Background Characterization for Metals and Organic Compounds in Northeast Washington Lakes

Part 2: Fish Tissue

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Cover photo: Ecology electrofishing boat (Casey Deligeannis)

Background Levels of Metals and Organic Compounds in Northeast Washington Lakes

Part 2: Fish Tissue

by

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Waterbody Numbers or Water Resource Inventory Area

Swan Lake	WRIA 52
Ellen Lake	WA-58-9015
South Twin Lake	WA-58-9040
Pierre Lake	WA-60-9040
Cedar Lake	WA-61-9010
Pepoon Lake	WA 60
Bayley Lake	WRIA 59
Sullivan Lake	WA-62-9190
Leo Lake	WA-62-9085
Browns Lake	WA-62-9030
Bead Lake	WA-62-9010
Colville River	WA-59-1010
Jumpoff Joe Lake	WA-59-9100
Pend Oreille River	WA-62-1020
Upper Priest Lake	Idaho
St. Joe River	Idaho

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Abstract

A range of potentially toxic metals and organic compounds were analyzed in sediments and fish collected during 2010-2011 from 17 northeast Washington lakes and rivers thought to be minimally impacted by local human activities. One lake and one river were also sampled in northern Idaho. The goal of the study was to provide regional-scale sediment and fish tissue data that will support contaminant studies and cleanup activities associated with northeastern Washington waterbodies. The present report has the results on fish tissue samples, obtained from 16 of the waterbodies in the study area. A previous report (Part 1) contains the results for sediment samples.

Fish fillets and whole fish were analyzed for mercury, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polybrominated diphenylethers (PBDEs). Whole fish were also analyzed for cadmium, lead, arsenic, antimony, zinc, and copper. Sensitive analytical methods were used to achieve low detection limits for the target chemicals.

Data presentation includes statistical summaries, figures showing data distribution, and waterbody samples ranked by concentration levels. Results are compared to previous fish tissue surveys in Washington and Idaho. Comparison with EPA human health criteria is evaluated and ecological benchmarks presented. Approximate fish tissue concentration values representative of the lakes and rivers sampled are calculated to support cleanup efforts at contaminated sites in the region or for other uses.

Acknowledgements

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1. Sheri Sears, Josh Hall, and Ed Shallenberger of the Colville Confederated Tribes provided fish samples from Swan, Pierre, Ellen, and South Twin lakes. Sheri Sears also had helpful background information on study area lakes.
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Introduction

An understanding of current background conditions provides an objective and consistent point of reference for assessing contaminated aquatic environments. Sediment chemistry, bioaccumulation, benthic community structure, and bioassay response are common measures where reference values are often established. San Juan (1994) lists a variety of potential uses for this type of information including defining background, screening contaminant data, risk assessments, regulatory compliance, evaluating waste streams, designing investigative studies, and research.

The goal of the present 2010 study is to provide data on the current status of freshwater sediments and fish that could be used as a reference for assessing and cleaning up various northeast Washington waterbodies potentially contaminated with toxic metals and halogenated[1] organic compounds. The sediment and fish tissue data are being reported separately. Part 1 reported the results for sediment samples (Johnson et al., 2011). The present report, Part 2, covers the sampling design, methods, results, and data interpretation for fish samples.

The guidance for cleanup targets in the Model Toxics Control Act (MTCA, WAC 173-340-200) draws a distinction between two types of background:

- **Natural background:** For the purposes of hazardous substance cleanup under MTCA, *natural background* refers to the concentration of a constituent that occurs naturally in the environment and has not been influenced by localized human activities. Metals that occur naturally in bedrock and soils are cited as an example. Man-made chemicals such as PCBs are included by MTCA as part of the *natural background* when their presence is due to widespread use and global atmospheric transport.

- **Area background:** MTCA defines *area background* as the concentrations of substances that are consistently present in the environment in the vicinity of a site and which are the result of human activities unrelated to releases from that site. Blakley et al. (1992) gives the example of different lead levels in Seattle soils compared to Tacoma, area background for lead would therefore be different for the two cities. Area background is a site-specific determination.

Determination of background levels has also been an aspect or focus of numerous water quality investigations in Washington. Two in particular provided an impetus for the present study:

In 2007-2008, the Washington State Department of Ecology (Ecology) conducted *An Assessment of the PCB and Dioxin Background in Washington Freshwater Fish* (Johnson et al., 2010). Ecology needed this information to help prioritize the state's resources for cleaning up waterbodies that did not meet U.S. Environmental Protection Agency (EPA) Federal Clean Water Act human health criteria for fish consumption. The study showed that levels of these chemicals were often lower in the far eastern counties.

[1] In this study, compounds containing chlorine or bromine.

Another statewide effort by Ecology, *Baseline Characterization of Nine Proposed Freshwater Sediment Reference Sites* (Sloan and Blakley, 2009), was designed to screen for reference areas for freshwater sediment investigations. The study revealed a general lack of information on chemical and biological conditions for aquatic sediments in eastern Washington.

In the context of these two studies, the terms *background* and *reference* are essentially synonymous, meaning waterbodies that were thought to exhibit relatively low impact from human activities. Given the extent of urban, industrial, and agricultural development in the Pacific Northwest and world-wide, all Washington waterbodies have been affected to at least some degree by humans.

The present report generally uses the term *background* when referring to northeastern Washington waterbodies that exhibit relatively low direct impact from human activities. These waterbodies are further affected to varying degrees by watershed-scale atmospheric influences.

Often, the ultimate goal of a cleanup action is to make lakes, rivers, or streams safe for fish consumers. A number of the chemicals of concern in the present study can be transported long distances through the atmosphere. Fish bioaccumulate these chemicals to levels several orders of magnitude higher than in their surrounding environment. This phenomenon, coupled with risk-based human health criteria in the low to sub-parts per billion range, make it particularly difficult to set achievable cleanup targets for fish consumption.

The regional variability and gaps in the background data on sediments and fish came to the attention of Ecology's Eastern Regional Office (ERO). ERO expressed concern that the use of statewide-based reference values for decision-making purposes in eastern and northeastern Washington would tend to inappropriately bias outcomes, particularly for cleanup actions. They saw a need for chemical data specific to northeast Washington. Sediment and fish tissue background assumptions affect the ability to differentiate between point-source impacts and appropriate background designations. In view of these concerns, Ecology initiated a project to survey a range of metallic and organic contaminants in sediments and fish from potential background eligible lakes in northeast Washington.

Project Summary

Current understanding of area or regional-scale conditions for chemical contaminants in aquatic environments in northeast Washington is limited. Therefore, a field study was conducted to achieve enhanced testing of selected waterbodies in Ferry, Stevens, and Pend Oreille Counties, as well as two representative waterbodies in northern Idaho. Bottom sediments were sampled from 14 lakes in Washington and one lake and one river in Idaho. Fish samples were obtained from 13 of these waterbodies plus three additional Washington lakes and rivers not sampled for sediment.

The objective of the study was to characterize the occurrence and levels of selected potentially toxic metals and halogenated organic compounds in bottom sediments and fish tissues from waterbodies that exhibit relatively low direct impact from human activities. Factors considered in waterbody selection included land-use development, proximity to historical mining, known industry and agriculture, general local watershed conditions, and known lake management history. The study focused principally on lakes whose quality was not believed to be influenced by notable human-oriented activities that are known to jeopardize environmental quality. Lakes dominated the study group since larger rivers and streams in the study area often could not be included due to a variety of known or potential anthropogenic influences.

The initial round of field work took place during the late summer and fall of 2010. An additional set of fish samples was collected in the spring of 2011 in an attempt to fill data gaps for certain waterbodies and species. Because of a delay in obtaining the final fish tissue data for the project, the fish and sediment data are being reported separately. A previous report covers the results on sediment samples. A summary of the chemical data obtained for sediments is provided in Appendix A of the present report.

Contaminants of interest at regional cleanup sites were selected as target analytes. Fish fillets and whole body samples were analyzed for mercury, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polybrominated diphenylethers (PBDEs). Whole fish were also analyzed for cadmium, lead, arsenic, antimony, zinc, and copper. The same analyses were conducted on sediment samples, with the addition of barium, chromium, manganese, and iron. Sensitive analytical methods were used to achieve low detection limits for the target chemicals.

The study was designed and conducted by Ecology's Environmental Assessment Program with the assistance of ERO. Samples were analyzed by the Ecology Manchester Environmental Laboratory and Pacific Rim Laboratories. The study followed a Quality Assurance Project Plan (Johnson, 2010) developed in accordance with the Ecology guidance in Lombard and Kirchmer (2004).

Study Design

Study Area

The study area for this project encompasses Ferry, Stevens, and Pend Oreille Counties. These counties include or are adjacent to the majority of cleanup and hazardous waste sites in northeast Washington. The study area provides a number of lakes and some rivers exhibiting relatively low impacts from development, compared to adjacent, more populated counties such as Spokane County.

ERO requested that Upper Priest Lake and the upper St. Joe River in northern Idaho be included among the sampling sites, in view of their remote locations in areas largely surrounded by wilderness and their proximity to eastern Washington. Upper Priest Lake lies within the Pend Oreille basin. The St. Joe River flows into Lake Coeur d'Alene, which drains to the Spokane River.

Target Chemicals

The fish tissue samples were analyzed for the metals and organic compounds listed in Table 1. These were identified by ERO as being of primary concern at regional cleanup sites. The term "congener" in Table 1 means one of many variants or configurations of a common chemical structure. For example, the PCBs analysis included 209 individual compounds or congeners.

In view of the low bioaccumulation potential of barium, chromium, manganese, and iron, metals analysis of the fish tissue samples was restricted to antimony, arsenic, copper, lead, mercury, and zinc. Fish muscle is a poor accumulator of metals in general, mercury being an exception. Whole fish, on the other hand, are indicators for a range of metals (e.g., Lowe et al., 1985). The metals analyzed in whole fish included antimony, arsenic, copper, lead, and zinc, in addition to mercury.

Mercury (as methyl mercury) and the organic compounds analyzed in this study are lipid (fat) soluble. Lipid content of the fish tissue samples was determined for possible use in normalizing chemical concentrations among fish species and waterbodies (Herbert and Keenleyside, 1995).

Mercury, cadmium, lead, PCBs, PCDDs, PCDFs, and PBDEs are persistent, bioaccumulative toxics (PBTs) that are a hazard for fish and other aquatic life, wildlife, and human health (www.ecy.wa.gov/programs/swfa/pbt). The other metals analyzed also have toxic properties, but seldom bioaccumulate in aquatic environments so are not classed as PBTs.

Detailed profiles on the target chemicals for this study have been prepared by the Agency for Toxic Substances & Disease Registry. These profiles describe health effects, physical/chemical properties, production and use, environmental occurrence, regulations, and analysis methods. (See www.atsdr.cdc.gov/toxprofiles/index.asp .) This website profiles hazardous substances found at National Priorities List (Superfund) sites.

Table 1. Target Chemicals and Conventional Parameters for Sediment and Fish Samples.

Chemical	Sediments	Fish Tissues (present report)	
		Fillet	Whole Body
Antimony (Sb)	X		**X**
Arsenic (As)	X		**X**
Cadmium (Cd)	X		**X**
Copper (Cu)	X		**X**
Lead (Pb)	X		**X**
Mercury (Hg)	X	**X**	**X**
Zinc(Zn)	X		**X**
Barium (Ba)	X		
Chromium (Cr)	X		
Manganese (Mn)	X		
Iron (Fe)	X		
PCBs (209 congeners)	X	**X**	**X**
PCDDs (7 congeners)	X	**X**	**X**
PCDFs (10 congeners)	X	**X**	**X**
PBDEs (36 congeners)	X	**X**	**X**
Grain size	X		
Total Organic Carbon	X		
% Lipids		**X**	**X**

The metals analyzed in this study are naturally occurring at crustal concentrations in rocks and soils, and have a long history of use in industry and domestic products. Mining and ore processing in particular are known in some cases to locally affect water quality and sediment chemistry in close proximity to historic operations within certain northeast Washington tributaries by mobilizing or releasing mercury, cadmium, lead, and other metals (USGS, 2010; Pelletier and Merrill, 1998; Raforth et al., 2004). On a watershed scale, the Spokane River drainage exhibits metals impacts due to historic world-class mining and milling operations in Idaho. And the upper Columbia River exhibits metals impacts caused by metals smelting operations in Trail, British Columbia.

PCBs came into use in 1929. Commercial PCBs were manufactured as mixtures with varying chlorine content. PCBs were used as insulators in electrical transformers and capacitors, in plasticizers, lubricants, and hydraulic fluids, as well as in inks and sealers for gaskets and furnaces. Manufacture and use of PCBs was banned by EPA in the 1970s and 1980s due to ecological concerns. Historically, the Spokane River had some of the highest PCB levels in Washington freshwater fish, exceeding 2 parts per million in some species (Serdar et al., 2011).

PCDDs and PCDFs, commonly referred to as dioxins and furans, are unintended byproducts found in association with certain industrial sites, waste incinerators, and combustion, especially of chlorinated material. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 16 related compounds with similar structure are particularly toxic. Pulp and paper mills that used chlorine in their bleaching process were a major historical source of dioxins and furans in the Pacific Northwest, and mills operating in British Columbia discharged these wastes to the upper Columbia River (EPA, 1991). This practice was discontinued in the 1990s.

Nationwide and in Canada, reductions in dioxin and furan emissions have occurred from a combination of regulatory activities, improved emission controls, voluntary actions on the part of industry, and the closing of a number of facilities. Serdar et al. (1994) reported a four-fold decrease in TCDD levels in lake whitefish from the upper Columbia (Franklin D. Roosevelt Lake) between 1990 and 1994, from average concentrations of 1.9 parts per trillion down to 0.5 part per trillion.

PBDEs are brominated flame retardant chemicals added to delay combustion in a wide variety of products such as upholstered furniture, computers, cable insulation, and textile coatings. PBDEs have been used extensively for the last 30 years, with the U.S. and Canada being the largest consumers of products treated with PBDEs (Ecology and WDOH, 2006). Studies have shown that toxic PBDEs leach from these products and accumulate in the environment.

Here again, the upper Columbia and Spokane rivers have figured prominently among the waterbodies with elevated chemical residues in fish. Total PBDE concentrations in mountain whitefish from the upper Columbia River in British Columbia were reported to double approximately every two years between 1992 to 2000, reaching 72 parts per billion (Rayne et al., 2003). The highest PBDE concentrations recorded in Washington fish have been from the Spokane River; approximately 1 part per million in 2005 (Johnson et al., 2006).

Three main types of PBDEs are used in consumer products: Penta-BDE, Octa-BDE, and Deca-BDE. Manufacturers of Penta-BDE and Octa-BDE agreed to voluntarily stop producing these two forms by the end of 2004. In 2009, three major producers of Deca-BDE arrived at an agreement with EPA to stop producing, importing, and selling Deca-BDE by the end of 2012. A Washington State ban on the manufacture, sale, and distribution of televisions, computers, and residential upholstered furniture containing Deca-BDE took effect in January 2011.

Fish Consumption Concerns in Northeast Washington

Table 2 provides a perspective on the role that the target chemicals for this study play in fish consumption concerns in northeast Washington. The Washington State Department of Health (WDOH) has issued fish consumption advisories for mercury, lead, PCBs, and PBDEs for four major northeast waterbodies, in addition to a statewide advisory that applies to mercury in largemouth bass, smallmouth bass, and northern pikeminnow www.doh.wa.gov/ehp/oehas/fish/fishadvisories.htm. Water Quality Improvement Projects (also known as TMDLs[2]) are underway for cadmium, lead, zinc, and PCBs in three major northeast waterbodies www.ecy.wa.gov/programs/wq/tmdl/index.html. Ecology has identified 43 other

[2] The Total Maximum Daily Load (TMDL) or Water Quality Improvement Project process was established by Section 303(d) of the Clean Water Act to set limits on pollutants that can be discharged to a waterbody and still allow state standards to be met.

waterbody segments in this region as being water quality limited for fish consumption due to elevated concentrations of PCBs, TCDD, or mercury (the Clean Water Act 303d list) www.ecy.wa.gov/programs/wq/303d/index.html.

Additionally, as of March 2011, Ecology has registered approximately 170 individual Hazardous Sites or National Priorities List sites in northeast Washington www.ecy.wa.gov/programs/tcp/mtca_gen/hazsites.html. Many of the Table 1 chemicals are at issue, although not necessarily directly linked to fish consumption concerns.

Table 2. Northeast Washington Waterbodies with Fish Consumption Concerns for Metals, PCBs, TCDD, or PBDEs (Pend Oreille, Stevens, Ferry, Okanogan, Chelan, Douglas, Lincoln, and Spokane Counties).

Category/Chemical	Waterbody
WDOH Fish Consumption Advisories	
Lead, PCBs, PBDEs	Spokane River/Lake Spokane
Mercury	Lake Roosevelt
PCBs	Okanogan River
PCBs	Wenatchee River
Mercury	Freshwaters Statewide
Water Quality Improvement Projects (TMDLs)	
Cd, Pb, Zn, PCBs*	Spokane River/Lake Spokane
PCBs	Okanogan River
PCBs	Lake Chelan
303(d) Listings for Edible Fish Tissue	
PCBs	34 listings in 16 waterbodies
TCDD	8 listings in 6 waterbodies
Mercury	1 listing in 1 waterbody

*under development

Waterbody Selection

ERO and Ecology's Environmental Assessment Program developed a preliminary list of potential minimally impacted lakes by examining Washington state maps and GIS coverages showing population density, agricultural land use, industrial and municipal outfalls, surface mines, and public lands. Recommendations were also provided by Bill Baker of the Washington Department of Fish and Wildlife (WDFW) and Sheri Sears, Resident Division Fish Manager for the Colville Confederated Tribes. This effort identified waterbodies, based on available records, that are believed to exhibit relatively low direct impact from human activities and have a low probability of local sources of contamination.

Each candidate lake was then checked against Ecology's Facility Site Identification System (www.ecy.wa.gov/fs/index.html) to identify potential activities that could affect their inclusion in the study. Facility Site identifies sites known to Ecology as having an active or potential impact on the local environment. Facility Site showed several mines or mining-related sites were located in the Cedar Lake watershed (Lucky Four Mine, Redtop Mine, and Northport Minerals). After further direct inspections it was decided to retain Cedar Lake in the study due to its favorable location in the uppermost part of the Columbia River drainage and a determination of the low potential for actual impact from mining and milling in the area.

Ecology and WDFW staff were contacted to determine if any of the lakes considered for study had been chemically treated to control aquatic plants, algae, or undesirable fish species. Records showed several of these lakes had been treated with rotenone in the past as part of a WDFW program to eliminate spiny-rayed fish and rehabilitate the trout fishery. The historic use of rotenone, a natural product derived from derris root, was not viewed as compromising a lake's usefulness for this study. Pepoon Lake was treated with toxaphene in 1962, also for fisheries enhancement. Toxaphene, a chlorinated pesticide, is not a regional chemical of interest in this study.

Based on the above evaluations, 26 lakes were preliminarily selected. After identifying location and condition of boat ramps or other means of access, contacting regional biologists to determine what fish species are present and fish stocking history, and field reconnaissance, 16 waterbodies were ultimately sampled (Table 3).

The initial round of field work took place during the late summer and fall of 2010. An additional set of fish samples was collected in the spring of 2011 to fill data gaps for certain waterbodies and species. This effort was successful in obtaining fish from Pepoon Lake and in expanding the number of species analyzed from Bead Lake. Three previously unsampled waterbodies – Jumpoff Joe Lake, Colville River (near Chewelah), and Pend Oreille River (above Box Canyon Dam) – were also sampled for fish in 2011. Location information for these three waterbodies is included in Table 3. Figure 1 shows the general locations of all waterbodies sampled for fish and sediments for the northeast Washington background study during 2010-2011.

An attempt was made to distribute the sampling effort more or less evenly across the study area, although this was not always possible. Most of the selected lakes lie in a north-south gradient along the Columbia or Pend Oreille river drainages. In addition, an emphasis was placed on selecting representative upland lakes near the Columbia River and international border due to documented transboundary pollution issues. Historically, the vicinity has been subject to significant air emissions from industries in British Columbia, as described in the Part 1 sediment report for this project (Johnson et al., 2011).

Potential pollutant source risks and geographic location distribution were defined as important lake selection factors; size was not. Larger lakes tend to have longer food chains, which may result in some species attaining higher levels of bioaccumulative chemicals in their tissues. High mountain lakes are subject to enhanced atmospheric deposition of synthetic organic compounds due to colder temperatures and larger amounts of precipitation (Wania and Mackay, 1993; Gillian and Wania, 2005; Moran et al., 2007). High lakes also typically have a low diversity of fish species. High mountain lakes were thus avoided for this study.

The study sampled a diverse range of lake sizes and elevations to obtain a regional assessment of the chemical background. The lakes selected for study range in size from less than 10 to over 1,000 acres, with maximum depths of 12 to 330 feet. Elevations are between about 2,000 and 4,500 feet; most lakes were below 3,000 feet.

Table 3. Lakes and Rivers Sampled for the Northeast Washington Background Study during 2010-2011.
Coordinates represent approximate lake center or river reach sampled.

Waterbody	County	Sediment	Fish	Elevation (feet)	Surface Area (acres)	Max. Depth (feet)	Latitude	Longitude
Swan Lake	Ferry	2010	2010	3,641	52	95	48.512	118.839
Davis Lake	Ferry	2010	- -	4,550	17	45	48.739	118.231
Ellen Lake	Ferry	2010	2010	2,300	78	34	48.501	118.256
South Twin Lake	Ferry	2010	2010	2,572	973	57	48.264	118.387
Summit Lake	Stevens	2010	- -	2,600	7	35	48.959	118.127
Pierre Lake	Stevens	2010	2010	2,012	106	75	48.905	118.139
Cedar Lake	Stevens	2010	2010	2,135	52	28	48.943	117.594
Pepoon Lake	Stevens	2010	2011	2,450	11	32	48.901	117.893
Williams Lake	Stevens	2010	- -	1,980	38	47	48.755	117.968
Bayley Lake	Stevens	2010	2010	2,400	17	12	48.420	117.664
Jumpoff Joe Lake	Stevens	- -	2011	2,030	105	25	48.136	117.691
Sullivan Lake	Pend Oreille	2010	2010	1,380	1,290	330	48.816	117.292
Leo Lake	Pend Oreille	2010	2010	2,588	39	37	48.648	117.495
Browns Lake	Pend Oreille	2010	2010	3,450	88	23	48.439	117.191
Bead Lake	Pend Oreille	2010	2010/2011	2,850	720	170	48.299	117.116
Upper Priest Lake	Bonner (ID	2010	2010	2,441	1,338	100	48.786	116.889
St. Joe River	Clearwater (ID)	2010	2010	3,198	na	na	47.202	115.516
Colville River	Stevens	- -	2011	1,660	na	na	48.175	117.730
Pend Oreille River	Pend Oreille	- -	2011	2,127	na	na	48.776	117.402

na: not applicable

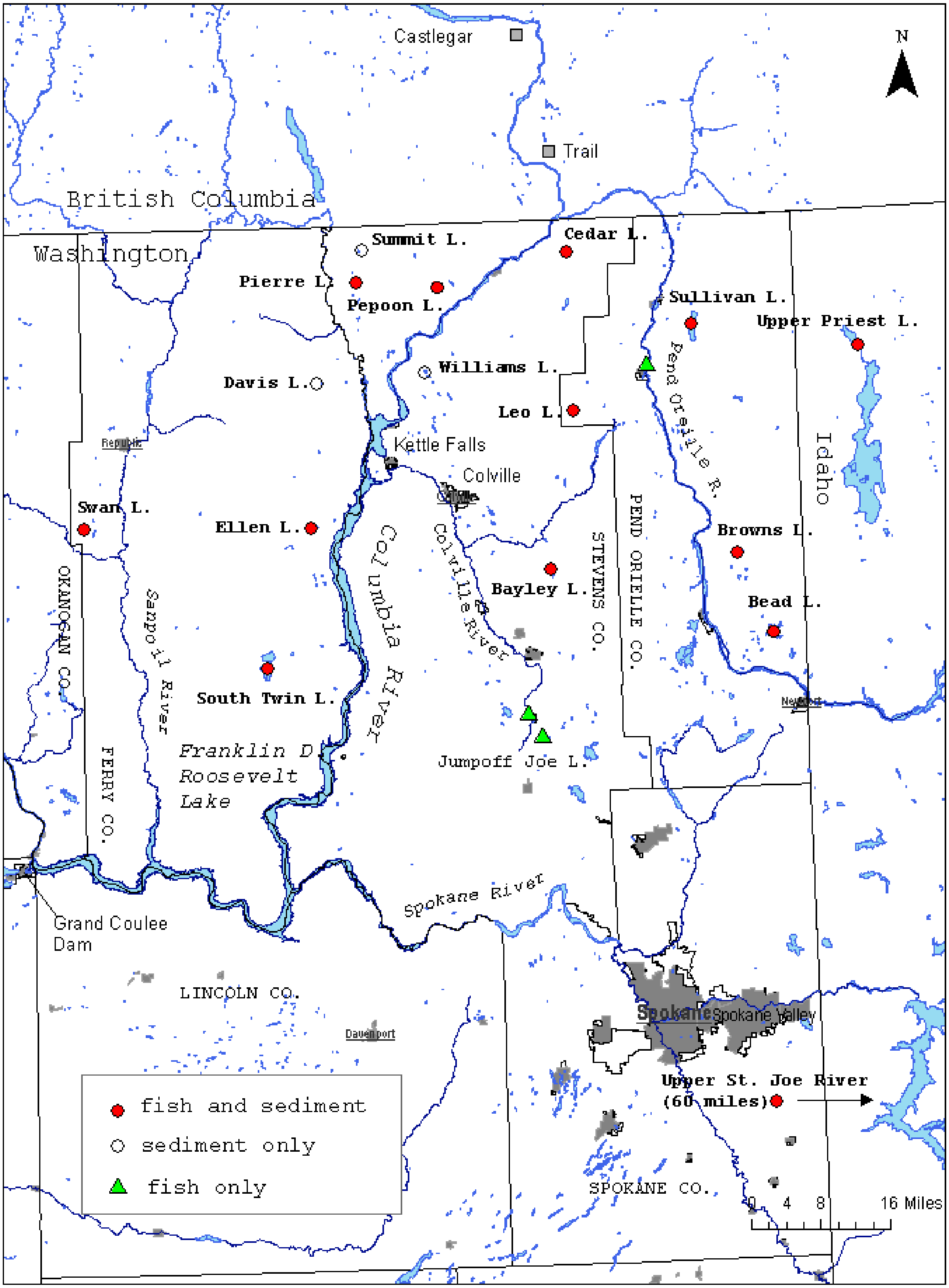

Figure 1. Waterbodies Sampled for the Northeast Washington Background Study during 2010-2011.

