Eastern Marathon County Lakes Study

Lilly 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 Lilly 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 LILLY 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. Lilly Lake is located in the township of Reid, east-northeast of Bevent. There are no boat launches on Lilly Lake. Lilly Lake is an 85 acre seepage lake with groundwater and surface runoff contributing most of its water. The maximum depth in Lilly Lake is 5.8 feet; the lakebed has a gradual slope (Figure 1). Its bottom sediments are mostly muck with sand and rock dispersed throughout.

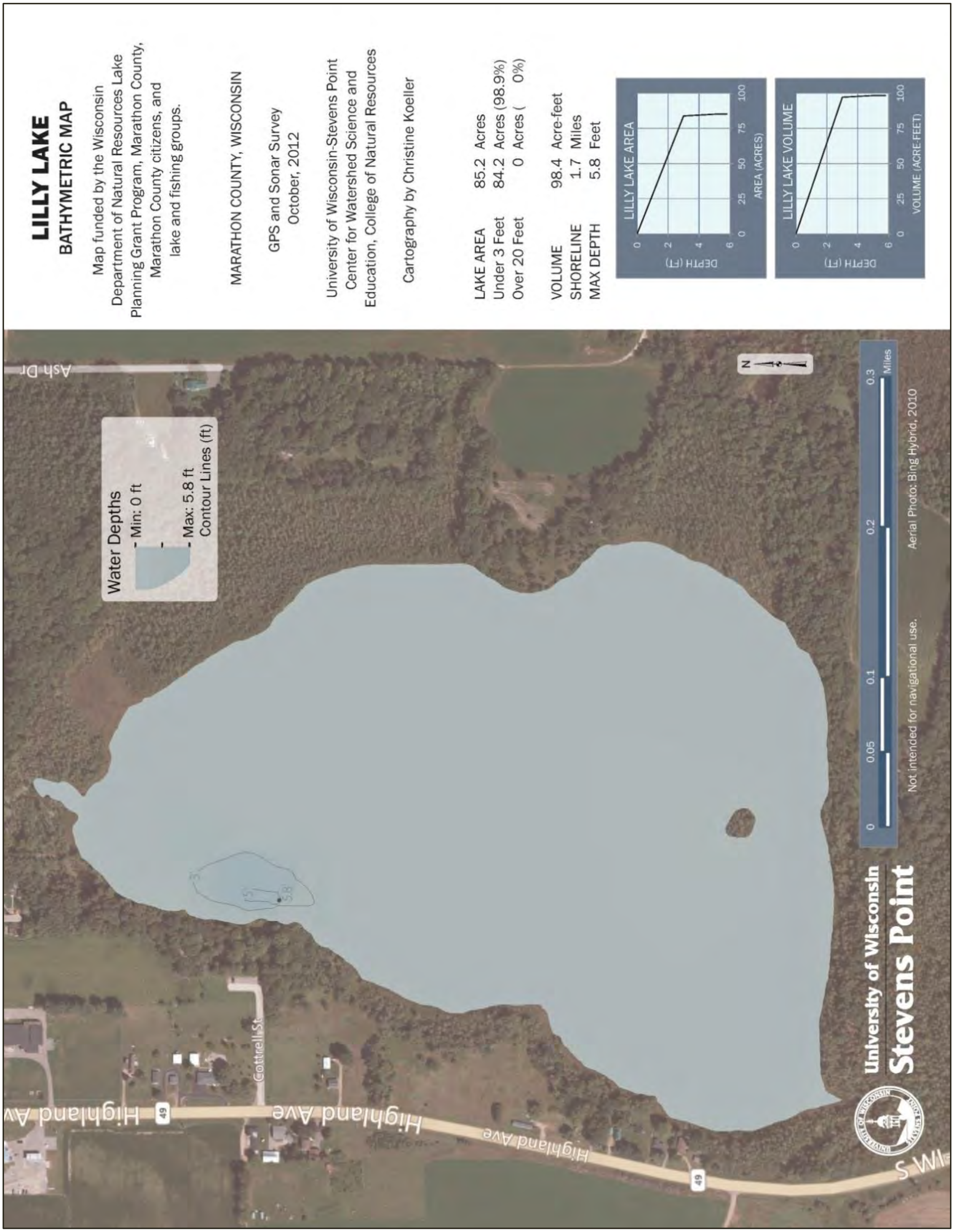


FIGURE 1. CONTOUR MAP OF THE LILLY LAKE LAKEBED.

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

The water quality in Lilly 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 Lilly 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 Lilly Lake is called a surface watershed. Groundwater also feeds Lilly Lake; its land area (groundwater watershed) is different from the surface watershed.

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

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

A variety of land management practices can be put in place to help reduce impacts to our lakes. Some practices are designed to reduce runoff. These include protecting/restoring wetlands, installing rain gardens, swales, and rain barrels, and routing drainage from roads and parking lots away from the lake. Some practices 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 Lilly Lake is approximately 1,639 acres (Figure 2). The dominant land uses in the watershed are agriculture and forests. The lands closest to the lake often have the greatest impact on water quality and habitat; land uses near Lilly Lake's shoreland include forests and wetlands.

