Levels of Metals in Water and Fish in Lakes of the Chibougamau and Oujé-Bougoumou Region (1998-2010)

Développement durable, Environnement, Faune et Parcs
Québec

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Production team

Author:	Denis Laliberté[1]
Scientific revision:	Véronique Thériault[1] Peter Campbell[2] Josée Brazeau[1] Malek Zetchi[3] Gaëlle Triffault-Bouchet [4]
Laboratory analyses:	Centre d'expertise en analyse environnementale du Québec
Sampling:	Direction de l'aménagement de la faune du Nord-du-Québec[1] Direction régionale du Nord-du-Québec[1]
Graphic design and cartography:	France Gauthier[1] and Yves Laporte[1]
Layout:	Murielle Gravel[1]

1 Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs

2 Université du Québec, Institut national de la recherche scientifique, Centre Eau Terre Environnement

3 Ministère des Ressources naturelles, Service du développement et du milieu miniers

4 Centre d'expertise en analyse environnementale du Québec

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SUMMARY

In order to assess concentrations of metals and other substances in water and fish stemming from mining operations in the Chibougamau and Oujé-Bougoumou region, the Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs (MDDEFP) conducted studies in lakes in the territory between 1998 and 2010.

The studies focused primarily on lakes near which the main mining operations were concentrated, i.e. Lac aux Dorés, Lac Chibougamau and the Obatogamau lakes and, secondly, on other lakes that the Oujé-Bougoumou Cree community uses for subsistence fishing. James Bay residents and Quebecers in general also engage in sportfishing on the lakes.

Water

The water samples collected in the lakes and watercourses in the Chibougamau and Oujé-Bougoumou region in June and July 2008 reveal that at all of the sampling sites the concentrations of all metals and non-metals fall below the chronic effects criteria for the protection of aquatic organisms. Consequently, the concentrations measured are not deemed to be likely to pose a threat to aquatic organisms. The concentrations of metals measured in the water also fall below the criteria respecting drinking water and are not deemed to pose a threat to human health. The total cyanide concentrations measured in the water were below the minimum detectable limit of 4 µg/L at all of the sites.

Fish flesh

Several of the metals sought in the flesh of the dorsal muscle, i.e. arsenic, barium, cadmium, chrome, cobalt, nickel, lead and vanadium, were not detected or displayed concentrations near the minimum detectable limit. Of these metals, only arsenic (3.5 mg/kg) and lead (0.5 mg/kg) are covered by Health Canada guidelines for the sale of fishery products for human consumption. The arsenic and lead concentrations measured in the flesh of fish all fall below the Health Canada guidelines.

What is more, the concentrations of six metals in fish flesh, i.e. copper, manganese, mercury, selenium, strontium and zinc, exceeded 0.1 mg/kg. With the exception of mercury concentrations, the concentrations measured in a given species are usually on the same order as the background measured in Lac Waconichi, the control lake. Of the metals, only mercury is covered by a Health Canada guideline (0.5 mg/kg) for the sale of fishery products.

The mercury concentrations measured in the flesh of medium and large piscivorous fish (yellow walleye, northern pike, lake trout and burbot) occasionally exceed the Health Canada guideline (0.5 mg/kg). The highest mercury concentrations were measured in large lake trout in Lac Cosnier (2.87 mg/kg), Lac Father (2.22 mg/kg) and Lac Chibougamau (1.70 mg/kg). The highest concentrations in yellow walleye were measured in Lac Gabriel (1.64 mg/kg) and Lac Father (1.48 mg/kg), while the highest concentrations in northern pike were measured in Lac Waposite (1.71 mg/kg) and Lac Gabriel (1.68 mg/kg).

It should be noted that mercury concentrations in the flesh of lake herring, lake whitefish, white sucker, northern sucker and yellow perch all fall below the Health Canada guideline for the sale of fishery products, set at 0.5 mg/kg. The handful of brook trout and fallfish specimens also display concentrations that fall below the guideline.

All of the mercury concentrations exceed the 0.033 mg/kg criterion for the protection of piscivorous terrestrial fauna.

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1 INTRODUCTION

To assess the quality of fishery resources in the Chibougamau and Oujé-Bougoumou region, since 1998 the Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs (MDDEFP) has analyzed metals and organic compounds present in fish flesh. The initial studies focused on Lac Chibougamau, Lac aux Dorés, Lac Waconichi and the Obatogamau lakes. Other lakes were subsequently added to broaden the spatial coverage of the study program.

The lakes are used, in particular, by the Cree communities for subsistence fishing and by James Bay residents and Quebecers in general for sportfishing.

Several mining sites are located on the shores of Lac Chibougamau and Lac aux Dorés, which encompass large lake trout pools located along the containment dikes in tailings management facilities. The Obatogamau lakes are affected by a mine in the Rivière Nemenjiche basin. Lac Waconichi serves as a control since neither mining activity nor significant mineralization is found in the vicinity.

In order to ascertain whether mining operations had contaminated the aquatic environment, starting in the summer of 2001 the MDDEFP measured concentrations of metals, polychlorinated biphenyls (PCBs) and dioxins and furans in mine effluent at two sites and in mine tailings, sediments and fish in the Chibougamau region. The work focused primarily on Lac Chibougamau, Lac aux Dorés, the Obatogamau lakes (La Dauversière) and Lac Waconichi (D. Laliberté and G. Tremblay, 2002; D. Laliberté, 2004a). Between 2001 and 2005, fish from 12 lakes were analyzed to determine metal and chlorinated organic compound concentrations. Aside from the lakes mentioned earlier, the studies focused on Lac Cosnier, the Obatogamau lakes (Fancamp), Lac Gabriel, Lac Obatogamau (Le Royer), Lac Nemenjiche, Lac Opémisca, Lac Scott and Lac Simon (D. Laliberté, 2008).

The findings of the studies conducted in 2001 and 2005 revealed that metal contamination of fish flesh was confined to mercury. Certain species displayed concentrations above the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg. However, such concentrations were not unusual and were comparable to those observed in several places in Québec. Moreover, the data do not show that mining operations near Lac Chibougamau and Lac aux Dorés increased mercury concentrations in fish.

However, the studies emphasized that PCB concentrations measured in lake trout in Lac aux Dorés and Lac Chibougamau warranted monitoring. The origin of the PCBs was not determined and no PCBs were detected in sediment in Lac Chibougamau and Lac aux Dorés.

High concentrations of several metals were found near tailings management facilities, i.e. arsenic, cadmium, copper, nickel and zinc. The sites located near the Copper Rand mine south of the Principale mine and at the foot of the Principale tailings site displayed the highest concentrations of the metals. The high concentrations of the metals were likely to harm aquatic organisms and were worrisome.

Studies devoted to metal and chlorinated organic compound concentrations in fish flesh continued between 2006 and 2010 in 10 new lakes, i.e. Lac Chevrillon, Lac David, Lac du Sauvage, Lac Father, Lac France, the Obatogamau lakes (Chevrier, Muscocho, Verneuil), Lac Opataca and Lac Waposite, and in five lakes studied previously.

Water samples from several of the lakes studied were also analyzed in 2008 in order to measure metal, cyanide, sulphate, phosphorous and dissolved organic carbon (DOC) concentrations and physical and chemical parameters.

The findings presented in this report are those obtained in 2008 concerning water and those revealed by fish sampled in lakes in the Chibougamau and Oujé-Bougoumou region between 1998 and 2010.

2 DESCRIPTION OF THE STUDY AREA

Mining operations in the Lac Chibougamau, Lac aux Dorés and Lac Obatogamau region began in the mid-1950s with copper and gold deposits (Figure 1). The processing of ore from mines in the Chibougamau region and the elimination of tailings generally occurred on the Copper Rand and Principale mine sites, which were the only ones that possessed concentrating plants and mine tailings sites. The Joe Mann mine was an exception since ore was processed on-site for several years when mining operations began there, between 1956 and 1959.

Copper Rand and Eaton Bay (Lac Chibougamau and Lac aux Dorés)

The Copper Rand mine site is located on the Gouin Peninsula, which physically separates Lac Chibougamau and Lac aux Dorés. Two tailings sites are located on the peninsula. The Eaton Bay tailings site, partly built on the shore of Lac Chibougamau, contains some 9.8 million tonnes of mine tailings and is inactive. It has not generated effluent since June 2002. The Copper Rand tailings site, built on the shore of Lac aux Dorés, is inactive and now contains some 11.5 million tonnes of mine tailings. All of the dikes on the tailings sites were built with mine waste. The permeability of the dikes is monitored periodically. Final mine effluent from the Copper Rand tailings site now flows into Lac aux Dorés. The extraction and concentration of ore ceased in 1997, resumed in March 2005, and ended again in 2009.

The former Principale mine (Lac aux Dorés)

The former Principale mine site is located on Île Merrill in Lac aux Dorés. All of the dikes surrounding the tailings sites, which contain a maximum of 19.3 million tonnes of tailings, were built in Lac aux Dorés when operations began in 1955. Like the mine tailings sites mentioned above, the dikes from the former Principale mine are built of mine waste and their permeability is monitored periodically. The flotation process was used to extract copper. A cyanidation circuit was then used to extract gold. Operations at the plant were interrupted from November 2000 up to and including January 2002 and were completely halted in February 2005. Until February 2005, mineral ore from the Joe Mann mine was processed at the former Principale mine using the same processes to extract copper, then gold. The final effluent from the tailings site of the former Principale mine flowed into Lac aux Dorés. It was closed in December 2003. However, it was opened for 15 days in September 2004 and for 73 days between August and October 2006. The tailings site of the Principale mine site is inactive.

The amalgamation process to recover gold using mercury has never been used on the Copper Rand and Eaton Bay mine sites, nor on the mine sites of the former Principale mine.

Joe Mann site (Rivière Nemenjiche and the Obatogamau lakes)

The Joe Mann mine site is located on the banks of the Rivière Nemenjiche in the Obatogamau lakes basin. Water from the river flows into Lac La Dauversière. At the outset of operations on the Joe Mann mine site, from 1956 to 1959, gold ore was processed by amalgamation, followed by a cyanidation circuit. The process required the use of mercury, part of which was recovered with the gold. Starting in February 2005, the ore was processed on the Copper Rand mine site until the Joe Mann mine closed in July 2008.

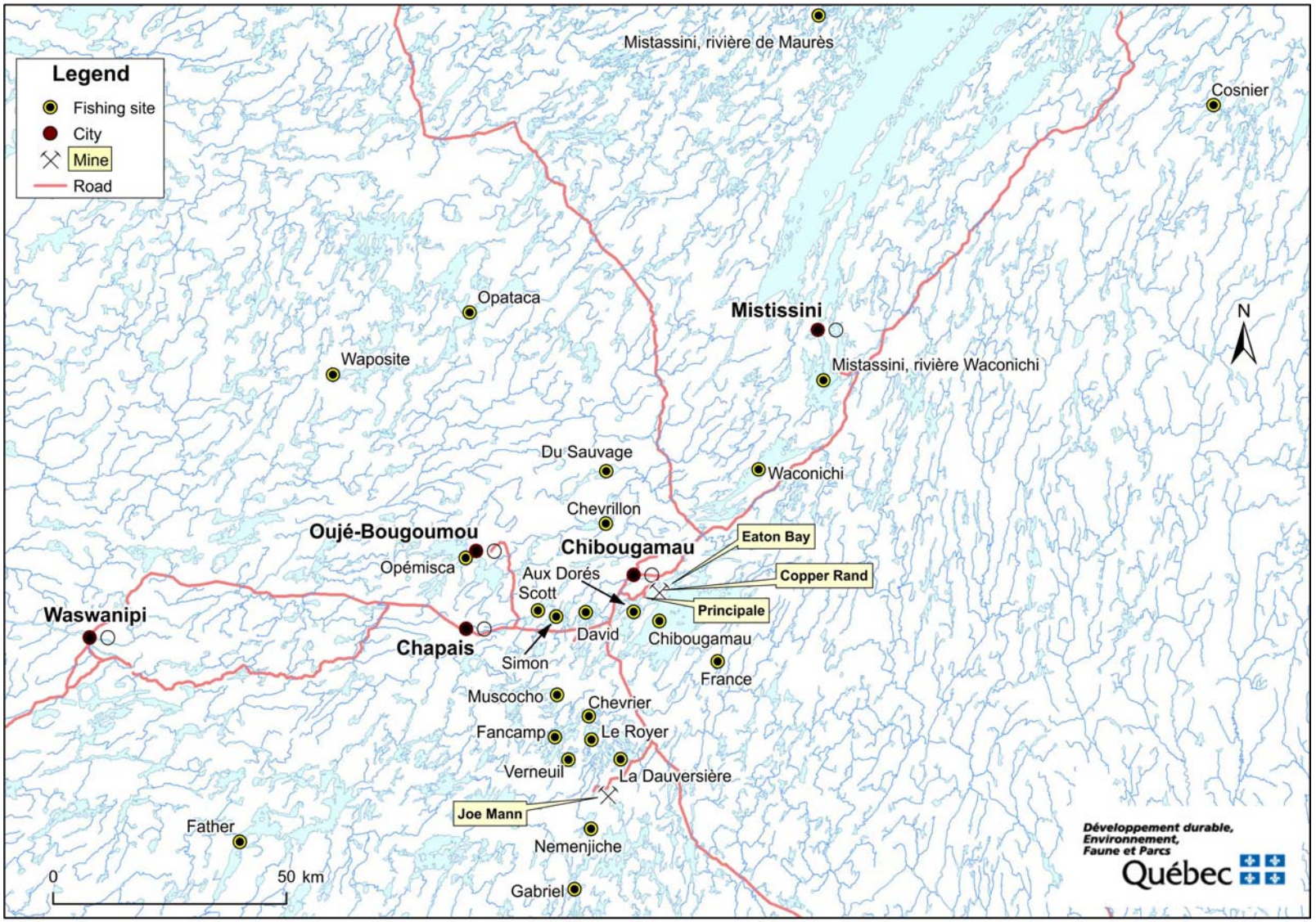


Figure 1 Location of the study area in the Chibougamau and Oujé-Bougoumou region

3 METHODS

3.1 Water sampling

The MDDEFP collected water samples at Lac aux Dorés (eight sites), Lac Chibougamau (three sites), the Obatogamau lakes (seven sites), Lac Waconichi (two sites), Lac Opémisca (two sites), Lac Scott (one site), Lac Simon (one site) and Lac David (one site) from June 10 to 12, 2008. In the summer of 2008, the community of Oujé-Bougoumou also collected water samples near Cree fishing camps. For the purposes of analyzing total metals, subsamples were drawn from the original sampling bottle.

3.1.1 Cyanide and metals

Water samples to measure total cyanide were collected at a depth of 30 cm using a Masterflex peristaltic pump. During collection, the sample flowed through a 2-m long low-density polyethylene (LDPE) tube, a Masterflex flexible tube connected to the pump, then a 30-cm long LDPE tube. The sample was then poured into a 500-mL polyethylene bottle, without preliminary filtering. Immediately after the sampling, a small amount of NaOH was added to the sample to obtain a pH reading above 12. The samples were preserved on ice (4°C) until they reached the laboratory.

As for the water samples used to measure metal concentrations, they were drawn at a depth of 30 cm using a peristaltic pump and were filtered on-site by means of a 0.45-µm Aquaprep-V Gelman P/N 4272 filter. The filtrate was collected in a 125-mL LDPE bottle containing 250 µL of concentrated HNO_3 as a preservative. The 125-mL bottle was placed in a polyethylene bag to avoid external contamination. During collection, the sample flowed through a 2-m long LDPE tube, a flexible Masterflex C-FLEX tube connected to the pump, then a PFA Teflon Tee Connector installed just before the filter and a 30-cm long LDPE tube attached to the Aquaprep filter (Figure 2).

The Teflon Tee Connector avoids the need to disconnect the tubing when the system is purged prior to filtering the sample. It also allows for the collection of an unfiltered sample once the system has been purged.

Before a sample intended to measure total metals was collected, one end of the Teflon Tee Connector was opened, thereby preventing the water from flowing toward the filter and making it possible to pump roughly 100 mL of water in the tubing and eliminate it before sampling. Once the tubing was rinsed, a 100-mL sample was collected to measure total metals.

The pump was then stopped and the Teflon Tee Connector was closed with a cork at the other end to send the water to the filter. To eliminate residual contamination in the filter, the first 30-mL were discarded before the sample was collected in a small 60-mL bottle placed in the same bag as the 125-mL collection bottle used to measure dissolved metals. A 100-mL sample of filtered water was then collected in the 125-mL bottle.

A transport blank was prepared in the laboratory by pouring 100-mL of NANOpure® water into a bottle identical to the one used for sampling. The transport blank is used to verify the contamination by metals of the material used and contamination that might occur during transportation between the laboratory and the analysis of the samples. It is not opened in the field.

Furthermore, three field blanks were prepared in the same way as for the samples but by pumping 100-mL of NANOpure® water from a 500-mL bottle prepared in the laboratory. A new group was used for each field blank. The field blanks are used to ascertain the contamination introduced during handling and contamination from the equipment and its transportation to the laboratory.

Before it is used, the equipment (except for the filters) was decontaminated by soaking it in 10% v/v nitric acid for 12 hours, then for three days in demineralized water, then rinsed seven times with demineralized water.

Following decontamination, the equipment was assembled under a laminar flow cabinet. The closed sampling bottle containing 250 µL of HNO_3 was sealed in a 1-litre polyethylene bag and all of the items, including the tubing, were placed in a large polyethylene bag. A separate sampling kit was prepared for each sampling site.

It proved to be preferable to avoid decontaminating the filter prior to use. The concentrations of metals released by the new, uncontaminated filter are almost all below their minimum detectable limit and are almost all below those observed several days after the decontamination.

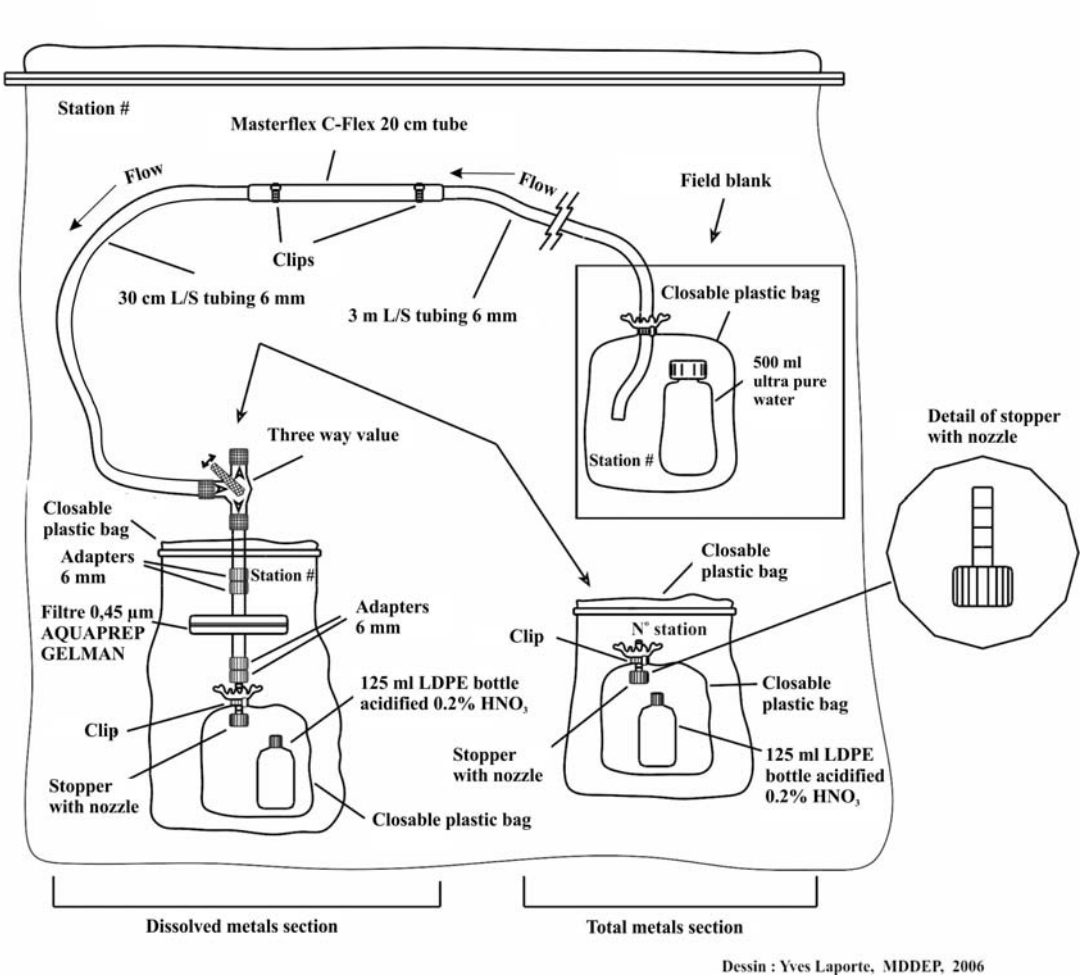


Figure 2 Diagram illustrating water sampling and the analysis of dissolved and total metals

3.2 Sampling of adult fish

Fish were caught according to the protocol described in the *Guide de normalisation des méthodes utilisées en faune aquatique au ministère de l'Environnement et de la Faune* (MEF, 1994). Experimental transparent monofilament nylon nets, consisting of 8 panels 7.6 m long by 1.8 m wide comprising meshing stretched to 25 mm, 38 mm, 51 mm, 64 mm, 76 mm, 102 mm, 127 mm and 152 mm and mounted to 50% were used. The nets were set in the preferred habitats and at the preferred depths of the species being sought. The mains species caught were lake herring (*Coregonus artedii*), yellow walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*), lake whitefish (*Coregonus clupeaformis*), burbot (*Lota lota*), lake chub (*Couesius plumbeus*), white sucker (*Catostomus commersoni*), northern sucker (*Catostomus catostomus*) and lake trout (*Salvelinus namaycush*) (Figure 3).

The fish were caught in 22 lakes from 1998 up to and including 2010 in September and October: Lac aux Dorés (2000, 2001, 2008), Lac Chibougamau (1998, 1999, 2000, 2001, 2002, 2008), Lac Chevrier (2009), Lac Chevrillon (2006), Lac Cosnier (2004), Lac David (2006), Lac du Sauvage (2007), Lac Fancamp (2002, 2009), Lac Father (2010), Lac France (2007), Lac Gabriel (2005), Lac La Dauversière (2001, 2002, 2008, 2009), Lac Le Royer (2004, 2008), Lac Muscocho (2009), Lac Nemenjiche (2004), Lac Opataca (2006), Lac Opémisca (2003, 2010), Lac Scott (2005), Lac Simon (2005), Lac Verneuil (2009), Lac Waconichi (2001, 2010) and Lac Waposite (2007).

The fish caught in Lac Chibougamau and Lac aux Dorés were divided into two subgroups in order to compare their mercury concentrations according to the proximity of mining infrastructure (Figure 1). Fish from the Obatogamau lakes were caught in the western sector (Lac Fancamp, Lac Verneuil), which was used as a control sector located far from mining operations, in the eastern sector (Lac La Dauversière), near the outlet of the Rivière Nemenjiche and roughly 7 km upstream and, lastly, in the northern sector (Lac Le Royer, Lac Chevrier and Lac Muscocho). Mining operations occur near the Rivière Nemenjiche and the final effluent flows into it. For the other sites, the fish were grouped together by lake without taking into account the sector in which they were caught.

Figure 3 Fish sampling

3.3 Methods of analysis

3.3.1 Water analysis methods

Major metals

Inductively coupled plasma optical emission spectrometry (ICP-OES) was used to detect major metals. The plasma is produced by induction in a torch located inside a coil. The sample is drawn into the plasma. The metals are atomized then ionized and when they recombine with electrons, they emit energy at wavelengths specific to them. The light emitted is separated by a dispersive network and its intensity is measured by means of a detector. The concentrations of minerals are determined by comparing the respective luminous intensities of the sample and the standard solutions. The quantification limits of the method for calcium, magnesium, potassium and sodium are 0.07 mg/L, 0.07 mg/L, 0.1 mg/L and 0.07 mg/L (CEAEQ, 2008a).

Trace metals

Inductively coupled plasma mass spectrometry (ICP-MS) was used to detect trace metals and other minerals in the water. The sample is drawn into a plasma in which metals are atomized and ionized at temperatures of up to 10 000 K. The ionized minerals are then sent to a mass spectrometer where they are separated according to their mass-to-charge ratio. The concentrations of minerals are determined by

comparing the respective luminous intensities of the sample and the standard solutions. The minimum detectable limit of the method for each element is indicated in the following table (CEAEQ, 2011a and CEAEQ, 2011b).

Élément	LDM (µg/l)	Élément	LDM (µg/l)	Élément	LDM (µg/l)	Élément	LDM (µg/l)
Ag	0,002	Fe	0,24	U	0,001	Pt	0,006
Al	0,4	Mn	0,004	V	0,007	Si	3
As	0,03	Mo	0,002	Zn	0,08	Sn	0,01
Ba	0,02	Ni	0,02	Br	0,5	Tl	0,005
Cd	0,006	Pb	0,01	I	0,5		
Co	0,007	Sb	0,003	Li	0,06		
Cr	0,004	Se	0,09	P	2		
Cu	0,02	Sr	0,05	Pd	0,005		

Dissolved organic carbon (DOC)

Infrared detection is used to determine the concentration of dissolved organic carbon. The sample containing organic compounds is introduced into a tube heated to 680°C containing a catalyst that acts as an oxidizing agent. The combustion and degradation compounds are in the form of CO_2, which is analyzed by means of infrared detection and quantified through comparison with a calibration curve. The dissolved organic carbon is the non-volatile organic carbon, which is measured by first acidifying the sample using 1N hydrochloric acid and sparging it with ultrapure air to eliminate the CO_2. The minimum detectable limit is 0.05 mg/L C (CEAEQ, 2011c).

Sulphate (SO_4)

The concentration of sulphate ions in the water is determined by means of ion-exchange chromatography with an electrolytic conductivity detector. A water sample is injected and drawn by a solution of carbonates and bicarbonates into a chromatographic column (anion exchange). The anions present in the sample are separated according to their relative affinity with the material of the column. They are identified by means of their retention time and are measured out by means of an electrolytic conductivity detector. The conductivity measured is proportional to the concentration of each anion in the sample. The minimum detectable limit for sulphates is 0.3 mg/L (CEAEQ, 2010).

Cyanide

Total cyanide content is determined in two steps. The first step consists in acidifying the sample to break down the cyanide complexes and distill the cyanides in the form of hydrocyanic acid outside the sample to eliminate interference.

In the second step, the cyanides distilled react with a solution of chloramine-T in a buffered medium to form cyanogen chloride. The cyanogen chloride thus formed reacts with pyridine and barbituric acid to form a red complex for which absorbance at 570 nm is proportional to the concentration of cyanides.

The minimum detectable limit for total cyanides is 0.006 mg/L. During tests, the relative error was 7.6% at a cyanide concentration of 0.08 mg/L (CEAEQ, 2004).

3.3.2 Fish analysis methods

Fish

The flesh of fish was analyzed to measure concentrations of several metals. Fish were only analyzed individually to measure mercury concentrations. All of the other analyses were conducted on composite samples of flesh from several fish of the same species and the same size class at a given sampling site. The concentrations are expressed in wet weight (mg/kg).

- Mercury (method used from 1998 up to and including 2004)

Biological tissues are mineralized using HNO_3 and H_2SO_4 solutions concentrated in a BD-40 block digester at a temperature ranging from 60°C to 90°C for two hours. A $KMnO_4$ solution (6%) is added to the cooled solution until the pink colouring persists. After resting overnight at ambient temperature, $(NH_2OH)_2.H_2SO_4$ (6%) is added until the MnO_2 dissolves. The supernatant is analyzed by adding a reducing solution consisting of sulfuric acid, NaCl, $(NH_2OH)_2.H_2SO_4$ and $SnSO_4$, then a stream of nitrogen draws the mercury out of the solution. Flameless atomic absorption spectrophotometry is used to ascertain the quantity of mercury by measuring absorbance at a wavelength of 254 nm. The minimum detectable limit of the method is 0.01 mg/kg in wet weight. Accuracy was 93% at a concentration of 0.28 mg/kg and 113% at a concentration of 0.47 mg/kg for biological tissues (CEAEQ, 2003a). The minimum detectable limit of the method is 0.04 mg/kg in dry weight.

- Mercury (method used from 2005 up to and including 2010)

Samples of biological tissues are broken down thermally in a furnace at a controlled temperature in the presence of oxygen. The combustion gases are then processed in a catalytic tube. Next, the mercury is amalgamated on a gold support. Following desorption by heating, the mercury is measured by UV spectrometry at 253.7 nm by means of two cells of different sensitivity placed in series. The signal is measured in each cell. The cell with the short course makes it possible to measure the high concentrations of mercury. When the absorbance in the cell with the long course (low concentration) exceeds 0.8 absorbance unit, the measurement is automatically conducted with the cell with the short course (high concentration). The minimum detectable limit is 0.01 mg/kg Hg (CEAEQ, 2011d).

- Arsenic (method used from 1998 up to and including 2004)

Biological tissues are mineralized overnight at ambient temperature using concentrated HNO_3 and a solution of $MgNO_3$ (80%). The solution is then dried on a heating plate. The residue is collected with the added HNO_3 and $MgNO_3$ until the dry residue is white or pale yellow. It is then placed in an oven at a temperature of 550°C for 12 hours. After cooling, the residue is dissolved with a solution of HCl (50%) and the solution is heated at near the boiling point for at least one hour. The arsenic is then converted to volatile hydride by making the sample react with sodium borohydride (NaBH4) in an acid medium. The arsine that is formed is then oxidized into elemental arsenic in a hot cell. The quantity of arsenic contained in the cell is determined by means of atomic absorption spectrophotometry by measuring absorbance at 193.7 nm. The minimum detectable limit for arsenic is 0.05 mg/L. Accuracy was 100% at concentrations of 14 mg/kg, 24.6 mg/kg and 18 mg/kg for reference materials NBS 1566a, TORT-1 and DORM-2, respectively (CEAEQ, 1990).

