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

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Cover photo: Spokane River at Riverfront Park (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 federal 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 implement strategies to reduce PCBs in the system. One of the data gaps identified was the contribution of fish hatcheries to PCBs in the Spokane River via wastewater 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 evaluate hatchery contributions of PCBs to the Spokane River. The primary study objectives were to (1) characterize PCB concentrations in hatchery discharges and hatchery-raised rainbow trout and (2) estimate PCB loads from hatchery operations to the Spokane River. In 2016, we sampled discharges from the Spokane Hatchery (the only permitted hatchery discharging to the Spokane River above Long Lake Dam) and collected fish from the two hatcheries that stock trout to the river (Spokane Hatchery and a private hatchery in the town in Soap Lake, WA). Water, whole fish tissue, fish feed, and sediment samples were analyzed for the 209 PCB congeners.

PCBs were detected in all samples. PCB concentrations in hatchery discharges ranged from 147–219 pg/L. In feed samples, PCB concentrations ranged from 3.9–31.5 ug/kg. PCB concentrations in fish caught from Lake Spokane four months after their release were higher (20.5–28.7 ug/kg) than in pre-released fish (4.0–11.3 ug/kg), suggesting that most of the PCB body burden in post-released fish was accumulated after being released into the environment. The mean PCB load from hatchery operations was estimated to be 7.8 mg/day, most of which was represented by discharges from the Spokane Hatchery.

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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 federal 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 multiple 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).

In 2012, the Spokane River Regional Toxics Task Force (SRRTTF) was formed to (1) develop a comprehensive plan for identifying, characterizing, and quantifying sources of PCBs to the Spokane River and (2) implement strategies to reduce PCBs to levels that are in compliance with Washington State 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 data gap identified in the comprehensive plan is the PCB load contributions of fish stocking and discharges from fish hatcheries.

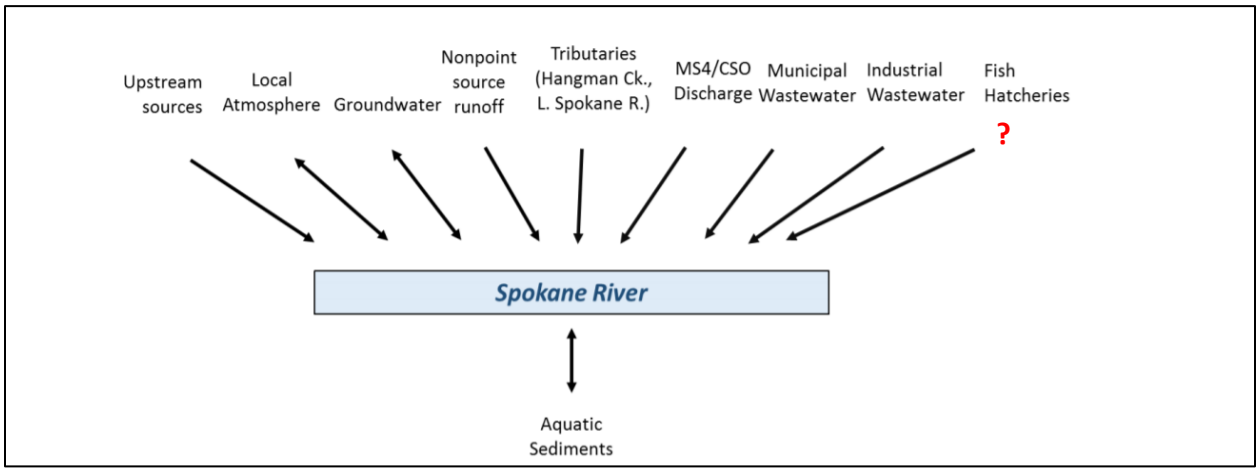

Figure 1. Example sources of PCBs to the Spokane River.
(Figure adapted from Limnotech, 2016).

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 consume. Commercial fish feeds often contain a mixture of fish oils and fish meal in their

[1] The Department of Ecology previously used FTECs for 303(d) listings of water bodies. It is calculated as: FTEC = Bioconcentration Factor x Human Health Criterion. Revisions to Policy 1-11, which establishes use of FTECs, are under review at the time of this report.

manufacture. Because PCBs are lipophilic and hydrophobic, commercial fish feeds, particularly those 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 hatchery fish tissue were found to be positively correlated with PCB concentrations in the commercial fish products they were fed (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 ug/kg. The study concluded that further consideration should be given to hatcheries as a potential source of PCBs to 303(d) listed waters or waters under consideration for listing.

Based on prior studies, PCBs in hatchery discharges are likely attributable to at least two sources: excretory products from fish that consume PCB-containing feed, 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 have not previously been quantified.

Goals and Objectives

The goals of this project were to determine PCB concentration ranges in hatchery discharges and hatchery trout and to 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.

The main study objectives were to:

1. Characterize PCBs in hatchery wastewater discharges to the Spokane River system
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 Hangman (Latah) 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 Prairie Aquifer nearer the Washington-Idaho state line, 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 a private hatchery in the town of Soap Lake. The Spokane Hatchery discharges to the Little

Spokane River. The hatchery 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. The private hatchery in Soap Lake is one of nine facilities in the Pacific Northwest owned and operated by a privately-owned company. In operation since 1945, the private company 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 system, the private hatchery does not discharge to the system.

