WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Persistent Organic Pollutants in Feed and Rainbow Trout from Selected Trout Hatcheries

April 2006

Publication No. 06-03-017

This report is available on the Department of Ecology home page on the World Wide Web at www.ecy.wa.gov/biblio/0603017.html

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Ecology's Project Code for this study is 05-056.

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Persistent Organic Pollutants in Feed and Rainbow Trout from Selected Trout Hatcheries

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April 2006

Waterbody numbers: Statewide

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Table of Contents

List of Figures and Tables

Page

Figures

Tables

Abstract

During 2005, persistent organic pollutants (POPs) were analyzed in fish feed and catchable rainbow trout from ten Washington Department of Fish and Wildlife (WDFW) hatcheries and the fish purchased by WDFW from one private hatchery operator. Fish originating from the same hatchery populations were also sampled approximately 2½ months following planting into unpolluted lakes in order to assess contaminant depuration or uptake. All feed and tissue (fillet) samples were analyzed for a variety of chlorinated pesticides, polychlorinated biphenyls (PCBs), a select group of polybrominated diphenyl ethers (PBDEs), and lipid content. A subset of feed and tissue samples was also analyzed for polychlorinated dioxins and furans (PCDD/Fs).

Feed samples had the following mean wet weight concentrations: ΣPCBs[1] – 13.8 ng/g, ΣDDT – 8.2 ng/g, ΣPBDEs – <0.25 ng/g, PCDD/F toxic equivalent – 0.75 pg/g. Fish tissue samples had the following respective mean wet weight concentrations in hatchery and planted rainbow trout: ΣPCBs – 13.0 and 3.1 ng/g, ΣDDT – 3.9 and 8.8 ng/g, ΣPBDEs – 0.66 ng/g for both. PCDD/F toxic equivalent averaged 0.032 pg/g in hatchery fish but was not analyzed in trout collected from lakes.

Other pesticides found in feed (f), hatchery fish (h), and planted fish (p) were: DDMU (f,h,p), dieldrin (f,h,p), hexachlorobenzene (f,h,p), pentachloroanisole (f,h,p), trans-nonachlor (f,h), cis-chlordane (f,h), trans-chlordane (f), methoxychlor (f), and toxaphene (f).

Results suggest that some portion of POP concentrations in trout from unpolluted waters may originate from hatcheries. In addition, some catchable trout contain POP concentrations above regulatory criteria when they are planted in lakes.

[1] Σ = Total

Acknowledgements

The authors would like to thank the following individuals for their contributions:

Staff with the Washington Department of Fish and Wildlife:

- John Kerwin, Hatchery Division Manager, helped conceive and develop this project
- Managers and staff of the trout hatcheries provided samples and answered our inquiries
- District biologists provided valuable suggestions and information on lakes and their trout populations
- Jeff Korth and Patrick Verhey helped collect fish in Warden Lake
- John Sneva aged the specimens
- John Kerwin and Sandie O'Neill reviewed the report

Staff with the Washington State Department of Ecology:

- Karin Feddersen contracted and reviewed the dioxin/furan analysis
- Dean Momohara conducted the lipid analysis
- Will White and Pam Covey handled and tracked samples
- Paul Anderson, Randy Coots, Casey Deligeannis, Brandee Era-Miller, Brandi Lubliner, Brenda Nipp, Brian Reese, Kirk Sinclair, and Trevor Swanson assisted with the collection and processing of fish samples
- Dale Norton and Art Johnson reviewed the report
- Carol Norsen and Joan LeTourneau edited and formatted the sampling plan and final report, respectively

Other contributors:

- Corey Bray assisted with fish collection
- Dave McBride, Washington State Department of Health, provided useful comments

Introduction

Recent reports have indicated that commercially farmed salmon, hatchery-raised trout, and the feed used to grow them may contain polychlorinated biphenyls (PCBs) and other persistent organic pollutants (POPs). For instance, Hites et al. (2004) showed that salmon raised in net-pens had substantially higher PCBs than those caught wild, presumably due to PCB-contaminated feed. Carline et al. (2004) found that concentrations of PCBs in hatchery rainbow trout (*Oncorhynchus mykiss*) fillets were correlated to concentrations in feed, and nearly all the body burden was due to PCBs in the diet. Other investigations have revealed detectable concentrations of dioxins, dieldrin, and endrin as well as PCBs in hatchery broodstock salmon and trout (Millard et al., 2004). In Pennsylvania, PCB contamination of edible tissues accumulated through dietary uptake in hatcheries exceeded thresholds for issuance of consumption advisories (Carline et al., 2004).

Currently there is no statewide program in Washington to evaluate toxic chemicals in hatchery feed or hatchery fish. At the same time, low levels of POPs in fish from lakes and streams across the state are being detected at an increasing rate (e.g., Seiders 2003; Seiders and Kinney, 2004) due to increased sampling coverage and better analytical detection limits. These waterbodies are often added to the list of impaired waters as required by the federal Clean Water Act section 303(d), and subsequently require a plan to control or clean up the contaminants. Many of the POPs found in fish tissue (e.g., PCBs, dioxins) are ubiquitous environmental contaminants and may be found globally through atmospheric deposition, historical releases, or food-web cycling. Fish may accumulate low concentrations of these chemicals through one or more of these pathways, although it is nearly impossible to distinguish and quantify these diffuse sources, and control and clean-up is often unrealistic. Due to recent data, however, contamination stemming from hatcheries is now considered a possible source of POPs in fish.

Study Description

Catchable rainbow trout – fish approximately six inches or more released into lakes and streams just prior to the opening of fishing season – were sampled from ten Washington Department of Fish and Wildlife (WDFW) hatcheries. Approximately 2½ months following planting, samples from un-mixed hatchery populations were sampled from stocked lakes. All feed and tissue (fillet) samples were analyzed for a variety of chlorinated pesticides, PCB aroclors, a select group of polybrominated diphenyl ethers (PBDEs), and lipid content. A subset of feed and tissue samples was also analyzed for polychlorinated dioxins and furans (PCDD/Fs). Specific project objectives were to:

- Measure concentrations of POPs in catchable rainbow trout released to lakes by WDFW.
- Measure concentrations of POPs in feed used to raise catchable rainbow trout in WDFW hatcheries to assess the correlation between diet and contaminant burdens in fish tissue.
- Estimate the degree of contaminant depuration or uptake in catchable rainbow trout following their release into lakes.

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Methods

Study Design

Fish feed and catchable rainbow trout were sampled from ten WDFW hatcheries during March 29 - April 5, 2005. Hatchery selection was made based on consultation with John Kerwin, Hatchery Division Manager with the WDFW Fish Program. Figure 1 shows locations of hatcheries. All ten hatcheries use well or spring water for hatching and rearing, although Tucannon River water is used in the final six-month rearing phase at the Tucannon Hatchery. Vancouver and Puyallup Hatchery personnel have also observed surface runoff entering hatcheries during rainy periods, but the extent of the exposure to fish is minor. POPs are much less likely to be present in groundwater and surface water due to their low solubility and immobility in soils.

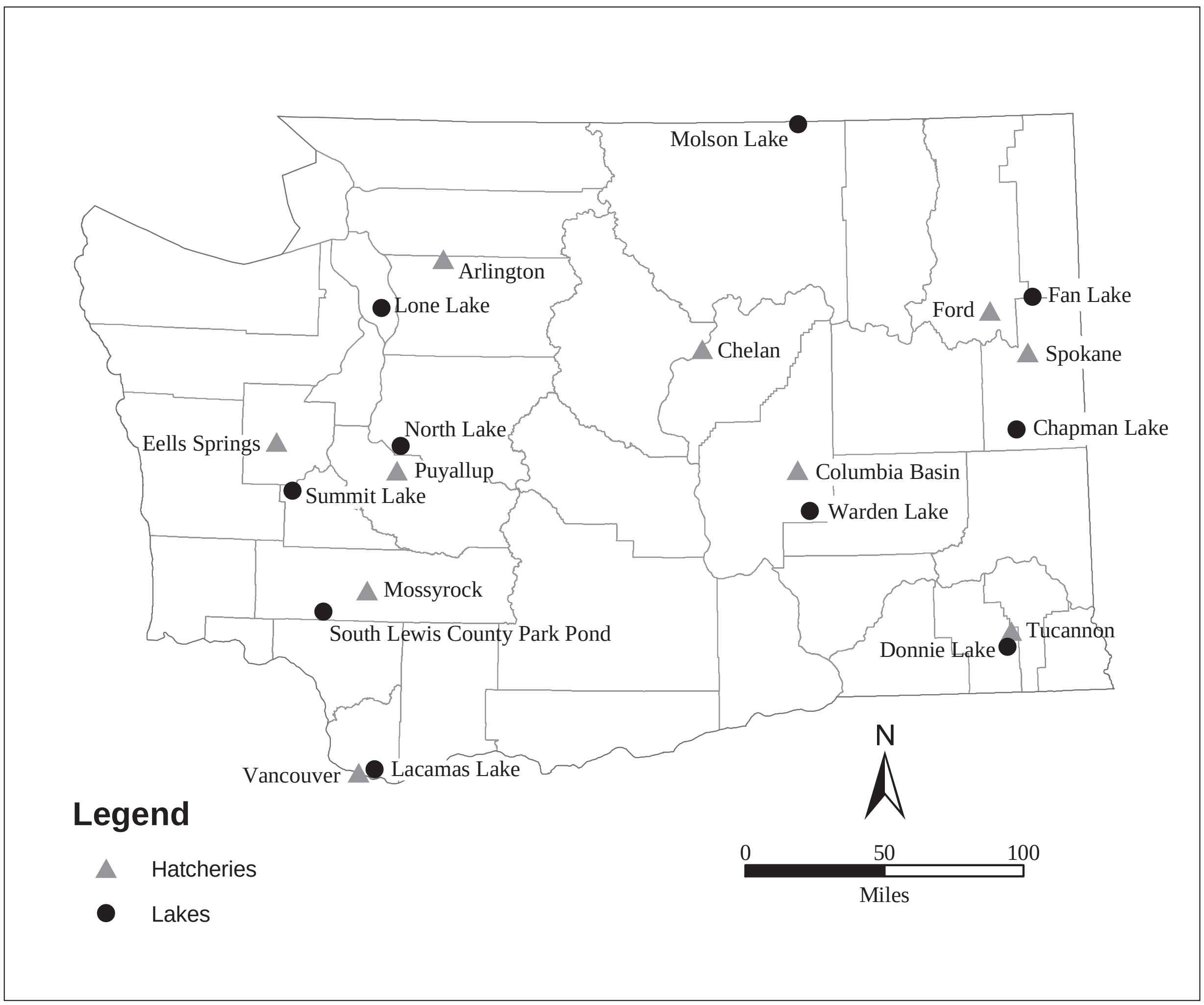

Figure 1. Locations of Hatcheries and Lakes Sampled for the 2005 Study of Persistent Organic Pollutants in Hatchery Feed and Hatchery Fish.

Hatchery personnel were interviewed about the feed used, schedule for changes in feed size and type, weight growth obtained using the sampled feed, hatchery water source, planting schedules, and other pertinent information related to the project. Feed samples consisted of material being fed to the trout at the time of sampling. In most cases, fish had been on the feed sampled for at least four months during which they had gained 50% - 80% of their mass (Table 1).

Table 1. Feed Analyzed from WDFW Hatcheries.

Hatchery	Feed Sampled	Pellet Size (mm)	Manufacturer	Period of use	Weight Gain
Arlington	Rangen	3.2	Rangen, Inc. Buhl, ID	6 mo.	76%
Chelan	Silver Cup Trout	3.0	Nelson & Sons, Inc., Murray, UT	6 mo.	76%
Columbia Basin	Silver Cup Fish Feed	3.2	Nelson & Sons, Inc., Murray, UT	6 mo.	80%
Eells Springs	Rangen	4.0	Rangen, Inc. Buhl, ID	4 mo.(a)	56%
Ford	Orient	4.0	Skretting, Vancouver, B.C.	na	50%
Mossyrock	Silver Cup Salmon	3.0	Nelson & Sons, Inc., Murray, UT	10 mo.	na
Puyallup	EWOS Vita	3.0	EWOS, Surrey, B.C.	na	na
Spokane	Silver Cup Fish Feed	3.2	Nelson & Sons, Inc., Murray, UT	na	78%
Tucannon	EWOS Pacific	3.0	EWOS, Surrey, B.C.	1 mo.(b)	70% (c)
Vancouver	Rangen	4.0	Rangen, Inc. Buhl, ID	6 mo.	82%

(a) fish fed Rangen since fry stage
(b) fish fed EWOS 2.0 for preceding 4 months, and EWOS 1.2 for 2 months prior to that
(c) weight gain during diet of EWOS 1.2, EWOS 2.0, and EWOS 3.0
na - not available

Ten rainbow trout specimens from each hatchery were randomly selected for sampling. They were from the general catchable populations which were in the process of being planted or were planned to be stocked within the subsequent weeks.

Ten triploid rainbow trout from Troutlodge, a private facility that supplies trout to WDFW, were provided by WDFW staff. Triploid trout are fish with three sets of chromosomes produced by pressure-treating the newly dividing fertilized eggs. Since they are sterile, more energy is used for somatic growth than gamete production, and the resulting triploid trout is larger than diploid fish of the same age. No feed samples or post-plant fish associated with Troutlodge were sampled for this study.

Lakes selected for sampling were based on the following criteria:

1. No known contaminant sources and low potential for appreciable contamination
2. Little or no natural rainbow trout production
3. Rainbow trout originating from a single hatchery planted between late-March and mid-April, 2005
4. Geographically dispersed to reflect a variety of ecosystem types, water chemistry, aquatic environments, and regions of the state containing differing preponderance of land use types.

Few of the approximately 380 lakes stocked annually with catchable trout have any contaminant data. Therefore, criterion 1 was assumed to be met unless a potential contaminant source was obvious. District WDFW biologists were interviewed to satisfy criterion 2. Criterion 3 was the most difficult to meet due to the common practice of multiple plantings of fish from different hatcheries. Lakes are also often planted at various intervals throughout the spring, which would yield uncertainties in fish residence periods; these lakes were avoided. Planting reports provided weekly by WDFW were reviewed in order to find lakes with single hatchery plants and fish residence times of approximately 2½ months. Criterion 4 was easily satisfied due to the geographic separation of the hatcheries and their associated lakes. Table 2 lists lakes where rainbow trout were sampled and their hatcheries of origin.

Table 2. Lakes Sampled and 2005 Rainbow Trout Plants.