Appropriate background lakes could not be readily identified in the southern parts of Ferry and Stevens Counties or in northern Spokane County, which are more highly developed. Northwest Ferry County is lacking in lakes meeting the selection criteria.

Fish Samples

An attempt was made to collect both a predator and bottom-feeding species from each waterbody, with a focus, in part, on popular food fish. This is EPA's recommended approach for initial screening of contaminant levels in lakes and rivers (EPA, 2000). Use of fish samples from two distinct ecological groups as target species reflects a range of habits, feeding strategies, and physiological factors that can result in differences in bioaccumulation of contaminants. Predators, for example, often have higher levels of chemicals that biomagnify. Bottom-feeders may be elevated in chemicals they come in contact with through the sediments.

Either fillets or whole body samples were analyzed. Fillet data on food fish such as trout, bass, and perch were desired for comparative assessments associated with human health concerns. Whole fish data are useful for ecological risk assessment. Whole largescale suckers or related species are frequently used to monitor toxic chemicals in lakes, rivers, and streams and were the bottom-feeder targeted in the present study.

Each sample consisted of a composite of pooled tissues from several fish, four individuals on average. Composite samples provide a more cost-efficient estimate of mean chemical concentrations than single fish samples.

Planted fish have been shown to accumulate PCBs and other target chemicals during hatchery rearing (e.g., Serdar et al., 2006). Because the chemical residues may not be entirely representative of their surrounding environment, planted fish were only analyzed as a last resort and then only if planted as small fish which had resided in that waterbody for at least one year.

Large fish often have higher levels of chemical contaminants than small fish. Larger and older fish tend to consume larger, more contaminated prey, to eat at higher trophic levels, and have higher lipid content. It was beyond the scope and budget of this study to assess the effect of fish size on chemical residues, except for a few size class samples analyzed for mercury.

The fish obtained for samples were either legal size or, for species with no size limits, large enough to reasonably be retained for consumption. Very large and very small fish were avoided.

The budget for this project assumed two fish fillet samples and one whole fish sample would be analyzed for each waterbody. This sample size is comparable to other fish tissue surveys that have assessed levels of chemical contaminants across a large number of waterbodies (Lowe et al., 1985; Schmitt and Brumbaugh, 1990; EPA, 1992, 2009; Seiders and Deligeannis, 2009).

Timing of Fish Collections

EPA (2000) recommends late summer to fall as the most desirable sampling period for surveying chemical contaminants in fish tissue. Lipid (fat) content is generally highest at this time and water levels are lower, making fish easier to collect. Most surveys of chemical contaminants in Pacific Northwest freshwater fish are conducted in late summer or fall.

Methylmercury and the organic compounds being analyzed are lipophilic, although many fish tissue studies have failed to demonstrate a correlation between bioaccumulative chemicals and lipid content (Herbert and Keenleyside, 1995; Stow et al., 1997). During late summer and fall, spring spawners are rebuilding their lipid reserves and winter spawners are approaching their highest lipid levels. In terms of an overall species average, late summer-fall probably represents a period of generally elevated lipid levels in fish populations.

The scientific literature does not provide clear and consistent conclusions about seasonal cycles of the chemical residues in fish tissues. Several researchers have recommended that fish be sampled for mercury during the summer or fall when uptake is most rapid and methylmercury production greatest (e.g., Cope et al., 1990; Slotton et al., 1995). Others have found the highest mercury levels in the spring (Ward and Neumann, 1999). Seasonal differences for metals and organic compounds in fish can often be attributed to an age/size effect.

Most of the fish samples for the northeast Washington background study were collected in August and October (2010). The supplemental fish collection in 2011 was conducted in May due to fiscal year constraints on the budget. The recreational fishing season in most eastside lakes and rivers is approximately April - October.

Analytical Methods and Detection Limits

Low-level methods were used to minimize the number of non-detects in the data. Metals were analyzed by Ecology's Manchester Laboratory using inductively-coupled plasma/mass spectrometry (ICP/MS) or cold vapor atomic absorbance techniques (CVAA, mercury only). Reporting limits for fish tissue were in the range of 20 ug/Kg for mercury and 0.l - 0.2 mg/Kg for other metals, except 5 mg/Kg for zinc (parts per billion or parts per million, respectively). Two whole fish samples were subcontracted to Brooks Rand, Seattle, WA in an effort to better quantitate low lead concentrations; the reporting limit here was 0.03 mg/Kg.

Organic compounds were analyzed by Pacific Rim Laboratory in Surrey, BC using high resolution gas chromatography/mass spectrometry (HR-GC/MS). Reporting limits in fish tissue were as low as 4 ng/Kg (parts per trillion) for PCBs, 0.04 ng/Kg for PCDDs/PCDFs, and 2 ng/Kg for PBDEs, depending on the congener in question. These are the lowest limits currently available through laboratories accredited by Ecology for these methods.

Methods

Fish Collection

Fish sampling followed the Environmental Assessment Program SOP (Sandvik, 2006a). Collection methods included electroshocking, gill net, and hook and line. Fish selected for analysis were killed by a blow to the head. Each fish was given a unique identifying number and its length and weight recorded. The fish were individually wrapped in aluminum foil, put in plastic bags, and placed on ice for transport to Ecology headquarters, where the samples were frozen pending preparation of the tissue samples.

Tissue Preparation

Tissue samples were prepared follow the Environmental Assessment Program SOP (Sandvik, 2006b). Techniques to minimize potential for contamination were used. People preparing the samples wore non-talc nitrile gloves and worked on heavy duty aluminum foil or a polyethylene cutting board. The gloves and foil were changed between samples, and the cutting board was cleaned between samples as described below.

The fish were thawed to remove the foil wrapper and rinsed with tap water, then deionized water, to remove any adhering debris. The entire fillet from one or both sides of each fish was removed with stainless steel knives and homogenized in a Kitchen-Aid blender. The fillets were scaled and analyzed skin-on. Whole fish were homogenized in a Hobart blender. The sex of each fish was recorded.

An average of four individual fish was used for each composite sample (range of two to ten). To the extent possible, the length of the smallest fish in a composite was no less than 75% of the length of the largest fish (EPA, 2000). The composites were prepared using equal weights from each fish. The pooled tissues were homogenized to uniform color and consistency, using three passes through the blender. The homogenates were placed in glass jars with Teflon lid liners, cleaned to EPA (1990) quality assurance/quality control specifications.

Cleaning of resecting instruments, cutting boards, and blender parts was done by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, de-ionized water, and pesticide-grade acetone. The items were then air dried on aluminum foil in a fume hood before use.

The fish tissue samples were refrozen for shipment with chain-of-custody record to the Ecology Manchester Laboratory. The samples were stored frozen at Manchester until analyzed (metals, and lipids) or shipped to Pacific Rim Laboratory (organic compounds). Excess tissue was retained for all samples where sufficient material was available and stored frozen at Ecology headquarters.

Sample containers and holding times for the project are listed in Table 4.

Table 4. Sample Containers, Preservation, and Holding Times.

Parameter	Container	Preservation	Holding Time
Metals	4 oz. glass w/ Teflon lid liner	Freeze	2 years (frozen); mercury 28 days
Organic Compounds	4 oz. glass w/ Teflon lid liner	Freeze	1 year (frozen)
Lipids	4 oz. glass w/ Teflon lid liner	Freeze	none established

Chemical Analysis

Table 5 shows the methods and laboratories used to analyze the fish tissue samples.

Table 5. Analytical Methods and Laboratories.

Analysis	Method	Reference	Laboratory
Antimony	ICP/MS	EPA 3050B / 200.8	Manchester
Arsenic	"	"	"
Cadmium	"	"	"
Copper	"	"	"
Lead	"	"	"
Zinc	"	"	"
Mercury	CVAA	EPA 245.5	"
Lead*	ICP/MS	EPA 1638	Brooks Rand
PCBs	HRGC/HRMS	EPA 1668A	Pacific Rim
PCDDs/PCDFs	"	EPA 1613B	Pacific Rim
PBDEs	"	EPA 1614	Pacific Rim
Lipids	Solvent extract	SOP #730009	Manchester

ICP/MS: Inductively coupled plasma - mass spectrometry
CVAA: Cold vapor atomic absorbance
HRGC/HRMS: High resolution gas chromatography/high resolution mass spectrometry
*Two low-level samples analyzed by this laboratory

Data Quality

Data Review and Verification

Ecology's Manchester Environmental Laboratory (MEL) reviewed and verified all the chemical data for this project.

For the metals and lipids results generated by MEL, final review was performed by the unit supervisor or an analyst experienced with the method. Quality assurance and quality control are described in MEL (2006, 2008).

MEL's quality assurance coordinator reviewed the analyses contracted to other laboratories. The organics review followed National Functional Guidelines for Superfund Organic Methods Data Review (EPA, 2005a).

MEL prepared written case narratives assessing the qualitative and quantitative precision and bias of these data. The reviews include a description of analytical methods and an assessment of holding times, calibration, internal standard recoveries, ion abundance ratios, method blanks, on-going precision and recovery, labeled compound recoveries, matrix spike recoveries, laboratory control samples, and laboratory duplicates, as appropriate. With few exceptions, the results met acceptance criteria for these analyses and the data are usable as qualified. The reviews and the complete data reports are available from the author on request.

Method Blanks

Laboratory method blanks were included with each sample batch analyzed for metals and organic compounds. No analytically significant levels of target analytes were detected in the method blanks for the metals.

Low levels of some target compounds were detected in blanks for the organics analyses. In cases where the concentration measured in a sample was at least five times greater than the blank, the blank result was considered insignificant relative to the native concentration in the sample and the data were used without further qualification (EPA, 2005a,b). Where the sample concentration was less than five times the blank, the result was flagged as not detected. Results between the estimated quantitation limit (EQL) and estimated detection limit (EDL) were raised to the level of the EQL and flagged as not detected.

Variability of the Data

The field variability inherent in chemical residues accumulated by fish was reduced by using composite samples.

Estimates of analytical precision were obtained by analyzing laboratory duplicates (one homogenized sample split into two subsamples). The results are summarized for selected target chemicals in terms of relative percent difference (RPD) in Tables 6, 7, and 8. RPD is the difference between duplicates expressed as a percent of the mean value.

Mercury analyses of fillet and whole fish duplicates agreed within 11% or better (Table 6). Duplicates for other metals analyzed only in whole fish agreed within 12% or better, except for antimony, lead, and arsenic in one sample (Table 7). Re-analysis suggested this whole fish sample was inhomogeneous with respect to these metals. The anomalous antimony result (0.60 mg/Kg) was discarded as an outlier, given that uniformly low antimony levels of <0.20 mg/Kg were measured in all other fish samples for this study.

Organic compounds were analyzed at the parts per trillion level where lower precision is typically achieved. Results agreed within a factor of approximately 2 or better in most cases (Table 8). Total PBDEs in one rainbow trout sample and TCDD TEQs in one kokanee sample had RPDs of 122% and 110%, respectively. The PBDE discrepancy was an artifact of applying the five times rule to concentrations that differed marginally between duplicates. The difference in TCDD TEQs was due to several penta- and hexa- PCDDs present in the region of the quantitation limit.

The average of duplicate results is used in the remainder of this report. In the few cases where one sample in a duplicate pair was non-detect, the detected result was used.

Table 6. Precision on Duplicate Fish Tissue Samples Analyzed for Mercury (ug/Kg, wet weight).

Species	Tissue	Sample No.	Subsample			RPD
			#1	#2		
Rainbow trout	Fillet	1102018-14/37	19	17	J	8%
Largemouth bass	Fillet	1102018-13/36	173	145		11%
Kokanee	Fillet	1106039-6	40	40		0%
Largemouth bass	Fillet	1106039-9	222	200		7%
Northern pike	Fillet	1106039-15	484	500		2%
Largescale sucker	Whole	1102018-16	87	90		2%
Largescale sucker	Whole	1106039-5	81	80		0.5%

RPD: Relative percent difference (range as percent of duplicate mean)
J: The analyte was positively identified. The associated result is an estimate

Table 7. Precision on Duplicate Fish Tissue Samples Analyzed for Other Metals (mg/Kg, wet weight).

Species	Tissue	Sample No.	Subsample	As		Cd		Cu
Largescale sucker	Whole	1102018-16	#1	0.12		0.10	U	1.4
			#2	0.18		0.10	U	1.3
			RPD=	45%		ND		6%
Largescale sucker	Whole	1106039-5	#1	0.098	U	0.098	U	1.3
			#2	0.101	U	0.101	U	1.1
			RPD=	ND		ND		12%
Species	Tissue	Sample No.	Subsample	Pb		Sb		Zn
Largescale sucker	Whole	1102018-16	#1	0.19		0.60		21
			#2	0.11		0.20	U	24
			RPD=	55%		>100%		12%
Largescale sucker	Whole	1106039-5	#1	0.172	U	0.20	U	17
			#2	0.171	U	0.20	U	15
			RPD=	ND		ND		8%

RPD: Relative percent difference (range as percent of duplicate mean)
U: The analyte was not detected at or above the reported result
ND: Not detected

Table 8. Precision on Duplicate Fish Tissue Samples Analyzed for Organic Compounds and Lipids (organics in ng/Kg; wet weight).

Species	Sample No.	Subsample	Total PCBs		PCB TEQs	Total PBDEs
Rainbow trout	1102018-14	#1	792		0.0038	112
	1102018-37	#2	660		0.0035	27
		RPD=	18%		6%	122%
Largemouth bass	1102018-13	#1	950		0.0033	528
	1102018-36	#2	1,259		0.0036	530
		RPD=	28%		8%	0.4%
Kokanee	1106039-6	#1	4,706		0.016	2,976
		#2	4,541		0.014	2,935
		RPD=	4%		11%	1%
Species	**Sample No.**	**Subsample**	**TCDD**		**TCDD TEQs**	**% Lipids**
Rainbow trout	1102018-14	#1	0.03	UJ	0.097	1.6
	1102018-37	#2	0.0535	UJ	0.134	1.4
		RPD=	ND		32%	15%
Largemouth bass	1102018-13	#1	0.1253	UJ	0.112	1.6
	1102018-36	#2	0.049	NJ	0.068	1.1
		RPD=	<88%		49%	39%
Kokanee	1106039-6	#1	0.091	UJ	0.165	8.8
		#2	0.030	UJ	0.048	NA
		RPD=	ND		110%	- -

RPD: Relative percent difference (range as percent of duplicate mean)
TEQ: Toxicity Equivalent
UJ: The analyte was not detected above the reported estimated quantitation limit
ND: not detected
NA: not analyzed

Results

Fish Samples Obtained

The fish samples analyzed for the northeast Washington background study are listed in Table 9. Table 10 summarizes the fish collection by species.

A total of 32 fillet and 5 whole fish composite samples were prepared, representing 13 lakes and 3 rivers. Fifteen different species were sampled. Eight of the 15 were salmonids (e.g., trout, kokanee, and whitefish) and seven were spiny-rayed species (e.g., bass, perch, and suckers). Rainbow trout, largemouth bass, and largescale suckers were most frequently encountered.

Many of the lakes in the study area have a low diversity of fish species due to a history of being managed primarily for the trout fishery. As a result, the goal of analyzing at least two species from each waterbody was sometimes not met. The number of species sampled ranged from as many as four in Sullivan Lake and the Pend Oreille River to as few as one species each in Swan, Pierre, Pepoon, Ellen, Cedar, Browns, and Bayley lakes. Due to staffing or logistical obstacles, fish were not obtained from Summit, Williams, or Davis lakes. These sites were sampled for sediment chemistry only (Johnson et al., 2011).

Fillets were analyzed from all species except largescale suckers which were analyzed whole. Mercury and organic compounds were analyzed in both types of samples. Metals analysis of whole fish was expanded beyond mercury to include arsenic, cadmium, copper, lead, antimony, and zinc, which primarily accumulate in tissues other than muscle. Organic compounds were not analyzed for the Colville River or Pend Oreille River fillet samples due to budget constraints.

Approximately 160 individual fish were ultimately analyzed for the project. The number of fish pooled to form each composite tissue sample averaged four, just under the target sample size of five. Lengths and weights of the fish used for samples are listed in Appendix B.

Table 9. Fish Samples Analyzed for the Northeast Washington Background Study.

Waterbody	Species	Date	Tissue Analyzed	Mercury	Organics	Metals (6)*
Swan Lake	Rainbow trout	11-Oct-10	Fillet	x	x	
Pierre Lake	Largemouth bass	"	Fillet	x	x	
Ellen Lake	Rainbow trout	"	Fillet	x	x	
South Twin Lake	Rainbow trout	21-Oct-10	Fillet	x	x	
South Twin Lake	Eastern brook trout	"	Fillet	x	x	
South Twin Lake	Largemouth bass	"	Fillet	x	x	
Cedar Lake	Rainbow trout	18-Oct-10	Fillet	x	x	
Pepoon Lake	Largemouth bass - sm	23-May-11	Fillet	x		
Pepoon Lake	Largemouth bass - lg	"	Fillet	x		
Pepoon Lake	Largemouth bass	"	Fillet		x	
Sullivan Lake	Kokanee	20-Oct-10	Fillet	x	x	
Sullivan Lake	Largescale sucker	"	Whole body	x	x	x
Sullivan Lake	Tiger trout	"	Fillet	x	x	
Sullivan Lake	Burbot	"	Fillet	x	x	
Leo Lake	Black crappie	19-Oct-10	Fillet	x	x	
Leo Lake	Rainbow trout	"	Fillet	x	x	
Leo Lake	Yellow perch	"	Fillet	x	x	
Browns Lake	Cutthroat	6-Oct-10	Fillet	x	x	
Bayley Lake	Rainbow trout	5-Oct-10	Fillet	x	x	
Jumpoff Joe Lake	Yellow perch	10-Ma-11	Fillet	x	x	
Jumpoff Joe Lake	Brown trout	"	Fillet	x	x	
Jumpoff Joe Lake	Largemouth bass	"	Fillet	x	x	
Bead Lake	Largescale sucker	7-Oct-10	Whole body	x	x	x
Bead Lake	Kokanee	11-May-11	Fillet	x	x	
Upper Priest Lake	Lake trout	1-Oct-10	Fillet	x	x	
Upper Priest Lake	Smallmouth bass	"	Fillet	x	x	
Upper Priest Lake	Largescale sucker	"	Whole body	x	x	x
Upper St. Joe River	Cutthroat	28-Aug-10	Fillet	x	x	
Upper St. Joe River	Mountain whitefish	"	Fillet	x	x	
Colville River	Rainbow trout	10-May-11	Fillet	x		
Colville River	Largescale sucker	"	Whole body	x	x	x
Pend Oreille River	Smallmouth bass	17-May-11	Fillet	x		
Pend Oreille River	Brown trout	"	Fillet	x		
Pend Oreille River	Largescale sucker	"	Whole body	x	x	x
Pend Oreille River	Northern pike - sm	"	Fillet	x		
Pend Oreille River	Northern pike - med	"	Fillet	x		
Pend Oreille River	Northern pike - lg	"	Fillet	x		

*Arsenic, cadmium, copper, lead, antimony, and zinc

Table 10. Summary of Fish Species Sampled.

Species	Scientific Name	Number of Waterbodies	Individuals per Waterbody
Salmonids			
Rainbow trout	*Oncorhynchus mykiss*	7	2-8
Kokanee	*Oncorhynchus nerka*	2	5
Cutthroat	*Oncorhynchus clarki*	2	5
Brown trout	*Salmo trutta*	2	5
Eastern brook trout	*Salvelinus fontinalis*	1	5
Lake trout	*Salvelinus namaycush*	1	5
Mountain whitefish	*Prosopium williamsoni*	1	4
Tiger trout	*Salmo trutta x Salvelinus fontinalis*	1	5
Spiny Rays			
Largescale sucker	*Catostomus macrocheilus*	5	2-5
Largemouth bass	*Micropterus salmoides*	4	2-7
Black crappie	*Pomoxis nigromaculatus*	2	6
Yellow perch	*Perca flavescens*	2	6-10
Smallmouth bass	*Micropterus dolomieu*	1	4-5
Burbot	*Lota lota*	1	3
Northern pike	*Esox lucius*	1	12*

*Analyzed in three separate size classes

Planted fish were collected from some lakes in an effort to obtain the desired sample size. As described previously, hatchery-reared fish are known to accumulate chemical contaminants from feed or other sources. To minimize this effect, planted fish were collected only when they had resided in the lake for over one year. Records obtained from WDFW and Colville tribal biologists show the residence time of the fish sampled for this study ranged from greater than one year to more than two years (Table 11).

Table 11. Lake Residence Times for Planted Species Analyzed.

Waterbody	Species	Plant Date	Length (mm)	Collection Date	Length (mm)	Residence Time
Swan Lake	Rainbow trout	June 2009	~75	11-Oct-10	252-309	1-2 years
Ellen Lake	Rainbow trout	May/June 2009	~75	11-Oct-10	210-262	>1 year
S. Twin Lake	Rainbow trout	April 2010	unknown	24-May-11	286-340	>1 year
S. Twin Lake	Eastern brook trout	October 2007,08	~150	24-May-11	350-405	2-3 years
Cedar Lake	Rainbow trout	May/June 2008,09	~75	18-Oct-10	300-349	1.5-2.5 years
Sullivan Lake	Tiger trout	April 2005-8	200-230	20-Oct-10	317-423	≥2.5 years
Browns Lake	Cutthroat trout	Oct. 2007,08	~50	6-Oct-10	279-315	1.5-2.5 years
Bayley Lake	Rainbow trout	May/June 2008,09	unknown	5-Oct-10	219-312	>1-2 years
Jumpoff Joe Lake	Brown trout	April/May 2008,09	230-260	10-May-11	363-428	>1 year

Results on Fillets

Fillets from popular sport fish species were analyzed to provide data in support of contaminant studies and cleanup activities where human health is a concern for fish consumers. The results are presented below. For each chemical or chemical group there is: (1) a table of results for individual samples, (2) a statistical summary and cumulative frequency plot[3] of the data, and (3) a figure ranking the waterbody samples by concentration. Plots and data analysis use the reporting limit for non-detected values. Appendix C has a summary table showing results for all chemicals or chemical groups analyzed in the fillets.

Here and in similar tables that follow, the lakes are ordered by drainage basin, starting with the Sanpoil River (Swan Lake) in the west and ending with Pend Oreille River (Upper Priest Lake, Idaho) to the east. Within each basin, the lakes are listed approximately north to south. Rivers are listed separately in the lower part of the tables, also ordered west to east.

Lipid Content

Mercury (as methylmercury) and the organic compounds analyzed in this study are lipophilic, tending to accumulate in fatty deposits of fish and other organisms. Lipid content of the tissue samples was therefore determined to assess the extent to which this variable might explain differences observed in chemical concentrations within or between waterbodies.

The results for percent lipids in the fillets are shown in Table 12; summary statistics are provided in Table 13. Figure 2 has a cumulative frequency plot of the data.

[3] The rank of a value in a data set plotted as a percentage of the data set.

Table 12. Summary of Results for Lipids in Fish Fillet Samples Analyzed for the Northeast Washington Background Study.

Waterbody	Species	% Lipids
Swan Lake	Rainbow trout	0.80
Cedar Lake	Rainbow trout	1.5
Pepoon Lake	Largemouth bass - sm	0.30
Pepoon Lake	Largemouth bass - lg	0.59
Pierre Lake	Largemouth bass	0.90
Ellen Lake	Rainbow trout	0.40
South Twin Lake	Rainbow trout	0.39
South Twin Lake	Eastern brook trout	0.69
South Twin Lake	Largemouth bass	1.3
Sullivan Lake	Kokanee	1.4
Sullivan Lake	Tiger trout	3.4
Sullivan Lake	Burbot	0.29
Leo Lake	Black crappie	0.20
Leo Lake	Rainbow trout	0.39
Leo Lake	Yellow perch	0.10
Browns Lake	Cutthroat	2.4
Bayley Lake	Rainbow trout	2.3
Bead Lake	Kokanee	8.8
Jumpoff Joe Lake	Yellow perch	0.10
Jumpoff Joe Lake	Brown trout	2.5
Jumpoff Joe Lake	Largemouth bass	0.74
Upper Priest Lake	Lake trout	6.5
Upper Priest Lake	Smallmouth bass	0.89
Colville River	Rainbow trout	1.6
Pend Oreille River	Smallmouth bass	0.30
Pend Oreille River	Brown trout	3.9
Pend Oreille River	Northern pike - sm	0.29
Pend Oreille River	Northern pike - med	0.19
Pend Oreille River	Northern pike - lg	3.2
Upper St. Joe River	Cutthroat	1.7
Upper St. Joe River	Mountain whitefish	4.6

Table 13. Summary Statistics for Lipids in Fillets (%).

