Eastern Marathon County Lakes Study

Big Bass 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 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 how 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 the study for Big Bass 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 BIG BASS 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. Big Bass Lake is located in the township of Bevent near the intersection of County Highway Y and County Highway C. One public boat launch is located on its southern side. Big Bass Lake is a 180 acre seepage lake with surface runoff and groundwater contributing most of its water. The maximum depth in Big Bass Lake is 10 feet (Figure 1). The lakebed has a gradual slope and its bottom sediments are predominantly muck with some areas of sand and gravel mixtures.

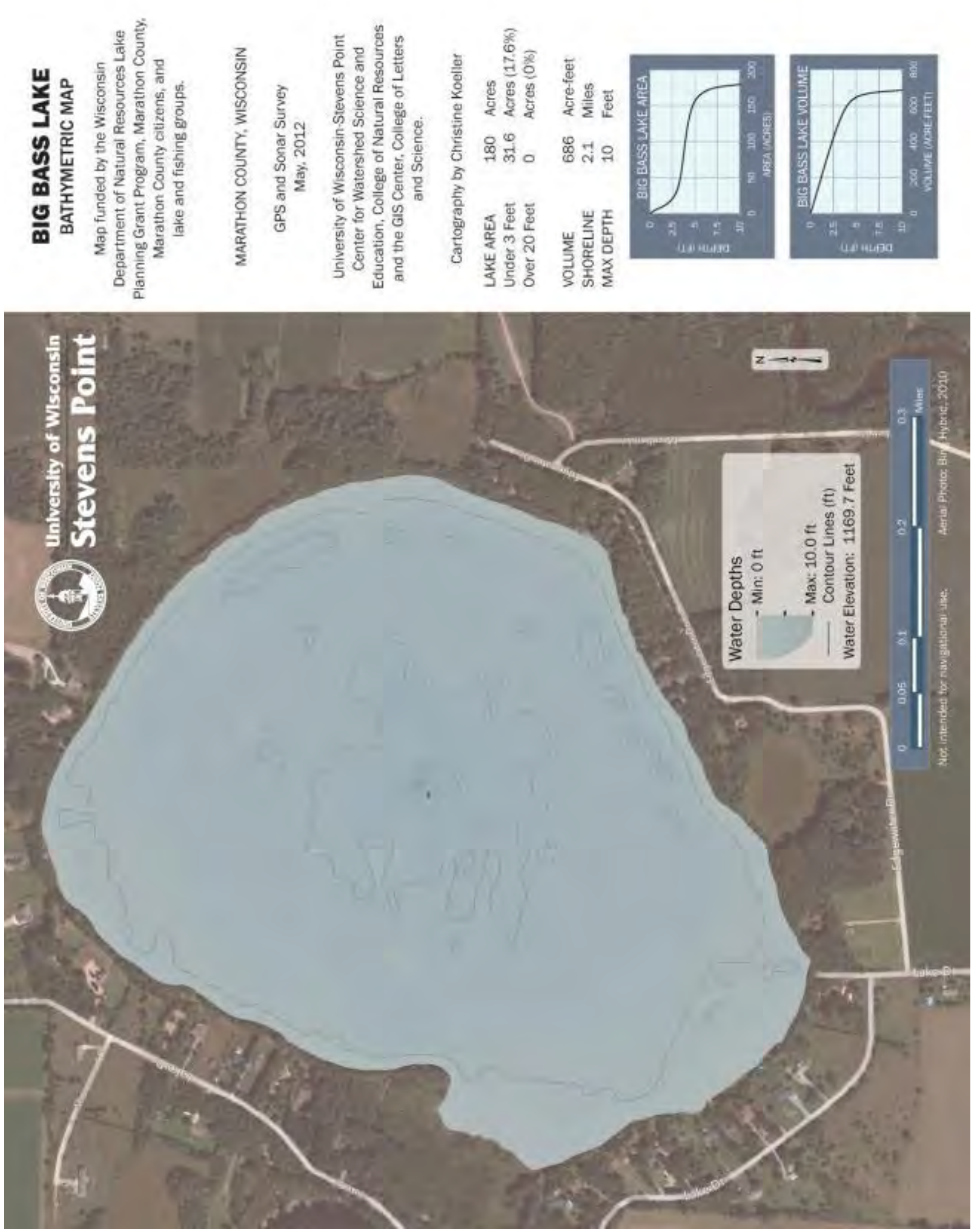


FIGURE 1. CONTOUR MAP OF THE BIG BASS LAKE LAKEBED.

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

The water quality in Big Bass 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 Big Bass 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 Big Bass Lake is called a surface watershed. Groundwater also feeds Big Bass 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 that 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 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 Big Bass Lake is approximately 503 acres (Figure 2). The dominant land uses in the watershed are agriculture, forests, and development. The lands closest to the lake often have the greatest impact on water quality and habitat; land uses near Big Bass Lake's shoreland include residential development, forests, and wetlands.

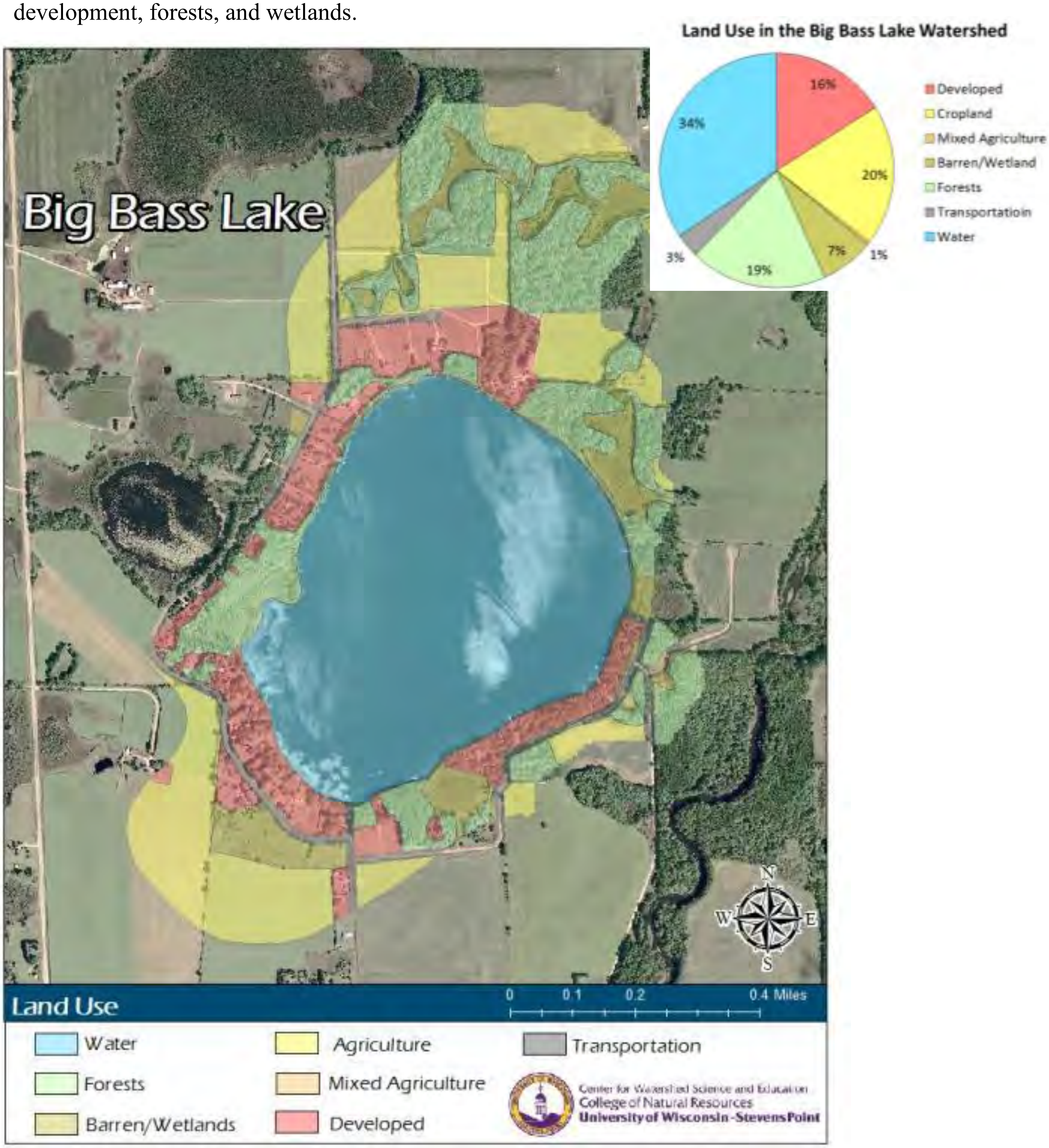
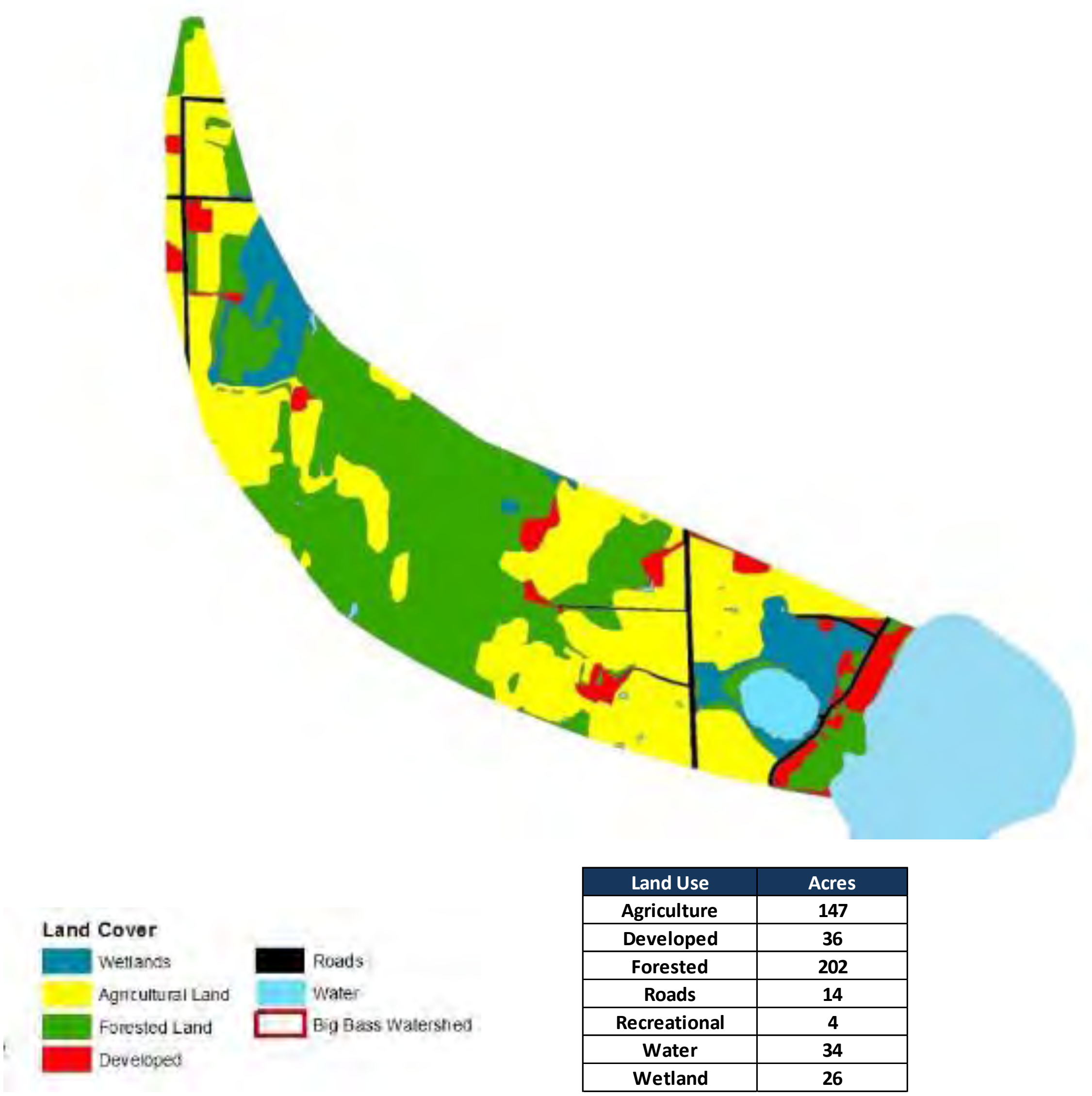


FIGURE 2. LAND USE IN THE BIG BASS LAKE SURFACE WATERSHED.