Lake	County	Area (hect.)	Mean Depth (meters)	2005 Stock Date	Number	Mean Weight (grams)	Hatchery
Lone	Island	41	2.7	30-Mar	4,060	114	Arlington
				18-Apr	593*	649	Troutlodge
Molson	Okanogan	9.3	1.8	12-Apr	4,160	142	Chelan
Warden	Grant	81	8.2	15-Mar	12,723	116	Columbia Basin
				18-Mar	11,596	108	
				5-Apr	685	123	
Summit	Thurston	214	16	28-Mar	400	1,746	Eells Springs
				29-Mar	402	1,681	
				14-Apr	10,048	142	
				15-Apr	646	825	
				22-Apr	15,097	138	
				25-Apr	9,810	153	
				26-Apr	5,056	142	
Fan	Pend Oreille	32	7.6	22-Mar	3,021	86	Ford
S. Lewis Co. Park Pond	Lewis	4.5	2.7	14-Apr	3,043	134	Mossyrock
North	King	23	4.3	20-Apr	8,500	114	Puyallup
Chapman	Spokane	61	20	15-Mar	5,925	91	Spokane
Donnie	Columbia	0.4	0.9	14-Apr	420	108	Tucannon
Lacamas	Clark	129	7.3	7-Mar	2,000	227	Vancouver
				8-Apr	3,000	267	
				26-Apr	4,000	197	

*Triploid fish

Sampling Procedures

Hatchery feed and pre-plant catchable rainbow trout samples were collected with assistance of hatchery staff. Fish averaged 235 mm total length and 152 gm in weight (excluding Troutlodge samples). Feed samples were placed directly in 1-liter organics-free glass jars with Teflon lid liners and certificates of analysis. Fish from hatcheries were killed with a blow to the skull, double-wrapped in aluminum foil, sealed in zip-lock polyethylene bags, and transported on ice to Ecology headquarters where they were weighed and measured prior to being stored frozen at –20° C.

Rainbow trout from lakes were collected by hook-and-line or electrofishing. Following capture, fish were observed for signs confirming previous hatchery residence. Specimens were then killed with a blow to the skull, weighed to the nearest gram and measured to the nearest millimeter, assigned a sample number, double-wrapped in aluminum foil, placed in zip-lock polyethylene bags, and transported on ice to Ecology headquarters where they were stored frozen at –20° C. Rainbow trout collected from lakes averaged 270 mm total length and 211 gm in weight.

When ready for processing, fish were partially thawed then scales were removed for aging by WDFW. Composite samples of homogenate tissue were prepared by methods described by EPA and the Washington State Toxics Monitoring Program (EPA, 2000; Seiders, 2003). Briefly, fish were scaled, skin-on fillets removed, and equal mass aliquots of tissue were homogenized with three passes through a Kitchen-Aid food processor for each composite. Homogenates were placed in a 4-oz organics-free glass jar with Teflon lid liner and certificate of analysis and stored frozen.

All resection was done with non-corrosive stainless steel implements on a clean aluminum foil surface. Persons preparing samples wore non-talc polyethylene or nitrile gloves changed between samples. Resection and homogenizing equipment was cleaned using Liquinox® detergent and hot tap water, followed by rinses with deionized water, pesticide grade acetone, and pesticide grade hexane, then air-dried in a fume hood before use.

Laboratory Analysis and Data Quality

Sample Preparation

Feed

Feed samples were first Soxhlet extracted using 1:1 methylene chloride/hexane, then solvent exchanged into hexane and adjusted to 10 ml. Extracts were split, half for PCB/chlorinated pesticide and half for PBDE and lipid analysis.

Extracts for PCB and chlorinated pesticide analysis were eluted through 2 gm micro Florisil® columns first with 100% hexane and collected as the “0% Florisil fraction”, followed by elution with 1:1 hexane/preserved diethyl ether, collected as the “50% Florisil fraction”. When the

"0% Florisil fractions" were solvent-reduced, the remaining extracts were as much as 50% lipids, unsuitable for gas chromatography (GC) analysis, and were therefore added to the "50% Florisil fraction". The combined extracts were then back-extracted with acetonitrile to remove lipids and re-eluted through 2 gm micro Florisil® columns with 100% hexane ("0% Florisil fraction") and 1:1 hexane/preserved diethyl ether ("50% Florisil fraction"). Each fraction was solvent-exchanged to iso-octane and concentrated to 1 ml. One-half of the "50% Florisil fraction" and the "0% Florisil fraction" were treated with concentrated sulfuric acid prior to analysis. The remainder of the "50% fraction" was analyzed without acid treatment.

Fish Tissue

Tissue samples were first Soxhlet extracted using 1:1 methylene chloride/hexane, then solvent exchanged into hexane and adjusted to 10 ml. Extracts were split, half for PCB/chlorinated pesticide and half for PBDE and lipid analysis.

Extracts for some PCB analyses (sample nos. 05248100 – 05248109) were eluted through 2 gm micro Florisil® columns with 100% hexane, solvent-exchanged to iso-octane, and concentrated to 1 ml. Extracts were treated with concentrated sulfuric acid prior to analysis.

For chlorinated pesticide analysis and some PCB analyses (sample nos. 05144080 – 05144090), extracts were eluted through 2 gm micro Florisil® columns with 100% hexane and collected as the "0% Florisil fractions", followed by elution with 1:1 hexane/preserved diethyl ether. The hexane/ether fractions were adjusted to 5 ml and back-extracted with acetonitrile to remove lipids and re-eluted through 2 gm micro Florisil® columns with 1:1 hexane/preserved diethyl ether, and collected as the "50% Florisil fraction". Each fraction was solvent-exchanged to iso-octane and concentrated to 1 ml. One-half of the "50% Florisil fraction" and the "0% Florisil fraction" were treated with concentrated sulfuric acid prior to analysis. The remainder of the "50% fraction" was analyzed without acid treatment.

Analyses for PCBs, chlorinated pesticides, and PBDEs were conducted at the Manchester Environmental Laboratory (MEL) using dual column GC/ECD. Sample preparation and analysis methods were modifications of EPA SW-846 Methods 3540, 3620, and 8081/8082.

Samples for PCDDs/PCDFs were analyzed at Pacific Rim Laboratories, Inc. (Surrey, B.C.) using high resolution GC/MS isotope dilution methodology of EPA Method 1613B. Percent lipid was analyzed gravimetrically at MEL. The complete list of analytes is in Appendix B.

Data Quality

Overall quality of the data was fair. Precision for Aroclor analysis was 11% relative percent difference. Analysis was also performed with a high degree of precision for DDT compounds (14%), other chlorinated pesticides (17%), PBDEs (17%), and PCDD/Fs (13%).

One standard reference material was analyzed along with feed and tissue; NIST 1974b – Organics in Frozen Mussel Tissue (https://srmors.nist.gov/tables/view_table.cfm?table=109-2.htm). Chlorinated pesticide analytes, including DDT compounds, were only 67% of certified concentrations on average. Total PCBs were 82% of the reference concentration. These results indicate a possible low bias for these analyte groups.

Data Analysis

PCB, DDT, PBDE, and lipid concentrations were compared between hatchery and lake rainbow trout using the Wilcoxon signed-rank test, a non-parametric equivalent of the paired t-test (Zar, 1984). Spearmann ranked correlations among contaminant groups and sample types were done using SYSTAT 9.01 software program (SPSS, 1998). Non-detected values were treated as zero for statistical tests to avoid misinterpretation of comparisons between hatchery tissue samples and the lake tissue samples, which had different detection limits for the same analytes.

Non-detects were also treated as zero for samples analyzed in duplicate. Therefore, values presented as the mean of duplicate analyses may be biased low. The complete set of chemistry data is in Appendix C.

Results

Field Observations

Physical observations of rainbow trout collected from lakes indicated that they originated from hatcheries sampled earlier in the year. Most specimens had gnawed pectoral fins, or dorsal and caudal fin erosion. Scale annuli patterns also indicated fish were from the year's stock of catchables (John Sneva, WDFW, written communication, 8/10/2005). This physical evidence, coupled with local knowledge from WDFW District Biologists and WDFW plant records, supports the conclusion that the trout had been raised as catchables from known hatcheries.

Rainbow trout collected from lakes in June were larger on average than just prior to their release from hatcheries (Table 3). Increases in total length averaged 15%, and weight gain was 39% on average. Mean condition factors in hatchery and planted trout were 1.11 and 1.02, respectively. Condition factors fell below 1.0 in half the lakes, suggesting food supply was limited. Gut contents were not examined, but aside from the fin erosion mentioned previously, the fish collected from lakes appeared healthy and took bait and lures readily in most cases.

Contaminants in Feed and Fish

PCBs, DDT, and PBDEs

Most feed and fish tissue samples contained measurable concentrations of PCBs (Table 4). Aroclor-1254 was the most commonly detected, followed by 1260, 1242, and 1248; none of the other Aroclors were detected.

All samples contained DDT compounds, with 4,4'-DDE comprising 74% of the ΣDDT on average. All but one of the tissue samples contained low levels of PBDEs; none of the feed samples had detectable PBDEs. PBDE-47 was the most common congener detected, followed by 99, 71/100, and 138/209.

Mean concentrations of lipids in feed were high (16.8%) compared to tissue. This high fat diet resulted in high lipid levels in hatchery rainbow trout fillet tissue (mean of 3.2%). Although the catchable rainbow trout increased in size following planting, it appears that muscle lipid was depleted to meet their energy requirements, with an average 60% decrease in lipid content (1.2%).

Table 3. Length and Weight of Rainbow Trout Collected from Hatcheries and Lakes.

Hatchery/Lake	2005 Collection Date	N	Total Length (mm, mean ± SD)	Weight (gm, mean ± SD)	Condition Factor (mean ± SD)
Arlington Hatchery	29-Mar	10	245 ± 16	165 ± 34	1.11 ± 0.09
Lone Lake	16-Jun	10	306 ± 12	334 ± 37	1.17 ± 0.06
Chelan Hatchery	5-Apr	10	253 ± 16	178 ± 37	1.08 ± 0.11
Molson Lake	13-Jun	10	296 ± 20	303 ± 59	1.16 ± 0.08
Columbia Basin Hatchery	5-Apr	10	230 ± 15	140 ± 31	1.15 ± 0.08
Warden Lake	9-Jun	10	251 ± 10	147 ± 23	0.93 ± 0.08
Eells Springs Hatchery	1-Apr	10	230 ± 8	142 ± 19	1.16 ± 0.07
Summit Lake	13-Jun	7	259 ± 13	160 ± 16	0.92 ± 0.12
Ford Hatchery	4-Apr	10	197 ± 15	83 ± 15	1.09 ± 0.06
Fan Lake	14-Jun	8	290 ± 14	271 ± 47	1.11 ± 0.15
Mossyrock Hatchery	5-Apr	10	260 ± 14	190 ± 31	1.08 ± 0.06
S. Lewis Co. Park Pond	14-Jun	8	259 ± 10	176 ± 24	1.01 ± 0.07
Puyallup Hatchery	1-Apr	10	218 ± 20	111 ± 31	1.04 ± 0.11
North Lake	13-Jun	10	245 ± 12	141 ± 21	0.96 ± 0.08
Spokane Hatchery	4-Apr	10	210 ± 13	98 ± 21	1.04 ± 0.08
Chapman Lake	15-Jun	4	243 ± 10	125 ± 13	0.87 ± 0.04
Tucannon Hatchery	4-Apr	10	206 ± 18	108 ± 30	1.21 ± 0.06
Donnie Lake	16-Jun	10	254 ± 19	145 ± 33	0.87 ± 0.07
Vancouver Hatchery	5-Apr	10	298 ± 24	303 ± 91	1.12 ± 0.10
Lacamas Lake	17-Jun	9	285 ± 14	249 ± 37	1.07 ± 0.06
Troutlodge Hatchery	4-Apr	10	374 ± 22	678 ± 133	1.29 ± 0.19

Condition Factor = (W[g] x 100/L[cm]^3)
N = number
SD = standard deviation

Table 4. Lipid, ΣPCB, ΣDDT, and ΣPBDE Concentrations in Feed and Rainbow Trout Fillet Tissue (ng/g, ww).

Sample Type/Location	% Lipid	ΣPCB	ΣDDT	ΣPBDE
Hatchery Feed				
Arlington	18.19	**13.8**	**6.3**	U(0.25-1.2)
Chelan	13.75	**34.8**	**9.4**	U(0.25-1.2)
Columbia Basin	14.47	**11.6**	**6.3**	U(0.24-1.2)
Eells Spring	12.70	**12.5**	**5.9**	U(0.24-1.2)
Ford*	25.85	U(2.5)	**3.7**	U(0.25-1.2)
Mossyrock	19.64	**27.6**	**11.0**	U(0.25-1.2)
Puyallup*	16.14	U(2.5)	**6.6**	U(0.25-1.2)
Spokane	15.79	**16.4**	**5.9**	U(0.25-1.2)
Tucannon	15.01	**8.2**	**21**	U(0.25-1.2)
Vancouver	16.08	**13.3**	**5.8**	U(0.25-1.2)
Hatchery Rainbows				
Arlington	3.97	**12.1**	**4.8**	**0.64**
Chelan	3.05	**67**	**4.1**	**1.09 J**
Columbia Basin	4.10	**18.5**	**6.5**	**0.90 J**
Eells Spring*	2.42	U(2.4)	**2.7**	**0.52**
Ford	2.35	U(2.5)	**2.5**	**0.24 J**
Mossyrock	2.69	**15.8**	**3.9**	**0.89 J**
Puyallup	3.07	U(2.3)	**2.4**	**0.24**
Spokane	2.48	**11.7**	**2.9**	**1.10 J**
Tucannon	3.69	U(2.4)	**5.3**	**0.27**
Vancouver*	4.00	**4.8**	**4.0**	**0.71 J**
Troutlodge	5.39	**14.4**	**5.7**	**0.84 J**
Planted Rainbows				
Lone Lake*	1.67	U(4.8)	**1.9**	**0.96 J**
Molson Lake	2.05	**8.6**	**5.8**	U(0.49-2.4)
Warden Lake	0.61	U(4.9)	**3.7**	**0.46 J**
Summit Lake*	0.40	**5.0**	**3.2**	**0.56**
Fan Lake	2.66	U(5.0)	**57**	**0.40 J**
South Lewis Co. Park Pond	0.77	**5.9**	**2.4**	**1.33 J**
North Lake	0.65	U(4.9)	**2.9**	**1.23 J**
Chapman Lake	0.44	**11.8**	**5.0**	**1.01 NJ**
Donnie Lake	1.29	U(5.0)	**3.6**	**0.25 J**
Lacamas Lake	1.50	U(5.0)	**3.0**	**0.42 J**

ΣPCB = the sum of detected Aroclors
ΣDDT = the sum of detected 4,4' and 2,4' homologues of DDD, DDE, and DDT
ΣPBDE = the sum of detected PBDE congeners analyzed
Detected concentrations in **bold**
* Samples analyzed in duplicate. Results shown are mean of laboratory analyses.
U - The analyte was not detected at or above the reported result
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.

