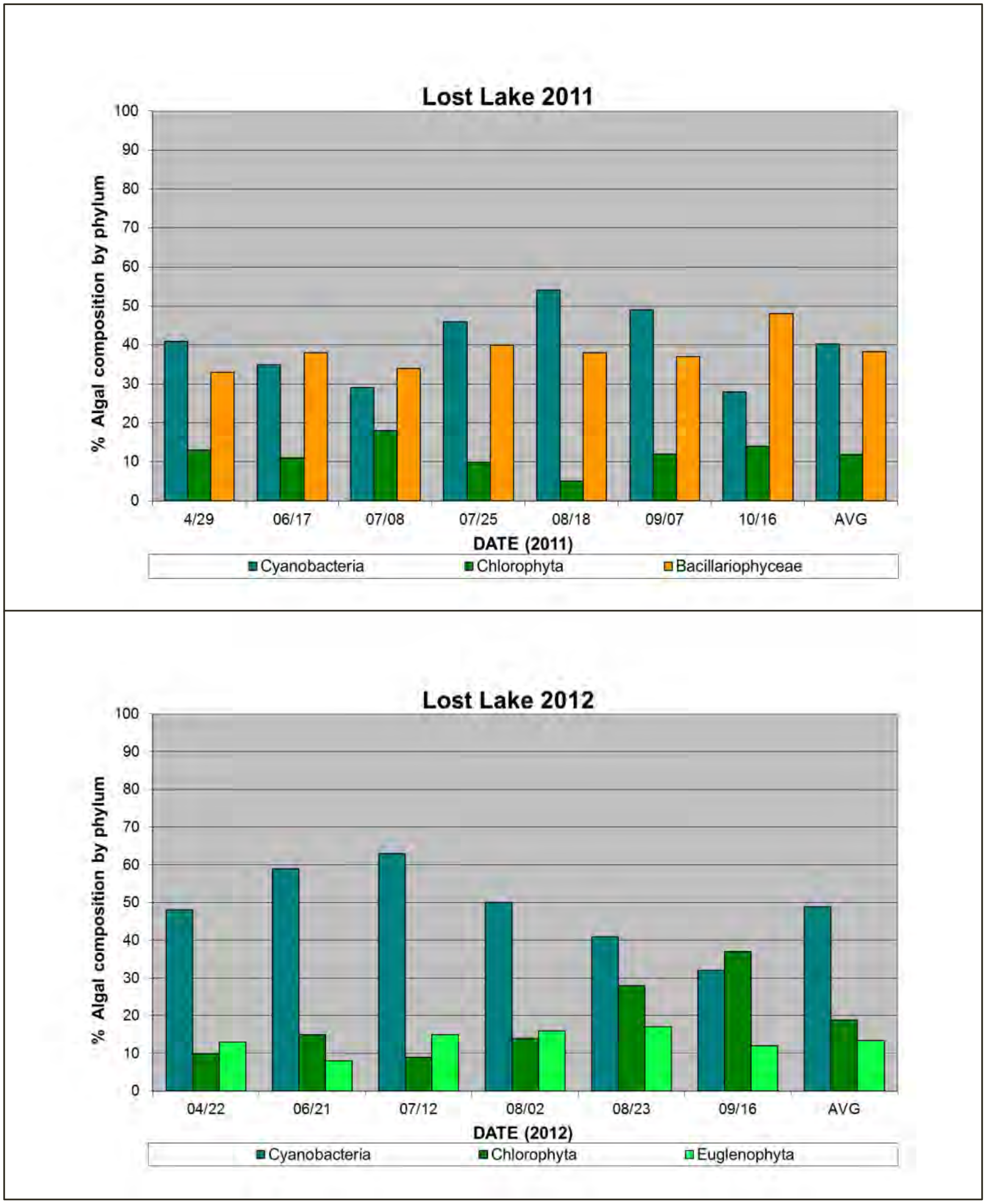


FIGURE 10. PERCENT ALGAL COMPOSITION IN LOST LAKE, 2011 AND 2012.

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 phosphorus 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 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.

LOST LAKE SHORELAND SURVEY RESULTS

The survey assessed 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 Lost Lake in Figure 12 depict the depth of vegetation along Lost 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.

Lost Lake had adequate shoreland vegetation along most of the lake shore. The overall findings showed that 5,218 linear feet of shoreline were classified as having a grass/forb buffer depth greater than 50 feet. Like the grass/forbs layer, the tree layer was also abundant, with nearly 80 percent of the shoreline classified as having buffer depth greater than 50 feet (Figure 11). Less abundant was the shrub layer, in which a majority of the shoreline was classified as 5-15 feet, which is less than the 35 feet minimum depth required by Wisconsin and Marathon County shoreland zoning ordinances. Although Lost Lake's shoreland was in good condition, changes can easily occur as development takes place. In order to minimize impacts from 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 Lost Lake.

