Lake Whatcom Fish Advisory

Washington State Department of
Health

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Overview

In 1998, the Department of Ecology (Ecology) conducted a screen-level survey of contaminants in various fish species in Lake Whatcom. Of particular note, the results of this survey indicated that mercury levels in smallmouth bass were elevated. Based on this information, the Whatcom County Health and Human Services (WCHHS) asked the Washington State Department of Health (DOH) to assess the potential health impacts to consumers of Lake Whatcom fish. To address these concerns DOH, working with the Washington State Department of Fish and Wildlife (DFW) and Ecology developed a fish tissue-sampling plan to obtain more comprehensive data on mercury concentrations found in fish species caught and consumed from Lake Whatcom. In addition, DOH conducted a fish consumption survey of local residents, shore and boat anglers to determine what fish people were consuming, how frequent they consume fish, and how much fish they were consuming from the lake. Using this information DOH conducted a health assessment to determine whether fish from Lake Whatcom pose a potential health threat to consumers. This health assessment resulted in DOH recommending to WCHHS that a fish advisory for smallmouth bass and yellow perch is prudent in order to protect sensitive populations including women of childbearing age and young children from potential adverse health effects of mercury.

Findings

Six finfish species and signal crayfish were collected by DFW and analyzed by Ecology. Concentrations of total mercury were assessed in fillets of 273 fish. Results indicated that average mercury concentrations were highest in smallmouth bass (0.49 ppm), followed by yellow perch (0.20 ppm), brown bullhead (0.16 ppm), kokanee (0.12 ppm), pumpkinseed (0.10 ppm), crayfish (0.10 ppm), and cutthroat trout (0.07 ppm). Smallmouth bass mercury levels while relatively high are within ranges seen across the U.S. and Canada.

Consumption survey results indicate that residential anglers consumed, in order of preference cutthroat trout, smallmouth bass, kokanee, and perch. Boat anglers primarily consumed cutthroat trout and smallmouth bass while shore anglers primarily consumed smallmouth bass. Fish consumption data averaged within each of the three angling populations were not significantly different from one another with the exception of the number of fish meals consumed per month. Shore anglers tend to consume fish from Lake Whatcom more frequently. Most anglers reported eating fish three or fewer months per year and those that were catching and eating fish were generally the older segment of the population.

Children had similar consumption patterns to adult household members. Survey respondents who consume fish from Lake Whatcom also reported consuming canned or fresh tuna on average of one meal per week. This suggests that tuna consumption may be a more significant source of mercury exposure for many local residents than fish from Lake Whatcom.

In conducting a health assessment, DOH compared the level of chemical contamination in fish tissue in conjunction with consumption data to derive a dose that was then compared to a safe dose established for mercury. DOH recently established a tolerable daily intake (TDI) for methylmercury that is unlikely to result in adverse health effects. This TDI is based on the most sensitive population at risk, women of childbearing age and children under the age of six. Based on the comparison between the calculated dose and the TDI for mercury, those individuals who consume smallmouth bass caught from Lake Whatcom on a weekly or monthly basis are likely to exceed this value and are potentially at risk of adverse health effects. Anglers who consume yellow perch once a week are likely to be at the TDI. In addition, survey respondents who consume more than one can of tuna per week will exceed the TDI (see statewide fish advisory for mercury). Based on this information, DOH recommendations to WCHHS are as follows.

Women of childbearing age and children under six should:

- Not eat smallmouth bass caught in Lake Whatcom
- Limit the amount of Lake Whatcom yellow perch they eat. Recommended weekly limits for yellow perch are based on body weight.

DOH is also providing consumption guidelines based on an individuals weight for other fish species caught and consumed from Lake Whatcom.

LAKE WHATCOM FISH ADVISORY

Introduction

This report provides recommended guidelines for consumption of fish from Lake Whatcom. These guidelines are provided to Whatcom County Health and Human Services (WCHHS) in response to findings of high levels of mercury in fish tested from Lake Whatcom. The aim of the guidance is to protect the public against possible adverse health effects that may result from consumption of mercury-contaminated fish. This report provides background information and a description of the data and criteria used to develop the guidelines.

Recently, several federal government agencies have presented data indicating that women of childbearing age who consume fish may be potentially over exposed to mercury. In 1999, the U.S. Congress tasked the National Academy of Science (NAS), National Research Council (NRC) to develop appropriate exposure limits for methylmercury (NRC 2000). The NAS report concludes that children of women who consume large amounts of fish and seafood during pregnancy might be at special risk for neurological problems. The report estimated that each year about 7% of women in the U.S. exceed the U.S. Environmental Protection Agency's (EPA) recommended limit for methylmercury exposure (0.1 microgram per kilogram per day). If that estimate is extrapolated to newborn infants, an estimated 60,000 babies born each year are at risk for toxic exposure. Potential effects might result in neurological damage that could lead to poor school performance due to children's exposure to methylmercury in utero. The chair of the NRC committee commented that "trends in methylmercury exposure, including regional differences, should be analyzed, as should subpopulations whose diets are high in fish and seafood. And we need to better understand how this chemical affects brain development in fetuses and children."

The Center for Disease Control and Prevention (CDC) analyzed preliminary estimates of blood and hair mercury levels from the 1999 National Health and Nutrition Examination Survey (NHANES 1999), and compared them with findings from the NRC report. Estimates from this analysis show that approximately 10% of women have mercury levels within one tenth of potentially hazardous levels. This indicates a narrow margin of safety for some women, and supports efforts to reduce methylmercury exposure (CDC 2001).

In response to these findings, The Washington State Department of Health (DOH) presents guidance and advice to WCHHS so they can inform individuals who consume fish caught from Lake Whatcom. This information is based on the NRC review, CDC's analysis, and DOH's review and evaluation of methylmercury.

Background

Lake Whatcom is located in the northwest corner of Washington State, in Whatcom County, at the western edge of the Cascade Range foothills. Lake Whatcom is a large lake extending approximately twelve miles from north to south with a surface area of approximately 4,836 acres. With its many bays and inlets, Lake Whatcom's shoreline extends approximately twenty-eight miles. Lake Whatcom has multiple uses including fishing, swimming, boating, and other forms of water recreation. It also is the drinking water source for the City of Bellingham. Information from the City of Bellingham's monitoring data for 1988-1999 show that the drinking water supply obtained from Lake Whatcom is safe (Personal communications, Steve Hulsman). In fact, analysis of the city of Bellingham's drinking water indicates that the lake is a good source.

Human health concerns over mercury contamination of Lake Whatcom fish were raised following a 1998 screening–level survey of fish conducted by the Washington State Department of Ecology (Ecology) (Serdar and Davis, 1999). A single composite sample of eight smallmouth bass (*Micropterus dolomieui*) fillets was found to contain 0.5 mg/kg (0.5 ppm: parts per million, wet weight) of mercury. Fish tissue mercury concentrations in the range of 0.5 ppm may be sufficiently high to pose a potential health concern for some segments of the population.

For clarification, mercury exists in several forms in the environment including metallic, inorganic and organic mercury. Some microorganisms and natural processes can change the mercury in the environment from one form to another. The most common organic mercury compound formed is methylmercury. Methylmercury is of particular concern because it can build up in certain edible freshwater and marine fish to levels that are many times greater than the levels in the surrounding water. The mercury in fish tissue is composed almost entirely of this organic form.

Mercury Levels in Fish from Lake Whatcom

To address this concern, the first step taken was to obtain more comprehensive data on mercury concentrations found in fish species caught and consumed from Lake Whatcom. The Washington State Department of Fish and Wildlife (WDFW) undertook sampling of Lake Whatcom fish, with the goal of quantifying mercury concentrations in fish species potentially consumed by Lake Whatcom anglers.

DOH, working with WDFW, Ecology and Whatcom County Health and Human Services (WCHHS) constructed a sampling plan that would help quantify mercury concentrations in fish species potentially consumed by Lake Whatcom anglers (DOH request letters to WDFW and Ecology) and help answer the question of whether fish from Lake Whatcom pose a potential human health threat. WDFW collected fish from Lake Whatcom from May 12 to June 2 of 2000. Samples of six finfish species and signal crayfish were collected from each of the three major basins of Lake Whatcom. Ecology then analyzed these fish for total mercury. Concentrations of total mercury were assessed in edible muscle (fillet) tissues in a total of 273 fish. Tissue from each fish was individually analyzed so as to determine fish tissue mercury concentrations variability in mercury concentration by fish species and location. Ecology's report, *Mercury Concentration in Edible Muscle of Lake Whatcom Fish*, March 2001 (Serdar et al., 2001) indicates that mercury concentrations were much higher in smallmouth bass (*Micropterus dolomieui*) compared to yellow perch (*Perca Flavescens*), brown bullhead (*Ameiurus nebulosus*), kokanee (*Oncorhynchus nerka*), pumpkinseed (*Lepomis gibbosus*), cutthroat trout (*Oncorhynchus clarki*), and signal crayfish (*Pacifastacus leniusculus*). A summary of average mercury concentrations and concentration ranges for these species can be seen in Table 1. Results of the tissue analysis are also described in Ecology's report (Serdar et al., 2001).

