SARA GROUP

Sudbury Area Risk Assessment
Volume II

Appendix G:

Metal Levels In Fish Tissues From Sudbury Lakes

EXECUTIVE SUMMARY

A Human Health Risk Assessment (HHRA) is currently being undertaken in the Greater Sudbury area as part of the Sudbury Soils Study. The Chemicals of Concern (COC) for the Sudbury Soil Study are arsenic, cobalt, copper, lead, nickel and selenium. One potential exposure route for humans for these COC is via fish caught in the area, which needs to be considered in the HHRA. The Fish Tissue Survey was intended to obtain site-specific data on the range of metal concentrations found in the tissue of fish caught in the Greater Sudbury area. These fish are caught and consumed within the local area, possibly comprising a portion of the dietary intake of the residents of the Greater Sudbury area. The results of the survey are intended to provide data specific to the Sudbury community to be used as part of the exposure assessment component of the HHRA. As a result, tissue samples were collected in a manner consistent with how they are normally collected by residents consuming this dietary source, and then analyzed for metal content.

Fish collection was undertaken between July 2 and October 30, 2003 by members of the Freshwater Co-op Unit of Laurentian University under contract from the Sudbury Soils Study. A total of eight local lakes were sampled: Ashigami, Crooked, Long, Massey, McFarlane, Ramsey, Vermillion and Whitson. Fish tissues were then analyzed for a suite of 20 parameters, including the COC for the Sudbury Soils Study.

The data provided in this report are intended to be specific to the Sudbury community and will be used as part of the exposure assessment component of the on-going HHRA for the area. Data collected in the course of this study will also be used in the exposure assessment component of the on-going ecological risk assessment (ERA) for the Sudbury Soils Study, as fish represent an important part of the local ecosystem.

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SUDBURY AREA RISK ASSESSMENT
FISH TISSUE SURVEY

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(CD 2)

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G-1.0 INTRODUCTION

A general introduction to the Sudbury Soils Study and the Human Health Risk and Ecological Risk Assessments is provided in Section G1.1 below. The specific objectives for this study are outlined in Section G1.2.

G-1.1 Background

Sudbury, Ontario is the home of two of the world's largest smelting complexes owned by Vale Inco and Xstrata Nickel. Nickel and copper have been mined in this area for more than a century. In 2001, the Ontario Ministry of the Environment (MOE) released a report that identified concentrations of nickel, cobalt, copper and arsenic in the area had exceeded the generic MOE soil quality guidelines. Under Ontario legislation, this triggers the need for more detailed study. Therefore, the MOE made two recommendations:

- That a more detailed soil study be undertaken to fill data gaps; and
- That a human health and ecological risk assessment be undertaken.

Both Vale Inco and Xstrata Nickel voluntarily accepted the recommendations and began working together to establish what is commonly referred to as "The Sudbury Soils Study". The mining companies partnered with four other major stakeholders in Sudbury to oversee this rigorous study. The community partners are Vale Inco, Xstrata Nickel, the MOE, the Sudbury and District Health Unit, the City of Greater Sudbury and Health Canada First Nations and Inuit Health Branch. These partners formed a Technical Committee to oversee the study. A Public Advisory Committee was also established to help address questions and concerns about the potential impact of elevated metal levels on the local environment and human health. As people who live and work in Sudbury, the members of this partnership share these questions and concerns.

The Sudbury Soils Study includes both an Ecological Risk Assessment (ERA) as well as a Human Health Risk Assessment (HHRA). The ERA will evaluate the possible risk and adverse effects from airborne particulate emissions resulting from smelting operations on the plants, animals and their habitats in the Sudbury area. The HHRA will evaluate the potential risks to the health of individuals within the study area from exposures to metals in environmental media such as air, soil, biota, food and drinking water.

Metal mining and smelting activities in the Sudbury area have resulted in widespread acidification of lakes as well as metal deposition to surface waters (Dixit *et al.*,1995). One example of biological impact to the lakes was the loss of sport fish species, such as lake trout (*Salvelinus namaycush*), brook trout

(*S.fontinalis*), walleye (*Stizostedion vitreum*) and smallmouth bass (*Micropterus dolomieui*) (Beamish and Harvey, 1972). Both mining companies have made technological improvements to their operations, which have dramatically reduced the sulphur and metal content of stack emissions (Pearson *et al.*, 1999). There are clear indications that the recent period of declining smelter emissions has resulted in both biological and chemical improvements in local lakes (Keller *et al.*, 1992; Keller *et al.*, 2004). Improved water quality has allowed successful restocking of extirpated fish populations in several Sudbury lakes. With the re-introduction of the fish populations comes renewed recreational activity by local residents, including an increase in the amount sport fishing and sport fish consumed by the local population.

The primary Chemicals of Concern (COC) for the Sudbury ERA and HHRA are nickel, copper, cobalt, arsenic, lead and selenium. Cadmium was subsequently added as a COC for the purpose of the ERA, but not the HHRA. This is discussed in Volume I of the report for the Sudbury Soils Study. Cadmium results for fish tissue are provided in this report, as they are utilized in the ERA (Volume III).

The element mercury was also measured in this fish study since methylmercury is known to occur in fish in northern Ontario, and the MOE provides fish consumption guidelines based on mercury levels in fish. Since fish eliminate mercury at a very slow rate, concentrations of this substance gradually accumulate and the potential for transfer in the food chain is important (MOE, 2001).

According to the 2001 *Guide to Eating Ontario Sport Fish* published by the MOE, metals such as lead, nickel, copper, arsenic, and selenium are found in fish tissue but not at levels that would suggest a need for consumption restrictions. Mercury is the only metal that has a consumption restriction guideline (0.45 mg/kg) in fish tissue. Mercury in fish was analyzed as a courtesy to the residents of Sudbury who may be consuming local fish and for scientific interest. However, mercury is not an element considered in the Sudbury Soils Study and the results are provided for information only.

This study was integrated with other programs on local Sudbury lakes being undertaken by the Cooperative Freshwater Ecology Unit at Laurentian University. In addition, as part of the Sudbury Soils Study, a creel survey of angler catch (species, numbers, *etc.*) was performed in the winter of 2003 on four of the study lakes. The results of the creel survey are reported separately (Morgan, 2004).

G-1.2 Objective of the Collection

There were two primary objectives for conducting this study:

- To measure metal concentrations in the edible portion of fish tissue being consumed by local anglers. This information will be used in the HHRA exposure pathway analysis.

- To provide metal concentrations in forage fish and predatory fish species for modeling metal uptake in the ERA exposure pathway analysis.

This document represents a data report prepared for the Sudbury Soils Study. The information in this report will be used within the context of other study components; therefore, there is intentionally little or no interpretation of the data contained in this report.

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G-2.0 METHODOLOGY

G-2.1 Study Sites

Site Selection

Fish for tissue analysis were collected from lakes in the Sudbury area by the Freshwater Co-op Unit of Laurentian University under contract from the Sudbury Soils Study.

A total of eight lakes were sampled: Ashigami, Crooked, Long, Massey, McFarlane, Ramsey, Vermillion and Whitson. These specific lakes were chosen based upon proximity to the smelters, urban populations and the predator-prey assemblages; four lakes with walleye and yellow perch (*Perca flavescens*) (Ashigami, Massey, Ramsey, Whitson) and four lakes with walleye, yellow perch and lake herring (*Coregonus artedii*) (Crooked, Long, McFarlane, Vermillion). All of the eight lakes are known to have a moderate amount of recreational fishing activity. The fish from these lakes generate important information for the HHRA because they are in close proximity to the smelters, likely represent lakes with the highest metal concentrations and local Sudbury residents fish and consume the fish from these lakes.

Site Locations

The location of the eight lakes is shown in Figure G-2-1. All of the lakes surveyed are within the District of the City of Greater Sudbury. There are no sampling sites delineated within a lake since the intent is to get a whole lake estimate; therefore, the entire lake is the primary sampling unit.

Site Description

A summary of descriptive information for the eight sample lakes, including lake names, surface area (ha) and perimeter (km), GPS coordinates and the lake's watershed is provided in Table G2.1.

Table G2.1 Descriptive information for the 8 sample lakes

Lake Name	Area (ha)	Perimeter (km)	UTM		Watershed
			Easting	Northing	
Ashigami	434.7	39.8	532121	5166616	Sturgeon River
Crooked	26.3	3.9	497250	5140885	Upper Junction Creek
Long	861.3	52.9	492911	5134619	Panache
Massey (Lac St.Jean)	78.5	5.4	511199	5168745	Wanapitei
McFarlane	166.1	9.6	502959	5140549	Panache
Ramsey	792.2	34	503620	5146649	Ramsey
Vermillion	1126	32.4	467532	5151144	Mid Vermillion
Whitson	473.4	45.9	501549	5158782	Whitson River

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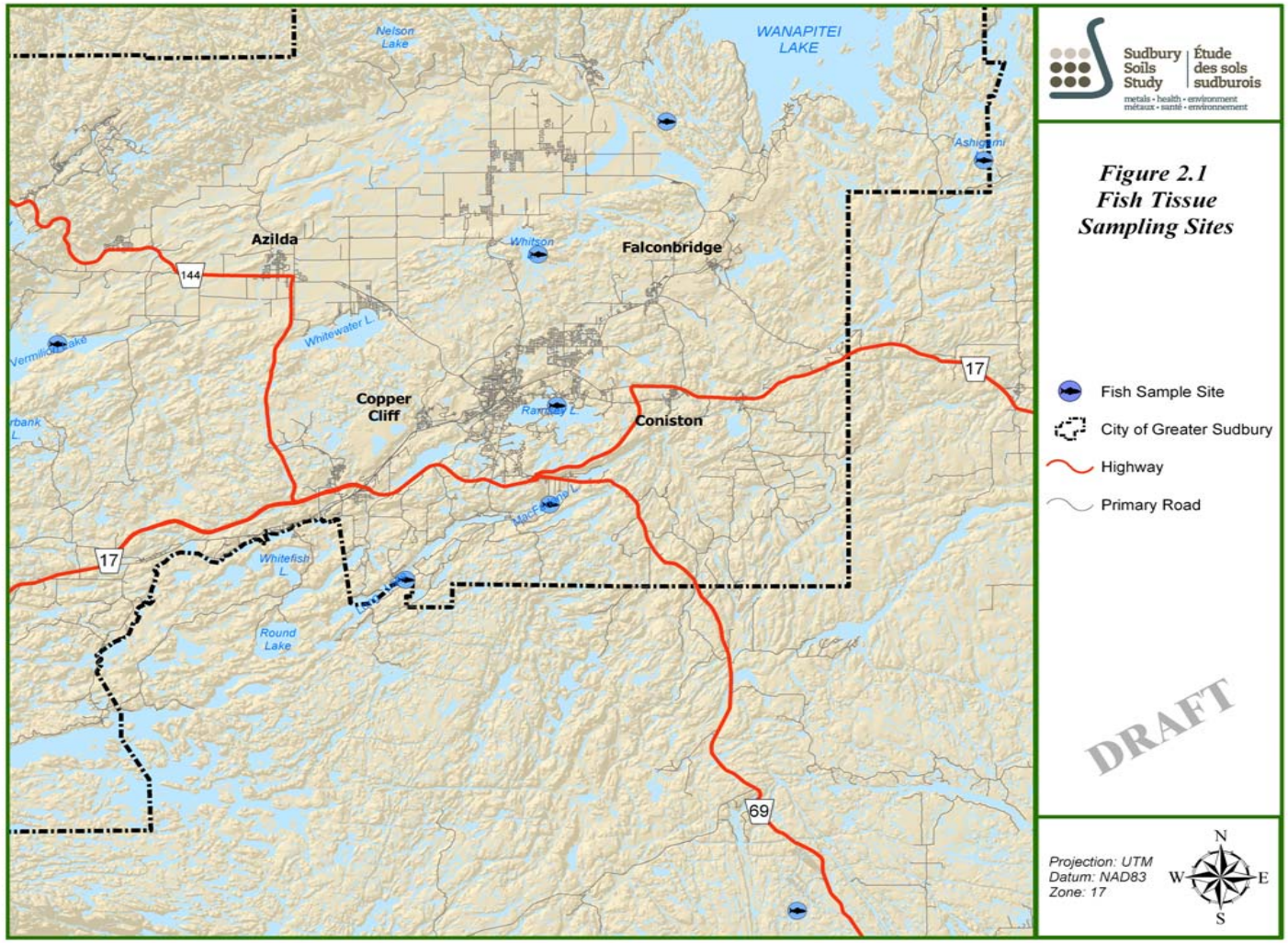

Figure G-2-1 Fish Tissue Sampling Sites

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G-2.2 Sample Collection

G-2.2.1 Netting Methods

Both Nordic and FWIN (Fall Walleye Index Netting) netting methods were used. These are standard Ontario Ministry of Natural Resources (MNR) methods for the collection of biological information to support management of a percid fishery dominated by walleye (Morgan, 2002). Sampling was done between July 2 and October 30, 2003. These methods use overnight sets of multi-mesh gillnets. The gillnet gang is made up of 8 panels of different size mesh, ranging from 25 mm to 152 mm (FWIN method) or 5 mm to 55 mm (Nordic method). At each site, one gillnet gang is set perpendicular to shore and left to fish overnight. Samples collected by the FWIN method involved two different depths at which the nets were set (2-5 m and 5-15 m). The depth at which the nets should be set is proportional to the area of the bathymetry that falls within each depth stratum.

The selection of sampling sites within a lake is random to minimize bias in locating sites and setting the gear.

A series of biological data were recorded for each fish captured. This included mesh size that the fish was captured in (EFF), fork length in mm (FLEN), total length in mm (TLEN), round weight in g (RWT), the sexual maturity (SEX), and reproductive maturity (MAT).

G-2.2.2 Sample Preparation

Whenever possible, tissue samples were collected from ten or more specimens of each species from each lake. For fish with a total length greater than 15 cm, a 50 g sample was taken from a boneless, skinless fillet of dorsal muscle, collected from above the lateral line near the insertion of the dorsal fin. Fish with a total length less than 15 cm were frozen whole with the intention of using the entire carcass for analysis.

Walleye and yellow perch (>15 cm fork length) were collected as representative predators and fish that might be used for human consumption. Smaller yellow perch (<15 cm fork length), lake herring and minnow species were collected to represent forage fish to be considered in the ERA. Fork length was used for qualification of yellow perch size (<15cm or >15cm), as it is a better indicator of fish size compared to measurement by total length, which may be affected by the state of the tail fin. For the sake of analysis, any yellow perch with a fork length equal to 15 cm were grouped with yellow perch having a greater than 15 cm fork length.

G-2.3 Sample Analysis

G-2.3.1 Tissue Preparation

Fish tissues were submitted to Testmark Laboratories in Sudbury for analysis of total metal levels. Entire fishes and/or fish tissues were chopped and homogenized. A subsample of tissue (1.0-1.7 g wet weight) was then digested and analyzed. Certified reference material (CRM) of dogfish muscle or liver were used during digestion and tested in every batch of fish samples.