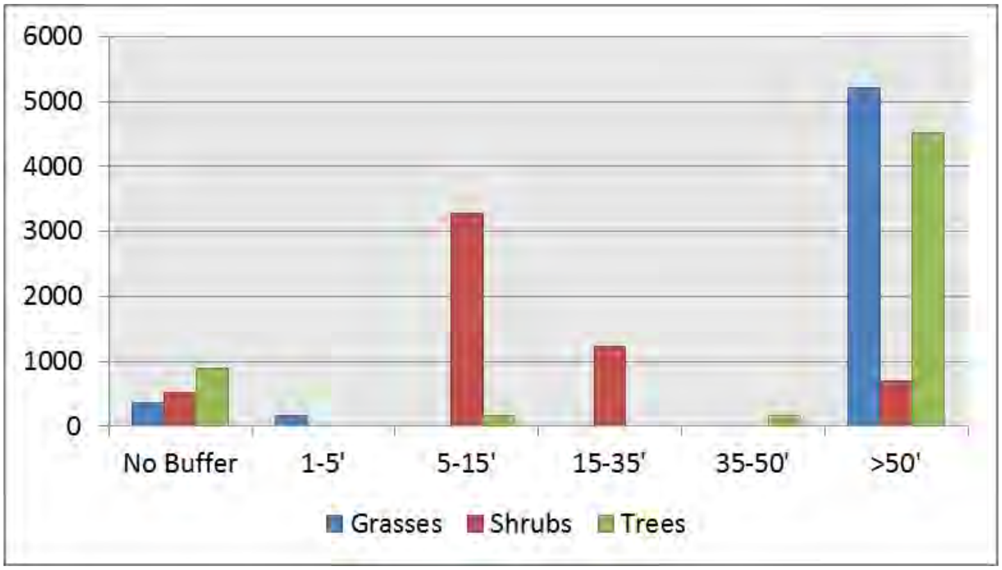


FIGURE 11. SHORELAND VEGETATION SURVEY RESULTS BY BUFFER DEPTH AROUND LOST LAKE, 2011.

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

TABLE 5. DISTURBANCES IDENTIFIED ON LOST LAKE, 2011.

Disturbance	No. of Occurrences
Artificial Beach	0
Dock	3
Riprap	0
Seawall	0
Erosion	0
Structures w/in 35'	0
Structures 35-75'	0

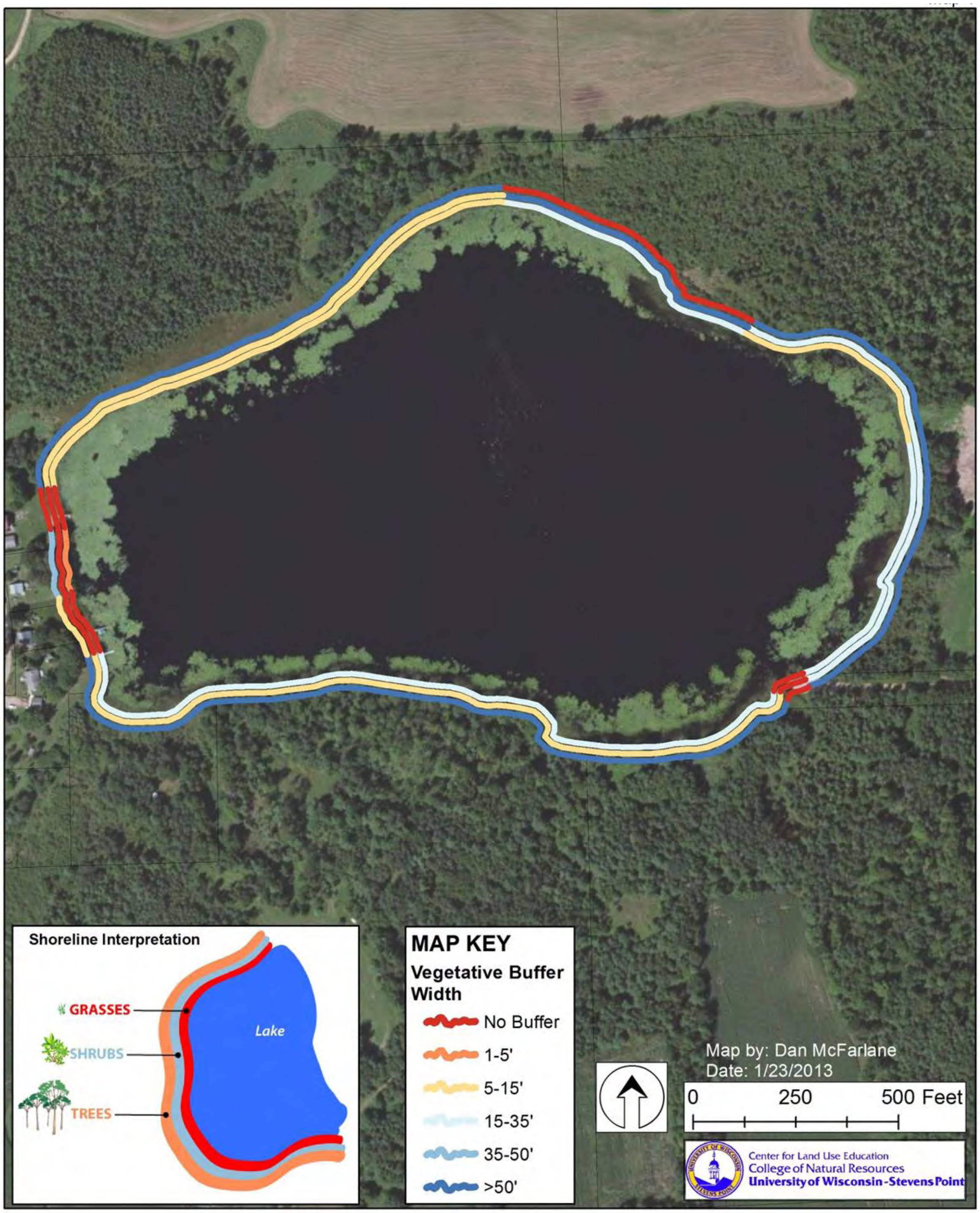


FIGURE 12. SHORELAND VEGETATION AROUND LOST LAKE, 2011.