Consumption Survey Results

DOH, in collaboration with WCHHS conducted a survey of Lake Whatcom residents and anglers between July 21 and July 24, 2000 to address questions pertaining to human exposure to mercury from Lake Whatcom fish. The purpose of the study was to gather baseline information on the consumption of Lake Whatcom caught fish by local residents. Another goal of the survey was to determine residents' perceptions related to fish advisories in general (DOH 2001a). The survey included three distinct groups who have access to the lake; residents who live on the lake's shore or in developments with direct access to the lake, boat anglers accessing the lake through public or private boat launches, and anglers using public access points for shore fishing. Consumption survey results were then used in conjunction with fish tissue mercury data and mercury toxicology information to assess the human health implications for consumers of Lake Whatcom fish.

In summary, survey results indicate that lakeside residents most commonly consume cutthroat trout, kokanee, smallmouth bass, perch and crayfish. Boat anglers also reported that the most commonly consumed fish were cutthroat trout, smallmouth bass, crayfish, kokanee, and perch. Shore anglers caught and consumed smallmouth bass, cutthroat trout, perch, and pumpkinseed. Estimated species-specific fish meal sizes for these can be seen in Table 2.

Respondents were also asked about their consumption rate of canned tuna over a four-week period. Lakeside residents who indicated they consume canned tuna did so on average of 4.2 times (range from one to twenty-eight times). Boat anglers who reported consuming canned tuna did so on average of 3.3 times (range of one to eight). Shore anglers who reported consuming canned tuna did so on average of 4 times (range two to five).

Toxicology of Methylmercury

Human exposure to methylmercury through the consumption of contaminated fish is a global concern. Exposure through diet has increased the body burden of methylmercury in animal and human populations. A spectrum of adverse health effects has been observed following methylmercury exposure. The severity of effects depends largely on the magnitude of exposure. Human health effects from exposure to methylmercury have been evaluated in several poisoning episodes that occurred from acute high-dose exposures in the 1950's, 1960's, and early 1970's (NRC 2000, Agency of Toxic Substances and Disease Registry [ATSDR] 1999). The first of these occurred in Japan, where fish were contaminated with very high levels of methylmercury due to mercury-containing factory waste being discharged into Minamata Bay. The consumption of these fish and the resulting poisoning outbreak indicated that the prenatal period was a very sensitive period for exposure to methylmercury. Severely brain damaged infants were born to mothers who hardly showed ill effects (Harada 1995). This episode provided the first evidence that methylmercury was bioaccumulating and biomagnifying in locally caught fish. A poisoning incident involving seed grain treated with methylmercury fungicide occurred in Iraq (Marsh et al., 1987). In this incident the grain was mistakenly used to make bread. Consumers developed permanent brain damage as a result of methylmercury exposure.

In each of these poisoning episodes, many people experienced severe adverse health effects. Deaths were seen in both adults and children. Until recently the more subtle effects from low-dose exposure to methylmercury had to be extrapolated from the data from acute, high-dose poisonings. It is important to note that the amounts of mercury ingested in these episodes were much higher than levels commonly consumed in the U.S. Methylmercury is known to cross the placental barrier following adult exposure, resulting in prenatal exposures that can lead to developmental effects. These effects were borne out by further studies on these communities that documented neurotoxic effects in children. An important finding recognized that infants born from women who were exposed while pregnant, showed nervous system damage even when mothers were only slightly affected or showed no signs of toxicity. Infants exposed during fetal development displayed blindness, deafness, impaired motor functions, abnormal reflexes, seizures, deficiencies in memory, learning, and psychological parameters. Effects on the developing nervous system are considered to be the most sensitive endpoint from methylmercury exposure. The available data clearly indicate that the populations of greatest concern consist of women of childbearing age, and children under the age of six (NRC 2000, ATSDR 1999).

More recently, three major scientific studies were conducted in the Seychelles and Faroe Islands, and New Zealand. Their purpose was to address potential health effects from exposure to methylmercury at the low levels that typically occur from consumption of seafood. Each of these studies was well designed and carefully conducted, and each examined prenatal methyl mercury exposures within the range to which the general U.S. population is exposed. The Seychelles Islands study investigated the effects of prenatal exposure to methylmercury through maternal fish consumption, by testing for fetal neurodevelopmental effects during infancy and childhood (Davidson et al., 1995, 1998). Similarly, the New Zealand study (Kjellstrom et al., 1986, 1989) used a research design and exposure pattern similar to that of the Seychelles study, however, examining a generally ethnically mixed population. The Faroe Islands study looked at the effects of prenatal exposure to methylmercury through maternal consumption of fish and whale (Grandjean et al., 1997). No observable adverse neurodevelopmental effects were seen in children in the Seychelles, nor were abnormalities observed based on clinical examinations of children in the Faroe Islands and New Zealand studies. However the studies showed that methylmercury exposure was associated with poor neurodevelopment functional outcomes, such as dysfunctions in language, attention and memory. Currently it is not known whether these effects from low-level exposure to methylmercury are transient or chronic in nature. EPA, NRC, Agency of Toxic Substances and Disease Registry (ATSDR), and office of Environmental Health Assessment (OEHA) each reviewed the results of the Seychelles, Faroe Islands, and New Zealand studies to derive a safe intake level.

In addition to neurologic effects, other health effects from exposure to methylmercury have been shown in studies involving humans and animals. Human epidemiological studies have not shown an association with mercury exposure and increases in overall cancer rates (NRC 2000); however two studies involving small population numbers cited an association with exposure to mercury and acute leukemia. A limitation of these studies was the inability to control for other risk factors. In animal studies, chronic high-level exposure to methylmercury increased the incidence of renal tumors in mice. This effect was, however, believed to be secondary to the cell damage and repair caused by the high dose. Based on human and animal data, the International Agency for Research on Cancer (IARC) and EPA has classified methylmercury as a “possible” human carcinogen. Evidence of human exposure causing genetic damage is inconclusive.

A variety of immune system effects have been demonstrated in animal studies (NRC 2000). These studies show that the immune systems of certain animals are sensitive to methylmercury. Occupational studies of mercury compounds other than methylmercury show an association with decreased immune response in workers. A variety of human reproductive effects including increased incidence of spontaneous abortions, decreased fertility and reproductive success have been linked to metallic or elemental mercury. No studies have been identified that evaluate human reproductive success and methylmercury exposure. However, numerous animal reproductive studies show a variety of toxic effects from methylmercury exposure including abnormal sperm production, fetal malformations, and more commonly, increased rates of abortion and decreased litter size.

Occupational exposure to mercury vapor is associated with adverse effects on the kidney but is rarely documented following human exposure to organic forms of mercury. The kidney is the target organ for inorganic mercury, as well as methylmercury induced renal toxicity, in animals.

While numerous studies have shown that fish consumption has protective affects against cardiovascular disease and is generally considered beneficial, the consumption of fish contaminated with methylmercury has been associated with adverse cardiovascular effects. Mercury accumulates in the heart, and exposures to organic and inorganic forms of mercury have been associated with blood-pressure alterations and abnormal cardiac function. These effects have also been observed in animal studies and two recent epidemiological studies conducted in Finland (Salonen et al., 1995; Sorensen et al., 1999). Further research is need before conclusions can be made regarding cardiovascular effects.

Although mercury can produce adverse effects on other organs systems, it is generally thought that the central nervous system is the most sensitive target. Protecting populations from the most sensitive endpoint will ultimately protect individuals from other possible adverse effects that occur at higher exposures. For further information regarding the toxicological effects of methylmercury, please refer to the NRC report (NRC 2000), ATSDR's toxicological profile for methylmercury (ATSDR 1999), EPA's report to Congress (EPA 1997) or DOH's Evaluation of Evidence Related to the Development of a Tolerable Daily Intake for Methylmercury (DOH 1999).

Comparison of Mercury Concentrations

Nearly all fish contain trace amounts of methylmercury. In areas where there is industrial pollution, the levels in fish can be quite elevated. Numerous studies have evaluated freshwater sport fish species in North America for various contaminants. The following describes the results of some of those studies. The U.S. Fish and Wildlife Service collected freshwater fish from 98 monitoring stations nationwide and analyzed them for mercury and other heavy metals as part of the National Pesticide Monitoring Program (NPMP), (May and McKinney 1981). Most of these sites were located in industrial areas. The average concentration of mercury reported was 0.11 ppm (range, 0.01-0.84 ppm). A follow up survey to the NPMP, conducted in 1980 – 1981 showed similar mercury concentrations (Lowe et al., 1985). From 1986 – 1989, the EPA monitored 60 toxic pollutants, including mercury, nationwide, in the National Study of Chemical Residues in Fish (NSCRF) (EPA 1992). The average concentration in fish from 373 monitoring sites was 0.26 ppm. These sites were a mixture of industrial and nonindustrial settings. A national survey conducted by EPA as part of their fish contaminant-monitoring program was conducted during 1990 - 1995 (EPA 1999). This program looked at mercury fish tissue residue data collected in 39 states. The two fish species (largemouth bass and channel catfish) that have the widest geographical distribution have maximum mercury concentrations of 4.36 and 2.57 ppm respectively. More recently a study analyzing mercury concentrations in a variety of freshwater sport fish, conducted in the Northeast and Eastern Canada (NESCAUM 1998), found that predatory fish (walleye, pickerel, large and smallmouth bass) had, on average, greater than 0.50 ppm mercury. More specifically, smallmouth bass had an average of 0.53 ppm (range, 0.08 – 5.0 ppm). Many of the sampling sites were remote lakes that did not have point sources of pollution. Mercury concentrations in crayfish sampled in 13 lakes in Ontario with no known point sources ranged from 0.02 to 0.64 ppm (Allan and Stokes 1989).