Microwave Digestion Method

The tissue sample is mixed with 5 mL of HNO_3 (Concentrated trace metal grade, Fisher Scientific) in a lined digestion vessel (CEM Corporation). Sample digestion (including blank) is performed in a microwave oven (MDS-200 system, CEM Corporation) with pressure control. The digestion program is outlined in Table G2.2.

Table G2.2 Digestion program for fish tissue

Stage	1	2	3	4	5
*Power	90	90	90	90	90
PSI	20	40	85	120	150
Time	5	10	10	10	10
Tap	5	5	5	5	5
Fan speed	100	100	100	100	100

*Power varies according to the number of samples.

A replicate sample was digested for every 12 fish tissue samples. After digestion, the sample was transferred to a volumetric flask and the vessel is washed three times with 2% HNO_3. The sample and washes are combined and diluted to 50.0 mL.

G-2.3.2 Analysis

The diluted sample was tested directly by ELAN 5000 Inductively Couple Plasma - Mass Spectrometer ICPMS (Perkin Elmer Corporation). Every 10 samples or less had a blank and a control standard to verify the calibration standard. Every 20 samples or less had a replicated sample to verify the precision of the measurements. The data were collected by computer and then calculated using the ICPMS program.

The ranges of minimum detection limits for the fish tissue survey provided by Testmark Laboratories are shown in Table 2.3. The instrument detection limit (IDL) is determined experimentally based on the method validation data. The minimum detection limit (MDL) for water is the same as the IDL for

undiluted samples. Results for water samples run on the ICP/MS are normally reported in µg/L or parts per billion (ppb). The IDL is used to calculate the real MDL for soil, biota and tissue samples. Therefore, the MDLs are based on the actual mass of sample digested and the final volume. The calculation is as follows:

$$MDL = \frac{IDL \times Vol(digest)}{mass(sample)}$$

Normally, a 1:10 dilution on the final volumes is carried out before running on the ICP/MS. This is to cut down on the amount of acid run through the mass spectrum detector. The ICP/MS can be run at higher acid concentrations but accuracy is sacrificed on the lower molecular weight analytes (Li, B, Be, P, *etc.*), but there is little problem with the metals with higher molecular weights. The biota results are reported in mg/kg or parts per million (mg/kg). For tissue samples, about 1 g of sample is digested in the microwave digestion vessel and diluted up to 50 mL.

In practice, every sample digested will have different weights. Therefore, MDLs reported will differ slightly between samples. Furthermore, dilutions resulting from high concentrations of metals or matrix effects may produce MDLs that differ by 1 or 2 orders of magnitude. It is appropriate when presenting large data sets to report the range of MDLs for the samples in the data set (Table G2.3).

Table G2.3 Detection limits for elements (mg/kg)

Element	MDL range	Element	MDL range	Element	MDL range
Al	0.020	Cu	0.020	Pb	0.006
As	0.002	Fe	0.100	Sb	0.001
B	0.040	Hg	0.003	Se	0.020
Ba	0.003	Mg	1.000	Sr	0.006
Cd	0.002	Mn	0.002	Ti	0.010
Co	0.001	Mo	0.001	V	0.001
Cr	0.010	Ni	0.006	Zn	0.020 (0.2)*

*Zn levels were higher by factor of 10 in some samples, in which case a suitable detection limit was used by lab.

G-2.3.3 QA/QC

Laboratory

Testmark Laboratories, Sudbury, have their own QA/QC procedures. Testmark Laboratories is accredited by the Canadian Association of Environmental Analytical Laboratories (CAEAL) and by the Standards Council of Canada (SCC). The methodology used by the laboratory for the cleaning, preparation and analysis of the sample was established prior to sample delivery.

Reference Material

Samples of certified reference material were submitted along with fish tissues as an additional quality control measure. Seventeen samples of dogfish muscle DORM-2 and eighteen samples of DOLT-2 (National Research Council of Canada) were submitted for analysis as part of this fish study.

G-2.3.4 Statistical analysis

Tissue metal results are summarized (mean, range, standard deviation) for each species by lake. The mean concentration of each COC in a species was compared between lakes by Analysis of Variance (ANOVA) to determine if there were between-lake differences. If ANOVA indicated a significant difference among lakes then a Tukey analysis was performed to determine which lakes contained fish, which were significantly different from each other. The statistical software SPSS v.11 was used for the analyses. A difference in mean metal level between lakes was considered significantly different when $p<0.05$.

G-3.0 RESULTS

G-3.1 Fish Samples

A total of 211 fish tissue samples were submitted for metal analysis. Some samples submitted for metal analysis were a composite of fish (5 or more) making the total number of fish used for sampling 424.

A summary of the numbers and species of fish caught from each lake, along with sampling dates, is provided in Table G3.1. Walleye, yellow perch and lake herring made up the majority of the samples submitted for metal analysis. There were five samples (composite) which included spottail shiner, golden shiner and trout perch.

Table G3.1 Fish samples caught and sampling dates for 8 lakes in the Sudbury Region

Lake	Fish Species and Number Caught*							Sampling Dates
	Walleye	Yellow Perch		Lake Herring	Spottail Shiner	Trout Perch	Golden Shiner	
		<15cm	>15cm					
Ashigami	10	11	9	-	-	-	-	Jul 2/03-Jul 5/03 Oct 5/03-Oct 7/03
Crooked	10	12 (9)	1	5	-	-	11 (1)	Jul 28/03-Jul 31/03 Sep 28/03-Sep 30/03
Long	10	10	-	10	-	-	-	Aug 17/03-Aug 29/03 Oct 27/03-Oct 30/03
Massey	10	22 (13)	7	-	-	-	-	Jul 2/03-Jul 4/03 Sep 26/03-Sep 28/03
McFarlane	10	13 (10)	5	-	-	-	-	Jul 20/03-Jul 24/03 Oct 08/03-Oct 10/03
Ramsey	10	21 (4)	9	-	-	-	-	Jul 7/03-Jul 15/03 Oct 19/03-Oct 22/03
Vermillion	10	27 (4)	9	5 (1)	41 (2)	28 (2)	-	Jul 20/03-Jul 24/03 Sep 29/03-Oct 1/03
Whitson	10	85 (6)	3	-	-	-	-	Aug 5/03-Aug 14/03 Oct 5/03-Oct 7/03

*Number in parenthesis represents number of samples submitted for analysis (represents composite sample of fish caught)

The mean fork length and weight of walleye and yellow perch (>15 cm) for each lake are summarized in Table G3.2. Complete biological data for each specimen is provided in Sub-Appendix A of Appendix G (this report). It is apparent that mean size of walleye differed significantly between the sample lakes. No attempt was made to age the fish or determine growth rates as part of this study.

Table G3.2 Summary of length (mm) and weight (g) of walleye and yellow perch (>15 cm fork length)

Species	Lake	Fork Length (mm)		Weight (g)	
		Mean	Range	Mean	Range
Walleye	Ashigami	297	216-477	324	103-1141
	Crooked	3522	91-619	850	7-2880
	Long	219	94-729	555	8-4700
	Massey	389	275-618	1031	211-3350
	Ramsey	239	179-301	118	42-230
	Vermillion	268	183-498	260	64-1221
	Whitson	175	78-390	128	4-584
Yellow Perch	Ashigami	188	152-210	83	40-119
	Crooked	222	222	154	154
	Long	-	-	-	-
	Massey	194	157-218	90	48-126
	Ramsey	188	158.215	89	49-132
	Vermillion	183	156-221	90	48-167
	Whitson	159	153-167	43	38-47

G-3.2 Tissue Metal Concentrations

Results of the tissue analysis are summarized in the following section. Results for each individual fish are provided in Appendix B of this report. If lab replicates existed, the average of the original and replicate sample were reported in Appendix B and used in any analysis performed. All values, originals and lab replicates can be found in the raw data (Appendix C).

G-3.2.1 QA/QC Results

Two types of certified reference material samples were analysed with each Testmark Laboratories work order, Dorm-2 and Dolt-2. Seventeen samples of Dorm-2 and 18 samples of Dolt-2 were analysed. The results are summarized below. The original results of the reference samples are located in each Testmark report in Appendix C of this report.

Certified reference samples summary (mg/kg)

The upper and lower acceptable limits for each of the COC for the Certified Reference Material (CRM) are provided in Table G3.3. Data are provided from the CRM sample.

Table G3.3 Upper and lower limits for dogfish reference samples

Sample	Limit	As	Cd	Co	Cu	Pb	Hg	Ni	Se
Dorm-2	LCL	16.50	0.03	0.15	1.80	0.05	4.30	16.00	1.20
	UCL	19.50	0.06	0.22	3.00	0.07	5.00	23.00	1.60
Dolt-2	LCL	14.00	19.30	0.18	24.00	0.19	1.60	0.16	5.00
	UCL	18.00	21.80	0.30	27.00	0.24	2.50	0.25	7.00

UCL= upper confidence limit
LCL= lower confidence limit

Results of CRM analysis in this study

The results of repeat analysis of the two types of CRM from this study are summarized in Table G3.4. In all cases the analytical results of the CRM fall within the upper and lower confidence limits for each of the COC and mercury. Therefore, the analytical results are considered accurate.

Table G3.4 Summary of dogfish tissue reference samples

Sample	Stat	As	Cd	Co	Cu	Pb	Hg	Ni	Se
Dorm-2	Range	17.00-19.20	0.034-0.057	0.15-0.17	1.90-2.50	0.053-0.070	4.30-4.90	16.50-19.00	1.40-1.50
	Mean	18.11	0.05	0.16	2.08	0.07	4.62	17.17	1.47
	Sample size	17	17	17	17	14	17	17	17
Dolt-2	Range	16.20-17.40	19.50-21.70	0.18-0.21	24.00-27.00	0.20-0.24	1.80-2.50	0.16-0.25	5.60-7.00
	Mean	16.83	20.31	0.19	25.44	0.21	2.19	0.20	6.40
	Sample size	18	18	18	18	15	18	15	18

G-3.2.2 Sudbury fish tissue metal levels

Metal concentrations (mg/kg wet weight tissue) for each COC and mercury in fish tissue, are summarized by lake in the following section. Complete results for all metal analysis are provided in Appendix B of this report. Where sample concentration was below the detectable limit the value was replaced with half of the minimum detection limit value. Copies of the original laboratory reports and sample chain of custody forms are provided in Appendices C and D, respectively.

The significant differences among lakes are indicated by the letters above each bar in the graphs that follow; using ANOVA (SPSS 11.0). Those lakes that contain the same letter are not significantly different. Statistical analyses are summarized in Appendix E and F, where 43 outliers were removed from the statistical analysis (out of a total of 1477 values (2.9%)). The determination of the outliers was based upon a combination of visual inspection of the data and statistical analysis with SPSS v.11. SPSS picks out the top 10 values most probable to be outliers. The potential outliers were then compared to the rest of the data set and those appearing to emanate from a different model were labelled as outliers and thus not used in the statistical analysis. This method was mentioned in Chambers, Cleveland, Kleiner, and Tukey (1983), *Graphical Methods for Data Analysis.*

In addition to this, as a measure of confirmation, most of the chosen outliers differed by a factor of ten relative to the other concentrations of the same metal, relative to the species of fish sampled and lake. The one exception to this was one sample (LON 331-01), which was quite higher than the other samples for Ni, but not by a factor of ten. It was ruled as an outlier as it was part of 5 out of 7 COC + mercury concentrations that were abnormally high relative to the other fish (yellow perch < 15cm) analysed.

Walleye

The concentrations of COC in walleye are summarized in Table 3.5. The results for each COC are illustrated in Figures G-3-1 to G-3-7 and discussed in the following text.

Table G3.5 Total metal concentrations (mg/kg wet weight) in walleye (*Stizostedion vitreum*) muscle from 8 Sudbury area lakes

Lake		Ni	Cu	Co	As	Pb	Se	Hg	Cd
Ashigami n=10	*Min*	0.014	0.096	0.003	0.030	0.0035	1.500	0.023	0.001
	Max	0.110	0.340	0.0075	0.065	0.039	2.200	0.084	0.015
	Mean	0.058	0.183	0.0047	0.045	0.025	1.930	0.055	0.005
	Std. dev.	0.026	0.065	0.0013	0.011	0.012	0.235	0.019	0.004
Crooked n=10	*Min*	0.014	0.083	0.001	0.025	0.003	0.295	0.025	0.001
	Max	0.074	0.460	0.026	0.068	0.044	0.740	1.050	0.012
	Mean	0.043	0.184	0.009	0.040	0.011	0.448	0.395	0.003
	Std. dev.	0.018	0.128	0.011	0.013	0.016	0.121	0.372	0.004
Long n=10	*Min*	0.140	0.200	0.005	0.029	0.018	1.200	0.012	0.001
	Max	0.680	0.900	0.043	0.150	0.055	1.900	0.063	0.050
	Mean	0.465	0.490	0.021	0.085	0.034	1.560	0.030	0.017
	Std. dev.	0.234	0.2200	0.012	0.036	0.011	0.259	0.017	0.016
Massey n=10	*Min*	0.0035	0.110	0.002	0.004	0.0033	1.300	0.032	0.001
	Max	0.076	0.530	0.026	0.061	0.020	2.200	0.270	0.003
	Mean	0.028	0.185	0.006	0.025	0.011	1.68	0.085	0.0012
	Std. dev.	0.027	0.125	0.007	0.020	0.007	0.257	0.088	0.001
McFarlane n=10	*Min*	0.0035	0.140	0.001	0.029	0.0035	0.610	0.016	0.001
	Max	0.062	0.230	0.005	0.087	0.052	0.850	0.067	0.002
	Mean	0.036	0.186	0.003	0.053	0.015	0.749	0.045	0.001
	Std. dev.	0.021	0.030	0.001	0.020	0.015	0.077	0.017	0.0003
Ramsey n=10	*Min*	0.033	0.185	0.004	0.044	0.0035	1.300	0.003	0.001
	Max	0.170	0.730	0.013	0.100	0.020	2.680	0.029	0.005
	Mean	0.097	0.363	0.006	0.069	0.011	1.850	0.013	0.002
	Std. dev.	0.045	0.179	0.003	0.017	0.006	0.383	0.010	0.001
Vermillion n=10	*Min*	0.140	0.240	0.003	0.047	0.015	0.540	0.250	0.001
	Max	0.430	0.650	0.010	0.086	0.037	0.92	0.966	0.001
	Mean	0.224	0.389	0.006	0.062	0.027	0.758	0.467	0.001
	Std. dev.	0.092	0.134	0.002	0.015	0.007	0.123	0.199	0.000
Whitson n=10	*Min*	0.053	0.097	0.005	0.019	0.003	1.600	0.0015	0.002
	Max	1.010	1.000	0.073	0.095	0.070	3.020	0.067	0.048
	Mean	0.470	0.506	0.035	0.054	0.027	2.250	0.016	0.028
	Std. dev.	0.326	0.299	0.026	0.028	0.023	0.474	0.020	0.017

Nickel

The mean concentration of nickel in walleye was generally below 0.23 mg/kg with the exception of walleye caught from Whitson Lake (0.47 mg/kg) and Long Lake (0.47 mg/kg) (Figure G-3-1). Nickel levels in walleye from Whitson Lake and Long Lake were significantly greater ($p<0.05$) than in the other lakes.

