Human Health Risk Assessment

Mercury in Fish

Rivers and Lakes, Southern Alberta

October 2009

Government of Alberta

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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.

In 1982 and 1983, Alberta Environment and Health Canada conducted surveys of mercury levels in fish in rivers and lakes of Alberta. Based on the results of these surveys, fish consumption advisories were issued in the early 1990s, and have been published in the *Alberta Guide to Sportfishing Regulation* annually. In 2006, Alberta Environment and Sustainable Resource and Development conducted a new survey of contaminant levels including mercury in various fish species from some rivers and lakes in Southern Alberta. Alberta Health and Wellness performed a human health risk assessment based on this new set of data to review existing fish consumption advisories.

This report deals with (1) concentrations of total mercury levels in various fish species, (2) temporal trends of mercury levels in fish over the past 25 years, (3) estimation of exposures, (4) fish consumption limits, (5) fish consumption advisories, and (6) health benefits of fish consumption. The results indicated that:

1. Concentrations of total mercury in fish from these rivers and lakes in Southern Alberta were within the literature-reported ranges for the same fish species from the rivers and lakes elsewhere in Canada and the United States.
2. Concentrations of total mercury in fish in 2006 were similar or lower than those in the same fish species from the same rivers in Southern Alberta in 1982/83.
3. The estimated human exposures to mercury were highest for the high fish intake group (over 100 g/d), especially if they consume fish-eating fish like walleye, northern pike, goldeye and sauger from the Red Deer River and South Saskatchewan Rivers.
4. Restriction of consumption of some fish species from specific rivers and lakes was indicated by the risk assessment, especially for women of reproductive age, pregnant women and young children.
5. 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

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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 per g of fish flesh or as a Provisional Tolerable Daily Intake (pTDI) in units of μg 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 TDI for women of reproductive age and children (Guideline);
3. 0.47 μg MeHg/kg bw/d TDI 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 μg/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.

In 1982 and 1983, the Alberta Environmental Centre with the Fish and Wildlife Division conducted surveys of contaminants including mercury in fish tissue in the South Saskatchewan River basin (AEC 1984). Based on the results of these surveys, Health Canada prepared and issued fish consumption advisories in the early 1990s. Alberta Energy and Natural Resources and Alberta Environment posted and made the advisories. The advisories were published in the *Alberta Guide to Sportfishing Regulation* annually (Appendix A). Fish consumption advisories related to mercury covered four rivers in Southern Alberta: the Bow River, Oldman River, Red Deer River and South Saskatchewan River. Fish species included walleye, sauger, northern pike, goldeye and burbot.

In 2006, Alberta Environment and Sustainable Resource and Development conducted a fish sampling program in some rivers and lakes of Southern Alberta. The main objectives of this program were to

1. repeat the survey of mercury residues in fish in the South Saskatchewan basin that was done in 1982 - 83;
2. evaluate whether fish consumption advisories are still needed and assess potential human health risk;
3. determine if any of a subset of emerging contaminants may also be a concern; and
4. determine the state of aquatic ecosystem health in Southern Alberta, as described in the Water for Life Strategy.

In September 2007, Alberta Environment and Sustainable Resource and Development submitted the data of mercury levels in fish to Alberta Health and Wellness for human health risk assessment.

The results of the 2006 survey are discussed as follows:

1. mercury concentrations in fish,
2. change over time in mercury concentrations in fish,
3. comparison of mercury concentrations in the same fish species in the rivers and lakes in Canada and the U.S.,
4. local fish consumption rates,
5. estimated exposures for women at reproductive age, children and adults,
6. fish consumption advisories, and
7. 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. μg/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. μg/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 **μg/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 **μg 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 Alberta Environment and Sustainable Resource Development between September and October 2006. Fish were collected by using gill netting in the lakes and electrofishing in the rivers. The sampling sites (Figure 1) included

- Bow River ① (near Calgary, downstream from Bearspaw Dam)
- Bow River ② (downstream from Highway 22x)
- Oldman River ① at Lethbridge (downstream from the weir),
- Oldman River ② at Lethbridge (at Paradise Canyon),

- Red Deer River ① (downstream at the mouth of the Blindman R.),
- Red Deer River ② (at km 497-501),
- South Saskatchewan River ① at Bindloss Ferry,
- South Saskatchewan River ② at Medicine Hat,
- Milk River Ridge Reservoir,
- Keho Lake,
- Lake Newell,
- Pigeon Lake, and
- Pine Lake.

Pigeon Lake is the one lake outside the South Saskatchewan River basin. Samples from this lake were included because it was part of a province-wide walleye survey.

