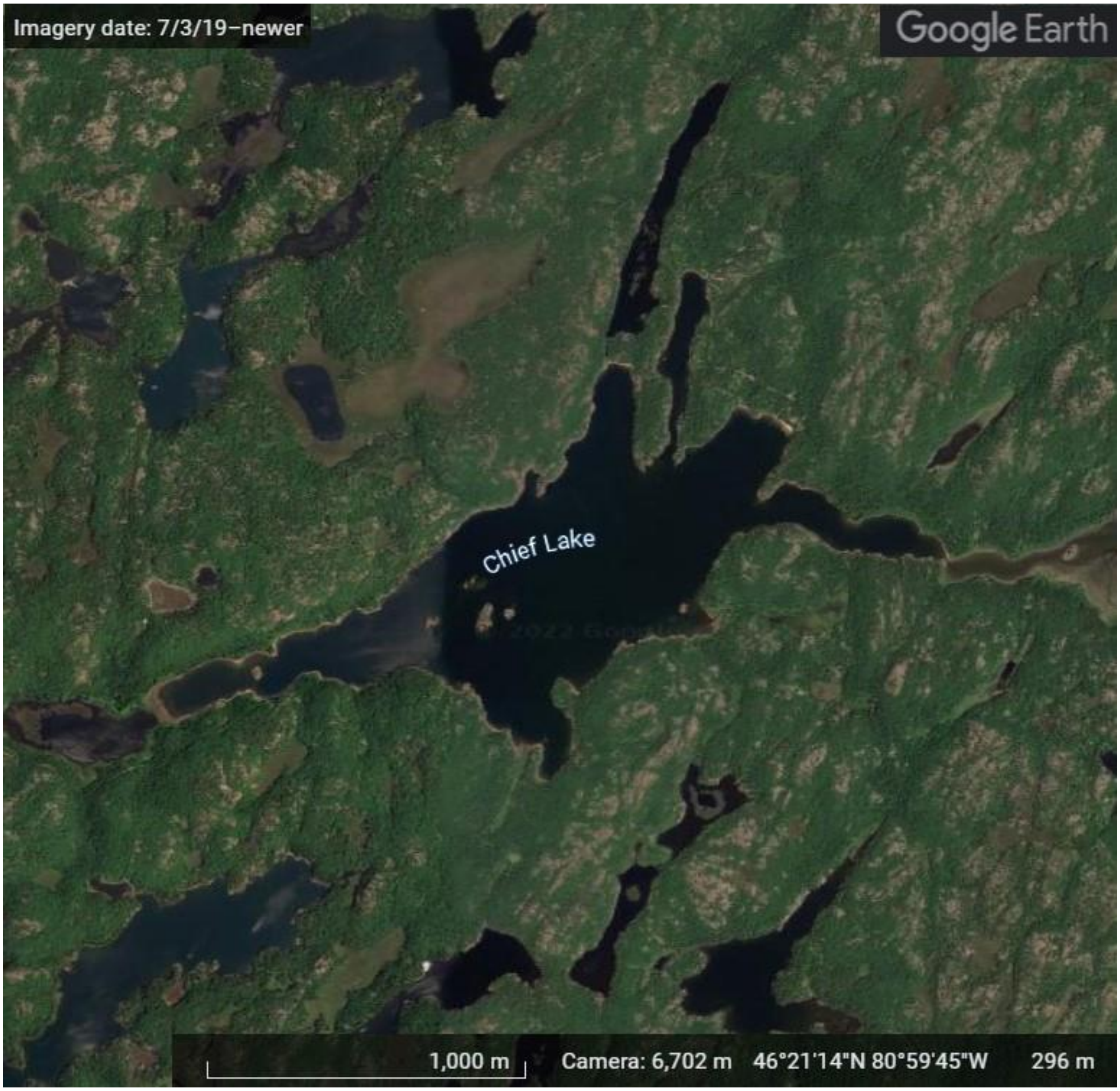
CHIEF LAKE

URBAN LAKES FISHERIES STUDY 2019/2021



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CHIEF LAKE

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INTRODUCTION

Chief Lake (46°21’41” N, 81°01’06” W) is a 115.2 ha lake located partially within the City of Greater Sudbury, in Broder/Tilton township. It is comprised of three basins and has a maximum depth of 34.0 m (Figure 3). A complete summary of physical characteristics can be seen in Table 1. Chief Lake is accessed by private road and has two seasonal residents with cottages on the lake. The lake is a year-round fish sanctuary. Angling for any species is prohibited (Government of Ontario, 2022)

