BRODILL LAKE

URBAN LAKES FISHERIES STUDY 2021

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INTRODUCTION

Brodill Lake (46°22'18" N, 80°56'39" W) is a 112.1 ha lake located partially within the City of Greater Sudbury, in Dill/Broder/Secord township. It is comprised of two main basins separated by a shallow, narrow channel, and has a maximum depth of 36 m (Figure 1). A complete summary of physical characteristics can be seen in Table 1.

Brodill Lake is accessed by private road. There is very little accessible Crown Land around Brodill Lake, therefore it is unlikely to receive angling pressure other than by the two seasonal residents on the lake.

Documented history of Brodill Lake is limited. The lake was surveyed as part of the Sudbury Urban Lakes Study that occurred from 1989 to 1991 (Poulin *et al*., 1991). The earliest documented water samples were collected in 1990 when the lake had a pH of 5.42 (Keller *et al*., 2004). A multi-gear fish survey in 1991 concluded that only yellow perch (*Perca flavescens*) existed in the lake (Poulin *et al*., 1991). Although no written records exist, there are verbal accounts of the lake once being inhabited by lake trout (*Salvelinus namaycush*) (Toivonen, personal communication, 2014). Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) records indicate that Brodill Lake has never been stocked (Fish ON-Line, 2022).

In 2014, as part of the Urban Lakes Study, field crews from Laurentian University's Cooperative Freshwater Ecology Unit surveyed Brodill Lake, along with several other lakes around Greater Sudbury. This was the first fisheries index netting survey in the history of Brodill Lake. This research has continued through 2019, however, this time following Broadscale Monitoring (BsM) protocol. An additional BsM survey was also conducted in 2021, providing the latest updates on the fish population recovery in this historically acid-damaged lake.

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

Township	Dill/Broder/Secord
Latitude/Longitude	46°22'18" N, 80°56'39" W
NDMNRF District	Sudbury
Watershed Code	2DB
Elevation (m)	241
Shoreline Development Factor	3.17
Number of Cottages/Lodges	2
Forest Type	Mixed forest
Shoreline Type	Bedrock/boulder
Lake Surface Area (ha)	112.1
Maximum Depth (m)	36.0
Mean Depth (m)	9.6
Volume ($x10^4 m^3$)	1061.1
Secchi (m)	5.15 (June 17, 2019)
Access	Private road off Kasten Lake Rd, ~ 15km south of Sudbury.

Secchi reading was 5.15 m in 2021

METHODS

Fisheries Community Assessment

The fish community of Brodill Lake was originally sampled using a multi-gear approach as part of the Co-op Unit Urban Lake Study in 1990-1991 (Poulin *et al*., 1991). In 2014, Brodill Lake was sampled using 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 the population's status (Morgan and Snucins, 2005).

In 2004, a new Ecological Framework for Fisheries Management (EFFM) was announced in Ontario (Sandstrom *et al*., 2018). The framework is referred to as the Broadscale Monitoring (BsM) protocol. The goal of the BsM protocol is to improve the way recreational fisheries are managed by considering a broader landscape approach rather than focusing on individual lake management (Sandstrom *et al*., 2018). Active management of lakes under the BsM protocol would therefore occur on a zone basis (Sandstrom *et al*., 2018). The BsM protocol includes a broad-scale fish community monitoring program which uses a combination of two types of gillnets: "Large mesh" gillnet that target fish larger than 20 cm in length and "Small mesh" gillnet that target smaller fish. The Large mesh gillnet (aka North American; NA1; 8 mesh sizes) is the standard net for angler harvested freshwater species in North America (Sandstrom *et al*., 2018). The Small mesh gillnet (aka Ontario Small mesh; ON2; 5 mesh sizes) was developed in Ontario, Canada and is a new standard (Sandstrom *et al*., 2018). In combination the large and small mesh gillnets have a length comparable to Nordic style "gang" net, which the standard in Europe (Sandstrom *et al*., 2018). The BsM protocol is considered the optimum choice due to the compromise between North American and European standards (Sandstrom *et al*., 2018). In addition, the separation of large and small net segments within the same gear offers the advantage of a being able to incorporate a more flexible project design to optimally meet survey needs (Sandstrom *et al*., 2018).

