Eastern Marathon County Lakes Study

Norrie Lake

Spring 2014

University of Wisconsin-Stevens Point

University of Wisconsin
Stevens Point

PRIMARY AUTHORS

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

Algae
Bob Bell

Aquatic Plants
Jen McNelly

Cultural Survey
Kristin Floress

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

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

Shoreland Assessments and Build Out
Dan McFarlane

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

Zooplankton
Chris Hartleb

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

Editor: Jeri McGinley

ACKNOWLEDGMENTS

We are grateful to many people for supporting this project by providing insight, enthusiasm, and funding. We would like to recognize our project partners:

Marathon County Concerned Citizens and Property Owners

Marathon County Conservation, Planning and Zoning Staff

Mayflower Lake District, Pike Lake Sportsman Club, and Wadley Lake Sportsman Club

Marathon County Environmental Fund

Wisconsin Department of Natural Resources Professionals, Buzz Sorge, Tom Meronek, Scott Provost

Wisconsin Department of Natural Resources Lake Protection Grant Program

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

UW-Stevens Point Water and Environmental Analysis Lab

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NORRIE LAKE STUDY RESULTS

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, habitat, and aquatic ecosystems. This information will help lake users, residents and municipalities by identifying ways to improve existing problems and make informed decisions to preserve and protect the lakes 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 summarizes the results of the study for Norrie 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 NORRIE 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. Norrie Lake is located in the township of Norrie, east of Hatley and County Highway Y. One public boat launch is located on its southern side. Norrie Lake is a 100 acre seepage lake with groundwater and surface runoff contributing most of its water. The maximum depth in Norrie Lake is 21 feet; the lakebed has a moderate to steep slope (Figure 1). Its bottom sediments are mostly muck with sand found on the eastern and northeastern edges.

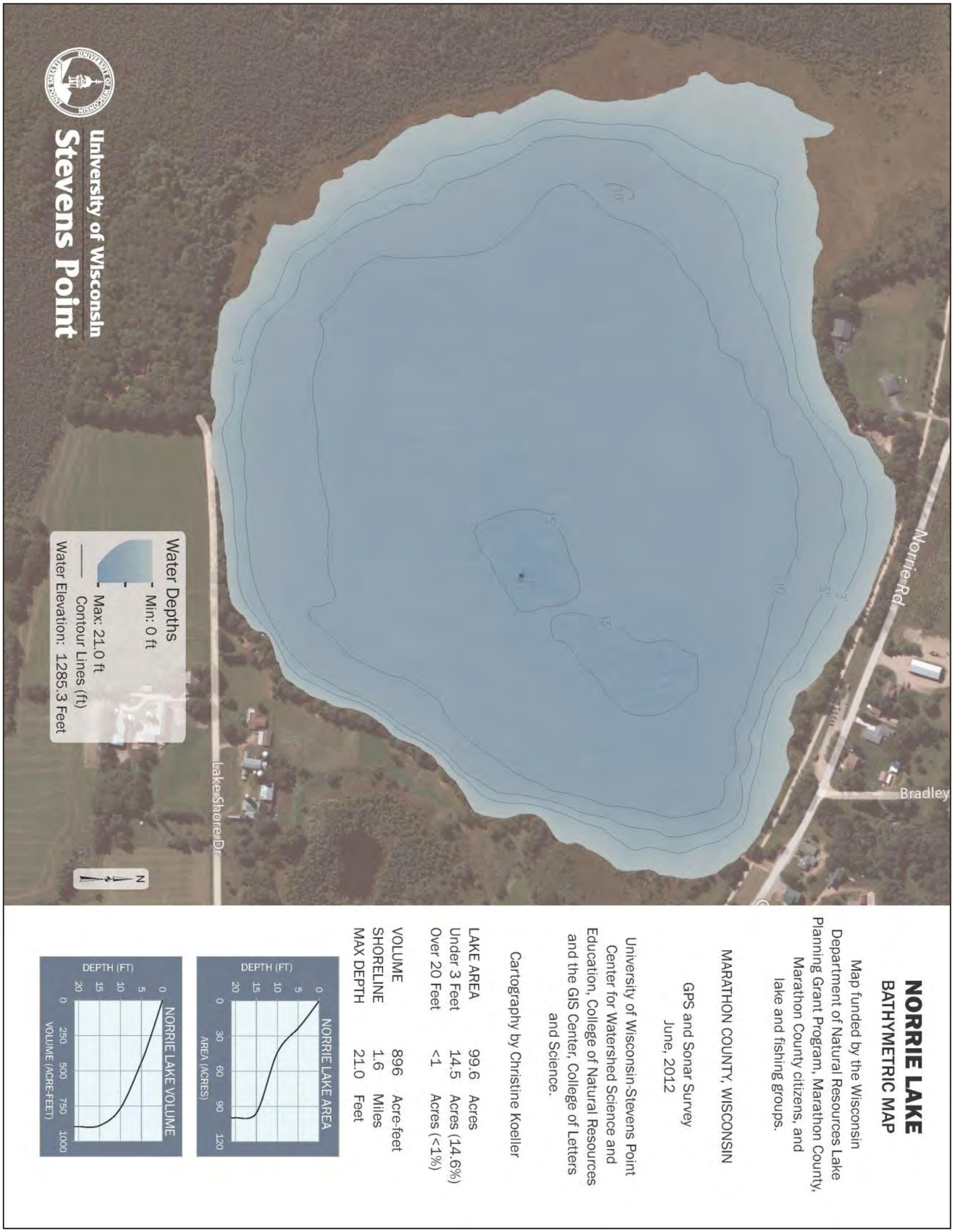


FIGURE 1. CONTOUR MAP OF THE NORRIE LAKE LAKEBED.

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

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

Land use and land management practices within a lake's watershed can affect both its water quantity and quality. While forests and grasslands allow a fair amount of precipitation to soak into the ground, resulting in more groundwater and better water quality, other types of land uses may result in increased runoff, less groundwater recharge, and may be sources of pollutants that can impact the lake and its inhabitants. Areas of land with exposed soil can produce soil erosion. Soil entering the lake can make the water cloudy, plug up fish spawning beds, and contains nutrients that increase the growth of algae and aquatic plants. Development often results in changes to natural drainage patterns, alterations in vegetation on the landscape, and may be a source of pollutants. Impervious (hard) surfaces such as roads, rooftops, and compacted soil prevent rainfall from soaking into the ground, which may result in more runoff carrying pollutants to the lake. Wastewater, animal waste, and fertilizers used on lawns, gardens, and agriculture can contribute nutrients that can 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 Norrie Lake is approximately 1,270 acres (Figure 2). The dominant land uses in the watershed are forests (52%) and agriculture (21%). The lands closest to the lake often have the greatest impact on water quality and habitat; land uses near Norrie Lake's shoreland include residential development, forests, agriculture, and recreational land.

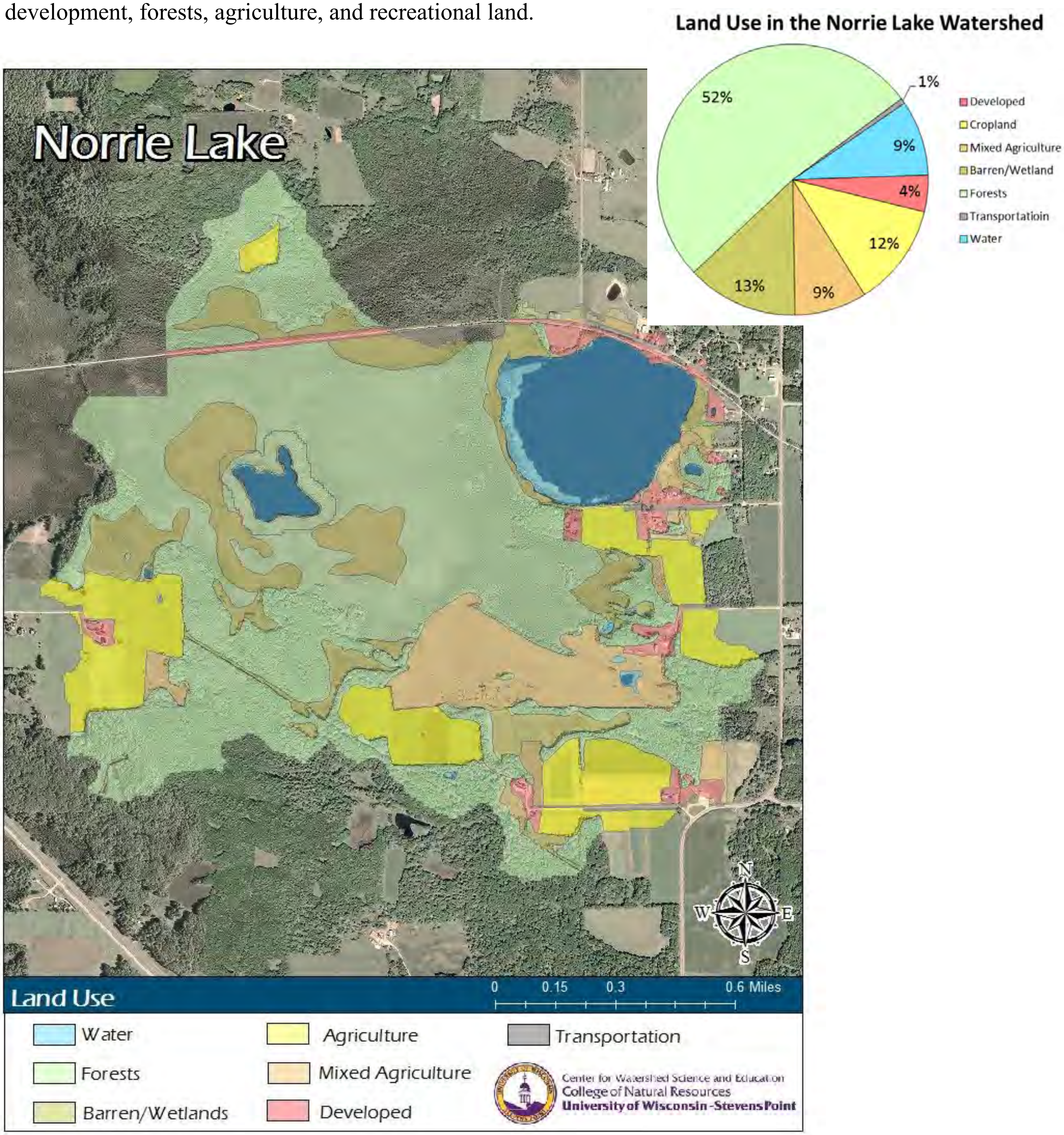


FIGURE 2. LAND USE IN THE NORRIE LAKE SURFACE WATERSHED.