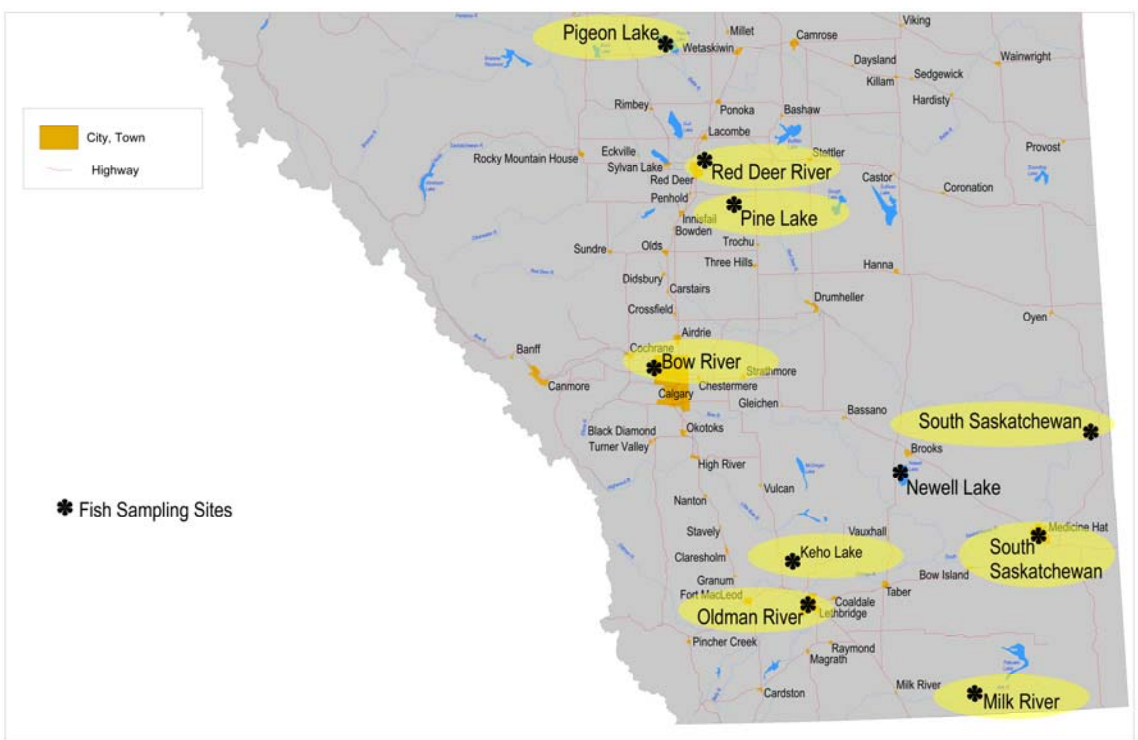

Figure 1 Map of Sampling Sites

Fish species included

- walleye (*Sander vitreus*),
- sauger (*Sander canadensis*),
- northern pike (*Esox lucius*),
- goldeye (*Hiodon alosoides*),

- rainbow trout (*Oncorhynchus mykiss*),
- brown trout (*Salmo trutta*),
- white sucker (*Catostomus commersoni*),
- longnose sucker (*Catostomus catostomus*),
- mountain whitefish (*Prosopium williamsoni*), and
- lake whitefish (*Coregonus clupeaformis*).

A total of 289 fish was collected for total mercury analysis. Of these 117 out of 289 samples were sent for methylmercury analysis. These were mainly piscivores that were expected to have higher total mercury levels, and commonly-angled rainbow and brown trout from the Bow River. The sample size, and mean of weight and fork length are summarized in Table 2.

Each sample was kept on ice, 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 Laboratory at the Alberta Research Council in Vegreville, Alberta.

2.3 Laboratory Analysis

Only fish muscle was analyzed. The fish specimens were analyzed for THg and a subsample was analyzed for MeHg. For MeHg analysis, approximately 0.2 g of fish muscle (non-homogenized) was dissolved in 5 mL of a 25% solution of KOH in methanol. Dissolution took place in an ultrasonic bath at room temperature for two hours. After two hours, an additional 5 mL of methanol was added to the solution. A small portion of this solution (0.5 mL) was acidified and treated with sodium borohydride to produce volatile methyl mercury hydride. This volatile hydride was collected on a carbotrap prior to gas chromatography separation and detection with atomic fluorescent spectroscopy. The method detection limit (MDL) was 0.03 μg/g, wet weight.

For THg analysis, 1 g of tissue (non-homogenized) was digested using 5mL nitric acid in a microwave digestion, then diluted to 100 mL with distilled water and preserved with BrCl. Mercury was then analyzed using Cold-Vapor Atomic Absorption Spectroscopy on a flow injection mercury system. The sample volume used was 500 μL. The MDL was 0.003 μg/g, wet weight.

Table 2 Sample Size and Mean of Weight and Length

Species	Sample Size (for MHg Analysis)	Fork Length (cm)	Wet Weight (g)
<u>Bow River</u>			
Brown Trout②	10 (7)	32.5	413
Longnose Sucker②	10	53.7	2013
Rainbow Trout①②	14 (7)	39.4	714
Mountain Whitefish①	10	37.8	560
<u>Oldman River</u>			
Northern Pike①②	15 (7)	47.9	1056
White Sucker①	10	44.4	1188
<u>Red Deer River</u>			
Mountain Whitefish②	8	36.6	851
Walleye②	7 (6)	47.7	1520
Northern Pike①②	7 (4)	55.1	1378
<u>South Saskatchewan River</u>			
Goldeye①	10 (10)	38.8	550
Lake Whitefish①	10	43.4	731
White Sucker①	10	44.6	1060
Northern Pike②	12 (12)	60.9	1879
Sauger①②	15 (15)	40.9	613
Walleye②	14 (10)	46.0	889
<u>Milk River Ridge Reservoir</u>			
Lake Whitefish	10	47.2	932
Northern Pike	10	68.0	2133
Walleye	10 (10)	51.0	1526
<u>Lake Newell</u>			
Northern Pike	6	72.1	2471
Walleye	7	56.6	2045
Lake Whitefish	10	47.3	912
<u>Keho Lake</u>			
Lake Whitefish	10	44.8	823
Northern Pike	12	78.1	2959
Walleye	10	58.1	2245
<u>Pine Lake</u>			
Northern Pike	11	63.1	1562
Walleye	11 (10)	52.1	1429
<u>Pigeon Lake</u>			
Lake Whitefish	9	45.2	1124
Walleye	10 (10)	52.9	1232

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 (μg/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, μg MeHg/kg bw/d) is determined by toxicological risk assessment on mercury (Health Canada 2007). The TDI for mercury 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 μg MeHg/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 mercury as 0.47 μg MeHg/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 (µg MeHg/kg bw/d),
BW is body weight (mass) in humans (kg), and
C (µg 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 µg Hg /g fish) are provided below as a reference point.

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

Consumption Limits for women of reproductive age
CR = (0.2µg MeHg/kg bw/d)(65 kg)(7 d/wk) / (0.5 µg Hg / g fish) = 180 g fish /week

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

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

3. Results and Discussions

3.1 Concentrations in Fish

The distributions of THg in fish are approximately normal because the size of fish sampled were in the group of large size according to the sampling protocol. The mean and 90th percentile concentrations of THg and mean of MeHg in fish fillets from all sampling sites are summarized in Table 3. The major form of the mercury in fish is MeHg. Mean mercury concentrations in five fish species are illustrated in Figure 2.

Walleye were collected at seven sites. A range of THg was 0.11 – 0.79 μg/g. This species accumulated relatively higher mercury concentrations than those of other fish species. The highest concentrations were observed in walleye from the Red Deer River (0.79 μg/g) and the South Saskatchewan River (0.62 μg/g). Mean THg concentration in sauger was 0.75 μg/g in South Saskatchewan River. Mean THg concentration in goldeye from South Saskatchewan River was 0.51 μg/g. Mean THg concentrations in northern pike ranged from 0.18 to 0.35 μg/g in seven sites. Brown trout and rainbow trout from Bow River contained low levels of mercury, 0.03 and 0.08 μg/g, respectively. The levels of mercury in lake whitefish and mountain whitefish were relatively low, ranging from 0.02 to 0.14 μg/g. The levels of mercury in longnose sucker and white sucker varied from 0.22 to 0.29 μg/g.