During the 2021 lake survey large and small mesh gillnets nets were spatially allocated as equally as possible to all regions of the lakes (Sandstrom *et al*., 2018). This was done by incorporating the total surface area, max depth, and total amount of depth strata to divide the lake into a number of approximately equal-sized areas (sectors) and randomly distribute the net locations to cover as much of these areas as possible (Sandstrom *et al*., 2018). Previously this process was done manually, however in 2016 a data package was developed by the Ministry of Natural Resources and Forestry called the "Broad-scale Monitoring (BsM) Map Creation Package" to automate the entire procedure (Dunkley, 2016). The data package uses a series of python script tools to identify depth contours of the lake, describe physical characteristics,

automate the stratified random distribution of net locations, and export all results into a comprehensive map, with accompanied spatial data for field technicians (Dunkley, 2016). In 2021 the sampling locations were the same as the 2019 sampling locations (Figure 2), a total of 24 BsM nets were set in Brodill Lake from June 29 to July 2, 2021. Nets were set for approximately 20 hours at randomly selected locations on the lake across multiple depth strata (5 nets in 1-3 m; 6 nets in 3-6 m; 4 nets in 6-12 m; 5 nets in 12-20 m; 4 nets in 20-35 m).

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 of each species across a size range for contaminant and stable isotope analysis. All other fish were measured for length only.

Baseline Organisms

Attempts were made to collect samples of clams (n=10), snails (n=30), Heptageniid mayflies (n=50), and Chaoborus sp. (n=300) from Brodill 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. Heptageniid mayflies were targeted by turning over rocks and woody debris along the shore of Brodill Lake and picking the organisms off the surface by hand or with a pair of tweezers. In 2019, Chaoborus sp. were targeted by conducting vertical zooplankton hauls with a 30cm diameter net (80 μm mesh) from the main basin of the lake.

Water Quality Assessment

A dissolved oxygen (mg/L) and temperature (°C) profile was measured in the main basin of Brodill Lake on June 17, 2019, using a YSI Model 52 dissolved oxygen – temperature meter. Readings were taken at 1 m intervals through the water column.

Water samples were collected on June 17, 2019, from the surface of Brodill 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, metals and major ions. Sampling locations can be seen in Figure 2.

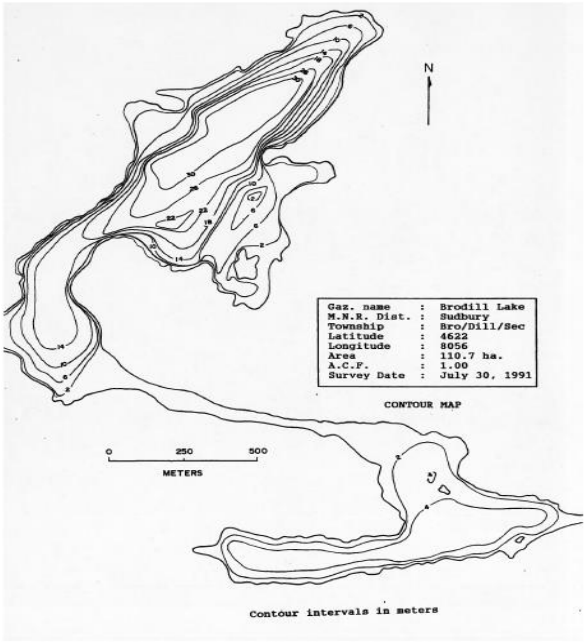

Figure 1 Bathymetric map of Brodill Lake.

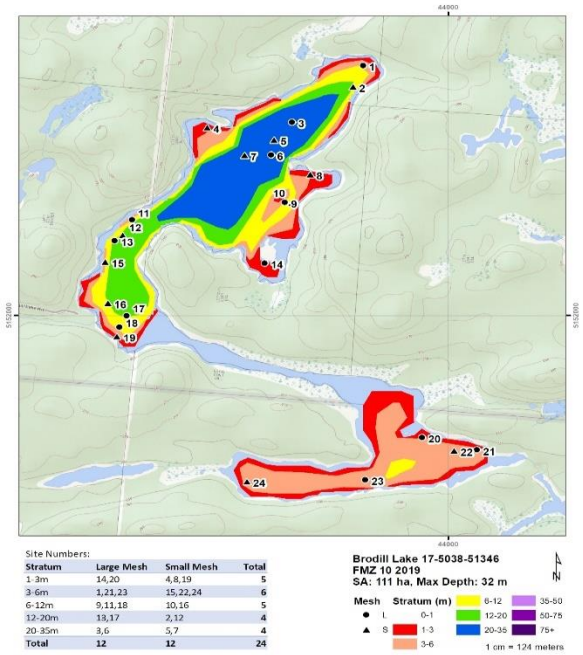

Figure 2 Map of Brodill Lake showing the location of depth stratums and sampling sites in 2019.

