# Washington State Toxics Monitoring Program: Freshwater Fish Tissue Component, 2008

November 2009

Publication No. 09-03-055

DEPARTMENT OF ECOLOGY
State of Washington

## Publication Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/0903055.html

Data for this project are available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID: WSTMP08.

Ecology's Project Tracker Code for this study is 02-500-01-07.

## Contact Information

For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600, Olympia, WA 98504-7600
Phone: (360) 407-6764

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia (360) 407-6000
- Northwest Regional Office, Bellevue (425) 649-7000
- Southwest Regional Office, Olympia (360) 407-6300
- Central Regional Office, Yakima (509) 575-2490
- Eastern Regional Office, Spokane (509) 329-3400

**Cover photo:** Fish collection with backpack electro-fisher.

# Washington State Toxics Monitoring Program: Freshwater Fish Tissue Component, 2008

*by*
*Keith Seiders and Casey Deligeannis*

Toxics Studies Unit
Statewide Coordination Section
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Waterbody Number(s): See Appendix B

*This page is purposely left blank*

# Table of Contents

# List of Figures and Tables

Page

## Figures



## Tables

*This page is purposely left blank*

# Abstract

Between 2001 and 2008, the Washington State Toxics Monitoring Program (WSTMP) exploratory monitoring component characterized toxic contaminants in 268 fish tissue samples from 129 sites. Results from the 2008 sampling are reported for 25 sites across Washington State representing 13 freshwater species of fish. Contaminants assessed were persistent, bioaccumulative, and toxic chemicals (PBTs) such as mercury, PCBs, dioxins and furans, chlorinated pesticides, and PBDE flame retardants.

Sample results spanned the range of values found in other studies of fish tissue in Washington. Mercury was detected in 100%, PBDEs in 92%, PCBs in 94% (combined Aroclor and congener analyses), and DDT compounds in 92% of the 36 samples analyzed. Dioxin/furans were detected in 85% of 33 samples analyzed.

A total of 67% of all samples did not meet National Toxics Rule (NTR) criteria for contaminants in fish tissue. Total PCBs, toxaphene, and 4,4'-DDE accounted for most of these exceedances. Other contaminants exceeding NTR criteria were hexachlorobenzene, dieldrin, and 2,3,7,8-TCDD.

This study recommends that six lakes and eight river sites be listed as Category 5, *Does Not Meet Criteria*, during the 2010 assessment cycle for the federal Clean Water Act Section 303(d) List for Washington State. Samples collected from the other 11 sites met Washington State water quality standards.

The current list of target analytes was also reviewed. Recommendations include discontinuing analysis of PCB congeners and the majority of chlorinated pesticides because of the limited information these analyses provide.

# Acknowledgements

The authors of this report would like to thank the following people for their contribution to this study:

- Marc Petersen and Jim Byrne, Washington Department of Fish and Wildlife (WDFW), for providing fish from Blue Lake and Cougar Creek, and other WDFW staff for providing site information and fish age data.
- Ed Shallenberger, Colville Tribe, for providing site information and field assistance.
- Tina Mayo and Cle Elum Ranger District, U.S. Forest Service (USFS), for site information, boat storage, and hand held-radio for emergency contact.
- Joe Zendt and Bill Sharp, Yakama Nation, for providing site information.
- Tom Fritsch, local Klickitat River fishing guide, for site information and fish collections.
- Judy Delavergne, Jeffrey Chan, and Scott Deeds, U.S. Fish and Wildlife Service (USFWS), for site information and permit coordination.
- Dave Gadwa and Bruce Baker, WDFW, for permit coordination.
- Gary Rule, National Marine Fisheries Service (NMFS), for permit coordination.
- Larry Caton and Greg Coffeen, Oregon Department of Environmental Quality (ODEQ), for cooperative work and permit coordination.
- Mike Rule and Nancy Curry, USFWS, for site information and permit coordination.
- Joe Adams and Cathryn Watanabe, Snohomish County Parks and Recreation, for providing site information.
- Marc Wicke, Tacoma Power, for providing site information and contacts.
- Scott and Nadine West, owners of Fish Lake Cove Resort, for site information, bags of ice, and hot chocolate.
- Bill and Mary Garoutte, owners of Bumping Lake Marina, for site information, lake access, and use of docks and facilities.
- Arny and Nita Grahn, owners of Conconully Reservoir Liar's Cove Resort, for site information and lake access.
- Washington State Department of Ecology, Environmental Assessment Program Staff:
  - Manchester Environmental Laboratory staff for analytical services: Karin Feddersen, Myrna Mandjikov, Debi Case, Dean Momohara, Dolores Montgomery, John Weakland, Kelly Donegan, Stuart Magoon, Aileen Richmond, and Leon Weiks.
  - For sample collection, processing, and data management: Dave Serdar, Patti Sandvik, Chad Furl, Brandee Era-Miller, Carolyn Lee, Randy Coots, Art Johnson, Kristin Carmack, Jenna Durkee, Scott Tarbutton, Daniel Dugger, Paul Anderson, Callie Meredith, Chris Moore, Brandon Sloan, Dylan Monahan, Michael Friese, and Nuri Mathieu.
  - Dale Norton for project guidance and design and review of the report; Joan LeTourneau, Cindy Cook, and Gayla Lord for formatting and editing the report; and Kristin Carmack for peer review of the final report.

# Background

During the 1980s and 1990s, the Washington State Department of Ecology (Ecology) and other agencies found toxic contaminants in fish, water, and sediment throughout Washington at varied levels of concern (www.ecy.wa.gov/toxics.html). In 2000, renewed concern about toxic contaminants in the environment led Ecology to revitalize a program to address toxic contaminants: the Washington State Toxics Monitoring Program (WSTMP).

The goals of the WSTMP are to:

- Conduct exploratory monitoring to characterize toxic contaminants in freshwater fish across Washington where historical data are lacking (the subject of this report).
- Conduct trend monitoring for persistent toxic chemicals.
- Improve access to information about monitoring contaminants in Washington: www.ecy.wa.gov/programs/eap/toxics/index.html.
- Establish cooperative efforts with other agencies and develop monitoring efforts to address topics of concern.

Between 2001 and 2008, 268 fish tissue samples from 129 sites were analyzed for various contaminants as part of the WSTMP Exploratory Monitoring component. Six annual reports have been published (www.ecy.wa.gov/programs/eap/toxics/wstmp.htm). Nearly 55,000 results are now available in Ecology's Environmental Information Management database (EIM) at www.ecy.wa.gov/eim/.

Ecology and the Washington State Department of Health (DOH) are developing strategies to address persistent, bioaccumulative, and toxic chemicals (PBTs) in our environment. These strategies involve learning more about the sources, uses, risks, and fate of these compounds. Mercury and flame retardants were the first PBTs for which chemical action plans were developed (www.ecy.wa.gov/programs/swfa/pbt/).

Fish are an important indicator of contaminant levels in the environment. Ecology evaluates fish tissue contaminant data to determine whether Washington State water quality standards are being met.

Contaminant concentrations in fish tissue that do not meet water quality standards are not necessarily high enough to warrant a fish consumption advisory to eat less fish. DOH evaluates the need for consumption advice based on multiple factors, including the benefits of eating fish as part of a healthy diet (www.doh.wa.gov/ehp/oehas/fish).

*This page is purposely left blank*

# Study Design

This exploratory monitoring component of the WSTMP targets resident freshwater fish from Washington. The primary purpose is to screen for PBT chemicals from areas where limited data are available on toxic chemicals in fish. The project plan describes the program in more detail (Seiders and Yake, 2002).

## Contaminants Assessed

An overview of target analytes for this component of the program is given below.

### Mercury

Mercury occurs in the earth's crust and is released to the environment from natural events (e.g., volcanoes, weathering, and forest fires) and human activities (e.g., fossil fuel combustion, mining, and industrial processes).

Methylmercury is the toxic form of mercury which persists in the environment as it accumulates in the food web. Eating fish and shellfish contaminated with methylmercury is the primary route for exposure to mercury for most people (ATSDR, 1999; Ecology and DOH, 2003; EPA, 2007).

### PCBs

Polychlorinated biphenyls (PCBs) are synthetic organic compounds historically used as cooling fluids in electrical equipment, and in inks, paints, and plastics. PCBs are stable, have low solubility in water, and have a high affinity for sediments and animal fats. The production of PCBs was banned in the U.S. in 1979 due to their persistence and toxicity (ATSDR, 2000).

There are 209 individual PCBs, or congeners. Commercial mixtures of PCB congeners were manufactured under various trade names. The most common in the U.S. used the trade name Aroclor. PCB Aroclors were analyzed in all 36 WSTMP samples from 2008; individual PCB congeners were analyzed in 30 (about 83%) of these samples.

PCBs in fish tissue were determined using two methods: EPA 8082 for PCB Aroclors and EPA 1668A for PCB congeners. The Aroclor method relies on matching patterns in results to patterns for the commercial mixtures making up Aroclors. The congener method measures concentrations of all individual PCB congeners in a sample. These methods are further discussed later in this report.

### Dioxins and Furans (PCDD/Fs)

Dioxins and furans, or polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs), are unintentional byproducts of combustion processes (e.g., burning household trash, forest fires, waste incineration), chlorine bleaching in paper production, and chemical and pesticide manufacturing. Agent Orange, which was used as a defoliant in the Vietnam War, contained dioxins (ATSDR, 2006).

Thirty-three of the 36 samples from 2008 were analyzed for the 17 most toxic congeners. These congeners have different levels of toxicity compared to 2,3,7,8-TCDD, the most toxic congener. The cumulative toxicity of mixtures of congeners in a sample can be expressed as a toxic equivalent (TEQ) to 2,3,7,8-TCDD. This TEQ is calculated by multiplying the result for each congener by its congener-specific Toxicity Equivalent Factor (TEF) and then summing the products (which are congener-specific TEQs) to obtain the 2,3,7,8-TCDD TEQ. This cumulative TEQ value is termed "dioxin/furan TEQ" in this report. The 2005 World Health Organization TEFs (Van den Burg et al., 2006) were used in this report.

## Chlorinated Pesticides

Pesticides include insecticides, herbicides, fungicides, and related chemicals used to control pests. Chlorinated pesticides were analyzed in this study because of their widespread occurrence and persistence in the environment.

Many of these pesticides are neurotoxins and are suspected or known carcinogens (EPA, 2000). Some pesticides were banned from use in the U.S. during the 1970s and 1980s as their hazards became evident. Some of the more frequently detected pesticides are described below.

- DDT (dichloro-diphenyl-trichloroethane) is a pesticide used to control insects in agriculture and insects that carry diseases such as malaria. Its use in the U.S. was banned in 1972 because of damage to wildlife. DDE (dichloro-diphenyl-dichloroethylene) and DDD (dichloro-diphenyl-dichloroethane) are contaminants or breakdown product of DDT. These chemicals stick strongly to soil and build up in fatty tissues of fish, birds, and other animals (ATSDR, 2002a).
- Hexachlorobenzene was widely used as a pesticide to protect the seeds and grains against fungus until 1965. It was also used to make fireworks, ammunition, and synthetic rubber. There are no current commercial uses of hexachlorobenzene in the United States. Like many other chlorinated pesticides, hexachlorobenzene can build up in tissues of fish, birds, and mammals. Hexachlorobenzene can also build up in wheat, grasses, and other plants (ATSDR, 2002b).
- Dieldrin is an insecticide that is very similar to aldrin. Aldrin quickly breaks down to dieldrin in the body and in the environment. These pesticides were widely used to protect corn and cotton. EPA banned most uses of aldrin and dieldrin in 1974 because of concerns about damage to the environment and human health. Their use continued for control of termites until 1987 when EPA banned all uses (ATSDR, 2002c).
- Toxaphene was one of the most heavily used insecticides in the U.S. until 1982, when it was canceled for most uses. It was used widely in the southern U.S. to control pests on cotton and other crops. It was also used to kill unwanted fish in lakes and to control pests on livestock. Toxaphene is a mixture of over 670 chemicals and has varied formulations (ATSDR, 1997).

## PBDE Flame Retardants

Flame retardants, specifically poly-brominated diphenyl ethers (PBDEs), are compounds added to plastic and foam products such as electronic enclosures, wire insulation, adhesives, textile coatings, foam cushions, and carpet padding. Increasing concentrations of PBDEs in humans and wildlife worldwide continue to raise concerns about their health effects. The highest levels of PBDEs in human tissue have been found in the U.S. and Canada (Ecology and DOH, 2005).

Similar to PCBs, there are 209 individual congeners of PBDEs. Thirteen of these congeners were analyzed for during this study: PBDE-47, 49, 66, 71, 99, 100, 138, 153,154, 183, 184, 191, 209.

# Site Selection

Sites are selected for sampling by examining various factors, such as the type of fish species present, the presence or absence of historical data, the value of the site for fishing, and the ability to cooperate with other monitoring or watershed planning efforts. Figure 1 shows the 25 sites sampled in 2008.

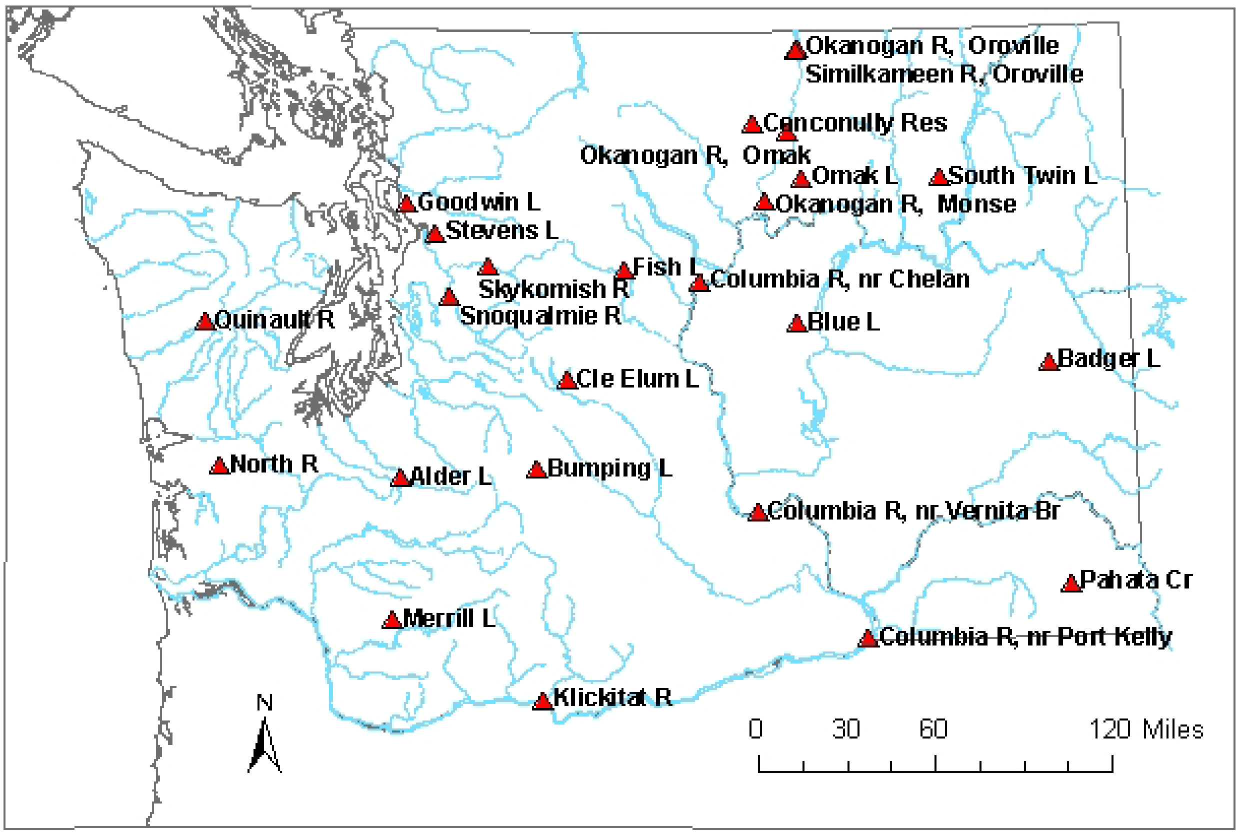



Figure 1. Sample Sites for the WSTMP, 2008.

The WSTMP cooperated with another Ecology study whose goal was to more thoroughly characterize PCBs and dioxins/furans in fish. This study targeted fish from 24 lakes and rivers in Washington that are considered to represent “background” conditions – or sites having no apparent local sources of PCBs or dioxins/furans (Johnson, 2008). Samples from 11 of these sites were also analyzed by the WSTMP in 2008 for other contaminants (PCB Aroclors, pesticides, PBDEs, mercury).

Another cooperative effort was with the EPA Mid-Columbia Toxics Study (EPA, 2008a). The goal of this study is to assess water quality and levels of toxic contaminants in fish from the mid-Columbia River (Grand Coulee Dam to Bonneville Dam). The initial year of this study (2008) included sampling fish at 19 sites from Wallula Gap to Grand Coulee Dam. Ecology analyzed three samples for dioxins/furans to supplement the analyses done by EPA.

Appendix B lists the 25 sample site locations and the species of fish sampled. Additional site and sample information, including analytical results, are available in Ecology’s EIM database at www.ecy.wa.gov/eim/index.htm. Search User Study ID: WSTMP08. The results for the “Background” study above are also stored in EIM under User Study ID WSTMP08 because so many samples were shared between the two studies.

# Field Procedures

Target fish species were chosen based on recommendations from the EPA (EPA, 2000) and previous experience with fish collection efforts. Most fish were collected in late summer or fall by electro-fishing, gill netting, angling, or trapping. Fish kept for analyses were given a unique identifying code, measured for length and weight, individually wrapped in aluminum foil and put in plastic bags, and transported to freezer storage.

Fish were later processed at Ecology facilities. Composite samples were made up of skin-on fillets of the same species from the same site. Typically, a composite sample consisted of five to ten individual fish, although some samples used more individuals because of their small size. The sex of each fish was determined when possible. Samples were then sent to laboratories for chemical analyses. Age was determined for individual fish by examining structures such as scales, otoliths, and spines. The collection and processing of samples are detailed in standard operating procedures, or SOPs (Sandvik, 2006a, 2006b, 2006c).

Fish from three Columbia River sites were collected by EPA’s Mid-Columbia Toxics Study (EPA, 2008 a or b). These samples were processed by Oregon Department of Environmental Quality staff. Aliquots were shipped to Ecology, frozen, where they were included for analysis of dioxins/furans (Caton, 2009).

# Analytical Methods

Table 1 describes analytical methods used in this study. Most analyses were performed by Ecology's Manchester Environmental Laboratory (MEL). Pacific Rim Laboratories, Inc. of Surrey, British Columbia, conducted analyses for PCB congeners and PCDD/Fs. At Ecology's request, PCDD/Fs results were reported down to the limit of detection, with values qualified as estimates if they were between the limit of detection and the quantitation limit.

Table 1. Analytical Methods for Fish Tissue Samples, WSTMP 2008.

| Analyte | Description | Method | Reporting Limit |
|---|---|---|---|
| PCB Aroclors | GC/ECD | EPA 8082 | 1.1 ug/kg, wet wt |
| PCB Congeners | HiRes GC/MS | EPA 1668A | 0.03 - 0.09 ug/kg, wet wt |
| Chlorinated pesticides | GC/ECD | EPA 8081 | 0.48 -10 ug/kg, wet wt |
| PBDEs | GC/MS SIM | EPA 8270 [1] | 0.38 – 4.3 ug/kg, wet wt |
| PCDD/PCDFs | HiRes GC/MS | EPA 1613B | 0.03 - 0.93 ng/kg, wet wt |
| Mercury (total mercury) | CVAA | EPA 245.6 | 0.017 mg/kg, wet wt |
| Lipids - percent | gravimetric | MEL SOP 730009 | 0.1 percent |

1. MEL SOP 730096, a modification of EPA 8270, was used in sample analyses.
GC = Gas Chromatography.
ECD = Electron Capture Detection.
MS = Mass Spectrometry.
SIM = Single Ion Monitoring.
HiRes = High Resolution.
CVAA = Cold Vapor Atomic Absorption.
SOP = Standard Operating Procedure.

Fish tissue was analyzed for total mercury because the analytical costs for methylmercury are prohibitively high. Methylmercury is also the predominant form of mercury found in free-swimming fish accounting for 95-100% of total mercury (Bloom, 1995). Both mercury and methylmercury are used as the basis for various water quality criteria or threshold values for the protection of human health and aquatic life.

# Data Quality

Data quality was assessed by reviewing laboratory case narratives, analytical results, and field replicate data. Case narratives were written by MEL analytical staff. The narratives described the condition of samples upon receipt, analytical quality control procedures, and data qualifications. Quality control procedures included a mixture of analyses such as: method blanks, calibration and control standards, matrix spikes, matrix spike duplicates, surrogate recoveries, and laboratory and field duplicates.

Overall, the 2008 data met most quality control criteria defined by MEL and the Quality Assurance Project Plan. The measurement quality objectives in the project plan were met in most cases, and all results were deemed usable as qualified. No data were rejected. Some data were qualified due to challenges encountered in analyses. Estimates of precision were mixed, ranging from good to poor, and appear typical for samples of fish tissue.

Appendix C summarizes results from quality control and quality assurance procedures. Other quality assurance information is available by contacting the authors of this report.

# Water Quality Criteria

Various criteria for the protection of human health exist because of changing knowledge about the toxic effects of chemicals and subsequent risks to consumers of fish. The various criteria and screening values are often based on different assumptions used in determining risk, such as daily consumption rates, toxicological data used in calculations, and risk levels. The criteria summarized below are the National Toxics Rule (NTR) criteria (used as Washington's Water Quality Standards), EPA's recommended criteria, and EPA's screening values

Fish tissue results from this study were compared to Washington's water quality standards to determine how sites should be assessed in Washington's Statewide Water Quality Assessment (the 303(d) assessment). This assessment also describes sampling requirements and other details about how environmental results are reviewed (Ecology, 2006).

Washington adopted the NTR criteria as the water quality standards for toxic compounds associated with human-health concerns. These criteria are one set of values that can be used in gauging the potential for human health risks from eating contaminated fish. EPA developed more recent criteria and guidance values which are described below. (See *EPA Recommended Water Quality Criteria* and *EPA Screening Values.*)

Results of this 2008 WSTMP study are not compared to these other two EPA values because Ecology lacks authority to begin corrective actions where these criteria are exceeded. Yet the EPA recommended criteria and screening values can be used by state, tribal, and local health jurisdictions in evaluating risks to human health from the consumption of contaminated fish.

Appendix D describes how Ecology and DOH evaluate fish tissue data. Table 2 shows the NTR (Washington's water quality standards criteria) and other EPA criteria and screening values for contaminants detected in this study.

