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Evaluation of Fish Hatcheries as Sources of PCBs to the Spokane River

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Cover photo: Spokane River
Photo taken by Siana Wong

Evaluation of Fish Hatcheries as Sources of PCBs to the Spokane River

by

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Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

WRIA

- WRIA-55-Little Spokane
- HUC- 17010308

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Abstract

Sections of the Spokane River, Little Spokane River, and Lake Spokane are currently listed as impaired for polychlorinated biphenyls (PCBs) on Section 303(d) of the Clean Water Act. To address the problem, the Spokane River Regional Toxics Task Force has been working with local entities to determine PCB sources, and to implement strategies to reduce PCBs in the system. One of the unknowns identified was the contribution of fish hatcheries to PCBs in the Spokane River via wastewater effluent discharges and fish stocking. Previous studies have shown that hatchery fish can contain PCBs.

The Washington State Department of Ecology undertook a screening level study to address this unknown. Main study objectives were to characterize PCBs in hatchery effluent and hatchery-raised rainbow trout, and to estimate instantaneous PCB loads from hatchery operations to the Spokane River. In 2016, we sampled effluent from the Spokane Hatchery (the only permitted hatchery discharging to the Spokane River above Long Lake Dam) and collected fish from the two hatcheries (Spokane Hatchery, Troutlodge Hatchery) that stock trout to the river. Water, whole fish tissue, fish feed, and receiving water sediment samples were analyzed for the 209 PCB congeners.

PCBs were detected in all samples. PCB concentrations in hatchery effluent ranged 147–219 pg/L. In feed samples, PCB concentrations were variable, ranging from 3.9–31.5 ug/kg. PCB concentrations in fish caught from Lake Spokane four months after their release were considerably higher (20.5–28.7 ug/kg) than in pre-released fish (4.0–11.3 ug/kg), indicating that most of the PCB body burden in hatchery fish was accumulated after being released into the environment. The PCB load from hatchery operations was estimated to be 7.8 mg/day, representing <1% of the total PCB loads previously estimated in the Spokane River.

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Introduction

Background

Sections of the Spokane River, Little Spokane River, and Lake Spokane are presently listed as impaired for polychlorinated biphenyls (PCBs) under Section 303(d) of the Clean Water Act. The listings are based on exceedances of Washington's prior freshwater human health criterion for PCBs (FR V.64 No.216, pp. 61182, 1999), expressed as a Fish Tissue Equivalent Concentration (FTEC)[1]. The first reports of elevated PCB concentrations in Spokane River fish occurred in the 1980s (Hopkins et al., 1985). Since then mutliple studies have documented PCB concentrations in fish from the Spokane River (e.g., Hopkins et al., 1985; Johnson, 1994; Serdar et al., 1994; Davis et al., 1995; EILS, 1995; Johnson, 1997; Johnson, 2000; Jack and Roose, 2002; Serdar and Johnson, 2006; Seiders et al., 2007; Serdar et al., 2011).

The Spokane River Regional Toxics Task Force (SRRTTF) was formed in 2012 to develop a comprehensive plan for identifying, characterizing, and quantifying sources of PCBs to the Spokane River, and for implementing strategies to reduce PCBs to levels that are in compliance with water quality standards. External source mechanisms of PCBs to the Spokane River include groundwater, stormwater, combined sewer overflows, tributaries, municipal and industrial wastewater facilities, upstream sources, and atmospheric deposition (Figure 1; Limnotech, 2016). One unknown identified in the comprehensive plan is the load contributions of fish stocking and wastewater effluent from fish hatcheries.

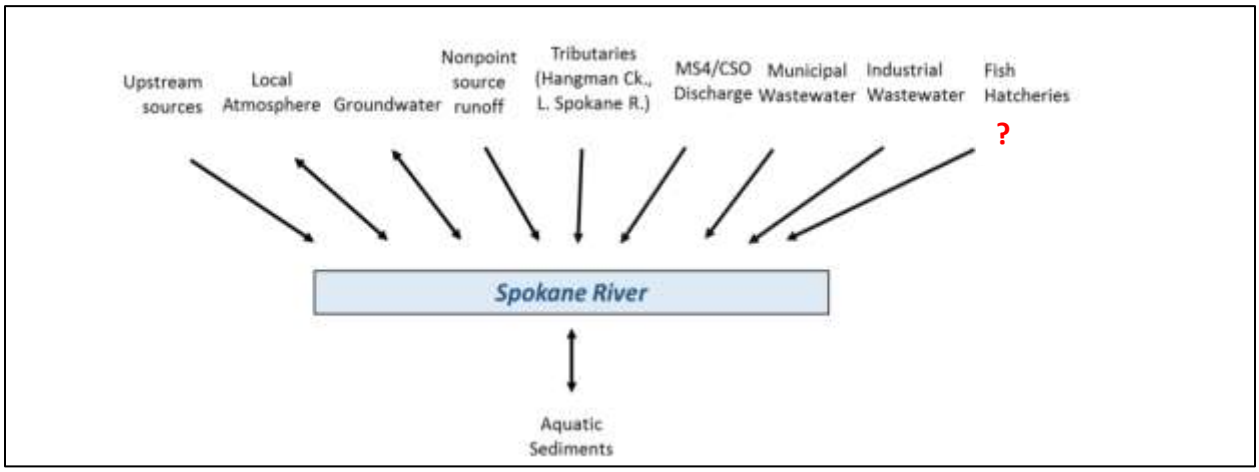

Figure 1. Example sources of PCBs to the Spokane River (figure adapted from Limnotech, 2016).

Hatchery fish can contain PCBs before being planted in the natural aquatic environment. One of the primary ways in which fish raised at hatcheries can accumulate PCBs is by the food they

[1] Ecology previously used FTECs for 303(d) listings of water bodies. It is calculated as: FTEC = Bioconcentration Factor x Human Health Criterion. Ecology is currently updating its listing policy for PCBs.

consume. Commercial fish feeds often contain a mixture of fish oils and fish meal in their manufacture. Because PCBs are lipophilic (fat-loving), commercial fish feeds with high fish oil and lipid content tend to contain measurable amounts of PCBs, which can bioaccumulate in the tissues of fish that consume the feed. In previous studies, PCB concentrations in fish tissue were found to be positively correlated with PCB concentrations in commercial fish feed (Carline et al., 2004; Serdar et al., 2006). Serdar et al. (2006) found that PCB concentrations in fish fillets collected from Washington State hatcheries often exceeded the FTEC of 5.3 micrograms per kilogram (ug/kg). The study concluded that consideration should be given to hatcheries as a potential source of PCBs to 303(d) listed waters or waters under consideration for listing.

PCBs in hatchery effluent come from at least two sources: waste products from fish that are fed PCB-containing feed (a primary source); and leaching from PCB-containing paints that are used to coat the surfaces of the fish tanks (Wilkinson, 2015). These sources of PCBs to the Spokane River system are not currently quantified.

Goal & Objectives

The goals of this project were to determine PCB concentration ranges in hatchery effluent and hatchery trout, and estimate instantaneous PCB loads contributed to the Spokane River system by hatchery operations. In this report, the term "Spokane River system" is used to refer collectively to the mainstem Spokane River and Lake Spokane. Hatchery operations in the Spokane River system include stocking of fish raised at the Spokane Hatchery in Spokane and Troutlodge Hatchery in Soap Lake, as well as effluent discharges from the Spokane Hatchery.

The main study objectives were to:

1. Characterize PCBs in Spokane Hatchery effluent
2. Characterize PCBs in hatchery rainbow trout (*Oncorhynchus mykiss*) planted to the Spokane River system before and after release
3. Estimate the PCB load to the Spokane River system contributed by hatchery operations

Study Area

The Spokane River watershed encompasses an area of over 6,000 square miles. From its source at Lake Coeur d'Alene in Idaho, the Spokane River flows west for about 112 miles, eventually emptying into the Columbia River (Figure 2). There are seven dams along the river that generate hydroelectricity. Upper Falls Dam (RM 74.3) creates the Upper Falls Reservoir, and is located in the central business district of Spokane. Nine Mile Dam (RM 58.1) creates the Nine Mile Reservoir, and is situated downstream of the City of Spokane. Long Lake Dam (RM 33.9) creates the 24-mile long reservoir, Lake Spokane (formerly named Long Lake). The Spokane River is fed by two major tributaries, the Little Spokane River and Latah (Hangman) Creek. Surface water/groundwater interactions also play an important role in Spokane River flows, with the river generally losing water to the Spokane Valley-Rathdrum Aquifer nearer the Washington-Idaho stateline, and gaining water in reaches further downstream (Federal Energy Regulatory Commission, 2006).

