# Contaminant Loads in Broodstock Fish in the Region 5 National Fish Hatchery System

An Informational Bulletin
from the
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By

Michael J. Millard
Northeast Fishery Center
Lamar, PA 16801

James G. Geiger, Daniel Kuzmeskus, William Archambault
R5 Regional Office; Fisheries Program
Hadley, MA

and

Timothy J. Kubiak
New Jersey Field Office - ES
Pleasantville, New Jersey

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## Background

A January 4, 2004 report in *Science*, and the media releases associated with the report, raised consumer safety concerns regarding farm-raised salmon and in fish consumption in general. The report documented elevated contaminant concentrations, including polychlorinated biphenyls (PCBs) and dioxins, in farm-raised salmon, and cited the likely source for the contaminants as the fish oil used in the commercial feed manufacturing process which the salmon subsequently bioaccumulate. While there are many regional and temporal differences in the feed manufacturing process, it is reasonable to assume that the exposure to contaminants by domestic broodstock within the U.S. Fish and Wildlife Service's (Service) National Fish Hatchery System (NFH) is comparable to that of commercially raised fish in the general region, as feed suppliers are often the same. While a plan for monitoring the contaminant load in the Service's Region 5 broodstock and feed sources is being developed, there remained a concern about body burdens in our existing surplus broodstock. Region 5 fisheries program administrators decided to evaluate whether these broodstock contain levels of PCBs, dioxins, and/or heavy metals that exceeded existing Federal consumption advisory safety limits. The concern was borne from the fact that surplus broodstock from the Service's hatcheries are released to various States for stocking for recreational fisheries, and subsequently may be consumed by people.

Prior to the normally scheduled release of surplus broodstock in spring of 2004, the Service notified the eligible receiving States about the issue with possible contamination of the fish and informed them of the initiation of the contaminants survey. The Service provided reference to consumption advisories for recreational-caught fish developed by the U.S. Environmental Protection Agency (EPA) and further asked that the States notify the angling public of the possible contamination issue with the Federally-supplied fish. Actual transfer of the fish was halted prior to the Service receiving and evaluating the results of the contaminants survey.

Controversy exists in the scientific community over the ramifications of the conclusions presented by Hites et al. (2004). Specifically, while the levels of contaminants in farm-raised salmon was 5-12 times higher than those found in wild salmon, the significance of those elevated levels, in terms of human health and safety, is debated among many scientists. While the reported overall average of PCB concentration in the farm-raised fish was well within the U.S. Food and Drug Administration (FDA) regulatory limits (2 ppm), these action levels are directed toward health risks associated with contaminant levels in commercial foodstuffs. The U.S. Environmental Protection Agency (EPA) uses a more rigorous risk-based approach for triggering fish consumption advisories in recreationally-caught fish. The EPA endpoints for selected contaminants result in more conservative guidelines when compared to FDA.

## Objectives

The contaminant loads in adult broodstock within the Region 5 NFH system which are or could be destined for release into the wild were evaluated. This includes Atlantic salmon domestic broodstock from Nashua NFH and White River NFH, lake trout from Allegheny NFH, and rainbow trout from White Sulphur Springs NFH. Additionally, Atlantic salmon smolts from Green Lake NFH and Atlantic salmon sea-run adults returning to the Merrimack River (most of which are released as smolts, reared at Green Lake NFH) were evaluated.

Specifically, the objectives were to assess contaminant loads of organochlorines and mercury in these broodstock. Target analytes included:

- PCB congener-specific scan,
- full scan for dioxins and furan (PCDD/F),
- lipid content, and
- total mercury
- dieldrin and endrin
- toxaphene
- numerous other organochlorines.

## Methods

Fish were sampled in late February and early March, 2004, by staff from the Northeast Fishery Center, Lamar PA. Fish tissue samples were collected using standard contaminant sampling protocols; these protocols were consistent with EPA sampling standards (*Guidance for Assessing Chemical Contaminant Data for Use In Fish Advisories. Volume 1: Fish Sampling and Analysis - Third Edition, National Guidance, EPA; http://www.epa.gov/ost/fishadvice/volume1/* ).

Fish species and groups (sex-by-age classes) comprised a single composite sample, with six fish generally included in a composite (Table 1). Total lengths, wet weights, sex, and age were collected for each whole specimen.

Skin-on samples were used to be consistent with conservative, worst-case results. Filleting and subsampling of fillets employed dedicated and decontaminated fillet stainless steel trays and knives for each composite sample. A standardized subsample of each fillet (a complete dorso-ventral slice, immediately posterior to the dorsal fin) was taken to negate the need to send whole, large fillets for processing. The subsamples from each of the two fillets per fish (right and left sides) were packaged independently; one was sent for analyses, and the other was retained for possible subsequent individual inspections. Total weight of composite samples ranged between 150g and 2500g. Decontaminated aluminum foil, zip-log bags, and labeling were used for packaging and transport. Each sample container was labeled and tamper-proof containment procedures were used to insure proper chain-of-custody protocols. Samples were frozen and shipped

FEDEX priority overnight to the Northeast Fishery Center in Lamar, PA, when possible. Once all project samples were received at NEFC, they were shipped *in toto* to the contract laboratories.

Target analytes included a full organochlorine (OC) scan, congener specific polychlorinated biphenyls (PCBs), dioxins and furans, and total mercury concentrations. We assumed that the reported total mercury level was predominately composed of methylmercury and, as such, the reported values were applicable to EPA consumption guidelines for methylmercury. Samples were processed through the Patuxent Analytical Control Facility (PACF) and standard QA/QC procedures, as specified in the PACF laboratory contract, were performed.

Dioxins, furans, and "dioxin-like" non-ortho and mono-ortho PCBs were treated similar to the methodology found in Hites et al. (2000). These compounds are collectively reported in parts per trillion (pg/g) World Health Organization toxic equivalents (TEQs), as described by Van den Berg et al. (1998). This group of compounds is collectively referred to as dioxins in our results.

Geometric means were calculated for species groups and categorized into EPA consumption advisories. The Shapiro-Wilk test for normality for the PCB concentrations in Atlantic salmon was significant ($W = 0.82$, $p < 0.01$), suggesting that the back-transformed mean of log-transformed data is a better measure of central tendency. The distribution of contaminant concentration data is usually positively skewed and as such is often modeled by the lognormal distribution (EPA 1997).

## Results

A total of 138 fish were sampled from the R5 National Fish Hatchery system: 90 Atlantic salmon, 24 lake trout, and 24 rainbow trout. These 138 fish comprised the 22 composite samples, grouped by species, age, and sex, that were analyzed by the laboratory (Table 1).

Total PCBs.