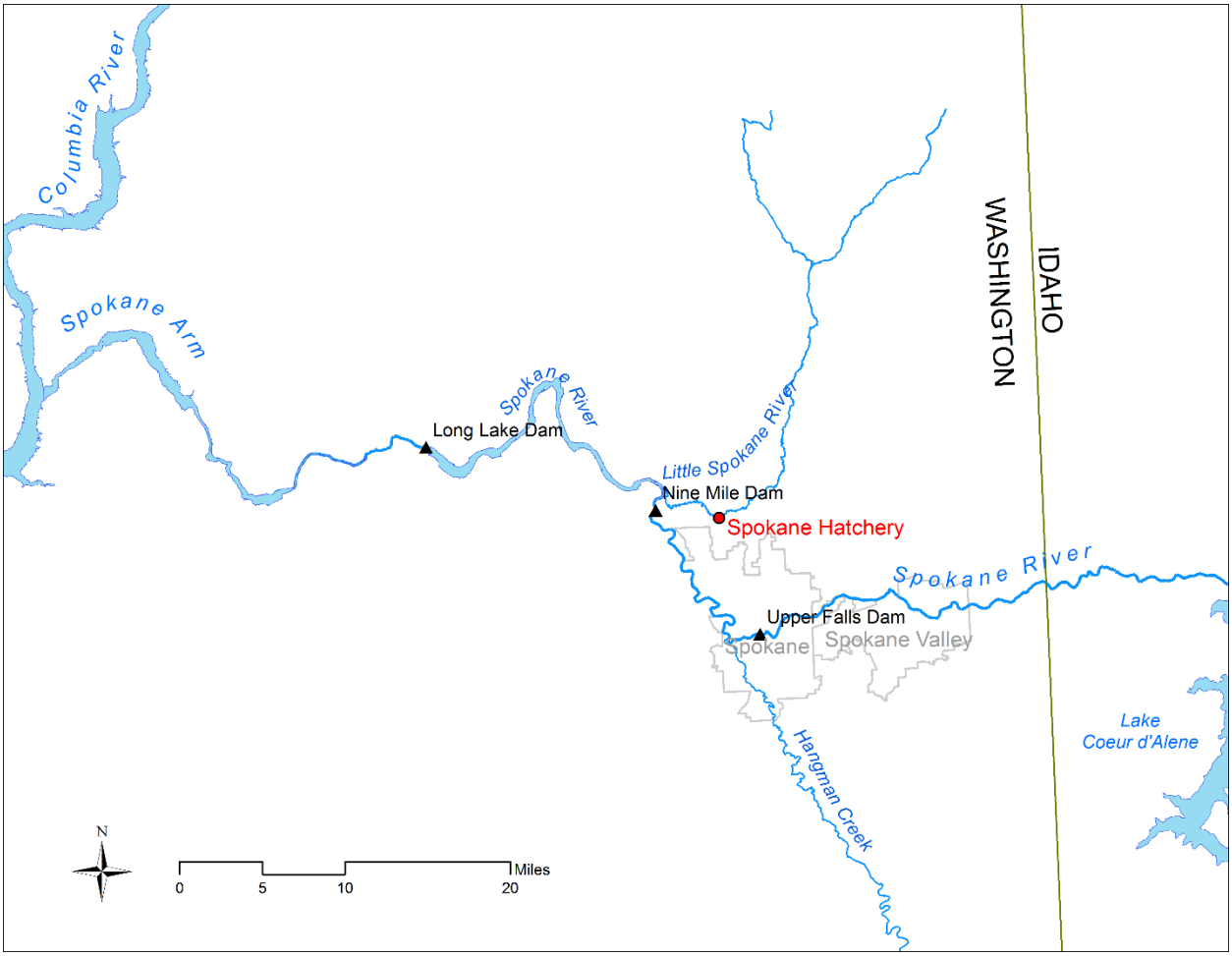

Figure 2. Overview map of the Spokane River and location of the Spokane Hatchery.

Under the 2009 License issued by the Federal Energy Regulatory Commission (FERC), Avista Corporation is required to stock 155,000 catchable-sized sterile rainbow trout annually to Lake Spokane (FERC Project No. 2545-091). Of these, 105,000 trout are raised at the private hatchery, and the remaining 50,000 trout are raised at the Spokane Hatchery from fertilized eggs supplied by the private hatchery. Avista's Lake Spokane stocking program began in 2014 and is scheduled through 2023 (Avista Corporation, 2013). Under the same License, Avista is required to stock 15,000 catchable-sized sterile rainbow trout 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 the private hatchery.

Methods

Field Sampling and Measurement

Water

Water sampling was conducted at the Spokane Hatchery to determine PCB concentrations in hatchery discharges and to 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 discharge pipe (SH-Pipe), and the drainage slough (SH-Slough) through which hatchery discharges enter 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 additional water sample was collected from the main discharge pipe concurrently as hatchery water was flushed from one of the fish holding ponds. This sample, collected to represent cleaning operations performed once per week, was not included in summary calculations (mean, minimum, maximum) 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 objective of compositing samples (including water, fish feed, sediment, and fish tissue samples) is to collect an average sample that integrates short-term or local variability. At each location, water was collected in a certified clean 1.5-L glass container, then transferred into a certified clean 2.5-L glass sample container (approximately one-quarter full per composite).

For the study, two duplicate samples were collected during field collection to assess the precision of PCB sampling and analysis. 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 discharge data were used to estimate PCB loads from the hatchery.

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

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, surface sediments were scooped using a decontaminated spoon at three sub-locations, composited and mixed in a decontaminated stainless steel bowl, then placed into certified clean glass sampling jars.

One field duplicate (split) sediment sample was also collected 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 Feed

Fish feed samples (SH-Feed) were collected and analyzed primarily to assist in interpreting corresponding fish tissue and water samples collected 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.

Fish Tissue

Rainbow trout raised at the Spokane Hatchery and private 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 PCB concentrations in these fish increased or decreased after spending 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 the private hatchery or the Spokane Hatchery, and were hatched from fertilized eggs supplied by the private hatchery. Fish were obtained from the hatcheries 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).

Private Hatchery

Fish raised at the private 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 the private hatchery on the two separate dates was to assess variability in PCB concentrations that might be associated with different releases.