The groundwater watershed is the area where precipitation soaks into the ground and travels below ground towards the lake. Big Bass Lake's groundwater watershed is approximately 463 acres (Figure 3). The primary land uses in the Big Bass 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. Residential development and forests are adjacent to Big Bass Lake where the groundwater enters.



Land Use	Acres
Agriculture	147
Developed	36
Forested	202
Roads	14
Recreational	4
Water	34
Wetland	26

FIGURE 3. LAND USE IN THE BIG BASS LAKE GROUNDWATER WATERSHED.

Locally, groundwater enters some parts of the Big Bass 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 Big Bass Lake (Figure 4). Most of the groundwater entered the lake on the northern and western sides (green triangles). Most of the groundwater outflow occurred on the eastern end and sporadically on the southern side of the lake (red markers). Areas with no connection between groundwater and the lake were mostly observed on the western side of the lake and sporadically around the rest of the lake (white circles). Additional groundwater may enter Big Bass 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 Big Bass 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 plays a role on the temperature and chemistry of the groundwater. Groundwater temperatures remain constant year round, so groundwater feeding Big Bass Lake will help to keep the lake water cooler during the summer months.

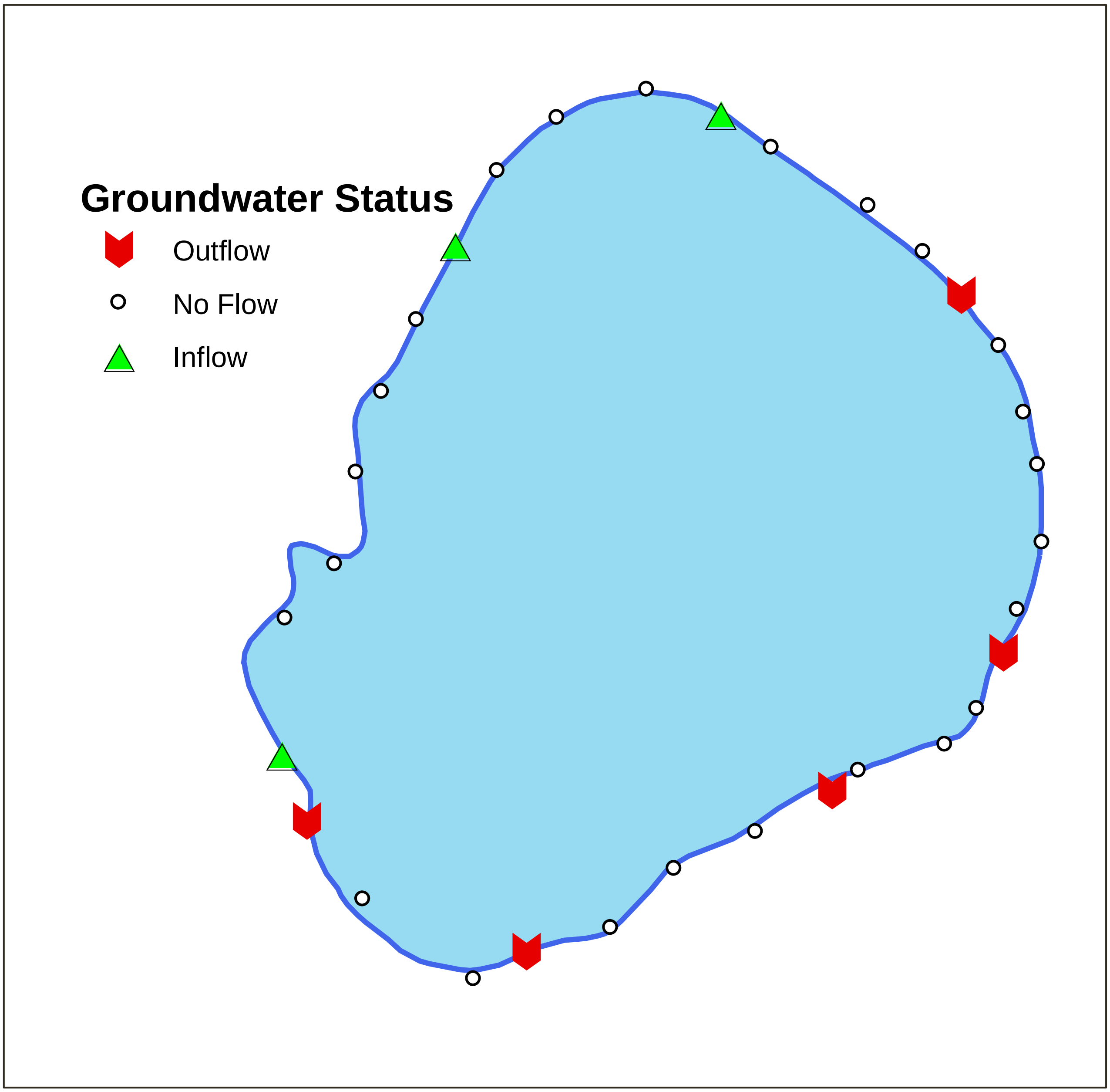


FIGURE 4. BIG BASS LAKE GROUNDWATER INFLOW AND OUTFLOW, 2011.

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 Big Bass Lake was assessed by measuring different characteristics including temperature, dissolved oxygen, water clarity, water chemistry, and the algal community.

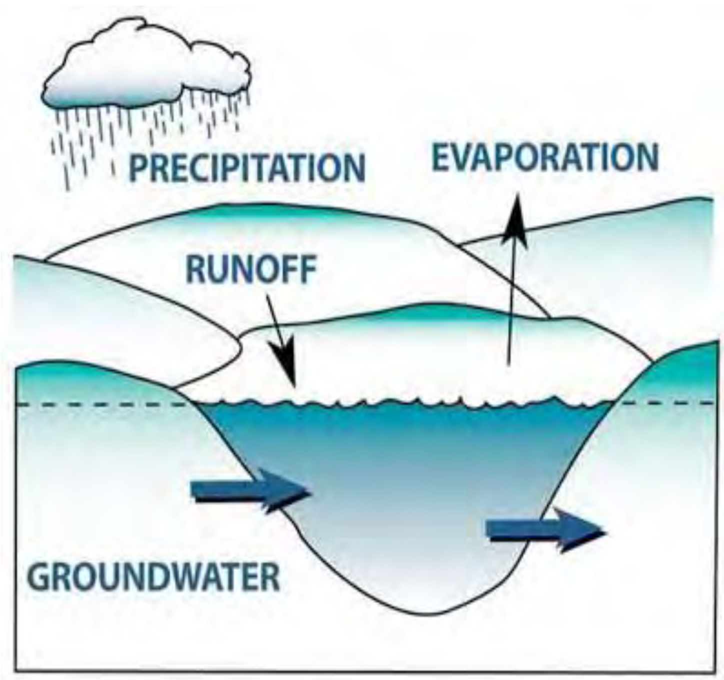


FIGURE 5. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN A SEEPAGE LAKE.

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. Big Bass 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. Examples for Big Bass Lake may include septic systems and agriculture.

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 Big Bass Lake dissolve, making the water hard. The average hardness for Big Bass Lake during the 2010-2012 sampling period was 98 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 111 mg/L; higher alkalinity in inland lakes can support higher species productivity. Hardness and alkalinity also play roles in the type of aquatic plants that are found in a lake (Wetzel, 2001).

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

Big Bass Lake	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as CaCO3)	Color SU	Turbidity (NTU)
Average	111	22.9	11.6	98	11.0	3.4

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 in the lake at elevated levels indicates the movement of pollutants from the landscape to the lake.

Chloride and sodium concentrations in Big Bass Lake were slightly elevated (Table 2). These concentrations are not harmful to aquatic organisms, but indicate that pollutants are entering the lake. Chloride sources include animal waste, septic systems, fertilizer, and road-salting chemicals. The average potassium concentration, 1 mg/L, was low for lakes in Marathon County. 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 Big Bass Lake.

TABLE 2. BIG BASS LAKE AVERAGE WATER CHEMISTRY, 2010-2012.

Big Bass Lake	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium	1.0			<.75	0.75 - 1.5	>1.5
Chloride		9.9		<3	3.0 - 10.0	>10
Sodium		3.3		<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 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.

In a lake, the water temperature 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 reduce habitat for sensitive cold water species of fish and other critters.

Water temperature and dissolved oxygen were measured in Big Bass Lake from the surface to the bottom at the time of sample collection (Figure 6). The temperature measurements illustrated that the lake was not stratified, which is typical of many shallow lakes. Late winter measurements taken in February 2011 and 2012 showed near freezing temperatures at the lake's surface with a gradual warming with depth to about 4C (39°F). Water temperatures varied from near freezing to approximately 28C (82°F) during the warmest periods of summer in late July. These temperatures were more or less uniform throughout the water column at each sampling event.

Like the temperature profiles, dissolved oxygen data indicated that Big Bass Lake was mixed throughout much of the year, with oxygen levels maintained above 7 mg/L throughout the water column (Figure 7). A few exceptions were observed in June 2011, August 2012 and September 2012 when oxygen concentrations abruptly dropped to near anoxic conditions. In June 2011, only the upper 3.5 feet of water had oxygen concentrations above 5 mg/L; this is not a typical time of year to for such low dissolved oxygen concentrations. A typical decline in dissolved oxygen with depth was observed in measurements collected in February. This is common in ice-covered lakes where light penetration with snow cover limits oxygen-generating photosynthesis by algae. The winter leading up to the February 2012 monitoring event was much milder than the previous year and this is reflected by the higher oxygen concentrations deeper into the water column.