	All Species	Salmonids	Spiny Rays
N=	31	17	14
Median*	0.90	1.7	0.30
Mean*	1.7	2.5	0.50
Minimum	0.10	0.39	0.10
Maximum	8.8	8.8	3.2
90th percentile*	4.1	5.3	0.90

*Size class samples averaged for these statistics

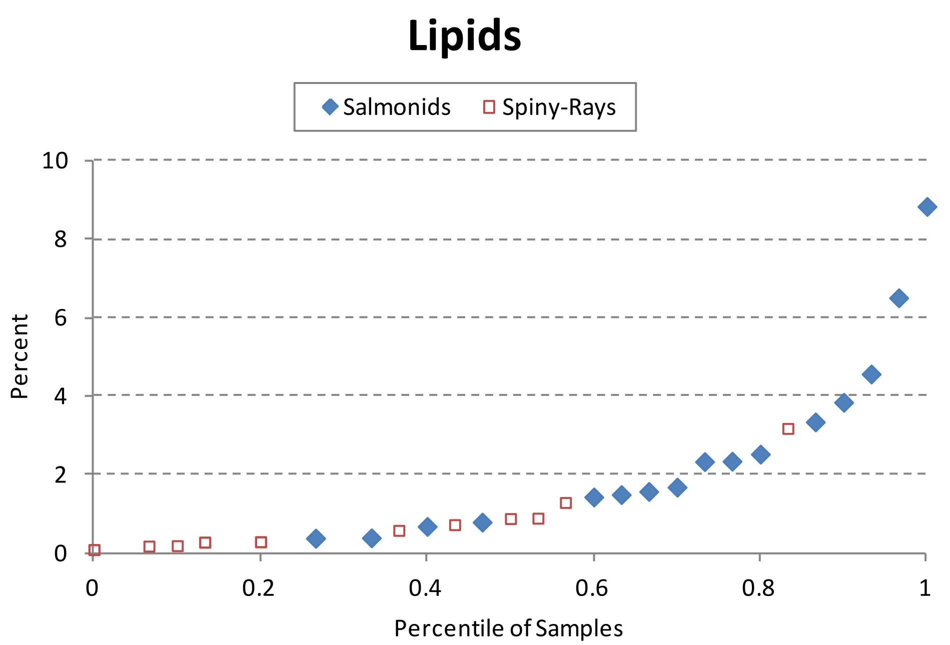

Figure 2. Cumulative Frequency Plot for Percent Lipids in Fillets.

Percent lipids ranged from 0.1% in yellow perch to 8.8% in kokanee (a land-locked sockeye salmon). The overall median and 90th percentile[4] were 0.9% and 4.1%, respectively. Trout and other salmonids had significantly higher lipid levels than spiny rayed species such as bass and perch (Mann-Whitney test, $p<0.05$[5]). Differences between these two groups are further illustrated in Figure 3.

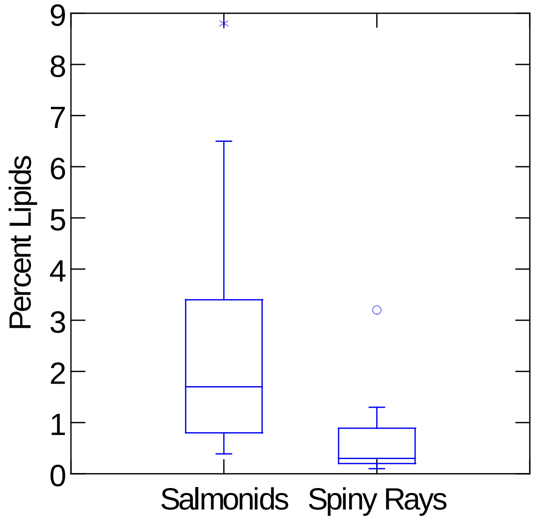

Figure 3. Lipid Content of Fillets: Salmonids vs. Spiny Rayed Species[6].

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[4] Percentiles describe a location in the distribution of data. For the 90th percentile, 10 percent of the data lie above the value and 90 percent lie below.

[5] p represents the probability of error in accepting a result of a statistical test as being valid and representative of the population being sampled. For example, at p= 0.05 (i.e., 1/20) there is a 5% probability that the difference between a variable measured in a set of samples is due to chance (a fluke). This report uses the 5% level as the cutoff for ascribing significant differences between results, i.e., 95% confidence.

[6] In box and whisker plots of this type, 50% of the values fall within the box, the horizontal line representing the median. The whiskers show the range of values that are within a factor of 1.5 of the spread of the box. Asterisks and empty circles are outside and far outside values, respectively.

Individual samples are ranked by percent lipids in Figure 4. Twelve of the 13 fillet samples with the highest lipids were from salmonids. Species with the greatest lipid content were kokanee, lake trout, mountain whitefish, brown trout, tiger trout, and the large size class of northern pike.

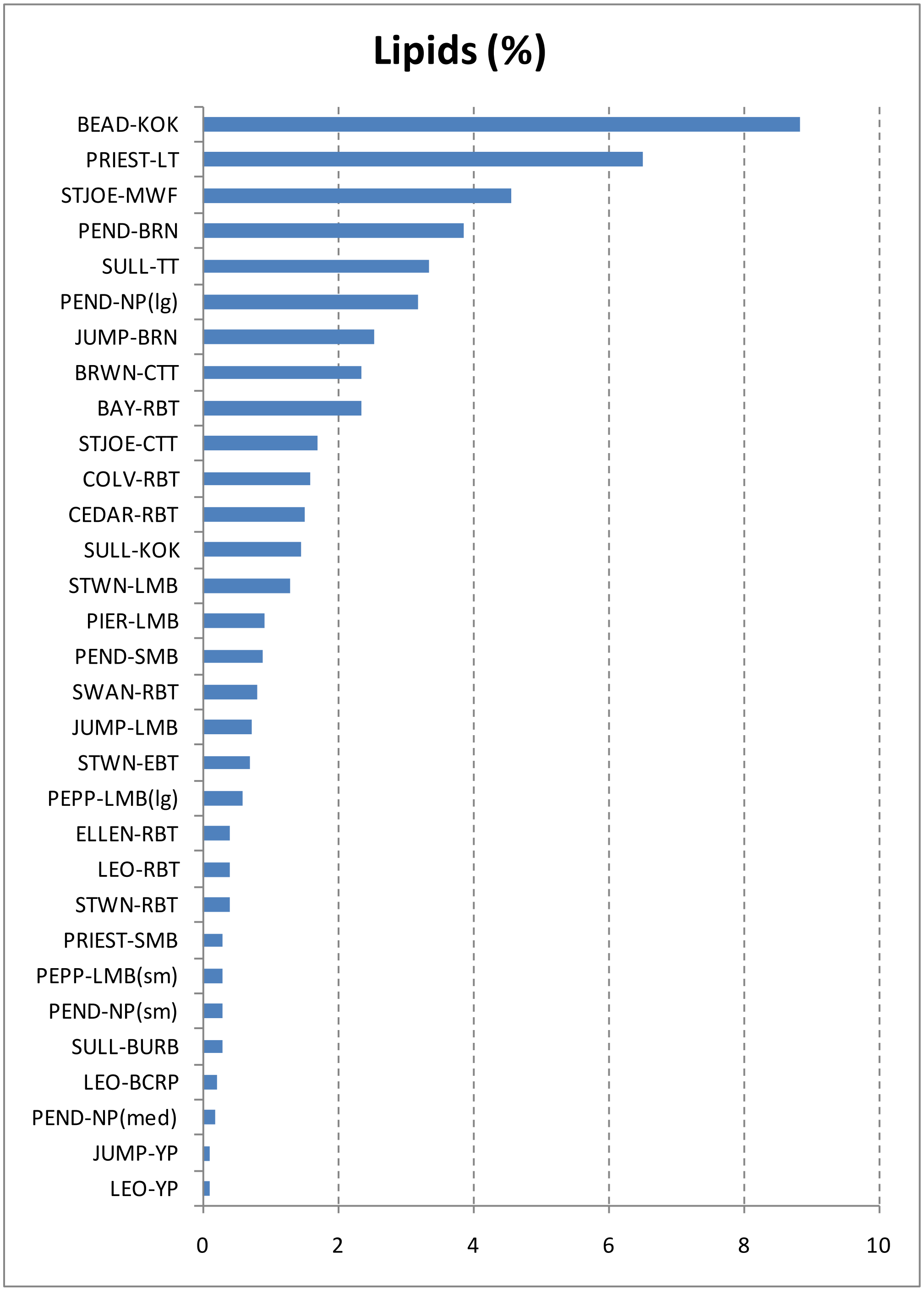


Figure 4. Fillet Samples Ranked by Lipid Content.

Mercury

Mercury concentrations measured in the fillets are shown in Table 14. Table 15 has summary statistics and Figure 5 shows the cumulative frequency plot. Spiny-rayed species often feed at higher trophic levels than salmonids and tend to have higher mercury concentrations as a result. Meredith et al. (2010) describes this phenomenon as observed in Washington state freshwater fishes. Separate statistics are therefore provided for salmonids and spiny-rays. Note that the several size class samples (Pierre Lake and Pend Oreille River) were averaged for the summary statistics in Table 15.

Mercury was analyzed in 31 fillet samples from 16 waterbodies. The median and 90th percentile concentrations were 76 ug/Kg and 237 ug/Kg, respectively (parts per billion). Medians differed by a factor of four between salmonids and spiny-rays (47 vs. 186 ug/Kg). Here again, the differences were significant (Mann-Whitney test, $p<0.05$; size class samples averaged.) The mercury data are plotted separately for salmonids and spiny-rays in Figure 6.

Figure 7 ranks the waterbody samples by mercury concentrations. The five highest concentrations (217 - 492 ug/Kg) were measured in fillets from northern pike, smallmouth bass, and burbot (a freshwater cod) from the Pend Oreille River, Upper Priest Lake, and Sullivan Lake. The lowest levels ($\leq$ 32 ug/Kg) were in trout and kokanee from Cedar, Jumpoff Joe, South Twin, and Ellen lakes. Yellow perch from Jumpoff Joe Lake also had a low mercury concentration, possibly due to the relatively small fish analyzed (172 mm average length.)

Essentially all the mercury present in fish tissue is methylmercury (EPA, 2001). Although this form of mercury is lipid soluble, the relationship between mercury and percent lipids in the fillet samples was weak ($R^2=0.32$)[7].

[7] R^2, the coefficient of determination, represents the proportion of common variation in two variables or strength of the relationship and can vary from 0 to 1.

Table 14. Summary of Results for Mercury in Fish Fillet Samples Analyzed for the Northeast Washington Background Study (ug/Kg, wet weight).

Waterbody	Species	Mercury
Swan Lake	Rainbow trout	82
Cedar Lake	Rainbow trout	18
Pepoon Lake	Largemouth bass -sm	57
Pepoon Lake	Largemouth bass -lg	55
Pierre Lake	Largemouth bass	108
Ellen Lake	Rainbow trout	32
South Twin Lake	Rainbow trout	31
South Twin Lake	Eastern brook trout	51
South Twin Lake	Largemouth bass	159
Sullivan Lake	Kokanee	46
Sullivan Lake	Tiger trout	99
Sullivan Lake	Burbot	245
Leo Lake	Black crappie	186
Leo Lake	Rainbow trout	47
Leo Lake	Yellow perch	94
Browns Lake	Cutthroat	70
Bayley Lake	Rainbow trout	214
Bead Lake	Kokanee	40
Jumpoff Joe Lake	Yellow perch	29
Jumpoff Joe Lake	Brown trout	24 U
Jumpoff Joe Lake	Largemouth bass	211
Upper Priest Lake	Lake trout	211
Upper Priest Lake	Smallmouth bass	282
Colville River	Rainbow trout	33
Pend Oreille River	Smallmouth bass	256
Pend Oreille River	Brown trout	94
Pend Oreille River	Northern pike - sm	177
Pend Oreille River	Northern pike - med	217
Pend Oreille River	Northern pike - lg	492
Upper St. Joe River	Cutthroat	37
Upper St. Joe River	Mountain whitefish	50

U: The analyte was not detected above the reported quantitation limit

Table 15. Summary Statistics for Mercury in Fillets (ug/Kg, wet weight).

	All Species	Salmonids	Spiny Rays
N=	31	17	14
Median*	76	47	186
Mean*	108	69	169
Minimum	18	18	29
Maximum	492	214	492
90th percentile*	237	144	256

*Size class samples averaged for these statistics

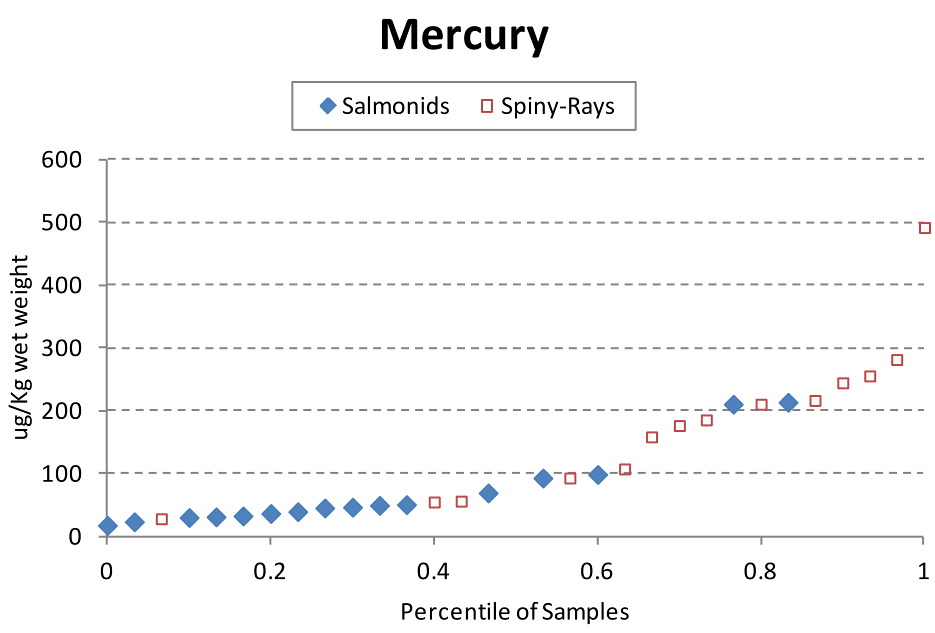


Figure 5. Cumulative Frequency Plot for Mercury in Fillets.

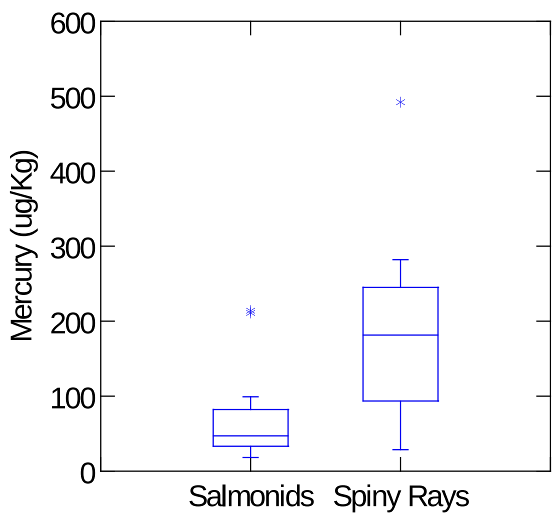


Figure 6. Mercury Concentrations in Fillets: Salmonids vs. Spiny Rayed Species (wet weight).

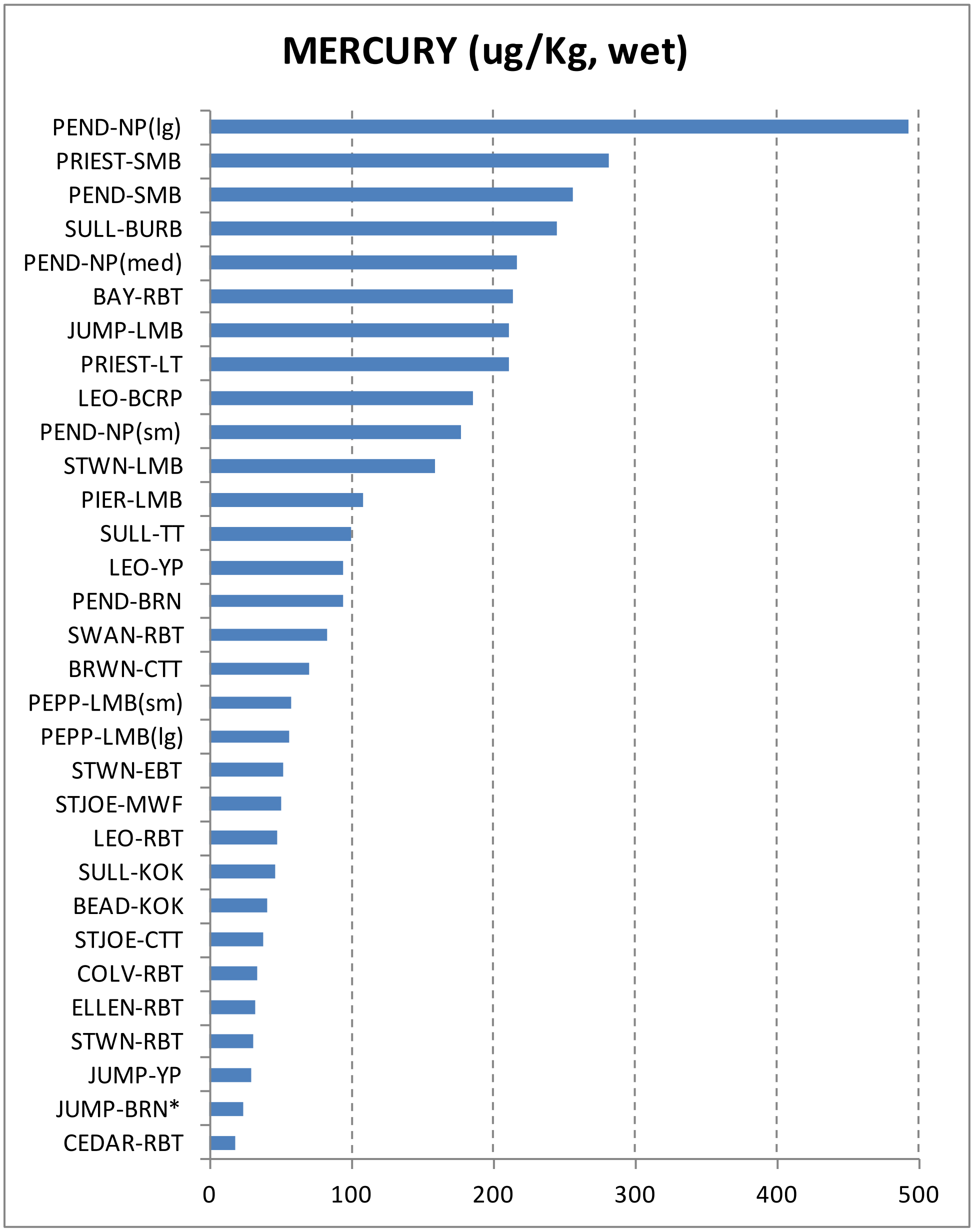


Figure 7. Fish Fillet Samples Ranked by Mercury Concentration.
**Not detected; plotted at the reporting limit (24 ug/Kg).*

Mercury levels in fish are strongly correlated with size and age. Although not a focus of the present study, mercury was analyzed in size class samples from two waterbodies: Pend Oreille River northern pike and Pepoon Lake largemouth bass. Large northern pike (930-975 mm total length) had 2-3 times higher mercury concentrations than medium and small northern pike (452-681 mm) (Table 14). A size class difference was not found for mercury in the largemouth bass, although this is routinely observed in bass throughout Washington (Meredith et al., 2010). The two bass samples averaged 160 mm and 237 mm total length.

PCBs

Twenty-four fillet samples from 13 lakes and one river were analyzed for 209 polychlorinated biphenyls (PCBs), 7 polychlorinated dibenzo-p-dioxins (PCDDs), 10 polychlorinated dibenzofurans (PCDFs), and 36 polybrominated diphenylethers (PBDEs). The PCB results are shown in Table 16, with a statistical summary in Table 17. In these tables and associated figures, total PCBs is the summed concentrations of the individual PCB compounds (congeners) detected. Non-detects were assigned a value of zero.

Table 16. Summary of Results for Total PCBs in Fish Fillet Samples Analyzed for the Northeast Washington Background Study (ng/Kg, wet weight).

Waterbody	Species	Total PCBs
Swan Lake	Rainbow trout	718
Cedar Lake	Rainbow trout	726
Pepoon L	Largemouth bass	81
Pierre Lake	Largemouth bass	763
Ellen Lake	Rainbow trout	760
South Twin Lake	Rainbow trout	417
South Twin Lake	Eastern brook trout	887
South Twin Lake	Largemouth bass	1,105
Sullivan Lake	Kokanee	4,295
Sullivan Lake	Tiger trout	4,592
Sullivan Lake	Burbot	1,765
Leo Lake	Black crappie	775
Leo Lake	Rainbow trout	1,791
Leo Lake	Yellow perch	1,494
Browns Lake	Cutthroat	1,239
Bayley Lake	Rainbow trout	470
Bead Lake	Kokanee	4,634
Jumpoff Joe Lake	Yellow perch	73
Jumpoff Joe Lake	Brown trout	1,903
Jumpoff Joe Lake	Largemouth bass	1,689
Upper Priest Lake	Lake trout	15,311
Upper Priest Lake	Smallmouth bass	1,586
Upper St. Joe River	Cutthroat	252
Upper St. Joe River	Mountain whitefish	723

Table 17. Summary Statistics for Total PCBs in Fillets (ng/Kg, wet weight).

	All Species	Lake Trout Excluded
N=	24	23
Detection Frequency	100%	100%
Median	996	887
Mean	2,005	1,423
Minimum	73	73
Maximum	15,311	4,634
90th percentile	4,503	3,817

PCBs were detected in all fish samples. Median and 90th percentiles for total PCBs in the fillets were 996 ng/Kg and 4,503 ng/Kg, respectively (parts per trillion).

One lake trout sample was obtained for this study from Upper Priest Lake and was particularly high in total PCBs (15,311 ng/Kg), as well as other organic compounds analyzed. Lake trout are long-lived, relatively fatty, and predatory - all characteristics which favor bioaccumulation. This is an introduced species with a restricted occurrence in northeast Washington (Wydoski and Whitney, 2003). In view of the skew caused in the data and because lake trout are poorly represented in the local fish assemblage, summary statistics were also calculated with the lake trout result excluded, both here and elsewhere in this report. For the reduced sample set, the median and 90th percentile for total PCBs are 887 ng/Kg and 3,817 ng/Kg. The cumulative frequency plot in Figure 8 excludes the lake trout sample.

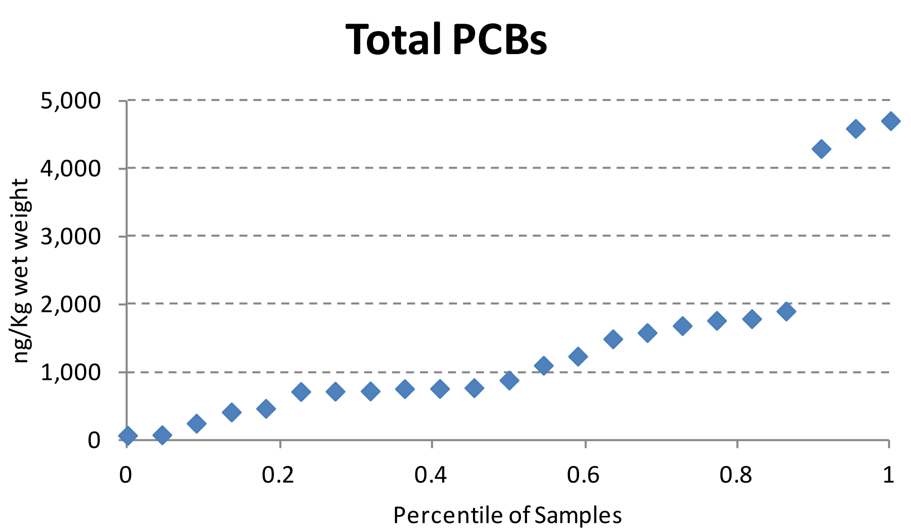


Figure 8. Cumulative Frequency Plot for Total PCBs in Fillets (lake trout sample excluded).

The fillet samples are ranked by total PCB concentrations in Figure 9. The six highest results were for salmonids. Four samples stand out as having elevated concentrations (15,311 – 4,295 ng/Kg) relative to other species and locations: Upper Priest lake trout, Bead Lake kokanee, Sullivan Lake tiger trout, and Sullivan Lake kokanee. Even with the lake trout outlier excluded, a relatively large range in PCB concentrations was observed across the study area, with a minimum total PCB concentration of 73 ng/Kg for yellow perch from Jumpoff Joe Lake and a maximum of 4,634 ng/Kg for kokanee from Bead Lake.

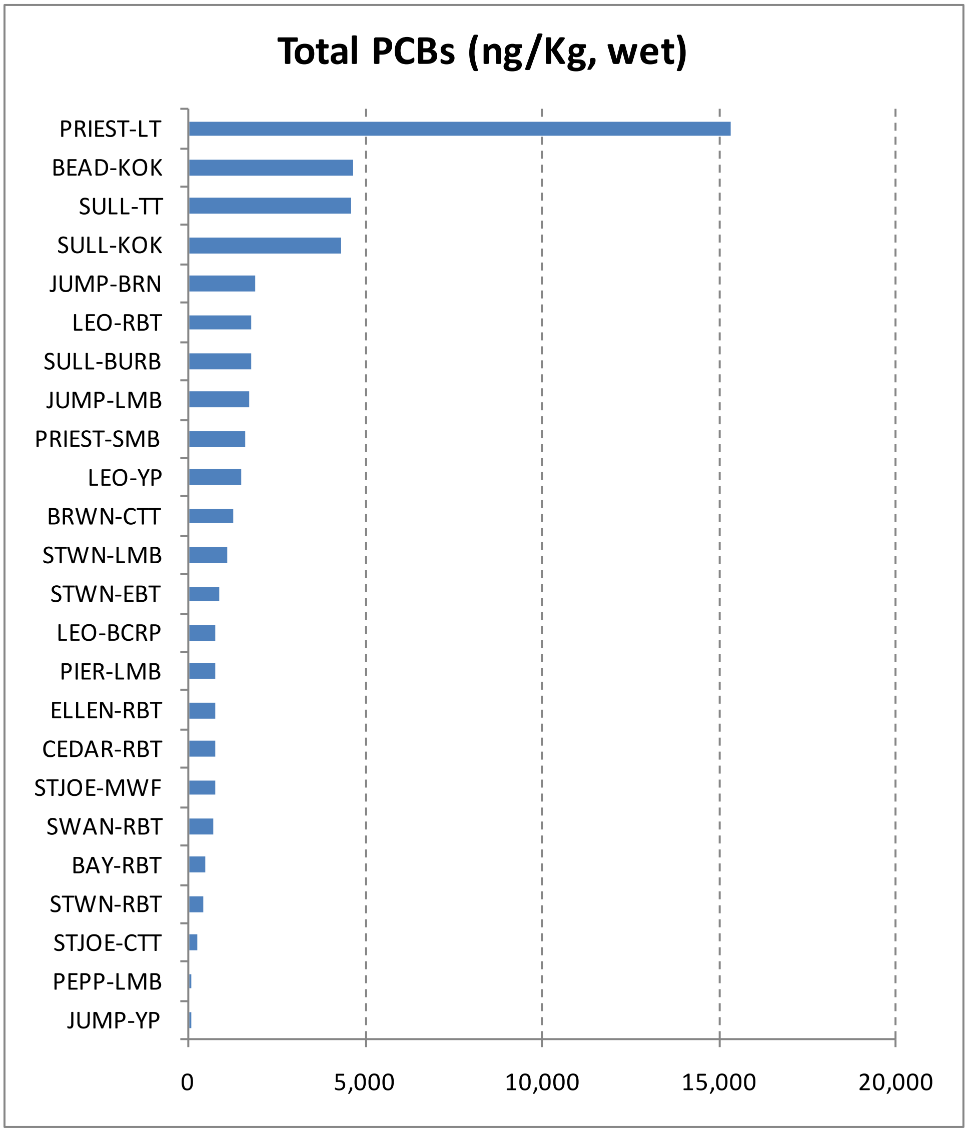


Figure 9. Fish Fillet Samples Ranked by Total PCB Concentration.