- Selenium (method used from 1998 up to and including 2004)

Biological tissues are mineralized overnight at ambient temperature using concentrated HNO_3 and a solution of $MgNO_3$ (80%). The solution is then dried on a heating plate. The residue is collected with the added HNO_3 and $MgNO_3$, then is heated until it is dry. Next, it is placed in an oven at a temperature of 550°C for 12 hours. After cooling, the residue is dissolved with a solution of HCl (50%) and the solution is heated at near the boiling point for at least one hour. This step reduces hexavalent forms of selenium to tetravalent forms. The selenium is then converted to volatile hydride by making the sample react with sodium borohydride ($NaBH_4$) in an acid medium. Lastly, the hydride that is formed is oxidized into elemental selenium in a hot cell. The quantity of selenium contained in the cell is determined by means of atomic absorption spectrophotometry by measuring absorbance at 196.0 nm. The minimum detectable limit for selenium is 0.05 mg/kg. Accuracy was 83% to 98% compared with the average certified value of 1.46 mg/kg for an MAB-3 reference material (CEAEQ, 2003b).

- Other metals (method used from 1998 up to and including 2004)

Biological tissues are dried and homogenized, then mineralized with nitric acid and hydrochloric acid in a sand bath maintained at a constant temperature of 150°C. Hydrogen peroxide is added to destroy organic matter.

The measurement is performed using an argon plasma emission spectrometer induced by radio frequency or ICP. Detection limits for wet weight samples are: 3 µg of Cd/kg, 25 µg of Cr/kg, 50 µg of Cu/kg, 25 µg of Mn/kg, 500 µg of Ni/kg, 100 µg of Pb/kg, 12 µg of Sr/kg and 25 µg of Zn/kg. Detection limits for dry weight are: 2 mg of Ba/kg, 15 µg of Cd/kg, 200 µg of Co/kg, 100 µg of Cr/kg, 200 µg of Cu/kg, 100 µg of Mn/kg, 115 µg of Ni/kg, 300 µg of Pb/kg, 50 µg of Sr/kg, 400 µg of V/kg and 100 µg of Zn/kg. Accuracy is: 98% Cd, 91% Cr, 89% Cu, 90% Mn, 83% Ni, 97% Pb, 96% Sr and 86% Zn (CEAEQ, 2003c).

- Metals and non-metals (method used from 2005 up to and including 2010)

Metal concentrations in biological tissues are determined by inductively-coupled plasma mass spectrometry (ICP-MS) after digestion with nitric acid and hydrochloric acid. The sample is first dried and homogenized. It is then mineralized using nitric acid and hydrochloric acid in a block digester.

Measurement is then performed using an inductively-coupled plasma mass spectrometer (ICP-MS). The sample is drawn into an argon plasma by means of a peristaltic pump and a nebulizer. The metals in the sample are atomized and ionized in the plasma. The ions produced are then introduced into the mass spectrometry chamber, where they are guided by a charged ion lens to a quadrupole, where the ionized metals will be separated according to their mass-to-charge ratio.

The concentration of an element with a specific mass is determined by comparison with the quantities of ions captured in the sample in the standard solutions. The findings are reported in wet weight. The minimum detectable limit of the method for each element is indicated in the following table (CEAEQ, 2008b).

Minimum detectable limit of the method:

Élément	LDM (mg/kg)*	Élément	LDM (mg/kg)*	Élément	LDM (mg/kg)*
As	0,02	Cu	0,02	Pb	0,0005
Ba	0,001	Fe	0,2	Se	0,05
Cd	0,009	Mn	0,004	Sr	0,005
Co	0,0006	Mo	0,0006	V	0,04
Cr	0,003	Ni	0,005	Zn	0,06

* Dry weight.

3.4 Methods to determine the age of fish

The age of yellow walleye and lake trout was determined by means of statoconia. The age of northern pike was determined by cleithrum assessment.

3.5 Comparison criteria respecting water and fish

Metal concentrations in water were compared with the MDDEP's criteria (MDDEP, 2009). The criteria for the protection of aquatic life ("chronic effect" and "acute toxicity") were used to assess the potential presence of toxicity for aquatic organisms.

In the case of fish, metal concentrations were compared to Health Canada guidelines for the sale of fishery products (Canadian Food Inspection Agency, 2011), i.e. 0.5 mg/kg for mercury and 3.5 mg/kg for arsenic. No guideline has been establish for selenium. Mercury concentrations were also compared with the criteria respecting the protection of piscivorous terrestrial fauna (birds and mammals), which is 0.033 mg/kg (Canadian Council of Ministers of the Environment, 2000).

3.6 Statistical analysis

3.6.1 Fish

Mercury concentrations were compared in yellow walleye, northern pike and lake trout caught at different sites by means of parametric covariance analyses using age as a covariable. Prior to the parametric analyses, mercury concentrations were transformed according to $\log_{10}$ (Hg +1) to reduce variance. The parametric analyses were used to determine the average adjusted mercury concentrations (after the antilogarithm was calculated), according to the average age of each fish population included in the statistical analysis.

The statistical analysis focused on the full data set for a given species in order to compare mercury concentrations for the same average age of fish populations in each of the lakes. It was not possible to obtain the equality of slopes for all relationships. The average mercury concentrations were determined according to individual regression lines.

For a given species, the length and weight of the fish caught at different sites were compared by means of parametric covariance analyses, using age as a covariable. The parametric analyses were used to determine the average adjusted lengths and average adjusted weights according to the average age of each fish population included in the statistical analysis.

The statistical analyses of length and weight according to age were used to determine whether the growth rate of a given fish species was similar from one site to the next, to ensure that, for a given average age, the fish displayed the same average lengths and weights. When significant differences were noted between the sites, this factor was highlighted as a variable that might explain existing differences between mercury concentrations at the different sites compared.

Statistical analyses were conducted on northern pike (400-575 mm), yellow walleye (300-600 mm) and lake trout (395-750 mm). The statistical analyses focused on limited size classes to allow for the comparison of similar samples. Accordingly, the biggest[1] and the oldest fish were excluded from the statistical analyses. In the same perspective, only specimens of yellow walleye and lake trout 17 years of age or under were considered.

The findings of the statistical analyses were deemed to be different when probability fell below 0.05 ($P < 0.05$).

[1] The biggest and oldest fish display striking age differences for a given size, which reduces the ability of the statistical analyses to detect significant differences between the groups compared.

4 FINDINGS

4.1 Water

4.1.2 Metals

Water samples were collected in lakes in the Chibougamau and Oujé-Bougoumou region from June 10 to 12, 2008 (25 samples) and from June 18 to July 8, 2008 in watercourses near Cree fishing camps. They were drawn in areas located near and far from mining operations (Figure 4). For the two sampling periods, the total fraction (total extractible metals) was analyzed in respect of several metals to determine whether their concentrations are likely to pose a threat to aquatic organisms. The filtered (dissolved) fraction was also analyzed for the period from June 10 to 12, 2008. Appendix 5 presents the findings.

In water, the toxicity criteria pertaining to several metals vary depending on water hardness. The data collected in 2008 reveal that at all of the sites sampled the concentrations of all of the metals and non-metals fall below the chronic effects criteria for the protection of aquatic organisms (Table 1 and Table 2). The criteria were calculated for water hardness of 30 mg/L of $CaCO_3$, which is the average hardness of the water in Lac aux Dorés and Lac Chibougamau (Appendix 3). It should be noted that the average water hardness in the Obatogamau lakes is 17 mg/L and provides slightly weaker criteria. By way of an example, the criterion for copper is 2.1 µg/L in the Obatogamau lakes, compared with 3.3 µg/L in Lac aux Dorés and Lac Chibougamau. Despite a weaker criterion, copper concentrations in the Obatogamau lakes fall below this level, which is also true of all of the metals.

Consequently, the concentrations of all metals and non-metal sought in the water are not deemed to be likely to pose a threat to aquatic organisms. The concentrations of metals measured in the water also fall below the criteria respecting drinking water and are not deemed to pose a threat to human health.

4.1.2 Cyanide

The total cyanide concentrations measured in the water were below the minimum detectable limit of 4 µg/L at all of the sites.

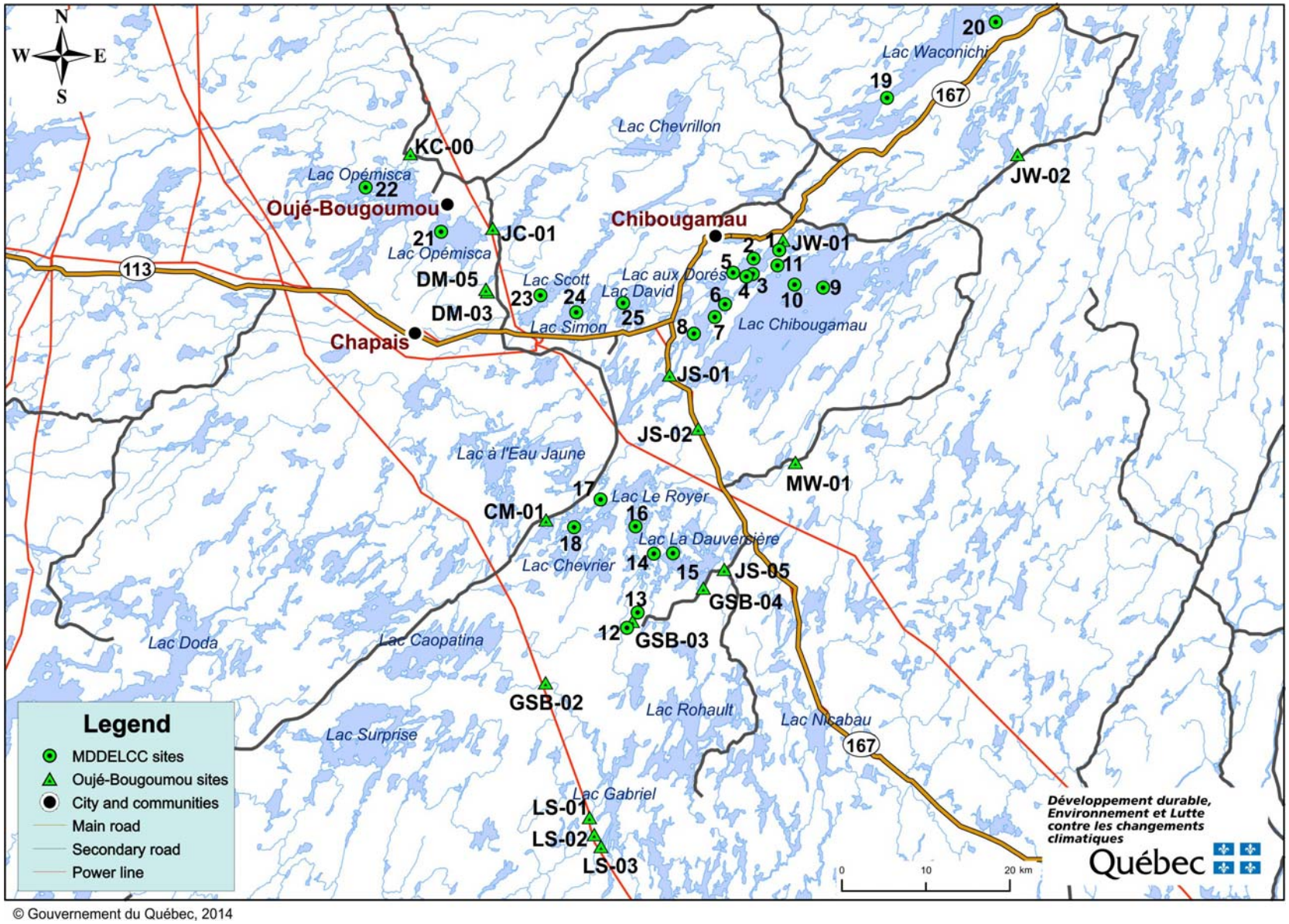


Figure 4 Location of water sampling sites in the Chibougamau and Oujé-Bougoumou region in 2008

Table 1 Concentration of the elements in <u>unfiltered</u> water samples from lakes in the Chibougamau and Oujé-Bougoumou region in 2008

N°	Site	Al µg/l	As µg/l	B µg/l	Ba µg/l	Br µg/l	Co µg/l	Cr µg/l	Cu µg/l	Fe µg/l	Mn µg/l	Mo µg/l	Ni µg/l	Si µg/l	Sr µg/l	U µg/l	V µg/l
	Median	19	0,21	2,0	3,6	6,4	0,027	0,17	1,2	34	4,7	0,11	0,38	0,85	12	0,016	0,08
	MDDELCC chronic effect guideline[1]	87	150	5 000	122		100	11	3,3	1 300	670	3 200	19		21 000	14	12
	MDDELCC acute toxicity guideline[1]	750	340	28 000	347		370	16	4,5	3 400	1 446	29 000	169		40 000	320	110
	LAC AUX DORÉS																
1	Rainbow Lodge, west	16	0,21	2,0	3,7	6,4	0,021	0,21	1,3	21	3,0	0,13	0,46	0,83	11	0,013	0,07
2	Pointe Est de la baie Cedar, west	18	0,22	2,0	3,4	8,3	0,046	0,17	2,2	18	3,2	0,17	0,45	0,80	12	0,016	0,07
3	Parc Copper Rand, north	14	0,23	2,1	3,4	8,4	0,050	0,17	2,2	18	3,4	0,19	0,46	0,79	13	0,017	0,07
4*	Île Lefebvre, northest	10	0,22	2,3	3,3	9,8	0,051	0,16	2,2	16	3,2	0,21	0,43	0,79	13	0,015	0,07
5	Mine Principale, north	11	0,23	2,1	3,3	9,2	0,064	0,16	2,6	20	3,2	0,21	0,46	0,78	13	0,017	0,10
6	Baie Ballicky, north	11	0,25	2,2	3,3	9,5	0,270	0,17	3,0	30	4,9	0,21	0,84	0,73	14	0,019	0,07
7	Baie Ballicky, southwest	16	0,25	2,2	3,3	8,9	0,230	0,14	2,8	30	4,2	0,20	0,80	0,75	13	0,018	0,06
8	Baie Malouf	20	0,26	2,1	3,3	8,7	0,240	0,15	2,9	37	4,5	0,19	0,83	0,73	13	0,018	0,06
	LAC CHIBOUGAMAU																
9	Île Lookout, east	12	0,17	1,9	3,2	5,9	0,027	0,15	1,0	20	2,7	0,10	0,35	0,80	10	0,011	0,06
10	Île Mermaid, north	15	0,16	1,9	3,3	6,2	0,016	0,16	1,1	22	2,8	0,11	0,37	0,83	10	0,012	0,06
11	Parc Eaton Bay, downstream	13	0,19	1,8	3,5	6,5	0,015	0,18	1,2	21	3,0	0,12	0,39	0,87	10	0,012	0,06
	LACS OBATOGAMAU																
12	Rivière Nemenjiche, upstream mine	80	0,21	1,7	5,4	4,3	0,047	0,25	0,3	189	26	0,04	0,33	1,06	8	0,010	0,18
13	Rivière Nemenjiche, downstream mine	78	0,25	2,0	6,3	16	0,064	0,25	0,5	189	29	0,07	0,35	1,16	23	0,025	0,19
14	Lac La Dauversière, rivière Nemenjiche	63	0,28	1,7	5,0	8,4	0,035	0,21	1,9	129	9,2	0,06	0,40	0,96	14	0,013	0,14
15*	Lac La Dauversière, île Weaver west	48	0,16	1,4	4,2	4,5	0,016	0,16	0,5	64	6,2	0,06	0,29	1,06	7	0,009	0,08
16	Lac Le Royer	51	0,20	1,6	4,3	6,3	0,017	0,16	1,0	73	6,6	0,05	0,29	1,06	10	0,011	0,09
17	Rivière Obatogamau	48	0,19	1,6	4,0	6,3	0,019	0,17	1,1	69	6,7	0,05	0,30	0,96	10	0,010	0,09
18	Lac Fancamp, north	46	0,21	1,5	3,7	5,7	0,017	0,17	0,9	71	6,3	0,05	0,26	0,92	9	0,008	0,08
	LAC WACONICHI																
19	Lac Waconichi, lac Richardson	9	0,17	1,8	8,1	4,8	0,014	0,06	0,3	16	1,8	0,09	0,10	0,92	15	0,025	0,07
20	Lac Waconichi, near outlet	3	0,16	1,7	8,2	4,5	0,013	0,05	0,2	9	1,3	0,09	0,09	0,84	15	0,026	0,06
	LAC OPÉMISCA																
21*	Oujé-Bougoumou, 3 km south	39	0,25	2,5	4,7	5,0	0,026	0,18	1,0	89	9,0	0,10	0,30	0,85	12	0,021	0,12
22	Oujé-Bougoumou, 9,5 km west	35	0,21	2,4	4,7	6,7	0,021	0,15	0,8	84	9,2	0,09	0,30	0,96	11	0,018	0,10
23	**LAC SCOTT**	31	0,21	2,2	3,5	5,6	0,027	0,18	1,3	80	7,4	0,15	0,38	0,89	12	0,014	0,12
24	**LAC SIMON**	22	0,22	2,3	3,5	6,4	0,033	0,18	2,1	51	4,8	0,12	0,47	0,76	12	0,016	0,10

[1] Criterion respecting the quality of water aimed at protecting aquatic life (MDDEP, 2009). * Station with field blank (findings in Appendix 4).

The criteria for Ba, Cu, Mn and Ni are calculated for average water hardness of 30 mg/L of $CaCO_3$.

The values indicated for Al, Fe and Si have been corrected by subtracting the average value of the blanks (1.9 µg/L for Al, 1 µg/L for Fe and 0.04 µg/L for Si).

Table 1 (continued) Concentration of the elements in <u>unfiltered</u> water from lakes in the Chibougamau and Oujé-Bougoumou region in 2008

N°	Site	Ag µg/l	Be µg/l	Cd µg/l	CN µg/l	F mg/l	I µg/l	Li µg/l	P µg/l	Pb µg/l	Pd µg/l	Pt µg/l	Sb µg/l	Se µg/l	Sn µg/l	Tl µg/l	Zn µg/l
	Median	< 0,001	< 0,004	0,005	< 4	< 0,03	0,9	0,24	2	< 0,03	< 0,005	< 0,006	0,024	< 0,3	< 0,01	< 0,005	< 0,7
	MDDELCC chronic effect guideline[1]	0,100	0,114	0,111	5	0,2		96	10	0,69			240	5		7,2	43
	MDDELCC acute toxicity guideline[1]	0,256	1,026	0,627	22	4		870		18			1 100			47	43
	LAC AUX DORÉS																
1	Rainbow Lodge, west	< 0,001	< 0,004	0,005	< 4	< 0,03	0,9	0,17	2	< 0,03	< 0,005	< 0,006	0,025	< 0,3	< 0,01	< 0,005	< 0,7
2	Pointe Est de la baie Cedar, west	0,002	< 0,004	0,004	< 4	< 0,03	0,9	0,19	3	< 0,03	< 0,005	< 0,006	0,027	< 0,3	< 0,01	< 0,005	< 0,7
3	Parc Copper Rand, north	0,001	< 0,004	0,005	< 4	< 0,03	0,9	0,20	4	< 0,03	< 0,005	< 0,006	0,027	< 0,3	< 0,01	< 0,005	< 0,7
4*	Île Lefebvre, northeast	< 0,001	< 0,004	0,005	< 4	< 0,03	1,0	0,22	< 2	< 0,03	< 0,005	< 0,006	0,027	< 0,3	< 0,01	0,006	< 0,7
5	Mine Principale, north	< 0,001	< 0,004	0,006	< 4	< 0,03	1,0	0,19	2	< 0,03	< 0,005	< 0,006	0,027	< 0,3	< 0,01	< 0,005	< 0,7
6	Baie Ballicky, north	< 0,001	< 0,004	0,007	< 4	0,25	0,9	0,21	< 2	< 0,03	< 0,005	< 0,006	0,027	< 0,3	< 0,01	< 0,005	< 0,7
7	Baie Ballicky, southwest	0,001	< 0,004	0,007	< 4	< 0,03	0,9	0,21	2	< 0,03	< 0,005	< 0,006	0,027	< 0,3	< 0,01	< 0,005	< 0,7
8	Baie Malouf	< 0,001	< 0,004	0,006	< 4	< 0,03	0,9	0,21	2	< 0,03	< 0,005	< 0,006	0,027	< 0,3	< 0,01	< 0,005	< 0,7
	LAC CHIBOUGAMAU																
9	Île Lookout, east	0,002	< 0,004	0,004	< 4	< 0,03	0,9	0,18	< 2	< 0,03	< 0,005	< 0,006	0,023	< 0,3	< 0,01	< 0,005	< 0,7
10	Île Mermaid, north	< 0,001	< 0,004	< 0,004	< 4	< 0,03	0,9	0,18	< 2	< 0,03	< 0,005	< 0,006	0,023	< 0,3	< 0,01	< 0,005	< 0,7
11	Parc Eaton Bay, downstream	0,007	< 0,004	0,005	< 4	< 0,03	1,0	0,19	< 2	< 0,03	< 0,005	< 0,006	0,025	< 0,3	< 0,01	< 0,005	< 0,7
	LACS OBATOGAMAU																
12	Rivière Nemenjiche, upstream mine	0,002	< 0,004	0,008	< 4	< 0,03	0,9	0,27	4	0,09	< 0,005	< 0,006	0,020	< 0,3	< 0,01	< 0,005	< 0,7
13	Rivière Nemenjiche, downstream mine	0,001	0,005	0,008	< 4	< 0,03	0,9	0,32	4	0,08	< 0,005	< 0,006	0,021	< 0,3	< 0,01	< 0,005	< 0,7
14	Lac La Dauversière, rivière Nemenjiche	0,001	0,004	0,005	< 4	< 0,03	0,7	0,29	3	0,08	< 0,005	< 0,006	0,022	< 0,3	< 0,01	< 0,005	< 0,7
15*	Lac La Dauversière, île Weaver west	< 0,001	< 0,004	0,004	< 4	< 0,03	0,8	0,31	2	0,04	< 0,005	< 0,006	0,022	< 0,3	< 0,01	< 0,005	< 0,7
16	Lac Le Royer	0,001	0,006	0,004	< 4	< 0,03	0,8	0,29	2	0,05	< 0,005	< 0,006	0,021	< 0,3	< 0,01	< 0,005	< 0,7
17	Rivière Obatogamau	0,001	0,004	0,005	< 4	< 0,03	0,7	0,25	3	0,06	< 0,005	< 0,006	0,024	< 0,3	< 0,01	< 0,005	< 0,7
18	Lac Fancamp, north	< 0,001	0,005	0,006	< 4	< 0,03	0,8	0,24	3	0,05	< 0,005	< 0,006	0,023	< 0,3	< 0,01	< 0,005	< 0,7
	LAC WACONICHI																
19	Lac Waconichi, lac Richardson	< 0,001	0,005	< 0,004	< 4	< 0,03	0,8	0,29	< 2	< 0,03	< 0,005	< 0,006	0,021	< 0,3	< 0,01	< 0,005	< 0,7
20	Lac Waconichi, near outlet	< 0,001	< 0,004	< 0,004	< 4	0,04	0,8	0,28	< 2	< 0,03	< 0,005	< 0,006	0,021	< 0,3	< 0,01	< 0,005	< 0,7
	LAC OPÉMISCA																
21*	Oujé-Bougoumou, 3 km south	0,001	< 0,004	0,006	< 4	< 0,03	0,7	0,26	< 2	0,06	< 0,005	< 0,006	0,021	< 0,3	< 0,01	< 0,005	< 0,7
22	Oujé-Bougoumou, 9,5 km west	< 0,001	< 0,004	0,006	< 4	< 0,03	0,7	0,24	4	0,06	< 0,005	< 0,006	0,030	< 0,3	< 0,01	< 0,005	< 0,7
23	**LAC SCOTT**	< 0,001	< 0,004	0,007	< 4	< 0,03	0,9	0,25	3	0,06	< 0,005	< 0,006	0,024	< 0,3	< 0,01	< 0,005	< 0,7
24	**LAC SIMON**	< 0,001	< 0,004	0,008	< 4	0,05	1,0	0,23	6	0,04	< 0,005	< 0,006	0,027	< 0,3	< 0,01	0,005	< 0,7

[1] Criterion respecting the quality of water aimed at protecting aquatic life (MDDEP, 2009). * Station with field blank (findings in Appendix 4).

The criteria for Be, Cd, Pb and Zn are calculated for average water hardness of 30 mg/L of $CaCO_3$.

Table 2 Concentration of the elements in <u>unfiltered</u> water samples collected near Cree fishing camps in 2008

N°	Site	Al µg/l	As µg/l	Co µg/l	Cr µg/l	Cu µg/l	Fe µg/l	Mn µg/l	Mo µg/l	Ni µg/l	Sr µg/l	U µg/l	V µg/l
	Median	70	0,29	0,07	0,26	0,69	155	20	0,093	0,59	13	0,019	0,18
	MDDELCC chronic effect guideline[1]	87	150	100	11	3,3	1 300	670	3 200	19	8 300	14	12
	MDDELCC acute toxicity guideline[1]	750	340	370	16	4,5	3 500	1 446	29 000	169	75 000	320	110
	MDDELCC drinking water guideline		25			1 000							20
GSB-02	Rivière Opawica	130	0,23	0,100	0,31	0,41	210	21	0,038	0,53	10	0,013	0,27
GSB-03	Rivière Nemenjiche	18	0,21	0,180	0,29	1,30	40	23	0,120	1,40	13	0,014	0,08
GSB-04	Brook south lac La Dauversière	90	0,20	0,069	0,23	0,97	140	13	0,057	0,54	8,1	0,011	0,14
LS-01	Rivière Cawcot – lac Gabriel	200	0,25	0,170	0,41	0,68	360	20	0,044	0,72	11	0,019	0,36
LS-02	Brook between rivière Cawcot and lac Gabriel	310	0,32	0,310	0,57	0,48	560	24	0,047	0,97	11	0,007	0,57
LS-03	Lac Gabriel	250	0,35	0,270	0,57	0,47	750	24	0,058	1,10	9,6	0,009	0,59
KC-00	Bridge rivière Opémisca	62	0,49	0,047	0,19	0,44	300	20	0,085	0,36	16	0,032	0,19
JC-01	Outlet lac Barlow	43	0,27	0,050	0,20	2,90	110	19	0,100	0,64	15	0,024	0,16
JW-01	Brook flowing into lac aux Dorés	1	0,67	0,045	0,10	4,50	4	0,2	3,600	1,60	27	0,031	0,01
JW-02	Brook southeast lac Ida	1	< 0,03	0,047	0,15	0,58	4	0,1	0,990	0,38	28	0,069	0,17
JS-01	Rivière Chibougamau, upstream lac Merrill	22	0,27	0,120	0,16	3,10	38	5,5	0,200	0,80	14	0,019	0,08
JS-02	Lac du Moulin, upstream	200	0,32	0,072	0,64	1,50	230	11	0,590	1,20	12	0,030	0,20
JS-05	Brook east lac La Dauversière	210	0,31	0,230	0,47	0,76	450	46	0,076	0,94	8,3	0,032	0,33
CM-01	Point located between the forest road and lac Chico	77	0,23	0,050	0,21	1,30	110	23	0,051	0,40	11	0,012	0,15
DM-03	Brook southeast lac Opémisca	100	0,33	0,088	0,33	0,36	170	19	0,200	0,52	13	0,015	0,23
DM-04	Ruisseau à la Loutre	33	0,52	0,056	0,19	0,70	180	26	0,390	0,46	22	0,022	0,17
DM-05	Brook southeast lac Opémisca	20	0,69	0,043	0,77	0,12	40	6	0,380	0,19	27	0,130	0,46
MW-01	Ruisseau Audet east lac Guy	8,5	0,15	0,013	< 0,04	0,28	13	7,4	0,004	0,05	1,0	< 0,001	0,04

[1] Criterion respecting the quality of water aimed at protecting aquatic life (MDDEP, 2009).

Table 2 (continued) Concentration of the elements in <u>unfiltered</u> water samples collected near Cree fishing camps in 2008

N°	Site	Ag µg/l	Be µg/l	B µg/l	Ba µg/l	Cd µg/l	Pb µg/l	Sb µg/l	Se µg/l	Zn µg/l	F mg/l
	Median	0,001	< 0,004	1,9	5,6	0,013	0,11	0,025	< 0,3	1,7	< 0,03
	MDDELCC chronic effect guideline[1]	0,100	0,114	1 900	122	0,111	0,69	240	5	43	
	MDDELCC acute toxicity guideline[1]	0,256	1,026	16 000	347	0,627	18	1 100		43	
	MDDELCC drinking water guideline			5 000	1 000	5	10	6	10		1,5
GSB-02	Rivière Opawica	0,001	< 0,004	1,7	5,5	0,015	0,18	0,024	< 0,3	1,5	
GSB-03	Rivière Nemenjiche	0,001	< 0,004	2	4,3	0,007	0,04	0,028	< 0,3	0,9	
GSB-04	Brook south lac La Dauversière	0,001	0,005	1,6	4,8	0,010	0,12	0,027	< 0,3	2,5	
LS-01	Rivière Cawcot – lac Gabriel	0,001	0,007	1,4	6,4	0,017	0,22	0,025	< 0,3	2,6	
LS-02	Brook between rivière Cawcot and lac Gabriel	0,001	0,007	1,5	7,3	0,019	0,31	0,031	< 0,3	13	
LS-03	Lac Gabriel	0,004	0,005	1,7	6,5	0,021	0,38	0,032	< 0,3	3,4	
KC-00	Bridge rivière Opémisca	0,001	0,004	2,7	6,0	0,009	0,10	0,021	< 0,3	1,3	0,05
JC-01	Outlet lac Barlow	0,001	< 0,004	2,6	5,6	0,020	0,32	0,027	< 0,3	2,7	0,07
JW-01	Brook flowing into lac aux Dorés	0,013	< 0,004	12	2,4	0,300	< 0,03	0,330	< 0,3	26	
JW-02	Brook southeast lac Ida	0,001	< 0,004	2,1	5,9	0,024	< 0,03	0,006	1,0	1,4	
JS-01	Rivière Chibougamau, upstream lac Merrill	0,001	< 0,004	2,4	3,9	0,007	0,06	0,032	< 0,3	1,4	
JS-02	Lac du Moulin, upstream	0,002	0,005	1,5	4,7	0,010	0,13	0,028	< 0,3	1,7	
JS-05	Brook east lac La Dauversière	0,001	0,009	1,5	7,2	0,014	0,15	0,025	< 0,3	1,9	
CM-01	Point located between the forest road and lac Chico	0,001	0,004	1,6	4,8	0,011	0,18	0,025	< 0,3	1,0	
DM-03	Brook southeast lac Opémisca	< 0,001	0,005	2,1	4,1	0,007	0,08	0,023	< 0,3	0,9	< 0,03
DM-04	Ruisseau à la Loutre	< 0,001	< 0,004	3,5	5,7	0,007	0,06	0,023	< 0,3	1,6	< 0,03
DM-05	Brook southeast lac Opémisca	< 0,001	< 0,004	3,2	7,4	< 0,004	< 0,03	0,010	< 0,3	< 0,7	< 0,03
MW-01	Ruisseau Audet east lac Guy	< 0,001	< 0,004	1,5	0,6	0,014	0,08	0,023	< 0,3	4,9	

[1] Criterion respecting the quality of water aimed at protecting aquatic life (MDDEP, 2009).
The criteria for Be, Cd, Pb and Zn are calculated for average water hardness of 30 mg/L of $CaCO_3$.