Table 2. Criteria and Guidelines Used for the Protection of Human Health for Contaminants Detected in Fish Tissue, WSTMP 2008.

| Analyte (ppb ww)[1] | National Toxics Rule (September 2009 Interpretation) | National Recommended Water Quality Criteria [2] | EPA Screening Values | | | |
|---|---|---|---|---|---|---|
| | | | Subsistence Fishers | | Recreational Fishers | |
| | | | Non-carcino-gens | Carcino-gens | Non-carcino-gens | Carcino-gens |
| Mercury | 770 | 300 | 49 | - | 400 | - |
| Total PCBs [3] | 5.3 | 2.0 | 9.83 | 2.45 | 80 | 20 |
| 2,3,7,8-TCDD [4] | 0.065 | 0.025 | - | - | - | - |
| Dioxin/furan TEQ [4, 5] | - | 0.025 [9] | - | 0.0315 | - | 0.256 |
| 4,4'-DDD | 44 | 17 | - | - | - | - |
| 4,4'-DDE | 32 | 12 | - | - | - | - |
| 4,4'-DDT | 32 | 12 | - | - | - | - |
| Total DDT [6] | - | - | 245 | 14.4 | 2000 | 117 |
| Chlordane [7] | 8.0 | 11 | 245 | 14.0 | 2000 | 114 |
| Chlordane (technical) | 8.0 | - | - | - | - | - |
| Dieldrin | 0.65 | 0.24 | 24 | 0.307 | 200 | 2.5 |
| DDMU [8] | - | - | - | - | - | - |
| Hexachlorobenzene | 6.5 | 2.4 | 393 | 3.07 | 3200 | 25.0 |
| Lindane (gamma-BHC) | 2.5 | 127 | 147 | 3.78 | 1200 | 30.7 |
| Mirex | - | | 98 | - | 800 | - |
| Pentachloroanisole | - | - | - | - | - | - |
| PBDEs | - | - | - | - | - | - |
| Toxaphene | 9.6 | 3.7 | 122 | 4.46 | 1000 | 36.3 |

1 - Values in parts per billion wet weight (ug/kg ww) unless otherwise noted.
2 - EPA 2009. www.epa.gov/waterscience/criteria/wqctable/index.html.
3 - Total PCBs is sum of Aroclors or congeners.
4 - Values in parts per trillion wet weight (ng/kg ww).
5 - The cumulative toxicity of a mixture of congeners in a sample can be expressed as a Toxic Equivalent (TEQ) to 2,3,7,8-TCDD, termed the "dioxin/furan TEQ" in this report.
6 - Total DDT is the sum of 2,4'- and 4,4'- isomers of DDD, DDE, and DDT. DDD = 4,4'-dichlorodiphenyldichloroethane. DDE = 4,4'-dichlorodiphenyldichloroethylene. DDT = 4,4'-dichlorodiphenyltrichloroethane
7 - The NTR criterion for chlordane is interpreted as the sum of five chlordane components: these can be individually quantified through laboratory analyses while chlordane cannot. The EPA screening values are for "Total Chlordanes" which is the sum of five compounds: cis- and trans- chlordane, cis- and trans- nonachlor, and oxychlordane.
8 - DDMU (1-chloro-2,2-bis(p-chlorophenyl)ethene) is another breakdown product of DDT.
9 - EPA (2002) states that the criterion for dioxin is expressed in terms of 2,3,7,8-TCDD and should be used in conjunction with the international convention of TEFs and TEQs to account for the additive effects of other dioxin-like compounds. When the TEQ is used, the toxicity of the single congener 2,3,7,8-TCDD is incorporated.

## National Toxics Rule (NTR)

Washington State's water quality standards for toxic substances (WAC 173-201A-040[5]) define human health-based water quality criteria by referencing 40 CFR 131.36, also known as the National Toxics Rule.

The NTR criteria were issued by EPA to Washington State in 1992. These criteria are designed to minimize the risk of adverse effects occurring to humans from chronic (lifetime) exposure to toxic substances through the ingestion of drinking water and contaminated fish and shellfish obtained from surface waters. The NTR criteria are regulatory values used by Ecology for a number of different purposes, including permitting wastewater discharges and assessing when waterbodies are adversely impacted by contaminants.

The NTR criteria values are based on a daily fish consumption rate of 6.5 grams/day and a risk level of $10^{-6}$. A risk level is an estimate of the number of cases of adverse health effects (e.g., cancer) that could be caused by exposure to a specific contaminant. At a risk level of $10^{-6}$, one person in a million would be expected to contract cancer due to long-term exposure to a specific contaminant.

Ecology expresses the NTR water column criteria as tissue concentrations in order to compare the criteria to laboratory results from fish tissue samples (Ecology, 2006). These tissue concentrations are derived by multiplying the NTR water quality criteria for human health by the bioconcentration factor (BCF) for the specific contaminant. The BCFs for specific contaminants are found in EPA's 1980 Ambient Water Quality Criteria documents (EPA, 1980).

The NTR gives two sets of criteria for the protection of human health. One set is for *consumption of water and organisms* and the other is for *consumption of organisms only*. The criteria for *consumption of water and organisms* are used when evaluating contaminant levels in freshwater fish while the *consumption of organisms only* criteria are used for evaluating salt-water fish.

In the past, Ecology usually evaluated freshwater fish tissue using the criteria intended for salt-water fish. Recognizing this inconsistency, Ecology is developing guidance on how these criteria should be applied to ensure correct interpretation of water quality standards. For many chemicals, the difference between the two interpretations of criteria is small. The criteria based on the *consumption of water and organisms* are used in this report for determining whether fish tissue results do not meet (exceed) Washington's water quality standards.

## EPA-Recommended Water Quality Criteria

EPA publishes *National Recommended Water Quality Criteria* for many pollutants such as mercury and pesticides (EPA, 2001, 2002a, 2003, and 2009). These criteria are periodically updated to incorporate the latest scientific knowledge. EPA recommends these criteria be used by states and Indian tribes to establish water quality standards and ultimately provide a basis for controlling discharges or releases of pollutants. Yet these EPA-recommended criteria are not regulatory levels. Most of EPA's *Recommended Water Quality Criteria* are based on a daily fish consumption rate of 17.5 grams/day and a risk level of $10^{-6}$.

## EPA Screening Values

Screening values (SVs) for carcinogenic and non-carcinogenic effects of substances were developed by EPA to help prioritize areas that may present risks to humans from fish consumption. The EPA SVs are considered guidance only; they are not regulatory thresholds (EPA, 2000). The approach in developing the EPA SVs was similar to the approach used for developing the NTR, yet differs in two key assumptions:

- A cancer risk level of $10^{-5}$.
- Two consumption rates: 17.5 grams/day for recreational fishers, and 142.4 grams/day for subsistence fishers.

A difference between the EPA SVs and NTR relating to PCDD/Fs is that the SVs use the dioxin/furan TEQ value while Ecology uses the single congener (2,3,7,8-TCDD) for 303(d) assessments (Ecology, 2006).

# Results and Discussion

Data are reported for 25 sites representing 13 species of freshwater fish. The concentrations of contaminants in fish tissue are expressed as wet weight using two units of measure: (1) ug/kg or parts per billion (ppb), and (2) ng/kg or parts per trillion (ppt).

Table 3 shows summary statistics for key contaminants in freshwater fish. Mercury was detected in all samples while PCBs (Aroclors or congeners) were detected in all but two samples. PBDEs and DDTs were detected in 92% of samples with chlordanes detected in 13% of the samples. A total of 85% of the 33 samples analyzed for dioxins/furans had one or more congeners that were detected.

The NTR criteria for various contaminants were exceeded in many of the samples: 47% of samples for PCBs, 17% for 4,4'-DDE, and 6% for 2,3,7,8-TCDD. The dioxin/furan TEQ exceeded the NTR criterion for the single congener 2,3,7,8-TCDD in 39% of samples. Overall, PCBs and 4,4'-DDE accounted for most of the NTR exceedances found in 2008.

Table 3. Summary Statistics for Selected Analytes in Fish Tissue Samples, WSTMP 2008.

| Analyte [1] | n | Min. | Max. | Median | Mean | Standard Deviation | Detection Frequency | NTR Criteria Exceedance Frequency |
|---|---|---|---|---|---|---|---|---|
| Total PCB Aroclors [2] | 36 | 1.1 U | 98 J | 3.0 | 9.61 | 17.76 | 72% | 39% |
| Total PCB Congeners [2] | 30 | 0.248 NJ | 87.7 | 4.79 | 10.34 | 17.29 | 100% | 47% |
| Total DDT [3] | 36 | 0.479 U | 332 | 2.63 | 36.40 | 87.04 | 92% | 17% |
| Total Chlordane [4] | 30 | 0.479 U | 2.44 J | 0.497 | 0.6531 | 0.39 | 13% | 0% |
| Total PBDE [5] | 36 | 0.17 J | 70 | 3.6 | 8.56 | 13.31 | 92% | NC |
| Dioxin/furan TEQ [6] | 33 | 0.007 | 0.395 | 0.050 | 0.0852 | 0.0920 | 85% | 39% |
| 2,3,7,8-TCDD (ng/kg) | 33 | 0.030 U | 0.094 NJ | 0.030 | 0.0347 | 0.0151 | 18% | 6% |
| Mercury (ug/kg) | 36 | 22 | 367 | 84.6 | 99.8 | 65.24 | 100% | 0% |

1 - Values in parts per billion wet weight (ug/kg ww) unless otherwise noted.
2 - Total PCBs is the sum of the individual Aroclors or congeners.
3 - Total DDT is the sum of 4,4' and 2,4' isomers of DDT, DDD, and DDE. Washington has no criterion for Total DDT but does have a criterion for 4,4'-DDE; this criterion was exceeded in 17% of the samples, all from the Okanogan River.
4 - Total chlordane is the sum of: cis- and trans- chlordane, cis- and trans- nonachlor, and oxychlordane.
5 - Total PBDE is the sum of the individual congeners.
6 - The dioxin/furan TEQ is a value expressing the cumulative toxicity of the 17 PCDD/F congener results using TEFs by Van den Berg et al., 2005. Washington discontinued using the dioxin/furan TEQ value for comparison to the NTR in 2006. The exceedance value is given here so that comparisons to historical data can be made.
N = number.
U = The analyte was not detected at or above the reported value.
J = The analyte was positively identified. The associated numerical result is an estimate.
NJ = The analyte was tentatively identified, and the associated numerical value represents an approximate concentration.
NC = No criteria for this parameter.
The summing process for "Total" values used only values qualified as estimates; non-detect values were excluded.

# Contaminants in Freshwater Fish

## Mercury

Mercury was detected in all samples. No samples exceeded the NTR criterion of 770 ug/kg, and only one sample had a mercury level greater than EPA's *Recommended Water Quality Criterion* for methylmercury of 300 ug/kg (EPA, 2001). The range of values was similar to those seen in past WSTMP samples (Figure 2) as well as in other mercury monitoring efforts in Washington (Furl and Meredith, 2008).

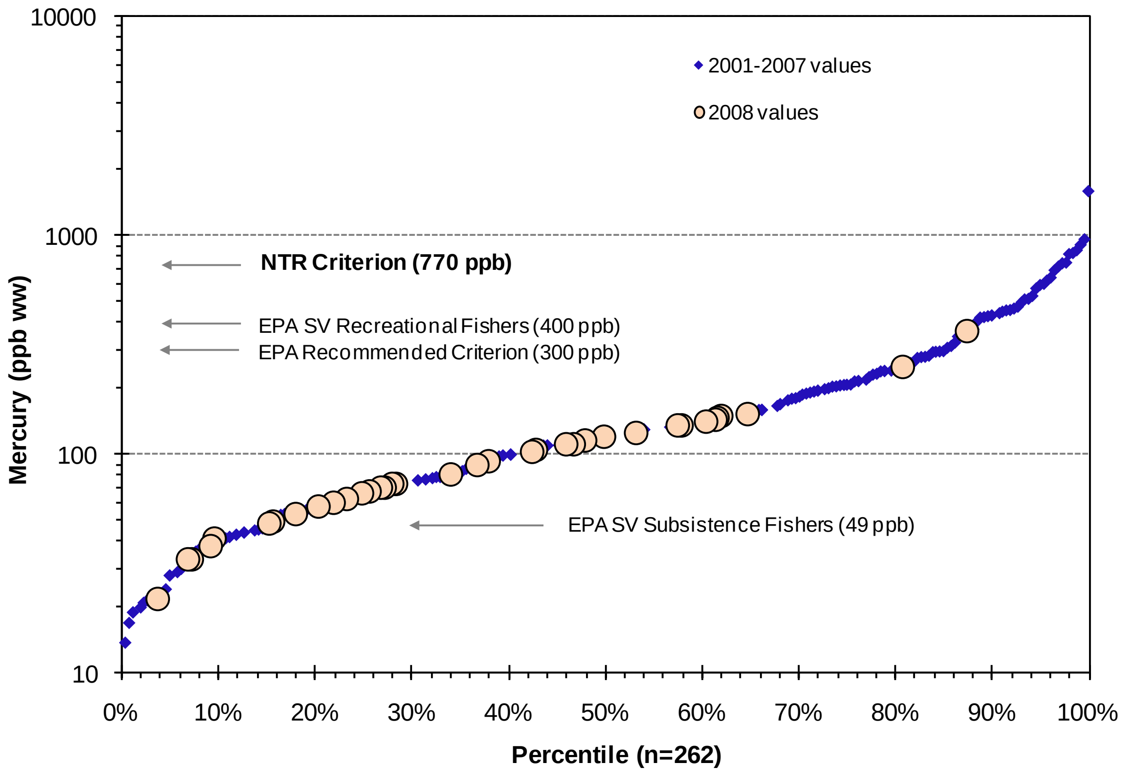



Figure 2. Distribution of Mercury in Edible Fish Tissue, WSTMP 2001-2008.

The highest level of mercury, 367 ug/kg, was found in the mountain whitefish sample from the Klickitat River. This is the highest level of mercury found in mountain whitefish during the WSTMP and ranks at the 87th percentile for all 2001-08 WSTMP samples. Fish in this sample were also among the largest and oldest mountain whitefish samples collected to date (mean total length of 413 mm and mean age of 5.0 years).

Common carp from the Okanogan River near Omak had the next highest mercury level: 249 ug/kg. This is also the highest mercury level of the seven carp samples collected by the 2001-08 WSTMP and ranks at the 81st percentile for all WSTMP samples. The carp sample from Omak consisted of larger and older fish: mean total length of 600 mm, mean weight of

2.9 kg, and mean age of 9.8 years. Levels of mercury in other samples from the Okanogan River were not as elevated as this sample from Omak.

## PCBs

PCBs were detected in 34 of the 36 samples with 47% of the samples exceeding the NTR criterion of 5.3 ug/kg total PCBs.

The highest levels of total PCBs were found in brown trout and northern pikeminnow from Fish Lake (98 and 42 ug/kg Aroclors, respectively). The next highest levels of PCB Aroclors were in common carp from the Okanogan River near Omak (35 ug/kg), and then in mountain whitefish from the mouth of the Similkameen River and largemouth bass from Fish Lake (each at 24 ug/kg). Fish from the remaining sites had total PCB levels less than 15 ug/kg.

Three species from Fish Lake had elevated PCB levels, ranking from the $79^{th}$ to $94^{th}$ percentile of all 2001-08 WSTMP samples. The elevated PCB levels may or may not be suggestive of something different about Fish Lake, such as the fish community being efficient at bioaccumulating PCBs, or the presence of a local source of PCBs. The fish used for the samples of brown trout, northern pikeminnow, and largemouth bass were all larger and older fish, and would be expected to have higher levels of contaminants. Yet levels of other contaminants such as DDTs, PBDEs, and dioxins/furans were not elevated compared to other WSTMP data.

Two other species from Fish Lake had low levels of PCBs. A sample of rainbow trout had 2.1 ug/kg total PCBs. The rainbow trout are stocked, so their levels of contaminants may not be representative of conditions in the lake. Two samples of largescale suckers also had low levels of PCBs (2.4 and 3.5 ug/kg). The largescale suckers were collected for a study on PCBs and dioxins/furans in fish from *background* sites having no apparent local sources. The effort by Johnson (2008) may further discuss levels of PCBs in fish from Fish Lake. Fish Lake, at about 500 acres, is located near Lake Wenatchee.

Figure 3 shows total PCB levels in edible fish tissue from 254 samples collected during the 2001-08 WSTMP. Two-thirds of the results from the 2008 sampling effort fell below the median ($50^{th}$ percentile) while 12 samples ranked above the median. Many of the sites selected in 2008 were representative of *background* conditions as described above, so levels of PCBs could be expected to be at the lower end of the distribution of all WSTMP samples. For all samples from 2001-08, about 54% exceed the NTR criterion for total PCBs of 5.3 ppb wet weight (ww) for the protection of human health. About 86% of the samples also exceed EPA's lower SV for Subsistence Fishers (2.45 ppb ww).

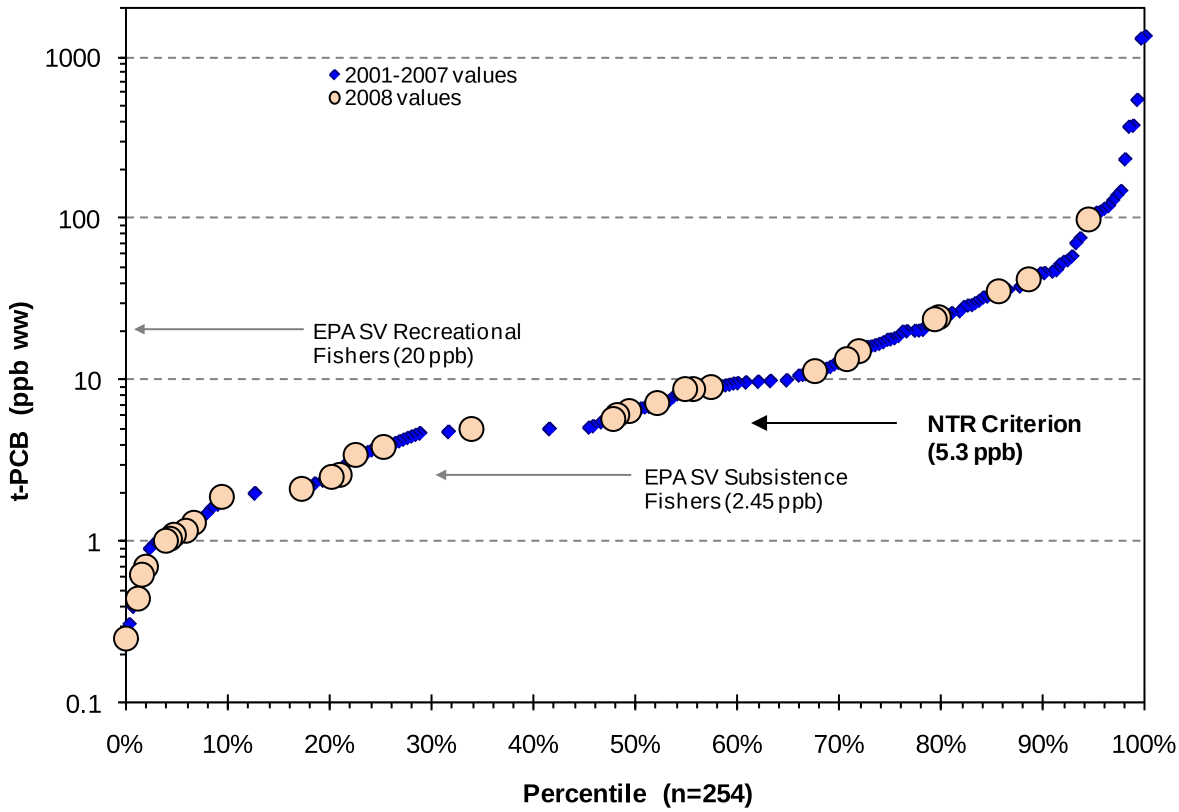



Figure 3. Distribution of Total PCBs in Edible Fish Tissue, WSTMP 2001-2008.

## Dioxins and Furans (PCDD/Fs)

Dioxins and furans were detected in 85% of the samples with 6% of samples exceeding the NTR criterion for 2,3,7,8-TCDD of 0.065 ng/kg. The highest levels of 2,3,7,8-TCDD were found in kokanee from Stevens Lake (0.094 ng/kg) and largescale sucker from the Columbia River near Vernita (0.090 ng/kg). These are the only two samples that exceeded the NTR criterion.

The highest values of dioxin/furan TEQ were found in Goodwin Lake rainbow trout, Columbia River largescale sucker from Vernita, and Snoqualmie River mountain whitefish (0.395, 0.310, and 0.298 ng/kg, respectively).

Figure 4 shows dioxin/furan TEQ values for all results from the WSTMP. The TEQ value, instead of the single 2,3,7,8-TCDD congener, is shown here because the TEQ is a more conservative expression of the risks posed by all 17 toxic dioxin and furan congeners. Most of the 2008 results were broadly distributed below the 60$^{th}$ percentile of all results from the WSTMP with some results being above the 60$^{th}$ percentile. As with PCBs, many of the sites selected in 2008 were representative of *background* conditions, so levels of dioxins/furans could be expected to be at the lower end of the distribution of all WSTMP samples. Overall, for the 73 samples where 2,3,7,8-TCDD was detected, 53% of these exceeded the NTR criterion of 0.065 ng/kg. TEQ values for about 84% of the WSTMP samples exceeded EPA's SV for Subsistence Fishers (0.032 ng/kg).

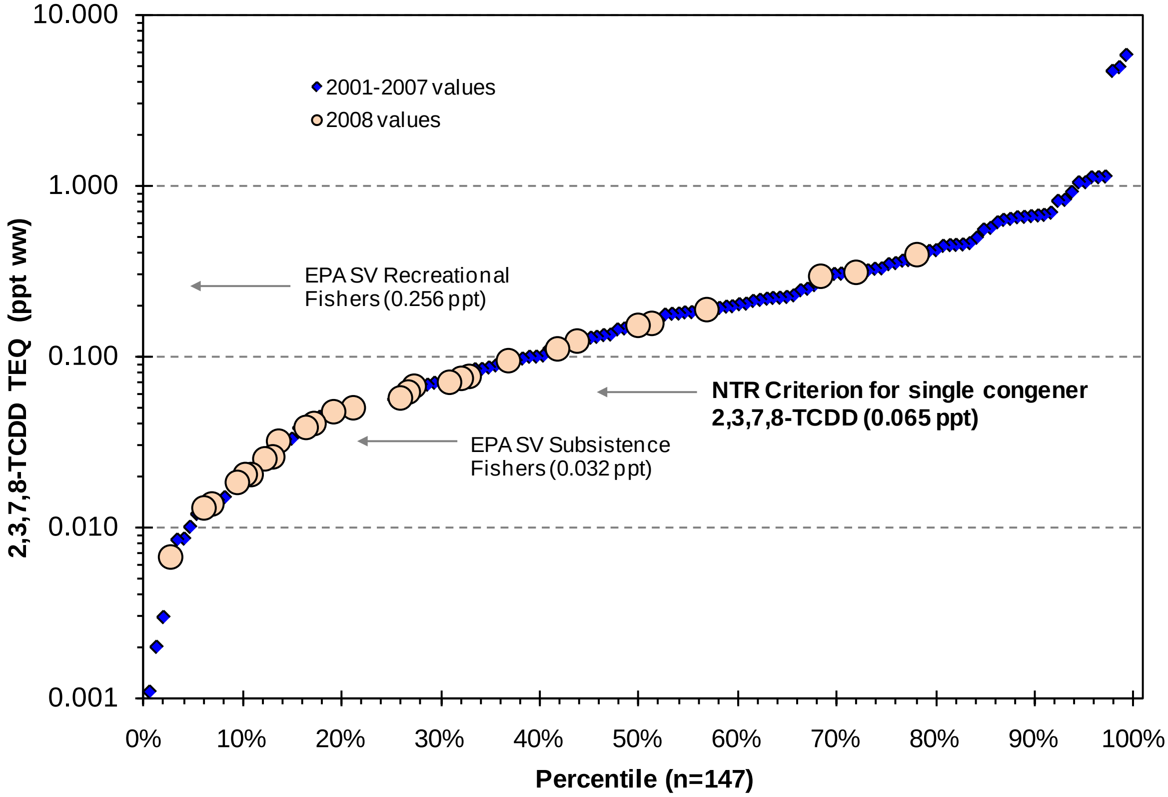



Figure 4. Distribution of Dioxin/Furan TEQ in Edible Fish Tissue, WSTMP 2001-2008.