Historic information on Chief Lake appears to be limited, however verbal accounts suggest that it supported native lake trout (*Salvelinus namaycush*) in the 1950s (Ken Sonoski, personal communication, 2014). The City of Greater Sudbury began monitoring phosphorus levels of Chief Lake, as well as other lakes in the area, as early as 1992 as part of their Lake Water Quality Program (Greater Sudbury, 2012). Chief Lake was stocked on June 5, 2008 with adult (6 – 7 years old; approx. 2.5 kg each), endangered Iroquois Bay, Great Lakes strain of lake trout by the Ministry of Natural Resources and Forestry (MNRF) (Selinger, personal communication, 2014). Chief Lake was chosen for these fish because they were too large to be kept in a culture facility and the MNRF was looking for an empty, former lake trout lake to put them in. A similar stocking effort occurred in 1995 when approximately 500 Iroquois Bay strain lake trout were stocked in Great Mountain Lake, an acid-damaged, former lake trout lake in Killarney Provincial Park (Gunn, personal communication, 2015). Chief Lake was stocked again in spring of 2021, when the District added 89 mature adult lake trout and 1000 yearling lake trout from Iroquois Bay (Johnston, personal communication, 2022).

In 2014, as part of the Urban Lakes Study, field crews from Laurentian University’s Cooperative Freshwater Ecology Unit surveyed Chief Lake, along with several other lakes around Greater Sudbury. The lake was part of the urban lake programming in 1990 and also had a Nordic Survey in 2006. 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 Chief Lake location and physical description (Poulin *et al*., 1991).

Township	Broder/Tilton
Latitude/Longitude	46°21’41” N, 81°01’06” W
MNRF District	Sudbury
Watershed Code	2CF
Elevation (m)	261
Shoreline Development Factor	-
Number of Cottages/Lodges	2
Forest Type	Deciduous
Shoreline Type	Bedrock/boulder
Lake Surface Area (ha)	115.2
Maximum Depth (m)	34
Mean Depth (m)	9.9
Volume ($x10^4m^3$)	1134.8
Secchi (m)	4.0 (June 24, 2019)
Access	Private road off Chief Lake Rd. approx. 14 km south of Sudbury.

Secchi reading was 5.42 m in 2014 – now 4.0 m 5 years later.

METHODS

Fisheries Community Assessment

In 2006 and 2014, the fish community of Chief 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 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 2019 and 2021 BsM surveys 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). The 2019 survey included the use of BsM nets, in addition to supplemental sampling using Nordic nets.

<u>2019</u>

A total of 29 nets were set in Chief Lake from June 24 to 27, 2019. This included the BsM nets as well as supplemental netting using NORDIC nets. Nets were set for approximately 20 hours at randomly selected locations on the lake across multiple depth strata (6 nets in 1-3 m; 6 nets in 3-6 m; 7 nets in 6-12 m; 5 nets in 12-20 m; 5 nets in 20-35 m). Figure 4 shows the locations of all gillnets set in Chief Lake during the 2019 survey.

<u>2021</u>

A total of 24 BsM nets were set in Chief Lake from June 15 to 18, 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; 5 nets in 3-6 m; 6 nets in 6-12 m; 3 nets in 12-20 m; 5 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 (2019/2021)

Attempts were made to collect samples of clams (*n*=10), snails (*n*=30), crayfish (*n*=20), and Heptageniid mayflies (*n*=50) from Chief 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 Chief Lake and picking the organisms off the surface by hand or with a pair of tweezers. In 2021, crayfish were targeted by setting minnow traps on long lines (x6 traps/line, total x2 lines – 1-3m and 3-6m depth strata) baited with dog kibble.

