Health Canada Santé Canada

Bureau of Chemical Safety
Food Directorate
Health Products and Food Branch

Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption

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Canada

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1.0 BACKGROUND

1.1 Purpose of This Document

This paper has two principal purposes:

- To describe the reassessment of mercury and retail fish undertaken by the Bureau of Chemical Safety (BCS), Food Directorate (FD), Health Product and Food Branch (HPFB), Health Canada (HC).
- To serve as documentation, describing both risks and benefits, to support the development of appropriate amendments to the risk management strategies and policies.

It is important to note that this document pertains to retail fish only. "Sport fish" usually fall under the jurisdiction of provincial or territorial governments, and occasionally under the jurisdiction of the federal Department of Fisheries and Oceans (for inland waters that have been created or altered under permission of a Fisheries Act Authorization) or Parks Canada (for waters within federal park boundaries).

Risk assessment refers to a process by which the degree and nature of a risk can be characterised. Through risk *assessment*, it can be determined whether there is a need for risk *management*. The words "risk management" refer to the prevention and control options that can be employed to reduce risk.

The need for a management strategy to reduce the risk of unacceptable exposures to mercury from fish consumption was first identified by the Health Protection Branch (now the Health Products and Food Branch) of Health Canada in the late 1960s, when it established a standard[1] for mercury in fish. For those who regularly consume fish, fish constitutes the main source of dietary exposure to mercury, which can cause adverse health effects in humans at sufficiently high exposures. More recently, the risk management strategy was further developed by recognising the positive role that fish plays in overall nutrition and the risks to health that can arise from decreasing fish consumption.

The risk management approach at the time of preparing this reassessment paper consisted of two elements:

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[1] The Bureau of Chemical Safety uses the word "standard" to refer to a maximum level that does not appear as a unique regulation in the *Food and Drug Regulations*. Maximum levels that appear in the *Regulations* are called "tolerances." Standards are enforceable by the CFIA under the provisions in Part I, Section 4 of the *Food and Drugs Act* which state, in part, that: "no person shall sell an article of food that a) has in or on it any poisonous or harmful substance and b) is unfit for human consumption".

1) Application of a standard of 0.5 parts per million (ppm) total mercury to all commercially-sold fish except three piscivorous[2] fish, namely, shark, swordfish, and fresh/frozen tuna.

(2) A consumer advisory, last re-issued in 2002, for the three fish that are exempted from the standard. The advisory recommends that the general adult population limit consumption of these fish to one meal per week and pregnant women, women of child-bearing age and young children limit consumption to no more than one meal per month.

The standard of 0.5 ppm total mercury is enforceable by the Canadian Food Inspection Agency. The advisory, issued by Health Canada, was available on the websites of both Health Canada and the Canadian Food Inspection Agency.

The current reassessment was undertaken in order to consider any data that had been generated since the last assessment. The most up-to-date data available on the levels of mercury in various types of fish available for sale in Canada were considered. A review of the available information on retail fish consumption by Canadians was also undertaken. An initial review of this information suggested that the risk management approach as described above may not have been adequately protective and therefore required more detailed reassessment and revision.

Similar reviews of the risk management of mercury in fish have been conducted in other jurisdictions. For example, health authorities in the United States, Australia and New Zealand, the United Kingdom, and Ireland each released updated consumer advisories on the consumption of these fish in 2004. These updates appeared not long after a review of the health hazards of methylmercury by the Joint World Health Organization/Food and Agriculture Organization Expert Committee on Food Additives (JECFA)[3].

1.2 Sources of Human Exposure to Mercury

Mercury is a naturally-occurring element that is released from soil and rocks through weathering, from volcanoes and forest fires, and is found in lakes and oceans. Certain human activities, such as combustion of fossil fuel and deforestation leading to soil erosion and lixiviation[4], can also release mercury to the environment (Roulet *et al*., 1999; Health Canada, 2004a). Concentrations

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[2] Piscivorous fish are those that preferably consume, through predation and possibly also by scavenging, other fish for food.

[3] JECFA is a committee of scientific experts convened through a joint program of the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO).

[4] Lixiviation is defined as the extraction of a soluble constituent from a solid mixture (Merriam-Webster's Collegiate Dictionary, 10th Ed., 1999). In this example, lixiviation is the process that allows mercury to be mobilised in runoff from soils.

of mercury in ambient air and water are extremely low and so do not constitute a significant source of mercury exposure in humans (Clarkson *et al.*, 2003; Goyer and Clarkson, 2001). Rather, humans are generally exposed to mercury through the diet.

Traces of mercury are present in all foods. Concentrations are quite low in fruits and vegetables because mercury uptake by plants from soil is low (European Commission, 2003). In contrast, levels are highest in certain types of fish although trace levels can be found in nearly all types of fish, which absorb mercury from the water and from the organisms that they consume. The Canadian Total Diet Studies, carried out by the Food Research Division (FRD), Bureau of Chemical Safety (BCS), in addition to other total diet studies conducted worldwide, have demonstrated that fish are the primary source of dietary mercury intake for the average population (Dabeka *et al.*, 2003).

Other possible sources of exposure to very low levels of mercury include mercury amalgam dental fillings; certain vaccines containing thimerosal, a preservative containing ethylmercury (Clarkson *et al.*, 2003); mercury-containing products (mercury thermometers or fluorescent lighting) that have been accidentally broken; and cigarette smoke. Exposure to mercury can also occur in occupational settings where mercury or mercury-containing compounds are used, for example, manufacturers of electric equipment, medical devices or automotive parts that contain mercury; chemical processing plants that use mercury; metal processing; municipal, medical, and hazardous waste incineration plants; medical facilities where equipment may contain elemental mercury; etc. (Health Canada, 2004).

1.3 The Chemical Forms of Mercury in Fish

Mercury exists in different chemical forms. Metallic mercury or elemental mercury is the silvery, shiny liquid that was once commonly used in, for example, thermometers. Other forms of mercury can be classified as either "inorganic" or "organic." Inorganic mercury includes inorganic mercury salts such as mercuric chloride (chemical symbol $HgCl_2$). Mercury is classified as organic when it is bound to a chemical species that is largely comprised of carbon. For example, ethylmercury (chemical symbol $CH_3CH_2Hg^+$) is the active ingredient in a preservative used in vaccines. Methylmercury (chemical symbol CH_3Hg^+) is another organic form of mercury that can be found in the aquatic environment, although normally at much lower levels than inorganic mercury (Environment Canada, 2005).

Mercury is not locked permanently in each of its different forms. Rather, various processes result in environmental cycling of mercury among its different chemical forms. For example, microbial activity is one process that can transform inorganic mercury to methylmercury.

With respect to the types of mercury found in fish, both inorganic and organic mercury may be present. However, methylmercury is the predominant form of mercury in fish. Its chemical properties allow it to rapidly diffuse and tightly bind to proteins in aquatic biota, including the proteins in the muscle tissue of fish. This leads to bioaccumulation in the fish, with the mercury level increasing with age of the fish. In turn, biomagnification along the food chain leads to higher mercury levels in piscivorous fish that are higher in the food chain than in fish and other organisms that are low in the food chain. Inorganic mercury can also bioaccumulate but to a far lesser extent than methylmercury.

1.4 The Ratio of Methylmercury to Total Mercury in Retail Fish

In the majority of cases, analyses of fish (and other food) samples involve the measurement of the sum of all mercury (or "total mercury") in the sample, regardless of the chemical form in which it is present. The analysis of individual mercury species, such as methylmercury, is more expensive than the analysis of total mercury.

From a human health perspective, it is the amount of methylmercury, rather than total mercury, that is of most interest, since methylmercury is much more readily absorbed into the human bloodstream. As a result, in the absence of detailed information on mercury speciation, it is simply assumed, for the purposes of health risk assessments, that 100% of total mercury is in the methylated form as methylmercury.

Several studies have measured the actual portion of total mercury that is present in fish as methylmercury. Levels can be variable, even among fish of the same species. For example, in four samples of sablefish, the percentage of total mercury that was in the organic form ranged from 81% to 95% (CFIA, 2003b). In samples of various species of tuna, the portion of total mercury present as methylmercury ranged from 70 to 77% (Yamashita *et al.*, 2005) and 61 to 94% (Forsyth *et al.*, 2004). In ten samples of swordfish, the percentage varied from 43 to 76% and in three samples of marlin, from 51 to 63% (Forsyth *et al.*, 2004). Yamashita *et al.* (2005) reported similar results, with an average percentage of 72% in seven samples of swordfish and an average percentage of 43% in seven samples of blue marlin. A wide range of percentages (30 to 79%) were also found in 37 samples of canned tuna (Forsyth *et al.*, 2004).

In Forsyth *et al.* (2004), the authors concluded that, based on the data, a fixed conversion factor to estimate methylmercury levels from total mercury concentrations may not provide accurate estimates of actual methylmercury levels for health risk assessment purposes. Based on findings such as these, and unless otherwise explicitly corroborated by recent data, human health risk assessors at Health Canada continue to make the conservative assumption, for the purposes of assessments, that 100% of total mercury is present as methylmercury.

2.0 HAZARD CHARACTERISATION:

HEALTH HAZARDS OF METHYLMERCURY

When ingested, organic mercury such as methylmercury, unlike elemental or inorganic forms, is almost completely absorbed from the gastrointestinal tract and distributed to all tissues. Methylmercury also readily crosses both the blood–brain barrier and the placenta. Some of the distributed methylmercury can be converted to inorganic mercury, mainly by microflora in the intestines (Clarkson, 2002).

A wide range of adverse health effects has been observed in humans following methylmercury exposure, the severity largely depending upon the magnitude of the dose and the duration of exposure. The central and peripheral nervous systems are generally considered to be the target organs of organic mercury-induced toxicity in humans.

For short- to long-term exposures to very high levels of methylmercury, the earliest neurological effects are non-specific symptoms such as paresthesia[5], malaise and blurred vision. Subsequently, other signs such as concentric constriction of the visual field, deafness, dysarthria[6] and ataxia[7] appear. At very high exposures, methylmercury poisoning can lead to coma and death. For example, in a widely cited environmental contamination incident which occurred in the Minamata Bay area of Japan beginning in the 1950s, more than 900 people died after eating highly contaminated seafood (up to 40 ppm methylmercury) (National Institute for Minimata Disease). An additional 20,000 individuals were thought to have suffered various other forms of neurological damage in this episode.

Chronic (long-term) exposure among adults to methylmercury at low doses may not result in readily observable symptoms. There have been limited experimental studies suggesting that the nutritional benefits of selenium and omega-3 fatty acids, both commonly found in fish and/or marine mammals, might counteract the adverse effects of methylmercury to some degree (Health Canada, 2004). It should be noted, however, that animal studies on selenium and mercury have employed relatively high doses of mercury and selenium. The significance of these results to human dietary regimes where mercury and selenium exposures are much lower is not clear. With respect to dietary effects on methylmercury toxicity, many studies have investigated possible effects, either beneficial or antagonistic, of certain foods and dietary habits on the toxicity of
mercury (Chapman & Chan, 2000). The authors noted that there is little evidence of nutrient

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[5] Paresthesia is "a sensation of pricking, tingling, or creeping on the skin that has no objective cause." (Merriam-Webster's Collegiate Dictionary, 10th Ed., 1999)

[6] Dysarthria is defined as "difficulty in articulating words due to disease of the central nervous system." (Ibid)

[7] Ataxia is "an inability to coordinate voluntary muscular movements that is symptomatic of some nervous disorders." (Ibid)

effects at the population level, although there are a number of studies demonstrating that nutrients interact with the metabolism of mercury at the physiologic level.

Chronic exposure to mercury compounds may have negative effects on the immune system (Moszczysnki, 1997) and there is emerging evidence of potential cardiovascular effects (Stern, 2005). For example, the results of a recent epidemiological study of men in eastern Finland suggested that high mercury content in hair may be a risk factor for acute coronary events and cardiovascular disease, coronary heart disease, and all-cause mortality (Virtanen *et al*., 2005). While the latter study suggests that effects related to cardiovascular disease are seen at similar hair mercury concentrations as those associated with effects related to neurodevelopment, these results should be regarded as preliminary.

The body of evidence available to date still suggests that the developing fetus is the most sensitive sub-population. Fetal exposure to methylmercury may affect the developing nervous system at substantially lower doses than in adults. Epidemiological studies, including recent studies in fish-eating populations in the Seychelle Islands in the Indian Ocean and the Faroe Islands in the North Atlantic Ocean, have employed very sensitive neurobehavioural tests to observe subtle neurodevelopmental effects in children. These studies have shown that nervous system domains involving fine motor function, attention, verbal learning and memory can be affected.

The World Health Organization (WHO, 1972) has established a provisional tolerable daily intake[8] (pTDI) of total mercury in adults (based on a 60 kg body weight) of 0.71 µg per kg body weight per day, of which no more than two-thirds or 0.47 µg/kg bw/day should be methylmercury (µg = microgram = 10^{-6} g). The values for total mercury and for methylmercury were thought to reflect the average ratio of total mercury to methylmercury in food. BCS concurs with this assessment and has employed the 0.47 µg/kg bw/day value for the general population for many years.

In 2003, based on more recent findings on the effects of methylmercury on fetal/infant neurodevelopment, the Joint WHO/FAO Expert Committee on Food Additives (JECFA) recommended a provisional tolerable *weekly* intake (pTWI) for methylmercury of 1.6 µg/kg bw/week (equivalent to 0.23 µg methylmercury/kg bw/day) in order to sufficiently protect the developing fetus (WHO, 2003). This pTWI value was based on the observed association between maternal methylmercury exposure (estimated intake of 1.5 µg/kg bw/day) and developmental effects in children. While the neuropsychological effects measured in the children were described by the committee as not appreciably adverse, the ultimate severity or long term consequences involving nervous system domains associated with cognition and learning are unknown.

[8] The Tolerable Daily Intake (TDI) is the maximum amount of a chemical that can be ingested on a daily basis over a lifetime without increased risk of adverse health effects.