Lipid catabolism in muscle and consequent contaminant mobilization may explain higher mean ΣPCB in hatchery fish compared to fish from lakes (13 and 3.1 ng/g, respectively; Figure 2). Differences between contaminant concentrations in hatchery and planted rainbow trout appear to be regulated by more than lipid decreases, however. Mean ΣDDT concentrations in tissue were higher in lakes (8.8 ng/g) compared to tissues from hatchery fish (3.9 ng/g), although concentrations were nearly identical when the outlier from Fan Lake was removed.

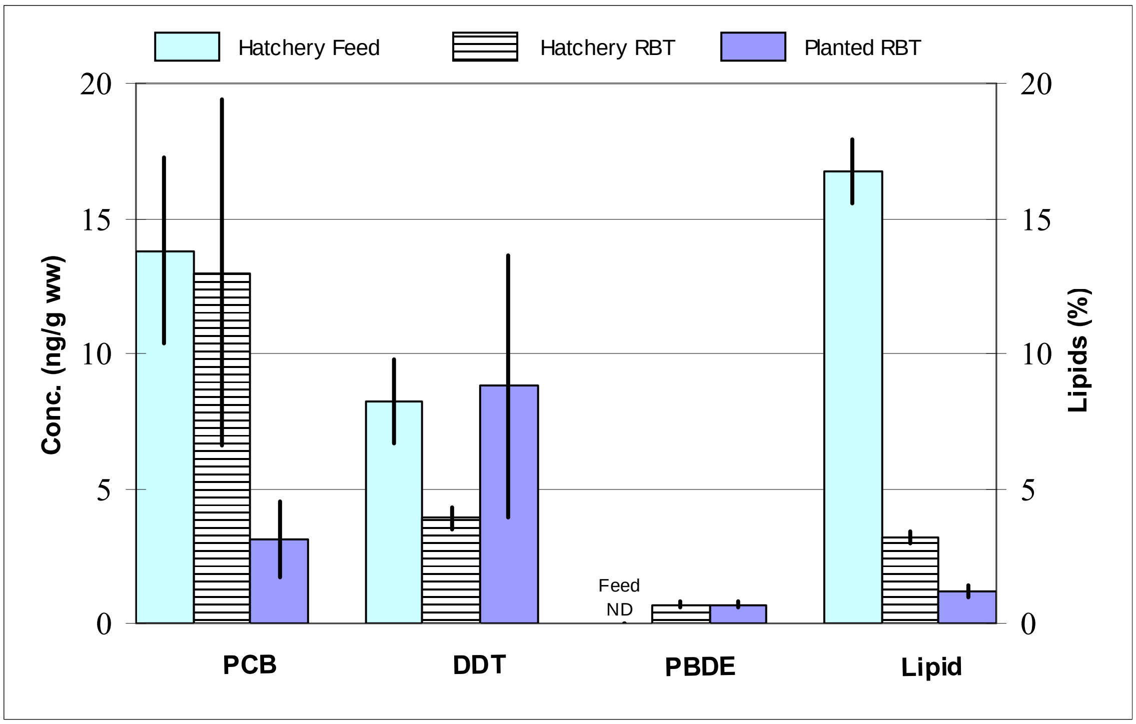

Figure 2. Mean (SE) Concentrations of ΣPCBs, ΣDDT, ΣPBDE, and Percent Lipid in Hatchery Feed, Hatchery Rainbow Trout, and Planted Rainbow Trout.

Neither ΣPCB nor ΣDDT were significantly different in hatchery fish compared to planted fish (Wilcoxon signed-rank test, $\alpha=0.05$). There was also no significant difference in PBDEs between groups, although this was not surprising since mean concentrations were identical (0.66 ng/g, respectively).

PCBs tended to be highest in hatchery fish whose food had comparatively high PCB concentrations. For example, the Chelan Hatchery had high ΣPCB in both feed and fish, while Ford and Puyallup Hatcheries had no detectable PCBs in either feed or fish. However, this pattern was not true for ΣDDT and ΣPBDE in hatchery samples.

To examine possible relationships among sample types and contaminants, a ranked correlation analysis was performed on major variables in hatchery and lake samples (Table 5). There were no strong correlations between contaminants in hatchery fish and their lake counterparts. With the exception of lipids and ΣDDT in hatchery fish, lipids were not highly correlated with ΣPCB, ΣDDT, or ΣPBDE, a somewhat surprising finding but lending support to the notion that factors other than lipid may be the primary determinants in contaminant residue levels, particularly for DDT compounds and PBDEs.

Table 5. Spearman Ranked Correlation Matrix of Major Variables in Feed and Tissue Samples.

	Hatch. Feed Lipid									
Hatch. Feed ΣPCB	-0.182	Hatch. Feed ΣPCB								
Hatch. Feed ΣDDT	-0.159	0.226	Hatch. Feed ΣDDT							
Hatch. Fish Lipid	-0.139	-0.012	0.256	Hatch. Fish Lipid						
Hatch. Fish ΣPCB	-0.156	**0.753**	0.280	0.356	Hatch. Fish ΣPCB					
Hatch. Fish ΣDDT	-0.333	0.280	0.402	**0.721**	**0.563**	Hatch. Fish ΣDDT				
Hatch. Fish ΣPBDE	-0.365	**0.817**	0.086	0.170	**0.822**	0.426	Hatch. Fish ΣPBDE			
Planted Fish Lipid	0.467	0.030	-0.030	0.042	0.125	0.127	-0.213	Planted Fish Lipid		
Planted Fish ΣPCB	-0.307	**0.753**	0.131	**-0.519**	0.405	-0.171	**0.685**	-0.294	Planted Fish ΣPCB	
Planted Fish ΣDDT	-0.285	-0.109	-0.293	-0.382	0.019	-0.042	0.182	0.176	0.246	Planted Fish ΣDDT
Planted Fish ΣPBDE	0.382	0.103	0.055	-0.103	-0.006	-0.394	0.043	**-0.539**	0.184	**-0.636**

Spearman correlation coefficients ≥|0.500| in **bold**

Dioxins and Furans

Four samples each of hatchery feed and rainbow trout tissue were analyzed for 2,3,7,8-substituted PCDDs and PCDFs (Table 6). Toxic equivalents (TEQs) were calculated using toxic equivalency factors (TEFs) proposed by Van den Berg et al., 1998.

Table 6. TEQ Concentrations (pg/g, ww) in Four Feed and Rainbow Trout Samples and Percent TEQ Contribution by Congener.

	Vancouver	Mossyrock	Ford*	Spokane
Hatchery Feed				
TEQ	0.562	1.226	0.028	1.194
2,3,7,8-TCDD	33%	30%	0%	16%
1,2,3,7,8-PeCDD	38%	44%	0%	53%
1,2,3,4,7,8-HxCDD	0%	0%	0%	0%
1,2,3,6,7,8-HxCDD	4%	4%	0%	4%
1,2,3,7,8,9-HxCDD	0%	3%	0%	3%
1,2,3,4,6,7,8-HpCDD	2%	1%	18%	1%
OCDD	0%	0%	1%	0%
2,3,7,8-TCDF	9%	7%	71%	12%
1,2,3,7,8-PeCDF	2%	2%	10%	1%
2,3,4,7,8-PeCDF	11%	9%	0%	10%
1,2,3,4,7,8-HxCDF	0%	0%	0%	0%
1,2,3,6,7,8-HxCDF	0%	0%	0%	0%
2,3,4,6,7,8-HxCDF	0%	0%	0%	0%
1,2,3,7,8,9-HxCDF	0%	0%	0%	0%
1,2,3,4,6,7,8-HpCDF	0%	0%	0%	0%
1,2,3,4,7,8,9-HpCDF	0%	0%	0%	0%
OCDF	0%	0%	0%	0%
Hatchery Rainbows				
TEQ	0.053	0.041	0.012	0.024
2,3,7,8-TCDD	0%	0%	0%	0%
1,2,3,7,8-PeCDD	0%	0%	0%	0%
1,2,3,4,7,8-HxCDD	0%	0%	0%	0%
1,2,3,6,7,8-HxCDD	0%	0%	0%	0%
1,2,3,7,8,9-HxCDD	0%	0%	0%	0%
1,2,3,4,6,7,8-HpCDD	0%	0%	0%	0%
OCDD	0%	0%	0%	0%
2,3,7,8-TCDF	35%	68%	35%	68%
1,2,3,7,8-PeCDF	11%	17%	0%	0%
2,3,4,7,8-PeCDF	39%	0%	0%	0%
1,2,3,4,7,8-HxCDF	13%	12%	56%	28%
1,2,3,6,7,8-HxCDF	0%	0%	0%	0%
2,3,4,6,7,8-HxCDF	0%	0%	0%	0%
1,2,3,7,8,9-HxCDF	0%	0%	0%	0%
1,2,3,4,6,7,8-HpCDF	2%	2%	9%	3%
1,2,3,4,7,8,9-HpCDF	0%	0%	0%	0%
OCDF	0%	0%	0%	0%

* Samples analyzed in duplicate. Results shown are mean of laboratory analyses.

TEQs were much higher in hatchery feed compared to rainbow trout, with the exception of Ford Hatchery feed which had a TEQ up to 40 times lower than the other hatcheries. Like other contaminants, it appears that TEQ concentrations were not determined primarily by lipid content. Congeners contributing to TEQ were markedly different between high and low TEQ samples, with tetra- and penta-substituted dioxin congeners providing approximately 70% of the toxicity. In contrast, the Ford feed sample had none of these congeners detected.

Congener patterns were even more distinct when feed and fish tissue samples were compared. None of the tissue samples contained detectable concentrations of PCDDs. Most of the toxicity in tissue samples was derived from tetra-, penta-, and hexa-substituted furan congeners.

Other Chlorinated Pesticides

In addition to DDT compounds, nine chlorinated pesticides or breakdown products were detected in feed samples, six were detected in hatchery rainbow trout, and four were found in trout collected from lakes (Figure 3). DDMU, like its parent DDT, was detected in all hatchery feed samples. Although DDMU was much higher in Fan Lake trout (4.4 ng/g) compared to other lakes, feed from the originating hatchery (Ford) had the lowest concentration (0.2 ng/g), and Ford Hatchery rainbow trout did not have a detectable DDMU concentration.

Dieldrin had an unusual detection pattern among samples; it was detected in only 10% (Mossyrock, one of ten) feed samples, and 20% of lake fish tissue samples, but was found in 70% of the hatchery tissue samples. It should be noted, however, that detection limits for dieldrin in feed samples were approximately three-to-five times higher than in tissue samples (see Appendix C). Hexachlorobenzene was found in only one sample from planted rainbow trout (Summit Lake, 0.7 ng/g) but not in fish from the original population at Eells Springs Hatchery. The comparatively high concentration and lack of apparent link to the hatchery suggests these fish may have accumulated hexachlorobenzene from a local source in Summit Lake.

Pentachloroanisole, a degradation product of pentachlorophenol, was the only additional compound detected in planted rainbow tissue. Concentration of pentachloroanisole doubled in Lacamas Lake fish compared with the original hatchery population, suggesting a possible local source. Tucannon hatchery rainbows also apparently accumulated pentachloroanisole from the hatchery feed, although residues in the hatchery fish did not persist while the fish were in a (Donnie) lake environment.

Nonachlor and cis-chlordane, two components of commercial-grade chlordane, were found in at least half of the hatchery feed and fish samples. Another chlordane component, trans-chlordane, was found in 40% of feed samples. Two other chlorinated pesticides, toxaphene and methoxychlor, were found in 30% and 20% of feed samples, respectively.

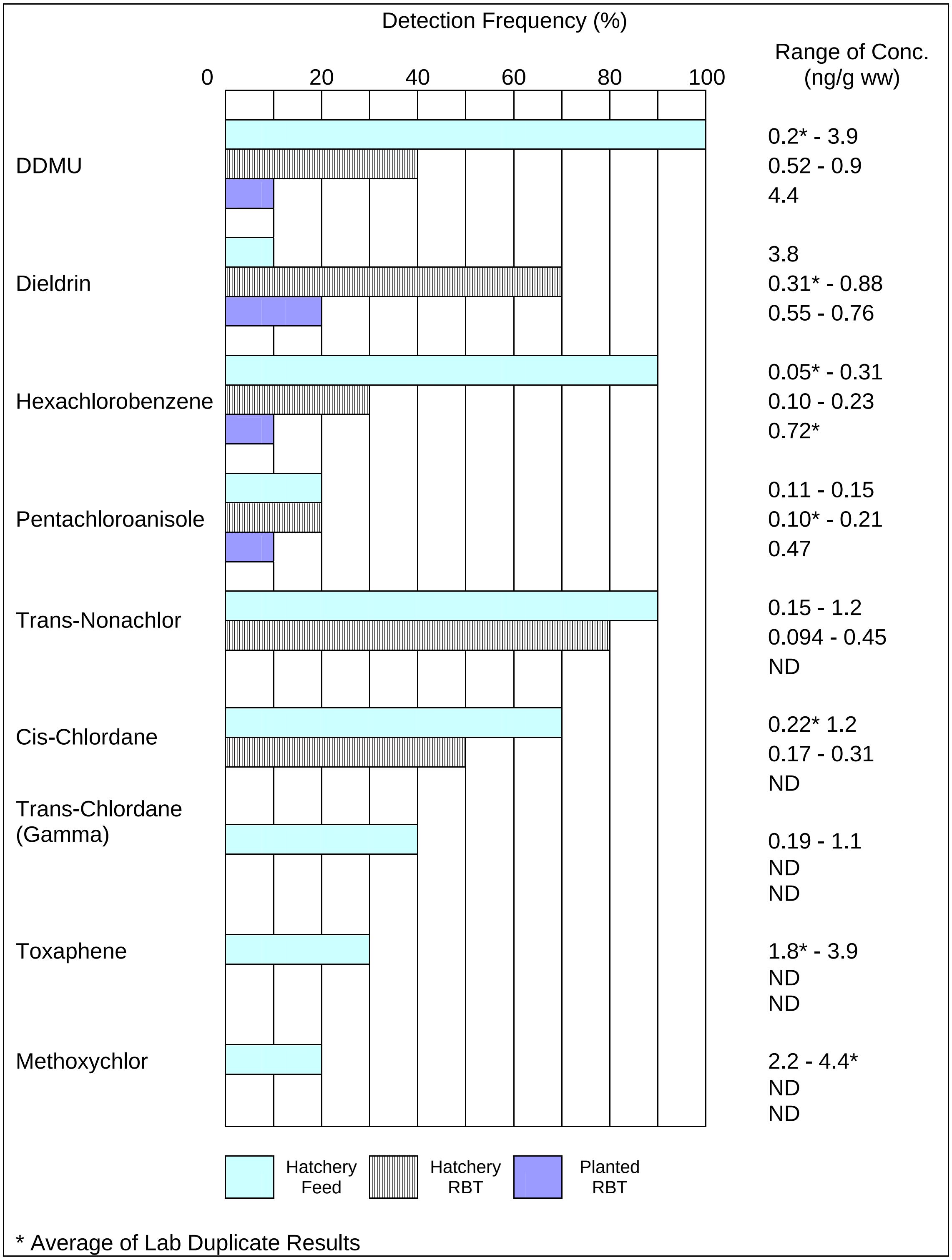

Figure 3. Detection Frequency of Chlorinated Pesticides (Excluding DDT Compounds) and Range of Detected Concentrations.

