Eastern Marathon County Lakes Study

Rice Lake

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EASTERN MARATHON COUNTY LAKES STUDY BACKGROUND

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

Eleven lakes in eastern Marathon County were selected for this study, which was aimed at obtaining a better understanding of the current conditions of the lakes' water quality, fisheries, habitats, and aquatic ecosystems. This information will help lake users and municipalities by identifying how to improve existing problems and make informed decisions to preserve and protect the lake from future issues. Data collected in studies completed between fall 2010 and fall 2012 focused on the fisheries, water quality, groundwater, algae, zooplankton, lake histories, shoreline habitats, watersheds, and residents' opinions. This report contains the results of these studies for Rice 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 RICE 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. Rice Lake is located in the Township of Elderon, south of County Highway II. One public boat launch is located on its northwestern side. Rice Lake is a 25 acre groundwater drainage lake with groundwater and surface runoff contributing most of its water. The maximum depth in Rice Lake is 13.5 feet; the lakebed has a moderate slope (Figure 1). Its bottom sediments are comprised entirely of muck.

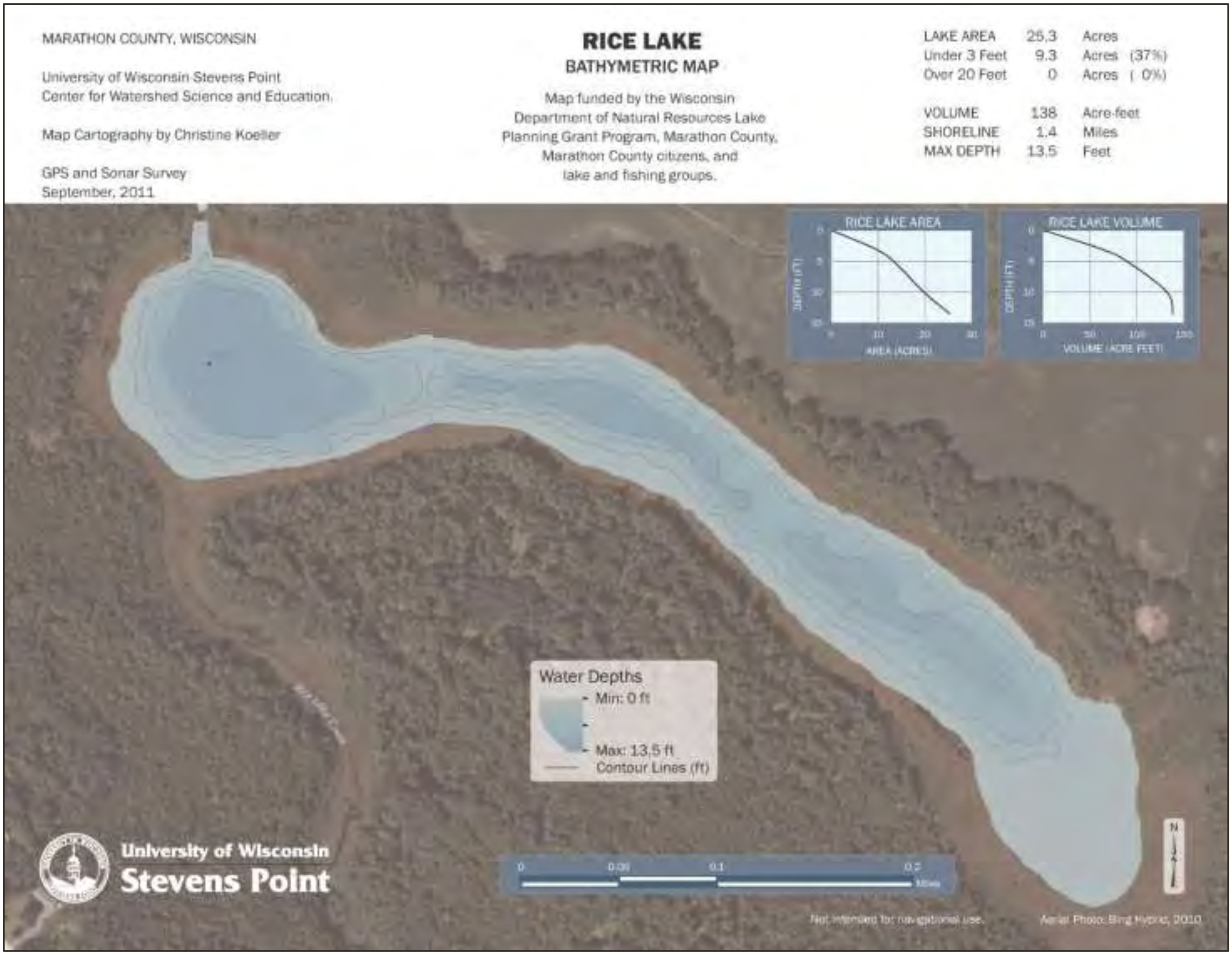


FIGURE 1. CONTOUR MAP OF THE RICE LAKE LAKEBED.

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

It is important to understand where Rice 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 Rice Lake is called a surface watershed. Groundwater also feeds Rice 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 and cover fish spawning beds, and contains nutrients that increase the growth of algae and aquatic plants. Development often results in changes to natural drainage patterns, alterations in vegetation on the landscape, and may be a source of pollutants. Impervious (hard) surfaces such as roads, rooftops, and compacted soil prevent rainfall from soaking into the ground, which may result in more runoff that carries pollutants to the lake. Wastewater, animal waste, and fertilizers used on lawns, gardens, and agricultural fields can contribute nutrients that enhance the growth of algae and aquatic plants in our lakes.

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

The surface watershed for Rice Lake is approximately 1,308 acres (Figure 2). The dominant land uses in the watershed are forests and agriculture. The lands closest to the lake often have the greatest impact on water quality and habitat; land uses near Rice Lake's shoreland include wetlands and forests.