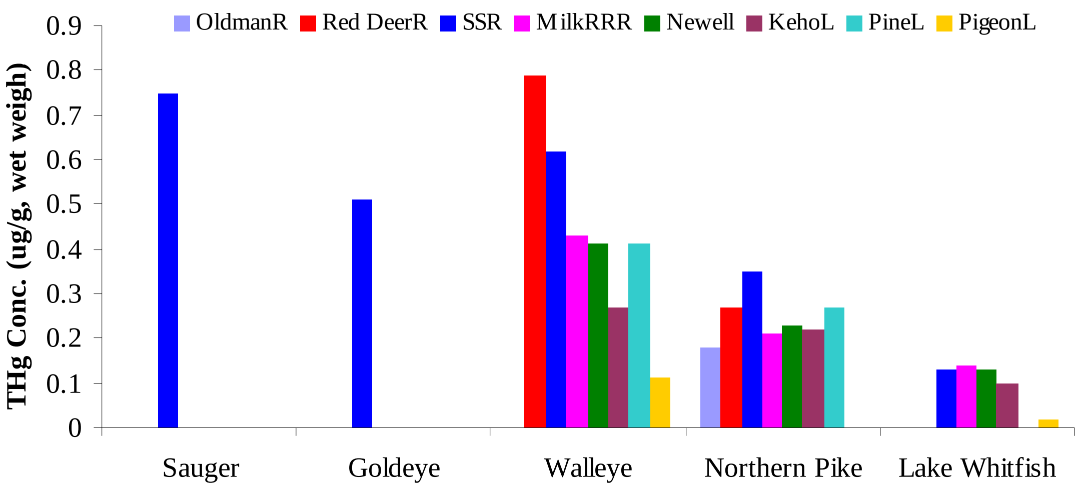

Figure 2 Mean THg Concentrations in Five Fish Species

Table 3 THg Concentrations in Fish (μg/g, wet weight)

Species	**THg** Mean	**THg** 90th Percentile	**MeHg** Mean
Bow River			
Brown Trout	0.03	0.04	0.02
Longnose Sucker	0.22	0.32	
Rainbow Trout	0.08	0.17	0.08
Mountain Whitefish	0.06	0.08	
Oldman River			
Northern Pike	0.18	0.27	
White Sucker	0.28	0.43	
Red Deer River			
Mountain Whitefish	0.12	0.17	
Walleye	**0.79**	1.07	0.73
Northern Pike	0.27	0.43	
South Saskatchewan River			
Goldeye	**0.51**	0.62	0.53
Lake Whitefish	0.13	0.17	
White Sucker	0.29	0.41	
Northern Pike	0.35	0.57	0.34
Sauger	**0.75**	1.08	0.58
Walleye	**0.62**	1.07	
Milk River Ridge Reservoir			
Lake Whitefish	0.14	0.17	
Northern Pike	0.21	0.22	
Walleye	0.43	0.58	0.42
Lake Newell			
Northern Pike	0.23	0.27	
Walleye	0.41	0.59	
Lake Whitefish	0.13	0.15	
Keho Lake			
Lake Whitefish	0.10	0.12	
Northern Pike	0.22	0.30	
Walleye	0.27	0.43	
Pine Lake			
Northern Pike	0.27	0.34	
Walleye	0.41	0.73	0.38
Pigeon Lake			
Lake Whitefish	0.02	0.02	
Walleye	0.11	0.13	0.10

THg or MeHg concentrations exceeding the 0.5 μg/g commercial fish limit are showed in **bold**.

Table 4 Mean THg Levels 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
	0.19 – 1.43	Mackenzie River Basin Lakes	Evans et al. 2005 a
Northern Pike	0.26 – 0.32	Reservoirs, Manitoba, Canada	Bodaly et al. 2007
	0.44 – 2.14	Wabigoon River system*, Ontario	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	Water bodies 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
	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
Sauger	0.573	Water bodies in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
Lake Whitefish	0.06 – 0.07	Reservoirs, Manitoba, Canada	Bodaly et al. 2007
	0.08 – 0.31	Wabigoon River system*, Ontario, Canada	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. 2005a
	0.11 – 0.13	Lakes in Northern Canada	Lockhart et al. 2005
	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

(Continued)

Specie	Mean (μg/g, ww)	Location	Reference
Brown Trout	0.305	lakes, rivers and reservoirs in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
Rainbow Trout	0.086	lakes, rivers and reservoirs in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
White Sucker	0.55 – 1.23	19 lakes, Haute Mauricie, Quebec, Canada	Garcia and Carignan, 2005
	0.186	lakes, rivers and reservoirs in northeastern of US and Canada (N=19,178)	Kamman et al. 2005
	0.099	Lakes in Northern Canada	Lockhart et al. 2005
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.

Mean THg concentrations in fish in Southern Alberta ranged from 0.02 to 0.75 μg/g (Table 3).The average THg concentrations in the Canadian market fish reported by Health Canada ranged from 0.02 to 1.82 μg/g (Health Canada 2007). Compared to the Canadian market fish for different fish species, mean THg concentrations in local fish in Southern Alberta were well within the ranges of Canadian market fish.

Mean THg levels for the same fish species from other water bodies in Canada and the U.S. reported in the literature are summarized in Table 4. Mean THg levels ranged from 0.06 to 2.55 μg/g. Mean mercury concentrations in goldeye and mountain whitefish were not found in the literature. Mean THg concentrations for all other fish species in the water bodies in Southern Alberta were within the ranges in the same fish species reported in the literature for other North American freshwater fish.

Mean THg concentration in fish fillets varied in other lakes, rivers and reservoirs in Canada and the U.S. Walleye and northern pike generally had higher mercury levels than lake whitefish. 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 μg/g. Higher 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 South Alberta survey, the fish caught was generally in the larger size group (Table 2).