## Chlorinated Pesticides

The most frequently detected chlorinated pesticides were 4,4'-DDE, 4,4'-DDT, 4,4'-DDD, hexachlorobenzene, and toxaphene. These were detected in 97% of samples for 4,4'-DDE and from 42% to 47% for the others. Eight other pesticides or breakdown products were detected at frequencies less than 17%. These were: Lindane (gamma-BHC), trans-nonachlor, DDMU, dieldrin, 2,4'-DDE, pentachloroanisole, cis-chlordane, and mirex.

While DDT compounds were detected in 92% of the samples, only 17% of the samples exceeded the NTR criterion for 4,4'-DDE of 32 ug/kg. The highest levels of total DDT were found in common carp, smallmouth bass, and mountain whitefish from the Okanogan and Similkameen Rivers (44-332 ug/kg). These results will be discussed in the *Okanogan River TMDL Effectiveness Monitoring Study* (Coffin, 2009). The remaining sites had fish containing less than 24 ug/kg total DDT. Levels of total DDT found during 2008 were within the range of values seen during the WSTMP (Figure 5).

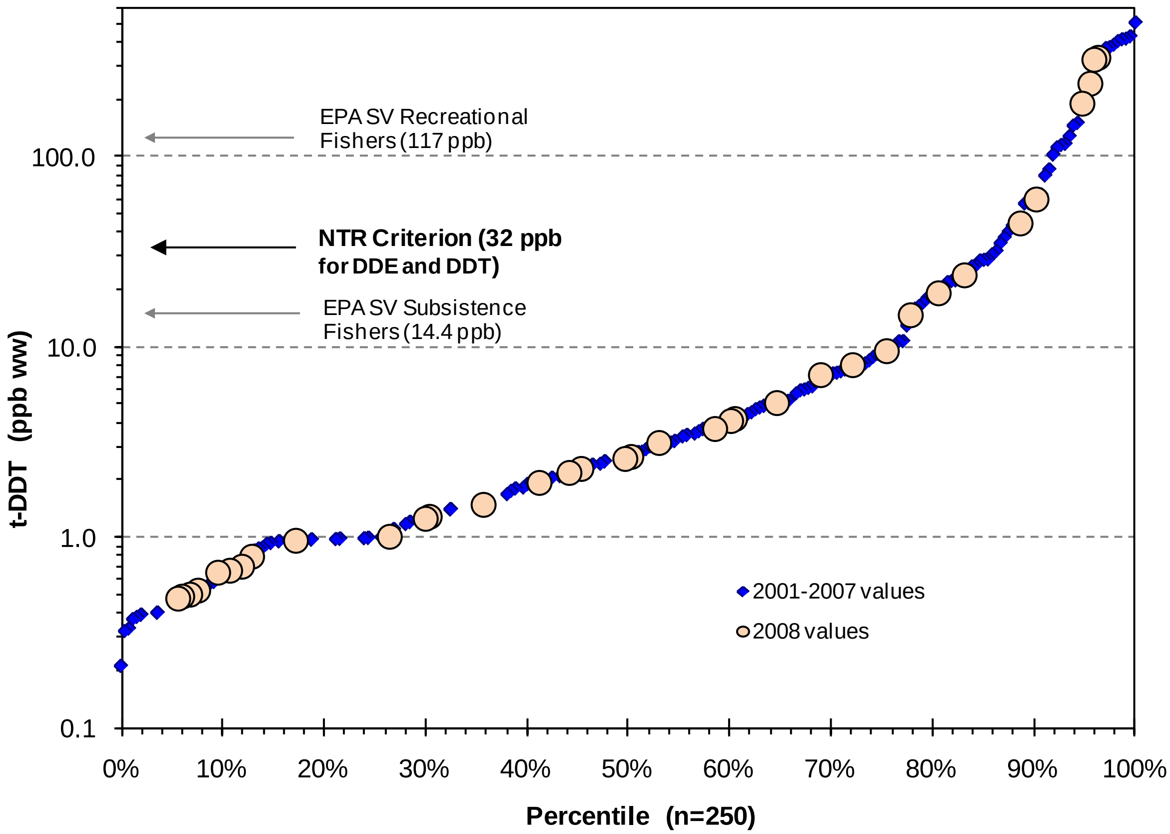



Figure 5. Distribution of Total DDT in Edible Fish Tissue, WSTMP 2001-2008.

Three other pesticides exceeded NTR criteria: hexachlorobenzene, dieldrin, and toxaphene. Hexachlorobenzene in rainbow trout, largemouth bass, and smallmouth bass from Goodwin and Stevens Lakes ranged from 9.8 - 22.7 ug/kg and exceeded the NTR criterion of 6.5 ug/kg. Kokanee from Stevens Lake had dieldrin at 1.58 ug/kg which exceeded the NTR criterion of .65 ug/kg.

Nine samples from six sites had toxaphene levels ranging from 9.9 – 20 ug/kg, all of which exceeded the NTR criterion of 9.6 ug/kg. The sites included Fish, Goodwin, Stevens, and Merrill Lakes, as well as the Klickitat and Snoqualmie Rivers. Species were mountain whitefish, brown trout, rainbow trout, cutthroat trout, and kokanee.

## PBDE Flame Retardants

PBDEs were detected in 92% of fish tissue samples with total PBDE values ranging from less than 1 to 70 ug/kg. The highest levels of total PBDEs were in mountain whitefish from the Similkameen River (70 ug/kg) and Klickitat River (36 ug/kg). Total PBDE levels in fish from seven other sites ranged from 8.2 to 26 ug/kg which were at or above the 80th percentile level for all 2001-08 WSTMP samples (Figure 6). These sites include the Snoqualmie, Skykomish, and Okanogan Rivers, as well as Blue, Stevens, and Badger Lakes, and Conconully Reservoir.

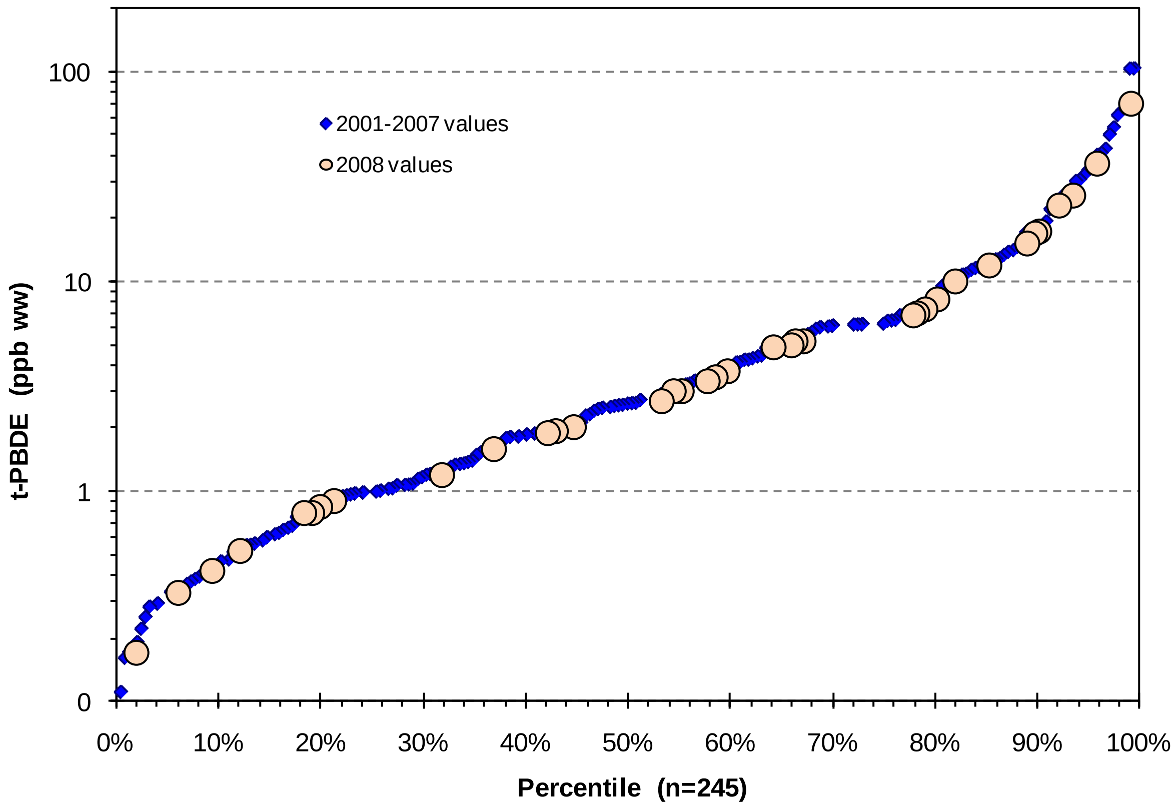



Figure 6. Distribution of Total PBDEs in Edible Fish Tissue, WSTMP 2001-2008.

## Water Quality Standards Exceeded

Fourteen of the 25 sites had fish tissue that did not meet one or more NTR criteria. Total PCBs and 4,4'-DDE accounted for 59% of these exceedances. The other exceedances were due to 2,3,7,8-TCDD, hexachlorobenzene, dieldrin, and toxaphene. Table 4 shows the 27 cases from 14 sites recommended for Category 5 classification, *Does Not Meet Criteria*, in Ecology's 303(d) assessment method (Ecology, 2006).

A total of 13 sites had fish where dioxin/furan TEQ values exceeded the NTR criterion for the single congener 2,3,7,8-TCDD (0.065 ng/kg). In 2006, Ecology changed how dioxin/furan data are used for the 303(d) assessment method. Prior to Ecology's 2006 documentation of the assessment methodology (Ecology 2006), TEQ values were used in classifying waters as Category 5, which is the 303(d) list. Currently, when TEQ values exceed the NTR criterion for the single congener 2,3,7,8-TCDD, the site is classified as Category 2. So, 13 sites are recommended for Category 2 classification, *Waters of Concern* (Table 4, last column on right).

Twenty-six sample analyses for aldrin, dieldrin, alpha-BHC, and heptachlor epoxide could not be compared to NTR criteria because the analyte was not detected at reporting limits that were greater than the respective criteria. These cases are recommended for a Category 3 classification, *Lack of Sufficient Data* (not shown in Table 4). The remaining results (n=732) that met NTR criteria are recommended for Category 1 classification, *Meets Tested Criteria*.

Table 4. Recommended 303(d) Listings for Fish Tissue Sample Results, WSTMP 2008.

| Recommended Category for 303(d) Assessment --> | | | 5 | | | | | | 2 |
|---|---|---|---|---|---|---|---|---|---|
| Site Name | Species Exceeding One or More NTR Criteria (New Interpretation) | Number of Category 5 | Total PCBs | 2,3,7,8-TCDD | 4,4'-DDE | Hexachloro-benzene | Dieldrin | Toxaphene | Dioxin/furan TEQ |
| Alder Lake | KOK, RBT | 1 | x | | | | | | X |
| Bumping Lake | BKT, CTT | 1 | x | | | | | | |
| Fish Lake | BNT, LMB, NPM, RBT | 2 | x | | | | | x | |
| Goodwin Lake | LMB, RBT, SMB | 3 | x | | | x | | x | X |
| Klickitat River | MWF | 2 | x | | | | | x | X |
| Merrill Lake | CTT | 1 | | | | | | x | |
| Okanogan River, Oroville | CCP, SMB | 2 | x | | x | | | | |
| Okanogan River, Omak | CCP, SMB | 2 | x | | x | | | | X |
| Okanogan River, Monse | SMB | 2 | x | | x | | | | |
| Omak Lake | PEA | | | | | | | | X |
| Quinault River | CTT | | | | | | | | X |
| Similkameen River, Oroville | MWF | 2 | x | | x | | | | |
| Skykomish River | MWF | 1 | x | | | | | | X |
| Snoqualmie River | MWF | 2 | x | | | | | x | X |
| South Twin Lake | BKT | | | | | | | | X |
| Stevens Lake | KOK, RBT | 5 | x | x | | x | x | x | X |
| Columbia River, Chelan | NPM | | | | | | | | X |
| Columbia River, Vernita | LSS | 1 | | x | | | | | X |
| Columbia River, Port Kelly | SMB | | | | | | | | X |
| Count of Recommended Category 5 Listings: | | 27 | 12 | 2 | 4 | 2 | 1 | 6 | |
| Percent of Recommended Category 5 Listings: | | | 44% | 7% | 15% | 7% | 4% | 22% | |
| Count of Recommended Category 2 Listings: | | | | | | | | | 13 |

Species codes: BKT = Brook trout, BNT = Brown trout, CCP = Common carp, CTT = Cutthroat trout, KOK = Kokanee salmon, LMB = Largemouth bass, LSS = Largescale sucker, MWF = Mountain whitefish, NPM = Northern pikeminnow, PEA = Peamouth, RBT = Rainbow trout, SMB = Smallmouth bass.

# Contaminant Scores for Samples and Sites

A contaminant scoring method was used to help compare results across many species and sites. The method used results for contaminants that were detected in more than 50% of samples. The sample scores and site scores give an overall picture of how far contaminant levels in fish are above benchmark values. This scoring was applied only to sites sampled by the WSTMP from 2001 through 2008.

## Sample and Site Scoring

Contaminant scores were developed for each sample, then for each site. For samples, levels of contaminants in each sample were divided by a benchmark value which produced a ratio of the contaminant concentration in the sample to the benchmark value. These ratios show whether individual contaminants are higher or lower than the benchmark values and by how much. The ratios for each contaminant were then summed to give a sample contaminant score. Finally, site contaminant scores were derived by averaging the sample contaminant scores from each site.

Table 5 shows how sample contaminant scores were calculated to develop and site contaminant scores. The benchmark values used were the NTR criteria or other value as described in the table's footnotes. Where results were qualified as non-detects, the reporting limit was used.

Table 5. Example Calculation of Sample and Site Contaminant Scores for the Stevens Lake Site near Everett, WSTMP 2008.

| Contaminant | Benchmark Value [1] | Sample Result Value | | | | Benchmark Exceedance Factor | |
|---|---|---|---|---|---|---|---|
| | | RBT | | KOK | | CTT | LMB |
| Total PCB Aroclors (ppb) | 5.3 | 5.8 | J | 11.3 | J | 1.1 | 2.1 |
| Total DDT (ppb) [2] | 32 | 2.2 | J | 5.0 | J | 0.1 | 0.2 |
| Total PBDE (ppb) [3] | 17.5 | 5.0 | J | 17.2 | J | 0.3 | 1.0 |
| Dioxin/furan TEQ (ppt) [4] | 0.065 | 0.020 | | 0.094 | J | 0.3 | 1.4 |
| Mercury (ppb) | 300 | 49.4 | | 59.6 | | 0.2 | 0.2 |
| Sample Contaminant Score: | | | | | | 1.9 | 4.9 |
| Site Contaminant Score: [5] | | | | | | 3.4 | |

1 - Benchmark values are NTR criterion value unless noted otherwise.
2 - Benchmark value is the NTR criterion for both 4,4'-DDE and 4,4'-DDT, the compounds which usually contribute the most to the total DDT value.
3 - There are no criteria for PBDEs. The benchmark value is the 90th percentile from WSTMP results, 2001-2008 (n=245).
4 - Benchmark value is the NTR criterion for the single congener 2,3,7,8-TCDD.
5 - The site contaminant score is the mean of the sample contaminant scores from that site.
U - The analyte was not detected at or above the reported result.
J - The analyte was positively identified. The associated numerical result is an estimate.
Species codes: RBT - Rainbow trout, KOK- Kokanee, CTT - Cutthroat trout; LMB - Largemouth bass.

Figure 7 shows the 2008 sample contaminant scores by site and species. The lowest contaminant scores for 2008 were for South Twin, Blue, and Bumping Lake samples (0.3 to 0.7). These samples did not exceed any benchmark values. The highest sample contaminant scores were for Fish Lake brown trout (20.4), Okanogan River near Omak common carp (18.5), and Similkameen River mountain whitefish (13.0). These samples exceeded one or more benchmark values, usually for total PCBs or total DDT.

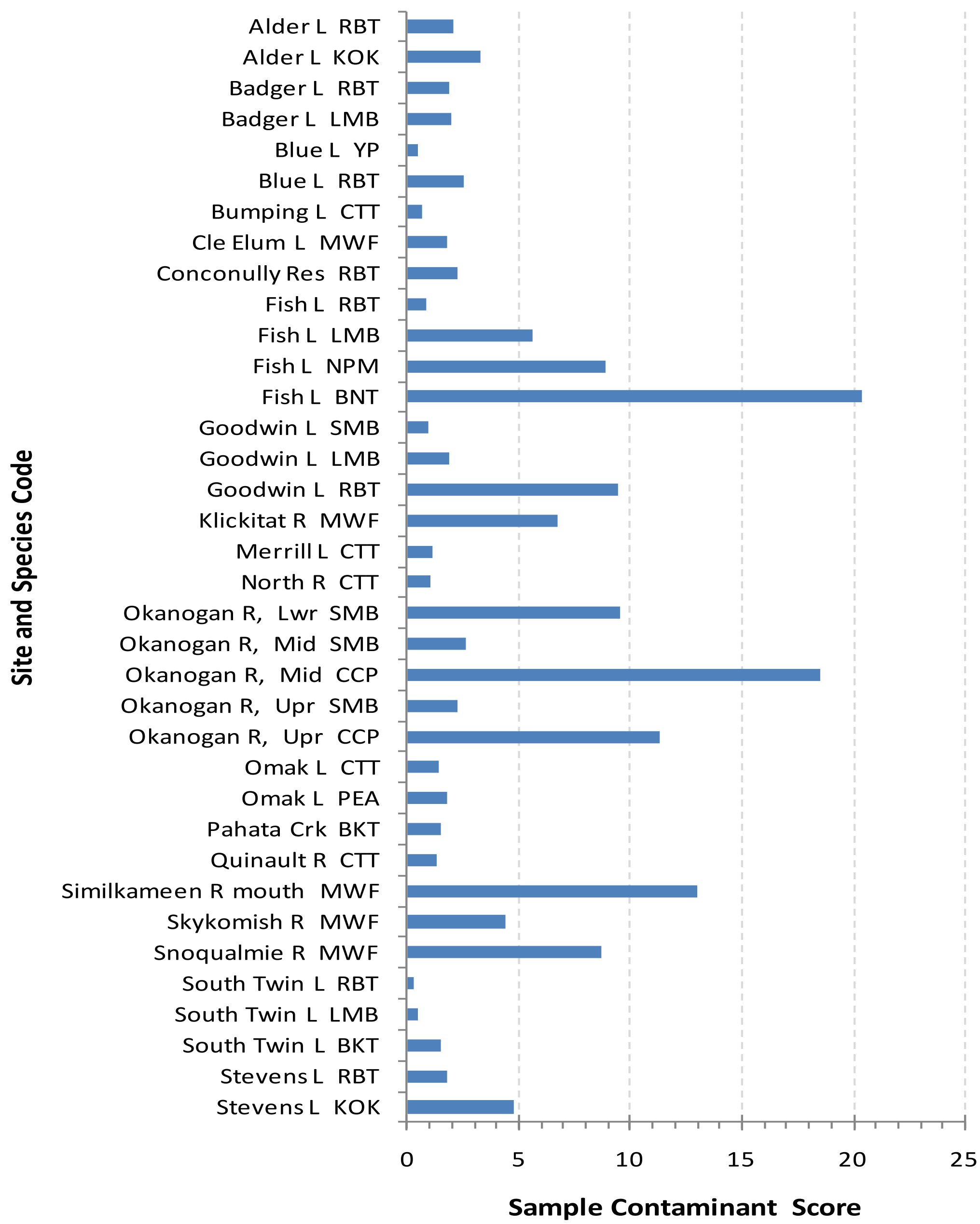



Figure 7. Sample Contaminant Scores, Sorted by Site, WSTMP 2008.
*Species codes are described in Table A1.*

The median score for all 2008 samples was 2.0. As in previous years, PCBs and dioxin/furan TEQ values contributed most to these scores. For example, the Goodwin Lake rainbow trout sample had a dioxin/furan TEQ level which exceeded the benchmark value of 0.065 ng/kg by a factor of 6.1, accounting for about 64% of that sample's contaminant score of 9.5. The PCB level in this same sample accounted for nearly 30% of the contaminant score. Overall, the 2008 sample contaminant scores ranged from the 1st to 91st percentiles for all scores from the 2001-2008 samples.

## Site Contaminant Scores, 2001-2008

Figure 8 shows the spatial distribution of the 2001-2008 site contaminant scores across Washington. The 25 labeled sites were sampled in 2008 and show lower levels of contamination than previously sampled sites. The highest scores for all WSTMP sites are for the Wenatchee River and Lake Washington (184 and 178, respectively). The next highest scores include the Columbia, Snake River, Spokane, and Cowlitz Rivers, as well as Green Lake in Seattle.

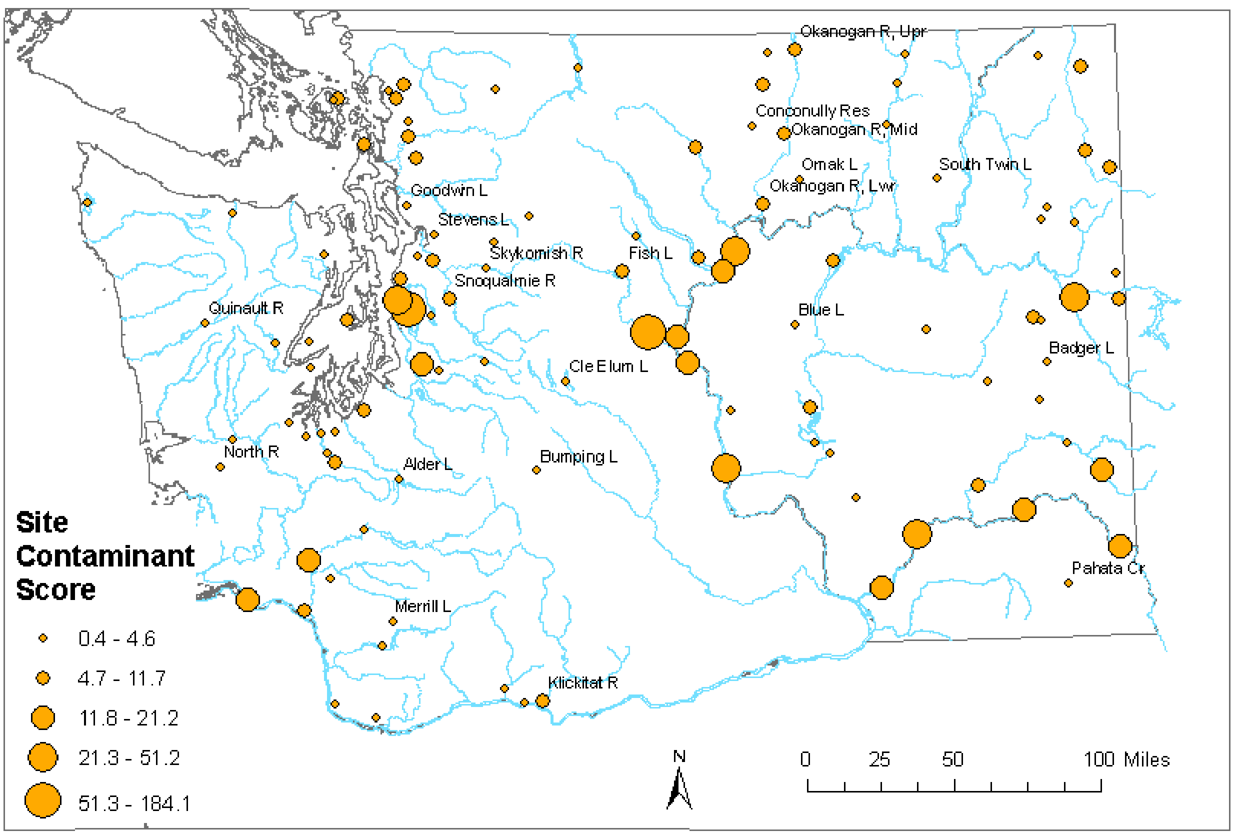



Figure 8. Site Contaminant Scores for Fish Tissue Results, WSTMP 2001-2008.