On June 9, 2016, 15 fish (comprising 3 composites of 5 fish) were provided by private hatchery 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 private hatchery 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 and Analysis

Treatment of Non-Detects

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

PCB congener results that were less than three times the detected method blank result were qualified as non-detect. In this screening level study, the use of the "<3xMB" censoring rule was deemed appropriate. The "<3xMB" rule 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). For this reason, results presented in this report are not intended to be used for permitting or regulatory purposes. Use of a different censoring method on the raw data compiled from this study would be more appropriate for objectives other than identifying sources. For example, under routine monitoring, a "<10xMB" censoring rule 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 censoring method typically depends on the study objective and intent of data use.

PCB Load Calculations

PCB load estimates were calculated as instantaneous loads for both water discharges and fish releases from the hatcheries to evaluate the contribution of hatchery operations to PCB loads in the Spokane River.

Water Discharges

Instantaneous PCB loads from the Spokane Hatchery outfall 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 hatchery pipe outflow 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 the Spokane Hatchery outfall, we made the assumption that the PCB concentrations measured in the main outfall 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 multiplied by the *total* hatchery discharge to estimate PCB loads from the Spokane Hatchery.

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 private hatchery-raised fish. For private 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 did 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 private hatchery loads:

$$\textbf{\textit{Load from Hatchery Operations = Spokane Hatchery Load + Private Hatchery Fish Load}}$$

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 congener patterns among water, fish, feed, and sediment samples. PCA is a statistical tool that groups a large number of variables (e.g., the 209 individual PCB congeners) into “principal components” (PCs). The first two PCs often explain much of the variability in the dataset, and thus are a common initial diagnostic tool. 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 and focus on PCB congener patterns, 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

Total PCB, TOC, TSS, and lipid content results for all samples collected during this study are provided in Appendix B. Summary PCB and lipid content data are provided in Tables 1 and 2.

Water

Total PCB concentrations in water samples ranged from 147–219 pg/L (Table 1). The PCB concentration of the sample collected during the flushing event (Sample ID 1607031-05) was higher than this range (563 pg/L). Though variability was observed between sampling stations and events, overall total PCB concentrations measured in the slough were generally similar to concentrations in the outfall (Figure 4).

TSS and TOC concentrations were mostly less than or near the reporting limit of 1.0 mg/L, with maximum TSS and TOC values of 2.0 mg/L and 1.1 mg/L, respectively. The flush sample had higher TSS and TOC concentrations (220 mg/L and 8.7 mg/L, respectively).

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 from 3.9–31.5 ug/kg (Table 1).

Table 1. Summary statistics of total PCB concentrations in water, sediment, fish feed, 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

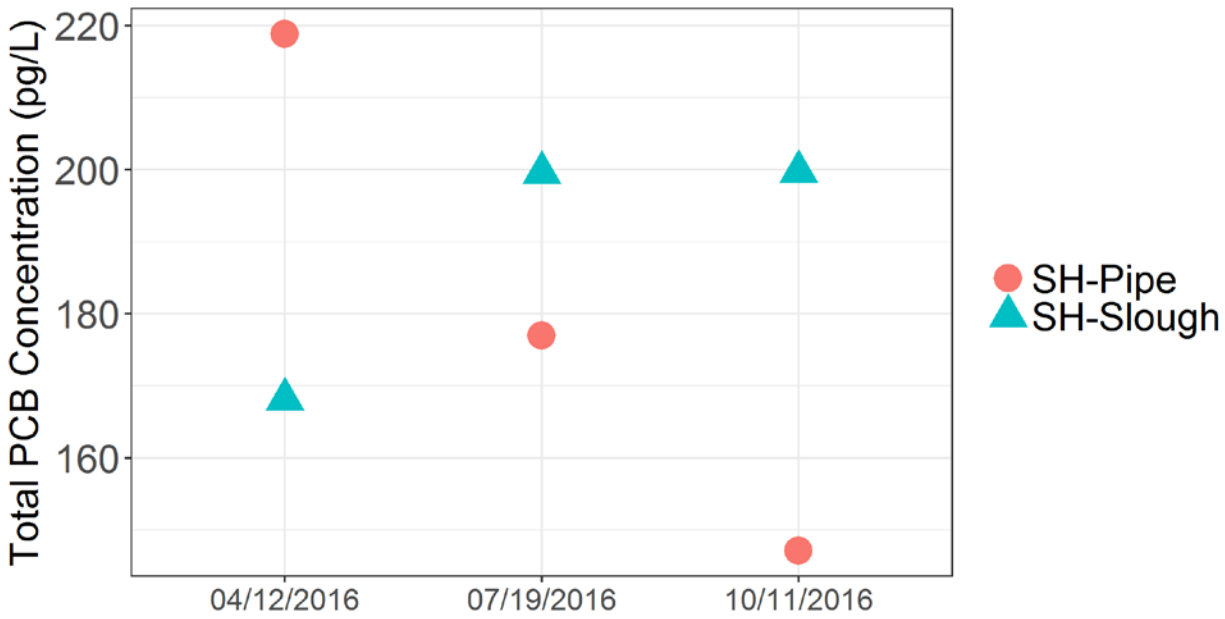

Figure 4. Total PCB concentrations in water samples collected at the Spokane Hatchery from the main discharge pipe and in the drainage slough.

Fish Tissue

Fish lengths of individual pre-released hatchery rainbow trout ranged from 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 of post-released fish was slightly lower than pre-released fish.

Total PCB concentrations in fish tissue from pre-released hatchery fish ranged from 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).