Discussion

Feed Ingredients and Residue Tolerances

The four brands of feed analyzed during the present 2005 survey have a wide range of contaminant levels. Rainbow trout collected at hatcheries gained approximately 50-80% of their final weight on these feeds, and may have gained most of their initial weight on starter feeds with similar ingredients.

Feed sack labels obtained at the time of sampling indicated that minimum amounts of crude protein (40-45%) were similar among feeds, as were maximum amounts of crude fiber (1.5-5%) and ash (9-12%). Crude fat was the other major component, constituting 10-24% of the weight which generally showed good agreement with lipid analysis in the present study (r^2=0.64).

In terms of contaminant residues, the origin of the lipids in the feed is probably a much greater concern than their percent by weight. All of the feeds sampled advertise fish oil as a major ingredient which is likely to be the major source of PCBs, chlorinated pesticides, PBDEs, PCDD/Fs, and other lipophilic contaminants (Jacobs et al., 2002).

The exact source of the fish oil and fish meal, as well as other major ingredients in hatchery feed (wheat flour, soybean oil, blood meal, feather meal, and poultry by-product), may change from batch to batch, depending on the availability and cost of the raw products. Fishmeal may derive largely from anchovy, menhaden, capelin, and herring, and fish oil is a by-product of the fishmeal manufacturing industry.

The negative correlation between lipids and major contaminants in feed is another indication that the source of fish oil is probably a more important determinant in contaminant residues than lipid content by weight. However, contaminant concentrations in feed apparently play a large role in accumulation by fish, probably due to the high rate of weight conversion from feed to fish (>80%). This is demonstrated by the strong correlation between ΣPCB in hatchery feed and hatchery fish (r=0.75), and a weaker yet positive correlation for ΣDDT (r=0.40).

In the case of the Tucannon hatchery, where the fish are raised in water from the Tucannon River for six months prior to stocking, fish weight gain actually exceeded the weight of feed provided (conversion of 163%) due to availability of natural prey items.

The only domestic regulation concerning POP contaminants is a federal PCB residue tolerance of 2,000 ng/g for feed components of animal origin (21 CFR 109.30). The Canadian Food Inspection Agency has an "actionable level" of 2,000 ng/g for PCBs, but it only applies to fish oil destined for animal feed (CFIA, 2003). In 2001, the European Union (EU) established maximum tolerable levels of PCDD/F TEQs in fish in various fish products and feeds. The maximum levels for fish feed and fish oil for use other than direct human consumption is 2.25 and 6.0 pg TEQ/g, respectively (Directive 2001/102/EC).

Table 7 shows a summary of major contaminants in hatchery feeds and commercial aquaculture feeds for salmonids. Care should be used interpreting the available data since information on the intended species is often not included. For instance, feed for commercial salmon aquaculture typically contains higher fish oil content than trout feed, and some species, such as catfish and tilapia, may be fed entirely vegetable-based feeds.

Table 7. Contaminant Concentrations in Various Hatchery and Commercial Aquaculture Feeds and Applicable Regulations (mean concentrations unless otherwise noted).

Source	ΣPCB (ng/g ww)	ΣDDT (ng/g ww)	ΣPBDE (ng/g ww)	Dioxin TEQ (pg/g ww)	Lipid (%)	Ref.
Contaminant Levels in Feed						
Feeds from 6 manufacturers used in 11 USF&WS National Fish Hatcheries	1.94*	11.33	nr	0.227	16.7	Maule et al., 2006
Mean of 8 commercial salmon aquaculture feeds from Scottish sources	105	12.1	5.1	nr	28.8	Jacobs et al., 2002
Mean of fish feed/fishmeal samples originating from Canada (n=14), U.S. (n=7), Iceland (n=1), Peru (n=1), and Russia (n=1)	Can.–30.7† U.S.–16.5† Ice.–12.1† Peru–0.6† Rus.–12.7†	Can.–21.1 U.S.–23.3 Ice.– <7 Peru–nr Rus.–nr	nr	Can.–1.0 U.S.–1.1 Ice.–0.23 Peru–ND Rus.–0.22	nr	CFIA, 2006
Feed from the 2 largest global suppliers for commercial salmon aquaculture; 9 samples from North and South America and 4 samples from Europe	15 (approx. Amer. median) 60 (approx. Eur. median)	nr	nr	1 (approx. Amer. median) 4 (approx. Eur. median)	nr	Hites et al., 2004
Confidential	nr	nr	nr	1.21	nr	Hermann et al., 2004
WDFW trout hatchery feed	*13.8*	*8.2*	*ND (<0.25)*	*0.75*	*16.8*	*present study, 2005*
Regulatory Levels in Feed						
U.S. Food and Drug Admin.	2,000	ne	ne	ne	ne	21 CFR 109.30(a)(6)
European Union	ne	ne	ne	2.25	ne	Directive 2001/102/EC 21

*sum of 14 dioxin-like congeners
†sum of 72 congeners
nr - not reported
ND – not detected
ne - not established

Maule et al. (2006) analyzed numerous batches of feeds used at eleven U.S. Fish and Wildlife Service (USF&WS) National Fish Hatcheries. They found a lower mean dioxin TEQ and ΣPCB than reported here, although the ΣPCB was derived from only 14 dioxin-like PCB congeners. Interestingly, the bulk of the dioxin TEQ was derived from 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD similar to the feed samples analyzed for the present survey. ΣDDT and percent lipid contents were similar between the two studies.

Comparison of contaminants in feed and salmon fillet from commercial aquaculture operations showed ΣPCB, ΣDDT, and ΣPBDE higher in feed compared to fish tissue at similar proportions to those reported here (Jacobs et al., 2002). Although the mean ΣDDT was similar to results for the present study, ΣPCB was an order of magnitude higher. The feeds, which were from Scottish sources, had much higher lipids (mean of 28.8%) than found here (mean of 16.8%). Hites et al. (2004) reported ΣPCB and dioxin TEQ levels approximately four-fold higher in commercial salmon aquaculture feeds from Europe compared to North and South America. Like other results, the Hites et al. (2004) study found POP concentrations slightly higher in feed compared to fish, on average, but lipid concentrations were not given.

The Canadian Food Inspection Agency (CFIA) analyzed 24 samples originating primarily from Canada and the U.S., but also from Iceland, Peru, and Russia, although little additional information is provided about the samples (CFIA, 2006). ΣPCB for U.S., Icelandic, and Russian samples were similar to those reported here, while Canadian feed had about twice the concentration on average. DDT levels were about twice the levels reported in other samples, while the dioxin TEQs tended to be within ranges reported by other investigators.

The only reported PBDE analysis of feed was done in the Jacobs et al. (2002) study which found ΣPBDE averaging 20 times the analytical reporting limits for the present study. PBDE-47 was the predominant congener found and, although not found in WDFW hatchery feeds, it was the major congener in rainbow trout from hatcheries and lakes and is one of the most abundant congeners found in Washington freshwater fish (Johnson and Olson, 2001).

None of the average POP concentrations reported in these studies violated residue tolerances from the applicable regulations, with the exception of the European median dioxin TEQ reported by Hites et al. (2004). A study by Herrmann et al. (2004), designed specifically to look at compliance with EU standards, found a mean concentration of dioxin TEQ about one-half the EU residue tolerance. However, 95^{th} percentile values for both fish feed (2.71 pg/g) and fish oil (6.30 pg/g) exceeded the dioxin TEQ standards.

Depuration/Uptake of Contaminants in Lakes

One of the underlying goals of this study was to determine if lakes act as purifying environments or if hatchery fish stocked in lakes accumulate additional contaminants. Cursory inspection of the data suggests depuration occurs for PCBs and chlorinated pesticides other than DDT compounds, and no differences are seen for ΣDDT (with the Fan Lake outlier removed) and ΣPBDE. Although pairwise comparisons show no statistical differences between ΣPCB in hatchery and lake rainbow trout, mean ΣPCB in hatchery fish are substantially higher, even when the outlier from Chelan Hatchery (67 ng/g) is removed.

Part of the decrease in ΣPCB may be the significant decrease in lipid content of the planted fish. It is a well-known fact that PCB concentrations are often positively correlated with lipid in tissue. Lipid metabolism, and in particular lipid catabolysis, to meet energy requirements may mobilize lipids from muscle to high lipid organs such as the liver, kidney, and brain, thus decreasing muscle PCB concentrations (Jørgensen et al., 2002). Gamete production is another mechanism for transfer of PCBs due to loss of muscle lipids, although it is unlikely that the fish examined had reached sexual maturity.

As mentioned previously, the absence of a strong correlation between lipids and ΣPCB suggests PCB concentrations are controlled by factors other than the percentage of lipid. One possible explanation for altered PCB concentrations is that some lakes allow PCBs to be shed from muscle tissue while others increase the PCB accumulated by fish. Molson, Warden, South Lewis County Park, and Lone lakes received fish with the highest ΣPCB, and all four lakes had the greatest depuration. Increases in ΣPCB only occurred where concentrations were low-to-moderate in hatchery fish (with the exception of the very small increase in Spokane Hatchery-Chapman Lake fish), suggesting net accumulation only occurs when PCB concentrations in tissue are initially low.

ΣDDT concentrations were low in muscle tissue of hatchery rainbow trout precluding an opportunity to observe substantial depuration. As many lakes had increased levels of ΣDDT as had decreases, all small changes with the exception of Fan Lake.

Fan Lake is a medium-sized (32 hectare) lake approximately 20 miles north of Spokane, situated in a small drainage basin (1,600 hectares). It is one of the lowermost in a chain of lakes along the West Branch of the Little Spokane River. Since the Fan Lake basin is relatively undeveloped and the lake is connected to other lakes only through its outlet, it appears unlikely that high ΣDDT accumulating in Fan Lake rainbow trout is a result of basin-wide or area-wide contamination.

Comparison of Tissue Concentrations to Applicable Criteria

Criteria to protect human health from harmful pollutants in ingested water and fish were issued to Washington State in EPA's 1992 National Toxics Rule (NTR, 40 CFR 131.36). The human health-based criteria, if met, will generally ensure that public health concerns do not arise, and that fish advisories are not needed. Sampling of either water or edible fish tissue may be conducted to assess compliance with the NTR criteria (Ecology, 1992), but tissue is generally preferred because POPs are often found at concentrations in water below reasonably available laboratory detection limits.

It should be recognized that POPs exceeding the NTR criteria in fish tissue do not necessarily signal the need for a fish consumption advisory, nor does it imply the existence of a public health concern. Assessment of risks to the fishing public and consumption advice is carried out by the Washington State Department of Health (DOH), often based on data collected by Ecology and WDFW. While DOH supports Ecology's use of the NTR criteria for identifying potentially contaminated waters and for developing source controls to keep water quality at or below criteria, it does not use the NTR criteria to establish fish advisories. Instead, DOH evaluates contaminants in fish tissue using established risk assessment paradigms. These include tools for:

1. Analysis of risks – calculating allowable meal limits based on known contaminant concentrations, estimates of exposure in specific groups or populations.
2. Risk management – e.g., reduction in contaminants through preparation and cooking techniques, known health benefits from fish consumption, contaminant concentrations or health risks associated with replacement foods, and cultural importance of fish.
3. Risk communication – the outreach component of a fish advisory or a conclusion that an advisory is unnecessary.

Table 8 shows NTR criteria for chemicals analyzed in the present 2005 survey compared to concentrations in rainbow trout. NTR criteria have not been established either for PBDEs or for some of the chlorinated pesticides analyzed here.

There are 15 instances where contaminants in rainbow trout exceed NTR criteria. Most of the exceedances are for ΣPCB (three lakes and six hatcheries), followed by dieldrin (one lake and four hatcheries) and 4,4'-DDE (one lake). In all, seven of the eleven hatchery samples (including Troutlodge) exceeded NTR criteria for at least one chemical, and five of the ten planted fish samples exceeded the criteria.

When criteria are not met, the waterbody is considered impaired and placed on the federal Clean Water Act section 303(d) list and may require a Total Maximum Daily Load (TMDL) study to address the impairment. TMDLs identify the sources of a pollutant and allocate pollutant loads among sources in order to bring the waterbody in compliance with standards.

One of the questions this study sought to answer is whether contaminants accumulated by fish in hatcheries could contribute, in whole or in part, to the water quality impairment of a waterbody and its consequent addition to the 303(d) list. This question was not intended to be directed at the lakes analyzed in the present survey. Instead, at issue is whether hatchery-derived contamination is worthy of inquiry by investigators who are conducting surveys on individual lakes and streams where the source of contamination is uncertain and where waterbodies may be considered for 303(d) listing.

Table 8. National Toxics Rule Criteria Compared to Contaminant Residues in Hatchery and Planted Rainbow Trout Fillet (ng/g ww except pg/g ww for 2,3,7,8-TCDD).

Contaminant	Criterion	Concentrations in present study	No. of Criterion Exceedances	Location(s) of Criterion Exceedance
ΣPCB	5.3	4.85 - 67	9	Chapman Lake Molson Lake South Lewis Co. Park Pond Chelan Hatchery Columbia Basin Hatchery Mossyrock Hatchery Troutlodge Arlington Hatchery Spokane Hatchery
4,4'-DDT	32	0.14 - 1.9		
4,4'-DDE	32	1.9 - 45	1	Fan Lake
4,4'-DDD	45	0.29 - 9.6		
2,3,7,8-TCDD	0.07	0.011 - 0.053		
Aldrin	0.65	ND		
Dieldrin	0.65	0.32 - 0.88	5	Warden Lake Mossyrock Hatchery Spokane Hatchery Arlington Hatchery Eells Springs Hatchery
Endrin	3,216	ND		
Endrin Aldehyde	3,216	ND		
alpha-BHC	1.7	ND		
beta-BHC	1.6	ND		
gamma-BHC (Lindane)	8.2	ND		
Chlordane (total)	8.3	ND		
Endosulfan I	540	ND		
Endosulfan II	540	ND		
Endosulfan Sulfate	540	ND		
Heptachlor	2.4	ND		
Heptachlor Epoxide	1.2	ND		
Hexachlorobenzene	6.7	0.10 - 0.73		
Toxaphene	9.8	ND		

ND - not detected

To examine this question on a statewide basis, results of the present survey were compared to all of the data on contaminants in tissue in Washington. In order to provide a suitably comparable data set, data that met the following conditions were extracted from Ecology's Environmental Information Management (EIM) database; 1) samples analyzed since 1998, 2) results only for rainbow trout, brown trout, and cutthroat trout since these are the primary resident species raised to catchable size at WDFW hatcheries, and 3) fillet data only. Only results for ΣPCB, 4,4'-DDE, and dieldrin were selected since these were the contaminants found here that exceeded NTR criteria. Waterbodies known to have large sources of these chemicals (e.g., Spokane River for PCBs, Yakima River for 4,4'-DDE and dieldrin) were removed.