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

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

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

Locally, groundwater enters some parts of the Norrie 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 Norrie Lake (Figure 4). Groundwater outflow occurred sporadically on the northeastern and southern sides of the lake (red markers). Areas with no connection between groundwater and the lake were mostly observed on the western side of the lake and sporadically around the rest of the lake (grey dots). Areas where groundwater is existing Norrie Lake were not identified in this survey. Additional groundwater may enter Norrie 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 Norrie 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. Only very small concentrations of minerals (calcium and magnesium) in the soil around Norrie Lake contribute to the water chemistry, resulting in a soft water lake. Groundwater temperatures are constant year round, so groundwater feeding Norrie Lake will help to keep the lake water cooler during the summer months.

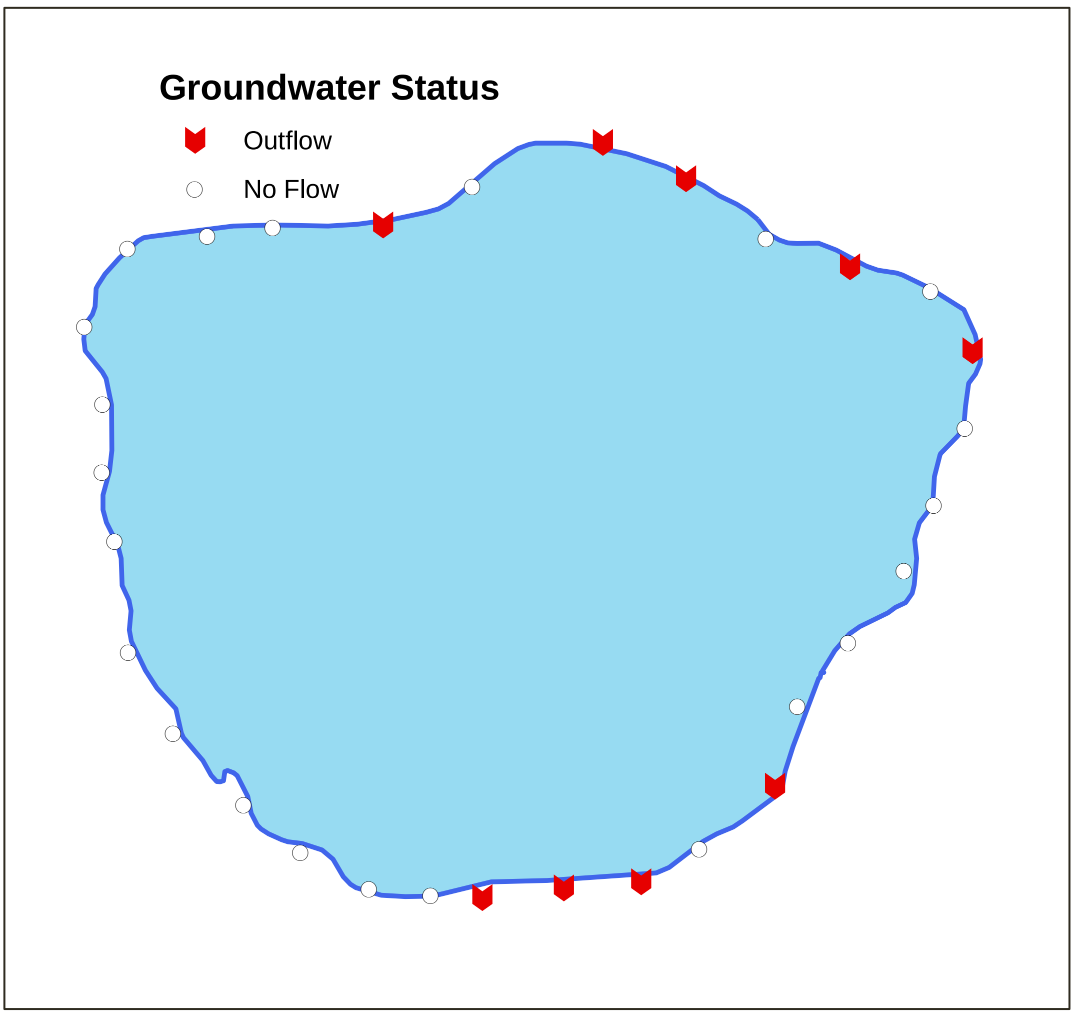
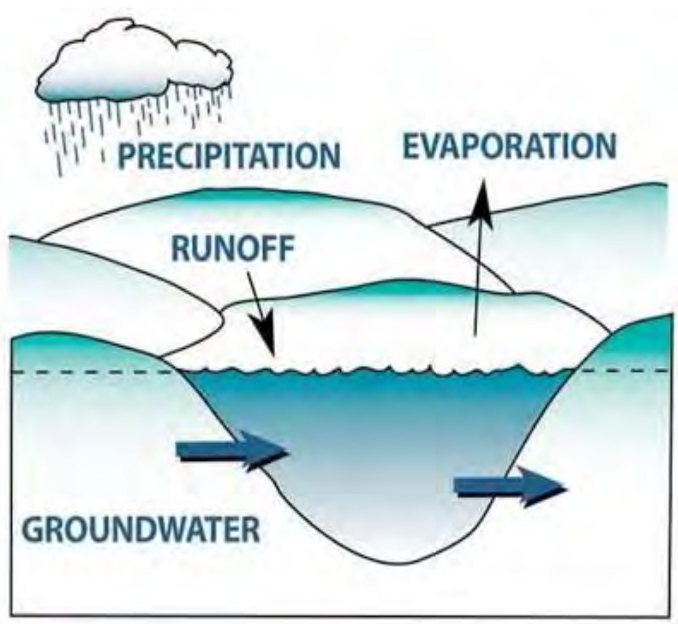


FIGURE 4. NORRIE LAKE GROUNDWATER INFLOW AND OUTFLOW, 2011.

Lake water quality is a result of many factors including underlying geology, climate and land use practices. Assessing lake water quality allows us to evaluate current lake health, changes from the past, and what is needed to achieve a more desirable state (or preserve an existing state) for aesthetics, recreation, wildlife and the fishery. During this study, water quality in Norrie 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 evaluating its water quality and quantity, and in choosing management practices to preserve or influence that quality or quantity. Norrie Lake is classified as a seepage lake. Water enters and leaves seepage lakes primarily through groundwater, and may also enter the lake via surface runoff and direct precipitation (Figure 5). Seepage lakes generally have a longer retention time (length of time water remains in the lake), which affects contact time with nutrients that feed the growth of algae and aquatic plants. These lakes are vulnerable to contamination moving towards the lake in the groundwater. Sources of contaminants for Norrie Lake may include septic systems, agriculture, and road salt.

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

The geologic composition that lies beneath a lake has the ability to influence the temperature, pH, minerals, and other properties in a lake. As groundwater moves through the soil, some substances are filtered out, but other materials dissolve into the groundwater (Shaw et al., 2000). If the soils around the lake are sandy and composed primarily of insoluble minerals, hardness and alkalinity will be low. This is the case in many areas of Wisconsin where the groundwater moves through glacial deposits containing little limestone. The average hardness for Norrie Lake during the 2010-2012 sampling period was 9.8 mg/L, which is considered soft (Table 1). Soft water can limit the biota as it does not provide the calcium necessary for building bones and shells for animals in the lake. The ability of soft water to buffer the effects of acid rain is also limited. The average alkalinity in Norrie Lake was 7 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 NORRIE LAKE, 2010-2012.

Norrie Lake	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as CaCO3)	Color SU	Turbidity(NTU)
Average	7	1.6	0.6	9.8	92.7	2.7

Chloride concentrations, and to lesser degrees sodium and potassium concentrations, are commonly used as indicators of impacts from human activity. The presence of these compounds in the lake at elevated levels indicates the movement of pollutants from the landscape to the lake.

Over the monitoring period, average concentrations of chloride, sodium and potassium were low in Norrie Lake (Table 2). Atrazine (DACT), an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L) in the samples that were analyzed from Norrie Lake.

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

Norrie Lake	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium	0.7			<.75	0.75 - 1.5	>1.5
Chloride	0.53			<3	3.0 - 10.0	>10
Sodium	0.5			<2	2.0 - 4.0	>4

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

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

Water temperature and dissolved oxygen were measured in Norrie Lake from top to bottom at the time of sample collection during the 2010-2012 study. As would be expected, near-freezing temperatures existed near the surface with slight gradual warming towards the bottom of the lake in late winter (February 2011 and 2012). Data collected in spring and fall indicated the water had mixed throughout the lake, replenishing oxygen in the lake bottom. Norrie Lake was somewhat stratified during the growing season (May-September) as surface water warmed. The stratification was weak enough that strong winds may have mixed the water. This is not ideal during the summer because the bottom water is often rich with nutrients released from the sediment, and mixing this nutrient-rich water with the warmer water near the surface may result in algal blooms. Water temperatures near the bottom of the lake ranged by only 15 degrees (reaching a high of 20 degrees in summer), while surface temperatures ranged by nearly 28 degrees (Figure 6).

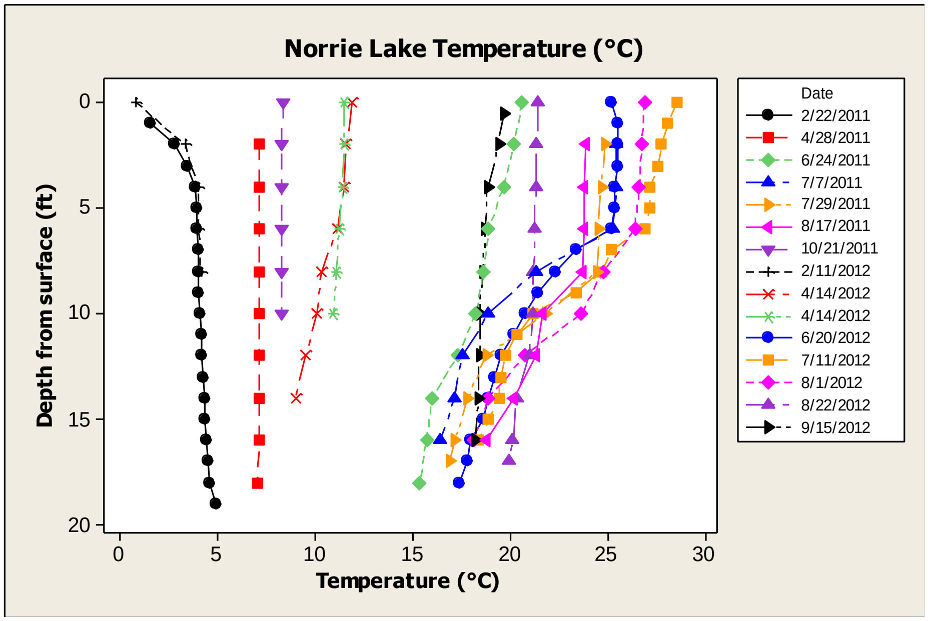


FIGURE 6. TEMPERATURE PROFILES IN NORRIE LAKE, 2011-2012.