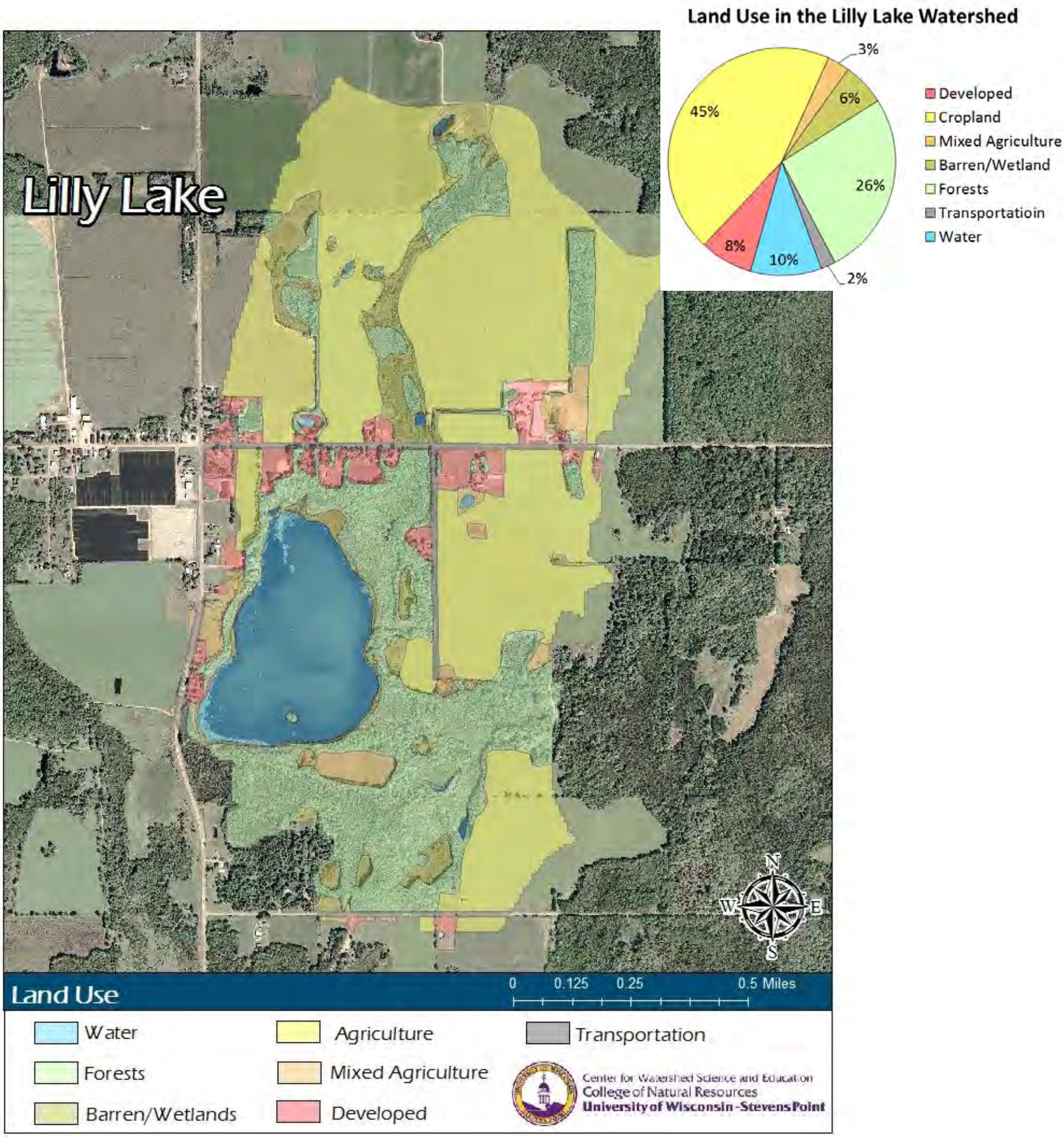
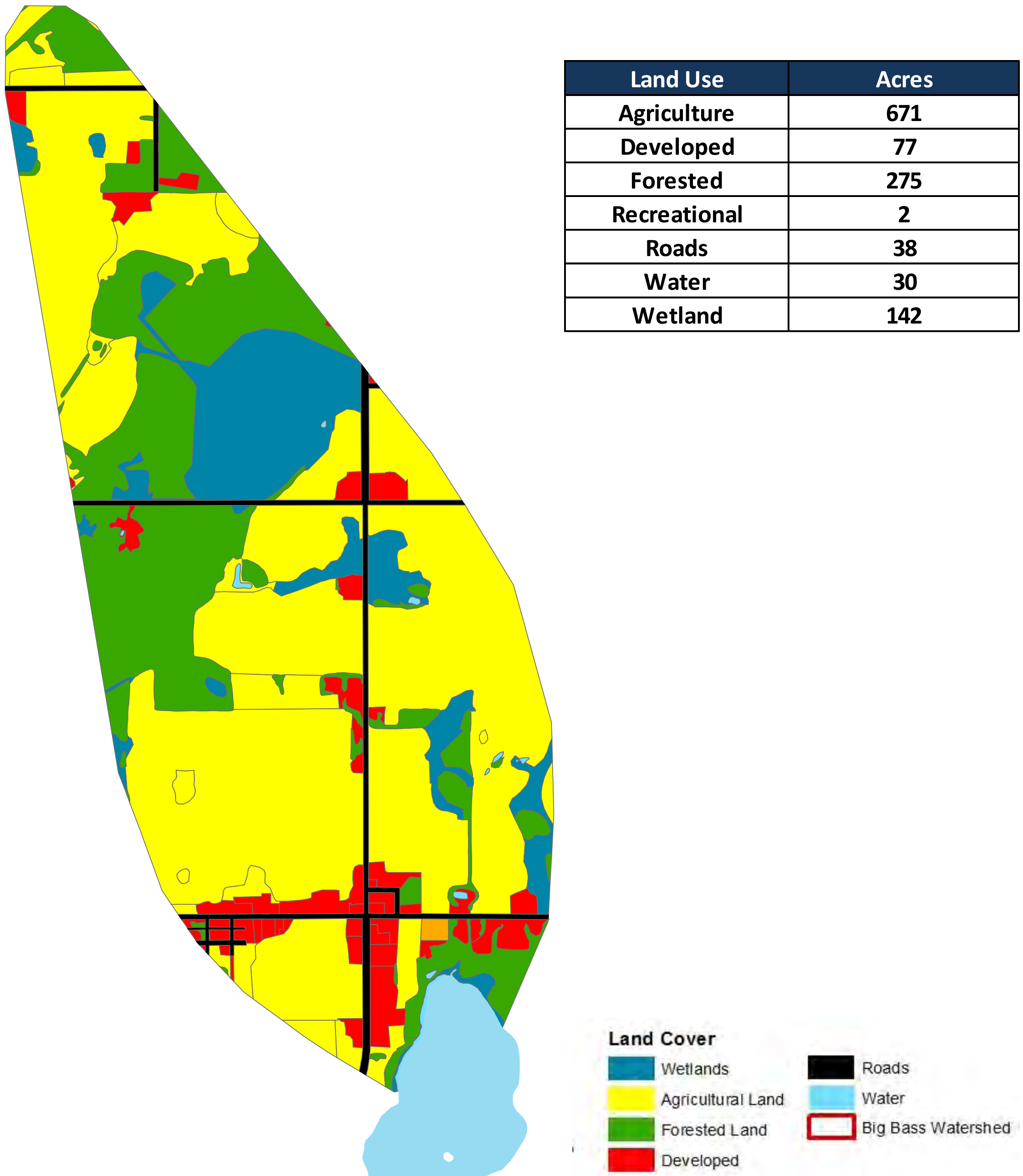


FIGURE 2. LAND USE IN THE LILLY LAKE SURFACE WATERSHED.

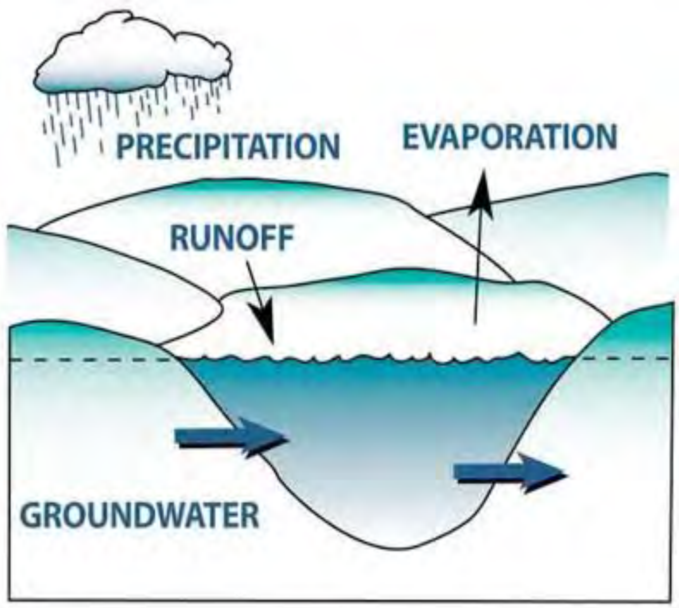
The groundwater watershed is the area where precipitation soaks into the ground and travels below ground towards the lake. Lilly Lake's groundwater watershed is approximately 1,236 acres (Figure 3). The primary land uses in the Lilly Lake groundwater watershed are agriculture and forests. In general, the land adjacent to the lake where most of the groundwater is entering has the greatest immediate impact on water quality. Forests and wetlands are adjacent to Lilly Lake where the groundwater enters.



Land Use	Acres
Agriculture	671
Developed	77
Forested	275
Recreational	2
Roads	38
Water	30
Wetland	142

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

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



The source of a lake's water supply is important in determining its water quality and in choosing management practices to preserve or influence that quality. Lilly Lake is classified as a seepage lake. Water enters and leaves the lake primarily through groundwater, surface runoff and direct precipitation (Figure 4). Seepage lakes have higher concentrations of minerals such as calcium and magnesium, which are picked up by groundwater moving through soil and rock. Lilly Lake is considered hard, which allows it to be more productive, hosting a greater variety of fish and other aquatic biota than softer counterparts. Seepage lakes are vulnerable to contamination moving towards the lake in the groundwater. Examples for Lilly Lake may include septic systems, agriculture, and road salt.

FIGURE 4. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN A SEEPAGE LAKE.

The geologic composition that lies beneath a lake has the ability to influence the temperature, pH, minerals, and other properties of the 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 Lilly Lake dissolve, making the water hard. The average hardness for Lilly Lake during the 2010-2012 sampling period was 144 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 121 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 LILLY LAKE, 2010-2012.

Lilly Lake	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as CaCO3)	Color SU	Turbidity (NTU)
Average	121	31.4	16.3	144	19.3	2.5

Chloride concentrations, and to lesser degrees sodium and potassium concentrations, are commonly used as indicators of how strongly a lake is being impacted by human activity. The presence of these compounds where they do not naturally occur indicates the movement of pollutants from the landscape to the lake.

Chloride, sodium, and potassium concentrations in Lilly Lake were exceedingly high for a lake in central Wisconsin. Lilly Lake had a high average chloride concentration of 51.5 mg/L over the monitoring period (Table 2). Chloride does not affect plant and algae growth and is not toxic to aquatic organisms at these levels, but it does suggest unwanted compounds are entering the lake. No septic systems are located immediately adjacent to the lake, but other chloride sources include animal waste, potash fertilizer, and road-salting chemicals. The average potassium concentration, 19.7 mg/L, was also extremely high for lakes in Wisconsin. Atrazine (DACT), an herbicide commonly used on corn, was detected (0.12 ug/L) in one of the two samples that were analyzed from Lilly Lake. The presence of this chemical suggested that agricultural activities in the surrounding area were impacting water quality. Some toxicity studies have indicated that reproductive system abnormalities can occur in frogs at these levels (Hayes et al., 2003 and Hayes et al., 2001).