Figure 4 shows the cumulative distribution of all ΣPCB data for fish in Washington using the selection process previously described. Sixty percent of the 46 samples exceed the NTR criterion, and approximately 50% of samples statewide had concentrations that fall into the range of detectable ΣPCB concentrations in hatchery rainbow trout, excluding the Chelan Hatchery sample. One hundred percent of samples fall into the hatchery ΣPCB range when all of the hatchery rainbows are considered.

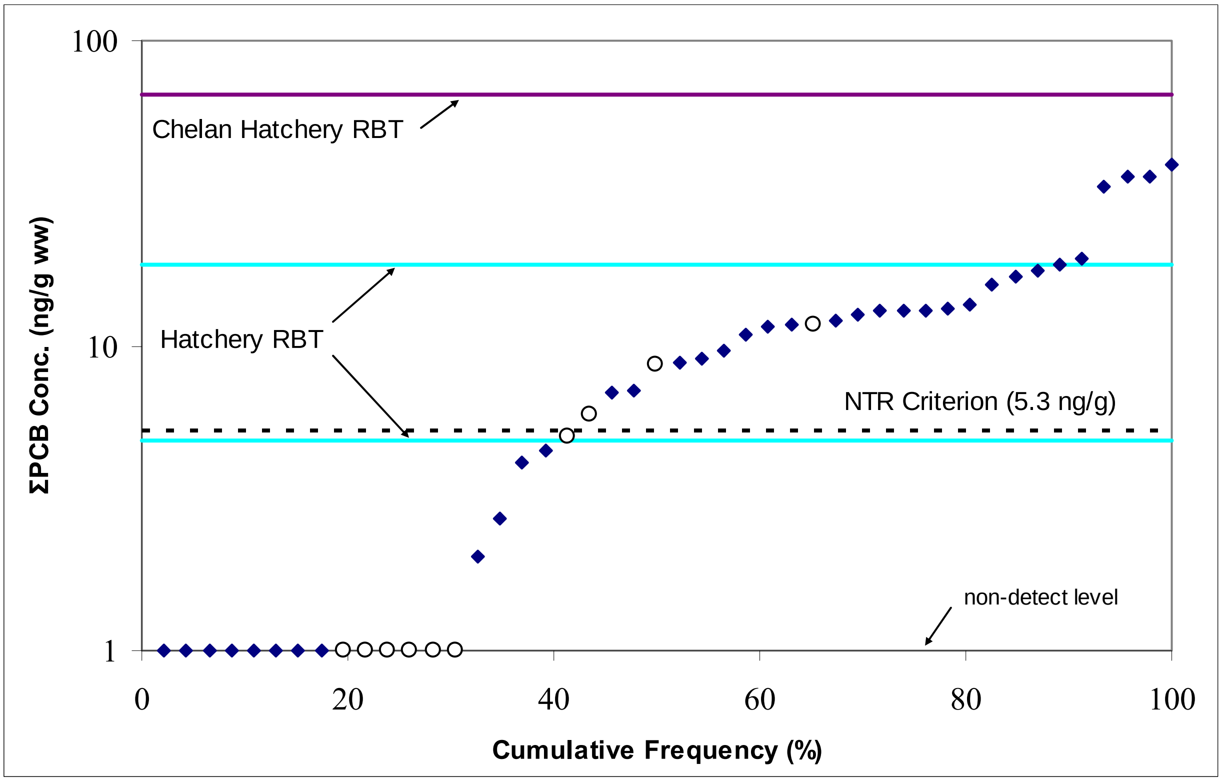

Figure 4. Cumulative Frequency Distribution of ΣPCB Concentrations in Fillet Tissue of Rainbow Trout (RBT), Cutthroat Trout, and Brown Trout from Washington Lakes and Streams. (Open circles represent data from lakes sampled in the present survey. Solid gray lines bound the range of detected ΣPCB concentrations in hatchery fish. Dashed line is the NTR criterion for ΣPCBs.)

Only two of the 38 trout samples (5%) exceed the NTR criterion for 4,4'-DDE, including the Fan Lake result found in the present survey (Figure 5). Approximately 40% of the samples are within the hatchery fish range, with more than 70% falling below the maximum 4,4'-DDE level in hatchery rainbows.

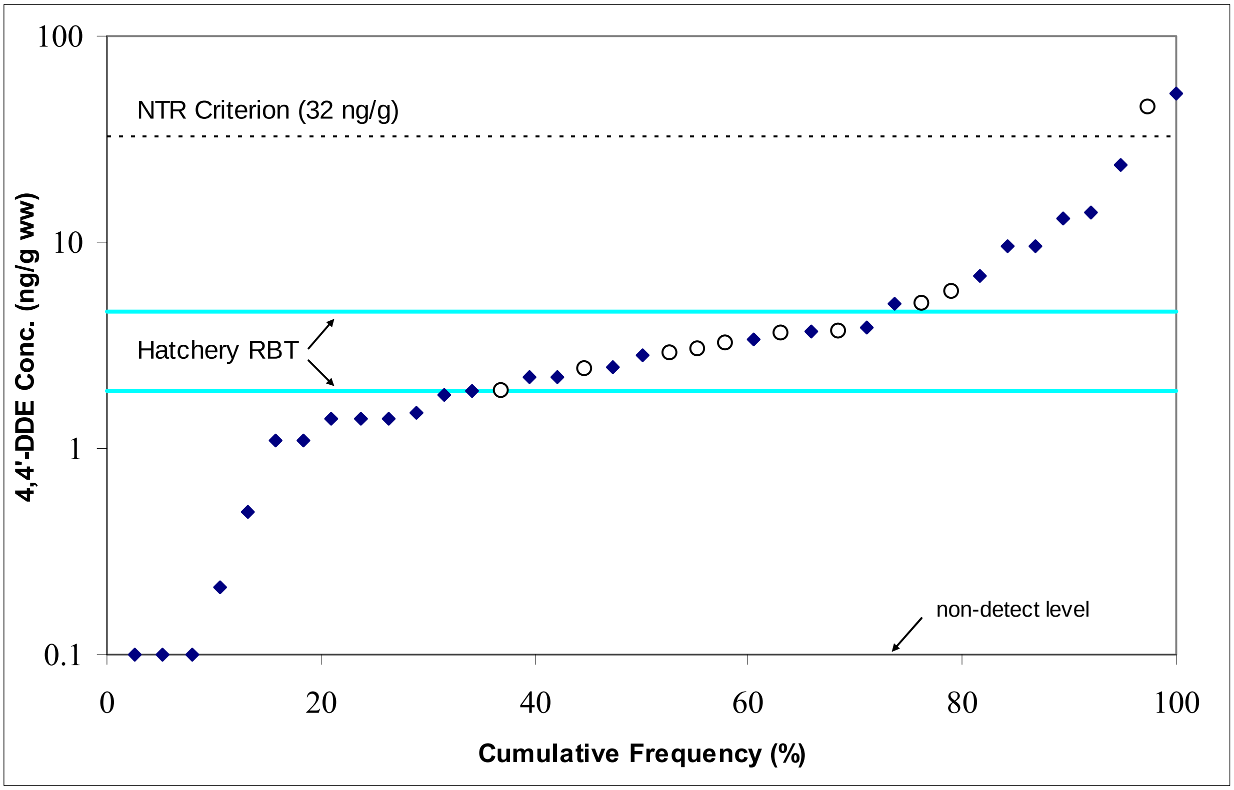

Figure 5. Cumulative Frequency Distribution of 4,4'-DDE Concentrations in Fillet Tissue of Rainbow Trout (RBT), Cutthroat Trout, and Brown Trout from Washington Lakes and Streams. (Open circles represent data from lakes sampled in the present survey. Solid gray lines bound the range of detected 4,4'-DDE concentrations in hatchery fish. Dashed line is the NTR criterion for 4,4'-DDE.)

None of the 38 samples screened from the EIM database had detectable levels of dieldrin; North Lake and Warden Lake are the only "unpolluted" sites where dieldrin has been detected in common trout species (Figure 6). Dieldrin in Warden Lake rainbow trout (0.76 ng/g) exceeds the NTR criterion (0.65 ng/g).

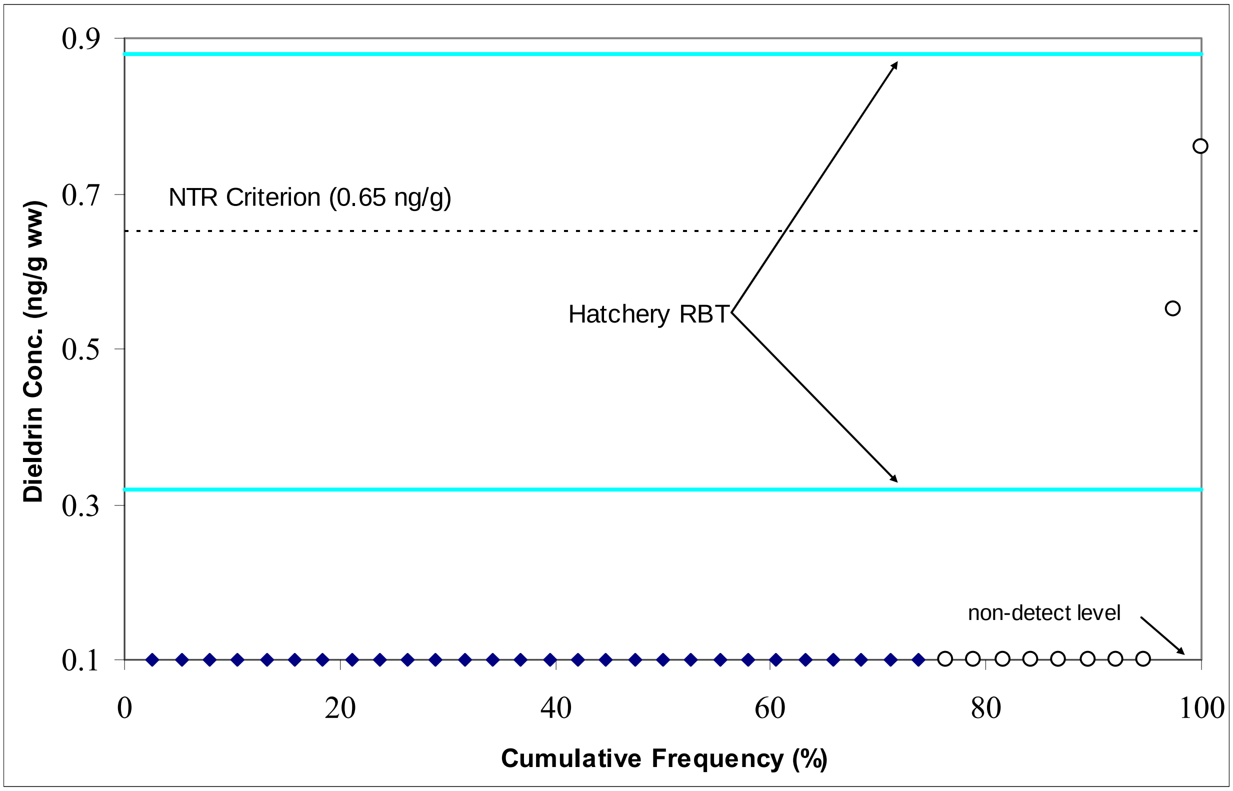

Figure 6. Cumulative Frequency Distribution of Dieldrin Concentrations in Fillet Tissue of Rainbow Trout (RBT), Cutthroat Trout, and Brown Trout from Washington Lakes and Streams. (Open circles represent data from lakes sampled in the present survey. Solid gray lines bound the range of detected dieldrin concentrations in hatchery fish. Dashed line is the NTR criterion for dieldrin.)

There are several inferences that may be drawn from these comparisons to screened data. One supposition is that some portion of POPs found in trout is derived from burdens obtained at a hatchery, although this presumes that the fish were planted. However, there is no concomitant information on the origin of the fish used for these comparisons.

The extent of hatchery-derived POPs remaining in planted fish is variable and appears to depend largely on the amount of time lapsed since stocking. Trout caught around the time of opening day – typically mid-to-late April – will have contaminant concentrations nearly identical to concentrations found in fish just prior to their removal from hatcheries. It appears that as the fishing season progresses, the concentrations in fillet tissue generally decrease, particularly for PCBs and some chlorinated pesticides, although this is a pattern which is less consistent for DDT compounds and PBDEs. Unfortunately, the planted cohorts that were sampled for each hatchery-planted pair could not be sampled further to track fillet concentrations during subsequent periods.

One of the implications of these results, particularly from the practical standpoint of a regulatory agency, is that waterbodies may be included on the 303(d) list due to contamination stemming from hatcheries. Taken further, 303(d) listed waters often require a TMDL to assess contaminant sources. Sources considered for TMDLs are typically point sources (e.g., piped effluent) and nonpoint sources (e.g., agricultural and urban runoff, atmospheric deposition) which normally occur in the vicinity of the impaired waterbody. However, no known TMDLs in Washington have included hatchery fish as a contaminant source. For PCBs, and to a lesser extent dieldrin, hatchery fish may contribute to impairment and, in some cases, may cause the bulk of impairment. Therefore, TMDL investigators may want to consider including hatchery fish as contaminant sources among other sources.

Conclusions

Rainbow trout acquire low-to moderate concentrations of persistent organic pollutants (POPs) while residing at Washington Department of Fish and Wildlife (WDFW) hatcheries. Feed used to raise rainbow trout to catchable size (≥6") contains concentrations of PCBs, DDT compounds, PCDD/Fs, and several additional chlorinated pesticides at higher wet-weight concentrations than in fillet tissue of the fish specimens analyzed, suggesting that the POP accumulation pathway is primarily through the feed. This is consistent with findings of other aquacultural studies, although other possible pathways of contaminant accumulation were not examined for this study. Low levels of PBDEs were also present in rainbow trout tissue, but were not detected in trout feed.

Fish feed is high in lipids and shows variable amounts of contaminants, but POP concentrations were not correlated with the percent lipid in feed samples. This suggests the source of lipids, largely derived from marine oil, is an important determinant in POP concentrations. The positive correlation between feed and fish ΣPCB and between feed and fish ΣDDT supports the conclusion that feed is the primary contaminant source to hatchery fish. WDFW trout hatchery feed has POP concentrations similar or lower than feeds analyzed in other studies, and appears to have much lower PCB concentrations than feeds used in commercial salmon aquaculture.

It appears that fillet tissue concentrations of some POPs, particularly PCBs, decrease following stocking in lakes, although this finding is inconclusive. ΣDDT concentrations may increase in the lake environment even as fillet lipid concentrations decrease significantly. Fish from only one location – Fan Lake in Pend Oreille County – showed a substantial increase in contaminants (DDT compounds) following residence in the wild.