Limited data on contaminant concentrations, including mercury, exist for freshwater fish in Washington State. Twenty-three samples of various fish species taken from lakes and rivers found mercury concentrations ranging from 0.02 – 0.54 ppm (Serdar et al., 2001). The largest dataset on mercury concentrations in Washington State comes from Lake Roosevelt, where forty-five walleye (*stizostedion vitreum*) samples had an average concentration of 0.28 ppm with a range of 0.11 – 0.44 ppm (Johnson et al., 1988, Munn and Short 1997).

Store bought or commercially caught fish (generally marine fish species) have typically been regulated at the national level. The FDA conducted a market basket survey in the early eighties, of foods that are representative of the total diet of the U.S. population (Gunderson 1988). In this survey, various industrial chemicals including mercury were analyzed. Mercury was detected in 129 foods. Fish and shellfish accounted for over 75% of the total mercury intake (see FDA market basket survey). In 1991, the FDA surveyed 220 random cans of tuna, and found an average methylmercury level of 0.17 ppm mercury (range, <0.10 – 0.75 ppm) (Yess 1993). Levels of methylmercury were higher in solid white (0.26 ppm) and chunk white tuna (0.31 ppm) than in chunk light (0.10 ppm) or chunk tuna (0.10 ppm). Certain species of predatory fish such as shark, swordfish, king mackerel, tilefish, and larger tuna typically have greater than 1 ppm (FDA 1995). The average concentration of methylmercury for commercially important species (mostly marine in origin) is less than 0.30 ppm.

Based on these finding as well as other factors, on January 12, 2001 the FDA and EPA issued national advice on limiting consumption of both freshwater and marine fish due to methylmercury contamination. EPA's national advisory was aimed at risks associated with mercury in freshwater fish caught by friends and family and recommended that women who are, or may become pregnant, nursing mothers, and young children to limit consumption to one meal per week (EPA 2001). The FDA advisory also warned of the hazards of consuming certain kinds of marine fish that may contain high levels of methyl mercury. The FDA is advising pregnant women and women of childbearing age who may become pregnant not to eat shark, swordfish, king mackerel, and tilefish (FDA 2001). FDA also advises women who eat an average of 12 ounces of fish from stores and restaurants, not to eat fish caught by their family or friends that week.

Regulatory Guidelines

In conducting a health assessment, OHEA uses an approach similar to EPA's risk-based approach to characterize and evaluate risks from exposure to chemicals. This approach compares the level of chemical contaminants in fish tissues in conjunction with consumption information to derive a dose that is then compared to a safe dose established for that chemical. EPA uses a reference dose (RfD) that is defined as an estimate, with uncertainty spanning perhaps an order of magnitude (one order of magnitude corresponds to a ten fold difference, two orders of magnitude corresponds to 100 fold difference, etc.), of the daily exposure of the human population, including sensitive subpopulations, to a potentially hazardous material that is likely to be without risk of deleterious noncancerous effects during a lifetime. Currently, EPA's RfD for methylmercury is 0.1 μg/kg/day based on information mainly from the Iraq episode. The Department of Health has established a tolerable daily intake (TDI) for methylmercury that is unlikely to result in adverse health effects (DOH 1999). This intake level, which is provided as a range, was based in part on information garnered from the Seychelles and Faroe Islands scientific studies, mentioned above, that investigated sensitive endpoints in children of mothers who consume mercury-contaminated fish over prolonged periods of time. The sensitive endpoints are impaired neurological development and, long-term and/or delayed neurotoxic sequellae. Based on OEHA's review of the available data, an intake of methylmercury in the range of 0.035 to 0.08 μg/kg/day constitutes a TDI that is deemed to not result in adverse health effects. What is not known is at what level of exposure above the TDI an adverse effect is likely to occur. A range is provided to account for uncertainties in the data. In evaluating fish from Lake Whatcom, DOH used the upper value of 0.08 μg/kg/day, based on supportive values from the EPA's and the NRC's review and recommendations.

The ATSDR uses Minimal Risk Levels (MRLs) in their health evaluations. However these estimates which are intended to serve as screening levels, are used by ATSDR health assessors to identify contaminants and potential health effects that may be of concern at hazardous waste sites. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. ATSDR derived a MRL of 0.3 μg/kg/day for methylmercury, based on the Seychelles Islands study.

The U.S. Food and Drug Administration has established an action level of 1 ppm for mercury in fish and shellfish sold and bought in interstate commerce. This value is based on assumptions about national fish consumption habits and levels of contamination in commercial seafood products. In setting this level, FDA assumes a consumption rate of 7 ounces of seafood per week, which translates to approximately 28 grams per day. Using this consumption rate, it is possible to calculate a mercury intake level for comparison with allowable daily mercury intake levels set by other agencies. FDA's calculated mercury intake level becomes 0.47 μg/kg/day. EPA does not support application of the FDA's standard to sport fish since the risks may be greater to fishers who consume large amounts of fish from local water bodies. EPA encourages states and tribes, whose responsibility is to assess and manage risks from contaminated sport fish, to use a risk-based approach in evaluating human health risks and issuing advisories.

While the FDA uses 1ppm as the limit (action level) for methylmercury concentration for commercially sold fish, DOH does not recognize this value as being protective. DOH's TDI is expressed on a microgram per kilogram per day (μg/kg/day) basis that is not directly comparable to a fish tissue concentration. As mentioned previously, an intake rate can be calculated for comparison with other regulatory values such as a TDI or RfD. FDA's value is nearly five times higher than allowed by EPA and nearly six times higher than the upper range of DOH's TDI. In promulgating a fish advisory for mercury, DOH is more protective of health than a fish advisory using FDA's action limit would be.

Exposures to mercury considered protective by different health and regulatory agencies often seem to be in conflict (see Table 3). Some of these differences are due in part to definitions of a safe level used by various agencies, such as an RfD or an MRL. Other differences occur because different agencies have differing regulatory mandates. In addition, various agencies rely on differing epidemiological or toxicological studies to derive a safe level. Application of differing consumption rates and uncertainty factors also can have an impact on the protective level of exposure derived. OEHA's recommended TDI, which was based mainly on the Faroe Island study, is more protective (lower exposure limits on a per weigh per day basis) than values derived by EPA, ATSDR, or FDA. However, the upper range of the TDI is similar to EPA's current value and in line with that proposed by the NRC.

It is important to note which assumptions are made in defining a safe level. Susceptibility to adverse effect can result from differences in frequency, duration and magnitude of exposure, or from variability in sensitivity to adverse effect. For instance, parameters taken from the studies described above reflect average intake on a daily basis. It is possible, however, that adverse effects of methylmercury exposure are more directly related to the magnitude of peak exposure, such as could result from one or a few closely spaced meals of fish with high mercury concentration, rather than the average exposure level over a month or year. Unfortunately, the design of the studies for low-level methylmercury exposure makes it impossible to distinguish the influence of average versus peak exposure. Other uncertainties that can change outcomes in protective level derivation are lack of knowledge about the variability within the different study populations. Some populations may differ in their sensitivity to toxic insult because of differences in genetic pre-disposition, age, gender, state of health and nutrition, or exposure to other contaminants.

Determining if Individuals are over the TDI

To estimate the Lake Whatcom angler's exposure to mercury, DOH used information from the Lake Whatcom consumption survey, coupled with fish tissue concentrations from Ecology's report. Anglers were divided into three groups; residential, boat, and shore anglers. Median meal size values for a specific species were coupled with the mean concentration of mercury for that species. The daily intake of mercury for smallmouth bass, yellow perch, kokanee, and cutthroat trout was estimated as the product of the median meal size and the mean fish tissue mercury concentration for that species in Lake Whatcom. This value was then multiplied by 7 to average the dose of a single meal over a week. Similarly, the value was multiplied by 30 to average the dose of a single meal over a month. This value was converted to units of micrograms per kg body weight per day (μg/kg/day) (assuming an average body weight of 60 kg) and compared to the upper range of the TDI (0.08 μg/kg/day) (see equation below).

$$Daily\ Intake = \left(Consumption\ rate\ x\ Conc.in\ Fish\right) \div \left(Body\ Weight\ \ x\ Unit\ Conversion\ Factor\right)$$

Results of this comparison are shown in Table 4.

As indicated in DOH's consumption survey for Lake Whatcom, only a small proportion of the local population fish the lake, and a substantially smaller fraction consumes the fish that they catch. Lake Whatcom anglers who consume fish that they catch do so on average of less than once per month, a few months out of the year. Shore anglers generally fish the lake most frequently, followed by boat anglers and then by residential anglers. Table 4 indicates that regardless of angler group, those that consume smallmouth bass from Lake Whatcom are likely to exceed the TDI for mercury based on mercury intake from a single meal averaged over a one-week period. This holds true for boat anglers even if their mercury intake from a single meal is averaged over a one-month period. In addition, residential anglers who consume perch are likely to reach the TDI based on mercury intake from a single meal, averaged over a one-week period.