The Spokane River is currently stocked with fish from two National Pollutant Discharge Elimination System (NPDES) permitted aquacultural facilities—the Spokane Hatchery and the Troutlodge Hatchery in Soap Lake, WA. The Spokane Hatchery discharges to the Little Spokane River. It receives source waters from Griffith Springs. The hatchery was built in 1934 and is owned and operated by the Washington Department of Fish and Wildlife (WDFW). It is one of the major rainbow trout and brood-stock facilities in Washington State. Troutlodge, Inc. operates nine facilities in the Pacific Northwest, including the Troutlodge Hatchery in Soap Lake. In operation since 1945, Troutlodge, Inc. is a major producer of salmonid eggs and supplier of rainbow trout for public and private stocking programs. Although fish from both hatchery facilities are used to stock the Spokane River, the Spokane Hatchery is the only permitted hatchery that discharges wastewater to the Spokane River watershed.

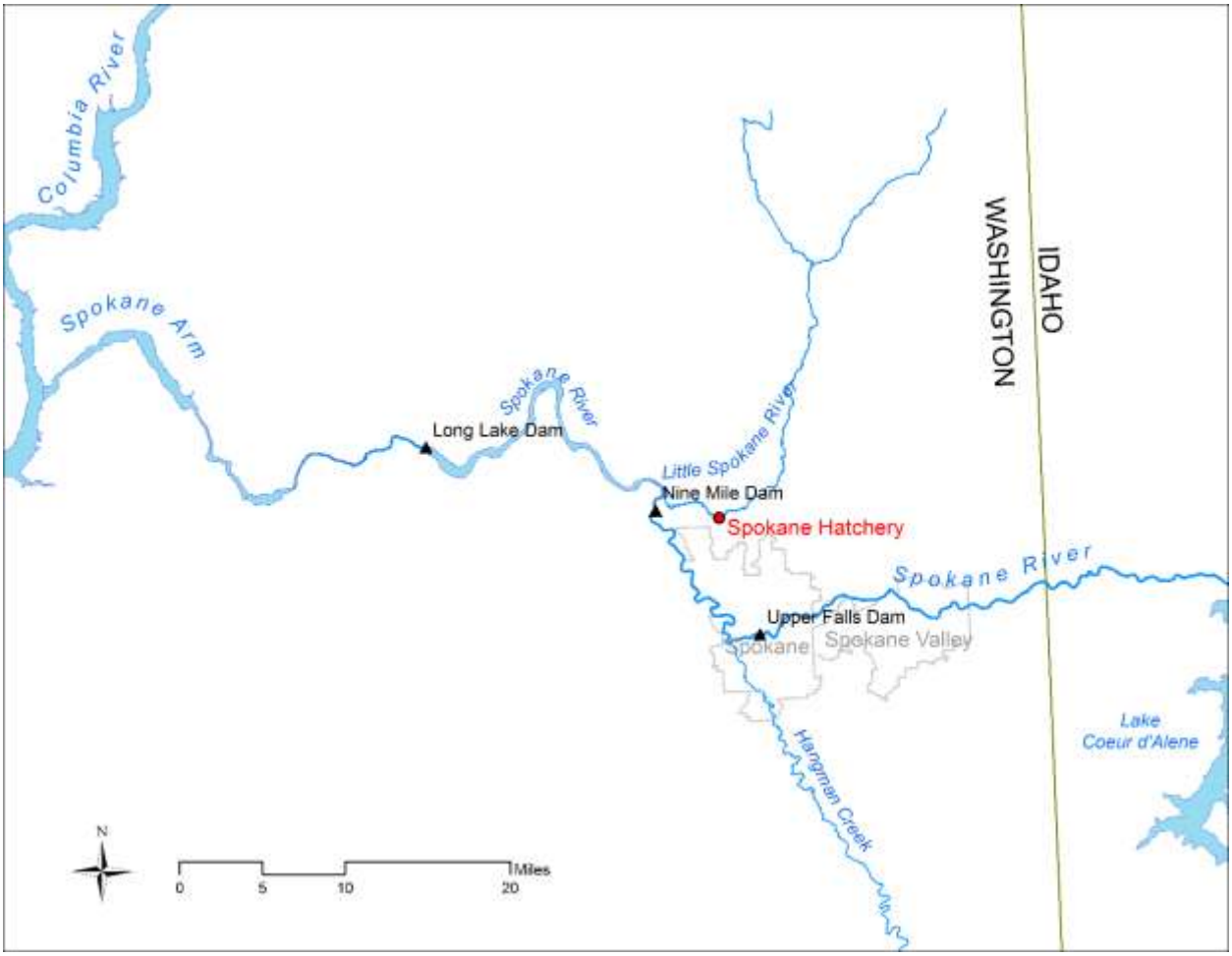

Figure 2. Overview map of the Spokane River and location of the Spokane Hatchery.

Under a 2009 hydroelectric dam relicensing agreement between the Federal Energy Regulatory Commission (FERC) and Avista Corporation, 155,000 catchable-sized sterile rainbow trout are stocked annually to Lake Spokane (FERC Project No. 2545-091). Of these, 105,000 trout are raised at Troutlodge Hatchery, and the remaining 50,000 trout are raised at Spokane Hatchery from fertilized eggs supplied by Troutlodge. Avista's Lake Spokane stocking program began in 2014 and is scheduled through 2023 (Avista Corporation, 2013). Under the same agreement,

15,000 catchable-sized sterile rainbow trout are stocked to the Spokane River: 6,000 trout to Upper Falls reservoir, and 9,000 trout to Nine Mile reservoir. The 15,000 trout are raised at Troutlodge Hatchery.

Methods

Field Sampling and Measurement

Water

Water sampling was conducted at the Spokane Hatchery to determine PCB concentrations in hatchery effluent and estimate the contribution of hatchery operations to PCB loads in the Spokane River system. To account for seasonal variation, sampling occurred during three events in 2016: April 12 (during spring planting of catchable trout); July 10 (during typical hatchery operations); and October 11 (during fall planting of fry).

Water samples were collected at two locations: the main effluent discharge pipe (SH-Pipe), and the drainage slough (SH-Slough) in which hatchery effluent enters before emptying into the Little Spokane River (Figure 3). Water samples were collected for analyses of PCB congeners, total suspended solids (TSS), and total organic carbon (TOC). TSS and TOC samples were collected and analyzed as ancillary parameters to help assess variability in PCB concentrations in the water samples. During the July sampling, an opportunitistic water sample was collected from the main discharge pipe concurrently as wastewater was flushed from one of the fish holding ponds to screen the level of PCBs that occur during flushing. This sample was not included in summary calculations (mean, min, max) for the three sampling events.

Water samples represented a composite of four grab samples collected throughout the day from about 8:00 A.M to 4:00 P.M. The general reason for compositing samples (including water, fish feed, sediment, and fish tissue samples) is to collect an average representation over a given sampling location or time. At each location, water was collected in separate, certified clean 1.5-L glass containers, then transered into each sample jar (approximately one-quarter full per composite).

For the study, two duplicate samples were collected to assess precision of PCB samples during field collection. One field blank was collected to assess equipment contamination during field sampling. One field duplicate and one field blank was collected for both TOC and TSS analyses.

Water samples were stored in a cooler on ice in the field, then transported to the walk-in cooler at Washington State Department of Ecology (Ecology) Headquarters in Lacey, WA until further processing. PCB samples were then shipped under chain of custody to Pacific Rim Laboratory in Surrey, British Columbia, Canada. TSS and TOC samples were delivered to Ecology's Manchester Environmental Laboratory (MEL) in Port Orchard, WA.

During each sampling event, flow was measured at the slough using a Marsh McBirney Flo-Mate flowmeter following Ecology's Standard Operating Procedures (Kardouni, 2012). Total

hatchery discharge data for each sampling event were provided by hatchery staff. Flow and dicharge data were used to calculate estimated PCB loads from the hatchery.

Figure 3. Map of sampling locations at the Spokane Hatchery.

