

Human Health Risk Assessment

Mercury in Fish

The Regional Aquatics Monitoring Program (RAMP)

October 2009

**Government
of Alberta** ■

Alberta ■

For more information on Fish Consumption Advisories

Contact:

Surveillance and Assessment
Alberta Health and Wellness
24th Floor, TELUS Plaza North Tower
10025 Jasper Avenue, STN Main
Edmonton, Alberta, T5J 1S6
Telephone: 1-780-427-4518
Fax: 1-780-427-1470

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Executive Summary

Mercury enters the environment through various natural processes and human activities. Methylmercury is transformed from inorganic forms of mercury via methylation by microorganisms in natural waters, and can accumulate in some fish. Humans are exposed to very low levels of mercury directly from the air, water and food. Fish consumers may be exposed to relatively higher levels of methylmercury by eating mercury-containing fish from local rivers and lakes. Methylmercury can accumulate in the human body over time. Because methylmercury is a known neurotoxin, it is necessary to limit human exposure.

Initiated in 1997, the Regional Aquatics Monitoring Program (RAMP) is a joint environmental monitoring program that assesses the health of rivers and lakes in the Oil Sands Region of northeastern Alberta. The program is designed to identify and address potential impacts of oil sands development and is frequently adjusted to reflect monitoring results, technological advances and community concerns (RAMP 2008). The monitoring of mercury concentrations in some fish species was part of the components of the RAMP program. In 2008, the RAMP committee submitted the monitoring results to Alberta Health and Wellness for human health risk assessment.

This report deals with (1) concentrations of total mercury levels in various fish species collected from the water bodies of the regional municipality of Wood Buffalo area, (2) estimation of exposures, (3) fish consumption limits, (4) fish consumption advisories, and (5) health benefits of fish consumption. The results indicate that:

1. Concentrations of total mercury in fish in the water bodies of the RAMP area were within the ranges for the same fish species from other water bodies in Alberta and the rivers and lakes elsewhere in Canada and the United States.
2. The estimated human exposures to mercury were high for the high fish intake group (over 100 g/d) who consume walleye and northern pike and lake whitefish from some rivers and lakes in the RAMP area.
3. Restriction of consumption of walleye, northern pike and lake whitefish from some lakes and rivers was indicated by the risk assessment, especially for women of reproductive age, pregnant women and young children.
4. Fish consumption advisories are voluntary measures to reduce potential health risk to local fish consumers. The balance between risk and benefits of consumption of mercury-containing fish needs to be understood and considered by consumers.

The Science Advisory Committee reviewed this document and made recommendations. The Public Health Management Committee made final decisions on fish consumption advisories and measures to inform the public accordingly.

Acknowledgments

Working Group

Surveillance and Assessment, Alberta Health and Wellness (AHW)
RAMP Committee

Science Advisory Committee

Dr. Steve Hruddy University of Alberta (Professor Emeritus)
Dr. Chris Le University of Alberta
Dr. Stephan Gabos Office of the Chief Medical Officer of Health, AHW

Public Health Management Committee

Office of the Chief Medical Officer of Health, AHW
Surveillance and Assessment, AHW
Health Protection, AHW
Office of Senior Medical Officer of Health, Alberta Health Service
Fisheries Management, Alberta Sustainable Resource Development
Environmental Assurance, Alberta Environment

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1. Introduction

Mercury (Hg) occurs naturally in the environment. There are three forms of mercury: elemental (metallic) mercury, inorganic mercury salts and organic mercury compounds. Mercury enters the environment through natural processes and human activities. The form of mercury most commonly found in the air is elemental mercury. Methylmercury (MeHg) is often formed from other forms of mercury during natural biological processes such as methylation by microorganisms in the water and sediment. MeHg can accumulate in some fish. People are exposed to very low levels of mercury in the air, water and food. Some people may be exposed to relatively higher levels of MeHg through eating mercury-containing fish. MeHg accumulates in the human body over time. Because MeHg is a known neurotoxin, it is necessary to limit human exposure.

To protect public health, Health Canada has proposed a few mercury guidelines, and advisories for different fish consumer groups (Health Canada, 1979; Feeley and Lo, 1998; Health Canada 2007, Feeley 2008) based on total mercury (THg) or MeHg. These values are expressed either in units of μg THg/MeHg per g of fish flesh or as a Provisional Tolerable Daily Intake (pTDI) in units of μg THg/MeHg per kg of consumer body mass per day (see Section 2.1):

1. 0.5 μg THg/g for all commercial fish/seafood (Guideline);
2. 0.2 μg MeHg/kg bw/d pTDI for women of reproductive age and young children (Guideline);
3. 0.47 μg MeHg/kg bw/d pTDI for the general population (Guideline);
4. 1.0 μg THg/g for certain commercial fish species such as fresh and frozen tuna, shark, swordfish, escolar, marlin and orange roughy which are known to be consumed less frequently (Advisory); and
5. 0.2 μg THg/g for subsistence consumers (Advisory).

The guidelines for commercial fish/seafood are used as a general screening criterion, with the knowledge that most species of commercial fish usually contain lower levels ($< 0.1 \mu\text{g/g}$) of mercury. This guideline is enforceable by the Canadian Food Inspection Agency (CFIA). For example, the CFIA has been monitoring total mercury (THg) levels in commercial fish caught from Lake Athabasca in Alberta since the early 1990s. The recommendation for subsistence consumers proposed by the First Nations and Inuit Health Branch (FNIHB) of Health Canada is used for the First Nations and Inuit people relying on subsistence fresh water fishing when FNIHB became aware of long-term fish consumption patterns of over 100 g/d (Health Canada 1979). The First Nations and Inuit consumers should limit their fish consumption if the mercury levels are over 0.2 μg THg/g and under 0.5 μg THg/g.

Fish consumption advisories are developed based on these pTDIs. These advisories provide the public with a warning of potential health risk resulting from consuming local mercury-containing fish. Fish consumption advisories are designed to minimize the potential health risks to fish consumers who can voluntarily restrict their fish consumption.

Initiated in 1997, the Regional Aquatics Monitoring Program (RAMP) is a joint environmental monitoring program that assesses the health of rivers and lakes in the Oil Sands Region of northeastern Alberta - the regional municipality of Wood Buffalo area. The program is designed to identify and address potential impacts of oil sands development and is frequently adjusted to reflect monitoring results, technological advances and community concerns (RAMP 2008). The monitoring of mercury concentrations in some fish species was part of the components of the RAMP program.

