Krohns Lake: A Comprehensive Lake Management Plan

Kewaunee County, Wisconsin

Developed and presented through the University of Wisconsin – Green Bay
2420 Nicolet Dr., Green Bay, WI 54311
December 2015

Krohns Lake

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Lake Management Plan

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Acknowledgements

This management plan is the result of student collaboration on behalf of the Limnology course offered at the University of Wisconsin – Green Bay. Special thanks to Steve Hogler (WDNR) and William Iwen (Tri-Lakes Association) for offering their extensive knowledge and experience in reference to Krohns Lake which heavily guided the development of this report.

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1.0 Introduction

1.1 Krohns Lake Physiography and Land Use Within The Watershed

Krohns Lake is an inland spring lake fed by groundwater inflows and predominately groundwater drainage located approximately six kilometers southwest of Algoma, Kewaunee County, WI (Map 1.1.1). Krohns Lake is one of the 139 lakes housed within the Twin-Door-Kewaunee basin that comprises 12 watersheds within Calumet, Door, Kewaunee, and Manitowoc counties, all of which overlie a Silurian bedrock dominated by calcareous dolomite. Krohns Lake specifically belongs to the smaller ~56 km^2 Mashek Creek sub-watershed within the Twin-Door-Kewaunee basin (Map 1.1.2). Land use within the Mashek Creek watershed is dominated by agricultural crops and pastureland, though additional land use includes: wetlands, developed areas, forest, and open water (Map 1.1.3; Table 1.1.1).

Table 1.1.1. Land use in the Mashek Creek Watershed. Derived from 2010 National Agricultural Statistics Service Cropland Data for Wisconsin.

Land Use	Percentage of Watershed (%)	Area of Watershed (km^2)
Agriculture	44.9	25.1
Fallow/Pasture	32.6	18.2
Wetlands	12.5	7.0
Development	6.5	3.6
Forest	2.7	1.5
Open Water	0.8	0.5
Total	**100.0**	**55.9**

Only one intermittent outlet, Three Mile Creek, is present in the northeastern area of Krohns Lake, while a spring exists on the western edge of the lake as well (Map 1.1.4). Additional springs were present in the northeastern area of the lake before the construction of the parking and boat launch area that resulted in the filling of these springs, though the evidence of the springs still exists. The area immediately surrounding the 1.42 km of shoreline is heavily wooded wetlands, and while there are approximately 15 residences abutting the lake, it is relatively undeveloped.

1.2 Krohns Lake Morphology

Krohns Lake exhibits dimictic mixing in that it is subjected to thermal stratification in the summer and winter months, while experiencing mixing events in the spring and fall. Of the 8.3 surface hectares that Krohns Lake encompasses, nearly two-thirds (61%) of the area maintains water depths greater than 6 m, while only 10.3% maintains water depths less than 1 m. With a maximum water depth of 11.6 m and mean water depth of 6.4 m, total lake volume is approximately 53.94 ha m. . Bottom substrates are described as predominately muck, typic of lakes within the region. Due to these soft sediments, only electric trolling or non-motorized boats are authorized on Krohns Lake to protect against the uprooting of aquatic plants that provide vital fishery spawning habitat.

1.3 Krohns Lake Management and Concerns

Today, Krohns Lake is managed under the Tri-Lakes Association and houses the Kewaunee County Park which includes a boat landing, fishing platform, and beach area promoting increased recreational usage of the lake. While the lake is considered moderately productive and is seemingly clear for the majority of the year, citizen-based monitoring over the past decade reports algal blooms as increasingly impairing water clarity and thus enjoyment of the lake for residents and visitors (particularly from July to August); a problem suggested to be partially attributed to slight increases in the nutrient status of Krohns Lake. The Tri-Lakes Association considers the potential increase in trophic state the most serious concern facing Krohns Lake, and attributes much of the source of increased nutrification of lakes in the area to be directly related to the high concentration of confined animal feeding operations (CAFOs) in Kewaunee County. Of particular concern for Krohns Lake is the close proximity of Ebert Enterprises which is currently permitted to house 5,714 animal units, and is expected to expand its permit to over 8,600 animal units by 2017. Given the karst bedrock present in Kewaunee County, this has led to concerns over groundwater contamination through excess manure applications made by CAFO's near Krohns Lake. The Tri-Lakes association is currently addressing issues of nutrient runoff and contamination in Krohns Lake by disseminating information to nearby residents about the effects of lawn fertilizer runoff on lake ecosystems, and has enlisted the help of the WDNR to identify major animal wastes in the area potentially hazardous to Krohns Lake.

An additional concern for the Tri-Lakes association and Wisconsin Department of Natural Resources, which stocks trout in Krohns Lake, includes the Krohns Lake fishery. Sporadic surveys conducted by the WDNR and consulting agencies (Onterra and Northern Environmental Group) enlisted by the lake association have produced variable results, though an overall decrease in abundance and richness of Krohns Lake fishes, particularly panfish, has been documented from the 1960's to present. Following a 2013 fishery survey, the WDNR suggests that more continuous monitoring of the Krohns Lake fishery be conducted to identify threats to the native and stocked fish.

Lastly, the Tri-Lakes association received grants to identify and manage the two aquatic invasive species documented in Krohns Lake within the last decade, including curly-leafed pondweed

(*Potamogeton crispus*) and Eurasian/hybrid water milfoil (*Myriophyllum spicatum; Myriophyllum sibiricum × spicatum*) that may contribute to potential damages in species diversity and the intrinsic value of Krohns Lake. Herbicide treatments were applied approximately five years ago in Krohns Lake using pelletized 2,4-D to manage the invasive species, though subsequent monitoring has shown that these aquatic invasive species are still prevalent in Krohns Lake today.

The purpose of this report is to provide an inclusive baseline description of the current chemical, physical, and biological characteristics of Krohns Lake. We provide a detailed description of water quality in Krohns Lake, a review of WDNR data on the Krohns Lake fishery, and the results from our vegetation, zooplankton, and benthic biota surveys. Within each description, we offer management suggestions for the WDNR and Tri-Lakes Association. All water quality sampling and zooplankton/benthic organism surveys were conducted at nine waypoints in Krohns Lake (Map 3.xxxx) while vegetation point surveys were conducted at approximately every 60 m around the lakeshore. All data for this report was collected 9/25/2015 and 10/5/2015.

2.0 Water Quality

2.1.1 Results

Secchi Depth

Secchi depth is the point at which an 8 in diameter, black and white secchi disk no longer becomes visible as it is lowered into the water column and is highly correlated with water turbidity/clarity.

Secchi depth was measured at all nine waypoints in Krohns Lake (Map 1.1.4) in September and October. The secchi disc was lowered by rope into the water column until it was no longer visible, at which point the depth was recorded. While the UW-Green Bay 2015 average secchi depth measurement shows an increase in secchi depth for Krohns Lake (Figure 2.1.1), it is important to note that our measurements were not conducted in July-August when water temperatures are highest and clarity is expected to be the lowest.

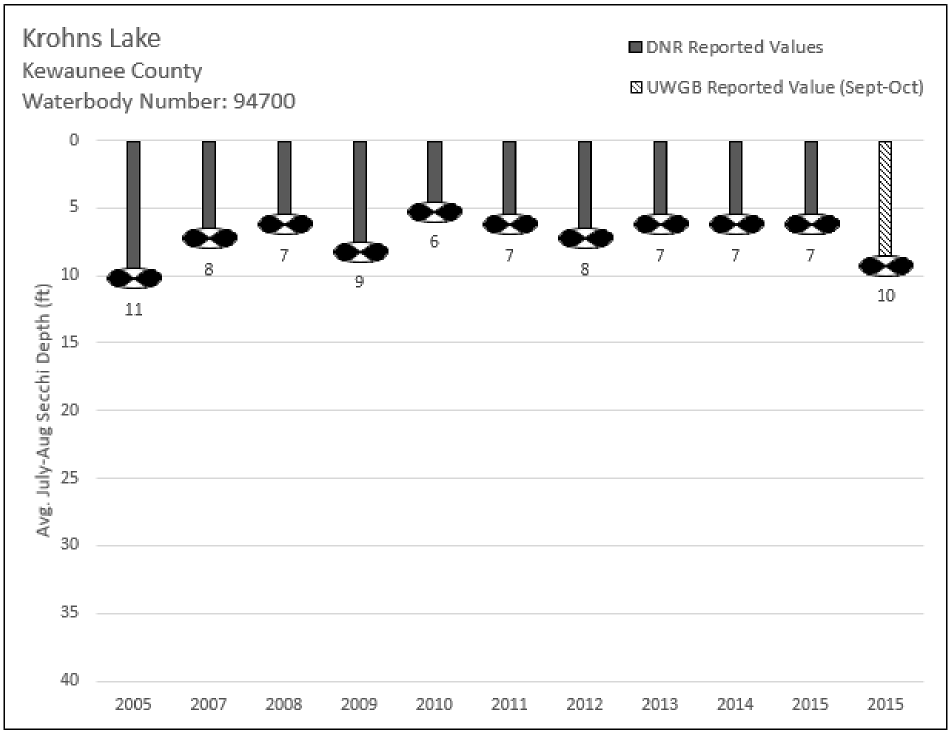

Figure 2.1.1. Mean secchi depth values of Krohns Lake by year. WI-DNR value for 2015 (July-Aug) is shown next to UWGB measurement (Sept-Oct, 2015).

Temperature

Temperature is an important measurement in limnology as the temperature of water determines its density. This relationship drives the process of thermal stratification and mixis events in lakes. Thermal stratification produces defined lake regions that can be identified by the lakes temperature profile.

Temperature measurements were made using a Quanta Hydrolab (Hydrolab Corp., Austin, TX) at all nine waypoints. The sonde was lowered into the water column and read at 1 m increments until the lake bottom was approached. The temperature profile of the Krohns Lake water column suggests that the epilimnion occurs in the first 0 to 3 m in depth, the metalimnion begins somewhere between 3 and 4 m in depth, and the hypolimnion from 6 to 11 m depth (Figure 2.2.2).

