MIDDLE LAKE

URBAN LAKES FISHERIES STUDY 2014

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INTRODUCTION

Middle Lake (46°26'21" N, 81°01'27" W) is a 28.1 ha lake located within the City of Greater Sudbury, in Broder township. It has one main basin with a maximum depth of 15 m (Figure 1). A complete summary of physical characteristics can be seen in Table 1.

Middle Lake is accessed by private road off Ester St. There are approximately 26 seasonal and permanent residences around the shoreline of the lake and no accessible public land. Angling for any species is prohibited on Middle Lake as it has been classified as a year-round fish sanctuary by the Ministry of Natural Resources and Forestry (MNRF) (Government of Ontario, 2014).

Middle Lake was limed with 20T of $Ca(OH)_2$ and 13.5T of $CaCO_3$ in in the fall of 1973 which resulted in an increase in pH, and rapid decline in metal concentration (Scheider *et al*., 1975; Dillon *et al*., 1979). The surrounding watershed of Middle Lake was treated again in the early 1980s with limestone and fertilizers as part of the Greening of Sudbury initiative (Ontario Ministry of the Environment, 1982), which, in combination with a decline in local industrial emissions, resulted in a decline in metal concentrations. Middle Lake has been studied and monitored since 1973 (Yan *et al*., 1996) and regular quantitative fisheries netting surveys (Nordic method) have occurred since 2004 (Cooperative Freshwater Ecology Unit, 2014). The lake was fishless when assessed in the early 1970s (Scheider et al. 1975). Recolonization of fish species in Middle Lake occurred in the late 1980s (Poulin *et al*., 1991) and MNRF records indicate that Middle Lake has never been stocked (Ontario Ministry of Natural Resources, 2013).

Table 1 Middle Lake location and physical description (Poulin *et al*., 1991).

Township	Broder
Latitude/Longitude	46°26'21" N, 81°01'27" W
MNRF District	Sudbury
Watershed Code	2CF
Elevation (m)	268
Shoreline Development Factor	197
Number of Cottages/Lodges	26
Forest Type	Birch transition
Shoreline Type	Bedrock/sand
Lake Surface Area (ha)	28.1
Maximum Depth (m)	15
Mean Depth (m)	6.2
Volume ($x10^4 m^3$)	250
Secchi (m)	4.5 (July 8, 2014)
Access	Culvert off South Shore Rd.

METHODS

Fisheries Community Assessment

In 2014 the fish community of Middle Lake was sampled according to the Nordic Index Netting protocol (Appelberg, 2000; Morgan and Snucins, 2005). This netting procedure was developed in Scandinavia and has been used extensively across northeastern Ontario since 1999 (Selinger *et al*., 2006) to assess the relative abundance and biomass of fish species and provide biological information on population status (Morgan and Snucins, 2005).

A total of 16 multi-mesh gillnets were set in Middle Lake from July 5 - 8, 2014. Nets were set for approximately 12 hours at randomly selected locations on the lake across multiple depth strata (5 nets in <3.0 m; 5 nets in 3.0 - 5.9 m; 3 nets in 6.0 – 11.9 m; 3 nets in 12.0 – 19.9 m). Figure 2 shows the locations of all gillnets set in Middle Lake during the survey.

All fish captured were identified to species and tallied by net. Biological information such as fork and total length (mm), weight (g), sex and maturity, and stomach contents were recorded for all large-bodied species. Ageing structures were collected from all of these species, and a muscle tissue sample was collected from up to 20 individuals per species across a size range for contaminant and stable isotope analysis. All other fish were measured (total length only) and bulk weighed for each net. A bulk sample of up to 20 individuals per species was collected for contaminant and stable isotope analysis.

Baseline Organisms

Attempts were made to collect samples of clams (n=10), snails (n=30), crayfish (n=20), Heptageniid mayflies (n=50), and aquatic plants from Middle Lake for food web studies.