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

Lilly Lake	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium			1.90	<.75	0.75 - 1.5	>1.5
Chloride			51.5	<3	3.0 - 10.0	>10
Sodium			19.7	<2	2.0 - 4.0	>4

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

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

Water temperature and dissolved oxygen were measured in Lilly Lake from the surface to the lake bottom at the time of sample collection in the 2010-2012 study. As is expected for a shallow lake, the temperature in the lake did not vary much from top to bottom on a given date (Figure 5). Data collected during late winter 2011 and 2012 showed freezing temperatures at the surface with a gradual warming with depth to about 4C (39°F). Water temperatures during the study varied from near freezing to approximately 28C (82°F) during the hottest parts of summer in late July.

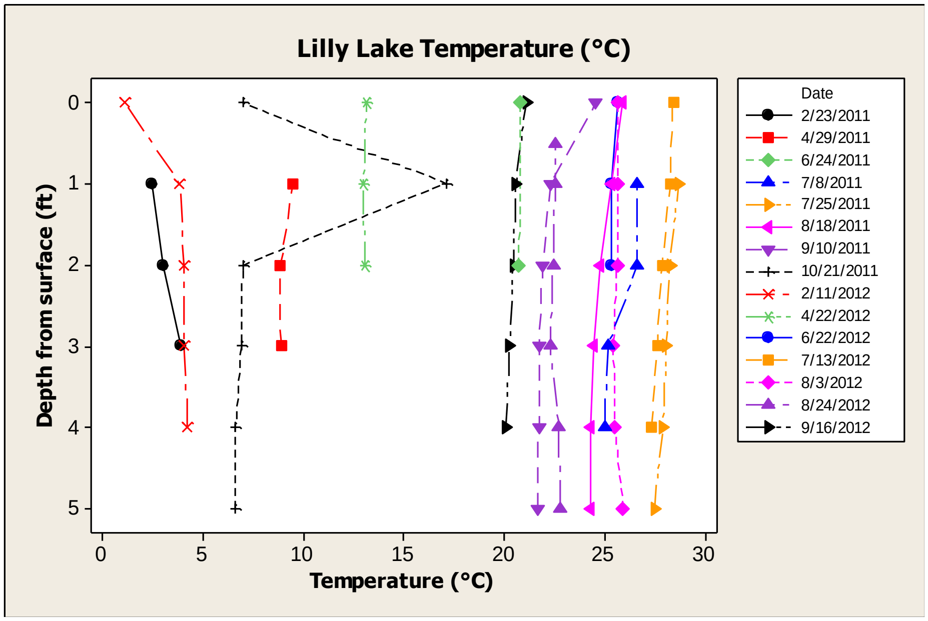


FIGURE 5. TEMPERATURE PROFILES IN LILLY LAKE, 2011-2012.

Similar to the temperature profiles, dissolved oxygen data indicated that Lilly Lake was mixed throughout much of the year (Figure 6). Dissolved oxygen concentrations were above 5 mg/L throughout the water column during most sampling events, with three exceptions: in August and September 2011, only the upper 3 feet of water had concentrations above 5 mg/L, and in February 2011 only the upper one foot of water contained dissolved oxygen above 5 mg/L.

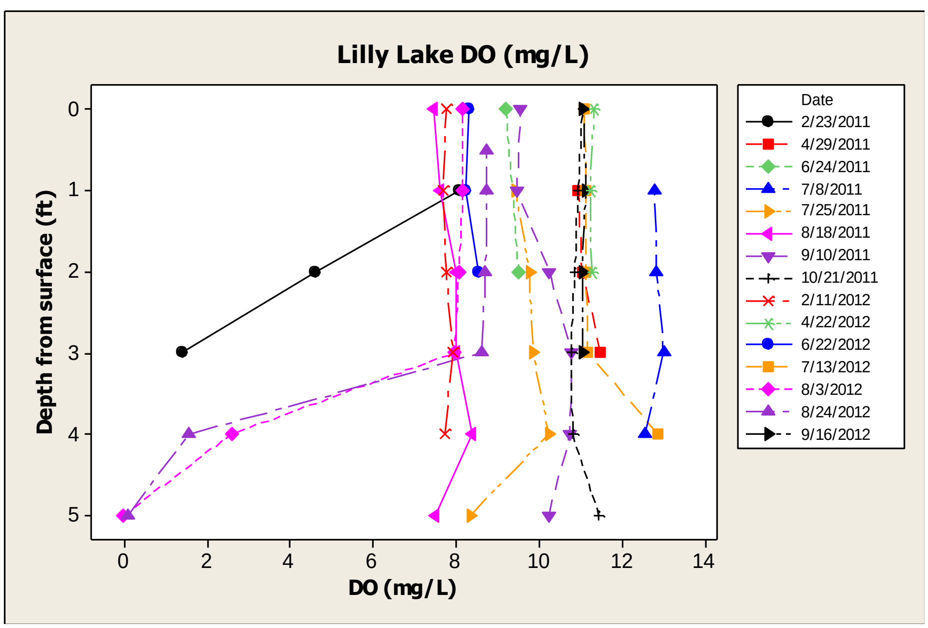
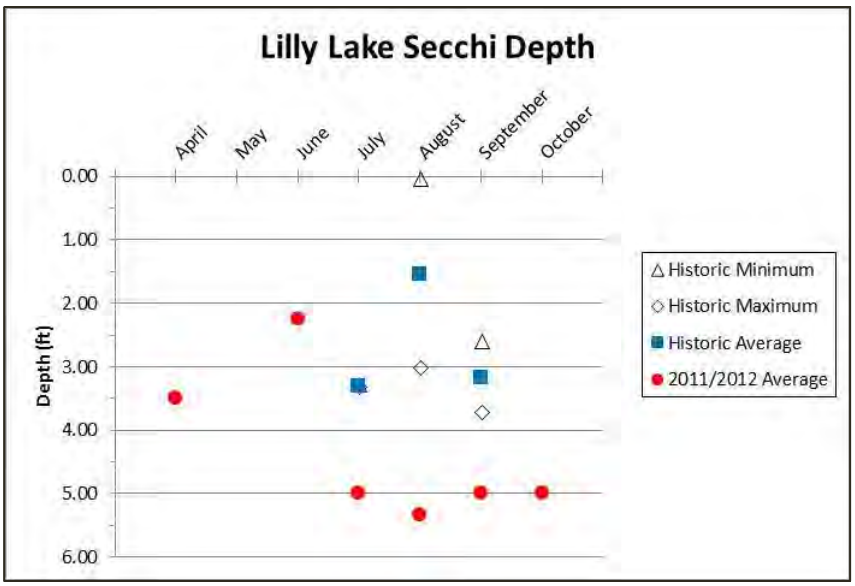


FIGURE 6. DISSOLVED OXYGEN PROFILES IN LILLY LAKE, 2011-2012.

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

In Lilly Lake, the color index was low (Table 1). The variability in water clarity in Lilly Lake was primarily due to fluctuating algae concentrations and re-suspended sediment following storms. The water clarity measured in Lilly Lake during the study was considered poor. The average water clarity measurements in Lilly Lake during the study were poorest in June and best in July-October (Figure 7). Past water clarity data was submitted sporadically between 1999 and 2010. When compared to this data, the average water clarity measured during the study was better.



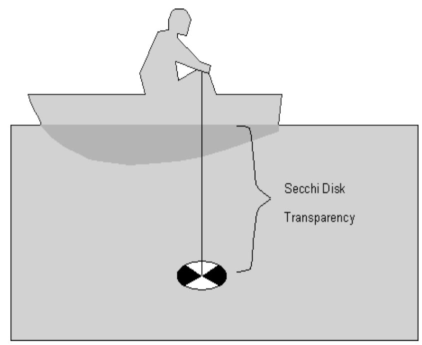


FIGURE 7. AVERAGE MONTHLY WATER CLARITY IN LILLY LAKE, 2010-2012.

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 Lilly Lake were quite variable, ranging from a high of 83 μg/L in April 2012 (following spring runoff) to a low of 7 μg/L in August 2012 (Table 3). The summer median total phosphorus was 22.5 ug/L and 21 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 averaged 1.20 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 LILLY LAKE, 2010-2012.

Lilly Lake	Total Phosphorus (µg/L)			Dissolved Reactive Phosphorus (µg/L)			Total Nitrogen (mg/L)			Inorganic Nitrogen (mg/L)			Organic Nitrogen (mg/L)		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Fall	17	21	27	3	9	14	1.77	1.90	2.02	0.49	0.62	0.74	1.03	1.28	1.53
Spring	19	51	83	4	5	6	1.84	2.02	2.20	0.90	1.20	1.50	0.70	0.82	0.94
Summer	7	21	31	4	4	4									
Winter	14	19	23	6	10	13	4.22	5.60	6.98	2.79	4.66	6.52	0.46	0.95	1.43

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Lilly 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. Agriculture comprised the greatest amount of land in the watershed and, based on water quality modeling results, had the greatest percentage of phosphorus contributions from the watershed to Lilly Lake (Figure 8). 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).