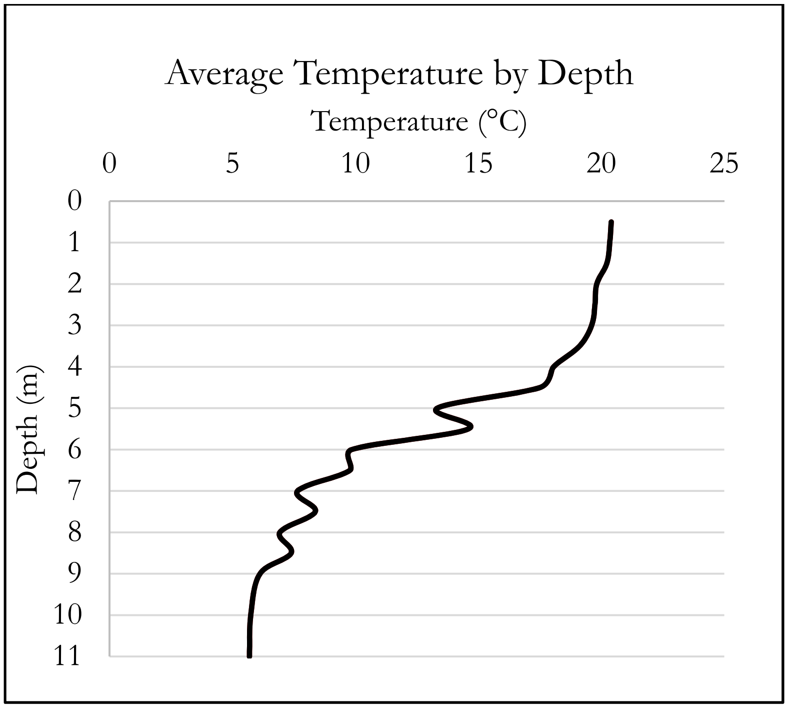

Figure 2.2.2. Mean water temperature profile for Krohns Lake. Measurements taken September – October, 2015.

Specific Conductance

Specific conductance is a standardized measure of the resistance of a waterbody to pass an electrical current. Conductivity is dependent on the abundance and species of dissolved ions present in the water, and should decrease with decreasing water temperature. Specific conductivity measurements were made using a Quanta Hydrolab (Hydrolab Corp., Austin, TX) at all nine waypoints. The sonde was lowered into the water column and read at 1 m increments until the lake bottom was approached.

Average specific conductivity increased with increasing water depth in Krohns Lake, a trend that we would not expect to occur (Figure 2.2.3). However, increasing variability was observed as well; this could be explained as a result of Krohns Lake having fewer sampling sites with depths approaching eleven meters. An additional consideration is that Krohns Lake overlies highly calcareous bedrock and receives most of the hydrologic inputs from groundwater seepage, which may result in increasing specific conductivity measurements with increasing water depth. Typical specific conductance measurements for lakes range from .01 -.10 mS/cm, which Krohns Lake falls within.

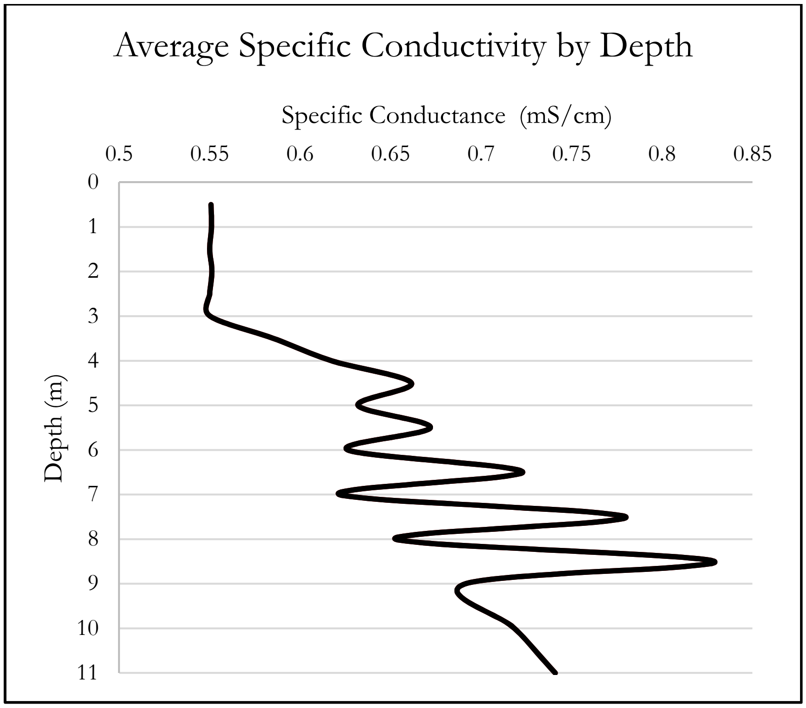

Figure 2.2.3. Mean specific conductivity (mS/cm) with depth observed in Krohns Lake. Measurements were taken September – October, 2015.

Alkalinity and pH

Alkalinity is the measure of the capacity of water to neutralize acids, whereas pH is a logarithmic measure of the hydrogen ion concentration in solution. Typical alkalinity for freshwater lakes is between 20 – 200 mg $CaCO_3$/L with 100 – 200 mg $CaCO_3$/L indicating that a system is well buffered to changes in pH. Alkalinity measurements were made using a Hach sulfuric acid drop count titration for surface water samples collected at all nine waypoints, and pH measurements were made using a Quanta Hydrolab (Hydrolab Corp., Austin, TX) at all nine waypoints in the field. The results suggest that Krohns Lake is highly alkaline, with mean surface water alkalinity measuring 193.9 mg $CaCO_3$/L. This suggests that Krohns Lake is very well buffered to changes in pH.

Epilimnion pH was relatively uniform at 9 but sharply declines at the metalimnion, ultimately settling just above neutral at 7.5 pH at the lowest depths. This pattern is not uncommon in freshwater ecosystems. Freshwater plants and algae use free hydrogen molecules when photosynthesizing, lowering the concentration of hydrogen ions, therefore raising pH.

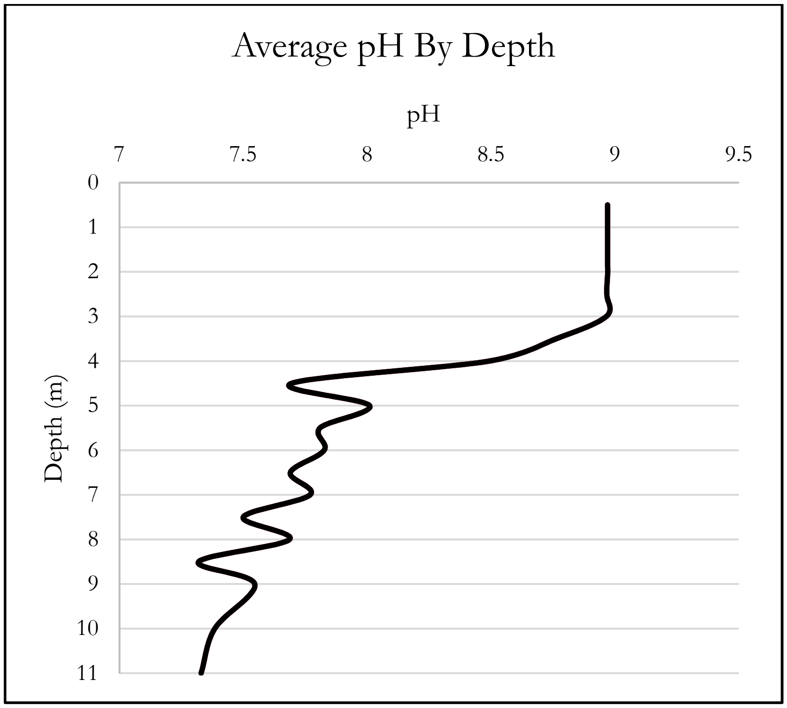

Figure 2.2.4. Mean pH with depth observed in Krohns Lake. Measurements were taken September – October 2015.

Dissolved Oxygen and Phosphorous

Dissolved oxygen is important factor in the health of a lake as it influences both the biotic community as well as various chemical reactions. Excess or reduced oxygen concentrations stress fish, which can lead to massive die-offs. Anoxic conditions in the hypolimnion can increase the release of phosphorus from sediments, which is the limiting nutrient in freshwater ecosystems. Phosphorous concentrations of uncontaminated surface waters falls between 10-50 mg P/L, though surrounding geology is responsible for a large amount of the variation in phosphorous concentration in freshwater lakes, with lakes overlying sedimentary rock typically producing low water phosphorous concentrations. Dissolved oxygen measurements were made using a Quanta Hydrolab (Hydrolab Corp., Austin, TX) at six waypoints and an optical DO probe at all 9 waypoints in the field. Total orthophosphate was measured using a Hach ascorbic acid reactive test kit with a 0 – 40 mg/L range.

Dissolved oxygen in Krohns Lake in September closely follows a clinograde curve, but the values are much lower than expected (Figure 2.2.5). Dissolved oxygen levels in Krohns Lake in October follow the opposite orthograde curve, which may be due to fall turnover (Figure 2.2.6) Dissolved oxygen levels at the lake bottom are extremely low in September, likely due to absorption from decomposers, and is likely to exert control over the benthic community. Mean orthophosphate measured 0 mg/L, suggesting that Krohns Lake is not highly productive, though additional measurements using a method with a higher range resolution is necessary to accurately describe Krohns Lake phosphorous concentration.