The JECFA pTWI is consistent with the pTDI for methylmercury of 0.20 µg/kg bw/day, established earlier (in 1997) by BCS [http://www.hc-sc.gc.ca/ahc-asc/branch-dirgen/hpfb-dgpsa/fd-da/bcs-bsc/index_e.html] in 1997, for women of child-bearing age and young children, in recognition of the increased susceptibility of the developing fetus and young children to the effects of methylmercury. The BCS [http://www.hc-sc.gc.ca/ahc-asc/branch-dirgen/hpfb-dgpsa/fd-da/bcs-bsc/index_e.html] pTDI was derived based on a 10 ppm maternal hair methylmercury level as the approximate threshold (Grandjean et al., 1997) for neuropsychological dysfunctions. This value was first converted to a corresponding blood methylmercury level and then to a dietary methylmercury intake level using an equation employed by the U.S. EPA (1995). A 5-fold uncertainty factor was applied to this intake level to obtain a pTDI of methylmercury for women of child-bearing age and young children of 0.20 µg/kg bw/day (Feeley and Lo, 1998).

BCS continues to periodically assess the pTDI, taking into consideration any new research findings on the toxicity of methylmercury.

The age at which neurodevelopment would not be as sensitive to the effects of methylmercury and at which sensitivity would be considered equivalent to that of the "general population" is not clearly established. By default, BCS tends to apply the lower pTDI value to young children up to the age of 12 years.

3.0 HEALTH BENEFITS OF FISH CONSUMPTION

Fish is considered an excellent source of high quality protein and is one of the best food sources of the long-chain omega-3 fatty acids, DHA and EPA[9]. The omega-3 fatty acids are required in the diet and are considered important to heart health, and brain and eye development. Fish is the most significant source of naturally-occurring Vitamin D which plays an important role in the body's use of calcium, a mineral required for sound teeth and bones. Fish and shellfish also contribute valuable minerals to the diet such as selenium, iodine, magnesium, iron and copper which the body requires for diverse functions such as growth, repair and proper functioning. The Bureau of Nutritional Sciences (BNS), Food Directorate (FD), Health Products and Food Branch (HPFB), Health Canada (HC) estimates that a 100 g serving of salmon provides slightly more than the Adequate Intake (AI)[10] of Vitamin D for those between 2 and 50 years. A 100 g

[9] DHA is the abbreviation for docosahexaenoic acid and EPA is the abbreviation for eicosapentaenoic acid. DHA is also referred to as (22:6, n-3) and EPA as (20:5, n-3). The first numbers (22 and 20 respectively) refer to the number of carbons that form the carbon-chain. The next numbers (6 and 5 respectively) refer to the number of what are called *cis* double bonds that are in the carbon chain. The "n-3" indicates that, starting from the end of the carbon-chain furthest from the acid portion of the molecule, the first double bond appears at the third carbon.

[10] The **Adequate Intake** (AI) is the recommended average daily nutrient intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people who are assumed to be maintaining an adequate nutritional state.

serving of canned tuna (just less than a drained 170-g can of tuna) furnishes 40% of the AI of Vitamin D, slightly exceeds the Recommended Dietary Allowance[11] for selenium, and significantly contributes to total intake of long-chain omega-fatty acids. Some studies have shown that one or more servings per week of fish can significantly decrease the risk of sudden cardiac death. There is some evidence that regular maternal fish consumption might have beneficial effects on fetal development.

The Office of Nutrition Policy and Promotion (ONPP), Health Products and Food Branch (HPFB), in consultation with BNS, examined the evidence surrounding fatty fish and health benefits as part of the revision process for Canada's recently revised Food Guide to Healthy Eating. Reports and publications from well established expert groups and organizations, including the WHO/FAO, the American Dietary Guidelines Advisory Committee, the (UK) Scientific Advisory Committee on Nutrition/Committee on Toxicology, and the Harvard Center for Risk Analysis were considered. These recent publications specifically assessed the relationship between fish and cardiovascular health through systematic reviews or published meta-analyses of prospective and intervention studies. For example, among the publications considered was one describing the results of a meta-analysis of cohort studies that examined the association between fish intake and coronary heart disease mortality (He *et al*., 2004). This study was considered to provide strong evidence of an association between the intake of fatty fish and cardiovascular health. BNS also conducted a review of the evidence relating fish consumption and EPA and DHA intakes to cardiovascular health. The evidence of an association between reduced risk of sudden cardiac death and fish consumption with a frequency of at least once a week was consistent.

ONPP's recommendation to consume fish, particularly high in omega-3 fatty acids, is based on scientific evidence and is included in the revised Food Guide to Healthy Eating.

One recent study has demonstrated that certain methods of cooking fish may reduce the health benefits of fish. Researchers in the U.S. studied fish intake and the risk of atrial fibrillation, a common arrhythmia (Mozaffarian *et al*., 2004). They found that among elderly adults, consumption of tuna or other broiled or baked fish, but not "fried fish or fish sandwiches", is associated with lower incidence of atrial fibrillation, even after adjustment for a variety of other factors. In a subsequent study (Mozaffarian *et al*., 2006), the researchers found that consumption of broiled or baked fish, including tuna, was associated with improved cardiac hemodynamics (blood flow patterns), but fried fish intake was associated with structural abnormalities indicative of systolic dysfunction (where the heart contracts less forcefully and cannot pump out as much of the blood that is returned to it) and potential coronary atherosclerosis (build-up of plaque in the arteries).

[11] The **Recommended Dietary Allowance** (RDA) is the average daily dietary intake level that is sufficient to meeting the nutrient requirement of nearly all (97 to 98 percent) healthy individuals in a particular life-stage and gender group.

It has been postulated that omega-3 fatty acids and micronutrients such as iodine, iron, and choline in fish may modify the toxic action of methylmercury in fish-eating populations (Clarkson and Strain, 2003). A more recent study found that higher fish consumption during pregnancy was associated with better visual recognition memory, which was used as a measure of infant cognition. The benefit appeared to be greatest among infants whose mothers had consumed more fish relative to others in the study group but also had lower hair mercury levels at delivery. The authors suggested that these observations were due to the type of fish that they were consuming. In the same study, higher maternal hair mercury levels relative to other mothers in the study group were associated with lower cognition in infants (Oken *et al.*, 2005). Observations such as these might help to explain why ongoing epidemiological studies of heavy fish consumers in the Seychelle Islands do not clearly reveal adverse effects on neurodevelopment.

In the assessment of risk of methylmercury exposure through fish consumption, BCS did not consider, in a *quantitative* manner, the nutritional benefits of fish consumption against the risks of methylmercury exposure.

A recent publication considered three fish consumption scenarios as theoretical responses to fish consumption advisories in the U.S. (Cohen, 2006). The author quantified the relative impacts of mercury exposure and omega-3 fatty acids on cognitive development as measured by IQ. The author also considered the net impact of omega-3 fatty acids and mercury on coronary heart disease mortality and the net impact of fish consumption on stroke incidence and mortality. Their analysis of the aggregated health outcomes suggest that overall population well-being would improve if all women of childbearing age shifted to low mercury fish without altering their rate of fish consumption (and with no change in fish consumption among others segments of the population). However, for a consumption scenario in which all segments of the adult population reduced fish consumption by 17%, their analysis suggested that the overall net effect would be negative. This was due to the negative cardiovascular impact such as coronary heart disease among adults, which outweighed the small benefit to infant cognition that remained after the 17% reduction in fish consumption.

It is considered essential that any communications to the public include information on the health benefits of fish consumption alongside information on the risks of methylmercury exposure so that citizens can consider both the benefits and risks in reaching their own decisions about appropriate fish consumption. Studies on the nutritional benefits of fish are supportive of efforts

to influence consumers' behaviour by modifying the types of fish regularly chosen rather than by decreasing overall fish consumption.

4.0 EXPOSURE ASSESSMENT

The exposure assessment evaluates the potential exposure to methylmercury from the consumption of retail fish. Potential exposure is a function of (1) the amount of fish that is consumed on a regular basis, and (2) the amount of methylmercury that is present in fish. Information relevant to these two components of the exposure assessment is provided in the following sections.

4.1 Relative Popularity of Various Types of Fish in Canada

The relative popularity of various types of fish in Canada can be evaluated using market share information. Since this information was not readily available to Health Canada, the volume of fish imports to Canada and the volume of domestic fish landings sold at retail in Canada (assumed to be the difference between what is landed and what is exported) were used as indicators of the relative amounts of different fish available in Canada on a yearly basis and, in turn, the relative popularity of different types of fish. This data was obtained from Fisheries and Oceans Canada (DFO, 2005 and 2006).

It has been assumed, for the fish listed in Table 4.1 (a), that all imports to Canada and domestic landings remaining in Canada enter the market for human consumption. A portion of imported fish (approximately 30% by volume but only 4% by value) is used to make fishmeal or fish oil for eventual use in the manufacture of livestock and fish feed (AAFC, 2003b). However, most of the fish used for this purpose are small, bony fish such as anchovies, sardines, Atlantic mackerel, herring, and whiting.

Data for various years for selected types of fish are listed in Table 4.1 (a) below. Barracuda, escolar, halibut, orange roughy, marlin, sablefish, sea bass, shark, swordfish, and certain types of tuna are included in the table because each were found, in at least one of the surveys listed in Appendix II, to contain total mercury at average levels approximating or greater than 0.5 ppm (these average values are highlighted in the table of Appendix II). Shrimp and cod are also included in the following table to demonstrate the high end of the range of quantities for all fish in the database.

There are no domestic commercial fisheries for barracuda, escolar, marlin, grouper or orange roughy (DFO, 2006). Although these fish are imported to Canada, as evidenced by their availability to the CFIA during compliance monitoring activities, there was no relevant data in DFO's import database. The absence of import data in DFO's database suggests that imports of these species are negligible (DFO, 2006).
The data in Table 4.1(a) suggest that, among those fish listed, shrimp, cod, skipjack/bonito tuna (which are available canned), are the most popular. Sablefish, and presumably barracuda, escolar, marlin, and orange roughy, are among the least widely-consumed fish. The data suggest that the availability of shark, swordfish, and bluefin tuna (sold as fresh/frozen steaks) is much lower than that of canned tuna. Although data below seem to suggest that dogfish shark is consumed in North America, no information on dogfish consumption in Canada was located.

One account states that there is no dogfish market in Canada (Hines, 2005). Rather, it is expected that most domestic dogfish is exported to Europe where it is served deep-fried (e.g. "fish and chips" in the United Kingdom), smoked (in Germany), etc. (Godknecht, 1999).

Table 4.1(a): Fisheries data for selected fish types in metric tonnes (1000 kg). Unless specifically noted, the source of this data is Fisheries and Oceans Canada (including DFO's Statistical Services: DFO, 2005). The remainder was provided directly to Health Canada by DFO (2006).

Fish Species	Imports (tonnes)			Domestic Landings (tonnes)			Exports (tonnes)			Landings + Imports - Exports		
	1990	**1999**	**2004**	**1990**	**1999**	**2004**	**1990**	**1999**	**2004**	**1990**	**1999**	**2004**
Barracuda (a)	–	3.7 (b)	1.7 (b)	–	–	–	–	–	–	–	–	–
Cod	8,286	30,134	26,321	401,257	56,314	26,018	141,780	26,653	17,388	267,763	59,795	34,951
Escolar (a)	–	–	–	–	–	–	–	–	–	–	–	–
Grouper (a)	–	–	–	–	–	–	–	–	–	–	–	–
Halibut, Atlantic	95	149	769	–	–	–	1 307	673	1 260	–	–	–
Halibut, Pacific	–	3,915	1 498	–	–	–	2 109	7 718	8 526	–	–	–
Halibut	3,999	4,765	7 927	7 448	8 868	8 968	–	–	–	–	–	–
Marlin (a)	–	–	–	–	–	–	–	–	–	–	–	–
Orange Roughy (a)	–	–	–	–	–	–	–	–	–	–	–	–
Sablefish / Black cod	–	15	0	5,125	4,888	3,024	–	2,758	1,494	–	2,145	1,530
Sea Bass	31	66	261	–	–	–	18	429	1	–	–	–
Shark (c)	–	205	490	124	1,103	326	–	–	–	–	–	–
Shark, Dogfish	492	233	11	5,425	5,833	7,820	3,101	1,895	4,140	2,816	4,171	3,691
Shrimp, Prawn	23,513	60,493	46,940	39,964	120,034	177,662	12,087	40,009	76,933 (e)	51,390	140,518	147,669
Swordfish (d)	–	–	–	912	1,119	1,203	572	827	937	340	292	266
Tuna, total	18,066	36,138	40,374	745	2,443	6,474	1,069	2,261	6,657	17,742	36,320	40,191
albacore	*516*	*783*	*1,879*	3	39	27	27	1,464	5,674	492	–	–
bonito	*10*	*8*	*4*	–	–	–	–	–	–	–	–	–
skipjack/bonito	*16,809*	*32,730*	*35,211*	–	–	–	627	146	107	16,182	32,584	35,104
bigeye	–	*0*	*529*	11	263	143	–	–	126	–	–	546
bluefin	–	*0*	*46*	437	576	539	–	367	416	437	209	169
yellowfin	*310*	*538*	*1,304*	15	22	303	11	67	267	314	493	1340
species not specified	*421*	*2,079*	*1,398*	4	–	–	404	217	67	21	1862	1331
Walleye /Yellow Pickerel	–	–	–	7,201	8,782	7,352 (e)	3,405	3,290	2,640	3,796	5,492	4,712

Notes: (a) While these fish are available for sale in Canada based on the fact that they have been sampled by the CFIA, the evidence suggests that quantities are limited. First, there are no Canadian commercial fisheries for **barracuda**, **escolar**, **marlin**, **grouper**, or **orange roughy**. Second, the absence of import data in DFO's database suggests that imports for these species are negligible (DFO, 2006).

(b) Barracuda data is based on import notifications that have been made to the CFIA. The actual import values may be higher.
(c) In 1989, 148 metric tonnes of shark were reported to have been imported (DFO, 1989).
(d) DFO data show no imports for swordfish in the years of interest, suggesting that imports were negligible (DFO, 2006). In a direct communication, DFO indicated that in the late 1980s, imports of swordfish were approximately 250 tonnes (DFO, 1989)
(e) 2003 data.

Piscivorous types of fish such as swordfish and shark have been considered in the past by Health Canada to be delicacies not frequently consumed by the Canadian population. Their higher cost and lower availability have contributed to their lower frequency of consumption relative to other types of fish.

A similar pattern in fish popularity is observed in the results of food surveys, of approximately 18 400 people from across Canada, that were conducted in the 1990's as part of the Health Canada / Canadian Heart Health Initiative (Health Canada and CHHI, 2004). Individuals were asked to recall what they had consumed in a 24-hour period. Information on the *frequency* of consumption of specified foods, including fish, was not obtained. However, the data allows calculation of the percentage of respondents consuming each particular type of fish, as well as typical adult serving sizes of various fish types (assuming that any fish reported to have been consumed during the 24-hour period was consumed at one meal, rather than during several meals over the day).