Clams and snails were targeted by visually scanning near-shore areas and picking the organisms by hand or with a dip net. Crayfish were targeted by setting three to five wire mesh minnow traps baited with canned cat food overnight in littoral areas. Heptageniid mayflies were targeted by turning over rocks and woody debris along the shore of Middle Lake, and picking the organisms off the surface by hand or with a pair of tweezers. A bulk sample of up to five plants of the same species was targeted by visually scanning the near-shore areas of Middle Lake and picked by hand.

Water Quality Assessment

A dissolved oxygen (mg/L) and temperature (°C) profile was measured in the main basin of Middle Lake on July 8, 2014, using a YSI Model 52 dissolved oxygen – temperature meter. Readings were taken at 0.5 m intervals through the water column. Water samples were collected on August 6, 2014 from the surface of Middle Lake. Samples were sent to the Ministry of Environment and Climate Change (MOECC) chemistry lab in Dorset, and analyzed for pH,

conductivity, total inflection point alkalinity, dissolved organic carbon, and metals and major ions.

The sampling location for water quality can be seen in Figure 2.

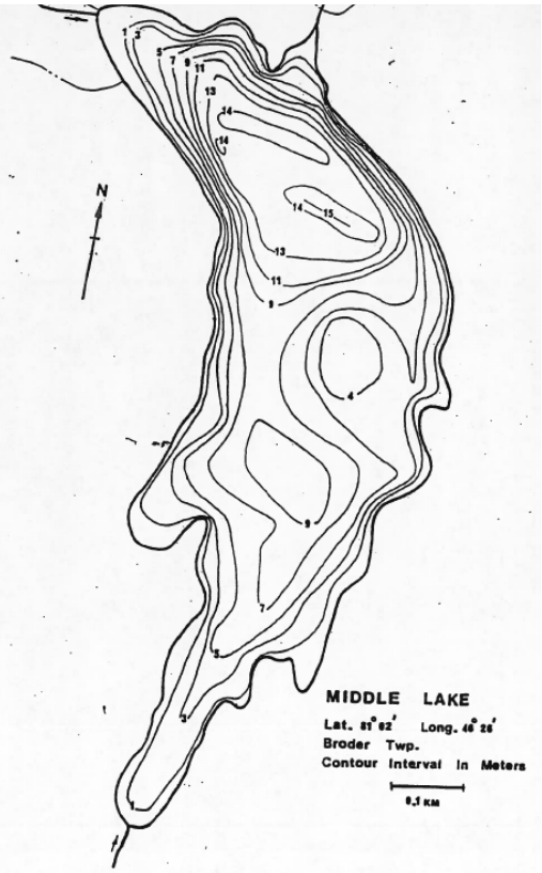

Figure 1 Bathymetric map of Middle Lake.