Dissolved oxygen concentrations in Norrie Lake ranged from plentiful to limited depending upon depth and time of year. Like temperature, dissolved oxygen was mixed from top to bottom during spring and fall. During the summer, dissolved oxygen concentrations became stratified as the surface water warmed, with sufficient reduction near the bottom where decomposition occurs. In winter of both years during the ice-covered period, the upper six feet of water provided sufficient dissolved oxygen concentrations to support many fish species (Figure 7). In years with long periods of snow and ice cover, a greater percent of the lake's water will have lower concentrations, potentially creating stressful conditions for some species of cold water fish.

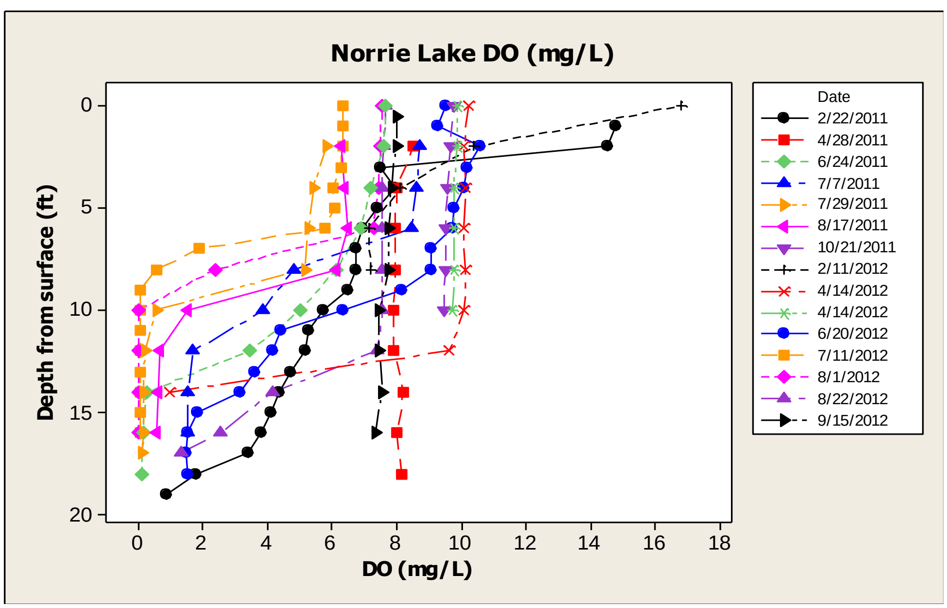
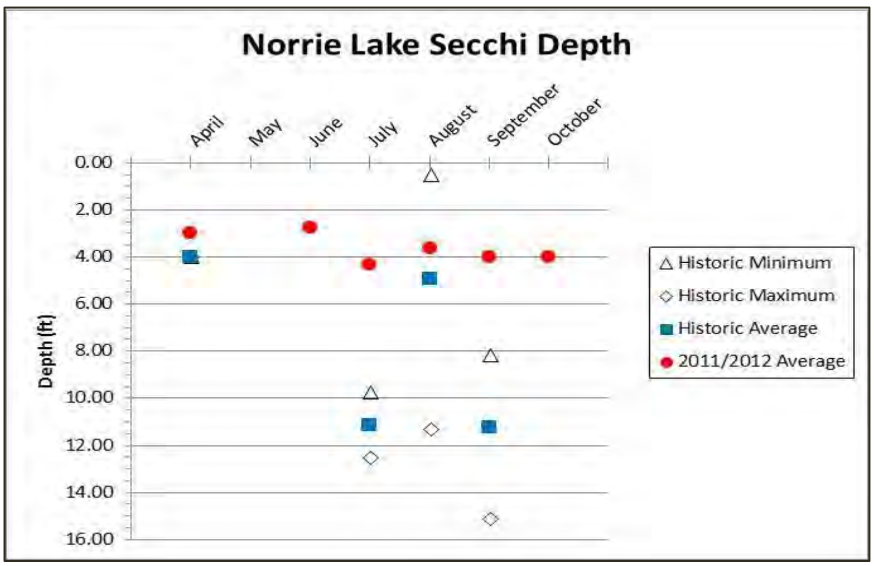


FIGURE 7. DISSOLVED OXYGEN PROFILES IN NORRIE LAKE, 2011-2012.

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 (chlorophyll *a*), so it is normal for water clarity to change throughout the year and from year-to-year. In Norrie Lake, the color index was moderate (Table 1). Brown staining from tannins in the surrounding wetlands and forest were the natural source of the moderately elevated color index. The presence of the stained water reduced the light penetration in Norrie Lake when compared to similar lakes with less stained water. While algal concentrations will increase and decrease throughout the summer, color remained somewhat uniform.

The water clarity measured in Norrie Lake during the study was considered poor. For Norrie Lake, water clarity ranged from 2.3 to 5 feet deep (Figure 8). Limited data had been submitted for Norrie Lake from 1979 to 2005. When compared with this historic data, the average water clarity measured during the study had declined for all months.



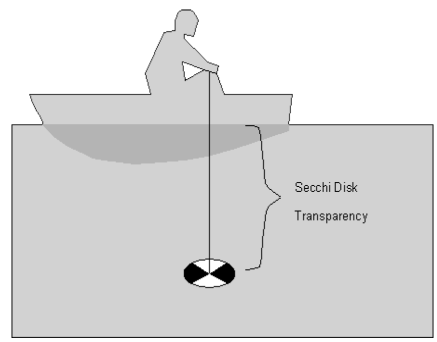


FIGURE 8. AVERAGE MONTHLY WATER CLARITY IN NORRIE LAKE, 2010-2012 AND HISTORIC.

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.

During the study, total phosphorus concentrations in Norrie Lake ranged from a high of 38 ug/L in April 2012 to a low of 17 ug/L in August 2012 (Table 3). The summer median total phosphorus was 30 ug/L and 29.5 ug/L in 2011 and 2012, respectively. This is below Wisconsin's phosphorus standard of 40 ug/L for shallow seepage lakes.

During the study, inorganic nitrogen concentrations in samples collected during the spring in Norrie Lake averaged 0.08 mg/L. These concentrations are low; concentrations above 0.3 mg/L are sufficient to enhance algal blooms throughout the summer (Shaw et al., 2000).

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

Norrie 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	24	28	33	3	4	4	0.63	2.11	3.58	0.08	1.42	2.75	0.55	0.69	0.83
Spring	24	29	33	8	8	8	0.64	0.65	0.66	0.07	0.08	0.08	0.56	0.58	0.59
Summer	28	30	38												
Winter	17	19	20	1	2	3	0.57	0.64	0.71	0.09	0.15	0.20	0.48	0.50	0.51

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Norrie 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. Forests comprised the greatest amount of land in the watershed, but modeling results indicated that agriculture contributed the most phosphorus from the watershed to Norrie 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).

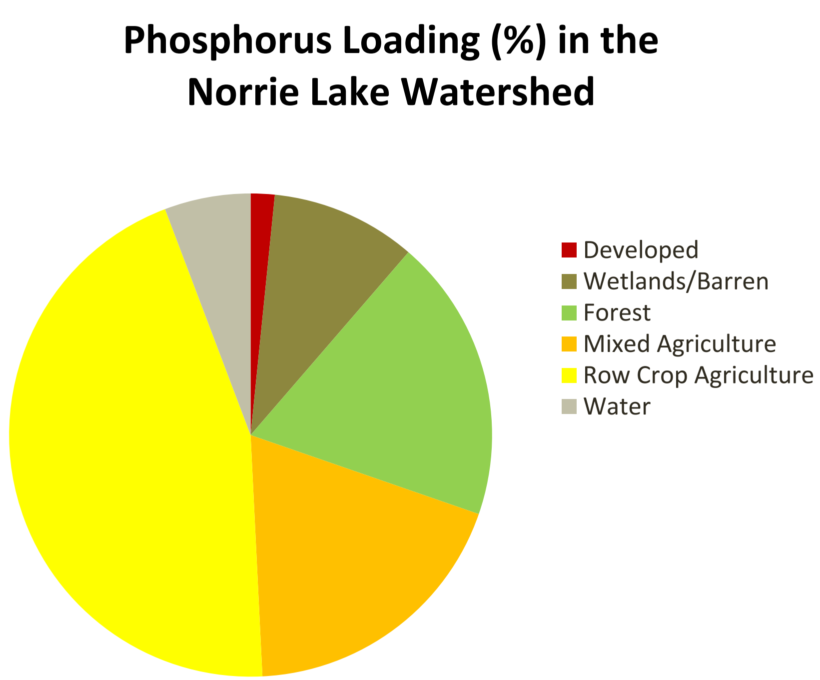


FIGURE 9. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE NORRIE LAKE WATERSHED.

