Washington State Toxics Monitoring Program

Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2001

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WASHINGTON STATE DEPARTMENT OF ECOLOGY

Washington State Toxics Monitoring Program

Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2001

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March 2003

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Abstract

The Washington State Toxics Monitoring Program began in 2001 with an exploratory monitoring component. The goal of this component is to investigate the occurrence and concentrations of toxic contaminants in edible fish tissue and surface waters from freshwater environments in Washington.

A total of 147 fish of five species were collected from 14 sites (13 lakes and one river) in 2001, and muscle tissue was analyzed for a range of toxic contaminants. One composite sample and 107 individual fish were analyzed for mercury. Analytes for six composite tissue samples included chlorinated pesticides, PCBs, polybrominated diphenyl ethers (PBDEs), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/Fs), and lipids. Water samples from four lakes were analyzed for 35 chlorinated pesticides; no pesticides were detected in any of these samples.

Several contaminants in all tissue samples analyzed exceeded some criteria for the protection of human health.

- Total PCB levels ranged from 10.8 to 132 parts per billion, wet weight (ppb ww), with all samples exceeding the National Toxics Rule (NTR) criterion of 5.5 ppb ww.
- Two tissue samples had levels of 4,4'-DDE (33 and 53 ppb ww) that exceeded the NTR criterion of 31.6 ppb ww.
- A total chlordane concentration of 35.6 ppb ww exceeded the NTR criterion of 8.3 ppb ww.
- PCDD/F concentrations in four samples ranged from 0.20 to 1.05 parts per trillion (ppt) ww, all of which exceed the NTR criterion of 0.07 ppt ww.
- Mercury was detected in all tissue samples analyzed. About 17% of the samples exceeded EPA's proposed Water Quality Criterion for the Protection of Human Health of 300 ppb ww. The NTR criterion of 825 ppb ww was exceeded by one sample with a mercury concentration of 1280 ppb ww.

Recommendations call for evaluating potential risks to human health from consumption of contaminated fish and determining how these sites are to be categorized for Washington's 303(d) listing assessment.

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Summary

Humans and wildlife continue to face a variety of risks due to toxic chemicals in the environment. For many areas of Washington, information is lacking about the levels of toxic contamination in freshwater fish and surface water. Renewed concern about toxic contamination of freshwater fish, water, and wildlife was rekindled in 2000, and resources were directed to the development of a Washington State Toxics Monitoring Program (WSTMP).

The first component of the WSTMP is exploratory monitoring to identify new instances and locations of toxics contamination in freshwater environments and freshwater fish tissue. This project aims to provide information to resource managers and the public about the status of toxics contamination in water and edible fish from freshwater environments in Washington.

In 2001, 147 fish of five species from 13 lakes and one river segment were collected for analysis of tissue contaminant levels. Fish tissue samples from six lakes were analyzed for chlorinated pesticides, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and lipids. Fish tissue samples from four lakes were analyzed for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/Fs). One composite sample and 107 individual fish, primarily bass, were analyzed for mercury. Fish tissue and water samples from additional sites will be sampled in 2002 and annually thereafter.

Water samples were collected from four lakes for analysis of 35 chlorinated pesticides. Ancillary parameters for water samples include lab determination of total organic carbon and total suspended solids. Field measurements included temperature, conductivity, and pH. No pesticides were detected in any of the water samples.

Many of the pesticides found during this study are among the most commonly detected pesticides found in Washington fish. Total PCBs, total DDT, and total chlordanes were detected in the six tissue samples analyzed. Total PCBs levels in tissue samples ranged from 10.8 to 132 parts per billion, wet weight (ppb ww). Total PCB levels in all samples exceeded the National Toxics Rule (NTR) criterion of 5.3 ppb ww (40 CFR 131), and exceeded EPA screening values for the protection of human health (EPA, 2000). Two tissue samples had levels of 4,4'-DDE (33 and 53 ppb ww) that exceeded NTR criterion (31.6 ppb ww). The total DDT levels in these same two samples exceeded EPA screening values for the protection of human health.

All samples contained PCDD/Fs at levels at least one to two orders of magnitude greater than the NTR criterion of 0.07 parts per trillion wet weight (ppt ww). PCDD/F concentrations ranged from 0.20 to 1.05 ppt ww.

Every fish tissue sample had detectable levels of mercury. Sixteen of the samples exceeded the recommended 300 ppb ww EPA Water Quality Criterion for the Protection of Human Health (EPA, 2001). Mercury concentration in one sample exceeded the 825 ppb ww NTR criterion. Many age classes were represented, with fish ages ranging from one year to 17 years.

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Introduction

Humans and wildlife face a variety of risks due to toxic chemicals in the environment. For many areas of Washington, information is lacking about the levels of toxic contamination in freshwater fish and surface water.

Contaminants of particular concern include polychlorinated biphenyls (PCBs), chlorinated pesticides, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/Fs), and mercury. Many of these chemicals are persistent; they do not break down easily and remain in the environment for decades. Many toxic contaminants also bioaccumulate and biomagnify in organisms; contaminant concentrations increase at higher trophic levels because the contaminant is not broken down or excreted by metabolic processes. The accumulation of these chemicals can have a variety of health effects on humans and wildlife such as reproductive abnormalities, neurological problems, and behavioral changes.

Past monitoring efforts in Washington have detected toxic contaminants in surface water, sediment, and aquatic animal tissues. In many studies, concentrations of toxic contaminants in water, sediment, and tissue have been high enough to threaten the health of humans, wildlife, and fish. The Washington State Department of Health (Health) currently has ten fish consumption advisories in Washington State due to contamination by mercury, PCBs, PCDD/Fs, chlorinated pesticides, and/or other metals and organic chemicals. Three consumption advisories exist for shellfish due to similar contaminants (Health, 2001).

Efforts to monitor toxic contamination in freshwater fish tissue, sediments, water, and wildlife in Washington declined over the last decade due to budget reductions. Renewed concern about toxic contamination of freshwater fish, water, and wildlife was rekindled in 2000, and resources were directed to develop a statewide Washington State Toxics Monitoring Program (WSTMP) which would:

- Conduct exploratory monitoring to identify new instances and locations of toxics contamination in freshwater environments and freshwater fish tissue.

- Conduct trend monitoring for persistent toxic contaminants using residues in edible fish tissue.

- Establish an Internet Web page featuring toxics monitoring efforts in Washington to disseminate and inform citizens about toxics contamination. (Established in June 2002: <http://www.ecy.wa.gov/programs/eap/toxics/index.html>).

- Develop other toxics monitoring efforts to address particular issues and establish cooperative programs with other agencies.

Exploratory monitoring was the first component of the WSTMP to be implemented. A project plan was developed in March 2001 (Seiders and Yake, 2001) which guided the initial year of the program. The objectives of the exploratory monitoring component are to provide:

- Information about the level of toxic contamination in surface water and edible fish tissue from freshwater lakes, rivers, and streams that have not yet been monitored or where relevant data are greater than ten years old.
- A screening level assessment of the potential for adverse effects of toxic chemicals on aquatic biota and other wildlife.
- Screening level information to the Washington State Department of Health that could be used to trigger additional studies for evaluating health risks associated with the consumption of fish.
- Information for resource managers and the public about the status of toxics contamination in water and edible fish from freshwater environments in Washington.

This report describes results from the first year of the exploratory monitoring component.

Methods

Study Design

The study approach for the exploratory monitoring component involved reviewing existing data on fish tissue and water contaminant levels and then selecting fish species, target analytes, and sites for monitoring. To address the human and wildlife concerns, contaminants that bioaccumulate and persist in fish tissue were selected as target analytes. Results would then be compared to various criteria for the protection of human health and wildlife. Gamefish were selected as the preferred species for monitoring because they are more commonly pursued and consumed by humans than are other species. Gamefish, being at a higher trophic level than many non-game fish, are expected to contain higher levels of contaminants due to the bioaccumulative and biomagnification of persistent contaminants in the environment.

Water quality sampling efforts aim to characterize pesticide contamination of water at various times throughout the growing season when pesticides are commonly used in urban and agricultural landscapes. Target analytes for water samples include organophosphorus and nitrogen pesticides which are less persistent than those analytes for fish tissue. For the first year, however, water sampling occurred only at four of the sites selected for fish tissue sampling and targeted the same analytes for fish tissue.

Data from this project will be compared to various regulatory and biological effects concentrations and findings from historical work, such as:

- Criteria in Washington's water quality standards (Chapter 173-201A WAC) and the National Toxics Rule (40 CFR 131).
- Risk-based consumption screening values as described by EPA (2000).
- Results from historical work in Washington, such as from Ecology's Washington State Pesticide Monitoring Program (WSPMP) and EPA's Columbia River Basin Fish Contaminant Survey (EPA, 2002).

Species and Site Selection

Target Fish Species

Target species were selected based on recommendations from EPA (2000) and previous experience with fish collection efforts in Washington. Edible game fish were the primary target for collection as described above. Target species for this study are listed in Appendix B.

The following criteria were used to select target species:

- Commonly captured and likely to be consumed by humans.
- Potentially bioaccumulate high concentrations of chemicals of interest.

- Abundant, easy to identify, and easy to capture.
- Large enough to provide adequate tissue for analysis.
- Resident fish and fish likely to stay relatively close to the sampling site.

Site Selection for Fish Tissue

The project plan describes the site selection process used for this 2001 monitoring effort (Seiders and Yake, 2002). In summary, historical data on fish tissue were reviewed and associated sites displayed using ArcView GIS. Locations of potential pollution sources (e.g., Superfund sites, chemical handlers, agricultural activity) were also identified and displayed using Ecology's Facility/Site database (Ecology, 2001) with ArcView GIS. Potential sites were then selected considering a number of factors which included:

- The potential for site contamination.
- Existences and nature of historical fish tissue data.
- Value and interest of the fish resource to consumers.
- Nature of the fish resource (e.g., species present, management practices).

For the WSTMP, fish tissue samples were obtained from 14 sites throughout the state (Figure 1) from June through December 2001. Fish were collected from some of the 14 sites in order to meet two emerging needs: further work regarding mercury contamination of Lake Whatcom fish (Serdar and Davis, 1999; Serdar, 2001), and monitoring related to a statewide mercury action plan (Anderson and Norton, 2002). Fish from the Whatcom County sites were collected by Washington Department of Fish and Wildlife (WDFW) crews in the course of their routine population surveys. Fish from two other sites were collected in the course of other projects (Jack and Roose, 2002; Serdar, 2002) and included in the mercury study: Long Lake near Spokane and the Okanogan River near Omak.

For the WSTMP, one to two species of fish were obtained from each site, with five to ten fish of each species forming a composite sample as recommended by EPA (2000).

Site Selection for Water

A small number of sites were selected for water sampling during this initial year of exploratory monitoring. Sites were selected to characterize pesticide concentrations in water where fish tissue sampling occurred. Selection criteria were thus similar to those described above for fish tissue site selection. Future site selection will include streams and lakes in urban and agricultural settings in order to characterize pesticide contamination of streams and lakes.

Locations where tissue and water samples were collected are shown in Figure 1. Appendix A lists the coordinates for these sampling sites.

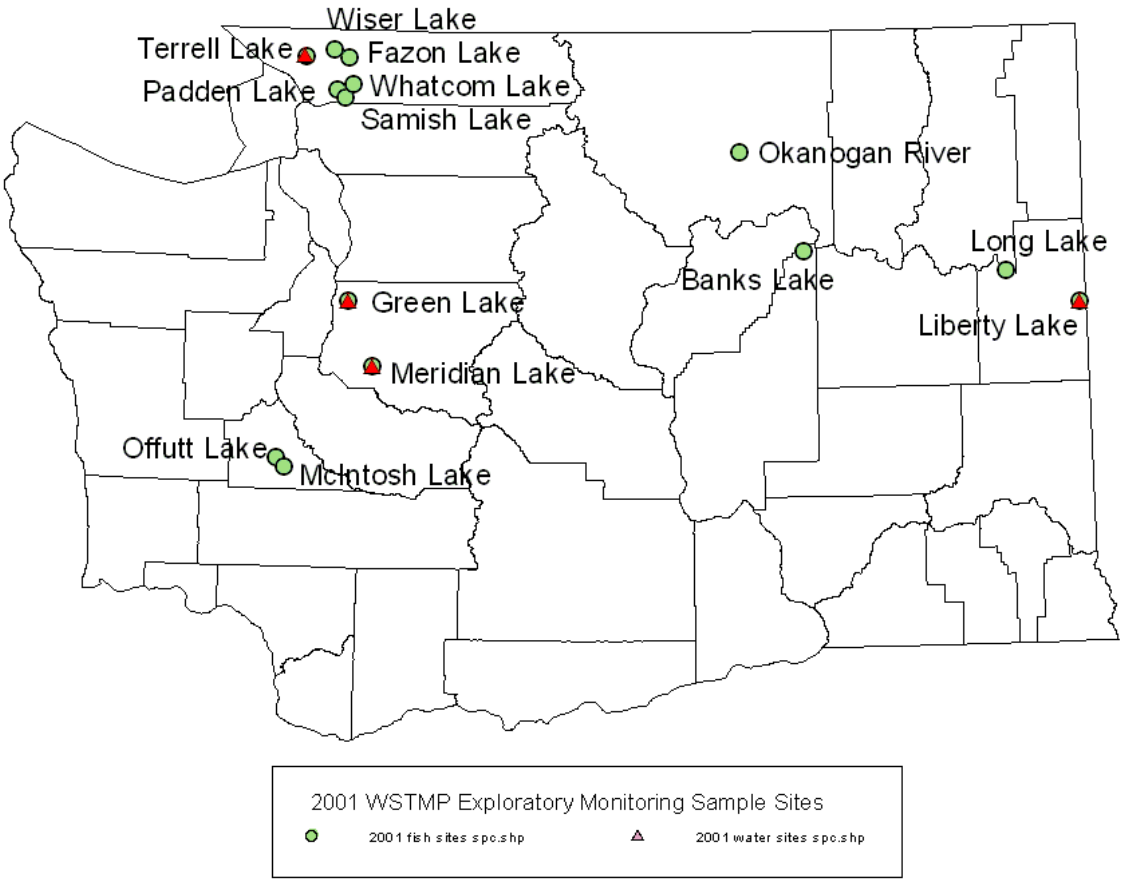

Figure 1. WSTMP Sample Sites for 2001.

Field Procedures

Fish Tissue

Methods for the collection, handling, and processing of fish tissue samples for analysis were guided by methods described by EPA (2000). Fish were captured by gillnetting or electrofishing with a 16’ Smith-Root electrofishing boat. Captured fish were identified to species, and target species were retained while non-target species were released. Retained fish were inspected to ensure that they were acceptable for further processing (e.g., proper size, no obvious damage to tissues, skin intact). Field preparation of individual fish involved assigning an identification code, measuring length and weight, wrapping in foil and plastic Ziploc bags, and placing on ice for transport to a freezer for storage at -18 C.

Fish were processed at a later date to form samples that would be sent to the laboratory for analysis. The edible portion of target species was used for individual and composite samples. For analysis of organic compounds, at least five fish were used to create a composite sample for each site. For analysis of mercury, individual fish were prepared for laboratory analyses. Field sampling procedures are described in Appendix B.

Water Samples

Water samples were collected from four lakes for analysis for chlorinated pesticides. A USGS DH-76 sampler was used to collect a depth-integrated sample from the deeper area of each lake. About ten casts of the sampler were needed to obtain the volume of water needed for analyses of pesticides, total organic carbon (TOC), and total suspended solids (TSS). Vertical profiles of temperature and conductivity were made at each site to help determine the degree of mixing or stratification of the lake. Field measurements of temperature, pH, and conductivity were determined from the depth-integrated composite sample. The appropriate sample containers were filled, identified, placed on ice, and delivered to the laboratory within 24 to 72 hours. Field sampling procedures are further described in Appendix B.

Field notebooks were used to record information gathered during each tissue or water sampling event. Information about individual fish was recorded on lab forms at the time fish tissue samples were processed and submitted for analyses.

Laboratory Procedures

Fish Tissue Processing

Frozen fish were processed at Ecology's Lacey laboratory and samples then sent to Manchester Environmental Laboratory for analyses. The edible portion of target species was used for individual and composite samples. For analysis of organic compounds, skin-on fillets from five to ten fish were used to create a composite sample for each site. For analysis of mercury, skin-off fillets of individual fish were used.

Fillets were passed through a KitchenAid™ model FGA food grinder two or three times to allow thorough grinding and homogenization of the sample. An aliquot of the homogenized tissue was placed in a pre-cleaned jar (I-Chem 200) for transport to the laboratory. The abdominal cavity of the fish was then opened to determine sex, and various anatomical structures were removed for age determination.

All utensils used for tissue processing were cleaned to prevent contamination of the sample. The cleaning procedure involved soap and water washes followed by acid and solvent rinses. Appendix B more fully describes the tissue processing procedures used.

Target Analytes

Analysis of fish tissue focused on various persistent, bioaccumulative, and toxic chemicals that have been found in water, sediments, and fish tissue in other monitoring efforts in Washington. Target analytes included: chlorinated pesticides, PCBs, polybrominated biphenyl ethers (PBDEs), PCDD/Fs, mercury, and lipids.

Target analytes for water included 35 chlorinated pesticides, TOC, and TSS. Field measurements included temperature, conductivity, and pH. Future water sampling efforts will include approximately 135 target analytes representing chlorinated, organophosphorus, and nitrogen-based pesticides.