Trophic level is a major factor in mercury accumulation by predatory (fish-eating) fish through biomagnifications (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. Predator 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, three distinct ecological fish groups were collected: insectivores (white sucker, longnose sucker, trout, lake whitefish and mountain whitefish), omnivores (goldeye), and piscivores (walleye, sauger, northern pike). Higher mercury levels were observed in walleye, sauger and goldeye in this survey.

3.2 Changes of Mercury Levels in 1982/83 and 2006

The mercury levels were relatively high in most fish species from the South Saskatchewan River and the Red Deer River, and low in those from the Bow River near Calgary and Pigeon Lake. The difference of THg levels in some fish species between 1982/83 and 2006 are shown in Table 5. The THg levels in brown trout and mountain whitefish from the Bow River were significantly lower in 2006 as compared to 1982/83 ($p < 0.01$) where fork lengths were similar. The THg levels did not significantly change in the following fish species ($p > 0.01$): rainbow trout and longnose sucker from the Bow River, northern pike and white sucker from the Oldman river, walleye and northern pike from the Red Deer River, and northern pike and sauger from the South Saskatchewan River.

Possible point sources of mercury entering water bodies in Southern Alberta have not been identified. Natural processes such as atmospheric deposition of elemental mercury through forest fire and leaching from rock, and human activities such as gold mining and combustion of fossil fuels including cement manufacturing and coal-fired power plants have been identified as indirect sources to the water (WHO 1990). In the natural environment, the accumulation of mercury in fish could result from physical factors such as water temperature and size of lakes, chemical factors such as low pH and high dissolved organic carbon, and biological factors such as fish length and age, trophic levels) factors in the water bodies (Evans et al. 2005). For example, MeHg was likely enhanced by flooding (Bodaly 1997, 2007). Forest fires can increase mercury volatilization to the air (Sigler et al. 2003) and increase the nutrient loading in the watershed that influences the formation of MeHg by aquatic microorganisms (Garcia and Carignan, 2005). The lack of evident change of mercury levels in fish in waterbodies in Southern Alberta may suggest that the major inputs of mercury entering these rivers could result from natural processes.

Table 5 Mean THg Concentrations between 1982/83 and 2006 (μg/g, wet weight)

Species	1982/823	2006	p value*
Bow River			
Brown Trout	0.16	0.03	**0.001**
Rainbow Trout	0.12	0.08	0.03
Longnose Sucker	0.17	0.22	0.22
Mountain whitefish	0.18	0.06	**0.000**
Oldman River			
Northern Pike	0.25	0.18	0.07
White Sucker	0.20	0.27	0.59
Red Deer River			
Walleye	0.68	0.79	0.28
Northern Pike	0.20	0.27	0.71
South Saskatchewan River			
Northern Pike	0.32	0.35	0.93
Sauger	0.63	0.75	0.02

* Independent T Test (SPSS V15): Statistical significance for p <0.01 showed in **bold**.

3.3 Local Fish Consumption Rates

Three surveys of fish consumption patterns were conducted in communities of Northern 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 Athabasaca River and tributaries at Hinton (EHSUA 2000). The 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 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.

Table 6 Local Fish Consumption Rates in Communities of Northern Alberta

Intake Group	**Subsistence Consumer** Lesser Slave Lake*****		**Local Fish Consumer** Swan Hills		**Local Fish Consumer** Athabasaca 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

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.

These three surveys were conducted with communities in Northern Alberta. No equivalent fish consumption surveys are available for Southern Alberta. For the purpose of risk assessment, fish consumption rates used for calculating exposure ratios for sport fishers were taken at 170 g/d for high intake group, 50 g/d for medium intake, 10 g/d for low intake group, and 2 g/d for very low intake group. For the First Nations people, the rate of 270 g/d for the high intake group was used. Because the fish consumption behaviors may differ from one First Nations community to another, this rate may not generalizable to other First Nations communities, but there are the only Alberta data available at present.

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.

3.4 Estimated Exposures

Estimated exposure ratios based on the pTDIs from Health Canada are summarized in Table 7 for women of reproductive age and Table 8 for other adults. Specific fish consumption rates were not available for women at reproductive age and young children. As a result, 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. The fish consumption rate of subsistence consumers from the Lesser Slave Lake communities was used for subsistence consumers in the Southern Alberta communities. Longnose sucker and white sucker are not included for estimating exposures because fish consumers rarely ate these fish.

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 walleye, northern pike, goldeye and sauger.

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 seen as a reference point for making risk management decisions. In particular, those exposure scenarios showing 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 three surveys in adults living in Northern Alberta. The consumption rates in local fish consumers in Southern Alberta may vary from the results from those in Northern Alberta although there is no reason to expect them to be higher. The estimated exposure was solely based on site-specific, fish from local specific sources. People may also be exposed to MeHg 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)
Bow River			
Brown Trout	<1	<1	<1
Rainbow Trout	1.1	<1	1.7
Mountain Whitefish	<1	<1	1.2
Oldman River			
Northern Pike	2.4	<1	3.8
Red Deer River			
Mountain Whitefish	1.5	<1	2.4
Walleye	10	3.0	17
Northern Pike	3.4	<1	5.6
South Saskatchewan River			
Goldeye	6.6	1.9	11
Lake Whitefish	1.7	<1	2.8
Northern Pike	4.4	1.3	7.2
Sauger	9.6	2.7	15.5
Walleye	7.8	2.2	13
Milk River Ridge Reservoir			
Lake Whitefish	1.8	<1	2.9
Northern Pike	2.6	<1	4.3
Walleye	5.5	1.6	8.9
Lake Newell			
Northern Pike	3.0	<1	3.0
Walleye	5.2	1.5	4.3
Lake Whitefish	1.6	<1	9.0
Keho Lake			
Lake Whitefish	1.3	<1	2.1
Northern Pike	2.8	<1	4.5
Walleye	3.4	<1	5.5
Pine Lake			
Northern Pike	3.5	<1	5.6
Walleye	5.3	1.5	8.5
Pigeon Lake			
Lake Whitefish	<1	<1	<1
Walleye	1.5	<1	2.4

Note: mean of total mercury listed in Table 3; body weight = 65 kg; pTDI = 0.2 μg/kg bw/d

