

1.0 Introduction

1.1 Report Organization

This report presents the results of an assessment of chemicals in fish and the risk estimates from consuming these fish based on data analysis and conclusions reached by EPA. It is organized into five volumes.

The study results are presented in 10 sections in Volume 1. Sections 1 and 2 describe the study background, methods, and the chemical concentrations in fish tissues. Sections 3,4, and 5 describe risk assessment methods. The risk characterization is presented in Section 6 for all chemicals except lead and radionuclides. Lead and radionuclide risk characterizations are presented in sections 7, and 8, respectively. The fish tissue residues from this study are compared to other fish contaminant studies as well as other food types in Section 9. Uncertainties in this study are presented in Section 10. The discussion of uncertainty includes all aspects of the risk assessment as well as the sections on fish tissue concentrations (Section 2) and the comparisons with other studies (Section 9). The uncertainty section contains additional calculations to show how the characterization of cancer risk and non-cancer hazards would change if different values had been used to estimate exposure or to characterize toxicity. Finally, conclusions for this study are discussed in Section 11.

Volume 2 provides all the chemical data from the results of the study, as well as sex, length and weight of the fish, and other descriptive data on fish collection. Volume 3 is the Field Operations Manager sampler's notebook(s) which provides a record for the collection of samples. Volume 4 is the Quality Assurance Report which includes a review of the field activities, sample preparation, laboratory measurements, quality assurance procedures, system audits, corrective actions, and the data quality assessment. The appendices to this volume contain all the project data including information about the field sampling locations. Volume 5 is the Quality Assurance Project Plan which was prepared in 1996. The Quality Assurance Project Plan contains the documentation for the study design, objectives, methods, and quality control procedures.

1.2 Study Background

After reviewing the results of the EPA 1989 national survey of pollutants in fish (USEPA, 1992a), EPA became concerned about the potential health threat to Native Americans who consume large amounts of fish from the Columbia River Basin. The cause for concern for native peoples in the Columbia River Basin was also raised by the Columbia River Intertribal Fish Commission (CRITFC) and its member tribes⁴.

In order to evaluate the likelihood that tribal people may be exposed to high levels of

⁴All references to "tribes" in this report are only applicable to CRITFC's member tribes: Confederated Tribes of Warm Springs, Yakama Nation, Umatilla Confederated Tribes, Nez Perce Tribe. They are collectively referred to as CRITFC's member tribes.

contaminants in fish tissue EPA, CRITFC and its member tribes designed a study in two phases. The first phase of this study was a fish consumption survey which was completed in 1994 by CRITFC (CRITFC, 1994). The results of this survey documented the importance of fish in the diet and culture of CRITFC's member tribes. The types and amounts of fish that were eaten by the four CRITFC's member tribes were identified. The primary fish that were consumed by CRITFC's member tribes were salmon and trout. The survey also demonstrated that the average daily fish consumption for adults (63.2 g/day) of CRITFC's member tribes was much higher than the national average for adults (6.5 g/day)⁵. This survey accentuated the need to complete a survey of contaminants in fish tissue to provide information on the quality of the fish being consumed by CRITFC's member tribes.

The plans for the fish contaminant survey began with the formation of a multi-agency task force with representatives from EPA, CRITFC, the Yakama Nation, the Umatilla Confederated Tribes, the Nez Perce Tribe, the Warm Springs Tribe, the Washington Departments of Ecology and of Health, the Oregon Departments of Environmental Quality and Health, the US Geological Survey (USGS), and the US Fish and Wildlife Service. A Memorandum of Agreement signed by EPA and CRITFC in 1996 established the basis for the continued interaction of the EPA staff and tribal members to complete the contaminant survey. With the help of members of CRITFC's member tribes as well as state and federal fish hatchery personnel, sample collection took place between 1996 and 1998. Chemical analyses were completed in 1999. The analyses were done by EPA and commercial laboratories.

This study was designed to estimate risks for a specific group of people (CRITFC's member tribes). The CRITFC fish consumption survey combined information from all the member tribes into a single distribution, therefore, the risk estimates in this study do not represent the risks of any specific tribe.

The types of fish, tissue types, and sampling locations were selected by the CRITFC's member tribes. Fish collection locations were selected because they were important to characterizing risks to CRITFC's member tribes. Chemicals were chosen because they were identified in other fish tissue surveys of the Columbia River Basin as well as being common contaminants found in the environment.

This type of sampling is biased with unequal sample sizes and predetermined sample locations rather random. This bias is to be expected when attempting to provide information for individuals or groups based on their preferences. The results of this survey should not be extrapolated to any other fish or fish from other locations.

The exposure assumptions used to estimate risk for CRITFC's member tribes were also predetermined from CRITFC fish consumption survey (CRITFC, 1994). While the study was designed to assess fish which were known to be important to CRITFC's member tribes, it was

⁵The average fish ingestion used by the EPA in risk assessments for the general public was changed from 6.5 g/day to 7.5 g/day in 2000 (USEPA 2000a)

assumed that other people would be concerned about the contaminant levels in fish from the Columbia River Basin. This decision to estimate risks for the general public was determined after the chemical analyses were completed. Thus, the consumption patterns used this assessment for the general public were not specific to people who eat fish from the Columbia River Basin. However, the risk estimates provide a point of departure for discussions of levels of contamination in the fish from this river basin.

The objectives of this study of chemical residues in the fish from the Columbia River Basin were to determine:

- 1) if fish were contaminated with toxic chemicals,
- 2) the difference in chemical concentrations among fish species and study sites, and
- 3) the potential human health risk due to consumption of fish from the Columbia River Basin.

This contaminant survey also provided information on those chemicals which were most likely to be accumulated in fish tissue and therefore pose the greatest risks to people.

1.3 Study Area

The Columbia River Basin dominates more than a dozen ecological regions as it flows 1,950 km from its source, Columbia Lake, located near the crest of the Rocky Mountains in British Columbia, to the Pacific Ocean. The Columbia River drains an area of about 670,800 km² of which about fifteen percent is in Canada. Eleven major tributaries enter the river: Cowlitz, Lewis, Willamette, Deschutes, Snake, Yakima, Spokane, Pend Oreille, Wenatchee, Okanagan, and Kootenay Rivers (Lang and Carriker, 1999). The study was confined to the Columbia Basin below Grand Coulee to the north, the Clearwater River to the east, just below Bonneville Dam to the west and the Willamette River to the south(Figure 1-1).

1.4 Sampling Locations

One hundred and two fishing locations were identified by the Yakama, Nez Perce, Umatilla, and Warm Springs tribal biologists. Due to resource constraints, all of these sampling locations could not be sampled. The study design (Volume 5) presents in detail the process that was used to reduce the number of sampling locations. Initially fishing locations that represented greater than 40% of each CRITFC's member tribes' fishing use for resident and anadromous fish species were identified. The number of fishing locations was further reduced by selecting sampling locations at the base of a watershed to represent the entire watershed (98, 30,101, 96) and limiting the number of sampling locations on the mainstream Columbia River to each of the dam reaches (6, 7,8,9,14). Additional sampling locations (48,49) were added because they were near local pollution sources. Sample location 49 on the Yakima River was also important for rainbow trout spawning (personal communication CRITFC's member tribes). Other sampling locations (3, 21,21b, 62,63) were selected because of the concern for a particular fish species.

The final sampling locations were located on 16 rivers and creeks and the mainstream Columbia (Figure 1-1, Table 1-1). The actual *sampling locations* were variable within a study reach because of the sampling techniques and/or mobility of fish species. To simplify the data analysis, similar *sampling locations* within a study reach were combined to yield one *study site*. The river miles for *sampling locations* are presented in Table 1-1. The latitude and longitude for each *sampling location* is presented in Volume II, Appendix A-2.

Table 1-1. Description, study site, sampling location, and river mile for Columbia River Basin fish sampling 1996-1998. Some of the *sampling locations* (S. Location) are combined into a single site for this study (SS = *study site*). Fish species are also listed. RM = river mile

Waterbody	SS	S. Location	RM	Fish Species
Columbia River below Bonneville Dam	3	3B	39-41	eulachon
Columbia River between Bonneville dam and Dalles dam	6	6C	154-155	white sturgeon
Columbia River between Dalles dam and John Day dam	7	7B,D 7A	203-207 197.5	walleye white sturgeon
Columbia River between John Day dam and McNary dam	8	8B,D,E,F,G,H,I	216-292	largescale sucker, white sturgeon, fall chinook salmon, steelhead trout
Columbia River below confluence with Snake River	9 L	9A,B,C,D	295-304	white sturgeon
Columbia River (Hanford Reach)	9 U	9 E,F,G, H, I, 9 N,O, P, Q	369-372 389-393	largescale sucker, white sturgeon mountain whitefish
Columbia River just below Priest Rapids Dam	14	14 hatchery	396	fall chinook salmon
Wind River	63	63 hatchery	18	spring chinook salmon
Little White Salmon River	62	62 hatchery	1	spring chinook salmon
Fifteen mile Creek	24	24	0.2-0.5	Pacific lamprey
Hood River	25	25	4	steelhead
Willamette Falls	21	21	26.6	Pacific lamprey
MF Willamette River	21B	21B-hatchery	203.6	spring chinook salmon
Deschutes River	98	98 A,B,C,D,E	55-59	mountain whitefish, rainbow trout, largescale sucker
Umatilla River at the mouth	30	30 30A , 30B	3 0-1	spring chinook salmon, coho salmon, fall chinook salmon largescale sucker, walleye,
Umatilla River upper river	101	101,101A	88.5-89.5	mountain whitefish, rainbow trout
Thomas Creek		101B	1.5-2.5	mountain whitefish, rainbow trout
Meacham Creek		101C	2-2.5	rainbow trout
Yakima River below Roza Dam	48	48 F, G 48 H, I, J	47.1 81-85	bridgelip sucker, largescale sucker, spring chinook salmon, fall chinook salmon, steelhead, mountain whitefish, spring chinook salmon, largescale sucker
Yakima River above Roza Dam	49	49	139-141	largescale sucker, rainbow trout
Klickitat River	56	56 56A hatchery 56 B, F	2.2 42.5 64-84	fall chinook salmon, steelhead spring chinook salmon rainbow trout
Snake River below Hell's Canyon Dams	13	13C,D,E,F	128-135	largescale sucker, white sturgeon
Snake River above Hell's Canyon Dams	93	93A hatchery	270	steelhead
Clearwater - Snake River	96	96 hatchery	40.5	steelhead
Looking Glass Creek - Grand Ronde	94	94 hatchery	0.1	spring chinook salmon
Icicle Creek - Wenatchee River	51	51 hatchery	2.8	spring chinook salmon

1.5 Fish Species

A total of 281 fish samples were collected including 132 whole body, 129 fillet, 11 egg, and 9 field duplicates (Table 1-2a,b). The fish species included anadromous fish species (Pacific lamprey, eulachon, coho salmon, fall and spring chinook salmon, steelhead) and resident fish species (largescale sucker, bridgelip sucker, mountain whitefish, rainbow trout, white sturgeon, walleye). These species were selected because of their importance to CRITFC's member tribes.

Table 1-2a. Resident fish species collected from the Columbia River Basin, 1996 -1998. The sample location and identification number and number of replicates are given for each species.

Fish species	Study Site	Replicates		Dup
		F	W	
White Sturgeon- <i>Acipenser transmontanus</i>	Columbia River - 6	3		1 fillet
16 single fillets without skin, BW = 9,525g - 34,927 g	Columbia River - 7	3		
8 single whole body, BW = 8,108g - 22,380 g	Columbia River - 8	3	3	
4 duplicates of single fish each	Columbia River - 9L	3	3	1 fillet
White sturgeon samples were individual fish.	Columbia River - 9U	1	2	1 fillet
	Snake River - 13	3		1 fillet
Rainbow Trout - <i>Oncorhynchus mykiss</i>	Deschutes River - 98	4	3	
7 fillet composites with skin; BW = 318g - 551 g	Umatilla River - 101		4	
Number in each composite = 7-11	Yakima River - 49	3	3	
12 whole body composites; BW = 47g - 475 g	Klickitat River - 56		2	
Number in each composite = 7 - 30				
Largescale Sucker - <i>Catostomus macrocheilus</i>	Columbia River - 8		2	
19 fillet composites with skin; BW = 809g- 1541 g	Columbia River - 9 U	3	3	
Number in each composite = 4 - 12	Umatilla River - 30	4	3	
23 whole body composites ; BW = 395g - 1,764 g	Deschutes River - 98	3	3	
Number in each composite = 5 - 12	Yakima River - 48	3	6	
	Yakima -River - 49	3	3	
	Snake River - 13	3	3	
Bridgelip sucker - <i>Catostomus columbianus</i>	Yakima River - 48		3	
3 whole body composites; BW = 588g - 637g;				
Number in each composite = 7				
Walleye - <i>Stizostedion vitreum</i>	Columbia River - 7		2	
3 fillet composites with skin; BW = 822g - 850g	Umatilla River - 30	3	1	
Number in each composite = 8				
3 whole body composites; BW = 749g - 1503g				
Number in each composite = 4 - 8				
Mountain Whitefish - <i>Prosopium williamsoni</i>	Columbia River - 9U	3	3	
12 fillet composites with skin; BW = 247g - 517g	Deschutes River - 98	3	3	1 fillet
Number in each composite = 9 - 35	Umatilla River - 101	3	3	
12 whole body composites; BW = 247g - 428 g	Yakima River - 48	3	3	
Number in each composite = 9 - 35				
1 duplicate composite				

BW = Body weight; F= fillet WB = whole body ; Dup = duplicate

Table 1-2b. Anadromous fish species collected from the Columbia River Basin, 1996 -1998. The sample location and identification number are given for each species. The number of replicates for each tissue type are listed after the location.

Fish Species	Study Site	Replicates			Dup
		F	WB	Egg	
Coho salmon - <i>Oncorhynchus kisutch</i> 3 fillet with skin composites; BW = 3,647g -3,960g Number in each composite = 6 3 whole body composite; BW = 2,855g - 3,455g Number in each composite = 4	Umatilla River 30	3	3	3	
Fall chinook salmon - <i>Oncorhynchus tshawytscha</i> 15 fillet composites with skin; BW = 3,790g - 10,970g Number in each composite = 4 15 whole body composites; BW = 4,160g - 8,623g Number in each composite = 6 1 egg composite ; 2 duplicate fillet composites	Columbia River - 8 Columbia River - 14* Umatilla River - 30 Yakima River - 48 Klickitat River - 56	3 3 3 3 3	3 3 3 3 3	1	1 fillet 1 fillet
Spring chinook salmon - <i>Oncorhynchus tshawytscha</i> 24 fillet composites with skin; BW = 4536g - 9373g Number in each composite = 3 - 5 24 whole body composites; BW = 4,292g - 7,058g Number in each composite = 5 6 egg composites; 1 duplicate composite	Little White Salmon River - 62* Wind River - 63** MF Willamette River - 21B** Umatilla River - 30 Yakima River - 48 Klickitat River - 56* Icicle Creek - 51* Grand Ronde River - 94*	3 3 3 3 3 3 3	3 3 3 3 3 3 3	3	1 fillet
Steelhead - <i>Oncorhynchus mykiss</i> 21 fillet composite with skin; BW = 1,784g - 5,537g Number in each composite = 3 - 4 21 whole body composite; BW = 1,633g - 6,440g Number in each composite = 3 - 8 1 egg composite sample; 1 duplicate composite	Columbia River- 8 Hood River - 25 Yakima River - 48 Klickitat River - 56 Snake River - 93* Clearwater River - 96*	6 3 3 3 3 3	6 3 3 3 3 3	1	1 fillet
Pacific Lamprey - <i>Lampetra tridentata</i> 3 fillet composites with skin; BW = 364g - 430g Number in each composite = 20 9 whole body composites; BW = 334g - 463g Number in each composite = 10 - 20	Fifteen mile Creek - 24 Willamette Falls - 21		3 6		
Eulachon - <i>Thaleichthys pacificus</i> 3 whole body composites BW = 37g; Number in composite = 144	Columbia River - 3		3		

* Fish taken from hatchery Dup = duplicate; F= fillet; WB = whole body BW = average body weight of the fish in a composite

With the exception of walleye, all these fish are cold water native species which are stressed by alteration of their natural habitat (Netboy, 1980; Dietrich, 1995; Close, et. al., 1995; Musick, et. al., 2000; DeVore, et. al., 1995; Beamesderfer, et. al.,1995; Coon ,1978; Lepla, 1994). Walleye were introduced to the Columbia River Basin from the late 1800s to the early and mid 1900s and are well established in some of the reservoirs (e.g., the John Day Reservoir).

In order to estimate risks for the general public, it was assumed that these species were also consumed by other people in the basin. While there were no comprehensive surveys of fish

consumption by the general public in the Columbia River Basin at the time of this study, there have been surveys in the Middle Fork Willamette River (EVS, 1998), lower Willamette River (Adolfson Associates, Inc., 1996), and Lake Roosevelt (WDOH, 1997). The types of fish identified (Table 1-3) in these surveys include some of the same types listed in the CRITFC consumption survey (CRITFC, 1994).

Table 1-3. Recent surveys of types of fish consumed by the general public in the Columbia River Basin.