4.2 Flesh of adult fish

Various fish species were caught in several lakes in the Chibougamau and Oujé-Bougoumou region between 1998 and 2010. The flesh of fish was analyzed to measure concentrations of several metals. Fish were only analyzed individually to measure mercury concentrations. All of the other analyses were conducted on composite samples of flesh from several fish of the same species and the same size class at a given sampling site. The analyses sought to ascertain the regional levels of concentrations in fish flesh and evaluate levels of exposure when the fish are consumed. In the case of mercury, they also sought to statistically compare the concentrations in the sectors under study.

4.2.1 Metal concentrations in fish flesh

Generally speaking, the median concentrations for a metal vary little between fish species and, in a given species, they vary little with the size of the fish. Only mercury concentrations are an exception to this rule: they are systematically higher in piscivorous species such as yellow walleye, northern pike, lake trout and burbot than in other species and they increase with the size of the fish (Table 3).

Several of the metals sought in the flesh, i.e. arsenic, barium, cadmium, chrome, cobalt, nickel, lead and vanadium, were not detected or displayed median concentrations near the minimum detectable limit. Of these metals, only arsenic (3.5 mg/kg) and lead (0.5 mg/kg) are covered by Health Canada guidelines concerning the sale of fishery products for human consumption. The arsenic and lead concentrations measured in the flesh of fish all fall below the Health Canada guidelines (Table 3).

What is more, the median concentrations of six metals in fish flesh, i.e. copper, manganese, mercury, selenium, strontium and zinc, exceeded 0.1 mg/kg. Of the metals, only mercury is covered by a Health Canada guideline (0.5 mg/kg) governing the sale of fishery products. Consequently, only mercury concentrations will be discussed.

The concentrations itemized of the different metals by site and species are presented in appendices 6 to 22.

Table 3 Median metal concentrations in fish flesh in lakes in the Chibougamau region (1998-2010)

Species	Arsenic			Barium			Cadmium			Cobalt			Chromium			Copper			Mercury		
	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Yellow walleye	0,06	0,03	0,05	0,007	0,006	<0,5	<0,009	<0,009	<0,009	0,002	0,004	<0,05	0,01	0,02	0,07	0,22	0,22	0,24	0,35	0,48	0,83
Northern pike	0,06	0,05	0,05	0,020	0,012	<0,5	<0,009	<0,009	<0,009	0,003	0,006	< 0,05	0,01	0,10	0,06	0,26	0,24	0,26	0,27	0,49	0,79
Burbot	0,09	0,07	0,05	0,070	0,065	<0,5	<0,009	<0,009	<0,009	< 0,05	< 0,05	< 0,05	0,04	0,06	0,06	0,32	0,25	0,22	0,31	0,37	0,48
Lake trout	0,04	0,06	0,07	0,004	0,008	0,010	<0,009	<0,009	<0,009	0,007	0,008	0,009	0,12	0,09	0,08	0,38	0,42	0,40	0,35	0,65	1,01
Lake herring	0,08	0,07	0,09	0,030	0,029	< 0,5	<0,009	<0,009	<0,009	0,003	< 0,05	< 0,05	0,030	0,080	0,031	0,35	0,28	0,33	0,15	0,19	0,20
Lake whitefish	0,08	0,07	0,06	0,009	0,007	< 0,5	<0,009	<0,009	<0,009	0,005	0,017	< 0,05	0,005	0,060	0,052	0,21	0,25	0,24	0,07	0,09	0,15
White sucker	0,06	0,05	< 0,05	0,040	0,037	< 0,5	<0,009	<0,009	<0,009	0,003	0,007	< 0,05	0,010	0,059	<0,03	0,27	0,26	0,31	0,07	0,07	0,19
Northern sucker	0,09	0,10	0,05	< 0,5	< 0,5	< 0,5	0,020	0,011	<0,009	< 0,05	< 0,05	< 0,05	0,07	0,08	0,02	0,29	0,27	0,36	0,12	0,16	0,30
Yellow perch	0,04	0,05	0,06	0,028	0,028		<0,009	<0,009		0,004	0,004		0,09	0,09		0,12	0,12		0,11	0,18	0,19
Minimum	**0,04**	**0,03**	**0,05**	**0,004**	**0,006**	**0,010**	**<0,009**	**<0,009**	**<0,009**	**0,002**	**0,004**	**0,009**	**0,01**	**0,02**	**0,02**	**0,12**	**0,12**	**0,22**	**0,07**	**0,07**	**0,15**
Maximum	**0,09**	**0,10**	**0,09**	**0,070**	**0,065**	**<0,5**	**0,020**	**0,011**	**<0,009**	**<0,05**	**<0,05**	**<0,05**	**0,12**	**0,10**	**0,08**	**0,38**	**0,42**	**0,40**	**0,35**	**0,65**	**1,01**

Species	Manganese			Nickel			Lead			Selenium			Strontium			Vanadium			Zinc		
	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Yellow walleye	0,09	0,09	0,06	0,01	0,04	<0,5	0,004	0,004	<0,1	0,33	0,38	0,37	0,03	0,03	0,03	<0,04	<0,04	<0,1	4,3	4,0	4,2
Northern pike	0,26	0,15	0,12	0,01	0,08	0,10	0,005	0,006	< 0,1	0,32	0,37	0,36	0,11	0,09	0,08	<0,04	<0,04	< 0,1	4,7	4,1	4,2
Burbot	0,23	0,18	0,13	< 0,2	< 0,2	< 0,2	< 0,1	< 0,1	< 0,1	0,29	0,27	0,27	0,10	0,10	0,07	<0,04	<0,04	<0,04	5,9	5,1	5,8
Lake trout	0,12	0,09	0,08	0,07	0,07	0,08	0,003	0,016	0,035	0,34	0,36	0,50	0,03	0,05	0,04	<0,04	<0,04	<0,04	3,4	3,4	3,4
Lake herring	0,25	0,27	0,23	0,008	0,085	< 0,2	0,007	0,005	0,029	0,28	0,41	0,45	0,19	0,21	0,13	< 0,04	< 0,04	< 0,04	5,6	5,9	4,4
Lake whitefish	0,13	0,13	0,11	0,006	0,033	< 0,2	0,005	0,006	< 0,1	0,42	0,50	0,51	0,14	0,07	0,08	<0,04	<0,04	<0,04	3,3	3,2	3,2
White sucker	0,32	0,32	0,39	<0,005	< 0,2	< 0,2	0,004	0,005	< 0,1	0,34	0,42	0,44	0,15	0,12	0,20	<0,04	<0,04	<0,1	3,3	3,1	3,3
Northern sucker	1,00	0,65	1,40	< 0,2	< 0,2	< 0,2	< 0,1	< 0,1	< 0,1	0,29	0,41	0,41	0,22	0,14	0,26	< 0,1	< 0,1	< 0,1	3,3	3,6	3,8
Yellow perch	0,59	0,61		0,009	0,012		0,01	0,007		0,53	0,47	0,25	0,21	0,27		<0,04	<0,04		4,2	4,5	
Minimum	**0,09**	**0,09**	**0,06**	**<0,005**	**0,01**	**0,08**	**0,003**	**0,004**	**0,029**	**0,28**	**0,27**	**0,25**	**0,03**	**0,03**	**0,03**	**<0,04**	**<0,04**	**<0,04**	**3,25**	**3,10**	**3,20**
Maximum	**1,00**	**0,65**	**1,40**	**0,07**	**<0,2**	**<0,5**	**<0,1**	**<0,1**	**<0,1**	**0,53**	**0,50**	**0,51**	**0,22**	**0,27**	**0,26**	**<0,1**	**<0,1**	**<0,1**	**5,90**	**5,85**	**5,80**

Yellow walleye : Petit : 30-40 cm; Moyen : 40-50 cm; Gros :>50 cm
Northern pike : Petit : 40-55 cm; Moyen : 55-70 cm; Gros : >70 cm
Burbot : Petit : 30-45 cm; Moyen : 45-60 cm; Gros : >60 cm
Lake trout : Petit : 45-55 cm; Moyen : 55-70 cm; Gros : >70 cm
Lake herring : Petit : 20-25 cm; Moyen : 25-30 cm; Gros : >30 cm
Lake whitefish : Petit : 35-40 cm; Moyen : 40-45 cm; Gros : >45 cm
White sucker : Petit : 30-35 cm; Moyen : 35-40 cm; Gros : >40 cm
Northern sucker : Petit : 30-35 cm; Moyen : 35-40 cm; Gros : >40 cm
Yellow perch : Petit : 15-20 cm; Moyen : 20-25 cm; Gros : >25 cm

4.2.2 Mercury concentrations in fish flesh

Among the metals sought, only mercury displays concentrations likely to pose a threat for human consumption or to piscivorous terrestrial fauna.

However, in the Chibougamau and Oujé-Bougoumou region, the median mercury concentrations according to the size classes of the different species (Table 3) are, in absolute value, lower than the average provincial concentrations (Table 4). Mercury concentrations in fish in the Chibougamau and Oujé-Bougoumou region are not abnormal but reflect widespread mercury contamination throughout Québec's territory (figures 5 up to and including 13).

Table 4 Average provincial mercury concentrations in fish according to the size class of species

Species	Provincial average for mercury			Size category		
	Small (mg/kg)	Medium (mg/kg)	Large (mg/kg)	Small (cm)	Medium (cm)	Large (cm)
Lake herring	0,21	0,17	0,22	20-25	25-30	>30
Yellow Walleye	0,50	**0,75**	**1,21**	30-40	40-50	>50
Northern pike	0,40	**0,64**	**1,08**	40-55	55-70	>70
Lake whitefish	0,18	0,20	0,28	35-40	40-45	>45
Burbot	0,38	**0,54**	**0,81**	30-45	45-60	>60
White sucker	0,17	0,22	0,32	30-35	35-40	>40
Northern sucker	0,17	0,22	0,32	30-35	35-40	>40
Lake trout	0,48	**0,75**	**1,24**	45-55	55-70	>70

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.
Source: Laliberté, 2004b.

The highest median mercury concentrations are observed in large fish of three piscivorous species, i.e. lake trout (1.01 mg/kg), yellow walleye (0.83 mg/kg) and northern pike (0.79 mg/kg) (Table 3). Medium and large fish of these species frequently display mercury concentrations that exceed the Health Canada guideline for the sale of fishery products (0.5 mg/kg). None of the mercury concentrations in small lake trout exceed 0.5 mg/kg. On the other hand, 66.7% of the average concentrations measured in medium fish and 93.3% of those observed in large fish exceed the guideline. Some 11.4% of the average mercury concentrations observed in small yellow walleye exceed the guideline, compared with 45.7% and 83.3% for medium and large fish, respectively. Some 0% of the average mercury concentrations noted in small northern pike exceed the guideline, as against 47.1% and 87.9% for medium and large fish, respectively. Yellow walleye and northern pike display similar levels of contamination, slightly below those observed in lake trout. The last species that displays mercury concentrations that exceed the guideline according to size class is burbot, with an average of 8.3% for small fish and 17.9% and 45.8% for medium and large fish, respectively (figures 5 up to and including 8). Concentrations that exceed the guideline mean that restrictions apply to the regular consumption of such species caught by sport fishermen, especially for young children, women who are planning to become or who are pregnant, and nursing mothers.

The highest average mercury concentrations were measured in large lake trout in Lac Cosnier (2.87 mg/kg), Lac Father (2.22 mg/kg) and Lac Chibougamau (1.70 mg/kg). The highest concentrations in yellow walleye were measured in Lac Gabriel (1.64 mg/kg) and Lac Father (1.48 mg/kg), while the highest concentrations in northern pike were measured in Lac Waposite (1.71 mg/kg) and Lac Gabriel (1.68 mg/kg) (figures 5, 6 and 8).

The lowest mercury concentrations were measured in yellow walleye in Lac aux Dorés, Lac Waconichi and Lac Verneuil. The average mercury concentrations in the three lakes in different size classes fell below the guideline (0.5 mg/kg). Northern pike in the first two lakes also displayed concentrations below or close to the guideline. As for lake trout, mercury concentrations exceed the guideline at all sites for large specimens. On the other hand, they fall below the guideline for medium fish at Lac Waconichi (figures 5, 6 and 8).

It should be noted that mercury concentrations in the flesh of lake herring (with the exception of one measurement), lake whitefish, white sucker, northern sucker and yellow perch all fall below the Health Canada guideline for the sale of fishery products, set at 0.5 mg/kg. The handful of brook trout and fallfish specimens collected also display concentrations that fall below the guideline. The species can thus be consumed without restriction (figures 9 up to and including 13).

The species that display mercury concentrations that exceed the guideline may, however, be consumed according to the recommendations in the *Guide de consommation du poisson de pêche sportive en eau douce* published jointly by the Ministère du Développement durable, de l'Environnement et des Parcs and the Ministère de la Santé et des Services sociaux (http://www.mddep.gouv.qc.ca/eau/guide/index.htm) or according to the recommendations of the Direction de santé publique du Nord-du-Québec.

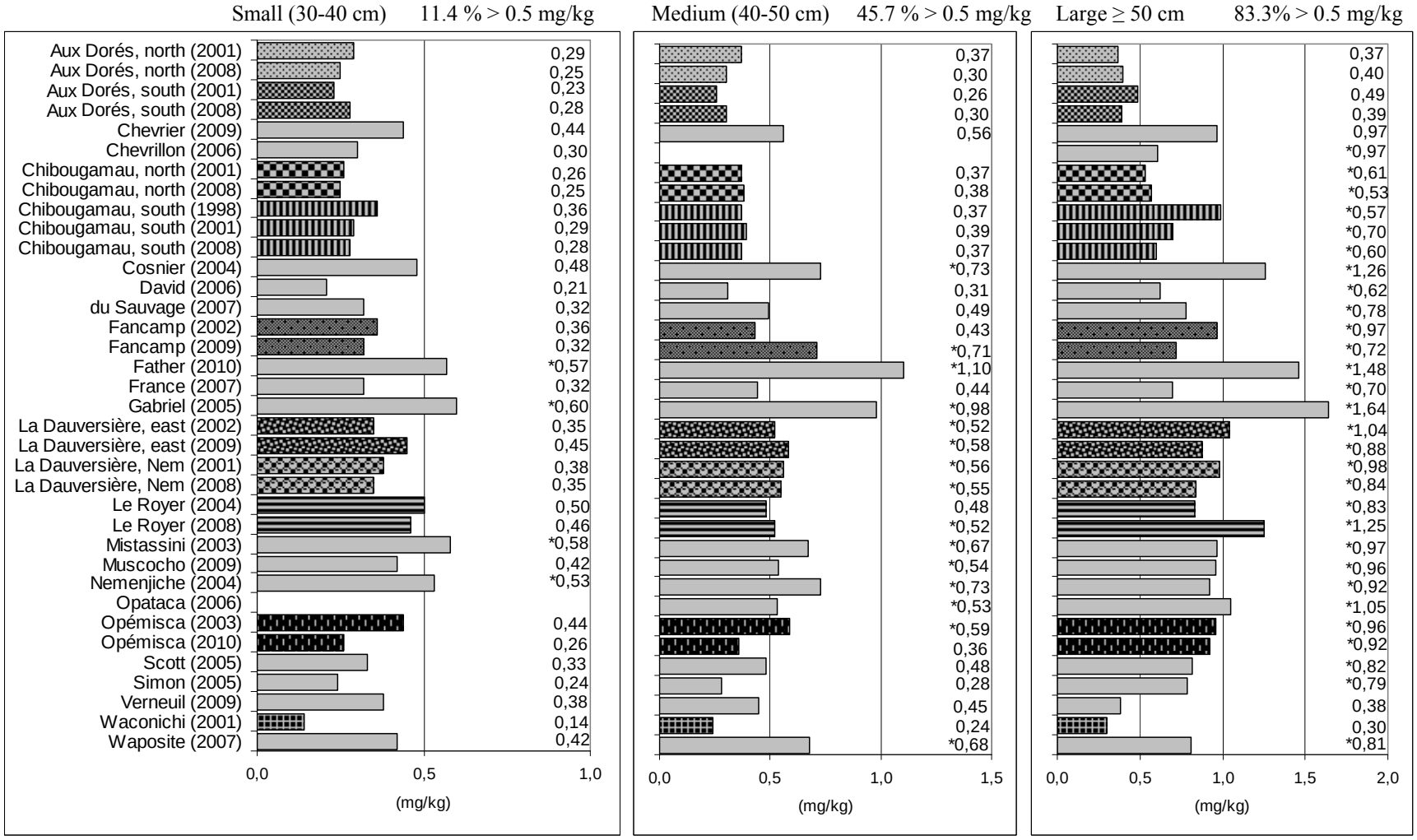
As for the protection of piscivorous terrestrial fauna (birds and mammals), all of the mercury concentrations exceed the 0.033 mg/kg criterion.

Depew *et al.* (2012) have inferred from the published findings of 20 laboratory studies on an array of fish species the threshold concentrations associated with adverse effects in fish following dietary exposure to methylmercury. Based on these concentrations, they proposed threshold concentrations that should not be exceeded in respect of different effects. The thresholds, based on wet weight are:

- 2.80 mg/kg (lethal effects);
- 1.44 mg/kg (effects on growth);
- 0.50 mg/kg (effects on behaviour);
- 0.04 mg/kg (effects on reproduction);
- 0.06 mg/kg (biochemical effects).

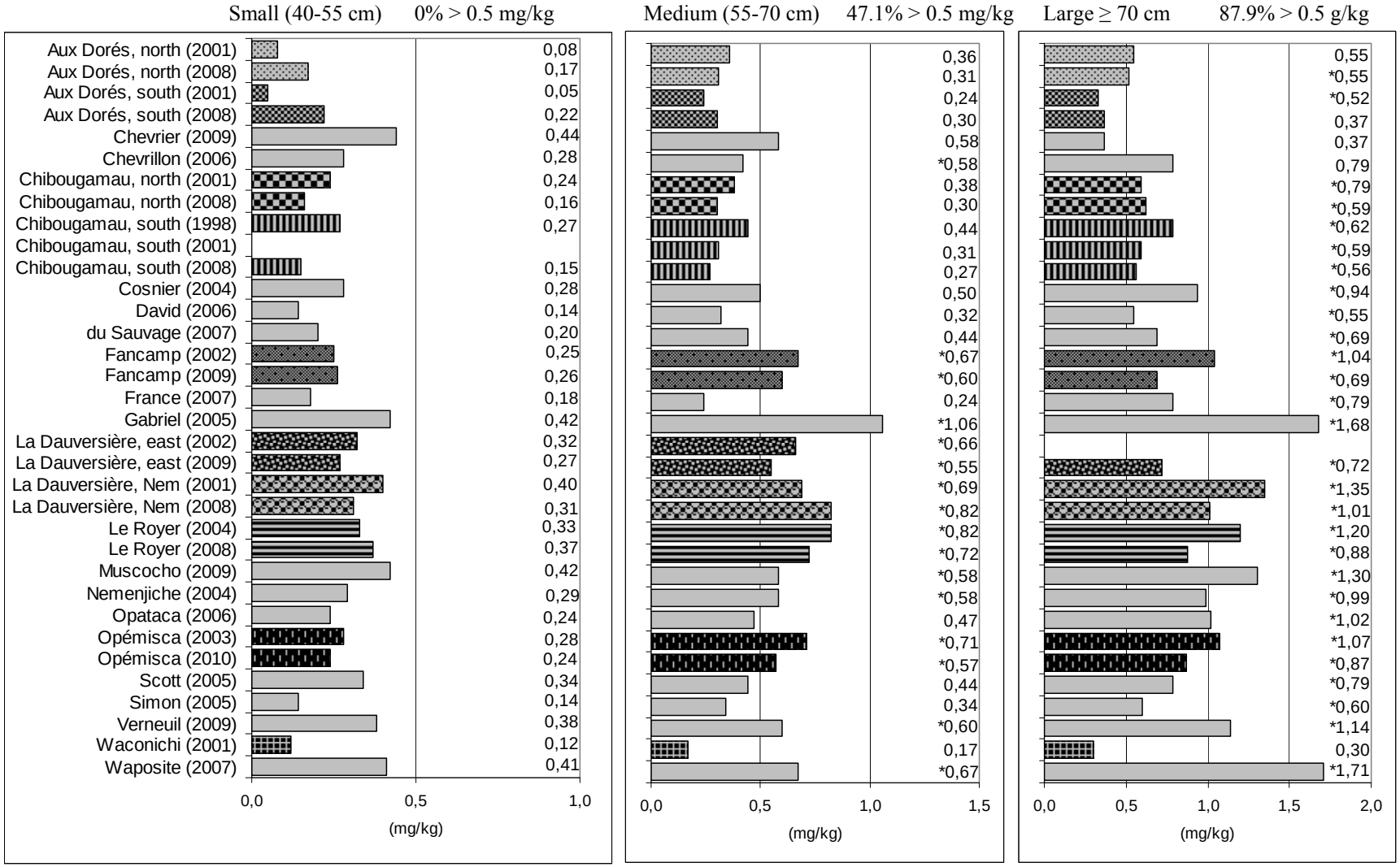
In the Chibougamau and Oujé-Bougoumou region, the median mercury concentrations measured in forage fish such as lake herring, white sucker, northern sucker, lake whitefish and yellow perch are all below the proposed thresholds concerning lethal effects and effects on growth and behaviour. On the other hand, they exceed the proposed thresholds respecting effects on reproduction and biochemical effects. The median mercury concentrations measured in small, medium and large fish of the five species range from 0.07 to 0.20 mg/kg, with one exception, i.e. large northern suckers, in which the median mercury concentration is 0.30 mg/kg. More specifically, at Lac Chibougamau, the median mercury concentrations in the five species range from 0.03 to 0.26 mg/kg (0.32 mg/kg in the case of the northern sucker). However, the mercury concentrations do not appear to have affected the reproductive success of lake trout in this lake.

In order to artificially stock lake trout, the Ministère des Ressources naturelles et de la Faune caught 76 spawners (20 males and 56 females) in Lac Chibougamau on October 8, 11 and 13, 2009 an used them for an artificial reproduction area with 73 500 eggs. Of this number, 13 500 fertilized eggs were deposited in a spawning grounds in Lac Chibougamau and 60 000 fertilized eggs were transported to the Baldwin fish farm in the Estrie region. The survival rate of the eggs on the fish farm after three months exceeded 83.7%, which is deemed to be excellent bearing in mind the transportation (Comité de direction des études menées dans la région d'Oujé-Bougoumou, April 2010).



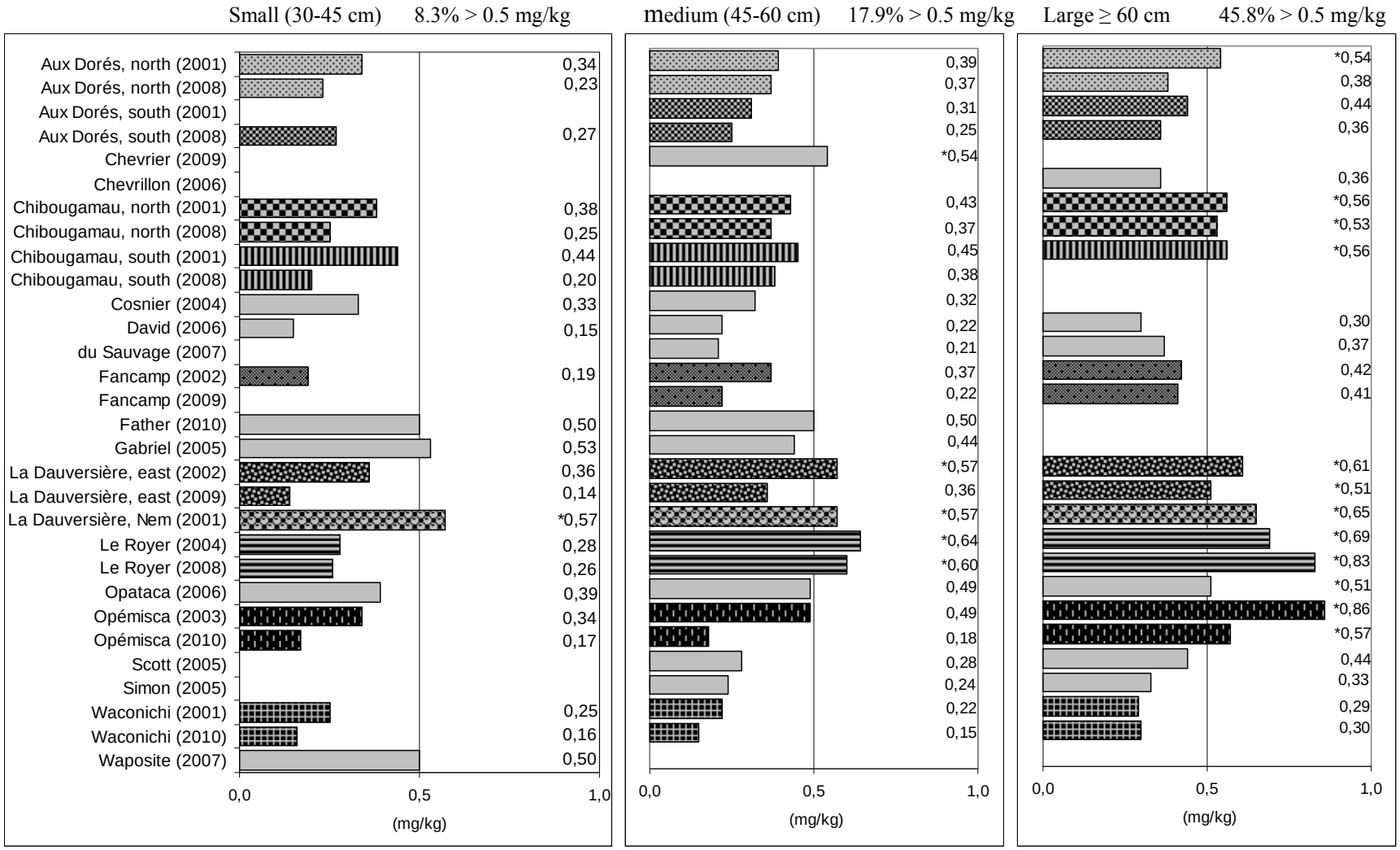
* Values that exceed the Health Canada guideline of 0.5 mg/kg.

Figure 5 Mercury concentrations in the flesh of yellow walleye in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)



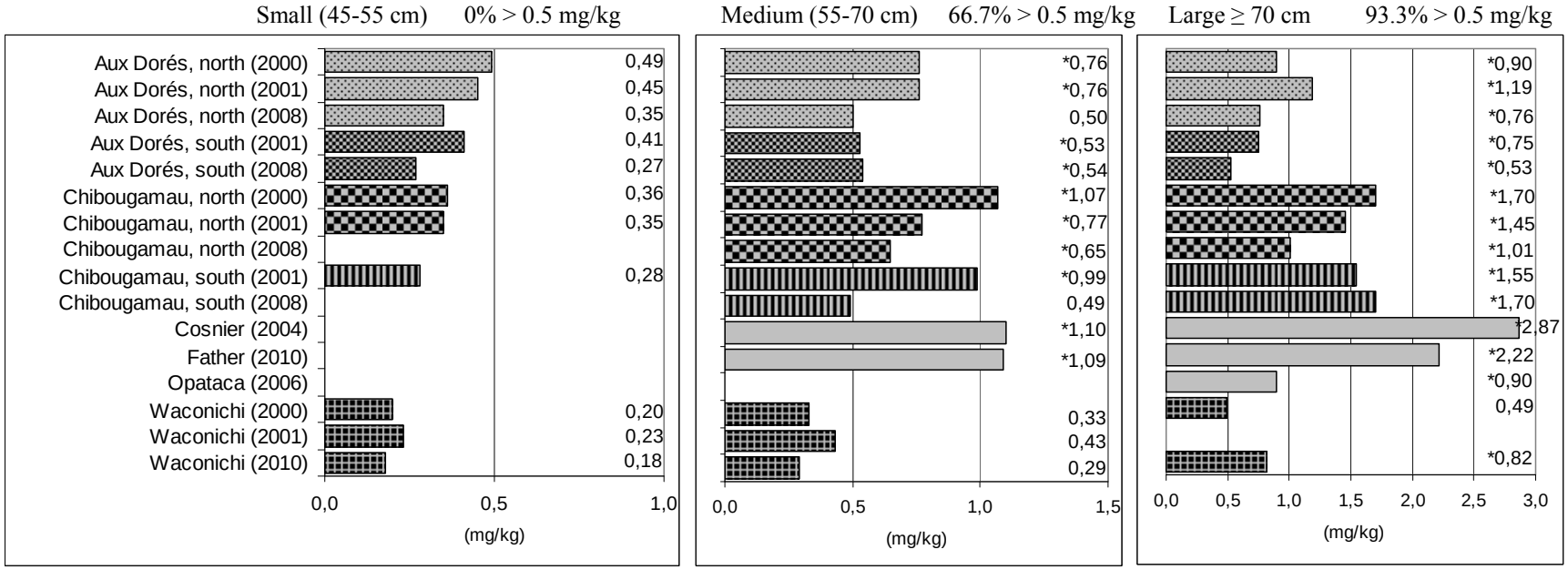
* Values that exceed the Health Canada guideline of 0.5 mg/kg.