RESULTS AND DISCUSSION

Fisheries Community Assessment

During the BsM survey conducted in 2021 from June 29 to July 2, a total of five different species were capture: largemouth bass (*Micropterus salmoides*) (n=1), pumpkinseed (*Lepomis gibbosus*) (n=3), smallmouth bass (*Micropterus dolomieu*) (n=42), white sucker (*Catostomus commersonii*) (n=3) and yellow perch (*Perca flavescens*) (n=87). Other species observed in previous netting surveys including central mudminnow (*Umbra limi*) and golden shiner (*Notemigonus crysoleucas*) were not captured in 2021 (Cooperative Freshwater Ecology Unit, 2021).

Yellow perch was the dominant fish species found in Brodill Lake in 2021 (Table 2) with fork lengths ranging from 70 mm to 238 mm. A length frequency histogram for yellow perch can be seen in Figure 3.

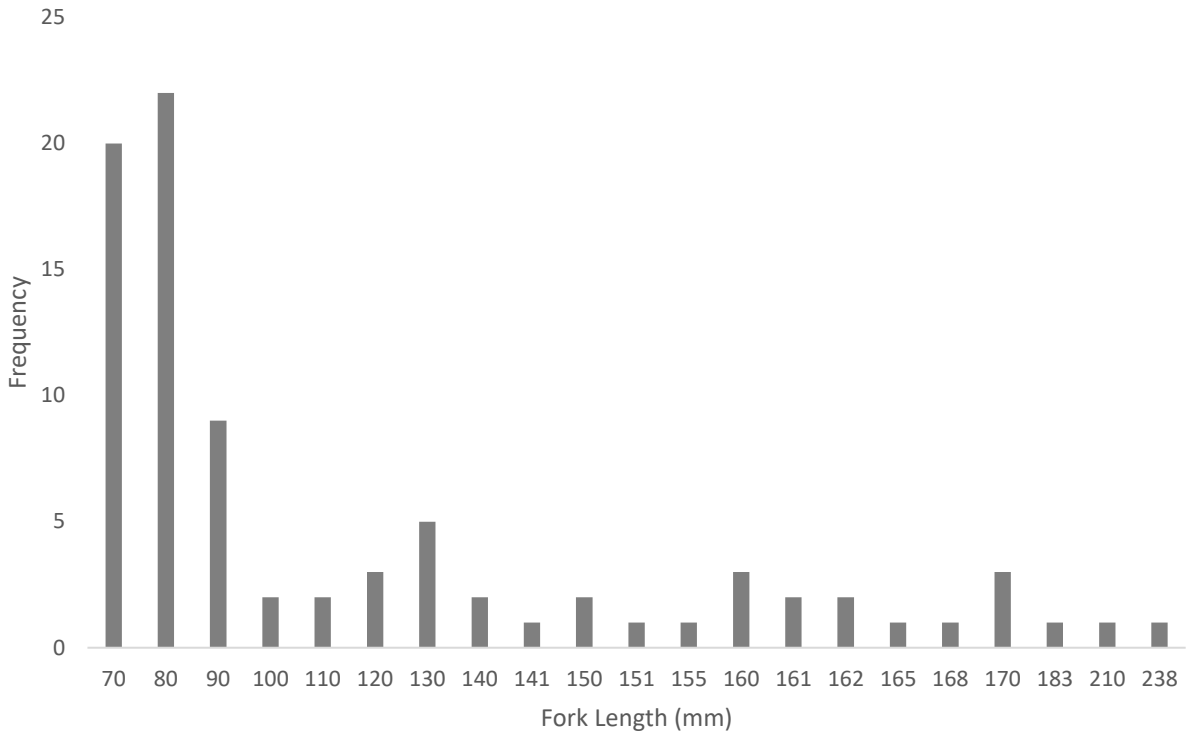

Figure 3. Length frequency histogram for yellow perch (n=85) captured in Brodill Lake June 29 – July 2, 2021.

Only yellow perch existed in the lake during the 1991 Urban Lakes Survey, prior to the use of the Nordic protocol. A total catch of 1090 fish was recorded at the time (Poulin *et al*., 1991). The 2014 Nordic survey indicated that yellow perch was still the numerically most abundant species in Brodill Lake, accounting for 88% of the total catch. This trend continued into 2019, with yellow perch accounting for 95% of the total catch. Species richness had greatly improved since 1991 to 2014, with a total of seven documented species. In 2019, however, only 4 species were captured. In 2021, species richness increased to 5 species captured. Species richness and proportion of total catch can be seen in Table 2.