The PCBs congeners that contributed most to the total were PCB-118, -138/160, -151, -153, -170, and -180, each comprising as much as 10-22%, depending on the sample in question. These penta-, hexa-, and heptachlorobiphenyls (5-7 chlorines) and other of the highly chlorinated PCBs are more persistent in the environment and tend to be retained in the tissues of fish and other organisms compared to less chlorinated congeners (McFarland and Clarke, 1989).

Fish tissue data on PCBs and similar fat-soluble organic compounds is often adjusted for variation in lipid content as a means of evaluating spatial or temporal patterns. Patterns seen in wet weight-based data may or may not hold once the data are normalized. As Herbert and Keenleyside (1995) point out, lipid normalizing is only appropriate when there is a significant relationship between the two variables. In the case of the present data set, the correlation between total PCBs and percent lipids was weak (R^2=0.26), improving only slightly when salmonids are considered separately (R^2=0.37).

PCB TEQs

TEQ is the Toxicity Equivalent of a mixture of polychlorinated dioxins and -furans or dioxin-like PCBs relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the most toxic of the dioxins and furans. TEQs were calculated for the present study using the human and mammalian Toxic Equivalency Factors (TEFs) which have been established for the seventeen 2,3,7,8-substituted dioxins and furans, and the twelve dioxin-like PCBs[8] (Van den Berg et al., 2006; Appendix D in the present report). The TEQ of a sample equals the sum of each congener concentration multiplied by its TEF. TCDD has a TEQ of 1.

Results for PCB TEQs in the fish fillet samples are shown in Table 18, Table 19, and Figure 10. Non-detects were set equal to zero.

The lake trout from Upper Priest Lake had a PCB TEQ of 1.4 ng/Kg, orders of magnitude higher than other fillet samples. The elevated TEQ was almost entirely due to the detection of PCB-126 at 12.6 ng/Kg. PCB-126 has a TEF of 0.1, compared to 0.03-0.0003 for other dioxin-like PCBs. With the lake trout sample excluded, the median and 90th percentile for PCB TEQs in the fillets are 0.004 ng/Kg and 0.011 ng/Kg, respectively). As can be seen in Figure 10, tiger trout from Sullivan Lake (a brown trout/eastern brook trout hybrid) had a high PCB TEQ relative to other samples, but this value exerts a minor effect on the 90th percentile (0.015 vs. 0.011 ng/Kg).

[8] PCB congeners with four or more lateral chlorines and with one or no substitution at the ortho (inner) position have dioxin-like properties.

Table 18. Summary of Results for PCB TEQs in Fish Fillet Samples Analyzed for the Northeast Washington Background Study (ng/Kg, wet weight).

Waterbody	Species	PCB TEQs
Swan Lake	Rainbow trout	0.0023
Cedar Lake	Rainbow trout	0.0037
Pepoon L	Largemouth bass	0.0004
Pierre Lake	Largemouth bass	0.0036
Ellen Lake	Rainbow trout	0.0027
South Twin Lake	Rainbow trout	0.0016
South Twin Lake	Eastern brook trout	0.0039
South Twin Lake	Largemouth bass	0.0035
Sullivan Lake	Kokanee	0.0064
Sullivan Lake	Tiger trout	0.11
Sullivan Lake	Burbot	0.0032
Leo Lake	Black crappie	0.0044
Leo Lake	Rainbow trout	0.0112
Leo Lake	Yellow perch	0.0089
Browns Lake	Cutthroat	0.0062
Bayley Lake	Rainbow trout	0.0020
Bead Lake	Kokanee	0.016
Jumpoff Joe Lake	Yellow perch	0.001
Jumpoff Joe Lake	Brown trout	0.006
Jumpoff Joe Lake	Largemouth bass	0.008
Upper Priest Lake	Lake trout	1.4
Upper Priest Lake	Smallmouth bass	0.0056
Upper St. Joe River	Cutthroat	0.0010
Upper St. Joe River	Mountain whitefish	0.0029

Table 19. Summary Statistics for PCB TEQs in Fillets (ng/Kg, wet weight).

	All Species	Lake Trout Excluded
N=	24	23
Median	0.004	0.004
Mean	0.069	0.0094
Minimum	0.0004	0.0004
Maximum	1.4	0.11
90th percentile	0.015	0.011

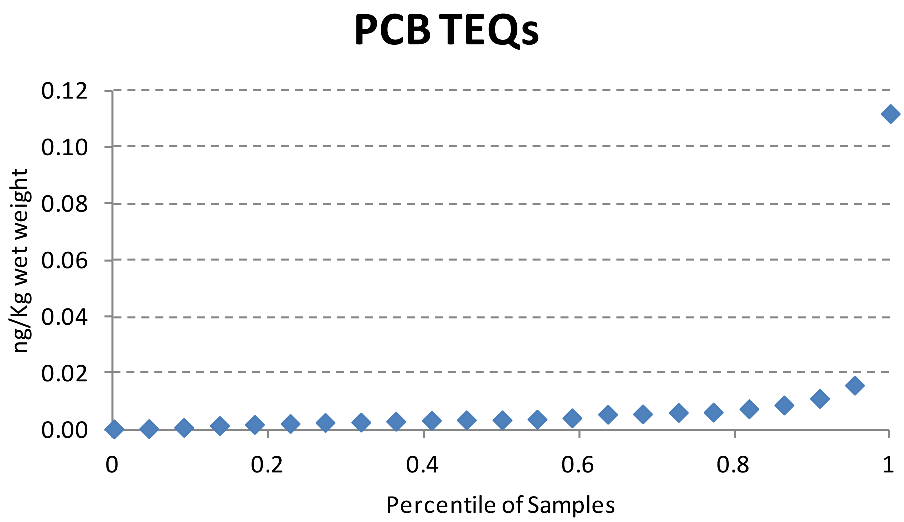


Figure 10. Cumulative Frequency Plot for PCB TEQs in Fillets (lake trout sample excluded).

The fillets are ranked by PCB TEQ in Figure 11. Not surprisingly, the three highest TEQs are the same samples highest in total PCBs: Upper Priest lake trout (1.4 ng/Kg), Sullivan Lake tiger trout (0.11 ng/Kg), and Bead Lake kokanee (0.016 ng/Kg). PCB TEQs comprised a relative narrow range of 0.11 to 0.004 ng/Kg in all other fillet samples.

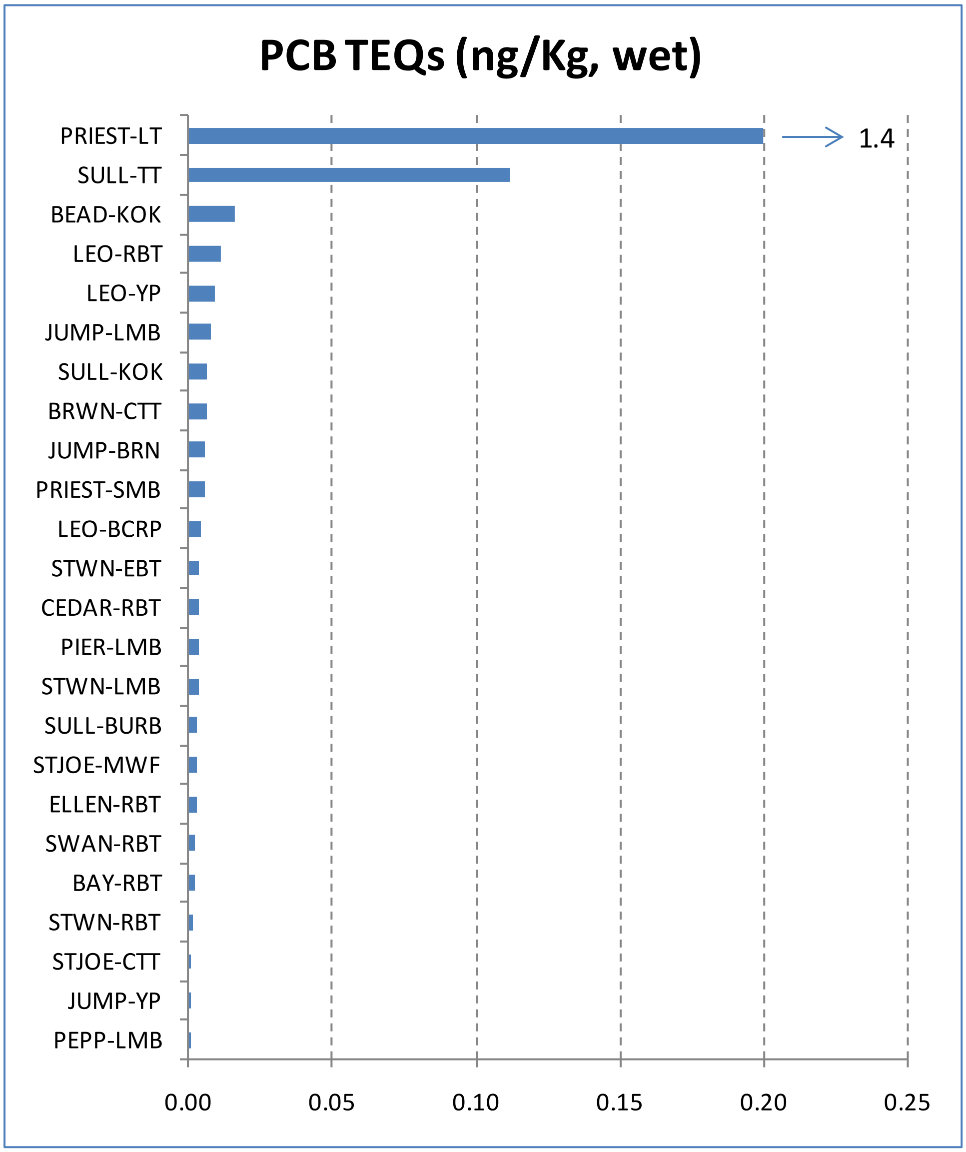


Figure 11. Fish Fillet Samples Ranked by PCB TEQ Concentrations.

TCDD

TCDD (dioxin) was only detected in four of the fillet samples (17% detection frequency): Upper Priest Lake lake trout, South Twin rainbow trout and largemouth bass, and Sullivan Lake burbot. Concentrations in these samples were estimated to be in the range of 0.030 – 0.10 ng/Kg. The quantitation limit for TCDD in other fillets was 0.03 – 0.05 ng/Kg. This finding is consistent with the sediment samples analyzed for this project, in which TCDD levels were generally low to non-detectable (Johnson et al., 2011).

Table 20. Summary of Results for TCDD in Fish Fillet Samples Analyzed for the Northeast Washington Background Study (ng/Kg, wet weight).

Waterbody	Species	TCDD	
Swan Lake	Rainbow trout	0.030	UJ
Cedar Lake	Rainbow trout	0.030	UJ
Pepoon L	Largemouth bass	0.039	UJ
Pierre Lake	Largemouth bass	0.030	UJ
Ellen Lake	Rainbow trout	0.030	UJ
South Twin Lake	Rainbow trout	**0.086**	**NJ**
South Twin Lake	Eastern brook trout	0.030	UJ
South Twin Lake	Largemouth bass	**0.049**	**NJ**
Sullivan Lake	Kokanee	0.030	UJ
Sullivan Lake	Tiger trout	0.030	UJ
Sullivan Lake	Burbot	**0.030**	**NJ**
Leo Lake	Black crappie	0.030	UJ
Leo Lake	Rainbow trout	0.030	UJ
Leo Lake	Yellow perch	0.040	UJ
Browns Lake	Cutthroat	0.044	UJ
Bayley Lake	Rainbow trout	0.032	UJ
Bead L	Kokanee	0.030	UJ
Jumpoff Joe L	Yellow perch	0.053	UJ
Jumpoff Joe L	Brown trout	0.043	UJ
Jumpoff Joe L	Largemouth bass	0.053	UJ
Upper Priest Lake	Lake trout	**0.10**	**NJ**
Upper Priest Lake	Smallmouth bass	0.030	UJ
Upper St. Joe River	Cutthroat	0.030	UJ
Upper St. Joe River	Mountain whitefish	0.030	UJ

Note: Detected values in bold font
UJ: The analyte was not detected above the reported estimated quantitation limit
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration

Table 21. Summary Statistics for TCDD in Fillets (ng/Kg, wet weight).

	All Species		Lake Trout Excluded	
N=	24		23	
Detection Frequency	17%		13%	
Median	0.030	UJ	0.030	UJ
Mean	0.040	UJ	0.037	UJ
Minimum	0.030	UJ	0.030	UJ
Maximum	0.10	NJ	0.086	NJ
90th percentile	0.053	UJ	0.052	UJ

UJ: The analyte was not detected above the reported estimated quantitation limit
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration

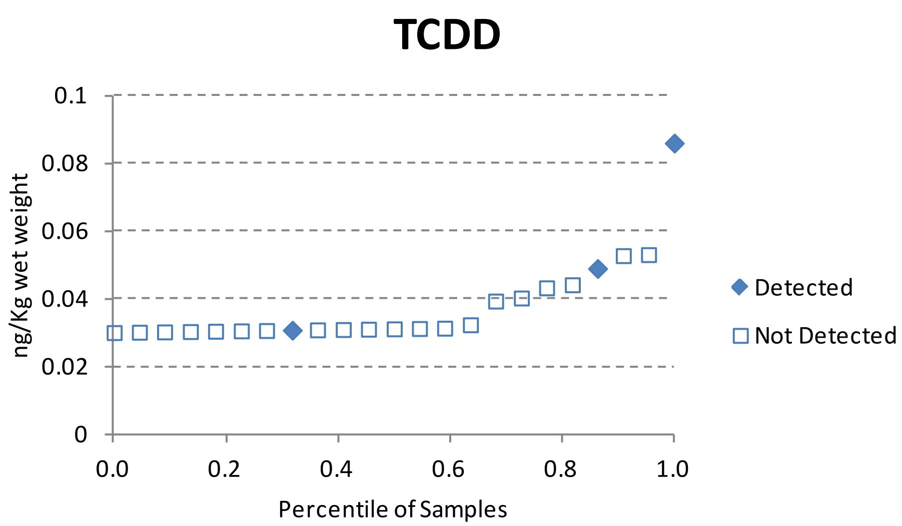


Figure 12. Cumulative Frequency Plot for TCDD in Fillets

Non-detects plotted at quantitation limit, lake trout sample excluded.

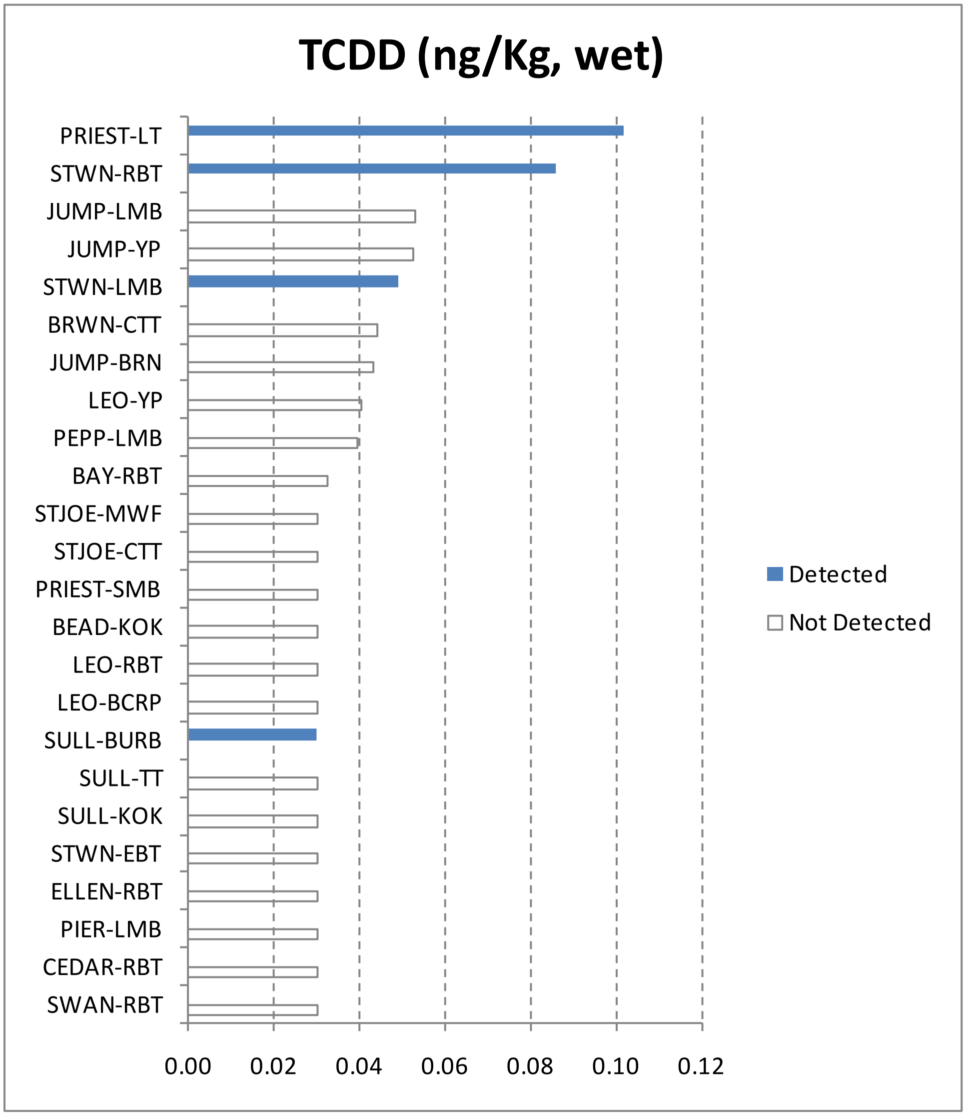


Figure 13. Fish Fillet Samples Ranked by TCDD Concentration.
Non-detects plotted at quantitation limit.

TCDD TEQs

Results for all 2,3,7,8-substituted PCDDs and PCDFs analyzed are summarized in terms of TEQs in Tables 22 and 23 and Figure 14. Only detected congeners were included in the TEQ.

Table 22. Summary of Results for TCDD TEQ Estimates in Fish Fillet Samples Analyzed for the Northeast Washington Background Study (ng/Kg, wet weight).

Waterbody	Species	TCDD TEQs*
Swan Lake	Rainbow trout	0.072
Cedar Lake	Rainbow trout	0.097
Pepoon L	Largemouth bass	0.000
Pierre Lake	Largemouth bass	0.015
Ellen Lake	Rainbow trout	0.023
South Twin Lake	Rainbow trout	0.086
South Twin Lake	Eastern brook trout	0.010
South Twin Lake	Largemouth bass	0.068
Sullivan Lake	Kokanee	0.085
Sullivan Lake	Tiger trout	0.037
Sullivan Lake	Burbot	0.035
Leo Lake	Black crappie	0.028
Leo Lake	Rainbow trout	0.024
Leo Lake	Yellow perch	0.14
Browns Lake	Cutthroat	0.000
Bayley Lake	Rainbow trout	0.058
Bead L	Kokanee	0.11
Jumpoff Joe L	Yellow perch	0.000
Jumpoff Joe L	Brown trout	0.040
Jumpoff Joe L	Largemouth bass	0.000
Upper Priest Lake	Lake trout	0.45
Upper Priest Lake	Smallmouth bass	0.13
Upper St. Joe River	Cutthroat	0.56
Upper St. Joe River	Mountain whitefish	0.003

*TEQ: Toxicity Equivalent

Table 23. Summary Statistics for TCDD TEQs in Fillets (ng/Kg, wet weight).

	All Species	Lake Trout Excluded
N=	24	23
Detection Frequency	83%	83%
Median	0.038	0.037
Mean	0.086	0.070
Minimum	0	0
Maximum	0.56	0.56
90th percentile	0.14	0.13

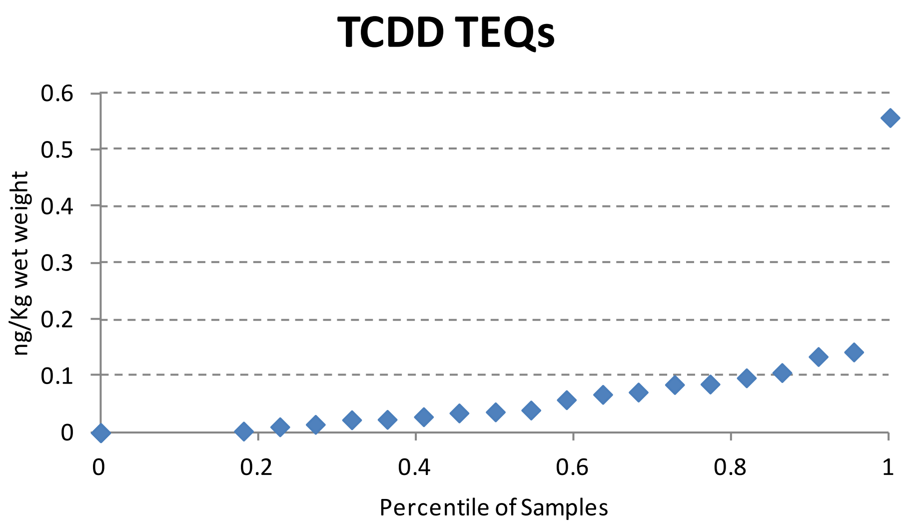


Figure 14. Cumulative Frequency Plot for TCDD TEQs in Fillets (lake trout sample excluded).

TCDD TEQs were higher than PCB TEQs by an order of magnitude or more. The median and 90th percentile for TCDD TEQs in the fillets was 0.038 and 0.14 ng/Kg vs. 0.004 and 0.015 ng/Kg for PCB TEQs.

The highest TCDD TEQ recorded was for cutthroat from the Upper St. Joe River (Figure 15). Pend Oreille lake trout had the second highest concentration at 0.45 ng/Kg. In both samples, 1,2,3,7,8-PeCDD (a pentachloro dioxin) was the major contributor to the TEQ, accounting for 40% and 67%, respectively, of the total. This congener has a TEF of 1.0, equivalent to TCDD. TCDD was responsible for an additional 23% of the TEQ in lake trout, but was not detected in the cutthroat sample. In this case, lake trout had a negligible effect on summary statistics for the TEQ.

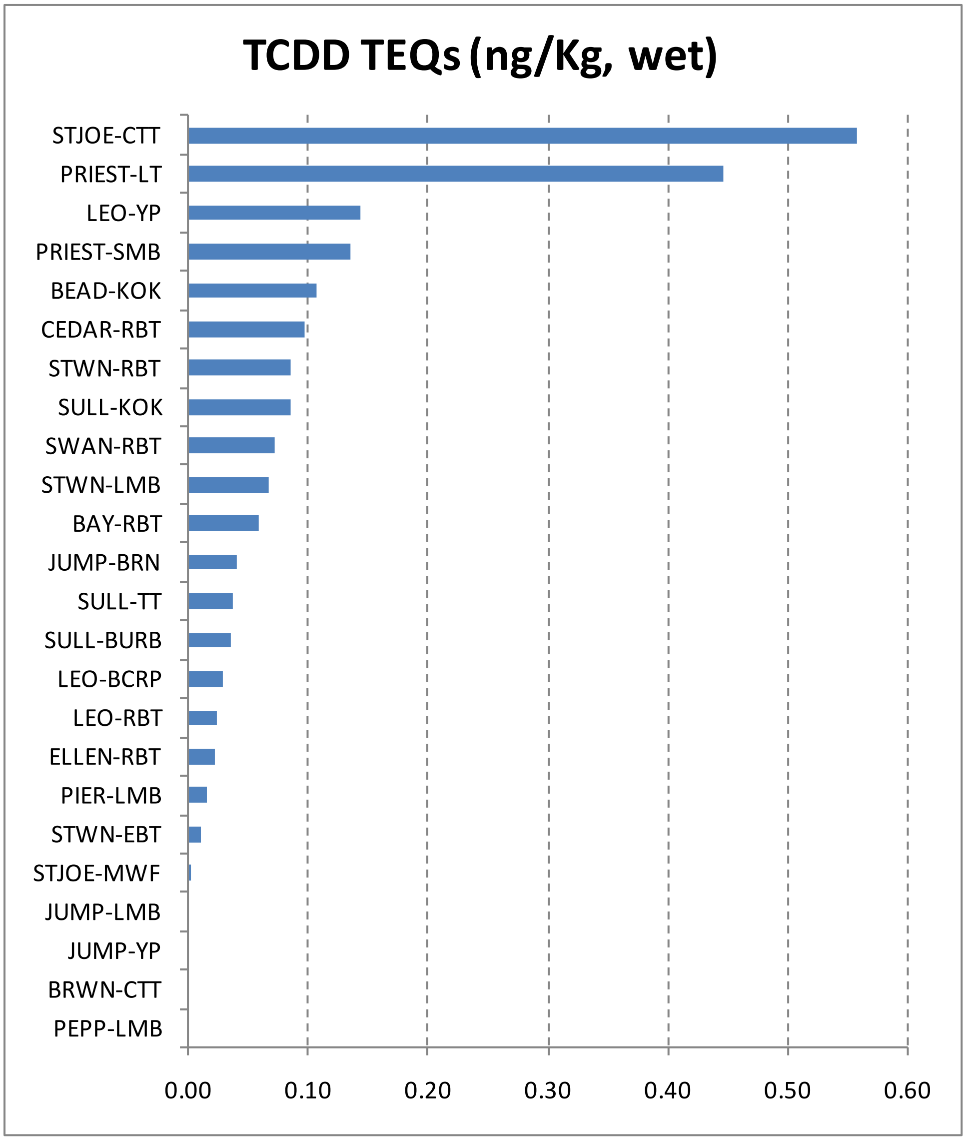


Figure 15. Fish Fillet Samples Ranked by TCDD TEQ Concentration.