Site contaminant scores for 2008 ranged from less than 1 (Bumping Lake and South Twin Lake) to 10.5 (Okanogan River near Omak) with the median score being 3.8. The 2008 site contaminant scores ranked from the 3rd to the 82nd percentile of all 2001-2008 sites. Highest scores (6.7 - 10.5) from were for Fish Lake and the Okanogan, Klickitat, and Snoqualmie Rivers. These sites represent a range of land uses, from national forest, agriculture, and rural. Fourteen of the 25 sites had at least one sample that exceeded NTR criteria as described earlier and shown in Table 4.

The site scoring included dioxin/furan TEQ data because about 68% of the samples were analyzed for dioxins and furans. Sites were also scored without using dioxin/furan data to see how much scores would change. The scores for 60% of the sites changed by no more than 10 points when the dioxin/furan data were excluded. While this difference in scores does lead to a different ranking when dioxin/furan data are excluded, the general ranking for the majority of sites changed little.

For the site contaminant scoring, sample results for some areas were consolidated to represent one site. For example, sample results from Lake Washington were associated with three areas (north, south, and entire lake) so samples from these areas were combined to represent Lake Washington as a single site. Similarly, samples from four areas along the Spokane River between river miles 64 and 85 were combined to represent the Spokane River as a single site. A sample from the mouth of the Similkameen River was combined with samples from the Okanogan River near Oroville. Other consolidations were for sites on the Wenatchee and Palouse Rivers. Three sites on the Columbia River sampled in 2008 in support of EPA's monitoring effort are excluded because only dioxin/furans were analyzed by Ecology.

## Summary of Species Sampled, 2001-2008

Since 2001, the WSTMP has analyzed 258 samples representing 24 species of fish. Figure 9 shows that six species accounted for two-thirds of the samples collected. The most commonly collected species were largemouth bass, rainbow trout, cutthroat trout, yellow perch, mountain whitefish, and northern pikeminnow. These species are common to many areas of Washington and would be useful for comparing contaminant results on a statewide basis. For example, largemouth bass is the target species for efforts to determine trends in mercury in fish across Washington (Furl and Meredith, 2008).

Most of the species collected are naturally reared while others are often raised in hatcheries and planted in lakes for managed fisheries. Rainbow trout at most sites were usually raised in hatcheries and planted as fry, fingerlings, or yearlings raised to a catchable size. Serdar (2006) found that rainbow trout accumulated PCBs, PBDEs, and chlorinated pesticides while being raised in hatcheries – sometimes to levels exceeding NTR criteria at the time fish were released into lakes. Other trout species sometimes raised at hatcheries include cutthroat, brown, and brook. Many kokanee salmon are also raised in hatcheries and released as fry. Some species tend to have higher contaminants levels than other species.

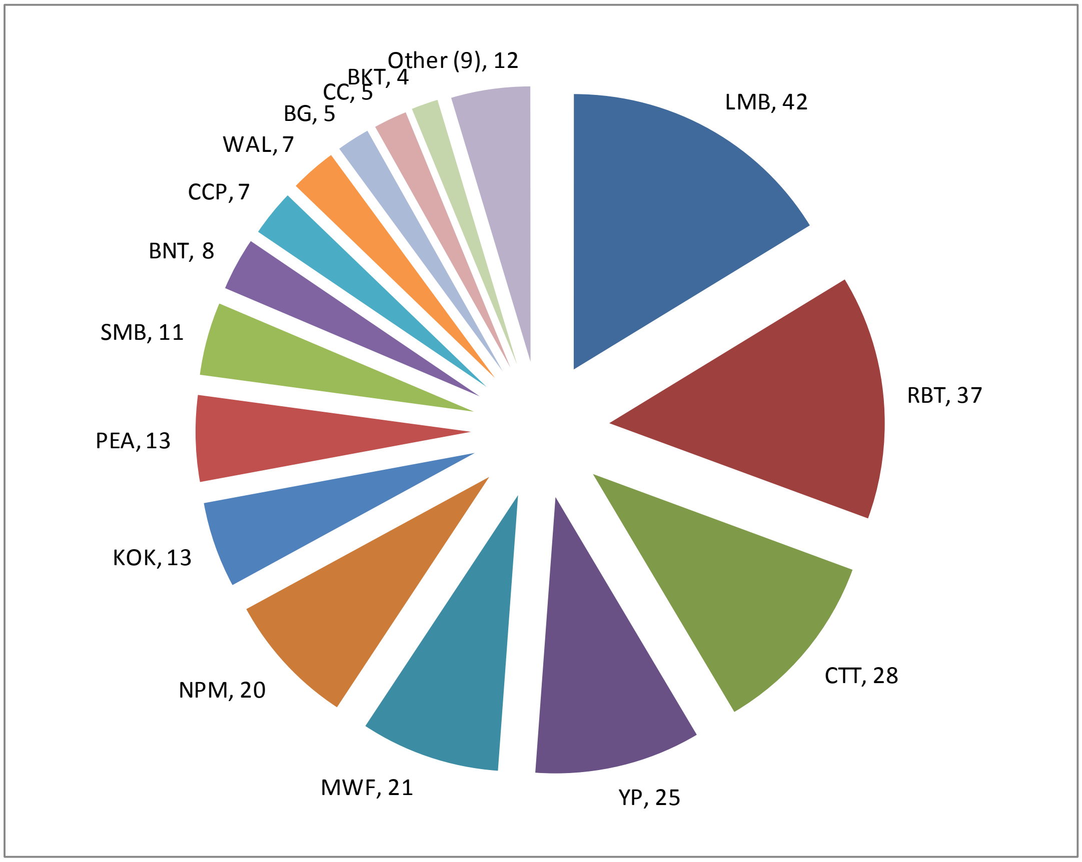



Figure 9. Number of Samples by Species Collected, WSTMP 2001-2008.
*Species codes are described in Table A1.*

Figure 10 shows boxplots of sample contaminant scores by fish species. Each boxplot depicts the 25$^{th}$ percentile (bottom of box), 50$^{th}$ percentile or median (horizontal line within box), and the 75$^{th}$ percentile (top of box) of the data in that group. The vertical lines extending above and below the box depict the upper and lower ranges of data. Symbols plotted beyond the vertical lines represent outliers. A single horizontal line and absence of a box indicates a single data point or a small data set such that quartiles could not be calculated.

Species having the higher contaminant scores in Figure 10 (median score > 5) are brown trout, channel catfish, common carp, lake whitefish, mountain whitefish, and northern pikeminnow. The higher scores are likely due to factors such as the fish being older and larger, having higher lipid content, being taken from more contaminated areas (e.g., Lake Washington), and piscivorous diet. Exceptions to piscivory are the whitefish which feed mostly on invertebrates (Wydoski and Whitney, 2003). Species that tend to have higher levels of contaminants may be useful for long-term monitoring to detect changes in contaminant levels over time.

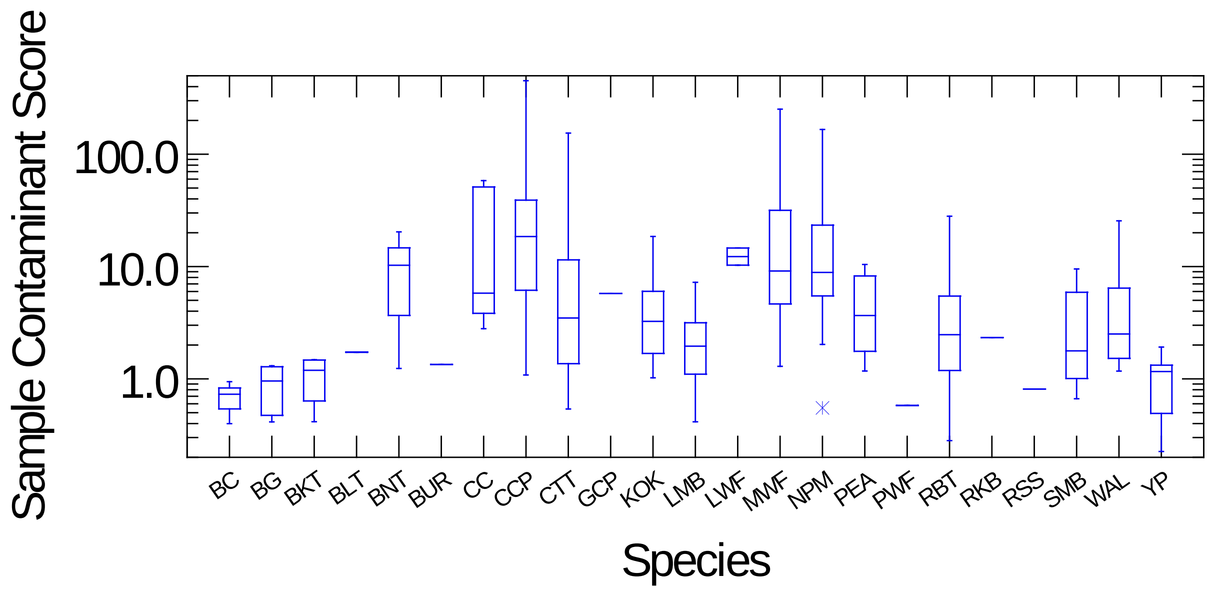



Figure 10. Boxplots of Sample Contaminant Scores by Species, WSTMP 2001-2008.
*Species codes are described in Table A1.*

Appendix E shows results for selected analytes in fish tissue samples for 2001-2008. Table E-1 lists results for key analytes for the 2008 samples only. Figure E-1 shows boxplots of contaminant concentrations by species, as well as the characteristics of the fish making up the samples, such as lipid content, total length, and age. Table E-2 summarizes results for selected analytes for each species sampled between 2001 and 2008.

## Review of Target Analytes: 2001-2008

The results and detection frequencies of target analytes from eight years of monitoring were reviewed to help determine the value of information gained from current analyses and help evaluate strategies for future monitoring efforts.

Results for over 250 samples from more than 100 sites across Washington were included in the review. Tables 6-9 shows detection frequencies, range of results, and frequencies that contaminants exceeded NTR criteria. Target analytes in each table are ranked in order from high to low detection frequency. For PCBs, two analytical methods are compared. Mercury is excluded here because it was detected in all samples and remains of high interest for continued monitoring.

### PCB Aroclors and PCB Congeners

PCB Aroclors were analyzed in nearly all samples. Table 6 shows that of the nine PCB Aroclors analyzed for, only Aroclors 1254 and 1260 were consistently detected. Aroclor 1248 was detected in nearly 5% of samples while the other Aroclors were never detected. Total PCBs as the sum of Aroclors exceeded NTR criteria in 75% of samples. The individual Aroclors that were detected frequently exceeded the NTR criterion for total PCBs.

Table 6. Detection Frequency and Range of Values for PCB Aroclors in Fish Tissue, WSTMP 2001-2008 (values in ug/kg).

| Analyte | Number of Analyses | Detection Frequency | Detects: Range | Non-Detects: Range | Detects: NTR Exceedance Frequency |
|---|---|---|---|---|---|
| PCB Aroclors Total | 253 | 64% | 1.2 - 1339 | 0.97 - 10 | 75% |
| PCB 1254 | 231 | 59% | 1.1 - 1300 | 0.92 - 10 | 69% |
| PCB 1260 | 231 | 52% | 1.2 - 512 | 0.96 - 10 | 56% |
| PCB 1248 | 231 | 4.8% | 2.8 - 170 | 0.92 - 38 | 55% |
| PCB 1016 | 223 | 0.0% | - | 0.92 - 38 | no detects |
| PCB 1221 | 223 | 0.0% | - | 0.92 - 38 | no detects |
| PCB 1232 | 223 | 0.0% | - | 0.92 - 38 | no detects |
| PCB 1242 | 223 | 0.0% | - | 0.92 - 46 | no detects |
| PCB 1262 | 152 | 0.0% | - | 0.39 - 48 | no detects |
| PCB 1268 | 152 | 0.0% | - | 0.39 - 10 | no detects |

PCB congeners were analyzed in a subset of each year's samples since 2004. Congener analysis was pursued in order to evaluate the accuracy and comparability of Aroclor analysis for meeting the needs of this screening level monitoring effort. Analyses for PCB Aroclor often had challenges such as poor pattern matches to standards. This was because of weathering or degradation as well as interference due to high lipids content or the presence of other analytes. These factors added to the difficulty of achieving the desired reporting limits of 2 ug/kg. However, lower reporting limits for Aroclors have recently been achieved more consistently at MEL with additional cleanup methods and changes in sample extraction methods.

Figure 11 shows that PCB Aroclor values compare fairly well with PCB congener values over three orders of magnitude. Viewing the relationship between the two sets of values, Aroclor values appear to be a bit lower than congener values and may underestimate the true concentration of PCBs in the samples. This difference is likely due to differences in analytical methods: Aroclor analysis is based on matching patterns of mixtures of selected congeners whereas the congener method is a direct measurement of all PCB congeners present. The difference in results produced by the two methods is likely negligible such that Aroclor analysis would be adequate to meet this project's needs.

The advantages and disadvantages of each method for quantifying PCBs need to be considered in monitoring efforts (Bernhard and Petron, 2001). Congener analysis provides a more accurate quantification at lower reporting limits (0.005 – 0.02 ug/kg) than Aroclor analysis (1.0 - 5.0 ug/kg). Analytical costs per sample are higher for congener analysis ($800 - $1000) than for Aroclor analysis ($200). PCB congener analysis also requires substantial effort to validate and verify the data and prepare it for loading into Ecology's EIM database. The time between sample submittal and readiness to load data into EIM is longer for congener data (6-10 months) than for Aroclor data (2-4 months).

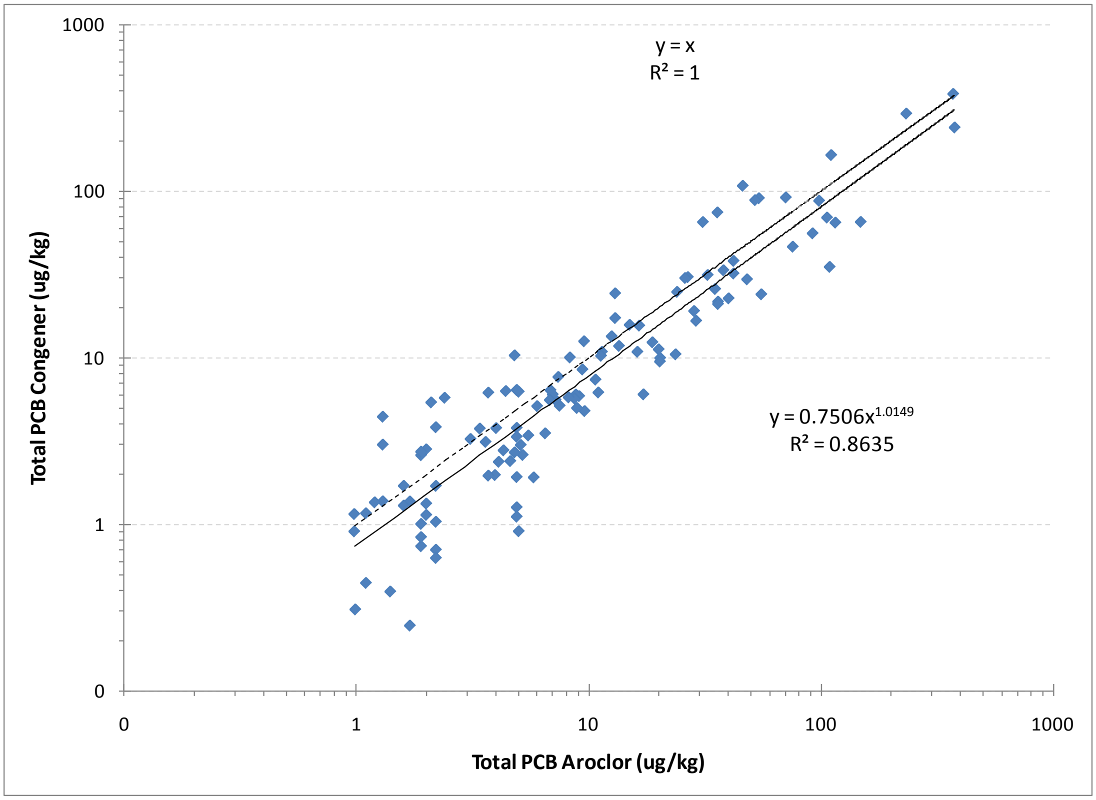



Figure 11. Total PCB Aroclors versus Total PCB Congeners, WSTMP 2001-2008 (n=120).

Given the factors described above, the use of PCB Aroclor analysis in the WSTMP effort would meet project needs at lower laboratory costs, lower data processing costs, and quicker turnaround times between sampling and data upload to EIM.

The consequences of underestimating PCB levels in fish tissue for this monitoring effort is likely negligible. So far, little or no action has been taken in cases where PCB levels in fish exceed the water quality standard of 5.3 ug/kg by factors ranging from 2-10, or even higher. In these cases, the PCB level as estimated by Aroclor analysis is likely adequate. Any further action would likely involve additional sampling, typically using larger sample sizes to obtain a better estimate of the level of PCBs in fish tissue.

The widespread occurrence of PCBs and dioxins/furans in fish tissue is a challenging problem to address, especially where identifiable and controllable sources of these contaminants cannot be identified. Results from the PCB and dioxin background study previously mentioned (Johnson, 2008) will help in prioritizing areas for additional work. An assessment and prioritization of 303(d) listings for PCBs and other toxic contaminants in Washington is also underway.

## Dioxins and Furans

The 17 individual dioxin/furan congeners were detected at various frequencies, ranging from 14% to 69% (Table 7). The most toxic congeners, 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD, were detected in 42% and 54% of samples, respectively. Nearly all samples (95%) had detections when values are expressed as dioxin/furan TEQ, making this the second-most frequently detected compound behind mercury. The single congener 1,2,3,7,8-PeCDD has a TEF of 1 so is considered to be as toxic as 2,3,7,8-TCDD: values of 1,2,3,7,8-PeCDD exceeded the NTR criterion for 2,3,7,8-TCDD in a large proportion (83%) of samples. Monitoring for dioxins/furans should be continued because of their widespread occurrence and frequent exceedance of NTR criteria when cumulative toxicity is considered.

Table 7. Detection Frequency and Range of Values for Dioxins and Furans in Fish Tissue, WSTMP 2001-2008 (values in ng/kg).

| Analyte (with 2005 TEF) | Number of Analyses | Detection Frequency | Detects: Range | Non-Detects: Range | Detects: NTR Exceedance Frequency |
|---|---|---|---|---|---|
| Dioxin/furan TEQ (1) | 171 | 95% | 0.0005 - 11.9 | 0.05 - 0.82 | 70% |
| 2,3,7,8-TCDF (0.1) | 184 | 69% | 0.033 - 9.58 | 0.024 - 0.61 | |
| 1,2,3,7,8-PeCDD (1) | 184 | 54% | 0.01 - 5.49 | 0.009 - 0.97 | 83% |
| 1,2,3,4,6,7,8-HpCDD (0.01) | 184 | 48% | 0.038 - 19.6 | 0.067 - 1.5 | |
| 2,3,7,8-TCDD (1) | 184 | 42% | 0.011 - 1.93 | 0.008 - 0.96 | 58% |
| 1,2,3,6,7,8-HxCDD (0.1) | 184 | 39% | 0.014 - 12.3 | 0.01 - 0.8 | |
| 1,2,3,4,7,8-HxCDF (0.1) | 184 | 38% | 0.015 - 0.64 | 0.012 - 0.73 | |
| 1,2,3,4,6,7,8,9-OCDF (0.0003) | 184 | 36% | 0.06 - 2.6 | 0.049 - 1.8 | |
| 1,2,3,7,8-PeCDF (0.03) | 184 | 35% | 0.21 - 1.67 | 0.016 - 0.934 | |
| 2,3,4,7,8-PeCDF (0.3) | 184 | 34% | 0.014 - 4.65 | 0.013 - 0.6 | |
| 1,2,3,4,6,7,8-HpCDF (0.01) | 184 | 32% | 0.073 - 2.5 | 0.032 - 3.4 | |
| 2,3,4,6,7,8-HxCDF (0.1) | 184 | 31% | 0.018 - 0.856 | 0.01 - 0.51 | |
| 1,2,3,4,7,8-HxCDD (0.1) | 184 | 23% | 0.01 - 2.01 | 0.006 - 0.78 | |
| 1,2,3,6,7,8-HxCDF (0.1) | 184 | 21% | 0.017 - 0.88 | 0.01 - 1.8 | |
| 1,2,3,4,6,7,8,9-OCDD (0.0003) | 184 | 21% | 0.255 - 18 | 0.14 - 3.3 | |
| 1,2,3,4,7,8,9-HpCDF (0.01) | 184 | 19% | 0.014 - 1.93 | 0.009 - 1 | |
| 1,2,3,7,8,9-HxCDD (0.1) | 184 | 19% | 0.014 - 0.913 | 0.01 - 0.74 | |
| 1,2,3,7,8,9-HxCDF (0.1) | 184 | 14% | 0.016 - 0.23 | 0.004 - 0.58 | |

**Chlorinated Pesticides**

Table 8 shows that three groups of pesticides were detected in more than 20% of the samples: DDT compounds, chlordane compounds, and hexachlorobenzene. Concentrations of these exceeded NTR criteria in up to 14% of samples. Dieldrin, toxaphene, other DDT breakdown products, and pentachloroanisole were detected at lesser frequencies (6% - 13%). Dieldrin and toxaphene exceeded NTR criteria in 65% of the samples where they were detected. There are no NTR criteria for pentachloroanisole, which is a breakdown product of pentachlorophenol and similar pesticides.