Table 2. Species richness and proportion of total catch for Brodill Lake (1. Poulin *et al*.,1991**;** 2. Cooperative Freshwater Ecology Unit, 2019; 3. Cooperative Freshwater Ecology Unit, 2021).

Survey Type	**Multi-Gear Survey**		**Nordic**		**BsM**		**BsM**	
Year	**[1]1991**		**[2]2014**		**[2]2019**		**[3]2021**	
Species	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Central Mudminnow	-	-	2	0.16	-	-	-	-
White Sucker	-	-	12	0.97	6	1.11	3	2.21
Golden Shiner	-	-	41	3.31	-	-	-	-
Pumpkinseed	-	-	52	4.2	12	2.21	3	2.21
Smallmouth Bass	-	-	44	3.56	8	1.48	42	30.88
Largemouth Bass	-	-	1	0.08	-	-	1	0.74
Yellow Perch	1090	100	1085	87.71	516	95.2	87	63.97
Total	**1090**	**100**	**1237**	**100**	**542**	**100**	**136**	**100**
Species Richness	1		7		4		5	

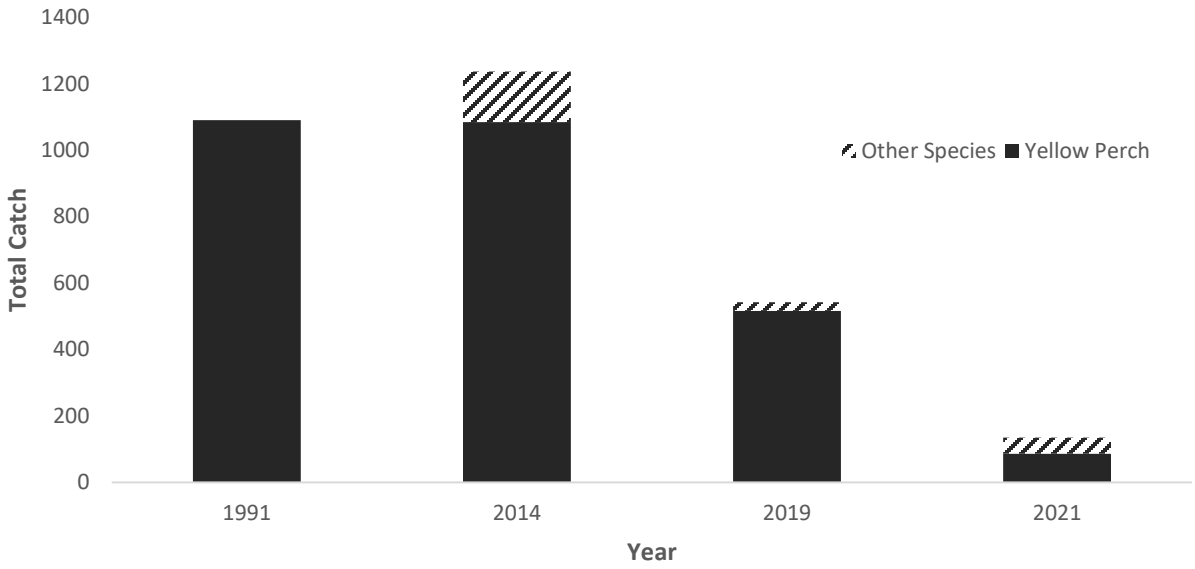

Figure 4. Total catch data from Brodill Lake (1991 – Multi-Gear Survey; 2014 – NORDIC Survey; 2019,2021 – BsM Survey).

