Eastern Marathon County Lakes Study

Wadley Lake

Spring 2014

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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 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 the study for Wadley 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 WADLEY 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. The lake is located in the township of Bevent, north of the intersection of County Highway J with County Highway Y. One public boat launch is located on its southwestern side. Wadley Lake is a 47 acre seepage lake with surface runoff and groundwater contributing most of its water. The maximum depth in Wadley Lake is 24 feet; the lakebed has a gradual to moderate slope (Figure 1). Its bottom sediments are mostly muck with some rock and sand dispersed along the shoreline.

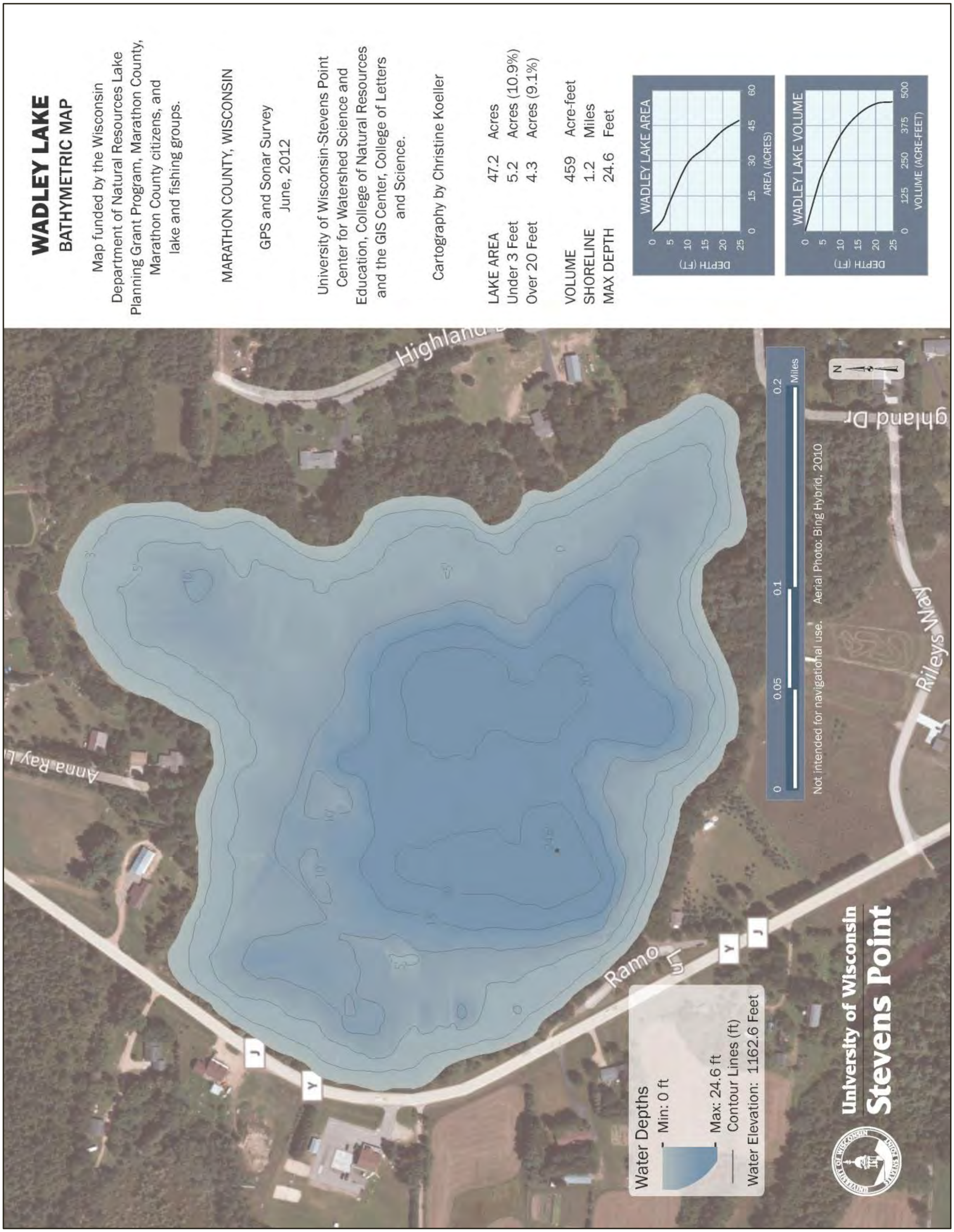


FIGURE 1. CONTOUR MAP OF THE WADLEY LAKE LAKEBED.

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

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

It is important to understand where Wadley 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 Wadley Lake is called a surface watershed. Groundwater also feeds Wadley Lake; its land area (groundwater watershed) is different from the surface watershed.

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

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

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

The surface watershed for Wadley Lake is approximately 306 acres (Figure 2). The dominant land use in the watershed is forest, followed by development. The lands closest to the lake often have the greatest impact on water quality and habitat; land uses near Wadley Lake's shoreland include residential development, forests, wetlands, and agriculture.

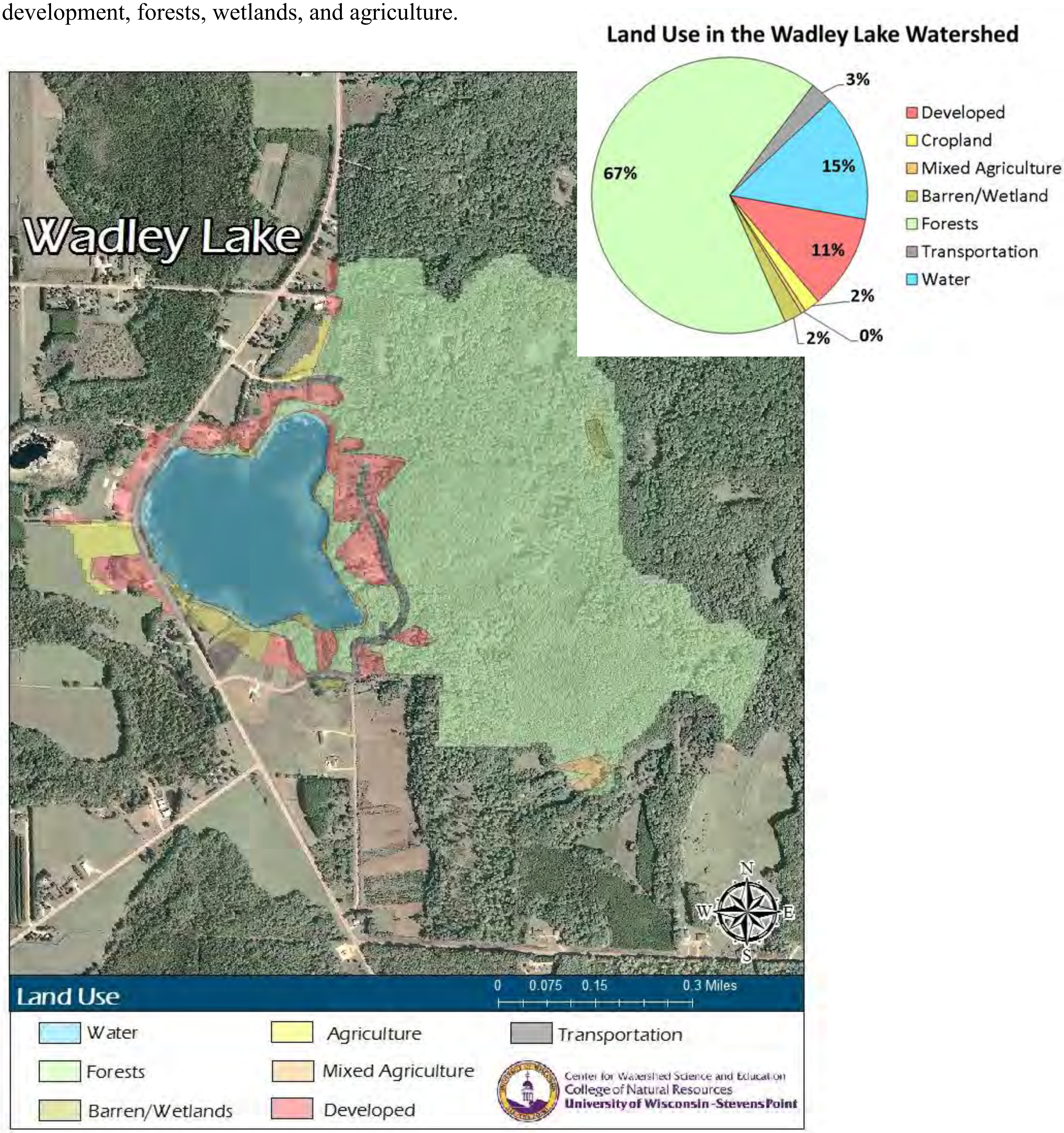
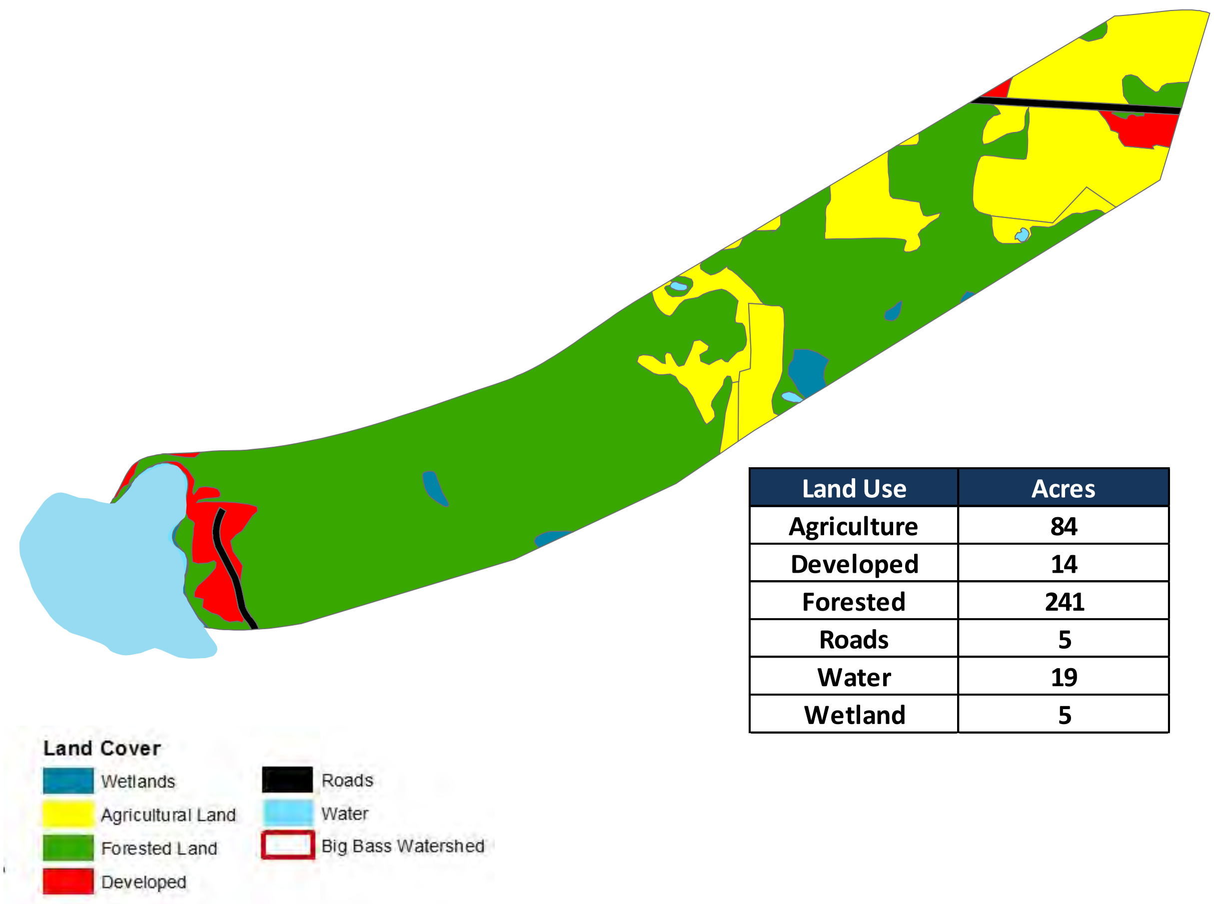


FIGURE 2. LAND USE IN THE WADLEY LAKE SURFACE WATERSHED.