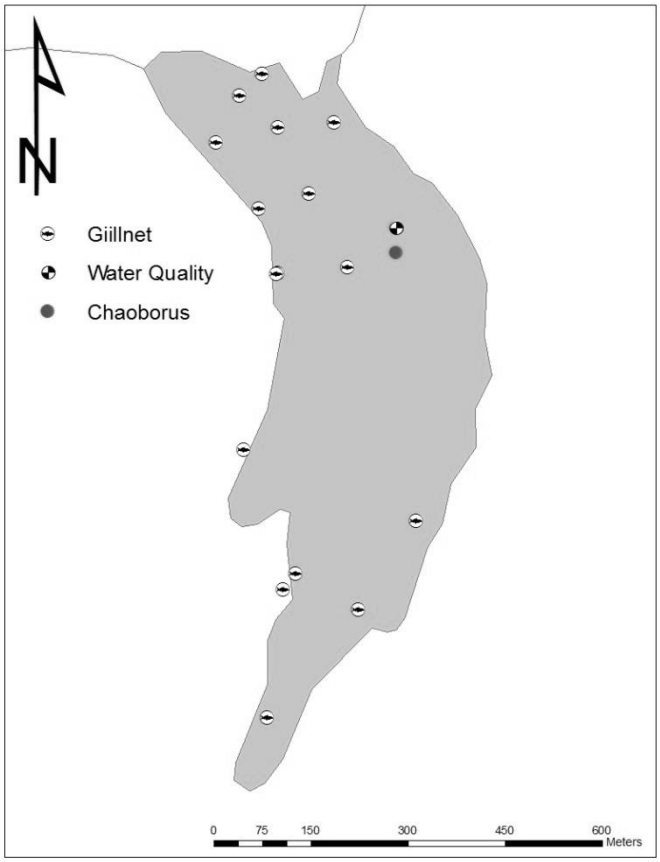

Figure 2 Outline map of Middle Lake showing the location of sampling gear or collected organisms.

RESULTS AND DISCUSSION

Fisheries Community Assessment

A total of five species were captured in 2014: northern pike (*Esox lucius*), pumpkinseed (*Lepomis gibbosus*), yellow perch (*Perca flavescens*), walleye (*Sander vitreus*) and Iowa darter (*Etheostoma exile*). Other species observed in previous netting surveys which include brown bullhead (*Ameiurus nebulosis*) and smallmouth bass (*Micropterus dolomieu*) were not seen in 2014 (Cooperative Freshwater Ecology Unit, 2014). Total catch, total weight (g) and catch-per-unit effort (CPUE) from the 2014 Nordic survey can be seen in Table 2.

Table 2 Catch summary and CPUE for all species captured in Middle Lake July 5 - 8, 2014. *Fish were not individually weighed. Total weight (g) and CPUE (g/net) measurements are based on total net biomass for that species.

Fish Species	Total Catch	Sample Size	Total Weight (g)	CPUE (fish/net)	CPUE (g/net)
Northern Pike	7	7	11127.1	0.4375	695.4438
Pumpkinseed*	70	66	325.3	4.375	20.3313
Yellow Perch*	599	577	8878.1	37.4375	554.8813
Walleye	1	1	866.0	0.0625	54.125
Iowa Darter	2	1	0.9	0.125	0.0563
Total	679	652	21197.4	42.4375	1324.84

The northern pike caught in 2014 had total lengths ranging from 390 mm to 812 mm. Only one walleye was caught in 2014 with a total length of 460 mm. A summary of morphological information for northern pike and walleye can be seen in Appendix I.

Yellow perch ranged in total lengths ranging from 41 mm to 191 mm. A length frequency histogram for perch is shown in Figure 3.