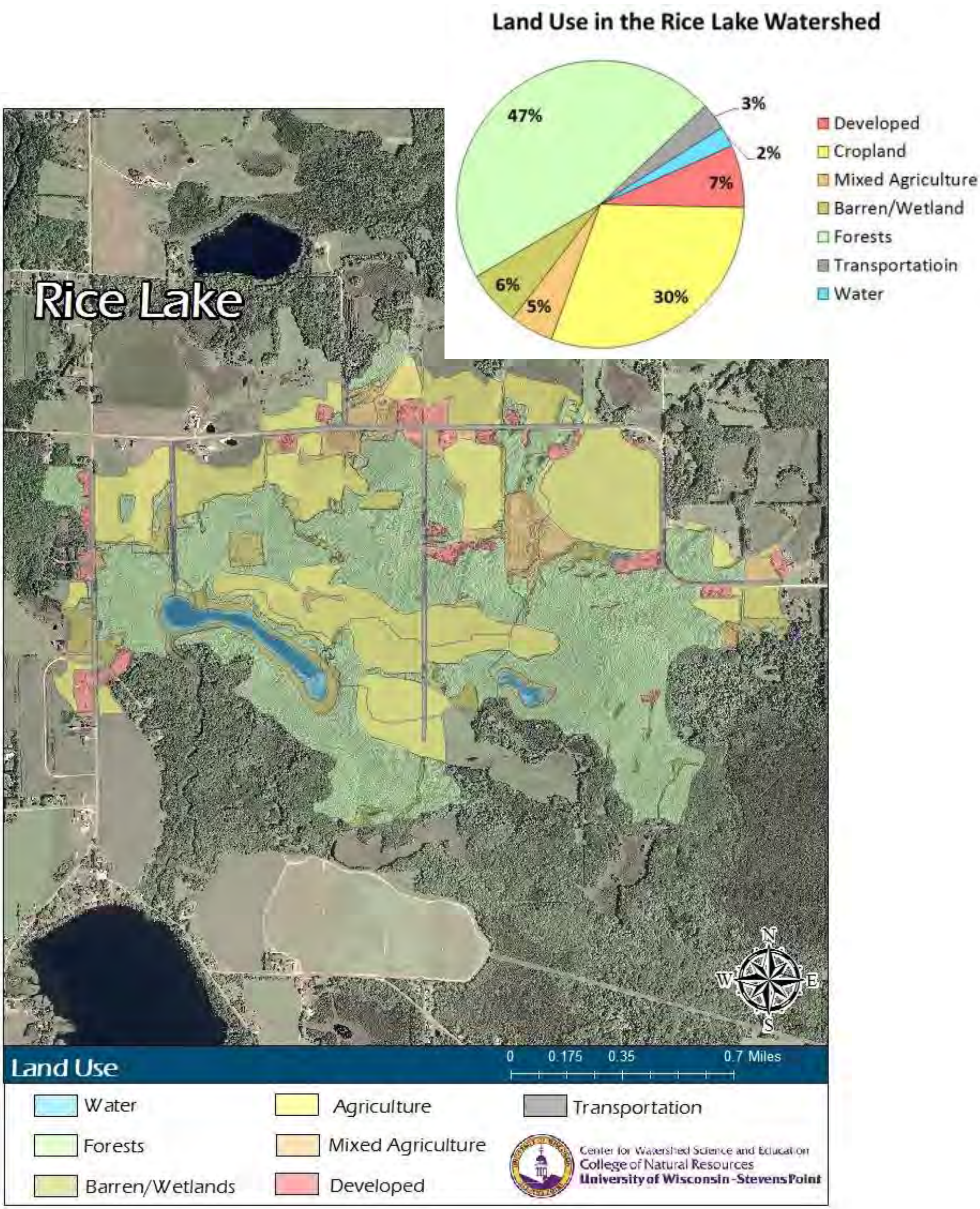
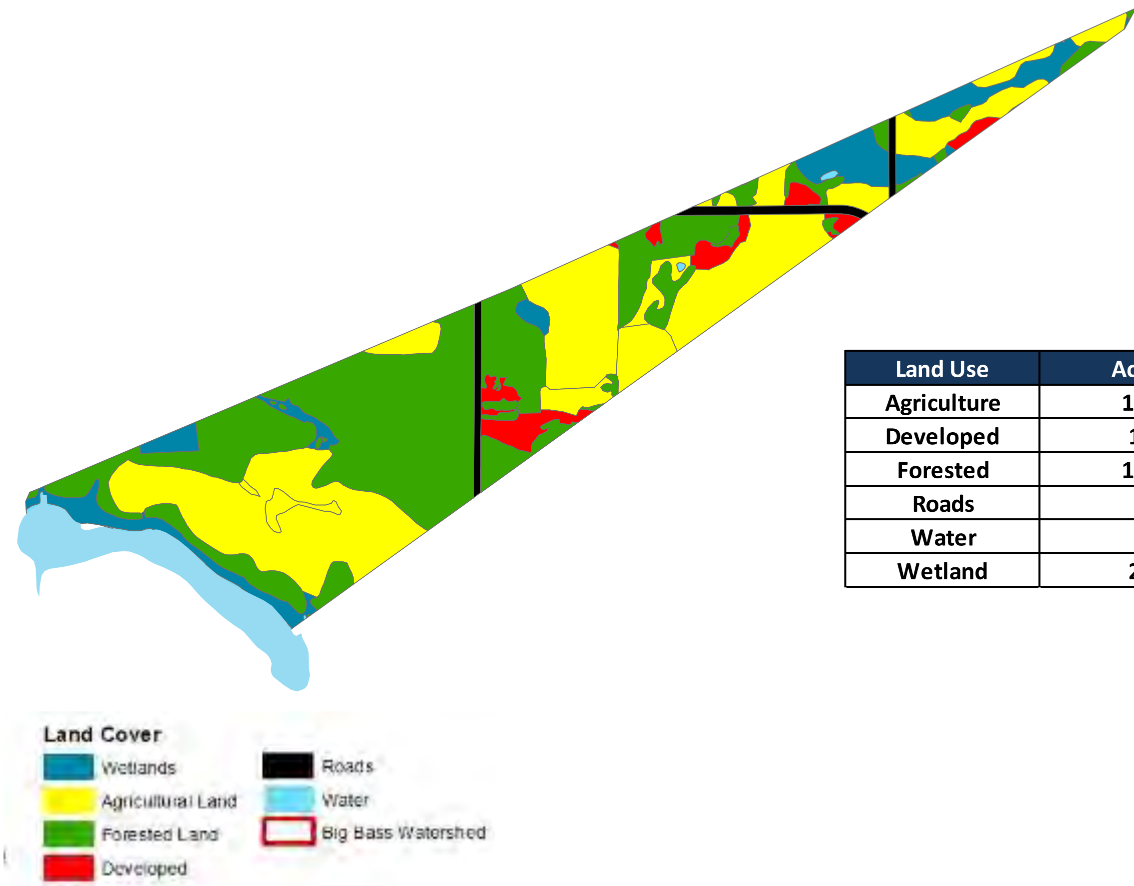


FIGURE 2. LAND USE IN THE RICE LAKE SURFACE WATERSHED.

The groundwater watershed is the area where precipitation soaks into the ground and travels below ground towards the lake. Rice Lake's groundwater watershed is approximately 293 acres (Figure 3). The primary land uses in the Rice 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 Rice Lake where the groundwater enters.



Land Use	Acres
Agriculture	118
Developed	12
Forested	118
Roads	7
Water	9
Wetland	29

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

Locally, groundwater enters some parts of the Rice 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 Rice Lake (Figure 4). Areas with no connection between groundwater and the lake were observed on the southern and western sides of the lake (white dots). The grey dots indicate locations where mini-wells could not be installed due to deep muck. Additional groundwater may enter Rice 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 may result in less groundwater entering Rice Lake.

The more lake water interacts with groundwater (inflow), 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 remain constant year round, so groundwater feeding Rice Lake will help to keep the lake water cooler during the summer months.

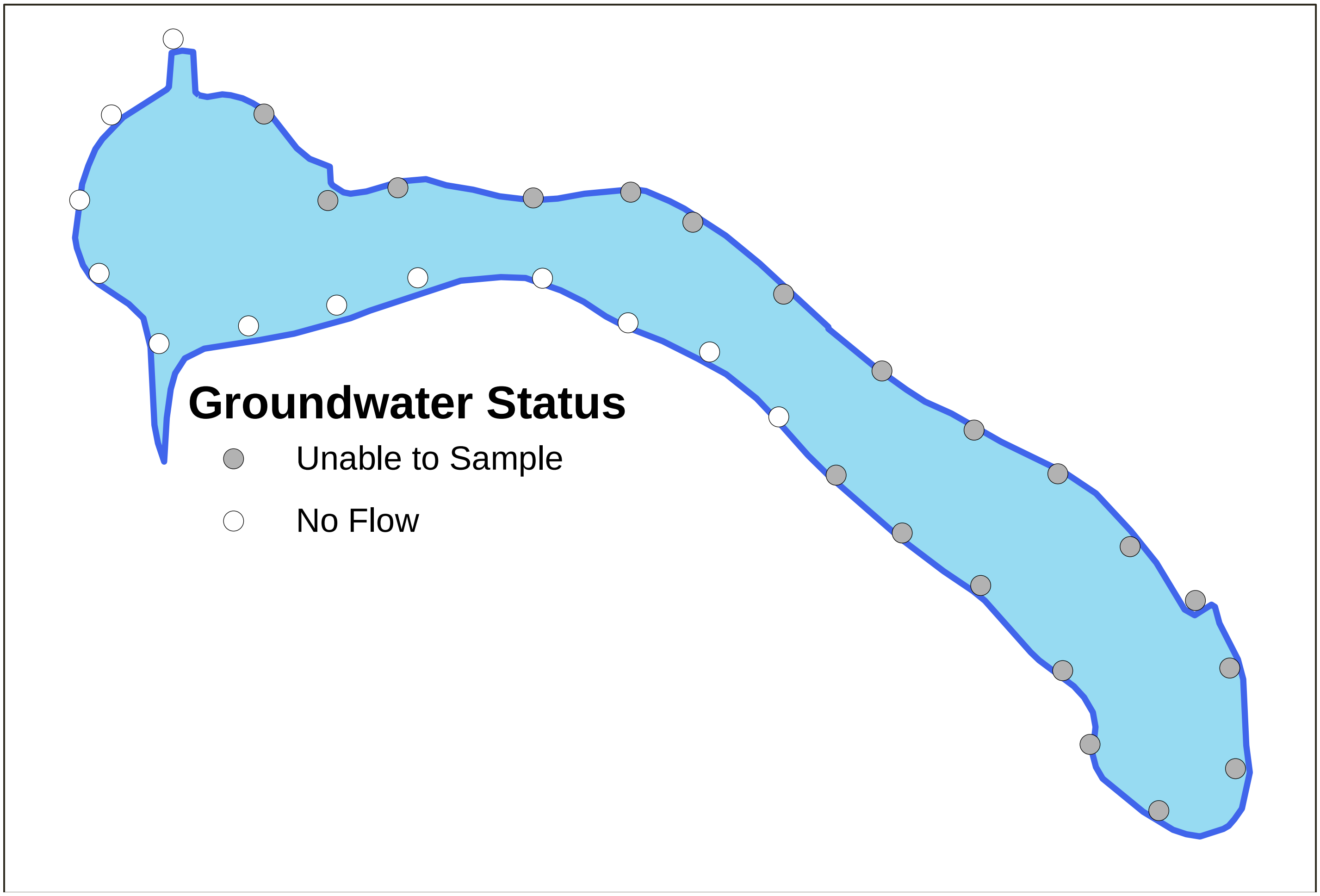


FIGURE 4. RICE LAKE GROUNDWATER INFLOW AND OUTFLOW, 2011.