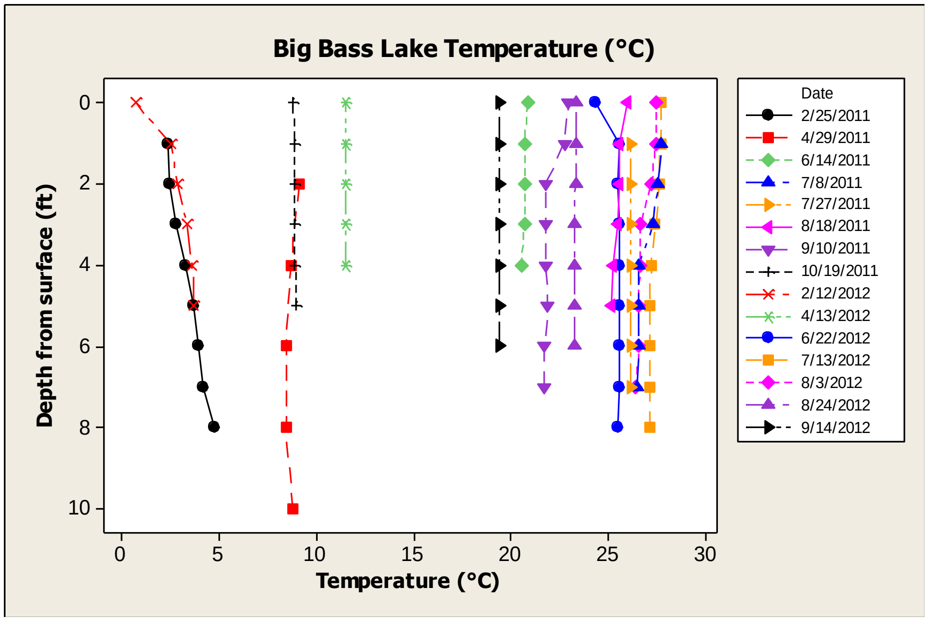


FIGURE 6. TEMPERATURE PROFILES IN BIG BASS LAKE, 2011-2012.

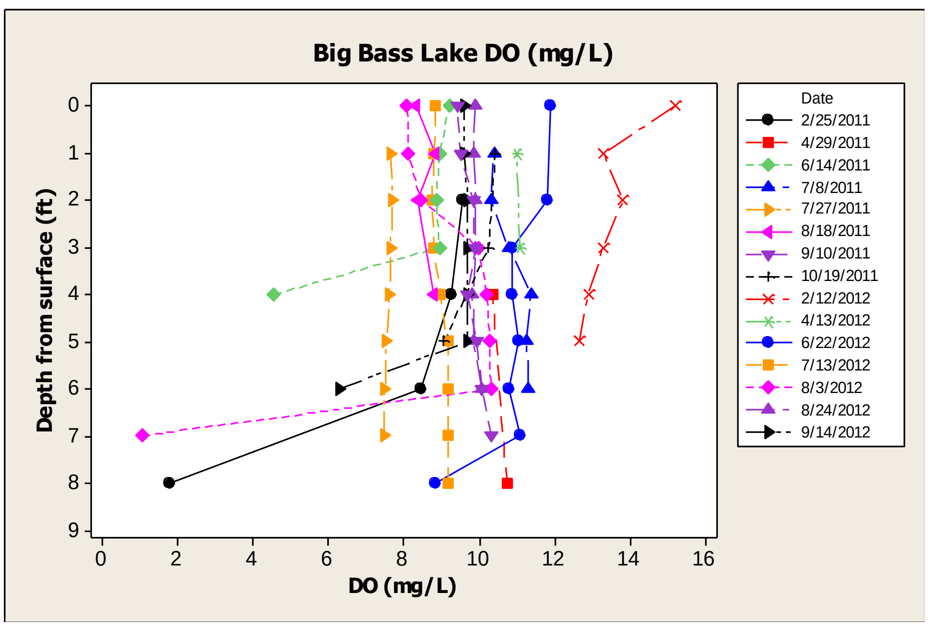
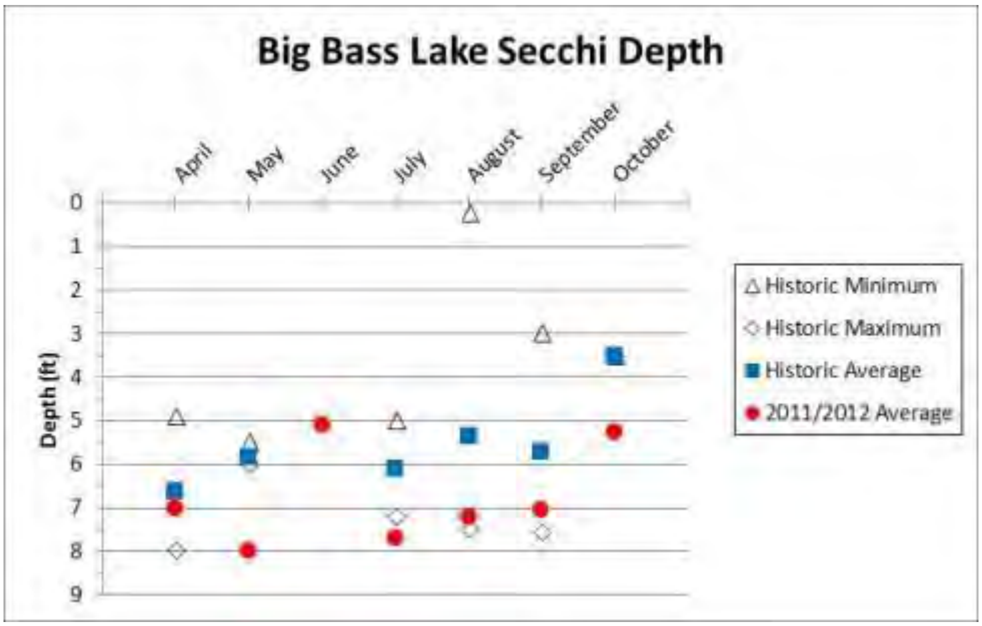


FIGURE 7. DISSOLVED OXYGEN PROFILES IN BIG BASS LAKE, 2011-2012.

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.

The color index in Big Bass Lake was relatively low, so the variability in transparency throughout the year was likely due to fluctuating algae concentrations, tannins entering the lake following storms, and/or re-suspended sediment following storms and/or heavy boating. The water clarity measured in Big Bass Lake during the 2010-2012 study was considered fair. During the study, water clarity depths ranged from 4.5 feet to 10.17 feet. During the growing season, the average water clarity was poorest in June and best in July (Figure 8). When compared with past data (1994-2010), the average water clarity measured during the study was slightly better for all months sampled.



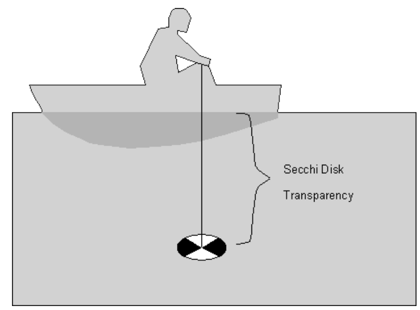


FIGURE 8. AVERAGE MONTHLY WATER CLARITY IN BIG BASS LAKE, 2010-2012.

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. 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 Big Bass Lake ranged from a high of 48 µg/L in April 2012 (following spring runoff) to a low of 13 µg/L in February 2011 and April 2011 and again in February 2012 over the two year data set (Table 3). The summer median total phosphorus concentrations were 28.5 ug/L and 22 ug/L in 2011 and 2012, respectively. This is below Wisconsin's phosphorus standard of 40 ug/L for shallow seepage lakes, but above the flag value of 15 ug/L.

During the study, inorganic nitrogen concentrations in samples collected during the spring in Big Bass Lake averaged 0.5 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. Sources of inorganic nitrogen include fertilizers, septic systems, and animal waste.

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

Big Bass 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	15	25	41	1	4	9	0.73	1.38	2.40	0.03	0.42	1.09	0.69	0.96	1.31
Spring	13	22	48	2	5	8	1.19	1.31	1.48	0.16	0.50	0.71	0.58	0.81	1.32
Summer	13	22	43												
Winter	13	13	13	3	4	4	1.62	1.83	2.03	0.69	0.89	1.08	0.93	0.94	0.95

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Big Bass 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. Row crop agriculture comprises the greatest amount of land in the watershed, and based on modeling results, has the greatest percentage of phosphorus contributions from the watershed to Big Bass 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).

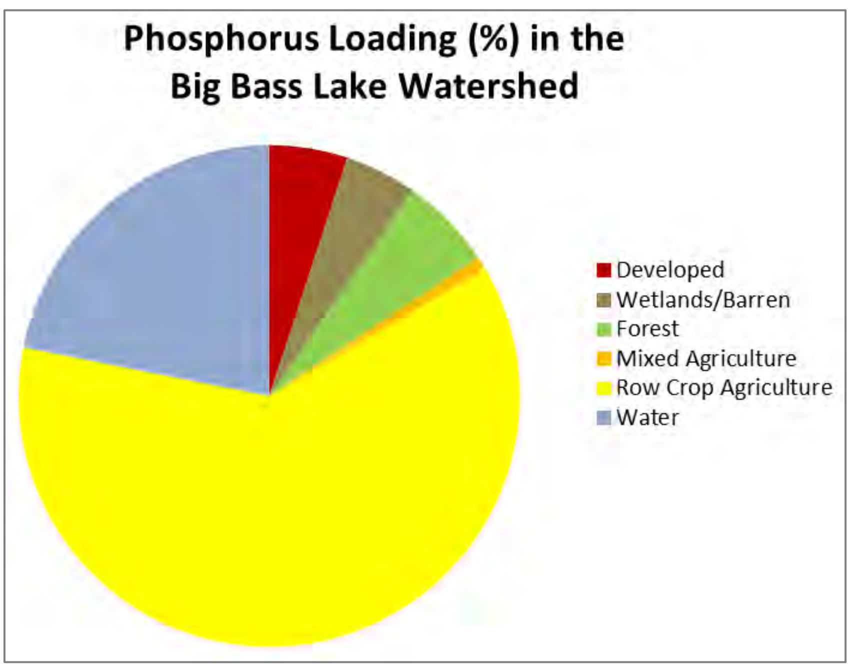


FIGURE 9. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE BIG BASS LAKE WATERSHED.

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

Big Bass Lake Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.10	179	**36**	16-48	28
Developed	0.04	83	**17**	4-7	**6**
Wetland/Barren	0.09	38	**8**	3-10	**6**
Forest	0.04	99	**20**	4-8	**8**
Mixed Agriculture	0.27	2	**0**	1-2	**1**
Row Crop Agriculture	0.45	101	**20**	45-90	**79**

*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 Big Bass Lake were low, ranging from a high of 14 µg/L in August 2011 to a low of 1 µg/L in August 2012. Concentrations were generally higher in 2011 than 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). The 2011 and 2012 algal communities in Big Bass Lake were diverse and primarily dominated by diatoms (Figure 10).

The total algal community and the specific species found during the study period are indicative of two possible water quality trajectories. The first, supported by the moderate total phosphorus value and most of the algal data, is of a late-stage oligotrophic lake that is transitioning into a mildly mesotrophic lake. The second, supported by improving water clarity measurements and some of the algal data, is that of a moderately mesotrophic lake that is seeing some improvement in water quality conditions. In either case, Big Bass Lake displays some of the best water quality indicators in the group of surveyed lakes. Two small but troubling indicators loom that merit continued attention : a rising number of blue-green algae and a green algae community of only minor abundance and relatively few species.