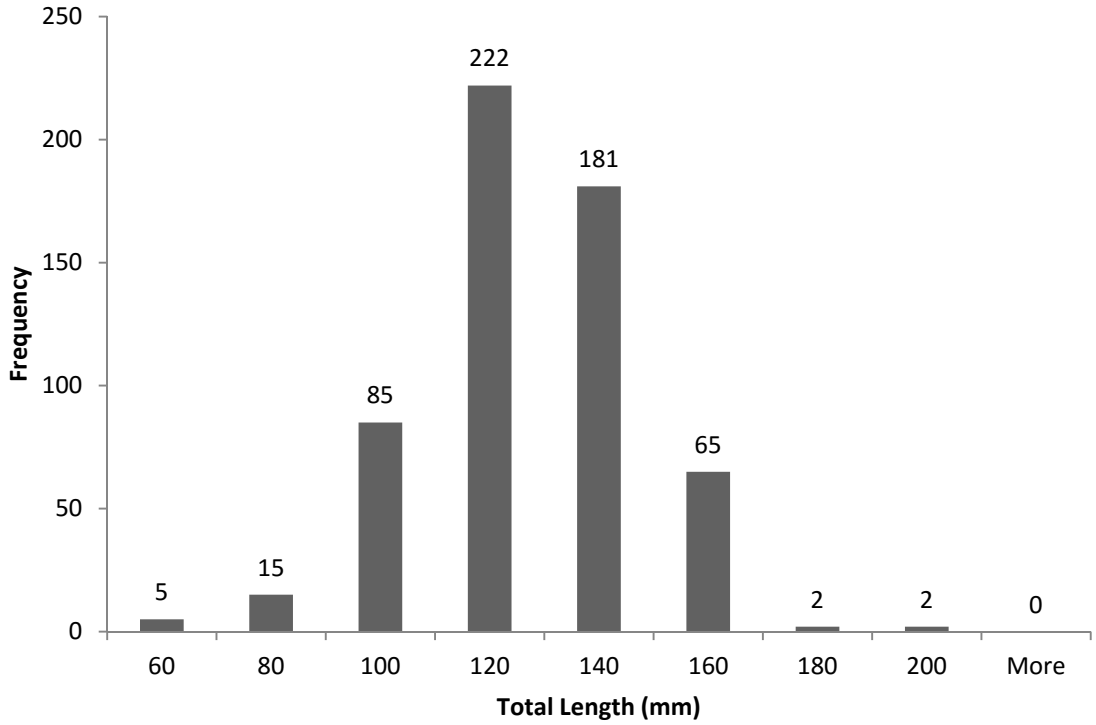

Figure 3 Length frequency histogram for yellow perch (n=577) captured in Middle Lake July 5 - 8, 2014.

Yellow perch was the most abundant species back in 1990, representing 99% of the total catch (Poulin *et al*., 1991). More recent Nordic surveys, which began in 2004, indicate that yellow perch remain the most abundant species in the lake. However this has declined by 10% from 2004 to 2014. This is likely a result of an increase in the abundance of northern pike (Cooperative Freshwater Ecology Unit, 2014). Species richness and proportion of total catch can be seen in Table 3.

Table 3 Species richness and proportion of total catch for Middle Lake (1. Poulin *et al*., 1991; 2. Cooperative Freshwater Ecology Unit, 2014).

Survey Type	**Multi-Gear Survey**		**Nordic**		**Nordic**		**Nordic**	
Year	**1990**[1]		**2004**[2]		**2009**[2]		**2014**	
Species	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Northern Pike	-	-	1	0.12	3	0.27	7	1.03
Golden Shiner	6	0.29	-	-	-	-	-	-
Brown Bullhead	-	-	1	0.12	-	-	-	-
Pumpkinseed	-	-	1	0.12	47	4.16	70	10.3
Smallmouth Bass	-	-	1	0.12	-	-	-	-
Yellow Perch	2052	99.4	812	99.1	1077	95.4	599	88.2
Walleye	-	-	1	0.12	-	-	1	0.15
Iowa Darter	5	0.24	2	0.24	2	0.18	2	0.29
Johnny Darter	2	0.1	-	-	-	-	-	-
Total	2065	100	819	100	1129	100	679	100
Species Richness	4		7		4		5	

While perch dominated the biomass in the early survey, northern pike now account for the majority of the total biomass. Total biomass data can be seen in Figure 5.

A steady increase in species diversity has been observed in Middle Lake as the abundance of the different species has changed over the years. In 2004, after the first Nordic survey was conducted on the lake, a “very low” Shannon H Diversity value of 0.0642 was calculated. This classification has improved to a “low” value of 0.2043 in 2009 and 0.4188 in 2014 (Morgan and Snucins, 2005). Species diversity values can be seen in Figure 6.

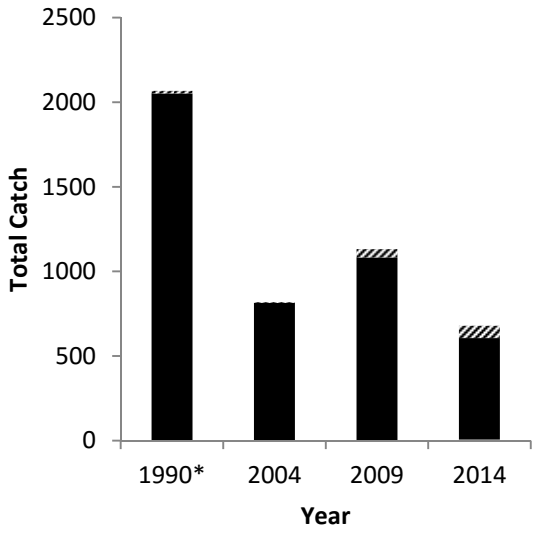

Figure 4 Total catch data from Middle Lake (*Nordic method was not used during the 1990 Urban Lakes Survey. Poulin *et al*., 1991).