Perhaps a much greater influence on mercury exposure (and therefore of greater concern for those anglers surveyed) is the consumption of canned tuna. Anglers were asked about their consumption of canned or fresh tuna over a four-week period. Respondents consumed canned tuna an average of 4.2 times more than sport fish, with individual consumption ranging from one to twenty-eight times. Women who responded consumed on average 3 meals of tuna per month, with a range of one to six meals per month. As discussed earlier, canned tuna has an average mercury concentration of 170 ppb (Yess 1993). Based on the average concentration of mercury in canned tuna as well as findings from the consumption survey, DOH has issued a statewide fish advisory that includes canned tuna. DOH recommends that a woman of childbearing age, who weighs approximately 130 pounds, not consume more than one can of tuna per week. Actual consumption recommendations are based on a women's weight (DOH 2001b). This level of consumption, barring exposure from any other source, would put a woman slightly under the TDI for mercury. Any additional intake of mercury from the consumption of fish from other sources would likely put a woman over the TDI. One limitation of the survey from Lake Whatcom is that the amount of canned tuna consumed was not determined. If it is assumed that the consumption is approximately one can of tuna (approximately 170 grams or 6 ounces per meal), then the concern is valid (see Table 5).

Determining Allowable Consumption Rates

Public Health officials are often asked not only whether the fish are safe to eat, (as determine by comparing the daily intake level of mercury with the TDI) but also how much a person can safely eat, regardless of the current consumption pattern. Providing an answer to this question allows anglers and fish consumers to make their own decisions regarding their consumption of fish. Such information should always be put in context of the known benefits of consuming fish. Answering this question is also helpful if consumption data is lacking, outdated, or inadequate. By using the known concentration of mercury in a fish species, it is possible to calculate an allowable amount that can be consumed for that species without exceeding the TDI. In this approach the TDI is used to back-calculate the quantity of fish a person of a given weight can safely consume, when the average contaminant concentration for a particular fish species is known. The equation used to calculate a safe consumption rate is seen below.

$$\frac{grams\ of\ fish}{day} = \left(TDI \times Body\,Weight \times Unit\ Conversion\ Factor\right) \div \left(Conc.\ of\ Hg\ \ in\ \ fish\right)$$

Based on this equation, there are two variables that affect the amount of fish a person can consume and remain below the TDI. These variables include the concentration of mercury in fish and an individual's body weight. Both the TDI and the unit conversion factors are constant. Reducing the consumption rate will also reduce exposure. The consumption rate is expressed as grams of fish per day. The TDI is expressed on a microgram per kilogram per day basis. The concentration of mercury in fish is the average concentration of mercury found in Lake Whatcom fish species that are caught and consumed, as determined in Ecology's fish tissue analysis. Body weight is the weight of an individual consuming fish. For illustration, the body weight of an average woman of 60 kg (approximately 132 lbs.) was used. This weight was chosen to ensure that the sensitive population (woman of child-bearing age) is factored into calculating the final consumption rate. Actual guidelines for fish consumption are based on body weight basis (see following section and figures) to account for differences in individual body weight, one of the variables that affects dose. The conversion factor is used to correct for proper units of measurement.

Applying the upper range (0.08 μg/kg/day) of the TDI and using the average concentration of mercury in small mouth bass of 0.49 ppm (490 μg/kg) the equation to calculate a safe consumption rate for a 60 kg woman becomes:

$$\frac{grams_{fish}}{day} = \left(\frac{0.08\,\mu g\ Hg}{kg_{person}\ day}\right) \div \left(\frac{490\ \mu g\ Hg}{Kg_{fish}}\right) \times \left(\frac{60\,kg_{person}}{1}\right) \times \left(\frac{1000\,gm_{fish}}{1kg_{fish}}\right)$$

For a 60 kg woman of childbearing age, the safe consumption rate is 9.8 grams of smallmouth bass per day. This is equivalent to approximately 0.35 ounces per day, or 2.45 ounces per week (16 ounces = 1 pound).

The allowable intake rates for chemical exposure for an individual are often expressed over a long period of time, i.e., on a monthly, yearly or lifetime. This is appropriate for certain types of chemicals that may produce chronic toxic effects such as cancer or chronic disease. Developmental toxicants such as mercury however elicit effects on a much shorter time frame. As mentioned above, the adverse effects of methylmercury may be more closely related to the magnitude of peak exposure that one would receive from a few closely spaced meals of fish with high mercury concentrations, than to an average exposure level over longer time periods. From a biological perspective it appears that what is important is to remain below the TDI on a daily basis. For this reason, it may not be appropriate to extrapolate the consumption rate from a daily basis to a weekly, monthly, or yearly basis. However, information used to confirm EPA's RfD and DOH's TDI are from studies that averaged exposure over longer periods of time and did not consider a short, onetime exposure scenario. Therefore we have chosen not to use these exposure limits strictly on a per day basis but rather to average the exposure out over a week. Another reason for this is that people tend to have a better idea of what that consumed over a week rather than for more extended time periods such as a month or year. Adjusting the TDI is accomplished by multiplying the RfD or TDI by 7 (days) to determine a tolerable weekly intake. Results of this approach for the various fish species by an individual's body weight are seen in Table 6.

Allowable consumption rates shown in Table 6 are based on individual fish species and not for combined consumption rates. It is important to keep in mind that people who consume fish from Lake Whatcom may be consuming multiple fish species and may also be consuming fish from other sources that are likely to have detectable levels of mercury. It is likely that their total exposure to mercury would be greater than that from Lake Whatcom fish. Without knowing whether other contaminated fish are consumed, or the amount that is consumed, or the level of contamination in consumed fish, it is not possible to determine a person's total exposure to mercury. Based on knowledge of mercury contamination globally, it is reasonable to assume that the consumption of different fish species from different sources will add to ones total body burden of mercury. Such consumption should be considered if an individual wants to consume fish and also wants to remain below the TDI for methylmercury.

Fish Consumption Guidelines Discussion

Fish consumption guidelines are meant to advise individuals about their own level of fish consumption by providing information on not only the potential risks associated with fish consumption but also the benefits from eating fish. The objective then is two fold. The first is to inform the public about potentially contaminated fish species by identifying those fish species that are contaminated to levels of concern, posing a greater health risk, and to limit the consumption of these fish species. The second objective is to ensure that people continue to consume fish species that are known to be low in contaminant concentrations and acknowledged to be a healthy source of protein. The intended goal is to protect the public from consuming more than the TDI of mercury while at the same time advocating the consumption of a healthy source of protein and other essential and healthful nutrients.

Fish are an excellent source of protein that is low in saturated fats, rich in vitamin D and omega-3 fatty acids as well as other nutrients. The health benefits of eating fish have been well documented and linked to the reduction of cardiovascular disease, osteoporosis, and partial reduction of certain types of cancer. These are major chronic diseases that afflict much of the U.S. population. A drawback is that fish accumulate contaminants from the water they live in, or the food upon which they feed. In certain fish species, some contaminants, such as methylmercury, build up over time to levels that pose a potential health threat. For that reason, rather than replace fish in the diet with other sources of protein such as red meat, that is known to contain saturated fat that has been linked to these diseases, the goal should be to increase the consumption of fish known to be low in methylmercury, and to decrease the consumption of fish known to have high methylmercury concentrations. Following these guidelines will help to reduce a person's exposure to methylmercury while allowing them to continue to eat fish.

The following specific guidelines were developed for the women of childbearing age, infants, and children as well as the general population that consume fish from Lake Whatcom. These guidelines are based on analysis of various fish species likely to be caught and consumed. They include smallmouth bass, yellow perch, brown bullhead, kokanee, pumpkinseed, cutthroat trout, and crayfish. Figures 1a-g are provided to determine how many meals of fish or crayfish an individual can consume based on the average concentration of mercury in specific fish species from Lake Whatcom and an individual's body weight. An average meal size of 8 oz. was used based on results from the Lake Whatcom Consumption Survey. EPA also uses this value in averaging the weight of a fish meal portion. In addition, consumption rates for a 4 oz. meal size is presented with the understanding that individuals who weigh less, such as children, are likely to consume smaller portion sizes. The exposure to mercury a person receives from eating fish is then expressed on a per weight basis to account for differences in body sizes that ultimately affect the dose as well as the amount that an individual is likely to consume.

It is important to note that the calculated number of meals that an individual could consume and remain below the TDI is based solely on the consumption of that species. For example, a 125-pound person could consume two meals per week of cutthroat trout and remain below the TDI provided that this was his or her only source of methylmercury (see Figure 1-g). This does not take into consideration other fish species consumed, either store bought or that an individual may have caught. An attempt is made below to help address the obvious shortcomings of presenting consumption data for a single species. See Figures 1 a-g.

DOH recommends an advisory for women of childbearing age and children under six not to consume smallmouth bass caught from Lake Whatcom, based on the concentrations of mercury in those smallmouth bass. This action is supported by information seen in Table 5 indicating that residential, boat, and shore anglers who consume smallmouth bass are likely to exceed the TDI.