In the 21 rainbow trout fillet samples analyzed (11 from hatcheries including Troutlodge and 10 from lakes), there are 15 instances where contaminants exceed (do not meet) regulatory criteria. Most of the exceedances are for ΣPCB (three lakes and six hatcheries), followed by dieldrin (one lake and four hatcheries) and 4,4'-DDE (one lake). Considering the POP levels in catchable rainbow trout just prior to planting, it appears likely that at least part of the contaminant burden is hatchery-derived, with the notable exception of DDT compounds in Fan Lake as described previously.

Based on comparisons between waterbodies in Washington State and POP data reported here, it is possible that trout caught in "unpolluted" lakes and streams contain contaminants originating from WDFW hatcheries. It is also possible that some listings for impaired waters, particularly listings for PCBs, may be due to hatchery-contaminated fish. Therefore, Total Maximum Daily Load (TMDL) project managers may want to consider hatchery fish as a source of contaminant loads.

Recommendations

Based on results of this 2005 study, it is recommended that fish feed and trout fillet tissue sampling be expanded to include all 26 WDFW hatcheries raising catchable trout. Samples should be analyzed for the persistent organic pollutants (POPs) in the present study, with PCDD/F analysis included for all samples. Water in hatcheries should also be sampled where contaminant levels in fish are exceptionally high. Any water sampling should be performed using semi-permeable membrane devices or other methods to achieve low detection limits for POPs.

More data are needed to assess depuration or accumulation of contaminants in catchable trout following planting in lakes. Ideally, fish could be sampled during several periods to better track trends in contaminant levels over time. Whole fish analysis should also be considered along with fillet sampling, to determine if contaminant burdens are conserved in fish following mobilization of lipids in muscle tissue.

A review of the current 303(d) list should be conducted to identify cases where tissue data used to assess impairment may have come from WDFW catchable trout plants. TMDL project managers should consider the implications of hatchery fish as a possible source of contaminants to waterbodies being assessed.

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Appendices

Appendix A – Glossary of Acronyms and Units

303(d) – Section 303(d) of the federal Clean Water Act
CFIA – Canadian Food Inspection Agency
DDD – 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane
DDE – 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene
DDT – 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane
DOH – Washington State Department of Health
ECD – electron capture detector
Ecology – Washington State Department of Ecology
EIM – Environmental Information Management
EPA – U.S. Environmental Protection Agency
EU – European Union
GC – gas chromatography
MEL – Manchester Environmental Laboratory
MS – mass spectrometry
NIST – National Institute of Standards and Technology
NTR – National Toxics Rule
PBDE – polybrominated diphenyl ether
PCB – polychlorinated biphenyl
PCDD – polychlorinated dibenzo-*p*-dioxin
PCDF – polychlorinated dibenzofuran
POP – persistent organic pollutant
SRM – standard reference material
TEF – toxic equivalency factor
TEQ – toxic equivalent
TMDL – total maximum daily load (water cleanup plan)
USF&WS – U.S. Fish and Wildlife Service
WDFW – Washington Department of Fish and Wildlife
ww – wet weight
Σ – sum of

Units of measurement

ng/g – nanograms per gram (parts per billion)
pg/g – picograms per gram (parts per trillion)

Appendix B – Target Analytes and Reporting Limits

Table B. Target Analytes and Reporting Limits

Analyte	Reporting Limit (ng/g ww)	Analyte	Reporting Limit (ng/g ww)	Analyte	Reporting Limit (pg/g ww)
PCBs		**Chlorinated Pesticides**		**PCDDs/PCDFs**	
Aroclor-1016	2.3 – 5.0	2,4'-DDE	0.47 – 1.0	2,3,7,8-TCDD	0.03 – 0.05
Aroclor-1221	2.3 – 5.0	2,4'-DDD	0.47 – 1.0	1,2,3,7,8-PeCDD	0.07 – 0.11
Aroclor-1232	2.3 – 5.0	2,4'-DDT	0.47 – 1.0	1,2,3,4,7,8-HxCDD	0.05 – 0.2
Aroclor-1242	2.3 – 5.0	4,4'-DDT	0.47 – 1.0	1,2,3,6,7,8-HxCDD	0.05 – 0.2
Aroclor-1248	2.3 – 5.0	4,4'-DDE	0.47 – 1.0	1,2,3,7,8,9-HxCDD	0.05 – 0.2
Aroclor-1254	2.3 – 5.0	4,4'-DDD	0.47 – 1.0	1,2,3,4,6,7,8-HpCDD	0.05 – 0.2
Aroclor-1260	2.3 – 5.0	DDMU	0.47 – 1.0	OCDD	0.36
PBDEs		Aldrin	0.47 – 1.0	2,3,7,8-TCDF	0.03 – 0.05
		Dieldrin	0.47 – 10	1,2,3,7,8-PeCDF	0.06 – 0.1
PBDE-47	0.23 – 0.65	Endrin	0.96 – 10	2,3,4,7,8-PeCDF	0.04 – 0.12
PBDE-66	0.25 – 0.50	Endrin Aldehyde	0.96 – 10	1,2,3,4,7,8-HxCDF	0.2
PBDE-71	0.25 – 0.50	Endrin Ketone	0.96 – 10	1,2,3,6,7,8-HxCDF	0.05 – 0.1
PBDE-99	0.25 – 0.50	alpha-BHC	0.47 – 1.0	2,3,4,6,7,8-HxCDF	0.05 – 0.2
PBDE-100	0.25 – 0.50	beta-BHC	0.47 – 1.0	1,2,3,7,8,9-HxCDF	0.05 – 0.2
PBDE-138	0.25 – 0.50	gamma-BHC (Lindane)	0.47 – 1.0	1,2,3,4,6,7,8-HpCDF	0.05 – 0.2
PBDE-153	0.25 – 0.50	delta-BHC	0.47 – 1.0	1,2,3,4,7,8,9-HpCDF	0.05 – 0.2
PBDE-154	0.25 – 0.50	cis-Chlordane (alpha)	0.47 – 1.0	OCDF	0.21 – 0.23
PBDE-183	0.25 – 0.50	trans-Chlordane (gamma)	0.47 – 1.0		
PBDE-190	0.25 – 0.50	Oxychlordane	0.47 – 1.0		
PBDE-209	1.2 – 6.2	Chlordane (technical)	0.98 – 5.0		
		Chlorpyriphos	0.96 – 10		
		Dacthal (DCPA)	0.96 – 10		
		Endosulfan I	0.96 – 10		
		Endosulfan II	0.96 – 10		
		Endosulfan Sulfate	0.96 – 10		
		Heptachlor	0.47 – 1.0		
		Heptachlor Epoxide	0.96 – 10		
		Hexachlorobenzene	0.47 – 1.0		
		Methoxychlor	0.47 – 1.0		
		Mirex	0.47 – 1.0		
		cis-Nonachlor	0.47 – 1.0		
		trans-Nonachlor	0.47 – 1.0		
		Pentachloroanisole	0.47 – 1.0		
		Toxaphene	0.98 – 10		

Appendix C – Complete Results of Lipid and Contaminant Analysis

Table C-1. Complete Results of Percent Lipids and PCB Aroclor Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Lipids (%)	PCB-aroclor 1016		PCB-aroclor 1221		PCB-aroclor 1232		PCB-aroclor 1242		PCB-aroclor 1248		PCB-aroclor 1254		PCB-aroclor 1260		PCB-aroclor 1262		PCB-aroclor 1268	
Hatchery Feed																				
Arlington	5144102	18.19	2.5	UJ	2.5	UJ	2.5	UJ	2.7	J	5.5	UJ	8.1	J	3	J	2.5	UJ	2.5	UJ
Chelan	5144096	13.75	2.5	U	2.5	U	2.5	U	5	UJ	8	NJ	18		8.8		2.5	U	2.5	U
Columbia Basin	5144098	14.47	2.4	UJ	2.4	UJ	2.4	UJ	2.4	UJ	4.7	UJ	7.6	J	4	J	2.4	UJ	2.4	UJ
Eells Spring	5144103	12.7	2.4	UJ	2.4	UJ	2.4	UJ	2.6	J	4.6	UJ	6.9	J	3	J	2.4	UJ	2.4	UJ
Ford	5144099	25.75	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ
Ford-Dup	5144099-Dup	25.95	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Mossyrock	5144097	19.64	2.5	UJ	2.5	UJ	2.5	UJ	3.8	J	10	UJ	16	J	7.8	J	2.5	UJ	2.5	UJ
Puyallup	5144104	15.75	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ
Puyallup-Dup	5144104-Dup	16.52	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Spokane	5144100	15.79	2.5	UJ	2.5	UJ	2.5	UJ	2.8	J	6.1	UJ	9.3	J	4.3	J	2.5	UJ	2.5	UJ
Tucannon	5144101	15.01	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.8	J	5.4	NJ	2.5	UJ	2.5	UJ	2.5	UJ
Vancouver	5144095	16.08	2.5	UJ	2.5	UJ	2.5	UJ	2.6	J	5.5	UJ	7.7	NJ	3	J	2.5	UJ	2.5	UJ
Hatchery Rainbows																				
Arlington	5144087	3.97	2.5	U	2.5	U	2.5	U	2.1	J	3.5	UJ	6.5	NJ	3.5	J	2.5	U	2.5	U
Chelan	5144081	3.05	2.4	U	2.4	U	2.4	U	8.5	UJ	20	NJ	47		3.4	UJ	2.4	U	2.4	U
Columbia Basin	5144083	4.1	2.5	U	2.5	U	2.5	U	2.5	U	3.5	J	9		6		3.6	UJ	2.5	U
Eells Spring	5144088	2.7	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Eells Spring-Dup	5144088-Dup	2.13	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U
Ford	5144084	2.35	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Mossyrock	5144082	2.69	2.4	U	2.4	U	2.4	U	2.4	U	4.8	UJ	9	J	6.8	J	2.4	U	2.4	U
Puyallup	5144089	3.07	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U
Spokane	5144085	2.48	2.5	U	2.5	U	2.5	U	2.5	U	2.6	J	5.2	NJ	3.9	J	2.5	U	2.5	U
Troutlodge	5144090	5.39	2.4	U	2.4	U	2.4	U	2.6	J	5.6	UJ	7.9		3.9	J	2.4	U	2.4	U
Tucannon	5144086	3.69	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U
Vancouver	5144080	4.86	2.5	U	2.5	U	2.5	U	2.5	U	3.2	NJ	3.6	NJ	2.9	NJ	2.5	U	2.5	U
Vancouver-Dup	5144080-Dup	3.14	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U

Table C-1 (cont'd). Complete Results of Percent Lipids and PCB Aroclor Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Lipids (%)	PCB-aroclor 1016		PCB-aroclor 1221		PCB-aroclor 1232		PCB-aroclor 1242		PCB-aroclor 1248		PCB-aroclor 1254		PCB-aroclor 1260		PCB-aroclor 1262		PCB-aroclor 1268	
Planted Rainbows																				
Chapman Lake	5248102	0.44	5	U	5	U	5	U	5	U	5	U	6.7	J	5.1	J	5	U	5	U
Donnie Lake	5248103	1.29	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Fan Lake	5248104	2.66	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Lacamas Lake	5248100	1.5	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Lone Lake	5248108	1.63	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U
Lone Lake-Dup	5248108-Dup	1.71	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U
Molson Lake	5248101	2.05	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	8.6	J	4.9	U	4.9	U	4.9	U
North Lake	5248106	0.65	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U
South Lewis Co. Park Pond	5248105	0.77	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	5.9	J	4.9	U	4.9	U	4.9	U
Summit Lake	5248109	0.35	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.7	J	4.8	U	4.8	U	4.8	U
Summit Lake-Dup	5248109-Dup	0.45	5.0	U	5.0	U	5.0	U	5.0	U	5.0	U	**5.2**	J	5.0	U	5.0	U	5.0	U
Warden Lake	5248107	0.61	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U

U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate
Dup - Duplicate

Table C-2. Complete Results of DDT Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	2,4'-DDD		2,4'-DDE		2,4'-DDT		4,4'-DDD		4,4'-DDE		4,4'-DDT	
Hatchery Feed													
Arlington	5144102	0.37	J	0.49	U	0.49	U	2.3		2.8		0.78	NJ
Chelan	5144096	0.57	UJ	0.5	U	0.5	U	3.1		4.8		1.5	
Columbia Basin	5144098	0.28	J	0.49	U	0.49	U	1.4		4.4		0.21	J
Eells Spring	5144103	0.38	J	0.48	U	0.48	U	2		2.8		0.72	J
Ford	5144099	0.12	J	0.5	U	0.12	J	0.61		2.3		0.31	J
Ford- Dup	5144099-Dup	0.17	J	0.5	U	0.13	J	0.86		2.4		0.38	J
Mossyrock	5144097	0.43	J	0.5	U	0.5	U	3.4		6		1.2	NJ
Puyallup	5144104	0.32	J	0.5	U	0.15	J	1.2		4.3		0.49	J
Puyallup-Dup	5144104-Dup	0.3	J	0.49	U	0.15	J	1.4		4.3	NJ	0.55	
Spokane	5144100	0.2	J	0.5	U	0.5	U	0.77		4.2		0.7	NJ
Tucannon	5144101	0.85		0.5	U	0.16	J	4.4		15		0.7	J
Vancouver	5144095	0.43	J	0.5	U	0.5	U	2.1		2.6		0.69	J
Hatchery Rainbows													
Arlington	5144087	0.12	J	0.49	U	0.49	U	0.84		3.8		0.49	U
Chelan	5144081	0.49	U	0.49	U	0.49	U	0.7		2.8		0.6	NJ
Columbia Basin	5144083	0.5	U	0.61	UJ	0.5	U	1.8		3.9		0.77	NJ
Eells Spring	5144088	0.1	J	0.5	U	0.5	U	0.55		1.8		0.25	J
Eells Spring-Dup	5144088-Dup	0.49	U	0.49	U	0.49	U	0.5		1.9		0.24	J
Ford	5144084	0.49	U	0.49	U	0.49	U	0.33	J	2.2		0.49	U
Mossyrock	5144082	0.48	U	0.48	U	0.48	U	0.91		2.7		0.24	NJ
Puyallup	5144089	0.47	U	0.47	U	0.47	U	0.29	J	2		0.14	J
Spokane	5144085	0.49	U	0.49	U	0.49	U	0.52		2.2		0.2	J
Troutlodge	5144090	0.15	J	0.49	U	0.49	U	1.5		3.4		0.65	J
Tucannon	5144086	0.49	U	0.49	U	0.49	U	0.52		4.6		0.18	J
Vancouver	5144080	0.5	U	0.5	U	0.5	U	0.7		4		0.26	J
Vancouver-Dup	5144080-Dup	0.12	J	0.5	U	0.5	U	0.59		2.1		0.27	J
Planted Rainbows													
Chapman Lake	5248102	1	U	1	U	1	U	1	U	5.1		1	U
Donnie Lake	5248103	1	U	1	U	1	U	1	U	3.6		1	U
Fan Lake	5248104	1	U	1	U	1	U	9.6	J	45		1.9	J
Lacamas Lake	5248100	1	U	1	U	1	U	1	U	3.0		1	U
Lone Lake	5248108	0.98	U	0.98	U	0.98	U	0.98	U	1.9	J	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	U	0.97	U	0.97	U	0.97	U	1.9	J	0.97	U
Molson Lake	5248101	0.98	U	0.98	U	0.98	U	0.98	U	5.8		0.98	U
North Lake	5248106	0.97	U	0.97	U	0.97	U	0.97	U	2.9		0.97	U
South Lewis Co. Park Pond	5248105	0.96	U	0.98	U	0.98	U	0.96	U	2.4		0.96	UJ
Summit Lake	5248109	0.96	U	0.96	U	0.96	U	0.96	U	3.0		0.96	U
Summit Lake-Dup	5248109-Dup	1.0	U	1.0	U	1.0	U	1.0	U	3.3		1.0	U
Warden Lake	5248107	0.97	U	0.97	U	0.97	U	0.97	U	3.7		0.97	U