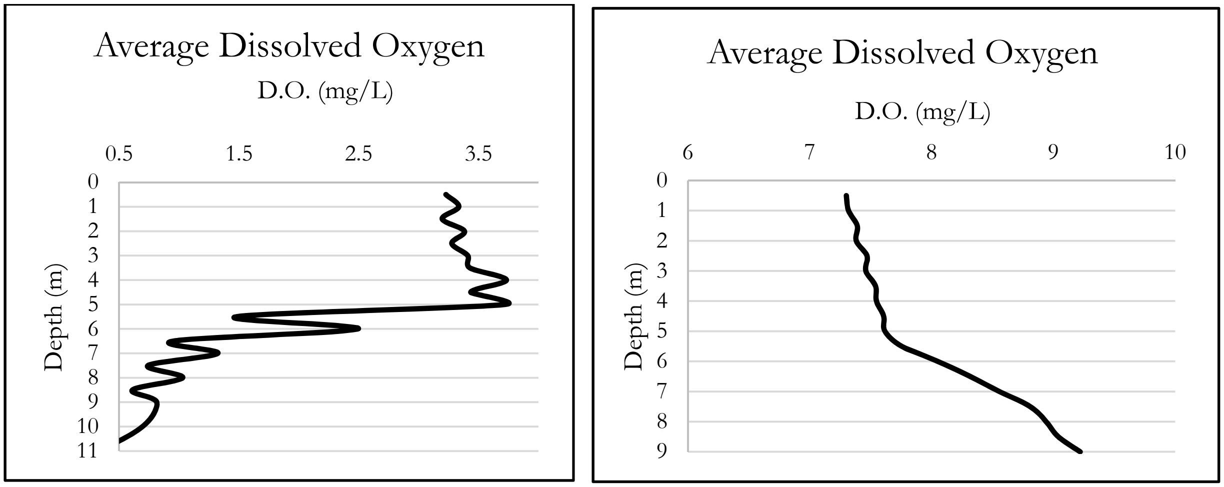

Figure 2.2.5 and Figure 2.2.6. Mean dissolved oxygen (mg/L) with depth observed in Krohns Lake. Figure 2.2.5 shows measurements made in September using a Hydrolab Quanta sensor, Figure 2.2.6 shows measurements made in October using an optical DO probe.

Total Dissolved Solids

Total dissolved solids is the sum of all disassociated electrolytes that constitute salinity, but also dissolved organic compounds. Sources of dissolved solids can come from organic sources, such as leaves, decaying organisms, or fertilizers, or from inorganic sources, such as rocks which contain calcium or phosphorus. Monitoring TDS is important in any lake management program, especially if fish are being stocked. Changes in the concentrations of TDS can be harmful to aquatic organisms because a change in osmotic pressure of cells with their external environment can be lethal. Typical TDS values in lakes and streams range from 50 – 250 mg/L.

Krohns Lake readings of TDS were high and stable across depths, with mean TDS equaling 420.4 mg/L, which suggests that Krohns Lake has high total dissolved solids (Figure 2.2.6).

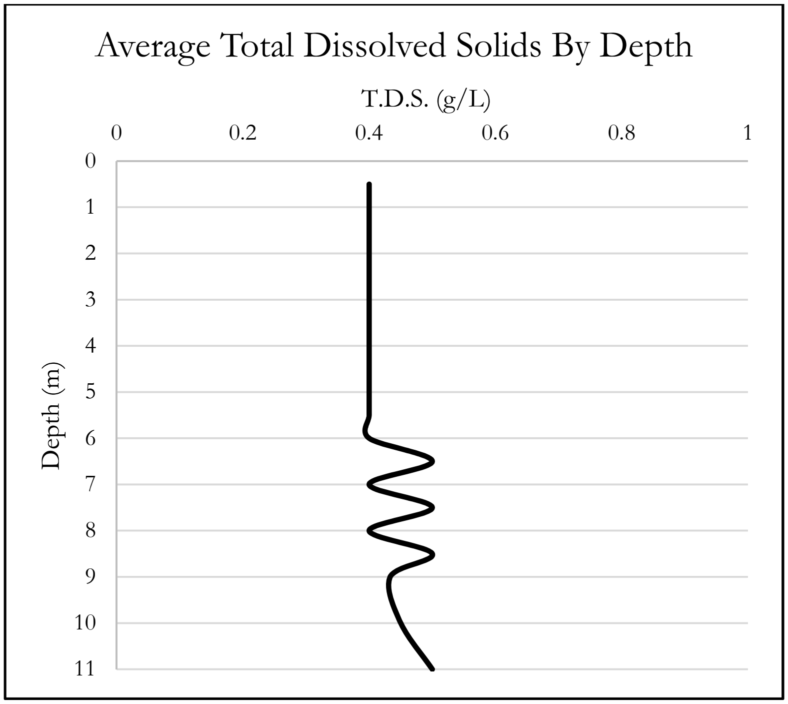

Figure 2.2.7. Mean total dissolved solids by depth observed in Krohns Lake. Measurements were taken September – October 2015.

2.1.2 Discussion

Overall water chemical analysis represents typical results from a dimictic lake system during the later summer season prior to fall turnover. The specific conductivity range (.552-.829 mS/m) falls within anticipated conductivity values, pH is slightly alkaline with the appearance of no significant human runoff impacting the system, and total dissolved solids fall within appropriate levels of a ground fed lake rich in calcium deposits.

During the initial survey date, low levels of DO were observed throughout the water column with oxygen levels barely reaching an amount that would support a large fish populous. Since pH levels fall within an expected alkaline value, it appears that the cause of the low dissolved oxygen values is not primarily due to nutrient loading from anthropogenic influences. Continued conjecture may support the idea that Krohns Lake contains a very high concentration of decomposing material in the benthic region, consuming nearly all of the oxygen within the hypolimnion. This speculation is supported by the amount of decaying material found in the ponar dredge samples, which will be discussed later.

Due to the faulty readings of the Quanta Hydrolab, dissolved oxygen measurements for the second survey period were taken using an optical DO probe. Data recorded during this sampling period tell an entirely different story from the first sampling date. DO values indicate that oxygen conditions may be in a tolerable zone (7.27-9.22 mg/L) for the fish species found in Krohns Lake. Speculation for the transition from an orthograde to a clinograde lake system may be due to faulty equipment or due to lake turnover; only further analysis of Krohns Lake will determine DO accuracy.

Best management practices for water chemical analysis at Krohns Lake calls seasonal sampling, consistent methodology and instrumentation, as well as sampling periods in both day and nighttime conditions. Only then will the chemical data become clear enough that practical approach be taken to understand the overall condition Krohns Lake is currently in.

2.1.3 Photos

3.0 Krohns Lake Biota

3.1 Krohns Lake Fishery

Freshwater ecosystems support a diverse biological community, including fishes (Nelson, 1994). Fish provide fundamental ecosystem services in freshwater ecosystems by contributing and redistributing more nutrients to than any other source and play an integral role in the regulation of food web dynamics by exerting strong top-down trophic cascades through predation (Holmlund and Hammer, 1999; Layman 2013). In addition, they are an important ecological link in the food chain, serving as food for other fish, herons, eagles, turtles, other wildlife and humans (Nelson, 1994). Additionally, fish provide ecosystem services to society by producing food, providing recreation, and are often the first indicator of ecosystem stress resulting in changes in water quality (Harris, 1995).

Krohns Lake is known within the region as being relatively unique due to its morphological capacity to maintain both a productive warm-water and cold-water fishery, though Krohns Lake originally supported a productive bass-bluegill warm-water fishery. Once public access to the lake became available in the 1950's, the WDNR took advantage of the two-story opportunity offered by Krohns Lake and has annually stocked both rainbow and brown trout since the 1970's and 1980's, respectively. Krohns Lake is open to angling year around, and state regulations apply. Management goals for Krohns Lake include a self-sustaining warm water fishery, and continued annual stocking of 2200 trout species (100 trout/surface area).

While electroshocking surveys have been conducted sporadically since 1960, they have yielded variable results for the Krohns Lake fishery, though the most recent survey reported substantially less panfish than previously recorded. We reviewed previously conducted surveys by the WDNR in an effort to observe changes in fishery populations and potential causes for fluctuations.

3.1.1 Results

A standard electroshocking method was employed for all of the following surveys. A DNR boom shocker was used with two dip netters at the bow. Each year, sampling took roughly 45 minutes to complete. Surveys were completed at night, sampling the entire 0.87 mile long shoreline once.

The electroshocking surveys present variable results. Data collection occurred every 17.6 years on average, making it difficult to obtain a high confidence level in the results. On average, overall fish richness and abundance decreased from 1960 to 2013 (Figure 3.1.1). Total catch per effort (CPE) went from 125 documented fish to 52.9.