Figure 1-a indicates that consuming one meal per week would put most individuals above the TDI. The consumption survey indicated that a few individuals consume yellow perch, which contains the second highest concentration of mercury in Lake Whatcom fish. Table 4 indicates that those individuals may consume the amount equal to the TDI based on a single meal of yellow perch averaged over a one-week period. Based on this information, restrictions on yellow perch may be warranted. Specifically, an average meal size of 8 ounces of yellow perch should not be consumed by women under 175 lbs and children. Reducing the meal size to 4 ounces would reduce the restrictions to women and children under 100 lbs (see Figure 1-b). Brown Bullhead and Kokanee, having mercury concentrations of 0.16 and 0.12 ppm respectively, do not warrant restrictions, due to low consumption rates, and relatively low mercury concentrations. Allowable consumption rates for these species are seen in Figures 1 c-d.

A statewide fish advisory for mercury by DOH also recommends that women of childbearing age, and children under the age of six limit consumption of store-bought canned tuna (DOH 2001b) that has similar mercury concentrations (average concentration of 0.17 ppm) to yellow perch and brown bullhead. The rationale for this state-wide advisory is that we assume that there are individuals consuming more than one can of tuna per week (one can of tuna weights approximately 170 grams or 6 ounces). Fish in Lake Whatcom that are below 0.16 ppm (brown bullhead, kokanee, pumpkinseed, cutthroat trout) do not warrant an advisory primarily due to the low consumption rates and because mercury concentrations in these fish are low. A 60 kg (132 lbs) woman can consume these fish species at rates of 7.4, 10, 11.9 and 17.7 ounces per week respectively, without exceeding the TDI. If a person were to consume enough of these fish species, it is conceivably possible to exceed a weekly tolerable intake rate for mercury. DOH has not identified any individuals that approach a sufficiently high consumption rate to exceed the TDI for these fish species and therefore we are not recommending an advisory for these fish.

Similarly, an advisory on crayfish is not recommended since few if any individuals were identified that consume these species. Some concern has been expressed that this species is commercially caught and sold at local markets and restaurants (personal communications with WDFW). Given the concentration of mercury in crayfish (0.10 ppm), a 60 kg individual could safely consume 11.3 ounces per week and stay below DOH's guidelines for mercury (Figure 1-f).

The recommendations for Lake Whatcom are aimed at protecting the most sensitive population (women of childbearing age and children under the age of six). This is based on DOH's TDI value, which is unlikely to result in adverse health effects. This value is about 25% lower (more protective) than what EPA uses. EPA' reference dose (RfD) uses a similar value aimed at protecting the most sensitive population. These values were confirmed by an independent review conducted by the National Research Council of the National Academy of Science. It is known that methylmercury can affect adults as well but at much higher concentrations than those seen in children. To illustrate this point, one need only to look at the poisoning episode that occurred in Minamata, Japan in the 1950's. Severe neurological and developmental effects have been shown for children of mothers who ingested mercury-contaminated fish. In many of these cases the mother had no symptoms. Effects in adults were seen but at much greater levels than seen in relevant fish concentrations here in Lake Whatcom. The critical or lowest level of observed adverse health effects in adults from Minamata is paresthesia (sensation of numbness). A calculated average long-term daily intake associated with health effects in the most susceptible adult population is 4300 μg/kg/day (Casarett and Doull 1996). This value is nearly 54 times greater than that for the TDI for the protection of women of childbearing age and children under six. If DOH were to use this dose in calculating what an adult could safely consume, for comparison sake, a 165 pound adult male could consume ten pounds a week of smallmouth bass containing 0.49 ppm of mercury and remain below the "safe dose" for an adult. Conversely, the mercury concentration that would put an adult over a "safe" level from eating a half-pound per week would be 9.9 ppm. Lake Whatcom bass have an average of 0.49 ppm. Given this consumption rate or concentration of mercury in fish, no advisory would be issued based solely on the general population. This is not to say that an adult could or should consume as much fish as he or she wants. Limited scientific information from human and animal studies suggests that possible health effects involving the cardiovascular or reproductive system to the general population might occur at lower levels. Currently it is not known if or at what level these effects might occur. More research is required to determine if low-level effects occur to the general population and if so, what that exposure level might be. For those individuals who are concerned about their exposure to mercury, following the same guidelines for women of childbearing age and children will likely provide a fair margin of safety.

Advising individuals regarding their total methylmercury exposure from fish is difficult since people often eat a variety of fish species caught from a variety of locations (both salt and freshwater) that may have varying concentrations of mercury. Concentrations of mercury have not been measured in all species of fish in all locations in the state's waters. Advisories based on a single species are useful for preventing individuals from consuming fish known to be high in a contaminant, but do little to address total exposure to a contaminant from a variety of species. One possible approach that ensures that individuals will remain below the TDI while consuming the FDA recommended 12 ounces of fish per week would be to determine the average mercury concentration in fish that would allow for this consumption rate. By rearranging the equation above, one can calculate the average concentration in fish that an individual could consume and remain below the TDI. A 60 kg body weight is assumed for women of childbearing age.

$$conc.\ of\ \ Hg_{fish}\left(\frac{mg\ \ Hg}{kg}\right)=\left(\frac{0.08\ mg\ \ Hg}{kg_{person}\ day}\right)\times\left(\frac{60\ kg_{person}}{1}\right)\times\left(\frac{1000\ gm_{fish}}{1\ kg_{fish}}\right)\div\left(\frac{48.6\ gm}{day}\right)$$

The resulting average concentration in various fish species making up the 12 ounces per week is approximately 0.10 ppm.

EPA determined that the top ten species of seafood consumed by the U.S. population (EPA1996) include: tuna, shrimp, pollack, salmon, cod, catfish, clam, flounder, crab, and scallop. The average mercury concentration for these species (excluding tuna) is approximately 0.080 ppm (Table 7). Aside from tuna, nine out of the ten species were below 0.15 ppm. This would suggest that if an individual whose diet contains these fish species at a consumption rate of 12 ounces per week would be consuming the FDA-recommended amount of fish per week, yet remain below the TDI for mercury. This assumes that an equal amount of each of the types of fish is consumed over a week's time. For tuna consumption, refer to DOH's statewide fish advisory for mercury (www.doh.wa.gov/fish).

Recommended Advisory for Lake Whatcom

Women of childbearing age, infants and children

Women of childbearing age (approximately 15-45 years of age), infants, and children under six years old, should not eat smallmouth bass from Lake Whatcom. Restrictions on the consumption of yellow perch are warranted. Specifically, yellow perch should not be consumed more than shown in figure 1-b. No restrictions have been placed on the consumption of brown bullhead, kokanee, pumpkinseed, cutthroat trout, or crayfish. Consumption rates for all fish species from Lake Whatcom are provided to help fish consumers identify those species that contain low concentration of mercury, and to meet the FDA nutritional recommendations of consuming 12 ounces of fish per week (Figures 1a through 1g).

General Adults

The recommendations for Lake Whatcom are aimed at protecting the most sensitive population (women of childbearing age and children under the age of six). Limited scientific information from human and animal studies suggests that possible health effects involving the cardiovascular or reproductive system to the general population might occur from over exposure to methylmercury. Currently it is not known if or at what level these effects might occur. More research is required to determine if effects occur to the general population and at what exposure level. For those individuals who are concerned about their exposure to mercury, following the same guidelines for women of childbearing age and children will likely provide a fair margin of safety.

It should be noted that Lake Whatcom is closed to fishing for cutthroat trout (see Washington State Department of Fish and Wildlife's Sport Fishing Rules "Fishing in Washington State" pamphlet).

Glossary

Acute short-term exposure to a chemical, i.e. one dose or multiple doses occurring for a limited duration (usually less than 14 days); the effects form such an exposure

Anthropogenic deriving from a human source

Bioaccumulation net accumulation of a chemical by an organism as a result of uptake form all routes of exposure (e.g. food, water, dermal absorption)

Biomagnification accumulation of a chemical to higher concentrations at higher levels in the food web through dietary accumulation

Carcinogen an agent capable of inducing a cancer response

C*hronic* multiple exposures occurring over an extended period of time, or a significant fraction of the organism's life-time; effects from chronic exposure, or long-term effects from high short-term exposures

Developmental toxicity adverse effects on the developing organism (including death, structural abnormality, altered growth, or functional deficiency) that may result from exposure prior to conception (in either parent), during prenatal development, or postnatally up to the time of sexual maturation, and which may be detected at any point in the life span of the organism

Dose-response the relationship between the amount or magnitude of exposure (dose) and the biological response or toxic injury produced by the chemical

Endpoint an observable or measurable biological or chemical event used as an index of the effect of a chemical on a cell, tissue, organ, or organism

Epidemiology the study of the distribution and determinants of disease and injuries in human populations.

Half-life the period required for a chemical to decrease in concentration to one-half of the original concentration

Neurotoxicity adverse effects in the nervous system caused by chemicals, pathogens, or trauma

Noncarcinogen a chemical or substance that causes noncancer health effects

ppb parts per billion (μg/kg or microgram per kilogram) = (0.000001g/1000g) ppm parts per million (mg/kg or milligram per kilogram) = (0.001g/1000g)

Reference dose (RfD) an estimate (with uncertainty spanning perhaps and order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime

Sensitivity the condition whereby adverse health effects that occur from exposure to a chemical contaminant are determined by quantitative differences; a chemical can produce the same effect in infants, children, or adults, but the magnitude of effect differs

Susceptibility the condition whereby adverse health effects from exposure to a chemical contaminant are due to qualitative differences; such as, unique processes of growth and development in the exposed organism, particularly in young, not fully matured individuals, changes due to aging, state of health, nutritional status, or genetic predisposition to harm.