The results from the RAMP program related to mercury in fish are discussed as follows:

1. mercury concentrations in fish,
2. comparison of mercury concentrations in the same fish species in the rivers and lakes in Canada and the U.S.,
3. local fish consumption rates,
4. estimated exposures for women at reproductive age, children and adults,
5. fish consumption advisories, and
6. health benefits of fish consumption.

2. Materials and Methods

2.1 Units Used for Expressing Mercury Data

A summary of the different units that may be used for expressing relevant mercury data is provided in Table 1. For the purposes of this report, to facilitate comparison of values reported from different sources, all data on mercury concentration in fish will be expressed as μg of mercury per g of fish, i.e. $\mu\text{g/g}$, which is equivalent to one unit of mercury per million units of fish (ppm). Likewise, human exposure will be expressed as μg of mercury per kg of human body mass, per day, i.e. $\mu\text{g/kg/d}$. Consumption advisories will be determined from human exposure limits and expressed as g of fish consumed per week, i.e. g/wk.

Table 1 Units Used for Expressing Mercury Data related to Fish

Measure	Preferred Unit	Alternate Unit	Equivalent Units
Hg Concentration	μg of Hg per g of fish, wet weight $\mu\text{g/g}$	mg of Hg per kg of fish, wet weight mg/kg	1 part Hg per million parts of fish ppm
pTDI for mercury by humans	μg of MeHg per kg of human body weight (mass) per day $\mu\text{g MeHg/ kg BW/ d}$		
Recommended fish consumption limits	g / mercury-containing fish fillet consumed per week g / wk	oz / mercury-containing fish fillet consumed per week oz / wk	1 oz = 28.35 g

2.2 Field Collection

The field collection was conducted by the RAMP implantation team between 1998 and 2007 (RAMP, 1998, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008). The fish sampling sites in the regional municipality of Wood Buffalo are (Figure 1) included

- Athabasca River (downstream at Ft. McMurray)
- Christina Lake
- Clearwater River
- Gregoire Lake
- Muskeg River
- Namur Lake
- Winefred Lake

Fish species caught for mercury analysis included

- walleye (*Sander vitreus*)
- northern pike (*Esox lucius*)
- Lake trout (*Salvelinus namaycush*)
- lake whitefish (*Coregonus clupeaformis*)
- goldeye (*Hiodon alosoides*)
- longnose sucker (*Catostomus catostomus*)

Fish were collected by gill-netting, angling and electrofishing. Each sample was kept on ice, and then frozen flat within five hours at - 20 °C. Samples were individually bagged and tagged with a label with a unique number. The samples were shipped to the ASL for laboratory analysis. The sample size, and mean of weight and fork length are summarized in Table 2.

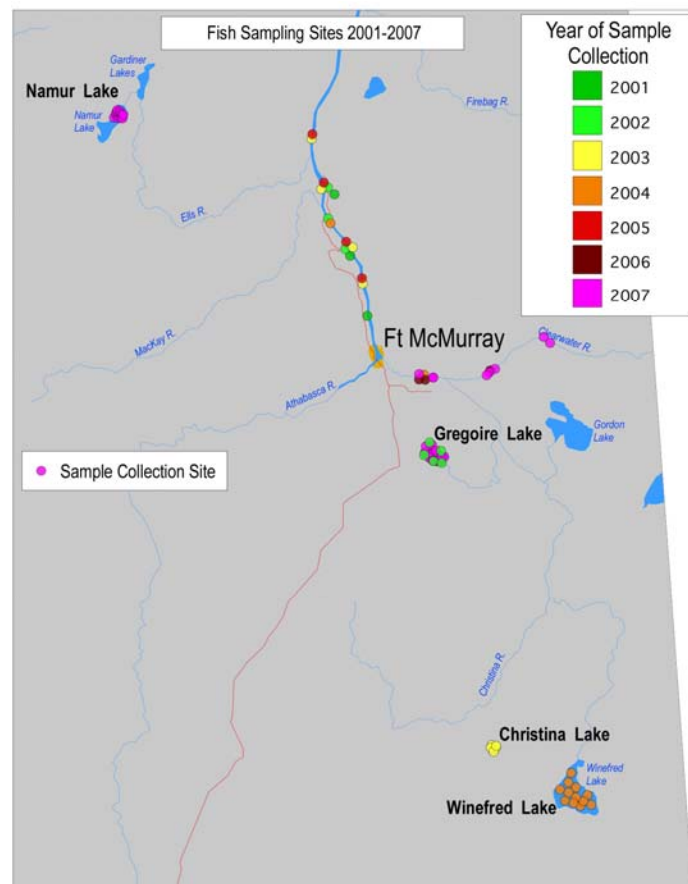


Figure 1 Sampling Locations

Table 2 Sample Size and Mean of Weight and Length

Species	Year	Sample Size	Length (mm)	Wet Weight (g)
<u>Athabasca River</u>				
Walleye	1998	23	442	1114
	2001	10	499	1511
	2002	25	400	830
	2003	25	437	1041
	2005	29	453	1218
Lake Whitefish	1998	7	431	1160
	2001	10	451	1408
	2002	25	429	1241
	2003	18	447	1531
	2005	26	434	1318
Goldeye	1998	10	337	472
Longnose Sucker	1998	24	454	919
<u>Christina Lake</u>				
Walleye	2003	20	531	1900
Lake Whitefish	2003	23	413	1186
Northern Pike	2003	13	749	4230
<u>Clearwater River</u>				
Walleye	2004	2	441	937
Northern Pike	2004	16	549	1351
	2006	26	481	560
	2007	31	505	1382
<u>Gregoire Lake</u>				
Walleye	2002	27	399	912
	2007	21	402	953
Lake Whitefish	2002	12	491	2188
	2007	13	452	1364
Northern Pike	2002	24	506	1092
	2007	26	540	1185
<u>Muskeg River</u>				
Northern Pike	2001	10	606	1720
	2002	6	344	515
	2004	5	545	1180
<u>Namur Lake</u>				
Lake Trout	2007	16	556	1794
<u>Winefred Lake</u>				
Walleye	2004	24	438	1450
Lake Whitefish	2004	18	452	1261
Northern Pike	2004	10	627	1940

2.3 Laboratory Analysis

Laboratory analysis was performed in the ALS Laboratory in Edmonton before 2005 and the Flett Research Ltd. after 2005. The analytical method was based on the modified USEPA methods 200.7 and 200.8 (USEPA 2001) by the ALS laboratory and the method of Total Mercury in Biological Tissues by Digestion, Purge and Trap, and CVAFS (T00110 Version 4) by the Flett Research Ltd.