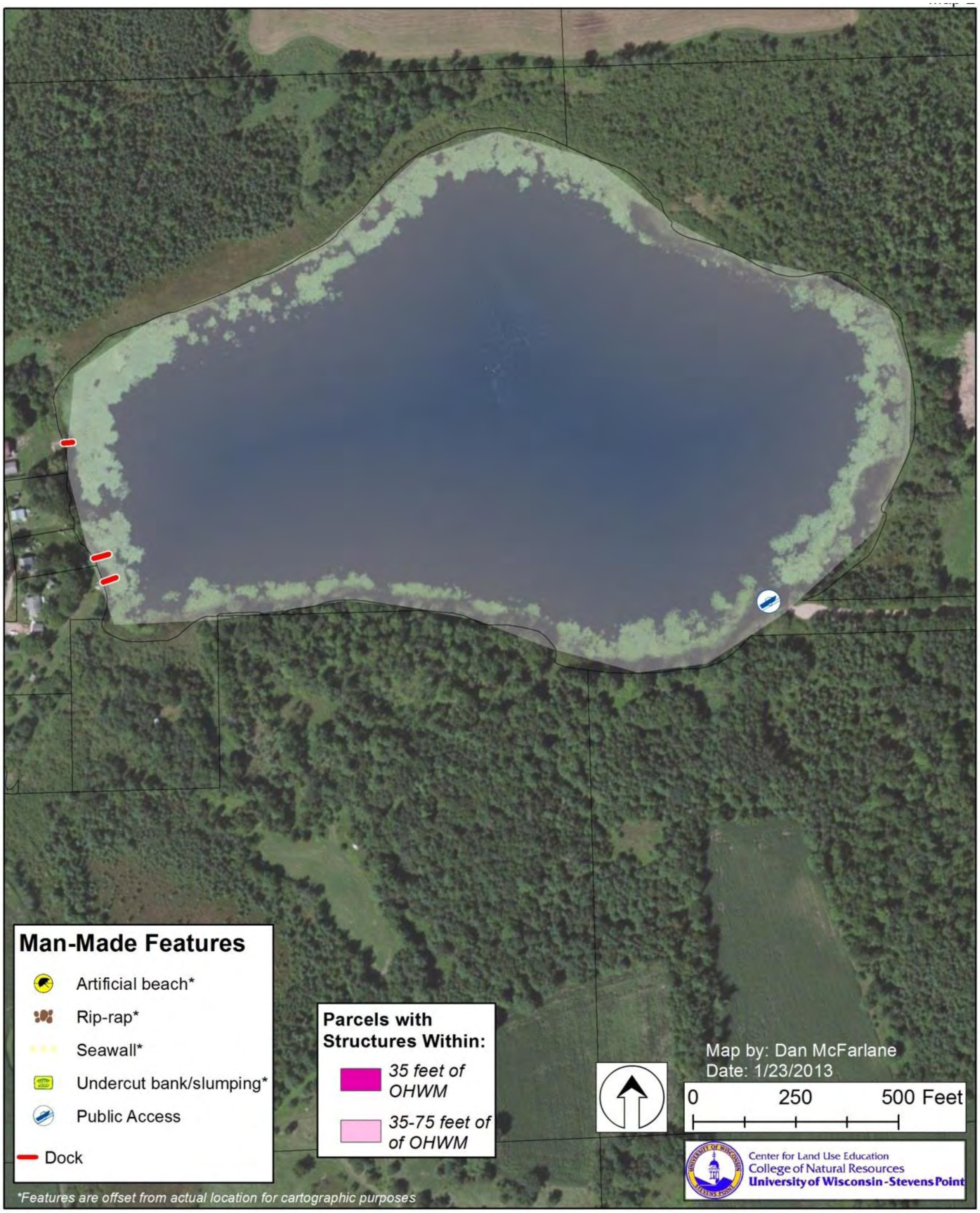


FIGURE 13. SHORELINE DISTURBANCE SURVEY OF LOST LAKE, 2011.

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.

People are also an important part of a healthy 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.

Lost Lake supports a warm water fish community. In 2011, ten fish species were sampled and identified. Since 1949, fourteen species have been recorded in surveys conducted by the Wisconsin Department of Natural Resources (Table 6). Although most species identified in 2011 had been previously reported, the Iowa darter (*Etheostoma exile*) was newly documented. Fish species documented previously but not detected during the 2011 survey included black bullhead (*Ameiurus melas*), common shiner (*Luxilus cornutus*), white sucker (*Catostomus commersoni*), and pumpkinseed x bluegill hybrid.

Bluegill (*Lepomis macrochirus*) were most abundant during the 2011 survey, with a maximum length of 10.1 inches (Table 7). Yellow bullhead (*Ameiurus natalis*) were also abundant, with lengths reaching 13.7 inches. Least common in the samples were the black crappie (*Pomoxis nigromaculatus*), Iowa darter (*Etheostoma exile*), golden shiner (*Notemigonus crysoleucas*) and pumpkinseed (*Lepomis gibbosus*). Although infrequently encountered, walleye (*Sander vitreus*) were the largest fish caught in Lost Lake, reaching 22.8 inches. Crayfish were not encountered during the survey.