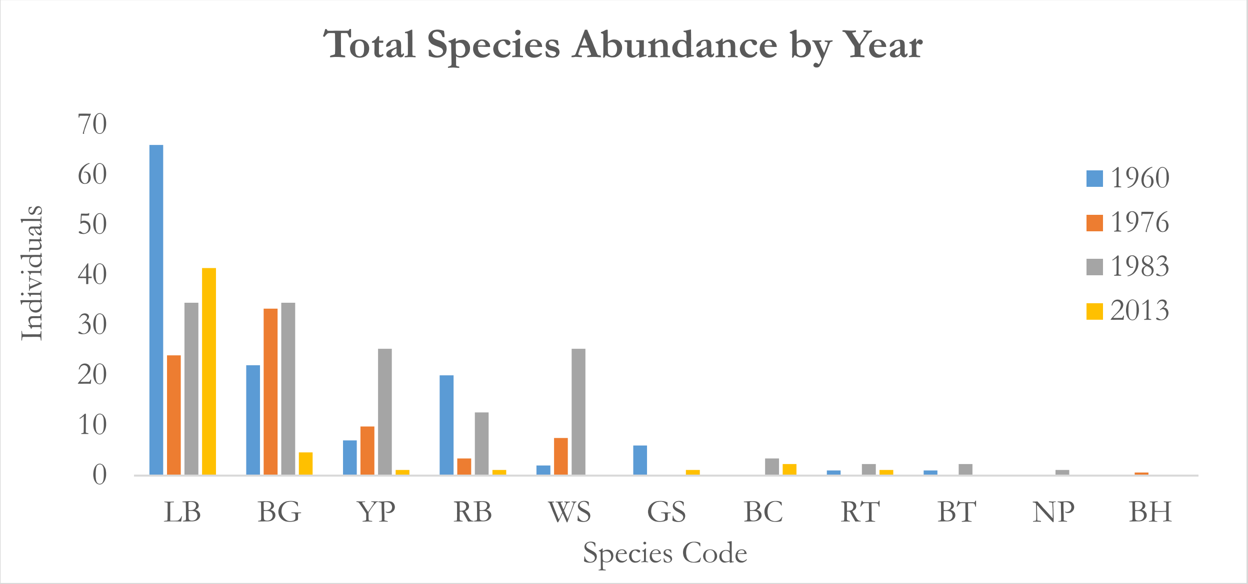

Figure 3.1.1 . Results of WDNR electroshock surveys conducted since 1960. Chart includes all species present during electroshock surveys. Species codes are as follows: LB = Largemouth Bass, BG = Bluegill, YP = Yellow Perch, RB = Rock Bass, WS = White Sucker, GS = Green Sunfish, BC = Black Crappie, RT = Rainbow Trout, BT = Brown Trout, NP = Northern Pike, BH = Bullhead

Overall, total abundance for largemouth bass, bluegill, yellow perch, and rock bass significantly decreased from 1960 to 2013 (Figure 3.1.2). Bluegill were in relatively high abundance from 1960 to 1983, collecting on average 37.5 individuals. Yet by 2013, only 4.6 individuals were documented, representing a significant decline in their population. Black crappie, one of the species anglers seek in Krohns Lake, were not documented in 1960 or 1976, and an average of 2.85 individuals were observed in 1983 and 2013. Many species were observed only once, including northern pike and a bullhead species. In 1960 there was a sustaining population of green sunfish, though subsequent surveys found no individuals until 2013, when one individual was documented. Green sunfish are an indicator species for warm water fish, so the low abundance may reflect a decrease in overall health of Krohns Lake.

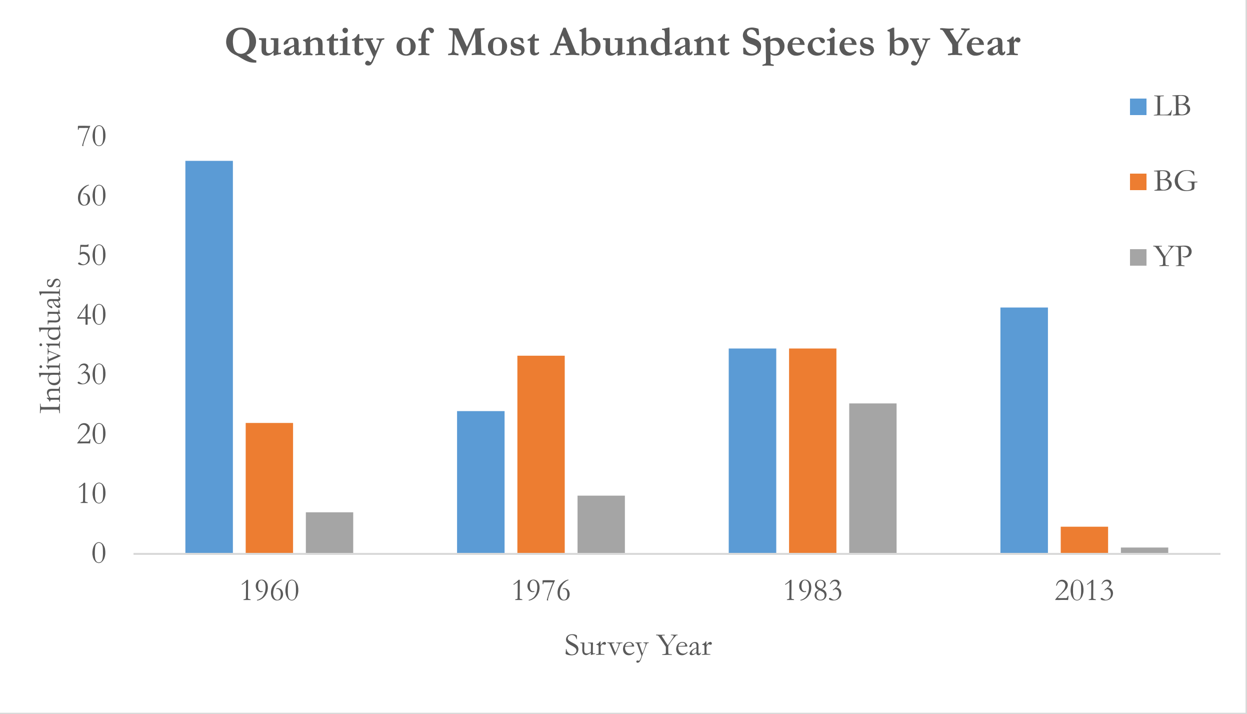

Figure 3.1.2. Results of WDNR electroshock surveys conducted since 1960. Chart includes species most frequently caught during electroshocking surveys. Legend: LB = Largemouth Bass, BG = Bluegill, YP = Yellow Perch

Multiple trout species have been stocked in Krohns Lake since 1976. The most common species are rainbow trout and brown trout. On average, around 2,000 fingerlings are added to the lake each year. Comparison of two years with complete data show the success rate of stocking trout fingerlings. 2,000 Brown Trout stocked in 1983, yet only 2.3 brown trout were captured during the electroshocking survey. In 2013, 2,100 Rainbow Trout were stocked, and 1.1 individuals were captured during electroshocking surveys. However, these results are not reflective of the favorability of Krohns Lake to sustain a cold water fishery as the electroshock survey methods primarily target the warm water fishes.

3.1.2 Discussion

Overall populations of all species present in Krohns Lake have been steadily decreasing since the lake was first surveyed in 1960. Even still, there are fishing regulations for highly sought-after species. There is a minimum length of 14" with a daily bag limit of 5 for anglers who catch largemouth bass, which was at one time the most abundant species. For panfish, which includes bluegill and green sunfish, there is no minimum length and the daily bag limit is 25. Comparing this bag limit to the quantity of bluegill and green sunfish documented in the electroshocking surveys, it's possible this bag limit is too high. Lowering the maximum catch could potentially aid these two species with increasing their populations to a more sustainable level.

While the electroshock surveys produced low CPE of stocked brown and rainbow trout, this is not necessarily indicative of an unsustaining population. The electroshocking method employed by the WDNR for these surveys reaches a water depth of only 2 m, and the surveys were conducted during the summer months when water temperature is at its highest, making it likely that most of the trout were out of the range of the electroshocking equipment. However, our surveys found low macroinvertebrate densities and low dissolved oxygen (DO) levels at the preferred temperature for stocked trout species, suggesting that the lake may not be favorable for trout to thrive or reproduce.

When comparing the available data across years, all species reflect declines in population. This could be due to the lack of food resources for these species, especially when they are in the young-of-the-year and juvenile life stage. This was evidenced by low zooplankton density, indicating that there may be low food availability in Krohns Lake. We suggest that the WDNR employ two separate, annual electroshock surveys that encompass both the warm and cold water fishery of Krohns Lake to better understand fishery population dynamics in the future.

3.1.3 Photos

3.2 Krohns Lake Aquatic Vegetation

Aquatic plants represent a key interface between terrestrial and open water ecosystems, often promoting a clear water state by mediating a variety of biological and physical processes (Khan and Kemp 1985; Carpenter and Lodge 1986). Biologically, macrophytes provide critical habitat for a wide variety of invertebrate phytoplankton grazers (Sculthorpe, 1967; Voigts 1976) and physically ameliorate abiotic stresses by dissipating wave energy and reducing sediment resuspension (Barko and James 1998; Koch et al., 2009). Aquatic plants also act as nutrient sinks throughout the growing season, further decreasing phytoplankton biomass (Van Donk et al., 1990).

Despite the many positive influences exerted by macrophytes, they are often considered to be a nuisance when occupying large areas of freshwater lakes as they can potentially limit recreational activities. This is particularly problematic if invasive species are able to gain a foothold in freshwater lakes, such as what has occurred in Krohns Lake with the introduction of Eurasian/hybrid milfoil (*Myriophyllum spicatum; Myriophyllum sibiricum x spicatum*) first documented in 1993 and curly-leafed pondweed (*Potamogeton crispus*) in 2006. In response to this issue, the Tri-Lakes association treated Krohns Lake with a common herbicide (2,4-D) approximately five years ago.

3.2.1 Results

A baseline limnological study conducted by Northern Environmental in 2003 found a species richness of 13 encompassing free-floating, floating leaved, and submerged aquatic plants but did not conduct a vegetation survey of the emergent plants of Krohns Lake (Table 3.2.1). Compared to the 2003 report, the survey conducted in 2015 found a species richness of 15 encompassing free-floating, floating leaved, submergent, and emergent aquatic plants (Table 3.2.2). The average coefficient of conservatism in 2003 was 5.44 compared to 5.33 in 2015. No threatened, endangered, or species of special concern were found in Krohns Lake. Differences in species richness between 2003 and 2015 may be attributable to differences in survey methodology.

The 2003 baseline survey employed both transect and point surveys that identified species presence and abundance. Our survey employed point surveys conducted by boat and by foot along approximately 60 m transects. We identified species present within an approximately ten foot radius from each point. We conducted all surveys the same distance from the shoreline as the water depth in Krohns Lake increases dramatically, containing the littoral zone to a small area.