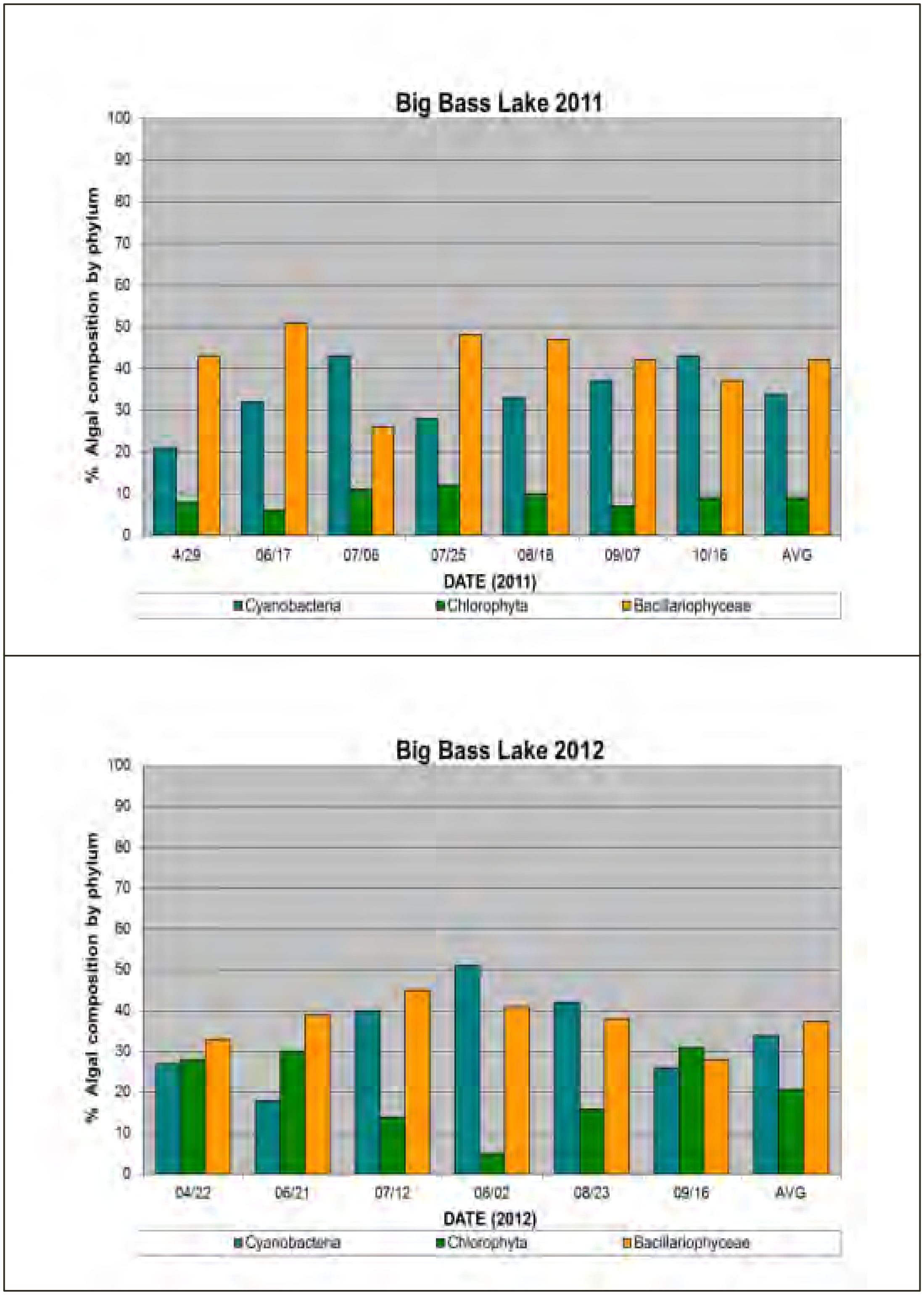


FIGURE 10. PERCENT ALGAL COMPOSITION OF BIG BASS LAKE, 2011 AND 2012.

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

BIG BASS 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 Big Bass Lake in Figure 12depict the depth of vegetation along Bass 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.

Big Bass Lake has 2.1 miles of shoreline, and was one of the more developed lakes in this study, with 46 developed waterfront lots. Despite being developed, nearly 40 percent of the shoreline had at least a 50-foot deep grass/forb buffer (along the undeveloped northern shore and portions of the western edge of the lake); however, 45% of the lake had a grasses/forbs buffer depth of less than 15 feet inland from the water's edge, which is less than the minimum depth of 35 feet required by Wisconsin and Marathon County shoreland zoning ordinances (Figure 11). Shoreline shrubs appear to be the least abundant vegetative layer. Over half of the lake had a shrub buffer depth of only 5-15 feet inland. The tree layer appears to be very abundant on Big Bass Lake, but significant tree thinning resulted in reduced canopy density in some areas. Most of this occurred along the northwestern and southwestern developed portions of the lake. Along Big Bass Lake's shoreline, 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.

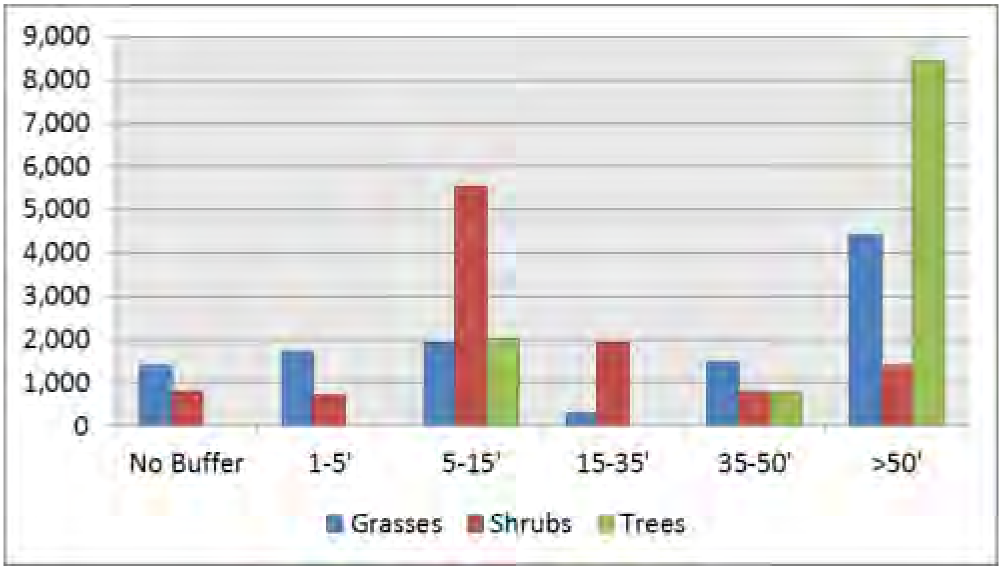


FIGURE 11. SHORELAND VEGETATION SURVEY RESULTS BY BUFFER DEPTH AROUND BIG BASS LAKE, 2011.

On the same day the vegetation surveys were conducted, an assessment of disturbances was conducted around Big Bass 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 beach often result in reduction of habitat. Docks and artificial beaches can result in altered in-lake habitat, including denuded lakebeds that provide 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 their collective impact on developed lakes can create problems for lake habitat and water quality.

TABLE 5. DISTURBANCES LOCATED ON BIG BASS LAKE, 2011 SURVEY.

Disturbance	No. of Occurrences
Artificial Beach	0
Dock	39
Rip-rap	4
Seawall	0
Erosion	1
Structures w/in 35'	1
Structures 35-75'	6

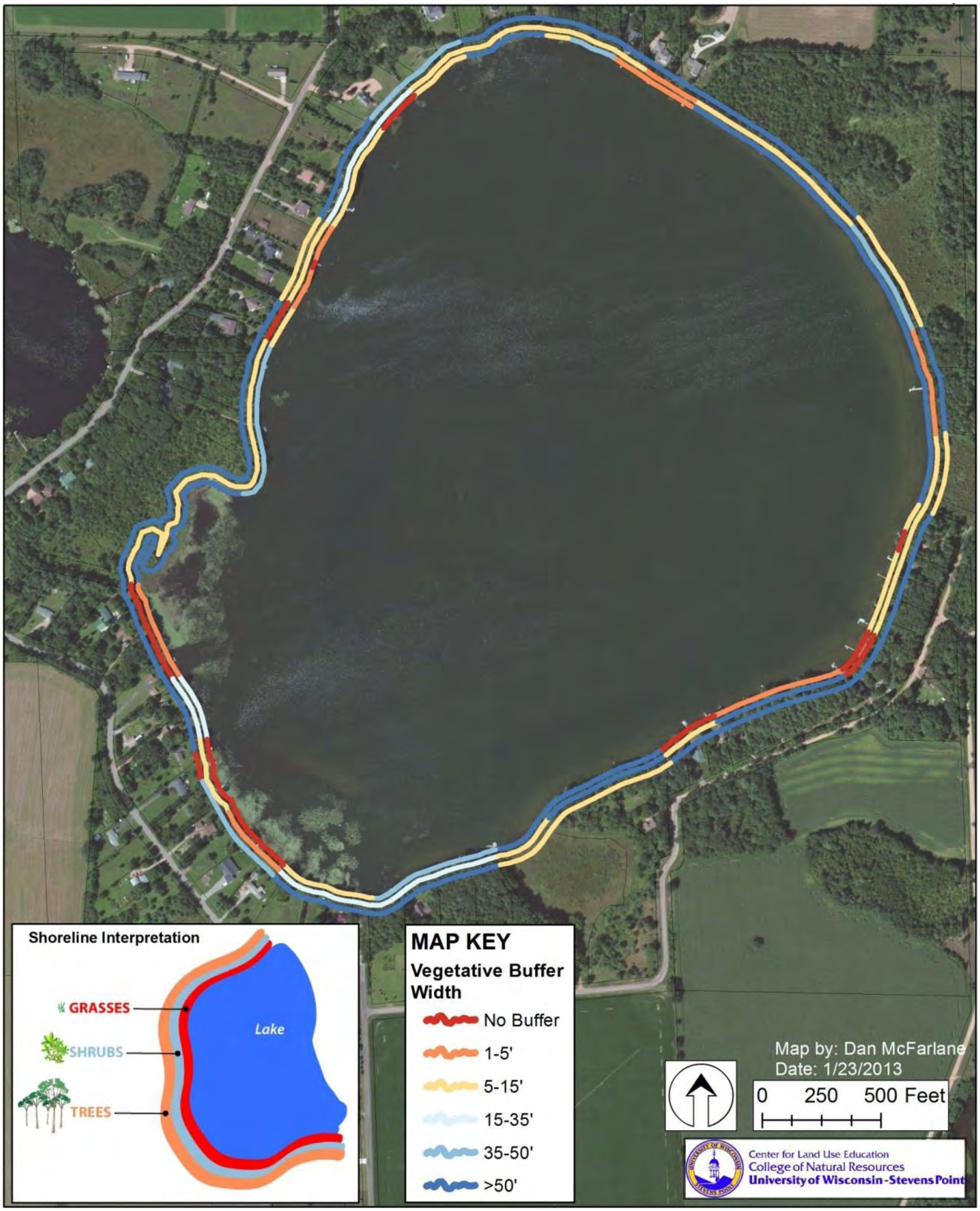


FIGURE 12. SHORELAND VEGETATION SURVEY OF BIG BASS LAKE, 2011.