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

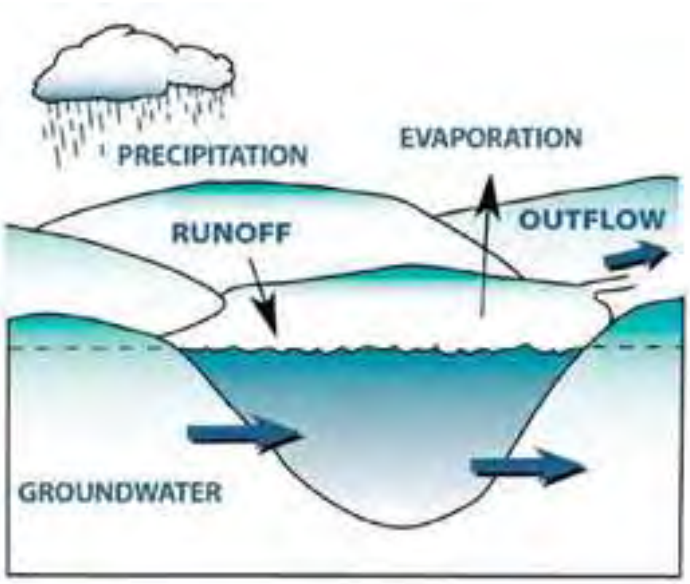


FIGURE 5. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN A GROUNDWATER DRAINAGE LAKE.

The source of a lake's water supply is important in determining its water quality and choosing management practices to preserve or influence that quality. Rice Lake is classified as a groundwater drainage lake. Water enters this type of lake primarily through groundwater, and to lesser extents, from precipitation and runoff. Water exits the lake primarily through its outflow stream at the western end (Figure 5). Groundwater drainage lakes have higher concentrations of minerals such as calcium and magnesium, which are picked up by groundwater moving through soil and rock. Groundwater drainage lakes are also more vulnerable to contamination moving towards the lake in the groundwater. Examples for Rice 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 of the lake. As groundwater moves through the soil, some substances are filtered out, but other materials dissolve into the groundwater (Wetzel, 2001). Minerals such as calcium and magnesium in the soil around Rice Lake dissolve, making the water hard. The average hardness for Rice Lake during the 2010-2012 sampling period was 184 mg/L, which is considered hard (Table 1). Hard water provides the calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 170 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 (Shaw et al., 2000).

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

Rice Lake	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as CaCO3)	Color SU	Turbidity (NTU)
Average	170	37.8	19.5	184	53.8	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, concentrations of chloride and potassium were high and sodium was slightly elevated (Table 2). These concentrations are not harmful to aquatic organisms, but indicate that pollutants are entering the lake. Sources of chloride and potassium include animal waste, septic systems, fertilizer, and road-salting chemicals. Atrazine (DACT), an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L) in the samples that were analyzed from Rice Lake.

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

Rice Lake	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium			1.6	<.75	0.75 - 1.5	>1.5
Chloride			10.1	<3	3.0 - 10.0	>10
Sodium		2.7		<2	2.0 - 4.0	>4

Dissolved oxygen is an important measure in aquatic ecosystems because a majority of organisms in the water depend on 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 Rice Lake from top to bottom at the time of each sample collection during the 2010-2012 study. As would be expected, near-freezing temperatures existed near the surface with slight gradual warming towards the bottom of the lake in late winter (February 2011 and February 2012). Data collected in spring and fall indicated the lake had mixed, thereby replenishing oxygen in the lake bottom. Based on temperature, the lake was somewhat stratified during the growing season (May-September) as surface water warmed. The stratification was weak enough that strong winds could have mixed the water. This is not ideal during the summer as the bottom water is often rich with nutrients from the sediment, and bringing this water into warmer conditions at the top may result in algal blooms. Water temperatures near the bottom of the lake ranged by only 9 degrees (reaching a high of 13 degrees in summer), while surface temperatures ranged by nearly 25 degrees (Figure 6).

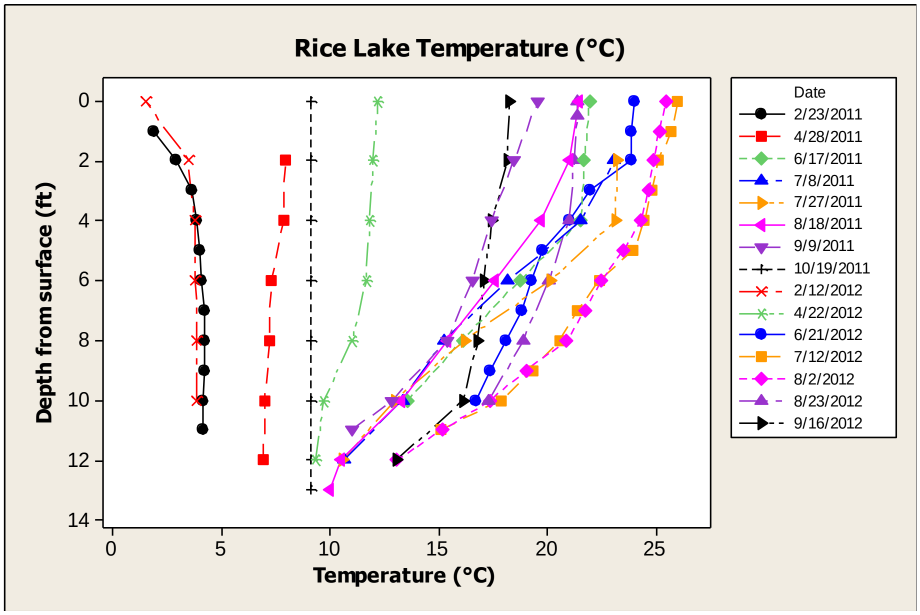


FIGURE 6. TEMPERATURE IN RICE LAKE, 2010-2012.

Dissolved oxygen concentrations in Rice Lake ranged from plentiful to limited, depending upon depth and time of year. Like temperature, dissolved oxygen was mixed from top to bottom during spring and fall. In the winter of both years, dissolved oxygen fell below concentrations needed to support many fish species during this ice-covered period (Figure 7). Following spring overturn, dissolved oxygen varied with depth as biological processes in the lake consumed or released oxygen. Algae blooms produced periodic spikes in dissolved oxygen concentrations at depths typically between 4 and 8 feet.

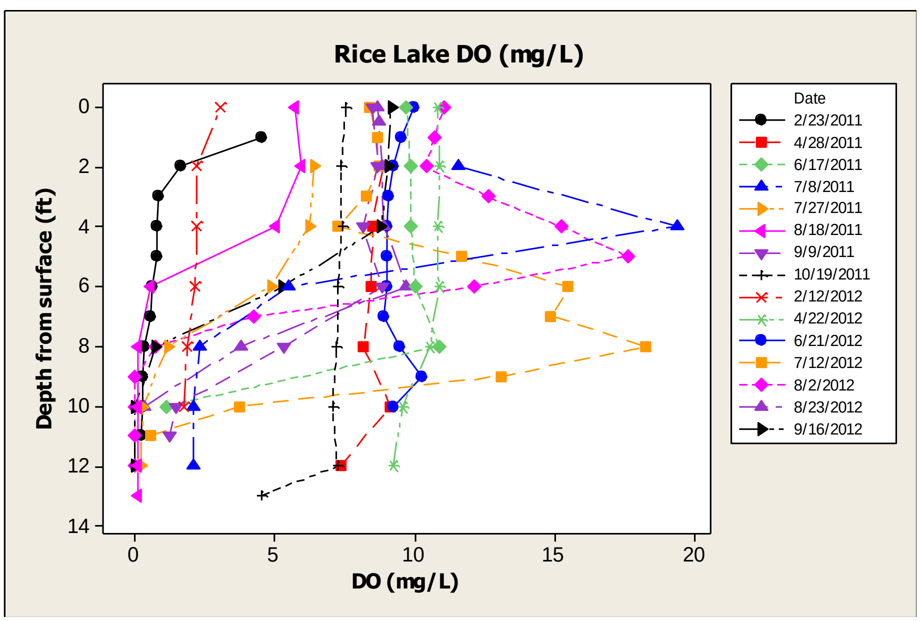


FIGURE 7. DISSOLVED OXYGEN (DO) IN RICE LAKE, 2010-2012.

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 Rice Lake, the color was moderately stained (Table 1). Brown staining from tannins in the surrounding wetlands and forest are the natural source of the slightly elevated color index.

The variability in water clarity throughout the year in Rice Lake was primarily due to fluctuating algae concentrations and re-suspended sediment following storms. The water clarity in Rice Lake is considered fair. The average water clarity measurements in Rice Lake during the study were poorest in September and best in October (Figure 8). Past water clarity data was submitted sporadically between 1999 and 2007. When compared with this historic data, the average water clarity measured during the study was slightly better in August and poorer in September. In 2011, water clarity remained fairly consistent throughout the monitoring period, with the exception of one measurement in early July. During 2012, water clarity in Rice Lake decreased as the year progressed.