Table 3.2.1. Aquatic vegetation survey results from Northern Environmental, 2003. A total of 13 species were found during this survey, encompassing 11 native and 2 exotic. Emergent plants were not surveyed. The average CC for Krohns Lake based on this study is 5.44 when including species for which a CC has been designated. None of the species present in this survey are considered threatened/endangered/special concern.

Life Form	Scientific Name	Common Name	Native/Exotic	Coefficient of Conservatism (CC)
Algae	Chara spp.	Stonewort	Native	-
Algae	Nitella spp.	Muskgrass	Native	-
Free-Floating	Lemna minor	Lesser Duckweed	Native	4
Floating Leaf	Nuphar variegata	Spatterdock	Native	6
Floating Leaf	Nymphaea odorata	White Waterlily	Native	6
Submergent	Myriophyllum spicatum	Eurasian Watermilfoil	Exotic	-
Submergent	Potamogeton crispus	Curly-leaf Pondweed	Exotic	-
Submergent	Ceratophyllum desmersum	Coontail	Native	3
Submergent	Myriophyllum sibiricum	Common Watermilfoil	Native	6
Submergent	Stuckenia pectinata	Sago Pondweed	Native	3
Submergent	Najas flexilis	Slender Naiad	Native	6
Submergent	Potamogeton praelongus	White-stemmed Pondweed	Native	8
Submergent	Potamogeton amplifolius	Broad-leaf Pondweed	Native	7

Table 3.2.2. Aquatic vegetation survey results from UW-Green Bay, 2015. A total of 15 species were found during this survey, encompassing 12 native and 3 exotic. The average CC for Krohns Lake based on this study is 5.33 when including species for which a CC has been designated. None of the species present in this survey are considered threatened/endangered/special concern.

Life Form	Latin Name	Common Name	Native/Exotic	Coefficient of Conservatism
Algae	Chara spp.	Stonewort	Native	-
Algae	Nitella	Muskgrass	Native	-
Free Floating	Lemna minor	Lesser Duckweed	Native	4
Floating Leaf	Nuphar variegata	Spatterdock	Native	6
Floating Leaf	Nymphaea odorata	White Waterlily	Native	6
Submergent	Myriophyllum spicatum	Eurasian Watermilfoil	Exotic	-
Submergent	Myriophyllum sibiricum	Common Watermilfoil	Native	6
Submergent	Potamogeton crispus	Curly-leaf Pondweed	Exotic	-
Submergent	Potamogeton amplifolius	Broad-leaf Pondweed	Native	7
Submergent	Stuckenia pectinata	Sago Pondweed	Native	3
Submergent	Najas flexilis	Slender Naiad	Native	6
Emergent	Sagittaria latifolia	Common Arrowhead	Native	4
Emergent	Schoenoplectus acutus	Hardstem Bulrush	Native	6
Emergent	Typha angustifolia	Narrow-leaved Cattail	Exotic	-

3.2.2 Discussion:

Overall species richness remained fairly constant from 2003 to 2015. While exotic species richness did increase in 2015 relative to the 2003 survey (from 2 species to 3 species), this is most likely the product of the additional emergent plant survey conducted in 2015 that found an additional exotic species (*Typha angustifolia*). Differences in species composition when not considering the additional emergent plant survey includes the exclusion of *Ceratophyllum desmersum* and *Potamogeton praelongus* from the 2015 survey. This could possibly be explained by the survey methodology differences between 2003 and 2015. However, while the departure of *Ceratophyllum desmersum* from the 2015 survey is not a cause for concern due to its low CC and generally weedy nature, the lack of *Potamogeton praelongus* from the 2015 survey may point to a change in water quality as this plant is considered an indicator species. Indeed, our study of the changes in water quality show that while trophic state has remained constant for Krohns Lake since 1976, a decrease in secchi depths since 2005 indicates that water clarity may be decreasing thus contributing to unfavorable conditions for some submerged aquatic species. Another reason why we may not have witnessed this species in 2015 is the degree to which the lake has become invaded by Eurasian watermilfoil. While we did not take cover estimates in our survey, our field notes indicate that much of the littoral zone in the lake was inhabited by Eurasian watermilfoil, and native submerged aquatic species may not be able to compete with this species as it can form a dense canopy at the surface of the water, thus impeding light acquisition.

We suggest that the Tri-Lakes Association train citizen scientists to monitor the aquatic plant community of Krohns Lake on an annual basis. Additionally, while we do not expect the invasive species present in Krohns Lake to inhibit recreational activities because of the small area comprised by the littoral zone, these invasive species may pose threats to future biodiversity in Krohns Lake by increasing canopy-level shading thereby decreasing light penetration for native submerged aquatics. The lake association should continue engaging in educational activities and disseminating information to visitors of Krohns Lake about the effects of invasive aquatic species.

3.2.3 Photos

3.3 Krohns Lake Zooplankton and Benthos Biota

Zooplankton are a group of mostly microscopic aquatic organisms found commonly in all bodies of water. These organisms play an integral role in aquatic ecosystems by occupying an intermediate trophic level, making them a key component in the partitioning of energy and nutrients (Jeyasingh et al., 2009). Zooplankton exert control on the freshwater food web by consuming periphyton and planktonic species, while additionally providing food for larval fish (Mathews, 2012). An additional, yet generally unexploited characteristic of zooplankton, is that they are highly adaptable to changes in environmental condition, making them a useful tool for tracking natural and anthropogenically-induced changes to aquatic ecosystems such as eutrophication and climate change (Adrian et al., 2009). This suggests that continuous monitoring programs designated to track changes in zooplankton community dynamics be implemented in aquatic ecosystem management and planning (Papa and Briones, 2014).

We undertook vertical zooplankton sampling tows at nine locations in Krohns Lake using a 63 micron mesh conical net fitted with a sampling jar. Each tow consisted of lowering the sampling net to bottom substrates, followed by rapidly pulling the net back up through the water column. Samples were kept in coolers while in the field and preserved within 3 hours of collection by the addition of 95% ethanol and stored until sorting/counting occurred. Sorting and counting of zooplankton was conducted by taking a 10 mL sample from each collection, adding 90 mL of distilled water for a 100 mL total subsample. From this 100 mL subsample, we sorted and counted zooplankton from a total of 5 mL using a standard dissecting microscope. Zooplankton were counted on three separate occasions using guides created by the St. Norbert's biology lab.

Benthic substrate samples were taken using a ponar dredge at each of the nine sampling locations. Samples were kept in coolers while in the field and frozen within 3 hours of collection until processed. Each benthic sample was then sorted for macroinvertebrates. Interestingly, we did not find any evidence of macroinvertebrates in the benthic substrates of Krohns Lake.

3.3.1 Results

The predominant group found in the Krohns Lake zooplankton collection was copepods, followed by cladocerans (Figure 3.3.1). Nauplii counts were included, but due to the difficult nature of distinguishing these larval zooplankton, they were not included into either major zooplankton group.

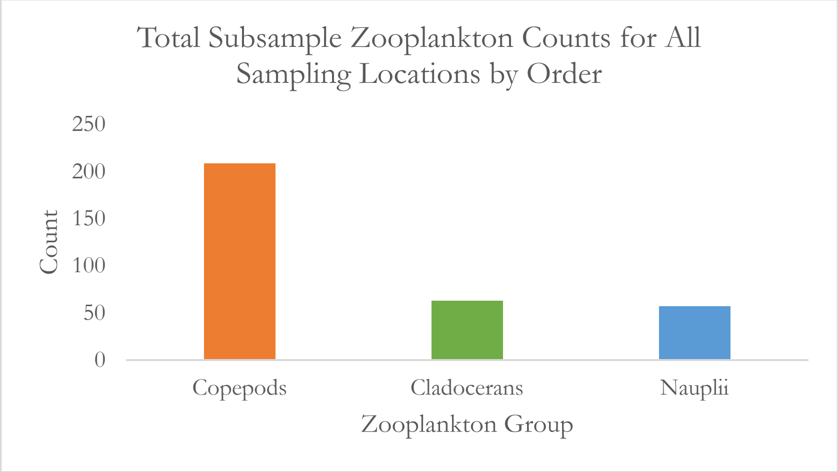

Figure 3.3.1. Total subsample zooplankton counts for all sampling locations.

Additionally, we were able to break these zooplankton orders down further into the following groups and genera including: cyclopoid copepods, calanoid copepods, nauplii (copepod/cladoceran), daphnia spp. (cladoceran), and diaphanosoma spp. (cladoceran) (Figure 3.3.2).

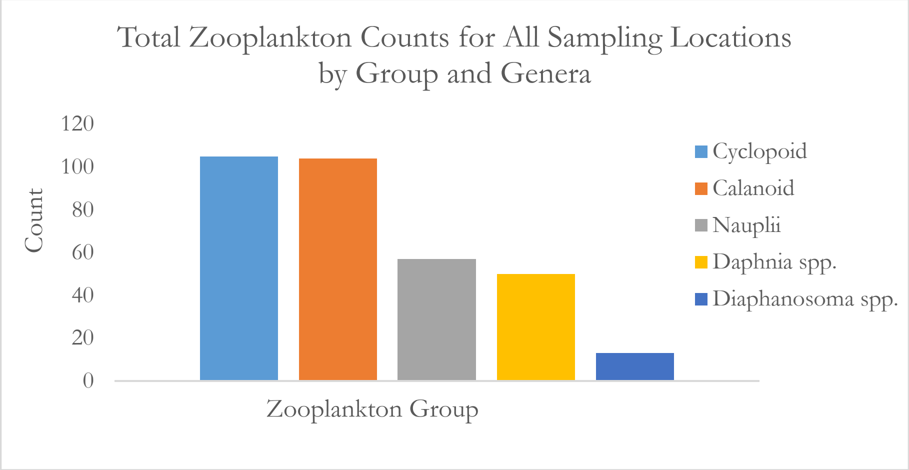

Figure 3.3.2. Total zooplankton subsample counts for all sampling locations by group and genera.