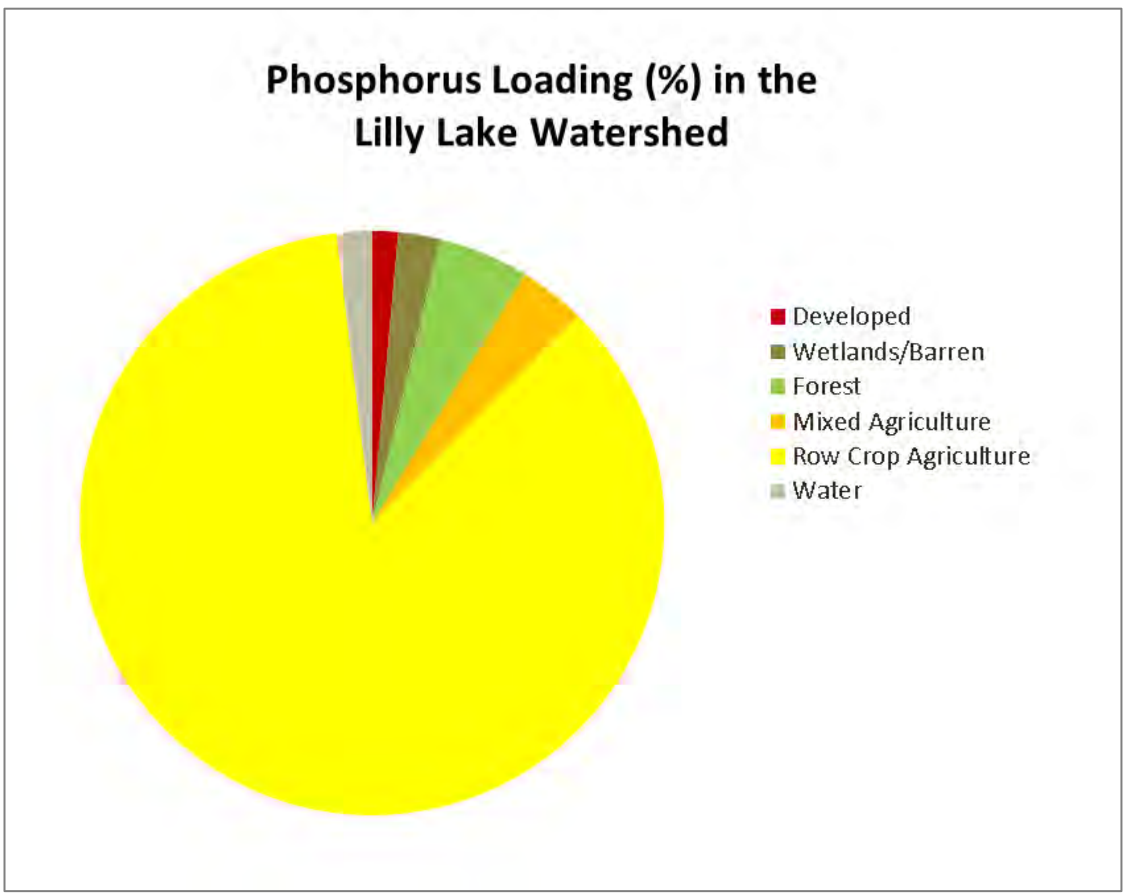


FIGURE 8. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE LILLY LAKE WATERSHED.

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

Lilly Lake Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.10	169	**10**	8-23	**2**
Developed	0.04	126	**8**	6-11	**1**
Wetland/Barren	0.09	102	**6**	9-27	**2**
Forest	0.04	439	**27**	20-35	**5**
Mixed Agriculture	0.27	53	**3**	14-38	**4**
Row Crop Agriculture	0.45	750	**46**	334-669	**87**
*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 Lilly Lake ranged from a high of 31 µg/L in July 2011 to a low of 0.5 µg/L in September 2012, with an average concentration of 7.65 µg/L.

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). Lilly Lake was dominated by diatoms and green algae during 2011 and 2012 (Figure 9). The algal community was composed of species usually found in mesotrophic waters. The blue-green algae were minor components of the community. The most common species of diatoms and green algae were unicellular or small colonial forms that are easy for most small consumers (invertebrates and fish) to ingest and digest. Additionally, these species are fairly palatable and nutritious. This should be able to support a decent fishery.

The story told by the algal community composition and density conflicts with those told by the total phosphorus value (relatively high) and the water clarity measures (relatively low). The latter data (total phosphorus and Secchi) point to a mildly eutrophic body of water, but the former data (algal community) predict a mildly to moderately mesotrophic lake. It is possible that these data are suggesting that Lilly Lake is seeing a slow improvement in water quality conditions, reflected first in the algae.

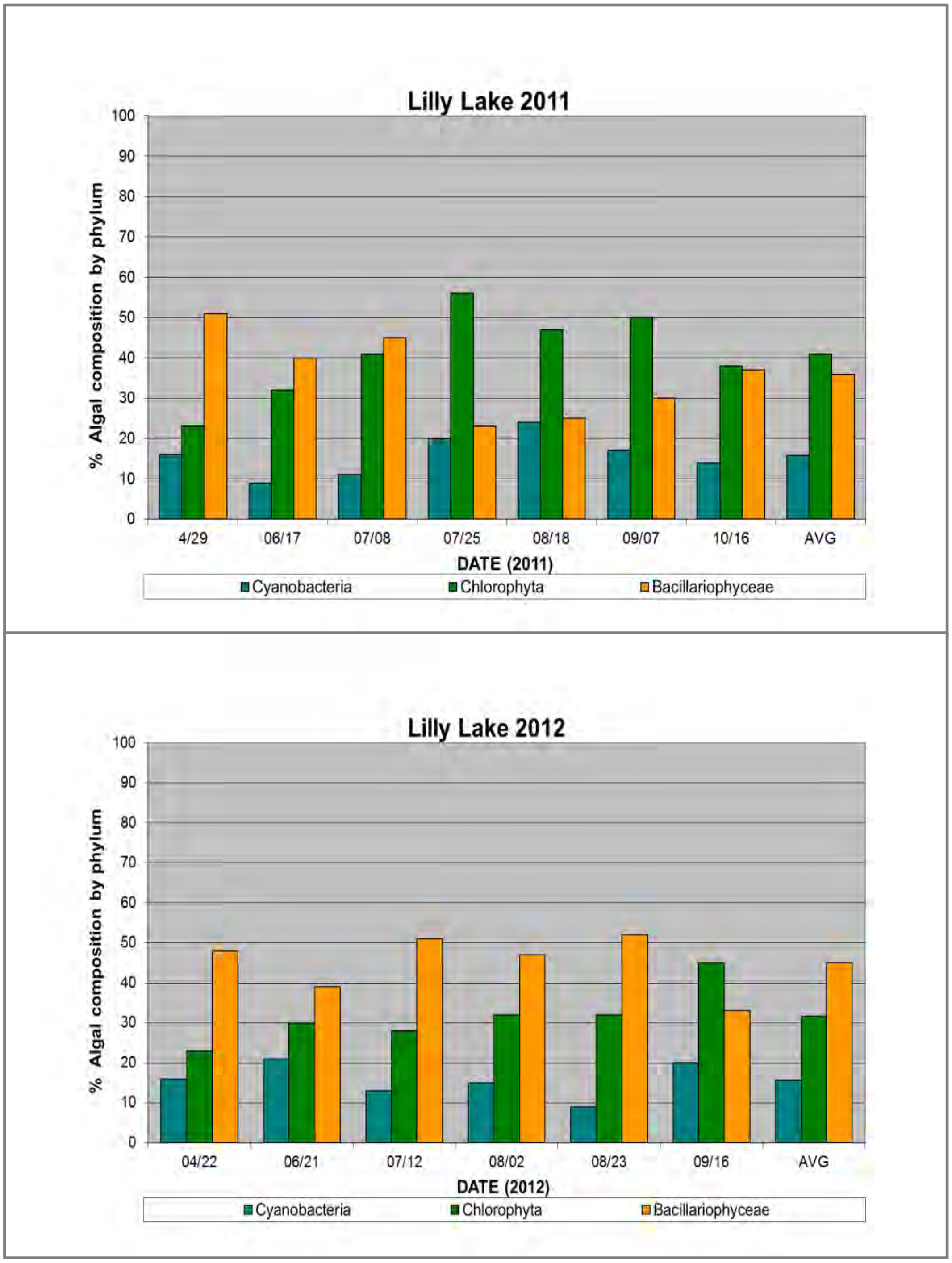


FIGURE 9. PERCENT ALGAL COMPOSITION OF LILLY LAKE, 2011-2012.