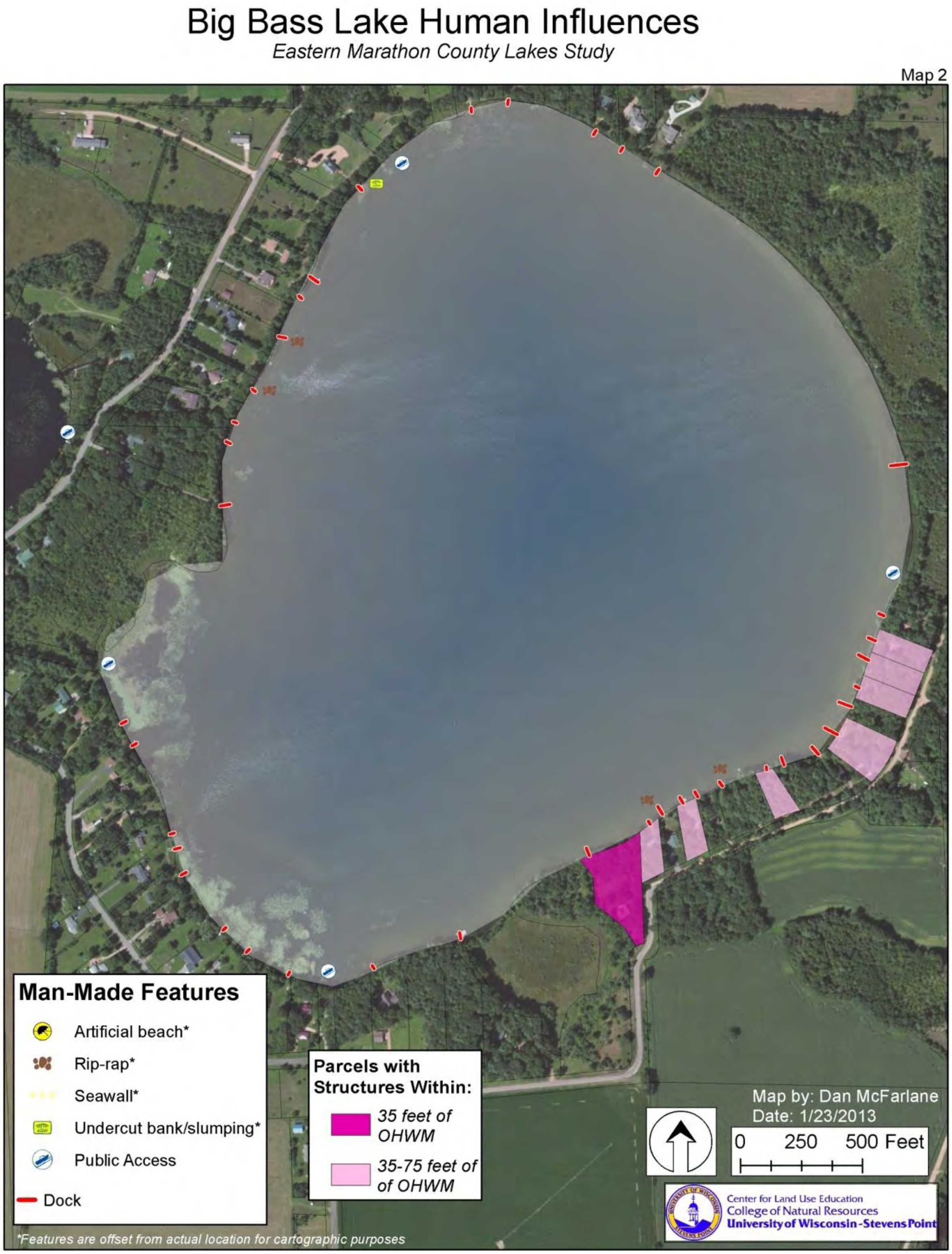


FIGURE 13. SHORELINE DISTURBANCE SURVEY OF BIG BASS LAKE, 2011.

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.

Big Bass Lake supports a warm water fish community. Of the seventeen total species that have been recorded in surveys dating back to 1955, nine fish species were sampled and identified in the 2012 fishery surveys. Records of past surveys were obtained from the Wisconsin Department of Natural Resources (Table 6). Although most species identified in 2012 had been previously reported, yellow bullhead (*Ictalurus natalis*) and Iowa darter (*Etheostoma exile*) were newly documented. Species documented previously but not detected during the 2012 survey included blacknose dace (*Rhinichthys atratulus*), brown bullhead (*Ameiurus nebulosus*), green sunfish (*Lepomis cyanellus*), northern pike (*Esox lucius*), pumpkinseed (*Lepomis gibbosus*), rainbow darter (*Etheostoma caeruleum*), and white sucker (*Catostomus commersoni*). Two of these species, blacknose dace and rainbow darter, require flowing water for spawning, and are atypical for lakes. Although it is possible that these two species could have been physically transported from the nearby Plover River where they are resident and placed in Big Bass Lake, they would not be expected to reproduce or sustain populations in this lake. Bluegills (*Lepomis macrochirus*) were most abundant during the 2012 survey, with a maximum length of 10 inches observed for this species (Table 7). Although infrequently encountered, walleye (*Sander vitreus*) was the largest fish species caught in Big Bass Lake, with individuals reaching 25.3 inches. Least commonly sampled were the black bullhead (*Ameiurus melas*) and golden shiner (*Notemigonus crysoleucas*). Crayfish were not encountered during the sampling period.

A variety of fish management techniques were attempted historically on Big Bass Lake. Fish stocking records for Big Bass Lake date back to 1952 according to Wisconsin Department of Natural Resources files (Table 8). Historic stocking primarily consisted of adult northern pike, but walleye, largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), and black crappie (*Pomoxis nigromaculatus*) were also stocked.. In 1952, the Wisconsin Department of Natural Resources stocked the lake with walleye fry in an attempt to make Big Bass Lake into a walleye rearing pond. Remaining walleye did well, and the effort was noted as a success. Several years later (1957), the entire lake was treated with toxaphene to "reset the system". The goal of the treatment was to destroy the small panfish community and then stock the lake with golden shiners. Northern pike were stocked in 1959. As time passed and stocking efforts continued (mainly northern pike and walleye), several winterkill events struck Big Bass Lake (1964, 1975, 1986), and stocking efforts were discontinued. During these struggles with winterkill, the lake was often opened up to the public for dip netting. As a result of frequent winter fish kill, an aerator system was installed in 1988 to help maintain healthy dissolved oxygen levels during the winter months.

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

Species	1955	1957	1985	1986	1968	1993	2000	2002	2005	2006	2012
Black bullhead				x	x		x				x
Black crappie	x	x	x			x	x		x	x	x
Blacknose dace							x				
Bluegill			x	x	x	x	x	x	x	x	x
Brown bullhead					x						
Bullheads		x	x		x						
Golden shiner	x	x		x		x	x				x
Green sunfish							x		x		
Iowa darter											x
Largemouth bass		x	x	x	x	x	x	x	x	x	x
Northern pike			x		x	x	x			x	
Pumpkinseed	x	x	x	x	x	x	x	x		x	
Rainbow Darter							x				
Walleye	x					x	x			x	x
White sucker	x	x	x	x	x	x	x				
Yellow bullhead											x
Yellow perch	x		x	x	x	x	x		x	x	x

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

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	0.9	10.0	3.7	345
Largemouth Bass	1.2	14.8	4.4	166
Black Crappie	2.5	7.0	5.8	51
Iowa Darter	1.3	2.4	2.0	26
Yellow Bullhead	5.1	15.4	11.9	21
Yellow Perch	3.9	12.4	9.5	17
Walleye	20.6	25.3	23.7	3
Black Bullhead	15.2	15.2	15.2	1
Golden Shiner	5.7	5.7	5.7	1

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

Year	Species	Age Class	Number Fish Stocked	Avg Fish Length (IN)
1952	Walleye	Fry	NA	
1959	N Pike	Fry	200,000	
1972	Northern pike	Adult	266	15
1973	Northern pike	Adult	300	
1976	Northern pike	Fingerling	250	11
1977	Northern pike	Adult	184	
1978	Northern pike	Adult	150	
1979	Northern pike	Adult	174	
1980	Northern pike	Adult	200	
1980	Bass	155	155	
1980	Walleye	145	145	
1981	Northern pike	Adult	150	
1982	Northern pike	Adult	233	
1984	Northern pike	Adult	250	15
1984	Walleye	Fingerling	2000	
1984	Smallmouth bass	NA	1300	
1986	Northern pike	Fry	683,027	1
1988	Largemouth bass	Fingerling	15,000	1
1988	Largemouth bass	Adult	450	7
1988	Black Crappie	Adult	250	6
1988	Northern pike	Fingerling	100	12
1989	Northern pike	Fingerling	445	9
1990	Northern pike	Fingerling	900	7
1991	Northern pike	Fingerling	870	8
1992	Northern pike	Fingerling	500	8
1992	Northern pike	Fingerling	348	8
1993	Northern pike	Fingerling	870	8
1995	Northern pike	Fingerling	765	8

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.

In-lake habitat was examined from the shoreline lakeward for a distance of 90 feet using side-scan sonar. Substrate in Big Bass Lake consisted of marl/muck (78%) and sand (22%) (Figure 14). In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build nests on marl. 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. Bulrush is present along areas of the shoreline in Big Bass Lake (Figure 14). 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 also utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young. When available, gravel areas are utilized as spawning habitat for many sunfish (bluegill, pumpkinseed, black bass), where males will construct nests and guard their young. The presence of young bass and abundant sunfish sampling indicated successful reproduction was occurring in Big Bass Lake. Yellow perch (*Perca flavescens*) and walleye prefer near-shore cobble substrate in oxygen-rich environments for spawning activity and offer no parental care. Conclusions could not be made about walleye and northern pike reproductive success without additional sampling efforts.

Coarse woody habitat (CWH), including downed trees and logs are sparse in Big Bass Lake (Figure 14). This structure is utilized by young prey fish and other aquatic organisms for foraging, protection, and spawning. The addition of CWH cover in Big Bass Lake would likely benefit the fish community.