*Atlantic salmon*. — The geometric mean PCB concentration in all salmon samples was 0.0335 ppm. The highest concentration of total PCBs found in Atlantic salmon was 0.0896 ppm (wet weight) recorded in the 4-year-old sea-run fish in Nashua NFH (Table 2). These salmon were brought into the facility around June, 2003, and have not fed on artificial diet since that time. The lipid content (1.4%) of these sea-run fish was the lowest observed (Table 1). The domestic broodstock in Nashua NFH ranked as the second highest group of fish with respect to total PCBs, with concentrations ranging between 0.0361 and 0.0482 ppm. Domestic broodstock from White River NFH ranged between 0.0225 and 0.0364 ppm. Not surprisingly, the younger-aged smolts from Green Lake NFH showed the lowest PCB body burdens, ranging from 0.0156 to 0.0236 ppm.

There was no significant trend regarding the rank of males vs. females (Wilcoxon test, $p > 0.10$).

With respect to the EPA consumption guidelines to minimize cancer risk, no samples triggered a "do not eat" advisory (>0.094ppm wet wt for the cancer health endpoints). Two samples from Nashua NFH (sea-runs, and age-3 domestic males) fell within the 0.5 meal/month category, and almost all other adult salmon samples fell within the 1 meal/month category (Figure 1). With respect to the EPA noncancer endpoints, all salmon were in the 2, 3, or 4 meals per month categories.

*Lake trout*. — The four lake trout samples from Allegheny NFH ranged between 0.0431 and 0.0832 ppm total PCBs (Table 2), with a geometric mean of 0.0635 ppm. As expected, the oldest age group (age 8) ranked the highest and the youngest (age 3)) ranked the lowest.

Three of the lake trout samples triggered an EPA cancer risk advisory of 0.5 meal/month and the remaining sample fell within the 1 meal/month advisory category (Figure 1).

*Rainbow trout*. — The rainbow trout samples from White Sulphur Springs NFH ranged between 0.0456 and 0.0727 ppm total PCBs (Table 2). These relatively high body burdens were surprising, given that these fish were all 2 and 3 year-olds. The geometric mean concentration for the rainbow trout samples was 0.0538, which fell within the 0.5 meal a month EPA advisory (Figure 1).

Dioxins.

*Atlantic salmon*. — The geometric mean concentration of dioxins in all salmon samples was 0.5330 ppt TEQs. As with PCBs, the sea-run fish in Nashua NFH recorded the highest dioxin concentrations (1.4068 ppt TEQs). As a group, the fish from Nashua had the highest dioxin levels, followed by fish from White River NFH and the younger smolts from Green Lake NFH (Table 3). Dioxin levels were not significantly correlated with age or sex of fish.

The mean dioxin concentration in salmon fell within the 1 meal/month EPA advisory for acceptable cancer-related risk. The sea-run adults from Nashua exceeded the EPA 1.2 ppt TEQ cutoff for consumption, and thus fell within the "do not eat" category. Six of the 14 individual salmon samples fell within the 0.5 meal/month category; all of these were fish from Nashua NFH (Figure 2). The remaining salmon samples fell within the 1 or 2 meal/month EPA advisory levels.

*Lake trout*. — Dioxin levels in the four lake trout samples from Allegheny NFH ranged between 0.4839 and 0.8491 ppt TEQs (Table 3), with a geometric mean of 0.7106 ppt TEQs. As expected, the youngest group (age 3) ranked the lowest. Three of the lake trout samples triggered an EPA cancer risk advisory of 0.5 meal/month and the remaining sample fell within the 1 meal/month advisory category (Figure 2).

*Rainbow trout*. — The rainbow trout samples from White Sulphur Springs NFH ranged between 0.718 and 0.847 ppt TEQs (Table 3). The geometric mean concentration for the rainbow trout samples was 0.7759, which fell within the 0.5 meal a month EPA advisory for acceptable cancer risk (Figure 2).

Mercury.

*Atlantic salmon*. — The mean concentration of mercury in salmon samples ranged from 0.0663 to 0.0203 ppm, with a geometric mean of 0.0306 ppm (Table 4). As with PCBs and dioxins, the sea-run fish in Nashua NFH recorded the highest mercury concentrations. In general, mercury levels were low, and the EPA noncancer-risk advisory for observed levels is 16 meals/month or unrestricted (Figure 3).

*Lake trout*. — Mercury levels in the four lake trout samples from Allegheny NFH ranged between 0.0157 and 0.0428 ppm (Table 4), with a geometric mean of 0.0256 ppm. As expected, the oldest age group (age 8) ranked the highest and the youngest (age 3)) ranked the lowest. The two oldest lake trout groups triggered an EPA advisory of 16 meals/month and the remaining two samples fell within the unrestricted advisory category (Figure 3).

*Rainbow trout*. — The White Sulphur Springs NFH rainbow trout contained mercury levels below the 0.029ppm level and did not trigger an EPA consumption advisory (Figure 3).

Dieldrin & Endrin (Pesticides).

*Atlantic salmon*. — The mean concentration of dieldrin in salmon samples ranged from 0.00026 to 0.00114 ppm (Table 5). Salmon in Nashua NFH ranked the highest and triggered an EPA consumption advisory (cancer endpoints) of 4 meals/month. Green Lake NFH and White River NFH fish exhibited lower levels of dieldrin, and triggered advisories between 8 and 16 meals/month (Table 5). Endrin levels were all below 0.00118 ppm and did not trigger any EPA consumption advisories (Table 6).

*Lake trout*. — Dieldrin levels in the four lake trout samples from Allegheny NFH ranged between 0.0005 and 0.00127 ppm (Table 5). The three older lake trout groups triggered an EPA advisory of 3 meals/month and the remaining sample of age-3 fish fell within the 8 meal/month advisory category. Endrin levels were all below 0.00017 ppm and did not trigger any EPA consumption advisories (Table 6).

*Rainbow trout*. — The White Sulphur Springs NFH rainbow trout contained dieldrin levels below 0.000551 ppm (Table 5). EPA advisories ranged from eight to sixteen meals per month. Endrin levels in the trout were all below reported detection levels (Table 6).