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)
Bow River			
Brown Trout	<1	<1	<1
Rainbow Trout	<1	<1	<1
Mountain Whitefish	<1	<1	<1
Oldman River			
Northern Pike	<1	<1	1.4
Red Deer River			
Mountain Whitefish	<1	<1	<1
Walleye	3.9	1.1	6.3
Northern Pike	1.3	<1	2.1
South Saskatchewan River			
Goldeye	2.5	<1	4.0
Lake Whitefish	<1	<1	1.1
Northern Pike	1.7	<1	2.7
Sauger	3.6	<1	5.9
Walleye	3.0	<1	4.9
Milk River Ridge Reservoir			
Lake Whitefish	<1	<1	1.1
Northern Pike	1.0	<1	1.6
Walleye	2.1	<1	3.4
Lake Newell			
Northern Pike	1.1	<1	1.8
Walleye	2.0	<1	3.2
Lake Whitefish	<1	<1	<1
Keho Lake			
Lake Whitefish	<1	<1	<1
Northern Pike	1.1	<1	1.7
Walleye	1.3	<1	2.1
Pine Lake			
Northern Pike	1.3	<1	2.1
Walleye	2.0	<1	3.2
Pigeon Lake			
Lake Whitefish	<1	<1	<1
Walleye	<1	<1	<1

Note: mean of total mercury listed in Table 3; body weight = 73 kg; pTDI = 0.47 μg/kg bw/d

3.5 Consumption Limits

For the purpose of quantitative fish advisories, the lifetime consumption limits were calculated for subgroups of women, young children and adults (Table 9-12). 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 in subpopulations. Walleye and sauger from specific rivers and lakes contain relatively higher mercury and should be limited for consumption at the lower amounts of 120 – 220 grams per week for women of reproductive age, 50 – 140 grams per week for children at age of 5 – 11 years old, and 25 – 75 grams per week for children at age of 1 – 4 years old. Fish preparation and cooking methods do not reduce the concentrations of total mercury in fish (Morgan et al. 1997).

3.6 Fish Consumption Advisories

Fish consumers may be exposed to MeHg via 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 to 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 TDIs proposed by Health Canada are intended to protect special susceptible populations.

Because mercury occurs naturally, mercury is found in all commercial or non-commercial fish and other foods at the low levels. People are exposed to very low levels of mercury via all 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 attention to 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 likely to be the primary source of dietary mercury intake for most of the surveyed populations.

Table 9 Lifetime Consumption Limits for Women of Reproductive Age

	Gram Per Week	Oz Per Week
Oldman River		
Northern Pike	500	18
Red Deer River		
Mountain Whitefish	780	28
Walleye	120	4
Northern Pike	340	12
South Saskatchewan River		
Goldeye	180	6
Lake Whitefish	680	24
Northern Pike	260	9
Sauger	120	4
Walleye	150	5
Milk River Ridge Reservoir		
Lake Whitefish	650	23
Northern Pike	450	16
Walleye	210	7
Lake Newell		
Northern Pike	390	14
Walleye	220	8
Lake Whitefish	730	26
Keho Lake		
Lake Whitefish	910	32
Northern Pike	420	15
Walleye	340	12
Pine Lake		
Northern Pike	340	12
Walleye	220	8

Note: mean of total mercury listed in Table 3; body weight = 65 kg; pTDI = 0.2 μg/kg bw/d

Table 10 Lifetime Consumption Limits for Children at age of 5 – 11 yrs

	Gram Per Week	Oz Per Week
Oldman River		
Northern Pike	200	7
Red Deer River		
Mountain Whitefish	320	11
Walleye	50	2
Northern Pike	140	5
South Saskatchewan River		
Goldeye	70	3
Lake Whitefish	280	10
Northern Pike	110	4
Sauger	50	2
Walleye	60	2
Milk River Ridge Reservoir		
Lake Whitefish	260	9
Northern Pike	180	6
Walleye	85	3
Lake Newell		
Northern Pike	160	6
Walleye	90	3
Lake Whitefish	300	10
Keho Lake		
Lake Whitefish	370	13
Northern Pike	170	6
Walleye	140	5
Pine Lake		
Northern Pike	140	5
Walleye	90	3

Note: mean of total mercury listed in Table 3; body weight = 26.4 kg; pTDI = 0.2 μg/kg bw/d

Table 11 Lifetime Consumption Limits for Children at Age of 1 – 4 yrs

	Gram Per Week	Oz Per Week
Oldman River		
Northern Pike	110	4
Red Deer River		
Mountain Whitefish	180	6
Walleye	25	1
Northern Pike	75	3
South Saskatchewan River		
Goldeye	40	1
Lake Whitefish	150	5
Northern Pike	60	2
Sauger	27	1
Walleye	30	1
Milk River Ridge Reservoir		
Lake Whitefish	140	5
Northern Pike	100	3
Walleye	50	2
Lake Newell		
Northern Pike	90	3
Walleye	50	2
Lake Whitefish	160	6
Keho Lake		
Lake Whitefish	200	7
Northern Pike	90	3
Walleye	75	3
Pine Lake		
Northern Pike	75	3
Walleye	50	2

Note: mean of total mercury listed in Table 3; body weight = 14.4 kg; pTDI = 0.2 μg/kg bw/d

Table 12 Lifetime Consumption Limits for Adults

	Gram Per Week	Oz Per Week
Oldman River		
Northern Pike	1300	46
Red Deer River		
Walleye	300	11
Northern Pike	900	32
South Saskatchewan River		
Goldeye	470	17
Northern Pike	700	24
Sauger	320	11
Walleye	390	14
Milk River Ridge Reservoir		
Northern Pike	1200	41
Walleye	560	20
Lake Newell		
Northern Pike	1000	37
Walleye	590	21
Keho Lake		
Northern Pike	1100	39
Walleye	590	21
Pine Lake		
Northern Pike	890	31
Walleye	590	21

Note: mean of total mercury listed in Table 3; body weight = 73 kg; pTDI = 0.47 μg/kg bw/d.

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 are voluntary activities unlike mandatory activities such as catch/release programs or outright fishing ban.

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 of food consumption advisories (Appendix B) in 1997. The advisories can take the form of non-consumption or restricted-consumption advisories for adults and sensitive subpopulations.