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

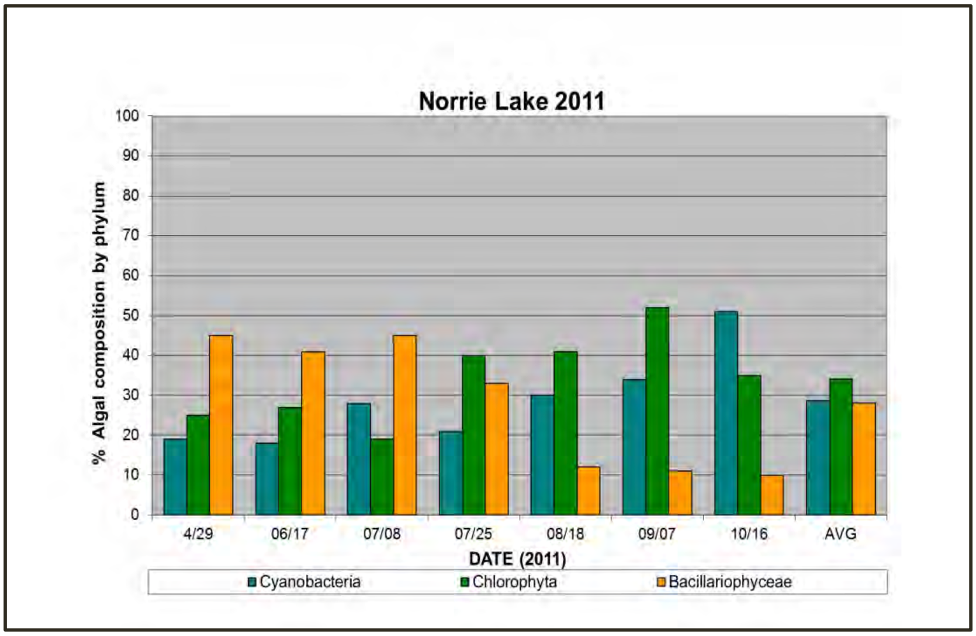
Norrie Lake Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.10	114	**9**	9-27	**6**
Developed	0.04	55	**4**	2-5	**2**
Wetland/Barren	0.09	168	**13**	15-45	**10**
Forest	0.04	655	**52**	29-53	**20**
Mixed Agriculture	0.27	109	**9**	29-78	**20**
Row Crop Agriculture	0.45	156	**12**	69-139	**48**
*Values are not exact due to rounding and conversion.					

Chlorophyll *a* is a measurement of algae in the water. Concentrations greater than 20 ug/L are perceived by many as problem blooms. Chlorophyll *a* concentrations in Norrie Lake were generally low, ranging from a high of 16 ug/L in July 2011 to a low of 2 ug/L in late August 2012.

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

In Marathon County lakes, there are three dominant groups of algae: blue-green algae (Cyanobacteria), green algae (Chlorophyta), and diatoms (Bacillariophyceae). The algae of Norrie Lake during 2011 and 2012 were diverse and balanced among the three dominant algal groups. Community composition patterns differed between the two years. The algal community reflected a moderately mesotrophic lake possibly moving to a more eutrophic status. In both years, the blue-green algae began as minor community components before rising to mid- or late-season dominance. The green algae and the diatoms each dominated early one year, but in no predictable way (Figure 10).

Norrie Lake showed an unsettled algal community with no regular seasonal patterns. The species present were a mixture of mesotrophic and eutrophic organisms, and the three major algal groups waxed and waned differently each year studied. The variable algal community, moderately high total phosphorus value, and fluctuating Secchi disk depths might indicate a lake undergoing a change in trophic status.



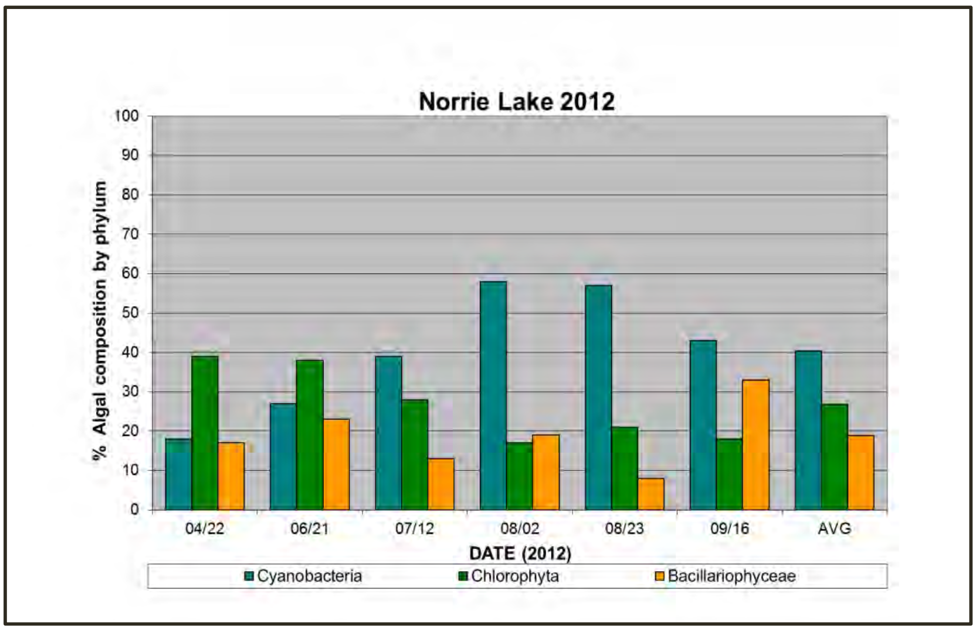


FIGURE 10. PERCENT ALGAL COMPOSITION IN NORRIE LAKE, 2011 AND 2012.

SHORELAND HEALTH

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

The addition of manmade features near the shoreland area can lead to more impervious surfaces. Runoff from driveways, rooftops, and buildings carries pollutants and sediments into the nearby lake. Minimizing the presence of impervious surfaces in the shoreland area can help reduce the amount of 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 the Marathon County staff to identify shoreland areas in need of restoration, as well as shorelands in need of protection. In addition, this information will provide a baseline database from which to measure and monitor success.

NORRIE LAKE SHORELAND SURVEY RESULTS

This survey assessed the vegetation present around the lake's shoreland and identified disturbances 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, water quality, 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 Norrie Lake in Figure 12 depict the depth of vegetation along Norrie 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 from the water's edge and includes a mixture of grasses, forbs, shrubs and trees.

Norrie Lake has approximately 1.5 miles of shoreline. Though much of the shoreland vegetation was primarily in a natural state, the northern portion of the lake lacked an adequate buffer. Grasses and forbs were the most prominent vegetative layer near the water's edge, while trees and shrubs were less common. Much of this was due to the abundance of wetlands adjacent to Norrie Lake where shorter wetland species dominated the shoreland area. Shoreland survey results are displayed in Figure 11. Although Norrie Lake's shoreland is in good shape now, changes can easily occur as development takes place. Minimizing impacts to Norrie Lake from future development should include planning to ensure that prospective developers have information to make informed decisions and that zoning is in place to achieve habitat, water quality, and aesthetic goals.

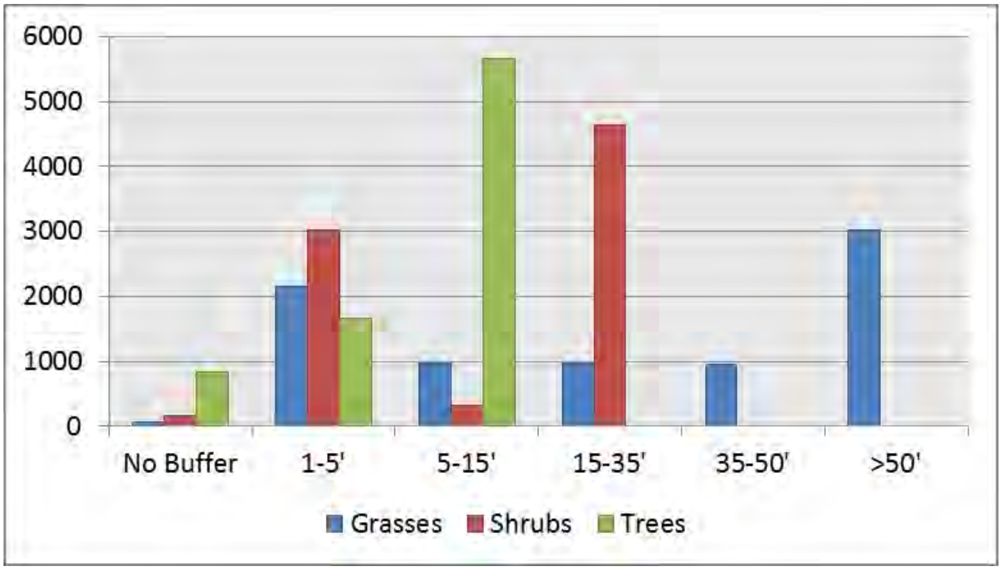


FIGURE 11. SHORELAND VEGETATION SURVEY RESULTS BY BUFFER DEPTH AROUND NORRIE LAKE, 2011.

On the same day the vegetation surveys were conducted, an assessment of disturbances was conducted around Norrie 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 summarizes the manmade structures found on Norrie Lake and Figure 13 displays the approximate locations of the disturbances. Structures such as seawalls, rip-rap (rocked shoreline), and artificial beach result in reduction of habitat. Docks and artificial beaches can result in altered in-lake habitat; denuded lakebeds provide opportunities for invasive species to become established and reduce habitat that is important to fish and other lake inhabitants. Erosion contributes 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 manmade feature is unlikely to pose a large problem to a lake; however, their cumulative impact can create problems for lake habitat and water quality.

TABLE 5. DISTURBANCES AND STRUCTURES LOCATED IN THE NORRIE LAKE SHORELAND, 2011.