	EVS 1998	Adolfson Associates	WDOH 1997
Location	Middle Willamette	Lower Willamette	Lake Roosevelt
Tissue Type	primarily muscle some skin, eggs, eyes	muscle	fillets primarily some skin, eggs, fish heads
Fish Type	bullhead carp sucker bass northern pikeminnow crappie bluegill trout white sturgeon lamprey salmon steelhead	yellow perch brown bullhead northern pikeminnow starry flounder white sturgeon	rainbow trout walleye bass

1.6 Sampling Methods

Sampling methods (Volume 4, Appendix A) for fish included: electrofishing, hand collection, hatchery collection, trapping at dams, dip netting, fish traps, and gill netting. The preferred method was dependent on the conditions at the sampling location, selected species, and legal constraints. A global positioning system (GPS) was used to identify the latitude and longitude for each sampling location (Volume 4, Appendix A).

After retrieval from sampling devices, each fish was identified to the species level by personnel familiar with the taxonomy of the fish in the Columbia River Basin. The length and weight were then measured for each fish to ensure that they met the size class as defined in the Quality Assurance Project Plan (Volume 5). The length and weight data are provided in Volume 2, Appendix A.

Four types of samples were collected: whole-body with scales, fillet with skin and scales, fillet without skin, and eggs. The white sturgeon is the only species where fillet without skin was collected. The armor-like skin of the white sturgeon was considered too tough for ingestion. Whole-body samples were selected to maximize the chances of measuring detectable levels of contaminants of concern and because data presented in the consumption study showed that CRITFC's member tribes may consume several fish parts in addition to the fillet (CRITFC, 1994). Eggs from spring chinook salmon, fall chinook salmon, and steelhead were measured because consumption data show that their eggs were widely consumed by CRITFC's member

tribes. The fish were not scaled as recommended in the EPA guidance (USEPA, 1998a). Based on conversations with CRITFC's member tribes, it was assumed that people consume the whole body or fillet with scales intact.

The Columbia River Basin is very large and the number of samples which could be analyzed was relatively small. Due to limited resources, composites were analyzed (with the exception of white sturgeon) instead of individual fish as being a better estimate of the average concentrations of chemicals from a study site. The number of fish in each composite are listed in Volume II, Appendix A-2. It is assumed that by compositing, the error in representativeness would be reduced. However, by using an average of individual fish the true variability in individual fish tissue samples was lost. Thus, the actual residues in individual fish from the Columbia River Basin may be higher or lower than the concentrations reported in this study. Due to the size and difficulty of homogenization, composites were not taken for white sturgeon. Instead, individual fish were sampled and analyzed from each sampling location. Since this study was designed for fish consumption and people eat what they collect, random samples of fish were selected for each composite rather than predetermined age or gender.

An attempt was made to collect three replicate samples for each fish type from each study site to estimate variability between study sites. However, this was not always possible due to availability of fish and problems with sampling gear. The final number of replicates for each fish species and tissue type are listed in Table 1-2 a,b. To reduce differences due to sampling error, replicate samples were collected at the same time and study site.

1.7 Chemical Analysis

The homogenization of samples, the lipid analysis, and chemical analysis of chlorinated dioxins and furans, and dioxin-like PCB congeners were conducted by AXYS Laboratory in Victoria, Canada. The remaining analyses were performed by the EPA Region 10 laboratory at Manchester, WA. Laboratory analytical protocols specified for this study are referenced in Volumes 4 and 5.

Chemical analysis of the fish tissue was completed in 1999. The fish samples were analyzed for 132 different chemicals (Tables 1-4 a,b,c,d,e,f,g), including the following classes: semi-vocatives, chlorinated dioxins and furans, dioxin-like PCB congeners, Aroclors, pesticides and selected trace metals⁶.

Of the 132 compounds analyzed, 40 were not detected (Tables 1-4 a,b,c,d,e,f,g). The individual chemical analyses of fish tissue samples are presented in Volume 2, and summarized in Volume 1, App D.

⁶ "Metals", as used in this report, also refers to metalloids or semi-metals. Antimony, selenium, boron, and arsenic are in the metalloid groups.

Table 1-4a. 51 semi-volatile chemicals analyzed.

22 detected	29 not detected
1,2-Diphenylhydrazine	Nitrobenzene
2,6-Dinitrotoluene	1,2-Dichlorobenzene
Acenaphthene	1,3-Dichlorobenzene
Acenaphthylene	1,4-Dichlorobenzene
Anthracene	1,2,4-Trichlorobenzene
Benz-a-anthracene	2,4-Dinitrotoluene
Benzo-a-pyrene	2-Chloronaphthalene
Benzo-b-fluoranthene	4-Bromophenyl-phenylether
Benzo-k-fluoranthene	4-Chlorophenyl-phenylether
Chrysene	bis(2-Chloroisopropyl)ether
Dibenz[a,h]anthracene	Hexachlorobutadiene
Fluoranthene	Hexachloroethane
Fluorene	Dibenzofuran
Indeno(1,2,3-cd)pyrene	2-Chlorophenol
Pyrene	4-Chloro-3-methylphenol
Phenanthrene	2,4-Dichlorophenol
Benzo(g,h,i)perylene	2,4-Dimethylphenol
Naphthalene	2,4,5-Trichlorophenol
1-Methyl-naphthalene	2,3,4,6-Tetrachlorophenol
2-Methyl-naphthalene	2,4,6-Trichlorophenol
Phenol	Pentachlorophenol
Retene	4-Chloroguaiacol
	3,4-Dichloroguaiacol
	4,5-Dichloroguaiacol
	4,6-Dichloroguaiacol
	3,4,5-Trichloroguaiacol
	3,4,6-Trichloroguaiacol
	4,5,6-Trichloroguaiacol
	Tetrachloroguaiacol

Table 1-4b. 26 pesticides analyzed.

21 Detected	5 Not Detected
Aldrin	gamma-Chlordane
cis-Chlordane	Heptachlor
gamma-Chlordane	Delta-HCH
oxy-Chlordane	Beta-HCH
cis-Nonachlor	Toxaphene
trans-Nonachlor	
alpha-Chlordane	
o,p' DDT	
p,p' DDT	
o,p' DDE	
p,p' DDE	
o,p' DDE	
p,p' DDE	
DDMU	
Endosulfan Sulfate	
Hexachlorobenzene	
Heptachlor Epoxide	
Alpha BHC	
Gamma-BHC (Lindane)	
Mirex	
Pentachloroanisole	

Table 1-4c. 18 Metals analyzed.

16 detected	2 not detected
Aluminum	Lead
Arsenic	Manganese
Barium	Mercury
Beryllium	Nickel
Cadmium	Selenium
Chromium	Thallium
Cobalt	Vanadium
Copper	Zinc
	Antimony
	Silver

Table 1-4d. 7 Aroclors analyzed

3 detected	4 not detected
Aroclor 1242	Aroclor 1016
Aroclor 1254	Aroclor 1221
Aroclor 1260	Aroclor 1232
	Aroclor 1248

Table 1-4e. 13 Dioxin-like PCB congeners analyzed. All Detected

PCB 77	PCB 157
PCB 105	PCB 167
PCB 114	PCB 169
PCB 118	PCB 170*
PCB 123	PCB 180*
PCB 126	PCB 189
PCB 156	

Table 1-4f. 7 chlorinated dioxins analyzed. All Detected

2,3,7,8-TCDD
1,2,3,7,8-PeCDD
1,2,3,4,7,8-HxCDD
1,2,3,6,7,8-HxCDD
1,2,3,7,8,9-HxCDD
1,2,3,4,6,7,8-HpCDD
OCDD

Table 1-4g. 10 chlorinated furans analyzed. All Detected

2,3,7,8-TCDF
1,2,3,7,8-PeCDF
2,3,4,7,8-PeCDF
1,2,3,4,7,8-HxCDF
1,2,3,6,7,8-HxCDF
1,2,3,7,8,9-HxCDF
2,3,4,6,7,8-HxCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,7,8,9-HpCDF
OCDF

1.7.1 PCB analysis

Two methods were used for measuring PCB congeners: 1) congener analysis, and 2) Aroclor analysis. PCB congeners are a group of synthetic organic chemicals that contain 209 individual chlorinated biphenyl compounds. Each molecule of a PCB congener has 10 positions in its ringed structure which can be occupied by a chlorine atom. The placement and number of chlorine atoms into these positions determine the physical and chemical properties and the toxicological significance of the specific PCB congener molecule in question. Each unique arrangement is called a “PCB congener”. The congeners which have chlorine atoms substituted in the “para” and “meta” positions acquire a structure which is similar to chlorinated dioxins and furans.

In the congener method only those congeners (Table 1-4e) which are believed to have the same toxicological mechanisms as 2,3,7,8 tetrachlordibenzodioxin (2,3,7,8-TCDD) were measured. Of the 209 possible PCB congeners 13 were analyzed. Of these 13 congeners only 11 were considered in the risk assessment. Two of the congeners (PCB 180 and PCB 170) were included because they were in the original EPA chemical method for measuring dioxin-like PCB congeners. However, subsequent methods do not include these congeners because there was “insufficient evidence on *in vivo* toxicity” to establish toxicity factors for these congeners (Van den Berg, et al., 1998). Although PCB 81 is considered to have the same toxicological mechanism as 2,3,7,8-TCDD, EPA Method 1668 (USEPA, 1997a) did not list it as a target compound. Therefore, it was not included in this study.

Commercially available PCB congener mixtures are known in the United States by their industrial trade name, “Aroclor”. The last two digits indicate the percentage of chlorine in the compound (i.e., 42% for Aroclor 1242 and 54% for Aroclor 1254). Each Aroclor mixture is further identifiable by a specific number; i.e., “Aroclor 1242”. The “12” portion of this designation refers to the fact that the molecule contains 12 carbon atoms (bound together in two six-sided phenyl rings; e.g., a “biphenyl”). The Aroclor analysis is the most common method for measuring total PCBs.

1.7.2 Mercury and Arsenic analysis

Mercury and arsenic occur in organic and inorganic forms. In this study, the chemical analyses were as total mercury and total arsenic. The fish tissue concentrations that are discussed in Section 2 and Section 9 are based on the measured total mercury and total arsenic. For the purposes of the risk assessment, the total mercury concentrations were assumed to be all methylmercury. Arsenic fish tissue concentrations was assumed to be 10% inorganic arsenic in the anadromous fish tissue and 1% inorganic arsenic in the resident fish tissue.

1.7.3 Total Chlordane and Total DDT

The pesticides chlordane and DDT include a series of respective metabolites which are assumed to act in the same manner with respect to human exposure and toxicity. For this study, all forms of chlordane (*cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane)

were summed as total chlordane to estimate tissue concentrations and risk estimates.

1,1,1-trichloro-2,2-*bis*(p-chlorophenyl)ethane (DDT) and its structural analogs and breakdown products: 1,1-dichloro-2,2-*bis*(p-chlorophenyl)ethylene (DDE), and 1,1-dichloro-2,2-*bis*(p-chlorophenyl)ethane (DDD) are organo-chlorine pesticides. DDT, DDE, and DDD also have two isomers: the para (p,p) and ortho- para isomers (o,p). The p,p' and o,p' isomers of each DDT structural analog (DDT, DDD, DDE) were combined into three concentration terms (DDT, DDD, DDE) for fish tissue concentrations, and for the estimate of carcinogenic risks. All the DDT structural analogs (p,p'-DDD, o,p'-DDD, o,p'-DDE, p,p'-DDE, o,p'-DDT, p,p'-DDT) were summed into a single concentration (total DDT) term to estimate non-carcinogenic risks.

Although, 1,1-*bis*(p-chlorophenyl)2 chloro-ethylene (DDMU) is another structural analog or breakdown of DDT it is not believed to exhibit the same toxicity as the other structural analogs. Therefore it was not included in the sum of DDT for fish tissue concentrations and for the risk assessment.

1.7.4. Lead Risk Characterization

Lead is not included in the risk characterization sections for other chemicals. The methods for assessing risks from exposure to lead are unique due to the ubiquitous nature of lead exposure and the reliance upon blood lead concentrations to describe lead exposure, toxicity, and risks. Human health risk assessment methods for lead also differ from other types of risk assessment because they integrate all potential sources of exposure to predict a blood lead level.

1.7.5 Data Quality Validation of Chemical Analyses

A total of 93 data validation reports (Volume 4, Appendix B) were prepared detailing the quality of project data. Data quality assessment involved the following determinations:

- 1) whether the data met the assumptions under which the data quality objectives described in Volume 5 were developed, and
- 2) whether the total error in the data was small enough to allow the decision maker to use the data.

No data were rejected in this study.

Nine field duplicate samples consisting of the opposite fillets of the same species and same type of sample were collected to estimate the error in sample preparation and analysis (see Table 1-2a-b for list of field duplicates). The range in duplicate concentrations is discussed in Section 10.

All the chemicals analyzed in fish tissue were within the requirements of the quality assurance limits. In the quality assurance review of the chemical data, certain chemical concentrations were qualified with a "J". The "J" qualifier designates a concentration which is estimated. Therefore, the analytical methodology suggests that the "J" qualified measurement may be

inaccurate. We chose to use these data in this study without conditions. No data were rejected.

1.7.6 Detection limits

The detection limits for chemicals were determined by performing a risk-based screening analysis of tissue contaminant data collected within the Columbia River Basin during the last ten years (1984-1994). The screening methods and quantitation limits are described in Volume 5. The analytical methods were chosen to provide detection or quantitation limits which were as low as possible within the constraints of available methods and resources.

The detection limits varied for each sample and each chemical. The concentrations of chemicals which are found at the detection limit could be treated as a zero; alternately they could also be equal to the detection limit or somewhere in between. For this study we assumed that the concentration of a particular chemical was one half of the detection limit. For comparison, the tissue chemical concentrations are presented in Appendix E assuming the concentration for a particular chemical equals 1) zero, 2) the detection limit, or 3) $\frac{1}{2}$ the detection limit

The following rules were used when calculating average chemical concentrations in fish tissue:

- 1) If a chemical was not detected in any sample for a given fish species and sample type, it was assumed to not be present and was not evaluated.
- 2) If a chemical was detected at least once in samples for a given fish species and sample type, a concentration equal to one-half the detection limit was assumed for values reported as not detected when calculating the average chemical concentration.
- 3) The paired duplicate sample concentration for a fish at a site was averaged to obtain one concentration for that fish at that site. In cases where one duplicate was reported as a measured concentration and the paired duplicate as a non-detected concentration, the measured concentration and one-half the detection limit for the non-detected value were averaged to obtain a single estimate of concentration. In cases where both duplicate samples were not detected, one-half the detection limit for each sample was used as the mean chemical concentration.

1.7.7 Statistical Data Summaries

All fish residue data are presented on a wet weight basis. All the data for each sample are included in Volume II, Appendix C. The summary statistics (average, minimum, maximum, and standard deviation) for each site and the basin are included in Volume 1, Appendix D.

The following statistical summaries include the non-detect rules described in Section 1.7.6. The data for each fish species were pooled and average chemical concentrations were calculated by site and by basin:

- 1) Site averages—All replicate samples for a given fish species and tissue type collected

at a given site were pooled to obtain an estimate of the average chemical concentration at each site.

2) Basin averages—All samples for a given fish species and tissue type collected during this study were pooled to obtain an estimate of the average chemical concentration within the basin.

1.8 Lipid Analysis

Most of the organic chemicals measured in this study were lipid soluble to a significant extent. The lipid content of all samples was analyzed as a measure of the likelihood of bioaccumulation of these types of organic chemicals. The percent lipid for each sample is given in Volume 4, Appendix A. The lipid normalized tissue concentrations are included in Volume 2, Appendix A.

Chemical residues were normalized to lipid using the following formula:

$$(Equation 1-1) \quad ug \text{ chemical} / kg \text{ lipid} = (ug \text{ chemical}/kg \text{ tissue} \times 100) \div \text{percent lipid}$$

For example if wet weight concentration = 40 ug DDT/kg and the percent lipid = 5%
 $(40 \mu g/kg \times 100) \div 5 = 800 \text{ ug DDT/kg lipid}$

The lipid normalized data were not used in the risk assessment.

1.9 Special Studies

Three additional studies were added after the original study was initiated:

- 1) fish tissue chemical concentrations in channel catfish and smallmouth bass,
- 2) exploratory study of acid-labile pesticide analysis using Gas Chromatograph/Atomic Emission Detector (GC/AED) methods for a limited number of samples, and
- 3) radionuclide analysis for fish possibly exposed to potential releases from the Hanford Nuclear Facility.

1.9.1 Channel Catfish and Smallmouth Bass

Due to interest in comparing the results of this study with other Columbia River Basin surveys, two additional species (channel catfish and smallmouth bass) were added to the initial study when additional resources became available (Table 1-5).

Table 1-5. Sampling study sites and numbers of replicates for survey of chemicals in tissues of smallmouth bass and channel catfish collected in the Columbia River Basin, 1996-1998.