Table 4.1(b) includes some of those fish types that contained total mercury at levels, on average, greater than 0.5 ppm in Appendix II. Information on barracuda, escolar, orange roughy, and marlin were not obtained but it is expected that the results would be at least similar to, if not lower than, those for sablefish and sea bass. Some fish types that contained lower than 0.5 ppm on average are also included for comparison.

Of the fish listed in the Table 4.1(b), the most widely consumed on the survey day was canned light tuna (various species). Canned white tuna (albacore), which is more expensive than light tuna, was consumed by a smaller number of respondents. It also ranked, in terms of percentage of survey respondents consuming it, behind canned salmon, farmed salmon and wild salmon, and crab.

The percent values for the remaining fish in Table 4.1(b) suggest that tuna (as steaks) is more widely consumed than shark and that smaller percentages (0.1% or less) of the respondents consumed sablefish, sea bass, and swordfish.

Table 4.1(b): Percentage (%) of survey respondents reporting consumption of the specified fish and the amount of fish consumed (weighted average) by "Eaters Only"[12] (EO) during the 24-hour survey period.

Fish	%		EO weighted average (g)	
	Men	*Women*	*Men*	*Women*
Clams	0.5	0.4	77	122
Crab	1.3	1.1	65	41
Halibut	0.7	0.5	137	82
Sablefish / Black cod	≤0.1	≤0.1	94	49
Salmon, canned	2.4	2.7	60	61
Salmon, farmed	0.1	0.1	164	73
Salmon, other (wild)	1.2	1.0	160	128
Sea bass	nc	≤0.1	nc	113
Shark	0.1	nc	40	nc
Swordfish	≤0.1	nc	88	nc
Tuna	0.2	0.1	16	22
Tuna, light canned	2.6	3	89	49
Tuna, white canned	0.3	0.6	85	88

Source: Data generated in 2004 by the Bureau of Biostatistics and Computer Applications (BBCA) using information gathered by the Health Canada and Canadian Heart Health Initiative between 1990 and 1997.

Notes: (1) "nc" means that none of the survey respondents reported consuming this particular type of fish during the specified 24-hour period.
(2) There are uncertainties in these estimates. The uncertainties would be higher in the case of EO values for fish that were consumed by only a small percentage of respondents.
(3) The category "tuna" included survey food codes: "bluefin", "skipjack", and "yellowfin (albacore, ahi)."

The popularity of canned tuna is also evident in the data generated as part of a national study that was conducted in 1990 for then Health and Welfare Canada by Market Facts of Canada Limited (1991). The survey examined the consumption of fish and shellfish, regardless of source (restaurant, grocery store, or caught by self). Of all seafood meals reported to have been consumed by respondents over the three-month survey period, 14% were tuna, the majority, 95%,

[12] The term "eaters only" is used to refer to a group of individuals all of whom have, as part of a survey, reported eating a particular food. For example, a mean consumption figure for fish based on the consumption reported by a group of "eaters only" is termed an "eaters only" mean consumption figure. An "all persons" consumption figure is based on data for all survey respondents, including those who did not eat the commodity.

of which was canned. Salmon and shrimp were also popular (17 and 11% respectively of all seafood meals).

Canned tuna may be particularly popular among children. Although recent Canadian data regarding children's consumption of canned tuna was not readily available, for children 14 and under in the United States, the most commonly consumed seafood species is tuna (U.S. EPA, 2002), most of which is likely to be canned.

The other fish varieties that contained, on average, 0.5 ppm or greater total mercury did not appear in the Market Facts list of fish that were consumed in at least 3% of the meals. The number of shark purchases was noted to be too small to allow reporting and the reported swordfish meals were "prepared outside the home" (inferred to mean purchased and consumed in a restaurant) in almost all cases.

The data appearing in both Tables 4.1(a) and (b) are somewhat consistent with observations in the United States, where per-capita consumption data were used as an indicator of fish popularity. The ten most popular fish, based on data from the U.S. National Marine Fisheries Service (National Fisheries Institute, 2005), are shrimp, canned tuna, salmon, pollock, catfish, tilapia, crab, cod, clams, and flatfish.

4.2 Fish Consumption Values for Canadians

The amount of fish consumed over a given period of time is a function of fish meal size and the frequency at which fish meals are eaten; that is, the number of fish meals eaten during that period of time. Such information was gathered from the monthly diaries (covering three months) of 3,815 respondents to the Market Facts survey (1991). It was determined that the average consumption of fish per day of the month among those adults reporting to consume fish ("eaters only") is 22 grams. This "eaters-only" value has been employed by BCS for assessments of most commercial fish and was recently reaffirmed in a review conducted by the Bureau of available information on fish consumption (BCS, 2004. For children, aged 1 to 5 years of age, average consumption of finfish was reported in the Market Facts report to be 10 grams per day of the month and for children 6 to 12 years of age, 14 grams per day of the month. In a review of available information on fish consumption in Canada (BCS, 2004), BCS recommended that these intake figures of 10 and 14 grams per day of the month for fish (excluding shellfish) would be appropriate for children aged 1 to 4 years and 5 to 11 years, respectively.

Certain fish varieties, such as shark, swordfish, and tuna steaks, that are not as widely available and are usually available in less abundant quantities, are considered to be consumed less frequently such that the daily intake over a month would be considerably less than 22 grams.

Similarly, it is possible that the mean consumption of canned tuna may be higher than 22 g/day, considering its wide availability, its cost, and convenience in terms of preparation for consumption (cooking is not required). BCS has received inquiries from adult members of the public who report consuming as much as two cans of light tuna every day, which is equivalent to 240g per day (based on the weight of two drained 170-g cans).

The Market Facts survey (1991) found that the 75th percentile of "eaters" of seafood (finfish and shellfish combined) ingested 33 g/day while the 90th percentile of "eaters only" ingested 49g/day. The Bureau currently employs 40 g as an estimate of daily fish intake by adults who are at the high end of fish intakes (BCS 2004).

4.3 Meal Portion Sizes for Specific Types of Fish

A review of information on fish consumption, including portion sizes, was conducted by BCS in 2004 (BCS, 2004). The data reviewed included per capita disappearance data and dietary survey data for Canada and other countries as well as the published literature. A weight of 150 g was determined to be the best estimate of average portion size for adults. For children 5-11 and 1-4 years of age, the best estimates of portion sizes, based on the available data, were 125 g and 75 g respectively.

Although some of the data that were reviewed supported a smaller portion size of 100 g for adults, the data supporting 150 g was favoured as a reasonable, and somewhat more conservative (e.g. protective), estimate of average meal size for an adult. Similarly, the portion sizes for children are also considered conservative.

BNS has defined the "reasonable daily intake" of "fish, shellfish" to be 100 g. Reasonable daily intake values for various foods appear in Part D, Schedule K of the Canadian *Food and Drug Regulations* and are mainly used as a basis upon which to determine the permissible levels at which certain vitamins and minerals may be added to food (various sections in Division 8, Part B and in Divisions 1 and 2 in Part D of the *Regulations*).

Since the promulgation of regulations requiring a "nutrition facts table" on the label of prepackaged foods, consumers have ready access to nutritional information that is provided on the basis of a "serving of stated size." However, the "serving of stated size" is not standardised. A review of frozen fish products in a grocery store in Ottawa, Ontario demonstrates that the food industry employs various values for the serving size depending on the product. For example, nutrition facts for frozen fillets were often provided on the basis of 142 g (1 fillet) although a 100 g and a 108 g serving size were also observed. Nutrition facts for frozen tuna and salmon burgers were on a 142 g (1 burger) basis and for other frozen fish, such as shrimp, lobster, calamari, octopus, and scallops, the reported serving sizes ranged from 49 g to 113 g, depending on the product.

The recently revised Health Canada Food Guide for Healthy Eating recommends at least 2

servings per week of fish. One serving of fish is defined as 75 g. However, the guide also recommends 2 to 3 food guide servings per day of "meat and alternatives", a category in which fish is included.
Portion sizes for canned tuna, in particular, may differ from the average portion size of finfish in general, due to tuna's availability in discrete containers (either cans or pouches). The size of the discrete package of tuna purchased will influence the portion size consumed. Cans of tuna, including their packing liquid (oil or water) typically weigh 170 g, and 120 g after draining, although other sizes are also available (e.g. 99 g and 198 g undrained). Pouches of tuna do not require draining and tend to contain less tuna than the cans (e.g. 85 g), although pouched tuna fillets in 142 g portions are available in the United States (their availability in Canada was unknown at the time of the preparation of this document) (BCS, 2004).

4.4 Levels of Mercury in Retail Fish

Certain types of fish available at retail tend to contain lower levels of total mercury than others. The table shown in Appendix I lists those fish species that were recently analysed by the Canadian Food Inspection Agency (CFIA) and found to contain total mercury at average levels either approximating or less than 0.2 ppm (this value was arbitrarily chosen but is less than half the current standard of 0.5 ppm). A wide variety of fish appear on this list including shellfish (e.g. oyster, clams, scallops, mussels), shrimp, salmon, trout, herring, cod, flounder, lobster, crab, and lake whitefish.

Fish that are higher on their respective food chains tend to contain higher levels of total mercury. The table in Appendix II lists those fish for which mean levels of total mercury were greater than 0.2 ppm. Barracuda, escolar, marlin, orange roughy, sablefish, sea bass, shark, swordfish, and certain types of tuna were found (in at least one of the surveys listed in the table) to contain total mercury (on average) at levels approximating or greater than 0.5 ppm (these mean values are highlighted in the table in Appendix II). Marlin, shark, swordfish, and fresh tuna were each reported at least once to contain total mercury at average levels greater than 1.0 ppm.

It is important to note that the CFIA data do not necessarily represent the mercury content of species that are available at the retail level. Imported fish are sampled on the premises of the importers. Sampling of domestic fish occurs at the processing plants. Some of these fish may not reach Canadian retail due to compliance activities or, in the case of the domestic catch, due to the fact that a large portion is exported to other markets. In evaluating potential exposure of Canadians to mercury in different types of fish, it has been assumed that the CFIA data is representative of retail-level fish. While this may not be the case, a certain amount of non-compliant fish will be found in the Canadian retail marketplace since it is not possible to achieve 100% compliance.

It should also be noted that industrial processing or domestic cooking techniques for fish do not appreciably reduce the mercury concentrations in fish (Goyer, 2001). Therefore, in evaluations of potential exposure to mercury from fish, the total mercury concentrations in raw fish serve as a reasonable approximation of concentrations in fish that has been prepared (e.g. baked, poached, smoked, cured, etc.) for consumption.

4.5 Exposure Assessment: Estimation of Human Exposure to Methylmercury in Fish

To determine possible exposures to methylmercury from the consumption of various fish, average Probable Daily Intake (PDI) values were calculated for (1) the general adult population; (2) pregnant women/women of reproductive age; (3) children aged 5-11 years of age; and (4) children 1-4 years of age:

$$\text{PDI } (\mu g/kg \text{ bw/day}) = \frac{\text{fish muscle intake } (g/day) \times [\text{methylmercury concentration } (\mu g/g)]}{\text{average body weight } (kg)}$$

Based on findings such as these, human health risk assessors at Health Canada continue to make the conservative assumption, for the purposes of assessments, that 100% of total mercury is present as methylmercury (see Section 1.4). Where CFIA data were used, it was assumed that the levels are representative of those found at the retail level, although this may not necessarily be the case (see Section 4.4). The consumption figures described in Section 4.2 were employed. Average body weights are from Nutrition Canada studies of the Canadian population: 60 kg for adults, 26.4 kg for children aged 5-11 years and 14.4 kg for children aged 1-4 years. More recent mean body weight values are higher; for example, 66.8 kg for females 19-30 years of age, approximately 31.8 kg for males aged 5-11 years, and 15.8 kg for females 1-4 years (Statistics Canada, 2004b). The lower body weight values were used as default values for the calculations.

Table 4.5: PDI values for different age/gender groups, if they were to regularly consume each type of fish to the exclusion of other types of fish. Only those fish that were found in recent surveys to contain, on average, at least 0.2 ppm total mercury (assumed to be 100% methylmercury) are included in the table. Cod, shrimp and light tuna, very popular types of fish which generally contain less than 0.2 ppm total mercury, are included for comparison. (See the additional notes at the end of the table.)

Fish Species	**Mean [MeHg] (µg/g)**	**PDI (µg/kg bw/day)**		
		Gen (60 kg)	**5-11 yrs (26.4 kg)**	**1-4 yrs (14.4 kg)**
Barracuda – from the U.S. Barracuda – not from U.S.	0.77 0.12	*0.28* *0.04*	*0.41* *0.06*	*0.53* *0.08*
Cod	0.06	*0.02*	*0.03*	*0.04*
Cusk	0.35	*0.13*	*0.19*	*0.24*
Escolar	0.53	*0.19*	*0.28*	*0.37*
Grouper	0.45	*0.17*	*0.24*	*0.31*
Halibut	0.31	*0.11*	*0.16*	*0.22*
Marlin	0.69	*0.25*	*0.37*	*0.48*
Orange Roughy / Slimehead	0.47	*0.17*	*0.25*	*0.33*

Sablefish / Black cod	0.20	*0.07*	*0.11*	*0.14*
Sauger	0.46	*0.17*	*0.24*	*0.32*
Sea Bass	0.62	*0.23*	*0.33*	*0.43*
Shark	1.36	*0.50*	*0.72*	*0.94*
Shark (Spiny Dogfish, Northern Shark)	0.64	*0.23*	*0.34*	*0.44*
Shark, Portbeagle	0.87	*0.32*	*0.46*	*0.60*
Shrimp / Prawn	0.05	*0.02*	*0.03*	*0.03*
Swordfish	1.82	*0.67*	*0.97*	*1.26*
Tuna, albacore, canned	0.36	*0.13*	*0.19*	*0.25*
Tuna, albacore, fresh or frozen	0.37	*0.14*	*0.20*	*0.26*
Tuna, skipjack, canned	0.06	*0.02*	*0.03*	*0.04*
Tuna, yellowfin, canned	0.05	*0.02*	*0.03*	*0.03*
Tuna, yellowfin, fresh	0.29	*0.11*	*0.15*	*0.20*
Tuna, canned (species not specified)	0.14	*0.05*	*0.07*	*0.10*
Tuna, Bigeye	0.65	*0.24*	*0.34*	*0.45*
Tuna, Southern Bluefin	0.28	*0.10*	*0.15*	*0.19*
Tuna, fresh or frozen (species not specified)	0.93	*0.34*	*0.49*	*0.65*
Wahoo	0.31	*0.11*	*0.16*	*0.22*
Walleye / Yellow Pickerel	0.37	*0.14*	*0.20*	*0.26*

<u>Notes to Table 4.5:</u>

- * Age groupings: "Gen" refers to adult men and to adult women who are not of reproductive age. "5-11 yrs" and "1-4 yrs" are the two age groupings for young children.
- * The daily fish intakes employed in the calculations were 22 g/day (adults, male and female); 14 g/day (5-11 yrs); and 10 g/day (1-4 yrs).
- * μg/g or micrograms per gram is equivalent to ppm or parts per million.
- * In the case of cusk and "tuna, canned (species not specified)", the methylmercury concentration was available for only one sample (*N*=1)[13].
- * For "barracuda – not from the U.S.", samples from the 1990's (results not shown in above table) were from Oman, New Zealand, and Portugal.
- * For marlin, the concentration used in the exposure calculations was the average of a relatively large data set (*N*=53) and the value is consistent with values for the other comparatively large data sets (see Appendix II).
- * For sablefish, the 0.71 ppm value from the 2002-2003 CFIA survey was not employed in the exposure assessment as it was for samples available <u>prior</u> to the implementation of a fisheries management strategy to eliminate the source of sablefish containing elevated mercury. (CFIA, 2003b)
- * For sea bass, although the value employed in the exposure calculations is not as recent as the 0.31 ppm value, it is based on a larger sample size.