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



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

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

Locally, groundwater enters some parts of the WadleyLake 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 Wadley Lake (Figure 4). Most of the groundwater entered the lake on the southeastern side of the lake (green triangles). Groundwater outflow occurred on the western end and sporadically on the eastern side of the lake (red flags). Areas with no connection between groundwater and the lake were mostly observed on the northern and southern sides of the lake and sporadically around the rest of the lake (white circles). Additional groundwater may enter Wadley Lake in areas that were deeper than the groundwater survey. It should be noted that the survey was conducted in 2011, which was a dry year with lower than normal groundwater levels. These conditions would result in less groundwater entering Wadley Lake.

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

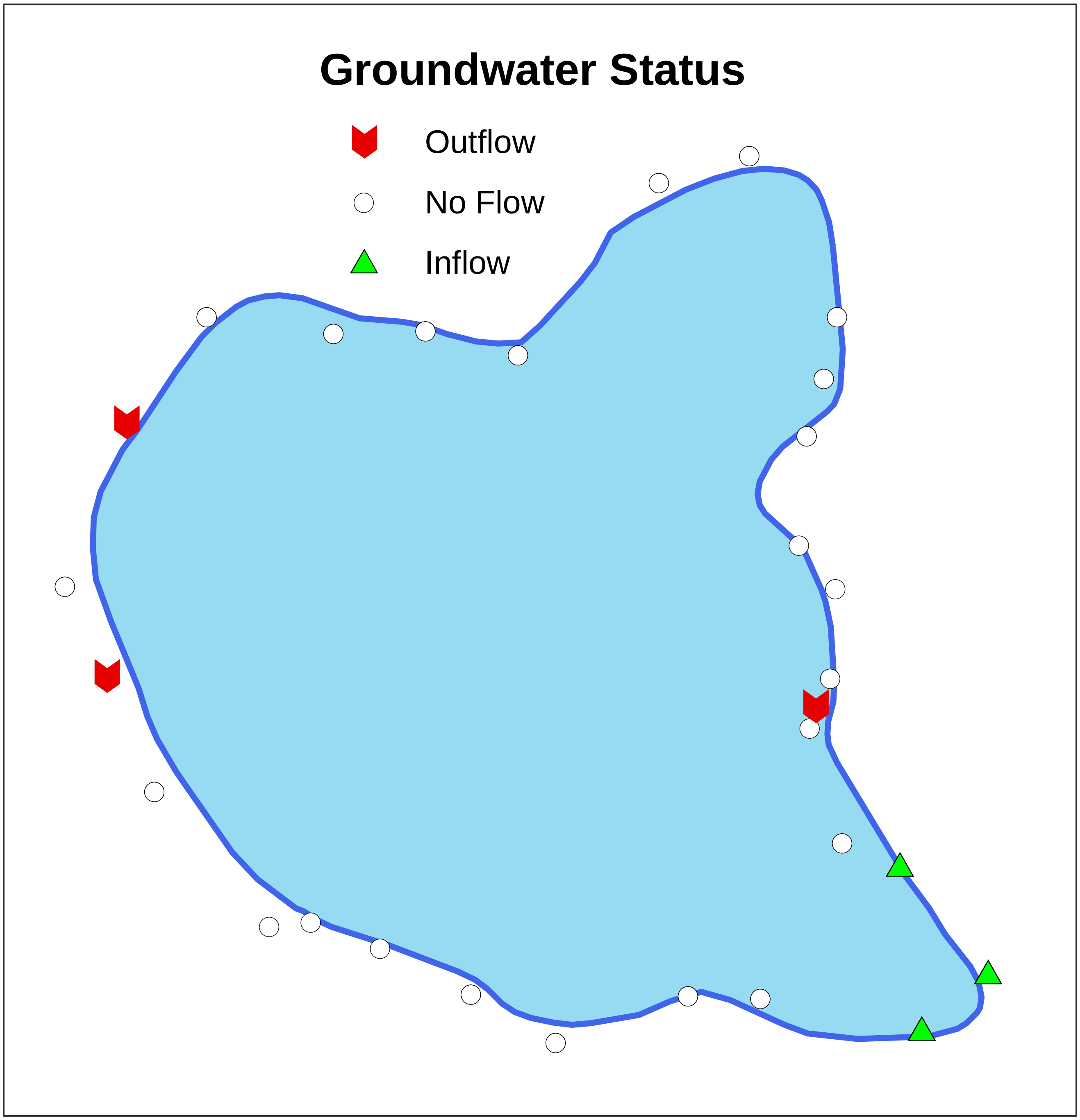
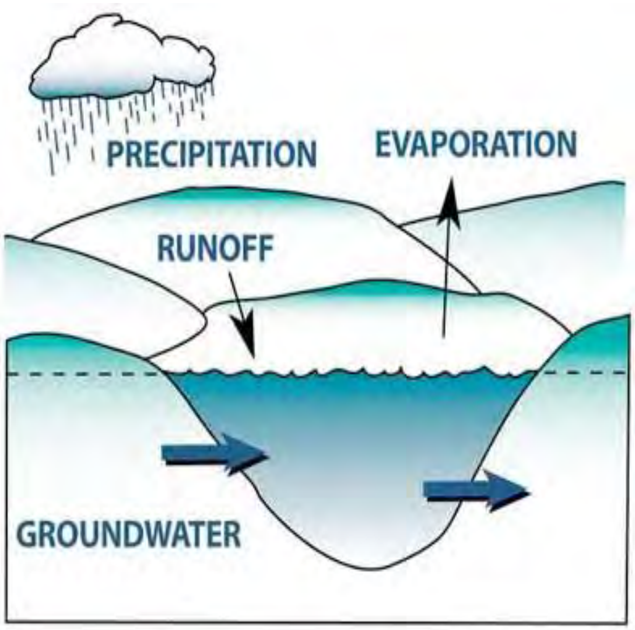


FIGURE 4. GROUNDWATER INFLOW AND OUTFLOW AROUND WADLEY LAKE, 2011.

WATER QUALITY

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

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

The geologic composition that lies beneath a lake has the ability to influence the temperature, pH, minerals, and other properties in a lake. As groundwater moves through the soil, some substances are filtered out, but other materials dissolve into the groundwater (Shaw et al., 2000). Minerals such as calcium and magnesium in the soil around Wadley Lake dissolve, making the water hard. The average hardness for Wadley Lake during the 2010-2012 sampling period was 107 mg/L, which is considered moderately hard (Table 1). Hard water provides the calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 114 mg/L; higher alkalinity in inland lakes can support higher species productivity. Hardness and alkalinity also play roles in the types of aquatic plants that are found in a lake (Wetzel, 2001).

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

Wadley Lake	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as CaCO3)	Color SU	Turbidity (NTU)
Average	114	27.4	13.0	107	10.7	2.1

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 a lake indicates the movement of pollutants from the landscape to the lake.

Over the monitoring period, concentrations of potassium and sodium were moderately high, but chloride was low (Table 2). These concentrations are not harmful to aquatic organisms, but indicated 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 Wadley Lake.

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

Wadley Lake	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium		1.1		<.75	0.75 - 1.5	>1.5
Chloride	2.9			<3	3.0 - 10.0	>10
Sodium		2.1		<2	2.0 - 4.0	>4

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

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

During the 2010-2012 study , water temperature was measured from the lake surface to its bottom at the time of sample collection. In Wadley Lake, temperature was uniform from top to bottom during most of the year. However, during the summer the lake became weakly stratified (Figure 6). During weak stratification, storms or heavy boating can result in the mixing of the lake and nutrients from the lake bottom can be brought to the top. The nutrient boost can enhance algal blooms. Temperatures ranged from 2 degrees Celsius (36°F) near the surface in February 2011 to 28 degrees Celsius (82° F) near the surface in August 2012.

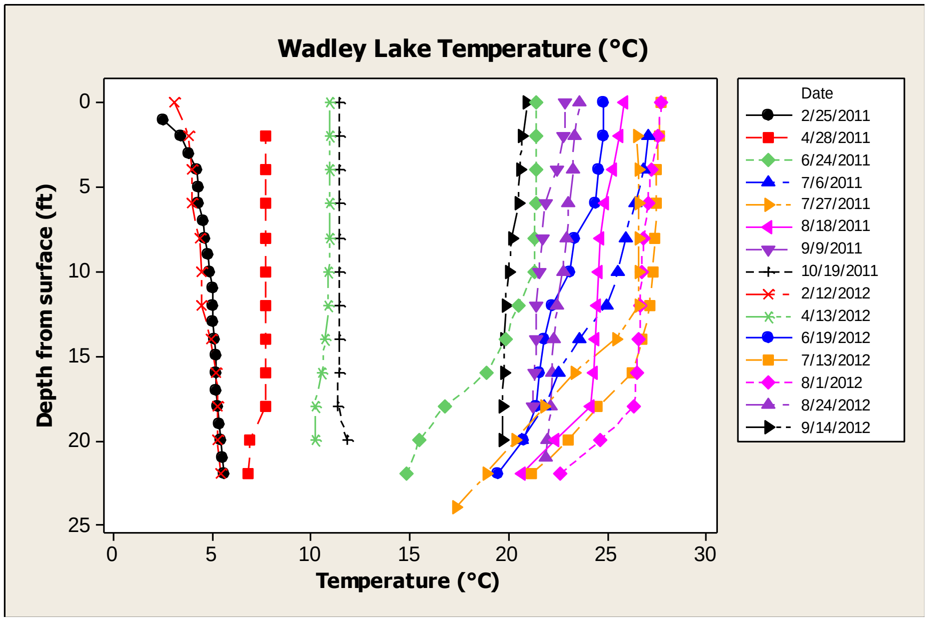


FIGURE 6. TEMPERATURE PROFILES IN WADLEY LAKE, 2011-2012.