Tolerable Daily Intake (TDI) a daily intake level for a chemical that is unlikely to result in adverse health effects

Toxicology the study of the nature and mechanism of adverse effects of substances on living organisms or biologic systems.

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Tables

Table 1

Mercury Concentration in Lake Whatcom Fish			
Species	**n**	**Average Hg Conc. (ppm)**	**Range (ppm)**
Smallmouth Bass	95	0.49	0.10 - 1.84
Yellow Perch	30	0.20	0.05 - 0.87
Brown Bullhead	13	0.16	0.03 - 0.78
Kokanee	30	0.12	0.07 - 0.25
Pumpkinseed	30	0.10	0.03 - 0.28
Cutthroat Trout	30	0.07	0.03 - 0.20
Signal Crayfish	45	0.10	0.03 - 0.54

n = number of samples

Table 2

Estimated Species-Specific Fish Meal Sizes (ounces) for Commonly Caught and Consumed Lake Whatcom Fish Species					
Group / Species	**Smallmouth Bass**	**Yellow Perch**	**Kokanee**	**Cutthroat Trout**	**Crayfish**
Residential Angler					
sample size (n)	9	6	10	14	4
Fish Meal Size					
Median (oz/meal)	7.8	5.7	1.4	1.9	0.9
IQR	(7.8 -15.5)	(3.5 - 17.5)	(1.0 - 2.3)	(1.5 - 3.7)	(0.4 - 2.6)
Boat Angler					
sample size (n)	4	-	-	6	-
Fish Meal Size					
Median (oz/meal)	11.6	-	-	1.9	-
IQR	(7.8 - 23.3)			(1.5 - 3.0)	
Shore Angler					
sample size (n)	7	4	-	5	-
Fish Meal Size					
Median (oz/meal)	7.8	3.5	-	1.5	-
IQR	(7.8 - 15.5)	(2.7 - 5.3)		(1.5 - 1.5)	

IQR - Inner Quartile Range 25th - 75th percentile

Table 3

Agency	Intake Level	Description	Date
FDA	0.47 ug/kg/day*	Action Level	1994
EPA	0.10 ug/kg/day	RfD	1997
ATSDR	0.30 ug/kg/day	MRL	1999
NRC	0.10 ug/kg/day	confirm RfD	2000
Washington State Dept. of Health	0.035 - 0.08 ug/kg/day	TDI	2000

Table 4

Estimated Daily Intake of Hg for Lake Whatcom Anglers*					
	Meal Size (grams)	**Fish Tissue Hg Concentration (ppm)**	**Estimated Hg Intake per Meal (ug/meal)**	**Estimated Hg Intake Averaged over 1 week** (ug/kg/day)**	**Estimated Hg Intake Averaged over 1 month*** (ug/kg/day)**
Residential Angler					
Smallmouth Bass	220	0.49	1.80	0.26	0.060
Yellow Perch	162	0.20	0.54	0.08	0.018
Brown Bullhead		0.16			
Kokanee	40	0.12	0.08	0.01	0.003
Pumpkinseed		0.10			
Cutthroat Trout	53	0.07	0.06	0.01	0.002
Signal Crayfish	24	0.10	0.04	0.01	0.001
Boat Angler					
Smallmouth Bass	330	0.49	2.70	0.39	0.090
Yellow Perch		0.20			
Brown Bullhead		0.16			
Kokanee		0.12			
Pumpkinseed		0.10			
Cutthroat Trout	53	0.07	0.06	0.01	0.002
Signal Crayfish		0.10			
Shore Angler					
Smallmouth Bass	220	0.49	1.80	0.26	0.060
Yellow Perch	99	0.20	0.33	0.05	0.011
Brown Bullhead		0.16			
Kokanee		0.12			
Pumpkinseed		0.10			
Cutthroat Trout	42	0.07	0.05	0.01	0.002
Signal Crayfish		0.10			

shaded values indicate intake at or above TDI of 0.08 ug/kg/day
* based on 60 kg body weight
** intake from a single meal divided by 7 days
*** intake from a single meal divided by 30 days

Table 5

Estimated Hg Intake from Canned Tuna*			
Meal Size (ounces)	**Hg Conc. (ppm)**	**Estimated Hg Intake per meal (ug/kg/meal)**	**Estimated Hg Intake Averaged over 1 week (ug/kg/day)**
6 (1 can)	0.17	0.48 ug/kg/day	0.07

*based on a average women's body weight of 132 pounds
for comparison DOH's TDI for Hg is 0.08 ug/kg/day

Table 6

Allowable Consumption Rates (ounces of fish per week) of Individual Fish Species from Lake Whatcom							
Body Weight (lbs)	**Smallmouth Bass**	**Yellow Perch**	**Brown Bullhead**	**Kokanee**	**Pumpkinseed**	**Cutthroat Trout**	**Crayfish**
25	0.46	1.12	1.40	1.87	2.24	3.20	2.24
50	0.91	2.24	2.80	3.73	4.48	6.40	4.48
75	1.37	3.36	4.20	5.60	6.72	9.60	6.72
100	1.83	4.48	5.60	7.47	8.96	12.80	8.96
125	2.29	5.60	7.00	9.33	11.20	16.00	11.20
150	2.74	6.72	8.40	11.20	13.44	19.20	13.44
175	3.20	7.84	9.80	13.07	15.68	22.40	15.68
200	3.66	8.96	11.20	14.93	17.92	25.60	17.92
225	4.11	10.08	12.60	16.80	20.16	28.80	20.16
250	4.57	11.20	14.00	18.67	22.40	32.00	22.40
275	5.03	12.32	15.40	20.53	24.64	35.20	24.64
300	5.49	13.44	16.80	22.40	26.88	38.40	26.88
325	5.94	14.56	18.20	24.27	29.12	41.60	29.12
350	6.40	15.68	19.60	26.13	31.36	44.80	31.36

Table 7

Mercury Concentrations in the Top 10 Types of Fish Consumed by the U.S. Population*	
Fish	**Mercury Concentration (ppm)**
Tuna	0.206
Shrimp	0.047
Pollack	0.150
Salmon	0.035
Cod	0.121
Catfish	0.089
Clam	0.023
Flounder	0.092
Crab	0.117
Scallop	0.042

* adopted from ATSDR 1999

Figures

Figure 1a.

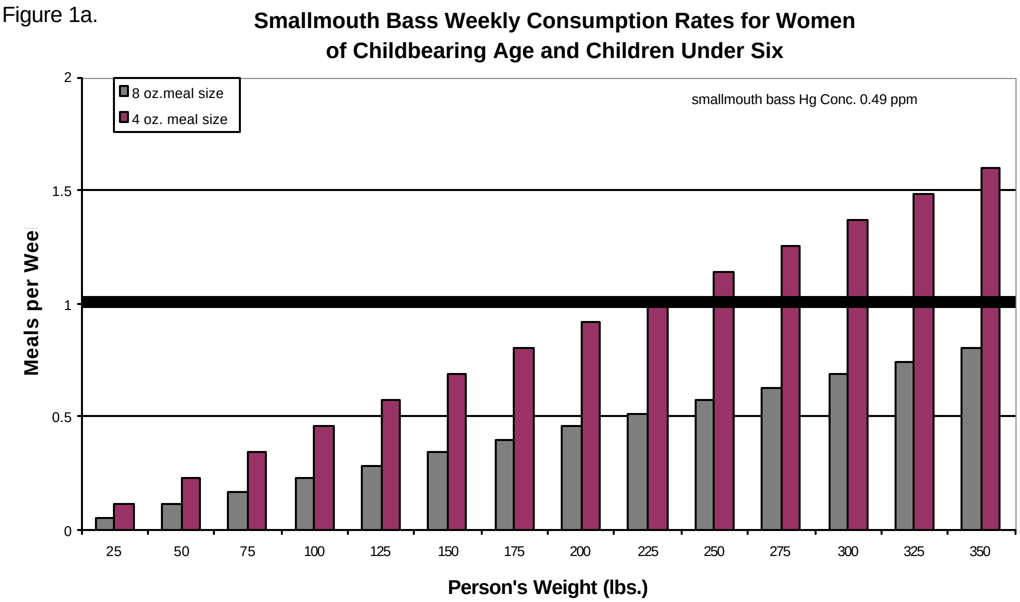

Smallmouth Bass Weekly Consumption Rates for Women
of Childbearing Age and Children Under Six
8 oz.meal size
4 oz. meal size
smallmouth bass Hg Conc. 0.49 ppm
Meals per Wee
2
1.5
1
0.5
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Person's Weight (lbs.)

Figure 1b.