Type of Disturbance	No. of Occurrences
Artificial Beach	1
Dock	7
Rip-rap	2
Seawall	1
Erosion	0
Structures w/in 35' of water's edge	3
Structures 35-75' of water's edge	0

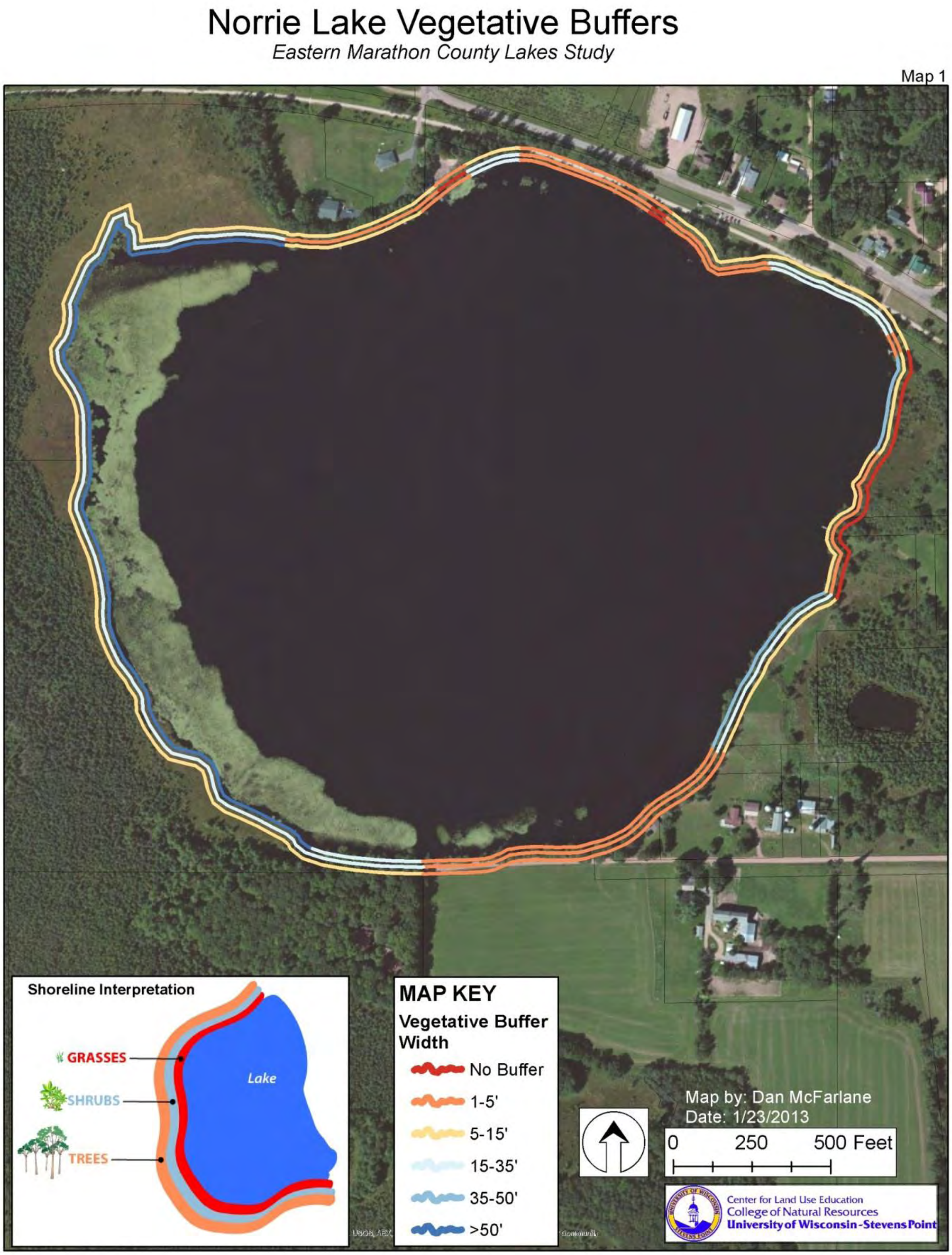


FIGURE 12. SHORELAND VEGETATION SURVEY OF NORRIE LAKE, 2011.

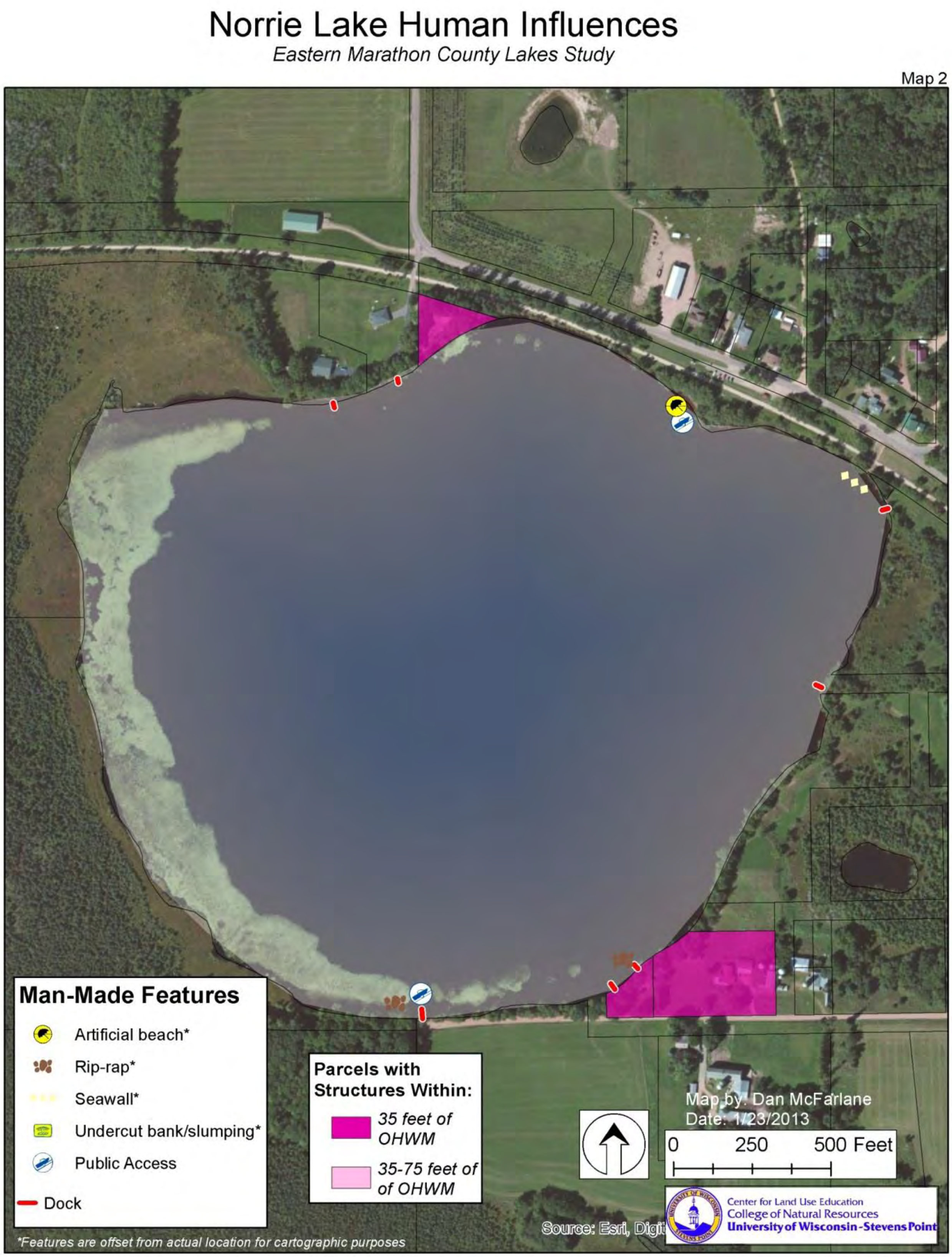


FIGURE 13. SHORELAND DISTURBANCE SURVEY OF NORRIE LAKE, 2011.

A sustainable fishery 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 species has different needs to be met in order to flourish, including adequate food sources, habitat, appropriate nesting substrate, and water quality.

Fish species have different water quality requirements. Each species has its preferred tolerance range for dissolved oxygen, pH, water clarity, temperature, and hardness. A few predatory species, such as largemouth bass, prefer good water clarity to effectively hunt their prey. Others, such as walleye, prefer more turbid waters. Even within a species, water quality preferences may vary during different stages of reproduction. If stocking does occur, choosing the wrong fish species for a lake's conditions will result in a less sustainable fishery, and outside inputs such as aeration or further stocking will be needed.

People are also an important part of a sustainable 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.

Norrie Lake supports a warm water fish community. In 2012, eight fish species were sampled and identified out of the ten species that have been recorded in surveys dating back to 1970. Past survey data were obtained from the Wisconsin Department of Natural Resources (Table 6). Although most species identified in 2012 had been reported previously, smallmouth bass (*Micropterus dolomieu*) was newly documented. Northern pike (*Esox lucius*) and pirate perch (*Aphredoderus sayanus*) were documented previously but not detected during 2012. Pirate perch is a species of special concern in Wisconsin. Bluegill (*Lepomis macrochirus*) and yellow perch (*Perca flavescens*) were most abundant during the 2012 survey, with maximum lengths reaching 9.3 inches and 4.8 inches, respectively (Table 7). Walleye (*Sander vitreus*) reached a maximum length of 22.4 inches. Pumpkinseed (*Lepomis gibbosus*) and black bullhead (*Ameiurus melas*) were least commonly sampled. Crayfish were not encountered during the sampling period.

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

Species	1970	1972	1977	1979	1986	1987	1988	2003	2012
Black Bullhead		x	x						x
Black Crappie		x	x	x	x	x	x	x	x
Bluegill		x	x	x	x	x	x		x
Largemouth Bass		x	x	x	x	x	x	x	x
Northern Pike		x				x			
Pirate Perch	x								
Pumpkinseed				x				x	x
Smallmouth Bass									x
Walleye					x	x	x		x
Yellow Perch		x	x	x	x	x	x	x	x

TABLE 7. TOTAL CATCH AND LENGTHS OF FISH SPECIES IN NORRIE LAKE, 2012 SURVEY.

Species	Min Length (in)	Max Length (in)	Average Length (in)	Total Catch
Bluegill	0.9	9.3	4.6	157
Yellow Perch	0.8	4.8	1.8	127
Largemouth Bass	0.9	4.1	1.9	66
Smallmouth Bass	1.4	2.8	2.1	24
Black Crappie	1.1	10.4	5.8	23
Walleye	5.8	22.4	14.9	16
Black Bullhead	0.9	14.6	9.8	7
Pumpkinseed	4.6	7.6	5.9	4

A variety of fish management techniques have been attempted in Norrie Lake. In 1959, Wisconsin Department of Natural Resources staff noted the potential to manage populations of northern pike, largemouth bass (*Micropterus salmoides*), and bluegill. In 1957 and 1958, adult northern pike were stocked and public opinion noted an increase in catchable-sized bluegill. Due to this success, recommendations for a complete renovation program with chemical treatment was proposed, but not passed. After a complaint from a local trout fisherman in 1967, a fish barrier was placed between Norrie Lake and the Embarrass River system to prohibit migration of northern pike that were thought to be negatively impacting the trout population. In 1972, fish management focused on producing stable populations of northern pike, largemouth bass, and panfish. Bluegill and black crappie (*Pomoxis nigromaculatus*) surveyed in 1972 were noted as slightly above-average in size. Walleye and muskellunge stocking was not recommended at this time (and reiterated in a 1978 report) due to a lack of good spawning habitat. Fish cribs were installed in various locations following a 1976 permit request. Fish stocking records for Norrie Lake date back to 1938 according to Wisconsin Department of Natural Resources files (Table 8). Historic stocking consisted of yellow perch, rock bass (*Ambloplites rupestris*), largemouth bass, black crappie, northern pike, muskellunge (*Esox masquinongy*), smallmouth bass (*Micropterus dolomieu*), and in recent years, walleye.