Analytical Methods

The analytical methods for target analytes were selected to achieve a balance of analytical sensitivity, comparability, and cost-effectiveness. The project plan describes the analytical methods used for water and fish tissue matrices: these methods are summarized in Appendix C. The quantitation limits of these methods are adequate for most analytes, yet some of the quantitation limits are higher than water quality standards or screening level criteria. For tissue samples, these analytes include toxaphene, PCBs, and PCDD/Fs. For water samples, the freshwater chronic criteria in Washington's water quality standards (Chapter 170-201A WAC) are lower than the selected method's quantitation limits for DDT and metabolites, chlordanes and nonachlors, aldrin and dieldrin, endrin, heptachlor, heptachlor epoxide, and toxaphene.

The EPA (2000) recognizes the unavailability of cost-effective analytical methods that can achieve lower quantitation limits for some of these analytes. The use of performance-based analytical techniques are encouraged by EPA to help in developing analytical methods that achieve needed detection limits for particular analytes.

Nearly all samples were analyzed at the Ecology/EPA Manchester Environmental Laboratory in Manchester, Washington. Triangle Labs, Inc. of Durham, North Carolina, analyzed tissue samples for PCDD/Fs.

Data Quality Assessment

Review of data quality is contained in Appendix D. Quality control and quality assurance data from laboratories were reviewed and indicated that analytical systems performed adequately with most data meeting objectives for quality control. Quality control procedures included analysis of method blanks, matrix spikes, matrix spike duplicates, surrogate recoveries, laboratory duplicates, and field duplicates.

Some tissue results were qualified as estimates for various reasons. For pesticide/PCB/PBDE analyses, several matrix spike recoveries fell outside the acceptable range. For PCDD/Fs analyses, all results were qualified as estimates because the ratios of analyte to internal standard fell outside the calibration curve. The precision of field and laboratory duplicate samples for lipids was mixed, yet most samples met precision targets. All tissue mercury results were qualified as estimates because the samples exceeded EPA's 28-day holding time for mercury analysis (Knox, 2002). Ecology and EPA holding time criteria for mercury may be overly conservative for fish tissue. The USGS NAWQA program uses a holding time for mercury in tissue of six months (Crawford and Luoma, 1993) and Bloom (1995) states that biota samples for mercury analysis may be stored indefinitely when frozen.

The laboratory noted that the water samples were exceptionally clean which was the likely reason for low recoveries for some surrogates. The lack of target analyte detections in field and lab duplicates precludes the estimation of precision.

Results

Fish Tissue

A total of 147 fish of five species were processed for analysis of tissue contaminant levels. Composite samples from five sites were created and analyzed for organic contaminants. Of the 107 individual fish analyzed for mercury, about 79% were largemouth bass, 9% were smallmouth bass, and 11% were cutthroat trout. A seven-fish composite sample from Green Lake common carp also was analyzed for mercury. Table 1 summarizes the levels of contaminants found in tissue samples. Table E1 (Appendix E) presents data on the fish comprising the composite samples. Table E2 includes data for all fish collected such as sample site, species, fish size, age, sex, sample type, and collection dates. Results for lipids and mercury analyses are also in Table E2. Results from tissue analyses are discussed below.

Water

No target analytes were detected in any of the water samples collected from four of the lakes. The laboratory noted that these water samples were exceptionally clean. Sample cleanliness was a likely factor in the analyses achieving very good detection limits (0.0008 – 0.0016 ug/L) which are from one to two orders of magnitude below those specified in the project plan (0.1 – 0.01 ug/L). The results of field measurements and conventional parameters appear typical for lakes in Washington (Table 2).

Table 1. Summary of Contaminant Levels Detected in Fish Tissue Samples, WSTMP 2001.

	Minimum Value		Maximum Value		Median Value	Frequency of Detection	Number of Samples
Pesticides (ppb ww)							
cis-Nonachlor	0.69		14		1.45	100%	6
trans-Nonachlor	0.37	J	9.8		1.205	100%	6
Oxychlordane	0.5		0.5		0.5	17%	6
cis-Chlordane (alpha)	0.26		6.9		0.44	50%	6
trans-Chlordane (gamma)	4.4		4.4		4.4	17%	6
Total Chlordane [1]	1.06		35.6		3.005	100%	6
2,4'-DDT	0.14	NJ	0.14		0.14	33%	6
2,4'-DDD	1.4		1.4		1.4	17%	6
4,4'-DDD	0.35		26		0.5	100%	6
4,4'-DDE	2.2	J	53	J	3.85	100%	6
4,4'-DDT	0.29	NJ	2.9	NJ	0.665	100%	6
Total DDT [1]	2.84		63.3		5.085	100%	6
DDMU	1.4		1.4		1.4	17%	6
Hexachlorobenzene	0.19	J	1.3		1.03	100%	6
Pentachloroanisole	0.23		0.61		0.58	50%	6
PCBs (ppb ww)							
PCB-1254	5.2	J	88		9	100%	6
PCB-1260	3.4	J	44	J	7.95	100%	6
Total PCBs [1]	10.8		132		15.7	100%	6
PBDEs (ppb ww)							
2,2',4,4'-TBDE	1.5		2.5		2.1	83%	6
2,2',4,4',5'-PeBDE	0.98		1.9		1.1	67%	6
Dioxin/Furans (ppt ww)							
PCDD/Fs as TEQ 2,3,7,8-TCDD [2]	0.204		1.047		0.555	100%	4
Metals (ppb ww)							
Mercury	22	J	1280	J	115.5	100%	108

[1] - Represents sum of components that were detected. Compounds not detected were also used to sum totals with one-half the detection limit as the value used for summing.

[2] - Represents sum of components that were detected, expressed as 2,3,7,8-TCDD toxicity equivalents. Compounds not detected were also used to sum totals with one-half the detection limit as the value used for summing.

ppb ww: parts per billion (ug/Kg), wet weight.

ppt ww: parts per trillion (ng/Kg), wet weight.

J: The analyte was positively identified. The associated numerical value is an estimate.

NJ: There is evidence that the analyte is present. The associated numerical result is an estimate.

Table 2. Results for Conventional Water Quality Parameters, WSTMP 2001.

Site	Liberty Lake	Green Lake	Lake Meridian	Lake Terrell
Date	11/8/01	12/21/01	12/21/01	12/27/01
Time	1615	1700	1400	1430
TSS (mg/L)	1	6	1 U	3
TOC (mg/L)	3.2	3.8	2.8	8.1
pH (S.U.)	7.38	6.99	7.65	7.09
Conductivity (umho/cm)	29 - 35	70 - 71	60 - 66	51
Temperature (deg. C)	8.1 - 8.5	5.2 - 5.4	6.1 - 7.4	1.5 - 1.8
Manchester Lab ID	1458040	1528008	1528005	1528009

U: Data qualifier indicating the analyte was not detected at the associated numerical result.

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Discussion

Fish Tissue Criteria for the Protection of Human Health

National Toxics Rule

Washington's water quality standards that deal with toxic substances define human health-based water quality criteria by referencing 40 CFR 131.36, also known as the National Toxics Rule (WAC 173-201A-040[5]). The standards state that risk-based criteria for carcinogenic substances should be based on a risk level of $1x10^6$. A risk level is an estimate of the number of cancer cases that would be caused by a specific contaminant or a group of contaminants. A risk level of $1x10^6$ estimates that one person in a million will contract cancer due to long-term exposure to a specific contaminant.

EPA Screening Values

The EPA developed screening values for about 25 contaminants in order to help states prioritize areas that may present risks to humans consuming fish from that area. EPA defines the term 'Screening Value' (SV) as a concentration of a contaminant in fish tissue that is a potential public health concern. The exceedence of a SV should be an indication that a more intensive site-specific evaluation of human health risk needs be conducted. The SVs were part of guidance that was developed as part of a Federal Assistance Program to help states standardize fish consumption advisories (EPA, 2000). Being guidance only, SVs are not regulatory thresholds as water quality criteria are.

Several assumptions are used in calculating SVs for carcinogenic and non-carcinogenic substances. Exposure assumptions include an acceptable risk level and the consumer's body weight, length of exposure, and consumption rate. The default values used by EPA for calculating SVs are a risk level of 1×10^5, a consumer body weight of 70kg, exposure over a 70-year lifetime, and consumption rates of 17.5 grams/day for recreational fishers and 142.4 grams per day for subsistence fishers (EPA, 2000). Calculation of SVs for non-carcinogenic effects use a reference dose developed from toxicological tests, while SVs for carcinogenic effects include a carcinogenicity potency factor.

The development of fish consumption advisories requires an intensive survey of substantial effort and resources to characterize health risks from eating contaminated fish. Such surveys involve determining local fish consumption patterns, contaminant levels, toxicological aspects of the contaminant, exposure assessment, and risk characterization. The Washington State Department of Health and local health departments are responsible for developing fish consumption advisories in Washington.

EPA Recommended Criterion for Mercury in Fish Tissue

The EPA recently updated its water quality criterion for methylmercury which was developed in 1980 (EPA, 2001). Methylmercury is a toxic form of mercury that comprises nearly all the mercury in fish tissue (Bloom, 1995). The new recommended water quality criterion for mercury is expressed as a fish tissue concentration of 300 ppb ww. This tissue concentration is the maximum advisable level of methylmercury (measured as total mercury) in freshwater and estuarine fish and shellfish tissue to protect consumers of these fish among the general population. EPA expects the criterion recommendation to be used as guidance by states and authorized tribes in establishing or updating their water quality standards.

The water quality criteria (expressed as tissue concentrations) serve a regulatory purpose to help manage mercury loading to waters, such as through Total Maximum Daily Load (TMDL) exercises and National Pollution Discharge Permit System (NPDES) permits. The National Toxics Rule (NTR) criterion of 825 ppb ww remains as the current regulatory threshold for Washington until a new criterion is adopted.

The calculation of the recommended water quality standards criterion of 300 ppb ww was similar to that for the SVs described above, yet different assumptions yielded different values. The SV for mercury described above for recreational fishers (general public) is 400 ppb ww while the recommended water quality criterion is 300 ppb ww. The difference between these two values is due to the SV's assumption that fish tissue is the consumer's sole source, or dose, of mercury. Calculation of the recommended water quality criterion assumes that the consumer is exposed to mercury from other sources which results in a reduced "dose" value from fish tissue in the calculation. This difference between the dose values used in the calculations results in the different values obtained. The SV for subsistence fishers is lower, at 49 ppb ww, because the calculation assumes a higher consumption rate than the other calculations (142.4 versus 17.5 grams/day).

Mercury

Human Health

The mercury data collected during this study are only summarized here since a new Ecology effort, *Screening Survey of Mercury Levels in Edible Fish Tissue from Freshwater Areas of Washington State* (Anderson and Norton, 2002), will provide a thorough discussion. The screening survey began as this 2001 WSTMP sampling effort progressed. Additional fish tissue mercury data were collected in the fall of 2002 and will be reported in the spring of 2003. The screening survey will characterize tissue mercury levels and related characteristics from 20 sites throughout the state.

Mercury levels in fish tissue from 12 sites sampled in 2001 are summarized in Table 3. The sites in the table are ranked by median mercury levels, from high to low median concentrations. The four sites having fish with the highest median mercury concentrations were Fazon, Samish, Meridian, and Wiser lakes.

Table 3. Summary of Mercury Levels, Lengths, and Ages of Fish Collected for the WSTMP, 2001.

Waterbody	Species	Count	Mercury (ppb ww)			Total Length (mm)			Age (years)		
			min	max	median	min	max	median	min	max	median
Fazon Lake	LMB	10	192	760	410.0	354	575	402.0	5	17	7.5
Samish Lake	LMB	10	90.3	1280	255.0	255	466	382.5	3	10	4.5
Meridian Lake	LMB	8	167	645	205.0	314	493	326.0	2	9	2.0
Wiser Lake	LMB	4	62.6	215	168.5	390	491	467.0	3	9	7.5
Terrell Lake	LMB	10	49.7	332	131.0	260	431	326.5	2	13	2.5
Okanogan River	SMB	10	104	312	129.5	260	433	302.0	2	7	3.0
Banks Lake	LMB	10	70	183	117.5	293	406	351.0	2	5	4.0
Padden Lake	LMB	8	63.1	223	84.9	177	422	191.5	1	4	1.0
Offutt Lake	LMB	10	46.5	112	79.9	191	255	221.5	1	1	1.0
Long Lake (upper)	LMB	10	22	181	76.5	312	441	403.0	3	12	6.5
Whatcom Lake	CT	12	46.7	124	72.8	272	373	323.5	3	5	4.0
Green Lake *	CCP	7	-	-	57.9	452	640	555.0	4	10	4.0
Green Lake	LMB	5	30.6	60.7	39.3	250	352	341.0	1	2	2.0
Statewide	n=24	594	5	1840	125.0	-	-	-	-	-	-

* This single sample was a composite of seven fish; the mercury value is a mean concentration.
LMB: Largemouth bass
SMB: Smallmouth bass
CCP: Common carp
CT: Cutthroat trout

Figure 2 depicts the mercury concentrations for individual fish tissue samples and indicates their relation to various criteria for the protection of human health.

Mercury was detected in every tissue sample, with one sample exceeding the NTR criterion of 825 ppb ww. About 14% of the samples exceeded EPA's proposed water quality criterion of 300 ppb ww. EPA's SV for subsistence fishers, 49 ppb ww, was exceeded by 93% of the samples. About 6% of the samples exceeded 400 ppb ww, the SV for recreational fishers. Many age classes were represented among all the fish, with ages ranging from one year to 17 years.

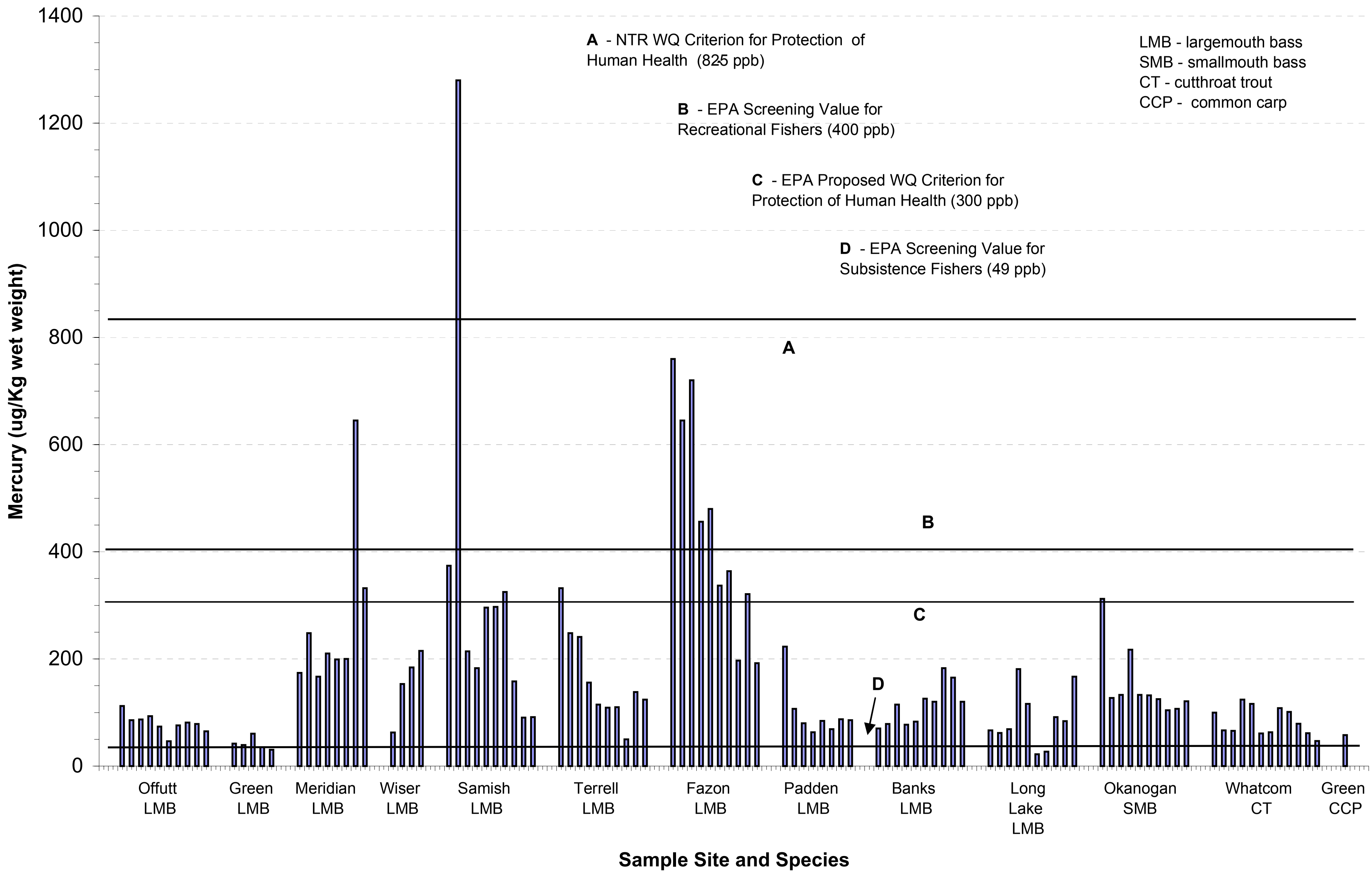

Figure 2. Mercury Concentrations in Fish Tissue Collected During the 2001 WSTMP.

A single largemouth bass from Samish Lake exceeded the current NTR criterion of 825 ppb ww with a tissue mercury level of 1280 ppb ww. The mercury level found in this ten-year-old fish approaches the highest mercury values (1300 and 1840 ppb ww) found in smallmouth bass from Lake Whatcom (Serdar et al., 2001).