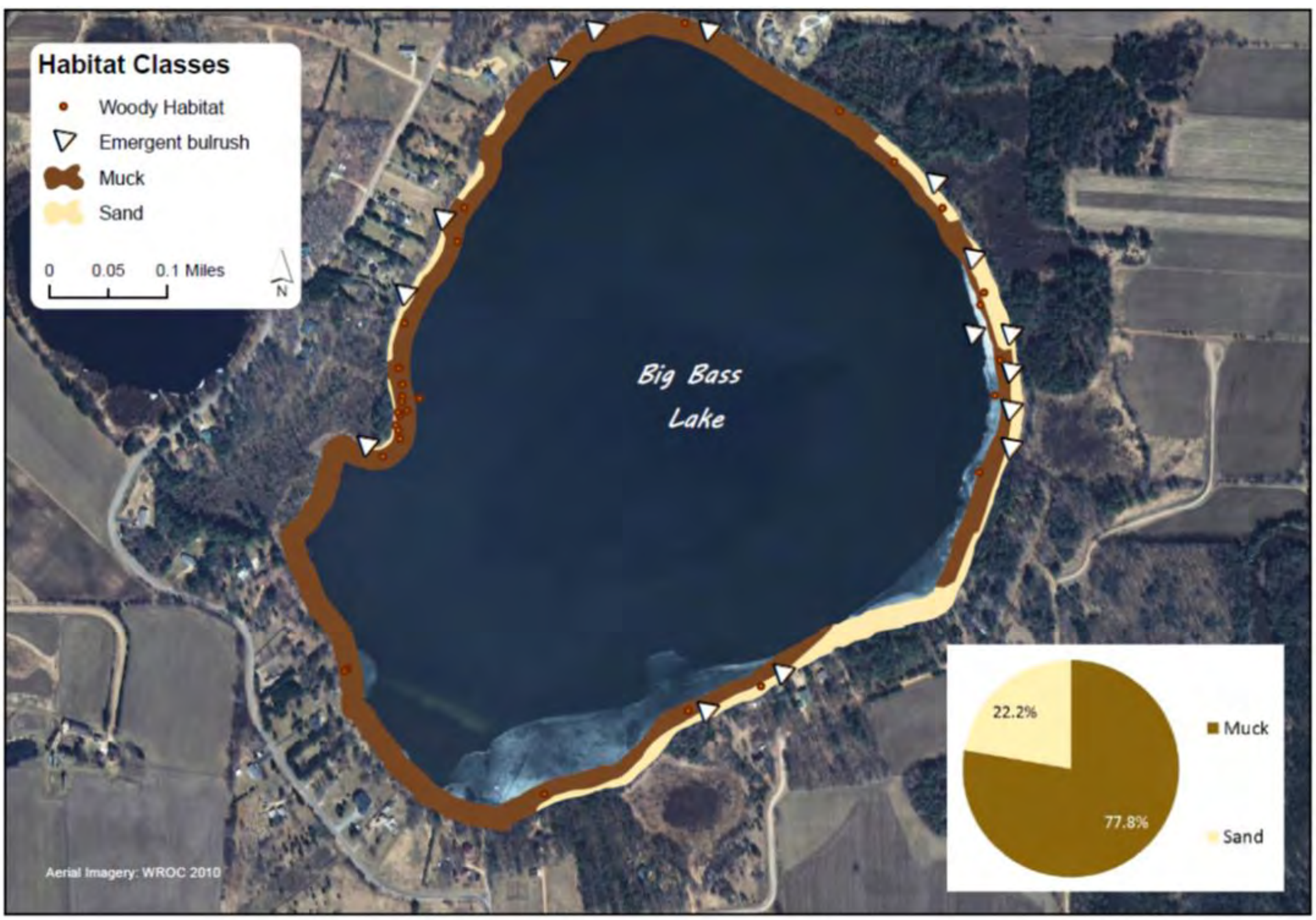
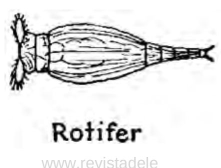


FIGURE 14. DISTRIBUTION OF SUBSTRATE, COARSE WOODY HABITAT, AND BULRUSH BEDS IN BIG BASS LAKE, 2012.

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 type 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.

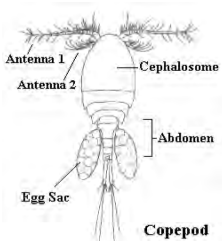


Rotifers are small invertebrate animals with simple body designs. They are usually not found uniformly throughout lakes, but congregate in areas of high food abundance (bacteria, algae, and other rotifers). Generally, a lake's trophic status influences, or can be predicted by, the abundance and diversity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

The zooplankton community of Big Bass Lake was moderately diverse during the 2011-2012 sampling season (Table 9, 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 groups of nano-plankton were copepods and cladocerans, with a variety of rotifers, cladocerans and copepods as subdominants.

- There were 455 individuals counted during this period:
    - 77 rotifers, 168 cladocerans, and 210 copepods.

The dominant group of net plankton was copepods and cladocerans, with cladocerans and rotifers as subdominants.

- There were 564 individuals counted during this period:
    - 16 rotifers, 243 cladocerans, and 306 copepods.

Copepods were the dominant taxa in five of seven sample periods during the 2011-2012 season, dominating every season except for summer, which was dominated by a cladoceran species. Rotifers and cladocerans were subdominant in fall and winter in both nano-plankton and net plankton samples. Copepods that prefer deep, coldwater lakes and copepods that prefer warm surface water were both found in Big Bass Lake at different times of the year.

The zooplankton community presented a picture of a fairly eutrophic lake when considered relative to the algal, phosphorus, and nitrogen values for Big Bass Lake. The 3 genera of rotifers, 5 genera of cladocerans, and 5 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 copepods suggested that Big Bass Lake may be eutrophic.

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

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 29	Copepod	*Eucyclops speratus*	Copepod	Nauplii	Copepod	*Leptodiaptomus sicilis*
June 14	Cladoceran	*Ceriodaphnia* spp.	Rotifer	*Asplanchna* spp.	Rotifer	*Keratella longispina*
October 19	Copepod	*Senecella calanoides*	Copepod	*Paracyclops fimbriatus poppei*	Cladoceran	*Bosmina longirostris*
March 9	Copepod	*Eucyclops speratus*	Copepod	*Limnocalanus macrurus*	Rotifer	*Polyarthra remata*

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

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 29	Copepod	*Eucyclops speratus*	Cladoceran	*Latona setifera*	Rotifer	*Asplanchna* spp.
June 14	Cladoceran	*Ceriodaphnia* spp.	Copepod	*Senecella calanoides*	Cladoceran	*Bosmina longirostris*
October 19	Copepod	*Eucyclops speratus*	Cladoceran	*Bosmina longirostris*	Copepod	*Senecella calanoides*
March 9						

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.

Twenty-five species of aquatic plants were found in Big Bass Lake during the 2012 aquatic plant survey of Big Bass Lake (Table 11), with the greatest diversity located in the middle of the lake (Figure 15). The number of aquatic plant species was above average when compared with the other lakes in the Eastern Marathon County Lakes Study. Fifty-five percent (154 of 282) of sites sampled had vegetative growth. Of the sampled sites within Big Bass Lake, the average depth was 4 feet and the maximum depth was 9 feet.

The dominant plant species in the survey was white-stem pondweed (*Potamogeton praelongus*), followed by slender naiad (*Najas flexilis*) and muskgrass (*Chara* spp.). White-stem pondweed is an important source of food for waterfowl, muskrat, beaver, and trout, and also provides valuable habitat for muskellunge. This aquatic plant is considered an indicator species for water quality due to its sensitivity to disturbances within the aquatic system. The stems, leaves, and seeds of slender naiad are also important food sources for waterfowl and marsh birds. This common aquatic species also provides habitat for 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 more intolerant of disturbance. The FQI for Big Bass Lake was 26.6. This value was slightly below average when compared with the other lakes in the Eastern Marathon County Lakes Study.

Of the aquatic plant species within Big Bass Lake, three had a C value of eight or greater: three-way sedge (*Dulichium arundinaceum*), Fries' pondweed (*Potamogeton friesii*), and white-stem pondweed (*Potamogeton praelongus*) (Table 11). This number of species tied Big Bass Lake with Mayflower Lake for seventh out of the eleven lakes within the Eastern Marathon County Lakes Study. No species of special concern within Wisconsin were found in Big Bass 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. Big Bass Lake had a SDI value of 0.89. This represents an above-average biodiversity when compared to all the lakes in the Marathon County study.

During the aquatic plant survey of Big Bass Lake, no non-native species were found. This is a good indicator of overall aquatic health within the lake. The lack of non-native species also demonstrates diligence by users of the lake in cleaning watercraft before entering the lake to prevent non-native species transfer.

Overall, the aquatic plant community in Big Bass Lake can be characterized as having very good species diversity and is impacted by some development of the shoreline. The dominance of white-stem pondweed within the lake is a positive sign of overall lake health. The habitat, food source, and water quality benefits of this diverse plant community should be focal points in future lake management strategies.

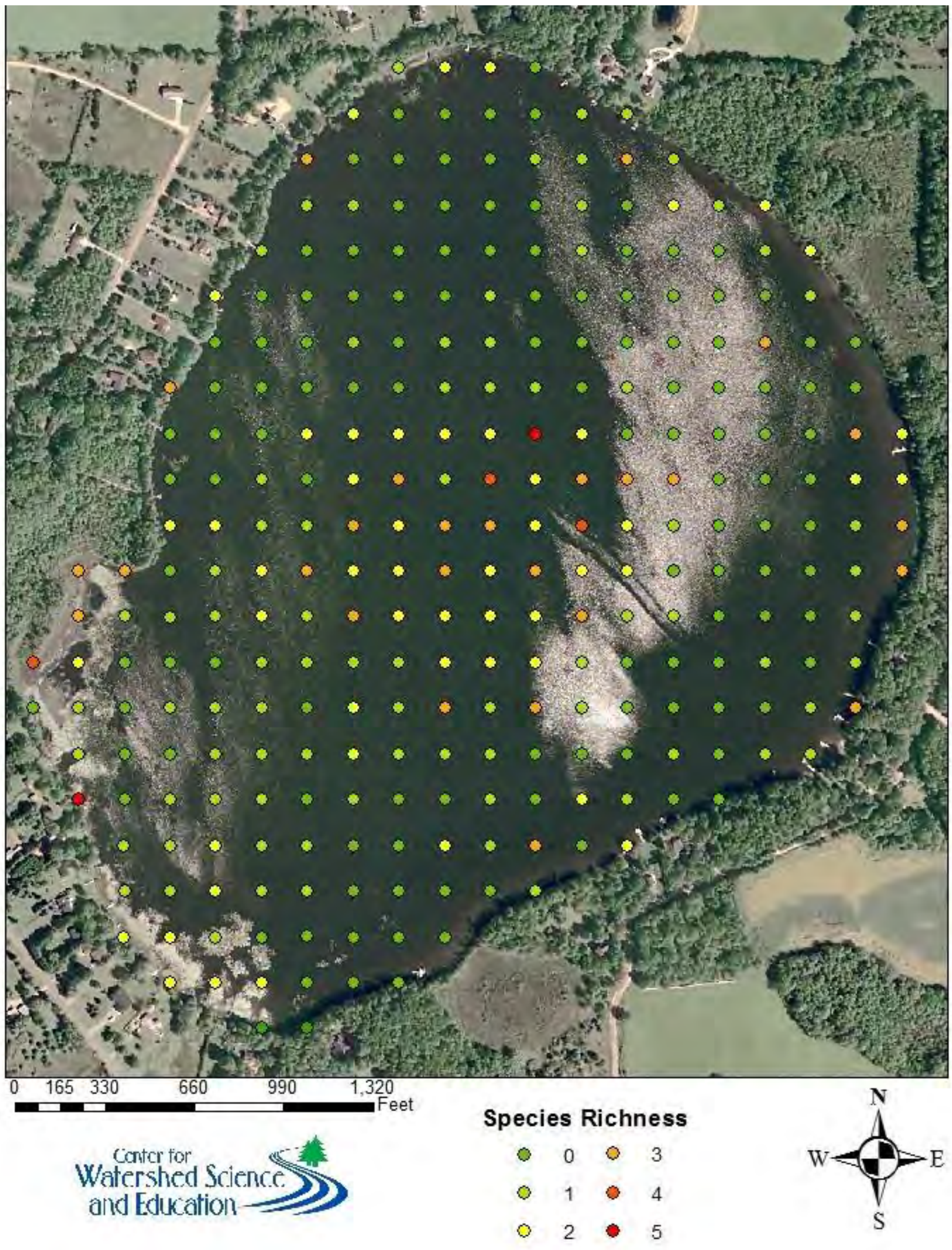


FIGURE 15. SPECIES RICHNESS AT AQUATIC PLANT SAMPLING SITES IN BIG BASS LAKE, 2012.