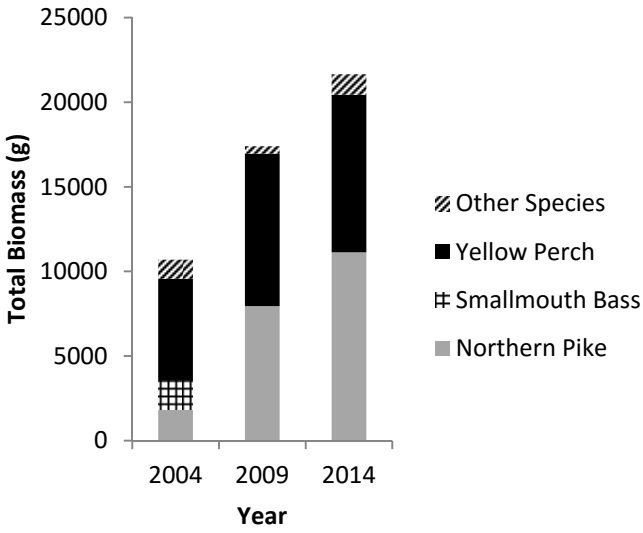

Figure 5 Total biomass (g) data from Middle Lake.

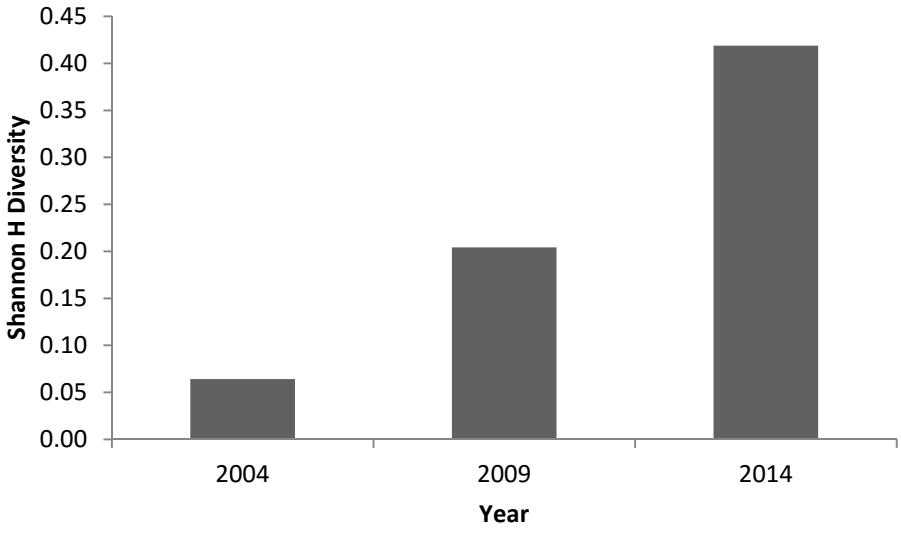

Figure 6 Species diversity (Shannon H Diversity) values for Middle Lake.

Baseline Organisms

No clams or snails were collected from Middle Lake. Approximately 50 mayflies were collected at various locations around Middle Lake. A total of eight crayfish were captured in traps set at various locations around Middle Lake. Two incidental crayfish were also collected from gillnets. Twenty-nine night time zooplankton hauls were conducted at Middle Lake on July 22, 2014. A sufficient stable isotope sample (approx. 50-300 individuals) of *Chaoborus* sp. was collected.

No aquatic plants were collected from Middle Lake.