[13] *N* symbolises the number of individual samples analysed. For example, "*N*=1" indicates that one sample was gathered.

* For shark, the concentration value employed in the calculations is recent but it is not based on a large sample size (*N*=12).

5.0 RISK CHARACTERISATION

5.1 Comparison of the PDI to the Provisional Tolerable Daily Intakes of Methylmercury

PDI values for methylmercury must be considered against the Provisional Tolerable Daily Intake (pTDI) for methylmercury (see Section 2.0) as a step in evaluating whether there is increased risk of adverse health effects from methylmercury exposure. A comparison of the two parameters is conveniently achieved by determining the ratio of the PDI to the pTDI, expressed as a percentage (PDI / pTDI × 100%). Values approaching or exceeding 100% identify those exposure scenarios where the toxicological reference value may be exceeded and that require more careful evaluation. Other factors that must be assessed in evaluating the risk and the degree of confidence in the assessment conclusions include the quality of the methylmercury concentration data, the likelihood of possible long-term exposure to the particular source of fish, etc.

Table 5.1: % pTDI values for different age/gender groups, assuming they regularly consume each type of fish to the exclusion of other types of fish. Only those fish that were found in recent surveys to contain, on average, at least 0.2 ppm total mercury (assumed to be 100% methylmercury) are included in the table. Cod, shrimp and light tuna, very popular types of fish which generally contain less than 0.2 ppm total mercury per serving, are included for comparison. (See the additional notes at the end of the table.)

Fish Species	Mean [MeHg] (µg/g)	% PTDI			
		Gen (60 kg)	Women (60 kg)	5-11 yrs (26.4 kg)	1-4 yrs (14.4 kg)
Barracuda – from the U.S. Barracuda – not from U.S.	0.77 0.12	59 25	140 60	205 30	265 40
Cod	0.06	4	10	15	20
Cusk	0.35	27	64	93	122
Escolar	0.53	40	95	140	185
Grouper	0.45	36	85	120	155
Halibut	0.31	23	55	80	110
Marlin	0.69	53	125	185	240
Orange Roughy / Slimehead	0.47	36	85	125	165
Sablefish / Black cod	0.20	15	35	55	70
Sauger	0.46	36	85	120	160
Sea Bass	0.62	49	115	165	215
Shark	1.36	106	250	360	470
Shark (Spiny Dogfish, Northern Shark)	0.64	49	115	170	220

Shark, Porbeagle	0.87	68	160	230	300
Shrimp / Prawn	0.05	4	9	13	17
Swordfish	1.82	143	335	485	630
Tuna, albacore, canned	0.36	28	65	95	125
Tuna, albacore, fresh or frozen	0.37	30	70	100	130
Tuna, skipjack, canned	0.06	4	10	15	20
Tuna, yellowfin, canned	0.05	4	10	15	15
Tuna, yellowfin, fresh	0.29	23	55	75	100
Tuna, canned (species not specified) (*N*=1)	0.14	11	25	35	50
Tuna, Bigeye	0.65	51	120	170	225
Tuna, Southern Bluefin	0.28	21	50	75	95
Tuna, fresh or frozen (species not specified)	0.93	72	170	245	325
Wahoo	0.31	23	55	80	110
Walleye / Yellow Pickerel	0.37	30	70	100	130

Notes to Table 5.1:

* Age groupings: "Gen" refers to adult men and adult women who are not of reproductive age. "Women" refers to females of reproductive age. "5-11 yrs" and "1-4 yrs" are the two age groupings for young children.
* μg/g or micrograms per gram is equivalent to ppm or parts per million.
* In the case of cusk and "tuna, canned (species not specified)", the methylmercury concentration was available for only one sample.
* For "barracuda – not from the U.S.", samples from the 1990's (results not shown in above table) were from Oman, New Zealand, and Portugal.
* For marlin, the concentration used in the exposure calculations was the average of a relatively large data set (*N*=53) and the value is consistent with values for the other comparatively large data sets (see Appendix II).
* For sablefish, the 0.71 ppm value from the 2002-2003 CFIA survey was not employed in the exposure assessment as it was for samples available prior to the implementation of a fisheries management strategy to eliminate the source of sablefish containing elevated mercury. (CFIA, 2003b)
* For sea bass, although the value employed in the exposure calculations is not as recent as the 0.31 ppm value, it is based on a larger sample size.
* For shark, the concentration value employed in the calculations is recent but it is not based on a large sample size (*N*=12).
* For sauger and fresh yellowfin, the weighted concentrations for sampling years 2003-04 and 2004-05 were employed.

The PDI values contained in Table 5.1 can be considered to represent the average exposure to methylmercury if an individual consumed each specified fish over a long-term period to the exclusion of all others. For example, a 14.4 kg (1-4 yr old) child consuming an average of about 10 g each day (70 g per week) of cusk containing 0.35 ppm methylmercury would consume 0.24

micrograms of methylmercury per kilogram body weight per day (0.24 µg/kg bw/day). This value approximates the pTDI for methylmercury (the PDI is 122% of the pTDI). However, cusk is a fish that is not widely available. Stocks are seriously depleted and it is no longer commercially fished in Canada. It is available in limited quantities as a by-catch from other fisheries (DFO, 2005 b). Therefore, the likelihood of this exposure scenario, where a small child consumes cusk on a regular basis, is considered remote. In addition, confidence in the methylmercury concentration value is low because only one sample was analysed.

5.2 Characterisation of the Risk

For members of the general adult population, based on the available data and the results shown in Tables 4.5 and 5.1, **swordfish** is the only fish for which regular weekly consumption would result in a PDI that exceeds the pTDI (%pTDI of 143%).

Regular consumption, by women of child-bearing age, of **barracuda (from the U.S.), escolar, marlin, sea bass, shark, swordfish, bigeye tuna,** and **"fresh" tuna** containing mercury at the levels shown in Tables 4.5(a) and 5.1(a) could result in the methylmercury pTDI being exceeded. These fish contained an average of 0.54 ppm or more total mercury, assumed to be 100% methylmercury. The intake of methylmercury from the regular consumption of grouper, orange roughy, and walleye, although somewhat high (80% of the pTDI), would not cause the pTDI to be exceeded. It is important to bear in mind that many of these fish were sampled early in the chain of distribution rather than at retail.

For young children (12 years of age and younger), regular consumption of fish that contain on average 0.3 ppm or more total mercury (assumed to be 100% methylmercury) could result in the PTDI being exceeded, as demonstrated in Table 5.1. In consideration of the relative popularity of different types of fish in general (as discussed in previous sections), it is not considered likely that a child would regularly consume the fish types listed in Table 5.1 except in the case of **canned albacore tuna**.

Canned tuna represents a unique case. It is widely available and relatively inexpensive. As discussed in Section 4.1, canned light tuna (e.g. yellowfin, skipjack, etc.) is a commonly consumed fish. However, its low mercury concentration leads to the estimation that it would not cause unacceptably high exposure to methylmercury in the diet. Canned albacore ("white") tuna, which is more expensive than canned light tuna, is less popular than canned light tuna. Nonetheless, the possibility exists that those regularly consuming canned tuna may be consistently choosing canned albacore tuna, which has a higher mercury content. This could potentially lead to an unacceptable high methylmercury exposure.

6.0 KNOWLEDGE GAPS/UNCERTAINTIES

Certain pieces of information would allow the risk assessment to be further refined. These include the following:

- Information on the amount of specific types of piscivorous or predatory fish consumed by Canadians and whether any have particular importance to the diets of certain groups

  within the population. Such information would also further inform the development of the risk management strategy and risk communications.

- Total mercury levels in a larger number of recent samples of certain types of fish (e.g. orange roughy, barracuda, etc.) which would provide results that are more representative of that which is available at retail and which would decrease uncertainty in the risk assessment for those types of fish.

- Actual methylmercury concentrations in the fish samples which would reduce uncertainty in the risk assessment. Applying the assumption that all of the mercury in fish is present as methylmercury results in a more conservative assessment.

- Information on mercury levels in human blood in Canada could serve as an index of exposure to mercury, the largest source of which is fish for many people. Such information would be an important consideration in the context of both risk assessment and risk management. Statistics Canada, with the support of Health Canada, is collecting socioeconomic and demographic information and physical measurements from a sample of the Canadian population. Statistics Canada is also considering other variables such as blood mercury levels from a sub-sample of the population (Statistics Canada, 2004).

- Halibut, sea bass, grouper, and walleye were found to contain average mercury at levels somewhat similar to those found in canned albacore tuna. In the case of canned albacore tuna, the available information led to the conclusion that consumption of canned albacore tuna may be higher than other seafoods, which could lead to an unacceptably high exposure to mercury. BCS did not have information that would allow it to assess whether there are groups in the Canadian population that consume halibut, sea bass, grouper, or walleye at relatively high rates.

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NOTE: Unless otherwise noted, all on-line documents were last accessed on February 23, 2007.

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APPENDIX I

Summary data for those samples of fish that were found by the Canadian Food Inspection Agency (unless otherwise noted) to contain, on average, approximately 0.2 ppm or less total mercury. Samples were collected at the importers' or at domestic processing plants during the periods April 1, 2002 to March 31, 2003 and April 1, 2003 to October 7, 2004 (unless otherwise noted). A concentration of zero indicates that mercury was not detected above the analytical detection limit.

Species	No. of samples (*N*)	Total Mercury Concentration (ppm)			
		Mean	**Median**	**Min**	**Max**
Amberjacks	3	0.17	0.14	0.11	0.27
Barracouta	1	0.06	0.06	0.06	0.06
Basa	5	0.02	0.02	0.02	0.02
Bullhead, Brown	2	0.09	0.09	0.07	0.1
Capelin	4	0.02	0.02	0	0.05
Carp	1	0.1	0.1	0.1	0.1
Catfish (Channel or unspecified)	16	0.15	0.14	0.02	0.37
Char, Arctic	5	0.09	0.10	0.05	0.05
Clam (various species)	40	0.03	0.01	0	0.08
Cockle, Greenland	1	0.05	0.05	0.05	0.05
Cod (Atlantic, Pacific or unspecified)	34	0.06	0.06	0	0.28
Crab (Dungeness, Rock, Snow)	19	0.09	0.07	0	0.37
Crawfish	1	0.1	0.1	0.1	0.1
Drum, Freshwater	2	0.22	0.22	0.03	0.4
Eel (American, Conger/sea, Spiny/spotted)	52	0.19	0.10	0	0.76
Eel (species not specified)	107	0.24	0.16	0.01	1.70
Flounder (various species)	22	0.06	0.06	0.03	0.12
Haddock	3	0.05	0.05	0.03	0.07
Hake, White	1	0.08	0.08	0.08	0.08
Herring (Atlantic, Pacific)	35	0.06	0.06	0.02	0.13
Jack (Blue Runner, Crevalle/Common)	13	0.15	0.12	0.03	0.43
Kamaboko	1	0.02	0.02	0.02	0.02
Kingfish / Spanish or King Mackerel	13	0.21	0.12	0.05	0.72
Lingcod	1	0.08	0.08	0.08	0.08
Lobster	59	0.09	0.08	0.03	0.26
Mackerel (Atlantic, unspecified)	12	0.04	0.04	0.02	0.07
Mahi Mahi / Dolphin Fish	121	0.22	0.21	0	0.99
Maria/ Burbot/ Ling	7	0.11	0.10	0.1	0.19
Monkfish	7	0.11	0.10	0.08	0.14
Mullet, Common	22	0.12	0.1	0.1	0.26