TABLE 11. AQUATIC PLANTS IDENTIFIED IN THE 2012 AQUATIC PLANT SURVEY OF BIG BASS LAKE.

Common Name	**Scientific Name**	**Coefficient of Conservatism Value (C Value)**
Emergent Species		
common arrowhead	*Sagittaria latifolia*	3
three-way sedge	*Dulichium arundinaceum*	9
hardstem bulrush	*Schoenoplectus acutus*	6
three square bulrush	*Schoenoplectus pungens*	5
softstem bulrush	*Schoenoplectus subterminalis*	4
bur-reed	*Spargenium,* spp.	5
broad-leaved cattail	*Typha latifolia*	1
Floating Leaf Species		
small duckweed	*Lemna minor*	4
spatterdock	*Nuphar variegata*	6
white water lily	*Nymphaea odorata*	6
floating leaf pondweed	*Potamogeton natans*	5
Submergent Species		
muskgrass	*Chara*	7
needle spikerush	*Eleocharis acicularis*	5
water stargrass	*Heteranthera dubia*	6
northern milfoil	*Myriophyllum sibiricum*	6
slender naiad	*Najas flexilis*	6
Fries' pondweed	*Potamogeton friesii*	8
variable pondweed	*Potamogeton gramineus*	7
Illinois pondweed	*Potamogeton illinoensis*	6
white-stem pondweed	*Potamogeton praelongus*	8
small pondweed	*Potamogeton pusillus*	7
flat-stem pondweed	*Potamogeton zosteriformis*	6
sago pondweed	*Stuckenia pectinata*	3
common bladderwort	*Utricularia vulgaris*	7
aquatic moss		

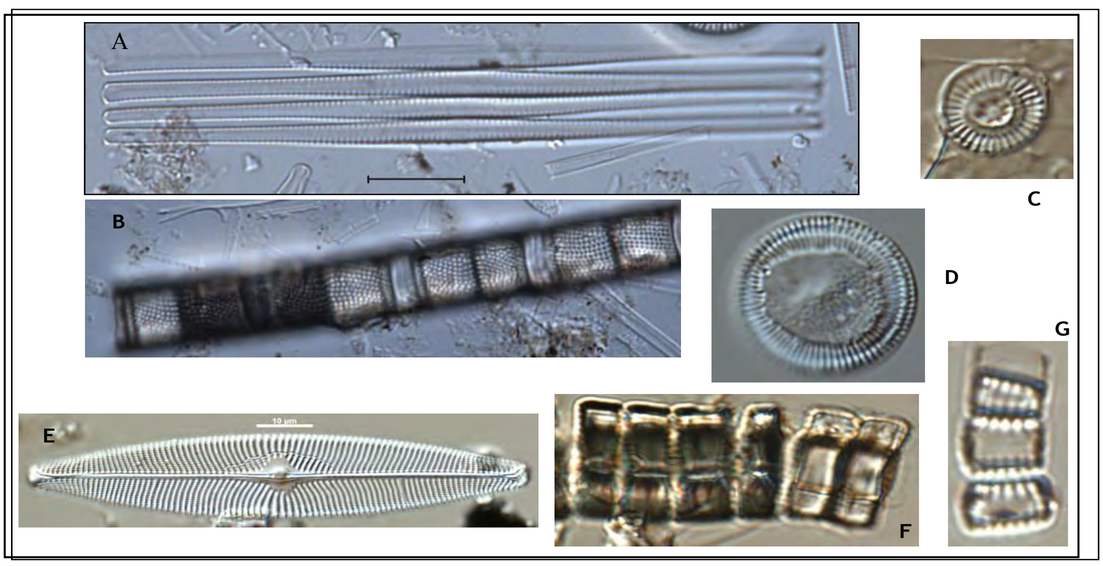
SEDIMENT CORE

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 delivered to the lake from the surrounding landscape and the atmosphere, or occur within the lake. The chemical composition of the sediment can help to decipher the composition of the past chemical environment in the lake. Lake sediment also contains remains such as diatom skeletons, cell walls of algal species, and the partially preserved remains of aquatic plants. By examining the remains trapped in the sediment, changes in the lake's ecosystem can be inferred.

Five lakes in the Marathon County lakes study were chosen for sediment core analysis. A single sediment core approximately 37 inches in length was collected for analysis from the deepest area in Big Bass Lake in 5.6 feet of water in November 2012. 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's composition responds rapidly 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. Most importantly, the cell walls of diatoms are made of silica, which enables them to be highly resistant to degradation and 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) IS 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 THE MARATHON COUNTY SEDIMENT CORES.

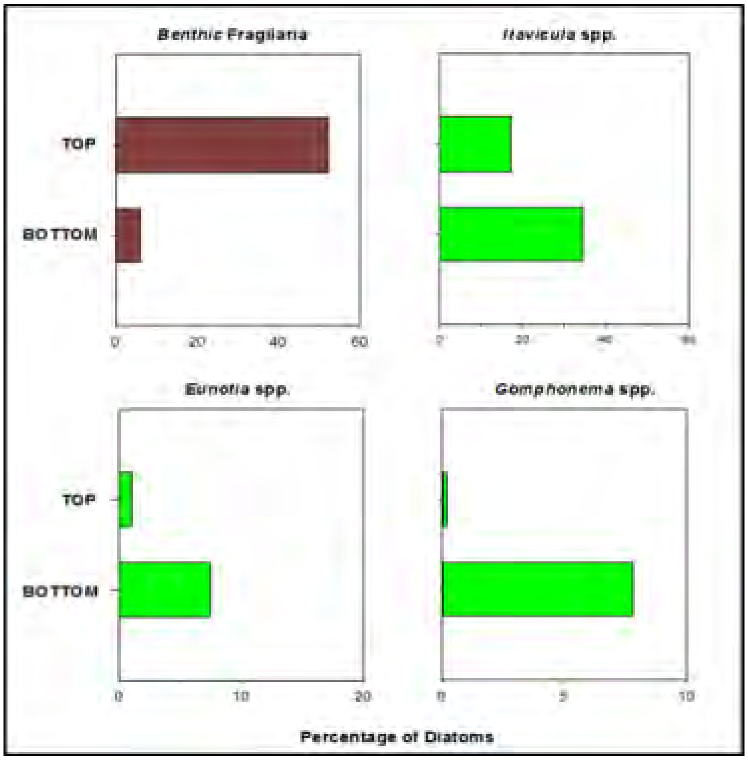


FIGURE 17. CHANGES IN ABUNDANCE OF DIATOMS FOUND AT THE TOP AND BOTTOM OF THE SEDIMENT CORE IN BIG BASS LAKE.

The diatom community was analyzed in top and bottom samples from Big Bass Lake's sediment core. The bottom of the core was dominated by *Navicula vulpina* and *N. aurora*, which are both benthic (bottom feeding) species that are associated with submerged aquatic plants and filamentous algae (Figure 17). In contrast, the top of the core was dominated by benthic *Fragilaria* , which indicated nutrient levels increased enough to support more filamentous algae for these diatoms to grow on. Diversity is high at the top of the core. This indicated increased shoreland disturbance in recent decades. This is common when moderate disturbance occurs along a lake's shoreland while the remainder of its watershed remains forested.

Relative dating techniques were used to provide 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 thus the depth of the ragweed spike in the lake sediment.

In Big Bass Lake, ragweed pollen grains and the ragweed index are fewer deeper in the core, but begin to increase at a depth of 17 inches and then taper off towards the top of the core (Figure 18). Even though ragweed values are lower towards the bottom of the core, they are still higher than a typical undisturbed landscape in central Wisconsin. Since ragweed increases with logging and land clearing and peaks when the remaining timber and undergrowth is removed for agriculture, the higher ragweed markers deeper in the core suggest early logging near the lake. The peak of ragweed at 17 inches is frequently associated with farming activities.

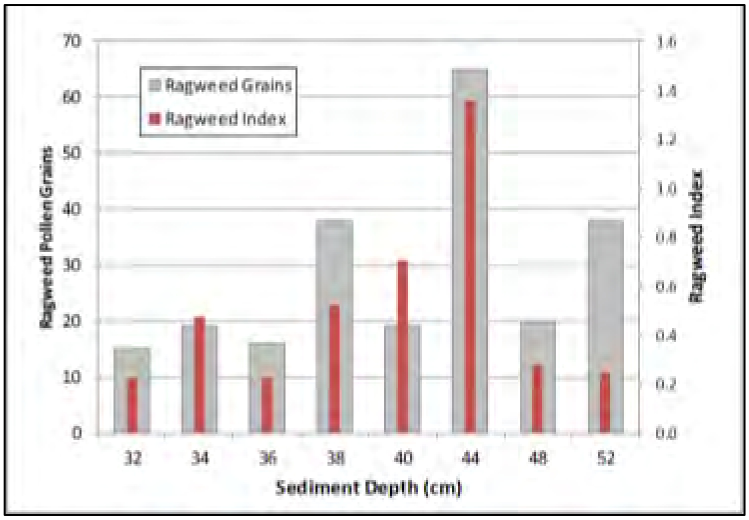


FIGURE 18. RAGWEED POLLEN IN THE BIG BASS LAKE SEDIMENT CORE, 2013.

PHYSICAL PROPERTIES OF SEDIMENT

Big Bass Lake's sediment is dark greenish-gray to black throughout the core. The dark color is the result of high amounts of organic matter or iron staining the sediment. As microbes and other organisms decompose in a lake, dissolved oxygen in the overlying water decreases and the sediment is 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 are few textural changes in the sediment core from Big Bass Lake. The sediment is fine-grained throughout, without visible inclusions of sand and coarse sand. Sand is indicative of shoreland disturbance related to erosion from land clearing and storm events.

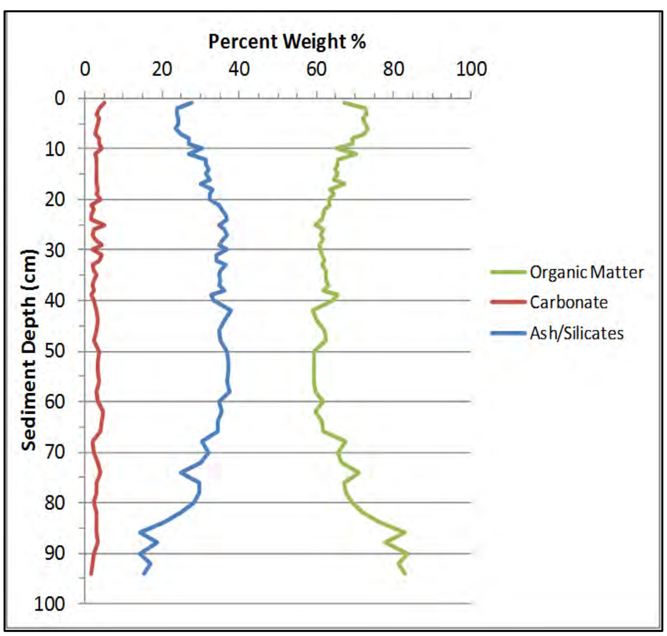


FIGURE 19. LOSS ON IGNITION RESULTS FOR BIG BASS LAKE, 2013.