Sample ID	N	Mean	Min	Max
Length (mm)				
LS-Fish	15	323	305	340
SH-Fish	20	197	160	234
TH-Fish	25	194	152	250
Weight (g)				
LS-Fish	15	387	353	418
SH-Fish	20	64.4	37.0	93.0
TH-Fish	25	73.2	24.0	152
Lipids (%)				
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

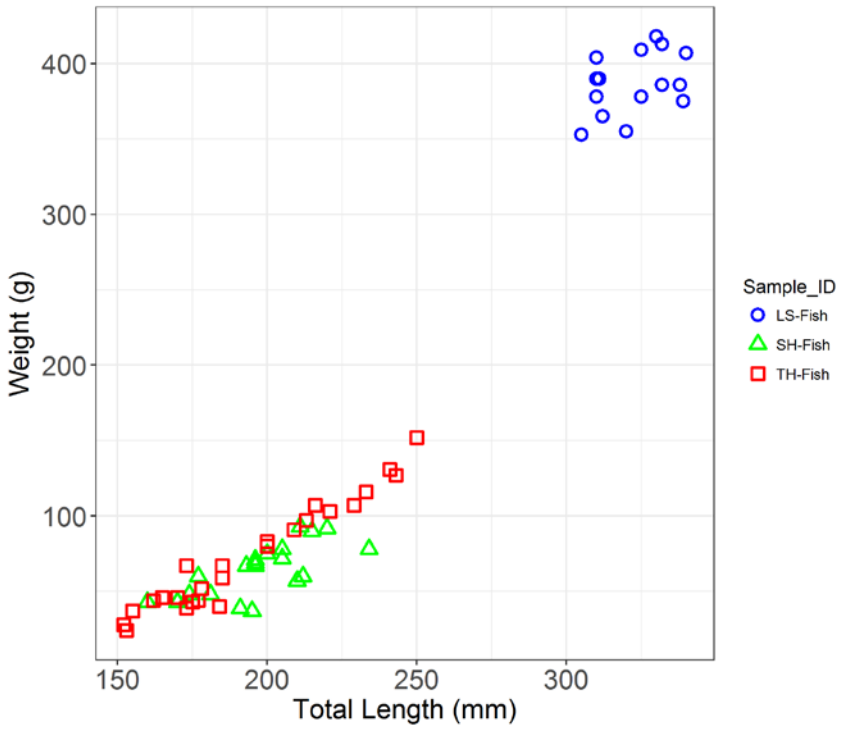

Figure 5. Scatter plot of length and weight of hatchery rainbow trout collected before their release to the Spokane River system (SH-Fish, TH-Fish), and after their release (LS-Fish).

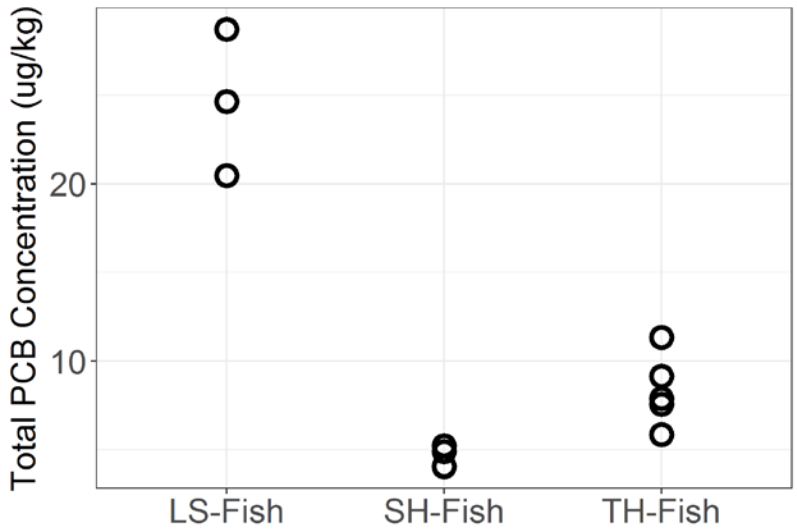

Figure 6. Total PCB concentrations in tissue collected from pre-released hatchery rainbow trout (SH-Fish, TH-Fish) and post-released hatchery rainbow trout (LS-Fish).

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 private 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.

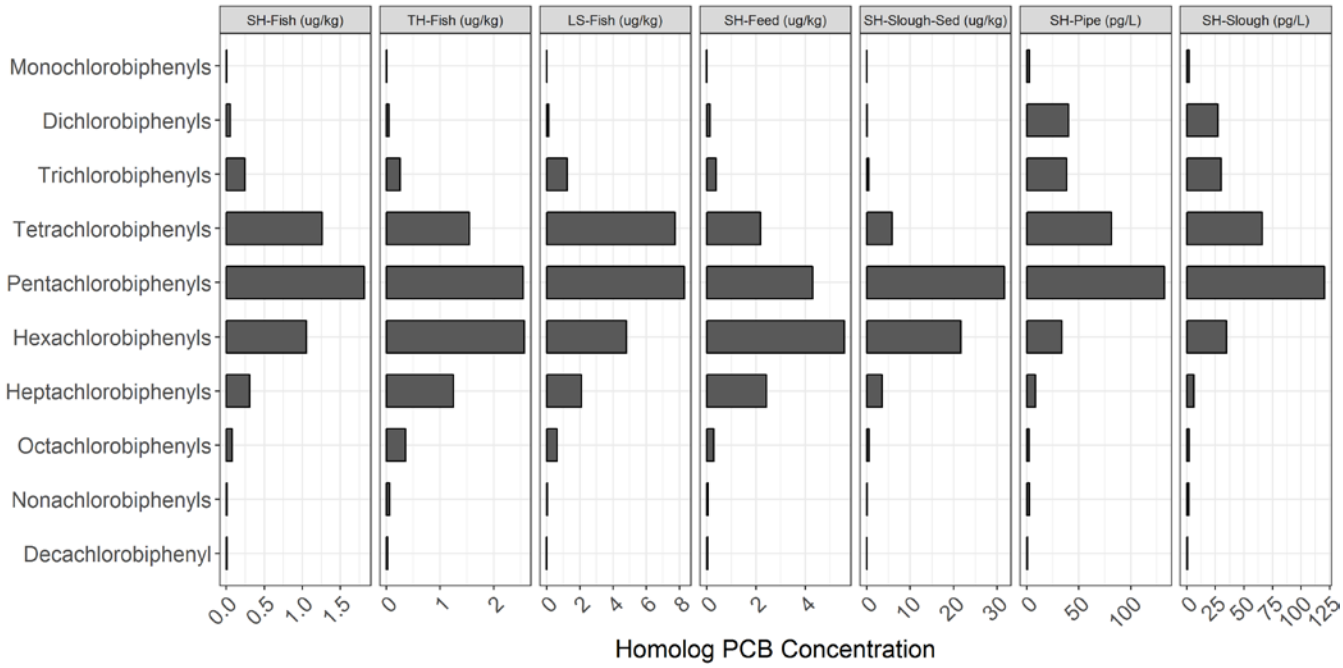

Figure 7. Average homolog PCB concentrations in fish tissue (SH-Fish, TH-Fish, LS-Fish), fish feed (SH-Feed), sediment (SH-Slough-Sed), and Spokane Hatchery water samples (SH-Pipe, SH-Slough).