Mussel, Blue	74	0.03	0.05	0	0.09
Species	**No. of samples (*N*)**	**Total Mercury Concentration (ppm)**			
		Mean	**Median**	**Min**	**Max**
Octopus	1	0.02	0.02	0.02	0.02
Oyster (Pacific, American, unspecified)	20	0.01	0.01	0	0.05
Perch (White, Yellow)	45	0.15	0.12	0.03	0.36
Periwinkle	6	0.03	0.02	0	0.07
Plaice, Canadian	1	0.06	0.06	0.06	0.06
Pollock, Alaska	3	0.02	0.02	0.02	0.02
Prawn	18	0.04	0.03	0.02	0.07
Pumpkinseed	1	0.12	0.12	0.12	0.12
Quahog/ Hardshell Clam	1	0.05	0.05	0.05	0.05
Rockfish	2	0.07	0.07	0.07	0.07
Salmon, all samples combined	116	0.03	0.03	0	0.12
Salmon, Atlantic	47	0.03	0.02	0	0.12
Salmon, Chinook	29	0.05	0.04	0.02	0.11
Salmon, Chum	18	0.02	0.02	0	0.04
Salmon, Coho	3	0.02	0.02	0.02	0.03
Salmon, Pink	1	0.02	0.02	0.02	0.02
Salmon, Sockeye	15	0.03	0.03	0.02	0.06
Salmon, species not unspecified	1	0.03	0.03	0.03	0.03
Salmon, Steelhead	2	0.03	0.03	0.02	0.04
Scallop (various species)	41	0.04	0.05	0	0.09
Sea Cucumber	10	0	0	0	0
Sea Urchin, Green	1	0	0	0	0
Shrimp (various species)	15	0.05	0.02	0	0.35
Skate	9	0.14	0.13	0.12	0.20
Smelt (Atlantic, Lake)	9	0.04	0.04	0	0.08
Snapper (Mangrove/Gray)	1	0.07	0.07	0.07	0.07
Sole (Dover, Petrale)	11	0.08	0.08	0.02	0.12
Sturgeon (Lake, White)	13	0.1	0.11	0.02	0.2
Tilefish (CFIA, 2005)	1	0.08	0.08	0.08	0.08
Trout (species not specified)	4	0.13	0.08	0.07	0.3
Trout, all samples	86	0.14	0.14	0.01	0.56
Trout, Lake	70	0.23	0.19	0.10	0.65
Trout, Rainbow	32	0.04	0.03	0.01	0.10
Tuna, Skipjack	3	0.07	0.05	0.03	0.13
Tuna, Canned Skipjack	114	0.06	0.05	0.01	0.22
Tuna, Canned Skipjack (retail)	7	0.09	0.05	0.04	0.17

Species	No. of samples (*N*)	Total Mercury Concentration (ppm)			
(Dabeka *et al*., 2004)					
		Mean	Median	Min	Max
Tuna, Canned Yellowfin	74	0.05	0.04	0.01	0.21
Tuna, Canned Tongol	1	0.02	0.02	0.02	0.02
Tuna, Canned Yellowfin (retail) (Dabeka *et al*., 2004)	11	0.09	0.04	0.02	0.59
Tuna, Canned Light (species not specified)	1	0.14	0.14	0.14	0.14
Tuna, Canned Light (retail) (Dabeka *et al*., 20040	5	0.05	0.05	0.03	0.07
Turbot	9	0.09	0.06	0.03	0.20
Whelk	2	0.07	0.07	0.07	0.07
Whitefish, Lake	64	0.1	0.10	0.02	0.28

APPENDIX II

Summary data for those fish species for which samples contained total mercury at levels greater than 0.2 ppm on average. Mean concentrations approximating or exceeding the standard are in bold font.

Fish Species	**Source of Data**	**No. of samples (*N*)**	**Total Mercury Concentration (ppm)**			
			mean	**median**	**minimum**	**maximum**
Cusk / Brismark / Moonfish	CFIA, 2002-2003	*1*	0.35	0.35	0.35	0.35
Barracuda	CFIA, 2000-2003	*2*	**0.77**	0.77	0.58	0.97
Escolar / Snake Mackerel	CFIA, 03-04	*20*	**0.51**	0.45	0.3	1.12
	CFIA, 02-03	*16*	**0.55**	0.46	0.28	1.56
Grouper	CFIA, 03-04	*7*	0.20	0.06	0.02	0.69
	CFIA, 02-03	*16*	**0.45**	0.43	0.05	1.12
Halibut	CFIA, 04-06	*19*	0.31	0.23	0.04	1.03
	CFIA, 93-02	*38*	0.23	0.18	0.02	0.69
	U.S. FDA, 2004	*46*	0.25	0.20	<0.01	1.52
Marlin	CFIA, 03-04	*53*	**0.69**	0.5	0.04	2.68
	CFIA, 02-03	*36*	**0.49**	0.28	0.08	2.3
	Dabeka et al., 2004	*4*	**1.43**	1.09	0.34	3.19
	CFIA, 2003	*8*	**1.2**	0.77	0.54	2.3
	CFIA, 02 (b)	*56*	**0.63**	0.44	0.04	3.49
	CFIA, 01	*13*	**1.05**	0.69	0.16	3.1
Orange Roughy	CFIA, 98-01	*7*	**0.47**	0.42	0.30	0.67
	CFIA, 05-06	*8*	0.40	0.31	0.22	0.72
Pike	CFIA, 02-04	*282*	0.25	0.22	0.08	1.22
Redfish	CFIA, 02-04	*4*	0.25	0.25	0.08	0.42
Sablefish / Black cod	CFIA, 03-04	*57*	0.20	0.10	0.04	0.70
	CFIA, 02-03	*23*	**0.71**	0.71	0.07	1.2
	CFIA,02 (b) (imported)	*4*	0.2	0.19	0.08	0.33
	CFIA, 02 (b) (domestic)	*15*	0.3	0.28	0.08	0.67
Sauger	CFIA, 03-04	*1*	0.18	0.18	0.18	0.18
	CFIA, 04-05	*11*	0.46	0.50	0.18	0.59
Sea Bass	CFIA, 03-04	*27*	0.31	0.28	0.05	0.87
	CFIA, 02-03	*30*	0.35	0.29	0.03	0.8
	CFIA, 01	*1*	**0.57**	–	–	–
	CFIA,02 (b)	*74*	**0.62**	0.57	0.08	1.6

Fish Species	Source of Data	No. of samples (*N*)	Total Mercury Concentration (ppm)			
			mean	median	minimum	maximum
Shark	Dabeka et al., 2004	*12*	**1.36**	1.33	0.39	2.73
	CFIA, 03-04	*1*	**0.86**	0.86	0.86	0.86
	Ottawa Citizen, 01	*4*	**1.63**	–	–	–
Shark, (Spiny Dogfish / Northern Shark)	CFIA, 2002 b	*24*	0.46	0.39	0.07	1.4
	CFIA, 03-04	*29*	**0.63**	0.60	0.07	1.11
	CFIA, 02-03	*38*	**0.64**	0.60	0.17	1.29
Shark, Porbeagle	CFIA, 04-05	*25*	**0.87**	0.77	0.05	2.08
	CFIA, 02-03	*10*	0.47	0.37	0.21	1.06
Swordfish	CFIA, 03-04	*10*	**0.85**	0.98	0.47	1.16
	CFIA, 02-03	*6*	**1.06**	1.06	0.69	1.43
	Dabeka et al., 2004	*10*	**1.82**	1.67	0.4	3.85
	CFIA, 02 (b)	*15*	0.5	0.5	0.06	0.83
	Ottawa Citizen, 01	*4*	**1.09**	–	–	–
Tuna, Albacore, canned	Dabeka et al., 2004	*16*	0.26	0.25	0.19	0.38
	CFIA, 02-03	*128*	0.36	0.35	0.18	0.64
	CFIA, 03-04	*30*	0.34	0.34	0.15	0.56
Tuna, Albacore fresh or frozen	CFIA, 03-04	*4*	0.37	0.34	0.33	0.49
	CFIA, 02-03	*23*	0.22	0.21	0.16	0.43
Tuna, Bigeye	CFIA, 03-04	*6*	**0.65**	0.64	0.11	1.34
	CFIA, 02-03	*7*	0.34	0.25	0.15	0.89
Tuna, Southern Bluefin	CFIA, 04-05	*2*	0.28	0.28	0.21	0.35
Tuna, Yellowfin, Fresh	CFIA, 03-04	*1*	0.22	0.22	0.22	0.22
	CFIA, 04-05	*3*	0.29	0.24	0.12	0.50
Tuna, Fresh/Frozen (species not specified)	CFIA, 02 b (imported)	*13*	0.29	0.28	0.04	0.48
	CFIA, 02 b (domestic)	*1*	0.25	–	–	–
	CFIA, 03-04	*2*	0.37	0.37	0.28	0.46
	CFIA, 02-03	*4*	**0.57**	0.52	0.09	1.16
	Dabeka et al., 2004	*13*	**0.93**	0.82	0.077	2.12
	Ottawa Citizen, 01	*4*	**1.27**	–	–	–
Fish Species	**Source of Data**	**No. of samples (*N*)**	**Total Mercury Concentration (ppm)**			
			mean	**median**	**minimum**	**maximum**
Wahoo	CFIA, 03-04	*6*	0.31	0.23	0.09	0.8

	CFIA, 02-03	*1*	0.3	0.3	0.3	0.3
Walleye / Yellow Pickerel	CFIA, 03-04	*51*	0.37	0.25	0.08	1.24
	CFIA, 02-03	*32*	0.37	0.24	0.05	0.88

Notes:
* Blank entries indicate that the data was not available to allow calculation of the specified parameter or that only 1 sample was analysed.
* For sources of data where CFIA has been cited but the particular year does not appear in the list of references, the data has been provided directly to Health Canada as part of this review.
* Note that the tuna samples whose source is cited as either "CFIA, 02-03" or "CFIA, 03-04" were not originally identified in the tables provided to Health Canada as to whether they were canned or fresh/frozen. A request for this information has been made to the CFIA and to date, information has been received for yellowfin tuna and samples identified as "species not specified."
* For the CFIA tuna results, samples for which the species is not identified may be so either because the required information was not entered into the results table or because the information was simply not available to the person sampling to allow them to identify the tuna species.
* The CFIA results from Burnaby were reported separately for imported samples and for domestic samples, hence they are reported separately in the above table.
* For swordfish samples analysed by the CFIA in 2003-2004, 11 samples were actually listed in the original data table, one of which was reported to contain 0 ppm total mercury. This sample was not included in the above table (hence 10 samples are reported).
* For the shark samples described in Dabeka *et al*., 2004, the raw data files describe results for 12 samples although the publication indicates that 13 were analysed. The summary results in the above table are based on the raw data files provided by Dr. Dabeka.

APPENDIX III

List of those fish for which at least one individual "pre-retail" sample was found, by the CFIA in recent monitoring or by Health Canada in recent surveys of retail fish, to contain greater than 0.5 ppm total mercury. Only those fish that are in bold font were considered for the list of fish to be considered for a change in their risk management approach (i.e. maximum level, consumption advice, etc…). Canned tuna is included for information. Tilefish has also been included in the list for information (tilefish is included in the U.S. Food and Drug Administration and U.S. Environmental Protection Agency's joint fish consumption advisory).

Species	Source of Data	Sample Count	Results > 0.5 ppm	% > 0.5 ppm	% > 1.0 ppm
Barracuda	CFIA 00-03	2	2	50%	0%
Eel (American, Conger/sea, Spiny/spotted)	CFIA 02-04	52	1	2%	0%
Eel (species not specified)	CFIA 02-04	107	1	1%	0%
Escolar / Snake Mackerel	CFIA 03-04	20	7	35%	5%
	CFIA 02-03	16	6	38%	6%
Grouper	CFIA 02-03	16	5	31%	13%
	CFIA 03-04	7	1	14%	0%
Halibut	CFIA 02-03	4	0	0%	0%
	CFIA 04-06	18	2	11%	6%
Kingfish / King Mackerel / Spanish Mackerel	CFIA 02-03	1	0	0%	0%
	CFIA 03-05	19	1	5%	0%
Mahi mahi / Dolphinfish	CFIA 02-03	34	0	0%	0%
	CFIA 03-04	70	4	6%	0%
Marlin (see Note 1)	CFIA 02-03	36	11	31%	14%
	CFIA 03-04	53	24	45%	15%
	Dabeka 2003	4	2	50%	50%
Orange roughy / Slimehead	CFIA 98-01	7	2	29%	0%
	CFIA 05-06	8	2	25%	0%
Pike	CFIA 02-03	97	0	0%	0%
	CFIA 03-04	88	1	1%	0%
Sablefish / Black cod (see Note 2)	CFIA 02-03	23	19	83%	13%
	CFIA 03-04	57	6	11%	0%

	CFIA 03-04	1	0	0%	0%
Sauger	CFIA 04-05	11	5	45%	0%
	CFIA 2002 b	74	43	58%	12%
Sea Bass (several species of fish sold as Sea Bass)	CFIA 02-03	30	6	20%	0%
	CFIA 03-04	28	2	7%	**0%**
	CFIA 02-03	10	3	30%	10%
	CFIA 03-04	1	1	100%	0%
Shark (species not specified)	Dabeka 2004	12	10	83%	67%
Species	**Source of Data**	**Sample Count**	**Results > 0.5 ppm**	**% > 0.5 ppm**	**% > 1.0 ppm**
	CFIA, 2002 b	24	9	38%	13%
Shark, Dogfish	CFIA 02-03	38	21	55%	24%
	CFIA 03-04	29	18	62%	14%
	CFIA 02-03	6	6	100%	67%
	CFIA 03-04	10	9	90%	30%
Swordfish	Dabeka 2004	**10**	9	90%	80%
Tilefish	**CFIA 2005**	**1**	0	0	0%
Trout, Lake	**CFIA 02-05**	**70**	6	9%	0%
	CFIA 02-03	211	16	8%	0%
Tuna - Albacore (canned)	Dabeka 2004	16	0	0%	0%
	CFIA 02-03	7	1	14%	0%
Tuna - Bigeye	CFIA 03-04	6	4	67%	17%
Tuna (fresh or frozen)	Dabeka 2004	13	8	62%	46%
Tuna – Skipjack (canned)	CFIA 02-04	114	0	0%	0%
Tuna - Skipjack	Dabeka 2004	7	0	0%	0%
	CFIA 03-04	74	0	0%	0%
Tuna - Yellowfin (canned)	Dabeka 2004 (canned)	11	1	9%	0%
	Dabeka 2004 (frozen)	1	0	0%	0%
Tuna - Southern Bluefin	CFIA 04-05	2	0	0%	0%
	CFIA 02-03	14	3	21%	7%
Tuna - Unspecified	CFIA 03-04	7	0	0%	0%

Wahoo / Ono	CFIA 02-03	1	0	0%	0%
	CFIA 03-04	6	1	17%	0%
Walleye / Yellow Pickerel	CFIA 02-03	32	11	34%	0%
	CFIA 03-04	51	10	20%	6%

Notes: (1) The samples described in Dabeka *et al*., 2003, were collected in 2002. For canned tuna in particular, the juice was NOT drained. Of the 13 samples of "Tuna (fresh or frozen)", one sample was specified as "yellowfin."

(2) For sablefish, the 0.71 ppm value from the 2002-2003 CFIA survey was not employed in the exposure assessment as it was for samples available prior to the implementation of a fisheries management strategy to eliminate the source of sablefish containing elevated mercury.