Water Quality Assessment

At the time of the Nordic Index Netting survey, Middle Lake was thermally stratified (Figure 7). Water temperatures ranged from 20.8 °C at the surface to 4.4 °C at 13 m. Dissolved oxygen levels ranged from 7.85 mg/L to 0.12 mg/L. Depth at the site of the temperature and dissolved oxygen profiles was 13 m and the secchi water clarity was 4.5 m.

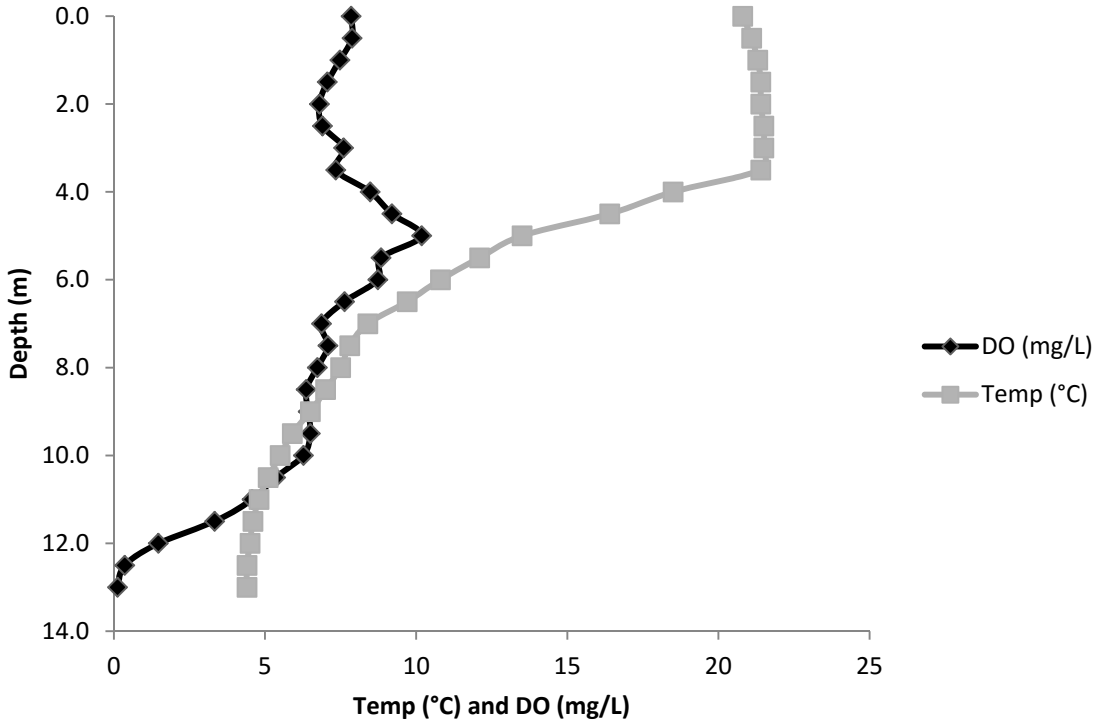

Figure 7 Temperature (°C) and dissolved oxygen (mg/L) profile for Middle Lake, measured July 8, 2014.

The water quality of Middle Lake has made a considerable recovery since 1973 (Table 3). During this time, the pH has increased from 4.40 to 7.55, along with an increase in TIA alkalinity from 5.78 mg/L $CaCO_3$ (1990) to 19.6 mg/L $CaCO_3$. Concentrations of metals such as Nickel (Ni), Copper (Cu), Iron (Fe) and Aluminum (Al) have declined over the past four decades. This improvement in water quality is likely a result of the neutralization experiments that occurred in the mid-1970s (Poulin *et al*., 1990) as well as a reduction in emissions from local smelting operations (Keller *et al*., 2007).