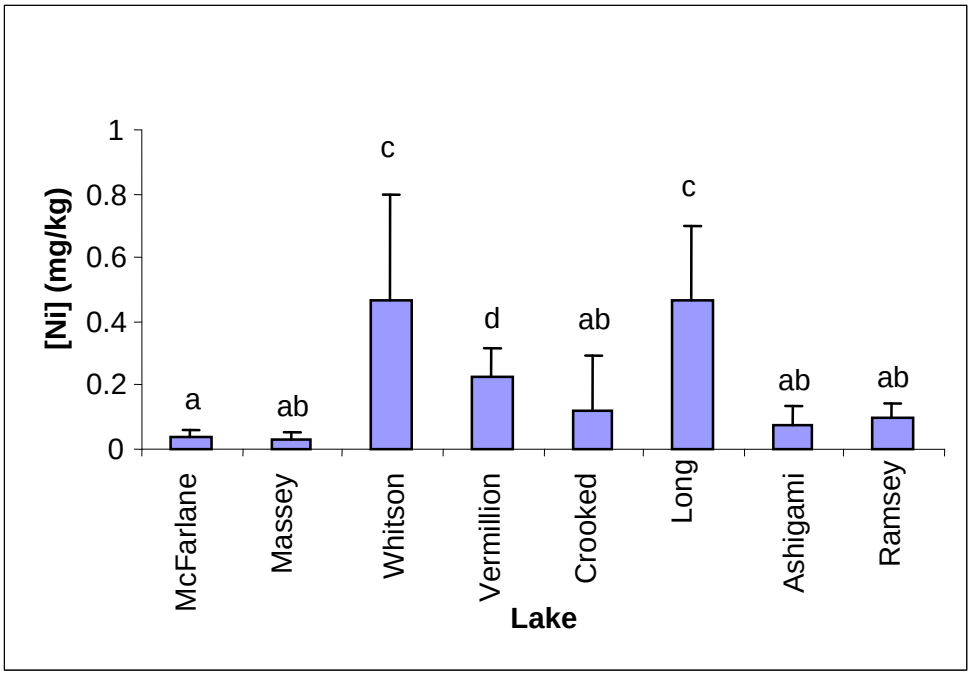

Figure G-3-1 Mean Nickel Concentration in Walleye for 8 Sudbury Area Lakes

Copper

The mean copper concentrations in walleye were generally below 0.40 mg/kg with the exception of Whitson Lake (0.51 mg/kg) and Long Lake (0.49 mg/kg).

Figure G-3-2 indicates that walleye copper concentrations from Whitson Lake and Long Lake were significantly greater ($p < 0.05$) than in five other lakes, but not significantly different from Vermillion Lake.

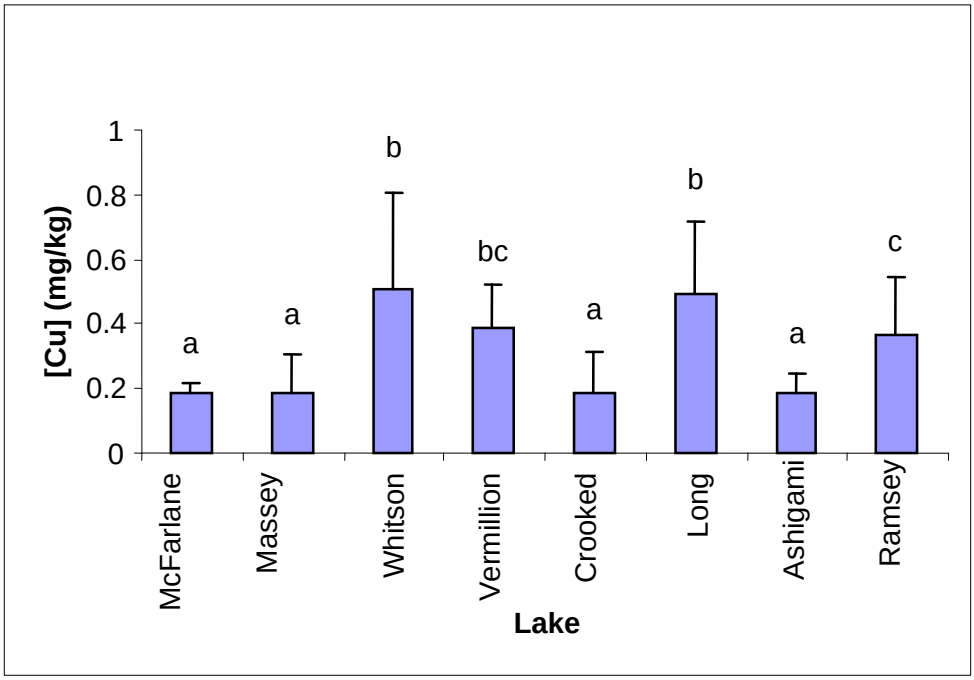

Figure G-3-2 Mean Copper Concentration in Walleye for 8 Sudbury Area Lakes

Cobalt

The mean cobalt concentrations in walleye were generally below 0.01 mg/kg with the exception of Whitson Lake (0.035 mg/kg) and Long Lake (0.021 mg/kg) (Figure G-3-3). Cobalt levels in walleye from Whitson Lake were significantly higher ($p < 0.05$) than the other seven lakes.

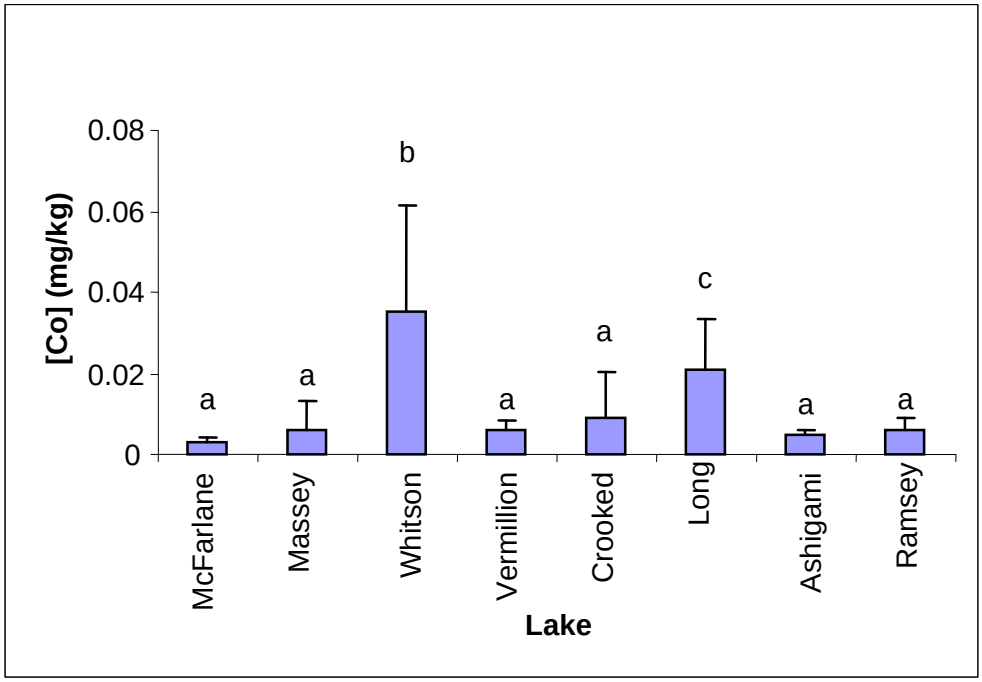

Figure G-3-3 Mean Cobalt Concentration in Walleye for 8 Sudbury Area Lakes

Arsenic

The highest mean arsenic levels were measured in walleye from Long Lake (0.085 mg/kg) that were significantly higher ($p < 0.05$) than in six other lakes (Figure G-3-4). The mean arsenic concentration in walleye for the other seven lakes was less than 0.070 mg/kg.

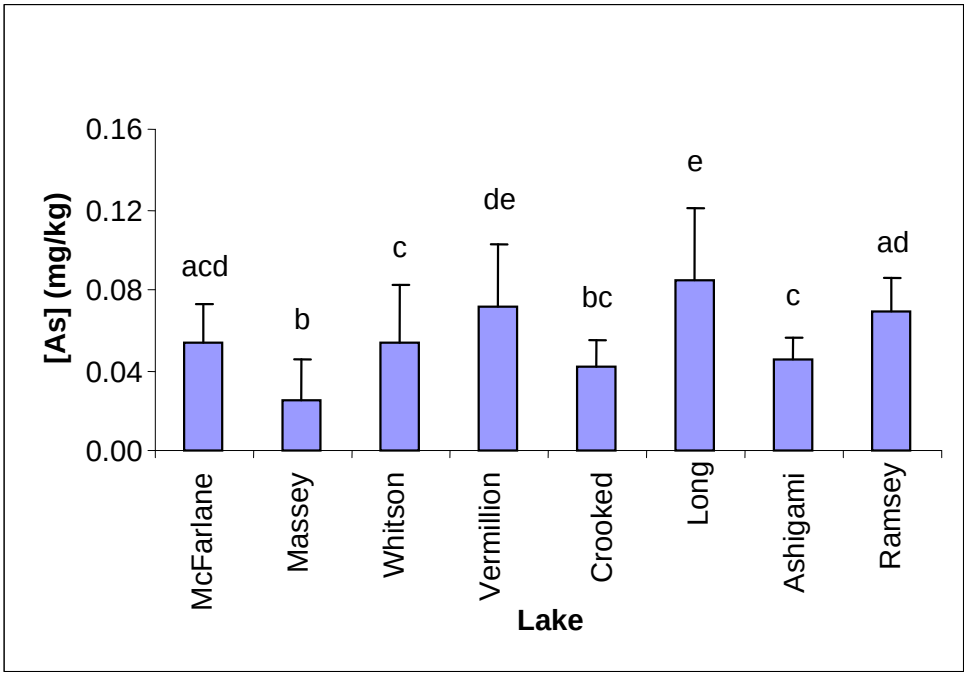

Figure G-3-4 Mean Arsenic Concentration in Walleye for 8 Sudbury Area Lakes

Lead

Walleye from Long Lake had a mean lead concentration of 0.034 mg/kg, which was similar to walleye from Whitson Lake, but was significantly greater ($p<0.05$) than walleye from McFarlane, Massey, Crooked, Ashigami and Ramsey Lakes (Figure G-3-5).

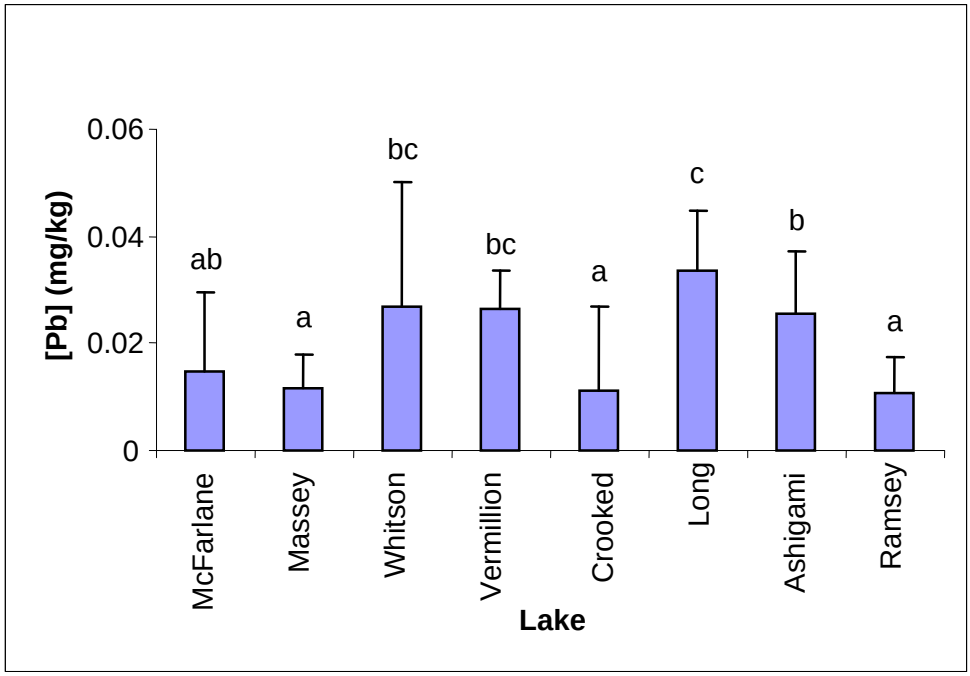

Figure G-3-5 Mean Lead Concentration in Walleye for 8 Sudbury Area Lakes

Selenium

Walleye from Whitson Lake contained significantly more selenium ($p < 0.05$) than walleye from the other seven lakes (Figure G-3-6). The mean selenium concentration in walleye from Whitson Lake was 2.25 mg/kg, while the mean selenium level in walleye from McFarlane, Vermillion, and Crooked Lakes was less than 0.80 mg/kg.

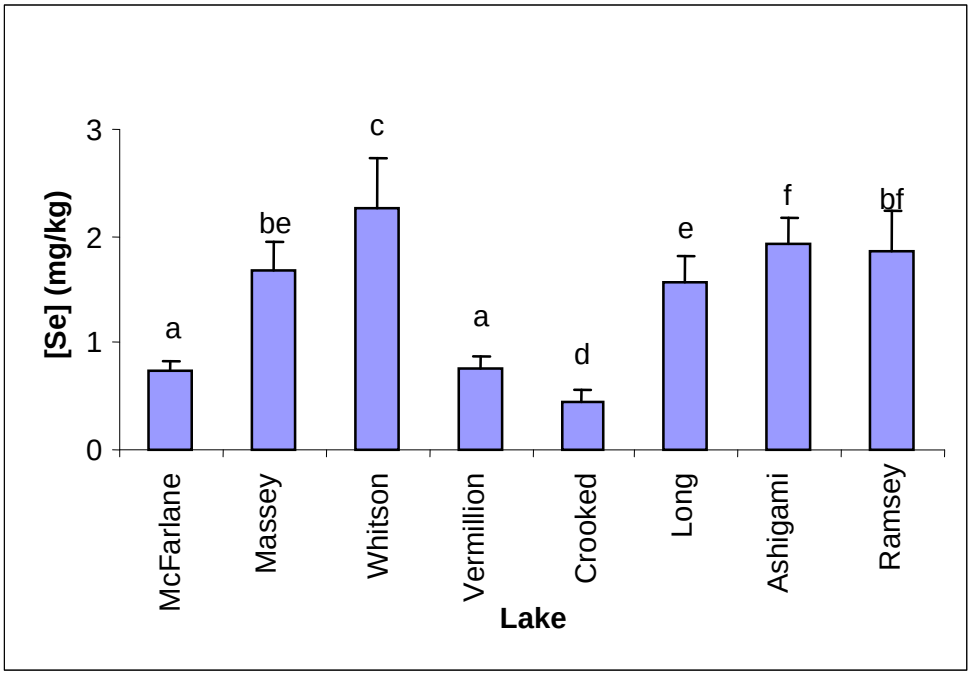

Figure G-3-6 Mean Selenium Concentration in Walleye for 8 Sudbury Area Lakes

Mercury

The mean mercury concentrations in walleye from Vermillion Lake (0.47 mg/kg) and Crooked Lake (0.40 mg/kg) were significantly greater ($p < 0.05$) than in walleye from the other six lakes. The mean mercury concentration in walleye for the other lakes was less than 0.085 mg/kg (Figure G-3-7). Walleye from Vermillion and Crooked Lakes were not larger than walleye from the other lakes (Table 3.2), so fish size should not be a factor in these higher mercury levels.