2.4 Estimation of Exposure Ratio

Estimated daily intake (EDI) was calculated as follows:

$$EDI = C * IR * BF / BW$$

C is a representative measured THg concentrations in fish muscle ($\mu\text{g/g}$). From a human health perspective, the amount of MeHg is of most interest. In mercury analyses of fish, the sum of THg in the sample is measured rather than MeHg because the analysis of MeHg is more expensive. Some studies reported that the percentage of MeHg in THg ranged from 81% to 95% (CFIA 2003). For the purposes of health risk assessments, 100% of THg is assumed to be MeHg thereby erring on the side of caution.

IR is the human rate of fish consumption (g/d).

BF is bioavailability factor (assumed to be 100%).

BW is average body weight in humans (kg). The average of body weight for male and female adults in Alberta is 73 kg. The average human body weights used by Health Canada are 65 kg for women of reproductive age, 26.4 kg for 5-11 years group and 14.4 kg for 1-4 years group (Health Canada 2007).

Exposure ratio (ER, unitless) was calculated by using the following equation:

$$ER = EDI / pTDI$$

The provisional tolerable daily intake (pTDI, $\mu\text{g MeHg/kg bw/d}$) is determined by toxicological risk assessment on mercury (Health Canada 2007). The pTDI for MeHg is the maximum amount of mercury that can be ingested on a daily basis over a lifetime without increased risk of adverse health effects. Health Canada proposed a pTDI of mercury as 0.2 $\mu\text{g Hg/kg bw/d}$ for women of reproductive (childbearing) age and for children. Children refer to two age groups: 5-11 years old group and 1-4 years old group. Health Canada proposed a pTDI of MeHg as 0.47 $\mu\text{g Hg/kg bw/d}$ for adults (adult men and adult women who are not of reproductive age).

2.5 Consumption Limits

For quantitative fish advisories, the lifetime average consumption limits (weekly basis) are calculated. The calculation of the consumption limits (CR, g fish per week) is based on the following equation:

$$CR = pTDI * BW (7 d/wk) / C$$

Where pTDI is provisional tolerable daily intake ($\mu\text{g MeHg/kg bw/d}$), BW is body weight (mass) in humans (kg), and C ($\mu\text{g Hg / g fish}$) is the measured THg concentration in fish muscle.

The consumption limits that correspond to the Health Canada pTDI and the commercial fish Hg recommendation (maximum concentration of $0.5 \mu\text{g Hg / g fish}$) are provided below as a reference point.

Consumption Limits for adult men and adult women not of reproductive age
 $CR = (0.47 \mu\text{g MeHg/kg bw/d})(73 \text{ kg})(7 \text{ d/wk}) / (0.5 \mu\text{g Hg / g fish}) = 480 \text{ g fish /week}$

Consumption Limits for women of reproductive age
 $CR = (0.2 \mu\text{g MeHg/kg bw/d})(65 \text{ kg})(7 \text{ d/wk}) / (0.5 \mu\text{g Hg / g fish}) = 180 \text{ g fish /week}$

Consumption Limits for children age 5 – 11 (body weight 26.4 kg)
 $CR = (0.2 \mu\text{g MeHg/kg bw/d})(26.4 \text{ kg})(7 \text{ d/wk}) / (0.5 \mu\text{g Hg / g fish}) = 74 \text{ g fish /week}$

Consumption Limits for children age 1 – 4 (body weight 14.4 kg)
 $CR = (0.2 \mu\text{g MeHg/kg bw/d})(14.4 \text{ kg})(7 \text{ d/wk}) / (0.5 \mu\text{g Hg / g fish}) = 40 \text{ g fish /week}$

3. Results and Discussions

3.1 Concentrations in Fish

The total mercury concentrations in wet weight in fish are summarized in Table 3 and Figure 2. The average THg concentrations in all fish species from surveyed rivers and lakes ranged from 0.04 to 0.47 µg/g. The highest THg concentrations were observed in walleye collected from the Athabasca River (0.84 µg/g) and Christina Lake (0.77 µg/g), northern pike collected from the Clearwater River (0.82 µg/g) and Gregoire Lake (0.58 µg/g), and Lake Trout from Namur Lake (0.77 µg/g).

The trends of THg concentrations in fish are shown in Figure 3 and p values listed in Table 3. THg levels in northern pike collected from the Clearwater River declined from 2004 to 2006/07 ($p < 0.05$). THg levels in northern pike collected from Muskeg River increased from 2001/02 to 2004 ($p < 0.05$).