Fish Feed

Fish feed samples (SH-Feed) were collected and analyzed primarily to help assess variability in PCB concentrations in hatchery effluent from the Spokane Hatchery. Samples were collected in separate certified clean glass jars by hatchery staff once per week during the month preceding a water sampling event. The fish feed types used and collected during each sampling event were:

- April 2016
  - EWOS Pacific, 4 mm pellets
- July 2016
  - EWOS Pacific, 2 mm pellets
  - Bio-Oregon Bio-Pro 2, 1.5 mm pellets
- October 2016
  - EWOS Pacific, 3 mm pellets
  - EWOS Pacific, 2 mm pellets

For each of the three sampling events, an aliquot of feed from each weekly jar was composited and ground into powder using a decontaminated (acetone and hexane-rinsed) mortar and pestle. One duplicate composite feed sample was also prepared. Feed samples were stored frozen at Ecology Headquarters until further processing.

Sediment

Two surface (~ top 5 cm) sediment samples (SH-Slough-Sed, SH-Slough-Sed2) were collected from the drainage slough of the Spokane Hatchery during the October sampling event. At each site, sediments were collected using a decontaminated spoon at three sub-locations, composited and mixed in a decontaminated stainless steel bowl, then scooped into certified clean glass sampling jars.

One field duplicate (split) sediment sample was also taken from one of the composited samples. Sediment samples were stored in a cooler on ice in the field until further processing. Back at Ecology Headquarters, sediment samples were settled and decanted before shipping to the laboratories for PCB and TOC analyses.

Fish

Rainbow trout raised at the Spokane Hatchery and Troutlodge Hatchery were provided by hatchery staff prior to their release to the Spokane River system. Rainbow trout were also collected from Lake Spokane about four months after their release. The purpose of collecting post-released fish was to determine if additional PCBs were being accumulated in the fish from outside the hatcheries after having spent several months inhabiting the lake.

All fish collected for this study were catchable (6–8 inch) one-year feminized triploid rainbow trout raised at either Troutlodge Hatchery or Spokane Hatchery, and were hatched from fertilized eggs supplied by Troutlodge. Fish obtained directly from Spokane and Troutlodge Hatcheries

were collected prior to their release to the Spokane River system. The 2016 stocking schedule was as follows:

- May 2016
  - 155,000 rainbow trout released to Lake Spokane
- June 2016
  - 9,000 rainbow trout released above Nine Mile Dam at Plese Flats Boat Launch
  - 3,000 rainbow trout released above Upper Falls Dam
- September 2016
  - 3,000 rainbow trout released above Upper Falls Dam

Immediately after collection, fish were measured for length and weight, wrapped in foil, stored in a cooler on ice during transport back to Ecology Headquarters, and then stored frozen until further processing. Fish processing, preservation, and transport in the field followed Ecology's Standard Operating Procedures (Sandvik, 2014a).

Spokane Hatchery

Fish raised at the Spokane Hatchery were collected from the hatchery on April 12, 2016, prior to being released to Lake Spokane in May 2016. A total of 20 individual fish were collected to comprise 4 composite tissue samples of 5 fish (SH-Fish). Fish from this batch were about 11 months old (Brian Russell, WDFW, personal communication).

Troutlodge Hatchery

Fish raised at Troutlodge Hatchery (TH-Fish) were collected prior to their release to the Spokane River on two separate dates. The purpose of collecting and analyzing fish from Troutlodge Hatchery on the two separate dates was to account for any variability in PCB concentrations that might be associated with different timings of release.

On June 9, 2016, 15 fish (comprising 3 composites of 5 fish) were provided by Troutlodge and Avista staff immediately prior to being released to the Spokane River at Plese Flats Boat Launch. Fish from this batch were hatched in November 2015 (Tim Vore, Avista, personal communication).

On September 21, 2016, 10 fish (2 composites of 5 fish) were provided by Troutlodge and Avista staff immediately prior to being released to the Spokane River above Upper Falls Dam. Fish from this batch were hatched in January/February 2016 (Tim Vore, Avista, personal communication).

Lake Spokane

Fish were collected from Lake Spokane to determine the range in PCB concentrations in the hatchery fish after they had been released and inhabiting Lake Spokane for several months. On September 21, 2016, a total of 30 hatchery rainbow trout were collected via gillnets set overnight by WDFW staff. Hatchery rainbow trout were identified by a clipped adipose fin. To ensure that adipose fin-clipped fish were in the same one-year age class, scale and otolith samples were

collected from each of the 30 fish and analyzed at WDFW's Fish Aging Laboratory prior to fish tissue processing. Of the 30 fish collected, 15 fish (3 composites of 5 fish; LS-Fish) that were determined to be in the one-year age class were processed and analyzed for PCBs.

Fish Tissue Processing

Fish samples were processed at Ecology Headquarters following procedures in Sandvik (2014b). Following procedures in Sandvik (2014b), each composite tissue sample consisted of five fish that were most similar in size. Fish were processed as whole fish in order to reflect overall inputs of PCBs to the Spokane River system. Two duplicate samples were also processed and prepared. Duplicate samples were processed as splits, in which fish tissue composites were split between two jars for PCB analysis.

Laboratory Methods

All water, fish tissue, fish feed, and sediment samples were analyzed for the 209 PCB congeners at Pacific Rim Laboratory using EPA method 1668C on a high resolution gas chromatography/high resolution mass spectrometer.

Water and sediment samples were analyzed for TSS and TOC by Manchester Environmental Laboratory. Standard Methods 2540D and SM5310B were used for TSS and TOC analysis of water samples, respectively. For analysis of TOC in sediments, method PSEP-TOC at 70° was used.

Quality Assurance/Quality Control

PCB congener data were reviewed and validated by a third party validator at MEL. Case narratives for each laboratory work order were provided by MEL and can be made available upon request. Measurement quality objectives (MQOs) were set in the Quality Assurance Project Plan for this project, and included laboratory control standards, laboratory duplicates, and internal standard recoveries (Friese, 2016).

Data quality and background contamination of samples were also assessed through analysis of field duplicates, equipment (field) blanks, and laboratory method blanks. Field duplicates (water, fish tissue, fish feed, and sediment samples) and field equipment blanks (water samples) were collected at 10% of the number of samples analyzed for this project. Method blanks were prepared by the laboratory and analyzed for each batch of samples.

Quality assurance results are shown in Appendix A. Overall, MQOs for laboratory control standards, laboratory duplicates, and internal recovery standards were met and data deemed acceptable. Across all media, about 66% of PCB congener results were qualified as non-detect. For water samples alone, about 78% of PCB congener results were qualified as non-detect. Across all media, about 6% of PCB congener results were qualified as non-detect due to method blank contamination. The most common congener result censored due to method blank contamination was PCB-011, accounting for about 7% of method blank-censored results.

Data Reporting & Analysis

Treatment of Non-Detects

All non-detect PCB congener results (those qualified as U, UJ, or NUJ) were not included in total PCB calculations. All detects, including NJ and J qualified results, were included in total PCB calculations.

PCB congener results that were less than three times the detected method blank result were qualified as non-detect. The "<3xMB" correction used in this study is in accordance with other PCB studies completed under SRRTTF, with the main objective of identifying PCB sources and conducting a semi-quantitative mass balance assessment in the Spokane River (Limnotech, 2016). Under routine monitoring, a "<10xMB" correction is often applied to PCB congener results, which provides the highest level of certainty that the quantified congener is present in the sample. The choice of blank correction method typically depends on the study objective and intent of data use.

PCB Load Calculations

PCB load estimates were calculated as instantaneous loads from water and fish tissue PCB concentrations. Load estimates were calculated to evaluate the relative contribution of hatchery operations to total loads in the Spokane River as part of larger efforts by SRRTTF to identify sources. Load estimates derived from data in this study are not intended to be used for regulatory purposes.

Water

Instantaneous PCB loads from the Spokane Hatchery pipe effluent and drainage slough were estimated using the following equation:

$$Daily\ load\ (mg/day) = Cw \times Q \times 0.00245$$

where:

- Cw = Concentration in water (pg/L);
- Q = Discharge; flow of delivery system (ft^3/sec);
- and 0.00245 = unit conversion factor into mg/day

Separate loads were calculated for the effluent and slough. Separate loads were also calculated for each of the three sampling events at the Spokane Hatchery, as well as the mean of the sampling events.