While a variety of zooplankton groups were identified, the amount of zooplankton collected at each sampling point was quite variable (Figure 3.3.3), though more zooplankton were observed at points with greater maximum depths (Figure 3.3.4), as we would expect.

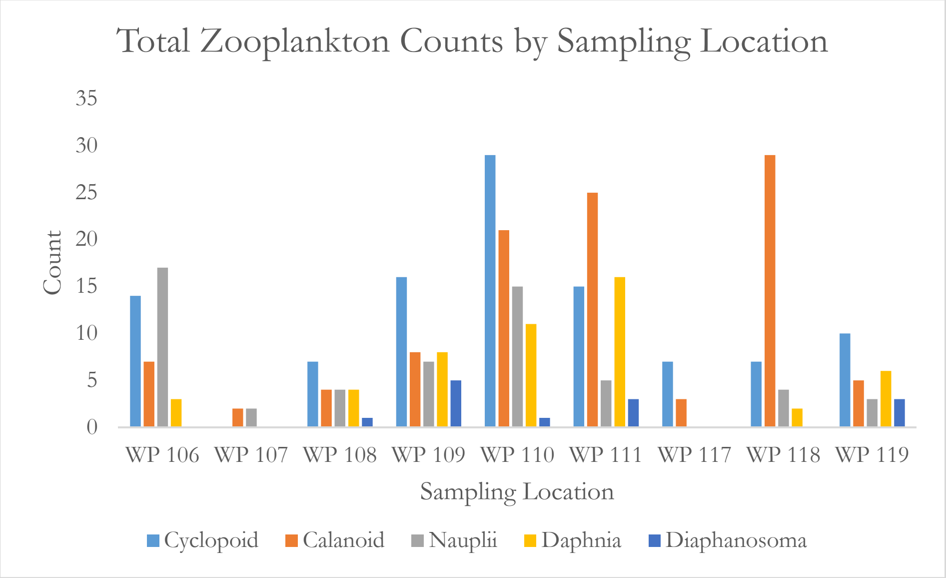

Figure 3.3.3. Total zooplankton counts at each sampling location in Krohns Lake.

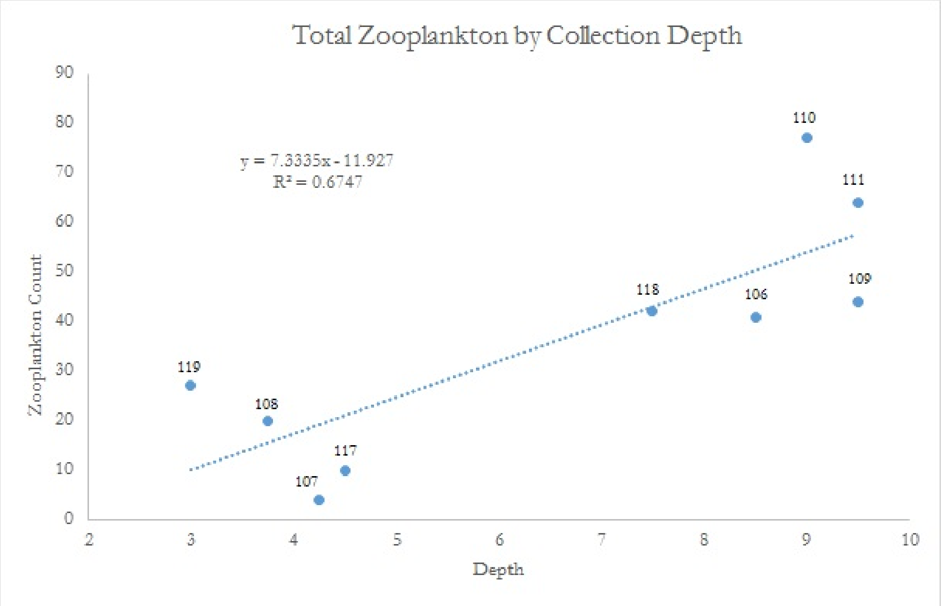

Figure 3.3.4. Total zooplankton counts by collection depth. Strong relationship between water depth and amount of zooplankton observed in each sample (R^2 = 0.6747)

3.3.2 Discussion

A total of 329 zooplankton were counted from the Krohns Lake subsamples, with approximately 2/3 encompassing the copepod order, the remaining 1/3 comprised of both the cladoceran order and larval nauplii. Scaled up, we found that for every one liter of water sampled at Krohns Lake, 4,000 copepod and 1,200 cladoceran species is expected to be found, though water depth will likely affect this number greatly. After breaking the orders down into finer groups and species, one liter of water sampled from Krohns Lake is expected to harbor 2,000 calanoid and cyclopoid copepods, 1,000 daphnia species (cladoceran), and 200 Diaphanosoma species (cladoceran). Our management suggestions for zooplankton are to establish an annual citizen science monitoring protocol for zooplankton as they are considered a "beacon of environmental change" and require little resources to monitor other than time and experience.

The relative abundance of zooplankton populations may help determine notable characteristics of Krohns Lake. Copepods and cladocerans generally employ dissimilar feeding strategies and the relative abundances of both can infer the nutritionals status of a lake (Cyr, 1998). Copepod food selection can be extremely sensitive with many species possessing the capacity to discriminate between food particles of different nutritional values (Becker et al., 2004). Copepods can preferentially select large food particles from the surrounding environment, which differs from the generalist feeding strategy employed by many cladoceran species (Becker et al., 2004). The structure of a zooplankton community can also be used to determine characteristics of the algal population, such as algal size. Algae that are round and small are consumed more efficiently by the generalist cladocerans than copepods, and further calculations of zooplankton grazing rates may be used to determine the size and composition of algal populations (Cyr, 1998). The high abundance of copepods present in our lake samples suggests that our lake may have a nutritional status that benefits selective feeders that can actively distinguish both larger, and more nutritious particles (Becker et al., 2004).

While a variety of zooplankton were found in Krohns Lake, we found it perplexing that no benthic organisms occurred in our ponar dredge samples. This could be in part due to the low dissolved oxygen conditions observed in Krohns Lake at the lake bottom, or possibly due to methodology issues (i.e. sampling season, small sample size). A consideration is that water depth in Krohns Lake drops dramatically mere feet from the shoreline, which may indicate that this lake does have favorable morphological conditions for a varied and abundant benthic assemblage. However, we suggest that additional benthic substrate sampling occur to identify if there truly is an inhibited benthic community, as this will have major implications for fishery health and sustainability.

3.3.3 Photos

Summary and Discussion

The purpose of this report was to provide the inclusive baseline data collected from Krohns Lake describing the current chemical, physical, and biological characteristics. Our analysis of the water quality data shows that while Krohns Lake remains in a mesotrophic state, there is some indication that the lake has seen slight increases in measured nutrients since water quality monitoring began in 1976. This is some cause for concern as the state index range for mesotrophic lakes is quite narrow, and Krohns Lake could potentially be pushed into the eutrophic range with small increases in nutrient concentrations. Additional concerns surround the dissolved oxygen levels in Krohns Lake, which were generally lower than the oxygen requirements for the warm and cold water fishery in the October survey period, though this may be a result of lake turnover. We suggest that the DNR and Tri-Lakes Association continue their water quality monitoring, efforts to disseminate pertinent information to landowners near the lake, and identify any major animal wastes that may be contaminating groundwater resources that feed Krohns Lake.

While the review of the data available for Krohns Lake fishery shows somewhat dismal results, much of the decrease in abundance of fishes may be partially attributed to differences and shortcomings of the sampling methods employed, or that not enough data has been collected to truly understand the community dynamics of the Krohns Lake fishery. However, the decrease in abundance for a majority of the species suggests that there may be some impediment to sustaining a healthy fishery in Krohns Lake. We suggest that the Tri-Lakes Association consider hiring a consulting company to conduct additional surveys in the WDNR survey interim to ensure that the Krohns Lake fishery is not under threat.

Little change was found between the vegetation surveys conducted by Northern Environmental in 2003 and our 2015 survey. This is somewhat problematic in that the lake has been treated for invasive species at least once between survey dates, though no change in invasive species presence was observed at Krohns Lake. Additionally, the species with the highest coefficient of conservatism (*Potamogeton praelongus*) was not observed in our 2015 survey, though it was present in the 2003 survey. While it is possible that our point surveys managed to miss this species altogether, the extent of the small littoral zone taken up by Eurasian watermilfoil (*Myriophyllum spicatum*) suggests that some of the less hardy native submergent species are potentially being displaced by this aggressive invasive. We suggest that the Tri-Lakes Association continues its efforts to inform the public of the consequences surrounding the introduction of exotic species at Krohns Lake. We also suggest that the lake association consider alternative methods of removal of the invasive species at Krohns Lake, such as annual removal as this control method is certainly manageable for such a small area.

Since this was the first attempt to sample the zooplankton and benthic community of Krohns Lake, we are limited in our suggestions for management outside of the establishment of a monitoring program that can continue to describe and track changes in the community. Continuous collection of zooplankton over an extended temporal scale would include seasonal variations that are not currently present in our data, and may lead to proper evaluations of the present trophic levels and predictions of future change. Further analysis of zooplankton populations during different trophic conditions within the same lake can also be used to evaluate the influence of trophic status on zooplankton dynamics (Straile, 2015). The value of protracted data collection of zooplankton was demonstrated by researchers that were able to calculate changes in freshwater fish composition from changes in zooplankton biomass (Hrbacek et al., 2003). The ability to indicate changes in fish composition may provide important data for the recreational fishing Krohns Lake is so well-known for housing. An enhanced understanding of present lake conditions and the potential for change would enable the development of more comprehensive management strategies.