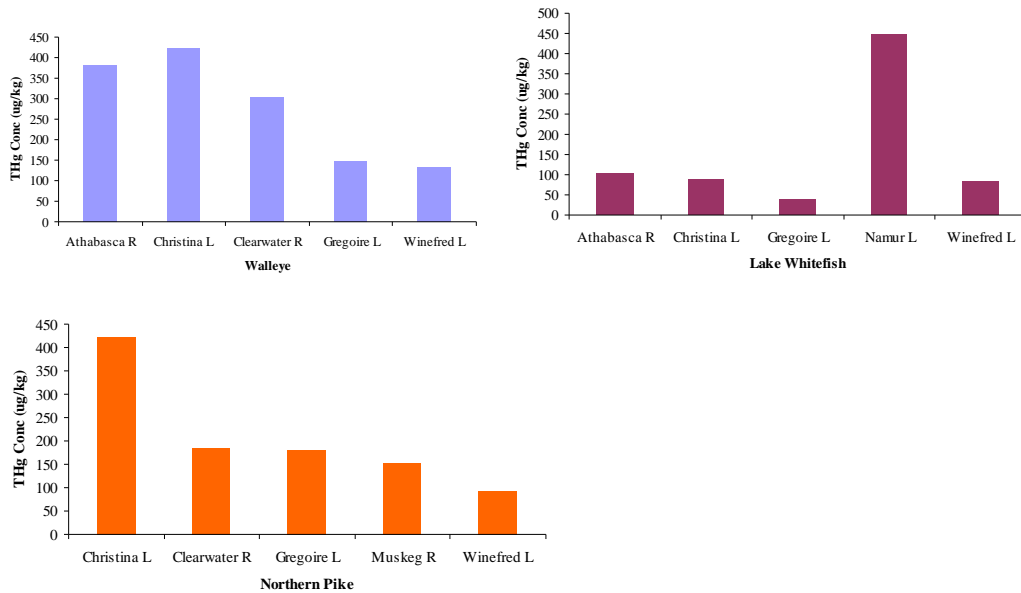


Figure 2 Mean Concentrations of Total Mercury in Fish

Table 3 Total Mercury Levels ($\mu\text{g/g}$, wet weight) in Fish

Species	Year	Mean	Min	Max	N	Trend (p value)
<u><i>Athabasca River</i></u>						
Walleye	1998	0.28	0.20	0.37	23	1998-2005 p > 0.05
	2001	0.41	0.36	0.46	10	
	2002	0.36	0.01	0.84	25	
	2003	0.39	0.15	0.72	25	
	2005	0.47	0.07	0.71	29	
Lake Whitefish	1998	0.09	0.08	0.09	7	1998-2005 p > 0.05
	2001	0.11	0.11	0.11	10	
	2002	0.13	0.04	0.45	25	
	2003	0.10	0.04	0.18	18	
	2005	0.09	0.03	0.17	26	
Goldeye	1998	0.17	0.16	0.18	10	
Longnose Sucker	1998	0.16	0.07	0.24	24	
<u><i>Christina Lake</i></u>						
Walleye	2003	0.42	0.26	0.77	20	
Lake Whitefish	2003	0.09	0.06	0.16	23	
Northern Pike	2003	0.42	0.27	0.66	13	
<u><i>Clearwater River</i></u>						
Walleye	2004	0.30	-	-	2	
Northern Pike	2004	0.23	0.10	0.82	16	2004 vs. 2006/2007 decreased p < 0.05
	2006	0.18	0.08	0.40	26	
	2007	0.15	0.01	0.62	31	
<u><i>Gregoire Lake</i></u>						
Walleye	2002	0.13	0.04	0.43	27	2002-2007 p > 0.05
	2007	0.16	0.04	0.43	21	
Lake Whitefish	2002	0.04	0.02	0.05	12	2002-2007 p > 0.05
	2007	0.04	0.02	0.06	13	
Northern Pike	2002	0.15	0.04	0.81	24	2002-2007 p > 0.05
	2007	0.21	0.02	0.58	26	
<u><i>Muskeg River</i></u>						
Northern Pike	2001	0.13	0.12	0.14	10	2001/2002 vs. 2004 increased p < 0.05
	2002	0.11	0.03	0.21	6	
	2004	0.22	0.19	0.25	5	
<u><i>Namur Lake</i></u>						
Lake Trout	2007	0.45	0.13	0.77	16	
<u><i>Winefred Lake</i></u>						
Walleye	2004	0.13	0.05	0.26	24	
Lake Whitefish	2004	0.08	0.03	0.18	18	
Northern Pike	2004	0.09	0.04	0.14	10	

THg concentrations exceeding the 0.5 $\mu\text{g/g}$ commercial fish limit are showed in **bold**.

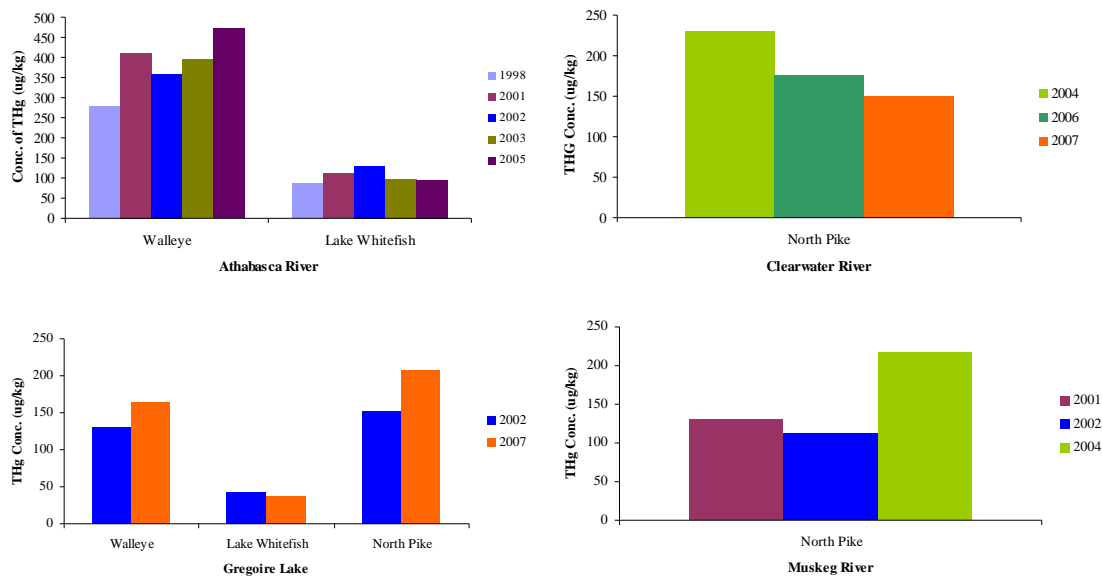


Figure 3 Trends of Mercury Concentrations in Fish

Mean THg concentrations in walleye, northern pike and lake whitefish collected from other water bodies of Alberta are listed in Table 4. Mean THg concentrations for the same fish species in the water bodies in the RAMP area were well within the ranges for the same fish species in other water bodies of Alberta.

The average THg concentrations in Canadian market fish reported by Health Canada ranged from 0.02 to 1.82 $\mu\text{g/g}$ (Health Canada 2007). Compared to Canadian market fish for different fish species, mean THg concentrations in local fish collected in the RAMP area were within the ranges of Canadian market fish.

Mean THg levels for walleye and northern pike from other water bodies in Canada and the U.S. reported in the literature are summarized in Table 5. Mean THg concentrations for the same fish species in the water bodies in the RAMP area were well within the ranges for the same fish species reported in the literature for other North American freshwater fish.