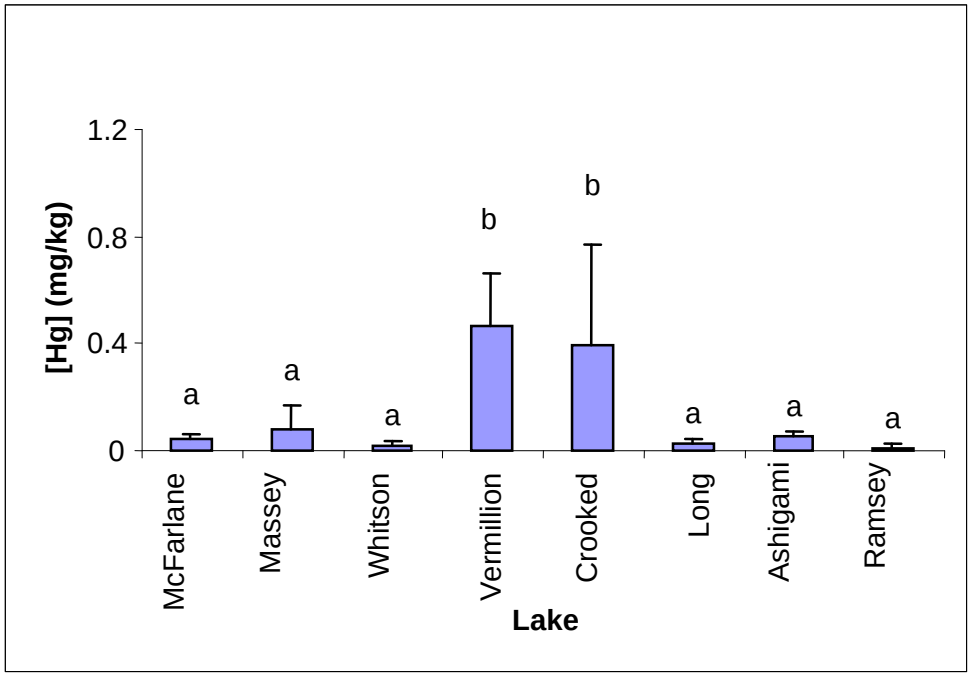

Figure G-3-7 Mean Mercury Concentration in Walleye for 8 Sudbury Area Lakes

Cadmium

The mean cadmium concentrations in walleye from Long Lake (0.017 mg/kg) and Whitson Lake (0.028 mg/kg) were significantly greater ($p < 0.05$) than in walleye from the other six lakes. The mean concentrations of cadmium from the other six lakes were less than 0.005 mg/kg (Figure G-3-8).

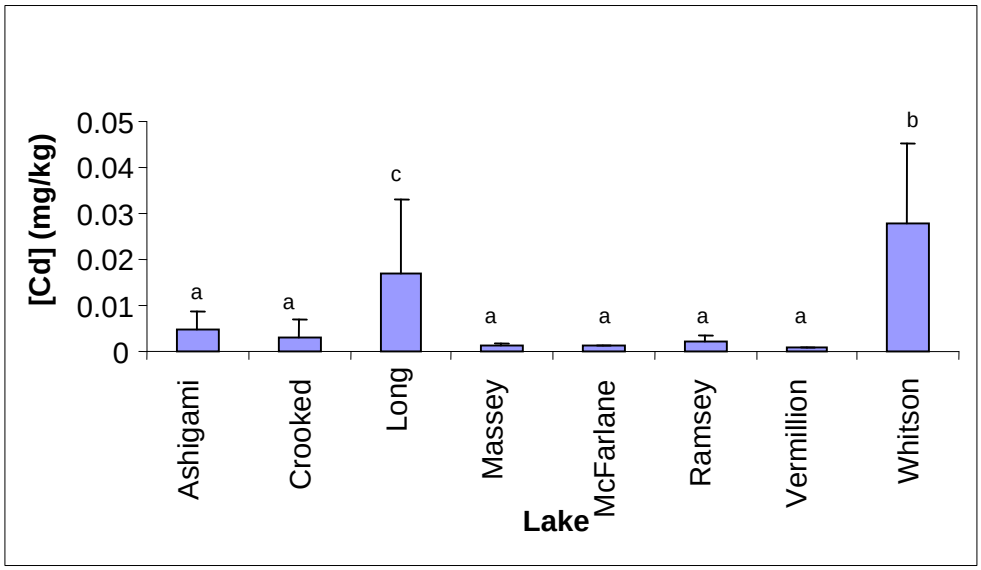

Figure G-3-8 Mean Cadmium Concentration in Walleye for 8 Sudbury Area Lakes

Figure G-3-9 provides a scatter-plot of mean mercury versus mean selenium levels in walleye for the eight Sudbury lakes. The scatter-plot suggests that walleye containing higher concentrations of mercury contained lower concentrations of selenium, and vice versa. Indeed, walleye from Vermillion and Crooked Lakes contained the highest mercury levels and lowest selenium levels.

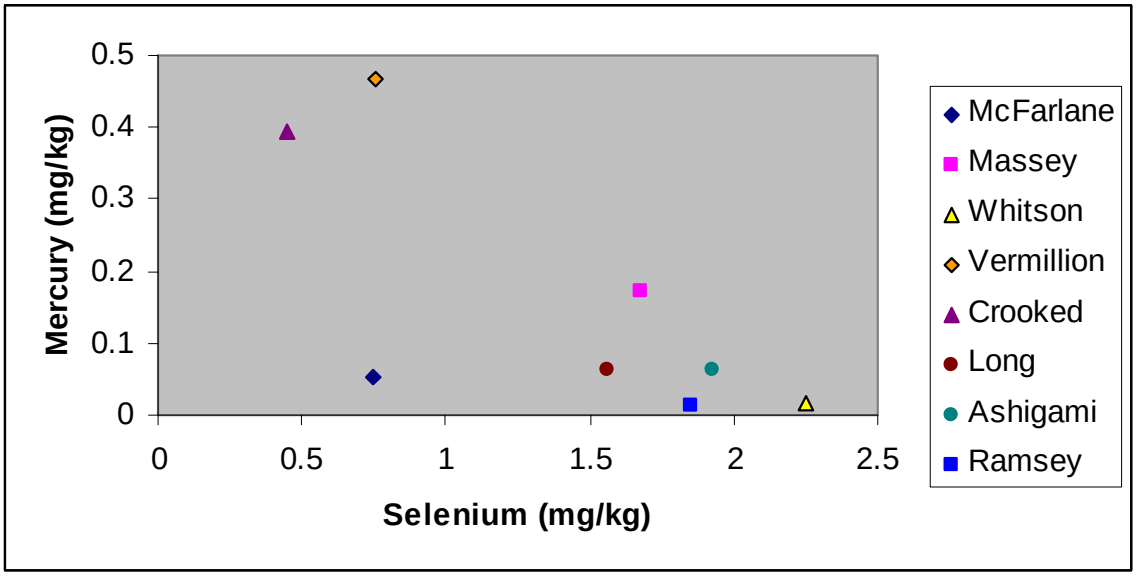

Figure G-3-9 Scatter-Plot of Mean Mercury versus Mean Selenium Concentrations for Walleye in 8 Sudbury Area Lakes

In summary, concentrations of the COC in walleye differed among the study lakes. The levels of nickel, copper, cobalt and cadmium were generally highest in Whitson and Long Lakes. The concentration of arsenic was highest in Long Lake. There is apparently an old gold mine at the end of Long Lake, which is locally thought to be leaching arsenic into the groundwater and surface waters. This may partially explain the elevated arsenic levels observed in walleye in Long Lake.

Yellow Perch (<15 cm fork length)

The concentration of each COC in yellow perch (<15cm in fork length) are summarized in Table G3.6 and discussed in the following section.

Table G3.6 Total metal concentrations (mg/kg wet weight) in yellow perch <15 cm (*Perca flavescens*) carcass from 8 Sudbury area lakes

Lake		Ni	Cu	Co	As	Pb	Se	Hg	Cd
Ashigami n=11	*Min*	0.220	0.230	0.019	0.040	0.010	2.000	0.008	0.011
	Max	0.590	0.720	0.061	0.093	0.088	2.830	0.026	0.322
	Mean	0.400	0.488	0.037	0.062	0.044	2.420	0.018	0.102
	Std. dev.	0.113	0.163	0.012	0.018	0.024	0.274	0.006	0.086
Crooked n=9	*Min*	0.170	0.170	0.018	0.012	0.004	0.330	0.028	0.006
	Max	0.778	1.000	0.070	0.077	0.170	0.685	0.110	0.090
	Mean	0.399	0.444	0.039	0.043	0.075	0.498	0.065	0.035
	Std. dev.	0.173	0.283	0.019	0.021	0.049	0.137	0.027	0.030
Long n=10	*Min*	0.610	0.430	0.023	0.081	0.035	1.500	0.014	0.059
	Max	1.970	0.930	0.081	0.160	0.160	2.780	0.031	0.317
	Mean	1.000	0.720	0.050	0.110	0.080	2.007	0.021	0.127
	Std. dev.	0.407	0.169	0.020	0.023	0.041	0.398	0.005	0.080
Massey n=13	*Min*	0.063	0.230	0.008	0.020	0.015	1.000	0.020	0.001
	Max	0.540	0.650	0.073	0.110	0.065	3.210	0.074	0.100
	Mean	0.282	0.402	0.031	0.054	0.037	1.900	0.034	0.039
	Std. dev.	0.155	0.126	0.020	0.027	0.015	0.622	0.016	0.028
McFarlane n=10	*Min*	0.310	0.260	0.013	0.037	0.012	0.640	0.002	0.015
	Max	0.840	0.760	0.049	0.445	0.063	1.000	0.012	0.120
	Mean	0.671	0.507	0.031	0.142	0.034	0.785	0.004	0.054
	Std. dev.	0.184	0.143	0.010	0.118	0.017	0.108	0.004	0.032
Ramsey n=4	*Min*	0.092	0.082	0.006	0.024	<0.007	2.000	0.002	0.001
	Max	0.650	0.780	0.048	0.120	0.130	2.700	0.021	0.085
	Mean	0.314	0.378	0.036	0.068	0.045	2.440	0.006	0.033
	Std. dev.	0.296	0.304	0.020	0.043	0.058	0.311	0.010	0.037
Vermillion n=4	*Min*	0.120	0.320	0.013	0.040	0.025	0.870	0.031	0.021
	Max	2.420	1.115	0.238	0.082	0.096	1.200	0.130	0.096
	Mean	1.040	0.645	0.106	0.059	0.051	1.020	0.073	0.062
	Std. dev.	0.976	0.394	0.097	0.018	0.032	0.136	0.045	0.038
Whitson n=6	*Min*	0.520	0.350	0.054	0.020	0.035	2.580	0.002	0.065
	Max	1.830	2.780	0.187	0.135	0.190	3.910	0.016	0.376
	Mean	1.173	1.444	0.127	0.085	0.111	3.086	0.010	0.214
	Std. dev.	0.509	0.934	0.053	0.050	0.067	0.494	0.005	0.104

Note: sample size represents samples analysed (may be a composite sample)

Nickel

The mean level of nickel in small perch from Whitson, Vermillion and Long Lake ranged from 1.00 mg/kg to 1.17 mg/kg (Figure G-3-10). Whitson Lake perch had a mean concentration of 1.17 mg/kg, which was significantly greater ($p < 0.05$) than in perch from the six other lakes. The small perch from the other lakes had mean nickel concentrations less than 0.67 mg/kg.

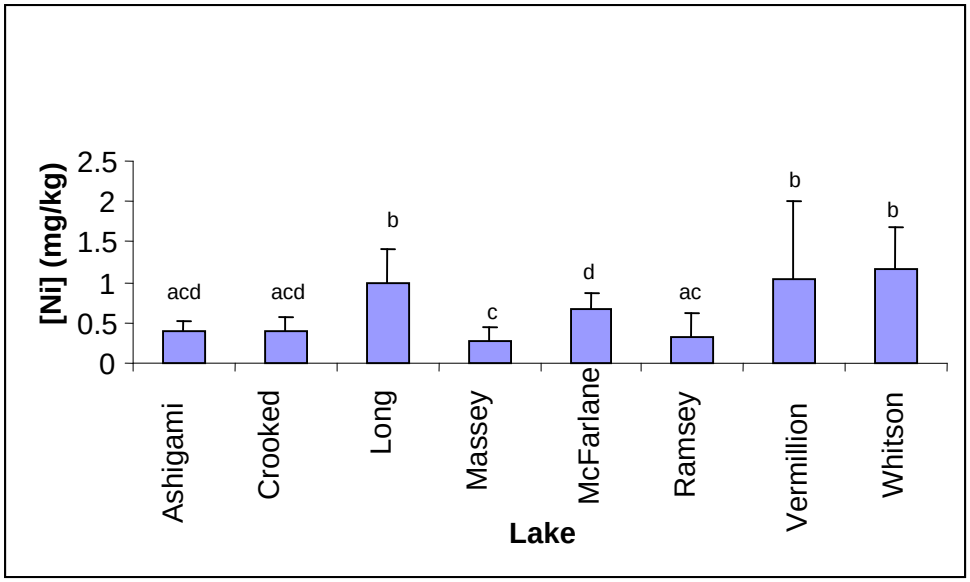

Figure G-3-10 Mean Nickel Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Copper

With the exception of Whitson Lake, the mean concentration of copper in small yellow perch was less than 0.72 mg/kg. Small yellow perch from Whitson Lake had a mean copper concentration of 1.40 mg/kg and was significantly greater ($p < 0.05$) from the other 7 lakes (Figure G-3-11).