PBDEs

PBDE flame retardant compounds were detected in all fillet samples. Results are summarized as total PBDEs, the sum of detected congeners, in Tables 24 and 25 and Figure 16. PBDEs by themselves do not have dioxin-like properties and are not currently included in the TEF concept (Van den Berg, 2006).

The median and 90th percentile concentrations for total PBDEs in the fillets were 819 ng/Kg and 2,331 ng/Kg, respectively. With lake trout excluded, these values drop to 765 ng/Kg and 1,731 ng/Kg.

Table 24. Summary of Results for Total PBDEs in Fish Fillet Samples Analyzed for the Northeast Washington Background Study (ng/Kg, wet weight).

Waterbody	Species	Total PBDEs
Swan Lake	Rainbow trout	1,076
Cedar Lake	Rainbow trout	70
Pepoon Lake	Largemouth bass	504
Pierre Lake	Largemouth bass	873
Ellen Lake	Rainbow trout	1,871
South Twin Lake	Rainbow trout	332
South Twin Lake	Eastern brook trout	765
South Twin Lake	Largemouth bass	529
Sullivan Lake	Kokanee	2,528
Sullivan Lake	Tiger trout	1,072
Sullivan Lake	Burbot	977
Leo Lake	Black crappie	180
Leo Lake	Rainbow trout	521
Leo Lake	Yellow perch	342
Browns Lake	Cutthroat	568
Bayley Lake	Rainbow trout	1,083
Bead Lake	Kokanee	2,956
Jumpoff Joe Lake	Yellow perch	97
Jumpoff Joe Lake	Brown trout	1,175
Jumpoff Joe Lake	Largemouth bass	1,026
Upper Priest Lake	Lake trout	15,995
Upper Priest Lake	Smallmouth bass	1,001
Upper St. Joe River	Cutthroat	162
Upper St. Joe River	Mountain whitefish	686

Table 25. Summary Statistics for Total PBDEs in Fillets (ng/Kg, wet weight).

	All Species	Lake Trout Excluded
N=	24	23
Detection Frequency	100%	100%
Median	819	765
Mean	1,516	887
Minimum	70	70
Maximum	15,995	2,956
90th percentile	2,331	1,731

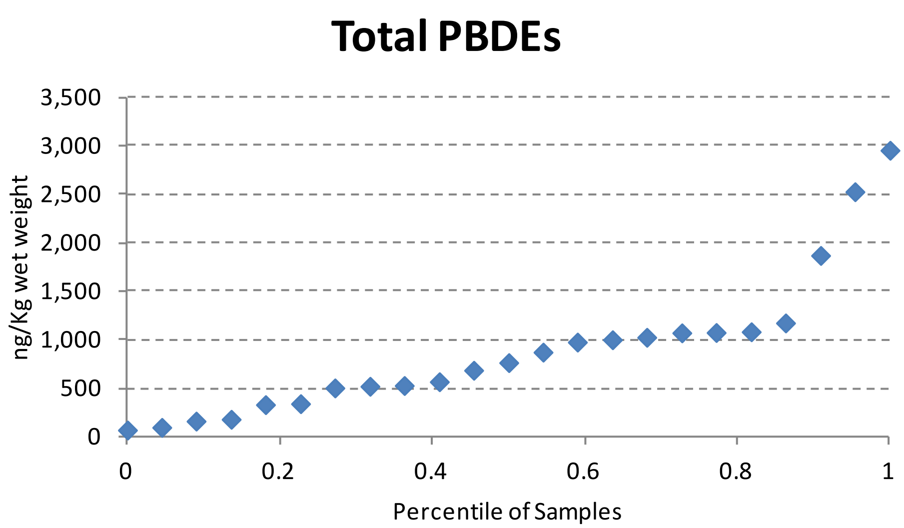


Figure 16. Cumulative Frequency Plot for Total PBDEs in Fillets (lake trout sample excluded).

The fillet samples are ranked by total PBDEs in Figure 17. As with PCBs, the highest PBDE levels were observed in salmonids. Upper Priest lake trout again had a much higher concentration than other samples (15,995 ng/Kg). Kokanee from Bead Lake (2,956 ng/Kg) and from Sullivan Lake (2,528 ng/Kg) had the second and third highest concentrations.

The PBDE congeners contributing most to the total concentration were -47, -99, and -209, which averaged 36%, 22%, and 12% respectively. These congeners tend to be the most frequently detected in environmental samples (Hites, 2004). However, their relative amounts varied considerably between samples, ranging from non-detected to as much as 83% of the total PBDE concentration. The generally low PBDE levels in the fillets made it difficult to clearly establish the relative importance of individual PBDE compounds.

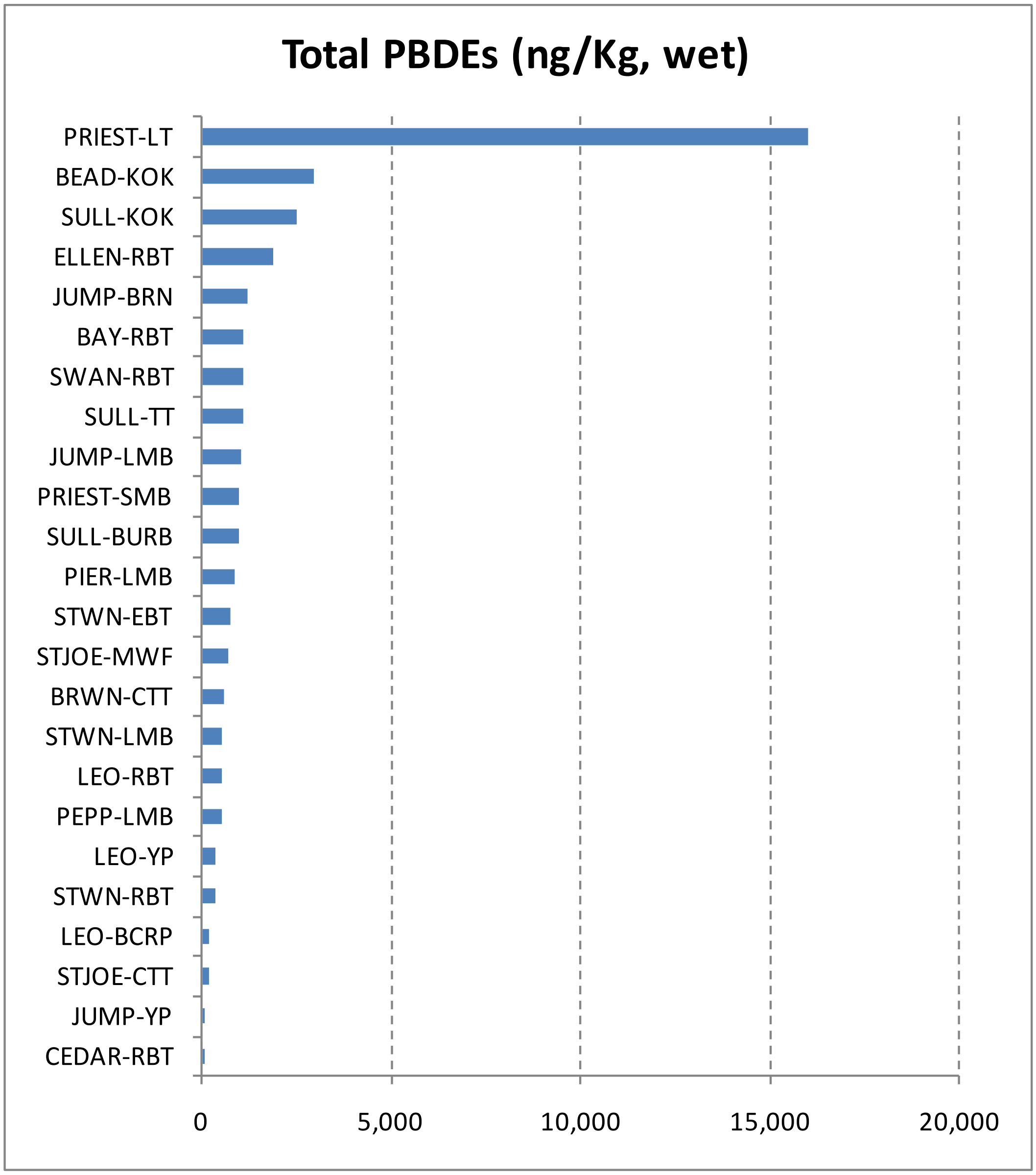


Figure 17. Fish Fillet Samples Ranked by Total PBDE Concentration.

Results on Whole Fish

Whole fish were analyzed to obtain data for potential use in ecological risk assessments conducted for contaminant studies or cleanup activities. Largescale suckers were targeted due to their bottom feeding habit and frequent use of sucker species as whole body samples in other chemical surveys of freshwater fish.

Suckers were only encountered in five of the 16 waterbodies where fish sampling was conducted: Sullivan Lake, Bead Lake, Upper Priest Lake, Colville River, and Pend Oreille River. All of these sites are in the eastern part of the study area.

Metals

The metals analyzed in whole suckers included mercury, arsenic, cadmium, copper, lead, antimony, and zinc. The results are summarized in Tables 26 and 27.

Table 26. Summary of Results for Metals Analyzed in Whole Fish Samples (Largescale suckers) for the Northeast Washington Background Study (mg/Kg, except ug/Kg for mercury, wet weight).

Waterbody	Sample No.	Hg	As		Cd		Cu	Pb		Sb		Zn
Sullivan Lake	1102018-16	89	0.15		0.10	U	1.3	0.15		0.20	U	23
Bead Lake	1102018-24	24	0.19		0.10	U	1.0	0.35		0.20	U	16
Upper Priest Lake	1102018-31	143	0.12		0.10	U	3.0	0.29		0.20	U	13
Colville River	1106039-5	80	0.10	U	0.10	U	1.2	0.02	J	0.20	U	16
Pend Oreille River	1106039-12	182	0.10	U	0.10	U	2.7	0.10	J	0.20	U	16

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

Table 27. Summary Statistics for Metals in Whole Fish (mg/Kg, except ug/Kg for mercury, wet weight).

	Hg	As		Cd		Cu	Pb	Sb		Zn
N=	5	5		5		5	5	5		5
Median	89	0.12		0.10	U	1.3	0.15	0.20	U	16
Mean	104	0.13		0.10	U	1.8	0.18	0.20	U	17
Minimum	24	0.10	U	0.10	U	1.0	0.02	0.20	U	13
Maximum	182	0.19		0.10	U	3.0	0.35	0.20	U	23
90th percentile	166	0.17		0.10	U	2.9	0.33	0.20	U	20

U: The analyte was not detected at or above the reported result

For the most part, metals concentrations in suckers were similar among waterbodies. Mercury, copper, and zinc were generally comparable within a factor of 2 to 3. Arsenic was near or below detection limits. Cadmium and antimony were not detected

For reasons not determined, the lead concentration in Colville River suckers was lower than the other samples by a factor of 5 or more (0.02 vs. 0.10 - 0.35 mg/Kg). The Ecology Manchester Laboratory's initial analysis of this sample indicated that the lead concentration was at or below 0.2 mg/Kg. A subsequent duplicate analysis by Brooks Rand Laboratory (Seattle) using a more sensitive method, gave closely agreeing results of 0.022 and 0.025 mg/Kg.

Organic Compounds

Results for organic compounds analyzed in the whole fish samples are summarized in Tables 28 and 29.

Table 28. Summary of Results for Organic Compounds and Lipids in Whole Fish Samples (largescale suckers) Analyzed for the Northeast Washington Background Study (ng/Kg, wet weight).

Waterbody	Total PCBs	PCB TEQs	TCDD		TCDD TEQs	Total PBDEs	% Lipids
Sullivan Lake	3,528	0.007	0.071	NJ	0.12	1,034	1.7
Bead Lake	6,155	1.9	0.096	UJ	0.002	1,820	3.5
Upper Priest Lake	7,624	2.5	0.14	NJ	0.20	4,186	5.6
Colville River	4,430	0.018	0.10	UJ	0.080	12,564	5.2
Pend Oreille River	48,597	1.3	0.044	UJ	0.14	73,475	9.6

UJ: The analyte was not detected above the reported estimated quantitation limit
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration

Table 29. Summary Statistics for Organic Compounds and Lipids in Whole Fish (ng/Kg, wet weight).

	Total PCBs	PCB TEQs	TCDD		TCDD TEQs	Total PBDEs	% Lipids
N=	4	4	4		4	4	4
Median	5,292	0.9	0.10	UJ	0.10	3,003	4.4
Mean	5,434	1.1	0.10	UJ	0.10	4,901	4.0
Minimum	3,528	0.007	0.071	UJ	0.002	1,034	1.7
Maximum	7,624	2.5	0.14	NJ	0.20	12,564	5.6
90th percentile	7,183	2.3	0.13	NJ	0.18	10,050	5.5

UJ: The analyte was not detected above the reported estimated quantitation limit
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration

Pend Oreille River suckers were a substantial outlier with respect to PCBs and PBDEs at 48,597 and 73,475 ng/Kg, respectively (Table 28). This did not appear to be a simple function of lipid content. Data corroborating the PCB finding is discussed later in this report. This sample was therefore not included in the statistical summary (Table 29). This study did not analyze organic compounds in fillets from other Pend Oreille River species.

A second noteworthy finding is the relatively high PCB TEQ in whole suckers from Bead Lake, Upper Priest Lake, and the Pend Oreille River compared to the TCDD TEQ. PCB-126 again contributed most of the PCB TEQ (71 - 87%). Bead Lake and Upper Priest Lake also had elevated PCBs in fillets from other species.

Discussion

Spatial Patterns

The companion sediment quality investigation for this project found much higher concentrations of antimony, lead, cadmium, arsenic, mercury, and zinc in lakes from the western part of the study area along the Columbia River (Johnson et al., 2011). This was attributed primarily to historical transboundary air pollution from the Trail lead and zinc smelter in British Columbia. TCDD (dioxin) was also elevated in sediments from the western lakes compared to eastern lakes, for reasons not determined.

Sediments can be a significant source of bioaccumulative metals and organic compounds to fish and other aquatic organisms. However, visual examination of the northeast Washington fish tissue data, by species or for all species, shows no clear evidence of this or other spatial patterns with respect to mercury, TCDD, or the other chemicals analyzed. The fish tissue and sediment data were tested for statistical correlations and none were found.

Between-lake differences in the species and size or age of the fish analyzed would act to obscure spatial patterns known or unknown in the study area. Even the most commonly encountered fish such as rainbow trout, largescale suckers, and largemouth bass were only analyzed in a subset of the 16 waterbodies sampled (seven, five, and four sites, respectively; see Table 10). Differences in the size and age of the fish analyzed add a further layer of variability.

Of the six metals showing sediment impacts only mercury was analyzed in fish fillets, the other metals having low accumulation rates in muscle tissue. Although these other metals were analyzed in whole suckers, this species was only encountered in the eastern half of the study area and thus was not useful for identifying spatial patterns.

Other Fish Tissue Data for Study Area

Present vs. Previous Samples

Several recent surveys have analyzed fish tissue samples from the same waterbodies and species as in the present 2010-11 study. Between 2005 and 2009, Ecology's Washington State Toxics Monitoring Program (WSTMP) analyzed mercury and organic compounds in fish fillets from South Twin, Leo, Pierre, and Bead Lakes, in the course of their annual monitoring effort (Seiders et al. 2007; Seiders and Casey, 2009; Seiders 2010). The South Twin PCB and dioxin results were incorporated in Ecology's statewide assessment of the PCB and dioxin background in freshwater fish, mentioned at the beginning of this report (Johnson et al., 2010). An earlier Ecology study analyzed fillets from Bead Lake fish in connection with a statewide survey of PBDE flame retardants (Johnson et al., 2006). Most recently, the Kalispel Tribe provided Ecology with metals and organics data for Pend Oreille River fish collected in 2009 (Merrill, 2011).

Tables 30-32 compare results from the above studies with the findings for the same species and waterbodies sampled in 2010-11. All samples were single composites from several individual fish. Some additional PCB data exist for the WSTMP samples (shown later in Table 33), but is not directly comparable due to the analytical method.

Table 30. Results of Present 2010-11 Study Compared to Previous Samples: Mercury in Fillets (ug/Kg; N=1).

Waterbody	Species	Present Study Result	Previous Result	Date of Previous Sample	RPD	Reference
South Twin L.	Brook trout - lg	51	49	2008	5%	1
South Twin L.	Largemouth bass	159	68	2008	81%	1
South Twin L.	Rainbow trout	31	22	2008	34%	1
Leo L.	Yellow perch	94	80	2009	16%	2
Leo L.	Black crappie	186	200	2009	7%	2
Pend Oreille R.	Northern pike - med	217	281	2009	26%	3
Pend Oreille R.	Smallmouth bass	256	80	2009	105%	3
Bead L.	Kokanee	40	30	2005	29%	4

RPD: relative percent difference
References:
1: Seiders and Deligeannis (2009)
2: Seiders (2010)
3: Merrill (2011)
4: Seiders et al. (2007)

Table 31. Results of Present 2010-11 Study Compared to Previous Samples: Organic Compounds in Fillets (ng/Kg; N=1).

Chemical	Waterbody	Species	Present Study Result	Previous Result	Date of Previous Sample	RPD	Reference
Total PCBs	South Twin L.	Brook trout - lg	887	1,170	2008	28%	1,2
"	South Twin L.	Largemouth bass	1,105	248 NJ	2008	126%	1,2
TCDD	South Twin L.	Brook trout - lg	0.03 UJ	0.03 U	2008	ND	1,2
"	South Twin L.	Largemouth bass	0.049 NJ	0.03 U	2008	NC	1,2
TCDD TEQs	South Twin L.	Brook trout - lg	0.10	0.075	2008	29%	1,2
"	South Twin L.	Largemouth bass	0.068	0.007	2008	163%	1,2
Total PBDEs	South Twin L.	Brook trout - lg	765	790 J	2008	3%	2
"	South Twin L.	Largemouth bass	529	170 J	2008	103%	2
"	South Twin L.	Rainbow trout	332	420 J	2008	23%	2
"	Bead Lake	Kokanee	2,956	2,600	2005	13%	3

RPD: relative percent difference
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration
U: The analyte was not detected at or above the reported result
UJ: The analyte was not detected above the reported estimated quantitation limit
J: estimated
ND: not detected
NC: not calculated
References: 1: Johnson et al. (2010); 2: Seiders and Deligeannis (2009); 3: Johnson et al. (2006)

Table 32. Results of Present 2010-11 Study Compared to Previous Samples: Whole Largescale Suckers from the Pend Oreille River.

Previous sample by the Kalispel Tribe (Merrill, 2011a,b); N=1.

Collection Date	2011 (Present study)	2009	RPD
Hg (ug/Kg)	182	117	43%
As (mg/Kg)	0.10 U	0.09 U	ND
Cd "	0.10 U	0.03	NC
Cu "	2.7	0.42	146%
Pb "	0.1	0.1 U	NC
Sb "	0.20 U	0.23 U	ND
Zn "	16	17	3%
Total PCBs (ng/Kg)	48,597	32,000	41%
TCDD "	0.044 UJ	0.03 U	ND
TCDD TEQs "	0.14	0.09	43%

RPD: relative percent difference
U: The analyte was not detected at or above the reported result
UJ: The analyte was not detected above the reported estimated quantitation limit
ND: not detected
NC: not calculated

Allowing for differences in size and age of the fish analyzed and seasonal effects, results from several independent efforts generally show good agreement on the levels of metals and organic contaminants at these locations. Most results agree within a factor of 2. The Kalispell's PCB finding for Pend Oreille River whole suckers (32,000 ng/Kg) is noteworthy in that it corroborates the elevated concentration measured in the current study (48,597 ng/Kg), suggesting impacts from undetermined point sources (Table 32)

The wider disparity between mercury levels in bass fillets (Table 30) can be attributed to fish size and age. Higher mercury concentrations were associated with the larger South Twin and Pend Oreille bass sampled for the present study than smaller fish analyzed previously (350 vs. 230 mm and 296 vs. 275 mm average total length, respectively). A recent study by Meredith et al. (2010) analyzed fillets from ten Pierre Lake smallmouth bass ranging from 351 to 442 mm total length. The fish aged out at 5 to 13 years with mercury concentrations of 111 to 363 ug/Kg, increasing with length and age. A different bass species, largemouth, was analyzed from Pierre Lake for the present study.

A much lower TCDD TEQ was reported in South Twin Lake largemouth bass collected in 2008 compared to 2010 (0.007 vs. 0.068 ng/Kg, Table 31). This seeming discrepancy is due to the detection of TCDD in the 2010 sample at 0.049 ng/Kg, whereas the 2008 sample was at or below a reporting limit of 0.030 ng/Kg, thus not contributing to the total TEQ.

The comparable data available for northeast Washington waterbodies suggest that concentrations of these chemicals in fish tissue can be adequately characterized at this level of resolution based on results from single composite samples. This, in turn, implies that the sampling design for the northeast Washington fish tissue study generally provided representative results within approximately a factor of 2 for a given species and location.

Pertinent Background Data

At the request of Ecology's Eastern Regional Office, the WSTMP fish collection of 2009 included three additional northeast Washington lakes selected as being representative of background conditions: Black Lake, located in the approximate middle of the present study area and Upper Twin and Amber Lakes to the south (Figure 18). Fish fillet data from these lakes and the other northeast Washington background lakes WSTMP sampled in 2008 and 2009 are summarized in Table 33.

The highlighted values within Table 33 were obtained using the same methods and similar reporting limits as in the present study. These results were therefore used in the calculation of background concentrations for northeast Washington fish, presented at the end of this report.

A range of other metals and chlorinated pesticides were also analyzed in these WSTMP fillet samples but rarely detected. The metals include those analyzed in whole fish for the present study and are therefore summarized in Appendix E. The only pesticide compound frequently detected was trace amounts of the DDT breakdown product DDE.

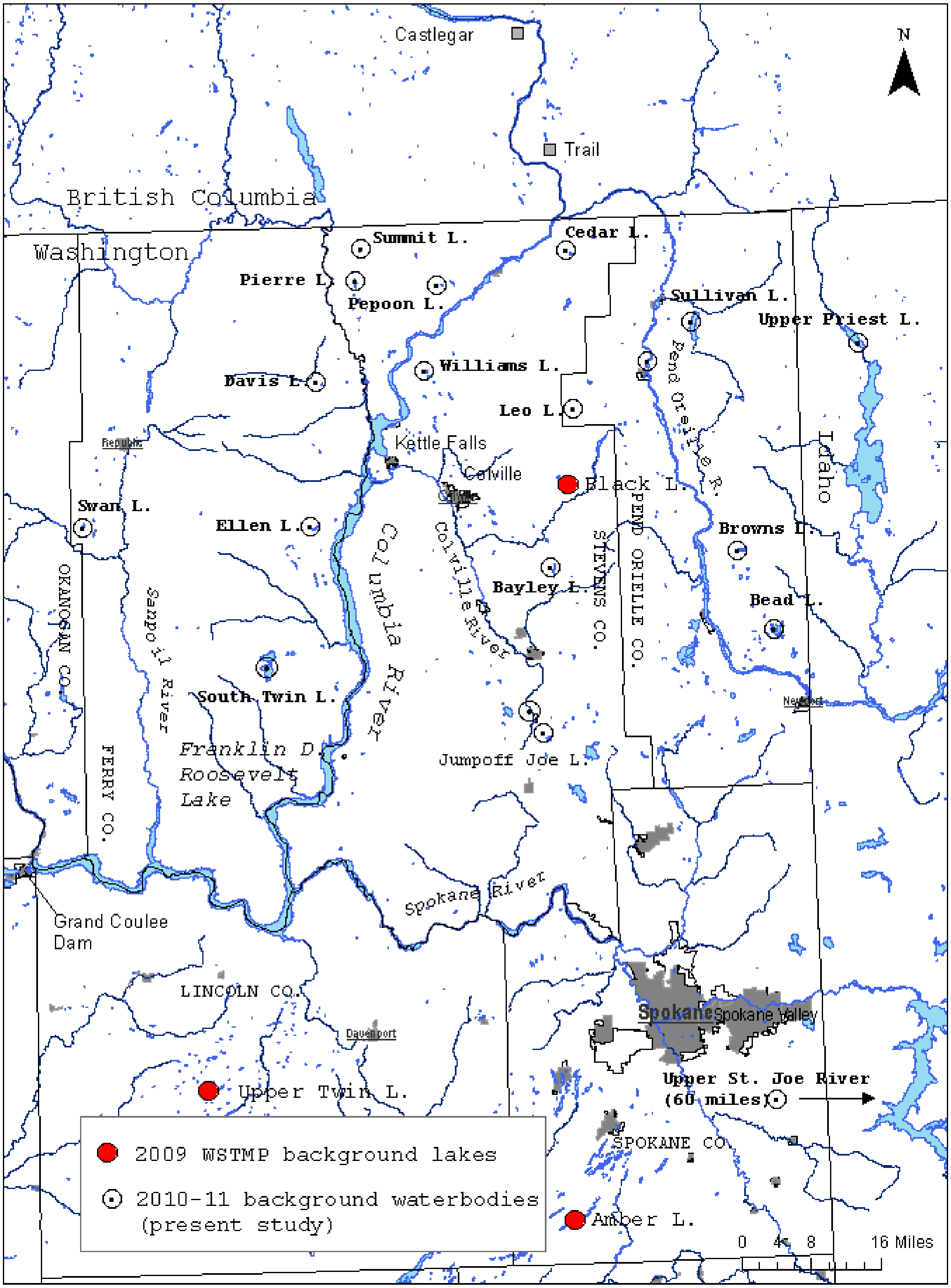


Figure 18. Location of Background Lakes Where Fish Samples were Collected in 2009 for the WSTMP.

Table 33. WSTMP Fish Fillet Data for Northeast Washington Background Lakes, 2008-09.

Mercury in ug/Kg; organics in ng/Kg; wet weight basis.