Appendix IV

Fish Consumption: Review of the Current Intake Figures for Canadian Consumers and Further Recommendations

Bureau of Chemical Safety, Food Directorate
Health Products and Food Branch
Health Canada

CONTENTS

EXECUTIVE SUMMARY

Following a review and analysis of the data on the daily intake figures and portion sizes of finfish, shellfish, and seafood (the combination of all finfish and shellfish), the following figures are recommended for the Canadian population. These figures will provide the basis for the more accurate estimate of contaminant exposure from the consumption of finfish and shellfish.

"All-persons" intake figures consider consumption values reported by entire number of respondents from a particular survey or study (i.e. those that reported eating <u>and</u> not eating the food in question). "Eaters-only" intake figures are averaged over the number of respondents that reported eating the food in question.

Table i. Consumption Figures for the Entire Population (all ages)

Fish Type	All-Persons Intake* (g/day)	Eaters-Only Intake* (g/day)
Finfish	17	22
Shellfish	4	9
Seafood	21	26

*Values reported as means

Table ii. Finfish Consumption Related Figures for Specific Age Groups

Consumer Age Group	Eaters-Only Commercial (g/day)	Eaters-Only Sport/Subsistence (g/day)	Portion Size (g/meal)	Consumption Frequency (meals/week)
1-4 years	10	20	75	<1
5-11 years	14	33	125	<1
20+ years	22	40	150	1¼

*Values reported as means

Fish Consumption: Review of Intake Figures for Canadian Consumers

INTRODUCTION

The Bureau of Chemical Safety (BCS), Food Directorate (FD), Health Product and Food Branch (HPFB), Health Canada (HC) has employed the intake figure of 22 g/day to represent the finfish consumption of commercial consumers and 40 g/day to represent the finfish consumption of sportfish or subsistence consumers for a number of years. The present review was undertaken to verify and update these figures with current information that is available regarding fish consumption in Canada. This paper presents the key sources of data pertaining to Canadian fish consumption, discusses and evaluates the validity of the applicable data, and provides recommendations for appropriate fish consumption figures and portion sizes for the Canadian population. The purpose of this review paper was to develop standardized consumption figures that could be used to more accurately determine contaminant exposure from finfish and shellfish consumption as required by human health risk assessments.

Throughout this document, the term "seafood" is used to refer to the combination of all finfish and shellfish. However, there may be some diversions from this practice when the results of other studies are discussed, as they may not have used similar terminology. Additionally, the terms "intake" and "consumption" are used interchangeably throughout this paper; both refer to the amount of food eaten. "All-persons" intake figures consider consumption values reported by entire number of survey respondents (i.e. those that reported eating and not eating the food in question). "Eaters-only" intake figures are averaged over the number of survey respondents that reported eating the food in question. Additionally, all figures presented herein have been rounded to the nearest two significant figures except values in the hundreds, which have been rounded to three significant figures.

REVIEW OF DATA SOURCES

Canadian data sources of fish consumption information are summarized in the following section. Intake data from other countries with similar geographical, cultural, and socioeconomic characteristics to Canada's can provide information on seafood consumption, but Canadian data are given priority unless they are inadequate or unavailable. Suitable sources of Canadian consumption data are available and will hence be the focus of this paper. These reports are summarized below as well as in Appendix A (Table A1).

1. Statistics Canada publishes an annual report, Canada Food Statistics (2002), which summarizes the food disappearance figures for Canada. The 2002 disappearance figure for the

edible portion of seafood is 9.9 kg/person or 27 g/day, which consists of 4.3 g/day of fresh/frozen fish, 0.44 g/day of freshwater fish, 3.1 g/day of processed seafish, and 2.1 g/day of shellfish. Per capita data are used to represent general population consumption trends but do not permit individual intake patterns to be deduced. For example, eaters are not distinguished from non-eaters and no information can be gleaned on the consumption habits of specific consumer groups or consumption frequency. Furthermore, these disappearance figures represent the net supply of food available for consumption (imports, exports, and manufacturing uses are accounted for) but do not consider losses at the individual or household level due to spoilage, preparation, cooking, and waste. Despite the fact that such losses are not accounted for, unadjusted disappearance data tend to underestimate actual consumption because the net supply of food is averaged over the entire population, both eaters and non-eaters.

The per capita consumption of seafood by Canadians in 2002 was, in the same report, adjusted for the estimated retail, household, cooking and plate loss and determined to be 7.2 kg/year or 20 g/day. Broken into categories, this was equal to 2.9 g/day of fresh/frozen fish, 0.29 g/day of freshwater fish, 2.7 g/day of processed seafish, and 1.4 g/day of shellfish.

2. Nutrition Canada (1973) conducted a nation-wide consumption survey for Health and Welfare Canada between 1970 and 1972. The Nutrition Canada Survey collected data from over 19 000 residents from ten provinces [1] and various aboriginal and Inuit groups; however, some regions, such as the Atlantic Provinces, were not as well-represented as others (Brulé, 1996). Respondents were interviewed in person at a community survey centre and clinical, anthropometric, and dental examinations were also undertaken. The amount of individual foods consumed over the last 24 hours was recorded using portion models and the frequency at which certain foods were consumed over the previous month was also noted.

Surveys based on 24-hour recall information do not capture normal variations in an individual diet and only capture information on the foods eaten on the survey day. While only a small proportion of people may report eating fish on the particular survey day, more people are likely to eat fish over the course of a week or month. Therefore, a particular food may be over or under represented relative to the actual frequency and magnitude of consumption. As a result, eaters-only data from 24-hour recall surveys are not deemed useful for determining average daily consumption unless frequency of consumption is considered. On the positive side, the sample size of this 24-hour recall survey was large and the eaters-only intake figures provide valuable information on portion size.
Fish intake data from this survey are summarized below. Table 1 lists the mean eaters-only and

1 British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador.

all-persons consumption figures of the entire population (> 1 year old) and for 1 to 4 and 5 to 11 year-old children.

Table 1. Mean Seafood Consumption

Fish Type	Entire Population (> 1 year) (g/day)		1-4 Year-Olds (g/day)		5-11 Year-Olds (g/day)	
	All-Persons	Eaters-Only	All-Persons	Eaters-Only	All-Persons	Eaters-Only
Atlantic	1.7	152	1.2	124	0.40	86
Pacific	2.2	109	0.90	46	1.6	91
Freshwater	2.1	200	0.60	54	3.2	261
Tuna*	1.0	56	0.040	16	1.1	47
Salmon*	1.6	68	0.10	17	0.40	44
Other*	1.8	66	0.30	34	0.70	48
Shellfish	0.6	82	0.30	35	0.30	105

*canned fish

The disparity between the all-persons and eaters-only intake figures that are highlighted in Table 1 is a result of seafood not being consumed by the majority of individuals combined with consumption data from high-end consumers (US EPA, 1999). Eaters-only seafood figures can therefore be much higher than those represented by all-persons figures, so caution should be exercised when using 24-hour recall data to estimate daily consumption means.

3. Data from the 1986 Statistics Canada Family Food Expenditure Survey were analyzed in a publication from the Department of Fisheries and Oceans (Sabry, 1990). This survey gathered data on household food purchases and used it as a proxy for food consumption. In 1986, the total amount of seafood purchased per household was 319 g/week and a household included 2.53 people. Average per diem consumption for each person in the household was calculated to be 18 g/day. This figure, however, represents the retail weight of the seafood and not the amount of seafood that is actually consumed or by whom. Nor does it represent the amount of seafood lost to spoilage, preparation, cooking, and waste. In addition, these figures do not consider seafood consumption from other sources such as restaurants or recreational fishing.

The most popular fresh or frozen seafood species reported by household were: salmon (29 g/week), flounder and sole (29 g/week), cod (21 g/week), haddock (12 g/week), all other sea fish (46 g/week), and freshwater fish (30 g/week). A total of 72 g/week of canned fish was consumed by each household, with the most popular being salmon (32 g/week) and tuna (30 g/week).

Shellfish was consumed at a rate of 52 g/week by each household. Geographical differences in seafood consumption were observed across the country. Consumption in the Atlantic and Pacific coastal regions was greater than in the Prairie Provinces. Shellfish consumption was highest in Prince Edward Island, Nova Scotia, New Brunswick, and British Columbia. The largest amount of cod was purchased by families in Newfoundland and the greatest amount of salmon was purchased in British Columbia.

4. Food consumption surveys were conducted in ten Canadian provinces (see footnote 1) in the 1990's as part of the joint Health Canada and Canadian Heart Health Initiative study. The interviewees consisted of approximately 2000 individuals from each province between the ages of 18 and 74 years, excluding residents of institutions, military camps, and First Nations reserves. Infants, children, and teenagers were also excluded. The surveys were based on 24-hour dietary recall data, a food frequency questionnaire, as well as height and weight measurements (Brulé, 1996). The same advantages and disadvantages of 24-hour recall surveys that were discussed with respect to the Nutrition Canada Survey (1973) also apply to these studies.

Results summaries from the Québec (Santé Québec, 1992) and Nova Scotia (Nova Scotia Department of Health, 1993) surveys have been provided to BCS and the pertinent results are summarized in Tables 2 and 3.

Table 2. Mean Seafood Consumption

Seafood Type	Number of Eaters*	All-Persons (g/day)	Eaters-Only (g/day)
Fish < 6% fat	135	7.4	122
Fish ≥ 6% fat	88	3.7	86
Shellfish	103	4.3	88

*2118 respondents in total

Table 3. Mean Seafood Consumption

Seafood Type	Number of Eaters*	All-Persons (g/day)	Eaters-Only (g/day)
Fish < 6% fat	317	16	115
Fish ≥ 6% fat	144	6.7	107
Shellfish	242	14	141

*2212 respondents in total

The data in the tables above illustrate that 11% of Québécois surveyed consumed finfish and 4.9% consumed shellfish in the previous 24-hour period. In Nova Scotia, 21% of the population surveyed consumed finfish and 11% consumed shellfish. Detailed information about the questionnaire and which fish species were classified into each of the two categories ('>' and '<' 6% fat) was not provided.

5. In the early 1990's Health and Welfare Canada commissioned an independent marketing organization, Market Facts Canada, to conduct a detailed survey on the fish consumption habits of Canadians aged one year and older. This survey (Market Facts, 1991) collected data from 3815 respondents nationwide over a 3-month period from December 1990 to February 1991. Each respondent was asked to record their seafood consumption, including which types of seafood were consumed, the form it was in when acquired (e.g. canned, fresh bought, fresh captured, frozen cooked), how it was prepared, the quantity eaten, and its origins (e.g. Canadian river/lake, Caribbean, fish farm, etc.). This information was recorded in diary format over a one-month period.

The Market Facts (1991) study summarized that 81% of Canadians reported eating seafood during the month, which is consistent with a Canadian Seafood Advisory Council estimate quoted by Sabry (1990) stating that 84% of Canadians consume fish. Of those that reported eating seafood, 49% consumed only finfish, 3% ate only shellfish, and the remaining 48% consumed both. For consumers, this was equivalent to 5 or 6 seafood meals each month. The average age of seafood eaters was 37 years and that of non-eaters was 28 years. Data were not provided on the frequency of consumption by gender, but men did consume slightly greater portions of seafood than women.

A total of 17 714 meals of seafood were reported to have been eaten over the month. Salmon was the most popular seafood consumed, being eaten in 17% of the meals reported. Next, in descending order, were tuna (14%), shrimp (11%), cod (9%), and sole (6%). One of every six seafood meals consumed was salmon, with canned salmon accounting for two-thirds of these meals. Similarly, one in seven seafood meals were tuna, with canned tuna accounting for 95% of these meals. A high correlation between 'canned fish' and 'consumed as sandwich' was reported.

Any form of canned seafood constituted one third of all seafood meals consumed. Fresh and frozen seafood constituted 18% and 19%, respectively, of consumed seafood meals reported. Of the fresh seafood consumed, 14% consisted of salmon, 12% of shrimp, 11% of cod, and less than 0.5% of fresh tuna. The proportion of frozen raw seafood was comprised of 18% sole, 17% cod, 9% haddock, and 8% shrimp. Twelve percent of seafood meals were frozen and pre-cooked.

Approximately 15% of seafood meals were prepared outside the home. In addition, 5% of seafood meals were 'self-caught' with the most frequently reported species being pike (68%), pickerel (46%), trout (38%), perch (25%), whitefish (16%) and bass (16%).

Survey respondents knew where the seafood originated in 68% of the meals reported as eaten. In total, 55% of the meals were of domestic origin: 28% from Atlantic Canada, 19% from Pacific Canada, 7% from a river or lake, and 1% from a fish farm. For 32% of the reported seafood meals, respondents did not know where the seafood had come from, though this figure may be influenced by the fact that 15% of seafood meals were prepared outside of the home.

The Market Facts (1991) study has been criticized for its low sample size, 3815 respondents. As well, the food diary approach has the potential to introduce biases to the data that are collected. Other potential drawbacks of the study include the fact that the survey was conducted in the winter when seafood availability is lowest, and seafood costs are highest. Also, the duration in which the study was carried out was short (1 month), and there was lack of focus on the intake patterns of sportfishers.

While these are valid concerns, Market Facts (1991) did capture the most pertinent information out of all of the other studies summarized in this document. Information on the consumption habits, portion sizes, frequency of consumption, and fish types that are popular among specific consumer groups were collected. Frequency of consumption data are particularly important for the calculation of mean daily intake figures for eaters. The sample size, though small, still manages to capture data pertaining to a fair number of individuals from the Canadian population - over three thousand people in ten provinces. The form of a written diary is the only feasible way in which to constantly record each aspect of fish consumption for an individual over an extended period of time. While a year-long study would be an ideal method in which to capture monthly or seasonal variation in fish consumption, this is an option that is not always feasible due to time and financial constraints. Furthermore, a month-long dietary survey is better at capturing variation in consumption habits than either a 24-hour recall study or a week-long study, both of which form the basis of all other Canadian intake studies discussed herein. Although the Market Facts (1991) refers to data collected back in the 1990s, it is still the most recent and comprehensive source of Canadian fish consumption information.

Due to the merits of the Market Facts (1991) study in relation to the other studies discussed above, all of the consumption-related figures generated herein are based solely or partially on data and information obtained from the Market Facts (1991) report.