As of August 6, 2014, Middle Lake has a circumneutral pH reading of 7.55 and a TIA alkalinity of 19.6 mg/L $CaCO_3$. Concentrations of metals have been declining, however Nickel (42.5 µg/L) and Copper (12.6 µg/L) concentrations remain above criteria set by the Ministry of Environment and Climate Change's (MOECC) Provincial Water Quality Objectives (PWQO) for

the protection of aquatic life. Aluminum (8.5 µg/L) and Iron (40 µg/L) concentrations remain below these levels (Ontario Ministry of Environment and Energy, 1994)

Table 4 Water chemistry from Middle Lake (1. Ontario Ministry of Environment and Energy, 1994; 2. Yan *et al*., 1996; 3. Keller *et al*., 2004).

Parameter	PWQO[1]	Year			
		1973[2]	1990[3]	2003[3]	2014
pH	6.5-8.5	4.40	6.57	6.91	7.55
TIA Alkalinity (mg/L $CaCO_3$)	-	-	5.78	11.71	19.6
Conductivity (µS/cm)	-	-	258.0	286.0	285
True Colour (TCU)	-	-	-	-	15.7
DOC (mg/L)	-	-	3.3	3.6	3.7
Ca (mg/L)	-	9.8	10.30	11.00	8.92
Mg (mg/L)	-	-	3.53	3.21	3.14
Na (mg/L)	-	-	29.70	40.30	29.8
K (mg/L)	-	-	1.510	0.730	1.4
SiO_3 (mg/L)	-	-	1.20	0.80	0.96
SO_4 (mg/L)	-	-	25.37	17.53	12.6
Total Cu (µg/L)	5	496	28	24	12.6
Total Ni (µg/L)	25	1068	230	114	42.5
Total Zn (µg/L)	30	-	16	11	1.7
Total Fe (µg/L)	300	-	<80	26	40
Total Mn (µg/L)	-	-	110	20	5.9
Total Al (µg/L)	75	-	<30	13	8.5

CONCLUSIONS

Middle Lake no longer exhibits signs of acidification as pH has increased from 4.40 in 1973 (Yan *et al*., 1996) to 7.55 to 2014. Metal concentrations have declined by 96% for Ni and 97% for Cu, however these concentrations are still above PWQO criteria for the protection of aquatic life (Ontario Ministry of Environment and Energy, 1994). Clams and snails were not observed in the lake, however crayfish and acid-sensitive mayflies appear to be a common occurrence. Middle Lake supports populations of five fish species, including northern pike and the occasional walleye, both predatory sport fish. No information exists on how these two species entered the lake, however it is assumed that the fish migrated in from Hannah Lake to the west, or were perhaps introduced by residents of the lake.

ACKNOWLEDGEMENTS

The urban lakes fisheries monitoring program in Sudbury is conducted by staff and students of the Cooperative Freshwater Ecology Unit with support from OMNRF, OMOECC, City of Greater Sudbury, Vale and Glencore. Over the past 25 years the program has been led by Rod Sein, Rob Kirk, George Morgan, Ed Snucins, Michelle Gillespie and John Gunn, with technical

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APPENDIX I

Morphological data for northern pike (*Esox lucius*) and walleye (*Sander vitreus*) from Middle Lake, July 5 – 8, 2014.

Species	Fish #	Fork Length (mm)	Total Length (mm)	Weight (g)	Sex 1-Male 2-Female 9-Unknown	Maturity 1-Immature 2-Mature 9-Unknown	Ageing Structure 0-None 2-Scales 4-Pectoral Ray 7-Dorsal Spine A-Otolith B-Operculum D-Cleithrum	Tissue 0-None 1-Flesh 8-Stomach 9-Gonads A-Whole Fish X-Genetic
Northern Pike	1	770	812	2725.7	2	2	AD	1
Northern Pike	42	683	730	2036.9	2	2	AD	1
Northern Pike	97	634	675	1745.4	2	2	AD	1
Northern Pike	98	643	696	1385.8	2	2	AD	1
Northern Pike	142	361	390	385.2	9	1	AD	1
Northern Pike	190	648	710	1660.9	1	2	AD	1
Northern Pike	374	551	600	1187.2	2	2	AD	1
Walleye	316	431	460	866	2	2	A	1