U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate

Table C-3. Complete Results of PBDE Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	PBDE-047		PBDE-066		PBDE-071		PBDE-099		PBDE-100		PBDE-138	
Hatchery Feed													
Arlington	5144102	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Chelan	5144096	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Columbia Basin	5144098	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ
Eells Spring	5144103	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ
Ford	5144099	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Ford-Dup	5144099-Dup	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Mossyrock	5144097	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Puyallup	5144104	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Puyallup-Dup	5144104-Dup	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Spokane	5144100	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Tucannon	5144101	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Vancouver	5144095	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Hatchery Rainbows													
Arlington	5144087	0.64		0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Chelan	5144081	0.95		0.24	U	0.14	J	0.24	U	0.24	U	0.24	U
Columbia Basin	5144083	0.65	J	0.25	U	0.16	J	0.089	NJ	0.25	U	0.25	U
Eells Spring	5144088	0.55		0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Eells Spring-Dup	5144088-Dup	0.49		0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Ford	5144084	0.24	J	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Mossyrock	5144082	0.73		0.24	U	0.16	J	0.24	U	0.24	U	0.24	U
Puyallup	5144089	0.24		0.23	U	0.23	U	0.23	U	0.23	U	0.23	U
Spokane	5144085	0.55		0.25	U	0.25	U	0.25	U	0.11	J	0.1	J
Troutlodge	5144090	0.62		0.24	U	0.15	J	0.07	J	0.24	U	0.24	U
Tucannon	5144086	0.27		0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Vancouver	5144080	0.72		0.25	U	0.13	J	0.25	U	0.25	U	0.25	U
Vancouver-Dup	5144080-Dup	0.56		0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Planted Rainbows													
Chapman Lake	5248102	0.91		0.5	U	0.5	U	0.1	NJ	0.5	U	0.5	U
Donnie Lake	5248103	0.25	J	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Fan Lake	5248104	0.4	J	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Lacamas Lake	5248100	0.29	J	0.5	U	0.5	U	0.5	U	0.13	J	0.5	U
Lone Lake	5248108	0.65		0.49	U	0.49	U	0.24	J	0.15	J	0.49	U
Lone Lake-Dup	5248108-Dup	0.54		0.48	U	0.48	U	0.13	J	0.20	J	0.48	U
Molson Lake	5248101	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ
North Lake	5248106	0.78		0.48	U	0.48	U	0.29	J	0.16	J	0.48	U
South Lewis Co. Park Pond	5248105	1		0.49	U	0.49	U	0.33	J	0.49	U	0.49	U
Summit Lake	5248109	0.87		0.48	U	0.48	U	0.12	J	0.14	J	0.48	U
Summit Lake-Dup	5248109-Dup	0.65	U	0.50	U	0.50	U	0.50	U	0.50	U	0.50	U
Warden Lake	5248107	0.46	J	0.48	U	0.48	U	0.48	U	0.48	U	0.48	U

Table C-3 (cont'd). Complete Results of PBDE Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	PBDE-153		PBDE-154		PBDE-183		PBDE-190		PBDE-209	
Hatchery Feed											
Arlington	5144102	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Chelan	5144096	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Columbia Basin	5144098	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	1.2	UJ
Eells Spring	5144103	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	1.2	UJ
Ford	5144099	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Ford-Dup	5144099-Dup	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Mossyrock	5144097	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Puyallup	5144104	0.25	U	0.25	U	0.25	U	0.25	U	1.2	U
Puyallup-Dup	5144104-Dup	0.25	U	0.25	U	0.25	U	0.25	U	1.2	U
Spokane	5144100	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Tucannon	5144101	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Vancouver	5144095	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Hatchery Rainbows											
Arlington	5144087	0.24	U	0.24	U	0.24	U	0.24	U	3.1	U
Chelan	5144081	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Columbia Basin	5144083	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Eells Spring	5144088	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Eells Spring-Dup	5144088-Dup	0.24	U	0.24	U	0.24	U	0.24	U	3.0	U
Ford	5144084	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Mossyrock	5144082	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Puyallup	5144089	0.23	U	0.23	U	0.23	U	0.23	U	2.9	U
Spokane	5144085	0.25	U	0.25	U	0.25	U	0.25	U	0.34	J
Troutlodge	5144090	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Tucannon	5144086	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Vancouver	5144080	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Vancouver-Dup	5144080-Dup	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Planted Rainbows											
Chapman Lake	5248102	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Donnie Lake	5248103	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Fan Lake	5248104	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Lacamas Lake	5248100	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Lone Lake	5248108	0.49	U	0.49	U	0.49	U	0.49	U	6.1	U
Lone Lake-Dup	5248108-Dup	0.48	U	0.48	U	0.48	U	0.48	U	6.0	U
Molson Lake	5248101	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ	2.4	UJ
North Lake	5248106	0.48	U	0.48	U	0.48	U	0.48	U	6.1	U
South Lewis Co. Park Pond	5248105	0.49	U	0.49	U	0.49	U	0.49	U	6.1	U
Summit Lake	5248109	0.48	U	0.48	U	0.48	U	0.48	U	6	U
Summit Lake-Dup	5248109-Dup	0.50	U	0.50	U	0.50	U	0.50	U	6.2	U
Warden Lake	5248107	0.48	U	0.48	U	0.48	U	0.48	U	6.1	U

U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate

Table C-4. Complete Results of PCDD/F Analysis of Feed Samples (pg/g ww)

Sample Number	TEF	Vancouver Hatchery			Mossyrock Hatchery			Ford Hatchery			Ford Hatchery			Spokane Hatchery		
		Sample 05144105		TEQ	Sample 05144106		TEQ	Sample 05144107		TEQ	Sample 05144107-Dup		TEQ	Sample 05144108		TEQ
2,3,7,8-TCDF	0.1	0.525		0.0525	0.798		0.0798	0.182		0.0182	0.222		0.0222	1.4		0.14
1,2,3,7,8-PeCDF	0.05	0.251	J	0.01255	0.591		0.02955	0.1	UJ	0	0.115	J	0.00575	0.218	J	0.0109
2,3,4,7,8-PeCDF	0.5	0.126	J	0.063	0.226	J	0.113	0.12	UJ	0	0.12	UJ	0	0.246	J	0.123
1,2,3,4,7,8-HxCDF	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,6,7,8-HxCDF	0.1	0.1	UJ	0	0.1	UJ	0	0.1	UJ	0	0.1	UJ	0	0.1	UJ	0
2,3,4,6,7,8-HxCDF	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,7,8,9-HxCDF	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,4,6,7,8-HpCDF	0.01	0.2	UJ	0	0.207	J	0.00207	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,4,7,8,9-HpCDF	0.01	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
OCDF	0.0001	0.404	J	0.00004	0.403	J	0.00004	0.32	J	0.00003	0.344	J	0.00003	0.377	J	0.00004
2,3,7,8-TCDD	1	0.186		0.186	0.367		0.367	0.05	UJ	0	0.05	UJ	0	0.192		0.192
1,2,3,7,8-PeCDD	1	0.215	J	0.215	0.534		0.534	0.11	UJ	0	0.11	UJ	0	0.637		0.637
1,2,3,4,7,8-HxCDD	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,6,7,8-HxCDD	0.1	0.235	J	0.0235	0.494		0.0494	0.2	UJ	0	0.2	UJ	0	0.437		0.0437
1,2,3,7,8,9-HxCDD	0.1	0.2	UJ	0	0.333		0.0333	0.2	UJ	0	0.2	UJ	0	0.339		0.0339
1,2,3,4,6,7,8-HpCDD	0.01	0.857		0.00857	1.6		0.016	0.524		0.00524	0.474		0.00474	1.25		0.0125
OCDD	0.0001	8.14		0.00081	16.5		0.00165	3.38		0.00034	3.3		0.00033	11.5		0.00115
TEQ total				0.56197			1.22581			0.02381			0.03305			1.19419

TEF - Toxicity Equivalence Factor from Van den Berg et al., 1998
TEQ - Toxic Equivalent
UJ - The analyte was not detected at or above the reported estimated result
J - The analyte was positively identified. The associated numerical value is an estimate

Table C-5. Complete Results of PCDD/F Analysis of Rainbow Trout Tissue Samples (pg/g ww)

Sample Number	TEF	Vancouver Hatchery			Mossyrock Hatchery			Ford Hatchery			Ford Hatchery			Spokane Hatchery		
		Sample 05144092		TEQ	Sample 05144093		TEQ	Sample 05144091		TEQ	Sample 05144091-Dup		TEQ	Sample 05144094		TEQ
2,3,7,8-TCDF	0.1	0.187		0.0187	0.282		0.0282	0.037	J	0.0037	0.042	J	0.0042	0.163		0.0163
1,2,3,7,8-PeCDF	0.05	0.111	J	0.00555	0.143	J	0.00715	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0
2,3,4,7,8-PeCDF	0.5	0.041	J	0.0205	0.04	UJ	0	0.04	UJ	0	0.04	UJ	0	0.04	UJ	0
1,2,3,4,7,8-HxCDF	0.1	0.07	J	0.007	0.051	J	0.0051	0.075	J	0.0075	0.053	J	0.0053	0.067	J	0.0067
1,2,3,6,7,8-HxCDF	0.1	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0
2,3,4,6,7,8-HxCDF	0.1	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0
1,2,3,7,8,9-HxCDF	0.1	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0
1,2,3,4,6,7,8-HpCDF	0.01	0.095	J	0.00095	0.078	J	0.00078	0.094	J	0.00094	0.105	J	0.00105	0.082	J	0.00082
1,2,3,4,7,8,9-HpCDF	0.01	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0
OCDF	0.0001	0.31	J	0.00003	0.225	J	0.00002	0.313	J	0.00003	0.289	J	0.00003	0.336	J	0.00003
2,3,7,8-TCDD	1	0.03	UJ	0	0.03	UJ	0	0.03	UJ	0	0.03	UJ	0	0.03	UJ	0
1,2,3,7,8-PeCDD	1	0.07	UJ	0	0.07	UJ	0	0.07	UJ	0	0.07	UJ	0	0.07	UJ	0
1,2,3,4,7,8-HxCDD	0.1	0.10000	UJ	0	0.10000	UJ	0	0.10000	UJ	0	0.10000	UJ	0	0.10000	UJ	0
1,2,3,6,7,8-HxCDD	0.1	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0
1,2,3,7,8,9-HxCDD	0.1	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0
1,2,3,4,6,7,8-HpCDD	0.01	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0
OCDD	0.0001	0.36	UJ	0	0.36	UJ	0	0.36	UJ	0	0.36	UJ	0	0.36	UJ	0
TEQ total				0.05273			0.04125			0.01217			0.01058			0.02385

TEF - Toxicity Equivalence Factor from Van den Berg et al., 1998
TEQ - Toxic Equivalent
UJ - The analyte was not detected at or above the reported estimated result
J - The analyte was positively identified. The associated numerical value is an estimate

Table C-5. Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Aldrin		Alpha-BHC		Beta-BHC		Chlordane		Chlor-pyriphos		cis-Chlordane	
Hatchery Feed													
Arlington	5144102	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	UJ	0.52	
Chelan	5144096	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.5	U
Columbia Basin	5144098	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.68	NJ
Eells Spring	5144103	0.48	UJ	0.48	U	0.48	U	2.4	U	2.4	UJ	0.47	NJ
Ford	5144099	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.19	J
Ford-Dup	5144099-Dup	0.50	UJ	0.50	U	0.50	U	2.5	U	2.5	UJ	0.25	J
Mossyrock	5144097	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	1.2	NJ
Puyallup	5144104	0.5	UJ	0.5	U	0.5	U	2.5	U	10	UJ	0.5	U
Puyallup-Dup	5144104-Dup	0.49	UJ	0.49	U	0.49	U	2.5	U	9.9	UJ	0.49	U
Spokane	5144100	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	UJ	0.39	NJ
Tucannon	5144101	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	UJ	0.5	U
Vancouver	5144095	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.52	
Hatchery Rainbows													
Arlington	5144087	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	U	0.24	NJ
Chelan	5144081	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.49	U
Columbia Basin	5144083	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.25	NJ
Eells Spring	5144088	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.5	U
Eells Spring-Dup	5144088-Dup	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.49	U
Ford	5144084	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	U	0.49	U
Mossyrock	5144082	0.48	UJ	0.48	U	0.48	U	2.4	U	2.4	U	0.31	NJ
Puyallup	5144089	0.47	UJ	0.47	U	0.47	U	2.3	U	2.3	U	0.47	U
Spokane	5144085	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	U	0.49	U
Troutlodge	5144090	0.49	UJ	0.49	U	0.49	U	2.4	U	1.2	J	0.44	NJ
Tucannon	5144086	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.17	J
Vancouver	5144080	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.2	NJ
Vancouver-Dup	5144080-Dup	0.50	UJ	0.50	U	0.50	U	2.5	U	2.5	U	0.17	NJ
Planted Rainbows													
Chapman Lake	5248102	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Donnie Lake	5248103	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Fan Lake	5248104	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Lacamas Lake	5248100	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Lone Lake	5248108	0.98	UJ	0.98	UJ	0.98	U	0.98	U	3.9	U	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	UJ	0.97	UJ	0.97	U	4.8	U	3.9	U	0.97	U
Molson Lake	5248101	0.98	UJ	0.98	UJ	0.98	U	4.9	U	3.9	U	0.98	U
North Lake	5248106	0.97	UJ	0.97	UJ	0.97	U	4.9	U	3.9	U	0.97	U
South Lewis Co. Park Pond	5248105	0.98	UJ	0.96	UJ	0.96	U	2.4	U	0.96	U	0.96	UJ
Summit Lake	5248109	0.96	UJ	0.96	UJ	0.96	U	4.8	U	3.8	U	0.96	U
Summit Lake-Dup	5248109-Dup	1.0	UJ	1.0	UJ	1.0	U	5.0	U	4.0	U	1.0	U
Warden Lake	5248107	0.97	UJ	0.97	UJ	0.97	U	4.9	U	3.9	U	0.97	U