RECOMMENDED FIGURES

Portion Size

In the Market Facts (1991) study, data were gathered on the average portion size consumed per eating occasion. Respondents were asked to approximate seafood serving sizes in 'cups' and these were then translated into metric grams according to conversion figures provided by Health and Welfare Canada. The average portion size of a finfish meal was 148 g, that of a shellfish meal was 105 g, and a general seafood portion was 137 g. However, 57% of seafood meals were 100 g or less and 73% of the meals were less than 150 g. In 11% of cases, servings were greater than 250 g (4% between 251 g and 300 g, 2% between 301 g and 350 g, 3% between 351 g and 400 g, and 2% over 400 g).

Portion sizes were positively correlated with respondent weight. Consumer body weights and the corresponding average seafood portion sizes from the Market Facts (1991) study are presented graphically in Figure 1.

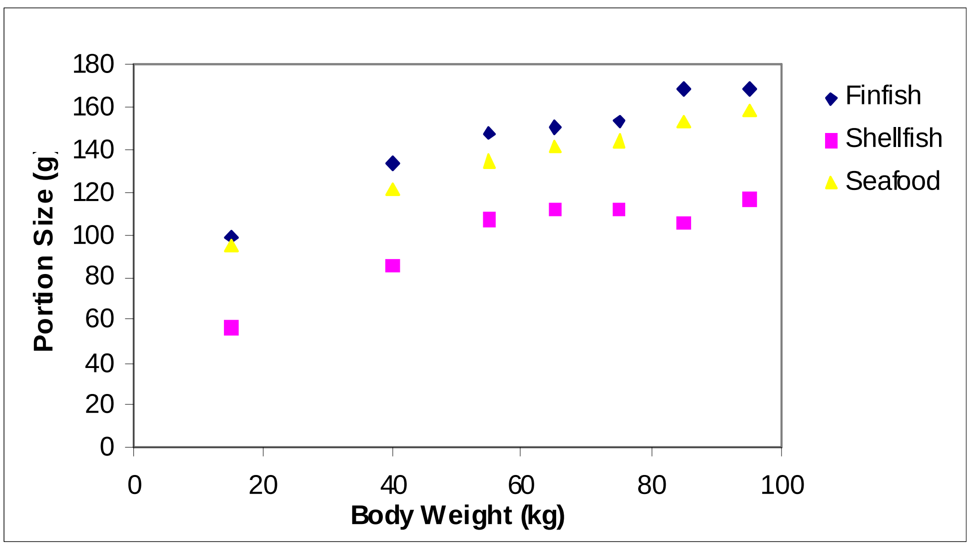

Figure 1. Eaters-only Mean Seafood Portion Size Relative to Body Weight
Source: Data from Market Facts (1991)
Lines of best fit: Finfish: $y = 0.85x + 93$ ($R^2 = 0.94$); Shellfish : $y = 0.70x + 57$ ($R^2 = 0.82$); Seafood: $y = 0.77x + 88$ ($R^2 = 0.97$).

Average portion size can be determined for consumers of any body weight by interpolating values from linear regression lines-of-best fit. The portion sizes of finfish, shellfish, and seafood meals for consumer body weights that are commonly used by BCS in risk assessments were interpolated from Figure 1 and are presented below in Table 4.

Table 4. Portion Sizes for Consumers of Various Age Groups*

Consumer Group		Body Weight (kg)	Portion Size (g/meal)		
			Finfish	Shellfish	Seafood
Toddlers	1-4 year-old	14	106	67	99
Children	5-11 year-old	26	116	75	109
Teens	12-19 year-old	54	140	94	130
Adults	20-70 year-old	60	145	99	134

*Age groups are those commonly employed by BCS in health risk assessments
Source: Interpolated from Figure 1

<u>Finfish Portion Size: Adults (20-70 Year-Olds)</u>
Finfish portion sizes are available from various Canadian sources. Twenty-four hour recall data from the Nutrition Canada Survey (1973) reported eaters-only finfish consumption for adults ranging from 50 g to 164 g, with a mean of 98 g[2]. Similarly, the provincial Nova Scotia (Nova Scotia Department of Health, 1993) and Québec (Santé Québec, 1992) surveys report mean, eaters-only daily adult finfish consumption of 86 g to 122 g, with an eaters-only mean of 107 g for the entire population considered (18 to 74 year-olds)[2]. In the Market Facts (1991) study the average finfish portion size for adults weighing between 61 and 90 kg is 161 g; data interpolated from Figure 1 illustrate that this figure could be closer to 145 g. A Canadian Food Inspection Agency (CFIA) reference document indicates that for “marine and freshwater animals without sauce,” the suggested serving size is between 60 g and 100 g of cooked fish (CFIA, 2003).

A 150 g portion size has been adopted by various international agencies. Food Standards Australia New Zealand (FSANZ) considers a finfish serving size to be equal to 150 g for adults (FSANZ, 2004) and in the UK, a portion of fish is represented by 140 g cooked fish (UK Food Standards Agency, 2004). In addition, 24-hour recall data from the US EPA (2002) reported the eaters-only mean intake of all types of seafood in people 14 years and older to range from 83 g/day to 112 g/day.

[2] In order to estimate portion size from 24-hour recall surveys, it must be assumed that the consumer ate a single fish meal the day of the survey.

Taking the above information into consideration, 150 g would be considered a reasonable, albeit conservative, estimate of an average finfish meal size for an adult.

Finfish Portion Size: Toddlers (1-4 Year-Olds)
Interpolated data in Table 4 indicate that a young child aged 1 to 4 years and weighing 14 kg would consume, on average, approximately 106 g of finfish per serving. However, this interpolation may overestimate portion size for toddlers as there is only one data point representing the mean finfish portion size of all children weighing less than 30 kg. Data from Market Facts (1991) illustrates that the finfish portion size per eating day for 1 to 5 year-olds is 90 g, which may slightly overestimate the portion of finfish consumed by 1 to 4 year-olds. Twenty-four hour recall data from the Nutrition Canada Survey (1973) indicate that the mean, eaters-only finfish portion size of 1 to 4 year-olds ranges from 16 g to 124 g, with a mean intake of 49 g (see footnote 2).

A 75 g portion size for children aged 6 years and under is employed by FSANZ (FSANZ, 2004).

It is recommended that the figure of 75 g be used to represent a typical finfish meal of a 1 to 4 year-old child.

Finfish Portion Size: 5-11 Year-Olds
For a child aged 5 to 11 years, interpolated data in Table 4 indicate that a typical finfish portion size is approximately 116 g. Market Facts (1991) reported finfish portion size per eating day to be 130 g for 6 to 12 year-olds. The Nutrition Canada Survey (1973) presented portion sizes for 5 to 11 year-old eaters ranging from 44 g to 261 g, with a mean of 96 g (see footnote 5).

It is recommended that 125 g conservatively be applied as a typical finfish portion size for a 5 to 11 year-old child.

Frequency of Consumption

The Market Facts (1991) study investigated the frequency of seafood consumption among eaters. Fifty percent of seafood eaters consumed seafood, on average, once a week or less. Thirty-three percent of consumers ate seafood more than once per week but less than twice per week, for a total of 83% of the respondents eating seafood less than twice per week. Sixteen percent consumed seafood more frequently than twice per week and 12% of the respondents reported eating seafood once every three days. For the entire population surveyed, seafood was consumed an average of 5 times over a 1-month period, or 1 ¼ times per week.

Seafood consumption was also observed to increase with age. Those aged 55 years and older consumed an average of 7 seafood meals each month while those under 18 years of age ate an average of 4 seafood meals each month.

Seafood was consumed by eaters in the entire population (> 1 year of age) 1 ¼ meals/week; those over 55 years ate 1 ¾ seafood meals/week and those under 18 years consumed only 1 seafood meal/week.

Average Daily Consumption Estimation

Eaters-Only

The average daily intake of a food is the figure that is commonly employed in human health risk assessments. Market Facts (1991) used consumption frequency and portion size information to develop mean monthly intake figures for finfish, shellfish, and seafood. Table 5 reports mean and maximum monthly intake figures for the entire population that was surveyed (> 1 year of age).

Table 5. Daily Intake Figures for Different Fish Types (Entire Population (>1 year))

Fish Type	Mean Daily Intake (g/day)	Maximum Daily Intake (g/day)
Finfish	22	31
Shellfish	9	11
Seafood	26	35

Source: Market Facts (1991)

The values listed in Table 5 for the entire population (> 1 year of age) closely approximate the mean monthly intake data for adults that are presented in Market Facts (1991). However, the figures in Table 5 overestimate consumption in children (aged 12 and under) since the proportion of children surveyed by Market Facts (1991) constituted a relatively small percentage (15%) of the total population surveyed. Market Facts (1991) specifically reports that the eaters-only mean daily finfish consumption rate for children aged 1 to 5 years is 10 g/day and that for children aged 6 to12 years is 14 g/day; these age classes are slightly greater than those commonly employed by BCS in health risk assessments (1 to 4 and 5 to 11 year-olds) and therefore may slightly overestimate the finfish consumption.

The average daily finfish intake figure recommended for 1 to 4 year-olds is 10 g/day and for 5 to 11 year-olds is 14 g/day; the recommended average daily finfish intake figure for adults is 22 g/day.

<u>All-Persons</u>
All-persons intakes can also be calculated using information provided in the Market Facts (1991) study with the assumption that there is an arithmetic distribution between eaters. The following figures are used to calculate the all-persons mean daily **finfish** intake for the entire survey population (> 1 year old):

81% of the respondents eat seafood
97% of these respondents consume finfish
22 g/day is the eaters-only mean finfish intake
All-persons mean finfish intake (> 1 year old) = 0.81*0.97*22 g/day
= 17 g/day

This figure, 17 g/day, is higher than the mean of 11 g/day from the Nova Scotia Provincial survey (1993) but is similar to those reported in the Canada Food Statistics survey, 16 g/day (Statistics Canada, 2002) and the Family Food Expenditure Survey, 15 g/day (Sabry, 1990). However, 17 g/day is much higher than the 1.0 g/day to 2.2 g/day finfish means listed in the Nutrition Canada Survey (1973), which, due to its 24-hour recall format, does not accurately capture true consumption trends.

All-persons shellfish consumption for the Canadian population can be calculated in the same manner as above, though it is thought that such a figure has a greater probability of being skewed as there were fewer **shellfish** consumers in the population surveyed by Market Facts (1991):

81% of the respondents consume seafood
51% of these respondents consume shellfish
9 g/day is the eaters-only mean shellfish intake
All-persons mean shellfish intake (> 1 year old) = 0.81*0.51*9 g/day
= 3.7 g/day

This figure of 3.7 g/day is relatively close to the all-persons shellfish consumption figure of 2.9 g/day from the Family Food Expenditure Survey (Sabry, 1990) and is similar to the all-persons Canada Food Statistics consumption estimate of 3.8 g/day (Statistics Canada, 2002). This figure is lower than the provincial all-persons means of 4.3 g/day in Québec and 14 g/day in Nova Scotia (Brulé, 1996; Santé Québec, 1992; Nova Scotia Department of Health, 1993), which could be attributed to the fact that only adults were surveyed in the Market Facts (1991) study.

The all-persons population mean for all types of **seafood** can be calculated using the following information from Market Facts (1991):

81% of the respondents consume seafood
26 g/day is the eaters-only mean shellfish intake
All-persons average seafood intake (> 1 year) = 0.81*26 g/day
= 21 g/day

The figure, 21 g/day, is consistent with a number of studies, including the Canada Food Statistics estimate of 20 g/day (Statistics Canada, 2002) and the Family Food Expenditure Survey figure of 18 g/day (Sabry, 1990). This figure also falls within the range of the means from the Provincial surveys of 15 g/day in Québec and 37 g/day in Nova Scotia (Brulé, 1996; Santé Québec, 1992; Nova Scotia Department of Health, 1993). Also, this figure is appreciably higher than the 0.6 g/day to 2.2 g/day estimated in the Nutrition Canada Survey (1973), but this is due to the nature of the 24-hour recall survey that allowed a small percentage of actual eaters to be captured since seafood is infrequently consumed.

It is recommended that the following mean, all-persons intake figures for the entire population (> 1 year) be adopted: 17 g/day for finfish, 3.7 g/day for shellfish, and 21 g/day for seafood.

DISTINCT POPULATION SUBGROUPS

It is useful to have standard finfish, shellfish, and seafood consumption values to apply to the Canadian population. However, it should be recognized that there are unique subgroups of the population that may consume more or less seafood than that of the average Canadian. Such population sub-groups are discussed briefly below.

Coastal Provinces

A number of studies illustrate that the frequency and magnitude of fish consumption varies throughout Canada. Sabry (1990) noted that those living in the coastal areas consumed more fish than those in the Prairie Provinces. Hunter et al. (1988) observed from the Nutrition Canada Survey (1973) that those living in Atlantic Canada had nearly twice the probability of reporting fish consumption the previous day than those living in the Prairie Provinces. The majority of all-persons and eaters-only 24-hour recall consumption rates reported by Nova Scotians were higher by as much as 2-fold than those reported by Québécois. Furthermore, between 1.6 and 2.3 more survey respondents reported eating seafood in Nova Scotia relative to Québec (Nova Scotia Department of Health, 1993; Santé Québec, 1992). Market Facts (1991) identified general geographic areas of high fish consumption; the Atlantic Provinces constituted only 8% of the total population sampled but possessed 19% of the heaviest consumers. The population surveyed from Québec was comprised of 26% of the survey population and included 29% of the heaviest consumers.

The Market Facts (1991) study noted that fish consumers from the Atlantic Provinces consumed significant amounts of cod. Additionally, Hunter et al. (1988) reported that Atlantic cod comprised 90% of the overall fish consumption of a small group of people living in coastal Newfoundland. In light of the cod fishery closures of the past decade, it is conceivable that Atlantic Canadians now consume other varieties of fish more frequently.

Adult Men

Demographic groups that consume greater-than-average amounts of seafood are generally older population sub-groups and males. In the Market Facts (1991) study, men over the age of 25 years consumed a greater quantity of seafood than women within the same age group. The greatest number of heavy consumers were men over 55 years of age. Since men weigh more than women, on average, they may consume larger portion sizes relative to their energy requirements and body weight. Moreover, it is conceivable that older men are advised by their physicians to eat greater amounts of fish in order to maintain their cardiovascular health. Sabry (1990) also suggested that older people may be more likely to follow traditional patterns of high fish consumption such as those of coastal fishers, First Nations groups, and certain minority groups.