Figure 6 Mercury concentrations in the flesh of northern pike in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)



* Values that exceed the Health Canada guideline of 0.5 mg/kg

Figure 7 Mercury concentrations in the flesh of burbot in lakes in the Chibougamau and Oujé-Bougoumou region (2001-2010)



* Values that exceed the Health Canada guideline of 0.5 mg/kg.

Figure 8 Mercury concentrations in the flesh of lake trout in lakes in the Chibougamau and Oujé-Bougoumou region (2000-2010)

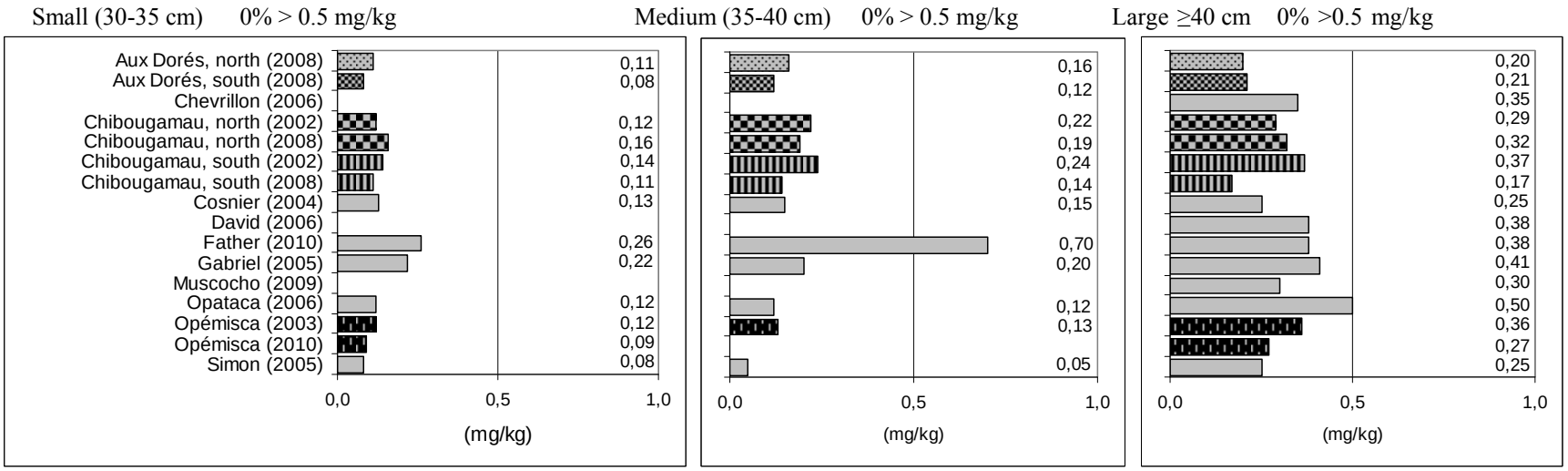
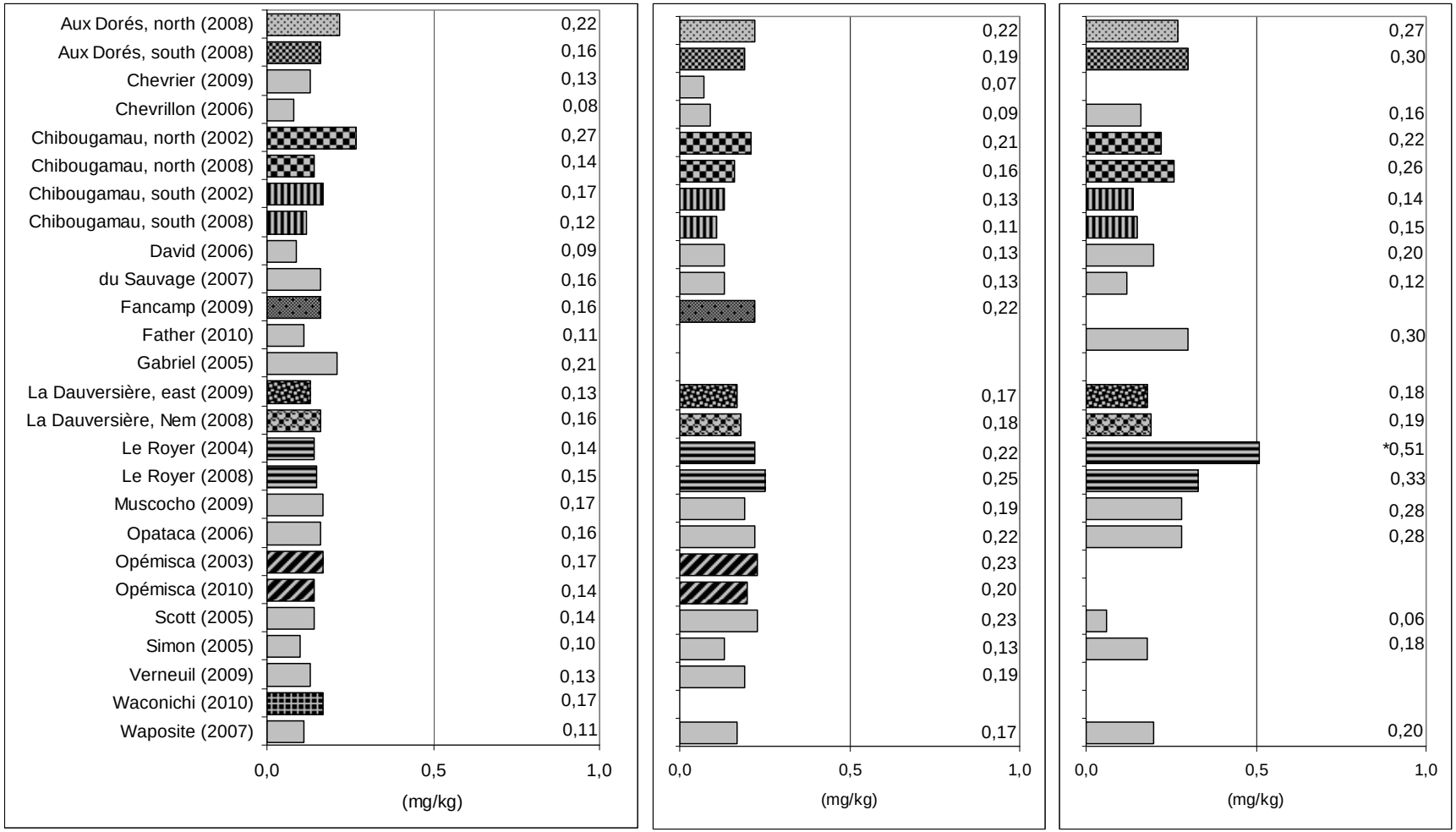


Figure 9 Mercury concentrations in the flesh of northern sucker in lakes in the Chibougamau and Oujé-Bougoumou region (2002-2010)



* Values that exceed the Health Canada guideline of 0.5 mg/kg.

Figure 10 Mercury concentrations in the flesh of lake herring in lakes in the Chibougamau and Oujé-Bougoumou region (2002-2010)

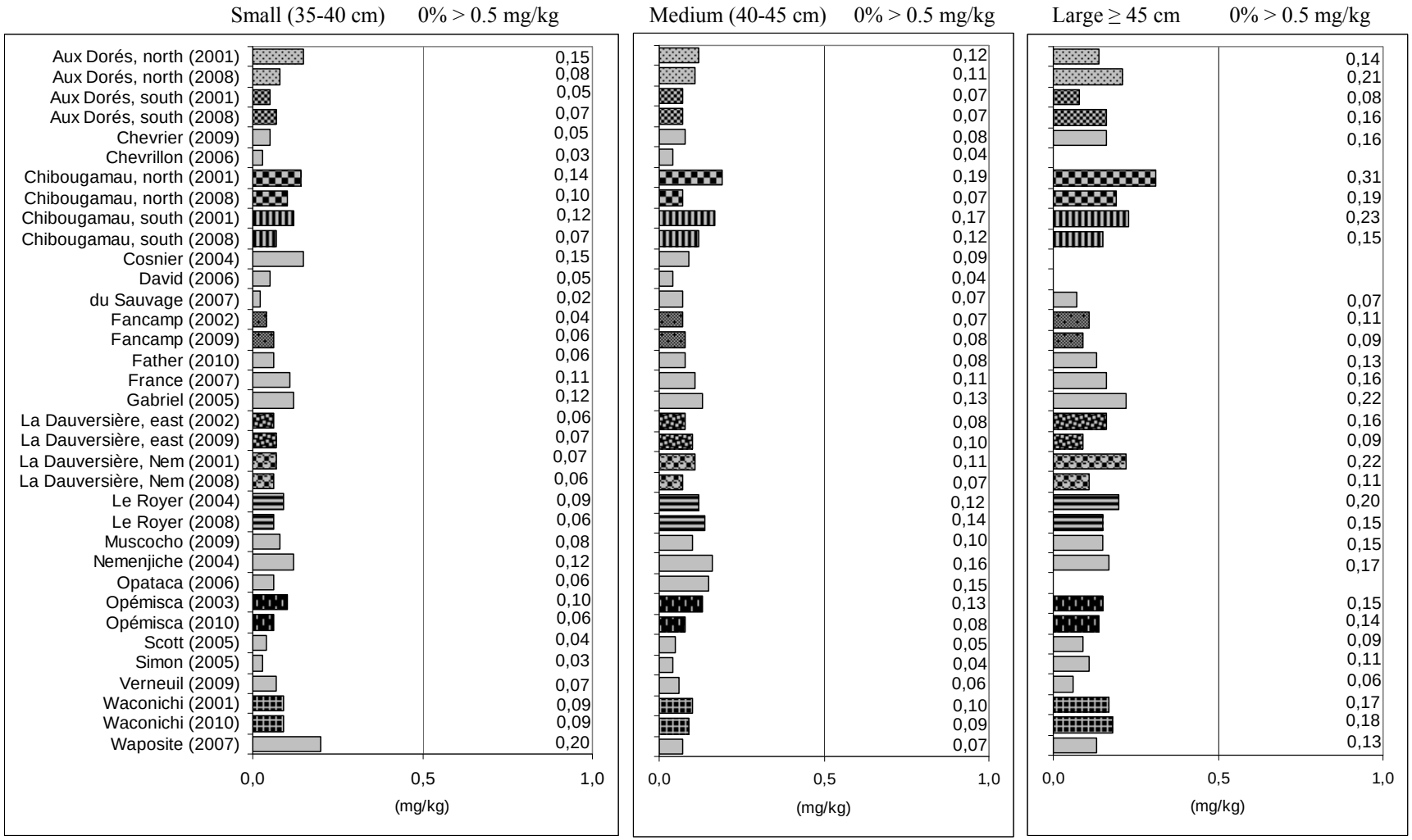


Figure 11 Mercury concentrations in the flesh of lake whitefish in lakes in the Chibougamau and Oujé-Bougoumou region (2001-2010)

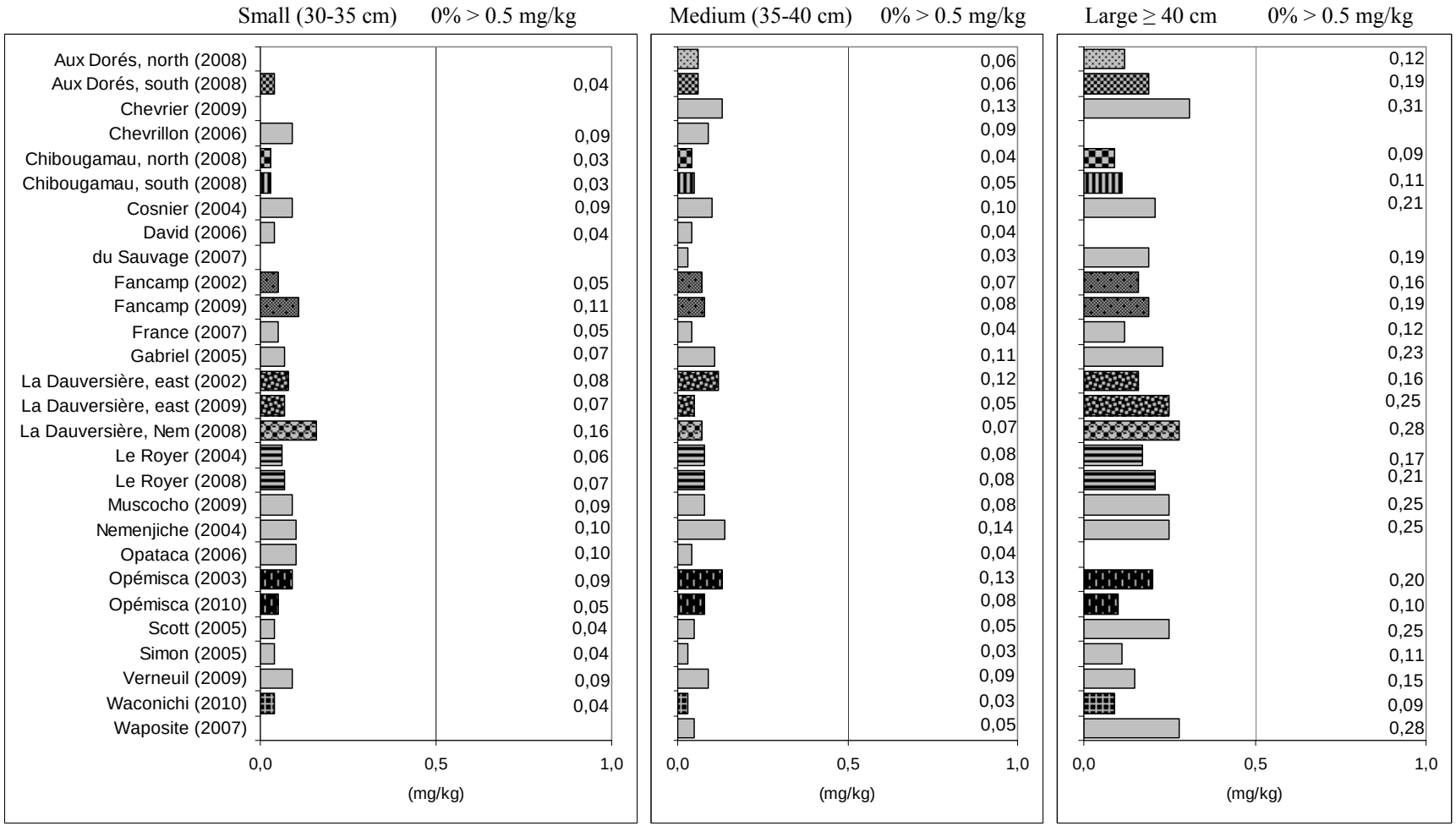


Figure 12 Mercury concentrations in the flesh of white sucker in lakes in the Chibougamau and Oujé-Bougoumou region (2002-2010)

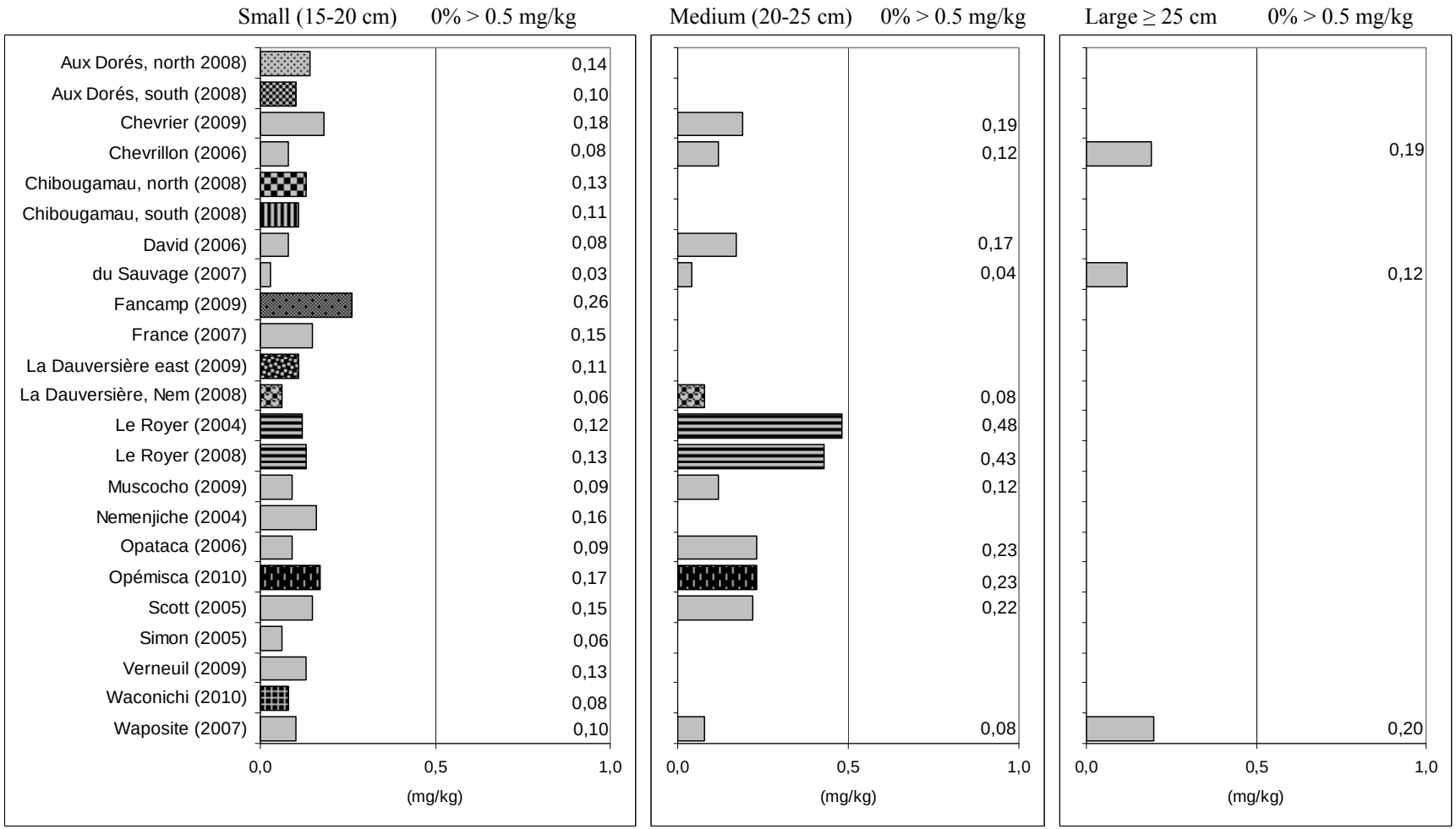


Figure 13 Mercury concentrations in the flesh of yellow perch in lakes in the Chibougamau and Oujé-Bougoumou region (2004-2010)

4.2.3 Mercury concentrations and previous years

At nine sites located at Lac aux Dorés, Lac Chibougamau, Lac Fancamp, Lac La Dauversière, Lac Le Royer, Lac Opémisca and Lac Waconichi, fish were sampled twice between 2001 and 2010 (figures 5, 6, 7 and 8).

To ascertain qualitative differences between the years, it is preferable to consider the average size class, which is more representative of the average contamination of the population. Medium fish integrate contamination over several years, which reduces interannual influence and such fish are usually of comparable size and age from one year to the next. The relative differences observed are mentioned for information only since the limited data per size class limits the comparison. A statistical analysis that uses the full data set is necessary to determine if there is a significant difference between the years. The findings of this analysis are presented in the following section.

Accordingly, average mercury concentrations in yellow walleye in the medium size class do not display significant differences at Lac aux Dorés (two sites: 0.37-0.30 and 0.26-0.30) and Lac Chibougamau (two sites: 0.37-0.38 and 0.39-0.37) for the period 2001-2008, at Lac La Dauversière, eastern sector (0.52-0.58) for the period 2002-2009, at Lac La Dauversière, Nemenjiche sector (0.56-0.55) for the period 2001-2008, nor at Lac Le Royer (0.48-0.52) for the period 2004-2008. Slightly bigger differences were noted at Lac Fancamp (0.43-0.71) for the period 2002-2009 and at Lac Opémisca (0.59-0.36) for the period 2003-2010 (Figure 5).

Average mercury concentrations in northern pike in the medium size class do not display significant differences at Lac aux Dorés (two sites: 0.36-0.31 and 0.24-0.30) and Lac Chibougamau (two sites: 0.38-0.30 and 0.31-0.27) for the period 2001-2008 nor at Lac Fancamp (0.67-0.60) for the period 2002-2009. Slightly bigger differences are observed at Lac La Dauversière, eastern sector (0.66-0.55) for the period 2002-2009, at Lac Le Royer (0.82-0.72) for the period 2004-2008, at Lac La Dauversière, Nemenjiche sector (0.69-0.82) for the period 2001-2008, and at Lac Opémisca (0.71-0.57) for the period 2003-2010 (Figure 6).

Average mercury concentrations in lake trout in the medium size class do not display significant differences at Lac aux Dorés, southern sector (0.53-0.54) for the period 2001-2008. Slightly bigger differences are observed at Lac aux Dorés, northern sector (0.76-0.50) and Lac Chibougamau (0.77-0.65 and 0.99-0.49) for the period 2001-2008 and at Lac Waconichi (0.43-0.29) for the period 2001-2010 (Figure 8).

Average mercury concentrations in burbot in the medium size class do not display significant differences at Lac aux Dorés (0.39-0.37 and 0.31-0.25) and Lac Chibougamau (0.43-0.37 and 0.45-0.38) for the period 2001-2008, at Lac Le Royer (0.64-0.60) for the period 2004-2008, nor at Lac Waconichi (0.22-0.15) for the period 2001-2010. Slightly bigger differences are observed at Lac Fancamp (0.37-0.22) for the period 2002-2009, at Lac La Dauversière, eastern sector (0.57-0.36) for the period 2002-2009 and at Lac Opémisca (0.49-0.18) for the period 2003-2010 (Figure 7).

With the exception of lake trout, there is a small difference in average mercury concentrations in the medium size class of the species mentioned earlier between the years at Lac aux Dorés and Lac Chibougamau. For the other lakes, the differences are variable, depending on the species. The relative differences, although not significant, are more often than not lower than the value prior to the beginning of the period: of 13 differences, 11 were lower. At Lac Opémisca, yellow walleye, northern pike and burbot display a negative difference in relation to the beginning of the period. Lake trout is not present in Lac Opémisca.

4.2.4 Statistical analyses of mercury concentrations in fish flesh

A statistical study of mercury concentrations in fish flesh was conducted to compare the level of mercury contamination in yellow walleye, northern pike and lake trout in the lakes in the Chibougamau and Oujé-Bougoumou region. The study comprised a spatial and temporal comparison of the sites that were sampled more than once. The relationships between mercury concentrations and the age of the fish were

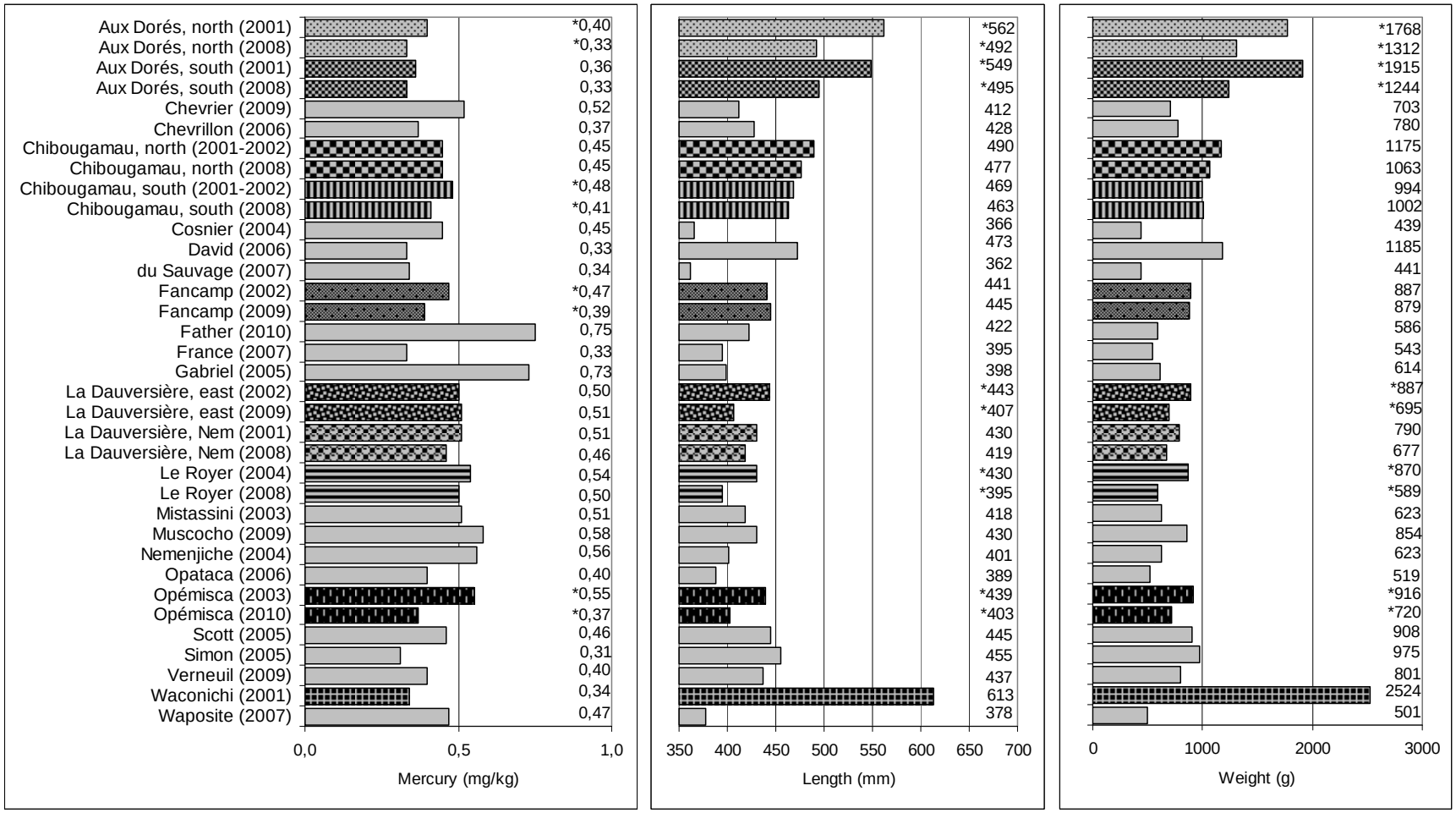
used for statistical analyses. The average adjusted mercury concentrations for each species were compared with the average age of the specimens analyzed. The average age of the specimens analyzed was 7 years in the case of yellow walleye, 4.2 years in the case of northern pike, and 9.4 years in the case of lake trout. While the average adjusted mercury concentrations at all of the sites were compared, only the findings of temporal comparisons at a given site will be discussed (figures 14, 15 and 16).

The findings of the statistical analyses reveal that, in the case of yellow walleye, the average adjusted mercury concentrations at four of the nine sites studied display significant differences between the two years of observation, i.e. at Lac aux Dorés, northern sector, between 2001 (0.40 mg/kg) and 2008 (0.33 mg/kg), Lac Chibougamau, southern sector, between 2001-2002 (0.48 mg/kg) and 2008 (0.41 mg/kg), Lac Fancamp between 2002 (0.47 mg/kg) and 2009 (0.39 mg/kg), and Lac Opémisca between 2003 (0.55 mg/kg) and 2010 (0.37 mg/kg). In all four cases, the average adjusted mercury concentrations appear to be lower during the second sampling campaign. At Lac Opémisca, where the biggest difference occurs, the fish were smaller in 2010 (403 mm, 720 g) than in 2003 (439 mm, 916 g). In the same way, at Lac aux Dorés, northern sector, the fish were smaller in 2008 (492 mm, 1312 g) than in 2003 (562 mm, 1768 g). In both cases, this factor may have affected the difference observed between the two years. Smaller fish consume smaller, usually younger prey, which are generally less contaminated. The relationships between mercury concentrations and age, the length or weight of the fish usually reveal an increase in mercury concentrations with an increase in these factors. Differences in the size and weight of fish may have affected comparisons at four other sites, i.e. Lac aux Dorés, southern sector, Lac La Dauversière, eastern sector, and Lac Le Royer, where the fish were smaller during the second sampling campaign in 2008-2009. The average adjusted mercury concentrations at the latter sites were not significantly different from those in 2001, 2002 and 2004 (Figure 14).

The findings of the statistical analysis concerning northern pike reveal that of the nine sites studied, only two sites displayed a significant difference in average adjusted mercury concentrations between the two years of observation, i.e. at Lac aux Dorés, southern sector, between 2001 (0.22 mg/kg) and 2008 (0.31 mg/kg), and Lac Chibougamau, northern sector, between 2001 (0.45 mg/kg) and 2008 (0.33 mg/kg). At Lac aux Dorés, southern sector, the average adjusted mercury concentration is apparently higher in 2008 than in 2001. It should be noted that effluent from the Prinicipale tailings site flowed upstream until December 2003 (it was opened twice, in 2004 and 2006). Halting the effluent probably altered the quality of water in Lac aux Dorés, southern sector. The average adjusted concentration at Lac Chibougamau, northern sector, appears to be lower in 2008 than in 2001. However, in the latter instance, the fish caught were significantly smaller in 2008 (658 mm, 1985 g) than in 2001 (690 mm, 2197 g). Differences were also noted at two other sites in the size and weight of fish, i.e. at Lac La Dauversière, Nemenjiche sector (537 mm, 886 g compared with 573 mm, 1188 g) and Lac Opémisca (587mm, 1342 g as against 645 mm, 1694 g). In both instances, the fish caught during the second sampling campaign were bigger (Figure 15).