Dissolved oxygen concentrations in Wadley Lake ranged from plentiful to limited depending upon depth and time of year (Figure 7). Like temperature, dissolved oxygen was mixed from top to bottom during spring and fall. Typical of many Wisconsin lakes, the dissolved oxygen in Wadley Lake stratified during the summer and winter. Even at its minimum, the lake always had concentrations of dissolved oxygen above 5 mg/L in the upper 9 feet of water. Increases in dissolved oxygen with depth were evident on three dates, July 6, 2011, June 14, 2012 and July 13, 2012. These increases were likely due to photosynthesis of algae.

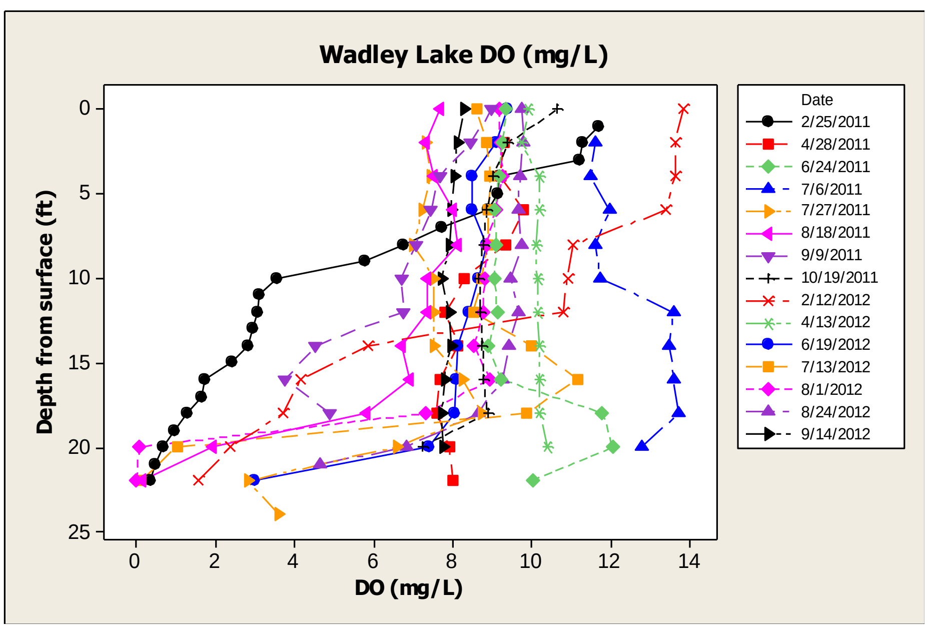
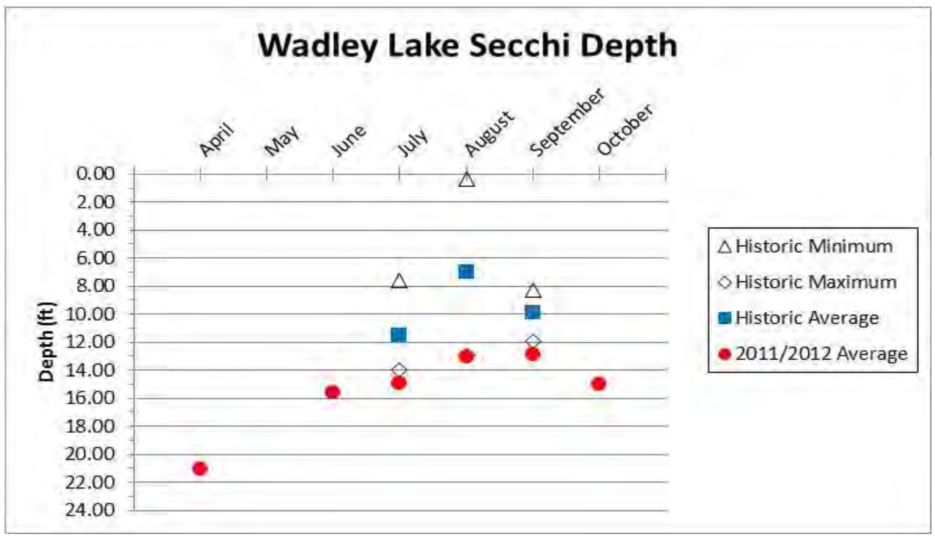


FIGURE 7. DISSOLVED OXYGEN PROFILES IN WADLEY LAKE, 2011-2012.

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

In Wadley Lake, the color index was relatively low, so the variability in water clarity in Wadley Lake is likely due to fluctuations in suspended sediment or algae. Overall, the water clarity measured in Wadley Lake during the study was considered good. During the 2010-2012 study, water clarity ranged from 9.5 feet to 22 feet (Figure 8). When compared with past data (1991-2005), the average water clarity measured during the study was slightly better in July, August, and September. Fluctuations throughout the summer are normal as algal populations and sedimentation increase and decrease. In Wadley Lake, there is a trend for water clarity to decrease as the summer progresses. This trend suggests that algal growth increases as the water warms.



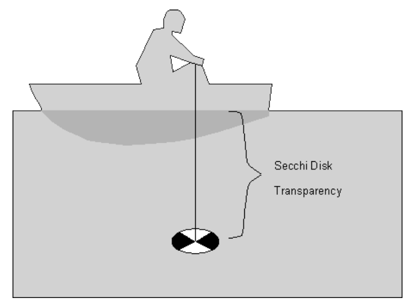


FIGURE 8. AVERAGE MONTHLY WATER CLARITY IN WADLEY LAKE, 2010-2012 AND HISTORIC.

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

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

Total phosphorus concentrations in Wadley Lake were fairly constant throughout the study. Extremes ranged from a high of 24 ug/L in April 2012 to a low of 3 ug/L in August 2012 (Table 3). The summer median total phosphorus was 12 ug/L and 12.5 ug/L in 2011 and 2012, respectively. This is well below Wisconsin's phosphorus standard of 40 ug/L for shallow seepage lakes and below the proposed flag value of 15 ug/L.

During the study, inorganic nitrogen concentrations in samples collected during the spring in Wadley Lake averaged 0.22 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 WADLEY LAKE, 2010-2012.

Wadley 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	12	16	20	1	2	3	0.80	0.92	1.04	0.05	0.08	0.10	0.75	0.85	0.94
Spring	14	19	24	7	7	7	0.73	0.87	1.01	0.15	0.22	0.28	0.58	0.66	0.73
Summer	3	12	17												
Winter	14	15	15	1	2	3	0.76	0.88	0.99	0.15	0.18	0.20	0.61	0.70	0.79

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

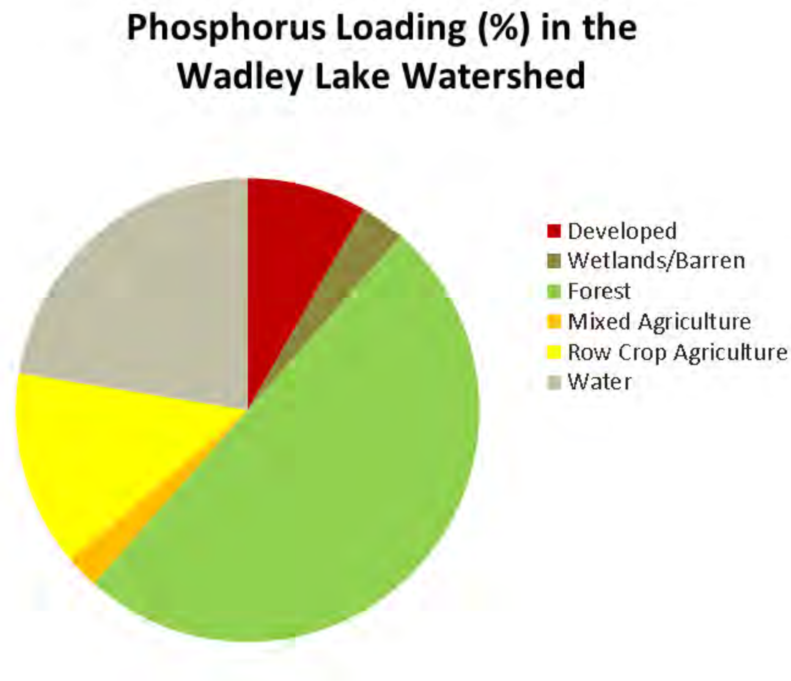


FIGURE 9. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE WADLEY LAKE WATERSHED.

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

Wadley Lake Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.10	46	**15**	4-13	29
Developed	0.04	35	**11**	2-3	**11**
Wetland/Barren	0.09	7	**2**	1-2	**4**
Forest	0.04	210	**69**	9-17	**65**
Mixed Agriculture	0.27	2	**1**	0.4-1	**3**
Row Crop Agriculture	0.45	6	**2**	3-5	**18**

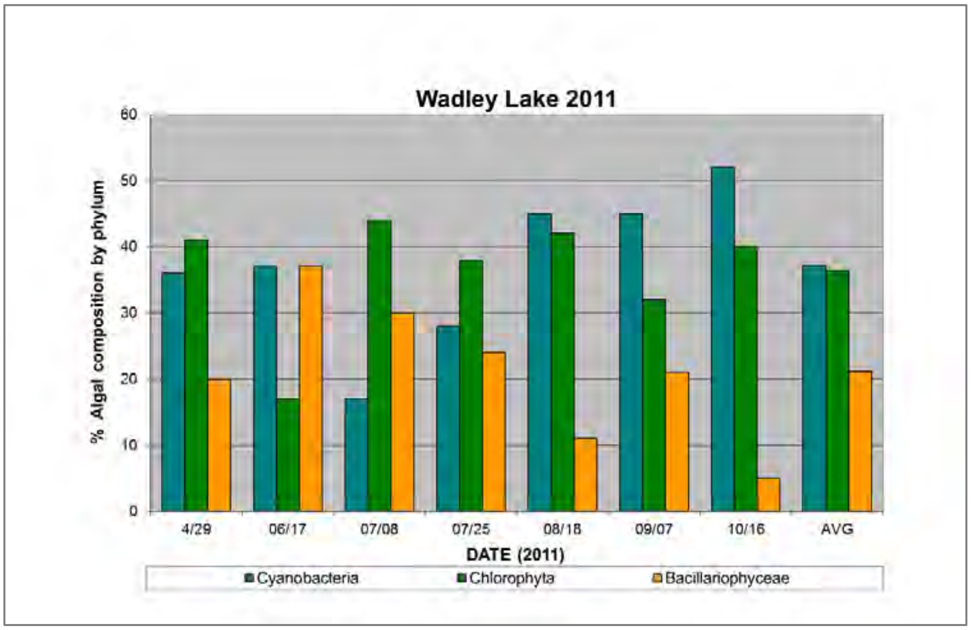
*Values are not exact due to rounding and conversion

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 Wadley Lake were low throughout the summers of 2011 and 2012, ranging from a high of 4 ug/L in September 2011 to a low of 1 ug/L in August 2012, with an average concentration of 2.2 ug/L during this study.