Species	Study site	Replicates	
		FS	WB
Channel Catfish - <i>Ictalurus punctatus</i>	Columbia River - 8	2	3
5 fillet with skin composites; BW = 1,236g - 2,555g Number in each composite = 2	Yakima River - 48	3	3
6 whole body composites; BW = 734g - 1,135g Number in each composite = 5 - 6			
Smallmouth Bass - <i>Micropterus dolomieu</i>	Yakima River -48	3	3
3 fillet with skin composites; BW = 1,413g - 1463g Number in each composite = 3			
3 whole body composites; BW = 1,313g - 1,487g Number in each composite = 3			

FS = fillet with skin; WB = Whole body BW= average body weight of fish in a composite

Since these were not species which were consumed in large amounts by CRITFC's member tribes, the assessment of chemicals in these fish were not included in the discussion of fish tissue concentrations in Section 2 or in the risk assessment (Sections 3-8). The results of chemical analyses in these fish are discussed in Section 9.

1.9.2 Acid-Labile Pesticides

In addition to the basic set of chemical analyses, EPA Region 10's laboratory measured 76 acid labile pesticides using advanced EPA Gas Chromatography/Atomic Emission Detection (GC/AED) method 8085 (Volume 5, Table 12). Of the 76 acid-labile pesticides measured only 17 were detected (Table 1-6). Method 8085 is applicable to the screening of semi-volatile organohalide, organophosphorus, organonitrogen, and organosulfur pesticides that are amenable to gas chromatography.

The chemical analytical results are included in Appendix L. Risk estimates were not completed for the acid labile pesticides. These analyses were done to ascertain only the presence or absence of these chemicals. A description of these chemicals is included in the toxicity profiles (Appendix C).

Table 1-6. AED pesticides detected in fish tissue from the Columbia River Basin, 1996-1998.

Atrazine	DACTHAL-DCPA	Endosulfan II	Pentabromodiphenyl ether
Bromacil	Dichlorobenzophenone	Endosulfan Sulfate	Propargite
Chlorpyrifos	Dieldrin	Hexabromodiphenyl ether	Tetrabromodiphenyl ether
Chlorpyrifos-methyl	Endosulfan I	Pendimethalin	Triallate
			Trifluralin

1.9.3 Radionuclide analyses

Due to the possibility of radionuclide contamination of fish in the mainstream Columbia River a subset of fish samples was selected for radionuclide analysis. These samples were collected in the mainstream Columbia River (sites 7, 8, 9L, 9U) and cooling ponds (K ponds) on the Hanford Reservation (Table 1-7). Additional samples were collected from the Snake River (Study Site 13)

as a background or reference sample for the samples collected at or in the vicinity of the Hanford Nuclear Facility.

Table 1-7. Radionuclide fish tissue samples including study site, species, and number of replicates from the Columbia River Basin, 1996-1998.

Study Site	Fish species	Replicates*		Duplicate
		F	WB	
Columbia River 7	white sturgeon	3		
Columbia River 8	white sturgeon	3	3	
	channel catfish	1	3	
	largescale sucker		2	
Columbia River 9 lower (L)	white sturgeon	3	3	1 whole body
Columbia River 9 upper (U)	white sturgeon	2	2	2 fillet
	mountain whitefish	3	3	1 whole body
	largescale sucker	3	3	
Hanford Reservation cooling ponds - 9K	white sturgeon		3	
Snake River 13	white sturgeon	3		1 fillet

* each replicate was a composite of 4-35 fish except white sturgeon which were single fish; Fillets were with skin, except white sturgeon which were fillets without skin; F - fillet; WB = whole body;

Radionuclides (Table 1-8) were measured by EPA National Air and Radiation Environmental Laboratory (NAERL) in Montgomery, Alabama, and a commercial laboratory (Barringer Laboratory) in Golden, Colorado.

Table 1-8. The radionuclides analyzed in fish tissue collected in the Columbia River Basin 1996-1998.

Uranium -234	Plutonium -239	Bismuth-214	Lead-212	Radon-224	Tellurium-208
Uranium-235+D	Strontium-90+D	Bismuth-212	Lead-214	Radon-226+D	Thorium-228+D
Uranium-238+D	Potassium-40	Cesium 137+D			

NAREL is a comprehensive environmental laboratory managed by the EPA Office of Radiation and Indoor Air. Among its responsibilities, NAREL conducts a national program for collecting and analyzing environmental samples from a network of monitoring stations for the analysis of radioactivity. This network has been used to track environmental releases of radioactivity from nuclear weapons tests and nuclear accidents.

Quality assurance requirements for the 45 samples (see Volume 4, Appendix A, Table A-1) selected for radionuclide measurements are described in the Quality Assurance Project Plan.. The radionuclide data are reported in Volume 1, Appendix K.

The radionuclide fish tissue measurements and risk assessment are discussed in Section 8. Radionuclides were not included with the other chemicals because radionuclides were not analyzed in all fish tissues. Although the method used to assess cancer risk from exposure to radionuclides is similar to that for other chemicals in this risk assessment, there are some unique aspects for radionuclides (e.g., analytical issues, estimation of risk coefficients) that make a separate discussion of them advantageous.

2.0 Fish Tissue Chemical Concentrations

In this section fish tissue chemical residues measured in this study are discussed. The fish tissue and egg samples were all composites with the exception of the white sturgeon which were individual fish. The concentrations discussed in this section include the rules for non-detected chemicals described in Section 1.7.6. In reviewing the results of this study the species were evaluated in two groups: 1) resident fish species (white sturgeon, mountain whitefish, walleye, bridgelip sucker, largescale sucker, rainbow trout) and the anadromous fish species (coho salmon, spring and fall chinook salmon, steelhead, pacific lamprey, eulachon). The resident fish species spend their life cycle in the Columbia River and its tributaries. Their exposure and uptake of chemicals will occur in fresh water in the vicinity of the locations where they were collected. The anadromous species spend most of their life cycle in open ocean. They reproduce in fresh water, but feed at sea. Therefore, their uptake of chemicals is likely to occur at sea rather than at the site where they were collected.

There were not equal numbers of samples of fish species or tissue types (Table 1-2a,b). In particular, the bridgelip sucker, coho salmon and eulachon were each collected at only one location; Pacific lamprey and walleye at only two locations. Thus the data reported for these species were not indicative of concentrations throughout the basin. Bridgelip sucker and eulachon were only collected as whole body fish tissue. Bridgelip sucker were collected opportunistically at this particular site. However, they were not part of the original study design. The eulachon were small fish. Therefore, it was necessary to collect 144 individual fish for each composite to obtain enough tissue for analysis. It was also impractical to attempt to fillet these fish. Therefore only whole body samples were collected. Despite these many variables, general trends in the monitoring of pollutants in these various species and tissues were evident.

The method for combining duplicate samples in this study was to average the duplicates. Thus, the two measurements would be treated as one number for the purposes of this assessment. The non-detects were included in the data summaries at ½ their detection limits. The actual detection limit is noted on the tables and in the text with a symbol for less than (<). See Sections 1.7.6 and 1.7.7 for a detailed description of these methods.

The basin-wide and study site specific average chemical concentrations reported in this section were used as the exposure concentrations in the estimation of risks discussed in Section 6.

2.1 Percent Lipid

The egg samples from the chinook salmon, and steelhead, had the highest percent lipid of all the fish tissue samples (Figure 2-1). The whole body and fillet tissues of Pacific lamprey and spring chinook salmon, and the whole body eulachon had higher percent lipid than the whole body or fillet tissues of any other species. Coho salmon, rainbow trout, walleye fillets, and largescale sucker had the lowest percent lipid.

With the exception of the walleye samples there was not a large difference in lipid content of whole body and fillet samples. The average whole body walleye samples contained 8% lipid as

compared to the 1.5% from the walleye filets. The technique used to fillet the samples was to keep as much of the skin and associated fatty tissue (lipid) intact. Thus, the chance of finding a clear differentiation between fillet and whole body was not preserved.

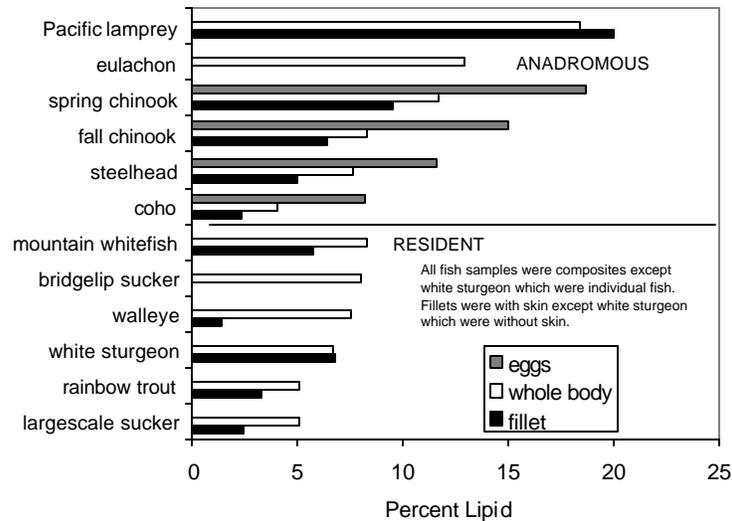


Figure 2-1. Basin-wide average percent lipid in fish collected from the Columbia River Basin. Study sites are described in Table 1-1. Sample numbers for each species are listed in Table 1-2.a,b

2.2 Semi-Volatile Chemicals

The semi-volatile chemicals include the guaicol, ethers, phenols, and polynuclear aromatic hydrocarbons (PAH). The number of samples with detectable levels of the semi-volatile chemicals was quite low (Table 2-1a,b). The guaicol and ethers were not detected in any sample. There were no semi-volatile chemicals detected in the fall chinook salmon or coho salmon tissue samples. The phenols were detected in only one white sturgeon sample from the main-stem Columbia River (study site 8). Many of these semi-volatile chemicals were not detected because they were not in the fish tissue, the detection limits were too high, or the chemicals may have been metabolized or otherwise degraded to chemicals which were not included in this survey.

The average concentrations for the PAHs were quite similar across species and chemicals. Of the PAHs, 2-methyl naphthalene (Table 2-1a,b) had the highest detection frequency. Pyrene was found at the highest concentrations of all the PAHs (450 ppb) in a rainbow trout collected from the upper Yakima River (study site 49). The largescale sucker was the fish species with the most frequent detection of PAHs. This may be due to the large number of largescale sucker samples rather than some unique exposure.

Table 2-1a. Basin-wide composite concentrations* of semi-volatile chemicals detected in resident fish species

Species/Chemical	T	N	F	µg/kg		Species/Chemical	T	N	F	µg/kg	
				Max	Ave					Max	Ave
bridgelip sucker						rainbow trout					
1,2-Diphenylhydrazine	WB	3	1	14	7	Anthracene	WB	12	1	27	5
Naphthalene, 1-methyl-	WB	3	1	10	5	Fluoranthene	WB	12	1	53	12
Naphthalene, 2-methyl-	WB	3	3	20	16	Naphthalene, 2-methyl-	FS	7	3	11	5
largescale sucker						Naphthalene, 2-methyl-	WB	12	1	27	6
1,2-Diphenylhydrazine	WB	23	1	120	12	phenanthrene	WB	12	1	50	9
9H-Fluorene	WB	23	1	26	5	Pyrene	WB	12	1	450	46
Acenaphthene	WB	23	1	53	11	Retene	WB	12	1	53	12
Acenaphthylene	WB	23	2	26	5	walleye					
Benzo(a)anthracene	FS	19	1	24	5	Naphthalene, 1-methyl-	WB	3	1	10	6
Benzo(a)pyrene	FS	19	1	24	5	Naphthalene, 2-methyl-	FS	3	2	10	6
Benzo(g,h,i)perylene	FS	19	1	47	10	Naphthalene, 2-methyl-	WB	3	1	16	9
Benzo[b]Fluoranthene	FS	19	1	24	5	white sturgeon					
Benzo[k]fluoranthene	FS	19	1	24	5	Naphthalene, 1-methyl-	FW	16	1	15	4
Chrysene	FS	19	1	24	5	Naphthalene, 2-methyl-	FW	16	1	25	5
Dibenz[a,h]anthracene	FS	19	1	47	10	Phenol	WB	8	1	530	230
Indeno(1,2,3-cd)pyrene	FS	19	1	47	10	mountain whitefish					
Naphthalene	WB	23	1	67	12	2,6-Dinitrotoluene	WB	12	1	40	16
Naphthalene, 1-methyl-	WB	23	2	26	5	Acenaphthene	WB	12	1	31	9
Naphthalene, 2-methyl-	FS	19	2	24	5	Naphthalene, 2-methyl-	WB	12	3	10	5
Naphthalene, 2-methyl-	WB	23	7	26	8						
Phenanthrene	WB	23	1	95	7						
Pyrene	WB	23	2	53	10						
Retene	WB	23	2	200	16						

Table 2-1b. Basin-wide composite concentrations* of semi-volatile chemicals detected in anadromous fish species from the Columbia River Basin, 1996-1998.

Fish Species	T	N	F	µg/kg	
				Max	Ave
eulachon					
9H-Fluorene	WB	3	1	170	56
Naphthalene, 2- methyl	WB	3	1	11	6
Phenanthrene	WB	3	1	170	60
Pacific lamprey					
Fluoranthene	WB	9	1	50	14
Naphthalene, 1- methyl	WB	9	4	25	12
Naphthalene, 2- methyl	FS	3	1	77	42
Naphthalene, 2- methyl	WB	9	4	44	22
Phenanthrene	WB	9	3	25	10
spring chinook salmon					
Acenaphthene	WB	24	1	81	13
Naphthalene, 2-methyl	FS	24	4	29	6
Naphthalene, 2-methyl	WB	24	5	40	8
Pyrene	WB	24	2	120	18
steelhead					
1,2-Diphenylhydrazine	FS	21	1	100	7
1,2-Diphenylhydrazine	WB	21	1	26	6
2,4-Dinitrotoluene	FS	21	2	48	9
2,4-Dinitrotoluene	WB	21	1	52	12
Benzo(a)pyrene	FS	21	1	24	5

*All samples were composites except white sturgeon which were individual fish;

T= tissue type; N= number of samples; F= detection frequency; FS = fillet with skin; FW= fillet without skin; WB = whole body;

Ave= average; Max = Maximum

2.3 Pesticides

Of the 26 pesticides that were analyzed the most frequently observed pesticides were hexachlorobenzene, mirex, pentachloroanisole, chlordane and related compounds, and the DDT series of structural analogs (DDT,DDE,DDD).

The basin-wide average concentrations of all pesticide residues were compared across fish species. With the exception of rainbow trout and walleye fillets, the average pesticide residue levels in the resident fish species were higher than in the anadromous fish species (Figure 2-2). The average concentrations of total pesticide residues were highest in white sturgeon (Figure 2-2).

Of the anadromous fish species, Pacific lamprey had the highest basin-wide average concentrations of total pesticides. Pacific lamprey also had the highest lipid content of any anadromous fish species (Figure 2-1). The concentrations of pesticides in the Pacific lamprey may have been due to this high lipid content. However, egg samples which had high lipid concentrations (Figure 2-1) did not have high pesticide concentrations as one would expect for lipophilic compounds.

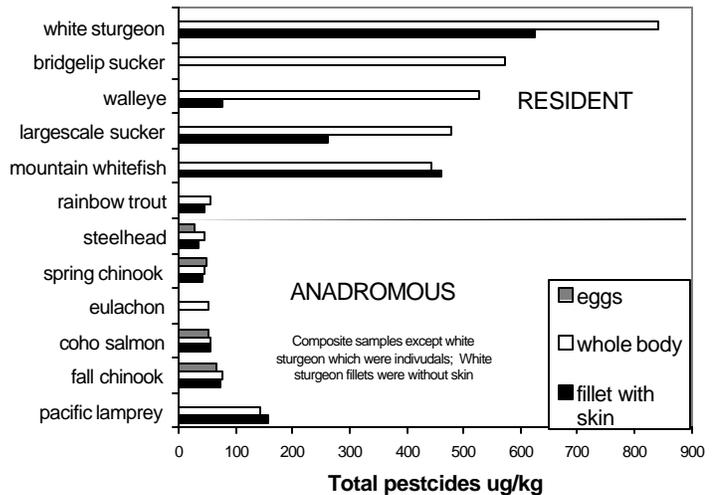


Figure 2-2. Basin-wide average concentrations of total pesticides in composite fish tissue collected from Columbia River Basin. Study sites are described in Table 1-1. Sample numbers are given in Table 1-2a,b.

2.3.1 DDMU, Hexachlorobenzene, Aldrin, Pentachloroanisole, and Mirex

DDMU, Aldrin, pentachloroanisole, and mirex were detected infrequently. The highest concentration (40 $\mu\text{g}/\text{kg}$) of DDMU was in fish tissue from largescale sucker and mountain whitefish. Aldrin was detected in only 2 species: mountain whitefish and white sturgeon (Table 2-2a). The maximum concentration (6 $\mu\text{g}/\text{kg}$) of aldrin occurred in mountain whitefish from the Hanford Reach of the Columbia River (study site 9U). The maximum concentration of pentachloroanisole occurred in largescale sucker (5 $\mu\text{g}/\text{kg}$). Mirex was only detected 9 times in all the fish tissue from this study. The maximum concentration of mirex (13 $\mu\text{g}/\text{kg}$) was detected in mountain whitefish. Hexachlorobenzene was detected over 100 times; most frequently in white sturgeon, spring and fall chinook salmon, and steelhead (Table 2-2a,b). The maximum concentration of hexachlorobenzene (19 $\mu\text{g}/\text{kg}$) occurred in white sturgeon (Table 2-2a).