Waterbody	Species	Date	Mercury		Total PCBs		TCDD		TCDD TEQs		Total PBDEs†		% Lipids
Amber Lake	Rainbow trout	15-Oct-09	90		2,000	U	0.03	J	0.05	UJ	400		0.54
Black Lake	Tiger trout	30-Sep-09	75		1,000	U	NA		NA		570	J	1.1
Upper Twin Lake	Rainbow trout	14-Oct-09	62		980	U	0.03	J	0.325	J	140	J	1.3
	Yellow perch	14-Oct-09	57		970	U	NA		NA		1,900	U	0.35
Pierre Lake	Smallmouth bass	29-Sep-09	202		1,900	J	NA		NA		980	J	0.51
Leo Lake	Yellow perch	1-Oct-09	80		1,000	U	NA		NA		1,890	J	0.18
	Pumpkinseed	1-Oct-09	79		990	U	NA		NA		390	J	0.09
	Black crappie	1-Oct-09	200		990	U	NA		NA		210	J	0.18
South Twin Lake	Eastern brook trout - lg	25-Jun-08	49		1170*		0.03	U	0.0747		790	J	2.2
	Eastern brook trout - sm	25-Jun-08	NA		827*		0.03	U	0.0347		NA		1.6
	Largemouth bass	25-Jun-08	68		248*	NJ	0.03	U	0.0066		170	J	0.64
	Rainbow trout	25-Jun-08	22		1,100	U	NA		NA		420	J	1.3

Note: Shaded values incorporated into present study calculation of background concentrations for northeast Washington fish

*Analyzed by HR/GCMS; other PCB data by less sensitive GC/ECD method

†Analyzed by GCMS method for a subset of PBDE congeners

U: The analyte was not detected above the reported quantitation limit

UJ: The analyte was not detected above the reported estimated quantitation limit

NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration

Comparisons with Statewide Data

Background Waterbodies

The Ecology PCB and dioxin background study of 2007-2008 (Johnson et al., 2010) obtained statewide data on fish fillet samples from 24 lakes and rivers across Washington. A subset of these samples was also analyzed for mercury and PBDEs through the WSTMP (Seiders and Deligeannis, 2009). This provides a consistent statewide data set for comparison with the northeast background study. The WSTMP PBDE data could be biased low relative to the present study because the analysis was by a low resolution GC/MS method that only targets the major congeners known to be a concern in environmental samples.

Table 34 compares the medians and 90th percentiles for fish fillets from the statewide and northeast background waterbodies (present study). In almost all cases, levels of chemical contaminants in northeast Washington fish are either equivalent to or lower than the corresponding statewide values. The statewide statistics for total PCBs, TCDD TEQs, and total PBDEs are higher by factors of approximately 1.5 to 2.0. TCDD is infrequently detected in both data sets: 27% of statewide samples and 13% of the northeast Washington samples.

The northeast 90th percentile for mercury is an exception to this pattern, being higher than the statewide 90th percentile (237 vs. 150 ug/Kg). Statewide and northeast Washington medians for mercury, however, are in close agreement (80 vs. 76 ug/Kg). The statewide samples were dominated by salmonids (81%) which explains the low 90th percentile for mercury relative to the northeast Washington (61% salmonids)

The distribution of values in the statewide and northeast Washington background data sets are shown in Figure 19. The TCDD data were not plotted due to the frequency of non-detects. For reasons of scale, one statewide total PCB outlier (87,700 ng/Kg) was excluded from the plot.

Comparison with statewide background bears out the concern that initially lead Ecology to conduct the northeast Washington background study, namely, that the level of chemical contamination appears lower in the far eastern counties and that the use of statewide-based reference values for decision-making could therefore inappropriately bias outcomes, particularly for cleanup actions.

Table 34. Comparison of Mercury and Organic Compounds in Fish Fillet Samples from Statewide and Northeast Washington Background Waterbodies.

	Statewide Background (2007-08 study)	Northeast Washington Background (2010-11 study*)
Mercury (ug/Kg)		
N=	32	31
Median	80	76
90th percentile	150	237
Total PCBs (ng/Kg)		
N=	52	23
Median	1,400	887
90th percentile	6,500	3,817
TCDD (ng/Kg)		
N=	52	23
Median	0.030 U	0.030 U
90th percentile	0.041	0.052 UJ
TCDD TEQ (ng/Kg)		
N=	52	23
Median	0.051	0.037
90th percentile	0.18	0.13
Total PBDEs (ng/Kg)		
N=	32	23
Median	1,560	765
90th percentile	3,810	1,731

*Upper Priest lake trout sample excluded from statistics for organic chemicals
UJ: The analyte was not detected above the reported estimated quantitation limit
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration

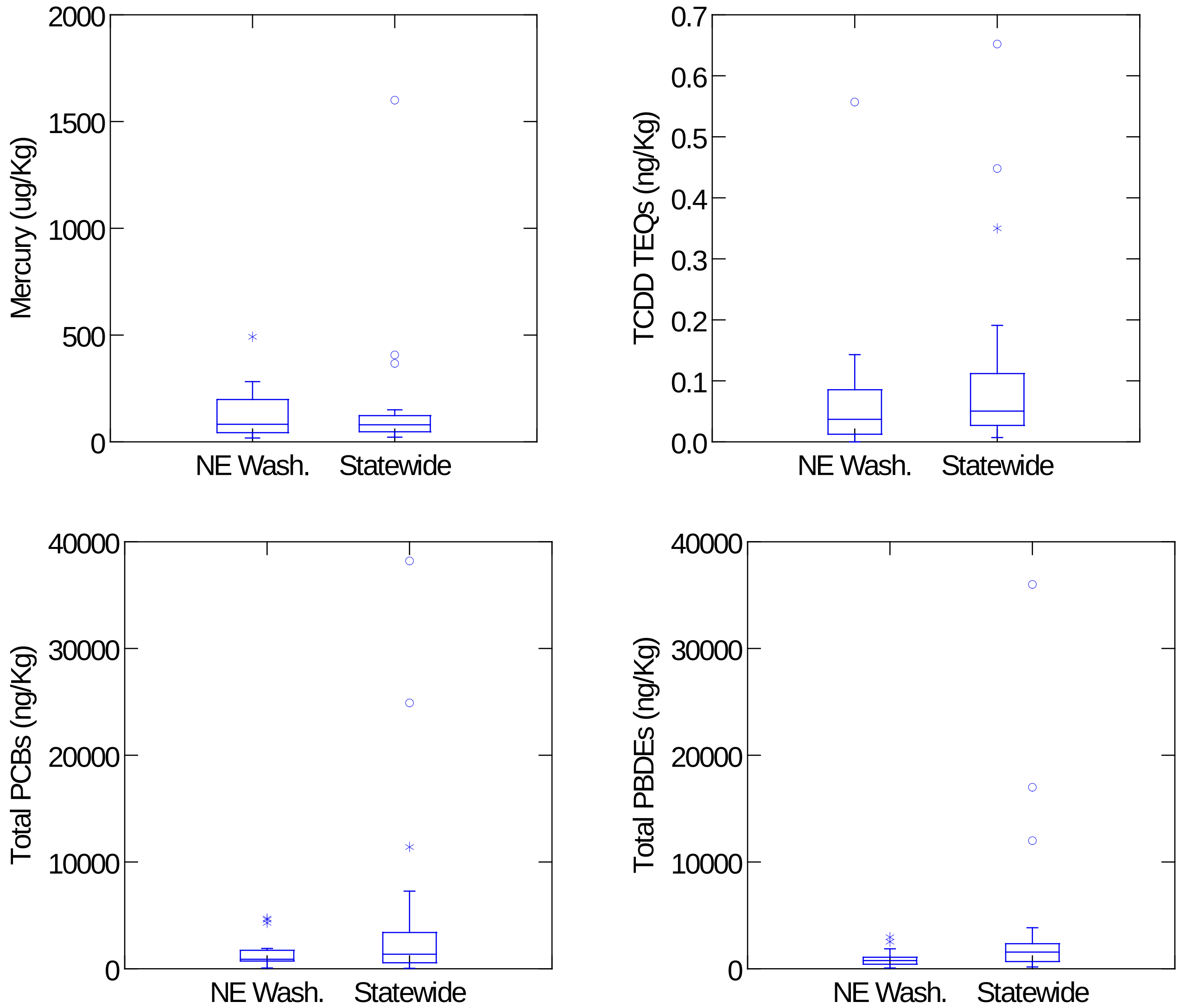


Figure 19. Comparison of Mercury, PCB, TCDD TEQ, and PBDE Levels in Fish Fillet Samples from Northeast Washington and Statewide Background Waterbodies.

Non-detects plotted at the reporting limit.

Non-Background Waterbodies

Washington

WSTMP is a screening-level effort that targets lakes, rivers, and streams across Washington. Results are primarily used to identify areas of concern for follow-up actions. For example, the bulk of the state's 303(d) water quality limited listings for edible fish tissue come from this program.

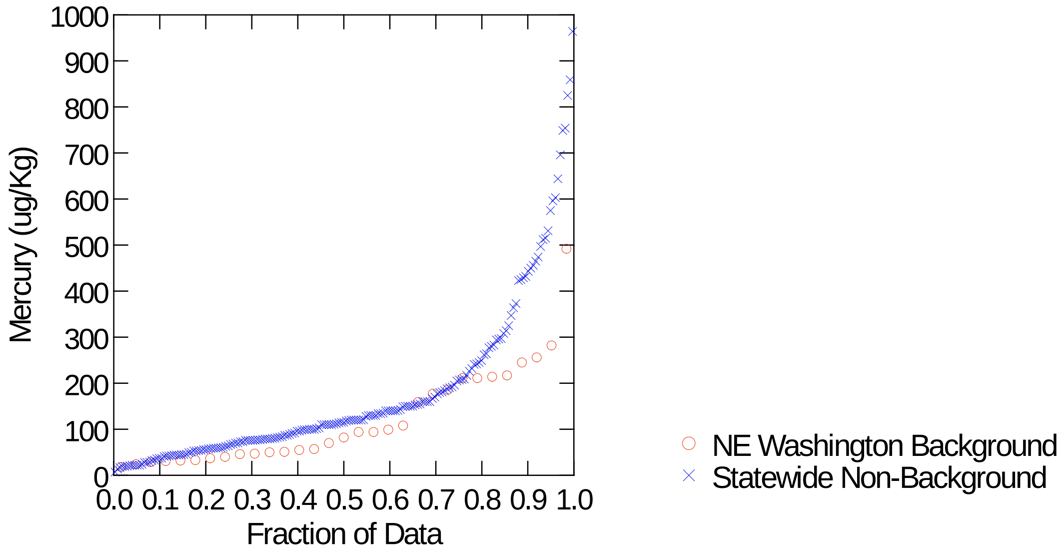
Fish fillet results from the northeast Washington background study were compared to WSTMP findings for 2001 through 2008 for fish collected from non-background waterbodies in urban and industrial watersheds statewide (Table 35, Figure 20). Two extreme statewide values (1,600,000 ng/Kg total PCBs and 1,140,000 ng/Kg total PBDEs) were excluded.

This comparison provides a qualitative illustration of the extent to which northeast Washington fish represent "cleaner" conditions than those known or likely to be from contaminated areas. Differences between background and non-background are evident across all chemicals, but are particularly notable for PCBs and PBDEs. The WSTMP does not analyze whole fish.

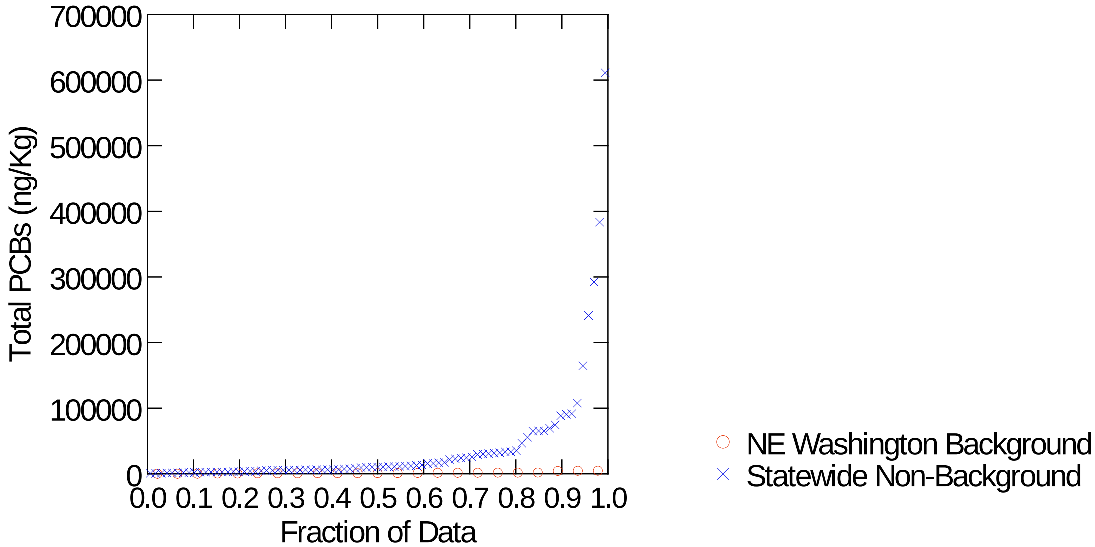
Table 35. Comparison of Mercury and Organic Compounds in Fish Fillet Samples from Statewide Non-background and Northeast Washington Background Waterbodies.

	Statewide Non-Background (2001-08 data)	Northeast Washington Background (2010-11 study*)
Mercury (ug/Kg)		
N=	187	31
Median	115	76
90th percentile	437	237
Total PCBs (ng/Kg)		
N=	84	23
Median	10,405	887
90th percentile	90,076	3,817
TCDD (ng/Kg)		
N=	109	23
Median	0.20	0.030 U
90th percentile	0.71	0.052 UJ
TCDD TEQ (ng/Kg)		
N=	109	23
Median	0.20	0.037
90th percentile	0.71	0.13
Total PBDEs (ng/Kg)		
N=	187	23
Median	3,210	765
90th percentile	22,340	1,731

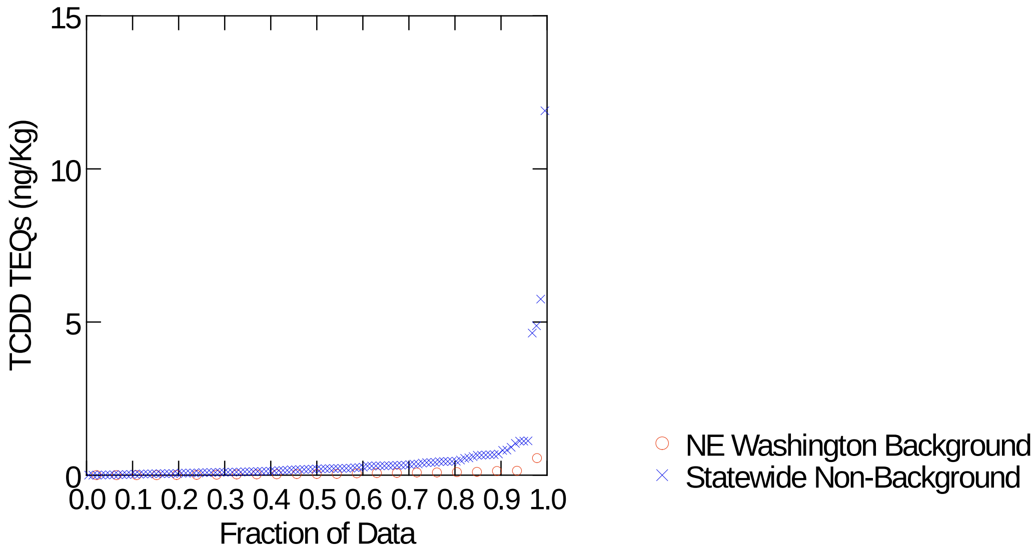
*Upper Priest lake trout sample excluded from statistics for organic chemicals
UJ: The analyte was not detected above the reported estimated quantitation limit
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration



Mercury (ug/Kg)
1000
900
800
700
600
500
400
300
200
100
0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Fraction of Data
NE Washington Background
Statewide Non-Background



Total PCBs (ng/Kg)
700000
600000
500000
400000
300000
200000
100000
0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Fraction of Data
NE Washington Background
Statewide Non-Background



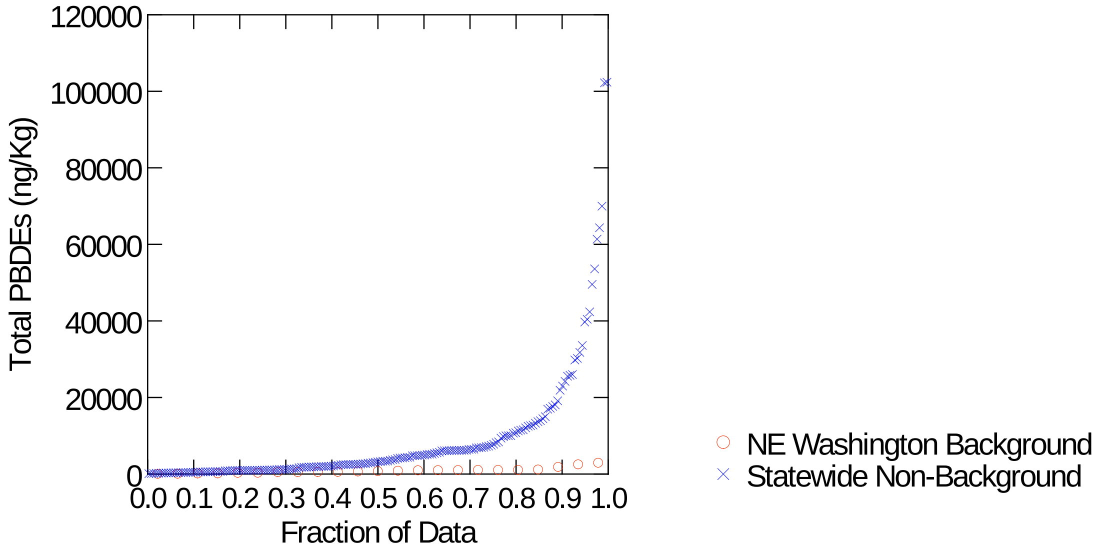


Figure 20. Comparison of Data on Mercury, PCBs, TCDD TEQs, and PBDEs in Fish Fillet Samples from Northeast Washington and Statewide Non-background Waterbodies (wet weight).

Non-detects plotted at the reporting limit.

Idaho

The Idaho Department of Environmental Quality recently completed a statewide assessment of mercury, arsenic, and selenium in fish from 50 Idaho lakes and reservoirs statewide, using a stratified random sampling design (Essig and Kosterman, 2008). Eighty-nine composite fillet samples were analyzed from 20 game fish species.

Table 36 has a statistical summary of the Idaho mercury data and compares it with the northeast Washington background study. As with the Washington non-background data set, much higher mercury levels are characteristic of Idaho lakes statewide.

Table 36. Comparison of Mercury Data on Fish Fillet Samples from Idaho Statewide Lakes Study and Northeast Washington Background Waterbodies (ug/Kg, wet weight).

	Salmonids		Spiny Rays	
	Idaho Statewide	NE Wash. Background	Idaho Statewide	NE Wash. Background
N=	37	17	52	14
Median	103	47	243	186
Mean	151	69	319	169
Minimum	26	18	20	29
Maximum	723	214	1,380	492
90th percentile	281	144	564	256

Arsenic was detected in only 11% of the Idaho samples and at concentrations only slightly above the 0.11 mg/Kg detection limit (0.12 – 0.30 mg/Kg). Inorganic arsenic was not detected (<0.003 mg/Kg). Selenium was generally confined to a narrow range of 0.1 – 0.5 mg/Kg.

Fish Tissue Criteria

When using background values to interpret contaminant data or aid in setting cleanup targets for aquatic environments, it is important to know the margin by which they are protective of human health and aquatic life. For comparative purposes only, results from the northeast Washington fish tissue study are contrasted with human health criteria and selected ecological benchmarks below. These comparisons do not include tribal or other consumption-based considerations.

Human Health

Ecology's current human health criteria for edible fish tissue are derived from EPA bioconcentration factors and human health water column criteria established for fish consumption under the EPA National Toxics Rule issued to Washington in 1992 (40 CFR Part 131; Federal Register Vol. 57, No. 246, as updated). The criteria provide cancer risk protection at the 10^{-6} (one-in-one million) excess lifetime cancer risk level. The criteria calculations are based on assumptions for average fish consumption among the general public (6.5 grams per day), average adult weight (70 Kg), a drinking water ingestion rate of 2 liters of water per day (for freshwater), and an exposure duration of 70 years. Including drinking water in the calculation has a negligible effect on the criteria because almost all the dose comes from fish consumption, water concentrations always being orders of magnitude lower than tissue.

The NTR criterion for mercury in edible freshwater fish tissue is 770 ug/Kg. Mercury affects the nervous system, but is not a carcinogen. The NTR criterion is based on a reference dose (0.1 ug/Kg body weight/day) that is likely to be without an appreciable risk of deleterious health effects during a lifetime. In 2001, EPA recommended a mercury water quality criterion to be used as guidance by states and tribes (EPA, 2001). For freshwater fish, this value equates to 300 ug/Kg methylmercury, based on a fish consumption rate of 17.5 g/day for the general adult population. Although expressed as methylmercury, EPA recommended states and tribes analyze total mercury on the assumption that all mercury in fish tissue is present in methylated form.

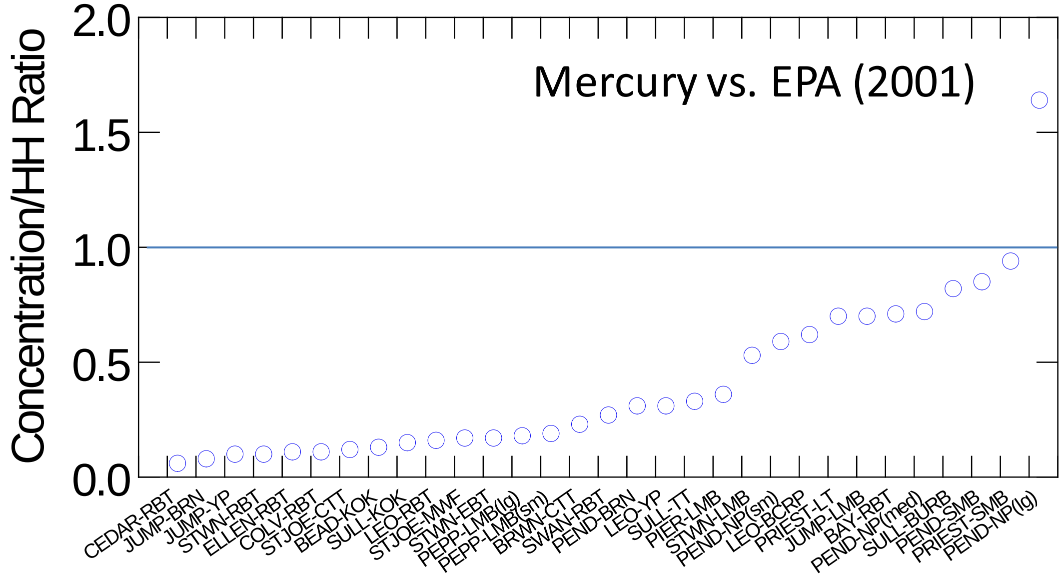
Table 37 compares the NTR and EPA (2001) human health criteria to results from the northeast Washington background study. Several criteria exceedances were observed for the highest mercury, TCDD, and TCDD TEQ concentrations recorded for the study area, but, except for Upper Priest lake trout, not for PCBs.

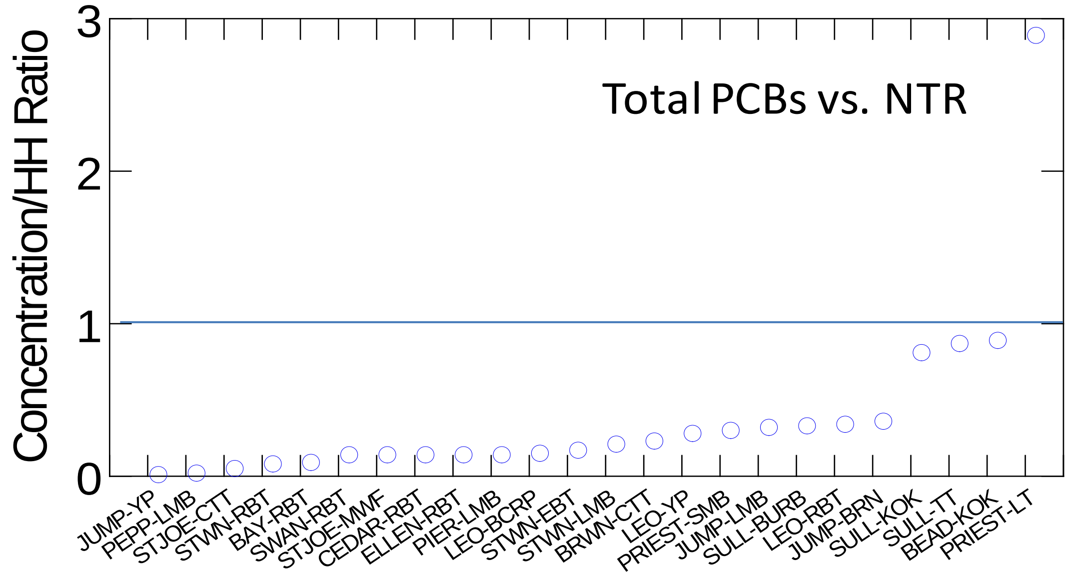
Table 37. National Toxics Rule and EPA (2001) Human Health Criteria for Edible Fish Tissue.
Mercury in ug/Kg; organics in ng/Kg; wet weight.

Pollutant (Source of Criteria)	Criterion	Concentrations Measured in Present Study*					
		N =	median	mean	90th percentile	maximum	Upper Priest lake trout
Mercury (NTR / EPA, 2001)	770 / 300	31	76	108	237	492	211
Total PCBs (NTR)	5,304	23	887	1,423	3,817	4,634	15,311
TCDD (NTR)	0.065	23	0.030 UJ	0.037 UJ	0.052 UJ	0.086 NJ	0.10 NJ
TCDD TEQ (NTR**)	0.065	23	0.037	0.070	0.13	0.56	0.45

*Lake trout sample excluded from statistics for organic chemicals. **TCDD criterion applied here to the TCDD TEQ, but not promulgated in NTR

A detailed comparison by individual sample and waterbody is provided in Figure 21, which plots the ratio of chemical concentration in the fish fillet samples to the NTR and EPA (2001) criteria. Ratios greater than 1 exceed the criterion. Mercury did not exceed the NTR 770 ug/Kg criterion and is thus not plotted.