When calculating the PCB load from Spokane Hatchery effluent, we made the assumption that the PCB concentrations measured in effluent from the main discharge pipe was representative of the average PCB concentrations that would be measured from the Spokane Hatchery's five

discharge pipes. The assumed representative PCB concentration measured from the main pipe was multipled by the *total* hatchery discharge to estimate PCB loads from Spokane Hatchery effluent.

Fish Tissue

PCB loads from hatchery trout were estimated using the following equation:

$$Daily\ load\ (mg/day) = Ct \times W \times N \times (2.74 \times 10^{-6})$$

where:

- Ct = Concentration in fish tissue (ug/kg);
- W = Mean weight of fish collected for this study (kg);
- N = Total number of fish released from hatchery in 2016;
- and 2.74×10^{-6} = unit conversion factor into mg/day

Separate PCB loads were calculated for Spokane Hatchery and Troutlodge Hatchery-raised fish. For Troutlodge Hatchery-raised fish, separate PCB loads for batches of fish released to Lake Spokane, Nine Mile Reservoir, and Upper Falls Reservoir, as well as the cumulative load to the Spokane River system were calculated. The fish released to Nine Mile Reservoir and Upper Falls Reservoir likely do not make it to Lake Spokane (Randall Osborne, WDFW, personal communication).

When estimating PCB loads from fish, we made the assumption that measured fish weights were representative of the population of fish that were released to the Spokane River system in 2016. We also do not account for fish that were caught or harvested, which would represent a PCB loss from the system.

Hatchery Operations

The estimated PCB load from the Spokane Hatchery is represented here as the sum of the hatchery's loads from the drainage slough and hatchery-raised trout:

$$Spokane\ Hatchery\ Load = Slough\ Load + Spokane\ Hatchery\ Fish\ Load$$

The estimated PCB load to the Spokane River contributed by hatchery operations is represented here by the sum of the Spokane Hatchery and Troutlodge Hatchery loads:

$$\boldsymbol{Load\ from\ Hatchery\ Operations = Spokane\ Hatchery\ Load + Troutlodge\ Hatchery\ Fish\ Load}$$

To compare our findings to other studies, PCB loads were expressed as daily loads in units of mg/day using the appropriate unit conversions.

PCB Congener Patterns

Principal Components Analysis (PCA) was used to explore similarities and differences in PCB congeners among water, fish, feed, and sediment samples. The goal of PCA is to identify the most important gradients in large, complex datasets. It is a statistical tool that works by grouping a large number of variables (e.g., individual PCB congeners) into fewer new variables called "principal components" (PCs), which decrease in order of importance. The first two PCs typically explain the most variability in the dataset. Plotting the sample data on a graph of the first two PCs as the X and Y axes (ordination plot) can be useful for interpreting similarities and differences in the dataset. Points on the plot that are more closely clustered together are more similar to each other than points that are further away.

To reduce the influence of total PCB concentration on the PCA results, PCB congener values for each sample were normalized to the total PCB concentration of the sample by dividing the two values: [PCB Congener]/[Total PCB].

Results

Water

Total PCB, TOC, TSS, and lipid content results for all samples collected during this study are provided in Appendix B.

Total PCB concentrations in water samples ranged 147–219 pg/L (Table 1). Total PCB concentrations measured in the slough were largely representative of concentrations in the pipe effluent. The highest total PCB concentration was measured in the pipe water sample in April and the lowest in the pipe water sample in October (Figure 4). Total PCB concentration in the slough sample was observed to be slightly higher in July and October than in April. The PCB concentration of the sample collected during the flushing event was 563 pg/L (Sample ID 1607031-05; Appendix B).

TOC concentrations in water samples were less than the reporting limit of 1.0 mg/L except in one sample (1.1 mg/L). TSS concentrations were also less than the reporting limit of 1.0 mg/L except in two samples (1.0 and 2.0 mg/L). The exception was the sample collected during flushing, which had a TSS value of 220 mg/L. TOC was not detected in this sample, but at a higher reporting limit of 8.7 mg/L.

Sediment

Total PCB concentrations in the two surface sediment samples were 32.7 and 95.0 ug/kg (Table 1). At the further downstream slough site (SH-Slough-Sed), total PCB concentration in the sediments was about half that collected in the more upstream slough site, closer to the main pipe (SH-Slough-Sed2).

Fish Feed

Total PCB concentrations in feed samples collected and composited over the month preceding each water sampling event at the Spokane Hatchery ranged 3.9–31.5 ug/kg (Table 1).

Table 1. Summary statistics of total PCB concentrations in water, sediment, fish, and fish tissue samples collected during this study.

Sample ID	EIM Location ID	Sample Type	N	Mean	Min	Max
SH-Pipe	SH-Pipe	Water (pg/L)	3	181	147	219
SH-Slough	SH-Slough	Water (pg/L)	3	189	168	200
SH-Slough-Sed	SH-Slough-Sed	Sediment (ug/kg)	1	32.7	32.7	32.7
SH-Slough-Sed2	SH-Slough-Sed2	Sediment (ug/kg)	1	95.0	95.0	95.0
SH-Feed	WDFW SPO	Fish Feed (ug/kg)	3	15.1	3.9	31.5
SH-Fish	WDFW SPO	Fish Tissue (ug/kg)	4	4.6	4.0	5.2
TH-Fish	WDFW TRO	Fish Tissue (ug/kg)	5	8.4	5.9	11.3
LS-Fish	Lake Spokane	Fish Tissue (ug/kg)	3	24.6	20.5	28.7

Figure 4. Total PCB concentrations in water samples collected at the Spokane Hatchery from the main discharge pipe and in the drainage slough.

Fish Tissue

Fish lengths of individual pre-released hatchery rainbow trout ranged 152–250 mm (about 6–10 inches), while lengths of the post-released hatchery rainbow trout captured from Lake Spokane ranged 305–340 mm (about 12–13 inches) (Table 2, Figure 5). On average, the hatchery fish caught from Lake Spokane weighed about five to six times more than the pre-released hatchery fish. Mean lipid content in fish feed was about three to four times higher than pre- and post-released hatchery fish. Mean lipid content of post-released fish was slightly lower than pre-released fish.

Total PCB concentrations in fish tissue from pre-released hatchery fish ranged 4.0–11.3 ug/kg (Table 1). The mean total PCB concentration in post-released hatchery fish from Lake Spokane was 24.6 ug/kg, about three to five times higher than mean concentrations in the pre-released fish (Table 1, Figure 6).

Table 2. Summary statistics of fish size and lipid content of pre-released hatchery rainbow trout (SH-Fish, TH-Fish), post-released hatchery rainbow trout (LS-Fish), and fish feed (SH-Feed).

Length (mm)				
Sample ID	**N**	**Mean**	**Min**	**Max**
LS-Fish	15	323	305	340
SH-Fish	20	197	160	234
TH-Fish	25	194	152	250
Weight (g)				
Sample ID	**N**	**Mean**	**Min**	**Max**
LS-Fish	15	387	353	418
SH-Fish	20	64.4	37.0	93.0
TH-Fish	25	73.2	24.0	152
Lipids (%)				
Sample ID	**N**	**Mean**	**Min**	**Max**
LS-Fish	3	4.7	3.4	7.0
SH-Fish	4	6.5	4.8	8.3
TH-Fish	5	6.9	4.2	14.7
SH-Feed	3	19.4	17.9	20.9

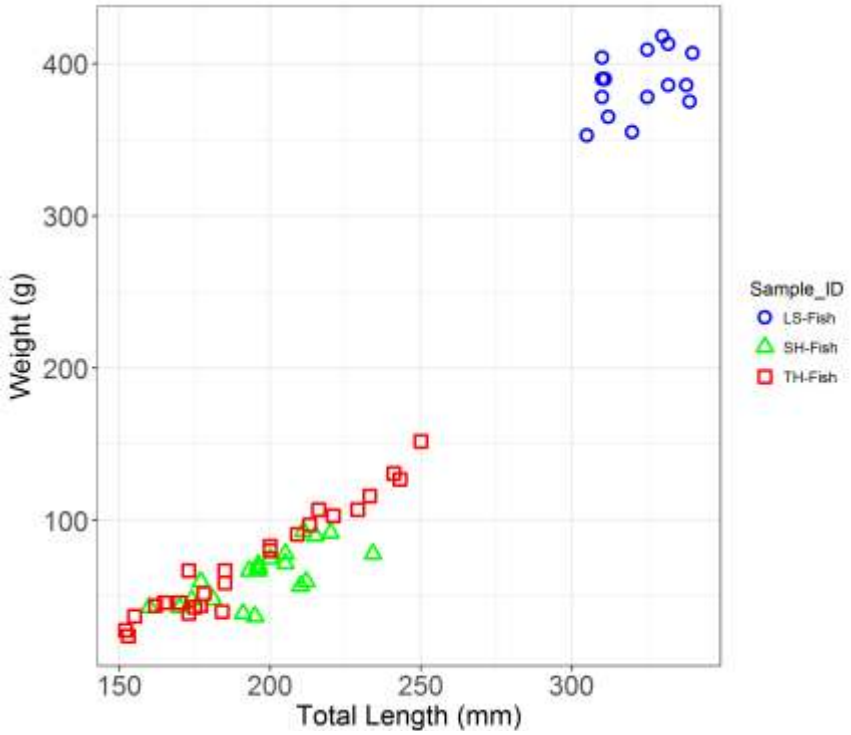

Figure 5. Scatter plot of length and weight of hatchery rainbow trout collected before their release to the Spokane River system (SH-Fish, TH-Fish), and after their release (LS-Fish).