Mean THg concentration in fish filets varied in other lakes, rivers and reservoirs in Canada and the U.S. The highest mean mercury levels in walleye and northern pike in the water bodies in eastern and northern Canada ranged from 1.00 to 2.98 $\mu\text{g/g}$. High levels tended to be found in larger, older fish. Fish absorb MeHg directly through their gills or through the consumption of prey which contain mercury. MeHg is tightly bound to proteins in all fish tissue resulting in larger, older fish containing higher mercury (Munn and Short 1997, Neumann

and Ward 1999). In this survey, the fish caught were generally in the larger size group (Table 2).

Trophic level is a major factor in mercury accumulation in predatory (fish-eating) fish through biomagnification (Cabana et al. 1994). Bottom-feeding species may accumulate high mercury concentrations from direct contact with contaminated sediment or by eating benthic invertebrates and epibenthic organisms. Predatory fish species may accumulate and biomagnify mercury concentrations via several trophic levels of the food chains (Suedel et al. 1994). Predators are commonly used as good indicators of mercury contamination. In this survey, the higher mercury levels were observed in walleye and northern pike. Northern pike and walleye are highly piscivorous predatory fish.

Table 4 Mean THg Concentrations in Fish Muscles in Alberta Water Bodies

Species	Mean (µg/g, ww)	Location	Reference	
Walleye	0.79	Red Deer River	AHW 2009a	
	0.68	South Saskatchewan River		
	0.43	Milk River Ridge Reservoir		
	0.41	Lake Newell		
	0.41	Pine Lake		
	0.27	Keho Lake		
	0.11	Pigeon Lake	AHW 2009b	
	0.52 – 0.79	Pine Coulee Reservoir		
	0.63	Lac la Nonne		
Northern Pike	0.13	Lac Ste. Anne	AHW 2009c	
	0.18	Oldman River	AHW 2009a	
		0.27		Red Deer River
		0.35		South Saskatchewan River
		0.21		Milk River Ridge Reservoir
		0.23		Lake Newell
		0.27		Pine lake
		0.22		Keho Lake
	0.13	Pine Coulee Reservoir	AHW 2009b	
	0.27 – 0.49	Willow Creek Downstream		
	0.44 – 0.56	Twin Valley Reservoir		
	0.27 – 0.59	Little Bow River downstream		
	0.04 – 0.29	Little Bow River downstream		
0.56	Lac la Nonne			
Lake Whitefish	0.14	Lac Ste. Anne	AHW 2009c	
	0.13	South Saskatchewan River	AHW 2009a	
	0.14	Milk River Ridge Reservoir		
	0.13	Lake Newell		
	0.10	Keho Lake		
0.02	Pigeon Lake			

Table 5 Mean THg Concentrations in Fish Muscles Reported in the Literature

Species	Mean (µg/g, ww)	Location	Reference
Walleye	0.05 – 0.99	18 Lakes, Northern Glaciated Plains, US	Selch et al. 2007
	0.19 – 0.30	Reservoirs, Manitoba, Canada	Bodaly et al. 2007
	0.42 – 2.98	Wabigoon River system*, Ontario	Kinghorn et al. 2007
	0.98 – 1.00	19 undisturbed lakes, Haute Mauricie, Quebec, Canada	Garcia and Carignan, 2005
	1.29 – 3.73	18 disturbed lakes, Haute Mauricie, Quebec, Canada	Garcia and Carignan, 2005
	0.759	Water bodies in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
	0.58	Great Lakes, US	Gerstenberger and Dellinger, 2002
	0.47	Lakes in Northern Canada	Lockhart et al. 2005
	0.05 – 1.34	Canadian Arctic, Canada	Braune et al. 1999
	0.32 – 1.26	29 Lakes in the La Grande complex watershed, Quebec, Canada	Verdon et al. 1991
Northern Pike	0.19 – 1.43	Mackenzie River Basin Lakes	Evans et al. 2005 a
	0.26 – 0.32	Reservoirs, Manitoba, Canada	Bodaly et al. 2007
	0.44 – 2.14	Wabigoon River system*, Ontario, Canada	Kinghorn et al. 2007
	1.00 – 2.55	19 undisturbed lakes, Haute Mauricie, Quebec, Canada	Garcia and Carignan, 2005
	1.90 – 6.44	18 disturbed lakes, Haute Mauricie, Quebec, Canada	Garcia and Carignan, 2005
	0.645	lakes, rivers and reservoirs in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
	0.16 – 1.1	Mackenzie River Basin, Canada	Evans, et al. 2005a
	0.12 – 0.74	Mackenzie River Basin, Canada	Evans, et al. 2005b
	0.378	Lakes in Northern Canada	Lockhart et al. 2005
	0.623 – 1.51	Yukon River, Kuskokwim River, US	Jewett et al. 2003
Lake Whitefish	0.11 – 0.63	Canadian Arctic, Canada	Braune et al. 1999
	0.25 – 0.90	29 Lakes in the La Grande complex watershed, Quebec, Canada	Verdon et al. 1991
	0.06 – 0.07	Reservoirs, Manitoba, Canada	Bodaly et al. 2007
	0.08 – 0.31	Wabigoon River system*, Ontario	Kinghorn et al. 2007
	0.54 – 1.18	19 undisturbed lakes, Haute Mauricie, Quebec, Canada	Garcia and Carignan, 2005
	0.51 – 1.18	18 disturbed lakes, Haute Mauricie, Quebec, Canada	Garcia and Carignan, 2005
	0.209	Water bodies in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
	0.01	Great Lakes, US	Gerstenberger and Dellinger, 2002
	0.04 – 0.35	Mackenzie River Basin, Canada	Evans, et al. 2005
	0.11 – 0.13	Lakes in Northern Canada	Lockhart et al. 2005
Lake Whitefish	0.02 – 0.82	Canadian Arctic, Canada	Braune et al. 1999
	0.07 – 0.30	29 Lakes in the La Grande complex watershed, Quebec, Canada	Verdon et al. 1991

Specie	Mean (µg/g, ww)	Location	Reference
Longnose sucker	0.187	lakes, rivers and reservoirs in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
	0.108	Lakes in Northern Canada	Lockhart et al. 2005
	0.06 – 0.32	29 Lakes in the La Grande complex watershed, Quebec, Canada	Verdon et al. 1991

* The highest reported levels reflect current recovery levels in the highly contaminated Clay Lake system that received over 10 tonnes of mercury discharge from a chlor-alkalai plant from 1962 to 1970.