**Discussion**

Hites et al. (2004) reported that farm-raised salmon sampled from east Canada and Maine showed total PCB levels of approximately 0.039 ppm and 0.026 ppm, respectively. Many of the NFH Atlantic salmon broodstock tested in this study reported higher levels. The sea-run salmon tested in this study, age-4 fish in Nashua NFH, were higher in total PCBs (0.089 ppm) than many of the European pen-reared fish (0.040-0.050 ppm) reported by Hites et al. (2004). The mean PCB level in R5 NFH Atlantic salmon (0.0335 ppm) appeared to be consistent with the levels reported by Hites et al. (2004) for farmed salmon (primarily Atlantic salmon *Salmo salar*) around the world. This might be expected if one assumes that PCBs in farmed fish are primarily introduced via lipids in commercially-available feed, and that all or most fish producers are procuring feeds approximately similar in lipid supply and content. However, the highest PCB levels in this study were found in sea-run fish which had not consumed any commercial feed, as adults, prior to sampling. These sea-run fish were most likely released as smolts reared at the USFWS Green Lake Hatchery; samples from this hatchery showed relatively low levels in PCBS in their smolts. This suggests that the sea-run salmon showing high PCB levels in this study acquired a high proportion of their body burden while in the natural environment. Natural prey and/or environmental inputs may be significant sources of PCBs in Atlantic salmon in the North Atlantic.

The levels of PCBs found in age-2 and age-3 rainbow trout from the White Sulphur Springs NFH ranged from 0.0285 to 0.0727 ppm. Carline et al. (2004) reported that PCB concentrations in rainbow trout feed was linearly related to PCB concentrations in fillets, although the slope of the relationship was small (0.18), suggesting that large increases in PCB levels in feed result in small increases in fillets.

Lake trout, as a group, exhibited the highest mean concentration of PCBs of all fish in this study, and the mature adults fell within the EPA consumption advisory of 0.5 meal/month. The levels were generally more than 1 order of magnitude below PCB levels found in lake trout in several of the Great Lakes.

Quantitation levels for many of the dioxin-like congeners were originally reported as "less than" values. Because the total dioxin equivalents or TEQs were at least two to three times the pen salmon values in Hites et al. (2004) when we included the face value, i.e the “less than” concentrations, the laboratory provided more meaningful data for interpretation. While estimates were used in some cases (above detection limits but below method limits that produce good quantitative results), we relied on instrument detection limits for the dioxins and furans and method detection limits for the dioxin-like PCBs. Where the congeners were reported "Not Detected", they were assigned a zero concentration. Where they were above the respective detection limits but below minimum quantitative values, the actual uncalibrated residue concentration was included to ensure all possible contamination was accounted for. Lastly, those congeners with real quantitated values were almost exclusively PCBs, which were the most important of the three chemical classes analyzed.

In terms of triggering EPA consumption advisories, the dioxin levels from the individual samples in the Region 5 NFH broodstock were generally as restrictive, or more so, than were the total PCB levels. Dioxin levels caused 6 of 14 Atlantic salmon samples, 3 of the 4 lake trout samples, and all 4 rainbow trout samples to fall within the 0.5 meals per month category. The sea-run salmon in Nashua triggered the only "do not eat" advisory. If the one hexa-chlorinated furan was not included (because it was an estimated concentration), the advisory for the sea-run sample would be less restrictive at the 0.5 meal per month category. The sea-run salmon, while having the highest dioxin-like and PCB contamination, had the lowest heptachlor epoxide concentrations, across all samples from Nashua NFH, suggesting there is no uniform way to predict contamination in sea-run salmon versus hatchery salmon. PCB levels only caused 2 samples to fall within the 0.5 meals/month category. Mercury, dieldrin, and endrin levels were far less restrictive than either dioxins or PCBs. For the reasons stated above, the dioxin data can reasonably be viewed as the "limiting factor" when considering the ultimate fate of these fish.

Dioxins are not created intentionally, but are produced inadvertently by a number of human activities. Dioxins are formed as a result of combustion processes such as commercial or municipal waste incineration and from burning fuels. EPA's draft dioxin risk assessment finds that anthropogenic emissions dominate current releases in the United States, but acknowledges the need for more data on natural sources. Chlorine bleaching of pulp and paper, certain types of chemical manufacturing and processing, and other industrial processes can create small quantities of dioxins.

The science of risk assessment with dioxin exposure is uncertain. A quote from EPA's website is instructional:

> **"*Q: Has it been determined what levels of dietary dioxin exposure cause adverse health effects in humans?***
>
> *A: No. Known incidents of high dioxin levels in humans have resulted from accidental exposure; not typical dietary exposures. Despite a large body of research and data collection, there are numerous questions and uncertainties regarding scientific data on and analysis of dioxin risk. This fact is acknowledged by the EPA's Science Advisory Board, which nonetheless also acknowledged that these uncertainties are unlikely to be resolved in the near future. We believe the National Academy of Science review of the 2003 draft reassessment will provide additional insight into this issue*."

Literature Cited:

Carline, R.F., P.M. Barry, and H.G. Ketola. 2004. Dietary uptake of polychlorinated biphenyls (PCBs) by rainbow trout. North American Journal of Aquaculture 66:91-99.

Hites, R.A., J.A. Foran, D. O. Carpenter, N.C. Hamilton, B.A. Knuth, and S. J. Schwager. 2004. Global assessment of organic contaminants in farmed salmon. Science 303:226-229.

U.S. EPA. 1997. The lognormal distribution in environmental applications. Ashok K. Singh, Anita Singh, and Max Engelhardt. EPA/600/R-97/006. December 1997.

Van den Berg, M. and 23 co-authors. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environmental Health Perspective 106(12):775-792

Table 1. Summary of fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System analyzed for contaminants in 2004. Individual composite samples are described (top) and a summary by species, strain, and facility is provided (bottom).