SHORELAND HEALTH

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

The addition of manmade features near the shoreland area can lead to more impervious surfaces. Runoff from driveways, rooftops, and buildings carries pollutants and sediments into the nearby lake. Minimizing the presence of impervious surfaces in the shoreland area can help reduce the amount of 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.

LILLY 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 Lilly Lake in Figure 11depict the depth of vegetation (inland from the water's edge) along Lilly 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.

Lilly Lake has approximately 8,141 linear feet of shoreline. The 2011 survey showed that there was adequate shoreland vegetation surrounding Lilly Lake. Most of Lilly Lake's shoreline has at least a 50 foot deep grass/forb buffer, which is greater than the minimum depth of 35 feet required by Wisconsin and Marathon County shoreland zoning ordinances. In contrast, the shrubs buffer along Lilly Lake is less than 15 feet in depth. Based on field observations, the limited shrubs buffer is offset by the abundance of dense grasses, forbs, and trees along the shoreline. A summary of the shoreland survey results for the vegetative categories are displayed in Figure 10. Although Lilly Lake's shoreland is in good shape now, changes can easily occur as development takes place. In order to minimize impacts to Lilly Lake 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.

On the same day the vegetation surveys were conducted, an assessment of disturbances was conducted around Lilly Lake. Surveyors paddled along the shoreline and documented artificial beaches, docks, rip-rap, seawalls, erosion, and any structures built near the water's edge (Figure 12). 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.

Most of Lilly Lake's shoreline exists in a natural condition with very few human modifications. There were no manmade features along the shoreline at the time of the survey of Lilly Lake. A total of four developed lots were present near Lilly Lake.

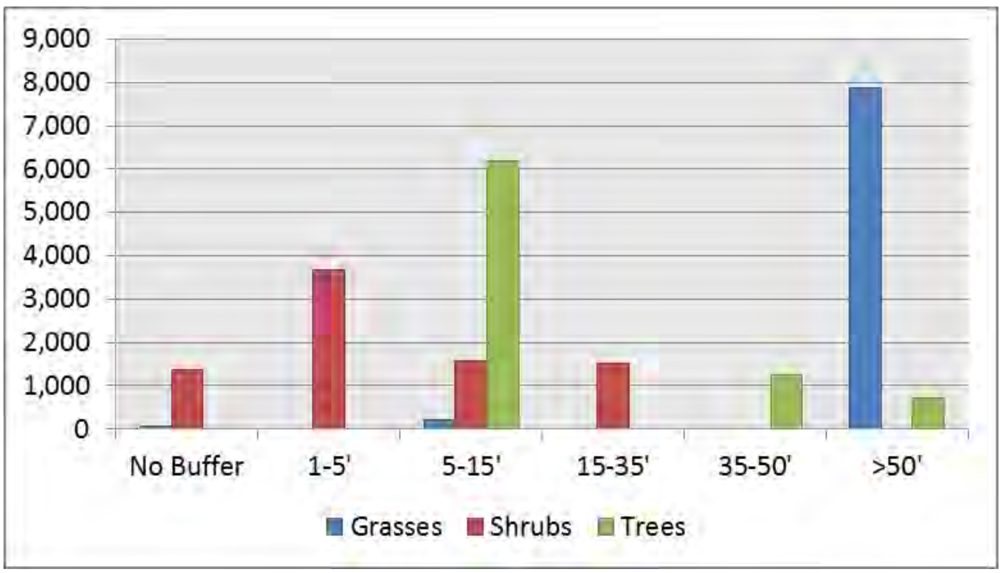


FIGURE 10. SHORELAND VEGETATION SURVEY RESULTS BY BUFFER DEPTH AROUND LILLY LAKE, 2011.

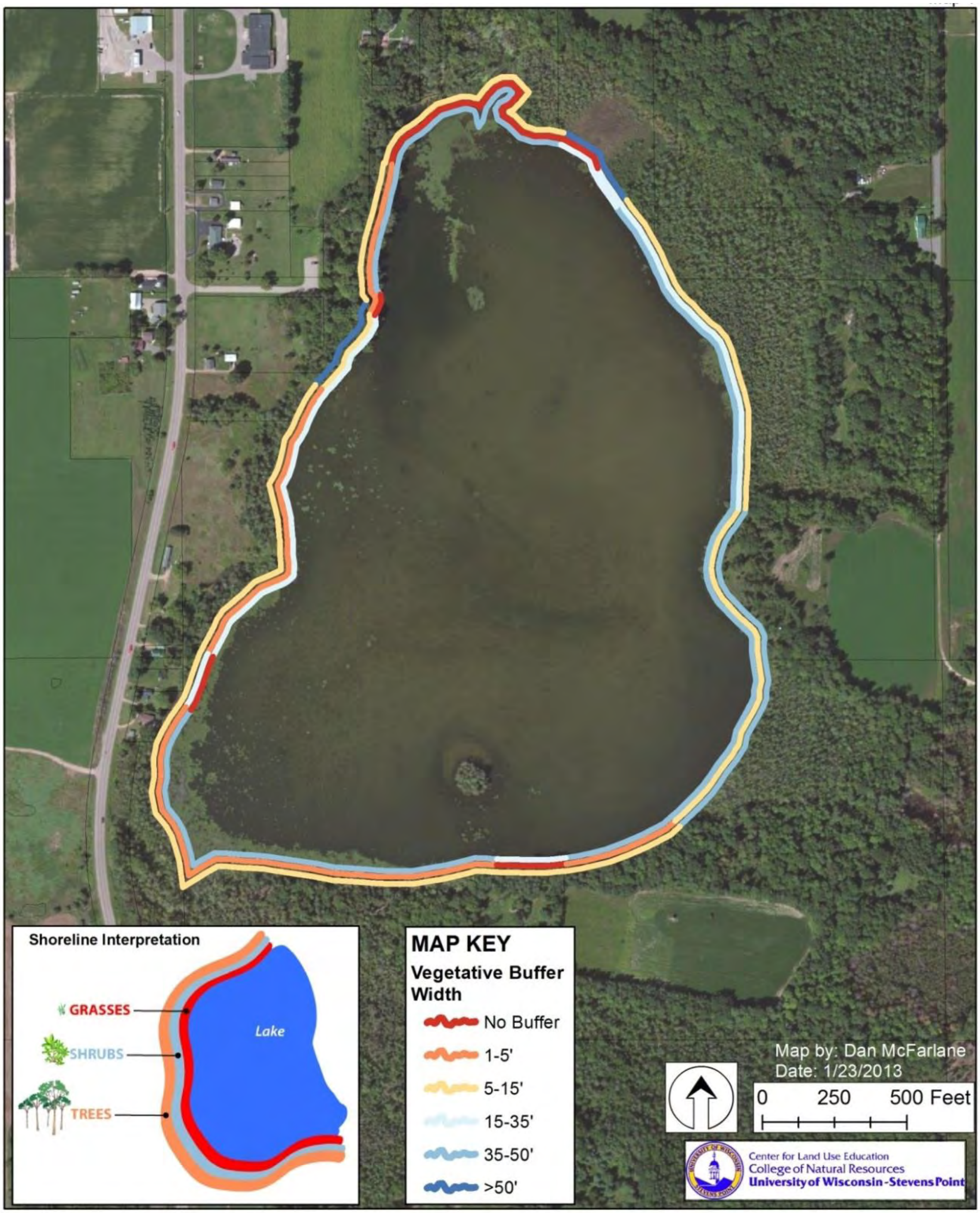


FIGURE 11. SHORELAND VEGETATION SURVEY AROUND LILLY LAKE, 2011.