Future monitoring could target only those pesticides that have been most commonly found or increase risks to human health from consumption of fish. These pesticides would include the DDT and chlordane compounds, hexachlorobenzene, dieldrin, and toxaphene. Achieving detection limits for toxaphene that are lower than the water quality standard has been challenging and may be worth pursuing for future monitoring efforts

Table 8. Detection Frequency and Range of Values for Chlorinated Pesticides in Fish Tissue, WSTMP 2001-2008 (values in ug/kg).

| Analyte | Number of Analyses | Detection Frequency | Detects: Range | Non-Detects: Range | Detects: NTR Exceedance Frequency |
|---|---|---|---|---|---|
| 4,4'-DDE | 269 | 84% | 0.21 - 440 | 0.37 - 1 | 14% |
| Hexachlorobenzene | 255 | 45% | 0.19 - 22.7 | 0.38 - 4.6 | 10% |
| 4,4'-DDD | 269 | 41% | 0.22 - 100 | 0.37 - 1 | 5.5% |
| Trans-nonachlor | 254 | 34% | 0.21 - 11.2 | 0.37 - 3.4 | a |
| Chlordane, total | 237 | 32% | 0.21 - 68 | 0.37 - 3.9 | 11% |
| 4,4'-DDT | 269 | 28% | 0.19 - 22 | 0.37 - 1 | 0.0% |
| DDMU | 252 | 21% | 0.23 - 59 | 0.27 - 3 | b |
| Dieldrin | 253 | 13% | 0.29 - 7.3 | 0.34 - 3.9 | 65% |
| cis-Chlordane (alpha) | 255 | 13% | 0.19 - 32.5 | 0.3 - 1 | a |
| 2,4'-DDD | 255 | 8.2% | 0.58 - 10 | 0.2 - 1 | b |
| Toxaphene | 253 | 7.9% | 5.6 - 20 | 0.97 - 27 | 65% |
| Cis-nonachlor | 255 | 7.8% | 0.25 - 19.7 | 0.37 - 4.3 | a |
| 2,4'-DDE | 254 | 7.1% | 0.23 - 5.1 | 0.19 - 5 | b |
| Pentachloroanisole | 255 | 6.3% | 0.41 - 4 | 0.2 - 1 | b |
| 2,4'-DDT | 255 | 5.5% | 0.12 - 4.3 | 0.11 - 1 | b |
| Chlordane (technical) | 153 | 4.6% | 3.8 - 14 | 2 - 27 | 29% |
| trans-chlordane (gamma) | 255 | 4.3% | 0.19 - 16 | 0.2 - 1 | a |
| Oxychlordane | 255 | 3.1% | 0.3 - 0.95 | 0.2 - 1 | a |
| gamma-BHC (lindane) | 255 | 2.7% | 0.24 - 0.7 | 0.2 - 1 | 0.0% |
| Mirex | 255 | 2.7% | 0.23 - 3 | 0.11 - 1.4 | b |
| Chlorpyrifos (OP pesticide) | 245 | 2.4% | 0.24 - 5.2 | 0.37 - 8.5 | b |
| Endosulfan Sulfate | 252 | 1.6% | 0.86 - 4.2 | 0.37 - 11 | 0.0% |
| Heptachlor epoxide | 252 | 1.6% | 0.23 - 0.81 | 0.2 - 2 | 0.0% |
| methoxychlor | 253 | 0.8% | 1.2 - 2.2 | 0.37 - 7.9 | b |
| beta-BHC | 254 | 0.8% | 0.3 - 0.33 | 0.2 - 1 | 0.0% |
| Endrin | 252 | 0.4% | 0.57 - 0.57 | 0.37 - 3.9 | 0.0% |
| Aldrin | 254 | 0.4% | 0.25 - 0.25 | 0.1 - 1.99 | 0.0% |
| alpha-BHC | 255 | 0.4% | 0.22 - 0.22 | 0.3 - 1 | 0.0% |
| Dacthal (DCPA) | 32 | 0.0% | - | 0.48 - 2 | b |
| delta- BHC | 252 | 0.0% | - | 0.2 - 3.2 | b |
| Endosulfan I (Alpha) | 252 | 0.0% | - | 0.2 - 7.9 | no detects |
| Endosulfan II (Beta) | 253 | 0.0% | - | 0.37 - 7.9 | no detects |
| Endrin Aldehyde | 253 | 0.0% | - | 0.37 - 7.9 | no detects |
| Endrin Ketone | 253 | 0.0% | - | 0.37 - 7.9 | b |
| Heptachlor | 255 | 0.0% | - | 0.11 - 1 | no detects |

a - This analyte is included in sum to obtain “Chlordane, total”.
b - There are no NTR criteria for this analyte.

**PBDEs**

For PBDEs, 6 of the 13 congeners were detected in more than 25% of samples (Table 9). PBDE congeners 47, 99, and 100 were the most commonly detected PBDEs and contribute most to the total PBDE values calculated for each sample. The detection limit for PBDE 209 has varied widely over the years, and this congener may be present more often than the data show. Monitoring for PBDEs should continue because of continued interest in these compounds, particularly through Washington's Chemical Action Plan for PBDEs (Ecology and DOH, 2005; www.ecy.wa.gov/biblio/0507048.html).

Table 9. Detection Frequency and Range of Values for PBDEs in Fish Tissue, WSTMP 2001-2008 (values in ug/kg).

| Analyte | Number of Analyses | Detection Frequency | Detects: Range | Non-Detects: Range |
|---|---|---|---|---|
| PBDE Total | 245 | 87% | 0.09 - 1136 | 0.68 - 6.2 |
| PBDE 047 | 262 | 82% | 0.16 - 63.3 | 0.11 - 2 |
| PBDE 099 | 262 | 57% | 0.1 - 28 | 0.21 - 2 |
| PBDE 100 | 261 | 57% | 0.07 - 10.7 | 0.1 - 2 |
| PBDE 049 | 182 | 44% | 0.06 - 7.3 | 0.1 - 0.5 |
| PBDE 154 | 261 | 41% | 0.08 - 1.5 | 0.21 - 2 |
| PBDE 153 | 261 | 31% | 0.1 - 2 | 0.21 - 2 |
| PBDE 066 | 223 | 13% | 0.1 - 1.2 | 0.1 - 0.55 |
| PBDE 209 | 216 | 10% | 1 - 23 | 0.49 - 28 |
| PBDE 183 | 223 | 4.0% | 0.18 - 0.66 | 0.42 - 1 |
| PBDE 190 | 41 | 2.4% | 0.45 - 0.45 | 0.45 - 2.5 |
| PBDE 071 | 223 | 0.9% | 0.24 - 1.2 | 0.1 - 0.5 |
| PBDE 138 | 223 | 0.4% | 0.11 - 0.11 | 0.21 - 1 |
| PBDE 184 | 182 | 0.0% | - | 0.21 - 1 |

# Conclusions

During 2008, PCBs, dioxin/furans, chlorinated pesticides, PBDE flame retardants, and mercury were frequently detected in fish collected from 25 lakes and rivers across Washington State.

A total of 24 of the 36 samples, from 14 of the 25 sites, did not meet National Toxics Rule (NTR) criteria for contaminants in fish tissue. Total PCBs, toxaphene, and 4,4'-DDE accounted for most of these exceedances. Other contaminants exceeding NTR criteria were 2,3,7,8-TCDD, hexachlorobenzene, and dieldrin.

Overall, the 2008 site contaminant scores ranked from the $3^{rd}$ to the $82^{nd}$ percentile of all 2001-2008 Washington State Toxics Monitoring Program (WSTMP) sites. Highest scores in 2008 were for the Okanogan, Klickitat, Snoqualmie, and Skykomish Rivers as well as Fish and Goodwin Lakes. These sites represent a range of land uses: national forest, agriculture, and rural. Fish species sampled from these sites include brown trout, largemouth bass, smallmouth bass, northern pikeminnow, rainbow trout, mountain whitefish, and common carp.

Levels of PCBs, DDT, PBDEs, dioxin/furan TEQ, and mercury in the 2008 samples were spread over a wide range which was representative of all sample results from 2001-2008.

Between 2001 and 2008, the WSTMP Exploratory Monitoring component characterized toxic contaminants in 268 fish tissue samples from 129 sites. Water quality standards were not met for about 76% of the sites and 69% of the samples. Contaminants that exceeded water quality standards were PCBs, dioxin/furans, DDT compounds, hexachlorobenzene, dieldrin, and toxaphene.

# Recommendations

Because the WSTMP is a screening-level assessment only, the Washington State Department of Health, local health jurisdictions, and affected tribes should evaluate the need for more detailed assessment of risks to human health from the consumption of contaminated fish. The initial focus should be on sites where contaminant levels did not meet the NTR criteria (Category 5 sites in Table 4).

Ecology should determine what follow-up actions to take for the most contaminated sites identified in 2008, particularly for Fish Lake in Chelan County where PCB levels were elevated in several species.

Watershed cleanup efforts in the Okanogan River basin should continue. Additional monitoring in this basin (Coffin, 2009) may help focus ongoing cleanup efforts under a watershed plan.

Ecology should review the fish tissue data from the 14 lakes and rivers listed in Table 4 for placement of these sites in Categories 5 and 2 of Washington State's 303(d) assessment. Other results from this 2008 sampling effort should be reviewed and the remaining sites placed in Categories 1 and 3 of the 303(d) assessment.

The current list of target analytes for the WSTMP Exploratory Monitoring component should be revised in order to use resources more efficiently. Some analytes could be discontinued such as PCB congeners and the majority of chlorinated pesticides.

# References

ATSDR, 1997. ToxFAQs™ for Toxaphene September 1997. Agency for Toxic Substances and Disease Registry, Atlanta, GA. U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/tfacts94.html.

ATSDR, 1999. Toxicological Profile for Mercury. Agency for Toxic Substances and Disease Registry, Atlanta, GA. U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/toxprofiles/tp46.html.

ATSDR, 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). Agency for Toxic Substances and Disease Registry, Atlanta, GA. U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/toxprofiles/tp17.html.

ATSDR, 2002a. ToxFAQs™ for DDT, DDE, and DDD. Agency for Toxic Substances and Disease Registry, Atlanta, GA. U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/tfacts35.html.

ATSDR, 2002b. ToxFAQs™ for Hexachlorobenzene September 2002. Agency for Toxic Substances and Disease Registry, Atlanta, GA. U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/tfacts90.html.

ATSDR, 2002c. ToxFAQs™ for Aldrin/Dieldrin September 2002. Agency for Toxic Substances and Disease Registry, Atlanta, GA. U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/tfacts1.html#bookmark01.

ATSDR, 2006. Dioxins. ToxFAQs™: Chemical Agent Briefing Sheets (CABS). Agency for Toxic Substances and Disease Registry, Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/cabs/dioxins/index.html.

Bernhard, T. and S. Petron, 2001. Analysis of PCB Congeners vs. Aroclors in Ecological Risk Assessment. Issue Paper: PCB Congeners in Ecological Risk Assessment. Naval Facilities Engineering Command. http://web.ead.anl.gov/ecorisk/issue/pdf/PCB%20IssuePaperNavy.pdf.

Bloom, N., 1995. Considerations in the analysis of water and fish for mercury. In National Forum on Mercury in Fish: Proceedings. U.S. Environmental Protection Agency, Office of Water, Washington D.C. EPA Publication 823-R-95-002.

Caton, L., 2009. Personal communication regarding sample processing and shipment. Oregon Department of Environmental Quality.

Coffin, C., 2009. Quality Assurance Project Plan: Okanogan River DDT and PCB Total Maximum Daily Load Effectiveness Monitoring. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-107. www.ecy.wa.gov/biblio/0903107.html.

Ecology, 2006. Water Quality Program Policy 1-11: Assessment of Water Quality for the Clean Water Act Sections 303(d) and 305(b) Integrated Report. September 6, 2006. Water Quality Program, Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/wq/303d/wqp01-11-ch1Final2006.pdf.

Ecology and DOH, 2003. Washington State Mercury Chemical Action Plan. Washington State Department of Ecology and Washington State Department of Health, Olympia, WA. Ecology Publication No. 03-03-001. www.ecy.wa.gov/biblio/0303001.html.

Ecology and DOH, 2005. Washington State Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Final Plan. Washington State Department of Ecology and Washington State Department of Health, Olympia, WA. Ecology Publication No. 05-07-048. www.ecy.wa.gov/biblio/0507048.html.

EPA, 1980. Ambient Water Quality Criteria Documents. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. Various EPA publication numbers. www.epa.gov/waterscience/criteria/library/ambientwqc/index.html.

EPA, 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories - Volume 1: Field Sampling and Analysis, Third Edition. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. Publication No. EPA-823-B-00-007. www.epa.gov/ost/fishadvice/volume1/.

EPA, 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C. Publication No. EPA-823-R-01-001.

EPA, 2002. National Recommended Water Quality Criteria: 2002. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C. Publication No. EPA-823-R-02-047.

EPA, 2003. Revised National Recommended Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Washington, D.C. www.epa.gov/waterscience/criteria/humanhealth/15table-fs.htm

EPA, 2007. Mercury. U.S. Environmental Protection Agency, Washington, D.C. www.epa.gov/pesticides/ Accessed February 2007.

EPA, 2008. Quality Assurance Project Plan (QAPP) for the Mid-Columbia Toxics Study: for probabilistic monitoring in Oregon and Washington. U.S. Environmental Protection Agency, Region 10. Seattle, WA. Unpublished Document.

EPA, 2009. Revised National Recommended Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Washington, D.C. www.epa.gov/waterscience/criteria/wqctable/index.html.

Furl, C. and C. Meredith, 2008. Measuring Mercury Trends in Freshwater Fish in Washington State: 2007 Sampling Results. Washington State Department of Ecology, Olympia, WA. Publication No. 08-03-027. www.ecy.wa.gov/biblio/0803027.html.

Johnson, A., 2008. Quality Assurance Project Plan: PCB and Dioxin Levels in Resident Fish from Washington Background Lakes and Rivers. Washington State Department of Ecology, Olympia, WA. Publication No. 08-03-102. www.ecy.wa.gov/biblio/0803102.html.

McBride, D., 2006. Personal communication. Overview of Health's and Ecology's approach to fish tissue evaluation. March 16, 2006. Washington State Department of Health, Olympia, WA.

Sandvik, P., 2006a. Standard Operating Procedures for Resecting Finfish Whole Body, Body Parts or Tissue Samples, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP007. www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP_SOP_007ResectingFinfishWholeBodyPartsTissueSamples.pdf.

Sandvik, P., 2006b. Standard Operating Procedures for Resecting DNA Samples and Aging for Finfish, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP008. www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP_SOP_008FishDNAAgingStructuresProcessing.pdf.

Sandvik, P., 2006c. Standard Operating Procedures for Field Collection, Processing, and Preservations of Finfish Samples at Time of Collection in the Field. Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP009. www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP_SOP_009FishFieldCollectionProcessing.pdf.

Seiders, K. and B. Yake, 2002. Washington State Toxics Monitoring Program: Exploratory Monitoring of Toxic Contaminants in Edible Fish Tissue and Freshwater Environments of Washington State. Quality Assurance Project Plan. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-065. www.ecy.wa.gov/biblio/0203065.html.

Serdar, D., 2006. Persistent Organic Pollutants in Feed and Rainbow Trout from Selected Trout Hatcheries. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-017. www.ecy.wa.gov/biblio/0603017.html.

Van den Berg, M., L. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, R. Peterson, 2006. The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxins-Like Compounds. Toxicological Sciences 2006 93(2):223-241. http://toxsci.oxfordjournals.org/cgi/reprint/kfl055v1?ijkey=pio0gXG6dghrndD&keytype=ref.

Wydoski, R. and R. Whitney, 2003. Inland Fishes of Washington, 2nd Edition. University of Washington Press, Seattle WA.

*This page is purposely left blank*

# Appendices

*This page is purposely left blank*

# Appendix A. Glossary, Acronyms, and Abbreviations

## Glossary

**Analyte:** Water quality constituent being measured (parameter).

**Anthropogenic:** Human-caused.

**Bioaccumulative pollutants:** Pollutants that build up in the food chain.

**Boxplot:** A graphical depiction of a data set showing the $25^{th}$ percentile, $50^{th}$ percentile or median, the $75^{th}$ percentile, range of data, and outliers.

**Clean Water Act:** A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

**Piscivorous:** Fish-eating.

**Total Maximum Daily Load (TMDL):** Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

**303(d) list:** Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

**90th percentile:** A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

## Acronyms and Abbreviations

| | |
|---|---|
| CFR | Code of Federal Regulation |
| DDMU | 1-chloro-2,2-bis(p-chlorophenyl)ethane |
| DDD | dichloro-diphenyl-dichloroethane |
| DDE | dichloro-diphenyl-trichloroethylene |
| DDT | dichloro-diphenyl-trichloroethane |
| DOH | Washington State Department of Health |
| Ecology | Washington State Department of Ecology |
| EIM | Environmental Information Management |
| EPA | Environmental Protection Agency |

| | |
|---|---|
| MEL | Manchester Environmental Laboratory |
| NTR | National Toxics Rule |
| PBDE | polybrominated diphenyl ethers |
| PBT | persistent, bioaccumulative, and toxic substance |
| PCB | polychlorinated biphenyls |
| PCDD/Fs | polychlorinated dibenzo-p-dioxins and -furans |
| SOP | Standard operating procedure |
| SRM | Standard reference material |
| SV | Screening values |
| TCDD | tetrachlorodibenzo-p-dioxin |
| TEF | Toxicity Equivalent Factor |
| TEQ | Toxic Equivalent |
| WAC | Washington Administrative Code |
| WDFW | Washington Department of Fish and Wildlife |
| WSTMP | Washington State Toxics Monitoring Program |

*Units of Measurement*

| | |
|---|---|
| mg/Kg | milligrams per kilogram (parts per million) |
| ng/Kg | nanograms per kilogram (parts per trillion) |
| ug/Kg | micrograms per kilogram (parts per billion) |
| ww | wet weight |

Table A-1. Fish Species Codes and Names for WSTMP 2001-2008.

| Species Code | Common name | Scientific name | Family name |
|---|---|---|---|
| BC | Black crappie | *Pomoxis nigromaculatus* | Centrarchidae |
| BG | Bluegill | *Lepomis macrochirus* | Centrarchidae |
| BKT | Brook trout | *Salvelinus fontinalis* | Salmonidae |
| BLT | Bull trout | *Salvelinus confluentus* | Salmonidae |
| BNT | Brown trout | *Salmo trutta* | Salmonidae |
| BUR | Burbot | *Lota lota* | Gadidae |
| CC | Channel catfish | *Ictalurus punctatus* | Ictaluridae |
| CCP | Common carp | *Cyprinus carpio* | Cyprinidae |
| CTT | Cutthroat trout [1, 2] | *Oncorhynchus clarki* | Salmonidae |
| GCP | Grass carp | *Ctenopharyngodon idella* | Ictaluridae |
| KOK | Kokanee salmon | *Oncorhynchus nerka* | Salmonidae |
| LMB | Largemouth bass | *Micropterus salmoides* | Centrarchidae |
| LWF | Lake whitefish | *Coregonus clupeaformis* | Salmonidae |
| MWF | Mountain whitefish | *Prosopium williamsoni* | Salmonidae |
| NPM | Northern pikeminnow | *Ptychocheilus oregonensis* | Cyprinidae |
| PEA | Peamouth | *Mylocheilus caurinus* | Cyprinidae |
| PWF | Pygmy whitefish | *Prosopium coulteri* | Salmonidae |
| RBT | Rainbow trout [2] | *Oncorhynchus mykiss* | Salmonidae |
| RKB | Rock bass | *Ambloplites rupestris* | Centrarchidae |
| RSS | Redside shiner | *Richardsonius balteatus* | Cyprinidae |
| SMB | Smallmouth bass | *Micropterus dolomieu* | Centrarchidae |
| WAL | Walleye | *Sander vitreus* | Percidae |
| YP | Yellow perch | *Perca flavescens* | Percidae |

1. Three Cutthroat trout subspecies exist and are grouped together for data management and analyses.
2. Some RBT hybridize with CTT such that fish may have characteristics of both species.

# Appendix B. Sites and Species: WSTMP 2008

Table B-1. The 25 Sites and Species Sampled: WSTMP 2008.

| Sample Site | County | WRIA | Species Sampled | Latitude | Longitude | WBID |
|---|---|---|---|---|---|---|
| Alder Lake | Pierce | 11 | KOK, RBT | 46.7950 | -122.2980 | WA-11-9010 |
| Badger Lake | Spokane | 34 | LMB, RBT | 47.3509 | -117.6279 | WA-34-9060 |
| Blue Lake | Grant | 42 | RBT, YP | 47.5650 | -119.4480 | WA-42-9040 |
| Bumping Lake | Yakima | 38 | BKT, CTT | 46.8500 | -121.3200 | WA-38-9010 |
| Cle Elum Lake | Kittitas | 39 | MWF | 47.2900 | -121.1100 | WA-39-9010 |
| Columbia River near Vernita Bridge | Grant | 36 | LSS | 46.6379 | -119.7441 | WA-CR-1030 |
| Columbia River near Chelan | Douglas | 44 | NPM | 47.7730 | -120.1447 | WA-CR-1040 |
| Columbia River near Port Kelly | Benton | 31 | SMB | 46.0144 | -118.9689 | WA-CR-1028 |
| Conconully Reservoir | Okanogan | 49 | RBT | 48.5459 | -119.7505 | WA-49-9100 |
| Fish Lake | Chelan | 45 | BNT, LMB, NPM, RBT | 47.8354 | -120.7041 | WA-45-9040 |
| Goodwin Lake | Snohomish | 7 | LMB, RBT, SMB | 48.1462 | -122.2950 | WA-07-9280 |
| Klickitat River | Klickitat | 30 | MWF | 45.7148 | -121.2608 | WA-30-1010 |
| Merrill Lake | Cowlitz | 27 | CTT | 46.0956 | -122.3250 | WA-27-9020 |
| North River | Grays Harbor | 24 | CTT | 46.8302 | -123.5893 | WA-24-1010 |
| Okanogan River near Monse | Okanogan | 49 | SMB | 48.1625 | -119.6705 | WA-49-1010 |
| Okanogan River near Omak | Okanogan | 49 | CCP, SMB | 48.5093 | -119.5074 | WA-49-1020 |
| Okanogan River near Oroville | Okanogan | 49 | CCP, SMB | 48.9178 | -119.4235 | WA-49-1040 |
| Omak Lake | Okanogan | 49 | CTT, PEA | 48.2800 | -119.4000 | WA-49-9250 |
| Pahata Creek | Garfield | 35 | BKT | 46.2596 | -117.5283 | WA-35-2013 |
| Quinault River | Jefferson | 21 | CTT | 47.5332 | -123.7404 | WA-21-2020 |
| Similkameen River near Oroville | Okanogan | 49 | MWF | 48.9043 | -119.4304 | WA-49-1030 |
| Skykomish River | Snohomish | 7 | MWF | 47.8436 | -121.6946 | WA-07-1200 |
| Snoqualmie River | King | 7 | MWF | 47.6921 | -121.9663 | WA-07-1060 |
| South Twin Lake | Ferry | 58 | BKT, LMB, RBT | 48.2700 | -118.3900 | WA-58-9040 |
| Stevens Lake | Snohomish | 7 | KOK, RBT | 48.0050 | -122.0824 | WA-07-9720 |

WRIA- Water Resource Inventory Area.
WBID- Waterbody Identification.
Latitude and longitude coordinates datum is NAD 83 HARN.
Species Codes: BNT = Brown trout, BKT = Brook trout, CCP = Common carp, CTT = Cutthroat trout, KOK = Kokanee salmon, LMB = Largemouth bass, LSS = Largescale sucker, MWF = Mountain whitefish, NPM = Northern pikeminnow, PEA = Peamouth, RBT = Rainbow trout, YP = Yellow perch.

# Appendix C.  Data Quality Assessment

Data quality was assessed by reviewing laboratory case narratives, analytical results, and field replicate data.  Case narratives were written by Manchester Environmental Laboratory (MEL) analytical staff.  The narratives described the condition of samples upon receipt, analytical quality control procedures, and data qualifications.  Quality control procedures included analysis of method blanks, calibration and control standards, matrix spikes, matrix spike duplicates, surrogate recoveries, and laboratory and field duplicates.

Lab duplicate samples were created at the analytical lab by analyzing splits of the sample.  Field duplicate samples consisted of two samples that were created from different, yet similar-sized, fish of the same species collected from the same site at the same time.  Individual fish were assigned to the two composite samples randomly.

Overall, the 2008 data met most quality control criteria defined by MEL and the Quality Assurance Project Plan.  No data were rejected.  Some data were qualified due to challenges encountered in analyses.  Estimates of precision appear typical for samples of fish tissue.  All results are usable for this project as qualified.  Table C-1 summarizes results from quality control and quality assurance procedures.

Up to 30 target analytes were detected in two sets of lab and field duplicate samples: these analytes included mercury, chlorinated pesticides, PCB Aroclors, and PBDEs.  Estimates of precision based on these results usually met requirements, so analytical and sampling precision was deemed adequate.

Intra-lab estimates of precision were good.  Five sets of lab duplicates by MEL had good precision with relative percent differences (RPDs) less than 10% except one pair with an RPD of 35%.  Four sets of lab duplicates by the contract lab also had good precision with RPDs from 6% to 26%.  Inter-laboratory analyses of 45 samples yielded precision values from moderate to poor, with RPDs ranging from 15% to 161%.  Differences in analytical methods and the extraction solvents used by the different labs likely contribute to poor inter-laboratory precision.  The 45 samples included those from another study by Johnson (2008).