Yellow Perch Weekly Consumption Rates for Women of Childbearing Age and Children Under Six

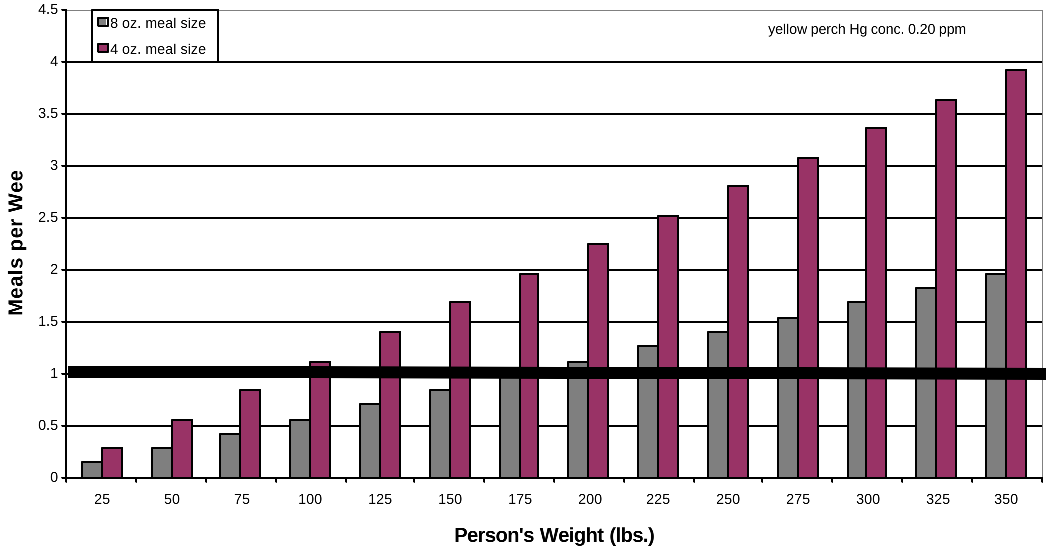


Figure 1c.

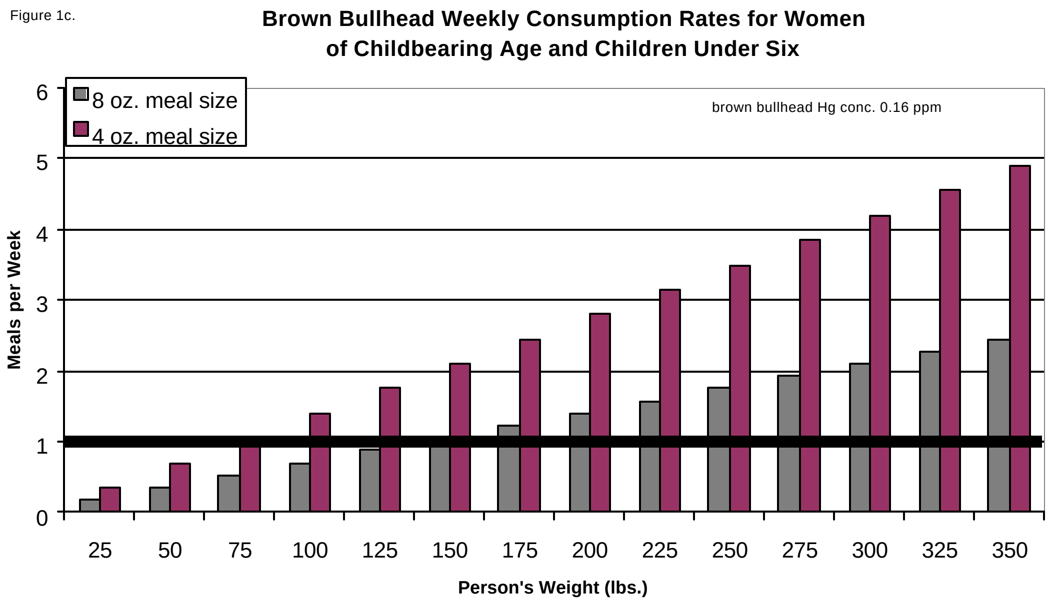

Brown Bullhead Weekly Consumption Rates for Women
of Childbearing Age and Children Under Six
8 oz. meal size
4 oz. meal size
brown bullhead Hg conc. 0.16 ppm
Meals per Week
0
1
2
3
4
5
6
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Person's Weight (lbs.)

Figure 1d.

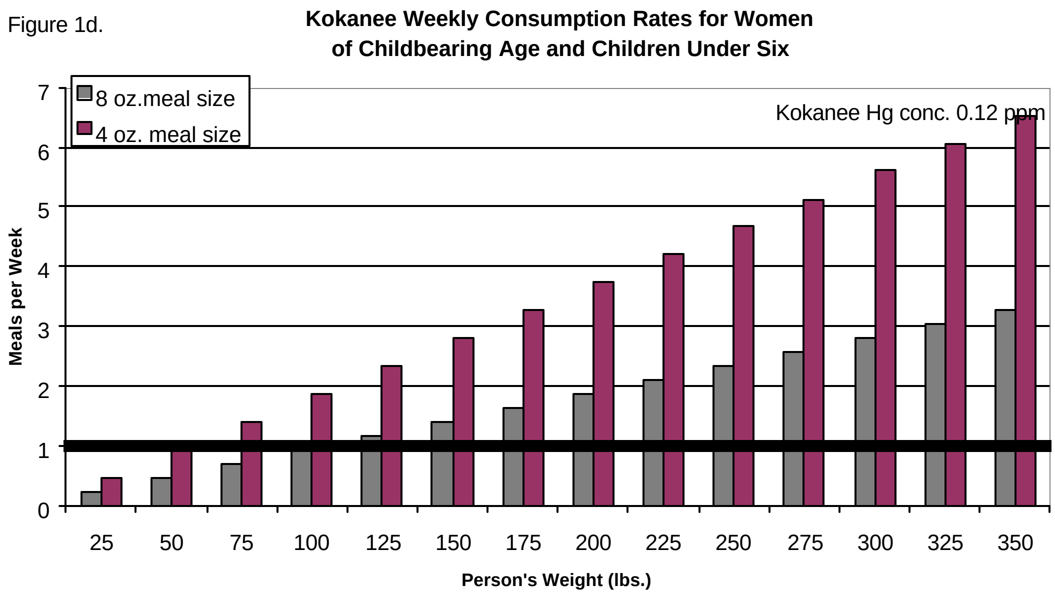

Kokanee Weekly Consumption Rates for Women
of Childbearing Age and Children Under Six
8 oz.meal size
4 oz. meal size
Kokanee Hg conc. 0.12 ppm
Meals per Week
0
1
2
3
4
5
6
7
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Person's Weight (lbs.)

Figure 1e.