3.2 Local Fish Consumption Rates

Three surveys of fish consumption patterns were conducted in communities of Central Alberta between 1997 and 2000. The first survey was conducted by Alberta Health and Wellness in Swan Hills communities in 1997 (AHW 1997). The second survey was conducted by the First Nations and Inuit Health Branch (FNIHB) of Health Canada for the First Nations people living in the Lesser Slave Lake area in 1999 (Health Canada 1999). The third survey was conducted by the Environmental Health Sciences Program at the University of Alberta for the residents living in the communities near the Athabasca River and tributaries at Hinton (EHSUA 2000).

Table 6 Local Fish Consumption Rates in Communities of Central Alberta

Intake Group	Subsistence Consumer Lesser Slave Lake*		Local Fish Consumer Swan Hills		Local Fish Consumer Athabasca River	
	mean (g/d)	%** (n=125)	mean (g/d)	% (n=127)	mean (g/d)	% (n=45)
High (>100g/d)	273	5	167	2	121	2
Medium (30-99 g/d)	46	14	47	13	51	6
Low (5-29 g/d)	13	38	13	28	15	26
Very Low (< 4g/d)	1.6	43	2	57	1.0	66

* mean from Phase I and Phase II studies (Health Canada 1999). ** % of surveyed population

Fish consumption rates in different intake groups from these surveys are summarized in Table 6. A small proportion of local fishers and the First Nation people consumed local fish over 100 grams per day. Five per cent of the First

Nations people in the Lesser Slave Lake communities were high consumers who ate local fish at an average of 273 g/d, much higher than the 2% of those in Swan Hills communities who were high consumers at an average of 167 g/d and those in the communities nearby Hinton who were high consumers at an average rate of 121 g/d. The local fish consumption rates in the survey of the Lesser Slave Lake were similar with the results of the Swan Hills survey in medium, low and very low intake groups. The majority of local fish consumers (85%-92%) consumed fish at a low rate of 1.0 - 15 g/d. The majority of the First Nations group (81%) consumed fish at a low rate of 1.6 – 13 g/d.

The most common fish species consumed by the surveyed populations were rainbow trout, northern pike, walleye, lake whitefish, and lake trout by the First Nations people in the Lesser Slave Lake communities, walleye, northern pike, perch, brook trout, lake whitefish and arctic grayling by the residents in Swan Hills communities, and rainbow trout, arctic grayling, mountain whitefish, northern pike and walleye by the residents in the communities nearby Hinton.

The results from the above surveys were derived from adults only. Fish consumption rates could vary in different subpopulations (USEPA 2000). Children may consume larger quantities compared to their body weight than adults. Prenatal exposure may occur through pregnant women. For the purpose of risk management, these subpopulations are considered as potential high risk groups for exposure to mercury from fish consumption.

3.3 Estimated Exposures

Exposure ratios were estimated for consuming walleye and northern pike. Estimated exposure ratios based on the pTDIs from Health Canada are summarized in Table 7 for women of reproductive age and Table 8 for adults. Specific fish consumption rates were not available for women at reproductive age and young children. As a result, the estimation of exposures for young children was not performed. The fish consumption rate for all adults was used for estimating exposures for women at reproductive age.

In general, the estimated exposure ratios were greater than one for the high intake group, especially for a subpopulation of women of reproductive age if consuming predatory fish like the larger walleye and northern pike. The values of pTDIs were derived from risk assessment approaches with many assumptions and uncertainties. The risk assessment is specifically designed to avoid underestimating risk. The results do not mean that specific individuals or populations face inevitable or even likely health consequences from mercury exposure. An estimated exposure ratio greater than one should be used as a reference point for making risk management decisions. In particular, those exposure scenarios with an exposure ratio greater than one warrant closer attention including the provision of information about maximum recommended

fish consumption to allow individual consumers the opportunity to make risk-informed choices.

Many factors influence the estimated exposure levels such as body weight and consumption rates. The body weight of 73 kg used in this assessment was derived from the 1994 National Population Health survey in Alberta adults. In this report, the age-specific body weights for women at reproductive age and young children in Alberta were not available. The average body weights used by Health Canada were 65 kg for women at reproductive age, 26.4 kg for 5-11 years old group, and 14.4 kg for 1-4 years old group. The consumption rates used in this report were based on the three surveys of adults living in Central Alberta. The estimated exposure was solely based on fish from local specific sources. People may also be exposed to mercury from market fish and other market food items.

Table 7 Estimated Exposure Ratios for Women of Reproductive Age

	Local Consumer High Intake (170 g/d)	Local Consumer Medium Intake (50 g/d)	Subsistence Consumer High Intake (270 g/d)
<u><i>Athabasca River</i></u>			
Walleye	4.9	1.4	7.9
Lake Whitefish	1.3	<1	2.1
Goldeye	2.2	<1	3.5
<u><i>Cristina Lake</i></u>			
Walleye	5.5	1.5	8.7
Lake Whitefish	1.4	<1	1.8
Northern Pike	5.4	1.5	8.7
<u><i>Clearwater River</i></u>			
Walleye	3.9	1.1	6.2
Northern Pike	2.4	<1	3.8
<u><i>Gregoire Lake</i></u>			
Walleye	1.9	<1	3.0
Lake Whitefish	<1	<1	<1
Northern Pike	2.4	<1	3.8
<u><i>Muskeg River</i></u>			
Northern Pike	2.0	<1	3.1
<u><i>Namur Lake</i></u>			
Lake Trout	5.7	1.6	9.2
<u><i>Winefred Lake</i></u>			
Walleye	1.7	<1	2.7
Lake Whitefish	1.1	<1	1.7
Northern Pike	1.2	<1	1.9

Note: mean of total mercury listed in Table 3 and the average THg levels for multiple years; body weight = 65 kg; pTDI = 0.2 µg/kg bw/d for women

Table 8 Estimated Exposure Ratios for Adults

	Local Consumer High Intake (170 g/d)	Local Consumer Medium Intake (50 g/d)	Subsistence Consumer High Intake (270 g/d)
<u><i>Athabasca River</i></u>			
Walleye	1.9	<1	3.0
Lake Whitefish	<1	<1	<1
Goldeye	<1	<1	1.3
<u><i>Christina Lake</i></u>			
Walleye	2.1	<1	3.3
Lake Whitefish	<1	<1	<1
Northern Pike	2.1	<1	3.3
<u><i>Clearwater River</i></u>			
Walleye	1.5	<1	2.4
Northern Pike	<1	<1	1.5
<u><i>Gregoire Lake</i></u>			
Walleye	<1	<1	1.1
Lake Whitefish	<1	<1	1.5
Northern Pike	<1	<1	1.2
<u><i>Muskeg River</i></u>			
Northern Pike	<1	<1	1.2
<u><i>Namur Lake</i></u>			
Lake Trout	2.2	<1	3.5
<u><i>Winefred Lake</i></u>			
Walleye	<1	<1	1.0
Lake Whitefish	<1	<1	<1
Northern Pike	<1	<1	<1

Note: mean of total mercury listed in Table 3 and the average THg levels for multiple years; body weight = 73 kg; pTDI = 0.47 µg/kg bw/d for adults.