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

Species	1949	1969	1984	2005	2011
Black Bullhead		x	x		
Black Crappie	x	x		x	x
Bluegill	x		x	x	x
Bullhead	x				
Common Shiner		x			
Golden Shiner	x	x		x	x
Iowa Darter					x
Largemouth Bass	x		x	x	x
Northern Pike		x	x		x
Yellow Perch	x		x	x	x
Pumpkinseed		x	x		x
Pumpkinseed x Bluegill hybrid		x			
Walleye		x			x
White Sucker	x			x	
Yellow Bullhead		x		x	x

TABLE 7. TOTAL CATCH AND LENGTHS (MIN/MAX/AVERAGE) OF FISH SPECIES IN LOST LAKE, 2012 SURVEY.

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	0.9	10.1	4.8	107
Yellow Bullhead	5.0	16.5	13.7	54
Golden Shiner	1.9	10.8	3.3	15
Largemouth Bass	3.1	17.9	7.0	6
Walleye	20.9	22.8	21.8	2
Black Crappie	6.5	6.5	6.5	1
Iowa Darter	2.4	2.4	2.4	1
Pumpkinseed	7.9	7.9	7.9	1
Yellow Perch	6.2	6.2	6.2	1
Northern Pike	12.1	12.1	12.1	1

A review of Wisconsin Department of Natural Resources records revealed little management information for Lost Lake. Public access permits were approved in 1960, leading to the land acquisition and development of the current boat launch and parking area. In 1982, dissolved oxygen concentrations in Lost Lake fell below optimal conditions for fish survival, and a temporary dip-netting permit was approved. During the winterkill of 1982, many black bullhead along with a few white sucker, pumpkinseed, and central mudminnow (*Umbra lima*) were reported dead. Bullhead abundance is another indication of winterkill, as they are more tolerant of low dissolved oxygen concentrations than many other species. Fish stocking records for Lost Lake date back to 1941 in Wisconsin Department of Natural Resources files (Table 8). Historic stocking primarily consisted of adult northern pike and fingerling largemouth bass. Early efforts to stock bluegill and black crappie were abandoned prior to 1950.

TABLE 8. WISCONSIN DEPARTMENT OF NATURAL RESOURCES FISH STOCKING SUMMARY FOR LOST LAKE, INCLUDING SPECIES, AGE CLASS, NUMBER STOCKED, AND AVERAGE LENGTH IN INCHES.

Year	Species	Age Class	Number Fish Stocked	Avg Fish Length (in)
1941	Bluegill	Adult	800	
1941	Bluegill	Fingerling	1,200	
1949	Crappie	Adult	750	
1947	Largemouth Bass	Fingerling	500	
1949	Largemouth Bass	Fingerling	200	
1952	Largemouth Bass	Fingerling	175	
1961	Northern Pike	Fry	162,516	
1962	Muskellunge	Fingerling	175	
1963	Northern Pike		717	
1964	Northern Pike	Fingerling	500	
1965	Walleye/Pike	Fingerling	6,000	
1970	Northern Pike	Adult	200	
1973	Northern Pike	Adult	178	
1973	Northern pike	Adult	178	15
1975	Northern pike	Adult	202	
1975	Northern pike	Adult	200	
1977	Northern pike	Adult	150	
1978	Northern pike	Adult	100	
1980	Northern pike	Adult	100	
1981	Northern pike	Adult	91	
1982	Largemouth bass	Fingerling	4,000	1
1982	Northern pike	Fry	200,000	
1996	Largemouth bass	Fingerling	7,100	2
1996	Northern pike	Fingerling	210	4
2011	Walleye	Yearling	900	8
2011	Yellow perch	Yearling	1,050	7

BOTTOM SUBSTRATE AND COARSE WOODY HABITAT

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 bulrushes, as well as gravel and cobble substrates, for spawning habitat.

Bottom substrate was examined with side-scan sonar from the shoreline out to a distance of 90 feet. Substrate in Lost Lake consisted primarily of a soft muck bottom (92.5%) and a few areas on the eastern side of the lake with harder substrate consisting of a mix of sand/gravel/cobble (7.5%) (Figure 14). Gravel areas are utilized as spawning habitat by many sunfish (bluegill, pumpkinseed, black bass), where males will construct nests and guard their young. In the absence of sand and coarser substrate, largemouth bass and sunfish are known to build nests on soft bottoms. 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 successful reproduction was occurring in Lost Lake. Yellow perch (*Perca flavescens*) and walleye prefer near-shore cobble substrate in oxygen-rich environments for spawning activity and offer no parental care. Reproduction success of walleye and northern pike could not be determined with the limited sampling data collected. Bulrush beds are present along areas of the eastern shoreline (Figure 14). Northern pike, which do not offer parental care, utilize areas with emergent or floating leaf vegetation in shallow or flooded areas for spawning. Black crappie also utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young. In areas of soft substrate, largemouth bass are also reported to spawn on woody habitat swept clear of sediments.

Due to heavy aquatic plant growth when the surveys were conducted, the abundance of coarse woody habitat (CWH) was not documented in Lost Lake. Woody habitat is an important habitat component. It is utilized by many fish for spawning, protection, and foraging, so the fish community may benefit from the addition of CWH in areas where it is sparse.