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	cis-Nonachlor		Dacthal (DCPA)		DDMU		Delta-BHC		Dieldrin	
Hatchery Feed											
Arlington	5144102	0.49	U	2.5	UJ	0.69	NJ	0.49	UJ	2.5	UJ
Chelan	5144096	0.5	U	2.5	U	1.5	NJ	0.5	UJ	2.5	U
Columbia Basin	5144098	0.49	U	2.4	UJ	0.73	NJ	0.49	UJ	2.4	UJ
Eells Spring	5144103	0.48	U	2.4	UJ	0.58	NJ	0.48	UJ	2.4	UJ
Ford	5144099	0.5	U	2.5	UJ	0.4	NJ	0.5	UJ	2.5	UJ
Ford-Dup	5144099-Dup	0.50	U	2.5	UJ	0.50	U	0.50	UJ	2.5	UJ
Mossyrock	5144097	0.5	U	2.5	U	1.2	NJ	0.5	UJ	3.8	NJ
Puyallup	5144104	0.5	U	10	UJ	1.1	NJ	0.5	UJ	10	UJ
Puyallup-Dup	5144104-Dup	0.49	U	0.49	UJ	1.0	NJ	0.49	UJ	9.9	UJ
Spokane	5144100	0.5	U	2.5	UJ	0.85	NJ	0.5	UJ	2.5	UJ
Tucannon	5144101	0.5	U	2.5	UJ	3.9	NJ	0.5	UJ	2.5	UJ
Vancouver	5144095	0.5	U	2.5	U	0.6	NJ	0.5	UJ	2.5	U
Hatchery Rainbows											
Arlington	5144087	0.49	U	2.5	U	0.9	NJ	0.49	UJ	0.77	J
Chelan	5144081	0.49	U	2.4	U	0.52	NJ	0.49	UJ	0.58	NJ
Columbia Basin	5144083	0.5	U	2.5	U	0.63	NJ	0.5	UJ	0.5	J
Eells Spring	5144088	0.5	U	2.5	U	0.5	U	0.5	UJ	0.75	J
Eells Spring-Dup	5144088-Dup	0.49	U	2.4	U	0.49	U	0.49	UJ	0.63	NJ
Ford	5144084	0.49	U	2.5	U	0.49	U	0.49	UJ	0.49	UJ
Mossyrock	5144082	0.48	U	2.4	U	0.48	U	0.48	UJ	0.88	NJ
Puyallup	5144089	0.47	U	2.3	U	0.47	U	0.47	UJ	0.47	UJ
Spokane	5144085	0.49	U	2.5	U	0.49	U	0.49	UJ	0.78	J
Troutlodge	5144090	0.49	U	2.4	U	0.49	NJ	0.49	UJ	0.75	J
Tucannon	5144086	0.49	U	2.4	U	0.62		0.49	UJ	0.49	UJ
Vancouver	5144080	0.5	U	2.5	U	0.5	U	0.5	UJ	0.33	NJ
Vancouver-Dup	5144080-Dup	0.50	U	2.5	U	0.50	U	0.50	UJ	0.30	J
Planted Rainbows											
Chapman Lake	5248102	1.0	U	4.0	U	1.0	U	1.0	UJ	0.79	UJ
Donnie Lake	5248103	1.0	U	4.0	U	1.0	U	1.0	UJ	0.79	UJ
Fan Lake	5248104	1.0	U	4.0	U	4.4		1.0	UJ	0.80	UJ
Lacamas Lake	5248100	1.0	U	4.0	U	1.0	U	1.0	UJ	0.80	UJ
Lone Lake	5248108	0.98	U	3.9	U	0.98	U	0.98	UJ	0.78	UJ
Lone Lake-Dup	5248108-Dup	0.97	U	3.9	U	0.97	U	0.97	UJ	0.78	UJ
Molson Lake	5248101	0.98	U	3.9	U	0.98	U	0.98	UJ	0.78	UJ
North Lake	5248106	0.97	U	3.9	U	0.97	U	0.97	UJ	0.55	NJ
South Lewis Co. Park Pond	5248105	0.96	U	0.96	U	0.98	U	0.96	U	0.96	U
Summit Lake	5248109	0.96	U	3.8	U	0.96	U	0.96	UJ	0.77	UJ
Summit Lake-Dup	5248109-Dup	1.0	U	4.0	U	1.0	U	1.0	UJ	0.80	UJ
Warden Lake	5248107	0.97	U	3.9	U	0.97	U	0.97	UJ	0.76	NJ

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Endo-sulfan I		Endo-sulfan II		Endo-sulfan Sulfate		Endrin		Endrin Aldehyde		Endrin Ketone	
Hatchery Feed													
Arlington	5144102	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Chelan	5144096	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Columbia Basin	5144098	2.4	UJ	2.4	UJ	REJ		2.4	UJ	REJ		REJ	
Eells Spring	5144103	2.4	UJ	2.4	UJ	REJ		2.4	UJ	REJ		REJ	
Ford	5144099	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Ford-Dup	5144099-Dup	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Mossyrock	5144097	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Puyallup	5144104	10	UJ	10	UJ	10	UJ	10	UJ	10	UJ	10	UJ
Puyallup-Dup	5144104-Dup	9.9	UJ	9.9	UJ	9.9	UJ	9.9	UJ	9.9	UJ	9.9	UJ
Spokane	5144100	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Tucannon	5144101	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Vancouver	5144095	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Hatchery Rainbows													
Arlington	5144087	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Chelan	5144081	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Columbia Basin	5144083	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Eells Spring	5144088	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Eells Spring-Dup	5144088-Dup	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Ford	5144084	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Mossyrock	5144082	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Puyallup	5144089	2.3	U	2.3	UJ	REJ		2.3	U	REJ		REJ	
Spokane	5144085	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Troutlodge	5144090	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Tucannon	5144086	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Vancouver	5144080	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Vancouver-Dup	5144080-Dup	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Planted Rainbows													
Chapman Lake	5248102	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Donnie Lake	5248103	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Fan Lake	5248104	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Lacamas Lake	5248100	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Lone Lake	5248108	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
Lone Lake-Dup	5248108-Dup	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
Molson Lake	5248101	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
North Lake	5248106	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
South Lewis Co. Park Pond	5248105	0.96	U	0.96	U	0.96	UJ	0.96	U	0.96	UJ	0.96	U
Summit Lake	5248109	3.8	U	3.8	U	3.8	UJ	3.8	U	3.8	UJ	3.8	U
Summit Lake-Dup	5248109-Dup	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Warden Lake	5248107	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Heptachlor		Heptachlor Epoxide		Hexachloro -benzene		Lindane		Methoxy-chlor		Mirex	
Hatchery Feed													
Arlington	5144102	0.49	U	2.5	UJ	0.16	J	0.49	U	2.5	UJ	0.49	UJ
Chelan	5144096	0.5	U	2.5	U	0.31	J	0.5	U	2.5	UJ	0.5	UJ
Columbia Basin	5144098	0.49	U	2.4	UJ	0.49	UJ	0.49	U	2.4	UJ	0.49	UJ
Eells Spring	5144103	0.48	U	2.4	UJ	0.15	J	0.48	U	2.4	UJ	0.48	UJ
Ford	5144099	0.5	U	2.5	UJ	0.16	J	0.5	U	2.5	UJ	0.5	UJ
Ford-Dup	5144099-Dup	0.50	U	2.5	UJ	0.19	J	0.50	U	2.5	UJ	0.50	UJ
Mossyrock	5144097	0.5	U	2.5	U	0.3	J	0.5	U	2.2	J	0.5	UJ
Puyallup	5144104	0.5	U	10	UJ	0.5	UJ	0.5	U	4.9	J	0.5	UJ
Puyallup-Dup	5144104-Dup	0.49	U	9.9	UJ	0.10	J	0.49	U	4.0	J	0.49	UJ
Spokane	5144100	0.5	U	2.5	UJ	0.12	J	0.5	U	2.5	UJ	0.5	UJ
Tucannon	5144101	0.5	U	2.5	UJ	0.16	J	0.5	U	2.5	UJ	0.5	UJ
Vancouver	5144095	0.5	U	2.5	U	0.17	J	0.5	U	2.5	UJ	0.5	UJ
Hatchery Rainbows													
Arlington	5144087	0.49	U	0.49	U	0.23	J	0.49	U	2.5	U	0.49	U
Chelan	5144081	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Columbia Basin	5144083	0.5	U	0.5	U	0.5	U	0.5	U	2.5	U	0.5	U
Eells Spring	5144088	0.5	U	0.5	U	0.5	U	0.5	U	2.5	U	0.5	U
Eells Spring-Dup	5144088-Dup	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Ford	5144084	0.49	U	0.49	U	0.49	U	0.49	U	2.5	U	0.49	U
Mossyrock	5144082	0.48	U	0.48	U	0.48	U	0.48	U	2.4	U	0.48	U
Puyallup	5144089	0.47	U	0.47	U	0.47	U	0.47	U	2.3	U	0.47	U
Spokane	5144085	0.49	U	0.49	U	0.1	J	0.49	U	2.5	U	0.49	U
Troutlodge	5144090	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Tucannon	5144086	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Vancouver	5144080	0.5	U	0.5	U	0.3	NJ	0.5	U	2.5	U	0.5	U
Vancouver-Dup	5144080-Dup	0.50	U	0.50	U	0.50	U	0.50	U	2.5	U	0.50	U
Planted Rainbows													
Chapman Lake	5248102	1	U	0.79	UJ	1	U	1	U	4	U	1	U
Donnie Lake	5248103	1	U	0.79	UJ	1	U	1	U	4	U	1	U
Fan Lake	5248104	1	U	0.8	UJ	1	U	1	U	4	U	1	U
Lacamas Lake	5248100	1	U	0.8	UJ	1	U	1	U	4	U	1	U
Lone Lake	5248108	0.98	U	0.78	UJ	0.98	U	0.98	U	3.9	U	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	U	0.78	UJ	0.97	U	0.97	U	3.9	U	0.97	U
Molson Lake	5248101	0.98	U	0.78	UJ	0.98	U	0.98	U	3.9	U	0.98	U
North Lake	5248106	0.97	U	0.78	UJ	0.97	U	0.97	U	3.9	U	0.97	U
South Lewis Co. Park Pond	5248105	0.98	U	0.96	U	0.98	U	0.96	U	0.96	U	0.98	U
Summit Lake	5248109	0.96	U	0.77	UJ	0.69	J	0.96	U	3.8	U	0.96	U
Summit Lake-Dup	5248109-Dup	1.0	U	0.80	UJ	0.76	J	1.0	U	4.0	U	1.0	U
Warden Lake	5248107	0.97	U	0.78	UJ	0.97	U	0.97	U	3.9	U	0.97	U

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Oxychlordane		Pentachloro-anisole		Toxaphene		trans-Chlordane		trans-Nonachlor	
Hatchery Feed											
Arlington	5144102	0.49	U	0.49	UJ	4.9	U	0.49	U	0.68	
Chelan	5144096	0.5	U	0.5	UJ	5	U	1.1	NJ	1.1	NJ
Columbia Basin	5144098	0.49	U	0.49	UJ	3.9	NJ	0.2	J	0.7	
Eells Spring	5144103	0.48	U	0.48	UJ	4.8	U	0.19	J	0.44	J
Ford	5144099	0.5	U	0.5	UJ	5	U	0.5	U	0.15	J
Ford-Dup	5144099-Dup	0.50	U	0.50	UJ	5.0	U	0.50	U	0.16	J
Mossyrock	5144097	0.5	U	0.15	J	5	U	0.2	NJ	1.2	
Puyallup	5144104	0.5	U	0.5	UJ	3.6	J	0.5	U	0.5	U
Puyallup-Dup	5144104-Dup	0.49	U	0.49	UJ	4.9	U	0.49	U	0.49	U
Spokane	5144100	0.5	U	0.5	UJ	2.6	J	0.5	U	0.8	
Tucannon	5144101	0.5	U	0.11	J	5	U	0.5	U	0.3	J
Vancouver	5144095	0.5	U	0.5	UJ	5	U	0.5	U	0.77	J
Hatchery Rainbows											
Arlington	5144087	0.49	U	0.49	U	4.9	U	0.49	U	0.27	J
Chelan	5144081	0.49	U	0.49	U	4.9	U	0.49	U	0.42	J
Columbia Basin	5144083	0.5	U	0.5	U	5	U	0.5	U	0.45	J
Eells Spring	5144088	0.5	U	0.5	U	5	U	0.5	U	0.2	J
Eells Spring-Dup	5144088-Dup	0.49	U	0.49	U	4.9	U	0.49	U	0.17	J
Ford	5144084	0.49	U	0.49	U	4.9	U	0.49	U	0.49	U
Mossyrock	5144082	0.48	U	0.48	U	4.8	U	0.48	U	0.3	NJ
Puyallup	5144089	0.47	U	0.47	U	4.7	U	0.47	U	0.094	J
Spokane	5144085	0.49	U	0.49	U	4.9	U	0.49	U	0.49	U
Troutlodge	5144090	0.49	U	0.49	U	4.9	U	0.49	U	0.57	J
Tucannon	5144086	0.49	U	0.18	J	4.9	U	0.49	U	0.12	NJ
Vancouver	5144080	0.5	U	0.21	J	5	U	0.5	U	0.3	J
Vancouver-Dup	5144080-Dup	0.50	U	0.50	U	5.0	U	0.50	U	0.20	J
Planted Rainbows											
Chapman Lake	5248102	1	U	1	U	9.9	U	1	U	1	U
Donnie Lake	5248103	1	U	1	U	9.9	U	1	U	1	U
Fan Lake	5248104	1	U	1	U	10	U	1	U	1	U
Lacamas Lake	5248100	1	U	0.47	J	10	U	1	U	1	U
Lone Lake	5248108	0.98	U	0.98	U	0.98	U	0.98	U	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	U	0.97	U	9.7	U	0.97	U	0.97	U
Molson Lake	5248101	0.98	U	0.98	U	9.8	U	0.98	U	0.98	U
North Lake	5248106	0.97	U	0.97	U	9.7	U	0.97	U	0.97	U
South Lewis Co. Park Pond	5248105	0.96	U	0.96	U	9.6	U	0.96	U	0.98	U
Summit Lake	5248109	0.96	U	0.96	U	9.6	U	0.96	U	0.96	U
Summit Lake-Dup	5248109-Dup	1.0	U	1.0	U	10	U	1.0	U	1.0	U
Warden Lake	5248107	0.97	U	0.97	U	9.7	U	0.97	U	0.97	U

Dup – Duplicate
U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate
REJ - Data are unusable for all purposes