3.4 Consumption Limits

For the purpose of quantitative fish advisories, the lifetime consumption limits were calculated for subgroups of women, young children and adults (Table 9). These consumption limits were specific to fish species and site. The values provide the information on the maximum amount of local fish that can be safely consumed on a weekly basis for a lifetime by subpopulations. Fish preparation and cooking methods do not reduce the concentrations of total mercury in fish (Morgan et al. 1997).

Table 9 Lifetime Fish Consumption Limits

Species	THg µg/g	Women		Children (5-11 yr)		Children (1-4 yr)		Adults	
		g/w	oz/w	g/w	oz/w	g/w	oz/w	g/w	oz/w
<i>Athabasca River</i>									
Walleye	0.38	240	8	100	3	50	2	630	22
<i>Chrstina Lake</i>									
Walleye	0.42	200	8	90	3	50	2	570	20
Northern Pike	0.42	200	8	90	3	50	2	570	20
<i>Clearwater River</i>									
Walleye	0.30	300	11	120	4	70	2	800	28
Northern Pike	0.19	480	17	200	7	100	4	-	-
<i>Gregoire Lake</i>									
Walleye	0.15	620	22	250	9	140	5	-	-
Northern Pike	0.18	500	18	200	7	100	4	-	-
<i>Muskeg River</i>									
Northern Pike	0.15	600	21	250	9	140	5	-	-
<i>Namur Lake</i>									
Lake Trout	0.45	200	7	90	3	50	2	550	19
<i>Winefred Lake</i>									
Walleye	0.13	700	24	280	10	150	5	-	-

Note: mean of total mercury is an average level from all years, body weight = 73 kg for adults, 65 kg for women, 26.4 for children 5 – 11 yr, and 14.4 kg for children 1 – 4 yr; pTDI = 0.2 µg/kg bw/d for women at reproductive age and young children, and 0.47 µg/kg bw/d for adults.

Walleye from these water bodies should be limited for consumption at the lower amounts of 200 - 700 grams per week for women of reproductive age, 90 - 280 grams per week for children at age of 5 – 11 years old, and 50 - 150 grams per week for children at age of 1 – 4 years old. Northern pike should be limited for consumption at the amounts of 200 - 700 grams per week for women of reproductive age, 90 - 250 grams per week for children at age of 5 – 11 years old, and 50 – 140 grams per week for children at age of 1 – 4 years old. Lake Whitefish from Namur Lake should be limited for consumption at the amounts of 200 grams per week for women of reproductive age, 90 grams per week for children at age of 5 – 11 years old, and 50 grams per week for children at age of 1 – 4 years old.

3.5 Fish Consumption Advisories

Fish consumers may be exposed to MeHg by consuming locally-caught fish. MeHg is rapidly absorbed after ingestion and distributed throughout the body

(WHO 1990). MeHg in the body is relatively stable and can cross the placental and blood/brain barriers (Kerper et al. 1992). The half-life of MeHg in the human body varies from 44 to 80 days (USEPA 2000). MeHg leaves the human body via urine, feces and breast milk. Small amounts of ingested MeHg are eliminated from the body with no overall adverse effects. At the high exposure levels, MeHg produces a variety of health effects. Larger amounts of MeHg may damage the nervous system. Neurotoxicity may occur in the developing embryo or fetus during pregnancy, young children and adults. As a result, it is prudent to reduce MeHg exposure for women of reproductive age and younger children. The pTDIs proposed by Health Canada are intended to protect susceptible populations.

Because mercury occurs naturally, mercury is found in all commercial or non-commercial fish and other foods at low levels. People are exposed to very low levels of mercury via sources such as breathing the air, mercury amalgam dental fillings and eating other foods. Alberta Health and Wellness conducted a survey of mercury levels in blood, urine and hair in adults and children living in the Wabamun Lake and surrounding area communities in 2006 (AHW 2006). The survey found that the average levels of total mercury in blood, urine and hair in Alberta participants were lower than people living in other areas and countries.

MeHg levels are high enough in some fish species in some rivers and lakes that limitation of fish consumption is warranted. Although fish consumers may be exposed to relatively higher levels of MeHg if they eat large amounts of local mercury-containing fish, the results from three surveys from Northern Alberta indicated that local fish consumption is not the primary source of dietary mercury intake for most surveyed populations.

In order to protect all human consumers, issuing a fish consumption advisory is one risk management option. Fish consumption advisories are designed to reduce potential health risks of consumption for local fish consumers. Advisories should provide the necessary information to the public, so that local fish consumers can voluntarily restrict their fish consumption to a level judged to be safe. Fish consumption advisories elicit voluntary actions unlike mandatory measures such as catch and release regulations or outright fishing bans which restrict consumer actions.

Since the early 1990s, some fish consumption advisories related to mercury have been issued and published in the *Alberta Guide to Sportfishing Regulation* annually. In Alberta, the provincial government is responsible for issuing and reviewing fish consumption advisories for non-commercial fish. The Ministries of Alberta Environment (then including the current Department of Sustainable Resource and Developments) and Alberta Health and Wellness established the process to issue food consumption advisories in 1997. The advisories can take the form of non-consumption or restricted-consumption advisories for adults and sensitive subpopulations.