Water Quality Assessment (2019)

A dissolved oxygen (mg/L) and temperature (°C) profile was measured in the main basin of Chief Lake on June 24, 2019, using a YSI Model 52 dissolved oxygen – temperature meter. Readings were taken at 1.0 m intervals through the water column.

Water samples were collected on June 24, 2019 from the surface of Chief 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.

RESULTS AND DISCUSSION

Fisheries Community Assessment

During the BsM survey conducted in 2019 from June 24 to 27, a total of seven different species were captured: lake trout (*Salvelinus namaycush*), white sucker (*Catostomus commersonii*), pearl dace (*Margariscus margarita*), creek chub (*Semotilus atramaculatus*), pumpkinseed (*Lepomis gibbosus*), yellow perch (*Perca flavescens*), and Iowa darter (*Etheostoma exile*). Previous netting surveys detected golden shiners (*Notemigonus crysoleucas*); however, none were captured in 2019 (Cooperative Freshwater Ecology Unit, 2019). In 2021, apart from pearl dace, the species captured remained the same as in 2019.

During the 2014 Nordic survey, two lake trout with no clips were captured, one was mature and the other was immature. A total of four lake trout were captured during the 2019 survey with total lengths ranging from 580 mm to 636 mm. Only one of the four fish had a fin clip, and all four fish were mature. In 2021, five lake trout were caught, four of which had fin clips – all five were mature. Two of the clipped mature lake trout were released back into the lake after recording length measurements. A complete summary of morphological data for lake trout captured in 2019 and 2021 can be seen in Appendix I and Appendix II, respectively.

Figure 1 Photo of an immature lake trout from Chief Lake in 2014.

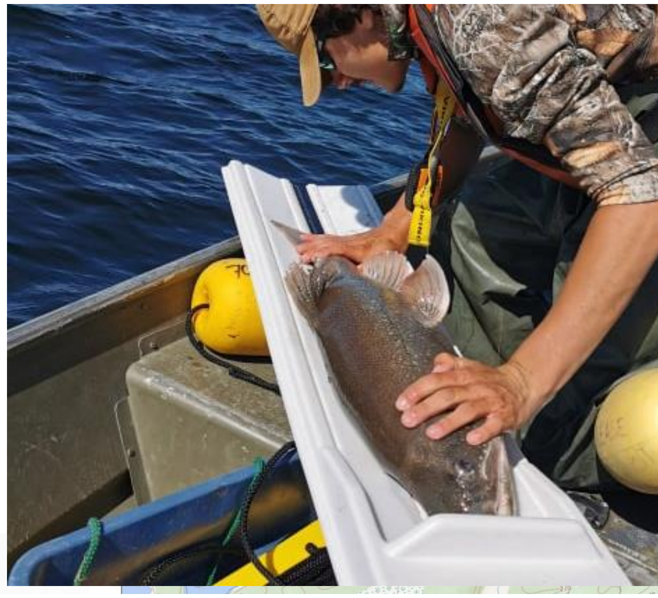


Figure 2 Photo of a mature stocked lake trout from Chief Lake in 2021 – recording length measurement before releasing it back into the lake.