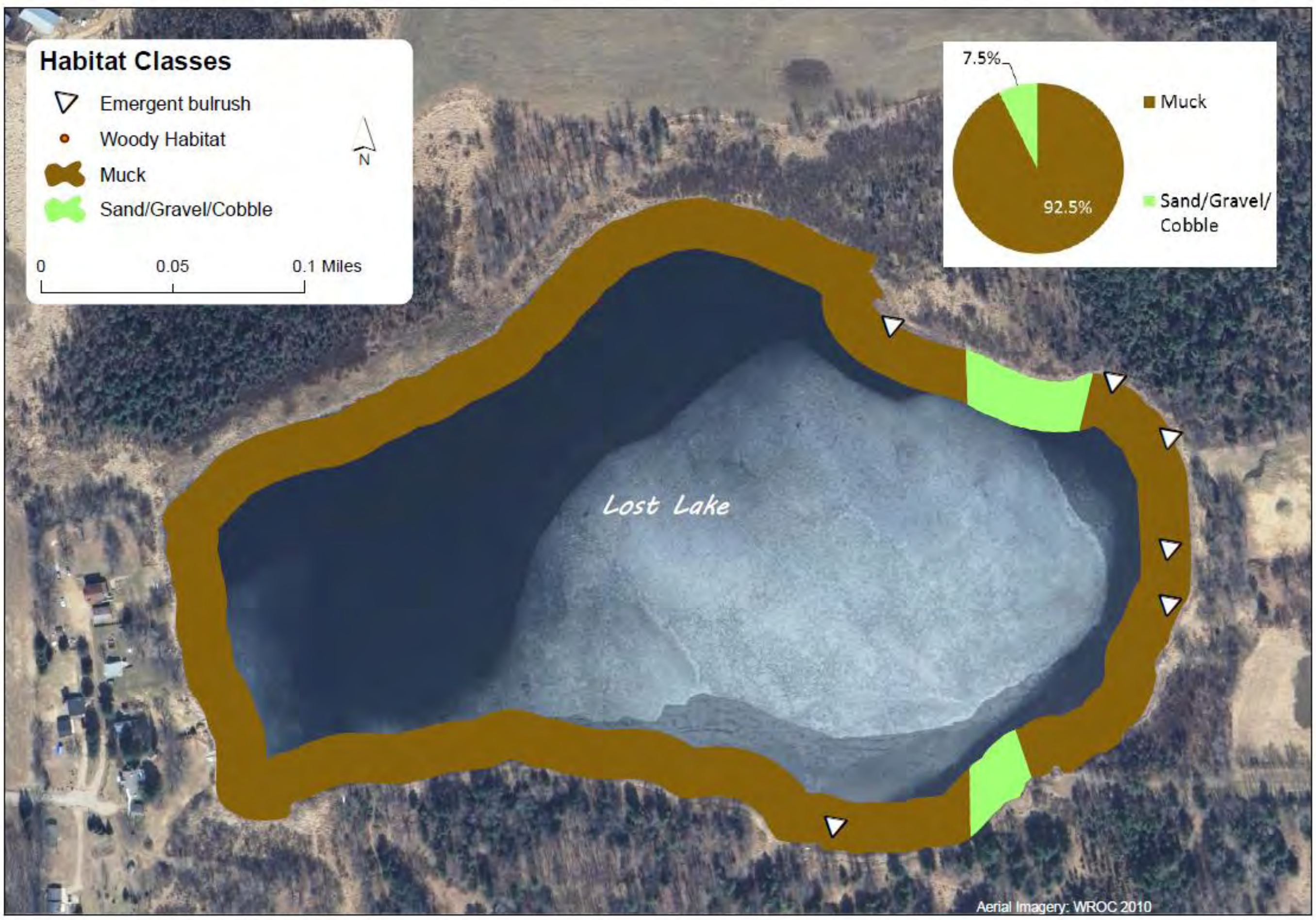
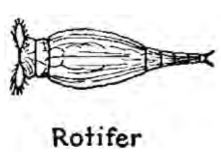


FIGURE 14. DISTRIBUTION OF SUBSTRATE, COARSE WOODY HABITAT, AND BULRUSH IN LOST LAKE, 2012.

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 and productive lives. Food (bacteria and algae), temperature, and water chemistry are important in determining the type of zooplankton that can live in a particular lake, along with fish predation which can 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.



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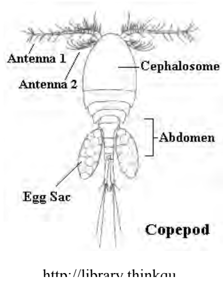
Rotifers are small invertebrate animals with simple body designs. They are usually not found uniformly throughout lakes, but congregate in areas of high food abundance (bacteria, algae, and other rotifers). Generally, a lake's trophic status influences, or can be predicted by, the abundance and diversity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

http://www.oocities.org

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 an avoidance response to heavy fish predation and can result in lower than expected cladoceran numbers during daytime collections.



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 to young fish.

The zooplankton community of Lost Lake was diverse (Table 9 and Table 10). Zooplankton were classified based on two general size categories: nano-plankton (80 um or less) or net plankton (210 um or less).

The dominant group of nano-plankton was rotifers, with rotifer and copepod subdominants.

- There were 3,154 individuals counted during this period:
  - 2,776 rotifers, 110 cladocerans, and 268 copepods

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

- There were 642 individuals counted during this period:
  - 80 rotifers, 281 cladocerans, and 281 copepods

Rotifers and copepods taxa dominated all four sample periods during all seasons. Smaller rotifer species were dominant in spring and summer in net plankton samples, while other copepods were most abundant in fall and winter, but diminished in spring. Cladocerans tended to be more abundant in summer and fall.