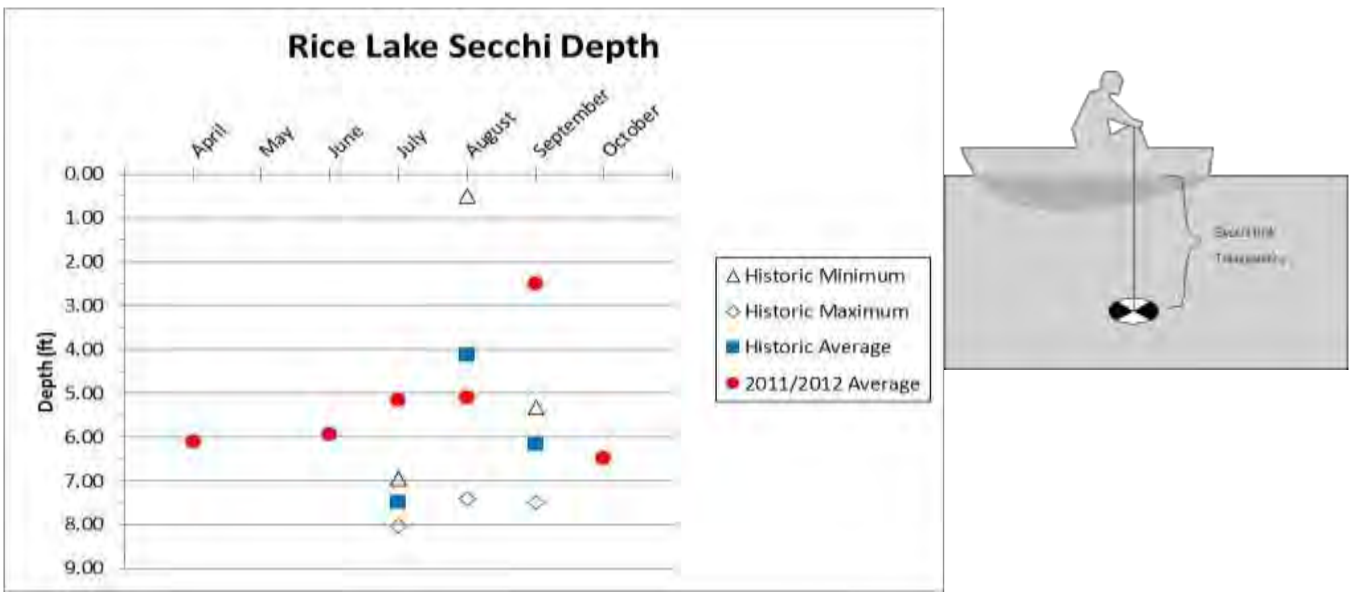


FIGURE 8. AVERAGE MONTHLY WATER CLARITY IN RICE LAKE, 2010-2012 AND HISTORIC.

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 Rice Lake ranged from a high of 82 µg/L in April 2012 (following spring runoff) to a low of 23 µg/L in February 2011 (Table 3). The summer median total phosphorus concentrations were 53 µg/L and 23.5 µg/L in 2011 and 2012, respectively. Concentrations in 2011 exceeded Wisconsin's phosphorus standard of 40 µg/L for shallow drainage lakes.

During the study, inorganic nitrogen concentrations in samples collected during the spring averaged 0.82 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.

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

Rice 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	30	44	67	6	6	6	2.05	2.26	2.46	0.76	0.99	1.21	0.84	1.27	1.70
Spring	32	57	82	5	7	9	1.43	1.49	1.54	0.77	0.82	0.86	0.57	0.67	0.77
Summer	25	39	63												
Winter	23	25	27	6	18	30	2.14	2.34	2.53	1.70	1.93	2.15	0.38	0.41	0.44

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Rice 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 distance from the lake also affect the contributions to the lake from a parcel of land. Although forested land comprised the greatest amount of land in the watershed, modeling results indicated that agriculture had the greatest percentage of phosphorus contributions from the watershed to Rice 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 RICE LAKE WATERSHED.

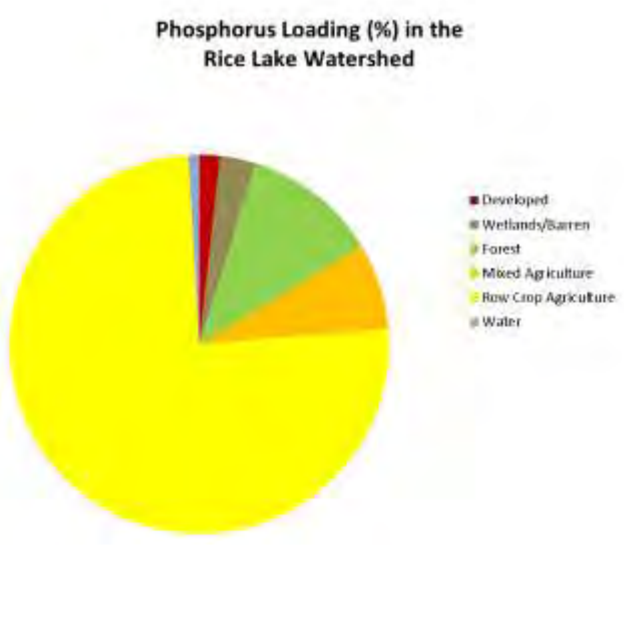


TABLE 4. MODELING DATA USED TO ESTIMATE PHOSPHORUS INPUTS FROM LAND USES IN THE RICE LAKE WATERSHED (LOW AND MOST LIKELY COEFFICIENTS USED TO CALCULATE RANGE IN POUNDS).

Rice Lake Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.10	31	**2**	2-7	1
Developed	0.13	95	**7**	4-8	**2**
Wetland/Barren	0.09	83	**6**	7-22	**3**
Forest	0.04	626	**48**	28-50	**12**
Mixed Agriculture	0.27	66	**5**	18-47	**7**
Row Crop Agriculture	0.45	407	**31**	182-363	**76**

*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 Rice Lake were generally high, ranging from a high of 116 µg/L in August 2011 to a low of 3 µg/L in August 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 enhance the evaluation of a lake's water quality because there are more species of algae than fish or aquatic plant species. 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). Blue-green algae exhibited a strong pattern of algal community dominance in Rice Lake during 2011 and 2012 (Figure 10). This pattern and the strength of the dominance (average of 50% of all cells counted across all samples) are typical of a very nutrient-enriched, eutrophic lake. The blue-green algal species found in Rice Lake are larger forms (colonial and filamentous) that are undesirable and mostly uneaten by consumers in the aquatic food web.

Many of the green algae present were filamentous and difficult to consume. The larger green algal filaments provide significant surface area for colonization by many of the small, attached blue-green species. The diatom species identified are common in nutrient rich (eutrophic) water and their colonial form inhibits their consumption.

All data (total phosphorus, Secchi disk depths, and algae) point to Rice Lake being a very enriched, eutrophic body of water. The water quality data summarized above describe a lake that is very productive (eutrophic), with a high probability of anoxic conditions in the hypolimnetic zone (lake bottom) during the summer and winter. Devoid of oxygen in late summer, the hypolimnion limits many species of fish and causes phosphorus release from sediments, as observed in periodic high phosphorus concentrations during fall and spring turnover.