TABLE 8. WISCONSIN DEPARTMENT OF NATURAL RESOURCES FISH STOCKING SUMMARY FOR NORRIE 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	15350	
1938	Rock Bass	Adult	150	
1938	Sunfish	Adult	100	
1939	Largemouth bass	Fingerling	5000	
1939	Crappie	Adult	528	
1941	Largemouth bass	Fingerling	10000	
1942	Largemouth bass	Fingerling	300	
1943	Largemouth bass	Fingerling	400	
1944	smallmouth Bass	Fingerling	50	
1947	Largemouth bass	Fingerling	1500	
1949	Largemouth bass	Fingerling	2000	
1950	Largemouth bass	Fingerling	1300	
1952	Largemouth bass	Fingerling	550	
1953	Largemouth bass		550	
1957	Northern pike	Adult	467	
1958	Northern pike		498	
1960	Northern pike	Adult	111	
1962	Muskellunge	Fingerling	550	
1963	Northern pike	Fingerling	825	
1964	Northern pike	Fingerling	1000	
1965	Northern pike	Fingerling	2900	
1966	Northern pike	Adult	1541	
1975	Northern pike	Adult	250	
1976	Northern pike	Fry	200,763	
1978	Northern pike	Adult	100	
1979	Northern pike	Adult	226	
1980	Northern pike	Adult	100	
1981	Northern pike	Adult	150	
1982	Northern pike	Adult	200	
1984	Northern pike	Adult	200	15
2007	Smallmouth bass	Fingerling	400	5
2007	Walleye	Fingerling	1,000	8
2008	Smallmouth bass	Fingerling	200	
2008	Walleye	Fingerling	1,200	5
2009	Smallmouth bass	Yearling	200	6
2009	Walleye	Fingerling	800	8
2010	Smallmouth bass	Fingerling	250	5
2010	Walleye	Fingerling	1,250	4
2011	Walleye	Fingerling	1,350	8

BOTTOM SUBSTRATE AND COARSE WOODY HABITAT

To successfully sustain a healthy fish community, a lake must have the habitat to support it. Habitat needs of fish include aquatic plants (not too many and not too few) and woody structure such as logs, fallen trees, and stumps. Woody structure provides cover for fish to hide, as well as habitat for invertebrates that are food for many fish species. Invertebrates, zooplankton and algae are the main food sources for many fish. These organisms often live on or around aquatic plants or woody structure. Many young fish prefer to dwell in adjacent wetlands that provide plenty of food, cover, and fewer large predators.

In-lake habitat was examined from the shoreline out to a distance of 30 meters. Substrate in Norrie Lake primarily consisted of a soft bottom, muck (80%), sand (5.2%), and mixtures of hard substrate (Figure 14). Gravel substrates 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. Bulrush is sparse in Norrie Lake. Yellow perch and walleye utilize near-shore cobble in oxygen-rich environments for spawning activity; parents do not offer parental care. Sand can be important habitat for reproduction of non-game minnow. The presence of young bass and abundant sunfish sampling indicated successful reproduction was occurring in Norrie Lake. The absence of young northern pike in 2012 sampling may be an indicator of poor reproduction, although more intense population sampling over several seasons would be required to determine the reproduction effort for individual fish species. Young walleye were present in Norrie Lake; however, conclusions about natural reproduction would be difficult without more intensive sampling efforts. The presence of young smallmouth bass, largemouth bass, and sunfish was an indication of successful reproduction for these species.

Coarse woody habitat (CWH), including downed trees and logs, were abundant in Norrie Lake (Figure 15). Norrie Lake has a unique habitat feature on its northeastern shoreline: scattered wood. A historic logging operation deposited large amounts of scrap wood, and many logs and pieces still cover the bottom today. This is an excellent spawning habitat, protective cover, and foraging site for aquatic organisms.

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

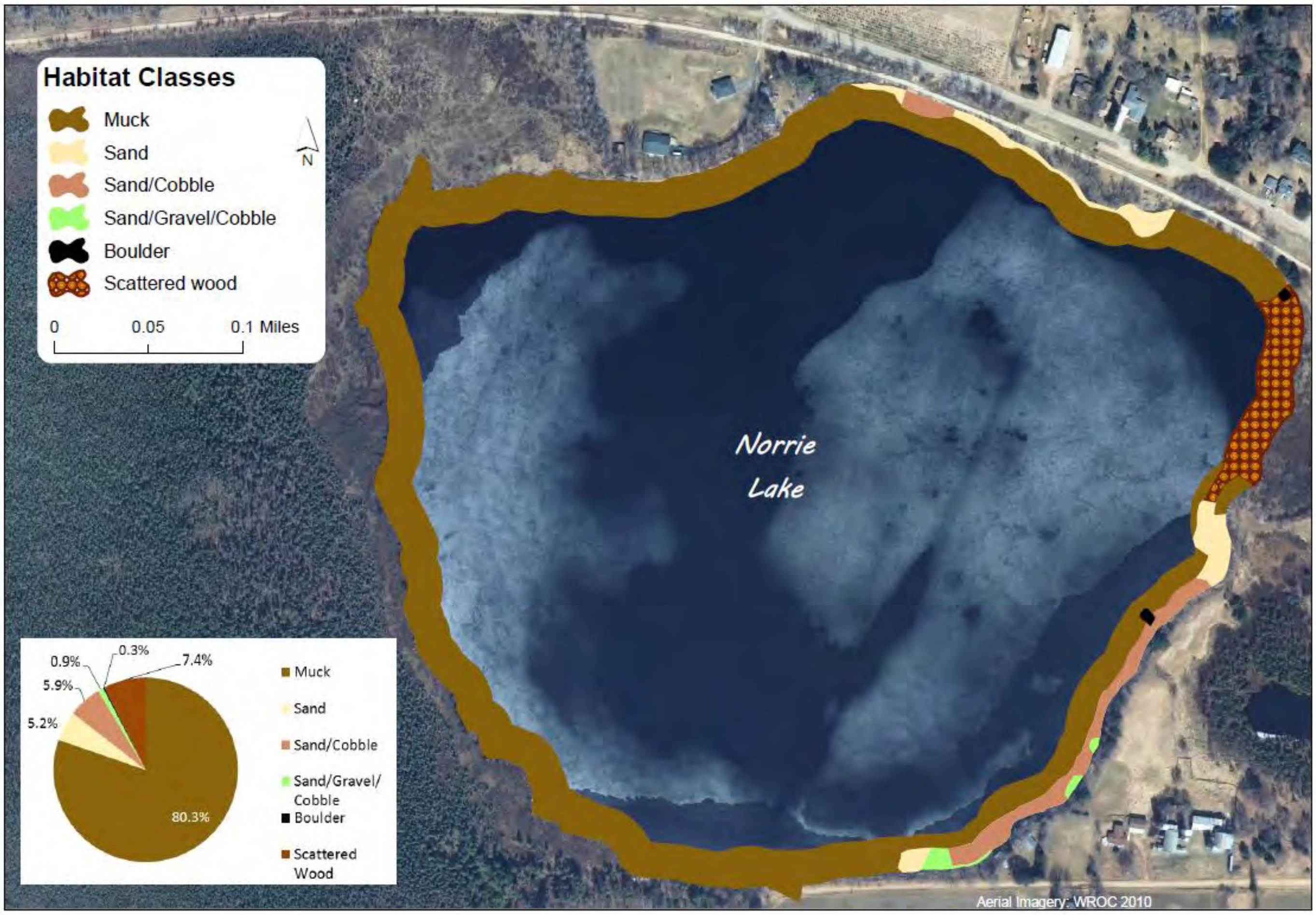


FIGURE 14. DISTRIBUTION OF SUBSTRATE HABITAT IN NORRIE LAKE, 2012.

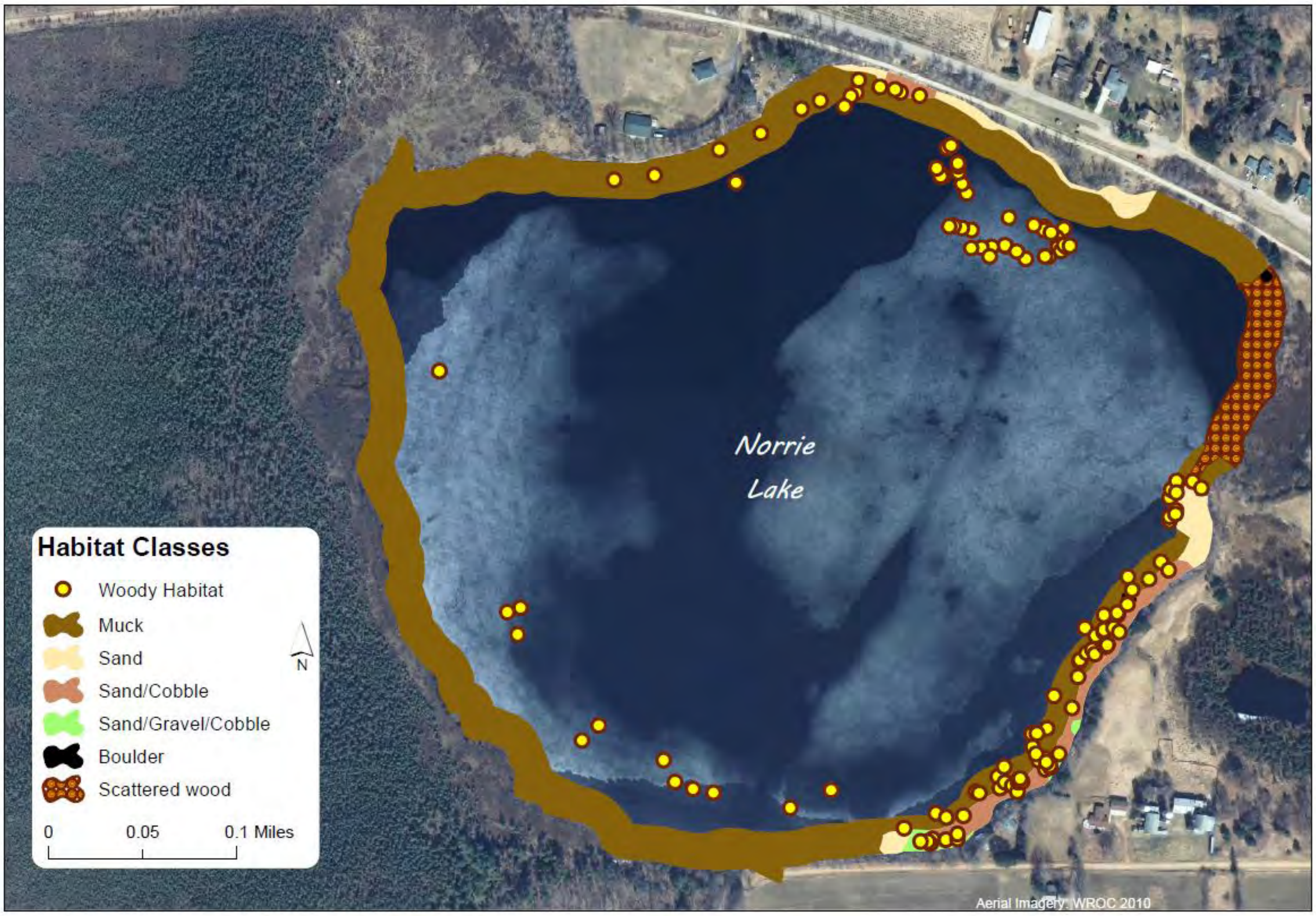
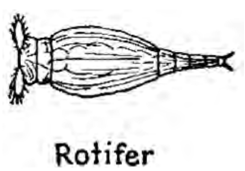


FIGURE 15. DISTRIBUTION OF COARSE WOODY HABITAT NEAR THE SHORES OF NORRIE LAKE, 2012.