The bioaccumulative and biomagnification nature of mercury generally results in older fish having higher levels of mercury. Largemouth bass from Fazon Lake represented many of the oldest and largest fish collected during the study; these fish generally had higher mercury levels than fish from other sites. Most fish exceeding EPA's recommended criterion of 300 ppb ww were five or more years old, with the exception of two four-year olds from Samish Lake. Meridian Lake, Lake Terrell, and the Okanogan River also had fish tissue mercury levels that exceeded EPA's recommended criterion.

Comparisons to Other Data

For a statewide perspective, tissue mercury levels in freshwater fish from various studies were plotted in Figure 3 as cumulative percentile. The various studies were conducted by Ecology, EPA, and the U.S. Geological Survey (USGS). These studies determined mercury levels in tissue from multiple species using individual fish as well as composite samples of a single species (EPA, 1992; EPA, 2002; EPA, 2002b; Hopkins et al., 1985; Hopkins, 1991; Johnson and Norton, 1990; Serdar et al., 1994; Serdar and Davis, 1999; Serdar et al., 2001; Munn et al., 1995).

About 90% of these results were obtained from edible tissue while the remaining 10% were obtained from samples using the whole body of the fish. The toxic form of mercury, methylmercury, accounts for nearly all (> 95%) of the total mercury in edible fish tissue such as muscle, whereas whole fish may contain a smaller proportion (> 90%) of methylmercury (Bloom, 1995). The median tissue mercury values for sites sampled in this study are indicated in Figure 3. The 50^{th} percentile of all mercury values was exceeded by six of the 12 sites sampled in 2001.

Wildlife Criteria - Mercury

In 1972, the National Academies of Sciences and Engineering (NAS/NAE, 1973) recommended criteria for the protection of wildlife. These criteria suggested that fish-eating birds should be protected if mercury levels in fish do not exceed 500 ppb ww. The NAS/NAE recognized that the 500 ppb ww criterion provided little or no safety margin for fish-eating wildlife and recommended that the criterion be updated.

Mueller et al. (2001) reviewed impacts of mercury in fish tissue on populations of Lake Whatcom fish. Effects vary among species and include disruption of the immune and endocrine systems, liver and kidney damage, and reproductive ability.

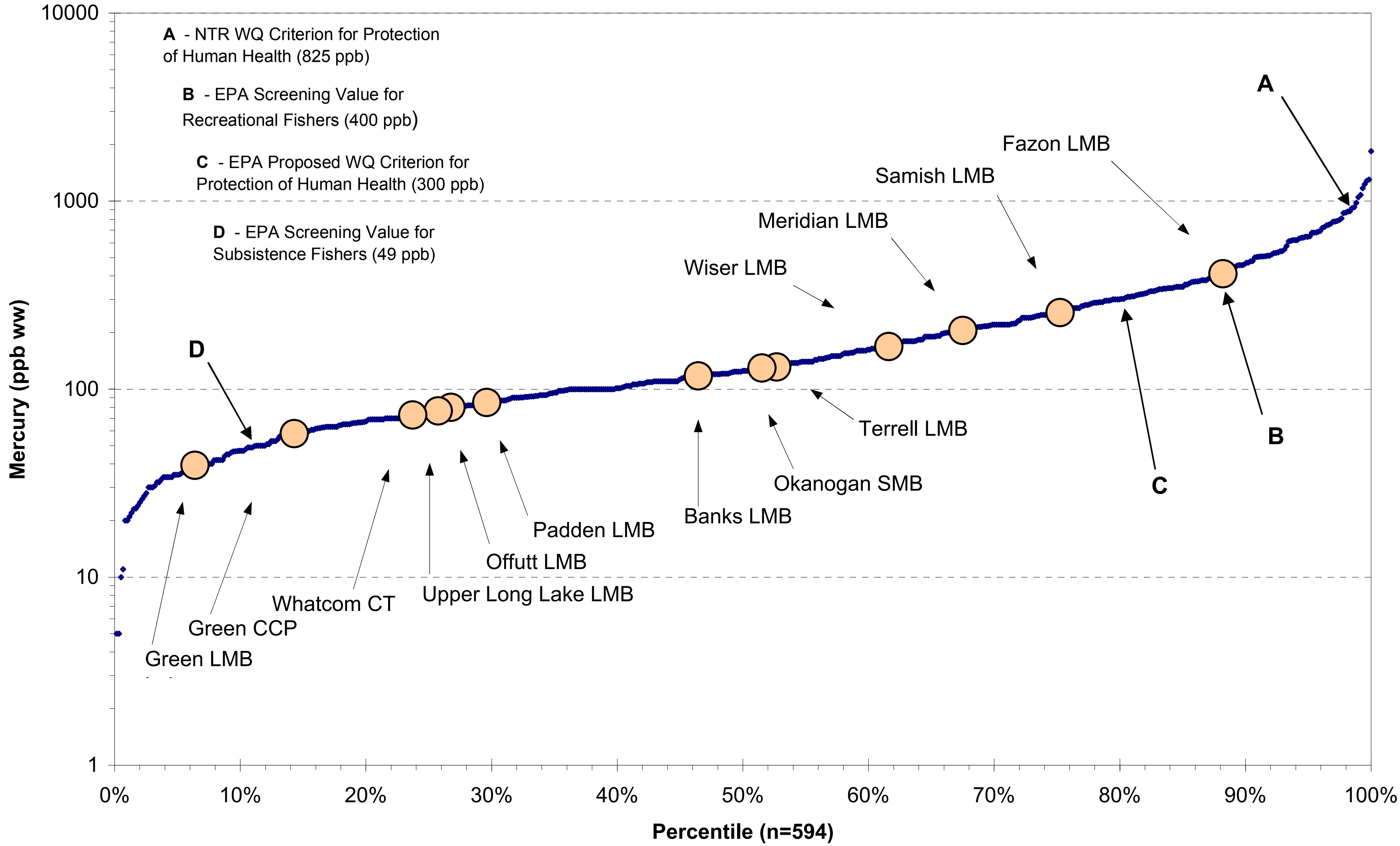

Figure 3. Cumulative Frequency Distribution of Mercury in Fish Tissue.

Organic Contaminants

Table 4 shows results for pesticides, PCBs, and PBDEs that were detected. Shaded values in Table 4 indicate values that exceeded Washington's water quality standards and/or EPA's SVs (EPA, 2000). Washington water quality standards for toxic contaminants in fish tissue are the criteria from the NTR for the protection of human health. Contaminants exceeding one or more human health criteria included total chlordane, total DDT, and total PCBs.

Water quality criteria for some individual compounds are expressed as a total value (i.e., total DDT, total chlordane), so results were summed as needed in order to compare them to criteria. Total DDT is the sum of the 4,4'- and 2,4'- isomers of DDT, DDD, and DDE. Total chlordane is the sum of five compounds: cis- and trans-chlordane, cis- and trans-nonachlor, and oxychlordane. Values qualified as estimates were included in the summing of compounds to obtain a "total" value.

For a compound that is not detected, that compound is assigned a value for the purpose of summing to obtain a total value. The value assigned to non-detects varies among studies and is usually one or more of three values: zero, one-half the reported detection limit, or the reported detection limit. EPA's guidance (2000) recommends assigning a value of zero, or a value equal to one half the detection limit, to data qualified as not detected. Many Ecology studies have assigned a value of zero to non-detects while EPA's *Columbia River Fish Contaminant Survey* (EPA, 2002) applied all three values to non-detects depending upon the nature of the results. In Table 4, the totals for chlordane, DDT, PCBs, and PBDEs were summed using an assigned value of zero to compounds not detected.

Pesticides

Human Health

Table 4 shows that the common carp tissue sample from Green Lake had levels of total chlordane (35.6 ppb ww) that exceeded the NTR criterion for the protection of human health (8.3 ppb ww) and EPA's SV for carcinogenic effects for subsistence fishers (14.0 ppb ww). The isomer 4,4'-DDE, at 33 ppb ww, exceeded the NTR criterion of 31.6 ppb ww. Total DDT in this sample (63.3 ppb ww) also exceeded EPA's SV for carcinogenic effects for subsistence fishers (14.4 ppb ww).

Levels of 4,4'-DDE in Liberty Lake brown trout exceeded the NTR criterion of 31.6 ppb ww. Three other pesticides were detected, and none exceeded any criteria for the protection of human health. Hexachlorobenzene was detected in every sample. This compound was used as a fungicide for wheat and other grain seeds since 1984. Pentachloroanisol, a metabolic product of pentachlorophenol, was detected in three samples at low levels. The pesticide DDMU, a breakdown product of DDE, was detected only at Liberty Lake during this monitoring effort.

Table 4. Summary of Pesticides, PCBs, and PBDEs Detected in Fish Tissue Samples with Comparison to Human Health Criteria, WSTMP 2001 (units in parts per billion, wet weight).

Target Analytes Detected	Green Lake	McIntosh Lake	Liberty Lake	Samish Lake	Lake Whatcom	Lake Padden	National Toxics Rule	EPA SVs: Subsistence Fishers		EPA SVs: Recreational Fishers	
	Common carp	Brown trout	Brown trout	Cutthroat trout	Cutthroat trout	Cutthroat trout		Non-carcino-genic	Carci-no-genic	Non-carcino-genic	Carci-no-genic
cis-Nonachlor	14	0.79	3.2	1.1	1.8	0.69					
trans-Nonachlor	9.8	0.41	2.3	0.61	1.8	0.37 J					
Oxychlordane	0.5										
cis-Chlordane (alpha)	6.9			0.26	0.44 NJ						
trans-Chlordane (gamma)	4.4										
Total Chlordane	**35.6**	1.2	5.5	2.0	4.0	1.1	*8.3*	245	*14.0*	2000	114
2,4'-DDD	1.4										
2,4'-DDT			0.14 NJ	0.14							
4,4'-DDD	26	0.35	2.5	0.51	0.49	0.41	45				
4,4'-DDE	33 J	2.2 J	53 J	3.7 J	4.0 J	3.4 J	*31.6*				
4,4'-DDT	2.9 NJ	0.29 NJ	1.2 NJ	0.67 NJ	0.66 NJ	0.44 NJ	31.6				
Total DDT	**63.3**	2.8	**56.8**	5.0	5.2	4.3		245	*14.4*	2000	117
DDMU [1]			1.4								
Hexachlorobenzene	1.1	0.55	1.2	1.3	0.96	0.19 J	6.7	393	3.07	3200	25.0
Pentachloroanisole	0.23			0.58		0.61					
PCB-1254	88	9.7	23	7.2	8.3 J	5.2 J					
PCB-1260	44 J	3.4 J	16 J	5.9 J	10 J	5.6 J					
Total PCB	**132.0**	**13.1**	**39.0**	**13.1**	**18.3**	**10.8**	*5.3*	*9.83*	*2.45*	*80*	*20*
2,2',4,4'-TBDE	2.1		2.5	1.8	1.5	2.2					
2,2',4,4',5'-PeBDE			1.1	1.1	0.98	1.9					
Total PBDE	2.1		3.6	2.9	2.5	4.1					
% Lipids	3.78	1.16	1.19	2.1	1.54	3.38					
Manchester Lab ID	2088424	2088425	2088426	2088428	2088492	2088493					

Shaded value: exceeds National Toxics Rule (NTR)

Bold value: exceeds EPA 2000 screening values (SVs)

Italic value: criterion that was exceeded

J: The analyte was positively identified. The associated numerical value is an estimate.

NJ: There is evidence that the analyte is present. The associated numerical result is an estimate.

1 - DDMU is a breakdown product of DDE: 1-Chloro-2,2-bis(4'-chlorophenyl)ethylene

Comparisons to Other Data

Many of the pesticides found during this study also are among the most commonly detected pesticides found in Washington fish during past efforts of the Washington State Pesticide Monitoring Program (WSPMP). For example, total DDT was detected at 97% of the 29 freshwater sites monitored during the WSPMP. Total chlordane was detected in tissues from 93% of the WSPMP sites. Hexachlorobenzene and DDMU were detected at 62% and 66%, respectively, of the WSPMP sites (Davis et al., 1998).

Other data for common carp tissue were compared to this study's results for Green Lake. Total chlordane in carp from the Walla Walla River (36 ppb ww) was comparable to total chlordane in Green Lake carp (35.6 ppb ww). Total DDT in Green Lake carp fillets was less than that found in carp fillets from three other sites in Washington during the WSPMP from 1993 to 1995. Total DDT in carp fillets from the Walla Walla, the Yakima, and Okanogan rivers were 707, 917, and 2853 ppb ww respectively.

Brown trout from Liberty Lake had higher total DDT levels than the other sites, except Green Lake. Total DDT levels were comparable to those found in rainbow trout from Lake Chelan in 1992 and 1994 (56 and 57 ppb ww, respectively) and cutthroat trout from the Cowlitz River (53 ppb ww) in 1995.

To gain a statewide perspective on total DDT, data were compiled from historical studies in Washington and plotted in Figure 4 as cumulative percentile. The various studies determined pesticide levels in tissue from multiple species, using individual fish as well as composite samples of a single species. These studies were conducted by Ecology and EPA (Davis and Johnson, 1994; Davis et al., 1995; Davis and Serdar, 1996; Davis et al., 1998; EPA, 1992; EPA, 2002a; EPA, 2002b; Hopkins et al., 1985; Hopkins, 1991; Johnson and Norton, 1990; Johnson, 1997a; Rogowski, 2000; Serdar et al., 1994; Serdar, 1998; Serdar and Davis, 1999; Serdar, 2003.

Figure 4 also shows the median value for total DDT from EPA's National Study of Chemical Residues in Fish (NSCRF) (EPA, 1992). Sample results from the Green Lake carp and Liberty Lake brown trout were close to the national median value of 58 ppb ww.

Wildlife Criteria - Pesticides

Pesticide concentrations in fish tissue were well below several criteria developed for the protection of wildlife (Table 5). The NAS/NAE (1972) criteria were not exceeded by any samples for any contaminant. The total DDT criterion of 1000 ppb ww is one to two orders of magnitude above DDT levels found in samples of fish tissue. For total chlordane, the NAS/NAE criterion is 100 ppb ww which is also well above most levels found in tissue samples from this study. The highest level of total chlordane (Green Lake carp, 35.6 ppb ww) found in samples was about one third of the NAS/NAE criterion of 100.

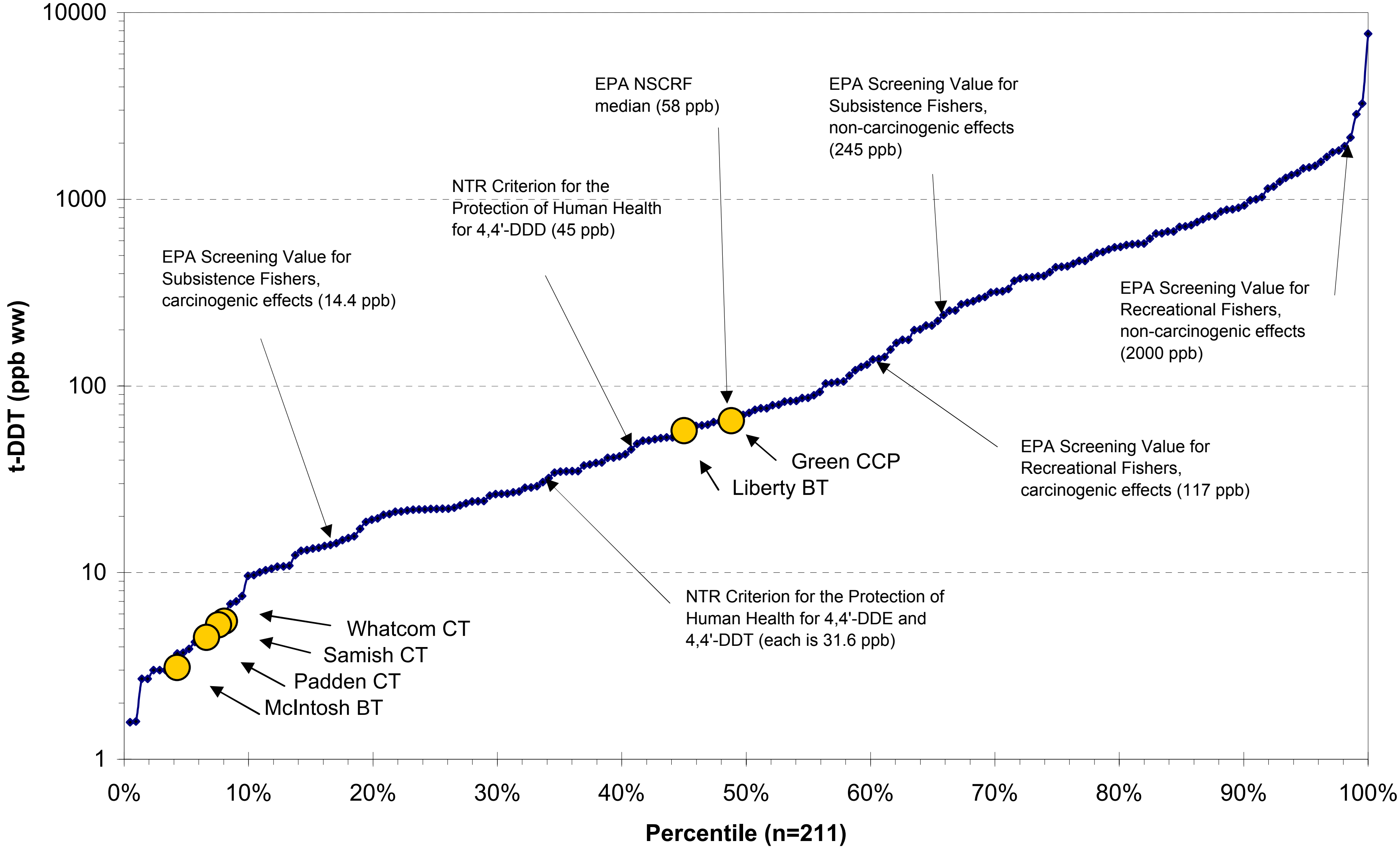

Figure 4. Cumulative Frequency Distribution of t-DDT in Edible Fish Tissue.