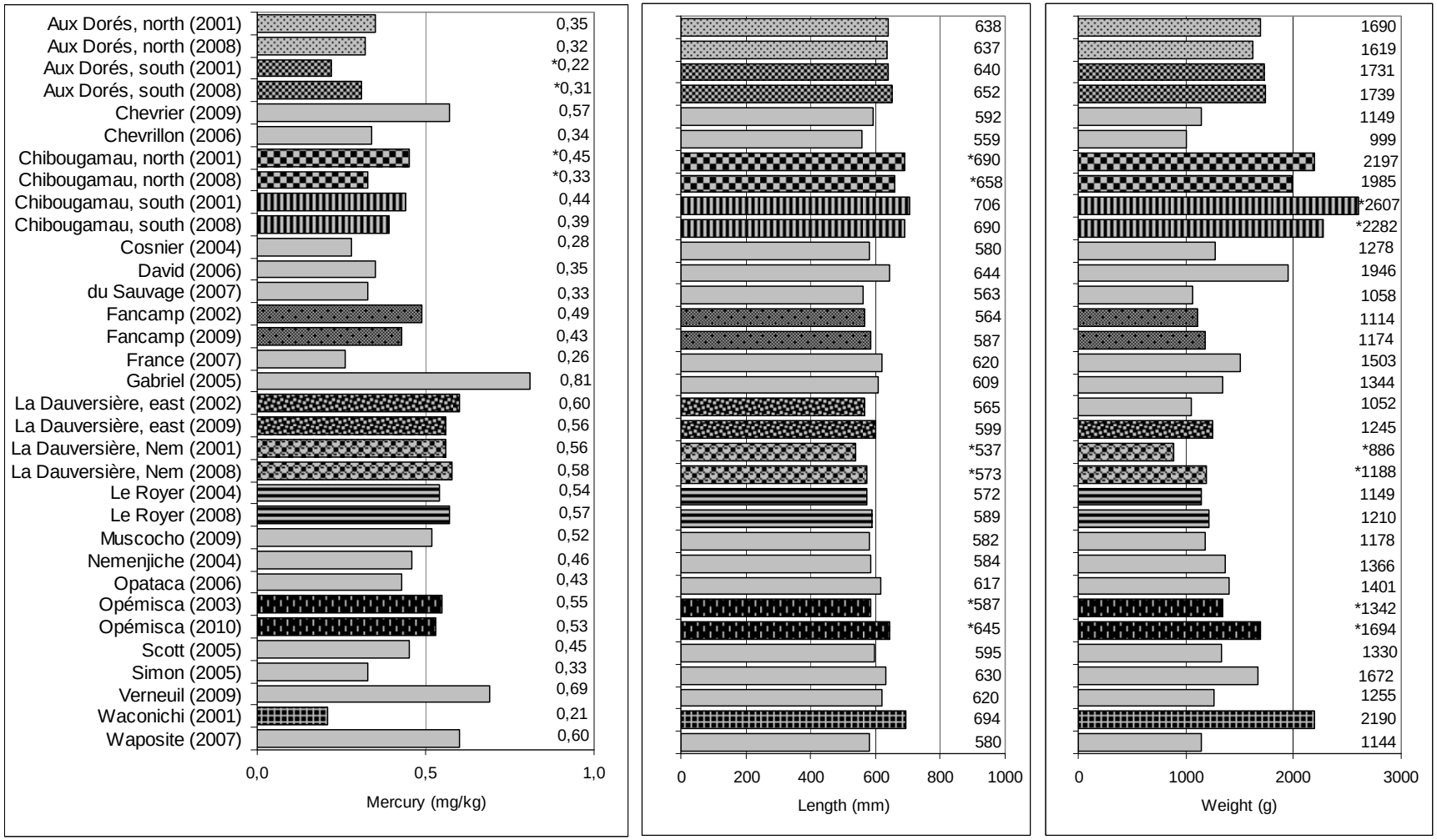
The findings of the statistical analysis concerning lake trout reveal that two of the five sites studied display significant differences in average adjusted mercury concentrations, i.e. at Lac Chibougamau, northern sector, in 2001-2002 (0.56 mg/kg) and in 2008 (0.79 mg/kg), and at Lac Chibougamau, southern sector, in 2001 (0.64 mg/kg) and in 2008 (0.95 mg/kg). In both instances, the average adjusted mercury concentrations in lake trout are higher in the sampling conducted in 2008. However, the average size and weight of the fish are also higher in 2008 (685 mm, 3199 g and 704 mm, 3073 g) than in 2001-2002 (582 mm, 1801 g and 628 mm, 2208 g). The average size and weight of lake trout are also significantly different at four of the five sites at which temporal comparisons were conducted (Figure 16).

Given the differences in the weights and lengths of the fish, it is impossible to discern convincing differences concerning temporal changes in the average adjusted mercury concentrations in the three species studied.



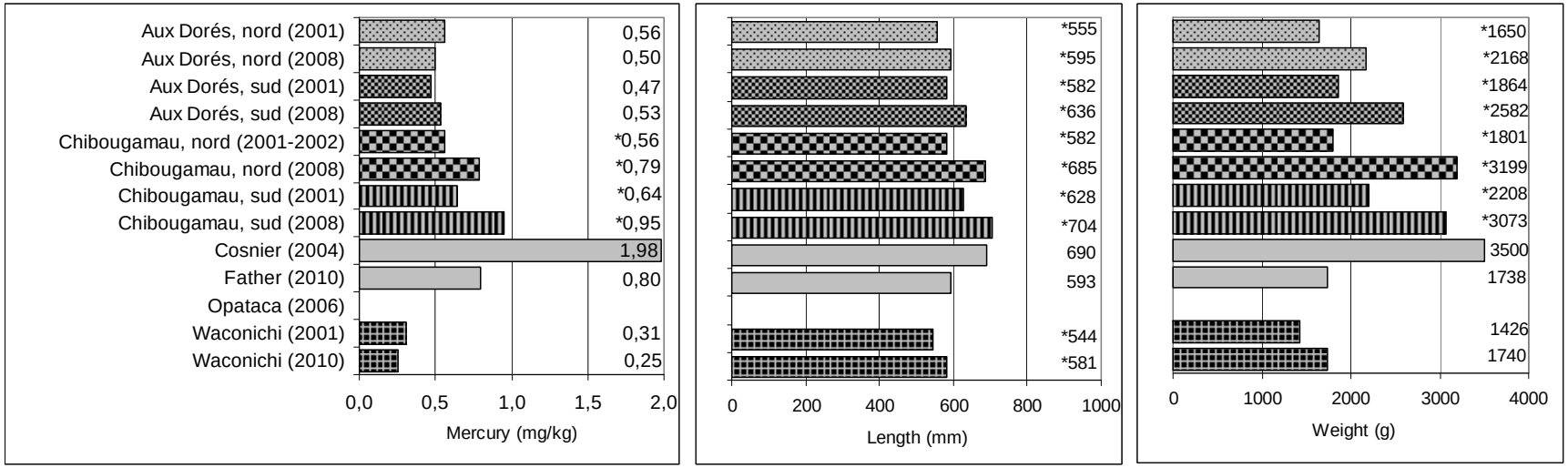
* The values differ significantly at a given site starting beyond the threshold of $P < 0.05$.

Figure 14 Average mercury concentrations and adjusted average lengths and weights for an age of 7 years of yellow walleye caught in the Chibougamau region (2001-2010)



* The values differ significantly at a given site beyond a threshold of $P < 0.05$.

Figure 15 Average mercury concentrations and average adjusted lengths and weights for an age of 4.2 years of northern pike caught in the Chibougamau region (2001-2010)



* The values differ significantly at a given site beyond a threshold of $P < 0.05$.

Figure 16 Average mercury concentrations and adjusted average lengths and weights for an age of 9.4 years in lake trout caught in the Chibougamau region (2001-2010)

4.3 Spatial analyses of mercury concentrations in fish flesh

Average mercury concentrations adjusted according to the length and adjusted average age in light of the length of each of the fish populations sampled at different sites are represented in the form of graphs (figures 17, 18 and 19).

The graphs reveal that, for a given average size of fish, the average mercury concentrations increase with the average age of the fish in the case of yellow walleye and northern pike. The variance for yellow walleye and northern pike between the sites is explained at 48% and 51%, respectively, by the average age of the fish populations (figures 17 and 18).

On the other hand, for a given average size of lake trout, the average mercury concentrations in the fish according to the average age of the populations does not display a significant relationship (Figure 19). The average mercury concentrations of lake trout populations appear to depend mainly on the site where they were caught. Accordingly, for a given size, an older population does not tend to display a higher average mercury concentration than another younger population with a higher growth rate.

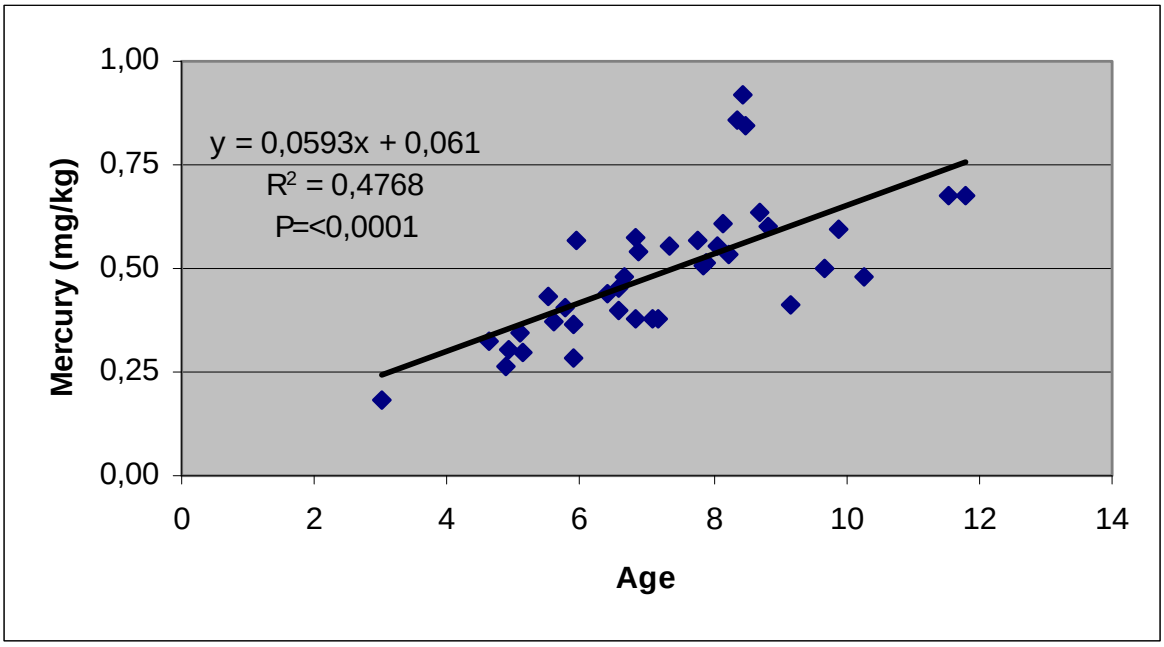


Figure 17 Average mercury concentrations adjusted according to the average adjusted age at a length of 433 mm for yellow walleye from the different lakes studied

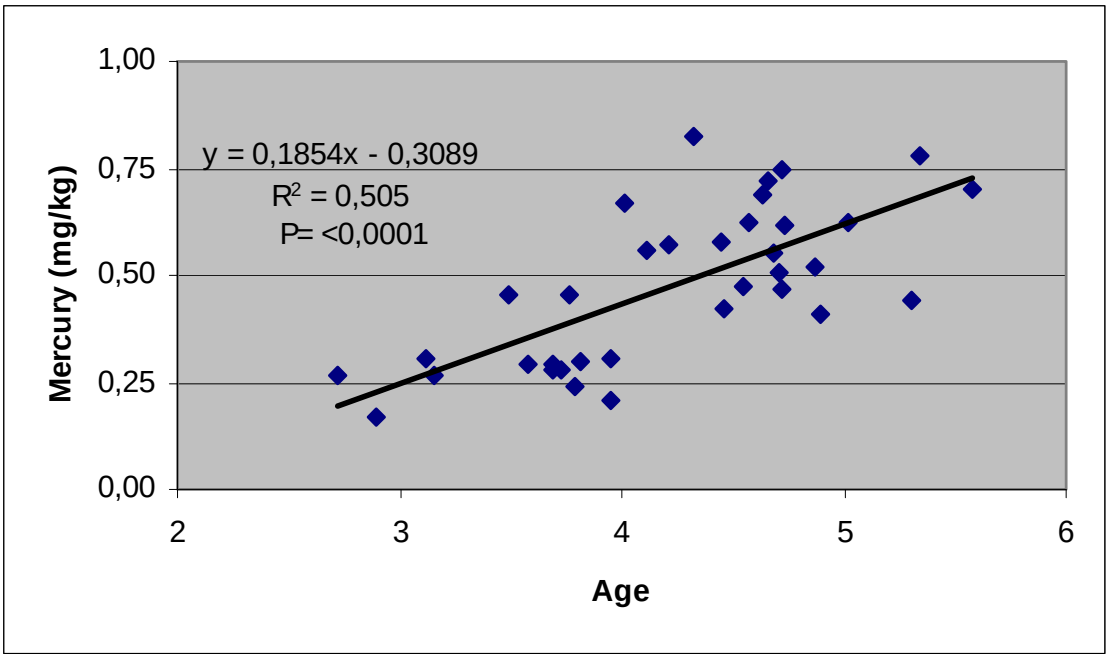


Figure 18 Average mercury concentrations adjusted according to the average adjusted age at a length of 611 mm for northern pike from the different lakes studied

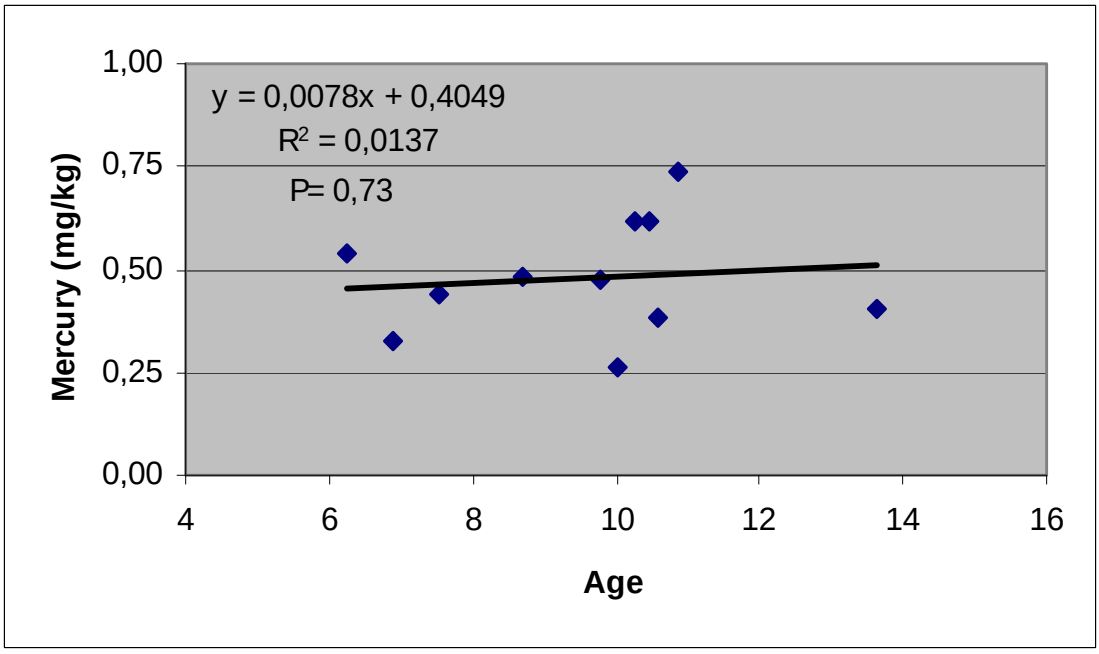


Figure 19 Average mercury concentrations adjusted according to the average adjusted age at a length of 593 mm for lake trout from the different lakes studied

5 CONCLUSION

In water, the concentrations of all of the metals and non-metals measured at all of the sampling sites are lower than the chronic effects criteria for the protection of aquatic organisms and the criteria respecting drinking water.

In fish flesh, arsenic, barium, cadmium, chrome, cobalt, nickel, lead and vanadium were not detected or present at concentrations near the minimum detectable limit. On the other hand, copper, manganese, mercury, selenium, strontium and zinc were found in concentrations in fish flesh that exceed 0.1 mg/kg. With the exception of mercury, the concentrations of the latter metals observed in the specimens of a given species are usually on the same order as the background measured in Lac Waconichi, the control lake. Among the same metals, only mercury is covered by the Health Canada guideline for the sale of fishery products, established at 0.5 mg/kg.

The highest mercury concentrations were measured in large lake trout in Lac Cosnier (2.87 mg/kg), Lac Father (2.22 mg/kg) and Lac Chibougamau (1.70 mg/kg). The highest concentrations in yellow walleye were measured in Lac Gabriel (1.64 mg/kg) and Lac Father (1.48 mg/kg), while the highest concentrations in northern pike were measured in Lac Waposite (1.71 mg/kg) and Lac Gabriel (1.68 mg/kg).

The mercury concentrations measured in the flesh of lake herring, lake whitefish, white sucker, northern sucker and yellow perch all fall below the Health Canada guideline.

All of the mercury concentrations exceed the 0.033 mg/kg criterion for the protection of piscivorous terrestrial fauna (CCME, 2000).

For the period 2001-2010, there are no significant differences between the years of study at a given site for the average adjusted mercury concentrations in yellow walleye, northern pike and lake trout.

In the case of yellow walleye and northern pike, the growth rate of the fish populations partly explains the mercury concentrations in the fish at different sites. Generally speaking, mercury concentrations increase with the average age of the population for a given size of fish. On the other hand, in the case of lake trout, the growth rate does not explain the differences in mercury concentrations at different sites. There is no significant relationship in this species between the average age of the fish populations for a given size and mercury concentrations. In other words, the length of exposure does not explain mercury concentrations in lake trout populations.

Generally, in the study overall, medium and large piscivorous fish such as yellow walleye, northern pike, burbot and lake trout display the highest mercury concentrations, which often exceed the Health Canada guideline for the sale of fishery products. However, the species can be consumed according to the recommendations in the *Guide de consommation du poisson de pêche sportive en eau douce* published jointly by the Ministère du Développement durable, de l'Environnement and des Parcs and the Ministère de la Santé et des Services sociaux (http://www.mddep.gouv.qc.ca/eau/guide/index.htm) or according to the recommendations of the Direction de santé publique du Nord-du-Québec.

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Appendix 1 Location of surface water sampling sites in 2008

N°	Site	UTM (Nad27) Coordinates		
		East	Zone	North
	LAC AUX DORÉS			
1	Rainbow Lodge, west	553 000	18	5 528 000
2	Pointe Est de la baie Cedar, west	550 044	18	5 526 703
3	Parc Copper Rand, north	550 140	18	5 524 867
4*	Île Lefebvre, northest	549 398	18	5 524 500
5	Mine Principale, north	547 788	18	5 524 805
6	Baie Ballicky, north	547 137	18	5 520 927
7	Baie Ballicky, southwest	546 061	18	5 519 331
8	Baie Malouf	543 743	18	5 517 105
	LAC CHIBOUGAMAU			
9	Île Lookout, east	558 677	18	5 523 983
10	Île Mermaid, north	555 232	18	5 524 014
11	Parc Eaton Bay, downstream	552 963	18	5 526 117
	LACS OBATOGAMAU			
12	Rivière Nemenjiche, upstream mine	538 929	18	5 481 278
13	Rivière Nemenjiche, downstream mine	540 061	18	5 483 215
14	Lac La Dauversière, rivière Nemenjiche	541 350	18	5 490 400
15*	Lac La Dauversière, île Weaver west	543 650	18	5 490 700
16	Lac Le Royer	538 882	18	5 493 497
17	Rivière Obatogamau	534 400	18	5 496 300
18	Lac Fancamp, north	531 566	18	5 492 692
	LAC WACONICHI			
19	Lac Waconichi, lac Richardson	564 250	18	5 547 305
20	Lac Waconichi, near outlet	576 394	18	5 557 530
	LAC OPÉMISCA			
21*	Oujé-Bougoumou, 3 km south	512 500	18	5 526 500
22	Oujé-Bougoumou, 9,5 km west	503 000	18	5 531 000
23	**LAC SCOTT**	525 000	18	5 519 900
24	**LAC SIMON**	529 500	18	5 518 350
25	**LAC DAVID**	535 000	18	5 520 000

* Field blank.

Appendix 2 Location of surface water sampling sites in 2008

N°	Site	Longitude		Latitude	
		DDMMSS.SS	Decimal degrees	DDMMSS.SS	Decimal degrees
GSB-02	Rivière Opawica	74° 35' 17,59	74,5882194	49° 25' 8,35	49,4189861
GSB-03	Rivière Nemenjiche	74° 27' 12,45	74,4534583	49° 29' 33,52	49,4926444
GSB-04	Brook south lac La Dauversière	74° 20' 30		49° 32' 05	
LS-01	Rivière Cawcot – lac Gabriel	74° 29' 52,07	74,4977972	49° 16' 42,88	49,2785778
LS-02	Brook between rivière Cawcot and lac Gabriel	74° 29' 13,62	74,4871167	49° 15' 38,07	49,2605750
LS-03	Lac Gabriel	74° 28' 27,99	74,4744417	49° 14' 54,77	49,2485472
KC-00	Bridge rivière Opémisca	74° 53' 19,41	74,8887250	49° 58' 27,13	49,9742028
JC-01	Outlet lac Barlow	74° 44' 26,27	74,7406306	49° 54' 7,47	49,9020750
MW-01	Ruisseau Audet east lac Guy	74° 12' 21,79	74,2060528	49° 40' 40,59	49,6779417
JW-01	Brook flowing into lac aux Dorés	74° 15' 21,31	74,2559194	49° 54' 54,96	49,9152667
JW-02	Brook southeast lac Ida	73° 52' 37,03	73,8769528	50° 1' 37,64	50,0271222
JS-01	Rivière Chibougamau, upstream lac Merrill	74° 25' 35,15	74,4264306	49° 45' 38,29	49,7606361
JS-02	Lac du Moulin, upstream	74° 22' 18,17	74,3717139	49° 42' 19,02	49,7052833
JS-05	Brook east lac La Dauversière	74° 18' 33,21	74,3092250	49° 33' 23,44	49,5565111
CM-01	Point located between the forest road and lac Chico	74° 36' 38,48	74,6106889	49° 35' 37,77	49,5938250
DM-03	Brook southeast lac Opémisca	74° 44' 22,68	74,7396333	49° 49' 59,24	49,8331222
DM-04	Ruisseau à la Loutre				
DM-05	Brook southeast lac Opémisca	74° 44' 35,75	74,7432639	49° 50' 8,82	49,8357833

Appendix 3 Physical and chemical parameters and Concentration of the elements in <u>unfiltered</u> water samples from lakes in the Chibougamau and Oujé-Bougoumou region in 2008

N°	Site	Conductivity µS/cm	Color ucv	Turbidity UTN	Oxygen dis. mg/l	pH	Temperature C	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	SO_4 mg/l	DOC mg/l	Hardness mg/l
	Median	54	18	1,0	9,9	6,80	14,6	7,1	2,2	0,9	0,26	2,3	4,6	27
	LAC AUX DORÉS													
1	Rainbow Lodge, west	55	18	0,7	10,1	6,25	14,0	7,6	2,2	1,7	0,19	2,3	4,2	28
2	Pointe Est de la baie Cedar, west	60	15	0,5	10,2	6,97	14,3	8,4	2,3	0,9	0,24	4,1	4,1	30
3	Parc Copper Rand, north	61	15	0,8	10,4	6,94	14,1	10,0	2,4	0,9	0,27	4,4	4,1	35
4*	Île Lefebvre, northest	62	15	0,6	10,4	6,73	14,2	9,2	2,4	1,0	0,27	4,9	4,1	33
5	Mine Principale, north	63	14	0,7	10,7	7,30	12,7	10,0	2,4	1,0	0,28	5,1	4,0	35
6	Baie Ballicky, north	69	15	1,5	10,0	7,41	14,7	9,5	2,5	1,0	0,28	8,0	3,9	34
7	Baie Ballicky, southwest	66	15	0,8	10,1	7,15	14,6	14,0	2,7	1,0	0,35	-	4,0	46
8	Baie Malouf	66	15	0,8	9,9	7,17	14,8	8,8	2,4	0,9	0,26	7,0	4,1	32
	LAC CHIBOUGAMAU													
9	Île Lookout, east	47	17	0,6	10,7	6,65	11,0	6,6	2,1	0,5	0,18	2,1	4,5	25
10	Île Mermaid, north	49	17	1,3	10,8	6,77	10,8	6,9	2,1	0,6	0,18	2,3	4,5	26
11	Parc Eaton Bay, downstream	50	17	0,7	11,2	6,25	8,8	7,1	2,2	0,6	0,20	2,3	4,6	27
	LACS OBATOGAMAU													
12	Rivière Nemenjiche, upstream mine	23	58	1,1	8,7	6,50	15,5	5,0	1,1	0,5	0,41	1,0	9,1	17
13	Rivière Nemenjiche, downstream mine	42	57	1,2	8,4	6,80	15,4	5,9	1,7	1,0	0,47	4,2	8,6	22
14	Lac La Dauversière, rivière Nemenjiche	32	53	1,2	8,3	6,80	16,1	4,7	1,3	0,8	0,35	2,6	8,6	17
15*	Lac La Dauversière, île Weaver west	28	39	1,3	9,3	6,70	14,7	4,3	1,1	0,9	0,23	1,5	7,8	15
16	Lac Le Royer	28	41	1,1	9,2	6,71	14,6	4,2	1,2	0,8	0,29	2,0	7,9	15
17	Rivière Obatogamau	30	43	1,0	8,9	6,90	16,0	4,5	1,2	0,8	0,26	2,0	8,1	16
18	Lac Fancamp, north	28	43	1,1	8,9	6,75	15,4	4,2	1,2	0,8	0,22	1,7	8,4	15
	LAC WACONICHI													
19	Lac Waconichi, lac Richardson	82	14	0,7	10,5	-	12,5	16,0	4,3	0,8	0,36	1,9	3,8	58
20	Lac Waconichi, near outlet	81	10	0,5	11,2	6,70	11,7	10,0	4,1	1,0	0,28	2,0	3,3	42
	LAC OPÉMISCA													
21*	Oujé-Bougoumou, 3 km south	51	36	1,3	9,0	7,24	14,4	6,9	2,4	0,8	0,22	2,3	6,3	27
22	Oujé-Bougoumou, 9,5 km west	44	40	1,2	9,3	6,91	14,1	6,0	2,1	0,6	0,22	2,0	6,6	24
23	**LAC SCOTT**	54	34	1,3	8,6	6,80	15,6	6,9	2,0	1,7	0,26	2,4	6,1	25
24	**LAC SIMON**	60	24	1,4	9,0	6,87	16,4	7,8	2,4	1,4	0,25	3,3	5,4	29
25	**LAC DAVID**	63	20	1,0	9,2	7,01	16,1	8,1	2,4	1,2	0,25	4,5	5,2	30

* Field blank.

Appendix 4 Concentration of the elements in the water for the field blanks

4 a) Unfiltered blanks in the Chibougamau and Oujé-Bougoumou region in 2008

N°	Site	Al	As	B	Ba	Br	Co	Cr	Cu	Fe	I	Li	Mn	Mo	Ni	Si	Sr
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LAC AUX DORÉS																
4*	Blank – Île Lefebvre, northeast	4,5	< 0,03	< 0,3	< 0,02	< 0,5	< 0,007	< 0,04	< 0,05	2,1	< 0,5	< 0,06	< 0,004	< 0,003	0,04	0,02	0,009
	LACS OBATOGAMAU																
15*	Blank – Lac La Dauversière, île Weaver west	0,3	< 0,03	< 0,3	< 0,02	< 0,5	< 0,007	< 0,04	< 0,05	0,6	< 0,5	< 0,06	< 0,004	< 0,003	< 0,02	0,08	< 0,004
	LAC OPÉMISCA																
21*	Blank – Oujé-Bougoumou, 3 km south	0,9	< 0,03	< 0,3	< 0,02	< 0,5	< 0,007	< 0,04	< 0,05	< 0,5	< 0,5	< 0,06	< 0,004	< 0,003	< 0,02	0,01	0,009

N°	Site	U	V	Ag	Be	Cd	Pd	Sb	Se	Sn	Tl	DOC
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l
	LAC AUX DORÉS											
4*	Blank – Île Lefebvre, northeast	< 0,001	< 0,01	< 0,001	< 0,004	< 0,004	< 2	< 0,03	< 0,005	< 0,006	< 0,004	< 0,3	< 0,01	< 0,005	< 0,7	0,4
	LACS OBATOGAMAU											
15*	Blank – Lac La Dauversière, île Weaver west	< 0,001	< 0,01	< 0,001	< 0,004	< 0,004	< 2	< 0,03	< 0,005	< 0,006	< 0,004	< 0,3	< 0,01	< 0,005	< 0,7	0,5
	LAC OPÉMISCA											
21*	Blank – Oujé-Bougoumou, 3 km south	< 0,001	< 0,01	< 0,001	< 0,004	< 0,004	< 2	< 0,03	< 0,005	< 0,006	< 0,004	< 0,3	< 0,01	< 0,005	1,5	0,5

* Field blank.