3.7 Benefits of Fish Consumption

The benefits and risk of fish consumption is a recent focus of public health interest. Fish is an important supplier 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 consistent evidence on 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 earlier 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 could 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 studies 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 suggested 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 toxicological perspective, fish is associated with environmental contaminants like methylmercury, which pose a potential threat to humans. Fish consumers are often confused by these potential 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 decision 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.

Establishment of guidelines for fish consumption is an important public health practices. 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 the 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 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 Southern Alberta consume commercial fish every day, recommended consumption amounts for different groups are presented in Table 13. If local residents do consume commercial fish frequently, they should reduce any additional exposure to local fish accordingly.

Table 13 Recommended Fish Consumption Limits

Water Body	Species	Fish Size (lb) Over	Consumption Limit (serving/week)			
			Women	Child 1 – 4 yr	Child 5 – 11 yr	Adult +
Red Deer River *(downstream at the mouth of the Blindman R and)*	Walleye	3	avoid	avoid	avoid	5
	Northern Pike	3	4	1	2	no limit
	Mountain Whitefish	2	8	2	4	no limit
South Saskatchewan River *(Bindloss Ferry and Medicine Hat)*	Walleye	2	avoid	avoid	avoid	5
	Sauger	1	avoid	avoid	avoid	8
	Goldeye	1	avoid	avoid	avoid	5
	Northern Pike	3	4	1	2	no limit
	Lake Whitefish	2	8	2	4	no limit
Oldman River *(Downstream Lethbridge - weir and Paradise Canyon)*	Northern Pike	3	4	1	2	no limit
Milk River Ridge Reservoir	Walleye	3	2	0.5	1	8
	Northern Pike	3	4	1	2	no limit
	Lake Whitefish	2	8	2	4	no limit
Lake Newell	Walleye	3	2	0.5	1	8
	Northern Pike	3	4	1	2	no limit
	Lake Whitefish	2	8	2	4	no limit
Keho Lake	Walleye	3	2	0.5	1	8
	Northern Pike	3	4	1	2	no limit
Pine Lake	Walleye	3	2	0.5	1	8
	Northern Pike	3	4	1	2	no limit

*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 to women of child-bearing age (15-49 yr) and pregnant women.
Adult+ includes adults and child over 12 yr.

4. Conclusions

Concentrations of total mercury in fish varied among fish species and water bodies in Southern Alberta, but were within the ranges reported in the literature for the same fish species from other rivers and lakes elsewhere in Canada and the U.S. The higher mercury levels were observed in large piscivorous (predatory) fish such as walleye, sauger and northern pike and the omnivorous fish, such as goldeye, as is expected from monitoring results elsewhere and our current understanding of how mercury contamination occurs in fish. Concentrations of total mercury in fish reported in 2006 were similar or lower than those in the same species caught from the same rivers in Southern Alberta in 1982/83.

The estimated mercury exposures warranted limitation of consumption for the higher fish intake group (over 100 grams per day), especially if they consumed some species like walleye, northern pike, goldeye and sauger caught from most sites. Restriction of consumption of some fish species at specific rivers and lakes was indicated for specific groups such as women of reproductive age, pregnant women and young children (Table 13). If the mercury levels in fish are over 0.5 μg/g, people in specific groups should avoid eating these fish and adults should limit fish consumption. If the mercury levels in fish are between 0.1 - 0.5 μg/g, people in specific groups should limit fish consumption.

Fish consumption advisories promote voluntary reduced consumption to minimize potential health risk to local fish consumers. The balance between risk and 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 most consumed fish (particularly in large predatory) in selected water bodies in Southern Alberta should continue to be monitored.

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

5. References

1. AEC (Alberta Environment Centre). Mercury in fish from six rivers in Southern Alberta. Vigreville, Alberta: Alberta Environment Centre, (1984).

2. AHW (Alberta Health and Wellness). Swan Hills Special Waste Treatment Centre - Human Health Impact Assessment. Edmonton, Alberta, Canada: Alberta Health and Wellness, (1997).

3. AHW (Alberta Health and Wellness). Wabamun and Area Community Exposure and Health Effects Assessment Program. Edmonton, Alberta, Canada: Alberta Health and Wellness, (2006).

4. Bodaly RA, St Louis VL, Paterson MJ, Fudge RJ, Hall BD, Rosenberg DM, Rudd JW. Bioaccumulation of mercury in the aquatic food chain in newly flooded areas. Met Ions Biol Syst 34:259-287 (1997).

5. Bodaly RA, Jansen WA, Majewski AR, Fudge RJ, Strange NE, Derksen AJ, Green DJ. Postimpoundment time course of increased mercury concentrations in fish in hydroelectric reservoirs of northern Manitoba, Canada. Arch Environ Contam Toxicol 53:379-389 (2007).

6. Bouzan C, Cohen JT, Connor WE, Kris-Etherton PM, Gray GM, Konig A, Lawrence RS, Savitz DA, Teutsch SM. A quantitative analysis of fish consumption and stroke risk. Am J Prev Med 29:347-352 (2005).

7. Braune B, Muir D, DeMarch B, Gamberg M, Poole K, Currie R, Dodd M, Duschenko W, Eamer J, Elkin B, Evans M, Grundy S, Hebert C, Johnstone R, Kidd K, Koenig B, Lockhart L, Marshall H, Reimer K, Sanderson J, Shutt L. Spatial and temporal trends of contaminants in Canadian Arctic freshwater and terrestrial ecosystems: a review. Sci Total Environ 230:145-207 (1999).

8. Cabana G, Tremblay A, Rasmussen JB. Pelagic food chain structure in Ontario Lakes: a determinant of mercury levels in Lake Trout. Canadian Journal of Fisheries and Aquatic Sciences 51:381-389 (1994).

9. Canadian Food Inspection Agency (CFIA). Draft Sablefish Mercury Report - Investigation of mercury in B.C. Sablefish sampled between October 2002 and November 2003. Unpublished document. (2003).

10. Chan HM, Egeland GM. Fish consumption, mercury exposure, and heart diseases. Nutr Rev 62:68-72 (2004).

11. Cohen JT, Bellinger DC, Connor WE, Shaywitz BA. A quantitative analysis of prenatal intake of n-3 polyunsaturated fatty acids and cognitive development. Am J Prev Med 29:366-374 (2005a).

12. Cohen JT, Bellinger DC, Connor WE, Kris-Etherton PM, Lawrence RS, Savitz DA, Shaywitz BA, Teutsch SM, Gray GM. A quantitative risk-benefit analysis of changes in population fish consumption. Am J Prev Med 29:325-334 (2005b).