| Sample # | Species | Age | Sex | # fish in composite | Hatchery/ Strain | % lipid | % moisture |
|---|---|---|---|---|---|---|---|
| ALORC1 | Lake trout | 8 | M | 6 | ALLEGHENY / Superior | 6.5 | 70.2 |
| ALORC2 | Lake trout | 6 | M | 6 | ALLEGHENY / Seneca | 4.7 | 72.2 |
| ALORC3 | Lake trout | 5 | BOTH | 6 | ALLEGHENY / Green Lake | 5.9 | 70.2 |
| ALORC4 | Lake trout | 3 | IMM | 6 | ALLEGHENY / Superior | 3.3 | 74.7 |
| GLORC1 | At. salmon | 1 | IMM | 12 | GREEN LAKE Domestics Penobscot | 3.6 | 72.8 |
| GLORC2 | At. salmon | 2 | IMM | 6 | GREEN LAKE Domestics Penobscot | 3.3 | 72.7 |
| GLORC3 | At. salmon | 3 | BOTH | 6 | GREEN LAKE Domestics Penobscot | 3.3 | 73.5 |
| NSORC1 | At. salmon | 4 | M | 6 | NASHUA Domestics Merrimack | 3.1 | 74.5 |
| NSORC2 | At. salmon | 4 | F | 6 | NASHUA Domestics Merrimack | 4.9 | 71.2 |
| NSORC3 | At. salmon | 3 | M | 6 | NASHUA Domestics Merrimack | 1.4 | 78.8 |
| NSORC4 | At. salmon | 3 | F | 6 | NASHUA Domestics Merrimack | 3.9 | 74.8 |
| NSORC5 | At. salmon | 2 | M | 6 | NASHUA Domestics Merrimack | 6.6 | 66.7 |
| NSORC6 | At. salmon | 2 | F | 6 | NASHUA Domestics Merrimack | 6 | 65.3 |
| NSORC7 | At. salmon | 4 | BOTH | 6 | NASHUA Sea-Runs Merrimack | 1.4 | 78.3 |
| WRORC1 | At. salmon | 5 | M | 6 | WHITE RIVER Domestics Connect. | 1.4 | 78.3 |
| WRORC2 | At. salmon | 5 | F | 6 | WHITE RIVER Domestics Connect. | 2.1 | 76.5 |
| WRORC3 | At. salmon | 4 | F | 6 | WHITE RIVER Domestics Connect. | 4.1 | 74.2 |
| WRORC4 | At. salmon | 4 | M | 6 | WHITE RIVER Domestics Connect. | 2.3 | 76.3 |
| WSORC1 | Rainbow trout | 2 | M | 6 | WHITE SULPHUR ERWIN | 5.5 | 72.4 |
| WSORC2 | Rainbow trout | 3 | F | 6 | WHITE SULPHUR ERWIN | 5.6 | 68.4 |
| WSORC3 | Rainbow trout | 3 | M | 6 | WHITE SULPHUR SHASTA | 3.5 | 71.7 |
| WSORC4 | Rainbow trout | 2 | M | 6 | WHITE SULPHUR SHASTA | 3 | 75.8 |

| Species / Hatchery / Strain | Total # of fish sampled |
|---|---|
| **Atlantic salmon** | |
| NASHUA NFH: Sea-Runs Merrimack | **6** |
| NASHUA NFH: Domestics Merrimack | **36** |
| WHITE RIVER NFH: Domestics Connect. | **24** |
| GREEN LAKE NFH: Domestics Penobscot | **24** |
| **Atlantic salmon total** | **90** |
| **Lake Trout** | |
| ALLEGHENY NFH : Superior | **12** |
| ALLEGHENY NFH : Seneca | **6** |
| ALLEGHENY NFH : Green Lake | **6** |
| **Lake trout total** | **24** |
| **Rainbow trout** | |
| WHITE SULPHUR : Shasta | **12** |
| WHITE SULPHUR : Erwin | **12** |
| **Rainbow trout total** | **24** |
| **GRAND TOTAL** | **138** |

Note: tissue from 6 fish generally comprised a single composite sample for contaminants analysis. "IMM" = immature.

Table 2. Total PCB concentrations and mean concentration, by species, in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System analyzed for contaminants in 2004. EPA consumption advisories for noncancer and cancer-related risks are provided. The advisory is associated with the mean concentration for the species.

Note: A full explanation of EPA protocol for risk assessment and advisory formulation can be found at *http://www.epa.gov/waterscience/fish/guidance.html*.

| Age | Sex | Hatchery/Strain | Total PCB (ppm wet wt) | Mean* conc (ppm) by species | Noncancer EPA Advisory, for spp mean | Cancer EPA Advisory, for spp mean |
|---|---|---|---|---|---|---|
| **Atlantic salmon** | | | | | | |
| 4 | BOTH | NASHUA Sea-Runs Merrimack | **0.0896** | | | |
| 3 | M | NASHUA Domestics Merrimack | **0.0482** | | | |
| 4 | M | NASHUA Domestics Merrimack | **0.0440** | | | |
| 2 | M | NASHUA Domestics Merrimack | **0.0440** | | | |
| 3 | F | NASHUA Domestics Merrimack | **0.0435** | | | |
| 4 | F | NASHUA Domestics Merrimack | **0.0421** | | | |
| 5 | M | WHITE RIVER Domestics Connect. | **0.0364** | **0.0335** | **4 meal/mo** | **1 meal/mo** |
| 2 | F | NASHUA Domestics Merrimack | **0.0361** | | | |
| 4 | F | WHITE RIVER Domestics Connect. | **0.0263** | | | |
| 5 | F | WHITE RIVER Domestics Connect. | **0.0242** | | | |
| 3 | BOTH | GREEN LAKE Domestics Penobscot | **0.0236** | | | |
| 4 | M | WHITE RIVER Domestics Connect. | **0.0225** | | | |
| 1-2 | IMM | GREEN LAKE Domestics Penobscot | **0.0215** | | | |
| 2 | IMM | GREEN LAKE Domestics Penobscot | **0.0156** | | | |
| **Lake Trout** | | | | | | |
| 8 | M | ALLEGHENY / Superior | **0.0832** | | | |
| 6 | M | ALLEGHENY / Seneca | **0.0716** | **0.0635** | **2 meal/mo** | **0.5 meal/mo** |
| 5 | BOTH | ALLEGHENY / Green Lake | **0.0633** | | | |
| 3 | IMM | ALLEGHENY / Superior | **0.0431** | | | |
| **Rainbow trout** | | | | | | |
| 3 | M | WHITE SULPHUR SHASTA | **0.0727** | | | |
| 2 | M | WHITE SULPHUR SHASTA | **0.0523** | **0.0538** | **3 meal/mo** | **0.5 meal/mo** |
| 3 | F | WHITE SULPHUR ERWIN | **0.0483** | | | |
| 2 | M | WHITE SULPHUR ERWIN | **0.0456** | | | |

* Geometric mean, by species. "IMM" = immature.