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

In Marathon County lakes, there are three dominant groups of algae: blue-green algae (Cyanobacteria), green algae (Chlorophyta), and diatoms (Bacillariophyceae). The Wadley Lake algal communities displayed similar patterns in 2011 and 2012 (Figure 10). These patterns are indicative of a fairly healthy lake transitioning from oligotrophic to mildly mesotrophic status. The green algae and blue-green algae were co-dominant groups (30-40% average composition each) in nearly every sample both years. The diatoms added 15-20% average composition and were rarely co-dominant.

The dominant green algal species were small unicellular colonial organisms that are palatable and easily digested. These algae can support a significant food web of herbivores and planktivorous fishes. Most diatom species present were associated with oligotrophic and mesotrophic waters, but several taxa were associated with eutrophic waters. Coupled with the co-dominance of the cyanobacteria, this supported the conclusion that Wadley Lake is an early mesotrophic lake with a diverse algal community.



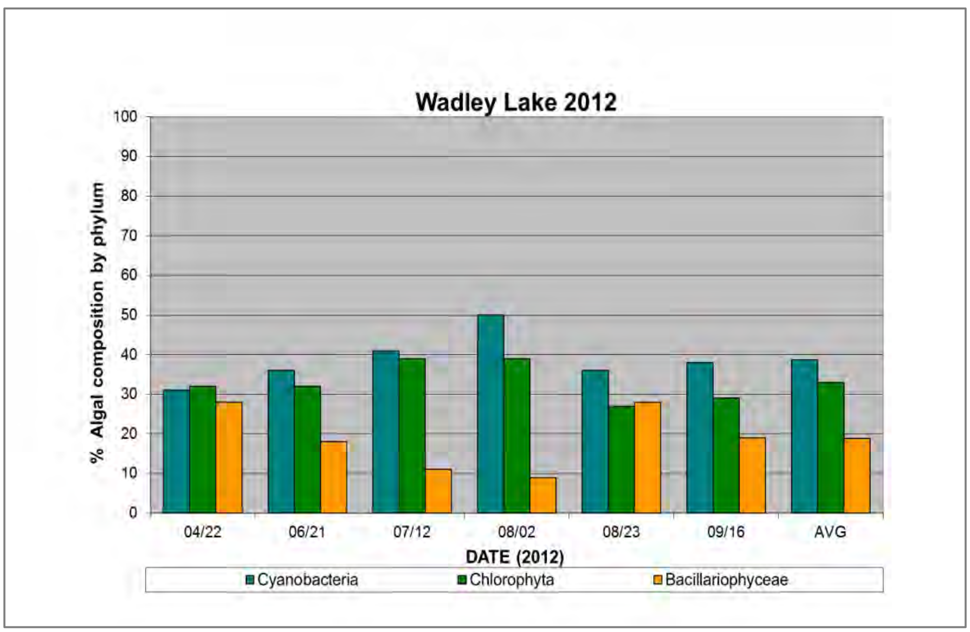


FIGURE 10. PERCENT ALGAL COMPOSITION OF WADLEY LAKE, 2011-2012.

SHORELAND HEALTH

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

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

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

WADLEY 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 Wadley Lake in Figure 12 depict the depth of vegetation inland from the water's edge along Wadley 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.

Wadley Lake has approximately 6,332 feet of shoreline. The survey showed that 3,361 linear feet of shoreline were classified as having a grass/forb buffer depth of less than 35 feet, which does not meet the requirement for shoreland vegetation in Wisconsin and Marathon County shoreland zoning ordinances (Figure 11). Over 4,400 linear feet of shoreline were classified as having a shrub layer less than 35 feet deep, the minimum depth required by Wisconsin and Marathon County shoreland zoning ordinances. Trees represented the most abundant vegetative layer around the lake with 2,548 linear feet classified as having a buffer depth greater than 35 feet. Although some of Wadley Lake's shoreland is in fairly good shape now, changes can easily occur as development takes place. In order to minimize impacts from current and future development, prospective developers should have the information needed to make good decisions, and zoning should be in place to achieve habitat, water quality, and aesthetic goals for Wadley Lake.

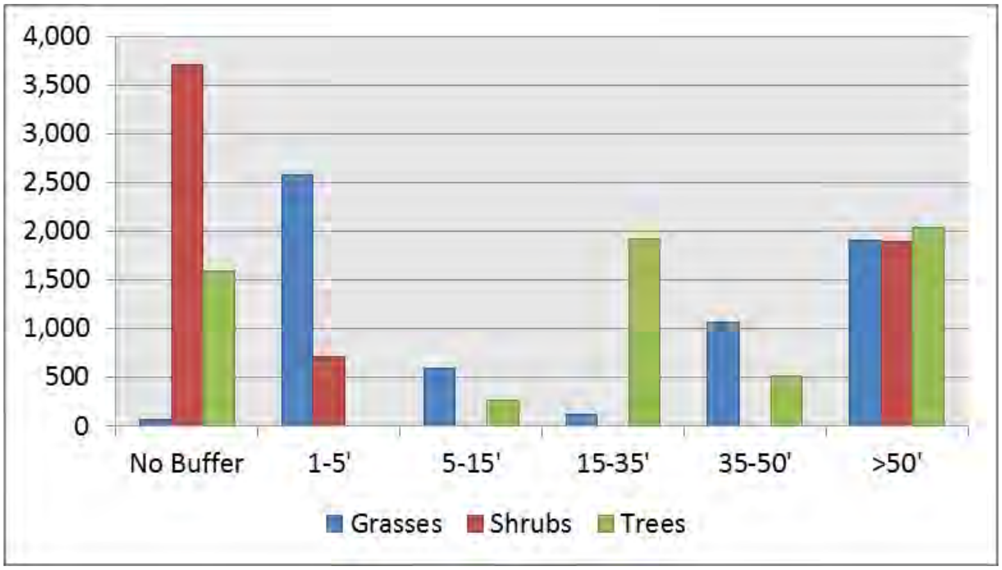


FIGURE 11. LINEAR FEET OF SHORELAND VEGETATION BY BUFFER DEPTH AROUND WADLEY LAKE, 2011.

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

TABLE 5. DISTURBANCES LOCATED ON WADLEY LAKE, 2011.

Disturbance	No. of Occurrences
Artificial Beach	0
Dock	14
Riprap	0
Seawall	0
Erosion	0
Structures w/in 35'	0
Structures 35-75'	4

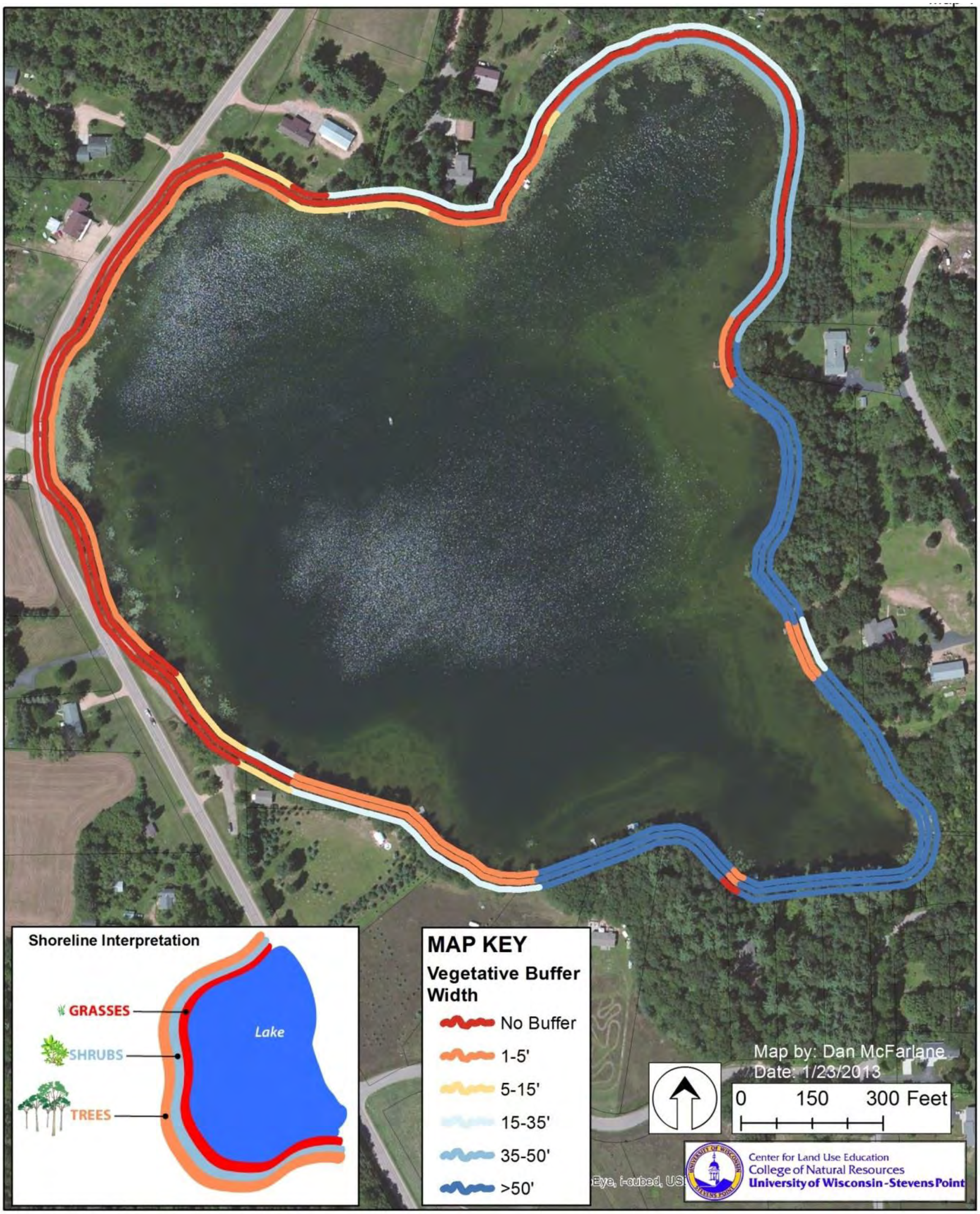


FIGURE 12. SHORELAND VEGETATION SURVEY OF WADLEY LAKE, 2011.