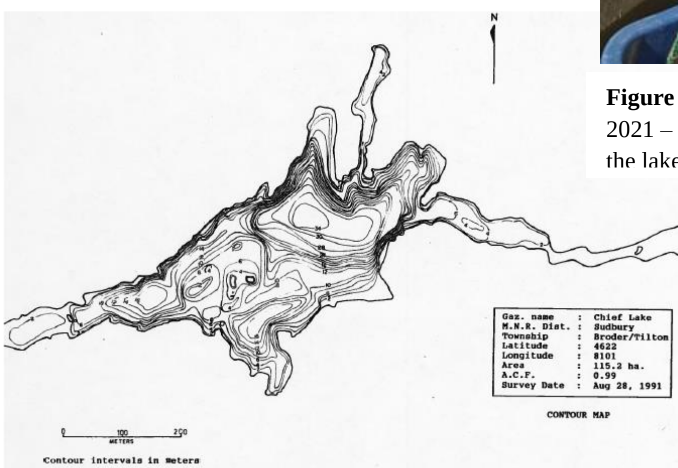
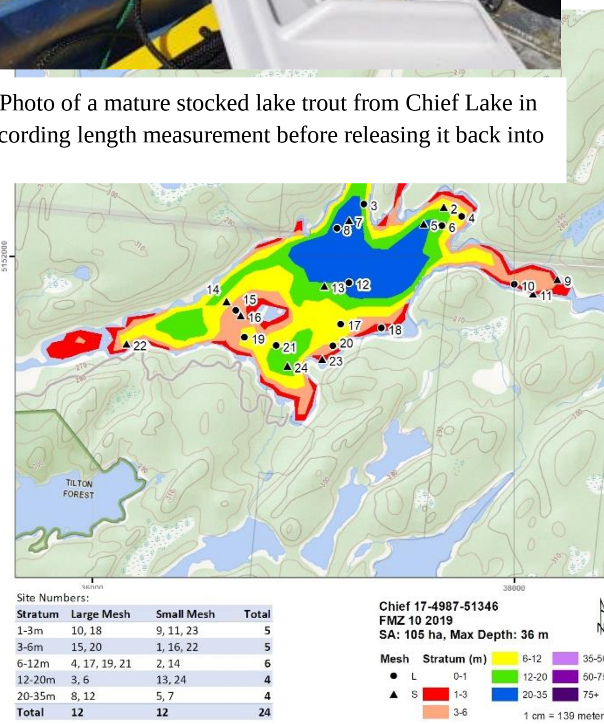


Figure 3 Bathymetric map of Chief Lake.



Stratum	Large Mesh	Small Mesh	Total
1-3m	10, 18	9, 11, 23	5
3-6m	15, 20	1, 16, 22	5
6-12m	4, 17, 19, 21	2, 14	6
12-20m	3, 6	13, 24	4
20-35m	8, 12	5, 7	4
Total	**12**	**12**	**24**

Figure 4. Map of Chief Lake showing the location of depth stratums and sampling sites in 2019.

Yellow perch was the dominant fish species found in Chief Lake (Table 3) with total lengths ranging from 50 mm to 190 mm (in 2019). A length frequency histogram for yellow perch caught in 2019 can be seen in Figure 5.