4 b) Filtered blanks in the Chibougamau and Oujé-Bougoumou region in 2008

N°	Site	Al	As	B	Ba	Br	Co	Cr	Cu	Fe	I	Li	Mn	Mo	Ni	Si	Sr
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LAC AUX DORÉS																
4*	Blank – Île Lefebvre, northeast	0,6	< 0,03	< 0,3	< 0,02	8,3	< 0,007	< 0,04	0,08	0,50	< 0,5	< 0,06	< 0,004	0,005	0,02	0,02	< 0,004
	LACS OBATOGAMAU																
15*	Blank – Lac La Dauversière, île Weaver west	0,9	< 0,03	< 0,3	< 0,02	5,2	< 0,007	< 0,04	< 0,05	< 0,50	< 0,5	< 0,06	< 0,004	< 0,003	< 0,02	0,01	< 0,004
	LAC OPÉMISCA																
21*	Blank – Oujé-Bougoumou, 3 km south	0,6	< 0,03	< 0,3	< 0,02	0,5	< 0,007	< 0,04	0,05	< 0,50	< 0,5	< 0,06	< 0,004	< 0,003	< 0,02	0,01	< 0,004

N°	Site	U	V	Ag	Be	Cd	P	Pb	Pd	Pt	Sb	Se	Sn	Tl	Zn	DOC
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l
	LAC AUX DORÉS															
4*	Blank – Île Lefebvre, northeast	< 0,001	< 0,01	< 0,001	< 0,004	< 0,004	< 2	< 0,03	< 0,005	< 0,006	0,140	< 0,3	< 0,01	< 0,005	< 0,7	0,4
	LACS OBATOGAMAU															
15*	Blank – Lac La Dauversière, île Weaver west	< 0,001	0,01	< 0,001	< 0,004	< 0,004	< 2	< 0,03	< 0,005	< 0,006	0,096	< 0,3	< 0,01	< 0,005	< 0,7	0,5
	LAC OPÉMISCA															
21*	Blank – Oujé-Bougoumou, 3 km south	< 0,001	< 0,01	< 0,001	< 0,004	< 0,004	< 2	< 0,03	< 0,005	< 0,006	0,061	< 0,3	< 0,01	< 0,005	< 0,7	0,5

* Field blank.

Appendix 5 Concentration of metals in <u>filtered</u> water samples from lakes in the Chibougamau and Oujé-Bougoumou region in 2008

N°	Site	Al µg/l	As µg/l	B µg/l	Ba µg/l	Br µg/l	Co µg/l	Cr µg/l	Cu µg/l	Fe µg/l	Mn µg/l	Mo µg/l	Ni µg/l	Si µg/l	Sr µg/l	U µg/l	V µg/l
	Median	15	0,22	1,9	3,5	19	0,017	0,17	1,5	19	0,43	0,11	0,41	0,89	13	0,016	0,07
	MDDELCC chronic effect guideline[1]	87	150	5000	122		100	11	3,3	1300	637		19		21000	14	12
	MDDELCC acute toxicity guideline[1]	750	340	2800	347		370	16	4,5	3400	1374		169		40000	320	110
	LAC AUX DORÉS																
1	Rainbow Lodge, west	9	0,20	1,8	3,5	12	0,012	0,19	1,5	10	0,26	0,14	0,42	0,89	11	0,013	0,08
2	Pointe Est de la baie Cedar, west	11	0,23	2,0	3,3	19	0,019	0,18	2,2	9	0,37	0,18	0,43	0,84	13	0,016	0,06
3	Parc Copper Rand, north	6	0,24	1,9	3,4	17	0,020	0,16	2,2	8	0,53	0,20	0,45	0,87	13	0,016	0,07
4*	Île Lefebvre, northeast	12	0,23	1,9	3,3	18	0,022	0,17	2,3	11	0,50	0,23	0,46	0,86	14	0,018	0,07
5	Mine Principale, north	16	0,23	2,0	3,3	19	0,026	0,17	2,9	11	0,39	0,23	0,50	0,83	13	0,017	0,06
6	Baie Ballicky, north	13	0,27	2,1	3,4	26	0,058	0,15	3,1	16	0,55	0,22	0,88	0,79	14	0,019	0,05
7	Baie Ballicky, southwest	7	0,24	2,1	3,4	30	0,053	0,14	3,0	17	0,53	0,21	0,81	0,81	14	0,017	0,05
8	Baie Malouf	10	0,25	2,3	3,4	21	0,054	0,14	3,1	21	0,47	0,20	0,82	0,80	14	0,017	0,05
	LAC CHIBOUGAMAU																
9	Île Lookout, east	10	0,17	1,8	3,2	13	0,010	0,15	1,2	11	0,13	0,11	0,36	0,85	10	0,011	0,04
10	Île Mermaid, north	11	0,17	1,7	3,2	16	0,011	0,17	1,4	11	0,24	0,11	0,49	0,86	10	0,012	0,05
11	Parc Eaton Bay, downstream	12	0,18	1,8	3,5	14	0,014	0,18	1,4	12	0,17	0,12	0,42	0,92	11	0,013	0,06
	LACS OBATOGAMAU																
12	Rivière Nemenjiche, upstream mine	64	0,23	1,5	5,1	16	0,032	0,25	0,4	130	17	0,04	0,41	1,10	8	0,009	0,13
13	Rivière Nemenjiche, downstream mine	60	0,24	2,0	6,3	32	0,054	0,25	0,7	130	25	0,07	0,41	1,20	25	0,024	0,14
14	Lac La Dauversière, rivière Nemenjiche	51	0,28	1,6	4,8	23	0,020	0,20	1,9	83	3,7	0,05	0,37	1,00	14	0,013	0,10
15*	Lac La Dauversière, île Weaver west	39	0,19	1,4	4,0	15	0,010	0,17	0,6	32	0,29	0,06	0,28	1,20	8	0,009	0,06
16	Lac Le Royer	36	0,19	1,3	4,2	15	0,010	0,17	1,1	38	0,36	0,05	0,31	1,10	10	0,009	0,07
17	Rivière Obatogamau	36	0,21	1,5	3,8	20	0,012	0,17	1,1	39	0,50	0,05	0,30	1,10	10	0,011	0,08
18	Lac Fancamp, north	42	0,18	1,6	3,3	19	0,011	0,16	1,0	37	0,51	0,04	0,36	1,00	10	0,009	0,05
	LAC WACONICHI																
19	Lac Waconichi, lac Richardson	19	0,14	1,9	7,5	21	0,015	0,06	0,5	10	0,28	0,09	0,12	0,94	16	0,030	0,04
20	Lac Waconichi, near outlet	3	0,15	2,0	7,8	22	0,013	0,05	0,4	6	0,29	0,10	0,11	0,92	16	0,028	0,04
	LAC OPÉMISCA																
21*	Oujé-Bougoumou, 3 km south	24	0,24	2,7	4,6	34	0,016	0,16	1,5	40	0,37	0,11	0,33	0,83	13	0,023	0,08
22	Oujé-Bougoumou, 9,5 km west	24	0,21	2,5	4,3	13	0,012	0,14	1,0	44	0,31	0,09	0,29	1,00	12	0,020	0,08
23	**LAC SCOTT**	18	0,22	2,2	3,2	15	0,017	0,17	1,6	45	0,96	0,15	0,39	0,89	12	0,015	0,10
24	**LAC SIMON**	13	0,21	2,3	3,4	36	0,019	0,18	2,4	28	0,61	0,14	0,49	0,79	12	0,017	

* Field blank.

[1] Criterion respecting the quality of water aimed at protecting aquatic life (MDDEP, 2009).
The criteria for Ba, Be, Cd, Cu, Mn, Ni, Pb and Zn are calculated for average water hardness of 30 mg/L of $CaCO_3$.

Note: The concentrations indicated have not been subtracted from those of the field blanks.

Appendix 5 (continued) Concentration of metals in <u>filtered</u> water samples from lakes in the Chibougamau and Oujé-Bougoumou region in 2008

N°	Site	Ag µg/l	Be µg/l	Cd µg/l	I µg/l	Li µg/l	P µg/l	Pb µg/l	Pd µg/l	Pt µg/l	Se µg/l	Sn µg/l	Tl µg/l	Zn µg/l	DOC mg/l
	Median	< 0,001	< 0,004	0,005	0,9	0,25	2	< 0,03	0,006	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	5,1
	MDDELCC chronic effect guideline[1]		0,114	0,111				0,69			5			43	
	MDDELCC acute toxicity guideline[1]		1,026	0,627				18			-			43	
	LAC AUX DORÉS														
1	Rainbow Lodge, west	0,003	< 0,004	< 0,004	0,9	0,21	< 2	< 0,03	0,011	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	4,7
2	Pointe Est de la baie Cedar, west	0,001	< 0,004	< 0,004	0,9	0,20	2	< 0,03	0,016	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	4,6
3	Parc Copper Rand, north	< 0,001	< 0,004	0,004	0,9	0,20	2	< 0,03	0,013	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	4,6
4*	Île Lefebvre, northeast	< 0,001	< 0,004	0,004	1,0	0,20	2	< 0,03	0,013	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	4,6
5	Mine Principale, north	< 0,001	< 0,004	0,006	0,9	0,20	2	< 0,03	0,010	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	4,5
6	Baie Ballicky, north	< 0,001	< 0,004	0,008	1,0	0,22	3	< 0,03	0,006	< 0,006	< 0,3	< 0,01	< 0,005	2,3	4,4
7	Baie Ballicky, southwest	< 0,001	< 0,004	0,007	1,0	0,22	3	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	5,9	4,5
8	Baie Malouf	< 0,001	< 0,004	0,006	0,9	0,22	2	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	1,3	4,6
	LAC CHIBOUGAMAU														
9	Île Lookout, east	< 0,001	< 0,004	< 0,004	0,9	0,19	< 2	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	5,0
10	Île Mermaid, north	< 0,001	0,004	0,005	1,0	0,19	3	< 0,03	0,008	< 0,006	< 0,3	< 0,01	< 0,005	11	5,0
11	Parc Eaton Bay, downstream	0,002	< 0,004	0,004	1,0	0,19	< 2	< 0,03	0,006	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	5,1
	LACS OBATOGAMAU														
12	Rivière Nemenjiche, upstream mine	< 0,001	< 0,004	0,006	0,9	0,29	3	0,05	0,007	< 0,006	< 0,3	< 0,01	< 0,005	5,2	9,6
13	Rivière Nemenjiche, downstream mine	< 0,001	< 0,004	0,006	0,9	0,36	3	0,05	0,006	< 0,006	< 0,3	< 0,01	< 0,005	3,6	9,1
14	Lac La Dauversière, rivière Nemenjiche	0,001	0,005	0,005	0,8	0,32	2	0,03	0,008	< 0,006	< 0,3	< 0,01	< 0,005	2,7	9,1
15*	Lac La Dauversière, île Weaver west	< 0,001	< 0,004	< 0,004	0,8	0,33	< 2	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	2,5	8,3
16	Lac Le Royer	< 0,001	0,005	< 0,004	0,8	0,30	< 2	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	8,4
17	Rivière Obatogamau	< 0,001	0,004	0,005	0,8	0,28	2	< 0,03	0,005	< 0,006	< 0,3	< 0,01	< 0,005	1,1	8,6
18	Lac Fancamp, north	< 0,001	< 0,004	0,006	0,8	0,25	2	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	3,9	8,9
	LAC WACONICHI														
19	Lac Waconichi, lac Richardson	< 0,001	< 0,004	< 0,004	0,8	0,29	2	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	4,3
20	Lac Waconichi, near outlet	< 0,001	< 0,004	< 0,004	0,9	0,31	3	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	3,8
	LAC OPÉMISCA														
21*	Oujé-Bougoumou, 3 km south	< 0,001	< 0,004	< 0,004	0,9	0,28	3	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	6,8
22	Oujé-Bougoumou, 9,5 km west	< 0,001	< 0,004	< 0,004	0,7	0,27	< 2	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	7,1
23	**LAC SCOTT**	< 0,001	< 0,004	0,005	0,9	0,24	< 2	< 0,03	0,007	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	6,6
24	**LAC SIMON**	0,001	< 0,004	0,005	1,0	0,25	3	< 0,03	< 0,005	< 0,006	< 0,3	< 0,01	< 0,005	< 0,7	5,9

* Field blank.

[1] Criterion respecting the quality of water aimed at protecting aquatic life (MDDEP, 2009).
The criteria for Ba, Be, Cd, Cu, Mn, Ni, Pb and Zn are calculated for average water hardness of 30 mg/L of $CaCO_3$.

Appendix 6 Average arsenic, mercury and selenium concentrations measured in the flesh of yellow walleye in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001			0,05	0,29	0,37	0,37			0,37
Aux Dorés, north	2008	0,02	0,02	0,02	0,25	0,30	0,40	0,39	0,42	0,24
Aux Dorés, south	2001			0,05	0,23	0,26	0,49			0,39
Aux Dorés, south	2008		0,03	< 0,02	0,28	0,30	0,39		0,41	0,35
Chevrier (1)	2009	0,07	0,06	0,07	0,44	**0,56**	**0,97**	0,32	0,28	0,32
Chevrier (2)	2009	0,07						0,36		
Chevrier, Muscocho	2009	0,05	0,08	0,07				0,30	0,35	0,34
Chevrillon	2006			< 0,05	0,30		**0,61**			0,34
Chibougamau, north	2001-2002			< 0,05	0,26	0,37	**0,53**			0,37
Chibougamau, north	2008	0,11	< 0,02	0,02	0,25	0,38	**0,57**	0,34	0,36	0,36
Chibougamau, south	1998			0,20	0,36	0,37	**0,99**			0,41
Chibougamau, south	2001-2002			0,05	0,29	0,39	**0,70**			0,36
Chibougamau, south	2008		0,02	0,02	0,28	0,37	**0,60**		0,38	0,37
Cosnier	2004		0,07	< 0,05	0,48	**0,73**	**1,26**		0,61	0,51
David	2006			< 0,05	0,21	0,31	**0,62**			0,37
du Sauvage	2007			0,07	0,32	0,49	**0,78**			0,32
Fancamp	2002			< 0,05	0,36	0,43	**0,97**			0,37
Fancamp	2009				0,32	**0,71**	**0,72**			
Fancamp, Verneuil	2009	0,07	0,09	0,08				0,39	0,40	0,38
Father	2010		0,19	0,68	**0,57**	**1,10**	**1,48**		0,29	0,27
France	2007			0,05	0,32	0,44	**0,70**			0,21
Gabriel	2005			0,06	**0,60**	**0,98**	**1,64**			0,60
La Dauversière, east	2002			< 0,05	0,35	**0,52**	**1,04**			0,36
La Dauversière, east	2009	0,08	0,06	0,07	0,45	**0,58**	**0,88**	0,33	0,30	0,32
La Dauversière, Nemenjiche	2001			0,05	0,38	**0,56**	**0,98**			0,42
La Dauversière, Nemenjiche	2008		< 0,02	0,04	0,35	**0,55**	**0,84**		0,59	0,42
Le Royer	2004		< 0,05	0,07	0,50	0,48	**0,83**		0,40	0,45
Le Royer	2008		< 0,02	0,05	0,46	**0,52**	**1,25**		0,45	0,45
Mistassini	2003			0,07	**0,58**	**0,67**	**0,97**			0,52
Muscocho	2009	0,05	0,05	0,06	0,42	**0,54**	**0,96**	0,32	0,38	0,35
Nemenjiche	2004		< 0,05	0,08	**0,53**	**0,73**	**0,92**		0,50	0,53
Opataca	2006			0,08		**0,53**	**1,05**			0,54
Opémisca	2003			0,10	0,44	**0,59**	**0,96**			0,39
Opémisca	2010	0,05	0,06	0,07	0,26	0,36	**0,92**	0,20	0,21	0,21
Scott	2005			< 0,05	0,33	0,48	**0,82**			0,45
Simon	2005			< 0,05	0,24	0,28	**0,79**			0,40
Verneuil	2009				0,38	0,45	0,38			
Waconichi	2001	< 0,05	< 0,05	< 0,05	0,14	0,24	0,30	0,32	0,34	0,35
Waposite	2007			0,04	0,42	**0,68**	**0,81**			0,35
Average		0,06	0,05	0,07	0,36	0,50	**0,82**	0,33	0,39	0,38
Median		0,06	0,03	0,05	0,35	0,48	**0,83**	0,33	0,38	0,37
>0,5 mg/kg (%)					**11,4**	**45,7**	**83,3**			
>0,5 mg/kg total (%)						**47,2**				

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.

* Yellow walleye: Small: 30-40 cm; Medium: 40-50 cm; Large: > 50 cm.

Appendix 7 Average arsenic, mercury and selenium concentrations (mg/kg) measured in the flesh of northern pike in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001			< 0,05	0,08	0,36	**0,55**			0,36
Aux Dorés, north	2008		< 0,02	< 0,02	0,17	0,31	**0,52**		0,33	0,35
Aux Dorés, south	2001			< 0,05	0,05	0,24	0,33			0,36
Aux Dorés, south	2008		0,03	< 0,02	0,22	0,30	0,37		0,28	0,32
Chevrier	2009		0,08		0,44	**0,58**	0,37		0,36	
Chevrier, Muscocho	2009	0,06		0,05				0,29		0,33
Chevrillon	2006				0,28	0,42	**0,79**			
Chibougamau, north	2001-2002			0,07	0,24	0,38	**0,59**			0,35
Chibougamau, north	2008	0,03	0,02	0,05	0,16	0,30	**0,62**	0,36	0,41	0,43
Chibougamau, south	1998	0,07	0,10	0,11	0,27	0,44	**0,79**	0,32	0,34	0,43
Chibougamau, south	2001-2002			0,05		0,31	**0,59**			0,40
Chibougamau, south	2008		< 0,02	0,06	0,15	0,27	**0,56**		0,38	0,35
Cosnier	2004		0,06	0,05	0,28	0,50	**0,94**		0,53	0,53
David	2006				0,14	0,32	**0,55**			
du Sauvage	2007			0,07	0,20	0,44	**0,69**			0,25
Fancamp	2002			0,05	0,25	**0,67**	**1,04**			0,34
Fancamp	2009				0,26	**0,60**	**0,69**			
Fancamp, Verneuil	2009	0,05	0,08	0,07				0,38	0,45	0,41
France	2007			0,06	0,18	0,24	**0,79**			0,44
Gabriel	2005			0,06	0,42	**1,06**	**1,68**			0,55
La Dauversière, east	2002		< 0,05		0,32	**0,66**			0,19	
La Dauversière, east	2009	0,06	0,07	0,09	0,27	**0,55**	**0,72**	0,33	0,31	0,31
La Dauversière, Nemenjiche	2001			< 0,05	0,40	**0,69**	**1,35**			0,41
La Dauversière, Nemenjiche	2008		< 0,02		0,31	**0,82**	**1,01**		0,45	
Le Royer	2004		0,06	0,09	0,33	**0,82**	**1,20**		0,40	0,42
Le Royer	2008		0,02	0,05	0,37	**0,72**	**0,88**		0,40	0,39
Muscocho	2009	0,05	0,04		0,42	**0,58**	**1,30**	0,28	0,26	
Nemenjiche	2004		0,08	0,06	0,29	**0,58**	**0,99**		0,51	0,57
Opataca	2006				0,24	0,47	**1,02**			
Opémisca	2003			0,06	0,28	**0,71**	**1,07**			0,27
Opémisca	2010	0,06	0,07	0,06	0,24	**0,57**	**0,87**	0,21	0,20	0,19
Scott	2005			< 0,05	0,34	0,44	**0,79**			0,42
Simon	2005			< 0,05	0,14	0,34	**0,60**			0,36
Verneuil	2009				0,38	**0,60**	**1,14**			
Waconichi	2001			< 0,05	0,12	0,17	0,30			0,37
Waposite	2007			0,06	0,41	**0,67**	**1,71**			0,35
Average		0,05	0,05	0,05	0,26	0,50	**0,83**	0,31	0,36	0,38
Median		0,06	0,05	0,05	0,27	0,49	**0,79**	0,32	0,37	0,36
>0,5 mg/kg (%)					**0,0**	**47,1**	**87,9**			
>0,5 mg/kg total (%)						**45,0**				

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.

* Northern pike: Small: 40-55 cm; Medium: 55-70 cm; Large: > 70 cm.

Appendix 8 Average metal concentrations measured in the flesh of burbot in lakes in the Chibougamau region (1998-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001			0,05	0,34	0,39	**0,54**			0,25
Aux Dorés, north	2008		<0,02	0,06	0,23	0,37	0,38		0,33	0,34
Aux Dorés, south	2001			< 0,05		0,31	0,44			0,31
Aux Dorés, south	2008			0,05	0,27	0,25	0,36			0,34
Chevrier	2009					**0,54**				
Chevrillon	2006						0,36			
Chibougamau, north	2001-2002	0,09	0,07	0,07	0,38	0,43	**0,56**	0,29	0,23	0,28
Chibougamau, north	2008	0,07	0,06	0,04	0,25	0,37	**0,53**	0,39	0,39	0,27
Chibougamau, south	1998	< 0,05			0,38			0,33		
Chibougamau, south	2001-2002	0,08	0,08	0,07	0,44	0,45	**0,56**	0,29	0,27	0,34
Chibougamau, south	2008		0,02		0,20	0,38			0,27	
Cosnier	2004		0,05		0,33	0,32			0,57	
David	2006				0,15	0,22	0,30			
du Sauvage	2007			0,04		0,21	0,37			0,21
Fancamp	2002			< 0,05	0,19	0,37	0,42			0,25
Fancamp	2009					0,22	0,41			
Father	2010				0,50	0,50				
Gabriel	2005				**0,53**	0,44				
La Dauversière, east	2002		0,05	< 0,05	0,36	**0,57**	**0,61**		0,27	0,18
La Dauversière, east	2009		0,08	0,06	0,14	0,36	0,51		0,32	0,25
La Dauversière, Nemenjiche	2001			0,05	**0,57**	**0,57**	**0,65**			0,29
Le Royer	2004			0,06	0,28	**0,64**	**0,69**			0,34
Le Royer	2008		0,07	0,02	0,26	**0,60**	**0,83**		0,30	0,24
Opataca	2006				0,39	0,49	**0,51**			
Opémisca	2003		< 0,05	0,06	0,34	0,49	**0,86**		0,23	0,27
Opémisca	2010	0,09	0,08	0,05	0,17	0,18	**0,57**	0,16	0,17	0,12
Scott	2005					0,28	0,44			
Simon	2005			< 0,05		0,24	0,33			0,32
Waconichi	2001			0,05	0,25	0,22	0,29			0,28
Waconichi	2010	0,15	0,13	0,06	0,16	0,15	0,30	0,27	0,20	0,16
Waposite	2007				0,50					
Average		0,08	0,06	0,05	0,32	0,38	0,49	0,29	0,30	0,27
Median		0,09	0,07	0,05	0,31	0,37	0,48	0,29	0,27	0,27
>0,5 mg/kg (%)					**8,3**	**17,9**	**45,8**			
>0,5 mg/kg total (%)						**23,7**				

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.
* Burbot: Small: 30-45 cm; Medium: 45-60 cm; Large: > 60 cm.

Appendix 9 Average metal concentrations measured in the flesh of lake trout, sauger, fallfish and brook trout in lakes in the Chibougamau region (2000-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Lake trout										
Aux Dorés, north	2000		< 0,10	< 0,10	0,49	**0,76**	**0,90**		0,42	0,36
Aux Dorés, north	2001		< 0,05	0,08	0,45	**0,76**	**1,19**		0,39	0,58
Aux Dorés, north	2008	< 0,02	< 0,02	< 0,02	0,35	0,50	**0,76**	0,39	0,37	0,51
Aux Dorés, south	2001			< 0,05	0,41	**0,53**	**0,75**			0,53
Aux Dorés, south	2008			0,05	0,27	**0,54**	**0,53**			0,33
Chibougamau, north	2000			0,20	0,36	**1,07**	**1,70**		0,37	**0,88**
Chibougamau, north	2001-2002	0,05	0,07	0,09	0,35	**0,77**	**1,45**	0,34	0,36	0,48
Chibougamau, north	2008		0,06	0,05		**0,65**	**1,01**		0,32	0,38
Chibougamau, south	2001-2002		0,07	0,09	0,28	**0,99**	**1,55**		0,36	0,50
Chibougamau, south	2008		< 0,02	0,07		0,49	**1,70**		0,34	0,50
Cosnier	2004			< 0,05		**1,10**	**2,87**			0,61
Father	2010		0,25	1,60		**1,09**	**2,22**		0,26	0,52
Opataca	2006						**0,90**			
Waconichi	2000			< 0,10	0,20	0,33	0,49		0,41	0,47
Waconichi	2001		0,06		0,23	0,43			0,34	
Waconichi	2010	0,04	0,09	0,20	0,18	0,29	**0,82**	0,17	0,25	0,34
Average		0,03	0,07	0,20	0,32	**0,69**	**1,26**	0,30	0,35	0,50
Median		0,04	0,06	0,07	0,35	**0,65**	**1,01**	0,34	0,36	0,50
>0,5 mg/kg (%)					**0,0**	**66,7**	**93,3**			
>0,5 mg/kg total (%)						**58,5**				
Sauger										
Gabriel	2005				0,40	**1,00**				
Fallfish										
Nemenjiche	2004					0,09	0,14			
Brook trout										
Simon	2005						0,15			

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.
* Lake trout: Small: 45-55 cm; Medium: 55-70 cm; Large: > 70 cm.
* Brook trout: Large: > 40 cm.
* Sauger: Small: 20-25 cm; Medium: 25-35 cm.

Appendix 10 Average arsenic, mercury and selenium concentrations in the flesh of lake herring in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2008		0,07		0,22	0,22	0,27		0,51	
Aux Dorés, south	2008		0,07	0,05	0,16	0,19	0,30		0,43	0,57
Chevrier	2009	0,07			0,13	0,07		0,25		
Chevrillon	2006				0,08	0,09	0,16			
Chibougamau, north	2002	0,15	0,09	0,10	0,27	0,21	0,22	0,34	0,41	0,39
Chibougamau, north	2008	< 0,02		0,04	0,14	0,16	0,26	0,34		0,49
Chibougamau, south	2002	0,08	< 0,05	0,11	0,17	0,13	0,14	0,33	0,47	0,43
Chibougamau, south	2008		0,03	0,07	0,12	0,11	0,15		0,45	0,49
David	2006				0,09	0,13	0,20			
du Sauvage	2007			0,06	0,16	0,13	0,12			0,33
Fancamp	2009				0,16	0,22				
Fancamp, La Dauversière, Verneuil	2009	0,09	0,07	0,11				0,28	0,26	0,44
Father	2010				0,11		0,30			
Gabriel	2005				0,21					
La Dauversière, east	2009				0,13	0,17	0,18			
La Dauversière, Nemenjiche	2008				0,16	0,18	0,19			
Le Royer	2004			0,21	0,14	0,22	**0,51**			0,59
Le Royer	2008		< 0,02	0,02	0,15	0,25	0,33		0,41	0,64
Muscocho	2009	0,05	0,07	0,12	0,17	0,19	0,28	0,20	0,32	0,45
Opataca	2006				0,16	0,22	0,28			
Opémisca	2003	0,12	0,17		0,17	0,23		0,28	0,27	
Opémisca	2010		0,13		0,14	0,20			0,17	
Scott	2005				0,14	0,23	0,06			
Simon	2005				0,10	0,13	0,18			
Verneuil	2009				0,13	0,19				
Waconichi	2010				0,17					
Waposite	2007			0,09	0,11	0,17	0,20			0,24
Average		0,08	0,07	0,09	0,15	0,18	0,23	0,29	0,37	0,46
Median		0,08	0,07	0,09	0,15	0,19	0,20	0,28	0,41	0,45
>0,5 mg/kg (%)					**0,0**	**0,0**	**5,3**			
>0,5 mg/kg total (%)						**1,5**				

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.

* Lake herring: Small: 20-25 cm; Medium: 25-30 cm; Large: > 30 cm.

Appendix 11 Average arsenic, mercury and selenium concentrations in the flesh of lake whitefish in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001			< 0,05	0,15	0,12	0,14			0,45
Aux Dorés, north	2008		0,06	0,06	0,08	0,11	0,21		0,57	0,50
Aux Dorés, south	2001			< 0,05	0,05	0,07	0,08			0,44
Aux Dorés, south	2008		0,03	< 0,02	0,07	0,07	0,16		0,42	0,46
Chevrier	2009				0,05	0,08	0,16			
Chevrier, Muscocho	2009	0,07	0,09	0,10				0,49	0,47	0,45
Chevrillon	2006				0,03	0,04				
Chibougamau, north	2001-2002			0,05	0,14	0,19	0,31			0,46
Chibougamau, north	2008	< 0,02	0,02	0,05	0,10	0,07	0,19	0,52	0,51	0,56
Chibougamau, south	1998		0,19			0,17	0,16		0,54	
Chibougamau, south	2001-2002			0,05	0,12	0,17	0,23			0,53
Chibougamau, south	2008		0,04	0,04	0,07	0,12	0,15		0,40	0,46
Cosnier	2004				0,15	0,09			0,61	0,51
David	2006				0,05	0,04				
du Sauvage	2007			0,09	0,02	0,07	0,07			0,39
Fancamp	2002			0,06	0,04	0,07	0,11			0,61
Fancamp	2009				0,06	0,08	0,09			
Fancamp, La Dauversière, Verneuil	2009	0,11	0,09	0,10				0,56	0,54	0,61
Father	2010	0,07	0,08	0,29	0,06	0,08	0,13	0,28	0,26	0,34
France	2007			0,09	0,11	0,11	0,16			0,34
Gabriel	2005			0,05	0,12	0,13	0,22			0,72
La Dauversière, east	2002			0,07	0,06	0,08	0,16			0,61
La Dauversière, east	2009				0,07	0,10	0,09			
La Dauversière, Nemenjiche	2001			< 0,05	0,07	0,11	0,22			0,54
La Dauversière, Nemenjiche	2008				0,06	0,07	0,11			
Le Royer	2004		0,07	0,09	0,09	0,12	0,20		0,67	0,66
Le Royer	2008		0,03	< 0,02	0,06	0,14	0,15		0,73	0,73
Muscocho	2009			0,08	0,08	0,10	0,15			0,50
Nemenjiche	2004			0,06	0,12	0,16	0,17			0,64
Opataca	2006				0,06	0,15				
Opémisca	2003		0,07	0,06	0,10	0,13	0,15		0,47	0,48
Opémisca	2010	0,08	0,07	0,10	0,06	0,08	0,14	0,41	0,43	0,38
Scott	2005			0,05	0,04	0,05	0,09			0,56
Simon	2005			< 0,05	0,03	0,04	0,11			0,54
Verneuil	2009				0,07	0,06	0,06			
Waconichi	2000	0,11	0,10	0,12	0,11	0,16	0,15	0,42	0,50	0,38
Waconichi	2001			0,10	0,09	0,10	0,17			0,54
Waconichi	2010	0,18	0,18	0,13	0,09	0,09	0,18	0,39	0,40	0,43
Waposite	2007			0,04	0,20	0,07	0,13			0,54
Average		0,09	0,08	0,07	0,08	0,10	0,15	0,44	0,50	0,51
Median		0,08	0,07	0,06	0,07	0,09	0,15	0,42	0,50	0,51
>0,5 mg/kg (%)					**0,0**	**0,0**	**0,0**			
>0,5 mg/kg total (%)						**0,0**				

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.
* Lake whitefish: Small: 35-40 cm; Medium: 40-45 cm; Large: > 45 cm.