The zooplankton community presented a picture of a fairly eutrophic lake when considered relative to the algal, phosphorus, and nitrogen values for Lost Lake. The six genera of rotifers, two genera of cladocerans, and three genera of copepods identified during the sample periods were relatively common and 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 smaller rotifers and copepods suggested that Lost Lake is fairly eutrophic.

TABLE 9. MOST COMMON (NANO) ZOOPLANKTON BY DATE IN LOST LAKE, APRIL 2011 TO MARCH 2012.

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 28	Copepod	Nauplii	Rotifer	*Keratella hiemalis*	Copepod	*Paracyclops fimbriatus poppei*
June 17	Copepod	Nauplii	Copepod	*Cyclopoid copepodite*	Rotifer	*Polyarthra dolichoptera*
October 19	Rotifer	*Keratella cochlearis*	Rotifer	*Keratella bostoniensis*	Rotifer	*Notholca* spp.
March 4	Copepod	Nauplii	Copepod	*Senecella calanoides*	Rotifer	*Asplanchna* spp.

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

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 28	Rotifer	*Notholca* spp.				
June 17	Rotifer	*Asplanchna* spp.	Copepod	*Paracyclops fimbriatus poppei*	Copepod	*Senecella calanoides*
October 19	Copepod	*Paracyclops fimbriatus poppei*	Cladoceran	*Daphnia pulex*	Cladoceran	*Daphnia retrocurva*
March 4	Cladoceran	*Bosmina longirostris*				

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 Lost Lake, eighteen species of aquatic plants were found (Table 11), with the greatest diversity located in the shallows on the eastern side of the lake (Figure 15). The number of species within Lost Lake was below average compared with other lakes in the Eastern Marathon County Lakes Study. Forty-four percent (68 of 153) of the sampled sites had vegetative growth, and an average depth of 11 feet and a maximum depth of 25 feet.

The dominant plant species in the survey was coontail (*Ceratophyllum demersum*), followed by common waterweed (*Elodea canadensis*) and spiny hornwort (*Ceratophyllum echninatum*). Coontail and spiny hornwort are both important food sources for a wide range of waterfowl species. A number of invertebrate and fish species use the bushy stems and stiff whorls of leaves on these plants as habitat, especially in the winter when other aquatic plants have died back. Spiny hornwort is also a species of special concern in Wisconsin. Common waterweed also provides food and habitat to waterfowl, fish, and invertebrates. This aquatic species is resistant to many diseases and can tolerate low light conditions in deeper water (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 more intolerant of disturbance. The FQI for Lost Lake was 26.5, which was slightly below average when compared with the other lakes in the Eastern Marathon County Lakes Study.

Of the aquatic plant species within Lost Lake, four had a C value of eight or greater (Table 11): three-way sedge (*Dulichium arundinaceum*), spiny hornwort (*Ceratophyllum echinatum*), white-stem pondweed (*Potamogeton praelongus*), and small bladderwort (*Utricularia minor*). Spiny hornwort is designated a species of special concern in Wisconsin. Lost Lake was one of only four lakes in the Eastern Marathon County Lakes Study that was host to a species of special concern.

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. Lost Lake had a SDI value of 0.88. This represents above-average biodiversity when compared to all of the lakes in the Eastern Marathon County Lakes Study.

No non-native aquatic plant species were observed during the aquatic plant survey of Lost Lake. This is a good indicator of overall aquatic health within the lake. The lack of non-native species may also demonstrate diligence by lake users in cleaning watercraft before entering the lake to prevent non-native species transfer.

Overall, the aquatic plant community in Lost Lake can be characterized as having good species diversity and a number of relatively uncommon species for central Wisconsin. The habitat, food source, and water quality benefits of this diverse plant community should be focal points in future lake management strategies.

TABLE 11. AQUATIC PLANTS IDENTIFIED IN THE AQUATIC PLANT SURVEY OF LOST LAKE, 2012.

Common Name	Scientific Name	Coefficient of Conservatism Value (C Value)
Emergent Species		
watershield	*Brasenia schreberi*	6
three-way sedge	*Dulichium arundinaceum*	9
water horsetail	*Equisetum fluviatile*	7
broad leaved cattail	*Typha latifolia*	1
Floating Leaf Species		
small duckweed	*Lemna minor*	4
spatterdock	*Nuphar variegata*	6
white water lily	*Nymphaea odorata*	6
Submergent Species		
coontail	*Ceratophyllum demersum*	3
spiny hornwort*	*Ceratophyllum echinatum*	10
common waterweed	*Elodea canadensis*	3
northern water-milfoil	*Myriophyllum sibiricum*	6
Nitella	*Nitella* spp.	7
Illinois pondweed	*Potamogeton illinoensis*	6
white-stem pondweed	*Potamogeton praelongus*	8
flat-stem pondweed	*Potamogeton zosteriformis*	6
small bladderwort	*Utricularia minor*	10
common bladderwort	*Utricularia vulgaris*	7
wild celery	*Vallisneria Americana*	6

*Species shaded in tan is a species of special concern in Wisconsin.