Few challenges were encountered during the PCB congener analysis, and some results were qualified as estimates.  Precision as determined through five lab and one field duplicate analyses was good to moderate, ranging from 0% to 47% RPD for lab duplicates and 0% to 40% RPD for field duplicates. Interestingly, where field and lab duplicate analyses were done on the same samples, the field duplicate often had better precision than the lab duplicate.

The dioxin/furan analysis produced data of good quality.  Few challenges were experienced. Detections that were above the Limit of Detection (LOD) yet below the Estimated Quantitation Limit (EQL) were qualified as estimates at the request of the project manager.  About 16% of results had no qualifiers attached while 78% of results were qualified as not detected.  The remaining 6% of results were qualified as estimates.  Precision as determined through lab and field duplicate analyses was generally good, with RPDs for five sets of lab duplicates ranging from 1% to 74%, and field duplicate RPDs being 19% and 20% for the two detections in the single field duplicate.

Table C-1. Summary of Quality Assurance/Quality Control Specifications and Data Review Findings, WSTMP 2008.

| Parameter | Analytical Method | Holding Time | Calibrations | Blanks | Reporting Limits [a] | Lab Dup (RPD) | Field Dup (RSD) | LCS (% recovery) | Surrogates (% recovery) | MS/MSD (% recovery) | Overall Decision |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mercury** | | | | | | | | | | | |
| Finding | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | NA | Acceptable | Acceptable |
| QAPP or PSN specification | EPA 245.6 (CVAA) [b] | 6 months [c] | NS | NS | 17 ug/kg | NS | 0%-14% | NS | NA | NS | - |
| LAB specification | EPA 245.6 (CVAA) | NS | See Method | g | 17 ug/kg | 0%-20% | NS | 85%-115% | NA | 75%-125%; RPD limit 20% | - |
| **Chlorinated pesticides** | | | | | | | | | | | |
| Finding | Acceptable | Acceptable [d] | Acceptable [n,o] | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable [r] | Acceptable |
| QAPP or PSN specification | EPA 8081 (GC/ECD); MEL SOP* | 1 year | NS | NS | most 0.5-2.0 ug/kg | NS | 0%-28% | NS | NS | NS | - |
| LAB specification | SW 8081 & 8082 (GC/ECD) | 1 year | See Method | g | most 0.5-3.0 ug/kg [i] | 0%-40% | NS | 50%-150% | 20%-130% [p] | 50%-150%; RPD limit 40% | - |
| **PBDEs** | | | | | | | | | | | |
| Finding | Acceptable [ag] | Acceptable | Acceptable [af] | Acceptable [h] | Acceptable | Acceptable [k] | Acceptable [L] | Acceptable | Acceptable [v] | Acceptable [e] | Acceptable |
| QAPP or PSN specification | EPA 8270 (SIM); MEL SOP* | 1 year | NS | NS | 0.38-2.0 ug/kg [f] | NS | 0%-28% | NS | NS | NS | - |
| LAB specification | EPA 8270 (SIM); SOP 730104 | 1 year | See Method | 5x rule [h] | 0.10-2.6 ug/kg; PBDE 209 1.9-4.3 ug/kg | 0%-40% | NS | 50%-150% | 50%-150% | 50%-150%; RPD limit 40% [e] | - |
| **PCB Aroclors** | | | | | | | | | | | |
| Finding | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable [t] | Acceptable | Acceptable | Acceptable | Acceptable [m] | Acceptable | Acceptable |
| QAPP or PSN | EPA 8082 (GC/ECD); MEL SOP* | 1 year | NS | NS | 1.0 ug/kg | NS | 0%-28% | NS | NS | NS | - |
| LAB specification | SW 8082 (GC/ECD) | 1 year | See Method | g | 1.1 - 44 ug/kg | 0%-40% | NS | 50%-150% | 50%-150% | 50%-150%; RPD limit 40% | - |

| Parameter | Analytical Method | Holding Time | Calibrations | Blanks | Reporting Limits [a] | Lab Dup (RPD) | Field Dup (RSD) | LCS (% recovery) | Surrogates (% recovery) | MS/MSD (% recovery) | Overall Decision |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PCB Congeners** | | | | | | | | | | | |
| Finding | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable [ad] | Acceptable [ad] | Acceptable | NA | NA | Acceptable |
| QAPP or PSN specification | EPA 1668A (HiRes GC/MS) | NS | NS | NS | 0.02 - 0.08 ug/kg | NS | NS | NS | NA | NA | - |
| LAB specification | EPA 1668A (HiRes GC/MS) | 1 year | See Method | 10x rule [w] | 0.003-0.01 ug/kg | NS | NS | z, ab, ac | NA | NA | - |
| **PCDD/Fs (17 congeners** | | | | | | | | | | | |
| Finding | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable [aa] | Acceptable [aa] | Acceptable [x,y,z] | NA | NA | Acceptable |
| QAPP or PSN | EPA 1613B (HiRes GC/MS) | 1 year | NS | NS | 0.03 - 0.5 ng/kg | NS | 0%-28% | NS | NA | NA | - |
| LAB specification | EPA 1613B (HiRes GC/MS) | NS | s | 10x rule [u] | EQL 0.017 - 0.5 ng/kg | NS | NS | See Method | NA | NA | |
| **Lipids** | | | | | | | | | | | |
| Finding | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable | Acceptable [ae] | Acceptable [ae] | NS | NA | NA | Acceptable |
| QAPP or PSN specification | MEL SOP 730009 | 1 year | NS | NS | 0.1% | NS | 0%-14% | NS | NA | NA | |
| LAB specification | MEL SOP 730009 | NS | See Method | g | 0.01% | 0%-20% | NS | NS | NA | NA | |

Abbreviations: NS - Not Specified, NA - Not Applicable, QAPP - Quality Assurance Project Plan, RPD - Relative Percent Difference, RSD - Relative Standard Deviation, MS/MSD - Matrix Spike and MS Duplicate.

Data Qualifiers: J - estimated value, NJ - target analyte tentatively identified at estimated value, E - estimate because value outside calibration range, U - not detected at reported result or estimated ("UJ") result.

PSN = Pre Sample Notification. This is an annual correspondence to MEL, prior to sample delivery, updating and describing analytical needs such as methods, reporting limits, and sample processing.

* - MEL modifications to analytical methods are documented in their Standard Operating Procedures.

a - The values given in the "Lab specification" row are the Reporting Limits achieved by the lab.

b - EPA method 245.5 was used for WSTMP samples from 2001-2003. EPA Method 245.6 has been used since 2004.

c - Holding time of six months was established for WSTMP fish tissue in 2002, after determining that 28-day holding time for tissue was unnecessary.

d - Many analytes were qualified as J (if detected) or UJ (if not detected) because analyses were done after the 40-day window between extraction and analysis.

e - Matrix spike recoveries were within limits except where high in four cases for PBDE 138, 183, 191, and 209. None of these compounds were detects in the native samples so no qualifiers were assigned. RPDs for duplicate spike recoveries were within limits.
f - Reporting limit for all congeners except PBDE 209 which is 1-6 ug/kg.
g - Case narratives state that no analytically significant levels of analyte, or no target analytes, were detected in the method blanks associated with these samples.
h - PBDE 209 was detected in three of four method blanks. Where sample results were more than 5 times the level of the blank result, no qualifiers were assigned. If the sample result was less than 5 times the blank value, the reporting limit was raised and qualified as UJ.
i - Most analytes met desired reporting limits. Many results for toxaphene and technical chlordane had higher reporting limits of 3 -10 ug/kg which were acceptable.
k - All RPD limits within range except PBDE 49 in one sample and PBDE 100 in another. Associated results for detected analytes were qualified J.
L - 15 of 15 pairs of detected congeners were within limits. PBDE 209 in one sample was qualified as NJ which led to an RSD of 49% for the total PBDE value for that sample. See comment # ag below.
m -All recoveries within limits except for one sample (0812011-21): all detections reported for this sample were qualified J.
n - Some analytes did not meet acceptable continuing calibration verification (CCV) standards (85%-115%) and results were qualified as UJ (for nondetects) or J (for detected analytes): aldrin, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, dieldrin, methoxychlor, endrin aldehyde, endrin, and heptachlor epoxide. These results may be biased low because of low recoveries in the continuing calibration verification.
o - Qualitative identification requirements for some analytes in some samples were not met. Some sample results when detected were qualified J, others when not detected had reporting limits raised and qualified as UJ. Analytes included: DDMU, 4,4'-DDT, alpha-chlordane, trans-nonachlor, heptachlor epoxide, gamma-chlordane, dieldrin, 4,4'-DDT, 2,4'-DDT, 4,4'-DDD, cis-nonachlro, mirex, chlorpyrifos, and 2,4'-DDE, 2,4'-DDD.
p - Surrogate recovery limits were recently revised by MEL and are specific to surrogate used: some limits are 20%-120%, others are 30%-130%.
r - Matrix spike recoveries were within acceptable limits except for endrin aldehyde, even though high lipid content in the samples used for one of the matrix spikes complicated the evaluation. Due to interference from other analytes, DDMU was not calculated "NC". RPDs for duplicate MS were within limits except for endrin aldehyde.
s - Calibration standards were within limits for target analytes and labeled reference compound with few exceptions which were deemed to not affect results.
t - Reporting limits for some analytes in some samples were higher than requested because of interference or dilutions to remove lipid interference. Reporting limits were greater than 4 ug/kg for aroclors that have not been detected in freshwater fish tissue from Washington: Aroclors 1016, 1221, 1232, 1242, 1260, and 1262. These high reporting limits for the non-detect aroclors were ignored when summing analytes for a total PCB value.
u - All four blanks had varied levels of contamination. One blank was reanalyzed. Results that were less than 10x the level found in the corresponding blank were qualified UJ (~7% of results). Where results were greater than 10x the level in the blank, results were not qualified.
v - All surrogate recoveries were within acceptable limits except one sample which had a high recovery (169%). All detected analytes for this sample were qualified J.
w -Few target analytes (~0.3%) were detected in blanks resulting in some qualifications of data. Where sample results were more than 10 times the level of the blank result, no qualifiers were assigned. If the sample result was less than 10 times the blank value, the reporting limit was raised and qualified as UJ.
x - The QC limits for Internal Standard recoveries were with limits.
y - On-going Precision and Recovery (OPR) and LCS were within limits (80%-110% for LCS).
z - Ion Abundance Ratios and Retention Time Criteria were met with few exceptions resulting in qualification of some data.
aa - RPDs achieved for 13 lab dup results were 1%-74% with a mean of 22%. RSDs achieved for field duplicates were 19%-20% (only two results available).
ab - OPR recoveries within QC limits of 50-100%. Labeled compound recoveries within QC limits of 30-140% for most labeled compounds.
ac - Internal Standard recoveries within QC limits of 15%-150% (some congeners) and 25-150% (most congeners) with a number of exceptions. Some recoveries were low while others were high. Such results were generally qualified J. Some samples were diluted and reanalyzed and these results were then used.
ad - RPDs for lab duplicates were 0%-47%. 96% of detected pairs had RPD less than or equal to 30%. RSDs for field duplicates were 0%-29%.
ae - One of five lab duplicates had RPD of 35% which was outside limits. Two of two field duplicates had RSDs of 19% which was just outside limit of 0%-14% RSD.
af - PBDE 209 was high in one continuing calibration check; leading to nine sample results being qualified J.
ag - PBDE 209 was tentatively identified in 6 samples. Results were qualified NJ and used in data evaluations. These results seemed elevated compared to results from other WSTMP samples.

# Appendix D. Data Evaluation by Ecology and DOH

Several state and federal agencies collect and evaluate fish tissue data in Washington State. These include the Washington State Departments of Ecology (Ecology), Health (DOH), and Fish and Wildlife; the U.S. Environmental Protection Agency; and the U.S. Geological Survey. Tissue data are evaluated differently by these agencies because their mandates and roles are varied. These multiple evaluations often lead to confusion and misunderstanding among agencies and the public on how fish tissue data are used and interpreted. Adding to potential confusion are the numerous criteria or screening values derived to provide guidance for determining the risks of consuming contaminated fish and protecting public health.

Most fish tissue contaminant data from Washington fish, regardless of who conducted the study, make their way to DOH for evaluation regarding the safety of consuming fish. Appendix E has information about health benefits of eating fish and potential risks from consuming contaminated fish. The following is an overview of how Ecology and DOH evaluate fish tissue data to meet different needs.

For the WSTMP and many other Ecology studies, fish tissue data are evaluated primarily to determine if (1) Washington State water quality standards are being met, and (2) potential risks to human health from consuming contaminated fish warrant further study and/or development of a fish consumption advisory. Ecology's role is to determine whether water quality standards are met and to begin the process to correct problems where standards are not met. DOH and local health departments are responsible for developing fish consumption advisories in Washington. There is some overlap in these evaluations because the water quality standards that fish tissue data are compared to were developed for the protection of human health.

## Washington State Water Quality Standards

Washington's water quality criteria for toxic contaminants were issued to the state in EPA's 1992 National Toxics Rule (NTR) (40CFR131.36). The human health-based NTR criteria are designed to minimize the risk of effects occurring to humans from chronic (lifetime) exposure to substances through the ingestion of drinking water and consumption of fish obtained from surface waters. *The NTR criteria, if met, will generally ensure that public health concerns do not arise, and that fish advisories are not needed.*

The NTR criteria are thresholds that, when exceeded, may lead to regulatory action. When water quality criteria are not met (exceeded), the federal Clean Water Act requires that the waterbody be put on a list and that a water cleanup plan be developed for the pollutant causing the problem. This list is known as the 303(d) list, and the water cleanup plan results from a Total Maximum Daily Load (TMDL) study and public involvement process. Ecology uses the TMDL program to control sources of the particular pollutant in order to bring the waterbody back into compliance with the water quality standards.

## Risk Management Decisions

While DOH supports Ecology's use of the NTR criteria for identifying problems and controlling pollutant sources so that water quality will meet standards, DOH does not use the NTR criteria to establish fish consumption advisories (McBride, 2006). DOH uses an approach similar to that in EPA's *Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories Vol. 1-4* for assessing mercury, PCBs, and other contaminants (EPA, 2000). These guidance documents provide a framework from which states can evaluate fish tissue data to develop fish consumption advisories. The framework is based on sound science and established procedures in risk assessment, risk management, and risk communication.

Neither the NTR criteria, nor the screening values found in the EPA guidance documents above, incorporate the varied risk management decisions essential to developing fish consumption advisories.

- **Risk Assessment** involves calculating allowable meal limits based on known fish contaminant concentrations. These calculations are conducted for both non-cancer and cancer endpoints using the appropriate Reference Dose (RfD) or Cancer Slope Factor (CSF), if available. These initial calculations are the starting point for evaluating contaminant data to determine whether a fish advisory is warranted. Additionally, known or estimated fish consumption rates help determine the potential magnitude of exposure and highlight the sensitive groups or populations that may exist due to elevated consumption rates.

- **Risk Management** includes (but is not limited to) consideration of contaminant background concentrations, reduction in contaminant concentrations through preparation and cooking techniques, known health benefits from fish consumption, contaminant concentrations or health risks associated with replacement foods, and cultural importance of fish. Other considerations are the possible health endpoints associated with a contaminant, the strength or weaknesses of the supporting toxicological or sampling data, and whether effects are transient or irreversible.

- **Risk Communication** is the outreach component of the fish advisory. The interpretation of the data from the risk assessment and risk management components drives how and when the fish advisory recommendations are issued to the public, dependent on whether the message is targeted toward a sensitive group or a population or the general public. DOH's dual objective is (1) how best to provide guidance to the public to increase fish consumption of fish low in contaminants to gain the benefits of eating fish, while (2) steering the public away from fish that have high levels of health-damaging contaminants.

# Appendix E. Summary of Results

Table E-1. Summary of Fish Tissue Sample Results, WSTMP 2008.

| Site | Species Code | MEL Sample ID | Date collect | Total PCB aroclors (ug/kg) | q | Total PCB congeners (ug/kg) | q | Total PBDE (ug/kg) | q | T-DDT (ug/kg) | q | Total Chlordane (ug/kg) | q | Dieldrin (ug/kg) | q | Dioxin/furan TEQ (ng/kg) | q | 2378 TCDD (ng/kg) | q | Mercury (ug/kg) | q | Lipid MEL (%) | q | Mean Total Length (mm) | q | Mean Weight (g) | q | Mean Age (years) | Study |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alder Lake | KOK | 081201124 | 11/24/08 | 3.4 | J | 3.77 | | 3.0 | J | 0.664 | J | 0.5 | U | 0.5 | U | 0.157 | | 0.03 | U | 153 | | 0.81 | | 311.6 | | 280.0 | | 2.6 | |
| Alder Lake | RBT | 081201125 | 11/24/08 | 9.1 | J | na | | 4.8 | J | 1.235 | J | 0.498 | U | 0.996 | UJ | na | | na | | 149 | | 4.12 | | 252.3 | | 142.7 | | 1.0 | |
| Badger Lake | LMB | 081201123 | 11/18/08 | 1.3 | | 1.38 | | 17 | NJ | 0.519 | | 0.492 | U | 0.492 | U | 0.050 | U | 0.03 | U | 105 | | 0.46 | | 244.0 | | 188.8 | | 3.0 | B |
| Badger Lake | RBT | 081201122 | 11/18/08 | 1.9 | U | 1.01 | | 12 | NJ | 0.96 | | 0.497 | U | 0.497 | U | 0.050 | U | 0.03 | U | 37.7 | | 0.63 | | 300.4 | | 278.6 | | 1.0 | B |
| Blue Lake | RBT | 081201129 | 10/15/08 | 2.2 | UJ | 0.631 | | 23 | NJ | 1.01 | | 0.5 | U | 0.5 | U | 0.050 | U | 0.03 | U | 103 | | 0.94 | | 321.8 | | 314.6 | | 1.2 | |
| Blue Lake | YP | 081201130 | 10/15/08 | 1.9 | U | na | | 1.9 | U | 0.479 | U | 0.479 | U | 0.479 | U | na | | na | | 33.3 | | 0.31 | | 219.5 | | 136.2 | | 1.3 | |
| Bumping L | BKT | 081201117 | 10/16/08 | na | | 7.27 | | na | | na | | na | | na | | 0.0252 | J | 0.03 | U | na | | 0.75 | | 236.7 | | 109.7 | | 2.7 | B |
| Bumping L | CTT | 081201115 | 10/16/08 | 1.9 | J | 2.61 | | 0.85 | J | 1.28 | | 0.499 | U | 0.998 | UJ | 0.0138 | | 0.03 | U | 40.8 | | 3.15 | | 256.2 | | 151.0 | | 1.0 | B |
| Cle Elum L | MWF | 081201102 | 10/30/08 | 6.0 | J | 5.14 | | 3.5 | J | 2.66 | | 0.494 | U | 0.494 | UJ | 0.0205 | J | 0.03 | U | 144 | | 2.32 | | 352.8 | | 427.8 | | 5.4 | B |
| Columbia R, nr Chelan | NPM | 081201141 | 8/3/08 | na | | na | | na | | na | | na | | na | | 0.122 | J | 0.037 | NJ | na | | na | | 309.4 | | 280.0 | | na | |
| Columbia R, nr Prt Kelly | SMB | 081201139 | 8/3/08 | na | | na | | na | | na | | na | | na | | 0.111 | | 0.03 | U | na | | na | | 391.3 | | 945.0 | | na | |
| Columbia R, nr Vernita Br | LSS | 081201140 | 8/3/08 | na | | na | | na | | na | | na | | na | | 0.310 | | 0.09 | | na | | na | | 539.6 | | 1500.8 | | na | |
| Conconully Res | RBT | 081201126 | 10/30/08 | 1.9 | | 2.74 | | 15 | NJ | 7.09 | | 0.496 | U | 0.496 | U | 0.050 | U | 0.03 | U | 80.5 | | 0.84 | | 383.6 | | 530.2 | | 1.8 | |
| Fish L | BNT | 081201109 | 7/16/08 | 98 | J | 87.7 | | 2.7 | J | 23.8 | J | 1.13 | UJ | 1.99 | UJ | 0.0621 | J | 0.03 | U | 62.9 | | 6.53 | | 486.6 | | 1429.6 | | 4.4 | B |
| Fish L | LMB | 081201106 | 7/16/08 | 24 | J | 24.9 | | 0.90 | J | 8.03 | J | 0.5 | U | 0.5 | UJ | 0.0477 | | 0.03 | U | 112 | | 1.94 | | 425.2 | | 1370.8 | | 7.4 | B |
| Fish L | NPM | 081201107 | 7/16/08 | 42 | J | 38.2 | | 1.6 | J | 14.6 | | 0.914 | | 0.991 | UJ | 0.0250 | J | 0.03 | U | 73.5 | | 3.43 | | 404.0 | | 619.8 | | 6.8 | B |
| Fish L | RBT | 081201108 | 7/16/08 | 2.1 | J | 5.41 | | 0.52 | J | 1.92 | | 0.5 | U | 0.5 | UJ | 0.0256 | | 0.03 | U | 33.4 | | 0.18 | | 313.0 | | 240.6 | | 1.0 | B |
| Goodwin L | LMB | 081201116 | 11/12/08 | 4.9 | J | 6.43 | | 5.2 | J | 0.664 | | 0.493 | U | 0.493 | UJ | 0.0387 | | 0.03 | U | 141 | | 0.7 | | 264.8 | | 257.2 | | 2.0 | |
| Goodwin L | RBT | 081201111 | 11/12/08 | 15 | J | 15.8 | | 7.3 | J | 3.73 | | 0.777 | | 0.493 | UJ | 0.395 | | 0.03 | U | 53.7 | | 1.89 | | 372.2 | | 620.2 | | 1.2 | |
| Goodwin L | SMB | 081201110 | 11/12/08 | 3.4 | J | na | | 5.2 | J | 0.648 | | 0.498 | U | 0.498 | UJ | na | | na | | 115 | | 0.56 | | 252.0 | | 209.6 | | 2.0 | |
| Klickitat R | MWF | 081201121 | 12/8/08 | 8.8 | J | 6.03 | | 36 | NJ | 4.08 | | 0.999 | U | 2 | UJ | 0.187 | | 0.041 | | 367 | | 5.89 | | 413.4 | | 723.6 | | 5.0 | B |
| Merrill L | CTT | 081201133 | 6/24/08 | 1.3 | J | 4.44 | | 1.95 | J | 0.781 | | 0.495 | U | 0.495 | UJ | 0.050 | U | 0.03 | U | 126 | | 1.58 | | 306.6 | | 274.4 | | 3.0 | B |
| North R | CTT | 081201132 | 8/29/08 | 2.2 | UJ | 1.04 | | 2 | U | 0.496 | U | 0.496 | U | 0.496 | UJ | 0.0320 | J | 0.032 | NJ | 70.7 | | 1.83 | | 219.2 | | 101.6 | | 2.0 | B |