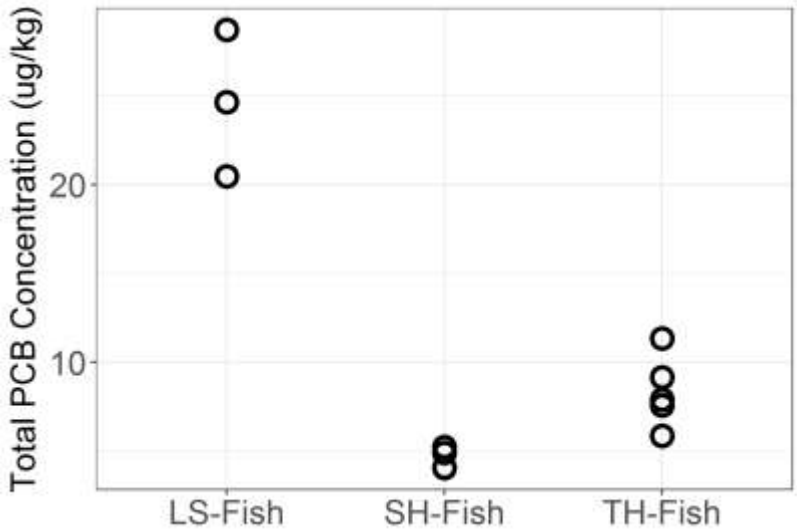

Figure 6. Total PCB conentrations in tissue collected from pre-released hatchery rainbow trout (SH-Fish, TH-Fish) and post-released hatchery rainbow trout (LS-Fish).

PCB Congeners

Overall, pentachlorobiphenyls represented the largest PCB homolog group in fish tissue, sediment, and water samples, while hexachlorobiphenyls represented the largest homolog group in fish feed samples (Figure 7). Lake Spokane fish tissue samples tended to have a larger proportion of tetrachlorobiphenyls than the Spokane Hatchery and Troutlodge Hatchery fish tissue samples. Water samples from the Spokane Hatchery slough and pipe tended to have larger proportions of the di- and trichlorobiphenyls compared to the fish tissue, feed, and sediment samples.

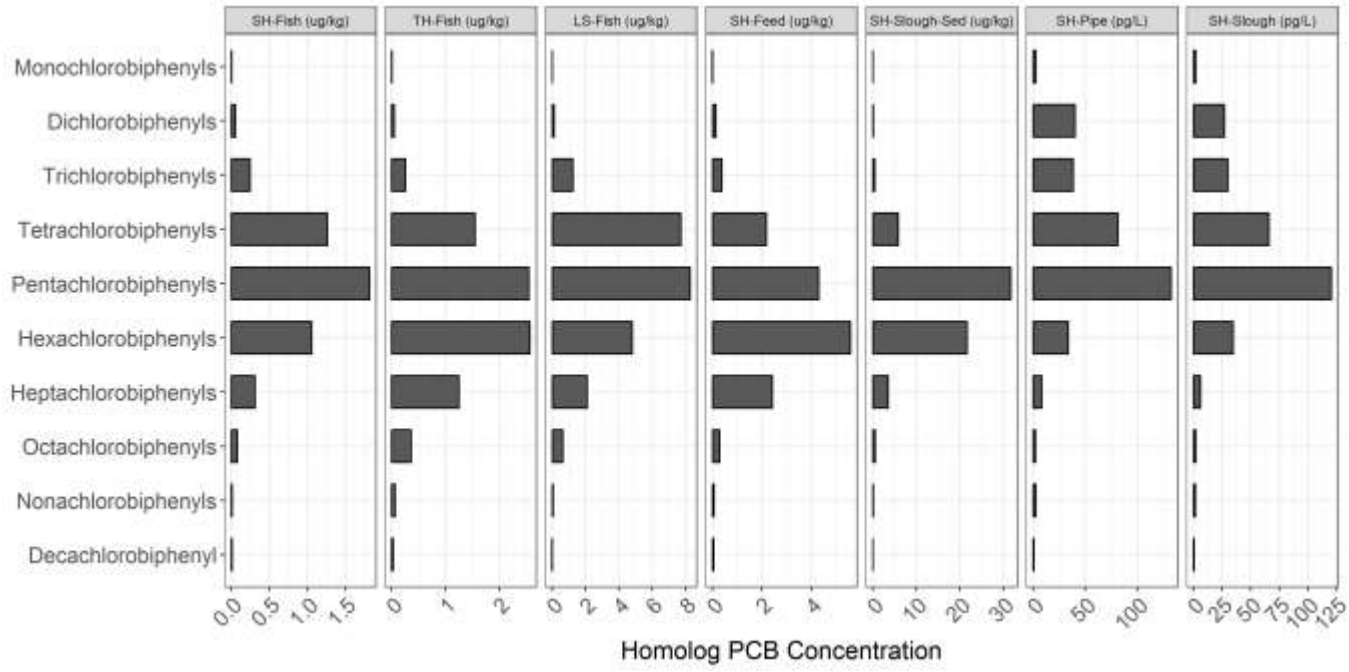

Figure 7. Average homolog PCB concentrations in fish tissue (SH-Fish, TH-Fish, LS-Fish), fish feed (SH-Feed), sediment (SH-Slough-Sed), and Spokane Hatchery water samples (SH-Pipe, SH-Slough). Note different scales and measurement units.

PCA performed on relative PCB congener composition showed separation of samples on the first two principal components (axes), which cumulatively represented 46% of the total variance in the dataset (Figure 8). Separation was greatest among sample matrices (water, fish tissue, feed, sediment), suggesting congener composition was the most dissimilar among different matrices rather than among different locations. Among fish tissue samples, the congener composition was most similar among fish from the same location (i.e., Spokane Hatchery, Troutlodge Hatchery, and Lake Spokane).