Table 2.2a. Basin-wide concentrations of pesticides in resident fish tissue from the Columbia River Basin, 1996-1998.

Species/Chemicals	T	N	F	µg/kg		Species/Chemicals	T	N	F	µg/kg	
				Max	Ave					Max	Ave
bridgelip sucker						white sturgeon					
Endosulfan Sulfate	WB	3	3	5.4	4.6	Hexachlorobenzene	WB	8	7	19.0	9.3
largescale sucker						Hexachlorobenzene	FW	16	16	13.0	5.5
Pentachloroanisole	WB	23	4	5.0	1.1	Heptachlor Epoxide	FW	16	1	2.0	1.0
Pentachloroanisole	FS	19	2	2.6	1.0	DDMU	WB	8	6	16.0	7.8
Mirex	WB	23	3	5.0	1.2	Alpha-Chlordene	FW	16	1	2.4	1.0
Mirex	FS	19	1	2.6	1.1	Aldrin	WB	8	4	2.0	1.1
Hexachlorobenzene	WB	23	4	5.0	1.3	Aldrin	FW	16	4	2.0	1.0
Endosulfan Sulfate	WB	23	2	6.5	1.5	walleye					
Endosulfan Sulfate	FS	19	3	2.6	1.3	Mirex	WB	3	2	4.1	2.8
DDMU	WB	23	13	40.0	8.8	Hexachlorobenzene	WB	3	2	3.8	2.3
DDMU	FS	19	8	19.0	4.5	DDMU	WB	2	2	8.3	8.1
mountain whitefish						rainbow trout					
Pentachloroanisole	WB	12	3	3.0	1.3	Pentachloroanisole	WB	12	2	5.4	1.1
Pentachloroanisole	FS	12	2	2.4	1.1						
Mirex	FS	12	3	13.0	2.9						
Mirex	WB	12	3	6.0	2.1						
Hexachlorobenzene	WB	12	6	3.0	1.4						
Hexachlorobenzene	FS	12	3	2.4	1.0						
DDMU	FS	12	6	40.0	14.0						
DDMU	WB	12	6	31.0	13.9						
Alpha-BHC	WB	12	3	3.0	1.2						
Aldrin	FS	12	1	6.0	1.4						
Aldrin	WB	12	3	3.0	1.3						

* All fish samples were composites except white sturgeon which were individual fish. T= tissue type; N = number of samples; F= detection frequency; Max = maximum; Ave = average; FS= fillet with skin; FW = fillet without skin; WB = whole body

Table 2.2b. Basin-wide concentrations of pesticides in anadromous fish tissue from the Columbia River Basin, 1996-1998. All anadromous fish samples were composites.

Species/Chemicals	Tissue Type	N	F	µg/kg	
				Max	Ave
coho salmon					
Hexachlorobenzene	WB	3	3	1.2	1.2
fall chinook salmon					
Hexachlorobenzene	WB	15	1	4.5	3.0
Hexachlorobenzene	FS	15	1	3.4	2.1
DDMU	WB	15	2	2.4	1.1
DDMU	FS	15	2	2.0	1.0
spring chinook salmon					
Pentachloroanisole	WB	24	6	4.2	1.1
Pentachloroanisole	FS	24	1	3.8	1.1
Hexachlorobenzene	WB	24	1	3.8	2.3
Hexachlorobenzene	FS	24	1	3.5	2.1
DDMU	WB	24	2	4.2	1.2
DDMU	FS	24	2	3.8	1.1
steelhead					
Hexachlorobenzene	WB	21	2	3.2	2.2
Hexachlorobenzene	FS	21	1	2.8	1.6
DDMU	WB	21	9	2.4	1.3
Endosulfan Sulfate	WB	21	3	2.1	1.0
Heptachlor Epoxide	WB	21	3	2.1	1.0
Pentachloroanisole	WB	21	2	2.1	1.0
Endosulfan Sulfate	FS	21	3	2.1	1.0
DDMU	FS	21	5	2.0	1.1
pacific lamprey					
Hexachlorobenzene	WB	9	6	11.0	6.3
Hexachlorobenzene	FS	3	3	8.0	7.6
DDMU	WB	9	6	6.9	3.9
DDMU	FS	3	3	5.6	4.5
Pentachloroanisole	WB	9	6	3.6	1.4
Pentachloroanisole	FS	3	3	1.7	1.6

T= tissue type; N = number of samples; F= detection frequency; Max = maximum; Ave = average; FS= fillet with skin; FW = fillet without skin; WB = whole body

2.3.2 Total Chlordane

Total chlordane is a mixture of several chemically related compounds (oxy-chlordane, gamma, beta and alpha chlordane, *cis* and *trans* nonachlor).

The fillet or whole body samples of bridgelip sucker, rainbow trout, eulachon, and coho salmon had no detectable concentrations of any of the chlordane compounds. The highest concentrations of total chlordane were in egg samples from the spring chinook salmon and the fillet and whole body Pacific lamprey.

The total chlordane concentrations in the whole body fish tissue samples were generally equal to or greater than the fillet samples with the exception of the Pacific lamprey where the fillet samples were slightly higher than the whole body samples (Table 2-3). The walleye samples had the most variation between whole body and fillet.

Table 2-3 . Basin-wide average concentrations of total chlordane (oxy-chlordane, gamma, beta and alpha chlordane, *cis* and *trans* nonachlor) in fish from the Columbia River Basin, 1996-1998.

Resident species	Fillet with skin		Whole body		Eggs	
	<i>N</i>	µg/kg	<i>N</i>	µg/kg	<i>N</i>	µg/kg
white sturgeon*	16	23	8	29		
walleye	3	6	3	20		
mountain whitefish	12	11	12	12		
largescale sucker	19	6	23	8		
rainbow trout	7	<5	12	<7		
bridgelip sucker	NS		3	<8		
Anadromous species						
Pacific lamprey	3	43	9	33		
eulachon	NS	NS	3	<10		
spring chinook salmon	24	7	24	8	6	66
fall chinook salmon	15	7	15	8	1	15
steelhead	21	6	21	7	1	15
coho salmon	3	<5	3	<5	3	33

* white sturgeon were single fish and fillets without skin

N = number of samples; NS= not sampled; Ave = average; < = chemicals not detected

2.3.3 Total DDT

Total DDT is the sum of the DDT structural analogs and breakdown products: p,p' and o,p' DDT, p,p' and o,p' DDD, and p,p' and o,p' DDE. DDMU is also a breakdown product of DDT which is not believed to exhibit the same toxicity as the other breakdown products. Therefore it was not included in the total DDT concentrations for fish tissue concentrations.

The concentrations of total DDT (Table 2-4) in the salmonids (chinook, coho, rainbow, and steelhead) and eulachon were much lower than in white sturgeon, largescale sucker, whole body walleye, and mountain whitefish. The Pacific lamprey DDT concentrations were higher than the salmonids but 3 to 8 times lower than the resident species. White sturgeon had the highest concentrations followed by bridgelip sucker. This is the same pattern observed with the total pesticides (Figure 2-2). The concentration of total DDT in walleye fillet was much less than in the whole body, similar to the distribution seen with total chlordane.

The concentrations in egg samples were much lower than the fish tissue of the white sturgeon, bridgelip and largescale suckers, whole body walleye, and mountain whitefish. The concentrations in egg samples from steelhead were higher than the other egg samples and fish tissues of the anadromous species and rainbow trout.

Table 2-4. Basin-wide average concentrations of total DDT (DDT, DDE, DDD) in composite fish tissue samples from the Columbia River Basin, 1996-1998.

Resident Species	Fillet with skin		Whole body		Eggs	
	N	µg/kg	N	µg/kg	N	µg/kg
white sturgeon*	16	578	8	787		
bridgelip sucker	NS	NS	3	529		
walleye	3	59	3	489		
largescale sucker	19	241	23	450		
mountain whitefish	12	424	12	405		
rainbow trout**	7	29	12	38		
Anadromous Species						
pacific lamprey	3	95	9	90		
coho salmon***	3	41	3	42	3	39
steelhead***	21	21	21	27	1	14
spring chinook salmon	24	22	24	27	6	24
fall chinook salmon****	15	21	15	25	1	14
eulachon****	NS	NS	3	21		

N= number of samples; NS = not sampled * white sturgeon were individual fish and fillets without skin; ** p,p'-DDE and p,p'-DDT were the only isomers detected; *** p,p'-DDD and p,p'-DDE were the only isomers detected; ****p,p'-DDE was the only isomer detected

DDT found in the environment gradually degrades to DDE. Because of it is ubiquitous, lipophilic, and persistent, DDE can be a useful surrogate in comparing fish species and study sites in terms of estimating general trends of “relative loading” from persistent and agriculturally derived organochlorines. p,p'DDE was the pesticide measured at the highest concentrations of all the DDT structural analogs in fish tissues from this study (Figure 2-3).

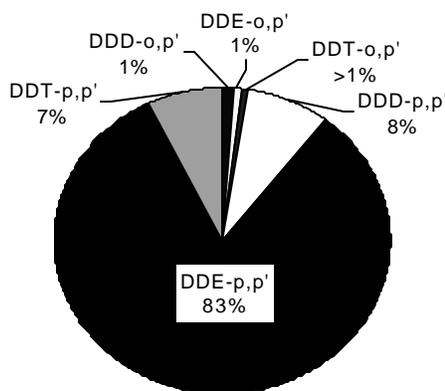


Figure 2-3. Percent contribution of DDT structural analogs to total DDT concentration in whole body largescale sucker. Basin-wide average of 23 fish tissue samples.

With the exception of walleye and rainbow trout fillet samples, the maximum concentrations of p,p'-DDE were higher in the resident fish species than the anadromous fish species (Table 2-5). The maximum concentrations were measured in the white sturgeon fillet (1400 µg/kg) and whole body largescale sucker (1300 µg/kg). The maximum concentration in the anadromous fish species was in the whole body Pacific lamprey (77 µg/kg).

Table 2-5. Basin-wide average and maximum concentrations of p,p'DDE in composite samples of fish from the Columbia River Basin, 1996-1998.

	Fillet With Skin				Whole Body				Egg			
			µg/kg				µg/kg				µg/kg	
	N	F	range	Ave	N	F	range	Ave	N	F	range	Ave
Resident Species												
white sturgeon*	16	16	100-1400	470	8	8	400-1100	620				
largescale sucker	19	19	14-740	200	23	23	28-1300	370				
mountain whitefish	12	12	8-910	360	12	12	13-770	340				
walleye	3	3	44-52	47	3	3	350-440	410				
rainbow trout	7	7	4-54	22	12	12	3-84	29				
bridgelip	NS		NS	NS	3	3	310-560	400				
Anadromous Species												
Pacific lamprey	3	3	46-55	50	9	9	35-77	53				
fall chinook salmon	15	15	4-26	12	15	15	5-53	15	1	1	6.6	
coho salmon	3	3	29-35	33	3	3	31-37	35	3	3	31-33	32
steelhead	21	21	5-28	11	21	21	5-33	15	1	1	6.5	
spring chinook salmon	24	24	6-18	12	24	24	11-22	15	6	6	10-16	12
eulachon	NS		NS	NS	3	3	10-11	11				

NS = not sampled; N = number of samples; F = detection frequency; Ave = average *White sturgeon samples were single fish and fillets without skin

The chemical concentrations in replicate fish tissue samples were compared across study sites for white sturgeon, largescale sucker, and mountain whitefish (Figure 2-4).

The concentrations across study sites were extremely variable for the three fish species. The highest concentrations of p,p'DDE observed in white sturgeon were from the Hanford Reach of the Columbia River (study site 9U; Figure 2-4a). These samples were duplicate fillets from opposite sides of the same fish. The duplicate sample concentrations were similar (1300 µg/kg and 1400 µg/kg). The concentrations of p,p'DDE in the two whole body samples from this site were much lower: 540 µg/kg and 640 µg/kg. The size of the fish from which the fillets (34,927g) were collected was greater than the two whole body fish samples (-10,000 and 20,000g). This may account for the difference in p,p'DDE concentrations between the whole body and fillets at study site 9U. The fillet samples from study site 9U were quite different than the other sites on the main-stem Columbia and Snake Rivers where white sturgeon were sampled. The duplicate samples from the lower Columbia River (study site 9L; 590 µg/kg, 630 µg/kg), main-stem Columbia River (study site 6; 410 µg/kg, 590 µg/kg) and the Snake River (380 µg/kg, 420 µg/kg) were similar to each other.

The maximum concentration (1300 µg/kg) for the whole body largescale sucker was from the Yakima River below Roza Dam (study site 48; Figure 2-4b). The concentrations of p,p'DDE in whole body largescale sucker from this site ranged from 390 to 1300 µg/kg while the fillets ranged from 430- 680 µg/kg. The largescale sucker composite samples from this study site (48) included 6 replicates. The number of replicates of the largescale suckers may have accounted for the range in concentrations.

Mountain whitefish p,p'DDE concentrations were lower than the white sturgeon and largescale sucker (Figure 2-4c). The highest concentrations occurred in the Hanford Reach of the Columbia River (study site 9U) and Yakima River (study site 48) similar to the largescale sucker and white sturgeon. The p,p'DDE fish tissue concentrations in the Deschutes and Umatilla River sites were

much lower than those in the Columbia or Yakima Rivers. The concentrations of p,p' DDE in duplicate fillet samples from the Deschutes River were similar (6.6 µg/kg and 9.4 µg/kg) to each other.

LEGEND
 FW = fillet without skin
 FS = fillet with skin
 WB = whole body

Study sites are listed by number and name and described in Table 1-1.
 Concentration points on graphs include each duplicate and chemicals at their

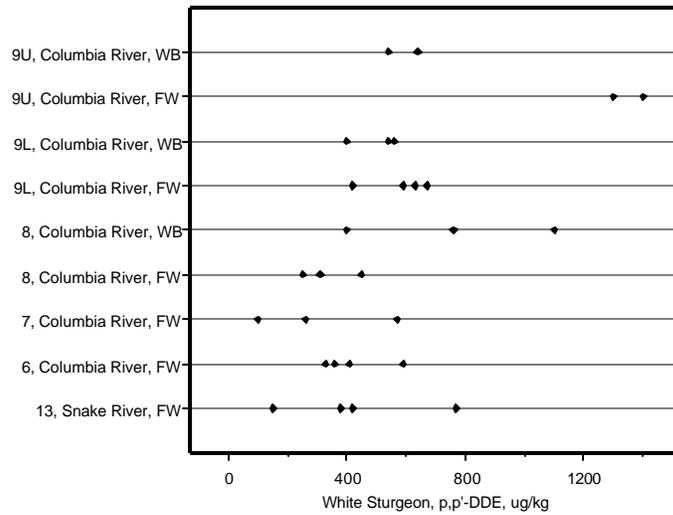


Figure 2-4a. Study site specific concentrations of p,p' DDE in white sturgeon individual fish tissue samples in the Columbia River Basin. Duplicate fillets were collected from study sites 9U, 9L, 6, and 13.

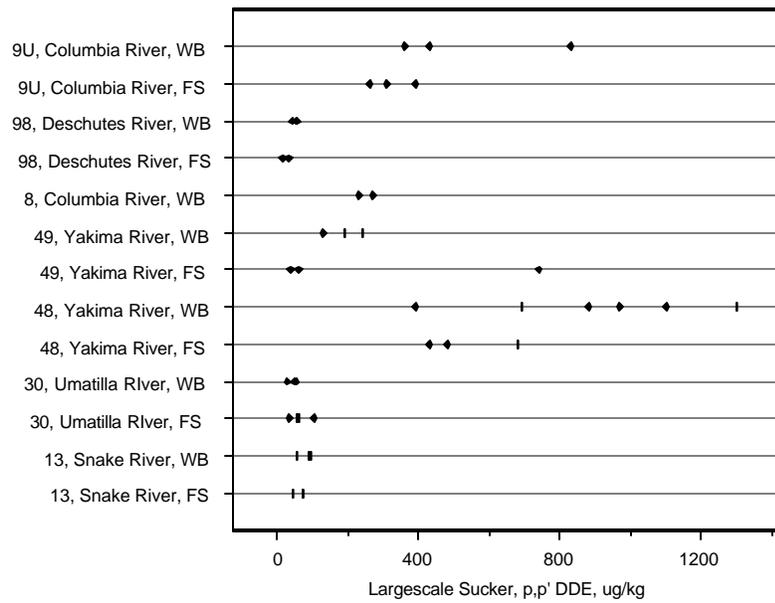


Figure 2-4b. Study site specific concentrations of p,p DDE in largescale sucker composite fish tissue samples from the Columbia River Basin.