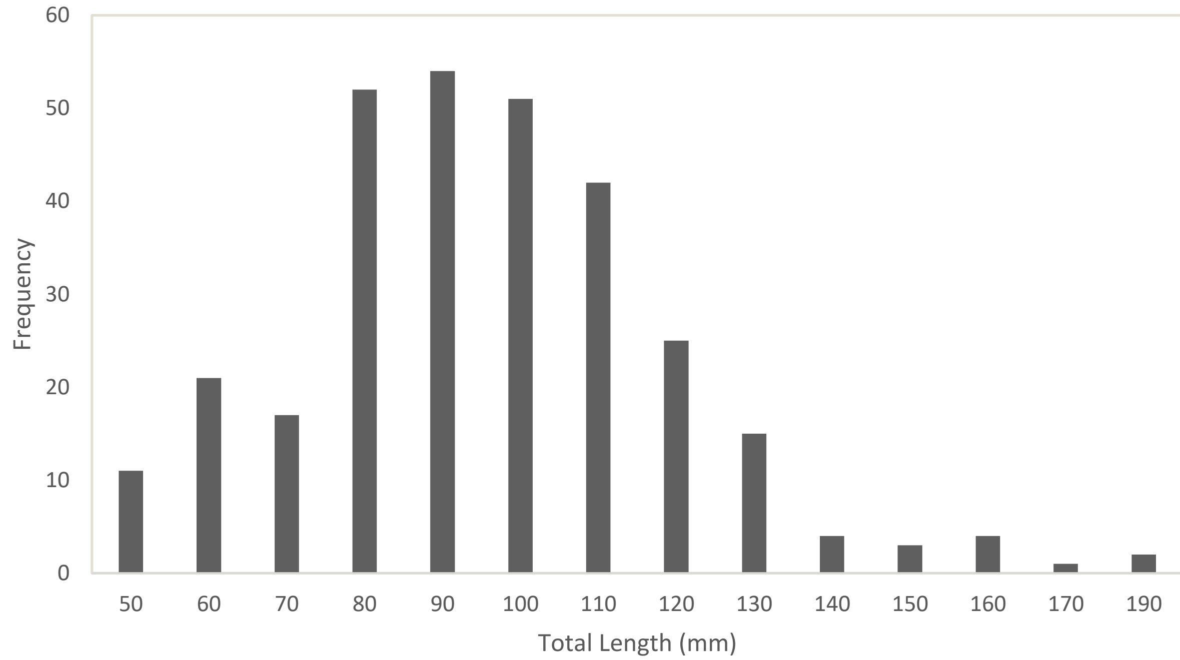


Figure 5 Length frequency histogram for yellow perch (n=302) captured in Chief Lake June 24 - 27, 2019.

Only central mudminnow (*Umbra limi*) existed in the lake during the 1990 Urban Lakes Survey with a total catch of 61 fish at the time (Poulin *et al*., 1991). In 2006, when Chief Lake was surveyed using the Nordic protocol for the first time, yellow perch was the only species recorded with a total catch of 1553 individuals (Cooperative Freshwater Ecology Unit, 2019). Species richness had significantly increased by 2014 when six species had been observed with a total catch of 1442 fish. In 2019, the species richness continues to increase, providing seven species in the BsM survey. Yellow perch was the most abundant species observed during this survey, accounting for 81% of the total catch (Figure 6). In 2021, species richness returned to six species, with yellow perch accounting for 72% of total catch. Species richness and proportion of total catch can be seen in Table 3.

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

Survey Type	**Multi-Gear Survey**		**Nordic**		**Nordic**		**BsM**		**BsM**	
Year	**1990[1]**		**2006[2]**		**2014[2]**		**2019[2]**		**2021[2]**	
Species	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Lake Trout	-	-	-	-	2	0.14	4	1.08	5	0.98
White Sucker	-	-	-	-	-	-	19	5.12	61	11.96
Pearl Dace	-	-	-	-	-	-	1	0.27	-	-

Central Mudminnow	61	100	-	-	-	-	-	-	-	-
Golden Shiner	-	-	-	-	4	0.28	-	-	-	-
Creek Chub	-	-	-	-	4	0.28	17	4.58	38	7.45
Pumpkinseed	-	-	-	-	32	2.22	17	4.58	36	7.06
Yellow Perch	-	-	1553	100	1390	96.39	302	81.40	365	71.57
Iowa Darter	-	-	-	-	10	0.69	11	2.96	5	0.98
Total	**61**	**100**	**1553**	**100**	**1442**	**100**	**371**	**100**	**510**	**100**
Species Richness	1		1		6		7		6	