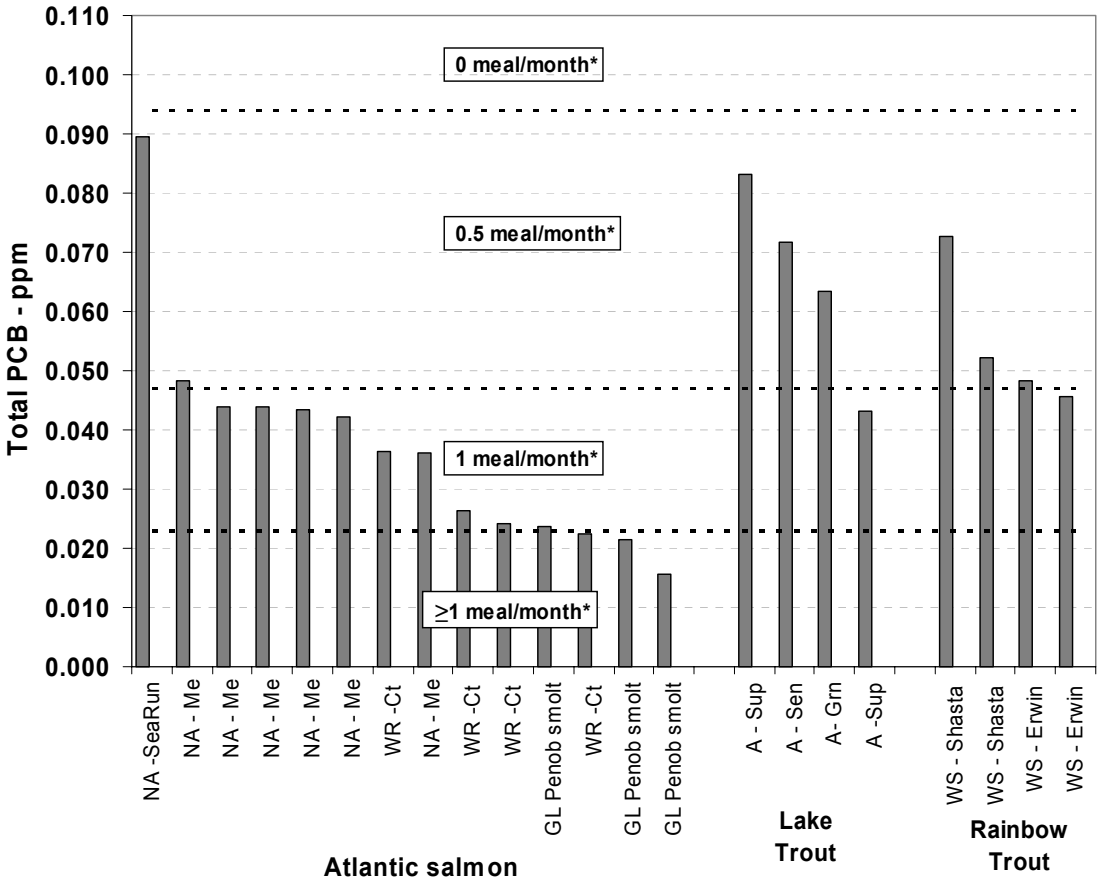


Figure 1. Total PCB concentrations in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System, 2004. Endpoints for EPA consumption advisories for cancer-related risks are indicated by the dark horizontal dashed lines. A=Allegheny; GL=Green Lake; NA=Nashua; WR=White River; WS=White Sulphur Springs.

Note: EPA advisories are noted in boxes. A full explanation of EPA protocol for risk assessment and advisory formulation can be found at h*ttp://www.epa.gov/waterscience/fish/guidance.html*.

Table 3. Total concentrations and mean concentration of dioxins, by species, in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System analyzed for contaminants in 2004. EPA consumption advisories for cancer-related risks are provided. The advisory is associated with the mean concentration for the species.

Note: A full explanation of EPA protocol for risk assessment and advisory formulation can be found at *http://www.epa.gov/waterscience/fish/guidance.html*.

| Age | Sex | Hatchery/Strain | Dioxins (pg TEQs/g) | Mean* (pg TEQs/g) for species | Cancer EPA advisory, for spp mean |
|---|---|---|---|---|---|
| **Atlantic salmon** | | | | | |
| 4 | BOTH | NASHUA Sea-Runs Merrimack | **1.406800** | | |
| 3 | M | NASHUA Domestics Merrimack | **1.076810** | | |
| 4 | F | NASHUA Domestics Merrimack | **0.852302** | | |
| 4 | M | NASHUA Domestics Merrimack | **0.799846** | | |
| 3 | F | NASHUA Domestics Merrimack | **0.798120** | | |
| 2 | M | NASHUA Domestics Merrimack | **0.733632** | | |
| 2 | F | NASHUA Domestics Merrimack | **0.613776** | **0.5330** | **1 meal/mo** |
| 5 | M | WHITE RIVER Domestics Connect. | **0.591758** | | |
| 1 | IMM | GREEN LAKE Domestics Penobscot | **0.396900** | | |
| 5 | F | WHITE RIVER Domestics Connect. | **0.317690** | | |
| 4 | F | WHITE RIVER Domestics Connect. | **0.313970** | | |
| 3 | BOTH | GREEN LAKE Domestics Penobscot | **0.291210** | | |
| 4 | M | WHITE RIVER Domestics Connect. | **0.257556** | | |
| 2 | IMM | GREEN LAKE Domestics Penobscot | **0.228830** | | |
| **Lake Trout** | | | | | |
| 5 | BOTH | ALLEGHENY / Green Lake | **0.8491** | | |
| 8 | M | ALLEGHENY / Superior | **0.8398** | **0.7106** | **0.5 meal/mo** |
| 6 | M | ALLEGHENY / Seneca | **0.7390** | | |
| 3 | IMM | ALLEGHENY / Superior | **0.4839** | | |
| **Rainbow trout** | | | | | |
| 3 | M | WHITE SULPHUR SHASTA | **0.8472** | | |
| 2 | M | WHITE SULPHUR SHASTA | **0.8128** | **0.7759** | **0.5 meal/mo** |
| 3 | F | WHITE SULPHUR ERWIN | **0.7324** | | |
| 2 | M | WHITE SULPHUR ERWIN | **0.7186** | | |

* Geometric mean, by species. "IMM" = immature.