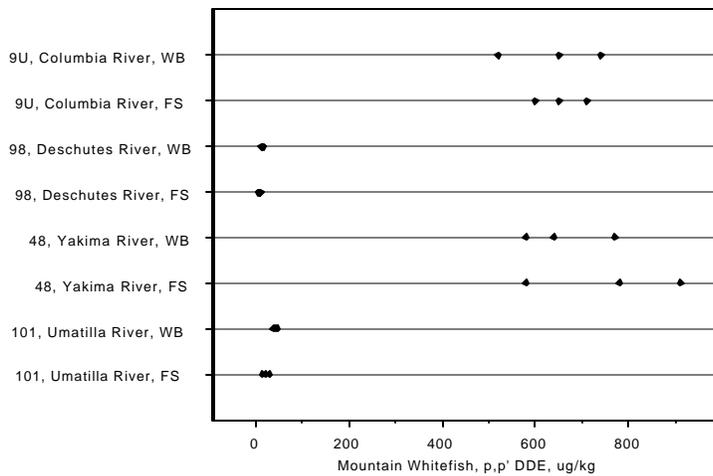


Figure 2-4c. Study site specific concentrations of p,p DDE in mountain whitefish composite fish tissue samples from the Columbia River Basin. Study site 98 includes duplicate fillet samples.

2.4 Aroclors

Of the seven Aroclors analyzed in this study (Aroclors: 1016,1221,1232,1248,1242,1254,1260) Aroclor 1016, Aroclor 1221, Aroclor 1232, and Aroclor 1248 never detected (Table 1-4d). The most frequently observed Aroclors were 1254 and 1260. Aroclor 1242 was only detected in the mountain whitefish samples.

The white sturgeon, mountain whitefish, whole body walleye, and Pacific lamprey had the highest concentrations of Aroclors (Table 2-6). The whole body concentrations of Aroclors in the walleye were higher than the concentrations in fillets. There were no Aroclors detected in the eulachon. The concentrations in the egg samples were similar to the anadromous fish fillet and whole body samples and less than the levels all the resident fish species except rainbow trout.

Table 2-6. Basin-wide average concentrations of total Aroclors (1242, 1254,1260) detected* in composite fish tissue samples from the Columbia River Basin.

Resident Species	Fillet with skin		Whole body		Eggs	
	N	µg/kg	N	µg/kg	N	µg/kg
white sturgeon**	16	120	8	173		
walleye	3	30	3	135		
mountain whitefish	12	190	12	123		
largescale sucker	19	52	23	78		
bridgelip sucker	NS	NS	3	70		
rainbow trout	7	33	12	32		
Anadromous Species						
pacific lamprey	3	106	9	114		
eulachon	NS	NS	3	<57		
spring chinook salmon	24	38	24	40	6	43
fall chinook salmon	15	37	15	40	1	31
coho salmon	3	35	3	38	3	34
steelhead	21	34	21	37	1	35

< = detection limit N= number of samples: NS= not sampled.\

*Aroclor 1242 was only detected in mountain whitefish; aroclors 1016, 1221, 1232, and 1248 were not detected in any fish or egg samples

**White sturgeon samples are individual fish and fillets without skin

Aroclors 1254 and 1260 were compared across study sites for white sturgeon (Figure 2-5a,b), largescale sucker (Figure 2-6 a,b), and mountain whitefish (Figure 2-7 a,b).

The maximum concentration for Aroclor 1254 was in the mountain whitefish (930 µg/kg) fillet sample from the Hanford Reach of the Columbia River (study site 9U; Figure 2-7a). The white sturgeon fillet samples from the Hanford Reach of the Columbia River (study site 9U) had the highest concentration (200 µg/kg) of Aroclor 1260 for all species and all sites (Figure 2-5b).

Aroclor 1254 and 1260 were quite similar in white sturgeon samples (Figure 2-5a,b). The highest concentrations for both Aroclors occurred in the fillet samples from the Hanford Reach of the Columbia River (study site 9U). Aroclor 1254 concentrations in the duplicate fillet samples from study site 9U were 170 µg/kg and 210 µg/kg. The whole body concentrations from this study site

were much lower (65 µg/kg in both samples). Aroclor 1260 concentrations were 190 µg/kg and 210 µg/kg in the duplicate fillets from study site 9U and 65 µg/kg in the whole body samples. The differences in sizes of the fillet and whole body fish (discussed in Section 2.3.3) from study site 9U, may account for the difference in PCB concentrations in the fillet and whole body samples.

The next highest Aroclor 1254 concentrations were from the main-stem Columbia River (study site 6) where the duplicate concentrations were quite different (47µg/kg and 160 µg/kg;

Figure 2-5a). The percent lipid (4.8%) of the duplicate with the higher Aroclor 1254 concentration was higher than percent lipid (3.1%) in the opposite fillet. Thus, the lipid may account for the difference in tissue levels. However, the concentration of Aroclor 1260 in the duplicate fillets from this site were similar (43 µg/kg and 40 µg/kg) to each other (Figure 2-5b).

The Aroclor concentrations in the duplicate fillets for Snake River (study site 13) and for the lower Columbia River (study site 9L) were similar to each other (Figure 2-5a,b).

LEGEND
 FW = fillet without skin
 WB = whole body
 Study sites are listed by number and name and described in Table 1-1.
 Study sites 9u, 9L 6, and 13 include duplicate fillet samples.
 Concentration points on graphs include duplicate fillets and chemicals at their detection limits.

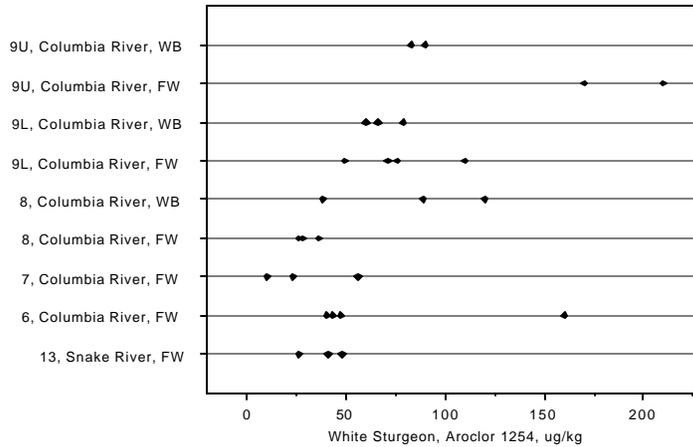


Figure 2-5a. Study site concentrations of Aroclor 1254 in white sturgeon individual fish tissue samples from the Columbia River Basin.

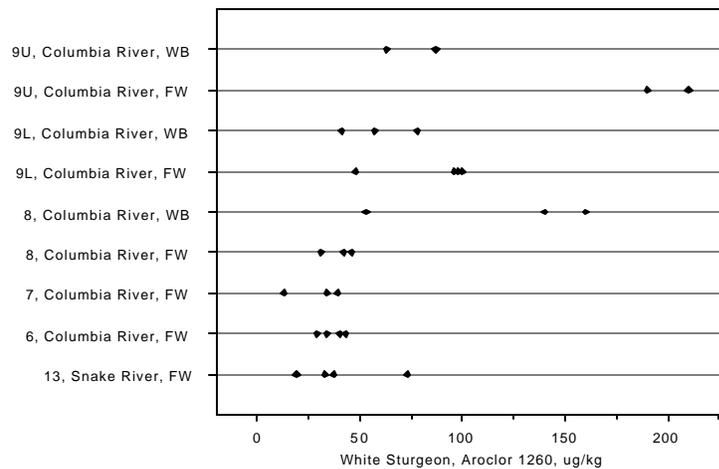


Figure 2-5b. Study site specific concentrations of Aroclor 1260 in white sturgeon individual fish tissue samples from the Columbia River Basin.

The concentrations of Aroclor 1254 and 1260 were variable in largescale sucker. Aroclor 1254 ranged from <18 µg/kg in the fillet composite from the Umatilla River to 65 µg/kg in the whole body sample from the Hanford Reach of the Columbia River (study site 9U; Figure 2-6a).

Aroclor 1260 concentrations ranged from <19 µg/kg in the Snake River (study site 13) and Deschutes River (study site 98) to 100 µg/kg in several whole body samples from the Hanford Reach of the Columbia River (study site 9U) and the Yakima River (study site 48) (Figure 2-6b).

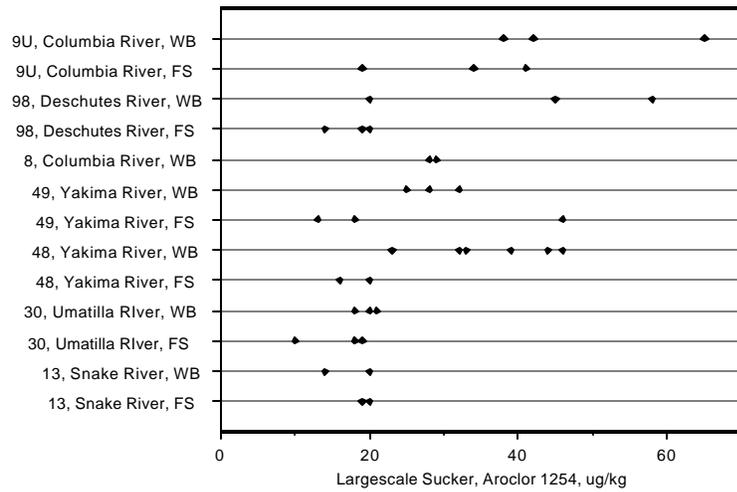


Figure 2-6a. Concentration of Aroclor 1254 in largescale sucker composite fish tissue samples from the Columbia River Basin.

LEGEND
 FS = fillet with skin
 WB = whole body
 Study sites are listed by number and name and described in Table 1-1. Concentration points on graphs include chemicals at their detection limits.

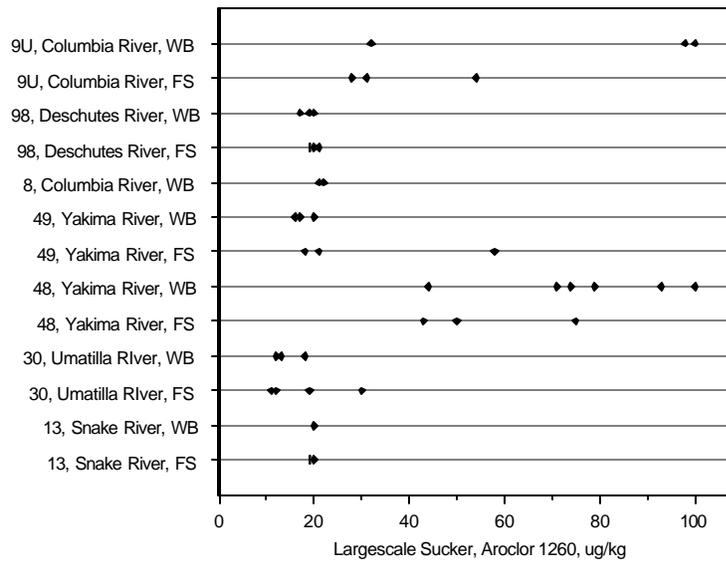


Figure 2-6b. Concentration of Aroclor 1260 in largescale sucker composite fish tissue samples from the Columbia River Basin.

In the mountain whitefish samples Aroclor concentrations from the Deschutes and the Umatilla River sites were low with <math><17 \mu\text{g}/\text{kg}</math> for Aroclor 1254 in the Umatilla River and <math><16 \mu\text{g}/\text{kg}</math> for Aroclor 1260 in the Deschutes River (Figure 2-7a,b). The duplicate fillet samples from the Deschutes River were equal or similar to each other. The maximum Aroclor 1254 concentration of 930 $\mu\text{g}/\text{kg}$ in the fillet fish tissue from the Hanford Reach of the Columbia River was much higher than the other fillet and whole body samples from this study site(Figure 2-7a). The three fillet samples from this study site had the same number of fish per composite (35), approximately the same weight (448-515g), length (352-369 mm) and percent lipid (7.9-7.7%). Thus, there was nothing in the fish size or lipid content which could account for the differences in concentrations.

The maximum Aroclor 1260 in the mountain whitefish fillet (190 $\mu\text{g}/\text{kg}$) was from the Yakima River (study site 48; Figure 2-7b).

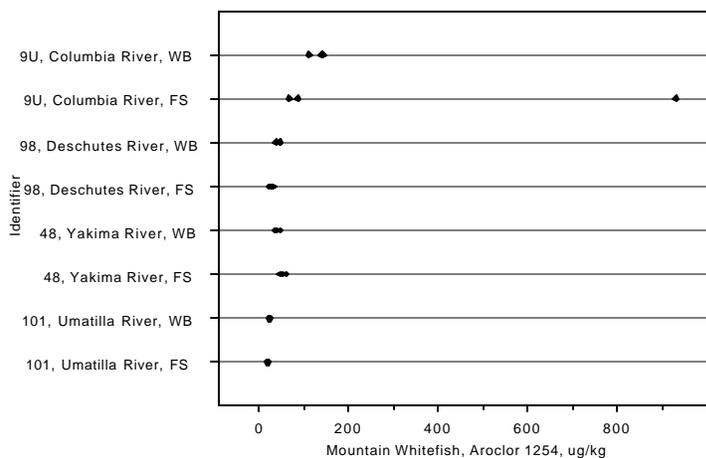


Figure 2-7a. Concentration of Aroclor 1254 in mountain whitefish composite fish tissue samples from the Columbia River Basin.

LEGEND
 FS = fillet with skin
 WB = whole body
 Study sites are listed by number and name and described in Table 1-1
 Study site 98 includes duplicate fillet samples.
 Concentration points on graphs include duplicate fillets and chemicals on their detection limits. .

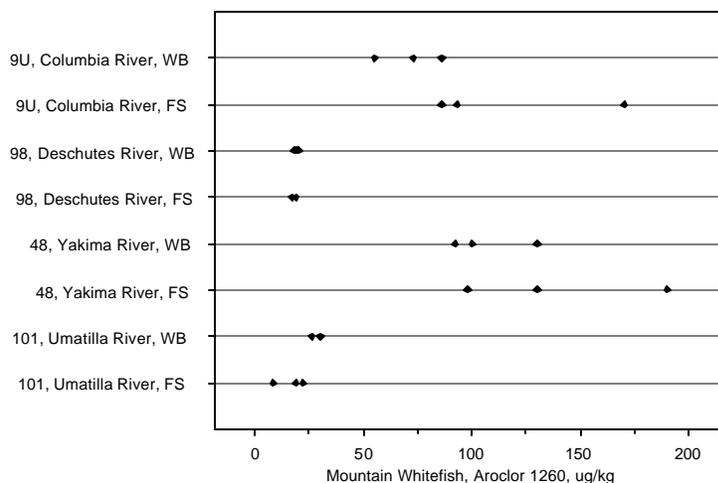


Figure 2-7b. Concentration of Aroclor 1260 in mountain whitefish composite fish tissue samples from the Columbia River Basin.

2.5 Dioxin-Like PCB congeners

When compared across all fish species, mountain whitefish fillet had the highest average concentration (25 µg/kg) of dioxin-like PCB congeners followed by the whole body walleye (11.7 µg/kg, Table 2-7).

There was considerable difference between the whole body walleye samples and the fillets. This was similar to the pattern observed in the walleye for DDT, chlordane, and Aroclors. This may be related to the amount of lipid in the whole body sample since dioxin-like PCB congeners are also lipid soluble similar to the pesticides.

The concentrations of dioxin-like PCB congeners (Table 2-7) in the egg samples from the anadromous fish were similar to the fillet and whole body samples of the coho salmon, eulachon, spring and fall chinook salmon, and steelhead.

Table 2-7. Basin-wide average concentrations of the sum of dioxin-like PCB congeners in composite fish samples from the Columbia River Basin, 1996-1998.

Resident Species	Fillet With		Whole Body		Eggs	
	N	µg/kg	N	µg/kg	N	µg/kg
		ave		ave		ave
mountain whitefish	12	25.0	12	10.2		
walleye	3	1.2	3	11.7		
white sturgeon*	16	6.5	8	10.0		
largescale sucker	19	3.1	23	5.1		
bridgelip sucker	NS		3	2.3		
rainbow trout	7	2.0	12	1.6		
Anadromous species						
Pacific Lamprey	3	5.5	9	5.5		
coho salmon	3	1.3	3	1.3	3	1.2
steelhead	21	1.0	21	1.1	1	0.6
fall chinook salmon	15	0.9	15	1.0	1	0.4
spring chinook salmon	24	0.8	24	1.0	6	0.8
eulachon	NS		3	0.5		

N= number of samples; NS = not sampled. * white sturgeon were individual fish; fillets without skin

The concentrations of dioxin-like PCB congeners 118 and 105 were the major contributors to the total dioxin-like PCB congeners (Figure 2-8a,b) for resident and anadromous fish species. PCB congeners 126, 169, and 189 each contributed less than 1% to the total dioxin-like PCB congeners in mountain whitefish (Figure 2-8a) and spring chinook (Figure 2-8b). PCB 126, the most toxic dioxin-like PCB congener, was at quite low concentrations with a range of 0.0006-0.096 µg/kg in mountain whitefish fillets and 0.00081- 0.028 µg/kg in whole body. PCB 126 was not detected in 5 of the 12 samples in mountain whitefish. The range of PCB 126 concentrations in spring chinook was 0.00081-0.0046 µg/kg in fillets and 0.00052-0.0047 µg/kg in whole body. Of the 24 samples of spring chinook, 7 fillet and 8 whole body samples were not detectable.