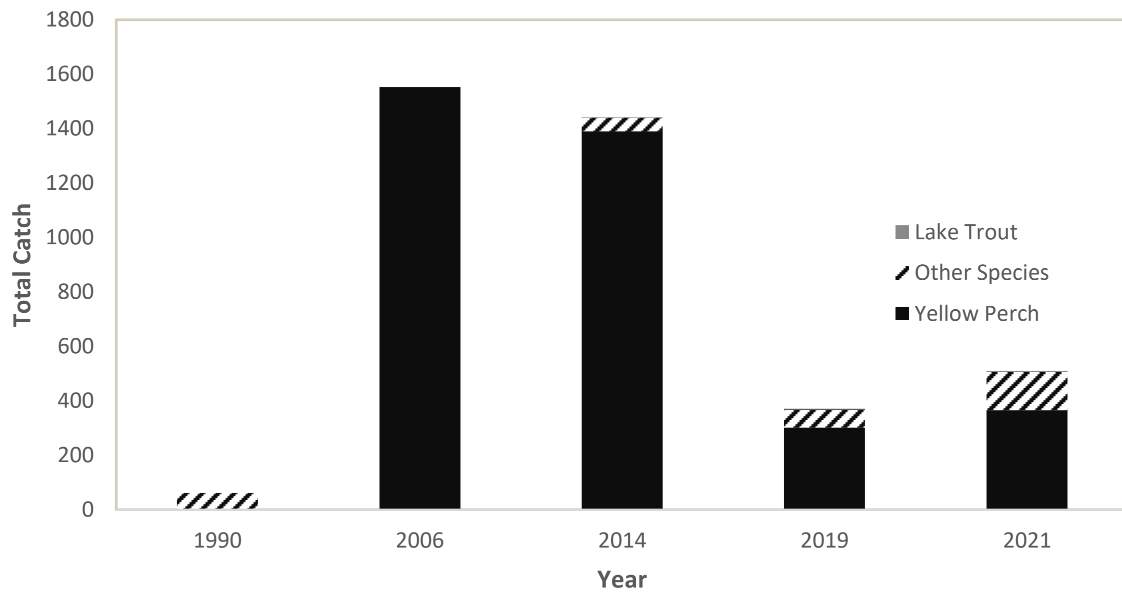


Figure 6 Total catch data from Chief Lake (1990 – Multi-Gear Survey; 2006 & 2014 – NORDIC Survey; 2019 – BsM Survey).

Since yellow perch was the only species caught during the 2006 Nordic survey, species diversity equals zero. As of 2014, with the addition of five different species, Shannon H Diversity had improved to a "low" value of 0.196, and now has climbed to 0.771 in 2019 (Morgan and Snucins, 2005). Although species richness went back to six in 2021, diversity continues to improve with species abundance (evenness), resulting in a new value of 0.965.

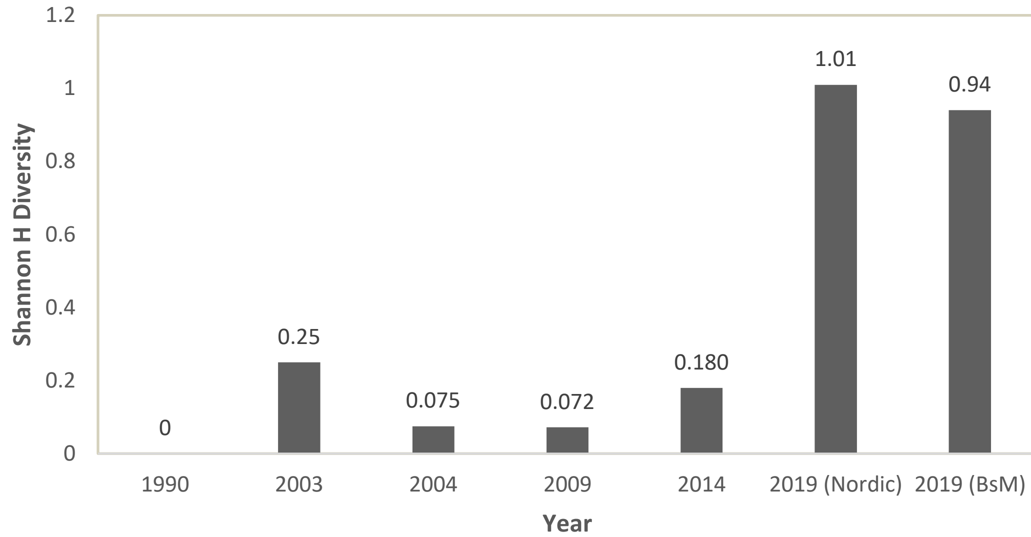


Figure 7. Species diversity (Shannon H Diversity) values from Chief Lake (Morgan and Snucins, 2005).

Baseline Organisms

No clams or snails were found at Chief Lake. At the northwest end of the lake, a total of 50 mayflies were captured in 2019, and 100 mayflies in 2021.