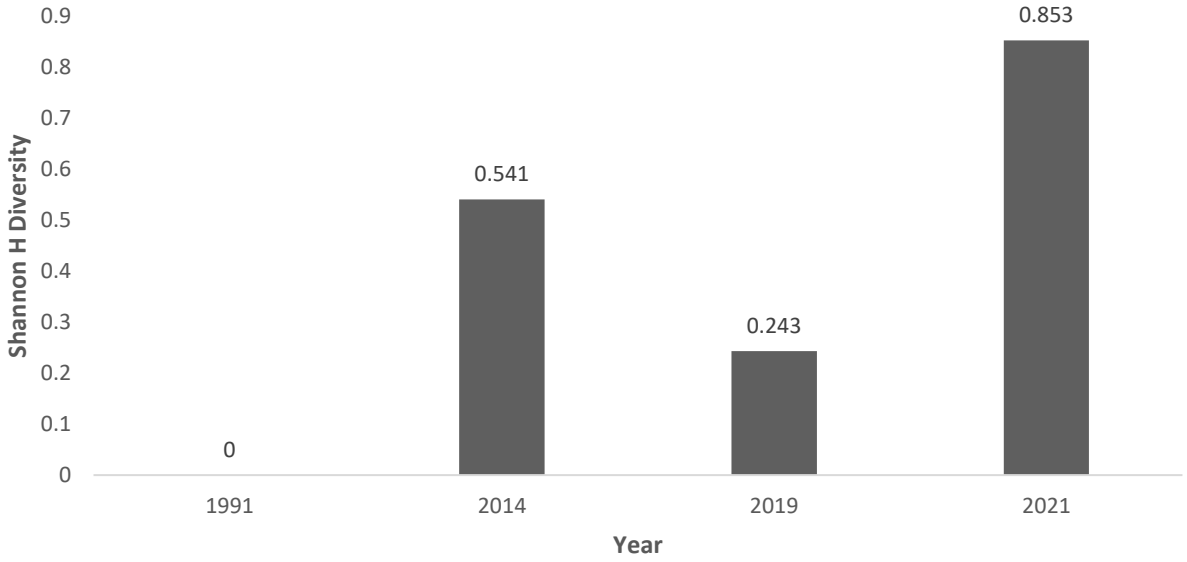

Figure 5. Species diversity (Shannon H Diversity) values from Brodill Lake (Morgan and Snucins, 2005).

Unlike the Nordic Index Netting protocol or the BsM, the Urban Lakes Survey that was conducted on Brodill Lake in 1991 did not use a standardized netting method. Therefore, species diversity was unable to be calculated. However, with only one species living in the lake at the time, the Shannon H Diversity value would equal zero. With six new species recorded in Brodill Lake, the 2014 Nordic survey resulted in a "low" Shannon H Diversity value of 0.5409, and the BsM survey in 2019 only produced 4 of those species, bringing the value down to 0.243 (Morgan and Snucins, 2005). In 2021, the Shannon H Diversity value increased to 0.853.

Baseline Organisms

In 2021, no clams or snails were found at Brodill Lake; however, mayflies were present and collected (n=50).

Water Quality Assessment

No water quality or secchi reading were recorded in 2021. At the time of the 2019 BsM Netting survey, Brodill Lake was thermally stratified (Figure 6). Water temperatures ranged from 18.0 °C at the surface to 4.2 °C at 32.0 m. Dissolved oxygen levels ranged from 10.32 mg/L to 0.72 mg/L. The secchi water clarity was 5.15 m.