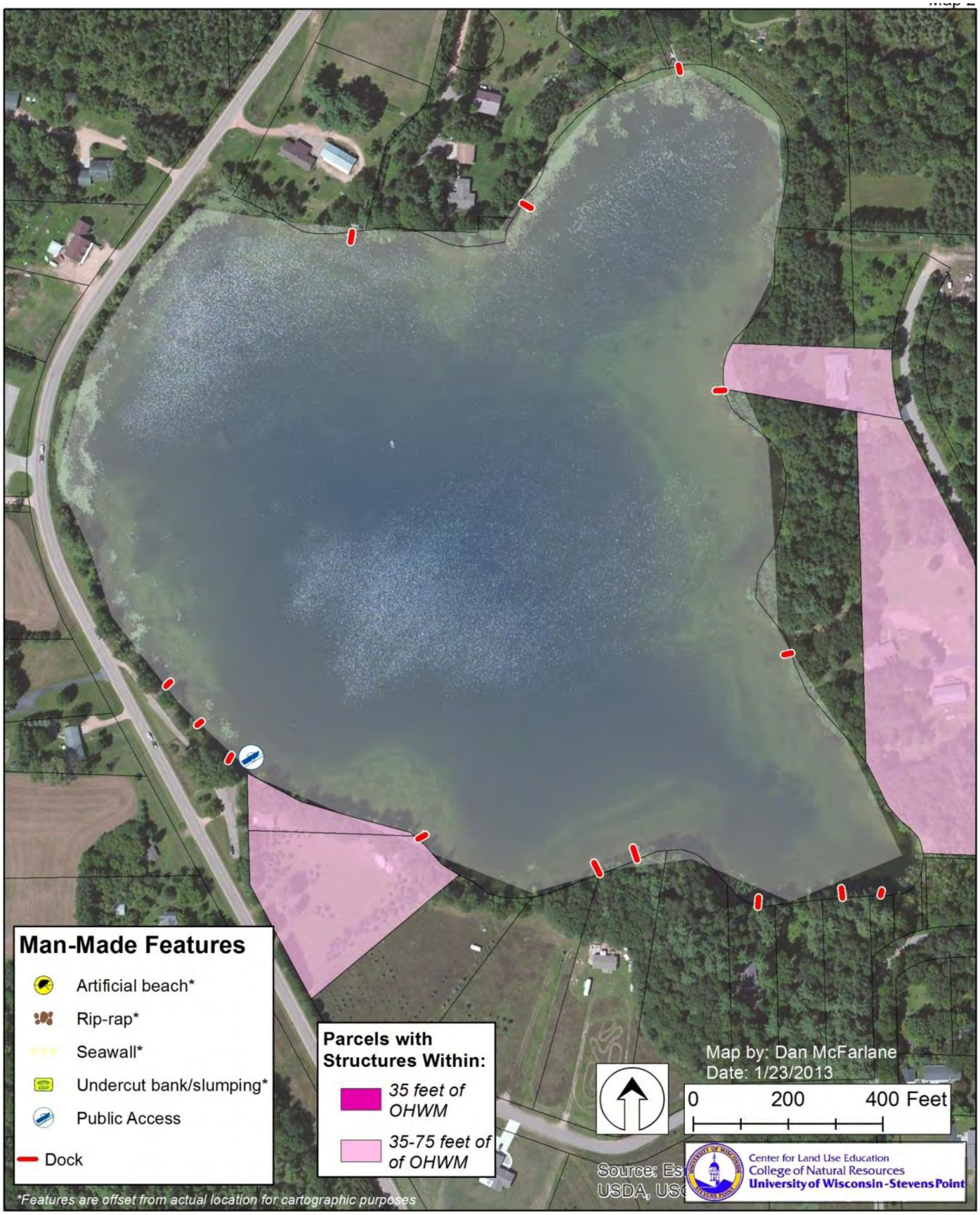


FIGURE 13. SHORELAND DISTURBANCE SURVEY OF WADLEY LAKE, 2001.

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.

Wadley Lake supports a warm water fish community. In 2012, eleven fish species were sampled and identified out of the sixteen total species that have been recorded since 1967 in surveys obtained from the Wisconsin Department of Natural Resources (Table 6). Although most species identified in 2012 had been previously reported, the bluntnose minnow (*Pimephales notatus*), Iowa darter (*Etheostoma exile*), and yellow bullhead (*Ameiurus natalis*) were newly documented. Species documented previously but not observed during the 2012 survey included brown bullhead (*Ameiurus nebulosus*), emerald shiner (*Notropis atherinoides)*, Johnny darter (*Etheostoma nigrum*), central mudminnow (*Umbra lima*), and pumpkinseed (*Lepomis gibbosus*). Bluegill (*Lepomis macrochirus*) were most abundant during both the fyke netting and shocking surveys in 2012. Bluegill reached a maximum size of 8.3 inches (Table 7 and Table 8). Green sunfish (*Lepomis cyanellus*), which are relatively uncommon to this area, were also present in the lake. Although infrequently encountered, walleye (*Sander vitreus*) reaching 22.3 inches were caught. Yellow perch (*Perca flavecens)* and northern pike (*Esox lucius*) were not frequently found during 2012 sampling efforts. Three non-native rusty crayfish (*Orconectes rusticus*) were captured during the sampling period.

Historically, little fishery-related management has been conducted on Wadley Lake. A 1948 Wisconsin Department of Natural Resources report stated a high proportion of catchable fish were present, with more than 50 % of the fish exceeding eight inch lengths. Black crappie (*Pomoxis nigromaculatus*) were specifically noted as being a desirable size. In 1967, average bluegill size was 6.1 inches, higher than the 2012 survey results. In 1967, an application was approved and land was acquired to provide a boat launch and public parking. Fish cribs were added in 2007 in an attempt to provide spawning habitat and cover for young fish. Recently, the lake was chemically treated in 2012 for control of Eurasian watermilfoil, an invasive aquatic plant species. Fish stocking records for Wadley Lake date back to 1938 in Wisconsin Department of Natural Resources files (Table 9). Largemouth bass (*Micropterus salmoides*) and walleye were stocked prior to 1966. Most recently, adult northern pike have been the focus of stocking.

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

Species	1967	1976	2012
Black Crappie	x	x	x
Bluegill	x	x	x
Bluntnose Minnow			x
Brown Bullhead		x	
Bullheads	x		
Emerald Shiner	x		
Green Sunfish		x	x
Iowa Darter			x
Johnny Darter	x		
Largemouth Bass	x	x	x
Mudminnow	x		
Northern Pike	x	x	x
Pumpkinseed	x	x	
Walleye		x	x
White Sucker		x	x
Yellow Bullhead			x
Yellow Perch	x	x	x

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

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill*	0.9	8.3	3.1	294
Bluntnose Minnow*	1.3	2.6	1.9	170
Iowa Darter*	1.2	2.2	1.7	84
Largemouth Bass*	1.4	13.3	3.4	37
Yellow Bullhead	1.9	14.0	10.8	24
Black Crappie	7.7	12.5	10.2	9
Yellow Perch*	5.1	5.1	5.1	5
Northern Pike	12.8	20.9	16.8	2
Walleye	22.0	22.3	22.2	2
White Sucker	10.7	19.6	15.2	2

*A subsample of the total catch was measured.

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

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	1.0	7.7	2.9	89
Bluntnose Minnow	1.0	7.1	2.4	59
Largemouth Bass	2.3	14.8	6.5	35
Yellow Perch	3.0	5.7	3.8	7
Black Crappie	5.9	8.5	7.3	5
Green Sunfish	3.4	7.3	5.7	4
Iowa Darter	1.8	1.8	1.8	1
Northern Pike	16.3	16.3	16.3	1

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

Year	Species	Age Class	Number Fish Stocked	Avg Fish Length (in)
1938	Perch	Fingerling	10,800	
1938	Rock Bass	Adult	30	
1938	Walleye	Adult	20	
1949	Largemouth Bass	Fingerling	1,000	
1950	Largemouth Bass	Fingerling	1,700	
1952	Largemouth Bass	Fingerling	450	
1953	Largemouth Bass		450	
1960	Walleye		9,000	
1962	Walleye	Fingerling	9,000	
1964	Walleye	Fingerling	9,000	
1966	Walleye	Fingerling	9,000	
1967	Northern Pike	Adult	400	
1978	Northern Pike	Adult	100	
1980	Northern Pike	Adult	100	

BOTTOM SUBSTRATE AND COARSE WOODY HABITAT

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

In-lake habitat was examined from the shoreline lakeward to a distance of 90 feet using side-scan sonar. The bottom substrate in Wadley Lake primarily consisted of marl (87%) (Figure 14). The eastern and southern shorelines contained areas with hard substrates, including mixtures of sand/gravel/cobble (2.4%). A fair amount of sandy substrate was also present (10.5%). Sparse areas of softstem bulrush (*Schoenoplectus tabernaemontani*) were present in Wadley Lake (Figure 15).

Gravel areas are utilized by many fish for spawning habitat, including sunfish (bluegill, pumpkinseed, and black bass), where males will construct nests and guard their young. Northern pike, which do not offer parental care, utilize areas with emergent and floating-leaf vegetation in shallow or flooded areas for spawning. Black crappie utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young. Yellow perch and walleye utilize near-shore cobble in oxygen-rich environments for spawning activity; parental care is not practiced. Sand can be important habitat for reproduction of non-game minnows. The reproductive success of northern pike could not be determined with the limited information collected, although a smaller individual (<13 inches) was reported in 2012. The presence of young bass and sunfish sampling indicated successful reproduction of these species.

Coarse woody habitat (CWH), including downed trees and logs, were present in Wadley Lake (Figure 15). This structure is utilized by young prey fish and other aquatic organisms for spawning, foraging, and protective cover. The addition of CWH cover would benefit the fish community.