Water Quality Assessment (2019)

At the time of the BsM survey in June of 2019, Chief Lake was thermally stratified (Figure 8). Water temperatures ranged from 20.4 °C at the surface to 4.5 °C at 36.0 m. Dissolved oxygen levels ranged from 9.92 mg/L to 0.49 mg/L. Dissolved oxygen remained above 6 mg/L as far as 34 m in depth, then dropped to anoxic levels within 2 m of reaching bottom. Depth at the site of the temperature and dissolved oxygen profiles was 36.5 m and the secchi water clarity was 4.0m.

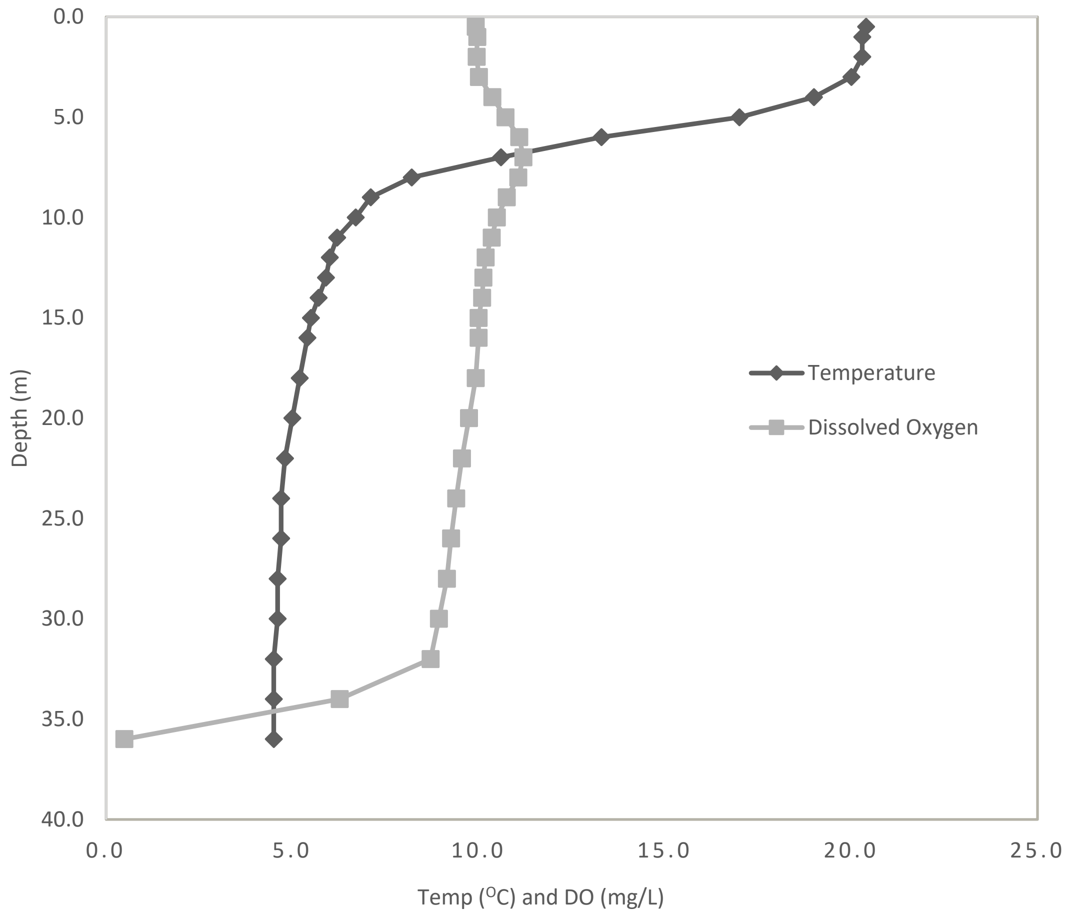


Figure 8. Temperature (°C) and dissolved oxygen (mg/L) profile for Chief Lake, measured June 24, 2019.