Children

The Nutrition Canada Survey (1973) illustrated lower rates of fish consumption in children; such a trend has also been noted by a number of other sources, including Sabry (1990). This trend can be explained by the lower energy needs and smaller portion sizes consumed by children and the fact that a smaller proportion of young people consume fish.

The Market Facts (1991) study indicated that 75% of children 12 and under consumed seafood and 91% of consumers over 55 years consume seafood. Among children seafood consumers, the average portion size per eating day was estimated to be between 87 g (1 to 5 year-olds) and 121 g (6 to 12 year-olds). However, when frequency of consumption was factored in, the mean monthly consumption rate for children seafood eaters 12 years and younger was between 10 g/day and 14 g/day of finfish, 4 g/day to 5 g/day of shellfish, and 10 g/day to 15 g/day for seafood. The US EPA (2002) reports that those 14 years and under most commonly consume tuna (1.5 g/day)[3], cod (0.66 g/day), shrimp (0.61 g/day), and marine salmon (0.28 g/day).

[3] Market Facts (1991) indicates that approximately 95% of tuna consumed is canned.

Pregnant Women and Women of Childbearing Age

The intake figures applied to pregnant women and women of childbearing age may vary from that of the general population. For example, intake of some large, predatory fish species may be lower in this sub-group due to the consumption advice that Health Canada has issued due to elevated mercury levels in these types of fish.

Recreational and Subsistence Fishers

In order to determine an intake figure for heavy consumers of seafood, a number of studies that include intake data in heavy consumers, ranging from recreational fishers, subsistence fishers, First Nations peoples, and certain ethnic groups, were examined. These studies are outlined below as well as in Appendix A (Tables A2 and A3). As numerous studies on this topic exist, it was not possible to evaluate them all.

1. As part of a cardiovascular study in Montréal (Godin et al. 2003), 112 St. Lawrence River anglers were surveyed about their seasonal consumption of finfish. All of the respondents were men. Finfish consumption was reported to be between 55 and 77 sportfish meals/year, in addition to 35 meals of commercial fish, for a total of 90 to 112 fish meals/year. The average weekly consumption of sportfish was estimated to be 1.5 meals - the definition of a meal was not specified although the use of fillet models and thickness indicators were mentioned. If it is assumed that a finfish portion size is 150 g, the average daily intake of sportfish would equal 27 g/day and that of commercial fish would be 14 g/day, for a total finfish intake of 41 g/day. However, the authors suggested that reported intakes were overestimated due to memory lapses, current seasonal intakes affecting previous seasonal intakes, and the respondents' tendency to inflate fish size.

2. A methylmercury exposure study of 94 recreational anglers in the James Bay area estimated average finfish consumption to be 87 g/day (Loranger et al. 2002). However, reported consumption figures may have been inflated due to past recall biases, unrealistically high reporting of meal frequencies and portion sizes, as well as a tendency to exaggerate fish size. In addition, study participants were specifically chosen from a pool of 300 anglers who were known to regularly eat their catch.

3. An Ontario Fish and Wildlife Consumption Survey (Great Lakes Health Effects Program, 1997) was carried out over a period of 3 years in order to identify fish eaters and their consumption frequency as well as the species consumed from five Areas of Concern in the Great Lakes. The subpopulation interviewed included over 4500 respondents. Fifty-two percent (52%) of the respondents consumed less than 11 finfish meals/year, 22% consumed between 12 and 25 meals/year, and 21% consumed between 26 and 95 meals/year. Approximately 6% of

those surveyed ate more than 97 meals/year. The definition of a meal was not defined. Since this was a draft document and because a number of questions were raised by BCS concerning the study methodology, it is recommended that this survey be given little weight in developing intake recommendations.

4. Results from a Lake Ontario Salmon/Trout Angler Intake survey conducted by the Ontario Ministry of the Environment (OMOE) Sportfish Contaminant Monitoring Program (1988) included data on finfish portion size and the number of finfish consumed each year. These data were also compared to the OMOE Guide to Eating Ontario Sportfish (1986), as outlined in Table 6 below.

Table 6. Fish Consumption Figures from Two Ontario Ministry of the Environment Sources

Parameter	Lake Ontario Salmon/Trout Angler Intake	Guide to Eating Ontario Sportfish (1986)
Mean Meal Size (g)	244	291
Annual Consumption (meals/year)	21	31
Mean Daily Intake (g/day)	14	25

5. Twenty immigrant Vietnamese women residing near Hamilton, Ontario participated in a questionnaire pertaining to their consumption of finfish from the Great Lakes. Their yearly consumption of freshwater fish was determined to be between 34 meal/year and 58 meals/year (Cavan et al. 1996). A marked seasonal effect demonstrated that consumption in the spring and summer was much higher than in the fall or winter. Assuming that the average number of meals per year is 46 and a typical finfish portion size is 150 g, the average daily fish intake would be 19 g/day.

6. Kostasky et al. (1999) reported that high-level sportfishers in Montreal eat 0.92 sportfish meals/week, approximating 18 kg/year or 50 g/day. Low-level sportfishers ate 0.38 meals/week or 3.3 kg/year which is equal to 9.0 g/day. None of the respondents reported eating fish more than twice each week.

7. Using two 24-hour diet recalls, Shatenstein et al. (1999) determined fish consumption among 18 Asian-origin sportfishers on the St. Lawrence River. Nine Bangladeshi fishers consumed an average of 47 sportfish meals/year while nine Vietnamese sportfishers consumed 41 meals/year. The definition of meal size was not given. If it is assumed that a typical finfish meal

size is 150 g, the average daily finfish intake is 19 g/day for Bangladeshi fishers and 17 g/day for Vietnamese fishers.

8. Dewailly et al. (2003) summarized data from the Santé Québec (1992) 24-hour recall survey and estimated that southern Québécois consumed 13 g/day of fish and marine products, James Bay Cree consumed 60 g/day, and Nunavik Inuit consumed 131 g/day.

9. A study of Ontario Amerindians estimated fish consumption rates found a geometric intake mean of 16 g/day, with males consuming 19 g/day and women consuming 14 g/day (Richardson and Currie, 1993). Fish consumption rates were found to increase with age and vary with season, with the highest consumption reported in the summer and the lowest in the winter.

10. Chan et al. (1999) determined that the average daily intake of locally caught freshwater fish for all fishers in a Mohawk First Nations community was 23 g/day and the eaters-only daily intake was 33 g/day. Fish consumption was highest in the spring and summer, with a reported frequency of usually less than once per week.

11. Indian and Northern Affairs (2003) reported fish consumption among 207 women residing in two Inuit communities, Repulse Bay and Pond Inlet. Data were obtained using both a 24-hour recall as well as a week-long food frequency questionnaire. Only the results of the 1997 weekly diary are reported here. In Repulse Bay, weekly consumption of fish was equal to 304 g/person, consisting of 32 g of canned salmon, 18 g of frozen fish sticks, and 3 g of canned sardines. Daily intake can thus be calculated to be 43 g/day for women from Repulse Bay. In Pond Inlet, the average weekly consumption of fish was 259 g, consisting of 13 g frozen fish sticks, 10 g canned pink salmon, and 10 g canned sardines. Thus, the weekly intake was approximately 37 g/day for female residents of Pond Inlet.

Of the studies examined, it was observed that the average intake of recreational or subsistence fishers in Canada ranges widely, from 9.0 g/day (Kostasky et al.1999) up to 87 g/day (Loranger et al. 2002). In the reports on First Nations and Inuit consumption habits, the mean intake ranged from 14 g/day (Richardson and Currie, 1993) to 131 g/day (Dewailly et al. 2003). These studies were all conducted in different manners for diverse purposes therefore it is difficult to directly compare intake values generated from each. Nevertheless, the average daily adult consumption rate was calculated from the numerous different intake figures presented herein, yielding a value of 38 g/day.

Market Facts (1991) also provided data on high-level consumers. The figures reported for consumers in the 75^{th} percentile for consumption were 28 g/day (all-persons) and 33 g/day (eaters-only) of seafood. The upper 90^{th} percentile seafood consumption rates were 45 g/day (all-persons) and 49 g/day (eaters-only).

Based on the information above, it is recommended that the current figure of 40 g/day continue to be used to represent adult heavy consumers of seafood.

It is not expected that children will consume the same amount of fish as adult heavy consumers; hence intake figures should be adjusted accordingly for this cohort. In the absence of representative data, it was assumed that a child of a recreational or subsistence fisher will have the same consumption frequency as their parent(s) but their portion size would be smaller. Using the portion sizes presented earlier in this document, the average daily intakes for heavy child seafood consumers can be calculated. For a 5 to 11 year-old, a typical serving of commercial fish (125 g) is approximately 83% of the size of a typical adult portion (150 g). Thus finfish intake for a 5 to 11 year-old child that is a heavy seafood consumer is 33 g/day (40*0.83). The typical portion of commercial fish (75 g) for a 1 to 4 year-old child is half the size of a typical adult portion (150 g), therefore the mean intake for heavy consumers within this age group is approximately 20 g/day (40* 0.5).

Based on the information above, it is recommended that the intake figure of 33 g/day be applied to 5 to 11 year-olds and the figure of 20 g/day be applied to 1 to 4 year-olds that are part of the subsistence or recreational fishing culture.

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APPENDIX A. SUMMARY OF STUDIES

Table A1. Summary of Canadian Studies of the General Population

Authors	**Study Details**	**Intake Figures**
Statistics Canada, 2002	Canada Food Statistics	27 g/day disappearance figure (based on net supply and not accounting for losses) 20 g/day consumption figure (adjusted for retail, household, cooking and plate loss)
Nutrition Canada, 1973	Nutrition Canada Survey, prepared for Health and Welfare Canada; 24-hour recall of 19 000 individuals in 10 provinces	Figures apply to all seafood 1.0-2.2 g/day, all-persons mean, > 1 year 56-200 g/day, eaters-only mean, > 1 year 0.04-1.2 g/day, all-persons mean, 1-4 year-olds 16-124 g/day, eaters-only mean, 1-4 year-olds 0.3-3.2 g/day, all-persons mean, 5-11 year-olds 44-261 g/day, eaters-only mean, 5-11 year-olds
Sabry, 1990	1986 Statistics Canada Family Food Expenditure Survey, prepared for the Department of Fisheries and Oceans; weekly purchase by household	18 g/day, retail weight of seafood (not accounting for losses)

Santé Québec, 1992	Quebec Nutrition Survey Report, (Health Canada/ Canadian Heart Health Initiative study); 24-hour recall of over 2000 respondents	Figures apply to 18-74 year-olds 3.7-7.4 g/day finfish, all-persons mean 86-122 g/day finfish, eaters-only mean 4.3 g/day shellfish, all-persons mean 88 g/day shellfish, eaters-only mean 15% of respondents reported seafood consumption
Nova Scotia Department of Health, 1993	Nova Scotia Nutrition Survey Report (Health Canada/ Canadian Heart Health Initiative study); 24-hour recall of over 2000 respondents	Figures apply to 18-74 year-olds 6.7-16 g/day of finfish, all-persons mean 107-115 g/day of finfish, eaters-only mean 14 g/day of shellfish, all-persons mean 141 g/day of shellfish, eaters-only mean 32% of respondents reported consumption of seafood
Market Facts Canada, 1991	National Seafood Consumption Study, one-month survey of 3815 individuals from all 10 provinces	Figures apply to adults (> 18 years) 22 g/day of finfish, eaters-only mean 9 g/day of shellfish, eaters-only mean 26 g/day of seafood, eaters-only mean Mean portion size of finfish (148 g), shellfish (105 g), and seafood (137 g) Seafood reported to be consumed an average of five times per month 81% of Canadians reported eating seafood (49% of eaters consumed only finfish, 3% consumed only shellfish, 48% consumed both)

Table A2. Summary of Canadian Studies of Subsistence and Recreational Fishers

Authors	**Study Details**	**Intake Figures**

Godin et al. 2003	Cardiovascular study surveying 112 male anglers along the St. Lawrence River, Montréal	Annual consumption of 55 to 77 sportfish meals and 35 commercial fish meals for a total of 90-112 seafood meals/year Equivalent to 27 g/day sportfish and 14 g/day of commercial fish, for a total seafood intake of 41 g/day
Loranger et al. 2002	Methylmercury exposure study examining 94 recreational anglers in James Bay	87 g/day, eaters-only mean
Great Lakes Health Effects Program, 1997	Ontario fish and wildlife consumption survey, conducted over 3 years, 4500 respondents	52% consumed 11 finfish meals/year 22% consumed 12-25 finfish meals/year 21% consumed 26-95 finfish meals/year 6% consumed > 97 meals/year Meal size was not defined
Ontario Ministry of the Environment, 1986	Guide to Eating Ontario Sportfish, sample size unknown	25 g/day or 31 meals/year Mean meal size 291 g
Ontario Ministry of the Environment, 1988	Sportfish Contaminant Monitoring Program, sample size unknown	14 g/day or 21 meals per year Mean meal size 244 g
Cavan et al. 1996	Freshwater fish consumption in 20 Vietnamese immigrant women near Hamilton, Ontario	34-58 meals/year or approximately 19 g/day
Kostasky et al. 1999	Contaminant exposure in 223 St. Lawrence ice-fishers in Montréal	18 kg/year or 50 g/day, high level fishers 3.3 kg/year or 9.0 g/day, low-level fishers

Shatenstein et al. 1999	Contaminant exposure and fish consumption of 18 St. Lawrence ice-fishers in Montréal	47 meals/year or 19 g/day, Bangladeshi fishers 41 meals/year or 17 g/day, Vietnamese sportfishers

Table A3. Summary of Canadian Studies of First Nations and Inuit Groups

Authors	**Study Details**	**Intake Figures**
Dewailly et al. 2003	Fish and marine product consumption and blood lipids in 3 ethnic groups in Québec, using data presented in the Santé Québec Heart Health Study	13 g/day, southern Québecois 60 g/day, James Bay Cree 131 g/day, Nunavik Inuit
Richardson and Currie, 1993	Determination of mercury exposure in 4327 adults at 58 aboriginal reserves across Ontario	Geometric mean 16 g/day; males 19 g/day and women 14 g/day
Chan et al. 1999	Contaminant exposure and freshwater fish consumption in 42 residents of a Mohawk Community	23 g/day, all fishers 33 g/day, eaters-only
Indian and Northern Affairs, 2003	Dietary surveys among 207 women in two Inuit communities, Repulse Bay and Pond Inlet	43 g/day, Repulse Bay 37 g/day, Pond Inlet