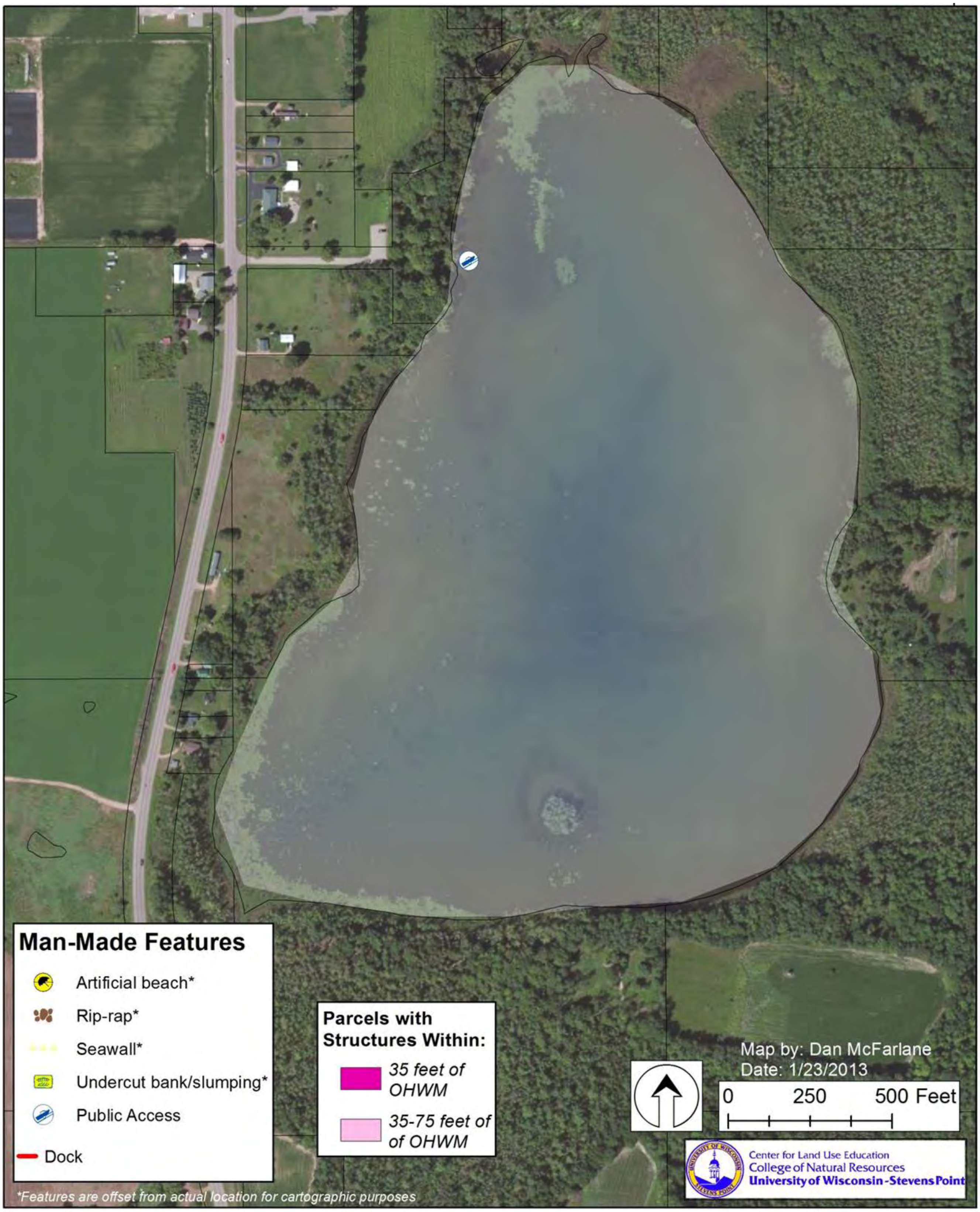


FIGURE 12. SHORELINE DISTURBANCE SURVEY OF LILLY LAKE, 2011.

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.

Lilly Lake supports a warm water fish community. In 2012, eight fish species were sampled (Table 5). According to Wisconsin Department of Natural Resources records that were available for review, these were the first fyke netting and seining surveys on Lilly Lake. Bluegill (*Lepomis macrochirus*) and young largemouth bass (*Micropterus salmoides*) were most abundant during the 2012 survey. Maximum bluegill length was 8.6 inches (Table 5). Largemouth bass did not exceed 4.0 inches. The presence of bluegill x pumpkinseed (*Lepomis gibbosus*) hybrid fish was also observed. Black crappie (*Pomoxis nigromaculatus*) reached a maximum of 10.6 inches. Least commonly found was yellow perch (*Perca flavescens*). Crayfish were not encountered during the sampling period.

TABLE 5. FISH SPECIES IN LILLY LAKE, 2012 SURVEY AND HISTORICAL WISCONSIN DEPARTMENT OF NATURAL RESOURCES RECORDS.

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	1.1	8.6	3.3	199
Largemouth Bass	0.8	4.0	1.4	103
Iowa Darter	1.1	2.4	1.8	29
Pumpkinseed	2.5	6.9	4.1	8
Black Crappie	2.5	10.6	7.1	8
Bluegill x Pumpkinseed hybrid	4.8	7.8	6.0	4
Yellow Perch	1.5	2.6	2.0	2
Northern Pike	26	26	26	1

There has been limited fishery management in Lilly Lake by fishery biologists with the Wisconsin Department of Natural Resources. Due to the shallow nature of Lilly Lake, dip netting was approved and opened to the public after reports of winter fish kills (1967 and 1975). After numerous reports of winter fish kills, the Lilly Lake Protection and Rehabilitation District filed a permit request to hydraulically dredge 44,000 cubic yards of material. The request was carried out and a five-foot hole remains near the public beach area of Elderon County Park. Fish stocking records for Lilly Lake do not exist in Wisconsin

Department of Natural Resources records. The ability to successfully manage the fish populations in Lilly Lake in the future will be limited because of its shallow nature and tendency to winterkill.

BOTTOM SUBSTRATE AND COARSE WOODY HABITAT

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

Bottom substrate and woody habitat were examined from the shoreline lakeward for a distance of 90 feet using side-scan sonar. Substrate in Lilly Lake is dominated by marl (95.5%) (Figure 13). In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build spawning 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 spawn on woody habitat swept clear of sediments. The presence of young sunfish during sampling indicated successful reproduction is occurring in Lilly Lake. Reproductive success of northern pike could not be determined with the limited sampling data collected.

Coarse woody habitat (CWH), including downed trees and logs, were sparse in Lilly Lake (Figure 13) compared to surrounding water bodies in the county. Woody structure is utilized by young prey fish and other aquatic organisms for foraging and protection. The fish community would benefit from the addition of CWH.

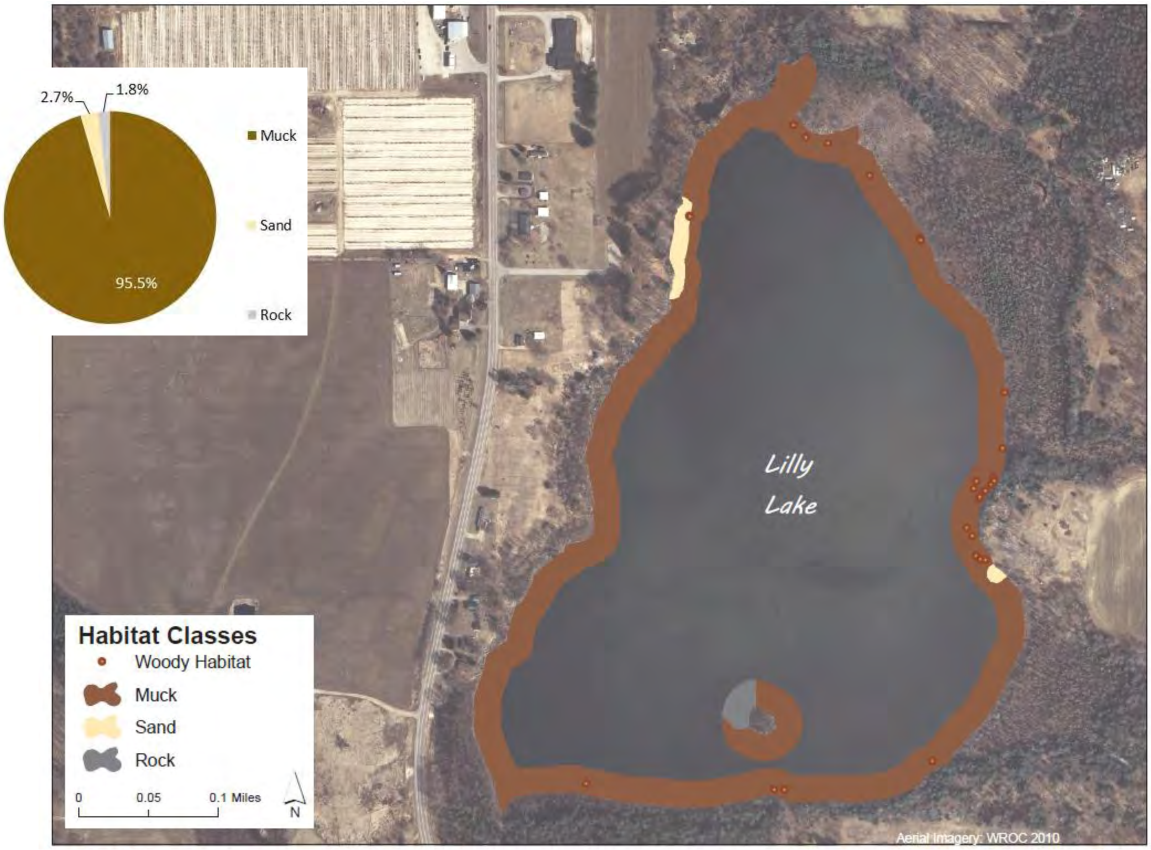
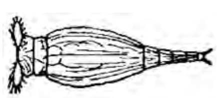


FIGURE 13. DISTRIBUTION OF SUBSTRATE AND COARSE WOODY HABITAT IN LILLY LAKE, 2012.