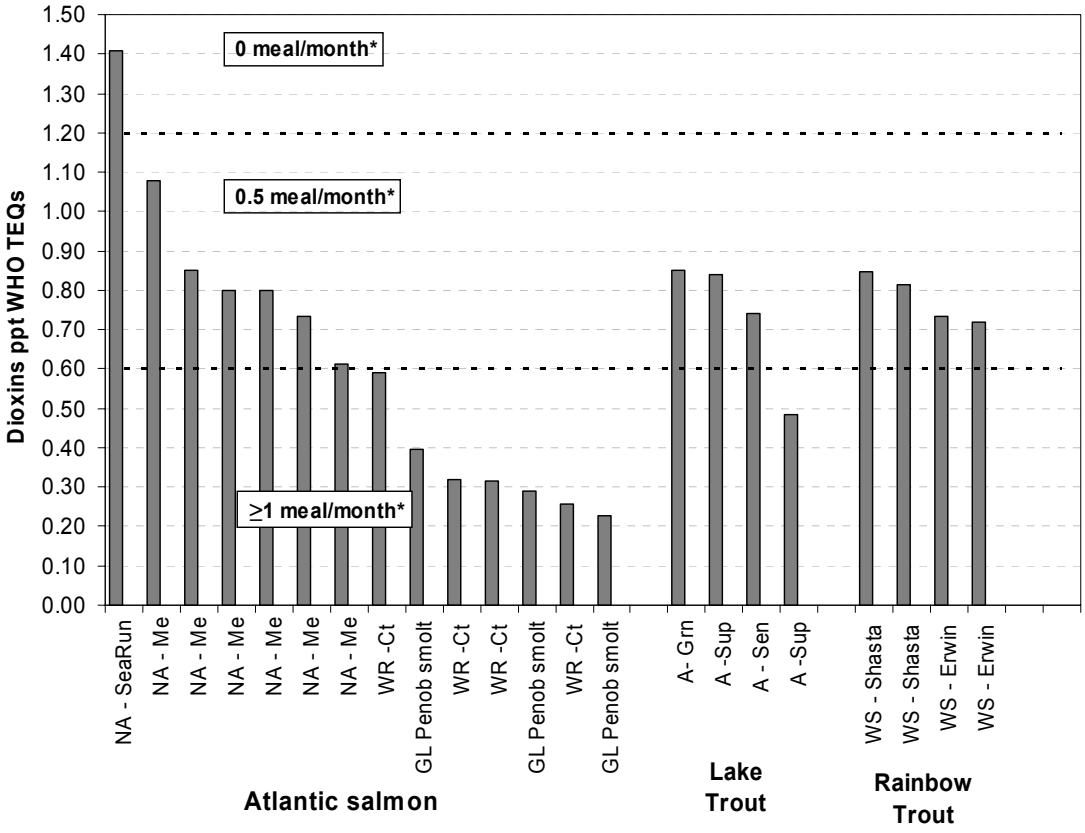


Figure 2. Dioxin concentrations in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System, 2004. Endpoints for EPA consumption advisories for cancer-related risks are indicated by the dark horizontal dashed lines. A=Allegheny; GL=Green Lake; NA=Nashua; WR=White River; WS=White Sulphur Springs.

Note: EPA advisories are noted in boxes. A full explanation of EPA protocol for risk assessment and advisory formulation can be found at *http://www.epa.gov/waterscience/fish/guidance.html*.

Table 4. Total concentrations and mean concentration of mercury, by species, in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System analyzed for contaminants in 2004. EPA consumption advisories for noncancer-related risks are provided. The advisory is associated with the mean concentration for the species. Mercury levels in samples were assumed to be comprised wholly of methylmercury.

Note: A full explanation of EPA protocol for risk assessment and advisory formulation can be found at *http://www.epa.gov/waterscience/fish/guidance.html*.

| Age | Sex | Hatchery/Strain | Hg (ppm wet wt.) | Mean* conc. (ppm wet wt.) | Noncancer EPA Advisory |
|---|---|---|---|---|---|
| **Atlantic salmon** | | | | | |
| 4 | BOTH | Nashua searuns Merrimack | **0.0663** | **0.0306** | **16 meals/mo** |
| 5 | F | White River domestics Connect. | **0.0450** | | |
| 4 | F | White River domestics Connect. | **0.0415** | | |
| 5 | M | White River domestics Connect. | **0.0411** | | |
| 3 | BOTH | Green Lake domestics Penobscot | **0.0390** | | |
| 4 | M | White River domestics Connect. | **0.0340** | | |
| 1 | imm | Green Lake domestics Penobscot | **0.0308** | | |
| 3 | F | Nashua domestics Merrimack | **0.0255** | | |
| 2 | imm | Green Lake domestics Penobscot | **0.0239** | | |
| 4 | M | Nashua domestics Merrimack | **0.0229** | | |
| 4 | F | Nashua domestics Merrimack | **0.0227** | | |
| 3 | M | Nashua domestics Merrimack | **0.0226** | | |
| 2 | M | Nashua domestics Merrimack | **0.0211** | | |
| 2 | F | Nashua domestics Merrimack | **0.0203** | | |
| **Lake Trout** | | | | | |
| 8 | M | Allegheny / Superior | **0.0428** | **0.0256** | **unrestricted** |
| 6 | M | Allegheny / Seneca | **0.0337** | | |
| 5 | BOTH | Allegheny / Green Lake | **0.0191** | | |
| 3 | imm | Allegheny / Superior | **0.0157** | | |
| **Rainbow trout** | | | | | |
| 3 | M | White Sulphur Shasta | **0.0179** | **0.0156** | **unrestricted** |
| 3 | F | White Sulphur Erwin | **0.0153** | | |
| 2 | M | White Sulphur Erwin | **0.0149** | | |
| 2 | M | White Sulphur Shasta | **0.0147** | | |

* Geometric mean, by species. "imm" = immature.