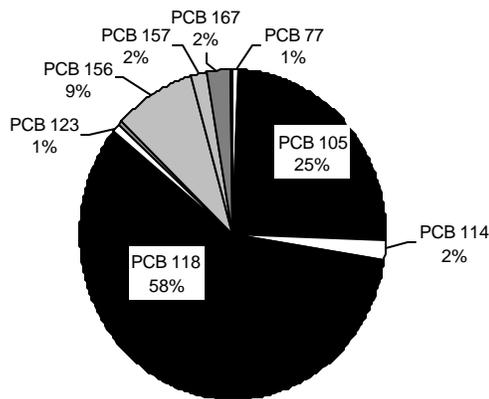


Figure 2-8a. Percent contribution of dioxin-like PCB congeners in mountain whitefish composite fillet samples from the Columbia River Basin.

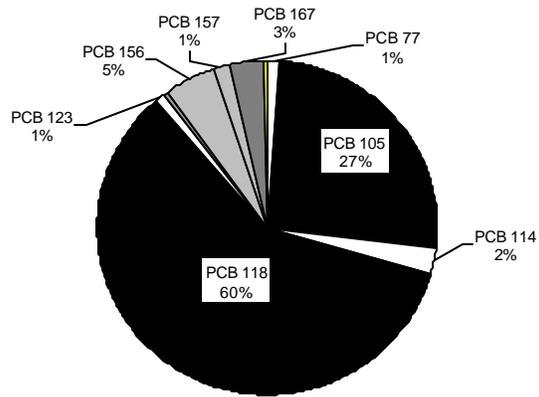


Figure 2-8b. Percent contribution of dioxin-like PCB congeners in spring chinook salmon composite fillet samples from the Columbia River Basin.

The concentrations of dioxin-like PCB congeners (Figure 2-9) were compared across study sites for white sturgeon and mountain whitefish. The average concentrations in mountain whitefish and white sturgeon fillets from the Hanford Reach of the Columbia River (study site 9U) were the highest of all the stations sampled. The levels in the lower Columbia River (study site 9L), Deschutes River, and Umatilla River were lower. The concentrations of dioxin-like PCB congeners in the white sturgeon and mountain whitefish (Figure 2-9) were consistent with the Aroclor tissue residues (Figure 2-5, 2-6, and 2-7). The white sturgeon fillet from the Hanford Reach of the Columbia River was an average of two fillets from the same fish.

The mountain whitefish were an average of three replicate composite samples with 35 fish per composite. The variability of dioxin-like PCB congener concentrations in the mountain whitefish fillets was similar to the distribution of Aroclors (Table 2-6). The mountain whitefish fillet from the Hanford Reach of the Columbia River (study site 9U) had a higher concentration (186 $\mu\text{g}/\text{kg}$) of dioxin-like PCB congeners than other replicates from that site (29 $\mu\text{g}/\text{kg}$, 36 $\mu\text{g}/\text{kg}$).

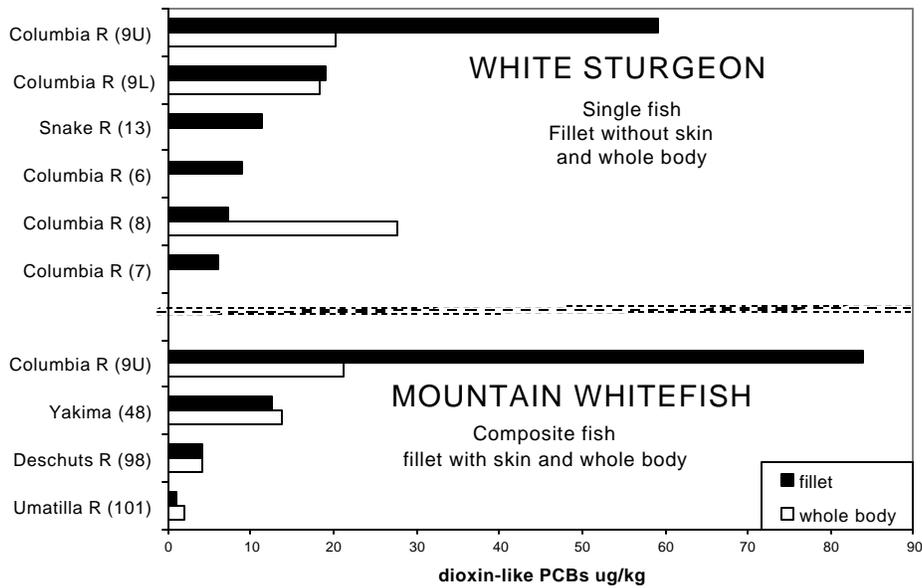


Figure 2-9. Study site average dioxin-like PCB congeners in white sturgeon and mountain whitefish samples from the Columbia River Basin. Study sites are described in Table 1-1. Sample numbers are listed in Table 1-2a,b.

The dioxin-like PCB congeners were highly correlated with Aroclors in whole body samples of fish tissue (Figure 2-10). The coefficient of determination (R^2) for these two variables was 0.94. The coefficient of determination is a measure of the degree of association of two variables. It can range from zero to 1, with 1 being a perfect association (Sokal and Rohlf 1981). The two variables are not dependent upon each other, it is simply that they are both effects of a common cause (Sokal and Rohlf, 1981). It is also evident from this graph that the white sturgeon, walleye, and mountain whitefish had the highest average concentrations of dioxin-like PCB congeners and Aroclors.

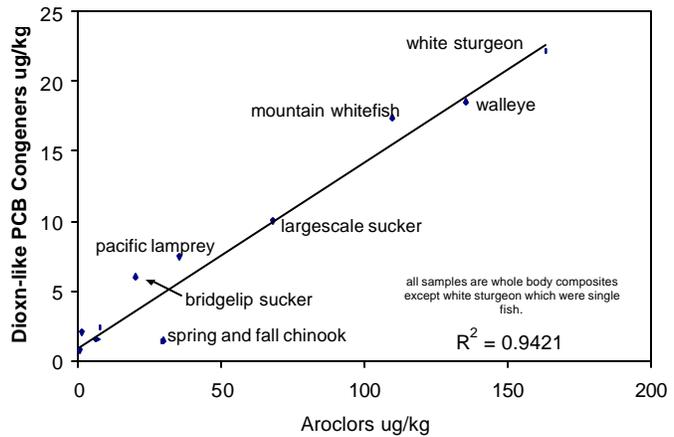


Figure 2-10. Correlation of basin-wide average concentrations of Aroclors 1242,1254,1260 (x axis) with dioxins like PCB congeners (y axis).

2.6 Chlorinated Dioxins and Furans

The average concentrations of chlorinated dioxins and furans in white sturgeon were higher than the all other fish by an order-of-magnitude (Table 2-8). The next highest average concentration was in the mountain whitefish. Coho salmon had the highest average concentrations of chlorinated dioxins and furans for the anadromous fish species although the levels were an order

of magnitude lower than the highest white sturgeon concentrations measured in this study. The egg samples from the steelhead and fall chinook were lower than the fillet or whole body fish tissues of all species. The egg samples from the coho salmon were higher than the other egg samples, as well as the fish tissue of spring and fall chinook salmon, steelhead, largescale sucker, and rainbow trout.

Table 2-8. Basin-wide average concentrations of the sum of chlorinated dioxins and furans in composite fish samples from the Columbia River Basin, 1996-1998.

Resident Species	Fillet with skin		Whole body		Eggs	
	N	µg/kg	N	µg/kg	N	µg/kg
white sturgeon*	16	0.020	8	0.030		
walleye	3	0.001	3	0.007		
mountain whitefish	12	0.006	12	0.006		
bridgelip sucker	NS	NS	3	0.003		
largescale sucker	19	0.001	23	0.002		
rainbow trout	7	0.002	12	0.002		
Anadromous Species						
eulachon	NS	NS	3	0.004		
pacific lamprey	3	0.003	9	0.004		
spring chinook salmon	24	0.002	24	0.002	6	0.002
steelhead	21	0.001	21	0.002	1	0.0008
fall chinook salmon	15	0.001	15	0.001	1	0.0009
coho salmon	3	0.001	3	0.008	3	0.003

N = number of samples; NS = not sampled . *white sturgeon were individual fish; fillets without skin

Chlorinated dioxins and furans concentrations were compared across study sites for mountain whitefish, white sturgeon, and largescale sucker (Figure 2-11). The largescale sucker samples were quite low compared to the mountain whitefish and the white sturgeon. The largescale sucker concentrations of chlorinated dioxins and furans (Figure 2-11), similar to the Aroclors (Figure 2-6a,b), were much lower than the levels observed in mountain whitefish or white sturgeon. However, the largescale sucker p,p'DDE concentrations (Figure 2-4b) were equal to the levels found in white sturgeon and mountain whitefish.

The total chlorinated dioxins and furans were highest in the white sturgeon fillet from the lower Columbia River (study site 9L, Figure 2-11). The distribution of dioxins and furans in white sturgeon across sites was different than the p,p' DDE (Figure 2-4a) and Aroclor (Figure 2-5a,b) fish tissue residue distribution. The p,p' DDE and Aroclor levels were higher in the Hanford Reach (study site 9U) and study sites 6 and 8 in the Columbia River.

The mountain whitefish chlorinated dioxins and furans concentrations were highest in the Hanford Reach of the Columbia River followed by the concentrations in the Yakima River (Figure 2- 11). This distribution was similar to the p,p' DDE (Figure 2-4c) and Aroclor 1260 levels (Figure 2-7b).

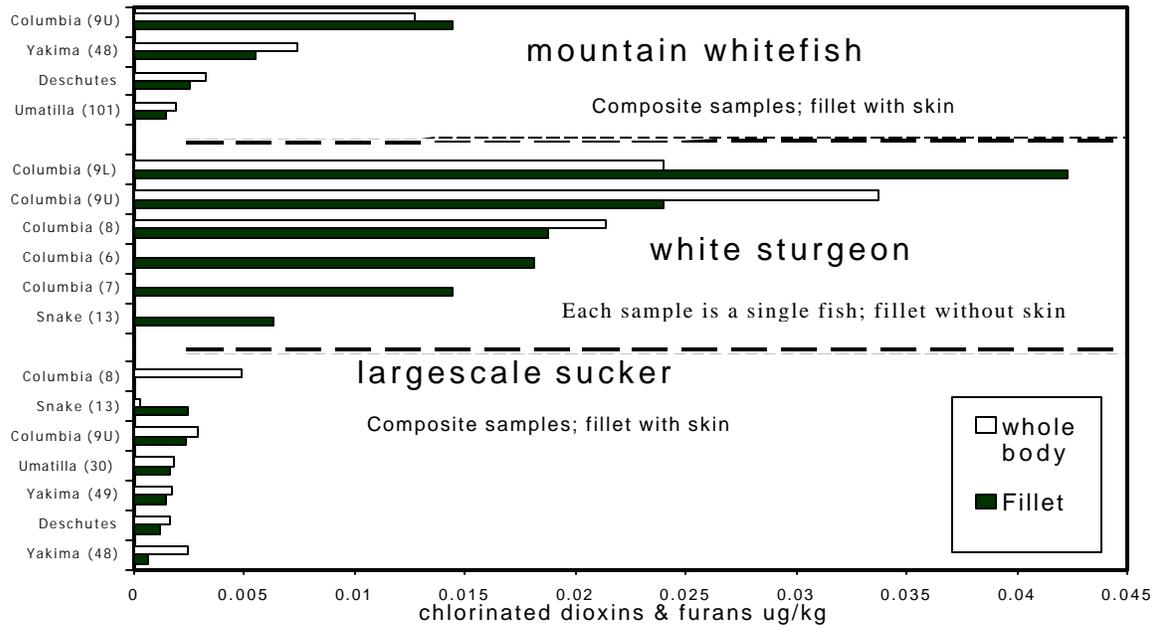


Figure 2-11. Study site average concentrations of chlorinated dioxins and furans in mountain whitefish, white sturgeon, and largescale sucker from study sites in the Columbia River Basin. Study sites are described in Table 1-1). The number of samples are listed in Table 1-2.

2,3,7,8-TCDD, the most commonly studied chlorinated dioxin was generally found at the lowest concentrations in all the samples. The most frequently detected and the highest concentrations of chlorinated dioxins and furans in fish tissue from this study were 2,3,7,8-TCDF and OCDD (Figure 2-12).

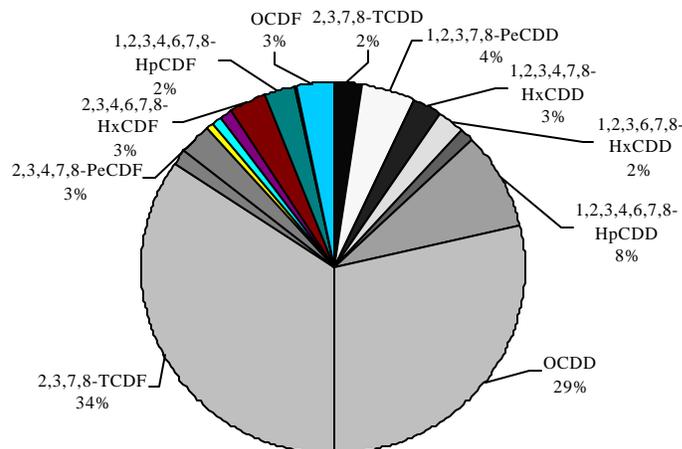


Figure 2-12. Percent contribution of each chlorinated dioxin and furan in largescale sucker. Basin-wide average of 23 composite whole body fish tissue samples. Only those congeners which exceed 1% of total chlorinated dioxin and furan concentrations are shown on the figure.

The maximum concentration of 2,3,7,8-TCDF was in the white sturgeon (Table 2-9). The fish species tended to cluster into three groups:

- 1) < 0.001 µg/kg = all the egg samples; walleye fillets, rainbow trout, spring chinook salmon fillets, steelhead, coho salmon, eulachon,
- 2) > 0.001 to < 0.010 µg/kg = largescale sucker, whole body walleye, bridgelip sucker, Pacific lamprey, fall chinook salmon, and whole body spring chinook salmon, and
- 3) > 0.010 µg/kg = white sturgeon and mountain whitefish.

Table 2-9a. Basin-wide concentrations of 2,3,7,8-TCDF in composite samples of fish tissue from the Columbia River Basin, 1996-1998.

	Fillet			Whole Body				
	µg/kg			µg/kg				
	N	F	Ave	N	F	Ave		
Resident species								
white sturgeon*	16	16	0.0025 - 0.054	0.017	8	8	0.008 - 0.047	0.021
mountain whitefish	12	12	0.00014 - 0.014	0.0045	12	12	0.0002 - 0.012	0.0044
largescale sucker	19	18	<0.0001 - 0.0015	0.0004	23	23	0.0008 - 0.0036	0.0009
walleye	3	3	0.0006 - 0.0008	0.0007	3	3	0.0038 - 0.0055	0.0046
rainbow trout	7	7	0.0001 - 0.0003	0.0002	12	11	0.0004 - 0.0005	0.0002
bridgelip sucker	NS				3	3	0.0008 - 0.001	0.001
Anadromous species								
Pacific lamprey	3	3	0.0012 - 0.0017	0.0014	9	9	0.0011 - 0.0032	0.0020
fall chinook salmon	15	14	<0.0003 - 0.0014	0.0007	15	15	0.0004 - 0.0014	0.0008
spring chinook salmon	24	24	0.0004 - 0.0007	0.0006	24	24	0.0006 - 0.0011	0.0007
eulachon	NS				3	3	0.0006 - 0.0008	0.0007
steelhead	21	21	0.0002 - 0.0007	0.0004	21	21	0.0003 - 0.0006	0.0004
coho salmon	3	3	0.0004 - 0.0005	0.0005	3	3	0.0004 - 0.0005	0.0004

N = number of samples; F = detection frequency; NS = not sampled; < = detection limit

*white sturgeon were individual fish and fillets without skin

Table 2-9b. Basin-wide concentrations of 2,3,7,8-TCDF in composite samples of eggs from anadromous fish species in the Columbia River Basin, 1996-1998.

	Egg		
	µg/kg		
	N	F	Ave
fall chinook salmon	1	1	0.00043
spring chinook salmon	6	6	0.0004 - 0.0007
steelhead	1	1	0.0002
coho salmon	3	3	0.0003 - 0.0007

N = number of samples; F = detection frequency

2.7 Toxicity Equivalence Concentrations of Chlorinated Dioxins and Furans, and Dioxin-Like PCB congeners

Chlorinated dioxins and furans are found in the environment together with other structurally-related chlorinated chemicals, such as some of the various dioxin-like PCB congeners. Therefore, people and other organisms are generally exposed to mixtures of these structurally similar compounds, rather than to a single chlorinated dioxin or furan, or dioxin-like PCB congener.

In order to estimate risks for exposure to dioxin-like chemicals (Table 1-4e,f,g) a method was developed to estimate a toxicity equivalence concentration (Van den Berg et al., 1998). In this methodology the toxicity equivalence factor for 2,3,7,8-TCDD is equal to 1; all other dioxin, furan, and dioxin-like PCB congeners are calculated as some relative percent of 1. The toxicity equivalence factors (Table 2-10) were derived by a panel of experts using careful scientific judgment after considering all available relative potency data (Van den Berg et al., 1998). Dioxin-like congener-specific toxicity equivalence factors (Table 2-10) are used to convert individual dioxin-like congener concentrations to 2,3,7,8-TCDD equivalents.