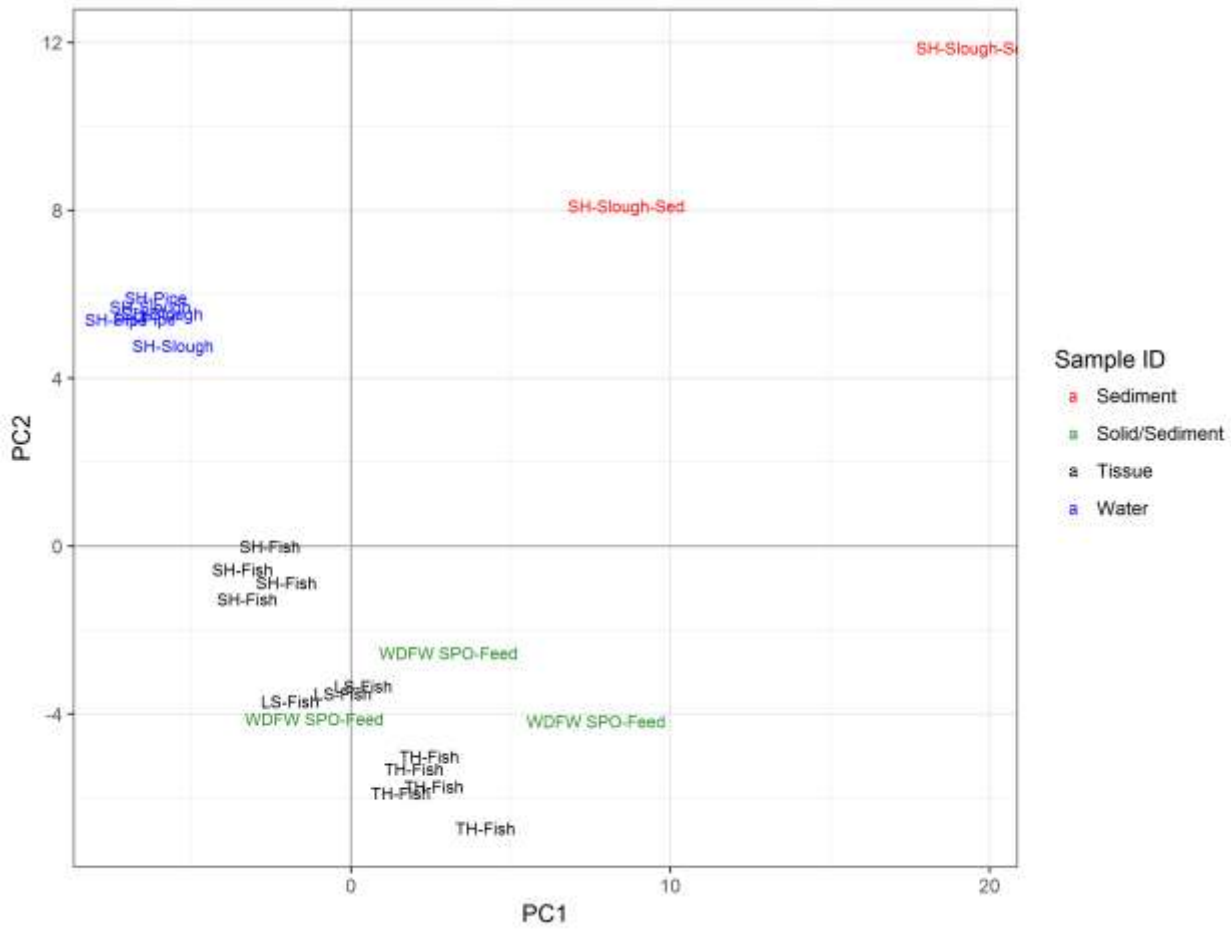

Figure 8. PCA ordination plot showing principal components 1 and 2 along the X and Y axes. Individual samples are labeled by Sample ID and colored by sample matrix.

Discussion

Sampling at the Spokane Hatchery

PCB concentrations from Spokane Hatchery water samples (147–219 pg/L) were comparable to mean concentrations measured previously in the Little Spokane River (199 pg/L; Serdar et al., 2011), and to concentrations measured in the mainstem Spokane River below Nine-Mile Dam (150–234 pg/L; Limnotech, 2016).

Water samples collected from the effluent and the slough showed limited variability in PCB concentrations among sampling events. TOC and TSS in water samples were mostly below the reporting limit of 1 mg/L, and so if any relationship between TOC or TSS and PCB exists, it could not be determined from these data.

One of the main purposes of collecting fish feed samples was to determine if variability in PCBs measured in fish feed could help explain variability in PCBs measured in the water samples (e.g.,

via consumption by fish, excretion into holding ponds, and subsequent discharge as wastewater); however, a relationship was not easily discernable from these data.

Fish feed PCB concentrations ranging 3.9–31.5 ug/kg were overall comparable to PCB concentrations measured previously in fish feed used by and collected from Washington State hatcheries (Serdar, et al. 2006). Serdar et al. (2006) found an average PCB concentration of 16.4 ug/kg measured in fish feed formerly used at the Spokane Hatchery (Silver Cup brand, 3.2 mm), and 8.2 ug/kg measured in the same brand fish feed (EWOS Pacific, 3.0 mm) used by Spokane Hatchery during the present study.

Similar to the present study, Serdar et al. (2006) found high lipid content in the fish feed used by different Washington State hatcheries. Although the objective of the present study was not to determine relationships between PCBs in fish feed and fish tissue, correlations between PCBs in fish feed and hatchery fish which consume the feed have been documented in other studies (Carline et al., 2004; Serdar et al., 2006). Fish feed containing high oils, fats, and lipids were believed to be the primary source of PCBs in unstocked hatchery-raised fish. The main fish feed brand used during the present study contains a mixture of 45% crude protein, 18% crude fat, fish meal and oil, poultry meal and fat, corn gluten, wheat, canola meal, among other ingredients; however, the source of these ingredients may vary from batch to batch.

Serdar et al. (2006) found that PCB concentrations in fish feed were considerably variable among batches of feed. The study noted that the origin of lipids in fish feed is probably more important in determining variability in PCB concentrations than the percentage lipid content by weight. For example, the exact source of fish meal, oil, and other ingredients may vary from batch to batch during the feed manufacturing process, depending on availability or price of the source ingredients. Variability in source ingredients among different batches of feed could explain the broad range in PCB concentrations measured in fish feed during this study: 3.9–31.5 ug/kg.

PCB concentrations in the Spokane Hatchery slough sediment were 32.7 and 95.0 ug/kg, below the total Aroclor-based sediment cleanup objective of 110 ug/kg (WA 173-204). However, sediment PCB concentrations in the slough were an order of magnitude higher than the PCB concentration range of 0.46–3.85 ug/kg previously measured in sediments collected from the Little Spokane River (Friese and Coots, 2016). This suggests that considerable amounts of PCBs settle into the sediments of the drainage slough before hatchery effluent is discharged into the Little Spokane River.

PCBs in Pre- and Post-Released Hatchery Rainbow Trout

Direct literature comparisons of PCB concentrations in whole fish tissue samples of hatchery rainbow trout were difficult because of the lack of historic data for the Spokane River system. Many studies of toxic contaminants in fish tissue also focus on determining contaminant concentrations in edible fish tissue (fillets). For example, Serdar et al. (2006) analyzed PCB concentrations in fillets of pre-released rainbow trout raised at both the Spokane Hatchery and Troutlodge Hatchery. In that study, the mean PCB concentration in Spokane Hatchery-raised fish was 11.7 ug/kg, and 14.4 ug/kg in Troutlodge Hatchery-raised fish. Interestingly, PCB concentrations in pre-released *whole* fish in the present study (4.0–11.3 ug/kg) were less than the

concentrations found in fillets in Serdar et al. (2006). The opposite (higher concentrations) might be expected considering that PCBs accumulate in the internal organs of fish (Karjalainen et al., 2006), as well as the more typically consumed fillets.

In Serdar et al. (2006), PCB concentrations in hatchery trout fillet tissue were compared before and after the fish were released to lakes with no known or suspected contamination sources. The study found lower concentrations in the released trout (3.1 ug/kg) versus pre-released trout (13 ug/kg), and concluded that PCB concentrations in fillet tissue were "diluted" in the lakes to which the fish were released. Our study found the converse, in which PCB concentrations in whole fish tissue of trout released to Lake Spokane were 3–5 times higher than the pre-released trout. The higher PCB concentrations in the released versus pre-released trout in our study suggest that PCBs from Lake Spokane were bioaccumulating in the fish during the four months of inhabiting the lake.

A dominant pathway of PCB contamination in fish is from bioaccumulation through the food web (e.g., consuming aquatic insects, zooplankton, and other prey which contain PCBs). Older fish and organisms at the tops of food chains in particular tend to have higher concentrations of biaccumulative chemicals (DeVault et al., 1989). Direct or indirect exposure to PCB-contaminated sediments has also been shown to be a dominant pathway (Serdar, 2003; Era-Miller et al., 2010).

PCB Congener Patterns

PCA analysis showed strong differences in the PCB congener composition among samples (Figure 8). For example, water samples clustered together, with the main PCB congeners in the di-, tri-, tetra-, and penta- homolog groups. PCB congener composition showed that water from the slough was largely representative of water from the pipe. Sediment samples demonstrated different PCB congener patterns from the other samples, predominantly composed of PCB congeners in the penta- and hexa- homolog groups (Figures 7 & 8).