Appendix 12 Average arsenic, mercury and selenium concentrations in the flesh of white sucker in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2008					0,06	0,12			
Aux Dorés, south	2008			0,03	0,04	0,06	0,19			0,38
Chevrier	2009			0,05		0,13	0,31			0,37
Chevrier, Muscocho	2009		0,04						0,27	
Chevrillon	2006				0,09	0,09				
Chibougamau, north	2008	< 0,02	< 0,02	< 0,02	0,03	0,04	0,09	0,40	0,27	0,52
Chibougamau, south	1998			0,20	0,07	0,09	0,22			0,61
Chibougamau, south	2008		0,05	0,03	0,03	0,05	0,11		0,38	0,44
Cosnier	2004	< 0,05	0,02	< 0,05	0,09	0,10	0,21	0,66	0,71	0,56
David	2006				0,04	0,04				
du Sauvage	2007			0,03		0,03	0,19			0,26
Fancamp	2002		0,05	< 0,05	0,05	0,07	0,16		0,42	0,44
Fancamp	2009				0,11	0,08	0,19			
Fancamp, La Dauversière, Verneuil	2009	0,06	0,06	0,06				0,35	0,42	0,45
France	2007			0,08	0,05	0,04	0,12			0,24
Gabriel	2005			< 0,05	0,07	0,11	0,23			0,73
La Dauversière, east	2002		0,05	< 0,05	0,08	0,12	0,16		0,44	0,43
La Dauversière, east	2009				0,07	0,05	0,25			
La Dauversière, Nemenjiche	2008			< 0,02	0,16	0,07	0,28			0,52
Le Royer	2004		0,06	0,03	0,06	0,08	0,17		0,56	0,50
Le Royer	2008		0,04	0,04	0,07	0,08	0,21		0,45	0,50
Muscocho	2009	0,06			0,09	0,08	0,25	0,17		
Nemenjiche	2004		< 0,05	< 0,05	0,10	0,14	0,25		0,54	0,65
Opataca	2006				0,10	0,04				
Opémisca	2003			< 0,05	0,09	0,13	0,20			0,36
Opémisca	2010	0,07	0,06	0,07	0,05	0,08	0,10	0,26	0,23	0,32
Scott	2005			< 0,05	0,04	0,05	0,25			0,48
Simon	2005			< 0,05	0,04	0,03	0,11			0,41
Verneuil	2009				0,09	0,09	0,15			
Waconichi	2010	0,06	0,09	0,05	0,04	0,03	0,09	0,32	0,36	0,35
Waposite	2007			0,08		0,05	0,28			0,37
Average		0,05	0,05	< 0,05	0,07	0,07	0,19	0,36	0,42	0,45
Median		0,06	0,05	< 0,05	0,07	0,07	0,19	0,34	0,42	0,44
>0,5 mg/kg (%)					**0,0**	**0,0**	**0,0**			
>0,5 mg/kg total (%)						**0,0**				

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.

* White sucker: Small: 30-35 cm; Medium: 35-40 cm; Large: > 40 cm.

Appendix 13 Average arsenic, mercury and selenium concentrations in the flesh of northern sucker and yellow perch in lakes in the Chibougamau and Oujé-Bougoumou region (1998-2010)

	Year	Arsenic			Mercury			Selenium		
Lake		Small*	Medium	Large	Small	Medium	Large	Small	Medium	Large
			(mg/kg)			(mg/kg)			(mg/kg)	
Northern sucker										
Aux Dorés, north	2008				0,11	0,16	0,20			
Aux Dorés, south	2008				0,08	0,12	0,21			
Chevrillon	2006	0,09		0,05			0,35	0,25		0,31
Chibougamau, north	2002	0,12	0,15	0,14	0,12	0,22	0,29	0,29	0,39	0,40
Chibougamau, north	2008		<0,02	0,12	0,16	0,19	0,32		0,33	0,41
Chibougamau, south	1998					0,21	0,27			
Chibougamau, south	2002	0,09	0,15	0,16	0,14	0,24	0,37	0,40	0,52	0,53
Chibougamau, south	2008		0,05	0,05	0,11	0,14	0,17		0,44	0,41
Cosnier	2004			< 0,05	0,13	0,15	0,25			0,93
David	2006						0,38			
Father	2010		2,1	0,87	0,26	0,70	0,38		0,43	0,72
Gabriel	2005			< 0,05	0,22	0,20	0,41			0,42
Muscocho	2009			0,05			0,30			0,49
Opataca	2006				0,12	0,12	0,50			
Opémisca	2003		< 0,05	< 0,05	0,12	0,13	0,36		0,35	0,34
Opémisca	2010				0,09		0,27			
Simon	2005			< 0,05	0,08	0,05	0,25			0,31
Average		0,10	0,41	0,14	0,13	0,20	0,31	0,31	0,41	0,48
Median		0,09	0,10	0,05	0,12	0,16	0,30	0,29	0,41	0,41
>0,5 mg/kg (%)					**0,0**	**0,0**	**0,0**			
>0,5 mg/kg total (%)						**0,0**				
Yellow perch										
Aux Dorés, north	2008				0,14					
Aux Dorés, south	2008				0,10					
Chevrier	2009	0,05	0,05		0,18	0,19		0,49	0,52	
Chevrillon	2006				0,08	0,12	0,19			
Chibougamau, north	2008				0,13					
Chibougamau, south	2008	0,04			0,11			0,61		
David	2006				0,08	0,17				
du Sauvage	2007				0,03	0,04	0,12			
Fancamp	2009	0,04			0,26			0,56		
France	2007			0,06	0,15					0,25
La Dauversière, east	2009	0,03			0,11			0,35		
La Dauversière, Nemenjiche	2008				0,06	0,08				
Le Royer	2004				0,12	0,48				
Le Royer	2008				0,13	0,43				
Muscocho	2009	0,03	0,04		0,10	0,12		0,41	0,42	
Nemenjiche	2004				0,16					
Opataca	2006				0,09	0,23				
Opémisca	2010				0,17	0,23				
Scott	2005				0,15	0,22				
Simon	2005				0,06					
Verneuil	2009	0,04			0,13			0,58		
Waconichi	2010				0,08					
Waposite	2007				0,10	0,08	0,20			
Average		0,04	0,05	0,06	0,12	0,20	0,17	0,50	0,47	0,25
Median		0,04	0,05	0,06	0,11	0,18	0,19	0,53	0,47	0,25
>0,5 mg/kg (%)					**0,0**	**0,0**	**0,0**			
>0,5 mg/kg total (%)						**0,0**				

In bold face: Mercury concentrations that exceed the Health Canada guideline for the sale of fishery products, which is set at 0.5 mg/kg.

* Northern sucker: Small: 30-35 cm; Medium: 35-40 cm; Large: > 40 cm.

* Yellow perch: Small: 15-20 cm; Medium: 20-25 cm; Large: > 25 cm.

Appendix 14 Average metal concentrations in the flesh of yellow walleye in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001						0,020						0,18			0,22			0,05
Aux Dorés, north	2008	0,007	0,004	0,018	<0,009	<0,009	<0,009	0,005	0,007	0,013	0,10	0,11	0,31	0,28	0,27	0,27	0,14	0,10	0,10
Aux Dorés, south	2001						0,023						0,07			0,23			0,06
Aux Dorés, south	2008		0,005	0,004		<0,009	<0,009		0,008	0,008		0,10	0,12		0,28	0,24		0,10	0,07
Chevrier (1)	2009	0,004	0,004	0,002	<0,009	<0,009	<0,009	0,002	0,002	0,002	0,01	0,01	0,01	0,21	0,22	0,26	0,09	0,08	0,07
Chevrier (2)	2009	0,005			<0,009			0,003			0,01			0,22			0,09		
Chevrier-Muscocho	2009	0,024	0,011	0,006	<0,009	<0,009	0,029	0,003	0,003	0,006	<0,003	<0,003	0,01	0,15	0,15	0,20	0,15	0,07	0,06
Chevrillon	2006			<0,5			<0,003			<0,05			0,08			0,18			0,05
Chibougamau, north	2001-2002			< 0,5			0,027			< 0,05			0,10			0,34			0,54
Chibougamau, north	2008	0,007	0,010	0,012	<0,009	<0,009	<0,009	0,025	0,002	0,003	0,06	0,01	0,02	0,22	0,26	0,29	0,10	0,08	0,08
Chibougamau, south	2001-2002						0,016						0,05			0,32			0,06
Chibougamau, south	2008		0,020	0,009		<0,009	<0,009		0,005	0,003		0,02	0,01		0,32	0,31		0,20	0,07
Cosnier	2004		< 0,5	< 0,5		0,003	< 0,003		< 0,05	< 0,05		0,11	0,08		0,20	0,21		< 0,03	0,06
David	2006			<0,5			<0,003			<0,05			0,06			0,33			0,06
du Sauvage	2007			<0,5			<0,003			<0,025			0,03			0,18			0,04
Fancamp	2002						0,010						0,08			0,18			0,05
Fancamp, Verneuil	2009	0,005	0,020	0,006	<0,009	<0,009	<0,009	0,002	0,002	0,001	0,014	0,007	0,004	0,31	0,24	0,24	0,09	0,10	0,08
Father	2010		0,006	0,004		<0,009	<0,009		0,002	0,003		0,007	0,004					0,09	0,06
France	2007			<0,5			<0,003			<0,025			<0,03			0,25			0,03
Gabriel	2005			< 0,5			0,003			< 0,05			0,07			0,25			0,08
La Dauversière, east	2002						0,010						0,08			0,22			0,10
La Dauversière, east	2009	0,012	0,004	0,002	<0,009	<0,009	<0,009	0,001	0,002	0,002	0,01	0,01	0,01	0,21	0,21	0,22	0,08	0,07	0,07
La Dauversière, Nemenjiche	2001						0,019						0,09			0,20			0,08
La Dauversière, Nemenjiche	2008		0,003	0,008		0,014	<0,009		0,006	0,008		0,13	0,29		0,22	0,18		0,10	0,09
Le Royer	2004		< 0,5	< 0,5		0,005	0,003		< 0,05	< 0,05		0,08	0,11		0,25	0,27		< 0,03	< 0,03
Le Royer	2008		<0,001	<0,001		<0,009	<0,009		0,006	0,003		0,25	0,14		0,22	0,21		0,10	0,05
Mistassini	2003			< 0,5			< 0,003			< 0,05			0,07			0,27			0,07
Muscocho	2009	0,003	0,003	0,001	<0,009	<0,009	<0,009	0,002	0,002	0,002	<0,003	<0,003	<0,003	0,22	0,21	0,18	0,07	0,07	0,05
Nemenjiche	2004		< 0,5	< 0,5		0,006	0,003		< 0,05	< 0,05		0,14	0,09		0,27	0,14		0,05	< 0,03
Opataca	2006			<0,5			<0,003			<0,05			0,07			0,18			0,06
Opémisca	2003			< 0,5			0,015			< 0,05			0,18			0,56			0,30
Opémisca	2010	0,008	0,005	0,002	<0,009	<0,009	<0,009	0,001	0,001	0,001	<0,003	0,005	0,004	0,21	0,19	0,22	0,09	0,09	0,06
Scott	2005			< 0,5			< 0,003			< 0,05			0,33			0,25			0,08
Simon	2005			< 0,5			0,004			< 0,05			< 0,03			0,38			0,05
Waconichi	2001				0,018	0,032	0,014				0,12	0,07	0,07	0,18	0,15	0,22	0,08	0,09	< 0,05
Waposite	2007			<0,5			<0,003			<0,05			<0,025			0,25			0,04
Median		0,007	0,006	<0,5	<0,009	<0,009	<0,009	0,002	0,004	<0,05	0,01	0,02	0,07	0,22	0,22	0,24	0,09	0,09	0,06

* Yellow walleye: Small: 30-40 cm; Medium: 40-50 cm; Large: > 50 cm.

Appendix 14 (continued) Average metal concentrations in the flesh of yellow walleye in lakes in the Chibougamau region (2001-2010)

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001						<0,1			0,08						5,2
Aux Dorés, north	2008	0,069	0,059	0,165	0,002	0,002	0,002	0,07	0,05	0,07	<0,04	<0,04	<0,04	4,9	5,3	5,5
Aux Dorés, south	2001						<0,1			<0,05						4,7
Aux Dorés, south	2008		0,06	0,07		0,002	0,002		0,09	0,06		<0,04	<0,04		4,9	3,7
Chevrier (1)	2009	0,01	0,01	0,01	0,004	0,003	0,002	0,02	0,02	0,02	<0,04	<0,04	<0,04	3,7	4,2	4,5
Chevrier (2)	2009	0,01			0,016			0,03			<0,04			4,5		
Chevrier, Muscocho	2009	<0,005	0,01	<0,005	0,005	0,004	0,003	0,24	0,03	0,03	<0,04	<0,04	<0,04	3,9	5,3	5,1
Chevrillon	2006			<0,5			<0,1			<0,02			<0,1			3,2
Chibougamau, north	2001-2002			<0,2			<0,1			<0,05			<0,1			4,7
Chibougamau, north	2008	0,12	0,03	0,01	0,003	0,004	0,003	0,04	0,06	0,09	<0,04	<0,04	<0,04	4,6	4,6	4,8
Chibougamau, south	2001-2002						<0,1			0,07						4,5
Chibougamau, south	2008		<0,005	<0,005		0,004	0,004		0,09	0,04		<0,04	<0,04		4,9	5,1
Cosnier	2004		<0,5	<0,5		<0,1	<0,1		0,12	0,12		<0,1	<0,1		3,3	3,9
David	2006			<0,5			<0,1			<0,02			<0,1			3,9
du Sauvage	2007			<0,5			<0,1			0,03			<0,1			3,7
Fancamp	2002			<0,2			<0,1			0,05						3,2
Fancamp, Verneuil	2009	0,007	0,01	0,013	0,004	0,008	0,007	0,03	0,03	0,03	<0,04	<0,04	<0,04	4,3	4,2	4,6
Father	2010		<0,005	<0,005		0,014	0,004		0,03	0,02		<0,04	<0,04		3,3	3,2
France	2007			<0,5			<0,1			0,03			<0,1			3,8
Gabriel	2005			<0,5			<0,1			0,03			<0,1			4,7
La Dauversière, east	2002			<0,2			<0,1			0,09						3,7
La Dauversière, east	2009	<0,005	0,01	<0,005	0,004	0,002	0,001	0,02	0,01	0,32	<0,04	<0,04	<0,04	3,6	3,4	
La Dauversière, Nemenjiche	2001						0,12			0,12						3,8
La Dauversière, Nemenjiche	2008		0,08	0,16		0,002	0,002		0,03	0,04		<0,04	<0,04		3,4	3,5
Le Royer	2004		<0,5	<0,5		<0,1	<0,1		0,02	<0,02		< 0,1	<0,1		4,0	4,1
Le Royer	2008		0,13	0,02		0,003	0,002		0,04	0,02		<0,04	<0,04		3,5	4,3
Mistassini	2003			<0,5			<0,1			0,06			<0,1			4,3
Muscocho	2009		<0,005	<0,005		0,003	0,002		0,02	0,02		<0,04	<0,04		3,8	3,9
Nemenjiche	2004		<0,5	<0,5		<0,1	<0,1		0,33	<0,02		<0,1	<0,1		3,6	2,4
Opataca	2006			<0,5			<0,1			0,04			<0,1			5,1
Opémisca	2003			<0,5			<0,1			0,05			<0,1			4,3
Opémisca	2010	<0,005	<0,005	<0,005	0,006	0,005	0,002	0,02	0,02	0,02	<0,04	<0,04	<0,04	4,0	3,3	3,4
Scott	2005			<0,5			<0,1			<0,02			<0,1			5,3
Simon	2005			<0,5						<0,02			<0,1			3,7
Waconichi	2001				<0,1	<0,1	<0,1	0,12	0,14	<0,05				4,6	6,5	4,5
Waposite	2007			<0,5			<0,1			0,06			<0,1			3,1
Median		0,01	0,04	<0,5	0,004	0,004	<0,1	0,03	0,03	0,03	<0,04	<0,04	<0,1	4,3	4,0	4,2

* Yellow walleye: Small: 30-40 cm; Medium: 40-50 cm; Large: > 50 cm.

Appendix 15 Average metal concentrations in the flesh of northern pike in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001						0,017						0,10			0,26			0,08
Aux Dorés, north	2008		0,007	0,011		<0,009	<0,009		0,006	0,012		0,11	0,14		0,26	0,34		0,11	0,18
Aux Dorés, south	2001						0,030						0,09			0,29			0,21
Aux Dorés, south	2008		0,014	0,005		<0,009	<0,009		0,016	0,012		0,26	0,15		0,25	0,30		0,24	0,11
Chevrier	2009		0,009			<0,009			0,003			0,02			0,24			0,13	
Chevrier, Muscocho	2009	0,019		0,006	<0,009		<0,009	0,004		0,003	0,04		0,01	0,29		0,22	0,27		0,10
Chevrillon	2006																		
Chibougamau, north	2001-2002			< 0,5			0,020			< 0,05			0,07			0,73			0,16
Chibougamau, north	2008	0,018	0,011	0,006	<0,009	<0,009	<0,009	0,005	0,005	0,004	0,07	0,01	0,01	0,25	0,29	0,30	0,17	0,13	0,08
Chibougamau, south	2001-2002						0,016						0,06			0,24			< 0,05
Chibougamau, south	2008		0,044	0,011		<0,009	<0,009		0,006	0,005		0,04	0,01		0,34	0,35		0,11	0,09
Cosnier	2004		< 0,5	< 0,5		< 0,003	< 0,003		< 0,05	< 0,05		0,14	0,18		0,26	0,31		< 0,03	0,12
du Sauvage	2007			<0,5			<0,003			<0,05			<0,025			0,24			0,06
Fancamp	2002						0,020						0,08			0,23			0,30
Fancamp, Verneuil	2009	0,022	0,012	0,038	<0,009	<0,009	<0,009	0,003	0,003	0,003	<0,003	0,01	0,01	0,30	0,36	0,26	0,28	0,15	0,25
France	2007						<0,003						0,46			0,39			0,17
Gabriel	2005			< 0,5			0,003			< 0,05			< 0,03			0,26			0,12
La Dauversière, east	2002					0,020						0,07			0,24			0,45	
La Dauversière, east	2009	0,025	0,022	0,014	<0,009	<0,009	<0,009	0,003	0,003	0,002	0,01	<0,003	0,01	0,25	0,24	0,21	0,39	0,24	0,23
La Dauversière, Nemenjiche	2001						0,016						0,06			0,27			0,12
La Dauversière, Nemenjiche	2008		0,001			<0,009			0,006			0,20			0,21			0,19	
Le Royer	2004		< 0,5	< 0,5		< 0,003	< 0,003		< 0,05	< 0,05		0,10	< 0,03		0,20	0,21		0,18	0,33
Le Royer	2008		<0,001	<0,001		<0,009	<0,009		0,110	0,004		0,34	0,16		0,19	0,16		0,15	0,17
Muscocho	2009	0,021	0,009		<0,009	<0,009		0,004	0,003		0,02	0,01		0,21	0,2		0,24	0,13	
Nemenjiche	2004		< 0,5	< 0,5		0,005	0,005		< 0,05	< 0,05		0,11	0,19		0,24	0,25		0,14	0,20
Opémisca	2003		< 0,5	< 0,5		0,018	0,020		< 0,05	< 0,05		0,13	0,10		0,20	0,17		0,77	1,07
Opémisca	2010	0,008	0,010	0,008	<0,009	<0,009	<0,009	0,003	0,002	0,002	0,01	0,01	0,01	0,27	0,32	0,38	0,12	0,15	0,08
Scott	2005			< 0,5			0,009			< 0,05			0,03			0,58			0,07
Simon	2005			< 0,5			0,007			< 0,05			< 0,03			0,43			0,06
Waconichi	2001						0,022						0,07			0,20			0,14
Waposite	2007			<0,5			<0,003			<0,05			<0,025			0,26			0,06
Median		0,020	0,012	<0,5	<0,009	<0,009	<0,009	0,003	0,006	< 0,05	0,01	0,10	0,06	0,26	0,24	0,26	0,26	0,15	0,12

* Northern pike: Small: 40-55 cm; Medium: 55-70 cm; Large: > 70 cm.

Appendix 15 (continued) Average metal concentrations in the flesh of northern pike in lakes in the Chibougamau region (2001-2010)

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001						0,11			0,07						3,7
Aux Dorés, north	2008		0,054	0,05		0,002	0,001		0,08	0,12		<0,04	<0,04		3,8	5,1
Aux Dorés, south	2001						<0,1			0,15						4,0
Aux Dorés, south	2008		0,14	0,07		0,004	0,003		0,16	0,07		<0,04	<0,04		4,4	4,1
Chevrier	2009		0,01			0,009			0,04			<0,04			4,2	
Chevrier, Muscocho	2009	0,01		<0,005	0,008		0,005	0,10		0,03	<0,04		<0,04	4,9		4,9
Chibougamau, north	2001-2002			<0,2			<0,1			0,09			<0,1			3,9
Chibougamau, north	2008	0,016	<0,005	0,019	0,002	0,003	0,004	0,13	0,09	0,04	<0,04	<0,04	<0,04	3,9	4,1	3,9
Chibougamau, south	2001-2002						<0,1			0,05						3,4
Chibougamau, south	2008		<0,005	<0,005		0,006	0,006		0,04	0,05		<0,04	<0,04		8,5	7,9
Cosnier	2004		<0,5	<0,5		<0,1	<0,1		0,06	0,06		<0,1	<0,1		3,7	3,6
du Sauvage	2007			<0,5			<0,1			0,03			<0,1			4,3
Fancamp	2002			<0,2			<0,1			0,23						4,4
Fancamp, Verneuil	2009	<0,005	0,01	0,013	0,005	0,006	0,006	0,09	0,06	0,18	<0,04	<0,04	<0,04	4,9	4,7	5,3
France	2007			<0,5			<0,1			0,09						4,3
Gabriel	2005			<0,5			<0,1			0,03			<0,1			4,6
La Dauversière, east	2002		< 0,2			<0,1			0,10						2,4	
La Dauversière, east	2009	0,01	0,01	<0,005	0,006	0,007	0,009	0,13	0,09	0,08	<0,04	<0,04	<0,04	4,5	4,1	3,9
La Dauversière, Nemenjiche	2001						0,12			0,10						4,6
La Dauversière, Nemenjiche	2008		0,11			0,007			0,15			<0,04			3,7	
Le Royer	2004		<0,5	<0,5		<0,1	<0,1		0,22	0,28		<0,1	<0,1		3,6	4,0
Le Royer	2008		0,19	0,09		0,003	0,002		0,11	0,10		<0,04	<0,04		3,6	3,5
Muscocho	2009	0,01	0,01		0,007	0,006		0,15	0,07		<0,04	<0,04		5,3	4,5	
Nemenjiche	2004		<0,5	<0,5		<0,1	<0,1		0,15	0,27		<0,1	<0,1		3,5	3,9
Opémisca	2003		<0,2	<0,2		<0,1	<0,1		0,17	0,19		<0,1	<0,1		4,4	4,9
Opémisca	2010	<0,005	<0,005	0,006	0,003	0,003	0,005	0,03	0,08	0,03	<0,04	<0,04	<0,04	4,1	4,6	4,1
Scott	2005			<0,5			<0,1			<0,02			<0,1			5,9
Simon	2005			<0,5			<0,1			<0,02			<0,1			5,4
Waconichi	2001						<0,1			0,07						3,8
Waposite	2007			<0,5			<0,1			0,10			<0,1			4,2
Median		0,01	0,08	0,10	0,005	0,006	< 0,1	0,11	0,09	0,08	<0,04	<0,04	< 0,1	4,7	4,1	4,2

* Northern pike: Small: 40-55 cm; Medium: 55-70 cm; Large: > 70 cm.

Appendix 16 Average metal concentrations in the flesh of burbot in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001						0,015						0,10			0,27			0,12
Aux Dorés, north	2008		0,008	0,009		<0,009	<0,009		0,004	0,007		0,06	0,10		0,36	0,42		0,13	0,21
Aux Dorés, south	2001						0,012						0,07			0,27			0,14
Aux Dorés, south	2008			0,008			<0,009			0,012			0,09			0,33			0,14
Chevrillon	2006			<0,5			<0,003			<0,05			0,11			0,28			0,17
Chibougamau, north	2001-2002	<0,5	<0,5	<0,5	0,020	0,017	0,015	<0,05	<0,05	<0,05	0,10	0,09	0,06	0,37	0,28	0,19	0,52	0,33	0,13
Chibougamau, north	2008	0,019	0,033	0,018	<0,009	<0,009	<0,009	0,004	0,005	0,004	0,04	0,03	0,01	0,32	0,32	0,35	0,17	0,16	0,12
Chibougamau, south	2001-2002	<0,5	<0,5	<0,5	0,020	0,020	0,012	<0,05	<0,05	<0,05	0,06	0,06	0,06	0,23	0,23	0,22	0,23	0,16	0,78
Chibougamau, south	2008		0,022			<0,009			0,006			0,02			0,28			0,27	
Cosnier	2004		<0,5			<0,003			<0,05			0,12			0,34			0,54	
David	2006			<0,5			<0,003			<0,05			0,05			0,23			0,11
du Sauvage	2007			<0,5			<0,003			<0,05			<0,03			0,21			0,10
Fancamp	2002						0,010						0,06			0,21			0,09
La Dauversière, east	2002					0,010						0,06			0,16			0,13	
La Dauversière, east	2009		0,097	0,022		<0,009	<0,009		0,003	0,002		0,00	0,01		0,24	0,22		0,31	0,17
La Dauversière, Nemenjiche	2001						0,033						0,10			0,22			0,29
Le Royer	2004		<0,5	<0,5		0,003	<0,003		<0,05	<0,05		0,11	<0,03		0,21	0,22		0,14	0,13
Le Royer	2008		<0,001	0,003		<0,009	<0,009		0,009	0,008		0,30	0,35		0,18	0,18		0,21	0,21
Opataca	2006			<0,5			<0,003			<0,05			0,12			0,20			0,11
Opémisca	2003		<0,5	<0,5		0,005	<0,003		<0,05	<0,05		0,08	0,06		0,25	0,20		0,18	0,17
Opémisca	2010	0,008	0,004	0,006	<0,009	<0,009	<0,009	0,003	0,002	0,002	0,01	0,005	0,004	0,29	0,24	0,29	0,13	0,13	0,10
Simon	2005			<0,5			<0,003			<0,05			<0,03			1,10			0,10
Waconichi	2001						0,020						0,09			0,24			0,15
Waconichi	2010	0,070	0,014	0,006	<0,009	<0,009	<0,009	0,005	0,003	0,002	0,01	0,003	0,004	0,37	0,28	0,20	0,25	0,18	0,12
Median		0,070	0,065	<0,5	<0,009	<0,009	<0,009	<0,05	<0,05	<0,05	0,04	0,06	0,06	0,32	0,25	0,22	0,23	0,18	0,13

* Burbot: Small: 30-45 cm; Medium: 45-60 cm; Large: > 60 cm.

Appendix 16 (continued) Average metal concentrations in the flesh of burbot in lakes in the Chibougamau region (2001-2010)

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001						0,10			0,10						5,8
Aux Dorés, north	2008		0,04	0,06		0,004	0,004		0,07	0,07		<0,04	<0,04		6,1	7,8
Aux Dorés, south	2001						<0,1			0,05						5,8
Aux Dorés, south	2008			0,053			0,006			0,10			<0,04			7,3
Chevrillon	2006			<0,5			<0,1			0,32			<0,1			**150**
Chibougamau, north	2001-2002	0,30	<0,2	<0,2	<0,1	<0,1	<0,1	0,08	0,07	0,10	<0,1	<0,1	<0,1	5,1	4,6	3,9
Chibougamau, north	2008	0,048	0,017	0,012	0,003	0,004	0,004	0,10	0,13	0,07	<0,04	<0,04	<0,04	5,9	6,5	6,2
Chibougamau, south	2001-2002	<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,36	0,24	0,08	<0,1	<0,1	<0,1	4,1	4,0	5,1
Chibougamau, south	2008		<0,005			0,009			0,10			<0,04			8,2	
Cosnier	2004		<0,5			<0,1			0,17			<0,1			4,6	
David	2006			<0,5			<0,1			0,03			<0,1			9,5
du Sauvage	2007			<0,5			<0,1			0,06			<0,1			5,6
Fancamp	2002			<0,2			<0,1			0,06						5,0
La Dauversière, east	2002		<0,2			<0,1			0,05						3,4	
La Dauversière, east	2009		<0,005	<0,005		0,006	0,005		0,32	0,11		<0,04	<0,04		6,4	6,5
La Dauversière, Nemenjiche	2001						0,14			0,80						3,2
Le Royer	2004		<0,5	<0,5		<0,1	<0,1		0,12	0,08		<0,1	<0,1		5,0	5,0
Le Royer	2008		0,16	0,22		0,007	0,005		0,06	0,06		<0,04	<0,04		4,4	4,1
Opataca	2006			<0,5			<0,1			0,07			<0,1			**250**
Opémisca	2003		<0,5	<0,5		<0,1	<0,1		0,23	0,25		<0,1	<0,1		5,1	4,7
Opémisca	2010	<0,005	<0,005	0,007	0,005	0,003	0,003	0,06	0,03	0,04	<0,04	<0,04	<0,04	6,0	5,1	6,1
Simon	2005			<0,5			<0,1			0,03			<0,1			7,7
Waconichi	2001						<0,1			0,28						5,9
Waconichi	2010	0,01	0,01	<0,005	0,006	0,010	0,005	0,16	0,05	0,03	<0,04	<0,04	<0,04	6,4	6,5	5,8
Median		<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,10	0,10	0,07	<0,04	<0,04	<0,04	5,9	5,1	5,8

* Burbot: Small: 30-45 cm; Medium: 45-60 cm; Large: > 60 cm.