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 in check. 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. 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 species within these groups wax and wane during the ice-free season as algae, temperature and fish predation change.



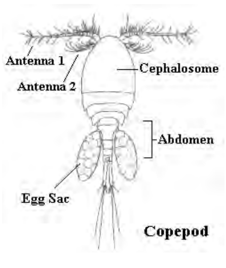
www.revistadeletr

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 based on 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 the algae are the preferred food of cladocerans. It is the cladocerans that are responsible for increasing water clarity in mid-summer by filtering algae that cause summertime blooms.

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



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

The zooplankton community of Norrie Lake was moderately diverse (Table 9, Table 10). Zooplanktons were classified based on two general size categories: nano-plankton (80 *u*m or less) or net plankton (210 *u*m or less).

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

- There were 391 individuals counted during this period:
    - 284 rotifers, 26 cladocerans, 82 copepods

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

- There were 228 individuals counted during this period:
    - 57 rotifers, 118 cladocerans, 53 copepods

Rotifers were the dominant taxa in two of four sample periods during the 2011-2012. These taxa dominated from early summer though fall before falling into subdominant positions in winter. Immature copepods were dominant in winter and early spring in both nano-plankton and net plankton samples, occupying the top abundance spots in March samples. Cladocerans were most abundant in summer and fall in net plankton samples, but faded from abundance in winter and spring. Net plankton rotifers were abundant in spring.

The zooplankton community when considered relative to the algal, phosphorus, and nitrogen values for Norrie Lake presented a picture of a mesotrophic lake. The 4 genera of rotifers, 5 genera of cladocerans, and 3 genera of copepods identified during the sample periods were a mixture of common and uncommon types, but none of those reaching numerical dominance in the sample counts were associated as invasive or exotic. A stable, seasonally changing zooplankton community dominated by smaller nano-plankton rotifers, cladocerans, and copepods suggested that Norrie Lake is fairly mesotrophic.

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

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 25	Copepod	Nauplii	Rotifer	*Notholca* spp.	Rotifer	*Keratella hiemalis*
June 17	Rotifer	*Keratella cochlearis*	Rotifer	*Notholca* spp.	Rotifer	*Polyarthra dolichoptera*
October 21	Rotifer	*Polyarthra vulgaris*	Rotifer	*Notholca* spp.	Rotifer	*Keratella cochlearis*
March 4	Copepod	Nauplii	Copepod	*Cyclopoid copepodite*	Rotifer	*Keratella cochlearis*

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

Date	Primary dominant	Species	Secondary dominant	Species	Tertiary dominant	Species
April 25	Rotifer	*Keratella longispina*	Rotifer	*Filinia terminalis*		
June 17	Cladoceran	*Ceriodaphnia* spp.	Cladoceran	*Daphnia pulex*	Copepod	Nauplii
October 21	Cladoceran	*Bosmina longirostris*	Rotifer	*Keratella cochlearis*	Copepod	*Diacyclops nanus*
March 4	Copepod	Nauplii				

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 Norrie Lake, fifty percent (61 of 121) of the sampled sites had vegetative growth. Of the sampled sites within Norrie Lake, the average depth was 6 feet and the maximum depth was 8 feet. Twenty-six species of aquatic plants were found in Norrie Lake (Table 11). Norrie Lake had the second highest number of species out of the eleven lakes in the Eastern Marathon County Lakes Study. The greatest diversity was located in the northwestern corner of the lake (Figure 16).

The dominant plant species in the survey was watershield (*Brasenia schreberi*), followed by ribbon leaved pondweed (*Potamogeton epihydrus*) and common bladderwort (*Utricularia vulgaris*). The seeds, leaves, and stems of watershield are food sources for a wide variety of waterfowl. The broad, floating leaves of the plant provide shade and shelter to fish and other species. Ribbon leaved pondweed also provides food to waterfowl. The leaves and stems of the plant are often colonized by invertebrates and offer foraging opportunities for fish. Bladderworts are carnivorous plants, using vacuums in their bladders to catch tiny insects. The free-floating common bladderwort provides food and cover for fish in areas that are not readily colonized by rooted plants (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 Norrie Lake was 33, which was well above average and ranked second highest among the lakes in the Eastern Marathon County Lakes Study.

Of the aquatic plant species within Norrie Lake, 13 had a C value of eight or greater (Table 11). Norrie Lake had had more high quality plants than any of the lakes in the Eastern Marathon County Lakes Study. Out of these thirteen species, three are designated as species of special concern in Wisconsin: Farwell's water milfoil (*Myriophyllum farwellii*), waterthread pondweed (*Potamogeton diversifolius*), and large purple bladderwort (*Utricularia purpurea*). Norrie Lake was one of only four lakes within the Eastern Marathon County Lakes Study hosting species of special concern.

The Simpson Diversity Index (SDI) quantifies biodiversity based on a formula that uses the number of species surveyed and the number of individuals per site. The SDI uses a decimal scale of zero to one with values closer to one representing greater biodiversity. Norrie Lake had a SDI value of 0.85, which represented average biodiversity when compared with other lakes in the Eastern Marathon County Lakes Study.

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

Overall, the aquatic plant community in Norrie Lake can be characterized as having good species diversity, with a number of relatively uncommon species to central Wisconsin. The wetlands surrounding Norrie Lake provide excellent habitat and an incredible variety of plant species. These wetlands also contribute to the dark color of the water. This limits light penetration and inhibits aquatic plant growth in areas of the lake deeper than eight feet. The habitat, food source, and water quality benefits of the diverse plant community in and around Norrie Lake should be focal points in future lake management strategies.

TABLE 11. AQUATIC PLANTS IDENTIFIED IN THE 2012 AQUATIC PLANT SURVEY ON NORRIE LAKE.

Common Name	Scientific Name	Coefficient of Conservatism Value (C value)
Emergent Species		
creeping spikerush	*Eleocharis palustris*	6
northern blue-flag	*Iris versicolor*	
common arrowhead	*Sagittaria latifolia*	3
pickerelweed	*Pontederia cordata*	8
American bur-reed	*Sparganium americanum*	8
common bur-reed	*Sparganium eurycarpum*	5
broad-leaved cattail	*Typha latifolia*	1
Floating Leaf Species		
watershield	*Brasenia schreberi*	6
spatterdock	*Nuphar variegata*	6
white water lily	*Nymphaea odorata*	6
floating-leaf pondweed	*Potamogeton natans*	5
Oakes pondweed	*Potamogeton oakesianus*	10
Submergent Species		
muskgrass	*Chara*	7
waterwort	*Elatine minima*	9
spiny spored quillwort	*Isoetes echinospora*	8
brown fruited rush	*Juncus pelocarpus f. submersus*	8
Farwells water-milfoil	*Myriophyllum farwellii**	8
dwarf water-milfoil	*Myriophyllum tenellum*	10
waterthread pondweed	*Potamogeton diversifolius**	8
ribbon leaved pondweed	*Potamogeton epihydrus*	8
water bulrush	*Schoenoplectus subterminalis*	9
twin-stemmed bladderwort	*Utricularia geminiscapa*	9
large purple bladderwort	*Utricularia purpurea**	9
common bladderwort	*Utricularia vulgaris*	7

*Species of special concern in Wisconsin.