13. Cohen JT, Bellinger DC, Shaywitz BA. A quantitative analysis of prenatal methyl mercury exposure and cognitive development. Am J Prev Med 29:353-365 (2005c).

14. Debes F, Budtz-Jorgensen E, Weihe P, White RF, Grandjean P. Impact of prenatal methylmercury exposure on neurobehavioral function at age 14 years. Neurotoxicol Teratol 28:536-547 (2006).

15. Domingo JL. Omega-3 fatty acids and the benefits of fish consumption: is all that glitters gold? Environ Int 33:993-998 (2007).

16. Dovydaitis T. Fish consumption during pregnancy: an overview of the risks and benefits. J Midwifery Women Health 53:325-330 (2008).

17. Dunstan JA, Simmer K, Dixon G, Prescott SL. Cognitive assessment of children at age 2(1/2) years after maternal fish oil supplementation in pregnancy: a randomised controlled trial. Arch Dis Child Fetal Neonatal Ed 93:F45-F50 (2008).

18. EHSUA (Environmental Health Sciences Program UoA. Development of A Fish Consumption Advisory Risk Communication/Public Participation Protocol for Alberta: A Case Study in Athabasaca River and Tributaries.unpublished, internal report, (2000).

19. Evans MS, Muir D, Lockhart WL, Stern G, Ryan M, Roach P. Persistent organic pollutants and metals in the freshwater biota of the Canadian Subarctic and Arctic: an overview. Sci Total Environ 351-352:94-147 (2005a).

20. Evans MS, Lockhart WL, Doetzel L, Low G, Muir D, Kidd K, Stephens G, Delaronde J. Elevated mercury concentrations in fish in lakes in the Mackenzie River Basin: the role of physical, chemical, and biological factors. Sci Total Environ 351-352:479-500 (2005b).

21. Feeley MM, Lo M-T. Risk Assessment for Mercury in Health Canada - Development of the Provisional Tolerable Daily Intake (pTDI) Value. In: Proceedings of the Conference on Mercury in Eastern Canada and the Northeast States, 21-23 September, 1998 (Pilgrim W, Burgess N, Giguère M-F,

eds).www.emanrese.ca/eman/reports/publications/98_mercury2/oralpresentations_day2.html#head2_1, (1998).

22. Feeley MM. Health Canada Mercury Guidelines. Personal communication.

23. Garcia E, Carignan R. Mercury concentrations in fish from forest harvesting and fire-impacted Canadian Boreal lakes compared using stable isotopes of nitrogen. Environ Toxicol Chem 24:685-693 (2005).

24. Gerstenberger SL, Dellinger JA. PCBs, mercury, and organochlorine concentrations in lake trout, walleye, and whitefish from selected tribal fisheries in the Upper Great Lakes region. Environ Toxicol 17:513-519 (2002).

25. Hallgren CG, Hallmans G, Jansson JH, Marklund SL, Huhtasaari F, Schutz A, Stromberg U, Vessby B, Skerfving S. Markers of high fish intake are associated with decreased risk of a first myocardial infarction. Br J Nutr 86:397-404 (2001).

26. Health Canada. Methylmercury in Canada Exposure of Indian and Inuit Residents to Methylmercury in the Canadian Environment. Ottawa:Health Canada, (1979).

27. Health Canada. Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption. Ottawa, Canada: Health Canada, (2007).

28. Health Canada. Lesser Slave Lake Health Study.Unpublished, Medical Service Branch, Health Canada, (1999).

29. Helland IB, Smith L, Saarem K, Saugstad OD, Drevon CA. Maternal supplementation with very-long-chain n-3 fatty acids during pregnancy and lactation augments children's IQ at 4 years of age. Pediatrics 111:e39-e44 (2003).

30. Jewett SC, Zhang X, Naidu AS, Kelley JJ, Dasher D, Duffy LK. Comparison of mercury and methylmercury in northern pike and Arctic grayling from western Alaska rivers. Chemosphere 50:383-392 (2003).

31. Kamman NC, Burgess NM, Driscoll CT, Simonin HA, Goodale W, Linehan J, Estabrook R, Hutcheson M, Major A, Scheuhammer AM, Scruton DA. Mercury in freshwater fish of northeast North America--a geographic perspective based on fish tissue monitoring databases. Ecotoxicology 14:163-180 (2005).

32. Kerper LE, Ballatori N, Clarkson TW. Methylmercury transport across the blood-brain barrier by an amino acid carrier. Am J Physiol 262:R761-R765 (1992).

33. Kinghorn A, Solomon P, Chan HM. Temporal and spatial trends of mercury in fish collected in the English-Wabigoon river system in Ontario, Canada. Sci Total Environ 372:615-623 (2007).

34. Konig A, Bouzan C, Cohen JT, Connor WE, Kris-Etherton PM, Gray GM, Lawrence RS, Savitz DA, Teutsch SM. A quantitative analysis of fish consumption and coronary heart disease mortality. Am J Prev Med 29:335-346 (2005).

35. Kris-Etherton PM, Harris WS, Appel LJ. Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. Arterioscler Thromb Vasc Biol 23:e20-e30 (2003).

36. Levenson CW, Axelrad DM. Too much of a good thing? Update on fish consumption and mercury exposure. Nutr Rev 64:139-145 (2006).

37. Lockhart WL, Stern GA, Low G, Hendzel M, Boila G, Roach P, Evans MS, Billeck BN, Delaronde J, Friesen S, Kidd K, Atkins S, Muir DC, Stoddart M, Stephens G, Stephenson S, Harbicht S, Snowshoe N, Grey B, Thompson S, DeGraff N. A history of total mercury in edible muscle of fish from lakes in northern Canada. Sci Total Environ 351-352:427-463 (2005).

38. Mahaffey KR, Clickner RP, Jeffries RA. Methylmercury and omega-3 fatty acids: co-occurrence of dietary sources with emphasis on fish and shellfish. Environ Res 107:20-29 (2008).

39. Mergler D, Anderson HA, Chan LH, Mahaffey KR, Murray M, Sakamoto M, Stern AH. Methylmercury exposure and health effects in humans: a worldwide concern. Ambio 36:3-11 (2007).