Table 2-10. Toxicity Equivalence Factors (TEF) for dioxin-like PCB congeners, dioxins, and furans (from Van den Berg et al., 1998).

PCBs	TEF	Dioxins	TEF	Furans	TEF
PCB 126	0.1	2,3,7,8-TCDD	1	2,3,4,7,8-PeCDF	0.5
PCB 169	0.01	1,2,3,7,8-PeCDD	1	2,3,7,8-TCDF	0.1
PCB 157	0.0005	1,2,3,4,7,8-HxCDD	0.1	1,2,3,4,7,8-HxCDF	0.1
PCB 156	0.0005	1,2,3,6,7,8-HxCDD	0.1	1,2,3,6,7,8-HxCDF	0.1
PCB 114	0.0005	1,2,3,7,8,9-HxCDD	0.1	1,2,3,7,8,9-HxCDF	0.1
PCB 77	0.0001	1,2,3,4,6,7,8-HpCDD	0.01	2,3,4,6,7,8-HxCDF	0.1
PCB 189	0.0001	OCDD	0.0001	1,2,3,7,8-PeCDF	0.05
PCB 123	0.0001			1,2,3,4,6,7,8-HpCDF	0.01
PCB 118	0.0001			1,2,3,4,6,7,8,9-HpCDD	0.01
PCB 105	0.0001			OCDF	0.0001
PCB 167	0.00001				

The toxicity equivalence concentration is the product of the toxicity equivalence factor multiplied by the concentration for an individual dioxin-like congener as shown in Equation 2-1:

$$\text{Equation 2-1)} \quad \text{TEC} = (\text{TEF}_i \times [\text{congener fish tissue concentration}]_i)$$

TEF = Toxicity equivalence factor

TEC = toxicity equivalence concentration

The toxicity equivalence concentrations for each dioxin, furan, and dioxin-like PCB congener are then summed to determine the total toxicity equivalence concentration.

The mountain whitefish fillet sample had the highest toxicity equivalence concentration (0.0063 µg/kg) followed by the white sturgeon (Table 2-11). The primary contributors to the mountain whitefish toxicity equivalence concentration were 2,3,7,8-TCDF and dioxin-like PCB congeners (118,126,156). The primary contributor to the high white sturgeon toxicity equivalence concentration was 2,3,7,8-TCDF and dioxin-like PCB congeners (105,118,156). The

Pacific lamprey had the highest concentration of toxicity equivalence concentrations of all the anadromous species. The concentrations 2,3,7,8 TCDF (Table 2-9), dioxinlike PCBs (Table 2-7) Aroclors (Table 2-6, and total pesticides (Figure 2-2) were also higher in Pacific lamprey than in any of the anadromous species.

Table 2-11. Basin-wide average concentrations of the toxicity equivalence concentrations for composite fish samples from the Columbia River Basin, 1996-1998.

	Fillet		Whole body		Anadromous Species	Fillet		Whole body	
	N	µg/kg	N	µg/kg		N	µg/kg	N	µg/kg
Resident Species									
white sturgeon*	16	0.0043	8	0.0051	Pacific lamprey	3	0.0027	9	0.0035
walleye	3	0.00049	3	0.0036	spring chinook salmon	24	0.0006	24	0.0009
mountain whitefish	12	0.0063	12	0.0033	steelhead	21	0.0.0009	21	0.0009
largescale sucker	19	0.0009	23	0.0016	eulachon	NS		3	0.0007
bridgelip sucker	NS		3	0.0013	coho salmon	3	0.0.0004	3	0.0006
rainbow trout	7	0.0008	12	0.0009	fall chinook salmon	15	0.0.0004	15	0.0005

N = number of samples; NS = not sampled.; *white sturgeon were individual fish and fillets without skin

2.8 Metals

Of the sixteen metals analyzed, antimony and silver were not detected. Thallium was only detected once in a mountain whitefish. Unlike the organic chemicals the high metal concentrations did not appear to be associated with certain species or locations.

The percent contribution of each of the metals to the sum of metals was compared in fillet samples of largescale sucker (Figure 2-13a) and spring chinook salmon (Figure 2-13b). While there was considerable variability in the percent contribution in fish tissue, zinc and aluminum were found at the highest concentrations in all species (Figures 2-13a,b). Arsenic was generally higher in the anadromous fish species than in the resident fish species.

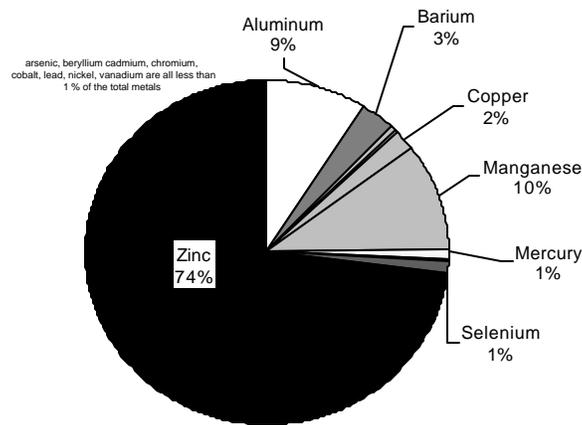


Figure 2-13a. Basin-wide average percent of individual metals in largescale sucker fillets. N= 23.

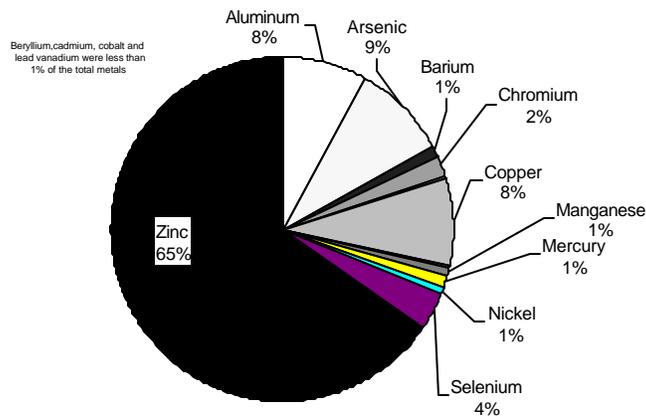


Figure 2-13b. Basin-wide percent of individual metals in spring chinook salmon fillets. N=24.

Basin-wide concentrations of metals were compared across species (Table 2-12, 2-13, 2-14). The maximum concentrations of individual metals (Table 2-12) were generally higher in the whole body fish samples with the exception of arsenic, copper, mercury, selenium, and zinc. Arsenic and mercury were higher in fillet samples while copper, selenium, and zinc were higher in the egg samples from the anadromous fish. The maximum concentrations of barium, cadmium, and manganese were in whole body largescale sucker samples from the Hanford Reach of the Columbia River (study site 9U). The maximum concentrations of chromium and cobalt were measured in the whole body white sturgeon from the main-stem Columbia River (study site 8).

Table 2-12. Basin-wide maximum concentrations * of metals in composite fish tissues measured in the Columbian River Basin, 1996 -1998.

Chemical	Species	N	Tissue type	µg/kg	Study Site**
Aluminum	Largescale sucker	2	WB	190000	Columbia River (8)
Arsenic	Steelhead	3	FS	1500	Hood River (25)
Barium	Largescale sucker	3	WB	4700	Columbia River (9U)
Cadmium	Largescale sucker	3	WB	250	Columbia River (9U)
Chromium	White sturgeon	3	WB	1000	Columbia River (8)
Copper	Steelhead	1	Egg	18000	Snake River (96)
Copper	Fall chinook	3	WB	14000	Columbia River (14)
Cobalt	White sturgeon	3	WB	420	Columbia River (8)
Lead	Fall chinook	3	WB	1200	Columbia River (14)
Manganese	Largescale sucker	3	WB	21000	Columbia River (9U)
Mercury	Spring chinooksalmon	3	FS	510	Klickitat River (56)
Nickel	Steelhead	3	WB	17000	Klickitat River (56)
Selenium	Spring chinooksalmon	3	egg	5500	Umatilla River (30)
Selenium	White sturgeon	1	FW	2700	Columbia River (9U)
Vanadium	Rainbow trout	4	WB	770	Umatilla River (101)
Zinc	Steelhead	1	egg	76000	Snake River (96)
Zinc	Mountain whitefish	3	WB	40000	Deschutes (98)

*All samples were composites except white sturgeon which were individual fish.; **study site name with study site number in parentheses
N = number of samples; FS = fillet with skin; FW = fillet without skin; WB = whole body.

Mercury was not detected in any anadromous egg sample (Table 2-13). The concentrations of copper, manganese, selenium and zinc were higher in the egg samples than any of the anadromous fish tissue samples (Table 2-12;Table 2-14).

Table 2-13. Basin-wide average concentrations of metals in samples of eggs from anadromous fish collected in the Columbia River Basin, 1996-1998. Barium and beryllium were not detected in any egg samples.

Chemical	fall chinook salmon	spring chinook salmon	coho salmon	steelhead
Number of samples	1	6	3	1
Concentration (µg/kg)				
Aluminum	500	950	850	4500
Arsenic	240	460	330	25
Cadmium	<4	35	<4	34
Chromium	<100	100	<100	220
Cobalt	35	43	12	170
Copper	5800	6200	4500	18000
Lead	<10	14	<10	41
Manganese	960	1500	700	2200
Mercury	<50	<79	<100	<43
Nickel	54	78	84	520
Selenium	2400	4200	1200	4500
Vanadium	19	13	28	110
Zinc	36000	43000	31000	76000

< = detection limit

Largescale sucker had the highest basin-wide average concentrations (Table 2-14) of aluminum (69,000 µg/kg), barium (2,300 µg/kg), manganese (14,000 µg/kg), mercury (240 µg/kg), and vanadium (310 µg/kg). White sturgeon had the highest basin-wide average concentrations of beryllium (8 µg/kg), chromium (360 µg/kg), cobalt (260 µg/kg), and selenium (1,100 µg/kg).

The basin-wide average whole body concentrations of cadmium, chromium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc were higher than the fillet concentrations (Table 2-14). This may be due to the concentrations of these chemicals in the internal organs, bones, and skin of the fish. Selenium was generally higher in the whole body fish tissue with the exception of the white sturgeon. The concentrations of barium and aluminum were higher in the whole body tissue of resident fish species. In the anadromous fish species the whole body aluminum and barium concentrations were equal to or less than the fillet.

Table 2-14. Basin-wide average concentrations of metals in composite samples of fish from the Columbia River Basin, 1996-1998.

Chemical	Tissue Type	fall	spring	coho	Pacific		largescale	*white	mountain	rainbow		bridgelip	
		chinook salmon	chinook salmon	salmon	steelhead	lamprey	eulachon	sucker	sturgeon	whitefish	walleve	trout	sucker
N-FS		15	24	3	21	3	NS	19	16	12	3	7	NS
N-WB		15	24	3	21	9	3	23	8	12	3	12	3
		µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
Aluminum	FS	630	790	<1000	1200	500		2400	3800	2600	2500	1100	
Aluminum	WB	510	610	<1000	550	1200	8800	69000	48100	11100	2400	27000	37000
Arsenic	FS	810	850	540	560	310		70	300	100	360	<50	
Arsenic	WB	860	830	500	580	260	890	160	370	140	490	120	280
Barium	FS	130	100	160	220	100		800	250	280	240	390	
Barium	WB	110	110	140	220	100	180	2300	1900	700	670	1200	2000
Beryllium	FS	2	2	2	2	2		3	2	2	2	5	
Beryllium	WB	2	2	2	3	2	2	5	8	2	2	3	5
Cadmium	FS	<4	10	<4	6	24		5	2	7	<4	2	
Cadmium	WB	6	120	22	57	110	9	55	42	28	7	12	29
Chromium	FS	71	180	140	81	80		120	65	130	90	70	
Chromium	WB	100	210	130	140	100	<100	310	360	120	110	93	180
Cobalt	FS	47	21	120	57	33		65	27	51	8	28	
Cobalt	WB	140	110	120	150	96	7	170	260	110	56	88	96
Copper	FS	640	790	1700	720	1200		550	250	620	570	500	
Copper	WB	3400	1400	1300	3200	4500	940	1400	990	1200	2500	1800	1200
Lead	FS	7	14	81	8	<10		29	8	15	<10	<10	
Lead	WB	220	21	15	45	16	500	170	120	35	190	26	54
Manganese	FS	87	90	190	150	380		2700	260	840	370	450	
Manganese	WB	320	370	500	460	390	500	14000	2700	3400	950	3200	18000
Mercury	FS	84	100	120	120	<110		240	150	80	180	77	
Mercury	WB	77	64	100	100	120	<35	130	140	67	180	73	32
Nickel	FS	75	63	54	44	15		110	56	76	260	59	
Nickel	WB	130	270	1200	900	110	50	1100	410	280	260	330	400
Selenium	FS	330	350	290	330	430		260	1100	510	390	220	
Selenium	WB	470	530	360	650	580	290	310	650	960	470	360	280
Vanadium	FS	6	5	7	14	10		11	9	29	5	17	29
Vanadium	WB	24	17	38	66	40	17	310	220	160	14	190	190
Zinc	FS	6700	6300	7100	7900	20000		20000	3800	15000	8700	12000	
Zinc	WB	27000	25000	30000	22000	22000	14000	23000	8200	27500	14000	29000	20000

* white sturgeon were single fish; fillets were without skin N= Number of samples; FS = fillet with skin; WB = whole body; < = detection limit

2.8.1 Arsenic

Arsenic and mercury are discussed in detail in this report because of their contribution to risk. They are often primary components of risk because of their toxicity as well as their ubiquitous distribution in the environment as natural minerals in soil and from mining activities, smelting (arsenic) and fossil fuel burning (mercury).

With the exception of Pacific lamprey, anadromous fish had higher arsenic concentrations than resident fish (Table 2-14). The whole body concentrations of arsenic were uniformly higher than the fillet concentrations in the resident fish species (Table 2-14). However, there was no consistent pattern in the whole body versus fillet arsenic concentrations in the anadromous fish species (Table 2-14). Pacific lamprey had the lowest arsenic concentrations of all the anadromous species, which was the inverse of the relationship for organic chemicals, where Pacific lamprey had the highest concentrations. The average concentrations (240 - 460 $\mu\text{g}/\text{kg}$) of arsenic in the egg samples (Table 2-14) was similar to the whole body and fillet fish tissue concentrations (70-860 $\mu\text{g}/\text{kg}$) except for the steelhead eggs (25 $\mu\text{g}/\text{kg}$) and rainbow trout fillets (<50) which had the lowest concentrations of all the samples.

Arsenic concentrations were compared across sites for white sturgeon (2-14a) largescale sucker (Figures 2-14b), mountain whitefish (2-14c), spring chinook (2-15a) and steelhead (2-15b)

White sturgeon arsenic concentrations were generally consistent within sites but with considerable variability across sites (Figure 2-14a). For instance, the concentration in whole body samples ranged from 240 $\mu\text{g}/\text{kg}$ in the white sturgeon from the Hanford Reach of the Columbia River (study site 9U) to 660 $\mu\text{g}/\text{kg}$ in the white sturgeon from the main-stem Columbia River (study site 8). The fillet samples ranged from 150 $\mu\text{g}/\text{kg}$ in the Snake River (study site 13) to 640 $\mu\text{g}/\text{kg}$ in the fillet sample from main-stem Columbia River (study site 7). The maximum concentration occurred in the whole body sample from the main-stem Columbia River (660 $\mu\text{g}/\text{kg}$; study site 8). The arsenic concentrations in the duplicate fillets were equal or similar to each other.

The highest arsenic concentrations of largescale sucker were measured in whole body and fillet samples from the main-stem Columbia River (200-320 $\mu\text{g}/\text{kg}$; study sites 9U, 8) and the whole body samples from the Snake River (study site 13; 200-270 $\mu\text{g}/\text{kg}$; Figure 2-14b). The lower concentrations ranged from 50-150 $\mu\text{g}/\text{kg}$ in whole body and fillet fish tissues from the Deschutes, Yakima, Umatilla Rivers and the fillet fish tissues from Snake River (Figure 2-14b).

Mountain whitefish arsenic concentrations ranged from 100 to 140 $\mu\text{g}/\text{kg}$ with the maximum at 180 $\mu\text{g}/\text{kg}$ in the whole body sample from the Umatilla River (Figure 2-14c). The lowest concentrations were measured in the Deschutes River fillet samples. There was some variability between fillet and whole body with the whole body samples being higher than the fillet samples from Umatilla River and Deschutes River. The arsenic concentrations in the duplicate fillets from the Deschutes River were similar to each other.

The concentrations of arsenic in spring chinook salmon showed no consistent trend within

stations or across stations (Figure 2-15a). The highest concentrations were in the whole body (1200 µg/kg) and fillet (1100 µg/kg) from the Little White Salmon River and the whole body (1100 µg/kg) and fillet (1200 µg/kg) from the Middle Fork of the Willamette River. The arsenic concentrations in the duplicate fillet samples from Looking Glass Creek (study site 94) were similar (777 µg/kg, 783 µg/kg) to each other.