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, there are usually three dominant groups of zooplankton – **Rotifers** (microscopic wheel organisms), **Cladocerans** (water fleas), and **Copepods**. The various zooplankton groups and even species within these groups wax and wane during the ice-free season as algae, temperature and fish predation change.



Rotifer

www.revistadele

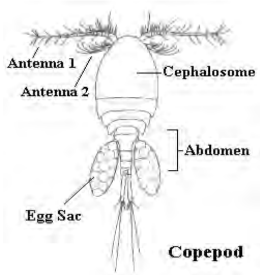
Rotifers are small invertebrate animals with simple body designs. They are usually not found uniformly throughout lakes, but congregate in areas of high food abundance (bacteria, algae, and other rotifers). Generally, a lake's trophic status influences, or can be predicted by, the abundance and diversity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

http://www.oocities.org

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

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

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



http://library.thinkquest.org

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 Lilly Lake was highly diverse for rotifers and moderately diverse for other zooplankton (Table 6, Table 7). 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 rotifers and copepods, with rotifer and cladoceran subdominants.

- There were 1,923 individuals counted during this period:
    - 994 rotifers, 207 cladocerans, and 722 copepods.

The dominant groups of net plankton were the copepod and cladocerans, with different species of copepods and cladocerans as subdominants.

- There were 465 individuals counted during this period:
    - 132 cladocerans and 334 copepods.

Rotifers were the dominant taxa in three of four sample periods during the 2011-12 season. These taxa dominated from early summer though winter before falling into subdominant positions in early spring. Numerous species of copepods were dominant in different parts of spring, summer and fall in both nano and net plankton samples. No net plankton were captured in winter sampling, either because of low abundance or an aversion to brightly-lit surface water. Cladocerans appeared more abundantly in the summer and fall.

The zooplankton community presented a picture of a mesotrophic lake when considered relative to the algal, phosphorus, and nitrogen values for Lilly Lake. The seven genera of rotifers, three genera of cladocerans, and two 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. The cyclopoid copepod *Acanthocyclops vernalis* is usually associated with warm, meso- or eutrophic lakes that contain significant amounts of loose sediment. A stable, little-changing zooplankton community dominated by rotifers copepods suggested that Lilly Lake is mesotrophic.

TABLE 6. MOST COMMON (NANO) ZOOPLANKTON BY DATE IN LILLY LAKE, APRIL 2011 TO MARCH 2012.

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 29	Copepod	Nauplii	Rotifer	*Keratella cochlearis*	Rotifer	*Polyarthra remata*
June 17	Rotifer	*Polyarthra remata*	Rotifer	*Asplanchna* spp.	Cladoceran	*Bosmina longirostris*
October 21	Rotifer	*Keratella cochlearis*	Rotifer	*Polyarthra vulgaris*	Copepod	Nauplii
March 9	Rotifer	*Polyarthra remata*	Copepod	Cyclopoid copepodite	Copepod	*Paracyclops fimbriatis poppei*

TABLE 7. MOST COMMON (NET) ZOOPLANKTON BY DATE IN LILLY LAKE, APRIL 2011 TO MARCH 2012.

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 29	Copepod	*Paracyclops fimbriatis poppei*				
June 17	Copepod	Nauplii	Cladoceran	*Ceriodaphnia* spp.	Cladoceran	*Bosmina longirostris*
October 21	Copepod	*Paracyclops fimbriatis poppei*	Cladoceran	*Bosmina longirostris*	Cladoceran	*Ceriodaphnia* spp.
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.

During the 2012 aquatic plant survey of Lilly Lake, seven species of aquatic plants were found (Table 8), with the greatest diversity located in the northern end of the lake (Figure 14). At the time of the survey, water temperatures in Lilly Lake were very warm and most aquatic plant growth had started to die back. This may have contributed to the low number of plant species found in the lake. The number of species within Lilly Lake ranked it last out of the eleven lakes in the Eastern Marathon County Lakes Study. Seventy percent (154 of 219) of the sampled sites had vegetative growth. Of the sampled sites within Lilly Lake, the average depth was 4 feet and the maximum depth was 6 feet.

The dominant plant species in the survey was coontail (*Ceratophyllum demersum*), followed by white water lily (*Nymphaea odorata*). Coontail offers an important food source for a wide range of waterfowl species. A number of invertebrate and fish species use the bushy stems and stiff whorls of leaves as habitat, especially in the winter when other aquatic plants have died back. The seeds of the white water lily provide food to waterfowl. The broad, floating leaves of this aquatic species offer shade and shelter to fish (Borman et al., 2001).

TABLE 8. AQUATIC PLANTS IDENTIFIED IN THE 2012 AQUATIC PLANT SURVEY OF LILLY LAKE.

Common Name	**Scientific Name**	**Coefficient of Conservatism Value (C Value)**
Emergent Species		
marsh cinquefoil		
broad-leaved cattail	*Typha latifolia*	1
Floating Leaf Species		
small duckweed	*Lemna minor*	4
white water lily	*Nymphaea odorata*	6
Submergent Species		
coontail	*Ceratophyllum demersum*	3
southern naiad	*Najas guadalupensis*	8
white water crowfoot	*Ranunculus aquatilis*	8

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 Lilly Lake was 12.9. This value was below average and was the lowest value for lakes within the Eastern Marathon County Lakes Study.

Of the aquatic plant species within Lilly Lake, two had a C value equal to or greater than 8. These high quality aquatic plants were southern naiad (*Najas guadalupensis*) and white water crowfoot (*Ranunculus aquatilis*). No species of special concern in Wisconsin were found in Lilly 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. Lilly Lake had a SDI value of 0.52. This represents below average biodiversity when compared to other lakes in the Eastern Marathon County Lakes Study.

All of the aquatic plant species observed during the aquatic plant survey of Lilly Lake were native species, which is desirable. Non-native aquatic invasive species can disturb an aquatic ecosystem and result in nuisance-level aquatic plant growth.