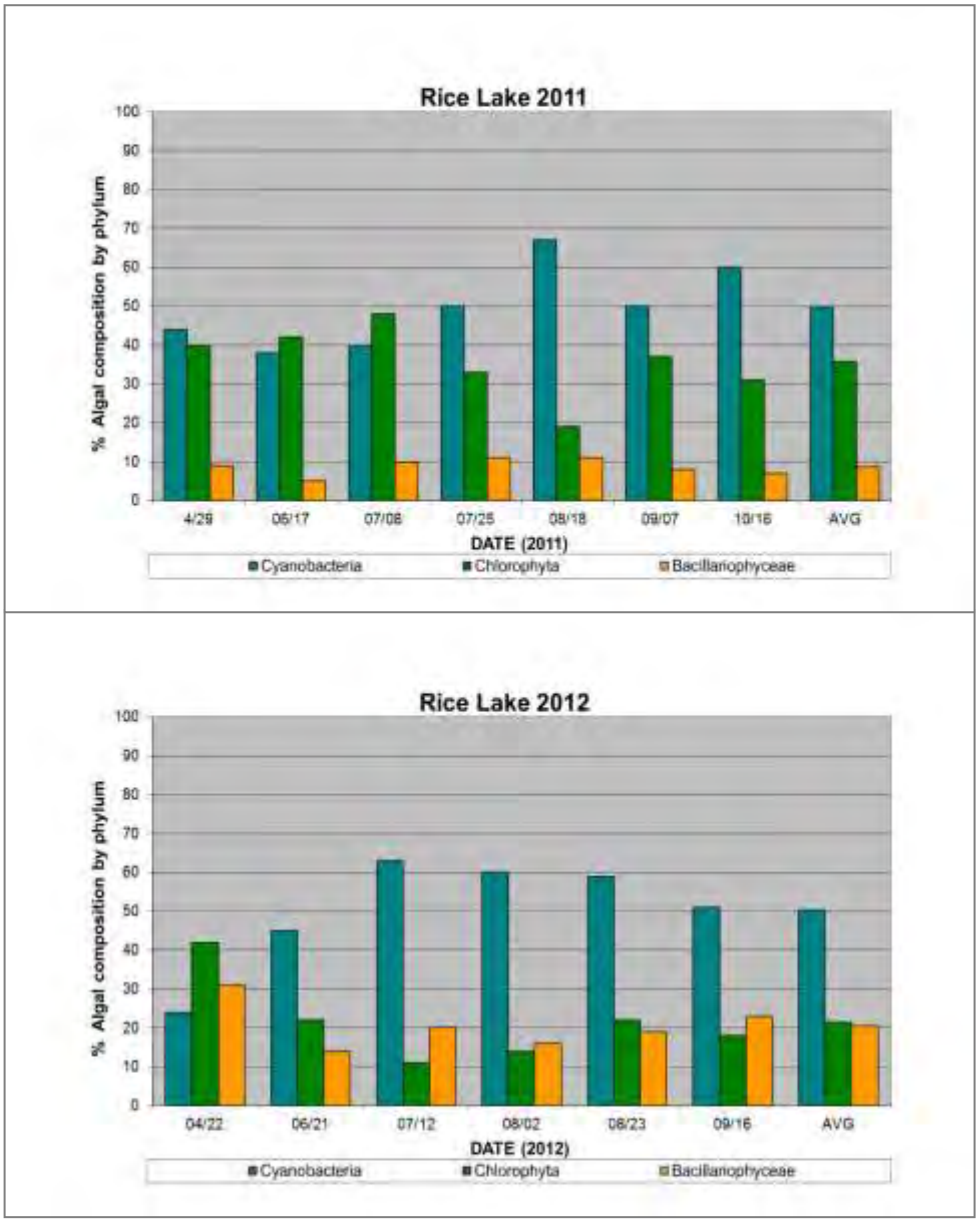


FIGURE 10. PERCENT ALGAL COMPOSITION OF RICE LAKE, 2011 AND 2012.

SHORELAND HEALTH

Shoreland vegetation is critical to a healthy lake 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 the 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.

RICE 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 water. The three rings surrounding Rice Lake in Figure 12**Error! Reference source not found.** depict the depth of vegetation along Rice 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.

Rice Lake has approximately 8,415 feet of shoreline. The overall findings showed that 8,371 linear feet of shoreline were classified as having a grasses/forbs buffer depth of greater than 35 feet, which is the minimum depth required by Wisconsin and Marathon County shoreland zoning ordinances. Similar results were observed for the shrubs buffer. Trees represented the least abundant vegetative layer around the lake, with 2,238 linear feet classified as having a buffer width greater than 35 feet. Shoreland survey results are displayed in Figure 11. Although Rice Lake's shoreland was observed to be in good shape during the survey, 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 Rice Lake.

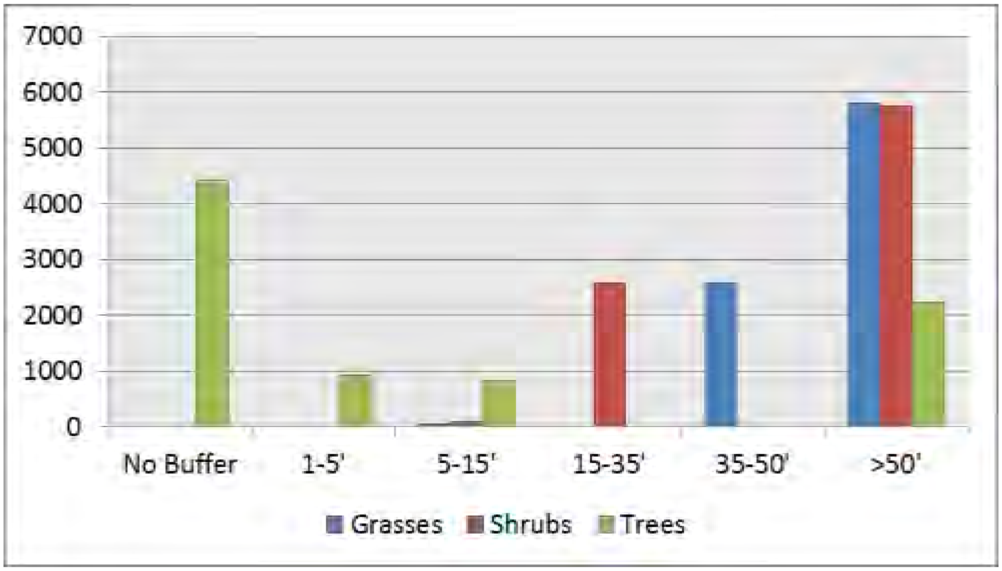


FIGURE 11. SHORELAND VEGETATION SURVEY RESULTS BY BUFFER DEPTH AROUND RICE LAKE, 2011.

As shown in Figure 13, there were no residential lots present on Rice Lake in 2011. In addition, there were no manmade features along the shoreline at the time of the survey. Most of Rice Lake's shoreline existed in a natural condition with very little human modifications.

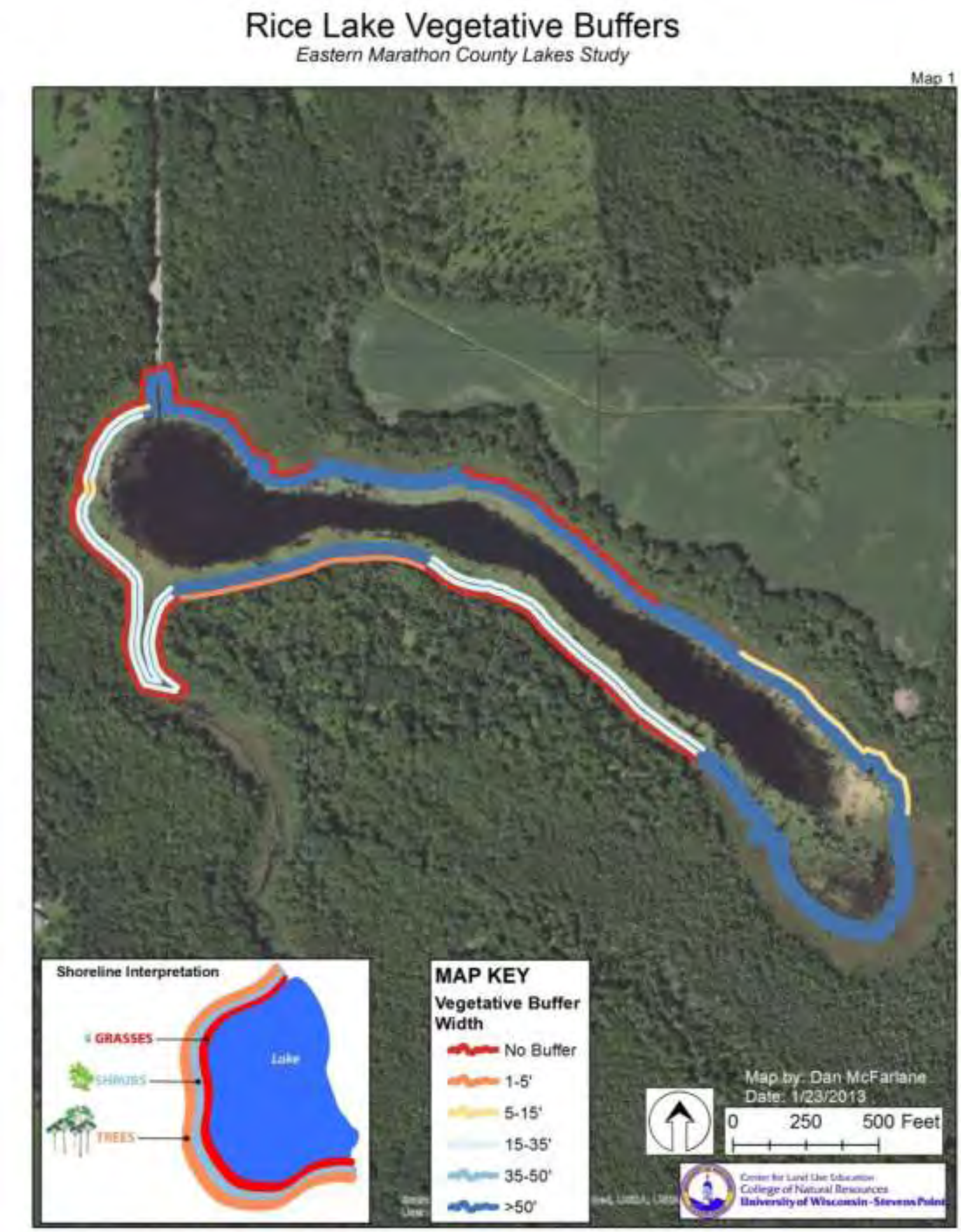


FIGURE 12. SHORELAND VEGETATION SURVEY OF RICE LAKE, 2011.

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

A sustainable fishery is one that is in balance with the lake's natural ability to support the fish community and is adaptable to reasonable fishing pressures without additional stocking or input. A healthy fish community has a balance between predator and prey species, and each species of fish has different needs in order to flourish, including food sources, habitat, nesting substrate, and water quality.

People are also an important part of a sustainable fishery, as the numbers and sizes of fish taken out of the lake can influence the fish community. Appropriate fishing regulations can help to balance the fishery with healthy prey and predatory species, and can be adjusted as needed. Each species has its preferred tolerance range for dissolved oxygen, pH, water clarity, temperature, and minerals. Predatory species, for example, need good water clarity to effectively hunt their prey. Even within a species, water quality tolerance ranges may vary for reproduction. Choosing the wrong fish species for a lake's conditions will result in an unsustainable fishery, requiring outside inputs such as aeration or additional stocking.