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, private hatchery, and Lake Spokane).

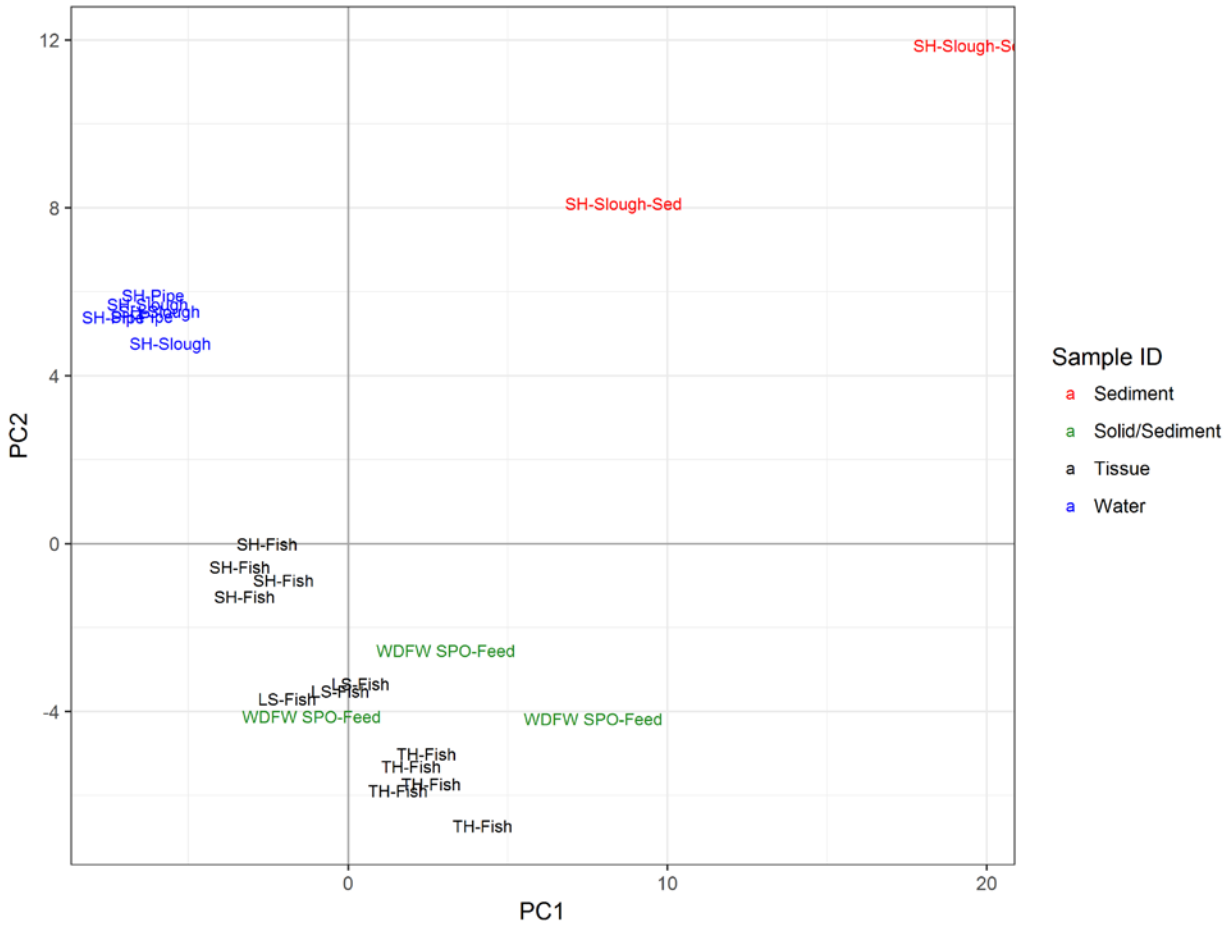

Figure 8. PCA ordination plot showing principal components 1 and 2 along the X and Y axes.

Individual samples are labeled by Sample ID and colored by sample matrix.

Discussion

Sampling at the Spokane Hatchery

PCB concentrations from Spokane Hatchery water discharge 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).

Similar to the present study, Serdar et al. (2006) found high lipid content in the fish feed used by different Washington State hatcheries. Fish feed containing high oils, fats, and lipids were believed to be the primary source of PCBs in unstocked hatchery-raised fish, and correlative relationships between PCBs in fish feed and hatchery fish that consume the feed have been documented (Carline et al., 2004; Serdar et al., 2006). 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 variable among batches of feed, similar to this study. 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.

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).

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). However, indirect comparisons can still provide useful context for discussion. Serdar et al. (2006) analyzed PCB concentrations in fillets of pre-released rainbow trout raised at both the Spokane Hatchery and the same private hatchery as sampled in this study. In Serdar (2006), the mean total PCB concentration (based on sum of aroclors) in Spokane Hatchery-raised fish was 11.7 ug/kg, and 14.4 ug/kg in private hatchery-raised fish. Mean PCB concentrations in pre-released whole fish in the present study (4.6 and 8.4 ug/kg for Spokane Hatchery and private hatchery-raised fish, respectively) were lower than the mean values in fillets from Serdar (2006).