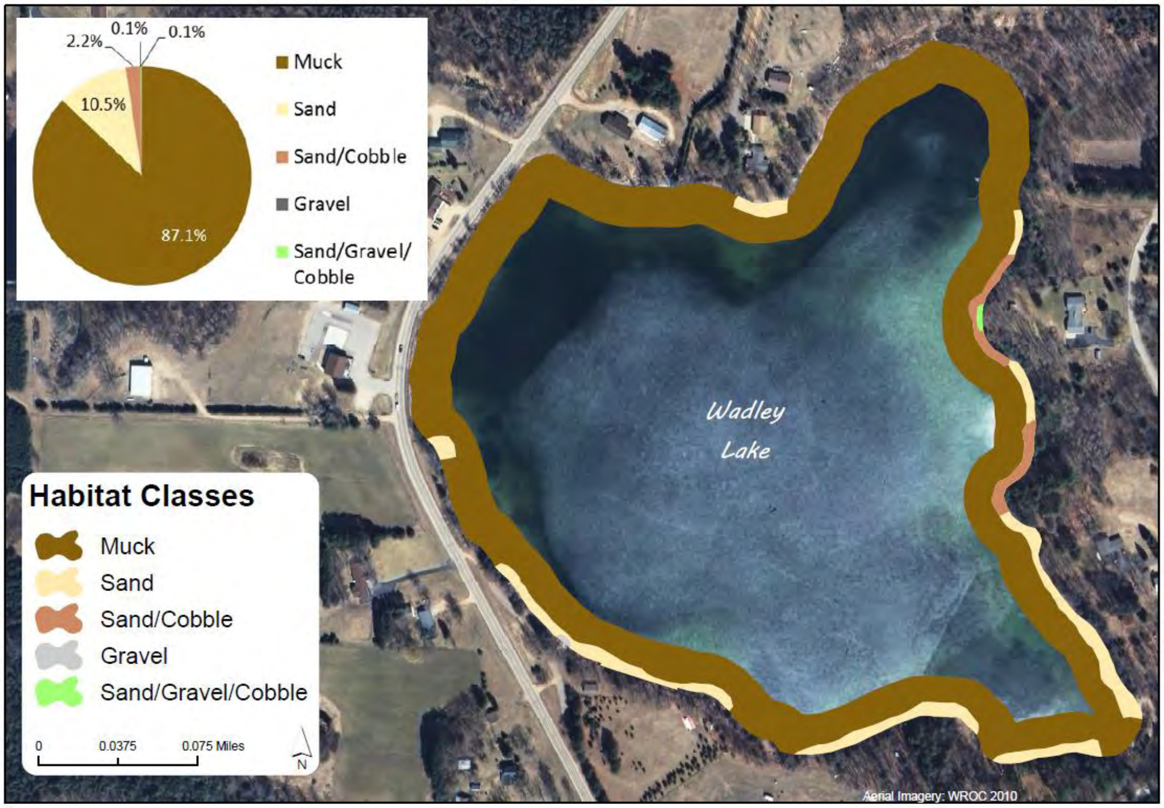


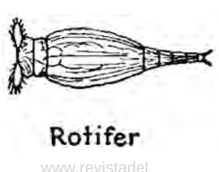
FIGURE 14. DISTRIBUTION OF SUBSTRATE IN WADLEY LAKE, 2012.

FIGURE 15. DISTRIBUTION OF COARSE WOODY HABITAT AND BULRUSH BEDS IN WADLEY LAKE, 2012.

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

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

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

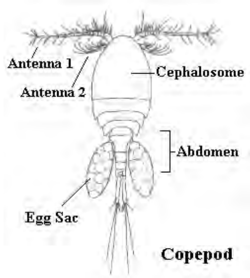


Rotifers are small invertebrate animals with simple body designs. They are usually not found uniformly throughout lakes, but congregate in areas of high food abundance (bacteria, algae, and other rotifers). Generally, a lake's trophic status influences, or can be predicted by, the abundance and diversity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

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

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

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



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

The zooplankton community of Wadley Lake was sparse with little diversity during the 2011-2012 sampling season (Table 10, Table 11). Zooplankton were classified based on two general size categories: nano-plankton (80 *u*m or less) or net plankton (210 *u*m or less).

The dominant groups of **nano-plankton** were the cladocerans and the copepods, with rotifers as subdominants.

- There were 527 individuals counted during this period:
  - 278 cladocerans, 232 copepods, and 17 rotifers.

The dominant group of **net plankton** was the copepods, with cladocerans as subdominant.

- There were 557 individuals counted during this period:
  - 289 copepods and 268 cladocerans.

Cladocerans and copepods were the dominant taxa in the four sample periods during the 2011-12 season. Both cladocerans and copepods dominated seasonally starting in spring and continuing throughout the year. Different species of cladoceran and copepod became subdominant in fall and winter. Rotifers were not dominant year round. No zooplankton were found in winter samples, indicating low productivity during this season.

The zooplankton community presented a picture of a lake transitioning to mesotrophic when considered relative to the algal, phosphorus, and nitrogen values for Wadley Lake. The one genus of rotifer, three genera of cladocerans, and two genera of copepods identified during the sample periods were relatively common and majority of those were not classified as invasive or exotic. A stable, little-changing zooplankton community dominated by cladocerans and copepods, such as that seen in Wadley Lake, suggested that it is an oligotrophic lake transitioning to mesotrophic. This is also supported by the generally good water clarity seen throughout the sampling period.

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

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 28	Cladoceran	*Daphnia pulex*				
June 20	Cladoceran	*Ceriodaphnia* spp.	Copepod	Nauplii	Copepod	*Cyclopoid copepodite*
October 19	Cladoceran	*Bosmina longirostris*	Cladoceran	*Daphnia schodleri*	Copepod	*Eucyclops speratus*
March 9	Copepod	*Leptodiatomus sicilis*	Copepod	*Eucyclops speratus*	Cladoceran	*Daphnia schodleri*

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

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 28	Copepod	*Eucyclops speratus*	Copepod	*Leptodiaptomus sicilis*		
June 20	Cladoceran	*Bosmina longirostris*	Cladoceran	*Daphnia schodleri*	Copepod	*Cyclopoid copepodite*
October 19	Cladoceran	*Bosmina longirostris*	Copepod	*Leptodiaptomus sicilis*	Cladoceran	*Daphnia schodleri*
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, 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 Wadley Lake, eighteen species of aquatic plants were found in Wadley Lake (Table 12), with the greatest diversity located in the northeastern and northwestern bays of the lake (Figure 16). The number of species in Wadley Lake was below average compared with the other lakes in the Eastern Marathon County Lakes Study. Eighty-seven percent (128 of 147) of the sites sampled had vegetative growth. Of the sampled sites, the average depth was 7 feet and the maximum depth was 20 feet.

TABLE 12. AQUATIC PLANTS IDENTIFIED IN THE WADLEY LAKE AQUATIC PLANT SURVEY, 2012.

Common Name	Scientific Name	Coefficient of Conservatism Value (C Value)
Emergent Species		
softstem bulrush	*Schoenoplectus tabernaemontani*	8
broad leaved cattail	*Typha latifolia*	1
reed canary grass	*Phalaris arundinacea*	
blue flag	*Iris versicolor*	
Floating Leaf Species		
spatterdock	*Nuphar variegata*	6
white water lily	*Nymphaea odorata*	6
water smartweed	*Polygonum amphibium*	5
floating leaf pondweed	*Potamogeton natans*	5
Submergent Species		
muskgrass	*Chara*	7
northern water-milfoil	*Myriophyllum sibiricum*	6
Eurasian water-milfoil	*Myriophyllum spicatum*	0
slender naiad	*Najas flexilis*	6
variable Pondweed	*Potamogeton gramineus*	7
Illinois pondweed	*Potamogeton illinoensis*	6
white-stem pondweed	*Potamogeton praelongus*	8
small pondweed	*Potamogeton pusillus*	7
flat-stem pondweed	*Potamogeton zosteriformis*	6
wild celery	*Vallisneria americana*	6

The dominant plant species in the survey was muskgrass (*Chara* spp.), followed by slender naiad (*Najas flexilus*) and Illinois pondweed (*Potamogeton illinoensis*). Muskgrass is a favorite food source for a wide variety of waterfowl. Beds of muskgrass offer cover and food for fish, especially young trout, largemouth bass, and smallmouth bass. The stems, leaves, and seeds of slender naiad are also important food sources for waterfowl and marsh birds. This common aquatic species provides habitat for fish as well. Illinois pondweed produces a fruit that can be a locally important food source for a variety of waterfowl. Fish and invertebrate make use of the plant for shade and cover (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 Wadley Lake was 22.2. This was only higher than Lilly Lake's FQI value and was below average compared with other lakes in the Eastern Marathon County Lakes Study.

Of the aquatic plant species within Wadley Lake, two had a C value of eight or greater: soft stem bulrush and white-stem pondweed (*Potamogeton praelongus*) (Table 12). No species of special concern within Wisconsin were found in Wadley 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. Wadley Lake had a SDI value of 0.85. This represents average biodiversity when compared to all the lakes in the Marathon County study.

Two species of non-native aquatic plants have been found in Wadley Lake during past surveys conducted by the Wisconsin Department of Natural Resources. In June 2011, a survey was conducted to document the abundance of curly leaf pondweed (*Potamogeton crispus*), CLP. No CLP was found during this survey or during the full vegetation survey in 2012. CLP offers habitat to invertebrates and fish during winter and spring, a time of year when most other aquatic plants are reduced to rhizomes and winter buds. This plant species can exist as a part of the aquatic plant community, but in some cases may become invasive. If large beds of CLP exist in a lake, it can be problematic because of its unusual life cycle. It grows early in the year and dies back in early summer. Its decomposing plant tissue releases nutrients into the warm water that can enhance algal blooms. The second non-native aquatic species, Eurasian water-milfoil (*Myriophyllum spicatum*), EWM, was found during the 2012 survey. This aquatic plant can grow under the ice and out-compete native species in the spring. It can quickly spread throughout a lake by several means. Fragments of the plant can break off, float away, and establish new plants elsewhere. Mature plants also produce seeds.

Overall, the aquatic plant community in Wadley Lake can be characterized as having low species diversity, possibly due to the chemical treatments that have been used to control EWM. The two non-native species found in Wadley Lake, CLP and EWM, should continue to be monitored to ensure that populations are not increasing or changing. In addition, habitat, food source, and water quality benefits of a diverse plant community should be focal points in future lake management strategies.