Rice Lake supports a warm water fish community. In 2011, six fish species were sampled and identified out of the eight total species that were recorded in surveys dating back to 1960 obtained from the Wisconsin Department of Natural Resources (WDNR) (Table 5). Four fish species were newly documented in 2011: yellow bullhead (*Ictalurus natalis*), brown bullhead (*Ameiurus nebulosus*), golden shiner (*Notemigonus crysoleucas*), and central mudminnow (*Umbra lima*). Two fish species were documented previously, but not observed during the 2011 survey: black bullhead (*Ameiurus melas*) and white sucker (*Catostomus commersoni*). Bluegill (*Lepomis macrochirus*) was most abundant during the 2011 survey; maximum length of this species was 8.5 inches (Table 6). Although infrequently encountered, northern pike (*Esox lucius*) reached 30.8 inches. Crayfish were not encountered during the survey.

TABLE 5. FISH SPECIES IN RICE LAKE, 2011 SURVEY AND HISTORICALWISCONSIN DEPARTMENT OF NATURAL RESOURCES RECORDS.

Species	1960	1975	2011
Black Bullhead		x	
Black Crappie	x	x	x
Bluegill	x	x	x
Brown Bullhead			x
Golden Shiner			x
Largemouth Bass	x	x	x
Central Mudminnow			x
Northern Pike	x	x	x
Pumpkinseed	x	x	x
White Sucker	x	x	
Yellow Bullhead			x
Yellow Perch	x	x	x

TABLE 6. TOTAL CATCH AND LENGTHS (MIN/MAX/AVERAGE) OF FISH SPECIES IN RICE LAKE, 2011 SURVEY.

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	1.5	8.5	5.6	71
Yellow Bullhead	8.5	15.0	10.6	29
Golden Shiner	1.5	2.3	2.1	11
Black Crappie	7.2	11.4	8.9	7
Pumpkinseed	3.9	8.5	6.0	6
Largemouth Bass	2.7	3.1	3.0	4
Brown Bullhead	10.5	11.5	10.8	3
Northern Pike	21.9	30.8	27.1	3
Yellow Perch	5.4	6.6	6.2	3
Mudminnow	1.5	2.6	2.0	2

A review of WDNR records revealed little fisheries management information for Rice Lake. In 1960, a WDNR fisheries report indicated northern pike and largemouth bass (*Micropterus salmoides*) were common in this system. In the same year, management recommendations were made to focus on northern pike and largemouth bass management, along with common panfish. Shortly after 1960, public access to the lake was approved and constructed. Fish stocking records for Rice Lake date back to 1962 in WDNR files (Table 7). Historic stocking consists of adult northern pike and muskellunge (*Esox masquinongy*) fingerlings.

TABLE 7. WISCONSIN DEPARTMENT OF NATURAL RESOURCES FISH STOCKING SUMMARY FOR RICE LAKE, INCLUDING SPECIES, AGE CLASS, AND NUMBER STOCKED.

Year	Species	Age Class	Number Fish Stocked
1962	Muskellunge	Fingerling	300
1967	Northern Pike	Adult	275

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 which 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 and woody habitat were examined from the shoreline lakeward to a distance of 30 meters. Substrate in Rice Lake is soft muck (100%) (Figure 14). In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build nests on soft bottoms. Depressions are deepened until some small amounts of coarser substrate, or 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. Gravel areas are used by many fish for spawning habitat, including sunfish (bluegill, pumpkinseed or *Lepomis gibbosus*, and black bass), where males will construct nests and guard their young. Northern pike, which do not offer parental care, use areas with emergent and floating leaf vegetation in shallow or flooded areas for spawning. Black crappie (*Pomoxis nigromaculatus*) also use bulrush habitat on gravel or sand substrates where they construct nests and guard their young. Yellow perch (*Perca flavescens*) seek near-shore cobble in oxygen-rich environments for spawning activity; no parental care is offered. Sparse areas of softstem bulrush (*Schoenoplectus tabernaemontani*) were present in Rice Lake (Figure 14). Sand can be important habitat for reproduction of non-game minnow. The absence of young northern pike in the 2011 sampling may be an indicator of poor reproduction, although more intense population sampling over several seasons would be required to determine the reproductive success for individual fish species. The presence of young bass and abundant sunfish sampling indicate successful reproduction of these species.

Coarse woody habitat (CWH) was not present in Rice Lake during the survey period. The soft substrate present around the lake would likely consume most logs and branches not secured to the shoreline. The near-shore areas of Rice Lake are densely vegetated during the summer and fall months with lily pads and coontail, which provide protective cover for a variety of aquatic life. The addition of stable CWH cover would benefit the fish community and other animals. For example, CWH would provide places for turtles to warm themselves in the sun and for birds to perch.

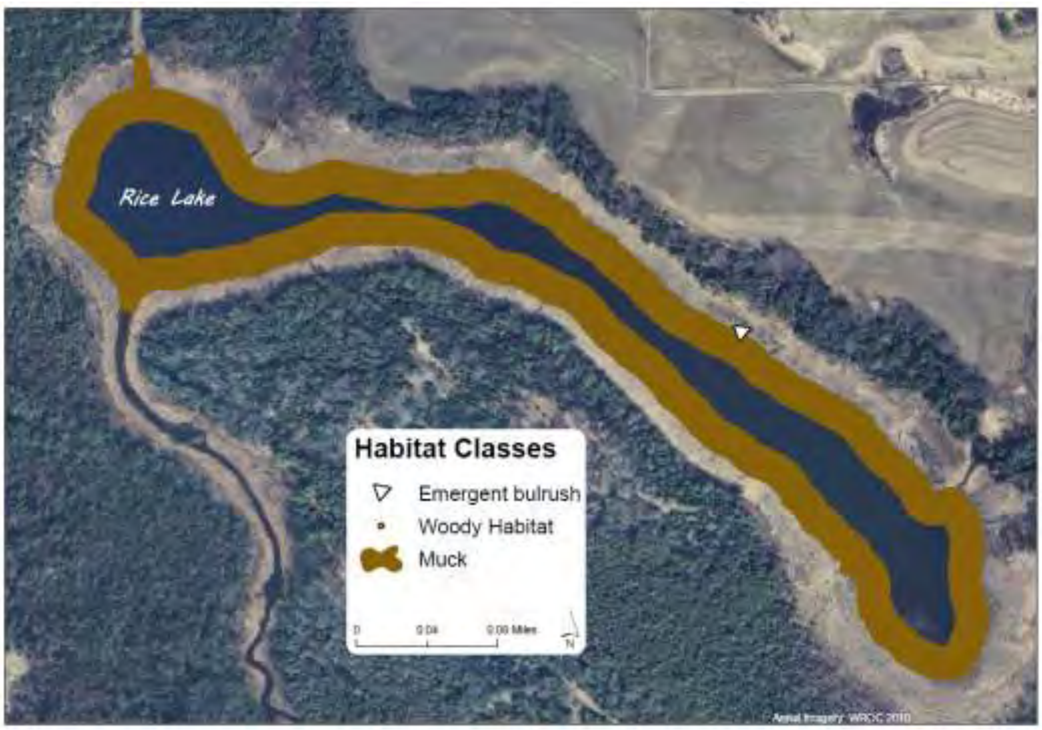


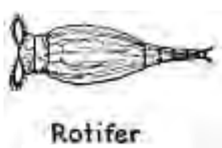
FIGURE 14. DISTRIBUTION OF SUBSTRATE AND COARSE WOODY HABITAT IN RICE LAKE, 2012.

Activities in and around a lake which can affect a fishery may include the disturbance of aquatic plants or substrates, chemical additions, removal of woody habitat, and shoreline alterations. Shoreland erosion can cause sediment to settle onto the substrate, causing the deterioration of spawning habitat. Ways in which habitat can be improved include restoring shoreland vegetation to control erosion, minimizing the removal of aquatic plants, and protecting wetlands and other areas of critical habitat.

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

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

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



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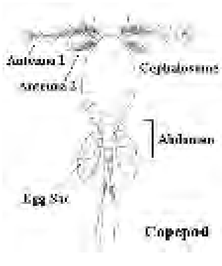
Rotifers are small invertebrate animals with simple body designs. They are usually not found uniformly throughout lakes, but congregate in areas of high food abundance (bacteria, algae, and other rotifers). Generally, a lake's trophic status influences, or can be predicted by, the abundance and diversity 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 a response to avoid heavy fish predation and can result in lower than expected cladoceran numbers during daytime collections.



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

The zooplankton community of Rice Lake was slightly diverse during the 2011-2012 sampling season (Table 8, Table 9). Zooplanktons were classified based on two general size categories: nano-plankton (80 *u*m or less) or net plankton (210 *u*m or less).

The dominant groups of nano-plankton were rotifers and copepods.

- There were 3,163 individuals counted during this period:
    - 2,510 rotifers, 485 copepods, 169 cladocerans

The dominant groups of net plankton were copepods and cladocerans, with some copepod species as subdominant.