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 bioaccumulative 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 and 8).

Clustering of fish tissue samples based on congener composition was also apparent, representing groups of fish raised at the Spokane Hatchery, private hatchery, and fish caught in Lake Spokane. Fish sampled in this study were most enriched with tetra-, penta-, and hexa-chlorobiphenyls. Differences in the private hatchery fish and Spokane Hatchery fish in the PCA could be explained by a tendency toward higher proportions of the heavier congeners representing the hexa-, hepta-, and octa- biphenyl groups in the private hatchery 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 and 8).

PCB Loads from Hatchery Operations

Instantaneous PCB loads calculated from mean concentration and flow data for water samples and from mean concentration 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 private hatchery are provided in Appendix C.

Table 3. Mean instantaneous PCB loads represented by the Spokane Hatchery and private 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 the private 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 calculated PCB load in the slough was represented by pipe discharges. Some PCB loading in the slough may be attributable to 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). While the slough appears to primarily receive PCB inputs from hatchery discharges, it is possible that the calculated PCB load in the slough also represents PCBs in water from Griffith Spring, and other unquantified inputs (e.g., sediment exchange).

The estimated instantaneous load from the Spokane Hatchery outfall based on the flush sample was calculated to be 18.6 mg/day. The magnitude and temporal extent that pulse loads from periodic flushing might influence average loads in the slough, and consequently to loads in the Little Spokane River, cannot be determined from this study.

A semi-quantitative mass balance using data from the present study, PCB concentration and flow data from Griffith Spring, and mass of fish feed used by the Spokane Hatchery in 2016 indicate that PCB source loads to the hatchery were less than output loads from the hatchery (Appendix D; Michael Hepp, Ecology, personal communication). This exercise showed that PCBs in fish feed and influent water may account for only a portion of the output load from hatchery discharges. 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 the private 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 the private hatchery. Still, mean PCB loads from hatchery-raised trout represented about 3% of the estimated mean load from hatchery operations found in this study. The majority of this load (7.8 mg/day) was represented by discharges from the Spokane Hatchery.

Limnotech (2016) provided estimates of PCB loading rates from various sources in the Spokane River system (Table 4). The estimated range in PCB loads from hatchery operations observed in this study (5.3–10.4 mg/day) provides a data gap for PCB sources to the Spokane River.

Table 4. Interquartile ranges (25^{th}–75^{th}) in estimated PCB loading rates for identified delivery mechanisms to the Spokane River.

Table is copied from Table 5 in Limnotech (2016).

Delivery Mechanism	PCB Loading Rate (mg/day)
Upstream sources (Lake Coeur d'Alene)	33 - 444
Groundwater loading	60 - 300
Tributaries	
Latah Creek	~0 - 215
Little Spokane River	15-200
WWTPs[3]	
Total Industrial	126 - 165
Total Municipal	51 - 125
Idaho	4-10
Washington	47-115
MS4 stormwater/CSOs	15 - 94
Bottom sediments	0.2 - 20
Fish hatcheries	Unknown
Atmospheric deposition to surface water	<0

[3] Advanced treatment technologies are currently being installed for the Dissolved Oxygen TMDL that will likely result in reductions of PCB loads to the Spokane River.

Based on Limnotech (2016), estimated instantaneous hatchery loads observed in this study were comparable to interquartile (25^{th} and 75^{th}) ranges in PCB loads estimated for several individual municipal wastewater treatment plants. From Table 7 in Limnotech (2016), the interquartile values for municipal treatment plants ranged 0.43–9.41 mg/day, excluding the City of Spokane (44.78–105.14 mg/day).

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 were likely accumulating PCBs from PCB-contaminated feed. A portion of the PCBs accumulated in fish through consumption of feed is excreted and ultimately ends up in hatchery discharges. However, data from this study suggest that there may be other sources of PCBs within the hatchery that were not evaluated or sampled.

Based on instantaneous load calculations, the mean PCB load from hatchery operations was estimated to be 7.8 mg/day, the majority of which was represented by discharges from the Spokane Hatchery, rather than hatchery trout. The estimated PCB loads from hatchery operations were comparable to PCB loads from individual municipal wastewater treatment plants.

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 caught in Lake Spokane was picked up after the fish had been released to the lake (for example accumulating PCBs through the food web).

Recommendations

Based on results from this 2016 study, recommendations are as follows:

- Data from this study suggest that there may be source(s) of PCBs other than fish feed to the Spokane Hatchery. 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, specifically fish feed, 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.
- This study filled a data gap by providing the first estimates of PCB loads contributed to the Spokane River by hatchery operations. Continued identification, tracking, and monitoring of PCB sources is recommended.