Table 5. Summary of Organic Contaminants Detected in Fish Tissue Samples with Comparison to Criteria for the Protection of Wildlife, WSTMP 2001.

Contaminant	Green Lake	McIntosh Lake	Liberty Lake	Samish Lake	Lake Whatcom	Lake Padden	NAS - NAE [a]	NY DEC [b]	NY DEC [c]
	Common carp	*Brown trout*	*Brown trout*	*Cutthroat trout*	*Cutthroat trout*	*Cutthroat trout*			
Total Chlordane (ppb ww)	35.6	1.2	5.5	2.0	4.0	1.1	100	370	500
Total DDT (ppb ww)	63.3	2.8	56.8	5.0	5.2	4.3	1000	270	200
Hexachlorobenzene (ppb ww)	1.1	0.55	1.2	1.3	0.96	0.19 J	-	200	330
Total PCB (ppb ww)	**132**	13.1	39	13.1	18.3	10.8	500	110	110
2,3,7,8-TCDD TEQ (ppt ww)	1.047	0.305	0.204	-	0.805	-	-	2.3	3.0

Bold values exceed one or more criteria.
a - NAS/NAE, 1973.
b - Newall et al., 1987. N.Y. Department of Environmental Conservation: One in 100 cancer risk criteria for piscivorous wildlife.
c - Newall et al., 1987. N.Y. Department of Environmental Conservation: Non-carcinogenic final fish flesh criteria for piscivorous wildlife.
J - The analyte was positively identified. The associated numerical value is an estimate.

Levels of pesticides in tissue samples were also below criteria developed by New York Department of Environmental Conservation for protecting fish-eating wildlife in the Niagara River basin (Newell et. al, 1987). Total DDT levels from Green Lake carp and Liberty Lake brown trout were about one fourth of the 200 ppb ww criterion for protecting fish-eating birds from non-carcinogenic effects. The criterion of 270 ppb ww was developed for protecting wildlife against carcinogenic effects at a risk level of 1 in 100.

Individually, the pesticides detected in fish tissue likely pose little risk to most wildlife. It is uncertain what the effects of combinations of pesticides would have since little is known about the synergistic effects of these contaminants.

PCBs

PCBs are a group of 209 synthetic chemicals whose production in the United States was banned in 1979 due to their toxicity and persistence in the environment. PCBs accumulate in organisms and their levels increase in organisms at higher trophic levels in the food web (biomagnification). Thirty-seven states have issued 679 fish consumption advisories due to PCBs levels in fish tissue exceeding criteria for the protection of human health. PCBs are responsible for about 27% of fish consumption advisories in the United States (EPA, 1999). Total PCBs refers to the sum of individual PCB congeners or Aroclors.

Human Health

PCBs from every tissue sample exceeded the NTR criteria (5.3 ppb ww) and EPA's screening values (SVs) for subsistence fishers. For subsistence fishers, EPA's SVs are 2.45 ppb ww for carcinogenic effects and 9.83 ppb ww for non-carcinogenic effects. The EPA SVs for recreational fishers are 20 ppb ww for non-carcinogenic effects and 80 ppb ww for carcinogenic effects (Table 4).

Tissue samples from these lakes exceeded one or more of the above criteria. The Green Lake carp sample had a PCB concentration of 132.0 ppb, a level which is about 25 times higher than the NTR criterion and about 27 and 13 times higher than the SVs for subsistence fishers. The carcinogenic effects SV for recreational fishers was also exceeded by a factor of 6. Brown trout from Liberty Lake had the next highest level of PCBs, 39.0 ppb ww, which is more than 7 times the NTR criterion and about 16 and 4 times higher than the SVs for subsistence fishers. The carcinogenic effects SV for recreational fishers was also exceeded by a factor of 2. Total PCBs in tissues from the other five sites ranged from 2 to 4 times greater than the NTR criterion and EPA's SVs for subsistence fishers.

Comparisons to Other Data

PCBs are frequently found in aquatic biota largely due to their persistence and widespread historical use. During the WSPMP monitoring, about 69% of the sites had fish contaminated with PCBs (Davis et al., 1998). The total PCB concentration in the Green Lake carp sample (132 ppb ww) is comparable to levels found in carp from the Yakima River (135 ppb ww) yet less than levels found in the Walla Walla River (300 ppb ww) during the 1993 WSPMP (Davis et al., 1995). Carp from the Okanogan River sampled in 1994 had a lower total PCB concentration of 45 ppb ww (Davis and Serdar, 1996). Total PCB values from Liberty Lake were similar to levels found in trout fillets from urban areas: 51 ppb ww for Mercer Slough in 1992, and 46 ppb ww for Clear Creek near Silverdale in 1995 (Davis et al., 1995).

For a broader perspective of total PCBs in fish tissue, data were compiled from historical studies in Washington (as was done for DDT discussed above) and plotted in Figure 5 as cumulative percentile (Davis and Johnson, 1994; Davis et al., 1995; Davis and Serdar, 1996; David et al., 1998; Ecology, 1995; EPA, 1992; EPA, 2002; EPA, 2002b; Hopkins et al., 1985; Hopkins, 1991; Jack and Roose, 2002; Johnson and Norton, 1990; Johnson, 1996; Johnson, 1997b; Johnson, 2000; Serdar et al., 1994; Serdar, 1998; Serdar and Davis, 1999; Serdar, 1999; Serdar, 2003).

These 336 results represent 25 different species and include fillet and muscle tissue from individual fish as well as composite samples of multiple fish. Figure 5 shows that nearly all edible tissue sampled for PCBs in the state exceed the NTR criterion of 5.3 ppb ww for the protection of human health and both of EPA's SVs for subsistence fishers (2.54 and 9.83 ppb ww). All results from this study fell below the median value (209 ppb ww) from the National Study of Chemical Residues in Fish (EPA, 1992).

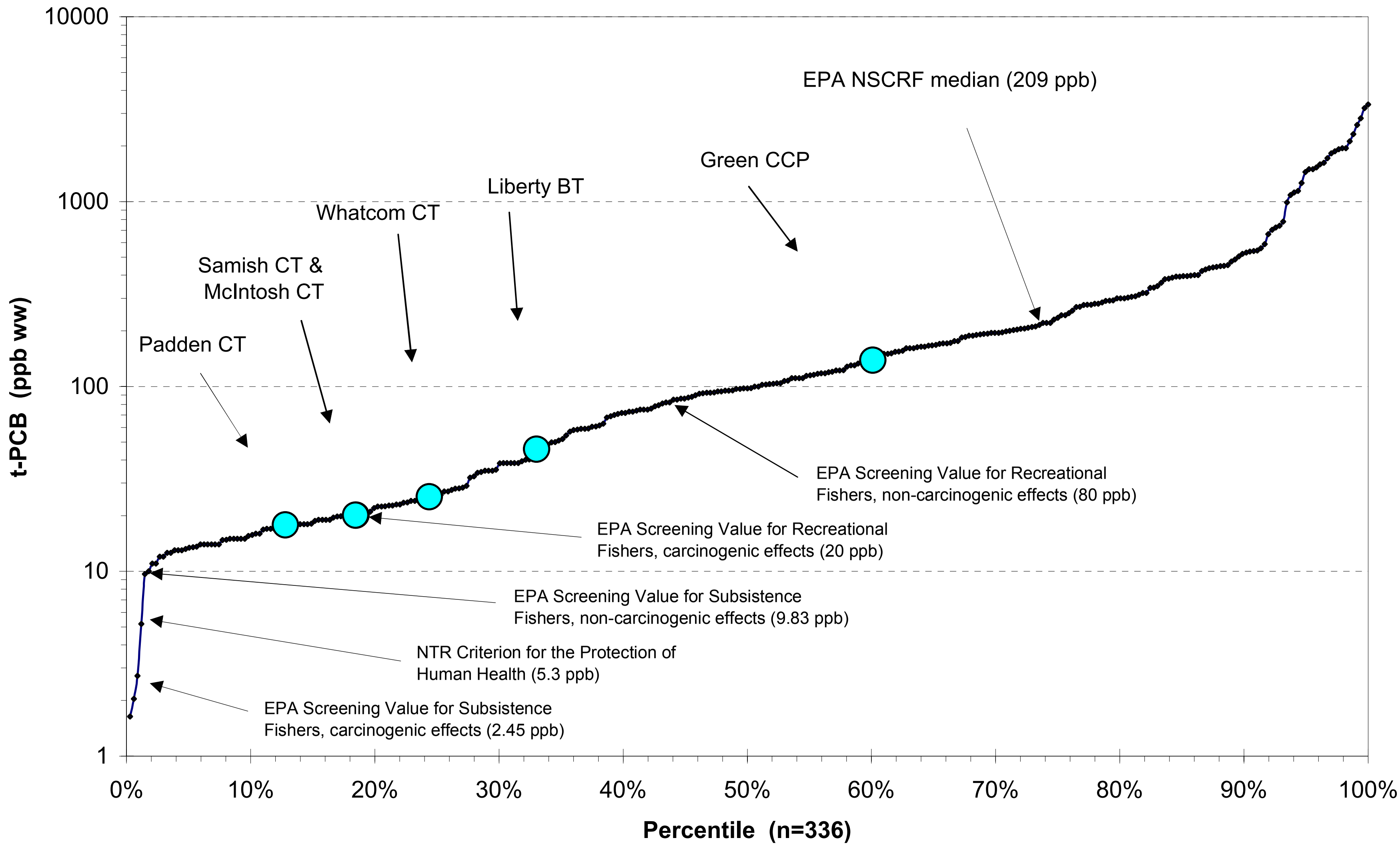

Figure 5. Cumulative Frequency Distribution of t-PCB in Edible Fish Tissue.

Wildlife Criteria - PCBs

The levels of total PCBs found in most samples were roughly one order of magnitude less than several criteria developed for the protection of wildlife (Table 5). Carp from Green Lake, with a total PCB level of 132 ppb ww, exceeded the New York DEC criteria of 110 ppb ww for non-carcinogenic and carcinogenic effects (Newell, 1987). The NAS/NAE (1972) criterion of 500 ppb ww was not exceeded by any of the samples.

PBDEs

Polybrominated diphenyl ethers (PBDEs) are a group of chemicals used as flame retardants for electronics plastics, building materials, and textiles. PBDEs can be classified into 10 main groups, composed of 209 theoretically possible congeners. Like PCBs, PBDEs are resistant to physical, chemical, and biologic degradation. The little data available suggests that PBDEs are transported and distributed in the global environment similarly to PCBs. The PBDEs are lipophilic and appear to bioaccumulate in aquatic environments. Limited information about the effects of PBDEs on humans indicate the target organs to be the liver, kidney, and thyroid gland. While research to date suggests that the possible consumer health risk from PBDEs is limited, concern remains about the effects of PBDEs on humans and other biota chiefly due to inadequate research on these compounds (Darnerud et al., 2001). There are no criteria for PBDEs for the protection of human health or wildlife.

Two PBDE congeners were detected at all sites except McIntosh Lake (Table 4). Concentrations of the two congeners (2,2',4,4' tetrabromo diphenyl ether and 2,2',4,4',5 pentabromo diphenyl ether) ranged from 0.98 ppb ww to 2.5 ppb ww. Summing the values of the two congeners for each site yields a total PBDE range from 2.1 to 4.1 ppb ww.

Johnson and Olsen (2001) reported results from 16 freshwater fish tissue samples in Washington which showed a range of total PBDEs of from 1.4 ppb ww in an undeveloped watershed to 1,250 ppb ww in fish from the Spokane River. Values found during this 2001 WSTMP are close to the 30th percentile of the range of PBDEs found in the Johnson and Olsen study. The largest fraction of the total PBDEs reported by Johnson and Olsen were the tetra- and penta- compounds. Darnerud et al. (2001) suggest that the tetra- and penta- forms are more bioavailable in sediment than are the more highly brominated congeners (octa- and deca-brominated diphenyl ethers), and that uptake by aquatic biota is greater for these less brominated compounds.

The levels of PBDEs found during this 2001 WSTMP were also lower than PBDEs found in salmon from the Lake Michigan area. Manchester-Neesvig et al. (2001) analyzed steaks from 16 coho and 5 chinook salmon from two tributaries to Lake Michigan. Concentrations ranged from 44.6 to 148 ppb ww, with a mean of 80.1 ppb ww.

Dioxins and Furans

Toxic Equivalency

The PCDD/F congeners considered to be toxic have different levels of toxicity as compared to the congener 2,3,7,8-TCDD, the most toxic form. In order to simplify assessment of various risks to human and environmental health, the concentrations of PCDD/F congeners are expressed as "toxic equivalents" (TEQs). The value of the TEQ is calculated by multiplying each congener result by its congener-specific toxicity equivalent factor (TEF) and then summing these products to obtain the TEQ. The TEFs used in this report are the "International TEFs/88" which were developed through a North Atlantic Treaty Organization committee (Barnes et al., 1989). In calculating the TEQs, one-half of the detection limit or the estimated detection limit was used where results were reported as non-detects (qualified as "U" or "UJ"). For results having estimated values (qualified with a "J" or "NJ"), the reported estimated value was used for TEQ calculations. Results for individual congeners and TEQs are given in Appendix F.

Human Health

Edible fish tissue from Green, McIntosh, Liberty, and Whatcom lakes were analyzed for PCDD/Fs in 2001. Table 6 summarizes TEQs and compares them to various criteria. Appendix F contains the results for individual congeners and calculated TEQs for tissue samples from the four lakes. All four of the composite tissue samples contained PCDD/Fs at levels that were at least one to two orders of magnitude greater than the NTR criterion of 0.07 parts per trillion wet weight (ppt ww). All samples exceeded EPA's SV for subsistence fishers (0.0315 ppt ww) by factors of 6 to 33. The SV for recreational fishers (0.256 ppt ww) was exceeded in two samples by factors of about 3 and 4.

Table 6. Results of PCDD/F Analyses of Composite Fish Tissue Samples, WSTMP 2001.

Site	Green Lake	McIntosh Lake	Liberty Lake	Lake Whatcom
Species	*Common carp*	*Brown trout*	*Brown trout*	*Cutthroat trout*
Manchester Lab ID	2088424	2088425	2088426	2088492
TEQ 2,3,7,8-TCDD (ppt ww)	**1.047**	**0.305**	**0.204**	**0.805**
Approximate exceedence factors for:				
NTR (0.07 ppt ww)	15	4	3	11
EPA SV subsistence (0.0315 ppt ww)	33	10	6	26
EPA SV recreational (0.256 ppt ww)	4	1	1	3
% lipids	3.4	1.0	1.1	1.4

Bold value: exceeds NTR and EPA 2000 SVs
ppt ww: parts per trillion, wet weight
SV: screening value

Comparisons to Other Data

Results from this study are comparable to the lower range of PCDD/F levels found in sportfish muscle tissue in Washington. Johnson et al. (1991) reports TEQs ranging from 0.3 to 5.1 ppt ww from burbot, walleye, and rainbow trout from Upper and Lower Lake Roosevelt. Fish from Rufus Woods Lake had TEQs of 0.6 ppt ww (rainbow trout), 0.8 ppt ww (walleye), and a high value of 16 ppt ww in lake whitefish. Mountain whitefish from Lake Wenatchee had a TEQ of 0.1 ppt ww. Lake whitefish from the Columbia River near Kettle Falls also had high values which were reported by Serdar et al., (1994); these levels were 14 ppt ww in 1990, 6.9 in 1992, and 3.8 in 1993.

Tissue concentrations of PCDD/Fs in fish from the Chehalis River and tributary Dillenbaugh Creek were investigated by Ecology in 1998 in response to lingering contamination from dioxin-contaminated pentachlorophenol spill in the 1980s. Largescale suckers from the Chehalis River had TEQs of 0.4 ppt ww to 0.6 ppt ww while mountain whitefish muscle had a TEQ of 0.52 ppt ww. Dillenbaugh Creek, which was directly affected by the spill, had single cutthroat trout TEQ of 2.64 ppt ww and bullhead TEQ of 4.51 ppt ww (Era-Miller et al., 2002).

Tissue levels of PCDD/Fs from the four lakes sampled in 2001 fall within the range of values for "background" sites sampled during EPA's National Study of Chemical Residues in Fish (EPA, 1992). Of the 388 sites sampled, 36 were considered "background" sites with TEQ values ranging from non-detects to 3.02 ppt ww, with a median value of 0.21 ppt ww. The highest TEQ values of the 388 sites were associated superfund sites (mean TEQ of 33.86 ppt ww) and pulp and paper mills using a chlorine bleaching process (mean TEQ of 25.84 ppt ww). A large number of species were sampled across the country which should be considered when comparing results.

Tissue data were compiled from historical studies in Washington (as was done for DDT and PCBs discussed above) and plotted in Figure 6 as cumulative percentile (Johnson and Yake, 1989; Johnson et al., 1991a; Johnson et al., 1991b; Serdar et al., 1991; Serdar, 1994; Era-Miller et al., 2002; EPA, 1992; EPA, 2002a). The results represent numerous species and include results from whole fish and edible tissue from both individual fish and composite samples of multiple fish. These data includes summary values from historical studies such as means of multiple composites from the same species and sites.

Figure 6 shows that nearly all edible tissue sampled for PCDD/Fs in the state exceed the NTR criterion of 0.07 ppt ww for the protection of human health and both of EPA's SV for subsistence fishers (0.032 ppt ww) and recreational fishers (0.256 ppt ww).