The maximum concentration (1500 µg/kg) of arsenic in all the fish samples was in the fillet sample from the Hood River (Table 1-12 and Figure 2-15b). The maximum whole body concentration from the Hood River was 1200 µg/kg. However there was considerable variability in the replicates for this site with most whole body and fillet samples at about 430 µg/kg. The samples from the other sites were between 290 and 800 µg/kg (Figure 2-15b). The duplicate fillet samples from the Clearwater River were not the same (480 µg/kg, 582 µg/kg) with the higher concentration (582 µg/kg) falling outside the range of the other samples from this site but lower than the maximum observed in the Hood River.

LEGEND
 FW = fillet without skin
 FS = fillet with skin
 WB = whole body
 Study sites are listed by number and name and described in Table 1-1
 Concentration points on the graphs include duplicate fillets and chemicals at their detection limits.

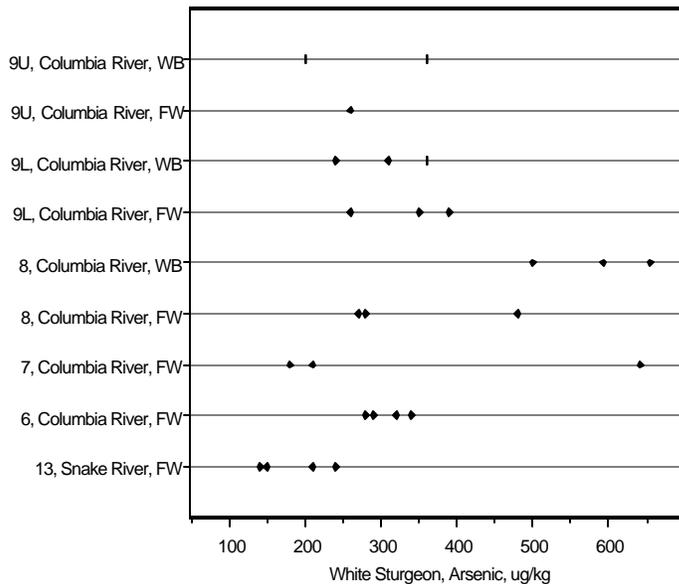


Figure 2-14a. Site specific concentrations of arsenic in white sturgeon individual fish tissue samples from the Columbia River Basin. Study sites 9U, 9L, 6, and 13 include duplicate fillet samples.

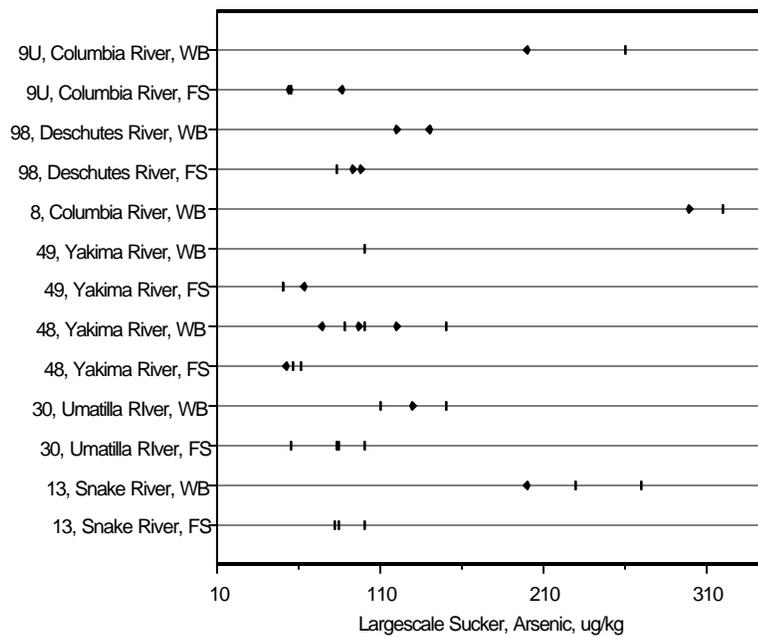


Figure 2-14b. Site specific concentration of arsenic in largescale sucker composite fish tissue samples from the Columbia River Basin.

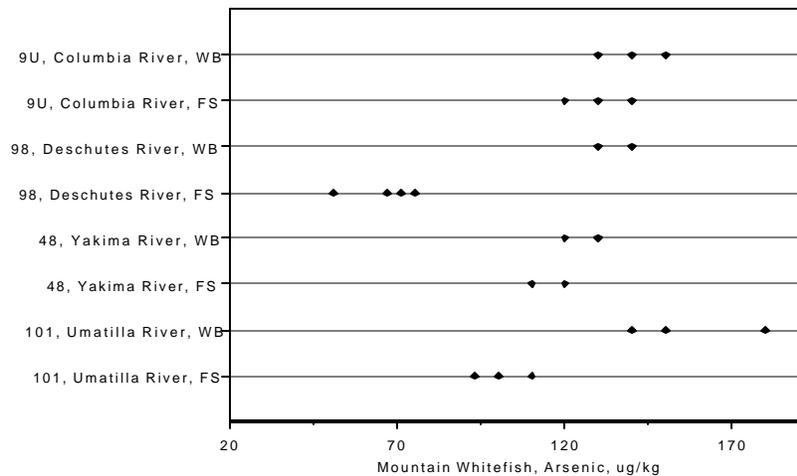


Figure 2-14c. Site specific concentration of arsenic in mountain whitefish composite fish tissue samples from the Columbia River Basin. Study site 98 includes duplicate fillet samples.

LEGEND

FS = fillet with skin
WB = whole body
Study sites are listed by number and name and described in Table 1-1.
Concentration points on graphs include duplicate fillets and chemicals at their detection limits.

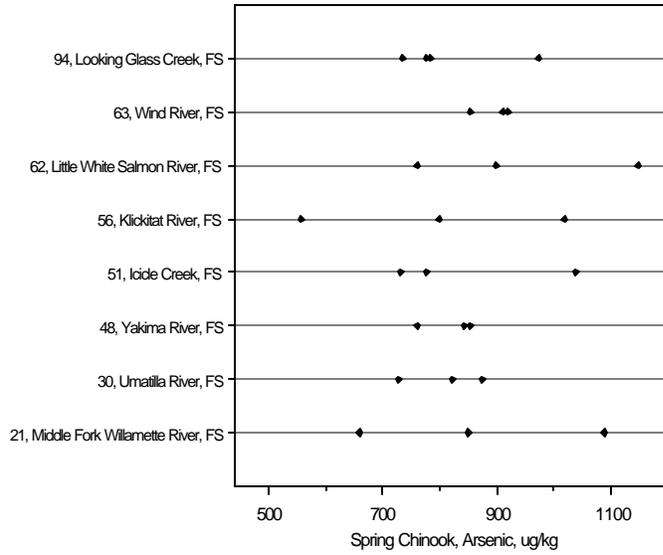


Figure 2-15a. Study site concentrations of arsenic in spring chinook composite samples from the Columbia River Basin. Study site 94 includes duplicate fillet samples.

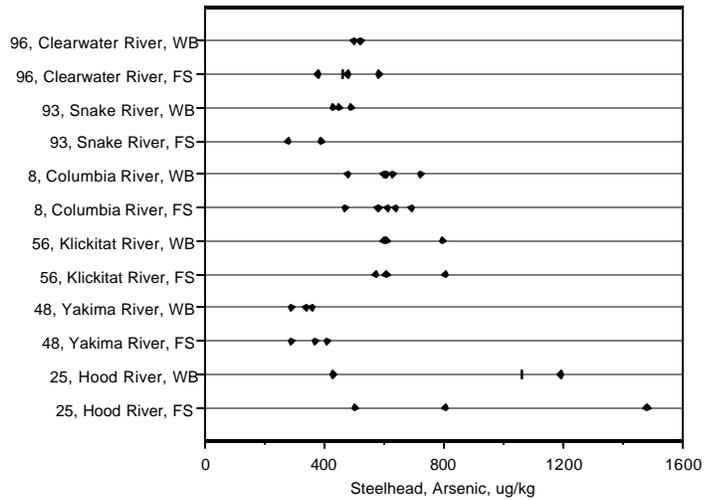


Figure 2-15b. Site specific concentrations of arsenic in steelhead composite fish tissue samples from the Columbia River Basin. Study site 96 includes duplicate fillet samples.

2.8.2 Mercury

The mercury levels in fish samples were extremely variable. The maximum concentration of mercury (510 µg/kg) was in the fillet sample of spring chinook salmon from the Klickitat River (Table 2-12).

There was no consistent pattern in mercury concentrations between whole body and fillet samples in the basin-wide average concentrations (Table 2-14). The average concentrations in fillet samples ranged from <91 µg/kg in the Pacific lamprey to 240 µg/kg in the largescale sucker. The whole body average concentrations ranged from <35 µg/kg in the eulachon to 180 µg/kg in the walleye.

Mercury concentrations were compared across study sites for white sturgeon, largescale sucker, mountain whitefish, spring chinook salmon, and steelhead (Figures 2-16a,b,c and 2-17a,b).

The maximum concentration (617 µg/kg) for white sturgeon was measured in the duplicate fillet from the Snake River (Figure 2-16a). The mercury concentrations in duplicate fillets from the Snake River were quite different from each other (617 µg/kg, 353 µg/kg) and the whole body samples (100 µg/kg) from this site. Since, the duplicate fillets from the same fish were averaged (430 µg/kg) in the data-set for this report, the maximum level of mercury for this study was reported as 510 µg/kg for spring chinook (Table 2-12). The concentrations in the duplicate fillets from study sites 9L, 6, and 13 were similar to each other.

The largescale sucker mercury concentrations were extremely variable across and within study sites. There was no distinct maximum although the fillet samples for the Umatilla and Snake Rivers were higher than the whole body samples from these study sites.

The mountain whitefish mercury concentrations were also variable. The maximum concentrations occurred in the Yakima, and Deschutes Rivers, although there was no difference in average concentrations. The duplicate fillets from the Deschutes River were equal to each other (71 µg/kg).

The concentrations of mercury in spring chinook salmon samples were at or near non-detectable levels, with the exception of the fillet samples from the Klickitat River, where the maximum concentration (510 µg/kg) was measured. This fillet sample also appeared to be an outlier for spring chinook salmon within this site and across all sites. The duplicate fillets from Looking Glass Creek were equal to each other (100 µg/kg).

The maximum concentration (420 µg/kg) was a single whole body sample from the Clearwater River. Except for the whole body sample from the Clearwater River, Steelhead mercury concentrations were all less than 180 µg/kg, with most samples in the 50-110 µg/kg range. The duplicate fillets from the Clearwater River were equal to each other.

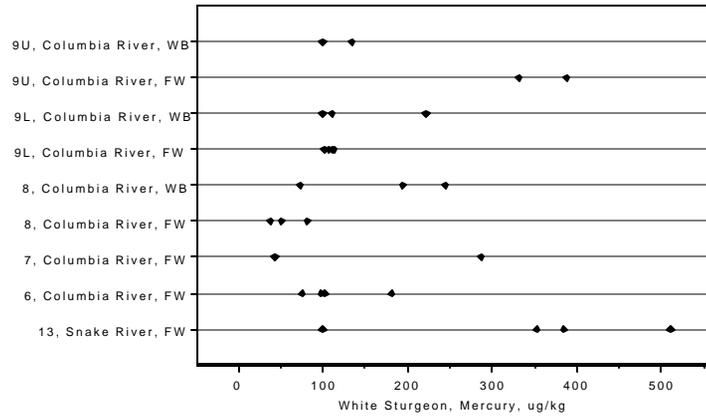


Figure 2-16a. Site specific concentrations of mercury in white sturgeon fish tissue samples from the Columbia River Basin. Study sites 9U, 9L, 13, and 6 include duplicate fillet samples.

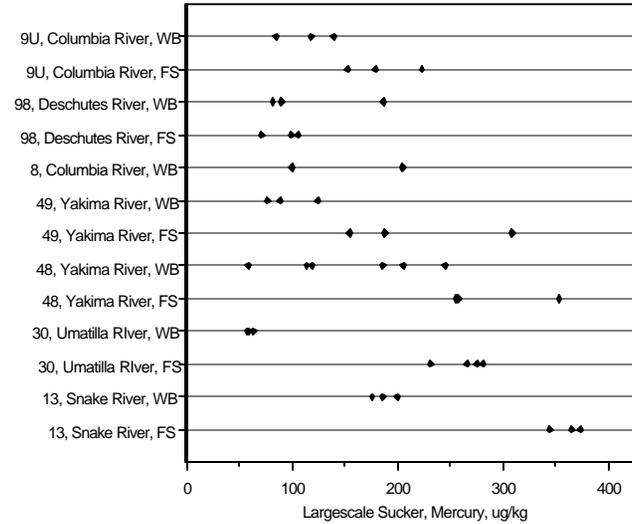


Figure 2-16b. Site specific concentrations of mercury in largescale sucker composite fish tissue samples from the Columbia River Basin.

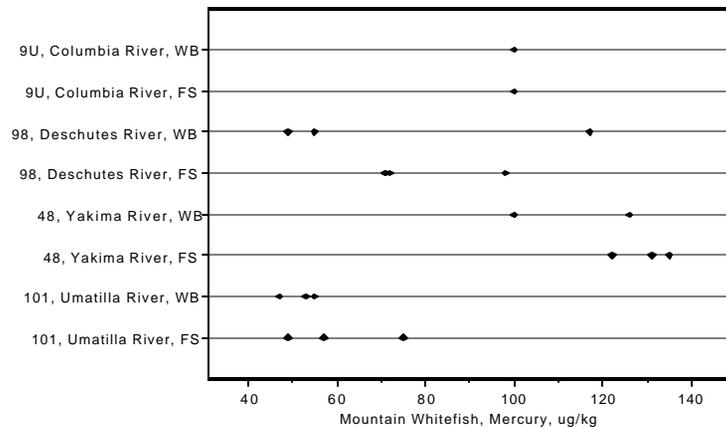


Figure 2-16c. Site specific concentrations of mercury in mountain whitefish composite fish tissue samples from the Columbia River Basin. Study site 98 includes duplicate fillet samples.

LEGEND

FW = fillet without skin
 FS = fillet with skin
 WB = whole body

Data points represent composite samples of fish tissue except white sturgeon which are individual fish. Study sites are listed by name and number and described in Table 1-1.

Concentration points on graphs include duplicate fillets and chemicals at their detection limits.

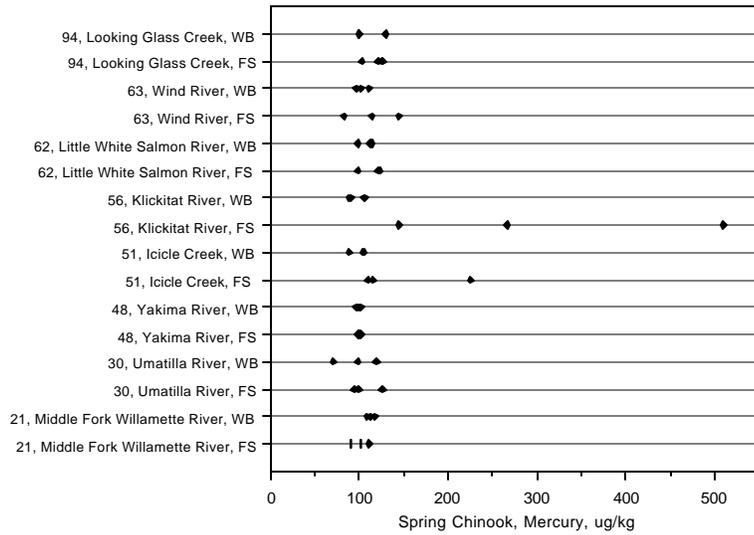


Figure 2-17a. Site specific concentrations of mercury in spring chinook salmon composite fish tissue samples from the Columbia River Basin. Study site 94 includes duplicate fillet samples.

LEGEND
 FS = fillet with skin
 WB = whole body
 Study sites are listed by name and number and described in Table
 .Concentration points on graphs include duplicate fillets and chemicals at their detection limits.

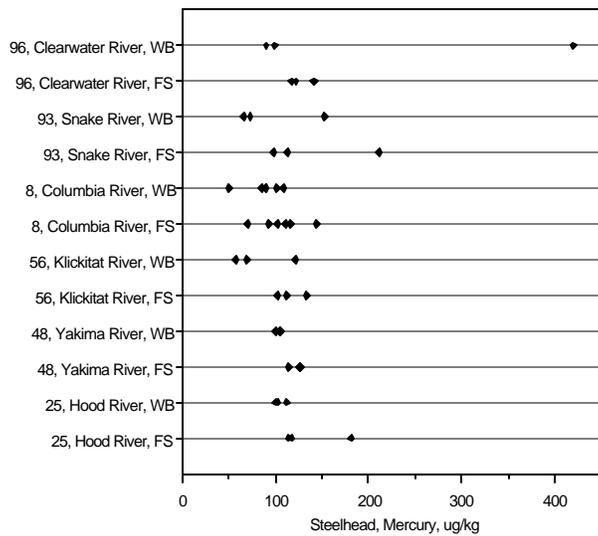


Figure 2-17b. Site specific concentrations of mercury in steelhead composite fish tissue samples from the Columbia River Basin. Study site 96 includes duplicate fillet samples.