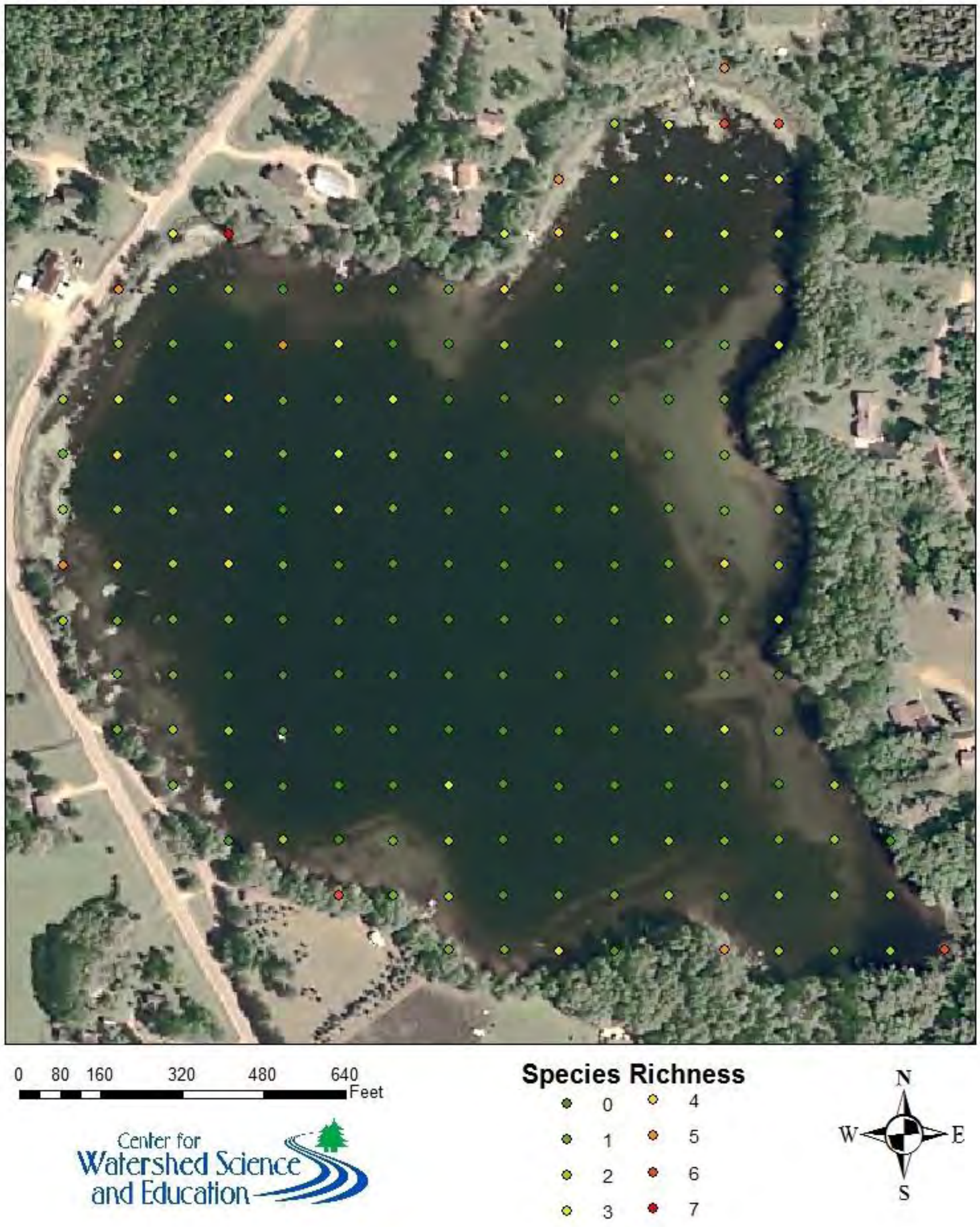


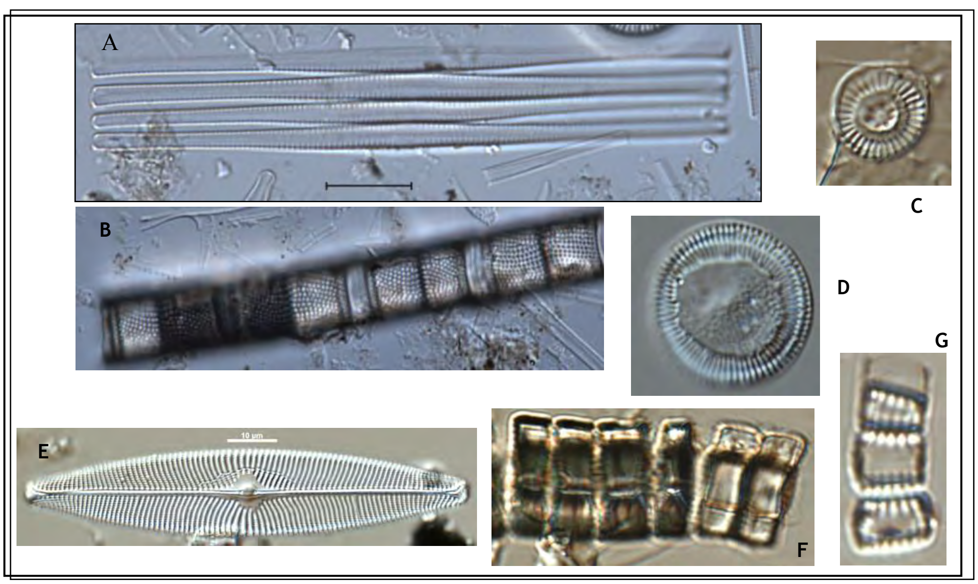
FIGURE 16. SPECIES RICHNESS AT SAMPLE SITES ON WADLEY LAKE, 2012.

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

Five lakes in the Marathon County Lakes Study were chosen for sediment core analysis. In November 2012, a 38 inch long core of sediment was collected for analysis from Wadley Lake's deepest area in 23 feet of water. It is estimated that the bottom portion of this core was deposited at least 150 years ago.

BIOLOGICAL COMPONENTS IN THE SEDIMENT CORE

Aquatic organisms can be good indicators of water chemistry because they live in direct contact with the water and are strongly affected by the chemical composition of their surroundings. Most indicator groups grow rapidly and are short-lived, so the community composition responds quickly to changing environmental conditions. Diatoms, a type of algae, are especially useful because they are usually abundant, are ecologically diverse and their ecological tolerances are well known. In addition, the cell walls of diatoms contain silica, which enables them to be highly resistant to degradation and well-preserved in sediments (Figure 17).



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

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

FIGURE 17. PHOTOMICROGRAPHS OF THE COMMON DIATOMS FOUND IN MARATHON COUNTY LAKE SEDIMENT CORES.

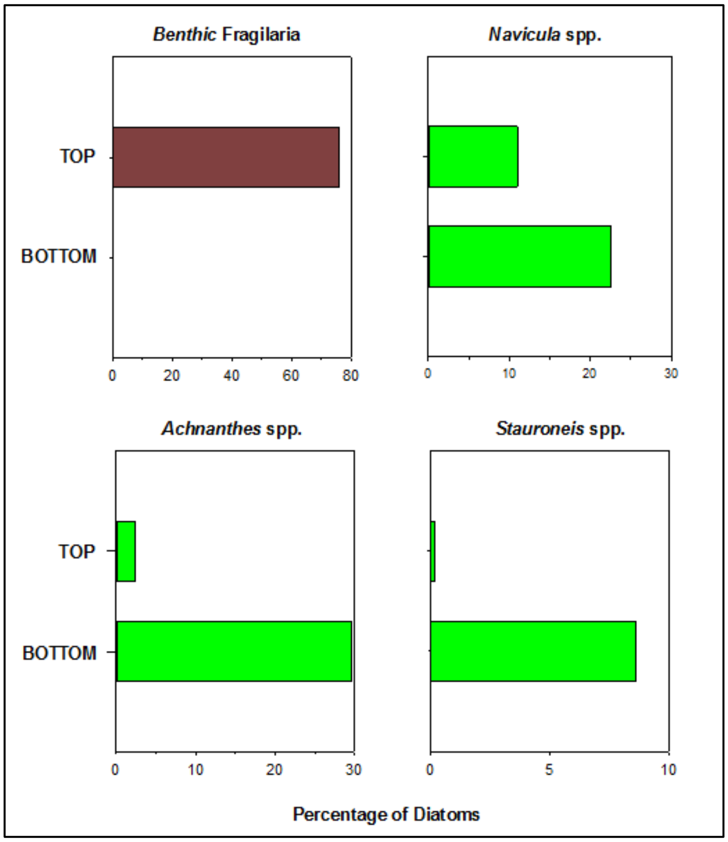


FIGURE 18. ABUNDANCE OF IMPORTANT DIATOMS FOUND AT THE TOP AND MIDDLE OF THE SEDIMENT CORE FROM WADLEY LAKE, 2012.

The diatom community was analyzed in samples from the top and bottom of Wadley Lake's sediment core. The species present in the bottom and the top of the core were nearly all benthic (bottom-feeding) species of diatoms (Figure 18). The bottom of the core is characterized by diatom species that grow on submerged aquatic plants and are associated with low to moderate nutrient concentrations in the water. In contrast, the top of the core was dominated by benthic *fragilaria,* which are associated with soft-bodied filamentous algae. Interestingly, there have been few recorded observations of a high abundance of filamentous algae in Wadley Lake, so other algal or aquatic plant community dynamics may be supporting this species. The change in diatom species from the bottom to the top of the sediment core suggested an increase in phosphorus concentrations. The species richness and diversity decreased toward the top of the core as well, which suggested an overall decline in the health of the lake.

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

In Wadley Lake, ragweed pollen is lower deeper in the core, increases substantially at 13 inches, and peaks at 11 inches (Figure 19). The growth of ragweed typically begins increasing as logging and land clearing occurs and peaks when the remaining undergrowth is cleared or burned for agricultural or other uses – which occurred near Wadley Lake during the late 19th century.

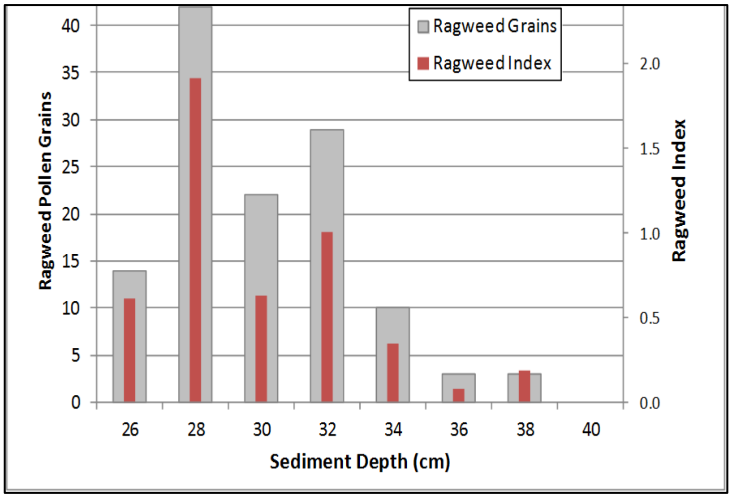
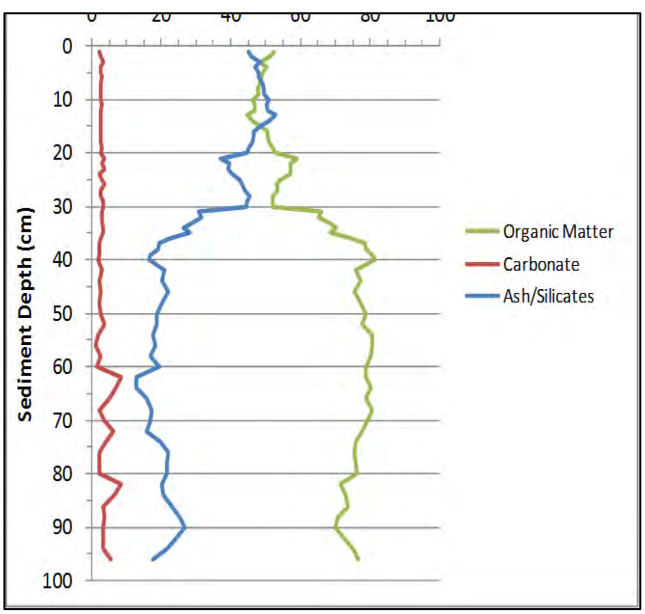


FIGURE 19. RAGWEED POLLEN IN WADLEY LAKE SEDIMENT CORE.

PHYSICAL PROPERTIES OF SEDIMENT

Wadley Lake's sediment was dark olive-gray to almost black throughout the core. The dark color at the top of the core is likely the result of high amounts of organic matter or iron staining the sediment. As microbes and other organisms decompose in a lake, dissolved oxygen in the overlying water decreases and the sediment is altered by the production of iron compounds. Although this typically occurs seasonally, it becomes more pronounced with an increase in nutrients, algae, and aquatic plants.