Table E-1. Continued

| Site | Species Code | MEL Sample ID | Date collect | Total PCB aroclors (ug/kg) | q | Total PCB congeners (ug/kg) | q | Total PBDE (ug/kg) | q | T-DDT (ug/kg) | q | Total Chlordane (ug/kg) | q | Dieldrin (ug/kg) | q | Dioxin/furan TEQ (ng/kg) | q | 2378 TCDD (ng/kg) | q | Mercury (ug/kg) | q | Lipid MEL (%) | q | Mean Total Length (mm) | q | Mean Weight (g) | q | Mean Age (years) | Study |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Okanogan R, Lwr | SMB | 081201138 | 8/6/08 | 8.7 | J,k | na | | 6.9 | J | 239 | k | na | | na | | na | | na | | 135 | | 1.30 | k | 313.0 | | 376.4 | | 3.3 | |
| Okanogan R, Mid | CCP | 081201136 | 8/6/08 | 35 | J,k | 25.9 | | 8.2 | | 332 | k | na | | na | | 0.0672 | J | 0.03 | U | 249 | | 2.00 | k | 600.0 | | 2887.6 | | 9.6 | |
| Okanogan R, Mid | SMB | 081201137 | 8/6/08 | 2.6 | J,k | na | | 3.73 | J | 60 | k | na | | na | | na | | na | | 111 | | 0.87 | k | 261.7 | | 232.3 | | 3.2 | |
| Okanogan R, Upr | CCP | 081201134 | 8/6/08 | 4.4 | k | 6.33 | | 3.37 | J | 320 | k | na | | na | | 0.0183 | | 0.03 | U | 134 | | 1.89 | k | 534.0 | | 2054.4 | | 7.4 | |
| Okanogan R, Upr | SMB | 081201135 | 8/6/08 | 2.5 | U,k | na | | 7 | J | 44 | k | na | | na | | na | | na | | 70.2 | | 0.95 | k | 220.0 | | 153.0 | | 2.0 | |
| Omak L | CTT | 081201118 | 7/1/08 | 2.2 | UJ | 3.84 | | 3.0 | J | 19.2 | J | 0.99 | UJ | 1.98 | UJ | 0.0130 | J | 0.03 | U | 66 | | 4.66 | | 384.6 | | 516.2 | | 2.2 | B |
| Omak L | PEA | 081201120 | 7/1/08 | 1.3 | J | 3.02 | | 1.2 | J | 9.51 | | 0.488 | U | 0.488 | UJ | 0.0770 | J | 0.03 | U | 120 | | 0.45 | | 233.3 | | 116.1 | | 9.0 | B |
| Pahata Crk | BKT | 081201114 | 10/15/08 | 2.2 | UJ | 0.707 | | 0.79 | U | 4.20 | | 0.496 | U | 0.496 | UJ | 0.0563 | J | 0.03 | U | 93.2 | | 0.59 | | 174.2 | | 50.8 | | 3.6 | B |
| Quinault R | CTT | 081201101 | 8/28/08 | 1.1 | U | 0.447 | | 0.33 | J | 0.489 | U | 0.489 | U | 0.489 | U | 0.0706 | J | 0.03 | U | 147 | | 0.41 | | 276.3 | | 174.5 | | 3.3 | B |
| Similkameen R, mouth | MWF | 081201142 | 9/24/08 | 13 | J,k | 24.4 | | 70 | | 190 | k | na | | na | | 0.0400 | J | 0.04 | NJ | 73.1 | | 6.05 | k | 336.3 | | 405.5 | | 4.9 | |
| Skykomish R | MWF | 081201112 | 7/28/08 | 7.2 | J | 5.60 | | 10 | J | 2.597 | J | 0.494 | U | 0.988 | UJ | 0.153 | | 0.03 | U | 57.5 | | 3.22 | | 297.0 | | 240.2 | | 4.3 | |
| Snoqualmie R | MWF | 081201113/1119 | 7/29/08 | 13.5 | J,m | 11.8 | | 25.8 | m | 3.1 | J,m | 0.982 | UJ,r | 1.96 | UJ | 0.298 | | 0.03 | U | 88.65 | m | 4.225 | m | 289.5 | m | 225.3 | m | 4.3 | |
| South Twin L | BKT | 081201103 | 6/25/08 | 1.1 | U | 1.17 | | 0.79 | J | 2.26 | | 0.496 | U | 0.496 | UJ | 0.0747 | | 0.03 | U | 48.5 | | 2.24 | | 297.0 | | 308.0 | | 1.2 | B |
| South Twin L | LMB | 081201104 | 6/25/08 | 1.7 | UJ | 0.248 | NJ | 0.17 | J | 0.702 | | 0.486 | U | 0.486 | UJ | 0.0066 | | 0.03 | U | 67.5 | | 0.64 | | 230.2 | | 193.2 | | 4.0 | B |
| South Twin L | RBT | 081201105 | 6/25/08 | 1.1 | U | na | | 0.42 | J | 1.48 | | 0.479 | U | 0.479 | UJ | na | | na | | 22 | | 1.25 | | 302.2 | | 320.8 | | 1.0 | B |
| Stevens L | KOK | 081201127/1131 | 11/13/08 | 11.3 | J,m | 10.3 | m | 17.2 | J,m | 5.0 | J,m | 2.44 | J,m | 1.6 | J,m | 0.094 | J,m | 0.094 | NJ,m | 59.6 | m | 2.045 | m | 336.0 | m | 372.8 | m | 2.0 | |
| Stevens L | RBT | 081201128 | 11/13/08 | 5.8 | J | 1.92 | | 4.97 | J | 2.19 | J | 0.495 | U | 0.287 | J | 0.0202 | | 0.03 | U | 49.4 | | 0.71 | | 256.0 | | 161.8 | | 1.0 | |

**Qualifier (q) codes:**

B = Samples shared with study: PCBs and Dioxin/Furans in Fish from Background Lakes and Rivers (Johnson, 2008).

J = The analyte was positively identified. The associated numerical result is an estimate.

NJ = The analyte was tentatively identified and the associated numerical value represents an approximate concentration.

U = The analyte was not detected at or above the reported value.

UJ = The analyte was not detected at or above the reported estimated result.

k = Values from Okanogan TMDL Effectiveness Monitoring study by Coffin and others (2009 in prep).

m = Mean value from analyses of field duplicates where two results are available. Where both values were non-detect, the highest value was usually used. Where one duplicate was qualified as a non-detect (U, UJ), the reported value was used in determining the mean value. For some duplicate pairs, analysis for PCDD/Fs and PCB congeners was done on only one of the samples; these results are not qualified with an "m".

na = not analyzed.

Species Codes: BKT = Brook trout, BNT = Brown trout, CCP = Common carp, CTT = Cutthroat trout, KOK = Kokanee salmon, LMB = Largemouth bass, LSS = Largescale sucker, MWF = Mountain whitefish, NPM = Northern pikeminnow, PEA = Peamouth, RBT = Rainbow trout, SMB = Smallmouth bass, YP = Yellow perch.

Figure E-1. Boxplots of Sample Results, WSTMP 2001-2008. (Species codes are in Table A1).

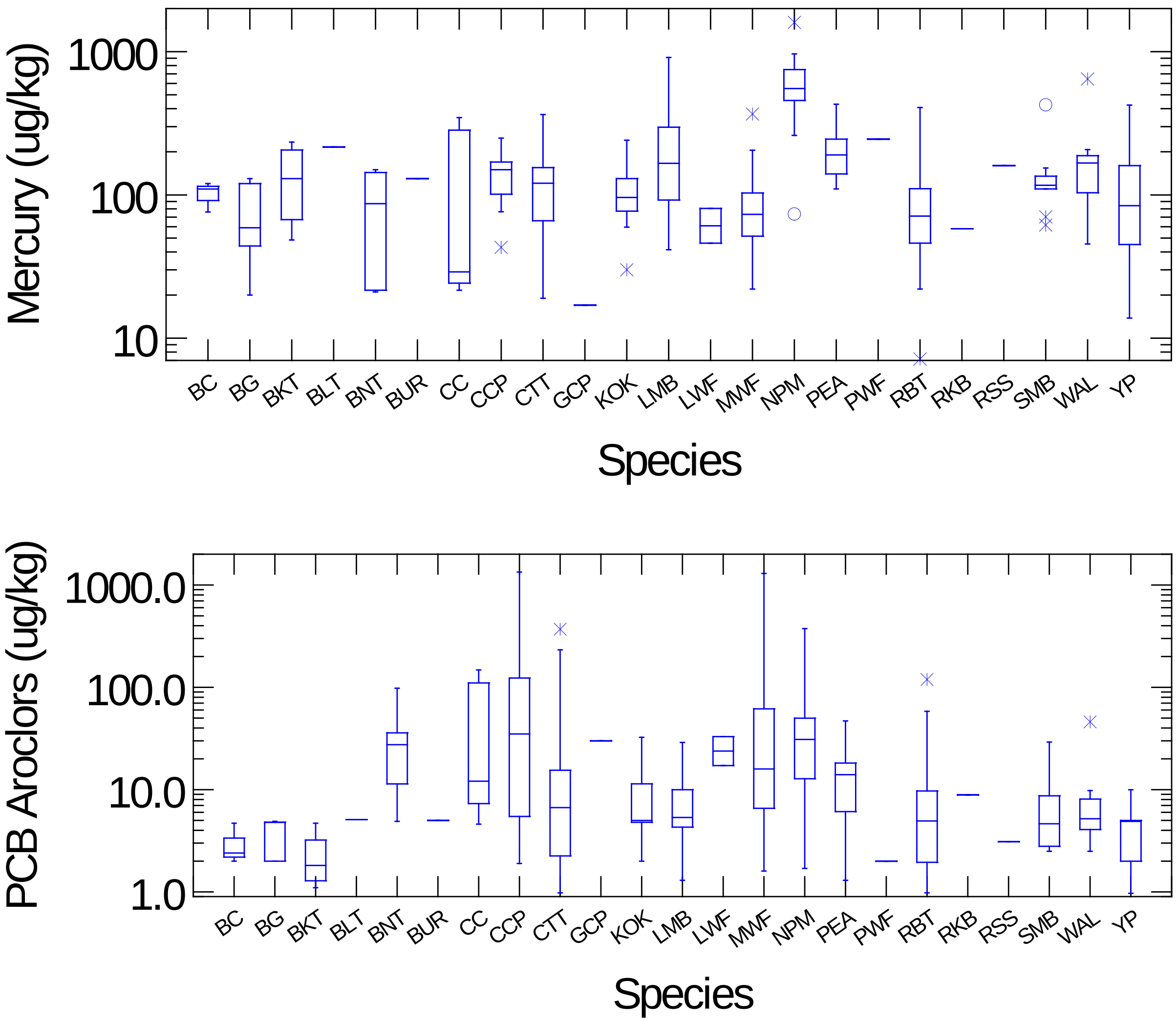
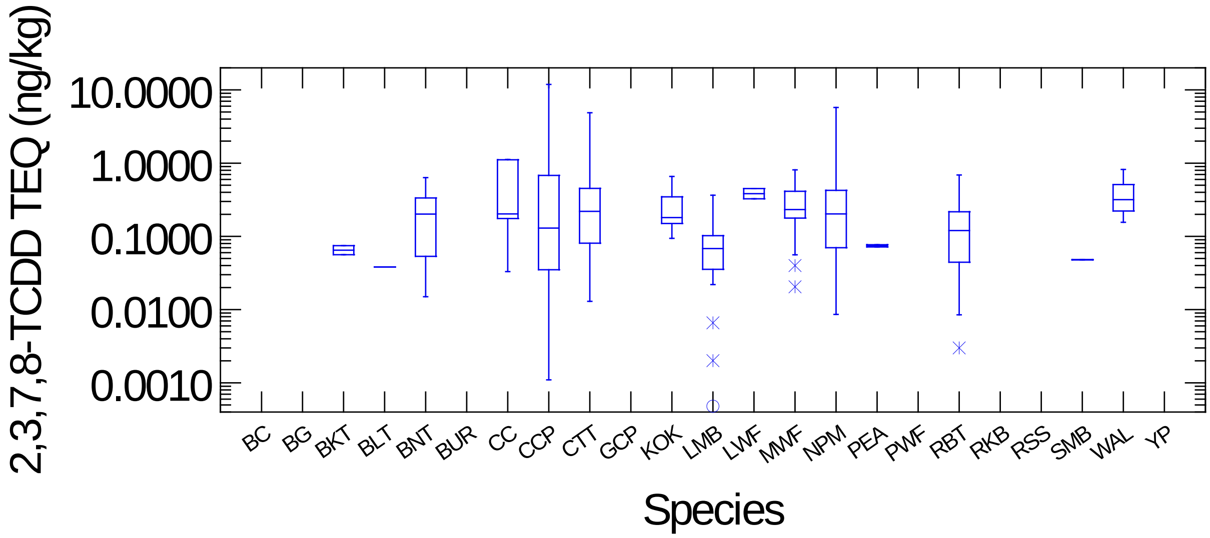
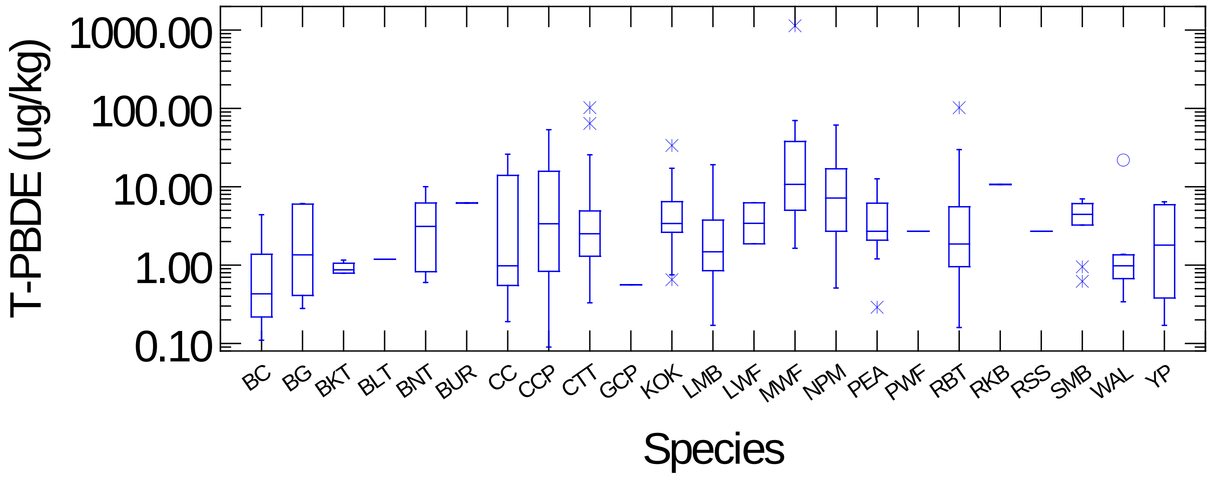


Figure E-1.  Continued.



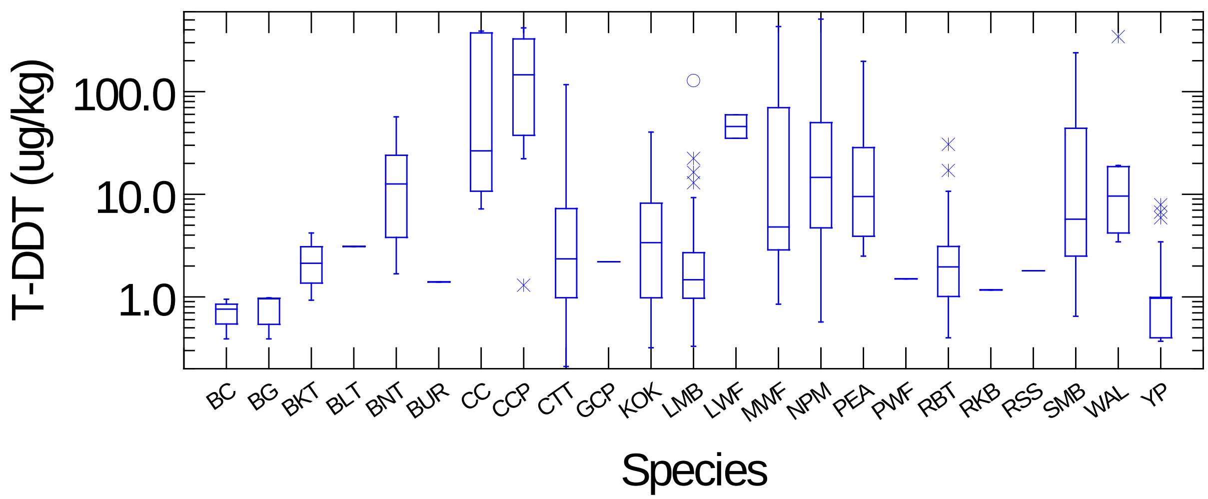
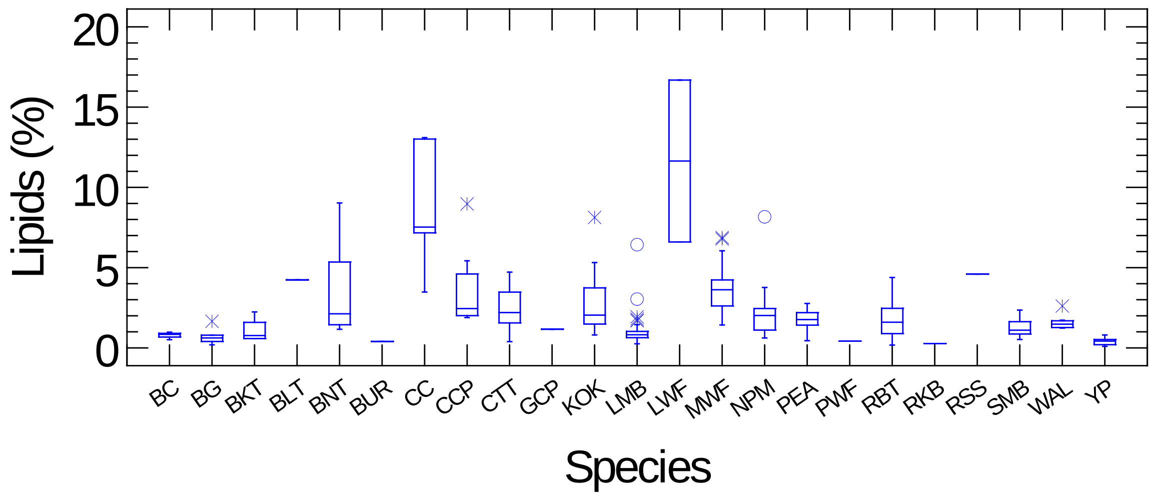
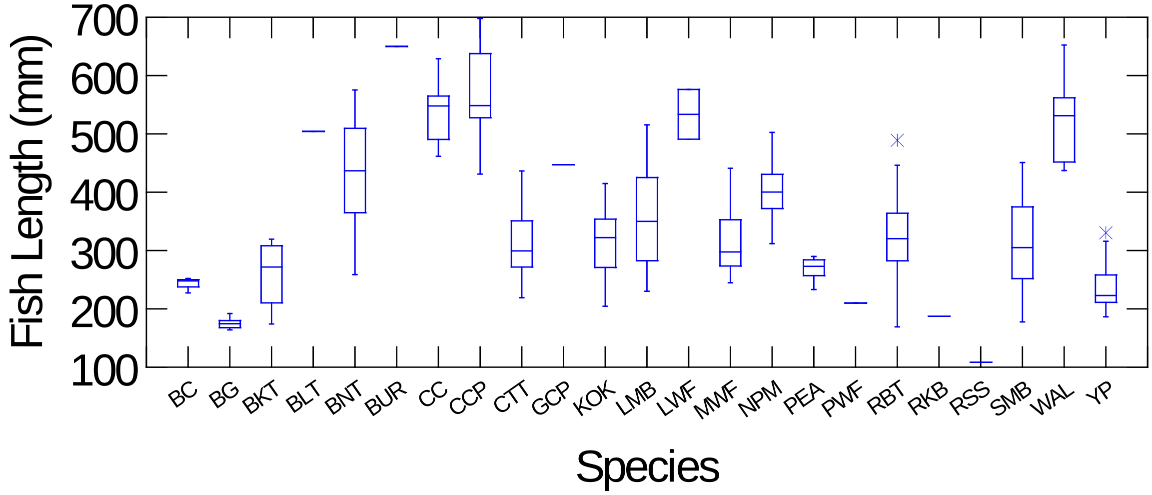



Figure E-1.  Continued.



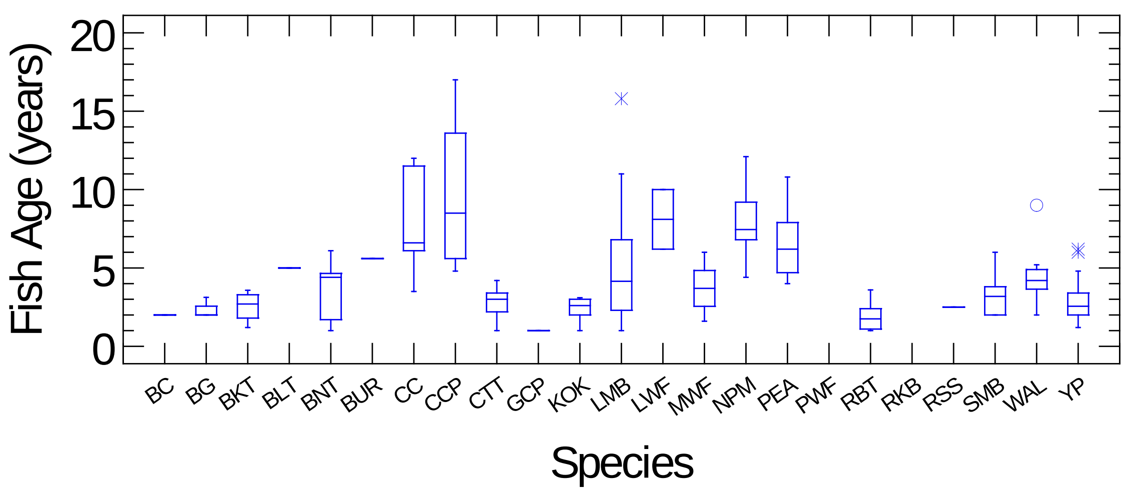



Table E-2. Summary of Fish Tissue Results, WSTMP 2001-2008.