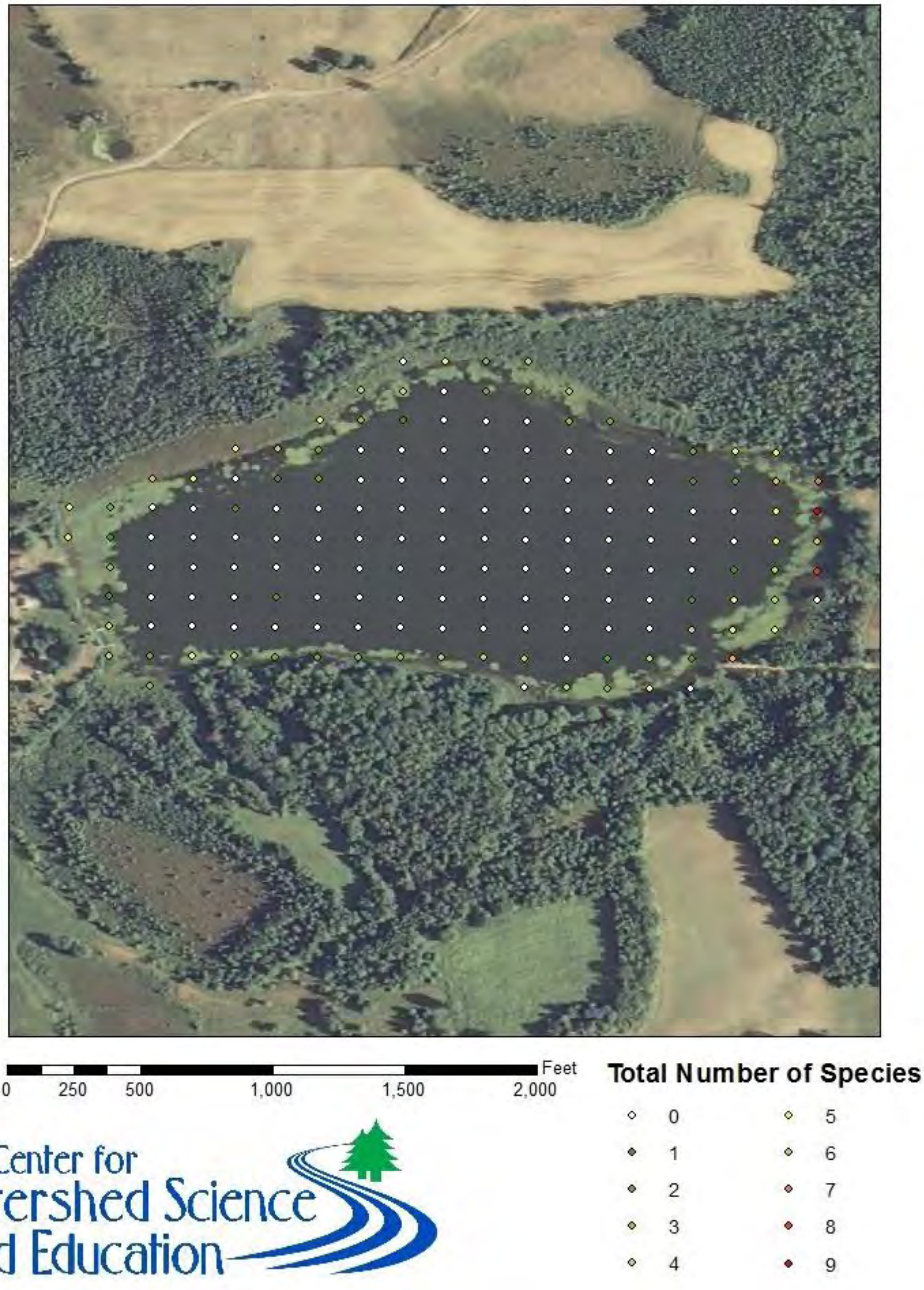


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FIGURE 15. SPECIES RICHNESS AT SAMPLE SITES IN LOST LAKE.

CONCLUSIONS & RECOMMENDATIONS

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.

- Lost Lake supports a warm water fish community.
- In 2011, ten fish species were sampled and identified.
- Bluegill were most abundant during the 2011 survey, with a maximum length of 10.1 inches. Yellow bullhead (Ameiurus natalis) were also abundant, with lengths reaching 13.7 inches.
- Although infrequently encountered, walleye were the largest fish caught in Lost Lake, reaching 22.8 inches.
- Iowa darters were newly documented in 2011.
- Fish species previously documented but not detected during the 2011 survey included black bullhead, common shiner, white sucker, and pumpkinseed x bluegill hybrid.
- Crayfish were not encountered during the survey 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 bulrushes, as well as gravel and cobble substrates, for spawning habitat.

- Substrate in Lost Lake consisted primarily of a soft muck bottom, and a few areas on the eastern side of the lake had a harder substrate consisting of a sand/gravel/cobble mix.
- Gravel areas are utilized as spawning habitat for many sunfish (bluegill, pumpkinseed), where males will construct nests and guard their young. In the absence of sand and coarser substrate, largemouth bass and sunfish are known to build nests on soft bottoms. 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 successful reproduction is occurring in Lost Lake.
- Yellow perch and walleye prefer near-shore cobble substrate in oxygen-rich environments for spawning activity and offer no parental care. Reproductive success of walleye and northern pike could not be determined with the limited sampling data collected.
- Bulrush beds are present along areas of the eastern shoreline in Lost Lake. Northern pike utilize areas with emergent or floating leaf vegetation in shallow or flooded areas for spawning. Black crappie also utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young.
- In areas of soft substrate, largemouth bass are also reported to spawn on woody habitat swept clear of sediments.