Wildlife Criteria – PCDD/Fs

Levels of TCDD/Fs in fish tissue were below the two criteria developed by the New York DEC for the protection of wildlife (Newell, 1987). These criteria are 2.3 and 3.0 ppt ww for carcinogenic (1 in 100 cancer risk) and non-carcinogenic effects, respectively. Again, Green Lake carp had the highest level (1.047 ppt ww TEQ 2,3,7,8-TCDD) of all sites sampled which is just under half the New York DEC criterion for non-carcinogenic effects.

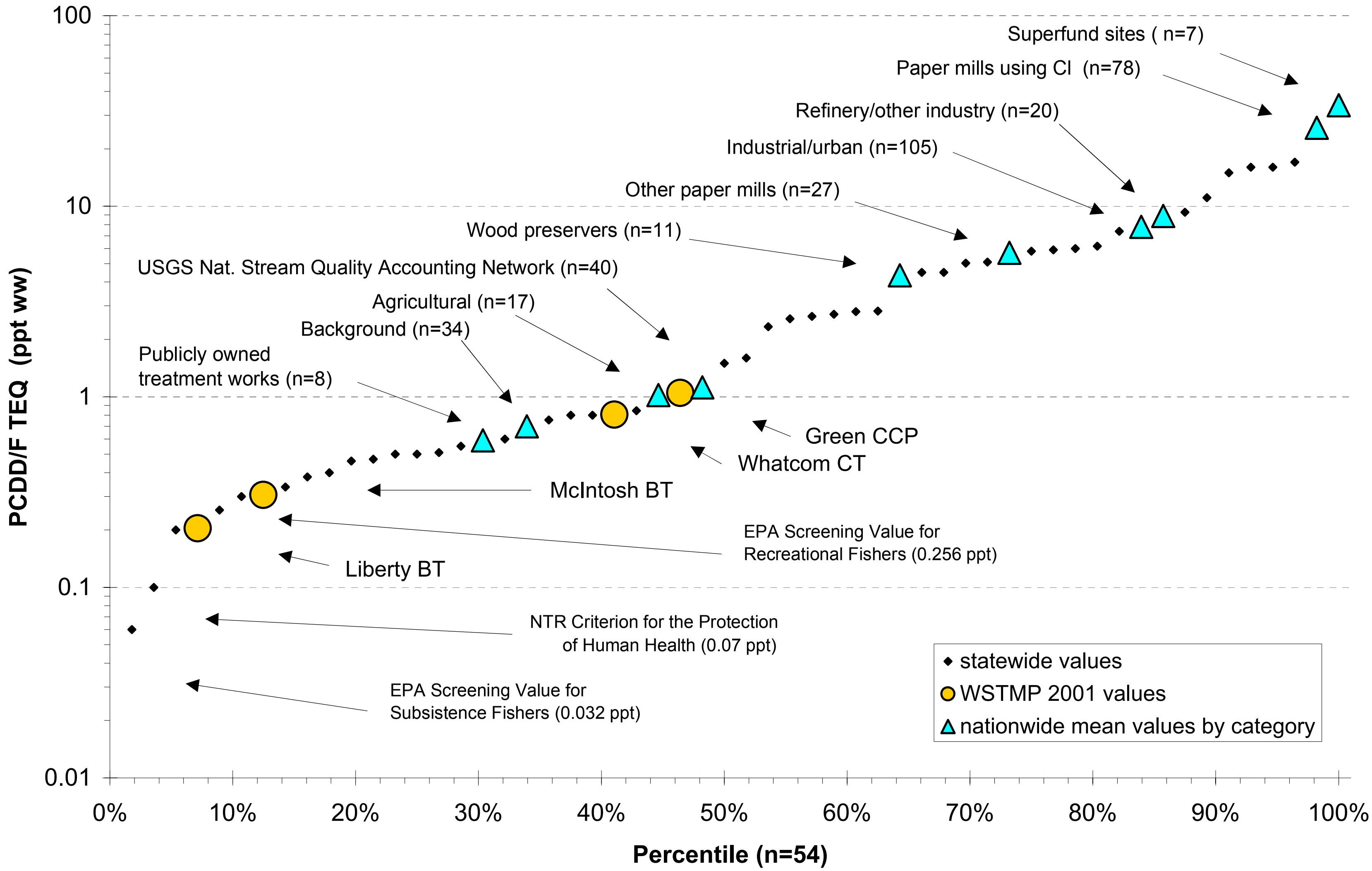

Figure 6. Cumulative Frequency Distribution of PCDD/F TEQs in Fish Tissue.

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Conclusions

- Mercury was detected in all 108 fish tissue samples from 12 sites in 2001. About 93% of the samples exceeded the EPA screening value for subsistence fishers (49 ppb ww). About 14% of the samples exceeded the EPA recommended water quality criterion of 300 ppb ww (fish from Meridian, Samish, Fazon, and Terrell lakes and the Okanogan River near Omak). About 6% of the samples exceeded the EPA screening value for recreational fishers (fish from Meridian, Samish, and Fazon lakes). One sample from Samish Lake exceeded the National Toxics Rule (NTR) criterion of 825 ppb ww.

- Fish from Green Lake exceeded criteria for the protection of human health. Common carp contained levels of total PCBs, PCDD/Fs, total chlordane, and 4,4'-DDE that exceeded NTR criteria. Total PCBs, PCDD/Fs, total chlordane, and total DDT exceeded one or more of the EPA screening values for subsistence and recreational fishers.

- Fish from Liberty Lake exceeded criteria for the protection of human health. Brown trout contained levels of total PCBs, PCDD/Fs, and 4,4'-DDE that exceeded NTR criteria. Total PCBs, PCDD/Fs, and total DDT exceeded one or more of the EPA screening values for subsistence and recreational fishers.

- Levels of total PCBs in brown trout from McIntosh Lake and cutthroat trout from Samish, Whatcom, and Padden lakes exceeded NTR criteria for the protection of human health. One or more of the EPA screening values for subsistence and/or recreational fishers also were exceeded in fish from these lakes.

- Levels of PCDD/Fs in brown trout from McIntosh Lake and cutthroat trout from Lake Whatcom exceeded NTR criteria for the protection of human health. These fish also exceeded EPA screening values for subsistence and recreational fishers.

- One sample exceeded the limited criteria that were reviewed for the protection of wildlife. Carp from Green Lake had levels of PCBs that exceeded the New York Department of Environmental Conservation criteria for the protection of piscivorous wildlife: 110 ppb ww for non-carcinogenic and carcinogenic effects. It is uncertain what the effects of combinations of pesticides would have since little is known about the synergistic effects of multiple contaminants.

- No chlorinated pesticides were detected in water samples from Liberty, Green, Meridian, and Terrell lakes. Conventional parameters (temperature, pH, conductivity, total suspended solids, total organic carbon) appeared typical for lakes in Washington.

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Recommendations

- The Washington State Department of Health, with local health departments, should evaluate the potential risk to human health from consumption of fish from all sites sampled. This evaluation should consider the combined potential effects from multiple contaminants that were found in fish from many sites sampled. Additional sampling should be conducted as needed for determining whether a fish consumption advisory is needed.

- Fish tissue results from this 2001 monitoring effort should be compared to criteria in Ecology's most recent federal Clean Water Act 303d listing policy, and sampled waterbodies should be placed on the 303d list or appropriate category as warranted.

- Additional methods should be considered for sampling water in order to increase temporal coverage and/or lower detection limits. For example, the use of semi-permeable membrane devices, rather than water samples, would allow a greater temporal coverage (up to one month) and thus produce a more representative sample.

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Appendices

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Appendix A

Sample Site Coordinates

Table A1. Fish Tissue and Water Sample Site Coordinates, WSTMP 2001.

Sites and coordinates for fish collection [1]

Site Name	Latitude North	Longitude West	WBID [4]	Waterbody Number [5]
Banks Lake [2]	47.9246	119.0636	WA-42-9020	296QRB
Liberty Lake	47.6459	117.0776	WA-57-9010	213DMS
Green Lake	47.6785	122.3371	WA-08-9150	670DAB
Meridian Lake	47.3627	122.1513	WA-09-9160	148NFC
Offutt Lake	46.9174	122.8259	WA-13-9110	123TXQ
McIntosh Lake	46.8669	122.7662	WA-13-9090	618HVI
Padden Lake	48.4030	122.4520	WA-01-9060	758LBQ
Samish Lake	48.6667	122.3848	WA-03-9160	054FYG
Whatcom Lake	48.7338	122.3293	WA-01-9170	205VNG
Fazon Lake	48.8663	122.3663	WA-01-9020	294MWE
Terrell Lake	48.8656	122.6872	WA-01-9120	356SOW
Wiser Lake	48.9036	122.4789	WA-01-9190	972LUC
Long Lake (upper)	47.8057	117.6025	WA-54-9040	QZ45UE
Okanogan R. nr Omak	48.4128	119.5151	WA-49-1020	YN58LL

Sites and coordinates for water samples [3]

Site Name	Latitude North	Longitude West	WBID [4]	Waterbody Number [5]
Green Lake	47.6783	122.3337	WA-08-9150	670DAB
Meridian Lake	47.3633	122.1537	WA-09-9160	148NFC
Terrell Lake	48.8682	122.6903	WA-01-9120	356SOW
Liberty Lake	47.6436	117.0779	WA-57-9010	213DMS

Datum: NAD27 for fish sample sites, WGS84 for water samples.

1 - Coordinates represent center of lake while fish were usually collected from many areas of the lake.

2 - Coordinates are for Osborne Bay where fish were collected.

3 - Coordinates from area in lake where water samples were taken.

4 - Ecology's "old" Water Body Identification Number (WBID).

5 - Ecology's "new" or current Water Body Number system.

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Appendix B
Field Sampling Procedures

Fish Tissue Samples

Methods for the collection, handling, and processing of fish tissue samples for analysis were guided by methods described in EPA (2000). Written sampling instructions accompanied field crews to ensure consistency in sample collection. Ecology crews collected fish by electrofishing with a 16' Smith-Root electrofishing boat. Fish collected by WDFW were captured by either electrofishing or gillnetting at the following sites: Padden, Samish, Whatcom, Fazon, Terrell, and Wiser lakes. Captured fish were identified to species and target species were retained while non-target species were released. Retained fish were inspected to ensure that they were acceptable for further processing (e.g. proper size, no obvious damage to tissues, skin intact).

Field preparation of individual fish involved:

- Sacrificing the fish by a blow to the head with a dull object.
- Rinsing in ambient water to remove foreign material from their exterior.
- Weighing to the nearest gram.
- Measuring the total length and fork length to the nearest millimeter.
- Double-wrapping individuals in foil with a tag identifying the date of capture, species, and fish identification number.
- Placing foil-wrapped fish into plastic zip-lock bags.
- Placing the bagged fish on ice in the field and transporting iced fish to the Ecology facilities in Lacey, Washington.
- Transferring fish to dedicated freezer and freezing to -20 degrees C.

Frozen fish were processed at Ecology's Lacey facility on a later date to form samples to be sent to the laboratory for analysis. The edible portion of target species was used for individual and composite samples. For analysis of organic compounds, at least five fish were used to create a composite sample for each site sampled. For analysis of mercury, individual fish were prepared for laboratory analyses. The processing of fish to create samples involved:

- Fish were removed from the freezer and partially thawed.
- Scales were removed using the dull side of a fillet knife.
- One or two fillets were removed from the fish, depending on the fish size and sample mass required for analysis.
- The skin was left on fillets when tissues were to be analyzed for organic compounds.
- The skin was removed from fillets when tissues were to be analyzed for mercury (with the exception of Lake Whatcom cutthroat trout where the skin was left on for mercury analysis of individual fish).
- Fillets were cut into smaller pieces prior to loading into a grinder

- Tissue was passed through a decontaminated KitchenAid model FGA food grinder two or three times to allow thorough grinding and homogenization of fillets from individual fish.
    - For mercury analyses of tissue from individual fish, 10 to 30 grams of ground tissue was put into a pre-cleaned I-Chem™ series 200 or 300 2-oz or 4-oz jar; the large sample mass provided for lipids analysis by the laboratory.
    - Composite samples were formed from at least five individual fish for analysis of organic compounds.
    - Fillets from individual fish were ground as described above and set aside.
    - Equal amounts of the ground and homogenized tissue from each fillet were combined and then homogenized mixing in a stainless steel bowl, passing this through the grinder once more, then homogenized a final time.
    - At least 90 grams of the composite sample was put into a pre-cleaned I-Chem series 200 or 300 4-oz or 8-oz jar.

- Sample jars were identified with the individual fish ID code and pre-assigned lab sample number; extra tissue was archived.
- Sample jars ready for analysis were returned to the freezer until transported to the laboratory.

After fillets were removed from the fish, anatomical structures were removed for determining the age of individual fish. A variety of anatomical structures were removed depending upon the species (Table B1). For fish collected by WDFW, scales were removed in the field and sent to WDFW Olympia office for age determination. Otherwise, scales were removed prior to filleting the fish during processing. Scales were mounted on acetate scale cards provided by WDFW biologists. Opercules, spines, and otoliths were also removed, depending upon the species. All aging structures were identified, packaged according to WDFW directions, and then sent to WDFW staff in Olympia, WA. WDFW later reported the age of individual fish via a spreadsheet or as written on the returned scale cards. The sex of each fish was determined by opening the abdominal cavity and identifying gonads as testes or ovary.

Water Samples

Depth integrated water samples for organic contaminant analyses were collected at four sample locations. At lake sites, a DH-81 sampler attached to a rope was lowered to within one or two meters of the bottom and then raised. The rate of lowering and raising was adjusted in order to obtain a nearly-full sample container upon retrieval. About ten casts of the sampler were needed to obtain the volume of water needed for analyses of pesticides, TSS, and TOC. Vertical profiles of temperature and conductivity were made at each lake where water samples were collected. The profiles helped determine the degree of mixing of the lakes upper and deeper layers. Temperature, pH, and conductivity were also determined from a depth-integrated sample.

The appropriate sample containers were filled, identified, placed on ice, and delivered to the laboratory within 24 to 72 hours.

Table B1. Anatomical Structures Used to Determine Age of Target Fish Species.

Common name	Scientific name	Structure used to determine age scales	otoliths	spines	opercules
Predator/Gamefish species					
Rainbow trout	*Oncorhynchus mykiss*	x	x		
Mountain Whitefish	*Prosopium williamsoni*	x	x		
Lake Whitefish	*Coregonus clupeaformis*	x	x		
Cutthroat trout	*Oncorhynchus clarki*	x	x		
Kokanee salmon	*Oncorhynchus nerka*	x	x		
Brown trout	*Salmo trutta*	x	x		
Lake trout	*Salvelinus namaycush*	x	x		
Brook trout	*Salvelinus fontinalis*	x	x		
Largemouth bass	*Micropterus salmoides*	x	x		
Smallmouth bass	*Micropterus dolomieu*	x	x		
Black crappie	*Pomoxis nigromaculatus*	x	x		
White crappie	*Pomoxis annularis*	x	x		
Yellow perch	*Perca flavescens*	x	x		
Walleye	*Stizostedion vitreum*	x	x		
Bottom-dwelling species					
Common carp	*Cyprinus carpio*	x		x	x
Channel catfish	*Ictalurus punctatus*		x	x	
Brown bullhead	*Ictalarus nebulosus*			x	
Largescale Sucker	*Catostomus macrochelius*	x			x
Longnose Sucker	*Catostomus catostomus*	x			x
Bridgelip Sucker	*Catostomus columbianus*	x			x
White Sturgeon	*Acipenser transmontanus*	fin rays used to age this species			

Decontamination Procedures

All utensils used for processing tissue samples were cleaned in order to prevent contamination of the sample. Utensils include bowls, knives, and tissue grinding appliances having plastic and stainless steel parts. Equipment contacting water samples during collection included glass jars, Teflon nozzles, and silastic gaskets. All utensils for fish tissue and water sampling were cleaned using the following procedure:

- Soap (Liquinox) and hot water wash.
- Tap water rinse.
- 10% nitric acid rinse (omitted for water sampling devices).
- Deionized water rinse (omitted for water sampling devices).
- Solvent rinses with pesticide-grade acetone followed by hexane and/or methanol.
- Utensils air-dried and then packaged in aluminum foil and plastic bags to prevent contamination.

The live well on the electrofishing boat, used to temporarily store fish when captured, was rinsed and scrubbed with ambient water prior to collecting and holding fish. The live well and retrieval nets were cleaned several times during the collection season at Ecology's Lacey facilities using a general boat washing soap followed by thorough rinsing with tap water.

Field Records

Information about each sampling event was recorded in field notebooks. Notes included:

- Date and time.
- Sampling personnel.
- General sampling location.
- Latitude/longitude coordinates of sample collection using a Magellan Model 320 Handheld GPS.
- General weather conditions.
- Method of sampling.
- Fish species collected.
- Weights and lengths for individual fish specimens.
- Results from field measurements such as temperature, pH, conductivity, and streamflow data.

Additional information was recorded at the time fish tissue samples were processed and submitted for laboratory analysis:

- Fish identification number.
- Preassigned laboratory sample number.
- Date of resection.
- Types of aging structures retained and their identification data.
- Sex of specimen.
- Which fillet(s) removed.
- Weight of fillet before grinding.
- Weight of sample transferred to sample jar.
- Whether an archive sample was retained and stored at Ecology's Lacey facility.
- Other observations or notes about processing the sample.