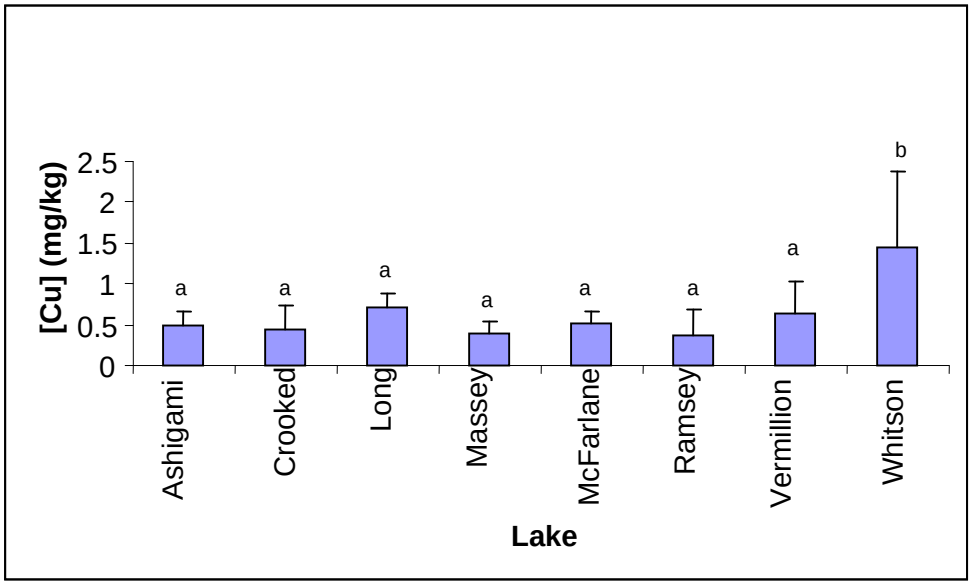

Figure G-3-11 Mean Copper Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Cobalt

With the exception of Whitson and Vermillion Lakes, the mean concentration of cobalt in small yellow perch was less than 0.05 mg/kg (Figure G-3-12). Small yellow perch from Whitson Lake had a mean cobalt concentration of 0.13 mg/kg while small yellow perch from Vermillion Lake had a mean cobalt concentration of 0.11 mg/kg, both of which were significantly greater ($p > 0.05$) than perch in the other six lakes.

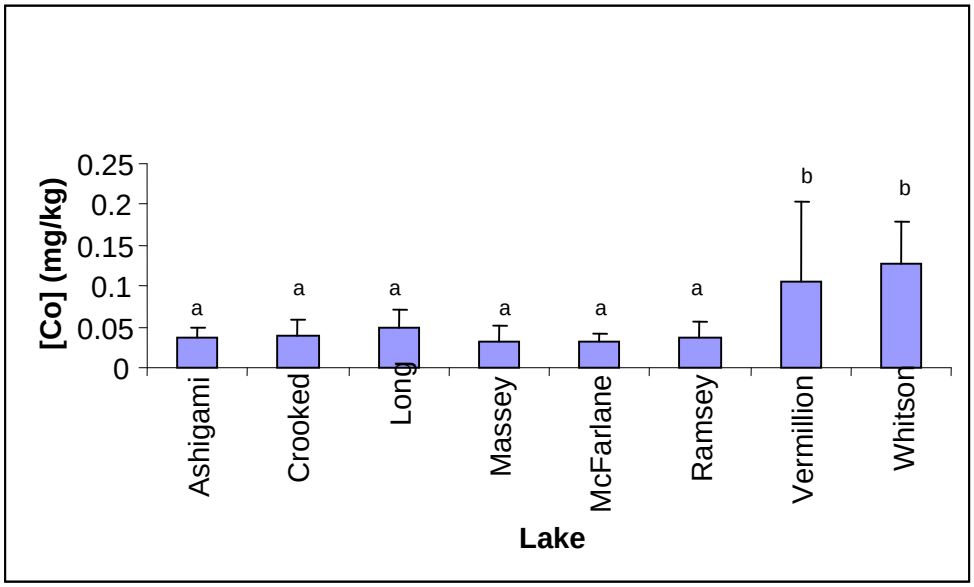

Figure G-3-12 Mean Cobalt Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Arsenic

The small yellow perch mean arsenic concentration in McFarlane Lake (0.14 mg/kg) was significantly greater ($p < 0.05$) than perch in the other lakes, with the exception of Long Lake (0.11 mg/kg). The mean arsenic concentration in small yellow perch from the other lakes was less than 0.085 mg/kg (Figure G-3-13).

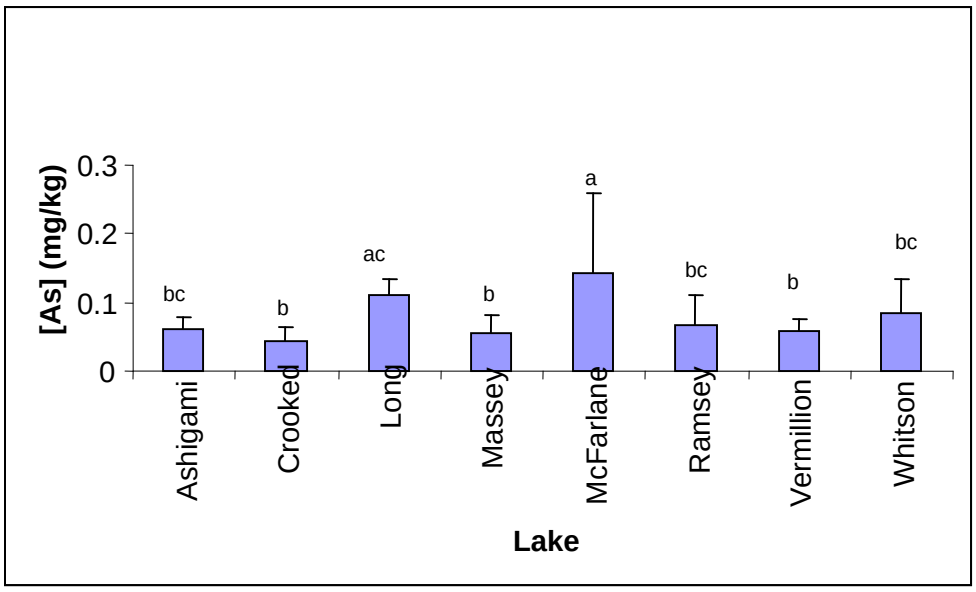

Figure G-3-13 Mean Arsenic Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Lead

The mean lead concentration in small yellow perch was generally less than 0.076 mg/kg, with the exception of Whitson Lake (0.11 mg/kg). Mean lead levels in small yellow perch from Whitson Lake were significantly greater ($p < 0.05$) than lead levels in perch from the other seven lakes (Figure G-3-14).

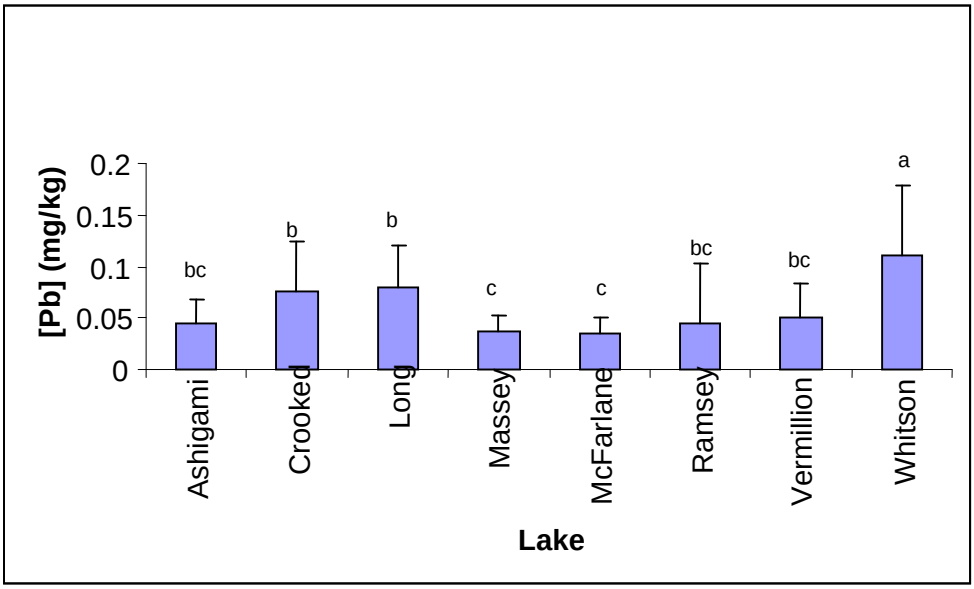

Figure G-3-14 Mean Lead Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Selenium

Small yellow perch caught from Whitson Lake had a mean selenium concentration of 3.09 m/kg, which was significantly greater ($p < 0.05$) than selenium in small yellow perch caught from the other seven lakes (Figure G-3-15).

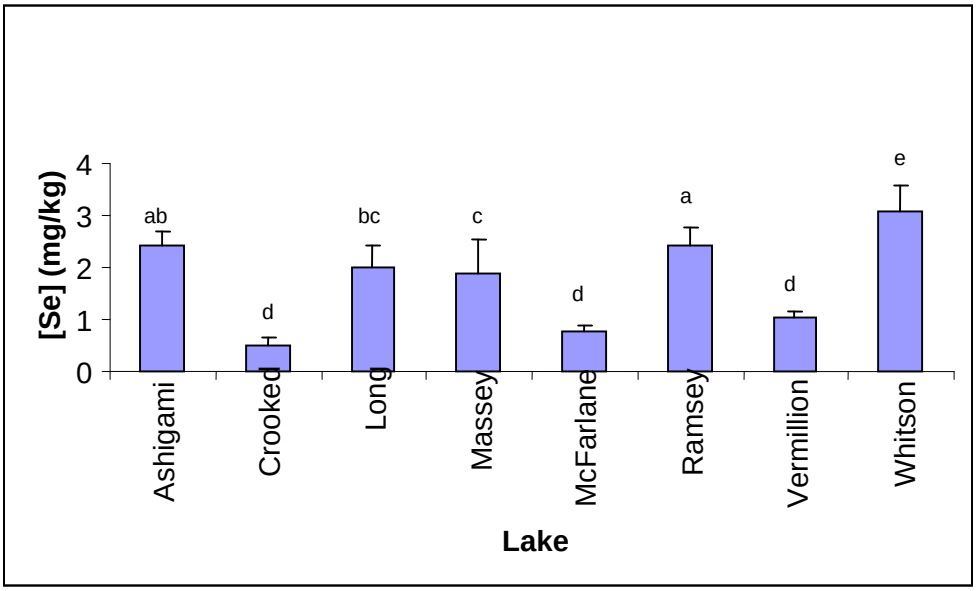

Figure G-3-15 Mean Selenium Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Mercury

Small yellow perch from Vermillion Lake and Crooked Lake had mean mercury concentrations of 0.073 mg/kg and 0.065 mg/kg, respectively. These levels were significantly greater ($p<0.05$) than mercury levels in small perch from the other six lakes. Again, selenium levels were lowest in perch tissues from these two lakes (Figure G-3-16).

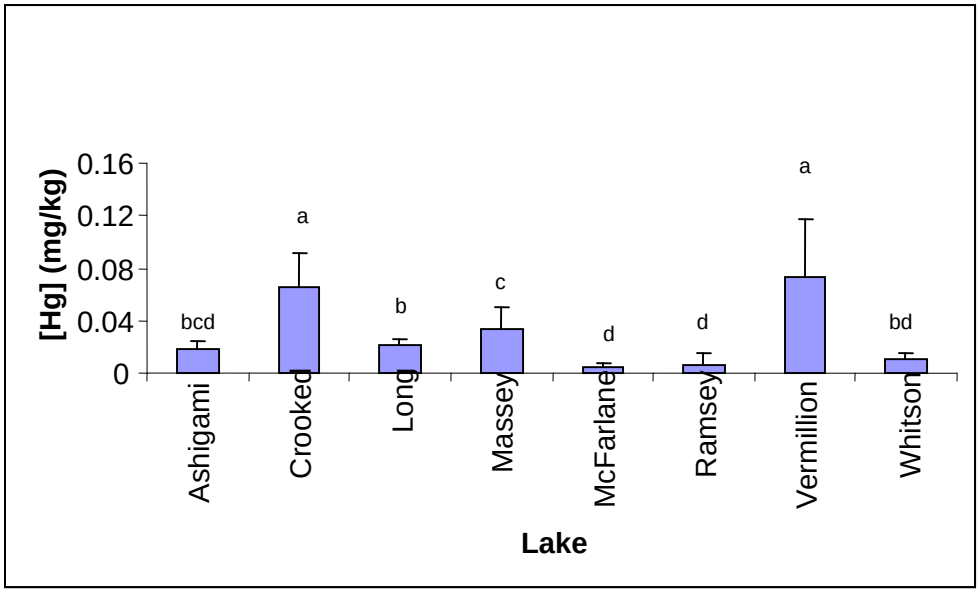

Figure G-3-16 Mean Mercury Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Cadmium

Small yellow perch from Whitson Lake contained a mean cadmium concentration of 0.21 mg/kg, which was significantly greater ($p<0.05$) than cadmium levels in small perch from the other lakes. The mean cadmium concentrations from the other seven lakes were less than 0.13 mg/kg (Figure G-3-17).

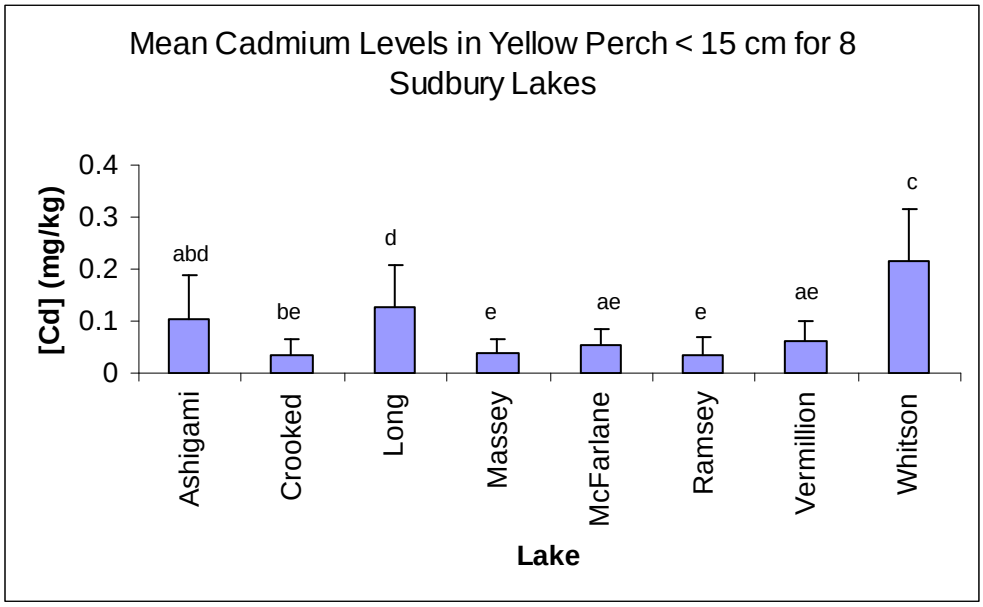

Figure G-3-17 Mean Cadmium Concentration in Yellow Perch (<15cm fork length) for 8 Sudbury Area Lakes

Yellow Perch (> 15 cm fork length)

The concentration of each COC in yellow perch (>15cm fork length) are summarized in Table G3.7 and discussed in the following section. There were no yellow perch greater than 15cm in fork length caught in Long Lake. The Crooked Lake data are based upon a single sample. Therefore, although the results from the statistical analysis are displayed in the following graphs, the Crooked Lake data should be interpreted with caution.