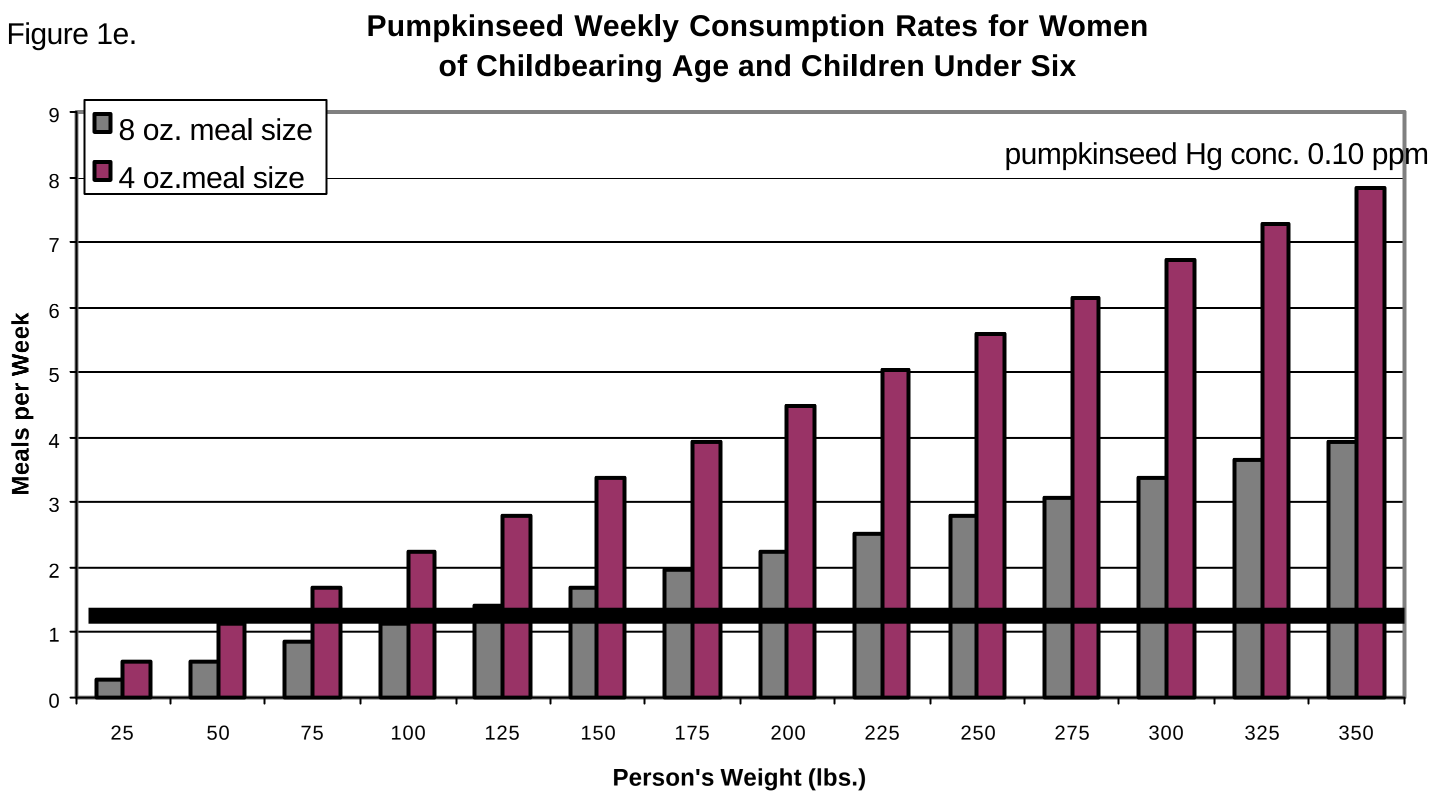
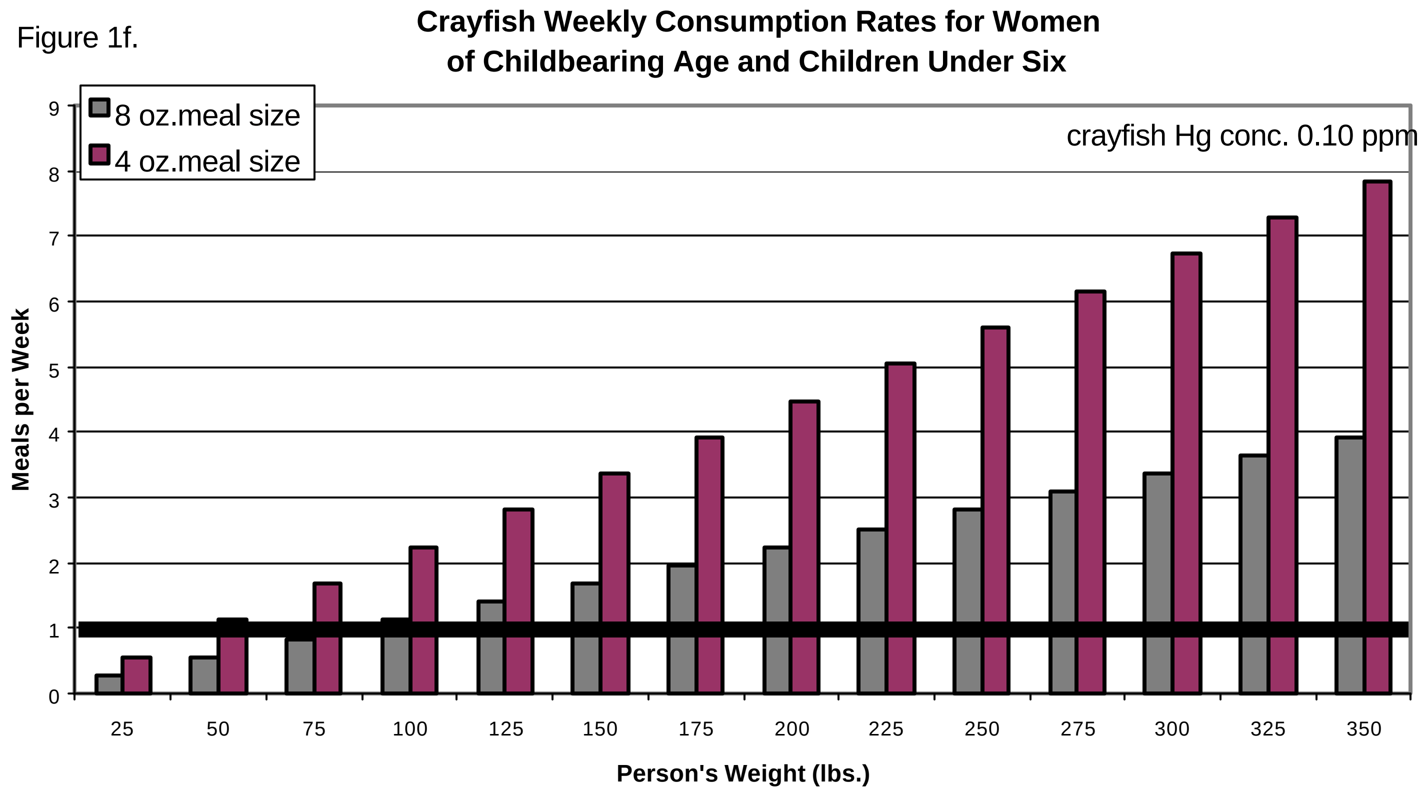
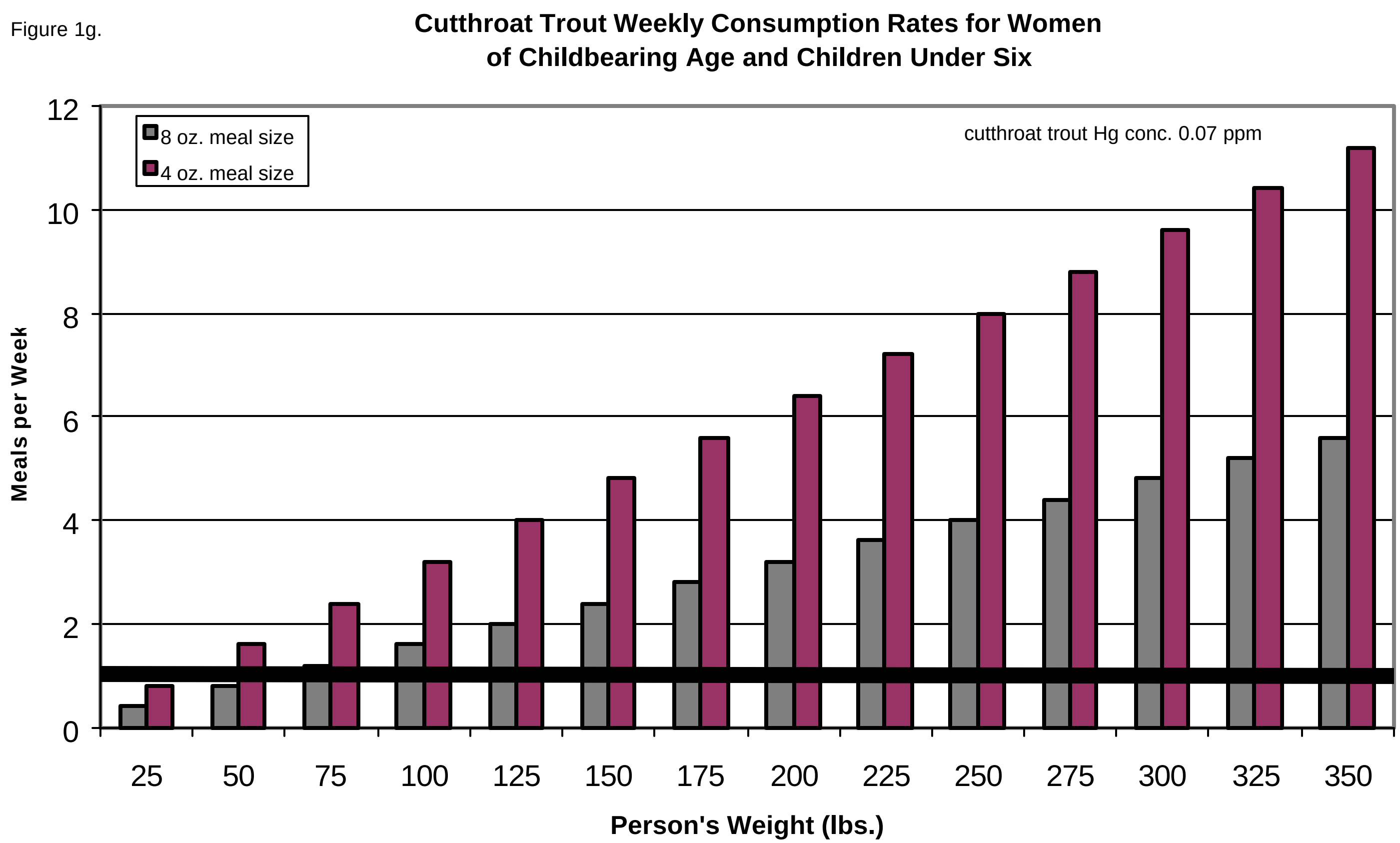

Pumpkinseed Weekly Consumption Rates for Women
of Childbearing Age and Children Under Six
8 oz. meal size
4 oz.meal size
pumpkinseed Hg conc. 0.10 ppm
Meals per Week
0
1
2
3
4
5
6
7
8
9
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Person's Weight (lbs.)

Figure 1f.



Crayfish Weekly Consumption Rates for Women of Childbearing Age and Children Under Six
8 oz.meal size
4 oz.meal size
crayfish Hg conc. 0.10 ppm
Meals per Week
0
1
2
3
4
5
6
7
8
9
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Person's Weight (lbs.)

Figure 1g.


Cutthroat Trout Weekly Consumption Rates for Women
of Childbearing Age and Children Under Six
Meals per Week
0
2
4
6
8
10
12
8 oz. meal size
4 oz. meal size
cutthroat trout Hg conc. 0.07 ppm
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Person's Weight (lbs.)