Mercury vs. EPA (2001)
Concentration/HH Ratio
2.0
1.5
1.0
0.5
0.0
CEDAR-RBT
JUMP-BRN
JUMP-YP
STWN-RBT
ELLEN-RBT
COLV-RBT
STJOE-CTT
BEAD-KOK
SULL-KOK
LEO-RBT
STJOE-MWF
STWN-EBT
PEPP-LMB(lg)
PEPP-LMB(sm)
BRWN-CTT
SWAN-RBT
PEND-BRN
LEO-YP
SULL-TT
PIER-LMB
STWN-LMB
PEND-NP(sm)
LEO-BCRP
PRIEST-LT
JUMP-LMB
BAY-RBT
PEND-NP(med)
SULL-BURB
PEND-SMB
PRIEST-SMB
PEND-NP(lg)


Total PCBs vs. NTR
Concentration/HH Ratio
3
2
1
0
JUMP-YP
PEPP-LMB
STJOE-CTT
STWN-RBT
BAY-RBT
SWAN-RBT
STJOE-MWF
CEDAR-RBT
ELLEN-RBT
PIER-LMB
LEO-BCRP
STWN-EBT
STWN-LMB
BRWN-CTT
LEO-YP
PRIEST-SMB
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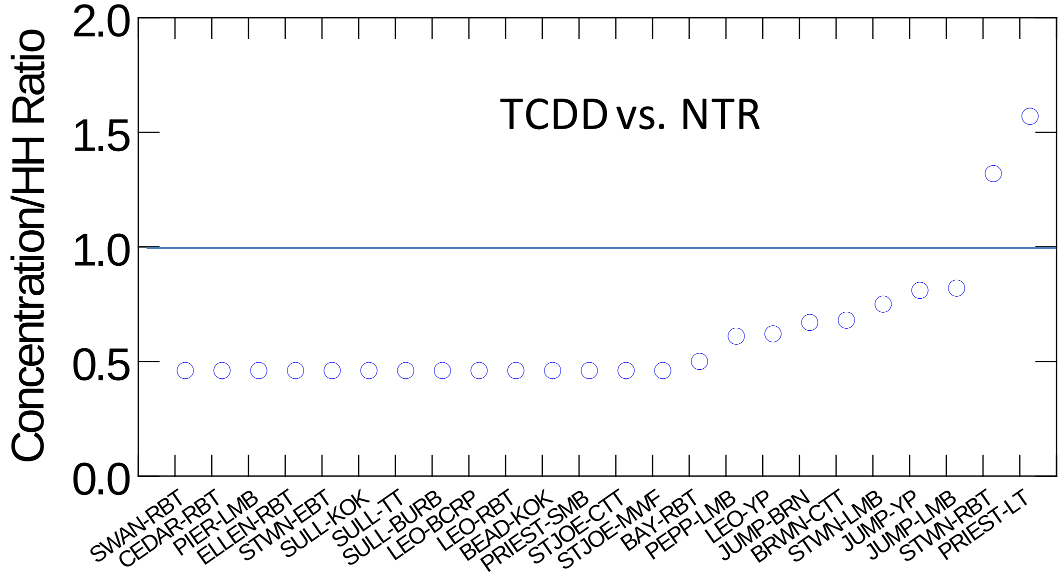
SULL-TT
BEAD-KOK
PRIEST-LT



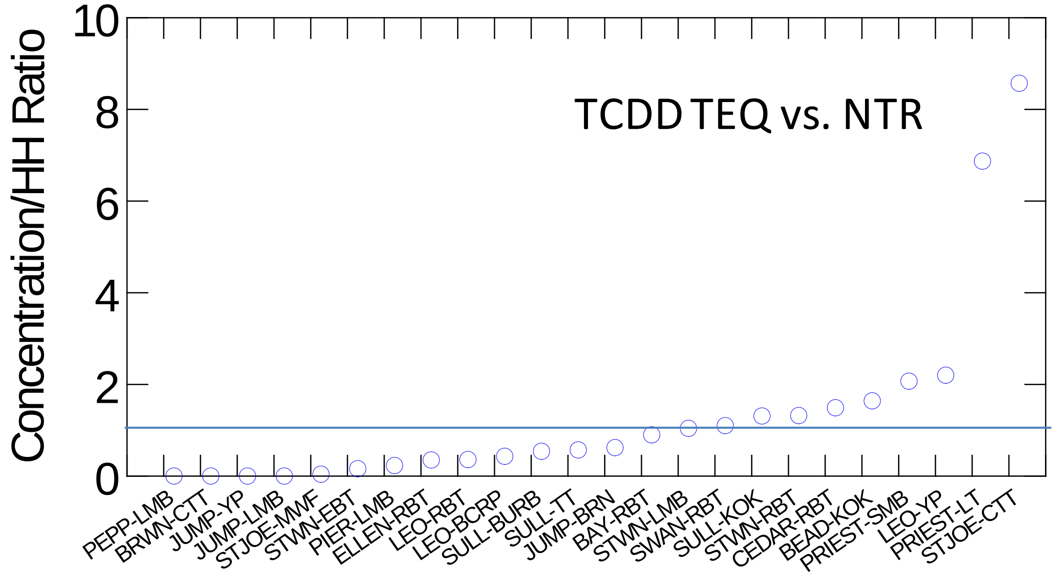


Figure 21. Mercury, PCBs, TCDD, and TCDD TEQs in Fish Fillets from the Northeast Washington Background Study Area Compared to NTR and EPA (2001) Human Health (HH) Criteria.

Ratios > 1 exceed criteria.

Table 38 lists the northeast Washington fish fillet samples that exceeded EPA human health criteria. Exceedances were relatively common for TCDD TEQs, with 38% of samples (68% of waterbodies) having concentrations greater the 0.065 ng/Kg criterion. A similar exceedance frequency of 40% (75% of waterbodies) was found for TCDD TEQs in fish analyzed for Ecology's statewide PCB and dioxin background study (Johnson et al., 2010), illustrating the ubiquitous nature of these contaminants.

Table 38. Fish Fillet Samples from Northeast Washington Study Area Lakes and Rivers that Exceeded Human Health Criteria.

Exceedance factor shown for NTR criteria, except EPA (2001) criteria for mercury

Waterbody	Species	Human Health Criterion Exceeded			
		TCDD TEQ	TCDD	Total PCBs	Mercury
Upper St. Joe River	Cutthroat	8.6	- -	- -	- -
Upper Priest Lake	Lake trout	6.9	1.6	2.9	- -
Leo Lake	Yellow perch	2.2	- -	- -	- -
Upper Priest Lake	Smallmouth bass	2.1	- -	- -	- -
Bead Lake	Kokanee	1.6	- -	- -	- -
Cedar Lake	Rainbow trout	1.5	- -	- -	- -
South Twin Lake	Rainbow trout	1.3	1.3	- -	- -
Sullivan Lake	Kokanee	1.3	- -	- -	- -
Swan Lake	Rainbow trout	1.1	- -	- -	- -
Pend Oreille River	Northern pike - lg	NA	NA	NA	1.6

NA: not analyzed

There were two exceedances for TCDD: Upper Priest lake trout and South Twin rainbow trout. Upper Priest lake trout and the large size class of Pend Oreille River northern pike exceeded for PCBs and for mercury, respectively.

The only instances where a criteria exceedance was by a factor of 2 or more were for TCDD TEQs (Upper St. Joe cutthroat, Upper Priest lake trout and smallmouth bass, and Leo Lake yellow perch) and for total PCBs (Upper Priest lake trout). With the exception of these several TCDD TEQ results and the Upper Priest lake trout sample, nearly all the fish analyzed in the northeast Washington background study were meeting or very close to meeting human health criteria for fish consumption, for the chemicals of interest.

EPA has not established water quality or fish tissue criteria for PBDEs. The California Office of Environmental Health Hazard Assessment recently used an EPA-determined reference dose to develop Fish Contaminant Goals (FCGs) for PBDEs (Klasing and Brodberg, 2011). FCGs are set at levels that are not likely to pose significant health risk to individuals consuming 32 grams/day over a lifetime. The California FCG for total PBDEs is 310,000 ng/Kg, far above any of the concentrations measured during the northeast Washington background study.

Ecological Risk

Chemical criteria to protect fish or their predators and backed by regulatory standing have not been established for whole fish or other fish tissues. However, tissue-based effects literature is available and has been used to derive values, variously referred to as Tissue Residue Effects, Residue Effect Thresholds, or Critical Body Residues (McCarthy et al., 2010). Selected examples of tissue effects concentrations are shown in Table 39 for mercury, PCBs, TCDD, TCDD TEQs, and PBDEs. The intent here is to provide a selection of benchmarks to gauge the margin between current background and levels thought to pose a potential risk to fish populations or their predators. Except for mercury, the margins are large.

Table 39. Examples of Tissue Residue Benchmarks for Effects of Mercury, PCBs, TCDD, TCDD TEQs, and PBDEs on Fish and Fish-eating Wildlife.

Fish				Fish-Eating Wildlife		
Chemical	Whole Body Concentration	Effect	Ref.	Concentration in Diet	Effect	Ref.
Mercury	200 ug/Kg	Protective	1	100 ug/kg	Protective	7
	570 ug/Kg	Reproduction	2	2,000 ug/Kg	Poisoning	8
	12,000 ug/Kg	Mortality	2			
PCBs	140,000 ng/Kg	Toxicity Threshold	3	110,000 ng/Kg	Protective	9
	120,000 ng/Kg*	Effects Threshold	4	160,000 - 240,000 ng/Kg	Effects Thresholds	10,11
TCDD	3 ng/Kg*	Protective	5	3 ng/Kg	Protective	9
TCDD TEQs	23 ng/Kg	Toxicity Threshold	6	17 – 130 ng/Kg	Toxicity Threshold	12,13
PBDEs	NA	NA	--	8,400 ng/Kg (PeBDE)	No Effect Level	14
	--	--	--	120,000 ng/Kg (DecaBDE)	"	14

NA: not available
* @5% lipids

References:
1: Beckvar et al. (2005)
2: McElroy et al. (2011)
3: Orn et al. (1998)
4: Meador et al. (2002)
5: Stevens et al. (2005)
6: MacDonald (2011)
7: Eisler (1987)
8: Thompson (1996)
9: Newell et al. (1987)
10: Delong et al. (2004)
11. Scott (1997)
12: Tillitt et al. (1996)
13: Nosek et al. (1992)
14: Environment Canada (2006)

Lakes-Dominated Background Values for Northeast Washington Fish

Although the data obtained through this project have a variety of possible uses, they were primarily collected in support of water quality- and toxics-based cleanup studies and actions for east and northeast Washington waterbodies.

The Model Toxics Control Act (MTCA) Cleanup Regulation (WAC 173-340) defines natural and area background concentrations as either the true 90th or true 80th percentile, depending on whether the data are distributed lognormally or normally. Background cleanup standards are constrained to no greater than four times the 50th percentile to address the possible significant increase in exposures and human health risks at 90th or 80th percentiles. Statistical approaches and considerations for determining a representative background concentration for soil and groundwater are described in the Cleanup Regulation and in Blakley et al. (1992).

The MTCA*Stat*97 Background Module (BCKGD97.xlt) was used to evaluate data distribution and calculate percentiles (www.ecy.wa.gov/programs/tcp/tools/toolmain.html) for sediment samples collected for the northeast Washington background study (Johnson et al., 2011). Because the data for the fish tissue component were derived from a wide range of species that differed among waterbodies, it was judged more appropriate to recommend background values based on the 90th percentile from simple ranks of the data, as was done in earlier sections of this report. These values have been summarized in Table 40. The Upper Priest lake trout results were excluded from statistics for organic compounds, for reasons previously discussed. Similar background values for whole fish can be found in Tables 27 and 29 but are based on a sample size of only four or five.

Certain of the WSTMP fish fillet data from 2009 and 2008 are pertinent to objectives of the northeast Washington background study, as highlighted previously in Table 33. These results were folded into the calculation of background concentrations for northeast Washington fish. In instances where the same species were analyzed from a given lake, the results were averaged. The average of the mercury concentrations that Meredith et al. (2010) reports for smallmouth bass in Pierre Lake, mentioned earlier, was also included in the background determinations.

Percentiles and other statistics for totaled organic compounds (such as total PCBs) were calculated in two ways: (1) using half the method detection limit for non-detects, following MTCA and recent practice of the Ecology Toxics Cleanup Program (Bradley, 2010) and (2) setting non-detects equal to zero, a common convention followed in earlier parts of this report. Being a single compound with an unknown concentration greater than zero, the TCDD background values used the reporting limit rather than zero for non-detects. The half-detection limit approach has a marked effect on the 90th percentiles for PCB TEQs and TCDD due to their low detection frequency, but a negligible effect on total PCBs, TCDD TEQs, and total PBDEs.

The fish tissue background values presented in Table 40 are intended to aid in site evaluations and to improve current understanding of the chemical area or natural background in northeast Washington aquatic environments. Users of these data should keep two important caveats in mind: (1) Species, feeding behavior, and age can significantly affect the types and levels of chemical residues retained by fish. Species-specific or even age-specific background data may be required in some cases. (2) The geochemical, biological, contaminant cycling, and hydraulic conditions and processes within river environments differ from those encountered in upland lakes. The current study sampled primarily lakes and, to a lesser degree, rivers for mercury, with the organics data being mostly from lake environments.

Table 40. Potential Lakes-Dominated Background Values (bold font) for Edible Fish Tissue in Northeast Washington.

Mercury in ug/Kg; organics in ng/Kg; wet weight.

Parameter	N =	90th percentile	Median	Mean	Minimum	Maximum
Mercury (all species)	34	**226**	79	107	18	282
" (salmonids)	20	**110**	50	70	18	214
" (spiny-rays)	15	**252**	193	157	29	282
Total PCBs (nd = 0)	23	**3,817**	775	1,408	73	4,624
Total PCBs (nd = 1/2 DL)	23	**3,833**	898	1,423	99	4,644
PCB TEQs (nd = 0)	23	**0.011**	0.004	0.009	0.0004	0.11
PCB TEQs (nd = 1/2 DL)	23	**0.70**	0.021	0.033	0.009	0.13
TCDD (nd = DL)	23	**0.050**	≤ 0.03	0.037	≤ 0.03	0.086
TCDD (nd = 1/2 DL)	23	**0.029**	0.014	0.02	0.005	0.086
TCDD TEQs (nd = 0)	25	**0.14**	0.040	0.079	0	0.56
TCDD TEQs (nd = 1/2 DL)	23	**0.15**	0.057	0.096	0.020	0.57
Total PBDEs (nd = 0)	23	**1,731**	765	887	70	2,956
Total PBDEs (nd = 1/2 DL)	23	**1,736**	771	895	81	2,965
Percent lipids (all species)	34	**3.7**	0.90	1.6	0.09	8.8
" (salmonids)	20	**4.8**	1.5	2.4	0.39	8.8
" (spiny-rays)	14	**0.90**	0.33	0.44	0.09	0.97

With consideration of the cautionary statements presented above, Ecology believes that the fish samples obtained in this study provide a generally representative area or natural background data set for a mixed species assemblage for this portion of northeast Washington. Resource managers and decision makers who are involved with fish tissue assessments and associated cleanups for east and northeast Washington waterbodies may find these background data useful for a variety of project needs. The data from this study are available through Ecology's Environmental Information Management System (EIM) for those wanting to analyze it in other ways (www.ecy.wa.gov/science/data.html).

Background Values Applied to Spokane River

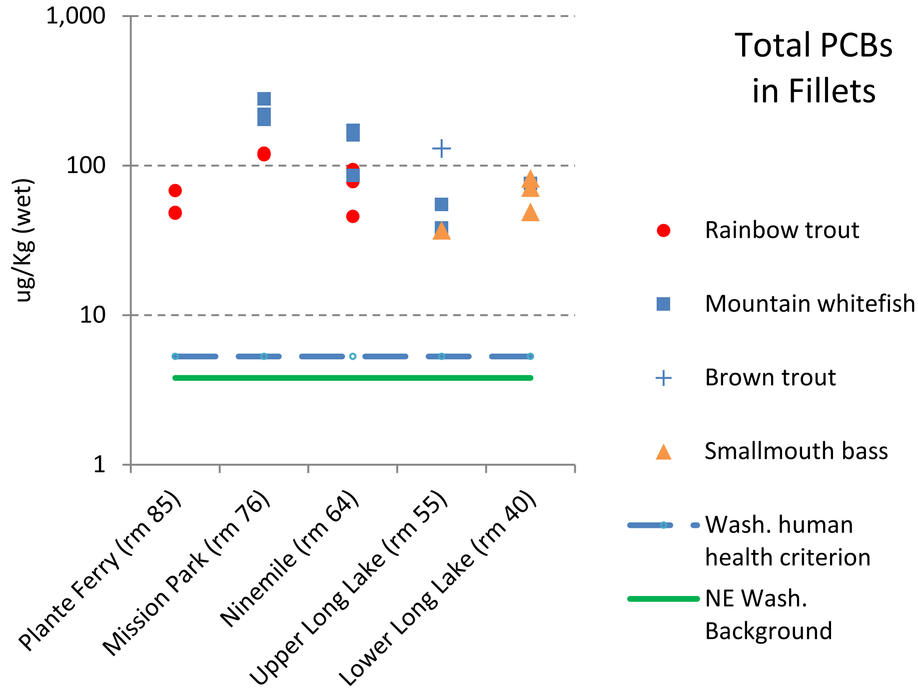
The Spokane River is associated with the most populated county in northeast Washington and site of extensive study for TMDLs. The background values developed in this study were applied to Spokane River fish tissue data to provide a perspective on implications for their use in water quality cleanup scenarios.

As noted at the beginning of this report, the Spokane River has significant toxics issues with respect to PCBs, PBDEs, cadmium, lead, and zinc. The most recent comprehensive data for these chemicals in Spokane River fish is from 2005 (Serdar and Johnson, 2006). Data were obtained on sportfish fillets and whole largescale suckers collected from six sites between the state line and Lake Spokane, the 25 mile-long lower river reservoir formerly known as Long Lake. PCB and PBDE concentrations generally increase from the state line to the city of Spokane and then decrease further downstream into Lake Spokane. The major sources are known or assumed to be located in the Spokane urban area. Metals contamination of the river is due to historic mining and milling operations in Idaho. The highest cadmium, lead, and zinc concentrations are found near the state line and decrease going downstream.

Mercury is not known to be a significant water quality concern for the Spokane River. For example, trend and toxics monitoring of largemouth and smallmouth bass demonstrate that mercury concentrations in fillets consistently exhibit 90th percentile values less than 100 ug/Kg (Jack and Rose, 2002; Seiders, 2003; Furl et al., 2007). The lower Spokane River does have two 303(d) listings for TCDD, but these are based on marginal exceedances of the human health criterion in one each rainbow trout and mountain whitefish fillet samples (0.096 and 0.083 vs. 0.07 ng/Kg, respectively; Seiders et al., 2007).

The 2005 Spokane River fish tissue data on PCBs, PBDEs, cadmium, lead, and zinc are plotted in Figures 22 (fillets) and 23/24 (whole fish) and compared to the 90th percentile background values from the present study (from Tables 27, 29, and 40). Note that for PCBs and PBDEs, a log scale is used (factors of 10) due to the wide range in concentrations and that the units are in ug/Kg (parts per billion) rather than ng/Kg.

As shown in these figures, PCB and PBDE concentrations in Spokane River fish are elevated above natural background by one to three orders of magnitude for the length of the river in Washington. Cadmium, lead, and zinc are elevated in upper river whole fish by factors of about 2, 10, and 4, respectively. All three metals decline to levels at or near background by lower Lake Spokane, giving validation to these background values as applied to the Spokane River system.



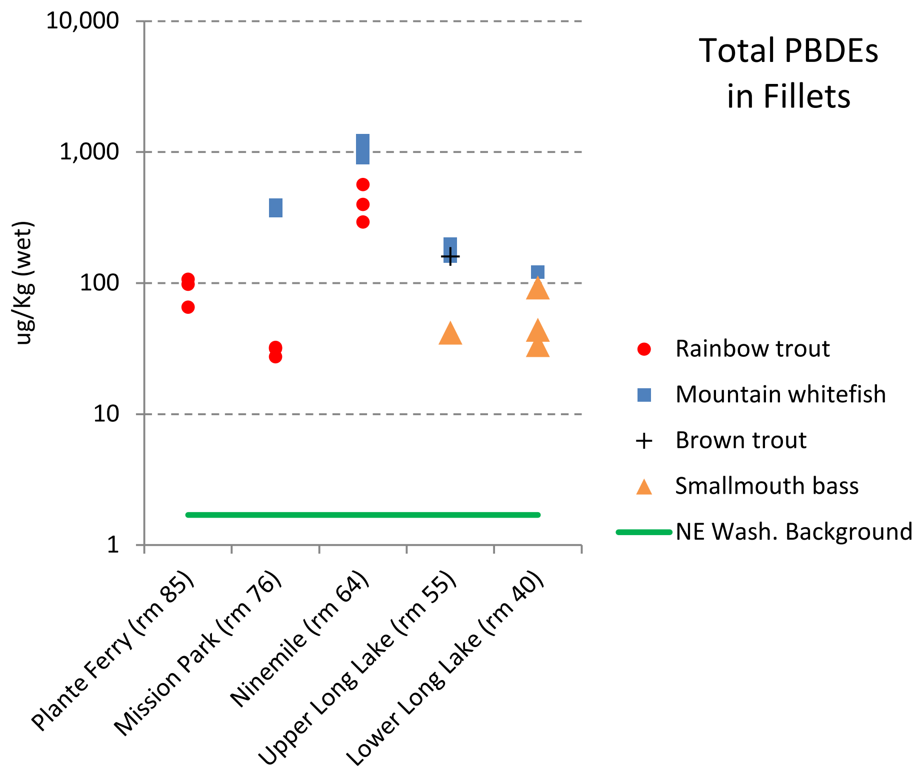
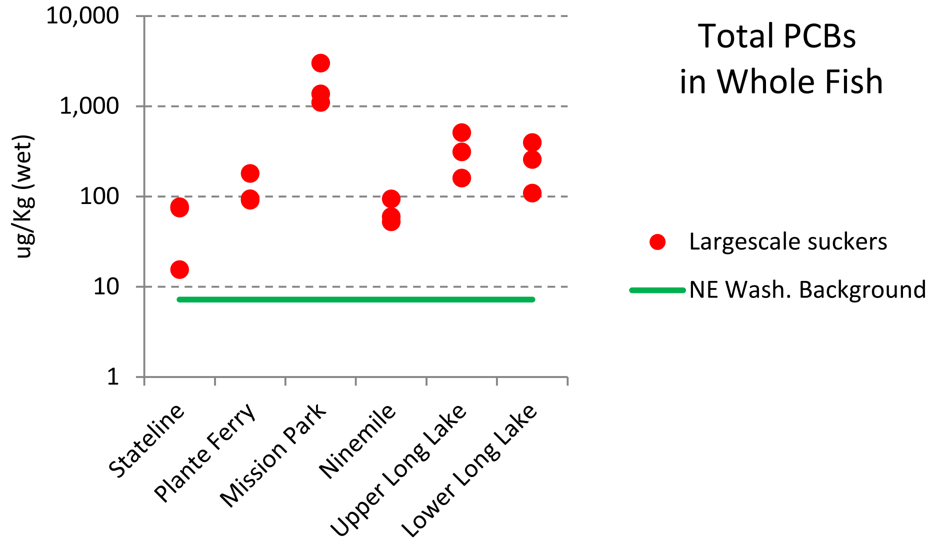


Figure 22. PCB and PBDE Concentrations in Spokane River Fish Fillets Collected in 2005 Compared to Northeast Washington Background (90th percentile from present study).

(Composite samples of five fish each.)