Table G3.7 Total metal concentrations (mg/kg wet weight) in yellow perch >15 cm (*Perca flavescens*) muscle from 8 Sudbury area lakes

Lake		Ni	Cu	Co	As	Pb	Se	Hg	Cd
Ashigami n=9	*Min*	0.040	0.100	0.003	0.029	0.004	2.440	0.022	0.001
	Max	0.190	0.400	0.023	0.063	0.054	3.930	0.081	0.083
	Mean	0..086	0.200	0.011	0.039	0.020	3.170	0.035	0.017
	Std. dev.	0.050	0.089	0.008	0.011	0.018	0.540	0.019	0.025
Crooked n=1	*Min*	0.043	0.140	0.005	0.066	0.004	0.440	0.758	0.001
	Max	0.043	0.140	0.005	0.066	0.004	0.440	0.758	0.001
	Mean	0.043	0.140	0.005	0.066	0.004	0.440	0.758	0.001
	Std. dev.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Massey n=7	*Min*	0.019	0.200	0.007	0.009	0.014	1.400	0.045	0.001
	Max	0.395	0.355	0.015	0.056	0.030	2.490	0.084	0.013
	Mean	0.116	0.254	0.011	0.028	0.024	1.780	0.063	0.005
	Std. dev.	0.127	0.067	0.004	0.014	0.006	0.367	0.016	0.005
McFarlane n=5	*Min*	0.024	0.150	0.003	0.009	0.008	0.810	0.016	0.001
	Max	0.067	0.390	0.021	0.030	0.040	1.100	0.058	0.007
	Mean	0.043	0.224	0.009	0.023	0.021	0.926	0.034	0.003
	Std. dev.	0.018	0.096	0.007	0.008	0.013	0.109	0.019	0.003
Ramsey n=9	*Min*	0.066	0.120	0.005	0.016	0.003	2.100	0.002	0.001
	Max	0.300	0.415	0.020	0.657	0.025	3.540	0.015	0.009
	Mean	0.127	0.246	0.010	0.098	0.008	2.600	0.005	0.004
	Std. dev.	0.078	0.092	0.005	0.210	0.007	0.506	0.005	0.003
Vermillion n=9	*Min*	0.042	0.260	0.009	0.028	0.015	0.980	0.074	0.001
	Max	0.450	1.930	0.021	0.062	0.087	1.400	0.170	0.016
	Mean	0.239	0.613	0.014	0.046	0.041	1.187	0.117	0.007
	Std. dev.	0.128	0.509	0.005	0.010	0.026	0.140	0.031	0.006
Whitson n=3	*Min*	0.068	0.210	0.017	0.016	0.016	3.030	0.009	0.007
	Max	0.140	0.290	0.039	0.064	0.047	4.470	0.024	0.015
	Mean	0.113	0.250	0.025	0.033	0.030	3.663	0.016	0.011
	Std. dev.	0.039	0.040	0.012	0.027	0.016	0.735	0.007	0.004

Nickel

Large perch from Vermillion Lake had a mean nickel concentration of 0.24 mg/kg, which was significantly greater ($p<0.05$) than perch in the other lakes (Crooked Lake excluded). With the exception of Vermillion Lake, the nickel concentrations in large yellow perch from the other lakes were less than 0.13 mg/kg (Figure G-3-18).

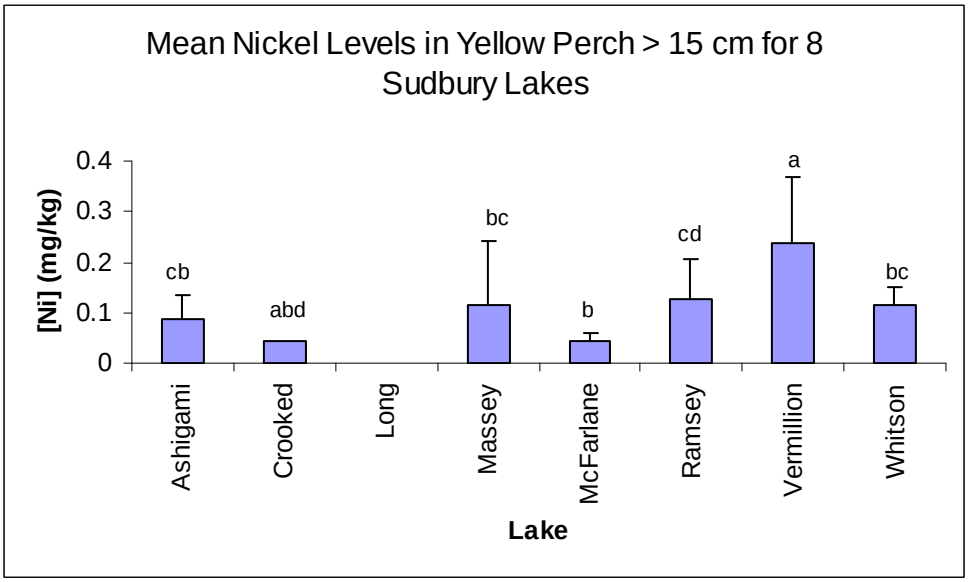

Figure G-3-18 Mean Nickel Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

Copper

The mean copper concentration in large yellow perch was generally less than 0.26 mg/kg for 6 lakes, except for large yellow perch from Vermillion Lake that had a mean copper concentration of 0.61 mg/kg. Copper levels in large yellow perch from Vermillion Lake were significantly greater ($p<0.05$) than large yellow perch caught in the other lakes (Crooked Lake excluded) (Figure G-3-19).

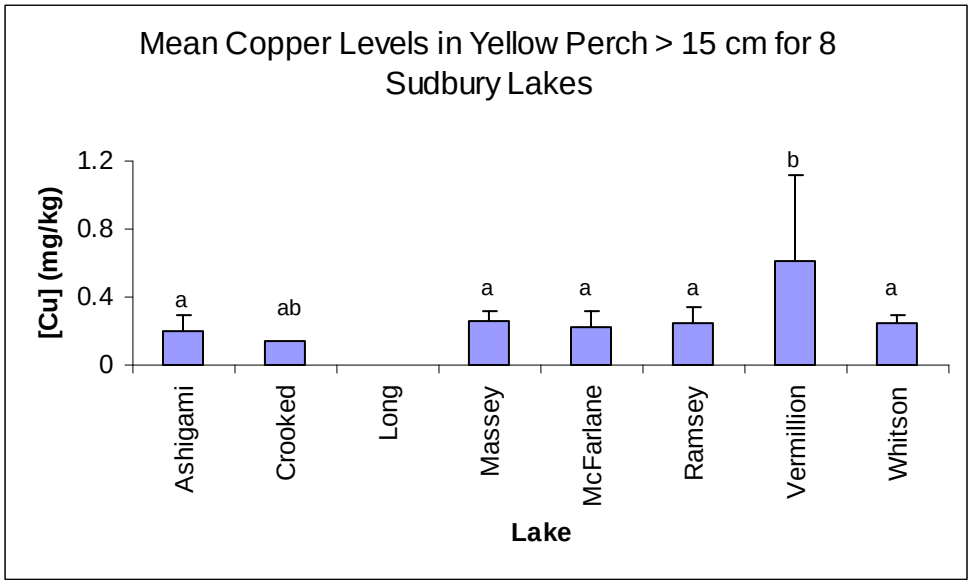

Figure G-3-19 Mean Copper Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

Cobalt

With the exception of Whitson Lake, the mean cobalt concentration in large yellow perch was less than 0.014 mg/kg. The mean cobalt concentration in large yellow perch caught from Whitson Lake was 0.025 mg/kg, which was significantly greater ($p<0.05$) than concentrations in large perch from five other lakes (Figure G-3-20).

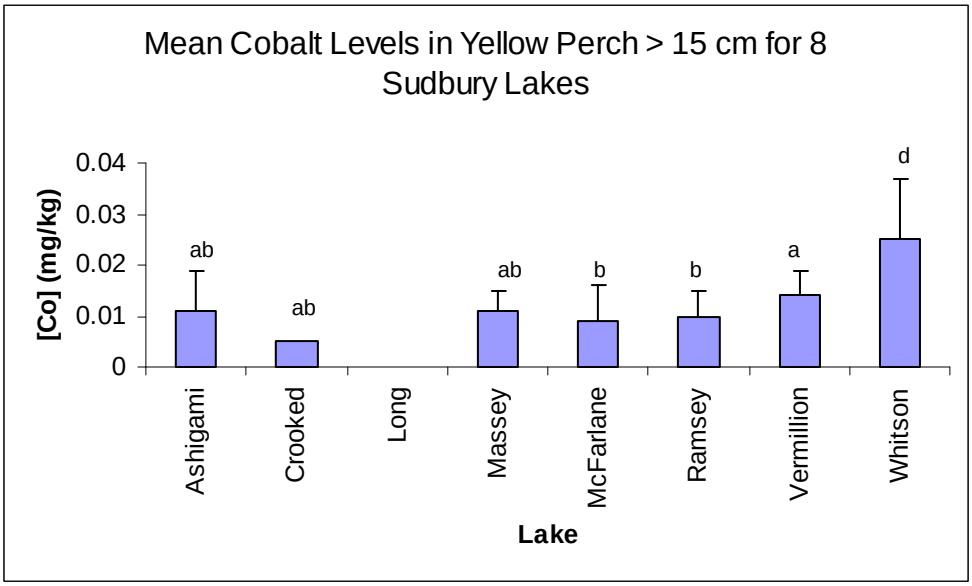

Figure G-3-20 Mean Cobalt Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

Arsenic

Large yellow perch from Ramsey Lake had the highest mean arsenic concentration (0.098 mg/kg), however, there was no significant difference among arsenic levels in the large yellow perch caught in any of the seven lakes (Figure G-3-21).

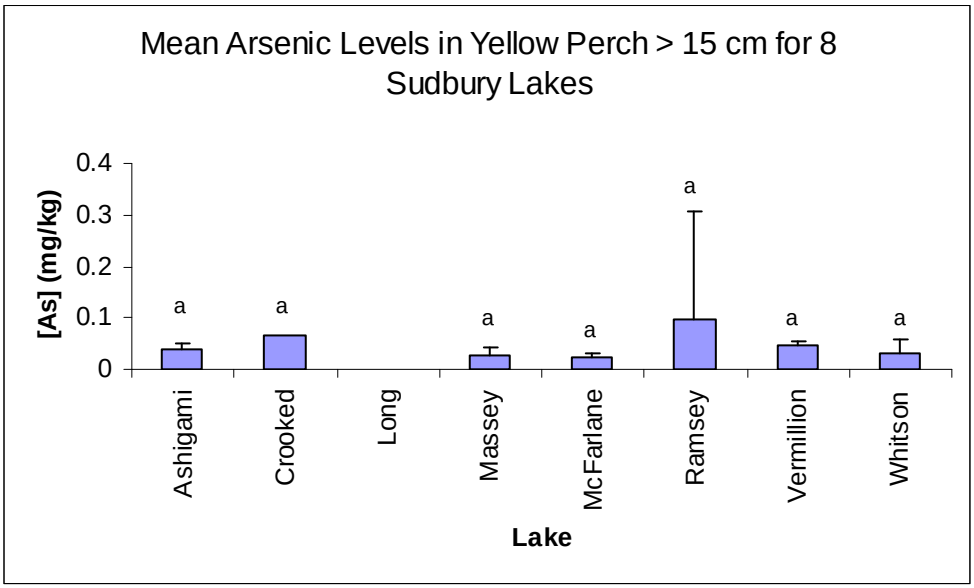

Figure G-3-21 Mean Arsenic Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

Lead

Large yellow perch from Vermillion Lake had a mean lead concentration of 0.041 mg/kg, which was significantly higher than levels in perch from all the other lakes except Whitson (Figure G-3-22).

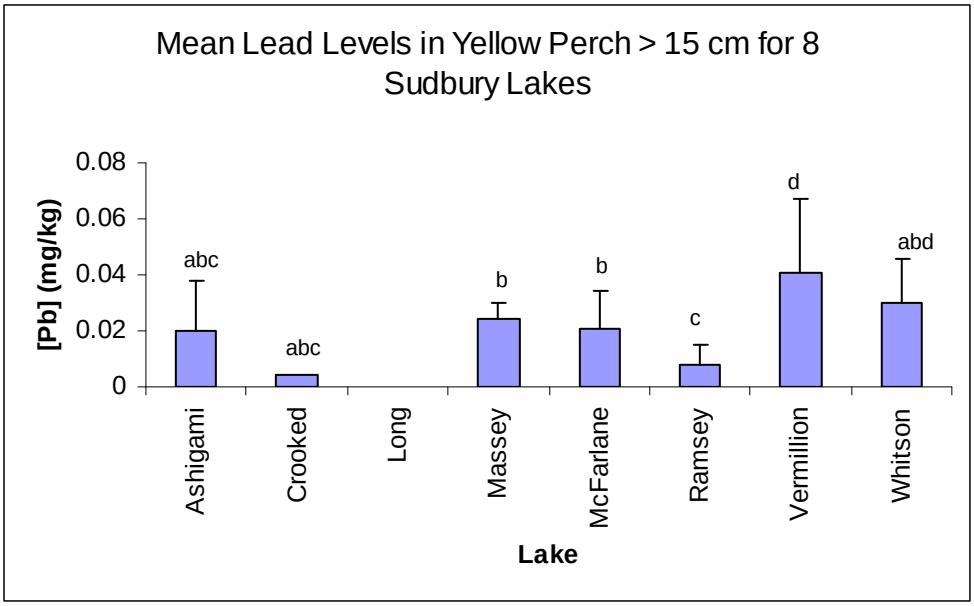

Figure G-3-22 Mean Lead Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

Selenium

Selenium levels in large yellow perch from McFarlane, Vermillion and Crooked Lake were less than 1.20 mg/kg. Massey, Whitson, Ashigami, and Ramsey Lakes had a mean selenium concentration that ranged from 1.78 mg/kg to 3.66 mg/kg. Mean selenium levels in large perch from Whitson Lake were significantly greater ($p<0.05$) from the other six lakes sampled (Figure G-3-23).