- There were 477 individuals counted during this period:
    - 283 cladocerans, 194 copepods

Rotifers and cladocerans displayed seasonal changes in dominance, and each seasonally fluctuated starting in spring. Cladocerans and rotifers were also collected in summer and fall. Several copepod species were subdominant in early spring and into summer. Several copepod species were dominant in summer, while other copepods were dominant in spring and subdominant in fall.

The zooplankton community presented the picture of a lake transitioning to eutrophic when considered relative to the algal, phosphorus, and nitrogen values for Rice Lake. The seasonal fluctuations, displaying a diverse and abundant nano-plankton and net-plankton of all three dominant groups, indicated a fairly eutrophic lake. The five genera of rotifers, three genera of cladocerans, and two genera of copepods identified during the sample periods were relatively common, and the majority were not classified as invasive or exotic.

TABLE 8. MOST COMMON (NANO) ZOOPLANKTON BY DATE IN RICE LAKE FROM APRIL 2011 TO MARCH 2012.

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 28	Rotifer	*Polyarthra remata*	Rotifer	*Filinia terminalis*	Copepod	Nauplii
June 17	Cladoceran	*Bosmina longirostris*	Copepod	*Senecella calanoides*	Copepod	Nauplii
October 19	Rotifer	*Kertella cochlearis*	Rotifer	*Notholca* spp.	Cladoceran	*Daphnia schodleri*
March 4	Rotifer	*Filinia terminalis*	Cladoceran	*Bosmina longirostris*		

TABLE 9. MOST COMMON (NET) ZOOPLANKTON BY DATE IN RICE LAKE FROM APRIL 2011 TO MARCH 2012.

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 28	Copepod	Cyclopoid copepodite				
June 17	Copepod	*Senecella calanoides*	Cladoceran	*Daphnia schodleri*	Cladoceran	*Ceriodaphnia spp.*
October 19	Cladoceran	*Daphnia pulex*	Copepod	*Senecella calanoides*	Copepod	Cyclopoid copepodite
March 4						

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

During the 2012 aquatic plant survey of Rice Lake, eighty-two percent (88 of 107) of sites sampled had vegetative growth. Of the sampled sites within Rice Lake, the average depth was 6 feet, with a maximum depth of 13 feet. Twenty-two species of aquatic plants were found in Rice Lake (Table 10), with the greatest diversity located in the shallows around the perimeter of the lake.

TABLE 10. AQUATIC PLANTS IDENTIFIED IN THE AQUATIC PLANT SURVEY OF RICE LAKE, 2012.

Common Name	Scientific Name	Coefficient of Conservatism Value (C value)
Emergent Species		
softstem bulrush	*Schoenoplectus tabernaemontani*	4
common bur-reed	*Sparganium eurycarpum*	5
broad-leaved cattail	*Typha latifolia*	1
wild rice	*Zinzania sp.*	8
Floating Leaf Species		
small duckweed	*Lemna minor*	4
forked duckweed	*Lemna trisulca*	6
spatterdock	*Nuphar variegata*	6
white water lily	*Nymphaea odorata*	6
Submergent Species		
coontail	*Ceratophyllum demersum*	3
muskgrass	*Chara*	7
waterwort	*Elatine minima*	9
northern water-milfoil	*Myriophyllym sibiricum*	6
slender naiad	*Najas flexilis*	6
leafy pondweed	*Potamogeton foliosus*	6
white-stem pondweed	*Potamogeton praelongus*	8
flat-stem pondweed	*Potamogeton zosteriformis*	6
whitewater crowfoot	*Ranunculus aquatilis*	8
sago pondweed	*Stuckenia pectinata*	3
flat-leaf bladderwort	*Utricularia intermedia*	9
small bladderwort	*Utricularia minor*	10
common bladderwort	*Utricularia vulgaris*	7

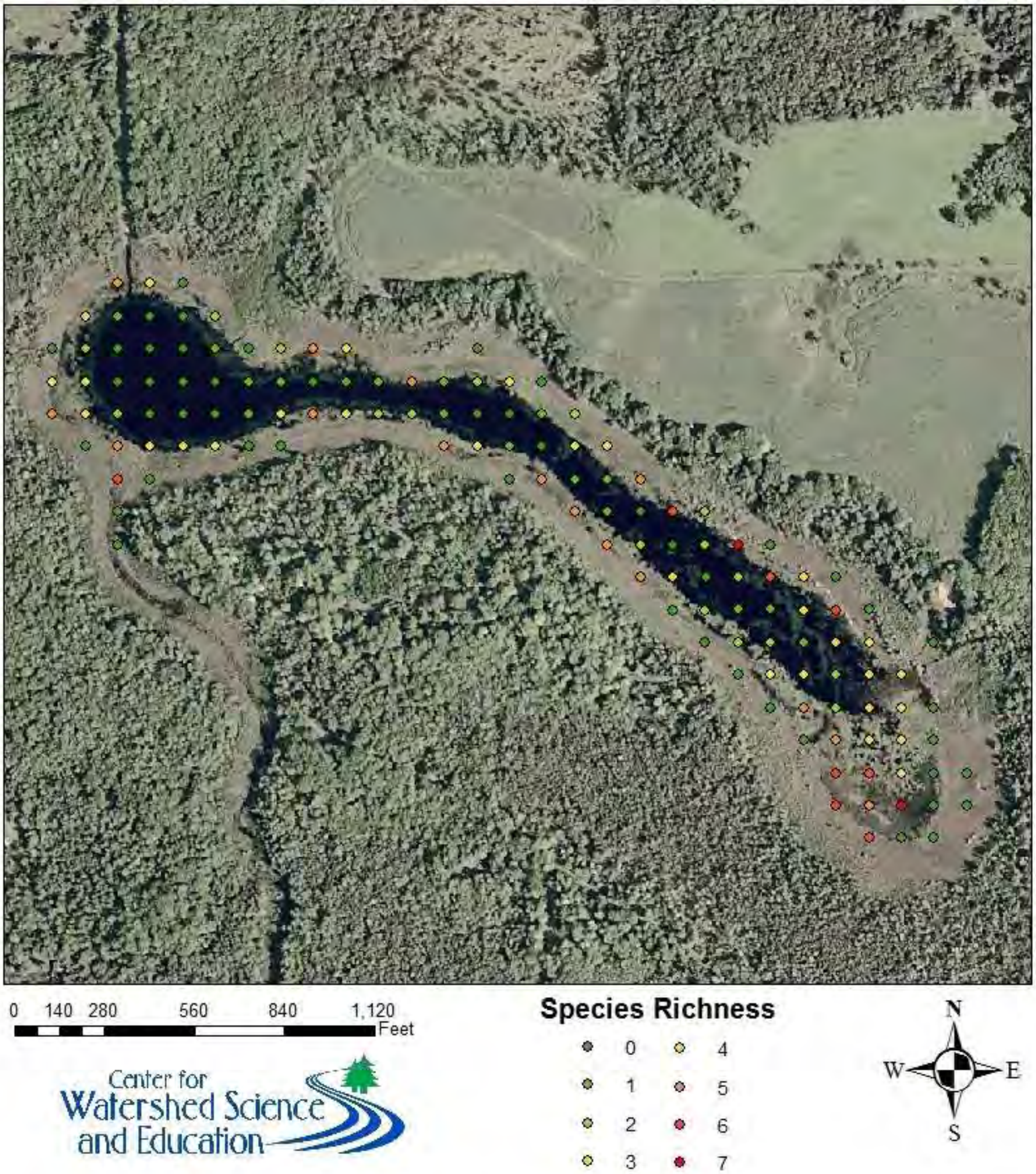

FIGURE 15. SPECIES RICHNESS AT AQUATIC PLANT SAMPLING SITES IN RICE LAKE, 2012.

Figure 15 shows the number of species that were identified at each sampling site. The twenty-two total species within Rice Lake ranked it fifth out of the eleven lakes within the Eastern Marathon County Lakes Study.

The dominant plant species in the survey was coontail (*Ceratophyllum demersum*), followed by flat-stem pondweed (*Potamogeton zosteriformis*) and white water lily (*Nymphaea odorata*). Coontail offers an important food source to a wide range of waterfowl species. A number of invertebrates and fish use the bushy stems and stiff whorls of leaves as habitat, especially in the winter when other aquatic plants have died back. Flat-stem pondweed also provides a food source for waterfowl. This native and widespread aquatic plant provides cover and grazing opportunities for fish. The seeds produced by white water lily are also a food source for waterfowl. The broad, floating leaves of the plant provide shade and shelter to fish and other species (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 Rice Lake was 26.2. This value was average compared to the other lakes in the Eastern Marathon County Lakes Study.

Rice Lake is home to six species of high-quality aquatic plants with C values of 8 or greater (Table 10). These species included small bladderwort (*Utricularia minor,* 10), flat-leaf bladderwort (*Utricularia intermedia,* 9), waterwort (*Elatine minima,* 9), wild rice (*Zinzania* spp., 8), white-stem pondweed (*Potamogeton praelongus,* 8), and white water crowfoot (*Ranunculus aquatilis,* 8). No species of special concern in Wisconsin were found in Rice 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. Rice Lake had a SDI value of 0.87. This represents slightly above-average biodiversity when compared to the other lakes in the Eastern Marathon County Lakes Study.