| Species Code | Stat | Total PCB aroclors (ug/kg) | Total PCB congeners (ug/kg) | Total PBDE (ug/kg) | T-DDT (ug/kg) | Hexachloro-benzene (ug/kg) | Total Chlordane (ug/kg) | Dieldrin (ug/kg) | Dioxin/furan TEQ (ng/kg) | 2378 TCDD (ng/kg) | Mercury 245.6 (ug/kg) | Lipid MEL (%) | Mean Total Length (mm) | Mean Weight (g) | Mean Age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All Species | N | 253 | 123 | 245 | 250 | 233 | 237 | 232 | 147 | 147 | 246 | 253 | 258 | 258 | 214 |
| | Max | 1339.0 | 1632.1 | 1135.6 | 508.6 | 22.70 | 68.20 | 6.80 | 11.899 | 1.930 | 1600 | 16.69 | 698 | 5559 | 17.0 |
| | Min | 1.0 | 0.2 | 0.1 | 0.2 | 0.19 | 0.21 | 0.29 | 0.000 | 0.014 | 7 | 0.10 | 109 | 11 | 1.0 |
| | Average | 31.6 | 41.9 | 11.9 | 30.2 | 1.93 | 2.18 | 0.83 | 0.414 | 0.136 | 179 | 2.11 | 339 | 638 | 4.2 |
| | SD | 127.0 | 162.7 | 73.4 | 84.8 | 2.60 | 7.34 | 0.73 | 1.206 | 0.241 | 199 | 2.18 | 105 | 757 | 2.9 |
| BC | N | 3 | 0 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 3 | 3 | 3 | 3 | 1 |
| | Max | 4.7 | 0.0 | 4.4 | 1.0 | 0.95 | 0.95 | 0.47 | 0.000 | 0.000 | 120 | 0.98 | 252 | 257 | 2.0 |
| | Min | 2.0 | 0.0 | 0.1 | 0.4 | 0.39 | 0.39 | 0.39 | 0.000 | 0.000 | 76 | 0.51 | 227 | 185 | 2.0 |
| | Average | 3.0 | | 1.6 | 0.7 | 0.58 | 0.58 | 0.42 | | | 102 | 0.78 | 243 | 229 | 2.0 |
| | SD | 1.5 | | 2.4 | 0.3 | 0.32 | 0.32 | 0.05 | | | 23 | 0.24 | 13 | 39 | |
| BG | N | 5 | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 0 | 5 | 5 | 5 | 5 | 3 |
| | Max | 4.9 | 0.0 | 6.1 | 1.0 | 0.98 | 0.98 | 0.49 | 0.000 | 0.000 | 130 | 1.66 | 192 | 176 | 3.1 |
| | Min | 2.0 | 0.0 | 0.3 | 0.4 | 0.39 | 0.39 | 0.39 | 0.000 | 0.000 | 20 | 0.19 | 164 | 95 | 2.0 |
| | Average | 3.7 | | 2.8 | 0.8 | 0.84 | 0.74 | 0.45 | | | 75 | 0.73 | 176 | 121 | 2.4 |
| | SD | 1.6 | | 3.0 | 0.3 | 0.25 | 0.32 | 0.05 | | | 48 | 0.57 | 11 | 33 | 0.6 |
| BKT | N | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 4 | 4 | 4 |
| | Max | 4.7 | 1.2 | 1.2 | 4.2 | 3.80 | 0.95 | 0.50 | 0.075 | 0.030 | 234 | 2.24 | 320 | 331 | 3.6 |
| | Min | 1.1 | 0.7 | 0.8 | 0.9 | 0.50 | 0.50 | 0.37 | 0.056 | 0.030 | 49 | 0.58 | 174 | 51 | 1.2 |
| | Average | 2.4 | 0.9 | 0.9 | 2.3 | 2.20 | 0.72 | 0.44 | 0.066 | 0.030 | 139 | 1.09 | 259 | 221 | 2.5 |
| | SD | 1.6 | 0.3 | 0.2 | 1.4 | 1.80 | 0.26 | 0.07 | 0.013 | 0.000 | 84 | 0.79 | 64 | 128 | 1.0 |

| Species Code | Stat | Total PCB aroclors (ug/kg) | Total PCB congeners (ug/kg) | Total PBDE (ug/kg) | T-DDT (ug/kg) | Hexachloro-benzene (ug/kg) | Total Chlordane (ug/kg) | Dieldrin (ug/kg) | Dioxin/furan TEQ (ng/kg) | 2378 TCDD (ng/kg) | Mercury 245.6 (ug/kg) | Lipid MEL (%) | Mean Total Length (mm) | Mean Weight (g) | Mean Age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BLT | N | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Max | 5.1 | 3.0 | 1.2 | 3.1 | 3.50 | 0.88 | 0.71 | 0.038 | 0.037 | 216 | 4.24 | 504 | 1184 | 5.0 |
| | Min | 5.1 | 3.0 | 1.2 | 3.1 | 3.50 | 0.88 | 0.71 | 0.038 | 0.037 | 216 | 4.24 | 504 | 1184 | 5.0 |
| | Average | 5.1 | 3.0 | 1.2 | 3.1 | 3.50 | 0.88 | 0.71 | 0.038 | 0.037 | 216 | 4.24 | 504 | 1184 | 5.0 |
| | SD | | | | | | | | | | | | | | |
| BNT | N | 8 | 3 | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 6 | 8 | 8 | 8 | 7 |
| | Max | 98.0 | 87.7 | 10.0 | 56.8 | 6.70 | 5.50 | 2.40 | 0.635 | 0.210 | 150 | 9.03 | 575 | 2521 | 6.1 |
| | Min | 4.9 | 19.1 | 0.6 | 1.7 | 0.55 | 0.56 | 0.53 | 0.015 | 0.030 | 21 | 1.16 | 259 | 187 | 1.0 |
| | Average | 31.6 | 45.8 | 4.1 | 17.7 | 2.24 | 1.77 | 1.28 | 0.240 | 0.119 | 86 | 3.50 | 432 | 1027 | 3.5 |
| | SD | 29.3 | 36.7 | 3.9 | 18.2 | 2.21 | 1.61 | 0.62 | 0.239 | 0.066 | 59 | 2.88 | 105 | 770 | 2.0 |
| BUR | N | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| | Max | 5.0 | 0.0 | 6.2 | 1.4 | 1.00 | 1.00 | 0.50 | 0.000 | 0.000 | 130 | 0.40 | 650 | 1846 | 5.6 |
| | Min | 5.0 | 0.0 | 6.2 | 1.4 | 1.00 | 1.00 | 0.50 | 0.000 | 0.000 | 130 | 0.40 | 650 | 1846 | 5.6 |
| | Average | 5.0 | | 6.2 | 1.4 | 1.00 | 1.00 | 0.50 | | | 130 | 0.40 | 650 | 1846 | 5.6 |
| | SD | | | | | | | | | | | | | | |
| CC | N | 5 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Max | 148.0 | 164.8 | 26.0 | 389.2 | 6.10 | 9.87 | 2.40 | 1.122 | 0.380 | 347 | 13.10 | 629 | 3433 | 12.0 |
| | Min | 4.6 | 2.4 | 0.2 | 7.2 | 0.64 | 0.58 | 0.92 | 0.033 | 0.082 | 22 | 3.48 | 462 | 1023 | 3.5 |
| | Average | 56.5 | 77.5 | 8.3 | 161.3 | 2.20 | 4.28 | 1.75 | 0.529 | 0.252 | 141 | 8.86 | 539 | 1810 | 7.9 |
| | SD | 67.8 | 81.9 | 11.5 | 200.9 | 2.28 | 4.76 | 0.76 | 0.541 | 0.138 | 160 | 4.15 | 65 | 965 | 3.7 |

| Species Code | Stat | Total PCB aroclors (ug/kg) | Total PCB congeners (ug/kg) | Total PBDE (ug/kg) | T-DDT (ug/kg) | Hexachloro-benzene (ug/kg) | Total Chlordane (ug/kg) | Dieldrin (ug/kg) | Dioxin/furan TEQ (ng/kg) | 2378 TCDD (ng/kg) | Mercury 245.6 (ug/kg) | Lipid MEL (%) | Mean Total Length (mm) | Mean Weight (g) | Mean Age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCP | N | 7 | 6 | 7 | 7 | 5 | 5 | 4 | 7 | 7 | 7 | 7 | 7 | 7 | 6 |
| | Max | 1339.0 | 611.3 | 53.6 | 418.3 | 5.40 | 68.20 | 2.40 | 11.899 | 1.930 | 249 | 8.97 | 698 | 5559 | 17.0 |
| | Min | 1.9 | 0.7 | 0.1 | 1.3 | 0.39 | 0.39 | 0.39 | 0.001 | 0.030 | 43 | 1.89 | 431 | 1122 | 4.8 |
| | Average | 233.5 | 119.1 | 14.0 | 186.2 | 1.91 | 22.05 | 1.06 | 1.949 | 0.358 | 142 | 3.79 | 573 | 3003 | 9.7 |
| | SD | 490.5 | 242.3 | 20.4 | 168.7 | 2.01 | 29.65 | 0.93 | 4.405 | 0.700 | 68 | 2.62 | 93 | 1468 | 4.8 |
| CTT | N | 28 | 21 | 28 | 28 | 26 | 28 | 26 | 23 | 23 | 26 | 28 | 28 | 28 | 27 |
| | Max | 370.0 | 383.6 | 102.4 | 117.0 | 8.30 | 66.25 | 2.50 | 4.883 | 0.876 | 364 | 4.73 | 437 | 1027 | 4.2 |
| | Min | 1.0 | 0.4 | 0.3 | 0.2 | 0.19 | 0.36 | 0.37 | 0.013 | 0.017 | 19 | 0.39 | 219 | 102 | 1.0 |
| | Average | 32.3 | 39.7 | 9.8 | 12.6 | 2.07 | 4.79 | 0.95 | 0.655 | 0.170 | 131 | 2.47 | 313 | 336 | 2.9 |
| | SD | 79.5 | 100.6 | 22.1 | 29.9 | 2.08 | 13.82 | 0.68 | 1.320 | 0.248 | 90 | 1.22 | 57 | 231 | 0.8 |
| GCP | N | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| | Max | 30.0 | 0.0 | 0.6 | 2.2 | 1.00 | 1.00 | 0.50 | 0.000 | 0.000 | 17 | 1.17 | 447 | 1249 | 1.0 |
| | Min | 30.0 | 0.0 | 0.6 | 2.2 | 1.00 | 1.00 | 0.50 | 0.000 | 0.000 | 17 | 1.17 | 447 | 1249 | 1.0 |
| | Average | 30.0 | | 0.6 | 2.2 | 1.00 | 1.00 | 0.50 | | | 17 | 1.17 | 447 | 1249 | 1.0 |
| | SD | | | | | | | | | | | | | | |
| KOK | N | 13 | 6 | 13 | 13 | 13 | 13 | 13 | 7 | 7 | 13 | 13 | 13 | 13 | 9 |
| | Max | 32.5 | 31.4 | 33.6 | 40.4 | 15.00 | 13.03 | 6.80 | 0.659 | 0.720 | 241 | 8.13 | 415 | 686 | 3.1 |
| | Min | 2.0 | 1.1 | 0.7 | 0.3 | 0.27 | 0.47 | 0.34 | 0.094 | 0.016 | 30 | 0.81 | 205 | 87 | 1.0 |
| | Average | 9.9 | 11.3 | 7.4 | 7.4 | 3.68 | 2.52 | 1.17 | 0.293 | 0.159 | 112 | 2.84 | 320 | 339 | 2.4 |
| | SD | 8.8 | 10.7 | 9.4 | 11.0 | 4.52 | 3.34 | 1.73 | 0.241 | 0.253 | 58 | 2.17 | 60 | 184 | 0.7 |

| Species Code | Stat | Total PCB aroclors (ug/kg) | Total PCB congeners (ug/kg) | Total PBDE (ug/kg) | T-DDT (ug/kg) | Hexachloro-benzene (ug/kg) | Total Chlordane (ug/kg) | Dieldrin (ug/kg) | Dioxin/furan TEQ (ng/kg) | 2378 TCDD (ng/kg) | Mercury 245.6 (ug/kg) | Lipid MEL (%) | Mean Total Length (mm) | Mean Weight (g) | Mean Age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LMB | N | 42 | 18 | 39 | 42 | 39 | 39 | 38 | 19 | 19 | 42 | 42 | 42 | 42 | 32 |
| | Max | 29.0 | 24.9 | 19.1 | 128.2 | 12.30 | 5.61 | 2.30 | 0.365 | 0.122 | 910 | 6.43 | 516 | 2745 | 15.8 |
| | Min | 1.3 | 0.2 | 0.2 | 0.3 | 0.24 | 0.21 | 0.29 | 0.000 | 0.015 | 41 | 0.26 | 230 | 170 | 1.0 |
| | Average | 8.1 | 6.1 | 3.1 | 6.2 | 2.03 | 1.03 | 0.67 | 0.089 | 0.044 | 243 | 1.05 | 355 | 898 | 5.0 |
| | SD | 6.4 | 6.1 | 4.3 | 19.8 | 2.74 | 0.86 | 0.44 | 0.092 | 0.028 | 216 | 1.00 | 80 | 620 | 3.4 |
| LSS | N | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| | Max | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.310 | 0.090 | 0 | 0.00 | 540 | 1501 | 0.0 |
| | Min | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.310 | 0.090 | 0 | 0.00 | 540 | 1501 | 0.0 |
| | Average | | | | | | | | 0.310 | 0.090 | | | 540 | 1501 | |
| | SD | | | | | | | | | | | | | | |
| LWF | N | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | Max | 33.0 | 6.0 | 6.2 | 59.5 | 4.00 | 6.70 | 3.80 | 0.450 | 0.153 | 80 | 16.69 | 576 | 2524 | 10.0 |
| | Min | 17.2 | 6.0 | 1.9 | 35.1 | 0.44 | 2.03 | 0.85 | 0.326 | 0.130 | 46 | 6.60 | 491 | 1107 | 6.2 |
| | Average | 25.1 | 6.0 | 4.1 | 47.3 | 2.22 | 4.37 | 2.33 | 0.388 | 0.142 | 63 | 11.65 | 534 | 1816 | 8.1 |
| | SD | 11.2 | | 3.1 | 17.2 | 2.52 | 3.30 | 2.09 | 0.088 | 0.016 | 24 | 7.13 | 60 | 1002 | 2.7 |
| MWF | N | 20 | 17 | 20 | 19 | 18 | 18 | 18 | 19 | 19 | 19 | 20 | 21 | 21 | 21 |
| | Max | 1300.0 | 1632.1 | 1135.6 | 430.3 | 3.90 | 3.40 | 2.20 | 0.809 | 0.960 | 367 | 6.88 | 441 | 859 | 6.0 |
| | Min | 1.6 | 1.3 | 1.6 | 0.9 | 0.23 | 0.32 | 0.34 | 0.021 | 0.014 | 22 | 1.43 | 245 | 103 | 1.6 |
| | Average | 119.7 | 120.4 | 76.0 | 86.2 | 1.33 | 1.06 | 0.93 | 0.291 | 0.090 | 94 | 3.77 | 313 | 322 | 3.8 |
| | SD | 302.4 | 391.0 | 250.1 | 149.7 | 1.29 | 0.75 | 0.67 | 0.221 | 0.212 | 80 | 1.58 | 52 | 195 | 1.2 |

| Species Code | Stat | Total PCB aroclors (ug/kg) | Total PCB congeners (ug/kg) | Total PBDE (ug/kg) | T-DDT (ug/kg) | Hexachloro-benzene (ug/kg) | Total Chlordane (ug/kg) | Dieldrin (ug/kg) | Dioxin/furan TEQ (ng/kg) | 2378 TCDD (ng/kg) | Mercury 245.6 (ug/kg) | Lipid MEL (%) | Mean Total Length (mm) | Mean Weight (g) | Mean Age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NPM | N | 19 | 18 | 18 | 19 | 18 | 19 | 18 | 17 | 17 | 18 | 19 | 20 | 20 | 18 |
| | Max | 375.3 | 241.2 | 61.4 | 508.6 | 4.00 | 37.43 | 3.90 | 5.754 | 0.684 | 1600 | 8.17 | 503 | 1643 | 12.1 |
| | Min | 1.7 | 0.9 | 0.5 | 0.6 | 0.23 | 0.49 | 0.38 | 0.009 | 0.015 | 74 | 0.62 | 309 | 244 | 4.4 |
| | Average | 53.2 | 40.2 | 12.8 | 70.5 | 1.45 | 2.90 | 0.92 | 0.592 | 0.100 | 621 | 2.23 | 397 | 656 | 8.1 |
| | SD | 83.5 | 55.5 | 15.6 | 141.7 | 1.13 | 8.37 | 0.84 | 1.363 | 0.158 | 327 | 1.69 | 51 | 319 | 2.0 |
| PEA | N | 13 | 2 | 13 | 13 | 13 | 13 | 13 | 2 | 2 | 13 | 13 | 13 | 13 | 11 |
| | Max | 47.0 | 15.6 | 12.6 | 197.1 | 3.80 | 2.12 | 2.40 | 0.077 | 0.031 | 429 | 2.77 | 290 | 4207 | 10.8 |
| | Min | 1.3 | 3.0 | 0.3 | 2.5 | 0.21 | 0.23 | 0.38 | 0.072 | 0.030 | 110 | 0.45 | 233 | 107 | 4.0 |
| | Average | 16.5 | 9.3 | 4.7 | 41.8 | 1.06 | 0.87 | 0.72 | 0.074 | 0.031 | 208 | 1.77 | 268 | 482 | 6.5 |
| | SD | 14.3 | 8.9 | 3.9 | 63.5 | 0.91 | 0.54 | 0.54 | 0.004 | 0.001 | 90 | 0.60 | 18 | 1120 | 2.2 |
| PWF | N | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| | Max | 2.0 | 0.0 | 2.7 | 1.5 | 0.40 | 0.40 | 0.40 | 0.000 | 0.000 | 245 | 0.43 | 210 | 58 | 0.0 |
| | Min | 2.0 | 0.0 | 2.7 | 1.5 | 0.40 | 0.40 | 0.40 | 0.000 | 0.000 | 245 | 0.43 | 210 | 58 | 0.0 |
| | Average | 2.0 | | 2.7 | 1.5 | 0.40 | 0.40 | 0.40 | | | 245 | 0.43 | 210 | 58 | |
| | SD | | | | | | | | | | | | | | |
| RBT | N | 36 | 23 | 36 | 34 | 34 | 34 | 34 | 30 | 30 | 35 | 36 | 37 | 37 | 30 |
| | Max | 119.5 | 33.5 | 102.2 | 30.7 | 22.70 | 1.50 | 1.00 | 0.690 | 0.690 | 407 | 4.39 | 489 | 1357 | 3.6 |
| | Min | 1.0 | 0.3 | 0.2 | 0.4 | 0.19 | 0.22 | 0.29 | 0.003 | 0.020 | 7 | 0.18 | 169 | 42 | 1.0 |
| | Average | 11.6 | 6.2 | 7.3 | 3.7 | 2.75 | 0.77 | 0.58 | 0.188 | 0.145 | 92 | 1.80 | 324 | 386 | 1.8 |
| | SD | 21.7 | 8.9 | 17.5 | 5.8 | 3.97 | 0.29 | 0.23 | 0.204 | 0.208 | 79 | 1.11 | 64 | 251 | 0.8 |

| Species Code | Stat | Total PCB aroclors (ug/kg) | Total PCB congeners (ug/kg) | Total PBDE (ug/kg) | T-DDT (ug/kg) | Hexachloro-benzene (ug/kg) | Total Chlordane (ug/kg) | Dieldrin (ug/kg) | Dioxin/furan TEQ (ng/kg) | 2378 TCDD (ng/kg) | Mercury 245.6 (ug/kg) | Lipid MEL (%) | Mean Total Length (mm) | Mean Weight (g) | Mean Age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RKB | N | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| | Max | 8.9 | 0.0 | 10.7 | 1.2 | 0.92 | 0.37 | 0.37 | 0.000 | 0.000 | 58 | 0.27 | 187 | 123 | 0.0 |
| | Min | 8.9 | 0.0 | 10.7 | 1.2 | 0.92 | 0.37 | 0.37 | 0.000 | 0.000 | 58 | 0.27 | 187 | 123 | 0.0 |
| | Average | 8.9 | | 10.7 | 1.2 | 0.92 | 0.37 | 0.37 | | | 58 | 0.27 | 187 | 123 | |
| | SD | | | | | | | | | | | | | | |
| RSS | N | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| | Max | 3.1 | 0.0 | 2.7 | 1.8 | 0.00 | 0.94 | 0.75 | 0.000 | 0.000 | 160 | 4.60 | 109 | 11 | 2.5 |
| | Min | 3.1 | 0.0 | 2.7 | 1.8 | 0.00 | 0.94 | 0.75 | 0.000 | 0.000 | 160 | 4.60 | 109 | 11 | 2.5 |
| | Average | 3.1 | | 2.7 | 1.8 | | 0.94 | 0.75 | | | 160 | 4.60 | 109 | 11 | 2.5 |
| | SD | | | | | | | | | | | | | | |
| SMB | N | 10 | 1 | 10 | 10 | 7 | 7 | 7 | 2 | 2 | 10 | 10 | 11 | 11 | 10 |
| | Max | 29.2 | 10.5 | 7.0 | 239.0 | 12.30 | 4.20 | 1.40 | 0.111 | 0.044 | 425 | 2.36 | 451 | 1386 | 6.0 |
| | Min | 2.5 | 10.5 | 0.6 | 0.6 | 0.88 | 0.50 | 0.50 | 0.048 | 0.030 | 61 | 0.53 | 178 | 72 | 2.0 |
| | Average | 8.7 | 10.5 | 4.3 | 38.6 | 3.00 | 1.35 | 0.81 | 0.080 | 0.037 | 142 | 1.23 | 315 | 565 | 3.4 |
| | SD | 9.6 | | 2.3 | 73.3 | 4.25 | 1.27 | 0.34 | 0.045 | 0.010 | 103 | 0.59 | 86 | 442 | 1.5 |
| WAL | N | 7 | 1 | 7 | 7 | 7 | 7 | 7 | 3 | 3 | 7 | 7 | 7 | 7 | 7 |
| | Max | 46.0 | 107.8 | 21.9 | 343.3 | 1.00 | 1.48 | 3.10 | 0.820 | 0.820 | 644 | 2.61 | 652 | 3601 | 9.0 |
| | Min | 2.5 | 107.8 | 0.3 | 3.4 | 0.24 | 0.66 | 0.49 | 0.156 | 0.030 | 45 | 1.24 | 437 | 765 | 2.0 |
| | Average | 11.2 | 107.8 | 3.9 | 57.4 | 0.62 | 0.97 | 1.44 | 0.431 | 0.387 | 209 | 1.61 | 521 | 1650 | 4.6 |
| | SD | 15.5 | | 7.9 | 126.2 | 0.32 | 0.25 | 0.92 | 0.346 | 0.401 | 201 | 0.48 | 80 | 965 | 2.2 |

| Species Code | Stat | Total PCB aroclors (ug/kg) | Total PCB congeners (ug/kg) | Total PBDE (ug/kg) | T-DDT (ug/kg) | Hexachloro-benzene (ug/kg) | Total Chlordane (ug/kg) | Dieldrin (ug/kg) | Dioxin/furan TEQ (ng/kg) | 2378 TCDD (ng/kg) | Mercury 245.6 (ug/kg) | Lipid MEL (%) | Mean Total Length (mm) | Mean Weight (g) | Mean Age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | N | 25 | 0 | 21 | 25 | 21 | 21 | 21 | 0 | 0 | 25 | 25 | 25 | 25 | 17 |
| | Max | 10.0 | 0.0 | 6.4 | 7.9 | 3.90 | 1.00 | 2.50 | 0.000 | 0.000 | 423 | 0.81 | 331 | 499 | 6.2 |
| | Min | 1.0 | 0.0 | 0.2 | 0.4 | 0.28 | 0.37 | 0.35 | 0.000 | 0.000 | 14 | 0.10 | 187 | 76 | 1.2 |
| | Average | 4.7 | | 2.5 | 1.6 | 1.07 | 0.73 | 0.56 | | | 111 | 0.40 | 238 | 192 | 3.0 |
| | SD | 3.0 | | 2.5 | 2.1 | 0.93 | 0.28 | 0.46 | | | 92 | 0.20 | 41 | 127 | 1.5 |

Stat = statistic.
N = number.
SD = standard deviation.
Species codes are described in Table A-1.

# Appendix F. Health Information about Fish

Fish is good food. Trying to balance the health benefits of fish with concerns about contaminant levels can be challenging, yet information is available to help consumers make healthy choices. Contaminants are found in most foods, and choosing fish wisely can be an excellent health choice. The key is to make smart decisions and choose fish that are low in mercury, PCBs, and other contaminants.

The American Heart Association recommends eating fish twice a week because fish are a great source of protein, vitamins, and nutrients. Fish are loaded with omega-3 fatty acids, which provide protection from heart disease and are great "brain food" for adults and children.

A valuable source of information about eating fish is the Washington State Department of Health (DOH) website:

www.doh.wa.gov/ehp/oehas/fish/default.htm

- Advice for women and children who eat fish.
- Waterbody-specific fish consumption advisories in Washington.
- How contaminants (mercury, PCBs, PBDEs, DDTs) get into fish.
- How you can help reduce contaminants.

www.doh.wa.gov/ehp/oehas/fish/fishchart.htm

- Healthy fish eating guide.
- Checklist to reduce contaminant exposure including the proper way to fillet and prepare fish meals.
- Health benefits of fish/recipes.

www.doh.wa.gov/ehp/oehas/fish

- Fish and shellfish consumption advisories.

The U.S. Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) also provide information on health benefits of fish:

www.epa.gov/waterscience/fish/

- What you need to know about mercury - 10 frequently asked questions.

www.cfsan.fda.gov/seafood1.html

- Seafood information and resources.