3.6 Benefits of Fish Consumption

The benefits and risk of fish consumption is a recent focus of public health interest. Fish is an important source of nutrition for people, because it contains beneficial nutrients like the long-chain omega-3 fatty acids like eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), vitamin D, selenium and iodine. Fish is considered an excellent source of high quality protein. The benefits of fish consumption include the prevention of cardiovascular diseases, myocardial infarction (heart attack) and arrhythmia, especially reduction of risk for ischemic heart disease and stroke (Zhang et al. 1999; Chan and Egeland 2004; Bouzanc et al. 2005; Koning et al. 2005; Kris-Etherton et al. 2005; Stern 2005). Health Canada reviewed the evidence showing an association between reduced risk of sudden cardiac death and fish consumption frequency at least once per week (Health Canada 2007). In one case-control study, researchers found that the reduced risk of myocardial infarction with fish consumption of at least one meal per week was not diminished by mercury (Hallgren et al. 2001). In contrast, one population-based cohort study found that the higher mercury levels in human hair samples attenuated the benefits of the omega-3 fatty acids (Virtanen et al. 2005).

Fish consumption is important for neurodevelopment in infant and young children. DHA is an integral structural component of the brain and essential nutrient for pregnant women. DHA can be easily and rapidly absorbed into the developing fetal brain during gestation and in the early years of life of young children (Dovydaitis 2008). DHA was found to improve the visual-motor development in healthy term infants (Uauy et al. 2003; Oken et al. 2008). Some studies showed that fish consumption can increase a child's intelligence quotient (Helland et al. 2003; Cohen et al. 2005a; Dunstan et al. 2008). Meanwhile, the Cohen et al. (2005b) analysis indicated that sufficient prenatal exposure to MeHg could decrease a child's intelligence quotient. A cohort study found that maternal fish consumption was associated with subtle neurodevelopment deficits in children (Debes et al. 2006). In another study, researchers found that the benefits of the modest fish consumption (1-2 servings per week) for women of reproductive age outweighed the potential risks from exposure to MeHg in fish (Mozaffarian and Rimm, 2006). Although scientific evidence in the literatures does not adequately demonstrate causation, evidence suggests that there are benefits from fish consumption, but consuming large quantities of fish containing high Hg levels should be avoided. (Cohen et al. 2005c; Mozaffarian and Rimm 2006; Domingo 2007; Mahaffey et al. 2008; Oken and Bellinger 2008).

From a nutritional perspective, regular fish consumption is beneficial to the general population. From a toxicological perspective, fish is associated with environmental contaminants like methylmercury, which pose a potential threat to humans. Fish consumers are often confused by the conflicting message. People appeared to be influenced more strongly by the danger message (toxicological risk of mercury) as compared to beneficial (nutritional) message (Verbeke et al. 2008). Following the issue of some national fish consumption advisories in the

U.S. in 2001, some pregnant women reduced their fish consumption (Oken et al. 2003). Communication to the public about the competition between benefits and risks is important to include in a fish consumption advisory. Fish consumption advisories should enable people to make informed decisions about what is a safe amount of fish consumption in order to address risks posed by environmental hazards, and to optimize the nutritional benefits of fish consumption with regard to preventable disease while improving neurodevelopment in infants and young children.

The establishment of guidelines for fish consumption is an important part of public health practice. The American Heart Association recommended fish consumption of at least two servings per week (125 g uncooked fish per serving) (Levenson and Axelrad 2006). For commercial fish, Health Canada's current advice is provided in Canada's Food Guide. For large predatory fish, adults can eat up to 150 g **per week**. Women who are or may become pregnant and breastfeeding mothers can eat up to 150 g **per month**. Young children between 5 and 11 years of age can eat up to 125 g **per month**. Very young children between 1 and 4 years of age should eat no more than 75 g per month of large predatory fish species.

Fish consumers can ingest both omega-3 fatty acids and MeHg. MeHg may attenuate the beneficial effects from the omega-3 fatty acids so the balance between the risks and benefits of consuming mercury-containing fish needs to be considered before issuing local fish consumption advisories (Mergler et al. 2007). For local fish, the fish-species-specific, site-specific consumption limits were calculated in this report. Unless local residents in Northeast Alberta consume commercial fish every day, recommended consumption amounts for different groups are presented in Table 10. If local residents do consume commercial fish frequently, they should reduce any additional exposure to local fish accordingly.

Table 10 Recommended Fish Consumption Limits

Water Body	Species	Fish Weight (lb) Over	Consumption Limit (serving/week)			
			Women	Child 1 – 4 yr	Child 5 – 11 yr	Adult +
Athabasca River (downstream Ft. McMurray)	Walleye	2	2	0.5	1	8
Clearwater River	Walleye	2	2	0.5	1	8
	Northern Pike	2	8	2	4	no limit
Muskeg River	Northern Pike	2	8	2	4	no limit
Christina Lake	Walleye	4	2	0.5	1	8
	Northern Pike	8	2	0.5	1	8
Gregoire Lake	Walleye	2	8	2	4	no limit
	Northern Pike	2	8	2	4	no limit
Winefred Lake	Walleye	3	8	2	4	no limit
Namur Lake	Lake Trout	4	2	0.5	1	8

*1 lb = 454 grams. **1 serving = 75 grams, ½ cup, 2.5 ounces, or a piece of cooked fish that fits into the palm of your hand. *** “Women” refers women at reproductive age (15-49 yr) and pregnant women.

Adult+ includes adults and child over 12 yr.

4. Conclusions

Concentrations of total mercury in fish collected from water bodies in the Regional Aquatics Monitoring Program area were within the ranges of other water bodies in Alberta, and those reported in the literature for the same fish species from other rivers and lakes elsewhere in Canada and the U.S.

The estimated mercury exposures warranted limitation of consumption for the higher fish intake group (over 100 grams per day). Restriction of consumption was indicated for specific groups such as women of reproductive age, pregnant women and young children (Table 10). The mercury levels in fish from the RAMP area were between 0.1 - 0.5 µg/g, and people in specific groups should limit fish consumption. Fish consumption advisories apply to local First Nations residents and recreational anglers.

Fish consumption advisories promote voluntary reductions in consumption to minimize potential health risk to local fish consumers. The balance between potential health risk and health benefits of consumption of mercury-containing fish needs to be considered.

The Science Advisory Committee reviewed the human health risk assessment document. The recommendations are made as below:

1. Consumption limits should be set for Alberta fish consumers to make informed decisions as outlined in this report;
2. The healthy benefits of fish consumption should be balanced with any mercury-related health risk; and
3. Mercury levels in fish in water bodies of the RAMP area should continue to be monitored.

Provincial Chief Medical Officer of Health issued the fish consumption advisories (Appendix). The information of new advisories is published in the *Alberta Guide to Sportfishing Regulation* and posted in Alberta government websites.

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