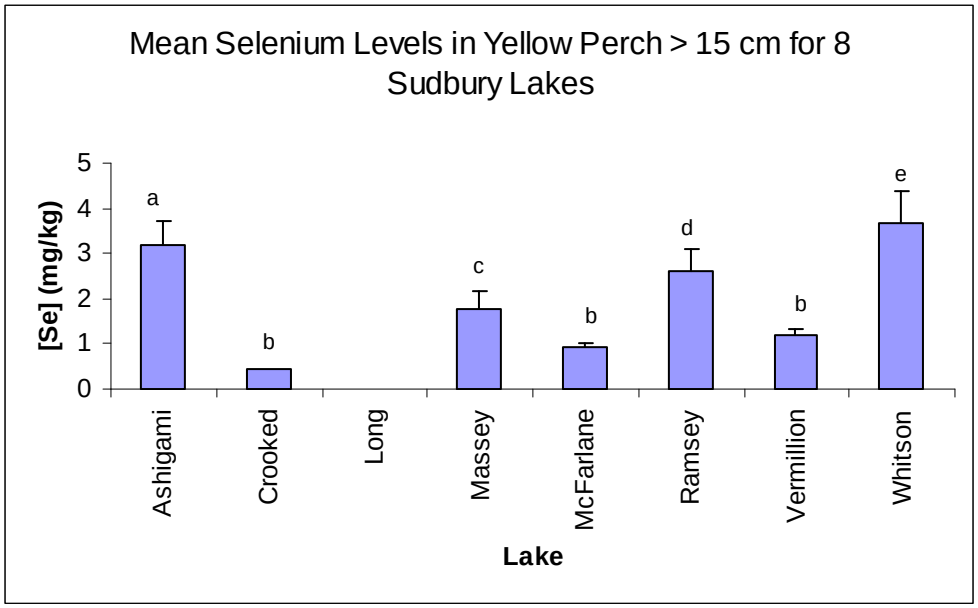

Figure G-3-23 Mean Selenium Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

Mercury

The mean mercury concentrations in large yellow perch were generally less than 0.065 mg/kg. However, a single large yellow perch from Crooked Lake contained a mercury concentration of 0.76 mg/kg. The mean mercury concentration in large perch from Vermillion Lake (0.12 mg/kg) was also significantly greater ($p<0.05$) than mercury levels in perch from the other lakes (Figure G-3-24).

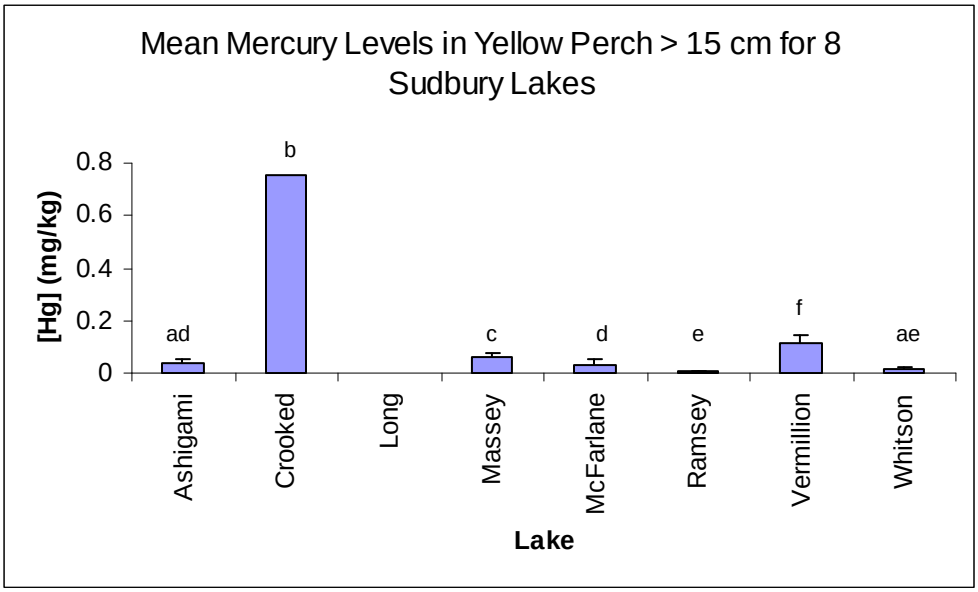

Figure G-3-24 Mean Mercury Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

Cadmium

Large perch from Ashigami Lake had a mean cadmium concentration of 0.017 mg/kg, which was significantly greater ($p<0.05$) than perch from five other lakes (Long Lake and Whitson Lake excluded). With the exception of Ashigami Lake, the cadmium concentrations in large yellow perch from the other lakes were less than 0.011 mg/kg (Figure G-3-25).

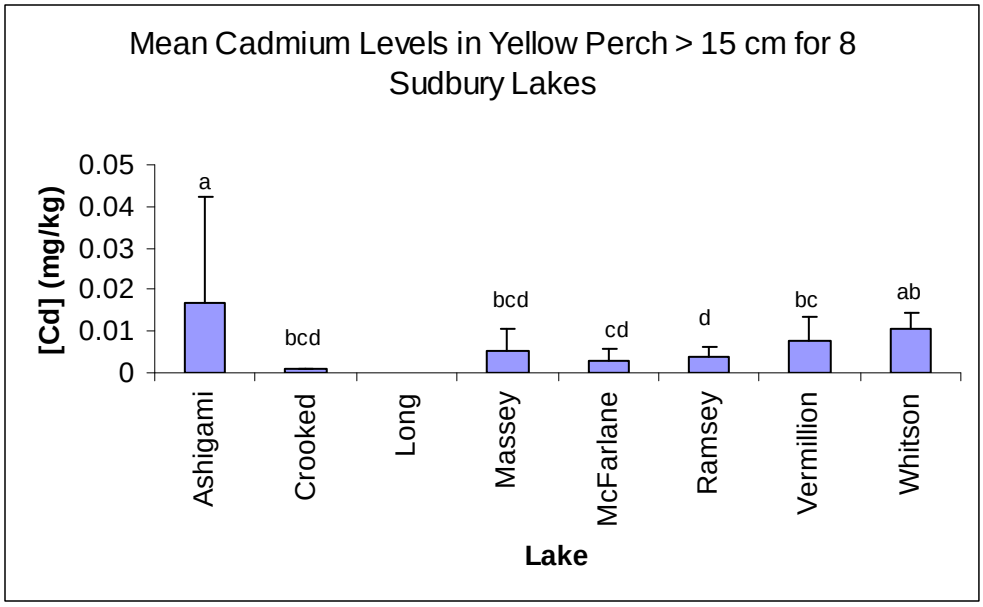

Figure G-3-25 Mean Cadmium Concentration in Yellow Perch (>15cm fork length) for 8 Sudbury Area Lakes

In summary, nickel and copper levels in perch (both sizes) were highest in Vermillion Lake. Mercury concentrations in large perch were also elevated in Vermillion and Crooked Lakes, similar to walleye.

Lake Herring

With respect to the following results it should be noted that there were fewer lake herring caught compared to yellow perch and walleye. Lake herring was only caught from Vermillion, Crooked, and Long Lakes. A total of 20 lake herring were caught, consisting of ten from Long Lake, five from Crooked Lake and five from Vermillion Lake (one composite sample). The five fish caught from Vermillion Lake were combined and sent as one sample for analysis; therefore the Vermillion Lake average was based upon a single sample possibly resulting in an inaccurate comparison to the other lakes.

The concentration of each COC in lake herring is summarized in Table 3.8 and discussed in the following section.

Table G3.8 Total metal concentrations (mg/kg wet weight) in lake herring (*Coregonus artedii*) carcass from 3 Sudbury area lakes

Lake		Ni	Cu	Co	As	Pb	Se	Hg	Cd
Crooked n=5	*Min*	0.085	0.210	0.015	0.037	0.007	0.310	0.051	0.003
	Max	0.210	0.600	0.041	0.071	0.011	0.560	0.140	0.100
	Mean	0.163	0.400	0.031	0.054	0.009	0.454	0.095	0.047
	Std. dev.	0.054	0.165	0.013	0.014	0.002	0.097	0.033	0.035
Long n=10	*Min*	0.270	0.140	0.023	0.083	0.006	1.450	0.003	0.089
	Max	0.878	0.780	0.063	0.655	0.033	2.200	0.028	0.571
	Mean	0.461	0.398	0.038	0.258	0.016	1.710	0.009	0.195
	Std. dev.	0.174	0.223	0.017	0.217	0.010	0.257	0.009	0.155
Vermillion n=1*		0.435	0.555	0.043	0.092	0.067	0.755	0.160	0.032

* Represents composite sample of 5 fish carcasses

Nickel

The mean nickel concentration in lake herring was less than 0.46 mg/kg for all three lakes (Figure G-3-26).

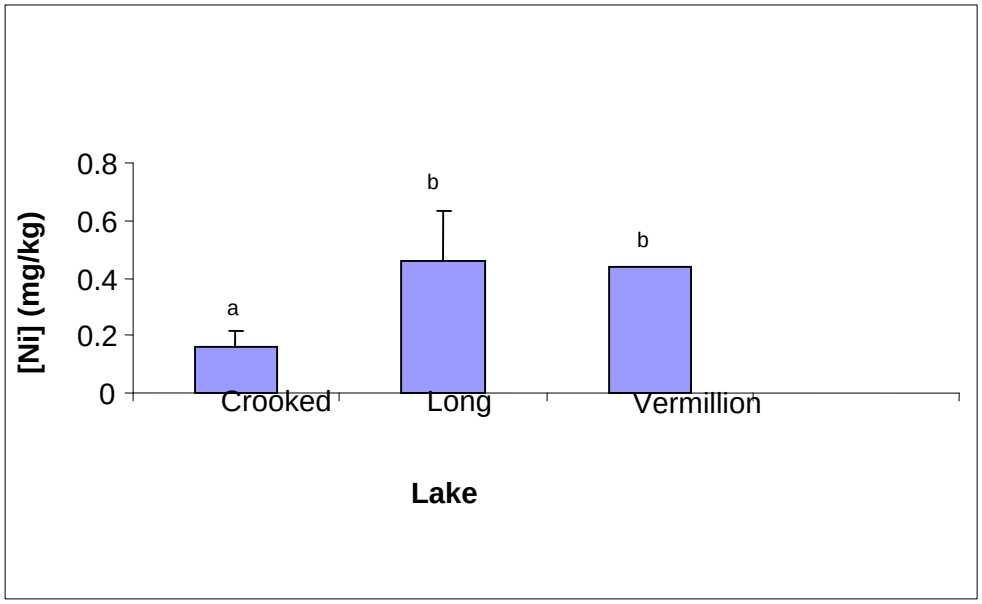

Figure G-3-26 Mean Nickel Concentration in Lake Herring for 3 Sudbury Area Lakes

Copper

The mean copper concentration in lake herring was less than 0.56 mg/kg in all of the three lakes. There was no significant difference in copper concentrations in lake herring from each of the three lakes (Figure G-3-27).

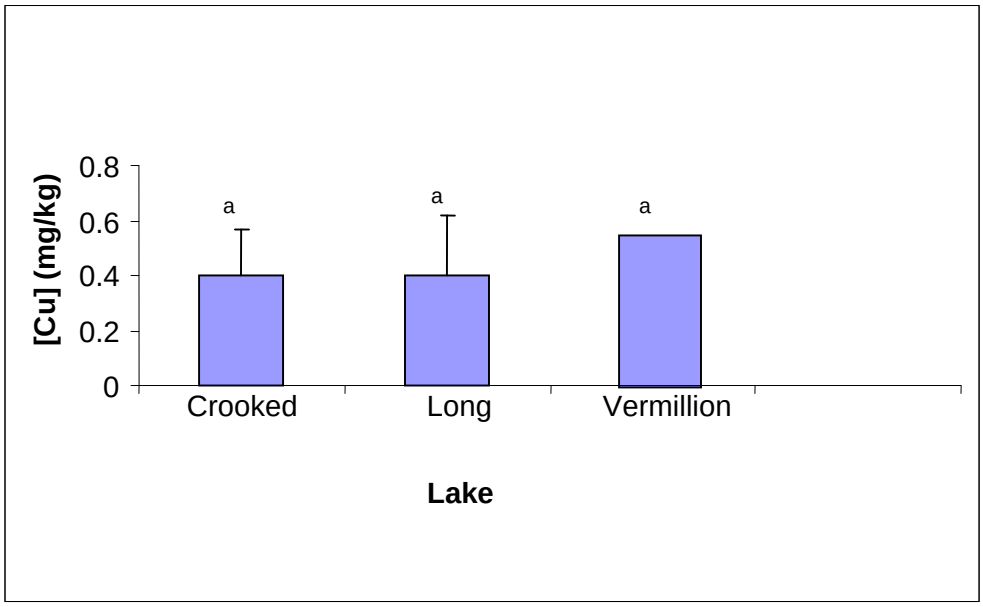

Figure G-3-27 Mean Copper Concentration in Lake Herring for 3 Sudbury Area Lakes

Cobalt

The mean cobalt concentration in lake herring was less than 0.043 mg/kg in all of the three lakes. There was no significant difference in cobalt concentrations in lake herring from each of the three lakes (Figure G-3-28).

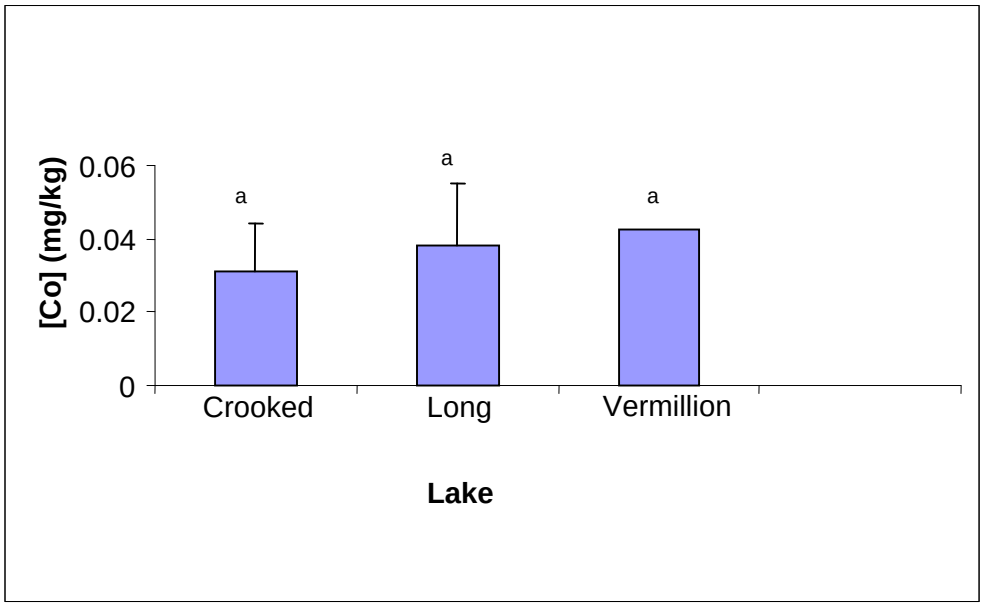

Figure G-3-28 Mean Cobalt Concentration in Lake Herring for 8 Sudbury Area Lakes

Arsenic

The mean arsenic concentration in herring from Long Lake (0.26 mg/kg) was significantly higher than in herring from Crooked Lake (Figure G-3-29).