Appendix 17 Average metal concentrations in the flesh of lake trout in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001					0,017	0,012					0,10	0,09		0,43	0,47		0,05	<0,05
Aux Dorés, north	2008	0,004	0,008	0,008	<0,009	<0,009	<0,009	0,007	0,011	0,008	0,26	0,32	0,25	0,38	0,46	0,38	0,12	0,12	0,11
Aux Dorés, south	2001						0,017						0,07			0,26			<0,05
Aux Dorés, south	2008		0,004	0,007		<0,009	<0,009		0,021	0,011		0,19	0,11		0,4	0,40		0,09	0,68
Chibougamau, north	2001-2002	<0,5	<0,5	<0,5	0,020	0,016	0,022	<0,05	<0,05	<0,05	0,12	0,10	0,10	0,44	0,35	0,36	0,19	0,22	0,15
Chibougamau, north	2008		0,008	0,006		<0,009	<0,009		0,004	0,003		0,01	0,04		0,46	0,36		0,09	0,06
Chibougamau, south	2001-2002		<0,5	<0,5		0,010	0,018		<0,05	<0,05		0,09	<0,05		0,23	0,49		0,06	<0,05
Chibougamau, south	2008		0,009	0,011		<0,009	<0,009		0,005	0,006		0,01	0,04		0,49	0,43		0,07	0,07
Cosnier	2004			<0,5			0,003			<0,05			0,13			0,47			0,05
Father	2010		0,005	0,004		<0,009	<0,009		0,006	0,006		0,05	0,01		0,70	0,40		0,10	0,08
Opataca	2006			<0,5			0,003			<0,05			0,06			0,34			0,07
Waconichi	2001					0,019						0,08			0,28			0,11	
Waconichi	2010	0,003	0,003	0,004	<0,009	<0,009	<0,009	0,002	0,003	0,003	0,01	0,05	<0,003	0,28	0,34	0,40	0,08	0,09	0,09
Median		0,004	0,008	0,010	<0,009	<0,009	<0,009	0,007	0,008	0,009	0,12	0,09	0,08	0,38	0,42	0,40	0,12	0,09	0,08

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001					<0,1	0,11		<0,05	<0,05					3,1	3,3
Aux Dorés, north	2008	0,13	0,19	0,18	0,003	0,004	0,002	0,056	0,049	0,068	<0,04	<0,04	<0,04	3,7	3,5	9,2
Aux Dorés, south	2001						0,10			0,07						3,3
Aux Dorés, south	2008		0,10	0,05			0,003		0,063	0,078		<0,04	<0,04		3,6	3,4
Chibougamau, north	2001-2002	0,40	0,40	0,50	<0,1	<0,1	<0,1	<0,05	<0,05	0,06	<0,1	<0,1	<0,1	3,5	2,6	3,4
Chibougamau, north	2008		0,049	0,039		0,002	0,001		0,057	0,027		<0,04	<0,04		3,4	3,1
Chibougamau, south	2001-2002		<0,2	<0,2		<0,1	<0,1		0,07	<0,05		<0,1	<0,1		2,8	3,4
Chibougamau, south	2008		<0,005	<0,005		0,003	0,004		0,035	0,076		<0,04	<0,04		4,7	0,4
Cosnier	2004			<0,5			<0,1			0,05			<0,1			4,1
Father	2010		0,02	0,01		0,016	0,005		0,027	0,022		<0,04	<0,04		3,7	3,8
Muscocho	2009	<0,005			0,002			0,026			<0,04			3,9		
Opataca	2006			<0,5			<0,1			0,03			<0,1			2,9
Waconichi	2001					<0,1			0,07						3,1	
Waconichi	2010	<0,005	0,01	<0,005	0,003	0,003	0,020	0,017	0,082	0,012	<0,04	<0,04	<0,04	3,1	3,3	3,8
Median		0,07	0,07	0,08	0,003	0,016	0,035	0,03	0,05	0,04	<0,04	<0,04	<0,04	3,4	3,4	3,4

* Lake trout: Small: 45-55 cm; Medium: 55-70 cm; Large: > 70 cm.

Appendix 18 Average metal concentrations in the flesh of lake herring in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2008		0,024			<0,009			0,019			0,130			0,21			0,25	
Aux Dorés, south	2008		0,022	0,13		0,009	<0,009		0,050	0,044		0,195	0,57		0,44	0,36		0,29	0,31
Chevrier	2009	0,03			<0,009			0,002			0,070			0,24			0,25		
Chibougamau, north	2002	<0,5	<0,5	<0,5	0,020	0,020	0,020	<0,05	<0,05	<0,05	0,08	0,08	0,08	0,36	0,24	0,25	0,50	0,25	0,31
Chibougamau, north	2008	0,015		0,016	<0,009		<0,009	0,005		0,006	0,024		0,007	0,35		0,58	0,18		0,21
Chibougamau, south	2002	<0,5	<0,5	<0,5	0,020	0,030	0,020	<0,05	<0,05	<0,05	0,07	0,09	0,11	0,30	0,33	0,41	0,41	0,36	0,29
Chibougamau, south	2008		0,014	0,013		<0,009	<0,009		0,005	0,007		0,066	0,076		0,27	0,36		0,19	0,25
du Sauvage	2007			<0,5			<0,003			<0,05			<0,025			0,29			0,07
Fancamp, La Dauversière, Verneuil	2009	0,048	0,034	0,016	<0,009	<0,009	<0,009	0,003	0,002	0,003	0,003	0,005	0,007	0,35	0,29	0,29	0,37	0,40	0,18
Le Royer	2004			<0,5			0,003			< 0,05			0,05			0,80			0,29
Muscocho	2009	0,03	0,02	0,007	<0,009	<0,009	<0,009	0,002	0,003	0,003	0,030	0,003	0,007	0,13	0,2	0,14	0,24	0,18	0,10
Opémisca	2003		<0,5			0,003			<0,05			0,08			0,35			0,32	
Opémisca	2010	0,010			<0,009			0,002			0,005			0,36			0,22		
Verneuil	2009																		
Waposite	2007			<0,5			<0,003			<0,05			<0,025			0,19			0,15
Median		0,030	0,029	<0,5	<0,009	<0,009	<0,009	0,003	< 0,05	< 0,05	0,030	0,080	0,031	0,35	0,28	0,33	0,25	0,27	0,23

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2008		0,07			0,002			0,23			<0,04			6,3	
Aux Dorés, south	2008		0,135	0,3		0,005	0,005		0,21	0,20		<0,04	<0,04		6,35	4,8
Chevrier	2009	0,008			0,007			0,31			<0,04			5,4		
Chibougamau, north	2002	<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,19	0,22	0,27	<0,1	<0,1	<0,1	5,9	4,6	4,4
Chibougamau, north	2008	<0,005		<0,005	0,004		0,006	0,09		0,07	<0,04		<0,04	5,8		4,6
Chibougamau, south	2002	<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,16	0,35	0,20	<0,1	<0,1	<0,1	5,0	6,1	6,9
Chibougamau, south	2008		0,041	0,051		0,003	0,002		0,17	0,12		<0,04	<0,04		4,45	4,3
du Sauvage	2007			<0,5			<0,1			0,14			<0,1			4,3
Fancamp, La Dauversière, Verneuil	2009	<0,005	0,005	0,005	0,007	0,0045	0,007	0,49	0,17	0,10	<0,04	<0,04	<0,04	6,8	5,6	5,2
Le Royer	2004			<0,5			<0,1			0,11			<0,1			3,4
Muscocho	2009	0,008	0,006	0,008	0,013	0,006	0,008	0,35	0,24	0,061	<0,04	<0,04	<0,04	5,6	4,5	3,6
Opémisca	2003		<0,5			<0,1			0,16			<0,1			6,6	
Opémisca	2010	<0,005			0,003			0,12			<0,04			5,0		
Waposite	2007			<0,5			<0,1			1,00			<0,1			3,3
Median		0,008	0,085	<0,2	0,007	0,005	0,029	0,19	0,21	0,13	< 0,04	< 0,04	< 0,04	5,6	5,9	4,4

* Lake herring: Small: 20-25 cm; Medium: 25-30 cm; Large: > 30 cm.

Appendix 19 Average metal concentrations in the flesh of lake whitefish in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
			(mg/kg)			(mg/kg)			(mg/kg)			(mg/kg)			(mg/kg)			(mg/kg)	
Aux Dorés, north	2001						0,020						0,09			0,22			0,09
Aux Dorés, north	2008		0,004	0,01		<0,009	<0,009		0,055	0,05		0,350	0,330		0,31	0,28		0,14	0,13
Aux Dorés, south	2001						0,023						0,07			0,22			0,20
Aux Dorés, south	2008		0,01	0,008		<0,009	<0,009		0,031	0,03		0,200	0,310		0,22	0,32		0,09	0,10
Chevrier, Muscocho	2009	0,01	0,004	0,004	<0,009	<0,009	<0,009	0,005	0,009	0,009	0,004	<0,003	0,012	0,22	0,21	0,25	0,15	0,13	0,11
Chibougamau, north	2001-2002	<0,5	<0,5	<0,5	0,020	0,020	0,026	<0,05	<0,05	<0,05	0,10	0,06	0,06	0,21	0,16	0,22	0,32	0,15	0,18
Chibougamau, north	2008	0,02	0,007	0,01	<0,009	<0,009	<0,009	0,014	0,010	0,01	<0,003	0,004	0,034	0,21	0,21	0,17	0,11	0,11	0,09
Chibougamau, south	2001-2002						0,023						0,08			0,14			0,08
Chibougamau, south	2008		0,013	0,026		<0,009	<0,009		0,017	0,03		0,125	0,044		0,32	0,24		0,13	0,12
du Sauvage	2007			<0,5			<0,003			<0,05			<0,025			0,28			0,08
Fancamp	2002						0,040						0,09			0,26			0,49
Fancamp, La Dauversière, Verneuil	2009	0,01	0,006	0,003	<0,009	<0,009	<0,009	0,005	0,007	0,077	0,005	0,003	<0,003	0,21	0,34	0,23	0,13	0,15	0,11
Father	2010	0,03	0,009	0,011	<0,009	<0,009	<0,009	0,007	0,008	0,010	0,009	0,008	0,010	0,26	0,42	0,23	0,12	0,08	0,14
France	2007			<0,5			<0,003			<0,05			0,040			0,47			0,08
Gabriel	2005			<0,5			0,004			<0,05			0,09			0,19			<0,03
La Dauversière, east	2002						0,020						0,07			0,23			0,18
La Dauversière, Nemenjiche	2001						0,023						0,07			0,19			0,16
Le Royer	2004		<0,5	<0,5		<0,003	0,004		<0,05	<0,05		0,07	0,04		0,24	0,26		0,19	0,26
Le Royer	2008		<0,001	<0,001		<0,009	0,023		0,075	0,01		0,230	0,250		0,35	0,36		0,12	0,14
Muscocho	2009			0,004			<0,009			0,012			0,007			0,27			0,10
Nemenjiche	2004			<0,5			0,003			<0,05			0,12			0,26			0,22
Opémisca	2003		<0,5	<0,5		0,017	0,007		<0,05	<0,05		0,09	0,09		0,15	1,00		0,61	0,15
Opémisca	2010	0,01	0,002	0,002	<0,009	<0,009	<0,009	0,005	0,002	0,005	0,009	0,006	<0,003	0,17	0,27	0,23	0,18	0,11	0,09
Scott	2005			<0,5			0,005			<0,05			<0,03			0,27			0,07
Simon	2005			<0,5			0,004			<0,05			<0,03			0,35			0,08
Waconichi	2001						0,015						0,06			0,06			0,07
Waconichi	2010	0,01	0,006	0,007		<0,009	<0,009	0,002	0,003	0,002	0,005	0,013	0,006	0,21	0,25	0,15	0,11	0,10	0,11
Waposite	2007			<0,5			<0,003			<0,05			<0,025			0,20			0,05
Médiane		0,01	0,007	<0,5	<0,009	<0,009	<0,009	0,005	0,017	<0,05	0,005	0,060	0,052	0,21	0,25	0,24	0,13	0,13	0,11

* Lake whitefish: Small: 35-40 cm; Medium: 40-45 cm; Large: > 45 cm.

Appendix 19 (continued) **Average metal concentrations in the flesh of lake whitefish in lakes in the Chibougamau region (2001-2010)**

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, north	2001						0,1			0,13						3,4
Aux Dorés, north	2008		0,19	0,18		0,003	0,002		0,07	0,08		<0,04	<0,04		4,1	3,8
Aux Dorés, south	2001						<0,1			0,29						3,2
Aux Dorés, south	2008		0,1	0,165		0,005	0,005		0,12	0,10		<0,04	<0,04		3,2	3,6
Chevrier, Muscocho	2009	0,008	0,015	0,028	0,004	0,005	0,005	0,14	0,06	0,04	<0,04	<0,04	<0,04	3,5	3,5	3,6
Chibougamau, north	2001-2002	<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,25	0,08	0,14	<0,1	<0,1	<0,1	3,3	2,6	2,9
Chibougamau, north	2008	<0,005	<0,005	0,015	0,004	0,004	0,003	0,14	0,11	0,05	<0,04	<0,04	<0,04	4,3	3,2	3,1
Chibougamau, south	2001-2002						<0,1			0,28						3,0
Chibougamau, south	2008		0,033	<0,005		0,008	0,009		0,07	0,17		<0,04	<0,04		7,9	7,4
du Sauvage	2007			<0,5			<0,1			0,06			<0,1			3,6
Fancamp	2002			<0,2			<0,1			0,78						3,6
Fancamp, La Dauversière, Verneuil	2009	<0,005	0,007	0,011	0,005	0,007	0,005	0,05	0,04	0,03	<0,04	<0,04	<0,04	3,0	3,4	3,0
Father	2010	<0,005	<0,005	<0,005	0,007	0,004	0,006	0,18	0,05	0,04	<0,04	<0,04	<0,04	3,3	3,1	3,0
France	2007			<0,5			<0,1			0,12			<0,1			3,4
Gabriel	2005			<0,5			<0,1			0,05			<0,1			3,3
La Dauversière, east	2002			<0,2			<0,1			0,11						3,1
La Dauversière, Nemenjiche	2001						<0,1			0,20						3,7
Le Royer	2004		<0,5	<0,5		<0,1	<0,1		0,09	0,47		<0,1	<0,1		2,7	2,7
Le Royer	2008		0,13	0,12		0,003	0,003		0,06	0,08		<0,04	<0,04		3,1	3,1
Muscocho	2009			0,012			0,005			0,04			<0,04			3,5
Nemenjiche	2004			<0,5			<0,1			0,13			<0,1			2,6
Opémisca	2003		<0,5	<0,5		<0,1	<0,1		0,26	0,14		<0,1	<0,1		2,8	3,0
Opémisca	2010	0,035	<0,005	<0,005	0,005	0,014	0,003	0,09	0,04	0,02	<0,04	<0,04	<0,04	3,0	2,9	2,9
Scott	2005			<0,5			<0,1			0,02			<0,1			3,2
Simon	2005			<0,5			<0,1			<0,02			<0,1			3,3
Waconichi	2001						<0,1			<0,10						3,6
Waconichi	2010	0,006	0,022	0,005	0,002	0,006	0,002	0,06	0,07	0,08	<0,04	<0,04	<0,04	3,2	3,3	3,0
Waposite	2007			<0,5			<0,1			0,09			<0,1			2,4
Median		0,006	0,033	<0,2	0,005	0,006	<0,1	0,14	0,07	0,08	<0,04	<0,04	<0,04	3,3	3,2	3,2

* Lake whitefish: Small: 35-40 cm; Medium: 40-45 cm; Large: > 45 cm.

Appendix 20 Average metal concentrations in the flesh of white sucker in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, south	2008			0,04			<0,009			0,11			0,17			0,32			0,48
Chevrier	2009			0,041			<0,009			0,005			0,00			0,25			0,68
Chevrier, Muscocho	2009		0,035			<0,009			0,0037			<0,003			0,18			1,00	
Chibougamau, north	2008	0,084	0,022	0,054	<0,009	<0,009	<0,009	0,008	0,008	0,0071	0,017	0,090	0,012	0,29	0,40	0,30	0,32	0,19	0,47
Chibougamau, south	2008		0,019	0,029		<0,009	<0,009		0,0064	0,007		0,057	0,05		0,21	0,28		0,21	0,30
Cosnier	2004	< 0,5	<0,5	<0,5	0,003	0,003	<0,003	<0,05	<0,05	<0,05	0,05	0,06	<0,03	0,16	0,18	0,20	0,49	0,47	1,00
du Sauvage	2007			<0,5			<0,003			<0,05			<0,025			0,33			0,07
Fancamp	2002		<0,5	<0,5		0,020	0,020		<0,05	<0,05		0,07	0,06			0,22		0,41	0,67
Fancamp, La Dauversière, Verneuil	2009	0,023	0,02	0,024	<0,009	<0,009	<0,009	0,002	0,0027	0,0052	0,003	<0,003	0,01	0,31	0,29	0,31	0,38	0,28	0,39
France	2007			<0,5			<0,003			<0,05			<0,025			0,33			0,27
Gabriel	2005			<0,5			0,004			<0,05			<0,03			0,34			0,72
La Dauversière, east	2002		<0,5	<0,5		0,010	0,010		<0,05	<0,05		0,07	0,07		0,17	0,23		0,36	0,39
La Dauversière, Nemenjiche	2008			0,02			<0,009			0,01			0,19			0,40			0,52
Le Royer	2004		<0,5	<0,5		< 0,003	<0,003		<0,05	<0,05		<0,03	0,13		0,32	0,38		0,63	0,36
Le Royer	2008		0,027	0,03		<0,009	<0,009		0,005	0,006		0,068	0,06		0,32	0,26		0,79	0,69
Muscocho	2009	0,018		0,018	<0,009		<0,009	0,003		0,005	0,003		0,00	0,24		0,25	0,31		0,34
Nemenjiche	2004		<0,5	<0,5		0,003	0,004		<0,05	<0,05		0,09	0,10		0,33	0,41		0,24	0,44
Opémisca	2003			<0,5			0,019			<0,05			<0,05			0,23			1,02
Opémisca	2010	0,009	0,010	0,009	<0,009	<0,009	<0,009	0,002	0,0016	0,002	0,017	0,005	<0,003	0,30	0,26	0,27	0,18	0,16	0,15
Scott	2005			<0,5			<0,003			<0,05			<0,03			0,52			0,29
Simon	2005			<0,5			0,003			<0,05			<0,03			0,45			0,17
Waconichi	2010	0,056	0,039	0,043	<0,009	<0,009	<0,009	0,003	0,0026	0,0029	0,003	0,023	0,008	0,22	0,16	0,24	0,25	0,17	0,22
Waposite	2007			<0,5			<0,003			<0,05			<0,025			0,32			0,36
Median		0,040	0,037	<0,5	<0,009	<0,009	<0,009	0,003	0,007	<0,05	0,010	0,059	<0,03	0,27	0,26	0,31	0,32	0,32	0,39

* White sucker: Small: 30-35 cm; Medium: 35-40 cm; Large: > 40 cm.

Appendix 20 (continued) **Average metal concentrations in the flesh of white sucker in lakes in the Chibougamau region (2001-2010)**

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Aux Dorés, south	2008			0,093			0,006			0,30			<0,04			3,6
Chevrier	2009			0,017			0,006			0,33			<0,04			3,4
Chevrier, Muscocho	2009		<0,005			0,005			0,35			<0,04			3,6	
Chibougamau, north	2008	<0,005	0,16	<0,005	0,007	0,005	0,006	0,19	0,09	0,29	<0,04	<0,04	<0,04	4,4	4,0	4,0
Chibougamau, south	2008		0,04	0,032		0,002	0,004		0,11	0,21		<0,04	<0,04		3,5	3,5
Cosnier	2004	<0,2	<0,5	<0,5	<0,1	<0,1	<0,1	0,31	0,31	0,87	<0,1	<0,1	<0,1	2,9	2,8	2,6
du Sauvage	2007			<0,5			<0,1			0,06			<0,1			3,3
Fancamp	2002		<0,2	<0,2		<0,1	<0,1			0,37		<0,1	<0,1		2,5	2,7
Fancamp, La Dauversière, Verneuil	2009	<0,005	<0,005	0,008	0,002	0,004	0,005	0,14	0,097	0,094	<0,04	<0,04	<0,04	3,2	3,1	3,1
France	2007			<0,5			<0,1			0,18			<0,1			3,6
Gabriel	2005			<0,5			<0,1			0,52			<0,1			3,8
La Dauversière east	2002		<0,2	<0,2		<0,1	<0,1		0,19	0,15					2,4	2,8
La Dauversière, Nemenjiche	2008			0,11			0,002			<0,005			<0,04			2,7
Le Royer	2004		<0,5	<0,5		<0,1	<0,1		0,17	0,17		<0,1	<0,1		3,1	3,0
Le Royer	2008		0,04	0,04		0,002	0,005		0,35	0,31		<0,04	<0,04		3,0	3,1
Muscocho	2009	<0,005		0,024	0,002		0,0035	0,096		0,12	<0,04		<0,04	3,3		3,3
Nemenjiche	2004		<0,5	<0,5		<0,1	<0,1		0,11	0,28		<0,1	<0,1		3,2	3,2
Opémisca	2003			<0,2			<0,1			0,27			<0,1			2,8
Opémisca	2010	0,022	<0,005	<0,005	0,006	0,004	0,002	0,033	0,042	0,048	0,06	<0,04	<0,04	3,1	2,7	2,8
Scott	2005			<0,5						0,08			<0,1			5,3
Simon	2005			<0,5			<0,1			0,06			<0,1			3,3
Waconichi	2010	<0,005	0,007	<0,005	0,003	0,002	0,003	0,16	0,12	0,16	<0,04	<0,04	<0,04	3,8	3,8	3,3
Waposite	2007			<0,5			<0,1			0,60			<0,1			2,8
Median		<0,005	<0,2	<0,2	0,004	0,005	<0,1	0,15	0,12	0,20	<0,04	<0,04	<0,1	3,3	3,1	3,3

* White sucker: Small: 30-35 cm; Medium: 35-40 cm; Large: > 40 cm.

Appendix 21 Average metal concentrations in the flesh of northern sucker in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Chibougamau, north	2002	<0,5	<0,5	<0,5	0,020	0,017	0,023	<0,05	<0,05	<0,05	0,07	0,10	0,09	0,31	0,39	0,36	1,10	0,69	1,40
Chibougamau, north	2008		0,007	0,04		<0,009	<0,009		<0,01	0,01		0,11	0,01		0,24	0,37		0,08	0,45
Chibougamau, south	2002	<0,5	<0,5	<0,5	0,020	0,020	0,020	<0,05	<0,05	<0,05	0,07	0,07	0,07	0,29	0,35	0,33	1,00	0,68	0,52
Chibougamau, south	2008		0,042	0,04		<0,009	<0,009		0,01	0,01		0,04	0,14		0,29	0,36		0,61	0,55
Cosnier	2004			<0,5			<0,003			<0,05			0,14			0,21			1,60
Father	2010		0,022	0,37		<0,009	<0,009		0,004	0,009		0,029	0,005		0,19	0,24		0,21	2,10
Gabriel	2005			<0,5			0,003			<0,05			<0,03			0,40			0,17
Muscocho	2009			0,28			<0,009			0,008			0,012			0,41			4,50
Opémisca	2003		<0,5	<0,5		0,019	0,019		<0,05	<0,05		0,08	0,08		0,17	0,25		1,60	1,55
Opémisca	2010	0,03		0,05	<0,009		<0,009	0,010		0,005	0,01		0,004	0,17		0,37	0,51		2,10
Simon	2005			<0,5			0,003			<0,05			<0,03			0,60			0,12
Median		<0,5	<0,5	<0,5	0,020	0,011	<0,009	<0,05	<0,05	<0,05	0,07	0,08	0,02	0,29	0,27	0,36	1,00	0,65	1,40

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Chibougamau, north	2002	<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,21	0,15	0,25	<0,1	<0,1	<0,1	3,3	3,7	3,5
Chibougamau, north	2008		<0,005	<0,005		0,003	0,005		0,04	0,11		<0,04	<0,04		5,1	5,0
Chibougamau, south	2002	<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,36	0,32	0,25	<0,1	<0,1	<0,1	3,8	3,4	3,4
Chibougamau, south	2008		0,03	0,07		0,003	0,006		0,13	0,20		<0,04	<0,04		4,7	4,4
Cosnier	2004			<0,2			<0,1			0,66			<0,1			3,0
Father	2010		0,080	0,010		0,007	0,010		0,04	2,40		<0,04	<0,04		2,6	3,8
Gabriel	2005			<0,5			<0,1			0,04			<0,1			4,0
Muscocho	2009			0,01			0,011			1,80			<0,04			4,4
Opémisca	2003		<0,2	<0,2		<0,1	<0,1		0,31	0,26		<0,1	<0,1		2,8	3,0
Opémisca	2010	0,03		<0,005	0,001		0,005	0,22		0,53	<0,04		<0,04	3,0		3,5
Simon	2005			<0,5			<0,1			<0,02			<0,1			4,0
Median		<0,2	<0,2	<0,2	<0,1	<0,1	<0,1	0,22	0,14	0,26	<0,1	<0,1	<0,1	3,3	3,6	3,8

* Northern sucker: Small: 30-35 cm; Medium: 35-40 cm; Large: > 40 cm.

Appendix 22 Average metal concentrations in the flesh of yellow perch in lakes in the Chibougamau region (2001-2010)

	Year	Barium			Cadmium			Cobalt			Chromium			Copper			Manganese		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Chevrier	2009	0,025	0,02		<0,009	<0,009		0,005	0,004		0,11	0,06		0,13	0,13		0,62	0,67	
Fancamp	2009	0,028			<0,009			0,004			0,01			0,15			0,91		
La Dauversière, east	2009	0,025			<0,009			0,002			0,024			0,12			0,33		
Muscocho	2009	0,038	0,036		<0,009	<0,009		0,004	0,003		0,12	0,11		0,12	0,10		0,59	0,55	
Verneuil	2009	0,032			<0,009			0,003			0,09			0,11			0,36		
Median		0,028	0,028		<0,009	<0,009		0,004	0,004		0,09	0,09		0,12	0,12		0,59	0,61	

	Year	Nickel			Lead			Strontium			Vanadium			Zinc		
Lake		Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large	Small	Medium (mg/kg)	Large
Chevrier	2009	0,01	0,01		0,01	0,006		0,192	0,15		<0,04	<0,04		4,2	4,7	
Fancamp	2009	0,055			0,009			0,223			<0,04			4,5		
La Dauversière, east	2009	0,007			0,012			0,18			<0,04			3,9		
Muscocho	2009	0,009	0,013		0,008	0,008		0,343	0,38		<0,04	<0,04		4,2	4,4	
Verneuil	2009	<0,005			0,01			0,213			<0,04			4,2		
Median		0,009	0,012		0,01	0,007		0,21	0,27		<0,04	<0,04		4,2	4,5	

* Yellow perch: Small: 15-20 cm; Medium: 20-25 cm; Large: > 25 cm.

Appendix 23 Location of fishing sites (2001-2010)

N° STATION	DESCRIPTION	LATITUDE	LONGITUDE	N° CARTE
08070031	Aux Dorés, south	49,8417077	-74,3598211	32G16
08070054	La Dauversière, rivière Nemenjiche	49,5549988	-74,4009072	32G09
08070153	La Dauversière, south	49,5462123	-74,3560861	32G09
08070226	Fancamp	49,5881040	-74,5630767	32G10
08070272	Opémisca	49,9180589	-74,8749162	32G15
08070283	Chibougamau, north	49,9035228	-74,1779670	32G16
08070286	Chibougamau, west	49,8286427	-74,2800568	32G16
08070287	Aux Dorés, north	49,9059534	-74,2726278	32G16
08070289	Le Royer	49,5885405	-74,4537665	32G09
08070300	La Dauversière, east	49,5636116	-74,3407419	32G09
08070302	Opémisca	49,8864432	-74,7838221	32G15
08070320	Némenjiche	49,4166652	-74,4333388	32G08
08070424	Chevrillon	50,0079470	-74,4648090	32J01
08070425	David	49,8333410	-74,5015090	32G16
08070453	France	49,7595200	-74,0978841	32G16
08070454	Du Sauvage	50,1086906	-74,4756802	32J01
08070466	Chevrier	49,6333333	-74,4666667	32G09
08070469	Father	49,3300748	-75,4651650	32G06
08080046	Opataca	50,3920814	-74,9292456	32J07
08080062	Waposite	50,2481391	-75,3226557	32J03
08100073	Waconichi	50,1361463	-74,0200683	32J01
08100079	Mistassini, rivière de Maurès	51,0217787	-73,9430641	32P04
08100082	Mistassini, rivière Waconichi	50,3179630	-73,8445940	32I05
08100086	Cosnier	50,8999937	-72,7166727	32I15
08070041	Gabriel	49,29716345	-74,46730770	32G08
08070337	Scott	49,82944045	-74,64502437	32G15
08070338	Simon	49,82026317	-74,58948456	32G15
08070468	Verneuil	49,54618381	-74,51735570	32G10
08070467	Muscocho	49,66979840	-74,56707292	32G10