Chief Lake was a very acid (pH 4.8) and metal contaminated lake in 1990 (Table 4). The metals and acidity have declined with reduced emissions from local smelters (Keller *et al*., 2007). As of June 2019, Chief Lake had a pH value of 6.25, increasing from 5.87 in 2014. Nickel (38.6 µg/L) and Copper (6.5 µg/L) concentrations are above criteria set by the Ministry of Environment and Climate Change's (MOECC) Provincial Water Quality Objective (PWQO) for the protection of aquatic life. Aluminum (42.9 µg/L), Iron (30 µg/L) and Zinc (4.3 µg/L) concentrations are below these criteria (Ontario Ministry of Environment and Energy, 1994).

*Copper PWQO 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.

Table 2 Water chemistry from Chief Lake (1. Ontario Ministry of Environment and Energy, 1994; 2. Watson 1992; 3. Chief Lake Urban Fisheries Study 2019).

Parameter	**PWQO**[1]	**Year**		
		1990[2]/91	**2014[3]**	**2019[3]**
pH	6.5-8.5	4.8	5.87	6.25
TIA Alkalinity (mg/L $CaCO_3$)	-	-1.5	0.805	1
Conductivity (µS/cm)	-	4	20	17.2
DOC (mg/L)	-	0.7	2.9	3.2
SO_4 (mg/L)	-	12.2	5.35	4.25
Total Ca (mg/L)	-	-	1.38	1.3
Total P (µg/L)	20	-	3.3	4
Total Cu (µg/L)	1, 5	31	7.3	6.5
Total Ni (µg/L)	25	120	47.9	38.6
Total Zn (µg/L)	30	17	5.4	4.3
Total Fe (µg/L)	300	40	30	30
Total Mn (µg/L)	-	130	29.9	22.4
Total Al (µg/L)	75	180	45.9	42.9

CONCLUSIONS

Although concentrations of Cu and Ni remain above the criteria for the protection of aquatic life (Ontario Ministry of Environment and Energy, 1994) the pH in 2014 of Chief Lake exceeded the pH level (pH 5.5) for natural reproduction of lake trout, and in 2019 the pH surpassed the threshold to sustain sensitive species (pH 6.0) (Beggs and Gunn, 1986). It is therefore very promising to see continued evidence of reproducing lake trout in this lake over a decade after initial stocking efforts took place. Lake trout is considered a primary indicator of overall lake health (Ryder and Edwards, 1985). As the water quality of this lake will likely continue to improve over time, further management efforts may be required in order to reestablish a full population of lake trout (Gunn and Mills, 1998). In addition, Chief Lake also supports populations of six other fish species. Clams and snails were not observed, however crayfish and acid-sensitive mayflies appear quite common.

ACKNOWLEDGEMENTS

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APPENDIX I

Morphological data for lake trout (*Salvelinus namaycush*) from Chief Lake, June 24 - 27, 2019.

Species Code	Fish #	Fork Length (mm)	Total Length (mm)	Weight (g)	Sex 1-Male 2-Female 9-Unknown	Maturity 10-Immature 20-Mature 99-Unknown	Clip 0-No clip 1-R pectoral 2-L pectoral 3-R ventral 4-L ventral 5-Adipose
81	1	570	620	2420	2	20	0
81	10	530	580	1900	2	20	0
81	11	560	613	2040	1	20	0
81	13	583	636	2320	2	20	5

APPENDIX II

Morphological data for lake trout (*Salvelinus namaycush*) from Chief Lake, June 15 - 18, 2021.

Species Code	Fish #	Fork Length (mm)	Total Length (mm)	Weight (g)	Sex 1-Male 2-Female 9-Unknown	Maturity 10-Immature 20-Mature 99-Unknown	Clip 0-No clip 1-R pectoral 2-L pectoral 3-R ventral 4-L ventral 5-Adipose
81	11	575	620	2500	1	20	0
81	12	750	769	6100	2	20	5
81	15	812	857	6900	1	20	5
81	16	895	920	.	.	.	5
81	17	785	820	.	.	.	5