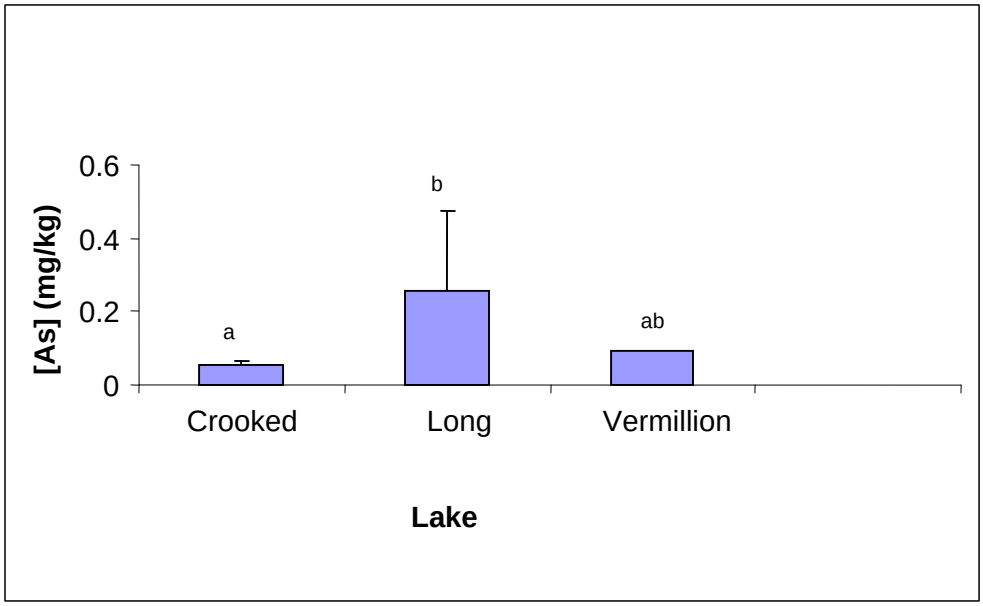

Figure G-3-29 Mean Arsenic Concentration in Lake Herring for 3 Sudbury Area Lakes

Lead

Mean lead concentrations in herring from the three lakes sampled ranged from 0.01 to 0.06 mg/kg (Figure G-3-30).

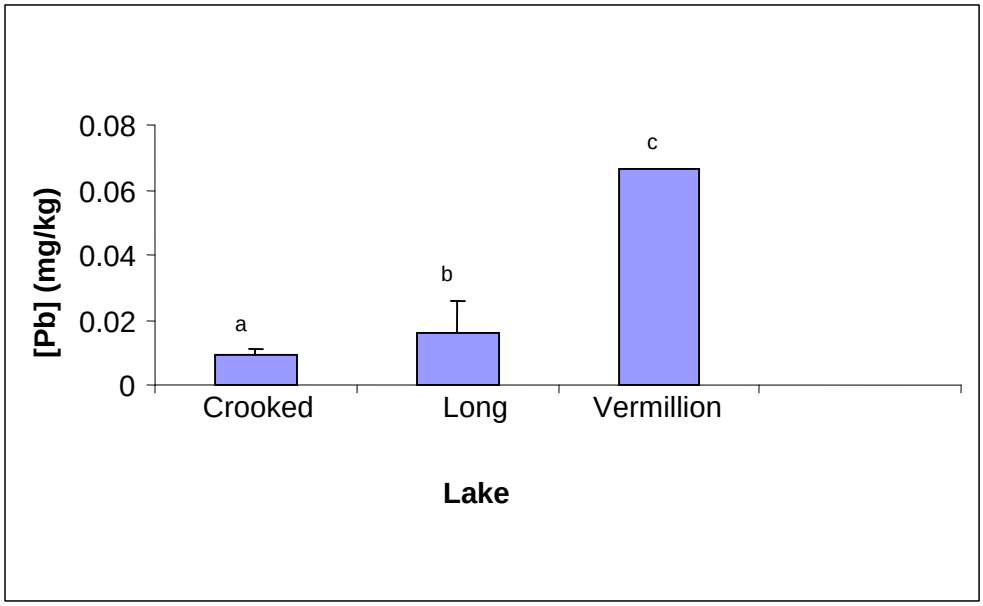

Figure G-3-30 Mean Lead Concentration in Lake Herring for 3 Sudbury Area Lakes

Selenium

The mean selenium concentrations in lake herring were highest ($p<0.05$) in Long Lake compared with the other two lakes (Figure G-3-31).

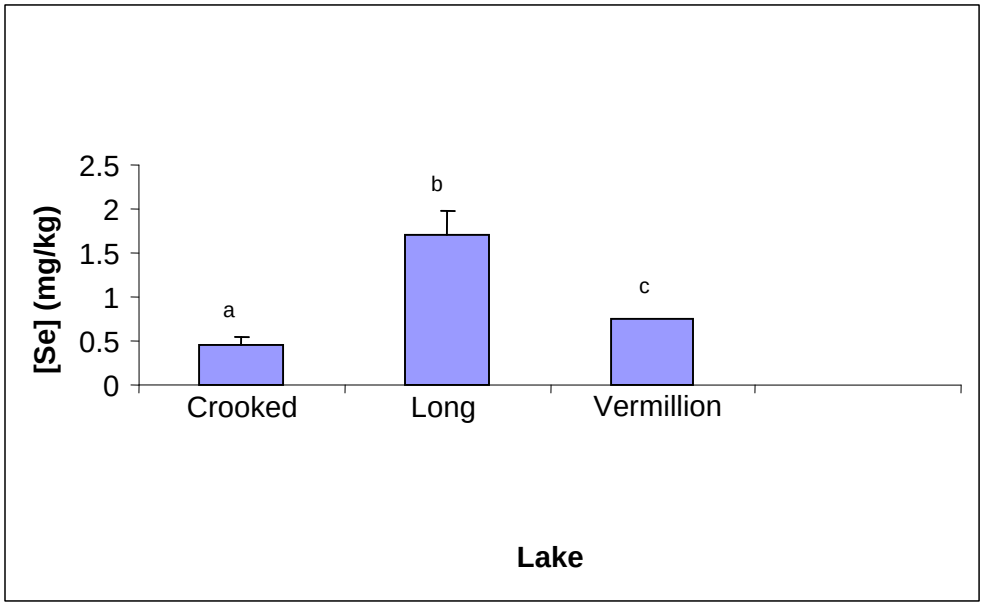

Figure G-3-31 Mean Selenium Concentration in Lake Herring for 3 Sudbury Area Lakes

Mercury

In contrast to selenium, the mean mercury concentration in lake herring was lowest (0.009 mg/kg) in Long Lake. The single sample from Vermillion Lake had a mercury concentration of 0.16 mg/kg. All three lakes were significantly different ($p<0.05$) from each other (Figure G-3-32).

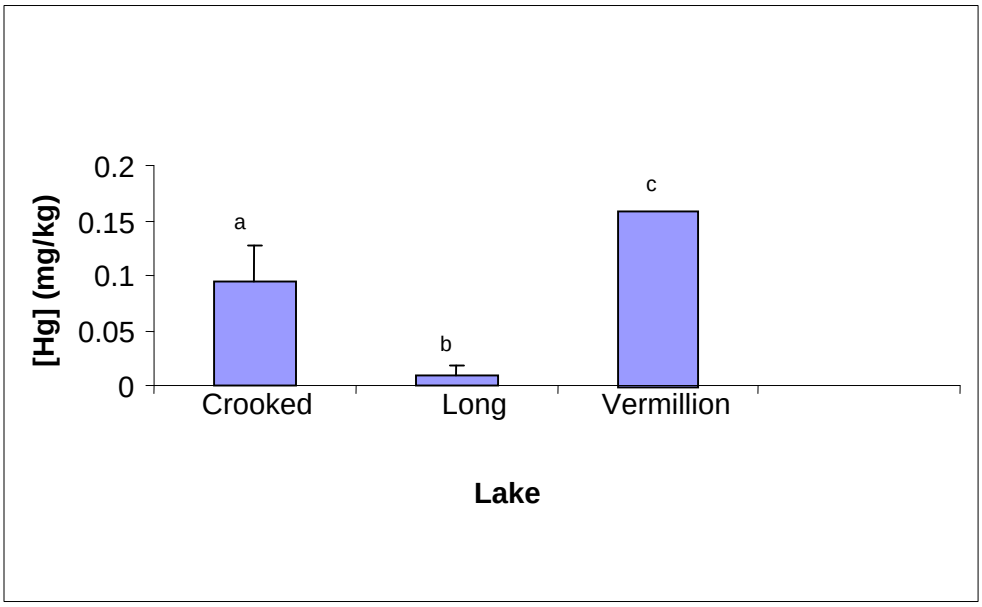

Figure G-3-32 Mean Mercury Concentration in Lake Herring for 3 Sudbury Area Lakes

Cadmium

The mean cadmium concentration in lake herring was 0.20 mg/kg in Long Lake; while the mean cadmium concentration for the other two lakes was less than 0.047 mg/kg (Figure G-3-33).

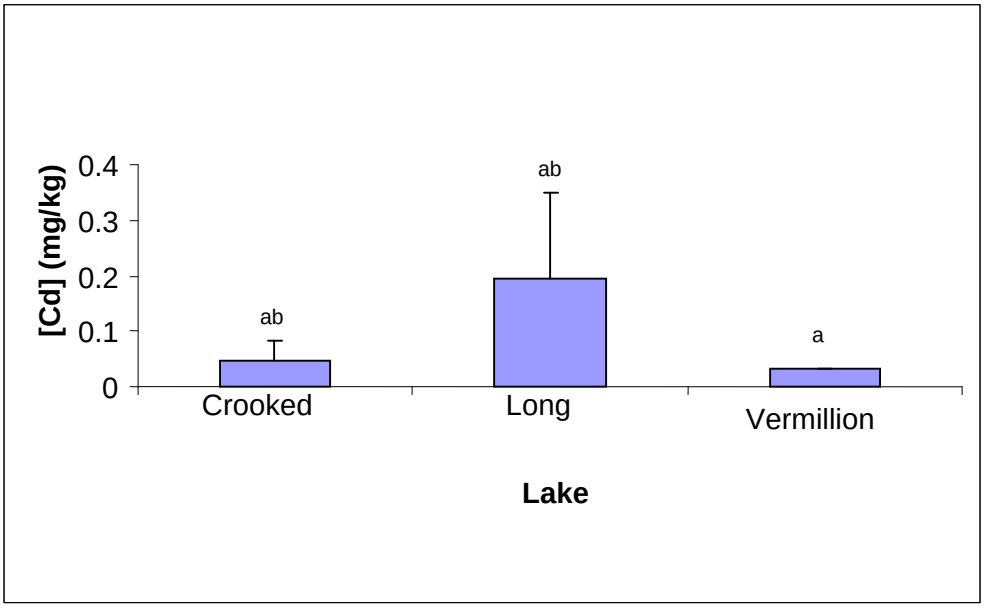

Figure G-3-33 Mean Cadmium Concentration in Lake Herring for 3 Sudbury Area Lakes

Forage Fish

Forage fish caught included spottail shiner, golden shiner, and troutperch. In total, five composite samples of forage fish were analysed. Eleven golden shiners (one composite sample) were caught from Crooked Lake, 41 spottail shiners (two composite samples) were caught from Vermillion Lake, and 28 troutperch (two composite samples) were caught from Vermillion Lake. The concentration of each COC in forage fish is summarized in Table G3.9 and discussed in the following section.

Table G3.9 Total metal concentrations (mg/kg wet weight) in forage fish (spottail shiner (*Notropis hudsonius*), trout perch (*Percopsis omiscomaycus*), golden shiner (*Notemigonus crysoleucas*)) carcass in Sudbury area lakes

Lake		Ni	Cu	Co	As	Pb	Se	Hg	Cd
Vermillion	Spottail Shiner (n=2)*								
	Min	0.759	1.100	0.047	0.094	0.048	0.860	0.160	0.140
	Max	0.839	1.790	0.049	0.100	0.055	0.880	0.190	0.173
	Mean	0.799	1.440	0.048	0.097	0.052	0.870	0.175	0.157
	Std. dev.	0.057	0.488	0.001	0.004	0.005	0.014	0.021	0.023
	Trout Perch (n=2)*								
	Min	1.120	0.640	0.081	0.080	0.045	0.940	0.065	0.089
	Max	1.340	1.300	0.122	0.087	0.056	1.000	0.083	0.130
	Mean	1.230	0.970	0.101	0.083	0.050	0.970	0.074	0.110
	Std. dev.	0.156	0.467	0.029	0.005	0.008	0.042	0.013	0.029
Crooked	Golden Shiner (n=1)*	0.430	0.460	0.036	0.029	0.046	0.345	0.026	0.027

* Sample size represents composite sample analysed

Due to the low number of fish samples analysed (composite) ANOVA was not performed on the forage fish.

Nickel

The mean nickel concentration in forage fish ranged from 0.43 to 1.23 mg/kg for Vermillion Lake and Crooked Lake.

Copper

The mean copper concentration in forage fish ranged from 0.46-1.44 mg/kg for Vermillion Lake and Crooked Lake.

Cobalt

The mean cobalt concentration in forage fish was less than 0.10 mg/kg for Vermillion Lake and Crooked Lake.

Arsenic

The mean arsenic concentration in forage fish ranged from 0.029 to 0.097 mg/kg for Vermillion Lake and Crooked Lake.

Lead

The mean lead concentration in forage fish ranged from 0.046 to 0.052 mg/kg for Vermillion Lake and Crooked Lake.

Selenium

The mean selenium concentration in forage fish ranged from 0.345 to 0.97 mg/kg for Vermillion Lake and Crooked Lake.

Mercury

The mean mercury concentration in forage fish ranged from 0.026 to 0.175 mg/kg for Vermillion Lake and Crooked Lake.

Cadmium

The mean cadmium concentration in forage fish ranged from 0.027 to 0.157 mg/kg for Vermillion Lake and Crooked Lake.

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G-4.0 REFERENCES

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SUB APPENDIX G-A:

BIOLOGICAL DATA FOR FISH SPECIMENS BY LAKE

SUB APPENDIX G-B:

FISH TISSUE METAL RESULTS

SUB APPENDIX G-C:

ORIGINAL LABORATORY DATA REPORTS

SUB APPENDIX G-D:

CHAIN OF CUSTODY FORMS FOR THE SAMPLES

SUB APPENDIX G-E:

ANALYSIS OF VARIANCE FOR METALS IN FISH TISSUE

SUB APPENDIX G-F:

STATISTICAL DIFFERENCES ANALYSIS FOR METALS IN FISH TISSUE