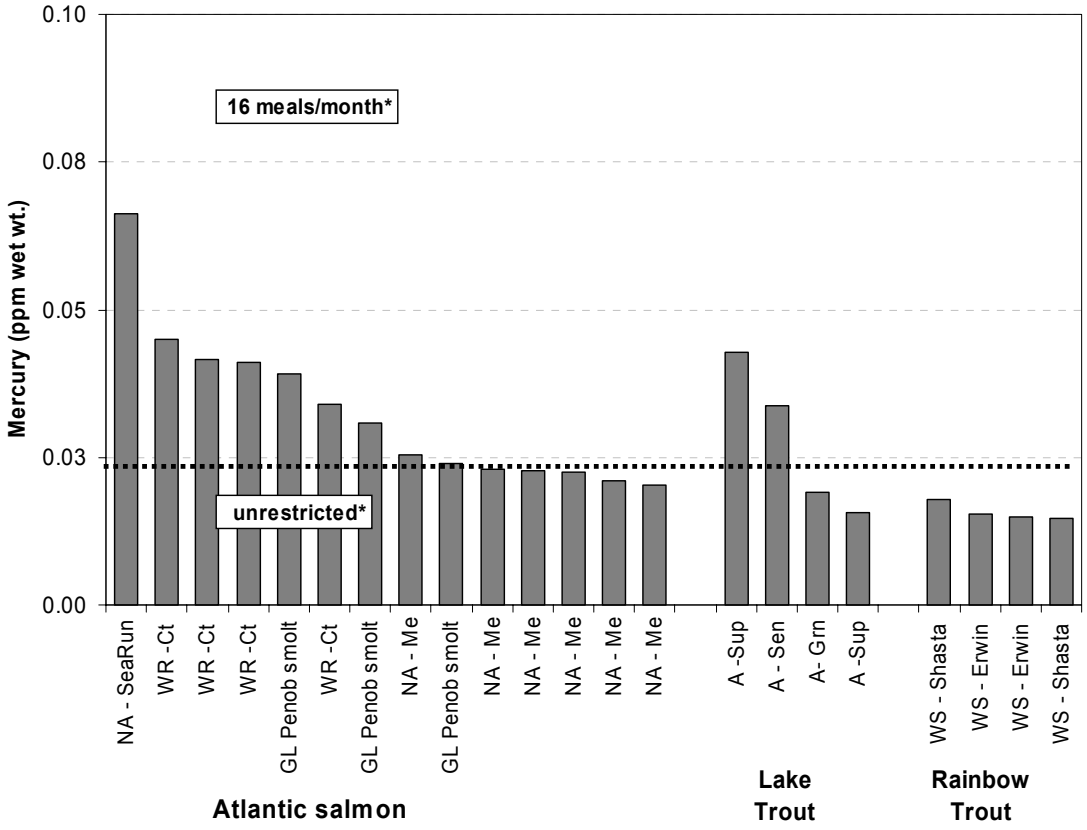


Figure 3. Mercury concentrations in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System, 2004. Endpoints for EPA consumption advisories for cancer-related risks are indicated by the dark horizontal dashed lines. Mercury levels in samples were assumed to be comprised wholly of methylmercury.

A=Allegheny; GL=Green Lake; NA=Nashua; WR=White River; WS=White Sulphur Springs.

Note: EPA advisories are noted in boxes. A full explanation of EPA protocol for risk assessment and advisory formulation can be found at *http://www.epa.gov/waterscience/fish/guidance.html*.

Table 5. Total concentrations and mean concentration of dieldrin, by species, in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System analyzed for contaminants in 2004. EPA consumption advisories for cancer-related risks are provided. The advisory is associated with the mean concentration for the species.

Note: A full explanation of EPA protocol for risk assessment and advisory formulation can be found at *http://www.epa.gov/waterscience/fish/guidance.html*.

| Age | Sex | Hatchery/Strain | Dieldrin (ppm wet wt.) | Cancer EPA Advisory |
|---|---|---|---|---|
| **Atlantic salmon** | | | | |
| 4 | F | NASHUA Domestics Merrimack | 0.001140 | **4 meals/mo** |
| 4 | BOTH | NASHUA Sea-Runs Merrimack | 0.001100 | |
| 3 | M | NASHUA Domestics Merrimack | 0.000958 | |
| 2 | M | NASHUA Domestics Merrimack | 0.000937 | |
| 3 | F | NASHUA Domestics Merrimack | 0.000852 | |
| 4 | M | NASHUA Domestics Merrimack | 0.000815 | |
| 2 | F | NASHUA Domestics Merrimack | 0.000799 | |
| 1 | IMM | GREEN LAKE Domestics Penobscot | 0.000602 | **8 meals/mo** |
| 3 | BOTH | GREEN LAKE Domestics Penobscot | 0.000454 | **12 meals/mo** |
| 4 | F | WHITE RIVER Domestics Connect. | 0.000434 | |
| 5 | M | WHITE RIVER Domestics Connect. | 0.000317 | **16 meals/mo** |
| 5 | F | WHITE RIVER Domestics Connect. | 0.000299 | |
| 4 | M | WHITE RIVER Domestics Connect. | 0.000281 | |
| 2 | IMM | GREEN LAKE Domestics Penobscot | 0.000261 | |
| **Lake Trout** | | | | |
| 8 | M | ALLEGHENY / Superior | 0.001270 | **3 meals/mo** |
| 5 | BOTH | ALLEGHENY / Green Lake | 0.001060 | |
| 6 | M | ALLEGHENY / Seneca | 0.001030 | |
| 3 | IMM | ALLEGHENY / Superior | 0.000567 | **8 meals/mo** |
| **Rainbow trout** | | | | |
| 2 | M | WHITE SULPHUR ERWIN | 0.000551 | **8 meals/mo** |
| 3 | F | WHITE SULPHUR ERWIN | 0.000488 | **12 meals/mo** |
| 3 | M | WHITE SULPHUR SHASTA | 0.000425 | |
| 2 | M | WHITE SULPHUR SHASTA | 0.000321 | **16 meals/mo** |

"IMM" = immature.

Table 6. Total concentrations and mean concentration of endrin in fish from the U.S. Fish and Wildlife Service Region 5 National Fish Hatchery System analyzed for contaminants in 2004. EPA consumption advisories for cancer-related risks are provided. The advisory is associated with the each sample.

Note: A full explanation of EPA protocol for risk assessment and advisory formulation can be found at *http://www.epa.gov/waterscience/fish/guidance.html*.

| Spp | Age | Sex | Hatchery/Strain | Endrin (ppm wet wt.) | Noncancer EPA Advisory |
|---|---|---|---|---|---|
| ATS | 3 | M | NASHUA Domestics Merrimack | 0.001180 | unrestricted |
| ATS | 3 | F | NASHUA Domestics Merrimack | 0.000990 | |
| ATS | 4 | M | NASHUA Domestics Merrimack | 0.000982 | |
| ATS | 2 | M | NASHUA Domestics Merrimack | 0.000964 | |
| ATS | 4 | F | NASHUA Domestics Merrimack | 0.000834 | |
| ATS | 2 | F | NASHUA Domestics Merrimack | 0.000694 | |
| ATS | 4 | BOTH | NASHUA Sea-Runs Merrimack | 0.000177 | |
| LKT | 8 | M | ALLEGHENY / Superior | 0.000170 | |
| LKT | 6 | M | ALLEGHENY / Seneca | 0.000159 | |
| ATS | 4 | M | WHITE RIVER Domestics Connect. | 0.000154 | |
| RBT | 3 | M | WHITE SULPHUR SHASTA | < 0.000169 | |
| RBT | 2 | M | WHITE SULPHUR SHASTA | < 0.000168 | |
| ATS | 2 | IMM | GREEN LAKE Domestics Penobscot | < 0.000166 | |
| RBT | 3 | F | WHITE SULPHUR ERWIN | < 0.000166 | |
| ATS | 3 | BOTH | GREEN LAKE Domestics Penobscot | < 0.000164 | |
| ATS | 1 | IMM | GREEN LAKE Domestics Penobscot | < 0.000161 | |
| RBT | 2 | M | WHITE SULPHUR ERWIN | < 0.000158 | |
| ATS | 4 | F | WHITE RIVER Domestics Connect. | < 0.000155 | |
| LKT | 3 | IMM | ALLEGHENY / Superior | < 0.000153 | |
| ATS | 5 | M | WHITE RIVER Domestics Connect. | < 0.000151 | |
| LKT | 5 | BOTH | ALLEGHENY / Green Lake | < 0.000145 | |
| ATS | 5 | F | WHITE RIVER Domestics Connect. | < 0.000142 | |

"IMM" = immature.

APPENDIX I. U.S. EPA consumption advisories tables for PCBs, dioxins/furans, and methylmercury.