40. Morgan JN, Berry MR, Graves RL. Effects of commonly used cooking practices on total mercury concentration in fish and their impact on exposure assessments. J Expo Anal Environ Epidemiol 7:119-133 (1997).

41. Mozaffarian D, Rimm EB. Fish intake, contaminants, and human health: evaluating the risks and the benefits. JAMA 296:1885-1899 (2006).

42. Munn MB, Short TM. Spatial heterogeneity of mercury bioaccumulation by walleye in Franklin D. Roosevelt Lake and the Upper Columbia River, Washington. Trans Am Fish Soc 126:477-487 (1997).

43. Neumann RM, Ward SM. Bioaccumulation and biomagnification of mercury in two warmwater fish communities. J Freshwater Ecol 14:487-494 (1999).

44. Oken E, Kleinman KP, Berland WE, Simon SR, Rich-Edwards JW, Gillman MW. Decline in fish consumption among pregnant women after a national mercury advisory. Obstet Gynecol 102:346-351 (2003).

45. Oken E, Radesky JS, Wright RO, Bellinger DC, Amarasiriwardena CJ, Kleinman KP, Hu H, Gillman MW. Maternal fish intake during pregnancy, blood mercury levels, and child cognition at age 3 years in a US cohort. Am J Epidemiol 167:1171-1181 (2008).

46. Oken E, Bellinger DC. Fish consumption, methylmercury and child neurodevelopment. Curr Opin Pediatr 20:178-183 (2008).

47. Selch TM, Hoagstrom CW, Weimer EJ, Duehr JP, Chipps SR. Influence of fluctuating water levels on mercury concentrations in adult walleye. Bull Environ Contam Toxicol 79:36-40 (2007).

48. Sigler JM, Lee X, Munger W. Emission and long-range transport of gaseous mercury from a large-scale Canadian boreal forest fire. Environ Sci Technol 37:4343-4347 (2003).

49. Stern AH. A review of the studies of the cardiovascular health effects of methylmercury with consideration of their suitability for risk assessment. Environ Res 98:133-142 (2005).

50. Suedel BC, Boraczek JA, Peddicord RK, Clifford PA, Dillon TM. Trophic transfer and biomagnification potential of contaminants in aquatic ecosystems. Rev Environ Contam Toxicol 136:21-89 (1994).

51. Uauy R, Hoffman DR, Mena P, Llanos A, Birch EE. Term infant studies of DHA and ARA supplementation on neurodevelopment: results of randomized controlled trials. J Pediatr 143:S17-S25 (2003).

52. USEPA (United States Environmental Protection Agency). Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories II Risk Assessment and Fish Consumption Limits. EPA 823-B-00-008. Washington, DC:Office of Sceince and Technology, Office of Water, USEPA,2000.

53. Verbeke W, Vanhonacker F, Frewer LJ, Sioen I, De Henauw S, Van Camp J. Communicating Risks and Benefits from Fish Consumption: Impact on Belgian Consumers' Perception and Intention to Eat Fish. Risk Anal (2008).

54. Verdon R, Brouard D, Demers C, Lalumiere R, Laperle M, Schetagen R. Mercury evolution (1978-1988) in fishes of the La Grande Hydroelectric complex, Quebec, Canada. Water, Air, and Soil Pollution 56:405-417 (1991).

55. Virtanen JK, Voutilainen S, Rissanen TH, Mursu J, Tuomainen TP, Korhonen MJ, Valkonen VP, Seppanen K, Laukkanen JA, Salonen JT. Mercury, fish oils, and risk of acute coronary events and cardiovascular disease, coronary heart disease, and all-cause mortality in men in eastern Finland. Arterioscler Thromb Vasc Biol 25:228-233 (2005).

56. WHO (World Health Organization). Methylmercury. Geneva: World Health Organization, (1990).

57. Zhang J, Sasaki S, Amano K, Kesteloot H. Fish consumption and mortality from all causes, ischemic heart disease, and stroke: an ecological study. Prev Med 28:520-529 (1999).

Appendix

Existing Fish Consumption Advisories

Alberta Guide to Sportfishing Regulations

http://www.albertaoutdoorsmen.ca/fishingregs/index.html

Mercury Contamination in Fish

Mercury
Health Canada has set fish consumption guidelines based on the concentration of mercury in fish tissue, and on the human body's ability to eliminate mercury at a slow rate. In Alberta, most mercury accumulations in fish appear to come from natural sources in soils and sediments.

Mercury can be passed through the food chain and become concentrated in fish-eating species such as Northern Pike and Walleye. Where mercury is present, the larger fish generally have higher concentrations in the liver, kidney and muscle.

As new data becomes available, the information provided here will be updated. Detailed information about mercury levels in fish from Alberta lakes and rivers may be obtained from your nearest Fish and Wildlife regional office.

Fish Consumption Advisory (Mercury)
The following consumption guidelines are recommended for the fish species taken from the water bodies indicated (●) in the table below:

●**WOMEN OF CHILD-BEARING AGE AND CHILDREN UNDER THE AGE OF 15 SHOULD NOT EAT THESE FISH.**
●**OTHERS SHOULD NOT EAT MORE THAN ONE MEAL OF THESE FISH PER WEEK.**

Water Bodies Containing Fish Species That May Have Mercury Contamination

Water body	Fish Species (WE - Walleye, SG - Sauger, NP - Northern Pike, GE - Goldeye, BB - Burbot, EB - Eastern Brook Trout					
	WE	SG	NP	GE	BB	EB
Athabasca River	•					
Bow River (below Bassano Dam)	•		•			
Chrystina (Windy) Lake (67-8-W-5)						•
Edith Lake (13-67-10-W5)						•
Edwards Lake (75-9-W4)			•			
Helena Lake (66-11-W4)	•		•			
Hilda Lake (63-3-W4)	•		•			
Ironwood Lake (65-11-W4)	•		•			
Lac La Nonne (57-3-W5)	•					
Moose Lake (61-7-W4)	•		•			
Muskwa Lake (82-4-W5)	•		•			
North Saskatchewan River (including Keephills Pond)	•	•	•	•		
Oldman River	•	•		•		
Red Deer River (below Dickson Dam)	•		•			
South Saskatchewan River	•	•	•	•	•	
Willow Creek (29-9-25-W4)			•			