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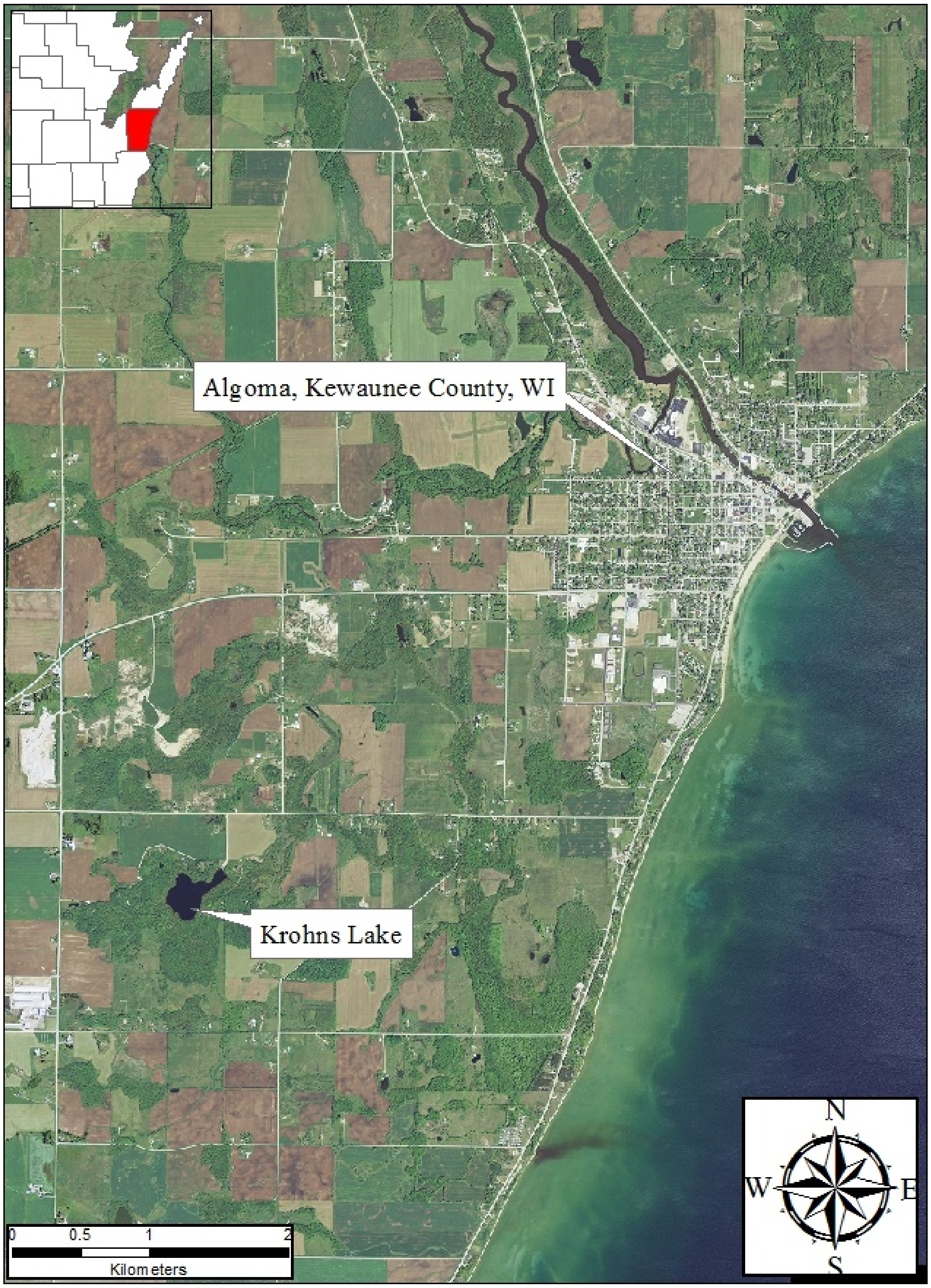
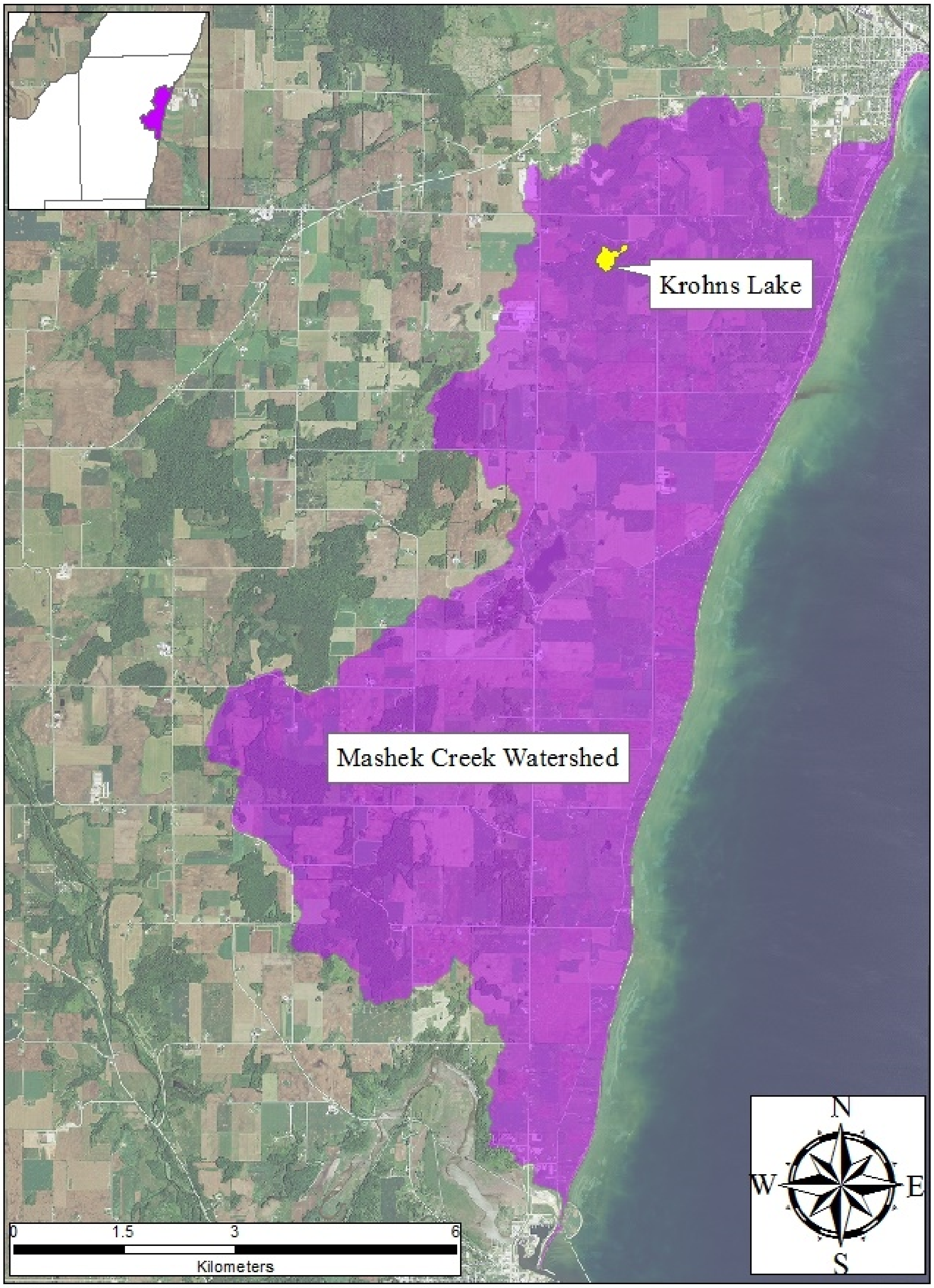
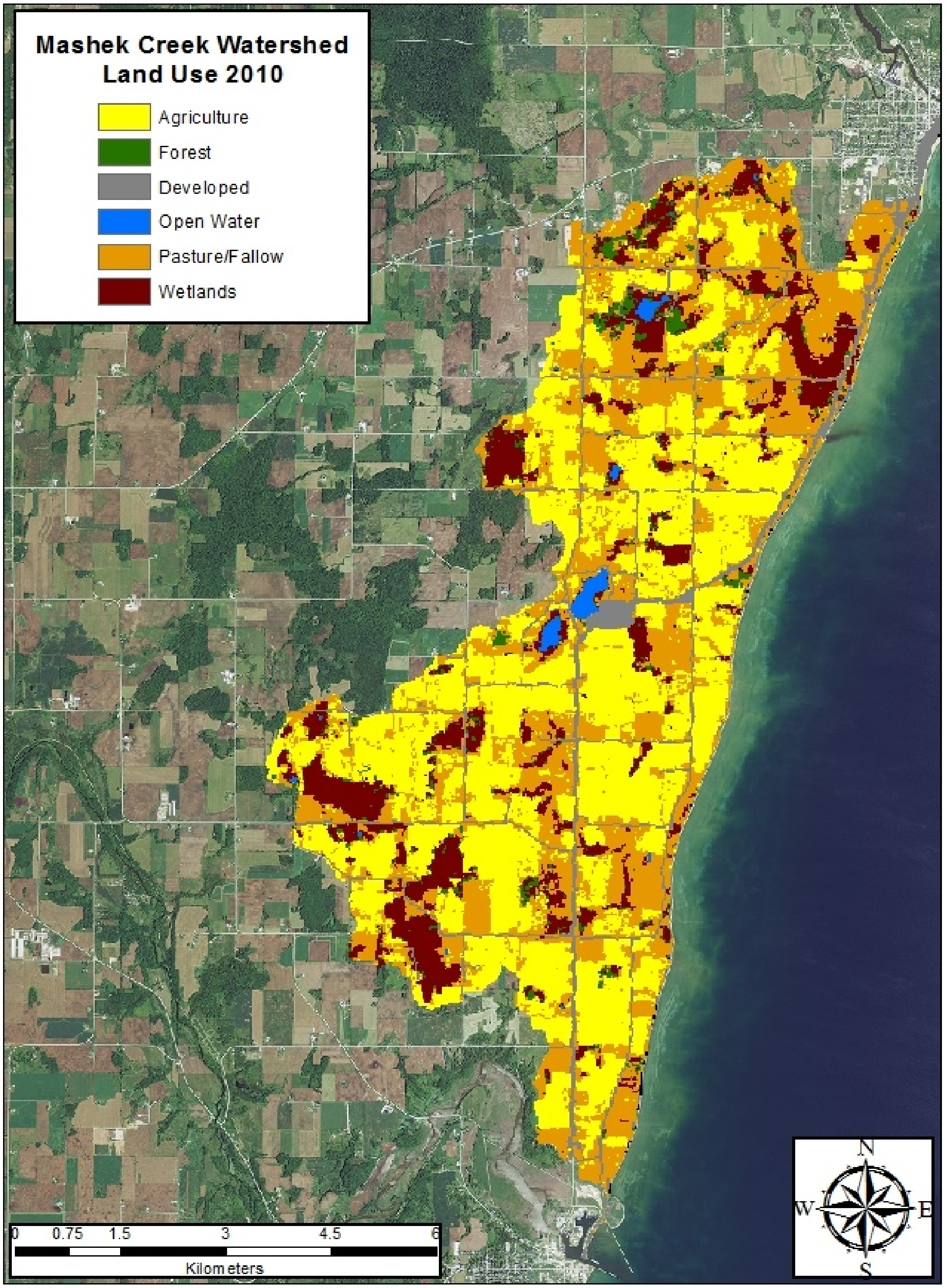
Maps