Source: U.S. EPA. National Guidance. Guidance for Assessing Chemical Contaminant Data for Use In Fish Advisories. Volume 2: Risk Assessment and Fish Consumption Limits - Third Edition.

Available at: http://www.epa.gov/waterscience/fishadvice/volume2/

**Table 4-24. Monthly Fish Consumption Limits for Carcinogenic and Noncarcinogenic Health Endpoints - PCBs**

| Risk Based Consumption Limit[a] | Noncancer Health Endpoints[b] | Cancer Health Endpoints[c] |
|---|---|---|
| Fish Meals/Month | Fish Tissue Concentrations (*ppm, wet weight*) | Fish Tissue Concentrations (*ppm, wet weight*) |
| Unrestricted (>16) | 0 - 0.0059 | 0 - 0.0015 |
| 16 | >0.0059 - 0.012 | >0.0015 - 0.0029 |
| 12 | >0.012 - 0.016 | >0.0029 - 0.0039 |
| 8 | >0.016 - 0.023 | >0.0039 - 0.0059 |
| 4 | >0.023 - 0.047 | >0.0059 - 0.012 |
| 3 | >0.047 - 0.063 | >0.012 - 0.016 |
| 2 | >0.063 - 0.094 | >0.016 - 0.023 |
| 1 | >0.094 - 0.19 | >0.023 - 0.047 |
| 0.5 | >0.19 - 0.38 | >0.047 - 0.094 |
| None (<0.5) | >0.38 | >0.094 |

[a] The assumed meal size is 8 oz (0.227 kg). The ranges of chemical concentrations presented are conservative, e.g., the 12-meal-per-month levels represent the concentrations associated with 12 to 15.9 meals.
[b] Chronic, systemic effects
[c] Cancer values represent tissue concentrations at a 1 in 100,000 risk level.
* Concentration reported in parts per quadrillion (nanogram per kg or 10-9 g/kg.

Notes:
1. Consumption limits are based on an adult body weight of 70 kg, and RfD of $2x10^{-5}$, and a cancer slope factor (CSF) of 2 $(mg/kg\text{-}d)^{-1}$.
2. NONE = No consumption recommended.
3. In cases where >16 meals per month are consumed, refer to Equations 3-1 and 3-2, Section 3.2.1.2, for methods to determine safe consumption limits.
4. The detection limit for PCBs (sum of Aroclors) is $2 \times 10^{-2}$ mg/kg.
5. Instructions for modifying the variables in this table are found in Section 3.3.
6. Monthly limits are based on the total dose allowable over a 1-month period (based on the RfD). When the monthly limit is consumed in less than 1 month (e.g., in a few large meals), the daily dose may exceed the RfD (see Section 2.3).

**Table 4-25. Monthly Fish Consumption Limits for Carcinogenic Health Endpoint - Dioxins/Furans**

| Risk Based Consumption Limit[a] | Noncancer Health Endpoints[b] | Cancer Health Endpoints[c] |
|---|---|---|
| **Fish Meals/Month** | **Fish Tissue Concentrations (*ppm, wet weight*)** | **Fish Tissue Concentrations (*ppt*-TEQ, wet weight*)** |
| Unrestricted (>16) | NA | 0 - 0.019 |
| 16 | NA | >0.019 - 0.038 |
| 12 | NA | >0.038 - 0.05 |
| 8 | NA | >0.05 - 0.075 |
| 4 | NA | >0.075 - 0.15 |
| 3 | NA | >0.15 - 0.2 |
| 2 | NA | >0.2 - 0.3 |
| 1 | NA | >0.3 - 0.6 |
| 0.5 | NA | >0.6 - 1.2 |
| None (<0.5) | NA | >1.2 |

[a] The assumed meal size is 8 oz (0.227 kg). The ranges of chemical concentrations presented are conservative, e.g., the 12-meal-per-month levels represent the concentrations associated with 12 to 15.9 meals.
[b] Chronic, systemic effects. An RfD is not available (NA) for this compound.
[c] Cancer values represent tissue concentrations at a 1 in 100,000 risk level.
* Concentration reported in parts per trillion (nanogram per kg or $10^{-9}$ g/kg

Notes:
1. Consumption limits are based on an adult body weight of 70 kg and a cancer slope factor (CSF) of $1.56 \times 10^{5}$ $(mg/kg\text{-}d)^{-1}$. No RfD available (June 1999).
2. None = No consumption recommended.
3. In cases where >16 meals per month are consumed, refer to Equations 3-1 and 3-2, Section 3.2.1.2, for methods to determine safe consumption limits.
4. The detection limit for dioxins/furans is $1 \times 10^{-6}$ mg/kg.
5. Instructions for modifying the variables in this table are found in Section 3.3.
6. Monthly limits are based on the total dose allowable over a 1-month period (based on the RfD). When the monthly limit is consumed in less than 1 month (e.g., in a few large meals), the daily dose may exceed the RfD (see Section 2.3).

**Table 4-3. Monthly Fish Consumption Limits for Noncarcinogenic Health Endpoint - Methylmercury**

| Risk Based Consumption Limit[a] | Noncancer Health Endpoints[b] |
|---|---|
| Fish Meals/Month | Fish Tissue Concentrations (*ppm, wet weight*) |
| Unrestricted (>16) | 0 - 0.029 |
| 16 | >0.029 - 0.059 |
| 12 | >0.059 - 0.078 |
| 8 | >0.078 - 0.12 |
| 4 | >0.12 - 0.23 |
| 3 | >0.23 - 0.31 |
| 2 | >0.31 - 0.47 |
| 1 | >0.47 - 0.94 |
| 0.5 | >0.94 - 1.9 |
| None (<0.5) | >1.9 |

[a] The assumed meal size is 8 oz (0.227 kg). The ranges of chemical concentrations presented are conservative, e.g., the 12-meal-per-month levels represent the concentrations associated with 12 to 15.9 meals.
[b] Chronic, systemic effects.

Notes:
1. Consumption limits are based on an adult body weight of 70 kg and an interim RfD of $1x10^{-4}$ mg/kg-d.
2. None = No consumption recommended.
3. In cases where >16 meals per month are consumed, refer to Equations 3-1 and 3-2, Section 3.2.1.2, for methods to determine safe consumption limits.
4. The detection limit for methylmercury is $1 \times 10^{-3}$ mg/kg.
5. Instructions for modifying the variables in this table are found in Section 3.3.
6. Monthly limits are based on the total dose allowable over a 1-month period (based on the RfD). When the monthly limit is consumed in less than 1 month (e.g., in a few large meals), the daily dose may exceed the RfD (see Section 2.3).