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Appendices

Appendix A. Quality Assurance Results

Table A-1. Measurement 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	Sample Matrix	Date	Sample Notes	Total PCB Concen-tration (Mean of Dups)	PCB Units	TOC (Water, mg/L; Sediment, %)	TSS (mg/L)	Lipids (%)
1605027-01	SH-Pipe	SH-Pipe	Water	4/12/2016		207 (219)	pg/L	1 U	1	-
1605027-02	SH-Slough	SH-Slough	Water	4/12/2016		168	pg/L	1.1	2	-
1605027-03	SH-Pipe	SH-Pipe	Water	4/12/2016	Dup of 1605027-01	230	pg/L	1 U	1 U	-
1605027-04	-	-	Water	4/12/2016	Field Blank	11	pg/L	-	-	-
-	-	-	Water	-	Lab Method Blank	86.2	pg/L			
1607031-01	SH-Pipe	SH-Pipe	Water	7/19/2016		177	pg/L	1 U	1 U	-
1607031-02	SH-Slough	SH-Slough	Water	7/19/2016		192 (200)	pg/L	1 U	1 U	-
1607031-03	SH-Slough	SH-Slough	Water	7/19/2016	Dup of 1607031-02	207	pg/L	-	-	-
1607031-04	-	-	Water	7/19/2016	Field Blank	-	pg/L	1 U	1 U	-
1607031-05*	SH-Pipe	SH-Pipe	Water	7/19/2016	SH-GP-2	563	pg/L	8.7	220	-
-	-	-	Water	-	Lab Method Blank	38.1	pg/L			
1610011-01	SH-Pipe	SH-Pipe	Water	10/11/2016		147	pg/L	1 U	1 U	-
1610011-02	SH-Slough	SH-Slough	Water	10/11/2016		200	pg/L	1 U	1 U	-
-	-	-	Water	-	Lab Method Blank	13.2	pg/L			
1610011-03	SH-Slough-Sed	SH-Slough-Sed	Sediment	10/11/2016		47.3 (32.7)	ug/kg	0.06	-	-
1610011-04	SH-Slough-Sed 2	SH-Slough-Sed 2	Sediment	10/11/2016		95.0	ug/kg	0.09	-	-
1610011-05	SH-Slough-Sed	SH-Slough-Sed	Sediment	10/11/2016	Dup of 1610011-03	18.0	ug/kg	-	-	-
-	-	-	Sediment	-	Lab Method Blank	0.1	ug/kg			
1611047-01	SH-Fish	WDFW SPO	Tissue	4/12/2016		5.2	ug/kg	-	-	6.7
1611047-02	SH-Fish	WDFW SPO	Tissue	4/12/2016		4.9	ug/kg	-	-	8.3
1611047-03	SH-Fish	WDFW SPO	Tissue	4/12/2016		4.0	ug/kg	-	-	4.8
1611047-04	SH-Fish	WDFW SPO	Tissue	4/12/2016		4.1	ug/kg	-	-	6.2
1611047-05	TH-Fish	WDFW TRO	Tissue	6/9/2016		7.9	ug/kg	-	-	4.5

MEL Sample ID	Sample ID	EIM Location ID	Sample Matrix	Date	Sample Notes	Total PCB Concen-tration (Mean of Dups)	PCB Units	TOC (Water, mg/L; Sediment, %)	TSS (mg/L)	Lipids (%)
1611047-06	TH-Fish	WDFW TRO	Tissue	6/9/2016		7.6	ug/kg	-	-	4.2
1611047-07	TH-Fish	WDFW TRO	Tissue	9/21/2016		11.3	ug/kg	-	-	14.7
1611047-08	TH-Fish	WDFW TRO	Tissue	9/21/2016		9.2	ug/kg	-	-	8.0
1611047-09	TH-Fish	WDFW TRO	Tissue	9/21/2016		6.2 (5.9)	ug/kg	-	-	5.0
1611047-10	LS-Fish	Lake Spokane	Tissue	9/23/2016		20.5	ug/kg	-	-	7.0
1611047-11	LS-Fish	Lake Spokane	Tissue	9/23/2016		24.7	ug/kg	-	-	4.1
1611047-12	LS-Fish	Lake Spokane	Tissue	9/23/2016		28.7	ug/kg	-	-	4.3
1611047-13	TH-Fish	WDFW TRO	Tissue	9/21/2016	Dup of 1611047-09	5.6	ug/kg	-	-	4.9
1611047-14	LS-Fish	Lake Spokane	Tissue	9/23/2016	Dup of 1611047-10	20.5	ug/kg	-	-	3.4
-	-	-	Tissue	-	Lab Method Blank	0.1	ug/kg			
1611047-15	SH-Feed	WDFW SPO-Feed	Feed	4/12/2016		3.8 (3.9)	ug/kg	-	-	17.9
1611047-16	SH-Feed	WDFW SPO-Feed	Feed	7/19/2016		9.9	ug/kg	-	-	20.9
1611047-17	SH-Feed	WDFW SPO-Feed	Feed	10/11/2016		31.5	ug/kg	-	-	18.5
1611047-18	SH-Feed	WDFW SPO-Feed	Feed	4/12/2016	Dup of 1611047-15	4.0	ug/kg	-	-	20.4
-	-	-	Feed	-	Lab Method Blank	0.1	ug/kg			

* 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)

Sampling Month	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 private 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 private 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	Private 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. Spokane Hatchery PCB Mass Balance Exercise

A PCB mass balance exercise was performed and is presented here for informational purposes only and to help inform any future sampling at the Spokane Hatchery. PCB load estimates were calculated as instantaneous loads based on data from this study and also from best available data from various sources.