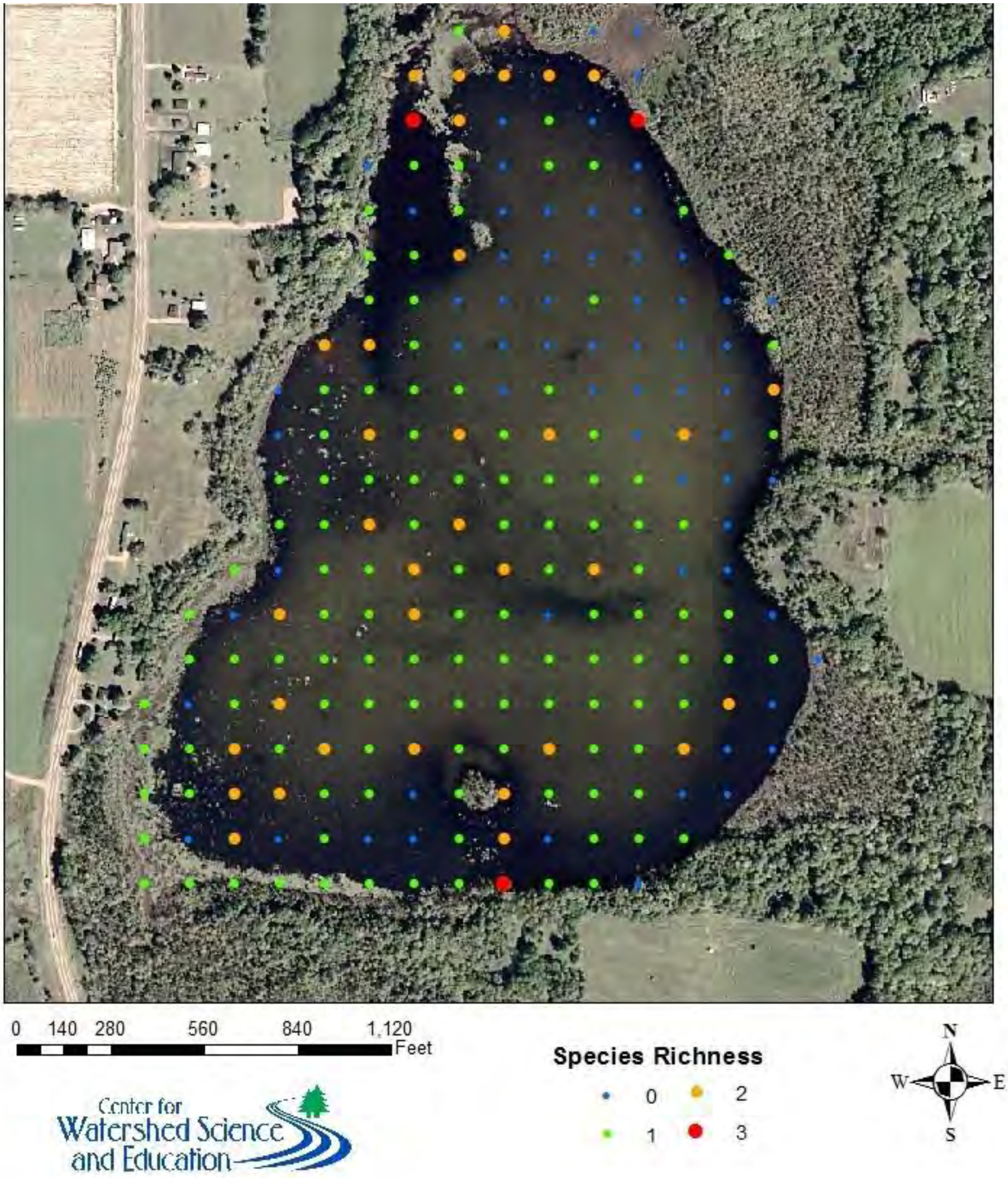


FIGURE 14. SPECIES RICHNESS AT SAMPLE SITES IN LILLY LAKE, 2012.

CONCLUSIONS & RECOMMENDATIONS

Overall, Lilly Lake may be considered a healthy lake; however, some of the study measurements suggested that Lilly Lake is being impacted by activities taking place in its watershed. Unchecked, these activities could result in degradation of the lake. In addition, the shallow depths and mucky bottom sediments in Lilly Lake create the risk of quick changes to the lake ecosystem as a result of additional nutrient inputs from the watershed or re-suspended sediments, and/or the establishment of aquatic invasive species.

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.

- During the study, inorganic nitrogen concentrations in samples collected during the spring in Lilly 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.
- Total phosphorus concentrations in Lilly Lake were quite variable during the study.
    - Overall concentrations of total phosphorus were not of concern, but several high concentrations were measured during the study. The higher concentrations were likely associated with sediment disturbance following storms, but could also have resulted from motorized boats.
    - The summer median total phosphorus was 22.5 ug/L and 21 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 proposed flag value of 15 ug/L.
- The hard water in Lilly Lake provides the calcium necessary for building bones and shells for animals in the lake and can help to buffer the effects of some additions of phosphorus.
- Chloride, sodium, and potassium concentrations in Lilly Lake were exceedingly high for a lake in central Wisconsin. Chloride does not affect plant and algae growth and is not toxic to aquatic organisms at these levels, but it does suggest pollutants are entering the lake. No septic systems are located immediately adjacent to the lake, but other chloride sources include animal waste, potash fertilizer, and road-salting chemicals. Sources of potassium include animal waste, septic systems, and fertilizers
- Atrazine (DACT), an herbicide commonly used on corn, was detected in the samples that were analyzed from Lilly Lake. Some toxicity studies have indicated that reproductive system abnormalities can occur in frogs at these levels. The presence of this chemical indicates that agricultural activities are influencing the water quality in Lilly Lake.

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 story told by the algal community composition and density conflicted with those told by the total phosphorus value (relatively high) and the water clarity measures (relatively poor). The water quality data (total phosphorus and water clarity) pointed to a mildly eutrophic body of water, but the algal community predicted a mildly to moderately mesotrophic lake. Perhaps what these data are telling us is that Lilly Lake is seeing a slow improvement in water quality conditions, reflected first in the algae.

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 zooplankton identified during the sample periods were relatively common and none of those that reached numerical dominance in the sample counts were associated as invasive or exotic.
- The cyclopoid copepod *Acanthocyclops vernalis* is usually associated with warm, meso- or eutrophic lakes that contain significant amounts of loose sediment.
- A stable, little-changing zooplankton community dominated by rotifers and copepods suggested that Lilly Lake is mesotrophic.

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.

- Lilly Lake supports a warm water fish community. In 2012, eight fish species were sampled. The survey revealed the presences of bluegill, pumpkinseed, bluegill x pumpkinseed hybrids, Iowa darter, black crappie, largemouth bass, northern pike, and yellow perch. Bluegill and young largemouth bass were most abundant during the survey.
- Crayfish were not encountered during the sampling period.
- The maximum bluegill length was 8.6 inches and largemouth bass did not exceed 4 inches. Black crappie reached a maximum of 10.6 inches.
- These were the first fyke netting and seining surveys on Lilly Lake according to records from the Wisconsin Department of Natural Resources.
- The ability to manage the fish populations in Lilly Lake in the future will be limited because of its shallow depths and tendency to winterkill due to low dissolved oxygen concentrations.
- After numerous reports of winter fish kills, the Lilly Lake Protection and Rehabilitation District filed a permit request to hydraulically dredge 44,000 cubic yards of material. The request was carried out and a five-foot hole remains near the public beach area of Elderon County Park.

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 Lilly Lake was dominated by marl (95.5%). In the absence of sand and coarser substrates such as gravel, largemouth bass and sunfish are known to build spawning 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 spawn on woody habitat swept clear of sediments.
- The presence of young sunfish during sampling indicated successful reproduction was occurring in Lilly Lake. Reproductive success of northern pike could not be determined with the limited sampling data collected.
- No bulrush beds were present during the survey.
- Coarse woody habitat, including downed trees and logs, were sparse in Lilly Lake compared to surrounding lakes. Woody structure is utilized by young prey fish and other aquatic organisms for foraging and protection.
- The fish community would benefit from the near shore addition of course woody habitat.

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.

- Seven species of aquatic plants were found in Lilly Lake, with the greatest diversity located in the northern end of the lake. The number of species within Lilly Lake ranked it last out of the lakes in the Eastern Marathon County Lakes Study.
- During this survey, the water temperatures in Lilly Lake were very warm and most aquatic plant growth had started to die back; it is likely that this contributed to the low number of plant species found in the lake.
- The dominant aquatic plant species was coontail, followed by white water. Coontail offers an important food source to a wide range of waterfowl species. A number of invertebrate and fish species use the bushy stems and stiff whorls of leaves as habitat, especially in the winter when other aquatic plants have died back. The seeds of the white water lily provide food to waterfowl. The broad, floating leaves of this aquatic species offer shade and shelter to fish.
- Of the aquatic plant species within Lilly Lake, two were high quality aquatic plants: southern naiad and white water crowfoot.
- No species of special concern in Wisconsin were found in Lilly Lake.
- All of the aquatic plant species observed during the aquatic plant survey of Lilly Lake were native species, which is highly desirable. Non-native aquatic invasive species can disturb an aquatic ecosystem and result in nuisance-level aquatic plant growth.
- 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.

In general, each type of land use contributes different amounts of phosphorus, nitrogen, and pollutants in runoff and through groundwater. The types of land management practices that are used and their distances from the lake affect the contributions to the lake from a parcel of land. Lilly Lake's surface and groundwater watersheds provide most of the water to the lake. Agriculture comprised nearly half of the 1,639 acre surface watershed, followed by forests and wetlands which comprised about 32% of the watershed. In the groundwater watershed, agriculture had the greatest percent land use (54%), followed by forests and wetlands (34%).

- Water quality modeling results indicated that agriculture had the greatest percentage (91%) of phosphorus contributions from the watershed to Lilly 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. Lilly Lake's shoreland was assessed for the extent of vegetation and disturbances. Shoreland vegetation provides habitat for many aquatic and terrestrial animals, including birds, frogs, turtles, and many small and large mammals. Vegetation also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs and trees extending at least 35 feet inland from the water's edge. Alone, each manmade disturbance may not pose a problem for a lake, but on developed lakes, the collective impact of these disturbances can be a problem for lake habitat and water quality.

- Lilly Lake has approximately 8,141 linear feet of shoreline. The 2011 survey showed that there was adequate shoreland vegetation surrounding Lilly Lake.
- Most of Lilly Lake's shoreline exists in a natural condition with very few human modifications. There were no manmade features along the shoreline at the time of the survey of Lilly Lake.
- Although Lilly Lake's shoreland has abundant development, efforts can be made to improve the shorelands. In order to minimize impacts to Lilly Lake 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.

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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 CaCO3. 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 (CaCO3) 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 (NO3-): 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 (NO3-N) plus ammonium-nitrogen (NH4-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."