During the aquatic plant survey of Rice Lake, no non-native aquatic plant species were found. 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 Rice Lake can be characterized as having good species diversity. The wetlands surrounding Rice Lake provide excellent habitat and an incredible variety of plant species. These wetlands also contribute to the dark color of the water, which limits light penetration and inhibits plant growth deeper in the lake. The habitat, food source, and water quality benefits of the diverse plant community in and around Rice Lake should be the focal points in decision-making concerning future lake management strategies.

CONCLUSIONS AND RECOMMENDATIONS

A sustainable fishery is one that is in balance with the lake's natural ability to support the fish community, and is adaptable to reasonable fishing pressures without additional stocking or input. A healthy fish community has a balance between predator and prey species, and each species of fish has different needs in order to flourish, including sufficient food, habitat, appropriate nesting substrate, and water quality.

- During the 2011 survey of the fishery in Rice Lake, ten species of fish were captured: black crappie, bluegill, brown bullhead, golden shiner, largemouth bass, central mudminnow, northern pike, pumpkinseed, yellow bullhead, and yellow perch.
- Of the species identified in the 2011 survey, four had not been identified in past surveys in Rice Lake. This may be due to differences in survey methodology.
- Two species identified in earlier surveys were not identified in the 2011 survey: black bullhead and white sucker.
- Bluegills were the most abundant species in the 2011 survey; maximum length of this species was 8.5 inches. Although infrequently encountered, northern pike reached 30.8 inches.
- Crayfish were not encountered during the 2011 survey period.
- Substrate in Rice Lake is soft muck. In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build nests on soft bottoms. Depressions are deepened until small amounts of coarser substrate, or fragments of snail shells, accumulate in the bottom of the nests. In areas of soft substrate, largemouth bass are also reported to nest on coarse woody habitat swept clear of sediments.
- Coarse woody habitat (CWH) was not present in Rice Lake during the survey period. The addition of stable CWH cover would benefit the fish community and other animals, like turtles for warming and birds for perching. Logs and branches that are added to the lake to enhance CWH should be secured to the shoreline to ensure that they do not sink into the soft substrate present around the lake.
- The near-shore areas of Rice Lake are densely vegetated in the summer and fall months by lily pads and coontail, which provide protective cover to fish and a variety of aquatic life.

Overall, the aquatic plant community in Rice Lake can be characterized as having good species diversity. The wetlands surrounding Rice Lake provide excellent habitat and an incredible variety of plant species. These wetlands also contribute to the dark color of the water, which limits light penetration and inhibits plant growth deeper in the lake. The habitat, food source, and water quality benefits of the diverse aquatic plant community in and around Rice Lake should be the focal points in decision-making concerning future lake management strategies.

- Twenty-two species of aquatic plants were found in Rice Lake, with the greatest diversity located in the shallows around the perimeter of the lake.
- Rice Lake is home to six species of high-quality aquatic plants with C values of 8 or greater: small bladderwort (*Utricularia minor,* 10), flat-leaf bladderwort (*Utricularia intermedia,* 9), waterwort (*Elatine minima,* 9), wild rice (*Zinzania* spp., 8), white-stem pondweed (*Potamogeton praelongus,* 8), and white water crowfoot (*Ranunculus aquatilis,* 8). No species of special concern in Wisconsin were found in Rice Lake.

- Non-native aquatic plant species were not found during the aquatic plant survey of Rice Lake; however, curly-leaf pondweed (*Potamogeton crispus*) had been identified in a 2010 survey. Curly-leaf pondweed can behave as a part of the aquatic plant community, but it can also become aggressive and invasive. This non-native species grows under the ice during late winter and early spring and typically begins to die back in late June and early July. This dieback releases nutrients into the water just as other species of aquatic plants and algae begin to grow. The input of nutrients fuels algal blooms and excessive plant growth. Action should be taken to reduce the populations in Rice Lake to reduce the spread in both Rice Lake and its downstream neighbor, Pike Lake.
- The amount of disturbed lake bed from raking or pulling of plants should be minimized, since these open spaces are ideal for aquatic invasive plants to become established.
- Boats and trailers that have visited other lakes can be a primary vector for the transport of aquatic invasive species (AIS). Volunteer boat inspectors at the boat landing, trained through the Clean Boats Clean Waters (CBCW) program, can help prevent new AIS introductions.

In Marathon County lakes, there are three dominant groups of algae: blue-green algae, green algae, and diatoms.

- In Rice Lake, blue-green algae exhibited a strong pattern of algal community dominance during 2011 and 2012. This pattern and the strength of the dominance are typical of a very nutrient-enriched, eutrophic lake. The blue-green algal species found in Rice Lake are larger forms (colonial and filamentous) that are undesirable and mostly uneaten by consumers in the aquatic food web.
- Similarly, many of the green algae present were filamentous and difficult to consume. The larger green algal filaments provide significant surface area for colonization by many of the small, attached blue-green algae species.
- The diatom species identified are common in nutrient rich, eutrophic water and their colonial form decreases their consumption.

The interdependence of algae, zooplankton, and young fish as predators and prey form the primary food web in most lakes. Zooplanktons 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 zooplanktons 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 in Rice Lake identified during the sample periods were relatively common and the majority of those were not classified as invasive or exotic. Some of the non-native and invasive zooplanktons are much larger in size than native zooplanktons; therefore, non-native zooplanktons can disturb the fishery in a lake because they are often too large to fit in the mouth of young fish.
- The seasonally-fluctuating zooplankton community, displaying diversity and abundance, suggested that Rice Lake is a fairly eutrophic lake.

Many water quality indicators suggest that Rice Lake is a nutrient-rich lake. Similar to Rice Lake, nutrient-rich lakes exhibit algal blooms and insufficient oxygen to support some aquatic organisms, including some species of fish. These indicators included water analyses, physical measures made in the lake, and the composition of the algal and zooplankton communities.

- During the study, dissolved oxygen concentrations in the winter dropped below levels needed to maintain many sportsfish; however, some fish may move to Pike Lake prior to times of stress. Spikes of dissolved oxygen were observed during summer months at depths of 4-8 feet, indicating production of oxygen by algal blooms.
- Water clarity measurements taken in Rice Lake were considered fair. The poorest clarity occurred in September.
- Total phosphorus concentrations in Rice Lake ranged from a high of 82 μg/L in April 2012 (following spring runoff) to a low of 23 μg/L in February 2011. The summer median total phosphorus concentrations were 53 μg/L and 23.5 μg/L in 2011 and 2012, respectively. Concentrations in 2011 exceeded Wisconsin's phosphorus standard of 40 μg/L for shallow drainage lakes.
- During the study, inorganic nitrogen concentrations in samples collected during the spring in Rice Lake averaged 0.8 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, so owners of private wells should have their well water tested to determine if nitrate concentrations are safe for consumption.
- Monitoring should be conducted in Rice Lake for water clarity, phosphorus, chlorophyll *a*, and inorganic nitrogen to evaluate changes over time. The monitoring strategy should be developed to include summer samples and spring/fall overturn samples. Dissolved oxygen should be monitored during periods of ice cover.

Rice Lake's surface and groundwater watersheds provide most of the water to the lake. Nearly half of the land use in the surface watershed is forested land. Agriculture is also a dominant land use, comprising 35% of the surface watershed. Forest and agriculture are also dominant in the groundwater watershed, each comprising approximately 40% of the land use.

- Identifying and taking steps to improve water quality in Rice Lake will be aided by understanding the sources of phosphorus to the lake and identifying those that are manageable. Although forest lands comprised the greatest amount of land in the watershed, modelling results indicated that agriculture had the greatest percentage of phosphorus contribution from the watershed to Rice Lake. Impacts to the lake can be reduced by employing water quality-based best management practices on the landscape.
- 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.

Rice Lake has approximately 8,415 feet of shoreline. The shoreland survey showed that 8,371 linear feet of shoreline was classified as having a grasses/forbs buffer depth of greater than 35 feet (inland from the water), which is the minimum depth required by Wisconsin and Marathon County shoreland zoning ordinances. Similar results were observed for the shrubs buffer. Trees represented the least abundant vegetative layer around the lake, with 2,238 linear feet classified as having a buffer depth greater than 35 feet. There were no manmade features along the shoreline at the time of the survey. Most of Rice Lake's shoreline exists in a natural condition with very little human modifications.

- Although Rice Lake's shoreland is in good shape now, changes can easily occur as development takes place. Efforts to minimize future impacts to Rice Lake should include:
  - Informing new and existing property owners about the importance of healthy shorelands and ways they can protect them.
  - Informing interested property owners about options for protecting undisturbed shoreland, such as conservation easements. Conservation easements allow property owners to determine how their land will be managed and which parts of the property will be protected, typically resulting in lower taxes. Unless public funds are used for the purchase of the easement, there is no requirement to allow access to the public.
  - Ensuring that prospective developers have the information needed 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."