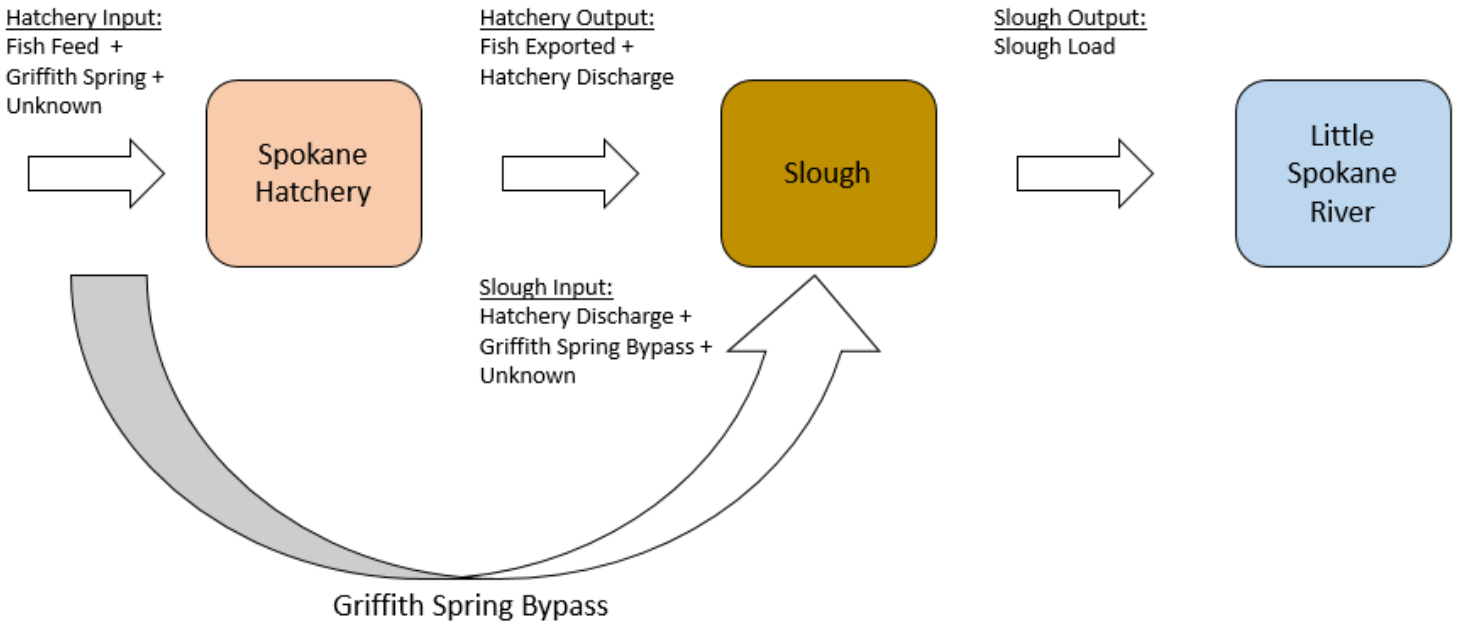

Figure D-1. Schematic diagram of Spokane Hatchery and slough PCB inputs and outputs.

Unknown- inputs represent potentially unknown and unevaluated PCB sources.

Table D-1. Spokane Hatchery input data and PCB load estimate calculations

Data	Mean	Max	Data Source
Mass of fish feed used in 2016	51868 kg	51868 kg	WA Department of Fish & Wildlife
PCB concentration in fish feed	15.1 ug/kg	31.5 ug/kg	WA State Department of Ecology-EAP (this study)
Griffith Spring flow[1]	25 CFS	25 CFS	WA State Department of Ecology-WR
Hatchery inflow[2]	14.1 CFS	15.3 CFS	WA State Department of Ecology-EAP (this study)
PCB concentration in Griffith Spring[3]	11.8 pg/L	31.1 pg/L	Spokane County Environmental Services
PCB Load Estimate Calculations	**Mean**	**Max**	
PCB load from fish feed	783 mg/year	1634 mg/year	
PCB load from influent	149 mg/year	425 mg/year	
Sum of known hatchery input PCB loads	932 mg/year	2059 mg/year	
Unknown[4]	1575 mg/year	1185 mg/year	

[1] Based on Spokane Hatchery water right
[2] Based on assumption that hatchery outflow = inflow in terms of water volume used
[3] Assumption made that PCB Concentration in Griffith Spring = PCB Concentration in Hatchery Influent
[4] Calculated as Sum of Hatchery Output PCB Loads - Sum of Known Hatchery Input PCB Loads
EAP: Environmental Assessment Program. WR: Water Resources Program

Table D-2. Spokane Hatchery output data and PCB load estimate calculations

Data	Mean	Max	Data Source
Mass of fish exported in 2016	51039 kg	51039 kg	WA Department of Fish & Wildlife
PCB concentration in fish	4.6 ug/kg	5.2 ug/kg	WA State Department of Ecology-EAP (this study)
Hatchery total discharge	14.1 CFS	15.3 CFS	WA State Department of Ecology-EAP (this study)
PCB concentration in main outfall	181 pg/L	219 pg/L	WA State Department of Ecology-EAP (this study)
PCB Load Estimate Calculations	**Mean**	**Max**	
PCB load from fish exported	233 mg/year	266 mg/year	
PCB load from hatchery discharge	2274 mg/year	2978 mg/year	
Sum of output PCB loads	2507 mg/year	3244 mg/year	

Table D-3. Slough input data and estimated PCB load estimate calculations

Data	Mean	Max	Data Source
Griffith Spring bypass flow[1]	10.9 CFS	9.7 CFS	WA State Department of Ecology-WR
PCB concentration in Griffith Spring[2]	11.8 pg/L	31.1 pg/L	Spokane County Environmental Services
PCB Load Estimate Calculations	**Mean**	**Max**	**Data Source**
PCB load from hatchery discharge	2274 mg/year	2978 mg/year	WA State Department of Ecology-EAP (this study)
PCB load from Griffith Spring bypass	115 mg/year	269 mg/year	
Sum of known slough input PCB loads	2389 mg/year	3247 mg/year	
Unknown[3]	370 mg/year	337 mg/year	

[1] Calculated as Griffith Spring flow - Hatchery Inflow

[2] Assumption made that PCB Concentration in Griffith Spring = PCB Concentration in Griffith Spring bypass

[3] Calculated PCB Load from Slough - Sum of known slough input PCB loads

Table D-4. Slough output data and PCB load estimate calculations

Data	Mean	Max	Data Source
PCB concentration in slough	189 pg/L	200 pg/L	WA State Department of Ecology-EAP (this study)
Slough flow	16.3 CFS	23.9 CFS	WA State Department of Ecology-EAP (this study)
PCB Load Estimate Calculation	**Mean**	**Max**	
PCB load from slough	2759 mg/year	3584 mg/year	

Appendix E. 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.

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
FTEC	Fish Tissue Equivalent Concentration
MEL	Manchester Environmental Laboratory
MQO	Measurement Quality Objective
NPDES	National Pollutant Discharge Elimination System
PCA	Principal Components Analysis
PCB	Polychlorinated Biphenyl
RM	River mile
RPD	Relative percent difference
SRRTTF	Spokane River Regional Toxics Task Force
TMDL	Total Maximum Daily Load
TOC	Total organic carbon
TSS	Total suspended solids
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
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)