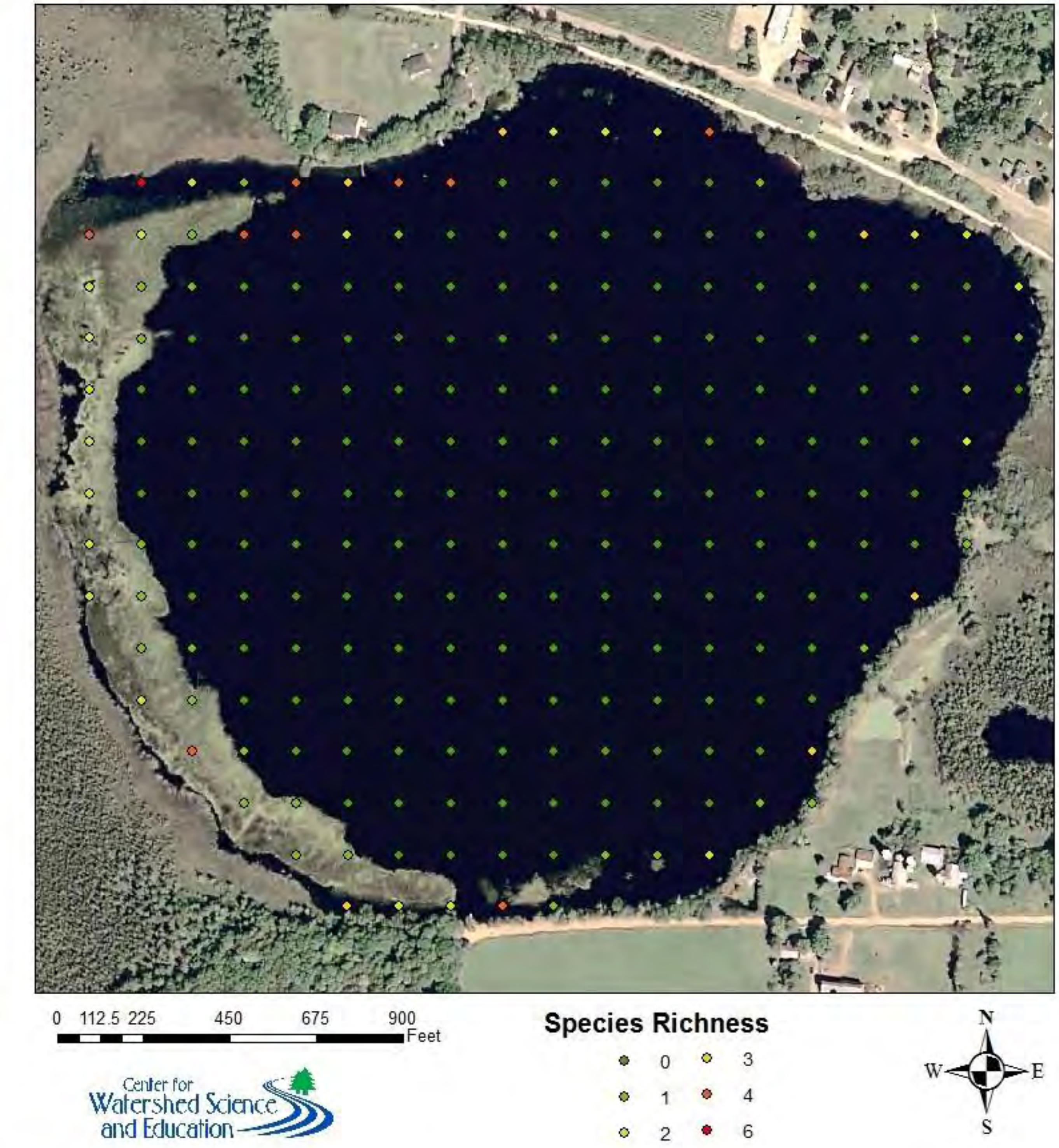


FIGURE 16. SPECIES RICHNESS AT SAMPLE SITES ON NORRIE LAKE, 2012.

CONCLUSIONS & RECOMMENDATIONS

Norrie Lake is a nutrient-rich lake. Its soft water makes it particularly susceptible and responsive to the addition of nutrients, especially phosphorus; therefore, care should be taken to minimize the addition of phosphorus to the lake from erosion, the addition of nutrients to the landscape within the watershed, and the re-suspension of lake sediments from boat wakes and/or disturbing the protective layer provided by aquatic plants.

- The average hardness for Norrie Lake during the study period was 9.8 mg/L, which is considered soft. Soft water can limit the plants and animals in a lake as it does not provide the calcium necessary for building bones and shells. The low calcium has minimal capacity to buffer the effects of acid rain and phosphorus additions.
- Over the study period, concentrations of chloride, sodium, potassium, and inorganic nitrogen were low, and atrazine, an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L) in the samples that were analyzed from Norrie Lake.
- During the study, total phosphorus concentrations in Norrie Lake ranged from a high of 38 ug/L in April 2012 to a low of 17 ug/L in August 2012. The summer median total phosphorus concentration was 30 ug/L and 29.5 ug/L in 2011 and 2012, respectively. While this is below Wisconsin's phosphorus standard of 40 ug/L for shallow seepage lakes, the water clarity measured in Norrie Lake during the study was considered poor. Water clarity ranged from 2.3 to 5 feet into the water. When the study data was compared with limited past data (1979 to 2005) submitted for Norrie Lake, average water clarity was found to have declined for all months.

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 the water temperature, nutrient availability, and overall water quality of a lake using algal populations.

- Norrie Lake showed an unsettled algal community with no regular seasonal patterns.
- The species present were a mixture of mesotrophic and eutrophic organisms, and the three major algal groups (blue-green, green, and diatoms) waxed and waned differently each study year.
- Similar patterns were observed for chlorophyll *a* measures, which were higher in 2011 and much lower in 2012. Chlorophyll *a* is a common measurement of algae in the water.
- The variable algal community, moderately high total phosphorus value, and fluctuating water clarity depths might indicate a lake undergoing a change in trophic status.

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 four genera of rotifers, five genera of cladocerans, and three genera of copepods identified during the sample periods were a mixture of common and uncommon types.
- None of the zooplankton that reached numerical dominance in the sample counts were associated as invasive or exotic.
- The zooplankton community, when considered relative to the algal, phosphorus, and nitrogen values for Norrie Lake, presented a picture of a mesotrophic lake.

A healthy fishery is one that seeks to be in balance with the lake's natural ability to support the fish community, and one in which populations do not decline over time because of fishing practices. The fish community should be adaptable to fishing without additional stocking or input. A balanced fish community has a mix of predator and prey species, each of which has different needs to flourish including sufficient food, habitat, appropriate spawning substrate, and water quality.

- Norrie Lake supports a warm water fish community. In 2012, eight fish species were sampled and identified out of the ten species that have been recorded in surveys dating back to 1970 (Wisconsin Department of Natural Resources).
- Smallmouth bass was newly documented during the 2012 survey.
- Northern pike and pirate perch were documented previously, but not detected during 2012. Pirate perch is a species of special concern in Wisconsin.
- Bluegill and yellow perch were most abundant during the 2012 survey, with maximum lengths reaching 9.3 inches and 4.8 inches, respectively**Error! Reference source not found.**.
- Walleye size reached a maximum length of 22.4 inches. Pumpkinseed and black bullhead were the least commonly sampled species.
- Crayfish were not encountered during the sampling period.

As a part of the fishery study, in-lake habitat was examined from the shoreline out to a distance of 90 feet. Substrate in Norrie Lake consisted of a soft bottom, muck (80%), sand (5.2%), and mixtures of hard substrate. Coarse woody habitat (CWH), including downed trees and logs, are abundant in Norrie Lake. Norrie Lake has a unique habitat feature on the northeastern shoreline: scattered wood. A historic logging operation deposited large amounts of scrap wood, and many logs and pieces still cover the bottom today. This is an excellent spawning habitat, protective cover, and foraging site for aquatic organisms.

- Yellow perch and walleye utilize near-shore cobble in oxygen-rich environments for spawning activity; parents do not offer parental care.
- Sand can be important habitat for reproduction of non-game minnows. The presence of young smallmouth bass, largemouth bass, and sunfish was an indication of successful reproduction for these species in Norrie Lake.
- Young walleye were present in Norrie Lake; however, conclusions about natural reproduction would be difficult without more intensive sampling efforts.
- Bulrush was sparse in Norrie Lake. Northern pike, which do not offer parental care, utilize areas with emergent and floating-leaf vegetation in shallow or flooded areas for spawning. The absence of young northern pike in the 2012 sampling may be an indicator of poor reproduction, although more intense population sampling over several seasons would be required to determine the reproduction effort for individual fish species. Black crappie utilize bulrush habitat on gravel or sand substrates where they construct nests and guard young.

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.

- The diversity of an aquatic plant community is defined by the type and number of species present throughout the lake. Norrie Lake had the second highest number of species of the 11 lakes in the Eastern Marathon County Lakes Study. Twenty-six aquatic plant species were observed during the survey in Norrie Lake.
- Norrie Lake had more high quality plants than any of the lakes in the Eastern Marathon County Lakes Study – 13 species were considered high quality with a C-value of eight or greater.
- Out of these 13 species, three are designated as species of special concern in Wisconsin: Farwell's water milfoil, waterthread pondweed, and large purple bladderwort. Norrie Lake was one of only four lakes within the Eastern Marathon County Lakes Study hosting species of special concern.
- The greatest diversity was located in the northwestern corner of the lake.
- No aquatic invasive plant species were observed in Norrie Lake during the aquatic plant survey in 2011.
    - 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.

Norrie Lake's surface and groundwater watersheds provide most of the water to the lake. In general, each type of land use contributes different amounts of phosphorus in runoff and through groundwater. The types of land management practices that are used and their distances from the lake also affect the contributions to the lake from a parcel of land.

- Identifying and taking steps to improve water quality in Norrie Lake will be aided by understanding the sources of phosphorus to the lake and identifying those that are manageable. Forests comprised the greatest amount of land in Norrie Lake's watershed, but modeling results indicated that agriculture contributed the most phosphorus from the watershed to the lake.
- 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. 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. Norrie Lake's shoreland was assessed for the extent of vegetation and disturbances.

- Norrie Lake has approximately 1.5 miles of shoreline. Although much of the shoreland vegetation is primarily in a natural state, the northern portion of the lake lacks adequate buffer.
- Strategies should be developed to ensure that healthy shorelands remain intact, and efforts should be made to improve shorelands that have disturbance. Efforts may include:
    - Informing new and existing property owners about the importance of healthy shorelands and ways they can protect them.
    - Informing interested property owners about options for protecting undisturbed shoreland, such as conservation easements. Conservation easements allow property owners to determine how their land will be managed and which parts of the property will be protected, typically resulting in lower taxes. Unless public funds are used for the purchase of the easement, there is no requirement to allow access to the public.
    - Ensuring that prospective developers have the information needed to make good decisions, and that zoning is in place to achieve habitat, water quality, and aesthetic goals.

REFERENCES

Borman, Susan, Robert Korth, Jo Temte, 2001. *Through the looking glass, a field guide to aquatic plants.* Reindl Printing, Inc. Merrill, Wisconsin.

Hayes, T., K. Haston, M. Tsui, A. Hoang, C. Haeffele and A. Vonk. 2003. *Atrazine-Induced Hermaphroditism at 0.1 PPB in American Leopard Frogs (Rana pipiens): Laboratory and Field Evidence.* Environmental Health Perspectives 111: 568-575.

Hayes, T.K. A. Collins, M, L,, Magdelena Mendoza, N. Noriega, A. A. Stuart, and A. Vonk. 2001. *Hermaphroditic, demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses.* National Academy of Sciences vol. 99 no. 8, 5476–5480.

Panuska and Lillie, 1995. *Phosphorus Loadings from Wisconsin Watershed: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds.* Bulletin Number 38, Bureau of Research, Wisconsin Department of Natural Resources.

Shaw, B., C. Mechenich, and L. Klessig. 2000. *Understanding Lake Data.* University of Wisconsin-Extension, Stevens Point. 20 pp.

Wetzel, R.G. 2001. *Limnology, Lake and River Ecosystems, Third Edition.* Academic Press. San Diego, California.

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."