Appendix C

Analytical Methods

Table C1. Analytical Methods for Tissue and Water Samples, WSTMP 2001

Parameter	Description	Method	Practical Quantitation Limit
Tissue Samples			
Mercury	CVAA	EPA 245.5; MEL SOP*	0.005 mg/kg, wet
Chlorinated pesticides	GC/ECD	EPA 8081; MEL SOP*	0.25 -15 ug/kg, wet
PCBs & PBDEs	GC/ECD	EPA 8082; MEL SOP*	0.25 ug/kg, wet
PCDD/PCDFs	HiRes GC/MS	EPA 1613B	0.1 - 1.0 ng/kg, wet
Lipids - percent	gravimetric	EPA 608.5	0.1%
Water Samples			
Chlorinated pesticides	GC/ECD	EPA 8081; MEL SOP*	0.01 ug/L
TOC	Combustion NDIR	EPA 415.1	1 mg/L
TSS	gravimetric	EPA 160.2	1 mg/L

MEL: Manchester Environmental Laboratory

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

- EPA 245.5: "Standard Operating Procedure for the Determination of Mercury by Cold Vapor Atomic Absorbance in Sediments US EPA SW846 7471B Modified, and 245.5, Modified (Sediment)." (also used for tissue)
- EPA 8081 and EPA 8082 - SOP # 730002: Analysis of Water/Soil/Sediment/Fish Tissue Samples for Organochlorine Pesticides, Polybrominated Diphenyl Ethers and Polychlorinated Biphenyls by GC/ECD

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Appendix D

Data Quality Assessment

Data Quality for Fish Tissue Sample Results

Organics –Pesticides/PCBs/PBDEs

Results from quality control and quality assurance practices for fish tissue samples indicate that the analytical system performed adequately with most data meeting objectives for quality control. Quality control procedures included analysis of: method blanks, matrix spikes, matrix spike duplicates, surrogate recoveries, laboratory duplicates, and field duplicates. The case narrative for the samples describes analytical performance and reasons for qualifying some sample results as estimates (Mandjikov, 2002b). Holding times for all analyses were met. Results from duplicate analyses and matrix spike duplicates are given in Tables D1 and D2.

Duplicate samples met precision criteria defined by Manchester Environmental Laboratory (MEL) and the project plan. Laboratory precision, expressed as the Relative Percent Difference (RPD), met MEL's criteria of being less than 20%. The field duplicate for tissue was a split of the field-processed tissue of the composite sample and not an entirely different group of fish collected from the same location. Results from the field duplicate sample met the project plan's target of 28% Relative Standard Deviation (RSD) for the compounds that were detected.

Most matrix spike recoveries were within the target range of 50%-150% of the theoretical values. Recoveries were generally good, with median values of 84% and 93%, and averages of 84% and 97%, for the spike and spike duplicate. The precision for the matrix spike recoveries was good, with the average RPD being 14% and the median at 12%. The spike recoveries for several compounds were outside the 50%-150% ranges. Sample results for compounds whose recoveries were below 50% (endosulfan sulfate and endrin aldehyde) were qualified as "UJ" (estimated). Sample results for compounds whose recoveries were above 150% (dieldrin, p,p'DDE, and Aroclor 1260) were qualified as "J" (estimated) due to possible high biased results. Dieldrin was not detected in any samples so is not qualified. No target analytes detected in laboratory method blanks.

The recoveries of three surrogate compounds added to each sample fell within the acceptable range of 50%-150% of the theoretical value, except for two instances. In each exception, the surrogate tetrachloro-m-xylene was below 50% or the theoretical value in one of the fractions of extract. The results for target analytes that eluted in this same fraction were qualified as "J" if detected, and "UJ" if not detected. (The qualifier "J" means that the analyte was positively identified, the associated numerical result is an estimate". The qualifier "UJ" means that the analyte was not detected at or above the reported estimated limit). Data qualifiers are also defined in Tables D1 and D2.

PCDD/Fs

Data generated by Triangle Labs, Inc. (TLI) of Durham, North Carolina were reviewed by MEL and then forwarded as part of a case narrative to the project manager (Feddersen, 2002). The data review included examination of holding times, blank results, calibration, internal standard recoveries, ion abundance ratios, and precision and recovery limits.

Some of TLI's data qualifiers were amended by MEL, such as qualifiers for estimated values or non-detects, in order to remain consistent with MEL's reporting conventions. Lab results for PCDD/Fs were reported as wet weight for fish tissue samples. The lipid content of samples were also determined and reported by TLI. Method 1613b and 8290 were used for TCDD/F analyses.

Reporting limits generally met the desired limits defined in the project plan (0.1 – 1.0 pptr). All reported results were qualified as estimates because the analyte to internal standard ratios were outside the calibration curve (Feddersen, 2002a). For some individual congeners that were not detected, reporting limits were also qualified as estimates.

Results from laboratory and field duplicate samples are shown in Table D3. Most of the RSDs for the estimated results of congeners met precision targets defined in the project plan (RSD less than or equal to 28%).

Lipids

The precision of field and laboratory duplicate samples for lipids was mixed. Field duplicate precision, expressed as RSD, ranged from 2% to 66% with an average of 21% and a median of 14% (n=13). Eight of the 13 pairs (62%) of field duplicates met the target RSD value of 14%. The precision for the laboratory duplicates was similarly mixed. Lab duplicate precision ranged from 1% to 45%, with an average RSD of 19% and a median of 16% (n=11). Five of the 11 pairs (45%) of lab duplicates met the target RSD value of 14% for field duplicates. Table D4 shows the duplicate data for lipids analyses.

For samples that were analyzed for dioxins, lipids were also determined by TLI. Interlaboratory precision was estimated using results from MEL and TLI. Precision of these results ranged from 6% to 10%, meeting the target RSD value of 14% (Table D4).

Mercury

Results from quality control and quality assurance practices for fish tissue samples indicate that the analytical system performed adequately with most data meeting objectives for quality control. Quality control procedures included analysis of: method blanks, tissue standards, matrix spikes, matrix spike duplicates, laboratory duplicates, and field duplicates. Results from the analyses of blanks, standards, matrix spikes, and matrix spike duplicates met all acceptance criteria established by MEL.

Results from duplicate analyses are given in Tables D5. Field duplicate precision, expressed as the RSD, ranged from 0% to 42%, with a mean of 8% and a median of 4% (n=11). Ten of 11 (91%) field duplicate pairs met the data quality objective of 14% RSD. Lab duplicate precision (as the RSD) was similarly varied with a range of 0% to 31%, a mean of 8%, and a median of

2% (n=10). Precision was poor for Samish14 (Lab No. 8444) and its field duplicate (RSD=42%). The result for the field and lab duplicate were thus qualified as estimates. Eighty percent of lab duplicates met MEL's acceptance precision limit of +/- 20% RPD. Matrix spikes were also performed and met MEL's acceptance limit of +/- 25% (Table D6).

Results from analyses of tissue standards and matrix spikes indicated that good accuracy and precision (Table D6). The tissue standards used were dogfish muscle and dogfish liver obtained by MEL from the National Research Council of Canada.

All mercury results were qualified as estimates because the samples exceeded EPA's the 28-day holding time for mercury analysis (Knox, 2002). Ecology and EPA holding time criteria for mercury may be overly conservative for fish tissue. The USGS NAWQA program uses a holding time for mercury in tissue of six months (Crawford and Luoma, 1993) and Bloom (1995) states that biota samples for mercury analysis may be stored indefinitely when frozen.

Data Quality for Water Sample Results

Results from quality control practices for water samples indicate that the analytical system performed adequately. Quality control procedures included analysis of: method blanks, matrix spikes, surrogate recoveries, laboratory duplicates, and field duplicates. Case narratives for each batch of samples described analytical performance and reasons for qualifying some sample results as estimates. Holding times for all analyses were met. No target analytes were found in blank samples.

Target analytes were not detected in any of the samples. The lack of target analyte detections in field and lab duplicates did not allow precision to be estimated by use of the RSD. The lab noted that these samples were exceptionally clean which was the likely reason for low recoveries for some surrogates (Mandjikov, 2002a). The detection limits achieved for these analyses were very good (0.0008 – 0.0016 ug/L) which are from one to two orders of magnitude below those specified in the project plan (0.1-0.01 ug/L). The cleanliness of the samples was a likely factor in achieving such low detection limits.

Results from analyses of a duplicate lab control samples show good precision with RSDs ranging from 0%-23% with a mean of 6% (Table7). One matrix spike was done and had recoveries ranging from 13% to 112%. Six of 31 (19%) did not meet MEL's acceptance criteria of +/-50% recovery. Low recoveries were likely due to the exceptional cleanliness of the water sample. Results from the duplicate analysis of a lab control sample and the single matrix spike are given in Table D7.

The quantitation limits for pesticides in water samples met, and were better than, those stated in the project plan. Still, quantitation limits for some contaminants were higher than water quality standards. For water samples, the freshwater chronic criteria in Washington's water quality standards (Chapter 170-201A WAC) are lower than the selected method's quantitation limits for: DDT and metabolites, chlordanes and nonachlors, aldrin and dieldrin, endrin, heptachlor, heptachlor epoxide, and toxaphene. The EPA (2000) recognizes the unavailability of cost-effective analytical methods that can achieve lower quantitation limits for some of these analytes. The use of performance-based analytical techniques are encouraged by EPA which may help in developing analytical methods that achieve needed detection limits for particular analytes.

Table D1. Results Duplicate Analyses for Pesticides in Fish Tissue, WSTMP 2001.

Site	Green Lake					Lake Whatcom				
Species	*common carp*					*cutthroat trout*				
Lab ID	2088424		2088424			2088492		2088540		
Analytes	sample result (ppt ww)		lab duplicate result (ppt ww)		RSD of lab duplicate	sample result (ppt ww)		field duplicate result (ppt ww)		RSD of field duplicate
cis-Nonachlor	14		13		5%	1.8		1.7		4%
trans-Nonachlor	9.8		9.3		4%	1.8		1.5		13%
Oxychlordane	0.5		0.55		7%					
cis-Chlordane (alpha-Chlordane)	6.9		7.2		3%	0.44	NJ	0.38	NJ	10%
trans-Chlordane (gamma)	4.4		4.8		6%					
Total Chlordane	35.6		34.9		2%	4.0		3.6		9%
2,4'-DDT								0.12		
2,4'-DDD	1.4		1.5		5%					
4,4'-DDD	26		26		0%	0.49		0.45		6%
4,4'-DDE	33	J	30	J	7%	4.0	J	3.8	J	4%
4,4'-DDT	2.9	NJ	2.8	NJ	2%	0.66	NJ	0.66	NJ	0%
Total DDT	63.3		60.3		3%	5.2		5.0		2%
PCB-1254	88		78		9%	8.3	J	7.8		4%
PCB-1260	44	J	38	J	10%	10	J	9.9	J	1%
Total PCB	132.0		116.0		9%	18.3		17.7		2%
2,2',4,4'-TBDE	2.1		2.2		3%	1.5		1.6		5%
2,2',4,4',5-PeBDE						0.98		1.0		1%
Hexachlorobenzene	1.1		0.93		12%	0.96		0.80		13%
Pentachloroanisole	0.23		0.25		6%					
% lipids	3.78		2.25		36%	1.54		1.59		2%

1 - DDMU is a breakdown product of DDE: 1-Chloro-2,2-bis(4'-chlorophenyl)ethylene
J - The analyte was positively identified. The associated numerical value is an estimate.
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

Table D2. Results of Matrix Spike and Spike Duplicates for Pesticides in Fish Tissue, WSTMP 2001. MEL Lab ID: 02088540, Lake Whatcom cutthroat trout

Analyte		Matrix Spike 1 (% recovery)	Matrix Spike 2 (% recovery)	RPD of recovery
alpha-BHC		76	75	1%
beta-BHC		83	79	5%
gamma-BHC (Lindane)		83	80	4%
delta-BHC		57	65	13%
Heptachlor		79	105	28%
Aldrin		50	67	29%
Heptachlor Epoxide		84	84	0%
trans-Chlordane (gamma)		84	84	0%
Endosulfan 1		85	93	9%
cis-Chlordane (alpha-Chlordane)		84	84	0%
Dieldrin		135	160	17%
4,4'-DDE		110	165	40%
Endrin		91	100	9%
Endosulfan 11		82	96	16%
4,4'-DDD		94	94	0%
Endrin Aldehyde		32	38	17%
4,4'-DDT		102	96	6%
Endosulfan Sulfate		31	27	14%
Endrin Ketone		105	112	6%
Methoxychlor		98	102	4%
Oxychlordane		81	80	1%
DDMU		93	117	23%
cis-Nonachlor		122	143	16%
2,4'-DDE		112	145	26%
trans-Nonachlor		90	135	40%
2,4'-DDD		90	87	3%
2,4'-DDT		90	113	23%
Mirex		104	139	29%
Hexachlorobenzene		84	119	34%
Dacthal (DCPA)		83	92	10%
Pentachloroanisole		51	51	0%
2,2',4,4'-TBDE		85	91	7%
2,2',4,4',5-PeBDE		68	70	3%
2,2',4,4',5,6'-HxBDE		56	66	16%
2,2',4,4',5,5'-HxBDE		56	65	15%
2,2',4,4',6-PeBDE		64	64	0%
PCB - 1016		95	136	35%
PCB - 1260		120	177	38%
	average	84%	97%	14%
	median	84%	93%	12%
	min	31%	27%	0%
	max	135%	177%	40%
	count	38	38	38

Table D3. Results of Duplicate Analyses for PCDD/Fs in Fish Tissue, WSTMP 2001.

Site - Sample	Lake Whatcom			Field Duplicate			Lab Duplicate				
Species	*Cutthroat trout*			*Cutthroat trout*			*Cutthroat trout*				
MEL Lab ID	088492			088540			088540 Dup				
Parameter	Reported Result (ppt ww)		Reporting Limit (ppt ww)	Reported Result (ppt ww)		Reporting Limit (ppt ww)	Reported Result (ppt ww)		Reporting Limit (ppt ww)	RSD for field duplicate	RSD for lab duplicate
1,2,3,4,6,7,8,9-OCDD	3.3	UJ	0.2	1.0	UJ	0.3	2.1	UJ	0.3	76%	50%
1,2,3,4,6,7,8,9-OCDF			0.2			0.2			0.2		
1,2,3,4,6,7,8-HpCDD	0.80	J	0.1	0.79	J	0.2	0.81	J	0.1	1%	2%
1,2,3,4,6,7,8-HpCDF			0.08			0.1			0.07		
1,2,3,4,7,8,9-HpCDF			0.1			0.1			0.1		
1,2,3,4,7,8-HxCDD			0.08			0.1			0.08		
1,2,3,4,7,8-HxCDF			0.05			0.06			0.05		
1,2,3,6,7,8-HxCDD	1.4	J	0.09	1.4	J	0.1	1.4	J	0.08	0%	0%
1,2,3,6,7,8-HxCDF			0.06			0.07			0.05		
1,2,3,7,8,9-HxCDD		J	0.2			0.1	0.16	J	0.08		
1,2,3,7,8,9-HxCDF			0.07			0.08			0.07		
1,2,3,7,8-PeCDD	0.52	J	0.1	0.53	J	0.1	0.42	J	0.09	1%	16%
1,2,3,7,8-PeCDF	0.09	J	0.07			0.09		J	0.2		
2,3,4,6,7,8-HxCDF	0.40	J	0.06	0.81	J	0.07	0.22	J	0.06	48%	81%
2,3,4,7,8-PeCDF	0.18	J	0.06	0.24	J	0.07		J	0.2	20%	
2,3,7,8-TCDD	0.19	J	0.08			0.1			0.07		
2,3,7,8-TCDF	0.45	J	0.07	0.42	J	0.08		J	0.4	5%	
TEQ 2,3,7,8 TCDD	0.805			0.731			0.522			7%	24%
% lipids	1.4			1.4			1.5			0%	5%

TEQ - Toxic Equivalent (to 2,3,7,8,-TCDD)
ppt ww - Parts per trillion, wet weight
U - The analyte was not detected at or above the reported value.
J - The analyte was positively identified. The associated numerical value is an estimate.
UJ - The analyte was not detected at or above the reported estimated result.
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

Table D4. Results of Duplicate Analyses for Lipids in Fish Tissue, WSTMP 2001.

Field ID	Species	Sample ID	Sample % Lipids	Field Dup ID	Field Dup % Lipids	Lab Dup ID	Lab Dup % Lipids		RSD Field Dup	RSD Lab Dup
GREEN-C hg	CCP	2078424	3.16	2088424	3.78	2088424	2.25		13%	36%
WHATCM12	CT	2088491	1.17	-	-	2088491	1.41		-	13%
WHATCM-C	CT	2088492	1.54	2088540	1.59	-	-		2%	-
BANKS01	LMB	2078411	0.53	2078531	0.35	2078531	0.21		29%	35%
FAZON01	LMB	2098462	1.10	2098537	0.48	2098537	0.52		55%	6%
FAZON03	LMB	2098464	1.14	2088538	1.17	2088538	1.11		2%	4%
GREEN04	LMB	2078404	0.58	2078530	0.34	-	-		37%	-
MERID04	LMB	2078419	0.47	2078532	0.17	-	-		66%	-
OFFUT05	LMB	2088436	0.89	2088534	0.73	-	-		14%	-
OM-28	LMB	2178105	2.36	2178115	2.26	2178115	2.42		3%	5%
PADDEN12	LMB	2098475	0.63	2098539	0.48	2098539	0.38		19%	16%
SAMISH14	LMB	2088444	0.89	2088535	1.09	2088535	0.78		14%	23%
TERREL13	LMB	2088456	0.44	2088536	0.52	2088536	0.53		12%	1%
WISER13	LMB	2078429	1.27	2078533	1.14	2078429	0.66		8%	45%
WISER13	LMB			2078533	1.14	2078533	0.81		-	24%
								average	21%	19%
								median	14%	15%
								min	2%	1%
								max	66%	45%
								count	13	10

Interlaboratory Precision for Lipids

Field ID	Species	Sample ID	MEL % lipids	TLI % lipids	RSD
Green	CCP	078424	3.78	3.4	7%
McIntosh	BT	088425	1.16	1.0	10%
Liberty	BT	088426	1.19	1.1	6%
Whatcom	CT	088492	1.54	1.4	7%
Dubl11	CT	088540	1.59	1.4	9%

CCP - Common carp
LMB - Largemouth bass
CT - Cutthroat trout
MEL - Manchester Environmental Laboratory
TLI - Triangle Laboratory, Inc.