Clustering of fish tissue samples based on congener composition was also apparent, representing groups of fish raised at the Spokane Hatchery, Troutlodge Hatchery, and fish caught in Lake Spokane. Fish sampled in this study were most enriched with tetra-, penta-, and hexachlorobiphenyls. Differences in the Troutlodge Hatchery fish and Spokane Hatchery fish in the PCA could be explained by a tendency torward higher proportions of the heavier congeners representing the hexa-, hepta-, and octa- biphenyl groups in the Troutlodge samples. Fish caught from Lake Spokane were enriched with a higher proportion of tetrachlorobiphenyls compared to the other samples, suggesting that the fish released to Lake Spokane were accumulating greater proportions of tetrachlorobiphenyls from their diet in Lake Spokane, unlike the pre-released hatchery fish (Figures 7 & 8).

PCB Loads from Hatchery Operations

Instantaneous PCB loads calculated from mean concentration and flow data for water samples and from mean concencentration and fish weight data for fish tissue samples are shown in Table

3. Calculation tables used to derive the estimated mean PCB loads, and estimated PCB loads represented by the Spokane Hatchery and Troutlodge Hatchery are provided in Appendix C.

Table 3. Mean instantaneous PCB loads represented by the Spokane Hatchery and Troutlodge Hatchery. Means represent the average calculated instantaneous load from three water sampling events, and the average load based on mean PCB concentrations in fish tissue.

Sample ID	Mean Total PCB Load (mg/day)
SH-Pipe	6.2
SH-Slough	7.6
SH-Fish	<0.1
TH-Fish (PCB Load from Troutlodge Hatchery)	0.2
PCB Load from Spokane Hatchery (SH-Slough + SH-Fish)	7.6
PCB Load from Hatchery Operations	**7.8**

The estimated mean PCB load from the Spokane Hatchery (slough load + fish load) was 7.6 mg/day. The majority (>99%) of this load was represented by PCBs in the drainage slough, compared to PCBs in fish. About 82% of the PCB load in the slough was represented by pipe effluent. It is possible that the remaining 18% of the slough load represents both internal loading from slough sediments and from PCBs coming directly from the Spokane Hatchery's source water, Griffith Spring. Part of Griffith Spring's flow enters directly into the drainage slough, unused by the hatchery. In two water samples collected from Griffith Spring, PCB concentrations (using a 3xMB correction) were 3.47 and 20.2 pg/L (Spokane County Environmental Services, 2017). Because PCBs have previously been detected in the hatchery's source water, the calculated PCB load in the slough likely represents PCBs in hatchery effluent, internal loading from slough sediments, and PCBs in water from Griffith Spring.

A semi-quantitative mass balance using data from the present study, PCB concentration and flow data from Griffith Spring (Spokane County Environmental Services, 2017), and mass of fish feed used by the Spokane Hatchery in 2016 indicate that PCB source loads from the hatchery were less than output loads from the slough, and that PCB source loads to the hatchery were less than output loads from the hatchery (Michael Hepp, Ecology, personal communication). This exercise showed that PCBs in fish feed and influent water likely do not account for all of the output load from the hatchery. However, a different study design and greater sample size accounting for all hatchery inputs and outputs would be more appropriate to identify and quantify this unknown.

The estimated mean PCB load from fish raised at Troutlodge Hatchery was about five times greater than the load from Spokane Hatchery fish both because of higher mean concentrations and higher numbers of fish released to Lake Spokane by Troutlodge Hatchery. Still, PCB loads from Spokane Hatchery and Troutlodge Hatchery-raised fish represented only about 3% of the total load from hatchery operations. Considering also that many of the trout released to Lake Spokane are caught and removed from the system, the contribution of hatchery trout to PCB loads in Lake Spokane is shown to be small relative to other sources.

The estimated mean PCB load from the drainage slough of the Spokane Hatchery, representing the load to the Little Spokane River, was 7.6 mg/day. This represents about 7.8% of the estimated 97 mg/day PCB load in the Little Spokane River (Serdar et al., 2011).

The estimated mean PCB load of 7.8 mg/day from hatchery operations represents about 0.2% of the estimated 3,664 mg/day PCB load in Lake Spokane from Serdar et al. (2011). Using more recent monthly mean PCB concentration and estimated flow data at Nine-Mile Dam (Limnotech, 2017), calculated instantaneous PCB loads at Nine-Mile Dam range from 399–4,176 mg/day. Based on this estimated load range for the Spokane River at Nine-Mile Dam, and estimated loads in the present study, the maximum load contribution from hatchery operations is <3%. The overall results in this study suggest that hatchery operations represent a relatively small source of PCBs to the Spokane River system.

Conclusions

In this 2016 study, PCBs were detected in water samples collected from the Spokane Hatchery, sediment samples from the hatchery's drainage slough, samples of hatchery fish feed, and samples of pre- and post-released hatchery fish. Based on previous studies, this result is not unexpected. Hatchery fish raised in a fairly contained environment were likely accumulating the majority of their PCBs from PCB-contaminated fish feed. A portion of the PCBs accumulated through consumption of fish feed are excreted and ultimately end up in wastewater. It should be noted, however, that other potential sources of PCBs within the hatchery were not evaluated or sampled.

From the time that fish were raised in the hatcheries, released to Lake Spokane, and have spent about four months living in the lake, the average concentrations of PCBs in fish tissue more than tripled. This suggests that most of the body burden of PCBs in the hatchery fish was picked up after they had been released to the lake, for example accumulating PCBs through the food web. Overall, the results suggest hatchery operations, as represented by hatchery wastewater discharges and stocking of rainbow trout, contribute a relatively small proportion of the total PCB load to the Spokane River system.

Recommendations

Based on results from this 2016 study, recommendations for further action include:

- Data from this study suggest that there may be source(s) of PCBs other than fish feed and influent water from Griffith Spring to the Spokane Hatchery. Data from this study also suggest that the slough may be a source of PCBs, for example through internal loading from the sediments. However, our limited sample size and design prevented us from sampling all inputs and outputs to the hatchery. To specifically identify and quantify PCB sources to the hatchery, a mass balance study accounting for all inputs and outputs is recommended.
- The current and previous studies have documented variability in PCB concentrations among different batches of fish feed. For the purpose of quantifying PCB sources to the hatchery,

the ranges and variability among different types and batches of fish feed used by the hatchery should be assessed.

- In four months after being released to Lake Spokane, PCB levels in hatchery fish more than tripled. Food web analysis or bioaccumulation modeling in Lake Spokane and in the Spokane River, including collection of data on different prey and trophic levels, is recommended to determine the mechanisms by which fish in the river system accumulate PCBs.
- Relative to estimated PCB loads in the Spokane River, the contribution of PCBs by hatchery operations is small. Continued tracking and identifying of alternative sources of PCBs to the Spokane River is recommended.

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Appendices

Appendix A. Quality Assurance Results

Table A-1. Measurent quality objectives (MQOs) and results for fish tissue, fish feed, water, and sediment samples. Field duplicate, field blank, and method blank contamination results are also shown.

Matrix	Analyte	Laboratory Control Standard/Spike		Laboratory Duplicate		Internal Standard Recovery		Field Duplicate	Field Blank Result	Method Blank Contamination (% PCB Congener Results Qualified)*
		MQO (% Recovery)	Results Meeting MQO (%)	MQO (Relative % Difference)	Results Meeting MQO (%)	MQO (% Recovery)	Results Meeting MQO (%)	Range [Median] (Relative % Difference)		
Fish Tissue	PCB Congeners	50 - 150	100	<50	96.6	25 - 150	100	0-115 [10]	-	1.6
	Lipids	-	-	<20	100	-	-	1-69	-	-
Fish Feed	PCB Congeners	50 - 150	100	<50	96.6	25 - 150	92.2	0-188 [15]	-	4.8
Water	PCB Congeners	50 - 150	99.5	<50	96.4	25 - 150	99.1	0-58 [3]	11.1 pg/L	10.3
	TSS	80 - 120	100	<20	100	-	-	<1	<1 mg/L	-
	TOC	80 - 120	100	<20	100	-	-	<1	<1 mg/L	-
Sediment	PCB Congeners	50 - 150	100	-	-	25 - 150	100	0-192 [84]	-	5.8

* Percentage of congener results censored when results were >3x the detected method blank concentration.