There were little textural changes and minimal color changes in the sediment core. The sediment was fine grained and smooth and contained variability in the amount of sand throughout the core. Sand is indicative of shoreland disturbance related to erosion from land clearing and storm events. The surrounding topography of Wadley Lake allows sand to easily collect at the lakes deepest area.



To determine the composition of Wadley Lake's sediment core, a test was conducted called loss on ignition (LOI). During the LOI analysis, components such as organic matter, marl (carbonate), and silica (sand, silt, and clay) are burned away to provide greater detail about the core's composition (Figure 20). LOI results indicated that organic matter was more abundant below 11.8 inches in the sediment core. Silica was most abundant in the top 11.8 inches of the core, which was indicative of shoreland disturbances that are often related to erosion from land clearing and/or storm events. Logging and agricultural practices as well as recreation around Wadley Lake could also have contributed to the increase in silica in the top of the sediment core by disturbing and redistributing lake sediment.

FIGURE 20. LOSS ON IGNITION RESULTS FOR WADLEY LAKE.

SEDIMENT CORE RESULTS SUMMARY

Analysis of the biological components and physical properties of Wadley Lake's sediment core indicated an increase in erosion-induced processes such as land clearing, storm events, and shoreland disturbance since the time of land settlement around the lake. The analyses indicated these activities did not occur abruptly. There has likely been an increase in nutrient delivery, including phosphorus and possibly filamentous algae, towards the top of the sediment core. Physical properties of the sediment suggested that the delivery of silica to the deepest part of the lake increased, along with an increase in suspended sediment, in the last century. The decrease in marl formation reflected a potential loss or change in the aquatic plant community or changes in groundwater flow to the lake. The results of these analyses also suggested that Wadley Lake experienced limited increase in phosphorus concentrations, but large changes in habitat during the last century.

CONCLUSIONS & RECOMMENDATIONS

Overall, the water quality in Wadley Lake is good. The water has high hardness, which provides the calcium necessary for building bones and shells for animals in the lake. Dissolved oxygen, which is required for the survival of many aquatic organisms, was sufficient throughout the year. Levels of pollutant indicators such as chloride, potassium and sodium were slightly elevated. The concentrations present in Wadley Lake are not harmful to aquatic organisms, but serve as an indication 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 in the two samples that were analyzed from Wadley Lake.

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, concentrations of inorganic nitrogen in Wadley Lake averaged 0.22 mg/L. Concentrations above 0.3 mg/L are sufficient to enhance algal blooms throughout the summer.
- Concentrations of total phosphorus were low.

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

- The algal community in Wadley Lake displayed patterns that are indicative of a fairly healthy lake transitioning from oligotrophic to mildly mesotrophic status.
- The dominant green algal species were small unicellular and colonial organisms that are palatable and easily digested. These algae can support a significant food web of herbivores and planktivorous fishes.
- Most diatom species which were present are associated with oligotrophic and mesotrophic waters, but several taxa are associated with eutrophic waters. Coupled with the co-dominance of the blue-green algae, this supported the conclusion that Wadley Lake is an early mesotrophic lake with a diverse algal community.

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 the majority of those were not classified as invasive or exotic.
- The stable, little-changing zooplankton community observed in Wadley Lake suggested that it is an oligotrophic lake transitioning to mesotrophic. This was also supported by the generally good water clarity seen throughout the study.

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.

- Bluegill were the most abundant during both the fyke netting and shocking surveys in 2012. Bluegill reached a maximum size of 8.3 inches.
- Green sunfish, which are relatively uncommon to this area, were also present in Wadley Lake.
- Wadley Lake supports a warm water fish community. In 2012, eleven fish species were collected during the survey.
- The bluntnose minnow, Iowa darter, and yellow bullhead were newly documented in 2012.
- Species documented previously but not observed during the 2012 survey included brown bullhead, emerald shiner, Johnny darter, central mudminnow, and pumpkinseed.
- Three non-native and potentially invasive rusty crayfish were captured during the sampling period. If conditions are right, the aggressive rusty crayfish can become invasive, altering the aquatic plant community's balance with algal populations and out-competing native crayfish.

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.

- The bottom substrates in Wadley Lake primarily consisted of a marl (87%), sand (10.5%), and hard substrates, including mixtures of sand/gravel/cobble (2.4%) along the eastern and southern shorelines.
    - Gravel areas are utilized by many fish for spawning habitat, including sunfish (bluegill, pumpkinseed, and black bass), where males construct nests and guard their young. The presence of young bass and sunfish indicated successful reproduction of these species.
    - Yellow perch and walleyes utilize near-shore cobble in oxygen-rich environments for spawning activity.
    - Sand can be important habitat for reproduction of non-game minnows.
- Sparse areas of softstem bulrush were present around Wadley Lake.
    - Northern pike utilize areas with emergent and floating-leaf vegetation in shallow or flooded areas for spawning. The reproductive success of northern pike could not be determined with the limited information collected, although a smaller individual (<13 inches) was reported in 2012.
    - Black crappie utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young.
- Coarse woody habitat, including downed trees and logs, were present in Wadley Lake. This structure is utilized by young prey fish and other aquatic organisms for spawning, foraging, and protective cover. Turtles utilize woody structure to sun themselves, which aids digestion of their food.
    - The addition of woody habitat around more of the lakeshores would benefit the fish community.

Aquatic plants are the forested landscape within a lake. They provide food and habitat for a wide range of species including fish, waterfowl, turtles, 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.

- Eighteen species of aquatic plants were found in Wadley Lake, with the greatest diversity located in the northeastern and northwestern bays of the lake. The number of species in Wadley Lake was below-average compared with the other lakes in the Eastern Marathon County Lakes Study. This may be a result of the chemicals used in Wadley Lake to manage Eurasian watermilfoil.
- The dominant plant species in the survey was muskgrass, followed by slender naiad and Illinois pondweed. Muskgrass is a favorite food source for a wide variety of waterfowl. Beds of muskgrass offer cover and food for fish, especially young trout, largemouth bass, and smallmouth bass. The stems, leaves, and seeds of slender naiad are also important food sources for waterfowl and marsh birds. This common aquatic species provides habitat for fish as well. Illinois pondweed produces a fruit that can be a locally important food source for a variety of waterfowl. Fish and invertebrate make use of the plant for shade and cover (Borman et al., 2001).
- Two of the aquatic plant species in Wadley Lake are rated as high quality with a C value of eight or greater: soft stem bulrush and white-stem pondweed. No species of special concern within Wisconsin were found in Wadley Lake.
- Two aquatic invasive species have been reported in Wadley Lake. In some situations, aquatic invasive species (AIS) can reach nuisance levels and disrupt the balance in the lake's ecosystem and impair recreational opportunities.
    - Eurasian watermilfoil (EWM) is present in Wadley Lake.
    - This aquatic plant is can grow under the ice and out-compete native species in the spring. It can quickly spread throughout a lake by several mechanisms. Fragments of the plant can break off, float away, and establish new plants elsewhere. Mature plants also produce seeds.
    - Curly leaf pondweed (CLP) is a non-native species which can exist as a part of the aquatic plant community; however, in some cases it may become invasive. If large beds of CLP occur in a lake, it can be problematic because of its unusual life cycle. It grows early in the year and dies back in early summer. Its decomposing plant tissue releases nutrients into the warm water which can enhance algal blooms.
    - CLP was not found in Wadley Lake in surveys conducted in June 2011 and July 2012. 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.
    - A plan should be developed to monitor the status of EWM and address strategies for management.
    - Early detection of aquatic invasive species (AIS) can help to prevent their establishment should they be introduced into the lake. Boats and trailers that have visited other lakes can be a primary vector for the transport of AIS.
    - Programs are available to help volunteers learn to monitor for AIS and to educate lake users at the boat launch about how they can prevent the spread of AIS.

The analysis of a lake's sediment core is an effective means to reconstruct some of the changes that have occurred over time. Lakes act as sediment traps for particles that are either delivered to the lake from the surrounding landscape and the atmosphere, or occur in the lake itself. By examining remains trapped in the sediment, changes in the lake ecosystem can be inferred.

- Analysis of the biological components and physical properties of Wadley Lake's sediment core indicated an increase in erosion-induced processes such as land clearing, storm events, and shoreland disturbance since the time of land settlement around the lake. The analyses indicated that these activities did not occur abruptly.
- Composition of the top of the sediment core indicated that there has likely been an increase in nutrient delivery to Wadley Lake, suggested by increased in-lake phosphorus and possibly filamentous algae.
- Physical properties of the sediment suggested that the delivery of silica to the deepest part of the lake has increased, along with an increase in suspended sediment, in the last century.
- A decrease in marl formation reflected a potential loss or change in the aquatic plant community or reductions in groundwater flow to the lake.
- The results of these analyses also suggested that Wadley Lake experienced a limited increase in phosphorus concentrations, but large changes in habitat during the last century.

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. Wadley Lake's surface and groundwater watersheds provided most of the water to the lake. Forests comprised 69% of the 306 acre surface watershed, followed by development which comprised about 11% of the watershed. In the groundwater watershed, forests also made up the greatest percent land use (67%), followed by agriculture (23%).

- Water quality modeling results indicated that forests had the greatest percentage (65%) of phosphorus contributions from the watershed to Wadley 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. Wadley 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.

- Wadley Lake has approximately 6,332 feet of shoreline.
  - The shoreland vegetation survey for Wadley Lake showed that 3,361 linear feet of shoreline were classified as having a grass/forb buffer depth of less than 35 feet and over 4,400 linear feet of shoreline were classified as having a shrub layer less than 35 feet deep.
  - The grasses, forbs, and shrubs vegetation buffers are required to be greater than 35 feet, according to Wisconsin and Marathon County shoreland zoning ordinances.
  - Trees represented the most abundant vegetative layer around the lake with 2,548 linear feet classified as having a buffer depth greater than 35 feet.
  - Unmanaged runoff from the rooftops of structures contribute runoff to the lake, often resulting in delivery of more sediment to the lake.
  - Docks result in altered in-lake habitat. Denuded lakebeds adjacent to docks provide opportunities for invasive species to become established and reduce habitat that is important to fish and other lake inhabitants.
  - Strategies should be developed to ensure that healthy shorelands remain intact and efforts should be made to improve shorelands that have disturbance. Depending upon the source of the disturbances, erosion should be controlled, vegetation should be restored, and/or excess runoff should be minimized.
- Although some of Wadley Lake's shoreland is in fairly good shape now, changes can easily occur as development takes place. Minimizing impacts to Wadley Lake from future development should include planning to ensure that prospective developers have information to make good decisions and that zoning is in place to achieve habitat, water quality, and aesthetic goals.
- Dissemination of relevant information to property owners is the recommended first step towards maintaining healthy shorelands.

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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."