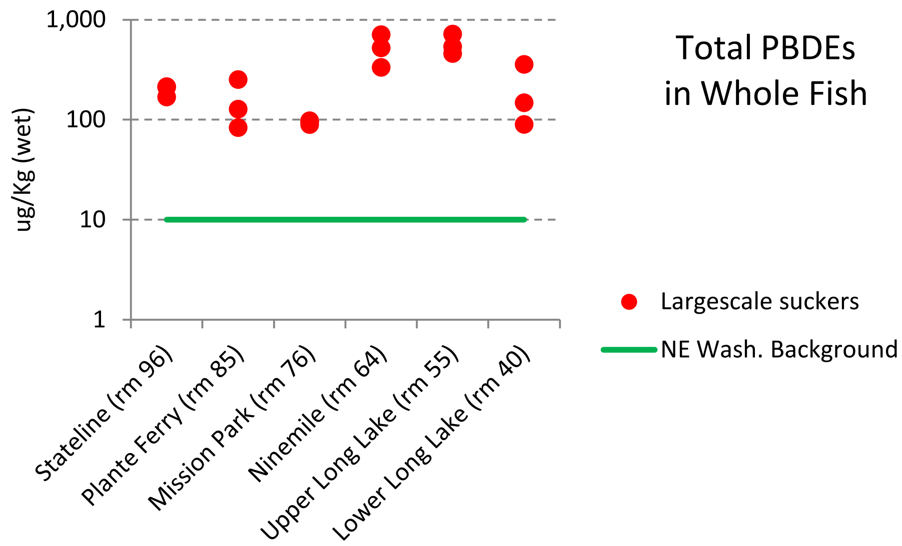
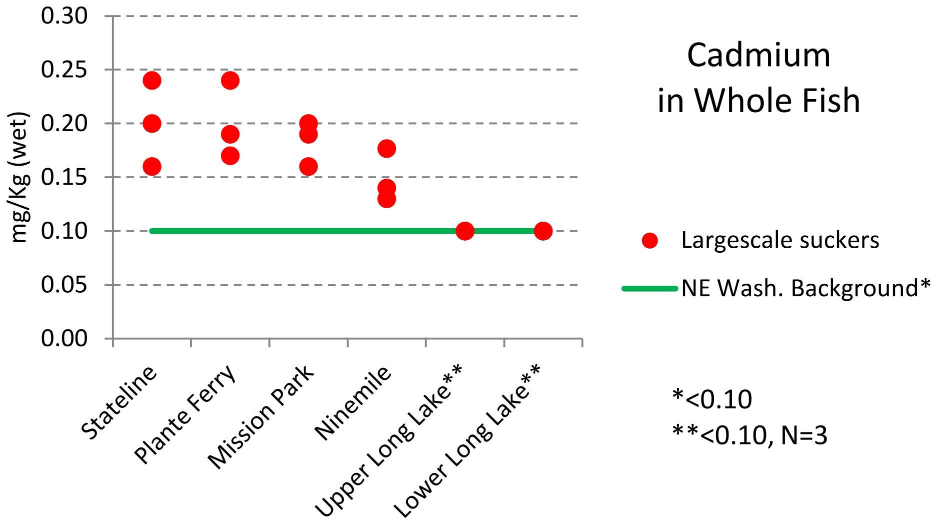
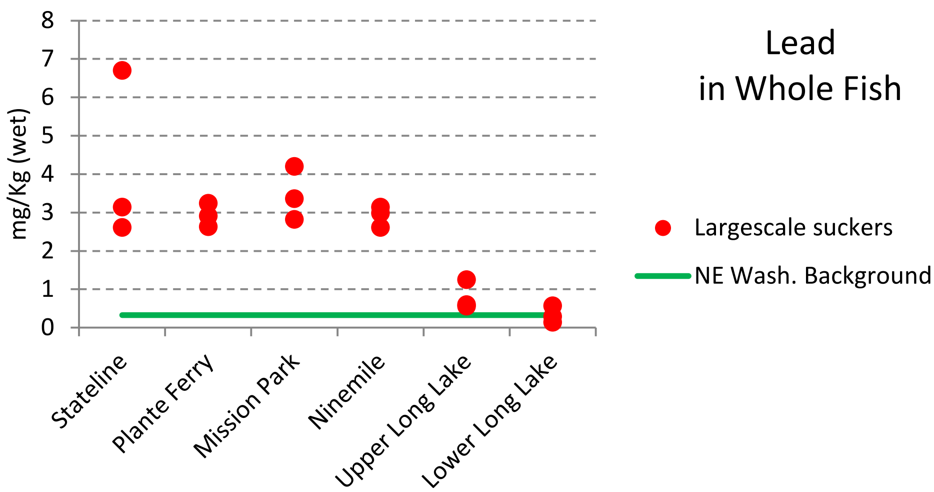


Figure 23. PCB and PBDE Concentrations in Spokane River Whole Largescale Suckers Collected in 2005 Compared to Northeast Washington Background (90th percentile from present study).

(Composite samples of five fish each.)





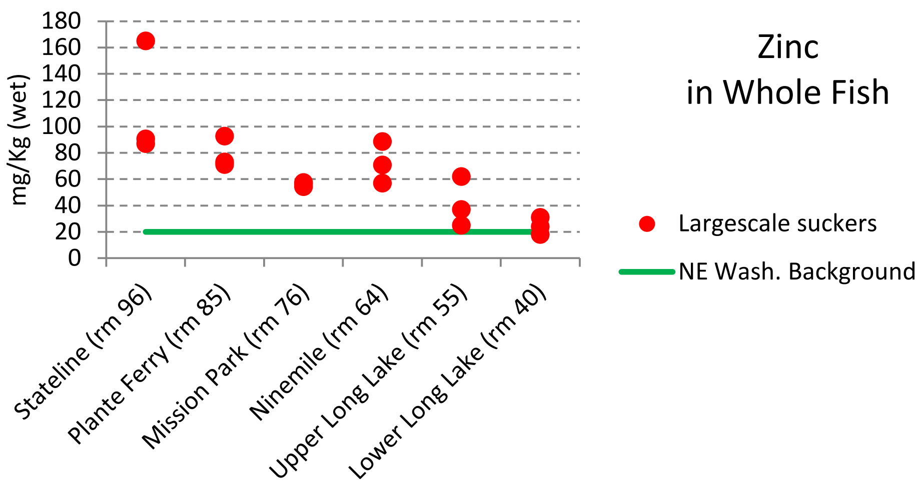


Figure 24. Cadmium, Lead, and Zinc Concentrations in Spokane River Whole Largescale Suckers Collected in 2005 Compared to Northeast Washington Background (90th percentile from present study). (*Composite samples of five fish each.*)

Table 41 provides a perspective on the magnitude of water quality improvements required to reduce the level of chemical contamination in Spokane River fish (based on 2005 data) to background levels estimated from the northeast Washington data. The reductions estimated as being needed are based on the average concentration (all species) in the most contaminated reach of the upper Spokane River and in Lake Spokane (data for upper and lower lake pooled).

Table 41. Estimates of Water Quality Improvements Needed to Reduce Chemical Contaminants in Spokane River Fish, Based on 2005 Data and Northeast Washington Background Estimates.

Contaminant	Sample Type	Reduction Required for Cleanup to Background		
		Mission Park		**Lake Spokane***
PCBs	Fillet	98%		94%
	Whole fish	99.6%		98%
		Ninemile		**Lake Spokane***
PBDEs	Fillet	99.8%		99%
	Whole fish	98%		97%
		Stateline - Ninemile		**Lake Spokane***
Cadmium	Whole fish	45%		0%
Lead		90%		42%
Zinc		75%		39%

*pooled data for upper and lower lake

The level of chemical contamination in the Spokane River has been decreasing over time due to cleanups, source controls, and natural attenuation (Serdar et al., 2011; Furl and Meredith, 2010; Ecology, 2009; Hopkins and Johnson, 1997; Pelletier, 1994). Water quality improvements needed to protect human health and aquatic life would likely be of a lesser extent now than was the case in 2005.

Conclusions and Recommendations

Conclusions

Background concentrations of potentially toxic metals and organic compounds have been characterized for fish tissue in northeast Washington, based on sampling 16 waterbodies, primarily lakes, including one lake and one river in Idaho. The waterbodies selected for sampling were judged to be minimally impacted by human activities, based on available records. Comparison with other data on Washington freshwater fish, EPA human health criteria, and ecological benchmarks suggests the levels of chemical contaminants measured in the majority of fish species are representative of natural background.

The companion sediment quality investigation for this project documented metals background concentrations and impacts in lakes from the western part of the study area along the Columbia River, attributed primarily to historical, regional smelter air pollution. The evaluation of fish tissue in the present study did not identify spatial relationships as observed in sediments, nor correlations between fish and sediments. Patterns that may exist can be obscured by sampling limitations or differences in fish species, ages, and sizes analyzed among waterbodies.

Recommendations

1. The Table 40 background values for mercury and organic compounds in edible tissues of northeast Washington fish represent appropriate supporting data for application at cleanup sites, screening contaminant data, and other applications. Data users should be cognizant of the potential for differences in chemical uptake among fish species and in lake vs. riverine environments, as well as the increased bioaccumulation potential of larger and older fish. Tables 27 and 29 present values for whole fish (suckers), but are based on a limited number of samples.

2. The Kalispel Tribe is further analyzing organic compounds in subsamples of the Pend Oreille River (upstream of Box Canyon Dam) fish fillets from the present study. The Tribe anticipates sharing these results with Ecology and the Washington State Department of Health. Review by the Washington State Department of Health is recommended.

3. Results of this study should be provided to Idaho resource agencies and Idaho Department of Health and Welfare due to new edible fish tissue data for Priest Lake (lake trout findings in particular) and the Upper St. Joe River.

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Appendices

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Appendix A. Chemical Data on Sediment Samples Analyzed for the Northeast Washington Lakes Background Study, 2010

Table A-1. Summary of Results for Metals Analyzed in Sediment Samples (mg/Kg, dry weight; parts per million).

Waterbody	Sb		Pb		Cd		As		Hg		Zn		Cu		Cr	Ba		Mn	Fe	% Fines
Swan Lake	0.68		53		1.1		8.1		0.197		78		24		8.9	115		410	15,900	58
Cedar Lake	3.4		141		3.0		12		0.075		151		13		3.8	182		270	6,120	100
Pepoon Lake	1.6		59		1.5		7.1		0.052		46		11		5.8	90		73	2,780	41
Summit Lake	0.70		27		0.77		8.0		0.099		20		8.1		19	32		228	2,940	47
Pierre Lake	0.73		41		1.4		14		0.133		76		77		53	83		69	19,300	79
Williams Lake	4.2	J	190	J	6.2		28	J	0.157		215	J	26	J	15	109	J	180	11,600	58
Davis Lake	1.6		63		1.5		10		0.208		62		11		7.5	79		225	19,900	50
Ellen Lake	1.2		89		2.3		11		0.202		104		23		8.7	96		289	16,500	40
S. Twin Lake	0.67		56		1.2		11		0.126		71		20		13	112		885	35,700	43
Sullivan Lake	0.03	J	9.9		0.24		4.5		0.031		63		23		15	111		243	23,500	54
Leo Lake	0.09	J	18		0.54		3.2		0.079		59		16		15	84		324	16,300	81
Browns Lake	0.07	J	21		0.51		4.6		0.060		62		17		12	83		103	11,300	71
Bayley Lake	0.13		14		0.58		3.7		0.103		50		22		9.5	140		475	14,000	58
Bead Lake	0.03		24		0.44		6.1		0.042		79		19		13	98		208	17,100	74
Upper Priest Lake	0.02	J	27		0.65		6.1		0.082		117		27		21	333		3,010	43,500	80
St. Joe River	0.03	J	2.3		0.05	U	3.2		0.007	U	19		14		8.6	42		146	16,700	9

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.

Table A-2. Summary of Results for Organic Compounds Analyzed in Sediment Samples (ng/Kg, dry weight; parts per trillion).

Waterbody	Total PCBs		PCB TEQs		TCDD		TCDD TEQs		Total PBDEs	% TOC
Swan Lake	2,416		0.007		0.22		2.0		853	18
Cedar Lake	264		0.001		0.11		0.55		541	16
Pepoon Lake	298		0.001		0.063	U	0.21		101	17
Summit Lake	1,766		0.005		0.23	NJ	1.9		795	13
Pierre Lake	2,583		0.008		0.095	U	3.0		526	13
Williams Lake	8,335		0.43		0.10	U	3.9		685	16
Davis Lake	2,687		0.005		0.56	NJ	2.7		1,946	24
Ellen Lake	4,794		0.013		0.53	NJ	3.8		1,338	19
S. Twin Lake	4,367		0.013		0.45	NJ	5.0		240	14
Sullivan Lake	112		0.000		0.053	NJ	0.20		126	3.5
Leo Lake	3,785		0.016		0.057	UJ	5.3		612	14
Browns Lake	2,843		0.012		0.038	U	0.78		1,190	6.6
Bayley Lake	478		0.002		0.051	U	1.5		1,288	22
Bead Lake	2,243		0.008		0.098		2.6		304	6.8
Upper Priest Lake	281		0		0.042	UJ	0.55		273	4.2
St. Joe R.	3		0		0.032	NJ	0.11		149	1.1

U: The analyte was not detected above the reported quantitation limit.
J: The analyte was positively identified; the associated numerical value is the approximate concentration.
NJ: The analyte has been "tentatively identified"; the associated numerical value is the approximate concentration.
UJ: The analyte was not detected above the reported sample quantitation limit.

Appendix B. Length and Weight Data for Fish Samples Collected in 2010 and 2011 for the Northeast Washington Lakes Background Study

Appendix B-1. Length and Weight Data for Fish Samples Collected in 2010.

Waterbody	Species	Date	Collector	Sample No. 1102018-	Length (mm)	Weight (gm)
Swan Lake	Rainbow trout	11-Oct-10	Colvilles	1	300	248
					309	260
					254	175
					252	150
Pierre Lake	Largemouth bass	"	"	5	300	378
					276	313
					280	306
Ellen Lake	Rainbow trout	"	"	8	262	156
					210	89
South Twin Lake	Rainbow trout	21-Oct-10	"	11	340	379
					286	213
South Twin Lake	Eastern brook trout	"	"	12	402	756
					405	713
					365	658
					350	561
					376	567
South Twin Lake	Largemouth bass	"	"	13/36/38	391	974
					390	887
					376	828
					295	353
					300	400
Cedar Lake	Rainbow trout	18-Oct-10	Ecology	14/37	349	395
					336	361
					314	359
					313	325
					300	318
Sullivan Lake	Kokanee	20-Oct-10	"	15	291	214
					290	212
					279	210
					284	210
					279	208
Sullivan Lake	Largescale sucker	"	"	16	338	399
					304	316
					321	306

Waterbody	Species	Date	Collector	Sample No. 1102018-	Length (mm)	Weight (gm)
					302	254
					292	246
Sullivan Lake	Tiger trout	"	"	39	317	352
					373	530
					390	522
					423	756
Sullivan Lake	Burbot	"	"	17	612	1437
					605	1408
					556	1278
Leo Lake	Black crappie	19-Oct-10	"	19	228	169
					217	146
					216	145
					221	143
					210	130
					204	123
Leo Lake	Rainbow trout	"	"	20	282	214
					266	203
Leo Lake	Yellow perch	"	"	21/33*	233	131
					226	117
					210	100
					190	66
					191	61
					174	54
					169	54
					171	50
					162	46
					159	45
Browns Lake	Cutthroat	6-Oct-10	"	23	301	246
					313	253
					308	280
					315	314
					279	216
Bayley Lake	Rainbow trout	5-Oct-10	"	22/34/35	492	1364
					496	1179
					478	1077
					447	920
					432	876
Bead Lake	Largescale sucker	7-Oct-10	"	24	397	593
					335	350
					355	419

Waterbody	Species	Date	Collector	Sample No. 1102018-	Length (mm)	Weight (gm)
Upper St. Joe River	Cutthroat	28-Aug-10	"	27	315	294
					284	200
					263	168
					260	157
					254	144
Upper St. Joe River	Mountain whitefish	"	"	28	342	391
					310	350
					325	338
					310	327
Upper Priest Lake	Lake trout	1-Oct-10	Idaho F&G	29	610	- -
					570	- -
					520	- -
					580	- -
					692	- -
Upper Priest Lake	Smallmouth bass	"	"	30	363	- -
					400	- -
					400	- -
					410	- -
					330	- -
Upper Priest Lake	Largescale sucker	"	"	31	471	1123
					431	927
					466	1284
					524	1808
					441	821

Table B-2. Length and Weight Data for Fish Samples Collected in 2011.

Waterbody	Species	Date	Collector	Sample No. 1106039-	Length (mm)	Weight (gm)
Pepoon Lake	Largemouth bass -sm	23-May-11	Ecology	-1	54	156
					54	165
					57	159
Pepoon Lake	Largemouth bass -lg	"	"	-2	223	348
					200	152
Pepoon Lake	Largemouth bass	"	"	-3	54	156
					54	165
					57	159
					223	348
					200	152
Colville River	Rainbow trout	10-May-11	"	-4	269	193
					245	150
					260	162
					326	212
Colville River	Largescale sucker	"	"	-5	412	907
					450	1210
Bead Lake	Kokanee	11-May-11	"	-6	263	150
					263	149
					254	141
					260	149
					255	139
Jumpoff Joe Lake	Yellow perch	10-May-11	"	-7	195	81
					176	56
					165	45
					170	57
					175	62
					156	42
Jumpoff Joe Lake	Brown trout	"	"	-8	428	808
					363	460
					390	565
					364	485
					359	456
Jumpoff Joe Lake	Largemouth bass	"	"	-9	485	2330
					440	1560
Pend Oreille River	Smallmouth bass	17-May-11	Kalispell	-10	251	193
					269	240
					285	277
					380	710

Waterbody	Species	Date	Collector	Sample No. 1106039-	Length (mm)	Weight (gm)
Pend Oreille River	Brown trout	"	"	-11	401	800
					363	640
					422	840
					394	723
					446	824
Pend Oreille River	Largescale sucker	"	"	-12	500	1389
					545	1957
					460	915
					556	2280
					490	1419
Pend Oreille River	Northern pike - sm	"	"	-13	480	737
					466	643
					504	846
					452	597
					490	710
Pend Oreille River	Northern pike - med	"	"	-14	606	1340
					595	1321
					600	1403
					681	1976
					560	1178
Pend Oreille River	Northern pike - lg	"	"	-15	930	5700
					975	6300

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Appendix C. Summary of Chemical Data on Fish Fillet Samples Analyzed for the Northeast Washington Lakes Background Study

Table C-1. 2010 Fillet Samples (ng/Kg, except ug/Kg for mercury; wet weight basis).

Waterbody	Species	Sample No. 1102018-	Mercury		Total PCBs		PCB TEQs		TCDD		TCDD TEQ		Total PBDEs		% Lipids
Swan Lake	Rainbow trout	1	0.0822		718		0.0023		0.03	UJ	0.0718		1,076		0.8
Cedar Lake	Rainbow trout	14	0.0193		792		0.0038		0.03	UJ	0.097		112		1.6
"	Rainbow trout - duplicate	37	0.0172	J	660		0.0035		0.0535	UJ	0.13439		27		1.4
Pierre Lake	Largemouth bass	5	0.108		763		0.0036		0.03	UJ	0.0147		873		0.9
Ellen Lake	Rainbow trout	8	0.0318		760		0.0027		0.03	UJ	0.0228		1,871		0.4
South Twin Lake	Rainbow trout	11	0.0307		417		0.0016		0.086	NJ	0.086		332		0.39
South Twin Lake	Eastern brook trout	12	0.0512		887		0.0039		0.03	UJ	0.0104		765		0.69
South Twin Lake	Largemouth bass	13	0.173		950		0.0033		0.1253	UJ	0.11188		528		1.6
"	Largemouth bass-dup.	36	0.145		1,259		0.0036		0.049	NJ	0.0676996		530		1.1
Sullivan Lake	Kokanee	15	0.0459		4,295		0.0064		0.03	UJ	0.0851		2,528		1.4
Sullivan Lake	Tiger trout	39	0.0992		4,592		0.11		0.03	UJ	0.0368047		1,072		3.4
Sullivan Lake	Burbot	17	0.245		1,765		0.0032		0.03	NJ	0.0349		977		0.29
Leo Lake	Black crappie	19	0.186		775		0.0044		0.03	UJ	0.0282107		180		0.2
Leo Lake	Rainbow trout	20	0.0471		1,791		0.0112		0.03	UJ	0.0235		521		0.39
Leo Lake	Yellow perch	21	0.0936		1,494		0.0089		0.0403	UJ	0.1427786		342		0.10
Browns Lake	Cutthroat	23	0.0698		1,239		0.0062		0.0442	UJ	0		568		2.4
Bayley Lake	Rainbow trout	22	0.214		470		0.0020		0.0324	UJ	0.0583		1,083		2.3
Upper Priest Lake	Lake trout	29	0.211		15,311		1.4		0.102	NJ	0.44627		15,995		6.5
Upper Priest Lake	Smallmouth bass	30	0.282		1,586		0.0056		0.03	UJ	0.134636		1,001		0.89
Upper St. Joe River	Cutthroat	27	0.0371		252		0.0010		0.03	UJ	0.5572789		162		1.7
Upper St. Joe River	Mountain whitefish	28	0.0500		723		0.0029		0.03	UJ	0.0027683		686		4.6

U: The analyte was not detected at or above the reported result. J: Estimated value.
UJ: The analyte was not detected above the reported estimated quantitation limit.
NJ: The analyte has been tentatively identified; the associated numerical value is the approximate concentration.

Table C-2. 2011 Fillet Samples (ng/Kg, except ug/Kg for mercury; wet weight basis)

Waterbody	Species	Sample No. 1106039-	Mercury		Total PCBs		PCB TEQs		TCDD		TCDD TEQs		Total PBDEs		% Lipids
Pepoon L	Largemouth bass - sm	-1	0.0568		na		na		na		na		na		0.30
Pepoon L	Largemouth bass - lg	-2	0.0554		na		na		na		na		na		0.59
Pepoon L	Largemouth bass - sm+lg	-3	na		81		0.0004		0.0394	UJ	0		504		0.45
Colville R	Rainbow trout	-4	0.0332		na		na		na		na		na		1.6
Bead L	Kokanee	-6	0.040		4706		0.016		0.0906	UJ	0.1647		2976		8.8
Bead L	Kokanee-duplicate	-6	na		4541		0.014		0.03	UJ	0.04786		2935		na
Jumpoff Joe L	Yellow perch	-7	0.0287		73		0.001		0.0528	UJ	0		97		0.10
Jumpoff Joe L	Brown trout	-8	0.0239	U	1903		0.006		0.0433	UJ	0.04		1175		2.5
Jumpoff Joe L	Largemouth bass	-9	0.211		1689		0.008		0.0531	UJ	0		1026		0.74
Pend Oreille R	Smallmouth bass	-10	0.256		na		na		na		na		na		0.30
Pend Oreille R	Brown trout	-11	0.0935		na		na		na		na		na		3.9
Pend Oreille R	Northern pike - sm	-13	0.177		na		na		na		na		na		0.29
Pend Oreille R	Northern pike - med	-14	0.217		na		na		na		na		na		0.19
Pend Oreille R	Northern pike - lg	-15	0.484		na		na		na		na		na		3.2

na: not analyzed.
U: The analyte was not detected at or above the reported result.
UJ: The analyte was not detected above the reported sample quantitation limit.

Appendix D. Human and Mammalian Toxic Equivalency Factors for Dioxins, Furans, and PCBs

Compound	WHO 2005 TEF*
Chlorinated Dibenzo-p-dioxins	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0003
Chlorinated Dibenzofurans	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-PeCDF	0.3
1,2,3,4,6,7,8-HpCDF	0.1
1,2,3,4,7,8,9-HpCDF	0.1
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.01
2,3,4,6,7,8-HxCDF	0.01
OCDF	0.0003
Non-ortho substituted PCBs	
PCB-77	0.0001
PCB-81	0.0003
PCB-126	0.1
PCB-169	0.03
Mono-ortho substituted PCBs	
PCB-105	0.00003
PCB-114	0.00003
PCB-118	0.00003
PCB-123	0.00003
PCB-156	0.00003
PCB-157	0.00003
PCB-167	0.00003
PCB-189	0.00003

*Van den Berg, M., L.S. Birnbaum, M. Denison et al., 2006. The 2005 World Health Organization Re-Evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds. Toxicological Sciences 93: 223 - 241.

Appendix E. Ecology WSTMP Data on Metals Concentrations in Fish Fillet Samples from Background Lakes in the Northeast Washington Study Area

(ng/Kg, except ug/Kg for mercury; wet weight basis)

Lake:	Amber		Black		Leo		Leo		Leo		Pierre		Upper Twin		Upper Twin	
Species:	Rainbow trout		Tiger trout		Yellow perch		Pumpkin-seed		Black crappie		Smallmouth bass		Rainbow trout		Yellow perch	
Collection Date:	10/15/09		9/30/09		10/1/09		10/1/09		10/1/09		9/29/09		10/14/09		10/14/09	
Aluminum	5.1	U	5.1	U	5	U	5	U	4.9	U	5	U	5.1	U	5.1	U
Antimony	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U
Arsenic	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U
Beryllium	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U
Cadmium	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U
Chromium	0.58		0.74		2.15		0.52		0.5	U	0.89		1.89		2.86	
Copper	1		0.71		0.42		0.97		0.37		2.18		0.4		1.92	
Lead	0.13		0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U
Mercury	90		75		80		79		200		202		62		57	
Nickel	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1		0.1	U	0.1	U
Selenium	0.51	U	0.51	U	0.5	U	0.5	U	0.49	U	0.56		0.51	U	0.51	U
Silver	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	UJ	0.1	U	0.1	U
Titanium	1.7		0.933	J	1.73		2.08		3.14		1.11	J	3.99		4.44	
Vanadium	0.51	U	0.51	U	0.5	U	0.5	U	0.49	U	0.5	U	0.51	U	0.51	U
Zinc	5.1	U	5.4		9.0		15.4		9.0		6.9		5.3		8.4	

U: The analyte was not detected at or above the reported result.
J: The analyte was positively identified. The associated
UJ: The analyte was not detected at or above the reported estimated result.

Appendix F. Glossary, Acronyms, and Abbreviations

Glossary

Anthropogenic: Human-caused.

Area background: Concentrations of substances that are consistently present in the environment in the vicinity of a site and which are the result of human activities unrelated to releases from that site.

Background site: A waterbody thought to exhibit relatively low impact from human activities. Reference site.

Benthic: Bottom-dwelling organisms.

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

Congener: One of many variants or configurations of a common chemical structure. For example, the PCBs analysis includes 209 individual compounds or congeners.

Fingerprint: A multi-parameter chemical signature (distinctive chemical pattern) used to characterize the source of contaminants in an environmental sample or to differentiate the sample from contaminants present in samples representing background conditions.

Grab sample: A discrete sample from a single point in the water column or sediment surface.

Natural background: The concentration of a constituent that occurs naturally in the environment and has not been influenced by localized human activities.

Outlier: A number that deviates markedly from other numbers in a sample population.

Percent fines: Sediment texture.

Point source: Source of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Sediment: Solid fragmented material (soil and organic matter) that is transported and deposited by water and covered with water (for example, river or lake bottom).

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from not meeting (exceeding) water quality standards.

Acronyms and Abbreviations

BC	British Columbia, Canada
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
ERO	Eastern Regional Office (Department of Ecology)

GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
MTCA	Model Toxics Control Act
NTR	National Toxics Rule
PBDEs	polybrominated diphenyl ethers
PBT	persistent, bioaccumulative, and toxic substance
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzodioxins
PCDFs	polychlorinated dibenzofurans
RPD	relative percent difference
SOP	standard operating procedures
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEQ	toxic equivalent
TMDL	(See Glossary above)
TOC	total organic carbon
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish & Wildlife
WDOH	Washington State Department of Health
WRIA	Water Resource Inventory Area

Metals

As	arsenic
Cd	cadmium
Cu	copper
Hg	mercury
Mn	manganese
Pb	lead
Sb	antimony
Zn	zinc

Units of Measurement

ft	feet
km	kilometer, a unit of length equal to 1,000 meters.
m	meter
mg/Kg	milligrams per kilogram (parts per million)
mm	millimeters
ng/Kg	nanograms per kilogram (parts per trillion)
ug/Kg	micrograms per kilogram (parts per billion)