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.

- Overall, the aquatic plant community in Lost Lake can be characterized as having good species diversity and a number of relatively uncommon species for central Wisconsin. The habitat, food source, and water quality benefits of this aquatic plant community should be focal points in future lake management strategies.
- The dominant aquatic plant species in the survey was coontail, followed by common waterweed and spiny hornwort. Coontail and spiny hornwort both offer important food sources to a wide range of waterfowl species. A number of invertebrate and fish species use the bushy stems and stiff whorls of leaves on these plants as habitat, especially in the winter when other aquatic plants have died back. Spiny hornwort is a species of special concern in Wisconsin. Common waterweed also provides food and habitat to waterfowl, fish, and invertebrates. This aquatic species is resistant to many diseases and can tolerate low light conditions in deeper water.
- Four aquatic plant species were considered high quality (with a C value of eight or greater). They were three-way sedge, spiny hornwort, white-stem pondweed, and small bladderwort.
- Spiny hornwort is designated a species of special concern in Wisconsin. Lost Lake was one of only four lakes within the Eastern Marathon County Lake Study that was host to a species of special concern.
- No non-native aquatic plant species were observed during the aquatic plant survey of Lost Lake.
- Keeping aquatic invasive species (AIS) out of a lake and identifying early infestations requires on-going effort.
  - 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.

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 and helping 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 smaller rotifers and copepods suggested that Lost Lake is fairly eutrophic.
- The zooplankton identified during the sample periods were relatively common and none of those that reached numerical dominance in the sample counts were associated as invasive or exotic.

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.

- The algal community of Lost Lake was dominated by blue-green algae. The most common species of this group are associated with nutrient-enriched water typical of eutrophic lakes. The large colonial and filamentous forms common in Lost Lake are difficult for zooplankton, small fish, and other creatures to eat, and grow at densities that reduce visibility in the water column. This leads to shallow water clarity values. Low visibility can become problematic for submerged aquatic plants that need penetration of sunlight to remain viable.
- Euglenophyta, rarely one of the most abundant phyla, were the third most common group just ahead of the diatoms. The euglenoids prefer organically-enriched waters with high turbidity.
- The diatoms were very abundant during 2011, but nearly disappeared in 2012 with no obvious explanation.
- The green algae, a preferred food, were only minor components of the community.
- This variable, unpredictable, and blue-green dominated algal community coupled with high total phosphorus values indicated Lost Lake has reached a very eutrophic state.

Lost Lake is a nutrient-enriched lake. Nutrients (nitrogen and phosphorus) were elevated in samples collected from Lost Lake. The sources of nutrients to Marathon County lakes can be natural, but can be enhanced by fertilizer, soil erosion, animal waste, and septic systems. The calcium in hard water lakes can buffer some of the effects of phosphorus, but Lost Lake lacks this buffering capacity because its water is soft. The brown-stained water in Lost Lake reduces the depth light can penetrate and hence, the depths aquatic plants can grow. This reduction in light penetration may benefit the algae that can float to the top of the water and use available nutrients. Dissolved oxygen concentrations were low in Lost Lake even during some parts of the summer, which is a symptom of a nutrient-rich lake. In 1982, a winter fish kill due to low dissolved oxygen concentrations in Lost Lake was documented.

- During the study, total phosphorus concentrations in Lost Lake ranged from 35 μg/L to 108 μg/L. The summer median total phosphorus was 43.5 μg/L and 39 ug/L in 2011 and 2012, respectively. This is well above Wisconsin's phosphorus standard of 20 ug/L for deep seepage lakes.
- Inorganic nitrogen concentrations in samples collected during the spring averaged 0.67 mg/L. Concentrations above 0.3 mg/L are sufficient to enhance algal blooms throughout the summer. Inorganic nitrogen typically moves to lakes with groundwater; however, ammonium (the largest form of inorganic nitrogen in Lost Lake samples) may be released from lake sediments when dissolved oxygen concentrations are low.
- Routine monitoring of water clarity, phosphorus and nitrogen would provide a better understanding of the mechanisms that are making Lost Lake eutrophic.

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. Lost Lake's surface and groundwater watersheds provided most of the water to the lake. Forests comprised 43% of the 1,195 acre surface watershed, followed by agriculture which comprised about 32% of the watershed. In the groundwater watershed, agriculture had the greatest percent land use (46%), followed by forests (38%).

- Water quality models indicated that agriculture had the greatest percentage (88%) of phosphorus contributions from the watershed to Lost 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 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.

- Lost Lake had adequate vegetation present along most of its shoreland. Although Lost Lake's shoreland is in good condition now, changes can easily occur as development takes place.
- Alone, each human-made feature is likely not a large problem to a lake, but on developed lakes where these features occur around the lake, their impacts can add up to be a problem for lake habitat and water quality.
- Docks and artificial beaches can result in altered in-lake habitat, with denuded lakebeds providing good opportunities for invasive species to become established and reduce habitat that is important to fish and other lake inhabitants. Three docks were located on Lost Lake.
- Strategies should be developed to ensure that healthy shorelands remain intact and efforts should be made to improve shorelands that have disturbance. In order to minimize impacts from 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 Lost Lake.
- Distributing information about the importance of healthy shorelands to property owners is a good first step.

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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 (N_2) 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 ($CaCO_3$), 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."