Table D5. Results of Duplicate Analyses for Mercury in Fish Tissue, WSTMP 2001.

Field ID (Ecy)	Sample Lab ID	Sample Hg (ppb ww)	Field Dup Field ID	Field Dup Lab ID	Field Dup Hg (ppb ww)	Lab Dup Hg (ppb ww)	Field Dup RSD	Lab Dup RSD
Green04	078404	35.3	Dubl 01	078530	37.3	35.9	4%	3%
Banks01	078411	126	Dubl 02	078531	153	155	14%	1%
Merid04	078419	210	Dubl 03	078532	194	213	6%	7%
Wiser13	078429	153	Dubl 04	078533	162	161	4%	0%
Offut05	088436	73.6	Dubl 05	088534	74.7	-	1%	-
Samish14	088444	214	Dubl 06	088535	392	392	42%	0%
Terrel13	088456	115	Dubl 07	088536	93.9	147	14%	31%
Fazon01	098462	760	Dubl 08	098537	775	775	1%	0%
Fazon03	098464	720	Dubl 09	088538	690	775	3%	8%
Padden12	098475	63.1	Dubl 10	098539	62.8	64	0%	1%
OM-28	178105	312	OM-REP	178115	307	211	1%	26%
						average	8%	8%
						median	4%	2%
						count	11	10
						minimum	0%	0%
						maximum	42%	31%

Table D6. Results of Fish Tissue Analyses of Standards, Matrix Spikes, and Spike Duplicates for Mercury, WSTMP 2001.

Results from Tissue Standards Sample No	Standard	Lab Result as % of Standard's Value
M2051BG2	DOLT	101
M2065BG3	DOLT	106
M2065BG4	DOLT	105
M2072BG1	DOLT	88
	average	100.0
M2051BG1	DORM	95
M2065BG1	DORM	88
M2065BG2	DORM	105
M2072BG2	DORM	101
M2092BG1	DORM	85
M2133BG1	DORM	87
M2133BG2	DORM	88
	average	92.7
M2065BG5	Lab 1461	98

Results from Matrix Spikes and Spike Duplicates Sample No	Matrix Spike Recovery (%)	Matrix Spike Duplicate Recovery (%)	RSD (%)
078530	75	76	1
078532	80	85	4
088491	82	82	0
088535	95	79	13
088536	120	120	0
098537	98	90	6
178105	84	83	1
178125	84	83	1
average	89.8	87.3	2

Standard Abbr.	Standard	Source
DOLT	Dogfish liver	National Research Council of Canada
DORM	Dogfish muscle	National Research Council of Canada
Lab 1461	Reference standard for mercury in water	National Institute of Standards and Technology (NIST)

Table D7. Results of Duplicate Analyses of Lab Control Samples and Matrix Spike for Pesticides in Water, WSTMP 2001.

	Lab Control Sample ID			Matrix Spike Sample ID
	OBF1360A1	OBF1360A2		528005
Analyte	Result (ug/L)	Result (ug/L)	RSD	Recovery
alpha-BHC	67	66	1%	75%
beta-BHC	42	48	9%	42%
gamma-BHC (Lindane)	74	76	2%	76%
delta-BHC	41	44	5%	42%
Heptachlor	61	72	12%	64%
Aldrin	33	41	15%	36%
Heptachlor Epoxide	81	81	0%	84%
trans-Chlordane (gamma)	75	72	3%	76%
cis-Chlordane (alpha-Chlordane)	77	81	4%	61%
Endosulfan 1	80	83	3%	86%
Dieldrin	108	109	1%	112%
4,4'-DDE	77	92	13%	94%
Endrin	78	79	1%	81%
Endosulfan II	61	62	1%	61%
4,4'-DDD	72	72	0%	72%
Endrin Aldehyde	13	14	5%	13%
Endosulfan Sulfate	43	45	3%	41%
4,4'-DDT	80	92	10%	88%
Endrin Ketone	52	53	1%	49%
Methoxychlor	58	58	0%	57%
Oxychlordane	85	85	0%	79%
DDMU	71	98	23%	87%
cis-Nonachlor	76	80	4%	79%
2,4'-DDE	100	90	7%	89%
trans-Nonachlor	71	90	17%	89%
2,4'-DDD	79	80	1%	80%
2,4'-DDT	80	94	11%	94%
Mirex	70	85	14%	72%
Hexachlorobenzene	57	67	11%	60%
Dacthal (DCPA)	65	68	3%	68%
Pentachloroanisole	70	76	6%	82%
		average	6%	71%
		median	4%	76%
		count	31	31
		min	0%	13%
		max	23%	112%
Surrogate Recoveries				
Tetrachloro-m-xylene	52%	58%	8%	54%
Dibutylchlorendate	81%	72%	8%	67%
Decachlorobiphenyl	86%	95%	7%	69%

Appendix E

Results for Individual Fish: Field Measurements, Tissue Mercury, and Lipids

Table E1. Fish Composite Sample Data for Organics Analyses, WSTMP 2001.

Site	Green Lake	McIntosh Lake	Liberty Lake	Samish Lake	Lake Whatcom	Lake Padden
Species	*Common carp*	*Brown trout*	*Brown trout*	*Cutthroat trout*	*Cutthroat trout*	*Cutthroat trout*
MEL Lab ID	2088424	2088425	2088426	2088428	2088492	2088493
No. fish in composite	7	5	10	10	10	8
Mean length (mm)	548.6	413.0	431.7	291.0	325.4	299.3
Mean weight (gm)	2878.6	695.4	742.1	213.0	298.8	301.8
Mean age (yr)	5.6	2.4	4.5	2.4	4.0	2.3
Lipids (%)	3.78	1.16	1.19	2.1	1.54	3.38

Table E2. Field Data for Fish Collected for the 2001 WSTMP Including Mercury and Lipids.

Waterbody	Field ID	Species	Total Length (mm)	Fork Length (mm)	Weight (gm)	Fish Age (yrs)	Sex	Sample Type	Fillet Taken	Fillet wt. (g)	Hg (ug/Kg ww)	Lipids (%)	MEL Lab No	Collection Date	Resection Date	Collector
Banks Lake	Banks01	LMB	364	350	764	4	m	F- no skin	r	140	126	0.53	02078411	11/7/01	1/23/02	Ecy
Banks Lake	Banks02	LMB	371	355	807	4	m	F- no skin	r	132	120	0.40	02078412	11/7/01	1/23/02	Ecy
Banks Lake	Banks03	LMB	406	387	1242	5	f	F- no skin	r	204	183	0.67	02078413	11/7/01	1/24/02	Ecy
Banks Lake	Banks04	LMB	384	362	887	5	f	F- no skin	r	148	165	0.99	02078414	11/7/01	1/23/02	Ecy
Banks Lake	Banks05	LMB	354	342	709	4	m	F- no skin	r	118	120	0.42	02078415	11/7/01	1/23/02	Ecy
Banks Lake	Banks06	LMB	348	340	671	3	f	F- no skin	r	115	70	0.71	02078406	11/7/01	1/23/02	Ecy
Banks Lake	Banks07	LMB	345	330	677	4	m	F- no skin	r	106	78.4	0.43	02078407	11/7/01	1/23/02	Ecy
Banks Lake	Banks08	LMB	334	320	701	3	m	F- no skin	r	122	115	0.81	02078408	11/7/01	1/23/02	Ecy
Banks Lake	Banks09	LMB	307	292	456	2	m	F- no skin	r	84	77.2	0.84	02078409	11/7/01	1/23/02	Ecy
Banks Lake	Banks10	LMB	293	285	430	2	m	F- no skin	r	108	82.8	0.81	02078410	11/7/01	1/24/02	Ecy
Fazon Lake	Fazon01	LMB	575	-	3747	17	f	F- no skin	r	561	760	1.10	02098462	9/26/01	2/21/02	DFW
Fazon Lake	Fazon02	LMB	557	-	3310	14	f	F- no skin	r	541	645	1.26	02098463	9/26/01	2/21/02	DFW
Fazon Lake	Fazon03	LMB	513	-	1783	10	f	F- no skin	r	319	720	1.14	02098464	9/26/01	2/14/02	DFW
Fazon Lake	Fazon04	LMB	472	-	1632	8	f	F- no skin	r	292	456	0.63	02088465	9/26/01	2/19/02	DFW
Fazon Lake	Fazon05	LMB	418	-	1088	8	m	F- no skin	l	199	480	0.48	02088466	9/26/01	2/19/02	DFW
Fazon Lake	Fazon06	LMB	386	-	820	7	f	F- no skin	r	145	337	0.52	02088467	9/26/01	2/19/02	DFW
Fazon Lake	Fazon07	LMB	380	-	779	7	m	F- no skin	l	130	364	0.53	02088468	9/26/01	2/19/02	DFW
Fazon Lake	Fazon08	LMB	376	-	656	7	m	F- no skin	r	117	197	0.48	02088469	9/26/01	2/19/02	DFW
Fazon Lake	Fazon09	LMB	362	-	590	5	f	F- no skin	l	101	321	0.46	02088470	9/26/01	2/19/02	DFW
Fazon Lake	Fazon10	LMB	354	-	671	6	f	F- no skin	r	122	192	0.44	02088471	9/26/01	2/19/02	DFW
Green Lake	Green01	LMB	352	341	883	2	m	F- no skin	l	108	41.9	1.31	02078401	12/27/01	1/22/02	Ecy
Green Lake	Green02	LMB	346	336	764	2	f	F- no skin	r	132	39.3	0.95	02078402	12/27/01	1/22/02	Ecy
Green Lake	Green03	LMB	341	332	832	2	m	F- no skin	r	114	60.7	1.17	02078403	12/27/01	1/22/02	Ecy
Green Lake	Green04	LMB	265	255	282	1	m	F- no skin	b	67	35.3	0.58	02078404	12/27/01	1/22/02	Ecy
Green Lake	Green05	LMB	250	243	253	1	f	F- no skin	b	71	30.6	0.75	02078405	12/27/01	1/22/02	Ecy
Green Lake	Green06	CCP	555	500	3184	4	f	C- skin on	r	502	-	-	-	12/27/01	1/29/02	Ecy
Green Lake	Green07	CCP	552	500	2917	6	f	C- skin on	r	458	-	-	-	12/27/01	1/29/02	Ecy
Green Lake	Green08	CCP	588	542	3456	10	m	C- skin on	r	681	-	-	-	12/27/01	1/29/02	Ecy

Table E2. Field Data for Fish Collected for the 2001 WSTMP Including Mercury and Lipids.

Waterbody	Field ID	Species	Total Length (mm)	Fork Length (mm)	Weight (gm)	Fish Age (yrs)	Sex	Sample Type	Fillet Taken	Fillet wt. (g)	Hg (ug/Kg ww)	Lipids (%)	MEL Lab No	Collection Date	Resection Date	Collector
Green Lake	Green09	CCP	568	508	2692	4	f	C- skin on	r	437	-	-	-	12/27/01	1/29/02	Ecy
Green Lake	Green10	CCP	485	433	2155	4	f	C- skin on	r	283	-	-	-	12/27/01	1/29/02	Ecy
Green Lake	Green11	CCP	452	402	1446	4	m	C- skin on	r	215	-	-	-	12/27/01	1/29/02	Ecy
Green Lake	Green12	CCP	640	575	4300	7	f	C- skin on	r	596	-	-	-	12/27/01	1/29/02	Ecy
Green Lake	**Green-C**	CCP	548.6	494.3	2878.6	5.6	-	C- skin on	-	453.1	57.9	3.47	02078424	12/27/01	1/29/02	Ecy
Liberty Lake	Librty01	BT	411	-	732	4	f	C- skin on	l	131	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty02	BT	440	-	926	5	m	C- skin on	l	189	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty03	BT	448	-	766	5	m	C- skin on	r	127	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty04	BT	434	-	780	4	m	C- skin on	r	172	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty05	BT	433	-	750	5	f	C- skin on	r	154	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty06	BT	461	-	875	4	f	C- skin on	r	182	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty07	BT	426	-	688	4	f	C- skin on	r	132	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty08	BT	409	-	575	5	f	C- skin on	l	127	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty09	BT	419	-	615	5	f	C- skin on	l	128	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	Librty10	BT	436	-	714	4	f	C- skin on	l	151	-	-	-	11/8/01	2/5/02	Ecy
Liberty Lake	**Librty-C**	BT	431.7	-	742.1	4.5	-	C- skin on	-	149.3	-	1.19	02088426	11/8/01	2/5/02	Ecy
McIntosh Lake	Mcint01	BT	437	-	818	2	f	C- skin on	r	167	-	-	-	12/3/01	1/30/02	Ecy
McIntosh Lake	Mcint02	BT	403	-	720	3	m	C- skin on	r	139	-	-	-	12/3/01	1/30/02	Ecy
McIntosh Lake	Mcint03	BT	422	-	649	2	f	C- skin on	l	143	-	-	-	12/3/01	1/30/02	Ecy
McIntosh Lake	Mcint04	BT	381	-	569	2	m	C- skin on	r	106	-	-	-	12/3/01	1/30/02	Ecy
McIntosh Lake	Mcint05	BT	422	-	721	3	m	C- skin on	r	151	-	-	-	12/3/01	1/30/02	Ecy
McIntosh Lake	**Mcint-C**	BT	413.0	-	695.4	2.4	-	C- skin on	-	141.2	-	1.16	02088425	12/3/01	1/30/02	Ecy
Meridian Lake	Merid01	LMB	314	302	446	2	f	F- no skin	r	60	174	0.53	02078416	12/5/01	1/24/02	Ecy
Meridian Lake	Merid02	LMB	330	320	597	2	f	F- no skin	r	90	248	0.38	02078417	12/5/01	1/24/02	Ecy
Meridian Lake	Merid03	LMB	322	309	538	2	f	F- no skin	r	93	167	0.37	02078418	12/5/01	1/24/02	Ecy
Meridian Lake	Merid04	LMB	317	306	446	2	m	F- no skin	r	77	210	0.47	02078419	12/5/01	1/25/02	Ecy
Meridian Lake	Merid05	LMB	315	302	442	2	f	F- no skin	r	62	199	0.49	02078420	12/5/01	1/25/02	Ecy
Meridian Lake	Merid06	LMB	344	330	604	3	m	F- no skin	r	92	200	0.44	02078421	12/5/01	1/25/02	Ecy

Table E2. Field Data for Fish Collected for the 2001 WSTMP Including Mercury and Lipids.

Waterbody	Field ID	Species	Total Length (mm)	Fork Length (mm)	Weight (gm)	Fish Age (yrs)	Sex	Sample Type	Fillet Taken	Fillet wt. (g)	Hg (ug/Kg ww)	Lipids (%)	MEL Lab No	Collection Date	Resection Date	Collector
Meridian Lake	Merid07	LMB	458	443	1645	9	m	F- no skin	r	192	645	0.25	02078422	12/5/01	1/25/02	Ecy
Meridian Lake	Merid08	LMB	493	473	2238	7	f	F- no skin	r	282	332	1.22	02078423	12/5/01	1/25/02	Ecy
Offutt Lake	Offut01	LMB	255	247	229	1	m	F- no skin	b	64	112	0.96	02078432	12/26/01	2/11/02	Ecy
Offutt Lake	Offut02	LMB	225	218	152	1	m	F- no skin	b	45	85.6	0.30	02078433	12/26/01	2/11/02	Ecy
Offutt Lake	Offut03	LMB	228	220	155	1	m	F- no skin	b	44	86.8	0.31	02078434	12/26/01	2/11/02	Ecy
Offutt Lake	Offut04	LMB	223	215	143	1	m	F- no skin	b	48	93	0.55	02078435	12/26/01	2/11/02	Ecy
Offutt Lake	Offut05	LMB	226	218	157	1	m	F- no skin	b	45	73.6	0.89	02088436	12/26/01	2/12/02	Ecy
Offutt Lake	Offut06	LMB	220	212	143	1	m	F- no skin	b	45	46.5	0.96	02088437	12/26/01	2/12/02	Ecy
Offutt Lake	Offut07	LMB	215	208	118	1	f	F- no skin	b	33	76	0.68	02088438	12/26/01	2/12/02	Ecy
Offutt Lake	Offut08	LMB	218	210	141	1	f	F- no skin	b	40	81.3	0.57	02088439	12/26/01	2/12/02	Ecy
Offutt Lake	Offut09	LMB	205	198	108	1	m ?	F- no skin	b	31	78.4	0.80	02088440	12/26/01	2/12/02	Ecy
Offutt Lake	Offut10	LMB	191	184	86	1	f	F- no skin	b	26	65.1	0.80	02088441	12/26/01	2/12/02	Ecy
Okanogan River	OM-28	SMB	433	-	1,330	6	f	F- no skin	-	420	312	2.36	02178105	9/17/01	-	Ecy
Okanogan River	OM-29	SMB	315	-	412	3	f	F- no skin	-	146	127	0.81	02178108	9/17/01	-	Ecy
Okanogan River	OM-30	SMB	296	-	332	3	m	F- no skin	-	122	133	0.60	02178110	9/17/01	-	Ecy
Okanogan River	OM-39	SMB	421	-	1,102	7	f	F- no skin	-	292	217	1.80	02178106	11/6/01	-	Ecy
Okanogan River	OM-40	SMB	360	-	641	4	f	F- no skin	-	190	133	1.04	02178107	11/6/01	-	Ecy
Okanogan River	OM-41	SMB	308	-	388	3	m	F- no skin	-	144	132	0.88	02178109	11/6/01	-	Ecy
Okanogan River	OM-42	SMB	288	-	303	3	-	F- no skin	-	82	125	0.93	02178112	11/6/01	-	Ecy
Okanogan River	OM-44	SMB	290	-	309	3	m	F- no skin	-	98	104	1.01	02178111	11/6/01	-	Ecy
Okanogan River	OM-46	SMB	270	-	273	3	f	F- no skin	-	94	107	0.76	02178113	11/6/01	-	Ecy
Okanogan River	OM-48	SMB	260	-	218	2	m	F- no skin	-	80	121	1.06	02178114	11/6/01	-	Ecy
Padden Lake	Padden01	CT	342	326	420	4	m	C- skin on	r	84	-	-	-	9/27/01	2/15/02	DFW
Padden Lake	Padden02	CT	332	316	397	3	f	C- skin on	b	187	-	-	-	9/27/01	2/15/02	DFW
Padden Lake	Padden03	CT	317	302	344	2	f	C- skin on	r	93	-	-	-	9/27/01	2/15/02	DFW
Padden Lake	Padden04	CT	317	298	341	2	f	C- skin on	r	97	-	-	-	9/27/01	2/15/02	DFW
Padden Lake	Padden05	CT	288	276	258	2	m	C- skin on	r	67	-	-	-	9/27/01	2/15/02	DFW
Padden Lake	Padden06	CT	278	267	242	2	m	C- skin on	r	59	-	-	-	9/27/01	2/15/02	DFW

Table E2. Field Data for Fish Collected for the 2001 WSTMP Including Mercury and Lipids.