To determine the composition of Big Bass Lake's sediment core, a test was conducted called loss on ignition (LOI). Various components that make up the lake's sediment core, such as organic matter, marl (carbonate), and silica (sand, silt, and clay), are burned away during this analysis to provide specifics about the core's composition in addition to color and textural analysis.

In Big Bass Lake, the LOI data indicated that organic matter was more abundant below 27.6 inches and in the top 3.9 inches of the sediment core. This indicated high abundance of aquatic plants and algae, and overall productivity. Silica increased slightly towards the middle of the core, which is indicative of erosion of the shoreland from land clearing and/or major storm events (Figure 19).

SEDIMENT CORE RESULTS SUMMARY

Analysis of biological components and physical properties of Big Bass Lake's sediment core indicated an increase in erosion-induced processes such as land clearing, storm events, and shoreland disturbance since the time of land settlement around the lake. The analyses indicated these activities occurred more frequently in recent decades, but appeared to have been minimized in recent years. There was likely an increase in nutrient delivery, including phosphorus, to the lake over this time period. While the diatom communities and the physical properties of the sediment did not directly show this increase in phosphorus, they did show an increase in aquatic plants and algae toward the top of the core. These analyses also suggested that Big Bass Lake experienced a limited increase in phosphorus concentrations, but large changes in habitat during the last century. The slight decrease in silica/ash in the top 3.9 inches indicated that there may have been some shoreline stabilization in recent years even if nutrient levels have remained high.

CONCLUSIONS & RECOMMENDATIONS

Unlike most of the lakes in the Eastern Marathon County Lakes Study, conclusions about the current state of Big Bass Lake by sub-study investigators were somewhat inconsistent, suggesting that Big Bass Lake is in a transitional state. Depending on sensitivity, different types of plants and animals respond to changes in water chemistry, algae or aquatic plants, and other chemical and physical factors at different rates. Routine monitoring would help to determine if Big Bass Lake is transitioning, and if so, whether improvement or degradation is occurring.

- Bass Lake is a moderately hard lake, making it somewhat resistant to nutrient inputs. Moderately hard water provides the calcium necessary for building bones and shells for animals in the lake.
- The chloride and sodium concentrations in Big Bass Lake were slightly elevated. These concentrations are not harmful to aquatic organisms, but indicate that pollutants are entering the lake. Chloride sources include animal waste, septic systems, fertilizer, and road-salting chemicals. The average potassium concentration was low, and atrazine, an herbicide commonly used on corn, was below the detection limit.
- 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.
    - Total phosphorus concentrations in Big Bass Lake ranged from 13 μg/L to 48 μg/L. The summer median total phosphorus concentrations were 28.5 ug/L and 22 ug/L in 2011 and 2012, respectively. This is below Wisconsin's phosphorus standard of 40 ug/L for shallow seepage lakes, but above the flag value of 15 ug/L.
    - During the study, inorganic nitrogen concentrations in samples collected during the spring in Big Bass Lake were elevated. Inorganic nitrogen typically moves to lakes with groundwater. Sources of nitrate include fertilizers, septic systems, and animal waste.
    - In a lake, nitrate can be readily used by aquatic plants and some types of algae, increasing their growth.
    - Water users around and upgradient of the lake should have the water from their private wells tested to determine if they exceed the health standards for nitrate in drinking water.

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 total algal community and the specific species found during the study period were indicative of two possible water quality trajectories:
    - The first, supported by the moderate total phosphorus value and most of the algal data, is of a late-stage oligotrophic lake that is transitioning into a mildly mesotrophic lake.
    - The second, supported by the improving water clarity measurements and some of the algal data, is that of a moderately mesotrophic lake that is seeing some improvement in water quality conditions.
- In either case, Big Bass Lake displays some of the best water quality indicators in the group of surveyed lakes.
- The algal communities in Big Bass Lake in 2011 and 2012 were diverse and primarily dominated by diatoms.

- Two small but troubling indicators loom that merit continued attention:
    - a rising number of blue-green algae, and
    - a green algae community of only minor abundance and relatively few species.

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).

- The types of zooplankton identified in Big Bass Lake were relatively common and none of those that reached numerical dominance in the sample counts were associated as invasive or exotic.
- Some of the non-native and invasive zooplankton are much larger in size than native zooplankton; therefore, non-native zooplankton can disturb the fishery in a lake because they are often too large to fit in the mouth of young fish. This can result in significant changes in the fishery in a lake.
- A stable, little-changing zooplankton community dominated by copepods suggested that Big Bass Lake may be eutrophic.

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 in order to flourish, including adequate food sources, habitat, appropriate spawning substrate, and water quality.

- Big Bass Lake supports a warm water fish community. Of the seventeen total species that have been recorded in surveys dating back to 1955, nine fish species were sampled and identified in the 2012 survey.
- Although most species identified in 2012 had been previously reported, yellow bullhead and Iowa darter were newly documented.
- Fish species documented previously but not detected during the 2012 survey included blacknose dace, brown bullhead, green sunfish, northern pike, pumpkinseed, rainbow darter, and white sucker. Two of these species, blacknose dace and rainbow darter, require flowing water for spawning, and are atypical in lakes. Although it is possible that these two species could have been physically transported from the Plover River where they are resident, they would not likely reproduce or sustain populations in Big Bass Lake.
- Bluegills were most abundant during the 2012 survey, with a maximum length of 10 inches observed for this species.
- Although infrequently encountered, walleye was the largest fish species caught in Big Bass Lake, with individuals reaching 25.3 inches.
- In the past, several winter kill events occurred in Big Bass Lake (1964, 1975, 1986), so fish stocking efforts were discontinued. During these struggles with winterkill, the lake was often opened up to the public for dip netting. As a result of frequent winter fish kill, an aerator system was installed in 1988 to help maintain sufficient dissolved oxygen concentrations during the ice covered periods.

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 Big Bass Lake consisted of marl/muck (78%) and sand (22%).
- In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build nests on marl. 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 have been reported to nest on woody habitat swept clear of sediments.
- Bulrush beds are present along areas of the shoreline in Big Bass Lake. Northern pike utilize areas with emergent and 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.
- The presence of young bass and abundant sunfish sampling indicated successful reproduction was occurring in Big Bass Lake.
- Yellow perch and walleye prefer near-shore cobble substrate in oxygen-rich environments for spawning activity. Conclusions cannot be made about walleye and northern pike reproductive success without additional sampling efforts.
- Coarse woody habitat (CWH), including downed trees and logs were sparse in Big Bass Lake. This structure is utilized by young prey fish and other aquatic organisms for foraging, protection, and spawning. The addition of near shore CWH in Big Bass Lake would likely benefit the fish community.

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.

- Twenty-five species of aquatic plants were found in Big Bass Lake during the 2012 aquatic plant survey, with the greatest diversity located in the middle of the lake. The number of aquatic plant species was above average when compared with the other lakes in the Eastern Marathon County Lakes Study.
- The dominant plant species in the survey was white-stem pondweed, followed by slender naiad, and muskgrass. White-stem pondweed is an important source of food for waterfowl, muskrat, beaver, and trout and also provides valuable habitat for muskellunge. This aquatic plant is considered an indicator species for water quality due to its sensitivity to disturbances within the aquatic system. The stems, leaves, and seeds of slender naiad are also important food sources for waterfowl and marsh birds. This common aquatic species also provides habitat for 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.
- Of the aquatic plant species within Big Bass Lake, three were high quality plants (with a C value of eight or greater): three-way sedge, Fries' pondweed, and white-stem pondweed. This number of species tied Big Bass Lake with Mayflower Lake for seventh out of the eleven lakes within the Eastern Marathon County Lakes Study.

- The Floristic Quality Index (FQI) evaluates the closeness of a plant community to undisturbed conditions. The FQI for Big Bass Lake was 26.6, which was slightly below average when compared with the other lakes in the Eastern Marathon County Lakes Study.
- No species of special concern within Wisconsin were found in Big Bass Lake.
- Non-native aquatic plant species were not found in Big Bass Lake during the 2012 survey. The lack of non-native species suggests diligence by lake users in cleaning watercraft before entering the lake to prevent the transfer of non-native aquatic plant species.
- 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.

Lakes act as sediment traps for particles that are delivered to the lake from the surrounding landscape and the atmosphere, or occur within the lake. The analysis of a lake's sediment core is an effective means to reconstruct some of the changes that have occurred over time.

- Analysis of biological components and physical properties of Big Bass Lake's sediment core indicated an increase in erosion-induced processes such as land clearing, storm events, and shoreland disturbance since the time of land settlement around the lake. The analyses indicated these activities occurred more frequently in recent decades, but appeared to have been minimized in recent years.
- There has likely been an increase in nutrient delivery, including phosphorus, to the lake over this time period. While the diatom communities and the physical properties of the sediment did not directly show this increase in phosphorous, they did show an increase in aquatic plants and algae toward the top of the core.
- These analyses also suggested that Big Bass Lake has experienced limited increase in phosphorus concentrations, but large changes in habitat during the last century.
- The slight decrease in silica/ash in the top 3.9 inches indicated that there may have been some shoreline stabilization in recent years even if nutrient levels have remained high.

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. Big Bass Lake's surface and groundwater watersheds provided most of the water to the lake. Land use in Big Bass Lake's 503 acre surface watershed was predominantly comprised of forests/wetlands (36%), agriculture (21%), and residential development (16%). In the groundwater watershed, forests/wetlands made up the greatest percent land use (49%), followed by agriculture (32%).

- Water quality modeling results indicated that agriculture had the greatest percentage of phosphorus contributions from the watershed to Big Bass 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. Big Bass 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, and 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.

- Big Bass Lake has 2.1 miles of shoreline. Big Bass Lake was one of the more developed lakes in this study, with 46 developed waterfront lots.
- Despite being developed, grass/forbs extended at least 50 feet inland from the water's edge for 40% of the shoreline along the undeveloped northern shore and portions of the western edge of the lake; however, 45% of the lake had a grasses/forbs buffer depth of less than 15 feet inland from the water's edge. The minimum depth required by Wisconsin and Marathon County shoreland zoning ordinances is 35 feet inland.
- Alone, each manmade feature may not pose a problem for a lake, but on developed lakes, the collective impact of disturbances can be a problem for lake habitat and water quality.
  - Structures such as seawalls, rip-rap (rocked shoreline), and artificial beach often result in habitat loss. Four sites had rip-rap along Big Bass Lake's shore.
  - Erosion can contribute sediment to the lake, which can alter spawning habitat and carry nutrients into the lake. Erosion was identified at one site along Big Bass Lake's shorelands.
  - Unmanaged runoff from rooftops of structures located near shore can also contribute sediment to the lake. There were seven structures within 75 feet of Big Bass Lake.
  - Docks and artificial beaches can result in altered in-lake habitat. Denuded lakebeds provide opportunities for invasive species to become established and reduce habitat that is important to fish and other lake inhabitants. There were 39 docks around Big Bass Lake. Impacts from docks can be reduced by properly managing the access to and around the docks, both on the land and in the water.
- Although Big Bass Lake's shoreland has abundant development, efforts can be made to improve the shorelands. Minimizing impacts to Big Bass Lake from current and future development should include planning to ensure that existing landowners and prospective developers have the right 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."