Appendix B. Total PCB, TOC, and TSS Results

Table B-1. Total PCB, TOC, TSS, and Lipid Content results for all samples collected during this study

MEL Sample ID	Sample ID	EIM Location ID	Date	Sample Notes	Total PCB Concentration (Mean of Dups)	PCB Units	TOC (Water, mg/L; Sediment, %)	TSS (mg/L)	Lipids (%)
1605027-01	SH-Pipe	SH-Pipe	4/12/2016		207 (219)	pg/L	1 U	1	-
1605027-02	SH-Slough	SH-Slough	4/12/2016		168	pg/L	1.1	2	-
1605027-03	SH-Pipe	SH-Pipe	4/12/2016	Dup of 1605027-01	230	pg/L	1 U	1 U	-
1605027-04	-	-	4/12/2016	Field Blank	11	pg/L	-	-	-
1607031-01	SH-Pipe	SH-Pipe	7/19/2016		177	pg/L	1 U	1 U	-
1607031-02	SH-Slough	SH-Slough	7/19/2016		192 (200)	pg/L	1 U	1 U	-
1607031-03	SH-Slough	SH-Slough	7/19/2016	Dup of 1607031-02	207	pg/L	-	-	-
1607031-04	-	-	7/19/2016	Field Blank	-	pg/L	1 U	1 U	-
1607031-05*	SH-Pipe	SH-Pipe	7/19/2016	SH-GP-2	563	pg/L	8.7 U	220	-
1610011-01	SH-Pipe	SH-Pipe	10/11/2016		147	pg/L	1 U	1 U	-
1610011-02	SH-Slough	SH-Slough	10/11/2016		200	pg/L	1 U	1 U	-
1610011-03	SH-Slough-Sed	SH-Slough-Sed	10/11/2016		47.3 (32.7)	ug/kg	0.06	-	-
1610011-04	SH-Slough-Sed 2	SH-Slough-Sed 2	10/11/2016		95.0	ug/kg	0.09	-	-
1610011-05	SH-Slough-Sed	SH-Slough-Sed	10/11/2016	Dup of 1610011-03	18.0	ug/kg	-	-	-
1611047-01	SH-Fish	WDFW SPO	4/12/2016		5.2	ug/kg	-	-	6.7
1611047-02	SH-Fish	WDFW SPO	4/12/2016		4.9	ug/kg	-	-	8.3
1611047-03	SH-Fish	WDFW SPO	4/12/2016		4.0	ug/kg	-	-	4.8
1611047-04	SH-Fish	WDFW SPO	4/12/2016		4.1	ug/kg	-	-	6.2
1611047-05	TH-Fish	WDFW TRO	6/9/2016		7.9	ug/kg	-	-	4.5
1611047-06	TH-Fish	WDFW TRO	6/9/2016		7.6	ug/kg	-	-	4.2
1611047-07	TH-Fish	WDFW TRO	9/21/2016		11.3	ug/kg	-	-	14.7
1611047-08	TH-Fish	WDFW TRO	9/21/2016		9.2	ug/kg	-	-	8.0

MEL Sample ID	Sample ID	EIM Location ID	Date	Sample Notes	Total PCB Concentration (Mean of Dups)	PCB Units	TOC (Water, mg/L; Sediment, %)	TSS (mg/L)	Lipids (%)
1611047-09	TH-Fish	WDFW TRO	9/21/2016		6.2 (5.9)	ug/kg	-	-	5.0
1611047-10	LS-Fish	Lake Spokane	9/23/2016		20.5	ug/kg	-	-	7.0
1611047-11	LS-Fish	Lake Spokane	9/23/2016		24.7	ug/kg	-	-	4.1
1611047-12	LS-Fish	Lake Spokane	9/23/2016		28.7	ug/kg	-	-	4.3
1611047-13	TH-Fish	WDFW TRO	9/21/2016	Dup of 1611047-09	5.6	ug/kg	-	-	4.9
1611047-14	LS-Fish	Lake Spokane	9/23/2016	Dup of 1611047-10	20.5	ug/kg	-	-	3.4
1611047-15	SH-Feed	WDFW SPO-Feed	4/12/2016		3.8 (3.9)	ug/kg	-	-	17.9
1611047-16	SH-Feed	WDFW SPO-Feed	7/19/2016		9.9	ug/kg	-	-	20.9
1611047-17	SH-Feed	WDFW SPO-Feed	10/11/2016		31.5	ug/kg	-	-	18.5
1611047-18	SH-Feed	WDFW SPO-Feed	4/12/2016	Dup of 1611047-15	4.0	ug/kg	-	-	20.4

* Sample collected during fish tank flushing

Appendix C. PCB Load Calculation Tables

Table C-1. Instantaneous PCB loads from the Spokane Hatchery main discharge pipe (SH-Pipe)

Sampling Month	Total PCB Concentration (pg/L)	Total Hatchery Discharge (CFS)	Hatchery Discharge (GPD)	PCB Load (mg/day)
Apr-16	219	15.3	9854404	8.2
Jul-16	177	13.5	8723570	5.8
Oct-16	147	13.5	8723570	4.9
Mean	**181**	**14.1**	**9100515**	**6.2**
*Jul-16 (GP-2)**	*563*	*13.5*	*8723571*	*18.6*

* Sample collected during fish tank flushing

Table C-2. Instantaneous PCB loads from the Spokane Hatchery drainage slough (SH-Slough)

	Total PCB Concentration (pg/L)	Measured Flow (CFS)	Measured Flow (GPD)	PCB Load (mg/day)
Apr-16	168	23.9	15422627	9.8
Jul-16	200	10.6	6867389	5.2
Oct-16	200	14.5	9390116	7.1
Mean	**189**	**16.3**	**10560044**	**7.6**

Table C-3. Instantaneous PCB loads from Spokane Hatchery-raised pre-released rainbow trout (SH-Fish)

	Total PCB Concentration (ug/kg)	Fish Mass from Study (kg)	Total # Fish Released Annually to Lake Spokane	Total Fish Mass Released Annually (kg)	PCB Load (mg/day)
Min	4.0	$3.7x10^{-2}$	50,000	1850	<0.1
Max	5.2	$9.3x10^{-2}$		4650	0.1
Mean	**4.6**	**$6.4x10^{-2}$**		**3218**	**<0.1**

Table C-4. Spokane Hatchery total PCB loads, calculated as the slough load + fish load

	Slough PCB Load (mg/day)	Fish PCB Load (mg/day)	SUM PCB Load (mg/day)
Min	5.2	$3.6x10^{-2}$	5.2
Max	9.8	$4.6x10^{-2}$	9.9
Mean	**7.6**	**$4.0x10^{-2}$**	**7.6**

Table C-5. PCB loads from the Troutlodge Hatchery-raised pre-released rainbow trout (TH-Fish)

	Total PCB Concentration (ug/kg)	Fish Mass from Study (kg)	Total # Fish Released Annually	Total Fish Mass Released Annually (kg)	PCB Load (mg/day)
Min	5.9	$2.4x10^{-2}$	120000	2880	$4.6x10^{-2}$
Max	11.3	0.2		18240	0.6
Mean	**8.4**	**$7.3x10^{-2}$**		**8784**	**0.2**

Table C-6. PCB loads from the Troutlodge Hatchery-raised pre-released rainbow trout by stocking location

Stocking Location	Mean Total PCB Concentration (ug/kg)	Mean Fish Mass from Study (kg)	Total # Fish Released Annually	Total Fish Mass Released Annually (kg)	PCB Load (mg/day)
Lake Spokane	8.4	$7.3x10^{-2}$	105000	7686	0.2
Nine Mile Reservoir	8.4		9000	659	<0.1
Upper Falls Reservoir	8.4		6000	439	<0.1

Table C-7. Total PCB loads to the Spokane River system represented by hatchery operations

	Spokane Hatchery PCB Load	Troutlodge Hatchery PCB Load	PCB Load (mg/day)
Min	5.2	$4.6x10^{-2}$	5.3
Max	9.9	0.6	10.4
Mean	**7.6**	**0.2**	**7.8**

Appendix D. Glossary, Acronyms, and Abbreviations

Glossary

Anthropogenic: Human-caused.

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

Diel: Of, or pertaining to, a 24-hour period.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants.

These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

Acronyms and Abbreviations

CWA	Clean Water Act
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
PCB	Polychlorinated Biphenyl
RM	River mile
RPD	Relative percent difference
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
m	meter
mg	milligram
mg/L	milligrams per liter (parts per million)
mm	millimeters
pg/L	picograms per liter (parts per quadrillion)
ug/kg	micrograms per kilogram (parts per billion)