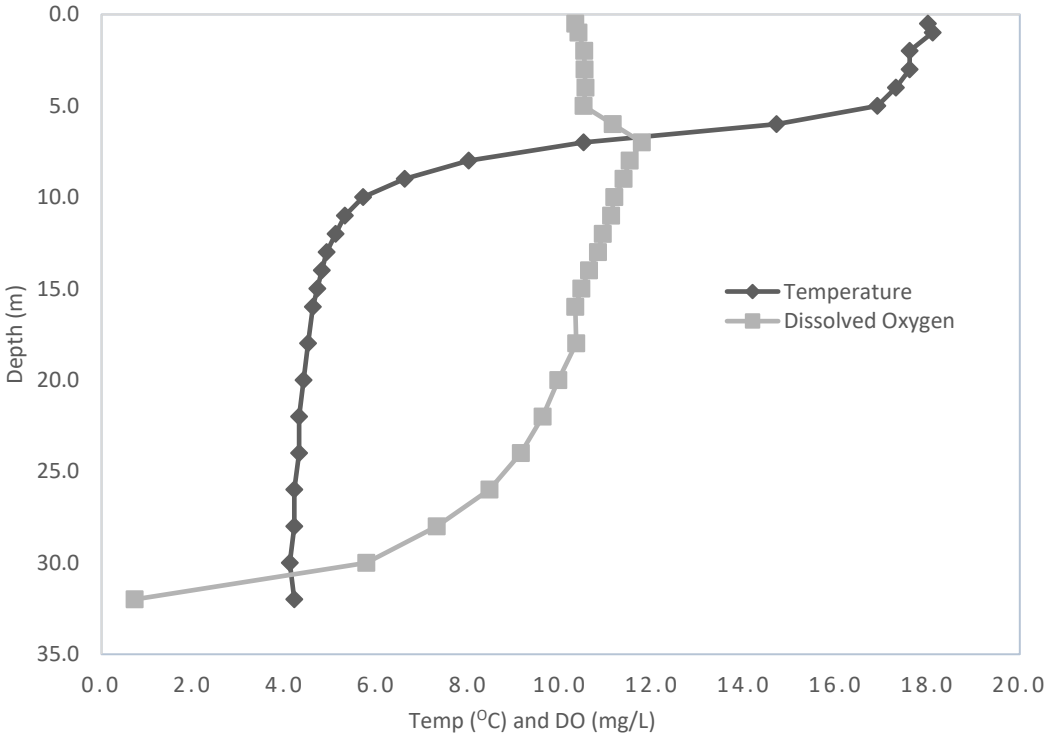

Figure 6 Temperature (°C) and dissolved oxygen (mg/L) profile for Brodill Lake, measured June 17, 2019.

The water quality of Brodill Lake appears to have considerably improved since 1990 (Table 3). Over this time period, the pH has increased from 5.42 (Keller *et al*., 2004) to 6.36 in 2019. Conductivity has decreased from 42.3 µS/cm to 20 µS/cm over the past two decades, as have concentrations of metals such as Copper (Cu), Nickel (Ni), Aluminum (Al), Iron (Fe) and Zinc (Zn). These improvements are likely a result of reduced emissions from local smelters (Keller *et al*., 2007).

*Copper has recently undergone an interim change based on new research suggesting that TIA Alkalinity $CaCO_3$ (mg/L) will depict the quantity of Total Cu that should be present (Canadian Council of Ministers of the Environment, 1998). In previous reports, 5 µg/L was the standard total Cu value for protection of aquatic life and now an interim change to the PWQO states that at a low TIA Alkalinity value 0-20 mg/L of $CaCO_3$ should not have Total Cu readings greater than 1 µg/L. Anything greater than 20 mg/L of $CaCO_3$ continues to have the 5 µg/L standard.

As of June 17, 2019, Brodill Lake remains slightly acidic with a pH of 6.36. Cu (7 µg/L) and Ni (36.6 µg/L) concentrations are continuing to decrease, however, remain above the criteria set by the Ministry of Environment and Climate Change's (MOECC) Provincial Water Quality Objective (PWQO) for the protection of aquatic life. Fluctuations of Al (57.1 µg/L), Fe (70 µg/L) and Zn (5.2 µg/L) can be observed throughout the years, although concentrations remain below these criteria (Ontario Ministry of Environment and Energy, 1994).

Table 3 Water chemistry from Brodill Lake (1. Ontario Ministry of Environment and Energy, 1994; 2. Keller *et al*., 2004; Brodill Lake Urban Fisheries Study, 2019).

Parameter	**[1]PWQO**	**Year**			
		[2]1990	**[2]2003**	**[3]2014**	**[3]2019**
pH	6.5-8.5	5.42	6.05	6.41	6.36
TIA Alkalinity (mg/L $CaCO_3$)	-	2.72	0.94	1.64	1.95
Conductivity (µS/cm)	-	42.3	27.2	23.2	20
DOC (mg/L)	-	-	-	3.4	3.8
SO_4 (mg/L)	-	12.2	8.17	5.65	4.85
Total Cu (µg/L)	*1, 5	19	9	8.1	7
Total Ni (µg/L)	25	100	56	44.6	36.6
Total Zn (µg/L)	30	12	14	6.2	5.2
Total Fe (µg/L)	300	<80	60	40	70
Total Mn (µg/L)	-	89	44	20.5	16.5
Total Al (µg/L)	75	<100	47	33	57.1

CONCLUSIONS

Although water quality appears to have improved since 1990, concentrations of Cu and Ni remain above the criteria for the protection of aquatic life (Ontario Ministry of Environment and Energy, 1994). Metal concentrations have, however, declined by 63% for Cu and 63% for Ni since 1990. Clams and snails were not observed in the lake, however acid-sensitive mayflies appear common. Brodill Lake now supports populations of four fish species, including smallmouth bass. In addition, the occasional largemouth bass first recorded in 2014 have been observed by the cottagers in recent years. No information exists on how the bass entered Brodill Lake; however, it is assumed that they may have migrated in from nearby Kasten (Bibby) Lake to the west and introduced by cottagers or anglers. Current pH of the lake suggests that species such as lake trout could survive and reproduce naturally (Beggs and Gunn, 1986).

ACKNOWLEDGEMENTS

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