Waterbody	Field ID	Species	Total Length (mm)	Fork Length (mm)	Weight (gm)	Fish Age (yrs)	Sex	Sample Type	Fillet Taken	Fillet wt. (g)	Hg (ug/Kg ww)	Lipids (%)	MEL Lab No	Collection Date	Resection Date	Collector
Padden Lake	Padden07	CT	266	256	227	2	m	C- skin on	r	66	-	-	-	9/27/01	2/15/02	DFW
Padden Lake	Padden08	CT	254	245	185	1	m	C- skin on	b	86	-	-	-	9/27/01	2/15/02	DFW
Padden Lake	**Padden-C**	CT	299.3	285.8	301.8	2.3	-	C- skin on	-	92.4	-	3.38	02088493	9/27/01	2/15/02	DFW
Padden Lake	Padden09	LMB	422	-	1505	4	f	F- no skin	r	221	223	2.86	02098472	9/27/01	2/21/02	DFW
Padden Lake	Padden10	LMB	226	-	192	2	m	F- no skin	l	30	107	0.58	02098473	9/27/01	2/21/02	DFW
Padden Lake	Padden11	LMB	197	-	119	1	f	F- no skin	b	39	79.7	0.79	02098474	9/27/01	2/21/02	DFW
Padden Lake	Padden12	LMB	192	-	98	1	m	F- no skin	b	30	63.1	0.63	02098475	9/27/01	2/21/02	DFW
Padden Lake	Padden13	LMB	191	-	94	1	m	F- no skin	b	28	84.3	0.51	02098476	9/27/01	2/21/02	DFW
Padden Lake	Padden14	LMB	187	-	95	1	f	F- no skin	b	32	68.8	0.65	02098477	9/27/01	2/21/02	DFW
Padden Lake	Padden15	LMB	186	-	97	1	f	F- no skin	b	31	87.4	0.55	02098478	9/27/01	2/21/02	DFW
Padden Lake	Padden16	LMB	177	-	74	1	m	F- no skin	b	25	85.5	0.68	02098479	9/27/01	2/21/02	DFW
Samish Lake	Samish01	CT	340	320	319	4	m	C- skin on	r	76	-	-	-	9/10/01	2/7/02	DFW
Samish Lake	Samish02	CT	307	291	254	3	f	C- skin on	b	96	-	-	-	9/10/01	2/7/02	DFW
Samish Lake	Samish03	CT	301	289	231	3	f	C- skin on	b	93	-	-	-	9/12/01	2/7/02	DFW
Samish Lake	Samish04	CT	301	284	233	2	m	C- skin on	b	92	-	-	-	9/10/01	2/7/02	DFW
Samish Lake	Samish05	CT	286	274	195	2	f	C- skin on	b	73	-	-	-	9/11/01	2/7/02	DFW
Samish Lake	Samish06	CT	285	268	182	2	f	C- skin on	b	76	-	-	-	9/10/01	2/7/02	DFW
Samish Lake	Samish07	CT	278	261	188	2	m	C- skin on	b	73	-	-	-	9/12/01	2/7/02	DFW
Samish Lake	Samish08	CT	277	259	187	2	m	C- skin on	b	71	-	-	-	9/10/01	2/7/02	DFW
Samish Lake	Samish09	CT	270	254	168	2	-	C- skin on	b	58	-	-	-	9/10/01	2/7/02	DFW
Samish Lake	Samish10	CT	265	250	173	2	f	C- skin on	b	72	-	-	-	9/11/01	2/7/02	DFW
Samish Lake	**Samish-C**	CT	291.0	275.0	213.0	2.4	-	F- skin on	-	78.0	-	2.1	02088428	9/11/01	2/7/02	DFW
Samish Lake	Samish12	LMB	466	-	1513	9	m	F- no skin	r	280	374	1.06	02088442	9/12/01	2/13/02	DFW
Samish Lake	Samish13	LMB	446	-	1440	10	f	F- no skin	r	224	1280	2.59	02088443	9/10/01	2/12/02	DFW
Samish Lake	Samish14	LMB	410	-	1061	5	f	F- no skin	r	212	214	0.89	02088444	9/12/01	2/12/02	DFW
Samish Lake	Samish15	LMB	390	-	992	5	m	F- no skin	l	205	183	1.40	02088445	9/12/01	2/12/02	DFW
Samish Lake	Samish16	LMB	384	-	936	4	f	F- no skin	r	180	296	1.82	02088446	9/12/01	2/12/02	DFW
Samish Lake	Samish17	LMB	381	-	903	4	f	F- no skin	l	179	297	2.11	02088447	9/12/01	2/12/02	DFW

Table E2. Field Data for Fish Collected for the 2001 WSTMP Including Mercury and Lipids.

Waterbody	Field ID	Species	Total Length (mm)	Fork Length (mm)	Weight (gm)	Fish Age (yrs)	Sex	Sample Type	Fillet Taken	Fillet wt. (g)	Hg (ug/Kg ww)	Lipids (%)	MEL Lab No	Collection Date	Resection Date	Collector
Samish Lake	Samish18	LMB	378	-	820	5	m	F- no skin	r	129	325	0.53	02088448	9/12/01	2/13/02	DFW
Samish Lake	Samish19	LMB	330	-	626	3	f	F- no skin	r	98	158	0.67	02088449	9/10/01	2/13/02	DFW
Samish Lake	Samish20	LMB	328	-	522	3	f	F- no skin	r	102	90.3	0.45	02088450	9/10/01	2/13/02	DFW
Samish Lake	Samish21	LMB	255	-	270	3	m	F- no skin	b	94	91.2	0.75	02088451	9/12/01	2/12/02	DFW
Terrell Lake	Terrel09	LMB	431	-	1313	13	-	F- no skin	r	203	332	0.36	02088452	9/26/01	2/14/02	DFW
Terrell Lake	Terrel10	LMB	430	-	1288	6	f	F- no skin	r	248	248	1.28	02088453	9/26/01	2/19/02	DFW
Terrell Lake	Terrel11	LMB	430	-	1362	5	f	F- no skin	l	255	241	1.44	02088454	9/26/01	2/19/02	DFW
Terrell Lake	Terrel12	LMB	420	-	1307	6	-	F- no skin	l	210	156	1.10	02088455	9/26/01	2/14/02	DFW
Terrell Lake	Terrel13	LMB	346	-	616	3	f	F- no skin	r	112	115	0.44	02088456	9/26/01	2/14/02	DFW
Terrell Lake	Terrel14	LMB	307	-	465	2	m	F- no skin	l	85	109	0.75	02088457	9/26/01	2/19/02	DFW
Terrell Lake	Terrel15	LMB	297	-	396	2	f	F- no skin	r	70	110	0.80	02088458	9/26/01	2/13/02	DFW
Terrell Lake	Terrel16	LMB	297	-	433	2	f	F- no skin	l	79	49.7	0.72	02088459	9/26/01	2/19/02	DFW
Terrell Lake	Terrel17	LMB	288	-	372	2	m	F- no skin	l	74	138	0.32	02098460	9/26/01	2/19/02	DFW
Terrell Lake	Terrel18	LMB	260	-	232	2	m	F- no skin	r	40	124	0.31	02098461	9/26/01	2/13/02	DFW
Upper Long Lake	ULL-43 c	LMB	434	-	1264	7	f	F- no skin	-	173	66.5	0.69	02178117	6/18/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-45 c	LMB	428	-	1406	9	m	F- no skin	-	226	61.8	0.93	02178118	6/18/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-46 c	LMB	392	-	832	6	f	F- no skin	-	103	69	0.61	02178121	6/18/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-47 c	LMB	441	-	1902	12	m	F- no skin	-	284	181	1.63	02178116	6/18/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-48 c	LMB	382	-	936	7	m	F- no skin	-	157	116	1.01	02178123	6/18/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-50 c	LMB	312	-	436	3	m	F- no skin	-	-	22	0.19	02178125	6/18/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-52 c	LMB	330	-	514	3	m	F- no skin	-	72	27	0.21	02178124	6/18/01	4/19/02	DFW/Ecy
Upper Long Lake	ULL-53 c	LMB	414	-	908	6	f	F- no skin	-	143	91.5	0.40	02178120	6/19/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-54 c	LMB	425	-	1088	7	m	F- no skin	-	166	84	0.99	02178119	6/19/01	4/22/02	DFW/Ecy
Upper Long Lake	ULL-56 c	LMB	392	-	852	6	f	F- no skin	-	119	167	0.25	021748122	6/19/01	4/9/02	DFW/Ecy
Whatcom Lake	Whatcm01	CT	373	356	453	5	m	F&C- skin on	b	203	100	1.86	02088480	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm02	CT	355	339	378	5	f	F&C- skin on	b	161	66.5	1.03	02088481	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm03	CT	356	338	371	4	m	F&C- skin on	b	171	65.6	1.77	02088482	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm04	CT	352	332	333	5	f	F&C- skin on	b	127	124	1.03	02088483	6/10/01	2/15/02	DFW

Table E2. Field Data for Fish Collected for the 2001 WSTMP Including Mercury and Lipids.

Waterbody	Field ID	Species	Total Length (mm)	Fork Length (mm)	Weight (gm)	Fish Age (yrs)	Sex	Sample Type	Fillet Taken	Fillet wt. (g)	Hg (ug/Kg ww)	Lipids (%)	MEL Lab No	Collection Date	Resection Date	Collector
Whatcom Lake	Whatcm05	CT	341	323	326	4	f	F&C- skin on	b	105	116	1.85	02088484	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm06	CT	328	308	317	4	m	F&C- skin on	b	138	60.8	2.54	02088485	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm07	CT	318	301	273	4	m	F&C- skin on	b	120	63	1.82	02088486	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm08	CT	315	299	266	4	m	F&C- skin on	b	111	108	1.40	02088487	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm09	CT	319	299	255	3	m	F&C- skin on	b	104	101	1.11	02088488	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm10	CT	299	281	242	4	f	F&C- skin on	b	94	79.1	1.80	02088489	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm11	CT	277	260	188	3	f	F- skin on	b	79	61.5	1.50	02088490	6/10/01	2/15/02	DFW
Whatcom Lake	Whatcm12	CT	272	255	183	3	m	F- skin on	b	85	46.7	1.17	02088491	6/10/01	2/15/02	DFW
Whatcom Lake	**Whatcm-C**	CT	325.4	307.6	298.8	4.0	-	F- skin on	-	124.8	-	1.54	02088492	6/10/01	2/15/02	DFW
Wiser Lake	Wiser11	LMB	491	-	2033	9	-	F- no skin	r	341	215	0.95	02078431	9/6/01	2/8/02	DFW
Wiser Lake	Wiser12	LMB	478	-	1936	9	m	F- no skin	r	232	184	0.46	02078430	9/6/01	2/8/02	DFW
Wiser Lake	Wiser13	LMB	456	-	1870	6	m	F- no skin	r	307	153	1.27	02078429	9/4/01	2/8/02	DFW
Wiser Lake	Wiser14	LMB	390	-	1107	3	f	F- no skin	r	187	62.6	0.91	02078427	9/5/01	2/8/02	DFW

Bold Field ID samples are composite samples of the preceding fish of the same species.
Data for composite samples is the average value of individual fish that make up the composite.
Whatcm01-Whatcm12 was composited for organics, individual fish done for mercury.
Green-C lipids value is average of two samples.
Sample Type: F=individual fillet, C=fillet taken for composite sample.
Fillet Taken: r=right, l=left, b=both.

LMB	Largemouth bass (*Micropterus salmoides*)
SMB	Smallmouth bass (*Micropterus dolomieu*)
CT	Cutthroat trout (*Onchorhynchus clarkii*)
BT	Brown trout (*Salmo trutta*)
CCP	Common carp (*Cyprinus carpio*)

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Appendix F

Results for PCDD/F Congeners from Composite Fish Tissue Samples

Table F1. Results for PCDD/F Congeners from Composite Fish Tissue Samples, WSTMP 2001.

Site		Green Lake				McIntosh Lake				Liberty Lake				Lake Whatcom			
Species		*Common carp*				*Brown trout*				*Brown trout*				*Cutthroat trout*			
MEL Lab ID		2088424				2088425				2088426				2088492			
Analyte	TEF	TEQ	RR		RL	TEQ	RR		RL	TEQ	RR		RL	TEQ	RR		RL
1,2,3,4,6,7,8,9-OCDD	0.001	0.0016	1.6	UJ	0.5	0.00088	0.88	UJ	0.3	0.0011	1.1	UJ	0.4	0.0033	3.3	UJ	0.2
1,2,3,4,6,7,8,9-OCDF	0.001	0.0002			0.4	0.0001			0.2	0.00015			0.3	0.0001			0.2
1,2,3,4,6,7,8-HpCDD	0.01	0.013	1.3	J	0.2	0.001			0.2	0.001			0.2	0.008	0.8	J	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.002	0.2	J	0.1	0.00045			0.1	0.0005			0.1	0.0004			0.1
1,2,3,4,7,8,9-HpCDF	0.01	0.001			0.2	0.0005			0.1	0.0005			0.1	0.0005			0.1
1,2,3,4,7,8-HxCDD	0.1	0.032	0.32	J	0.2	0.005			0.1	0.005			0.1	0.004			0.1
1,2,3,4,7,8-HxCDF	0.1	0.005			0.1	0.003			0.1	0.0035			0.1	0.0025			0.1
1,2,3,6,7,8-HxCDD	0.1	0.075	0.75	J	0.2	0.005			0.1	0.005			0.1	0.14	1.4	J	0.1
1,2,3,6,7,8-HxCDF	0.1	0.015		J	0.3	0.0035			0.1	0.004			0.1	0.003			0.1
1,2,3,7,8,9-HxCDD	0.1	0.01		J	0.2	0.005			0.1	0.005			0.1	0.01		J	0.2
1,2,3,7,8,9-HxCDF	0.1	0.005			0.1	0.0045			0.1	0.005			0.1	0.0035			0.1
1,2,3,7,8-PeCDD	0.5	0.25	0.5	J	0.2	0.025			0.1	0.05			0.2	0.26	0.52	J	0.1
1,2,3,7,8-PeCDF	0.05	0.0175	0.35	J	0.1	0.00225			0.1	0.0025			0.1	0.0045	0.09	J	0.1
2,3,4,6,7,8-HxCDF	0.1	0.02	0.2	J	0.1	0.004			0.1	0.005		J	0.1	0.04	0.4	J	0.1
2,3,4,7,8-PeCDF	0.5	0.15		J	0.6	0.0175			0.1	0.02			0.1	0.09	0.18	J	0.1
2,3,7,8-TCDD	1	0.3	0.3	J	0.2	0.21	0.21	J	0.1	0.05			0.1	0.19	0.19	J	0.1
2,3,7,8-TCDF	0.1	0.15	1.5		0.1	0.017	0.17	J	0.1	0.046	0.46	J	0.1	0.045	0.45	J	0.1
TEQ 2,3,7,8 TCDD		**1.047**				**0.305**				**0.204**				**0.805**			
Exceedence factors for:																	
NTR (0.07 ppt ww)		15				4				3				11			
EPA SV Subsistence (0.0315 ppt ww)		33				10				6				26			
EPA SV Recreational (0.256 ppt ww)		4				1				1				3			
% lipids		3.4				1.0				1.1				1.4			

TEF -	Toxicity Equivalent Factor
TEQ -	Toxic Equivalent (to 2,3,7,8,-TCDD) in ppt ww
RR -	Reported Result in ppt ww
RL -	Reporting Limit in ppt ww
ppt ww -	Parts per trillion, wet weight
U -	The analyte was not detected at or above the reported value.
J -	The analyte was positively identified. The associated numerical value is an estimate.
UJ -	The analyte was not detected at or above the reported estimated result.
NJ -	There is evidence that the analyte is present. The associated numerical result is an estimate.