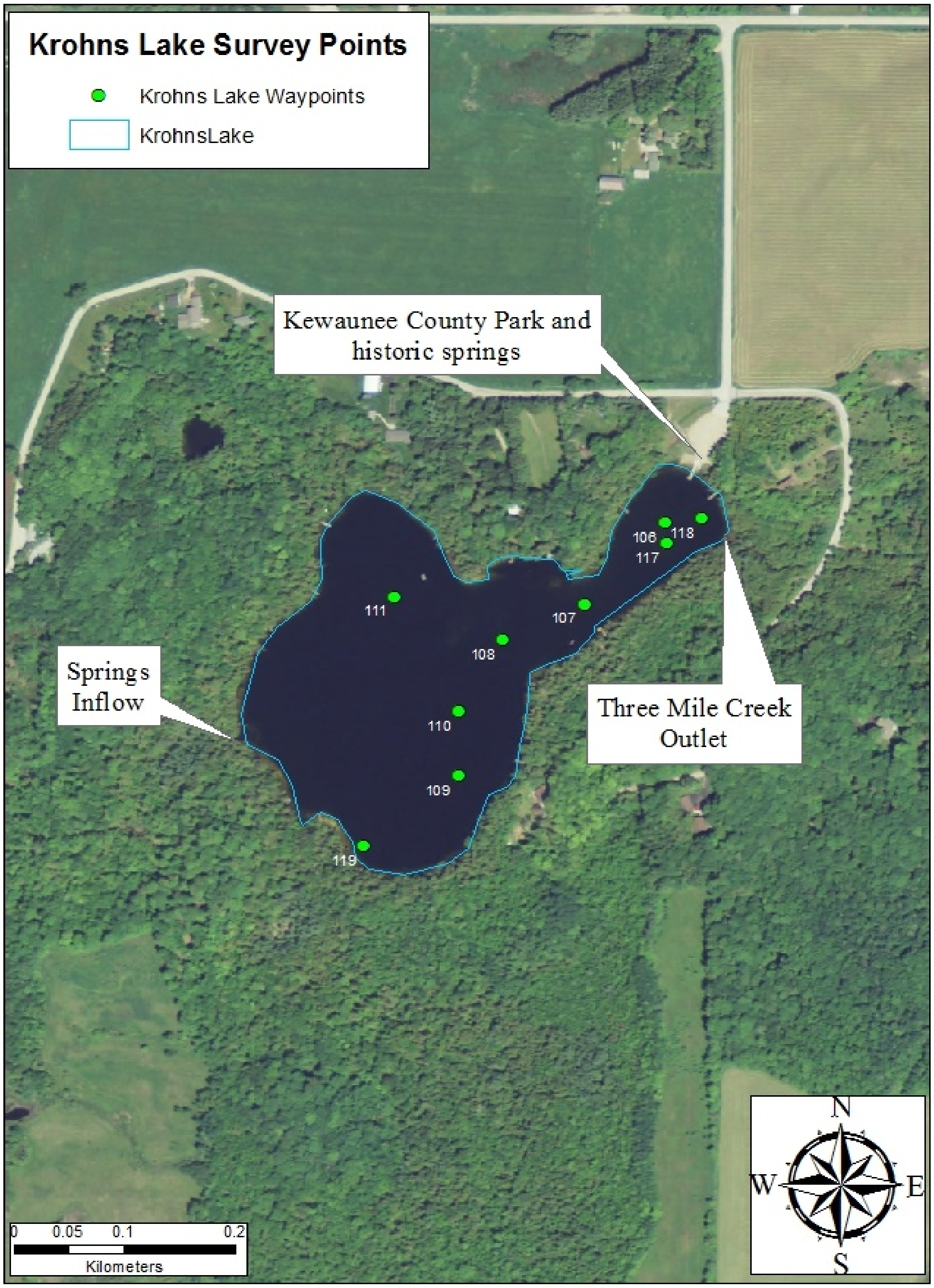
Map 1.1.1. Map showing location of Krohns Lake in relationship to Algoma, Kewaunee County, WI. Krohns Lake is located approximately 4.8 km southwest of Algoma.



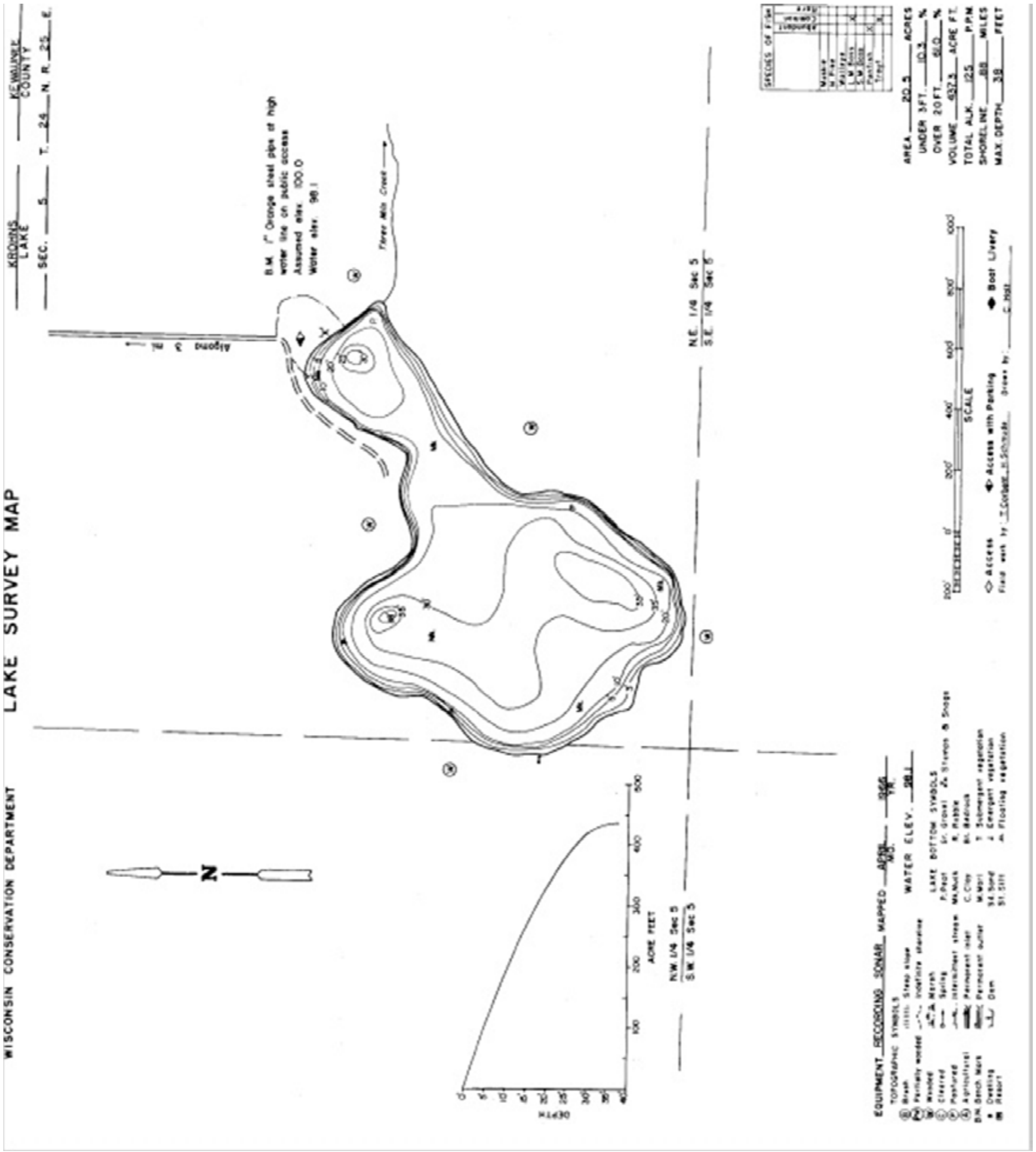
Map 1.1.2. Map showing the location of the Mashek Creek Watershed which houses Krohns Lake.



Map 1.1.3. Land use within the Mashek Creek Watershed. Derived from the 2010 National Agricultural Service Statistics for Wisconsin.



Map 1.1.4. Map showing water quality, zooplankton, and benthic biota survey points. Callouts indicate areas where inlets or outlets are present.



Map 1.1.5. Contour map of Krohns Lake (WDNR)