DEPARTMENT OF ECOLOGY
State of Washington

Wenatchee River PCB Source Assessment

2016 and 2017

March 2018

Publication No. 18-03-010

Publication information

This report is available on the Department of Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1803010.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website EIM Database. Search Study ID WHOB002.

The Activity Tracker Code for this study is 17-005.

Suggested Citation:

Hobbs, W. 2018. Wenatchee River PCB Source Assessment: 2016 and 2017. Washington State Dept. of Ecology. Olympia, WA. Publication No. 18-03-010.
https://fortress.wa.gov/ecy/publications/summarypages/1803010.html

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Wenatchee River
PCB Source Assessment

2016 and 2017

by

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

- WRIA - 45 (Wenatchee River basin)
- HUC number - 17020011

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Abstract

In 2014 and 2015 the Washington State Department of Ecology completed a water quality survey of the Wenatchee River basin. This earlier study identified two possible source areas of polychlorinated biphenyls (PCBs) to resident biota in the Wenatchee River:

- A section of the river near the City of Cashmere.
- A section of the river near the City of Wenatchee, at the river's confluence with the Columbia River.

The objectives of the current study were to:

- Further delineate and characterize sources of PCBs in the lower Wenatchee River.
- Sample fish, macroinvertebrate tissues, and biofilms in the lower Wenatchee River for PCBs to supplement existing data to be used in compiling a future bioaccumulation model for the lower Wenatchee River.

Sampling in 2016 and 2017 confirmed that two chemically-distinct PCB sources are impacting the lower Wenatchee River: one near the City of Cashmere and the other downstream near the confluence with the Columbia River. The upstream (Cashmere) source has been isolated to 500 feet (150 m) of river bank and is likely entering the river through groundwater. The location of the downstream (confluence) source is less certain. It is possible that sediments in the backwater channels in this confluence area are contributing PCBs.

Concentrations of PCBs in fish feeding near the downstream (confluence) source are higher than the upstream source. Concentrations in the biofilms and invertebrates are higher during low-flow periods; however, the PCB load is lower during this time. PCB loads over the period 2014 to 2017 have been variable. However, the chemical profile of each PCB source is consistent over time and between high- and low-flow periods. The concentrations of PCBs in resident mountain whitefish continue to be well above state thresholds for consumption, suggesting that current Washington State Department of Health advisories should remain in place.

Acknowledgements

The authors of this report thank the following people for their contributions to this study:

- Chelan County Department of Natural Resources
  - Mike Kaputa
  - Mary-Jo Sanborn
  - Alan Schmidt
  - Pete Cruikshank
- Port of Chelan
- SGS/AXYS Environmental
  - Coreen Hamilton
  - Georgina Brooks
- Environmental Sampling Technologies
  - Terri Spencer
- Washington State Department of Ecology - current
  - Siana Wong
  - Molly Gleason
  - Melissa McCall
  - Andrew Beckman
  - Patti Sandvik
  - Keith Seiders
  - Stephanie Estrella
  - Lynda Jamison
  - Tom Mackie
  - Mark Peterschmidt
- Washington State Department of Ecology – Manchester Environmental Lab
  - Nancy Rosenbower
  - Leon Weiks
  - Ginna Grepo-Grove
  - Dean Momohara
  - Crystal Bowlen
- Washington State Department of Ecology - former
  - Casey Deligeannis
  - Michael Friese

Introduction

Over the last 10 to 15 years, some of the highest concentrations of polychlorinated biphenyls (PCBs) in fish tissue within Washington State have been found in resident fish of the Wenatchee River, mainly mountain whitefish (MWF; *Prosopium williamsoni*). This led to fish consumption advisories being placed on the river by the Washington State Department of Health (WDOH) and water quality listings as *impaired* under the federal Clean Water Act (Section 303d) by the Washington State Department of Ecology (Ecology). As part of the process to reduce the concentrations of PCBs found in resident fish tissues in the Wenatchee River, Ecology initiated a source assessment study to identify and prioritize sources of PCBs to the river (Hobbs and Friese, 2016).

PCBs are a class of 209 compounds or congeners which contain 1 to 10 chlorine atoms attached to two rings of biphenyl. PCBs were created to resist degradation and persist, which has made them a ubiquitous environmental contaminant, despite being banned in 1979 and many of their uses being in so-called *closed systems*. They are particularly soluble in lipids (fats), leading to the accumulation and biomagnification of PCBs in biological systems. PCBs are carcinogenic and can also affect the immune system, endocrine system, nervous system, and reproductive system.

In 2014 and 2015, Ecology completed a spatially-broad water quality survey of the Wenatchee River basin, identifying two possible source areas for PCBs (Hobbs and Friese, 2016). A section of the river near the City of Cashmere and a section near the City of Wenatchee, at the confluence with the Columbia River, were identified as possible source areas. Results from the previous work showed that the two PCB sources to the Wenatchee River are chemically distinct and the concentrations present in the river water and biota are higher during periods of low-flow (e.g. September).

During the previous study by Hobbs and Friese (2016), sampling was also conducted to understand the Wenatchee River food web and the bioaccumulation of PCBs within the food web. Biofilms are a collection of mainly periphyton, along with microbial biomass and fine sediments, attached to the river bottom, rocks, or debris in a river. Biofilms are the base (beginning) of the food web in a river. During the initial study of PCBs, we showed that PCB concentrations and congener fingerprints between water and biofilms are positively correlated and highly statistically significant. Furthermore, PCB concentrations in macroinvertebrates that consume the biofilms are higher in locations with higher PCB concentrations in water and biofilms.

The MWF in the Wenatchee River appear to have a very selective diet, consisting of caddisfly and mayfly larvae, and occasionally midge larvae. This finding is based on gut analysis (Hobbs and Friese, 2016) and is consistent with other studies on the feeding habits of MWF (Northcote and Ennis, 1994; Thompson and Davies, 1976). The previous study was able to establish diet but did not measure the PCB concentrations of fish tissues sampled. The higher PCB concentrations in lower trophic levels (water, biota and macroinvertebrates) at the two possible

PCB source areas suggests that the MWF appear to be feeding and accumulating PCBs in the lower Wenatchee River.

The objectives of the current study (2016-17 sampling) were to:

- Further delineate and characterize sources of PCBs in the lower Wenatchee River.
- Sample fish, macroinvertebrate tissues, and biofilms in the lower Wenatchee River for PCBs to supplement existing data to be used in compiling a future bioaccumulation model for the lower Wenatchee River.

An additional objective of the study was to complete a bioaccumulation model for PCBs and DDT in the lower Wenatchee River. The data from the 2016-17 sampling and the previous work (Hobbs and Friese, 2016) will be used in the bioaccumulation model. This objective will be addressed in a separate report at a later date.

Methods

Study Location and Sample Sites

An in-depth description of the biogeographic setting of the Wenatchee River Basin can be found in the previous study by Hobbs and Friese (2016). Briefly, the Wenatchee River basin is situated in central Washington, on the east side of the Cascade Mountains. The river flows from headwater tributaries in the mountains to Lake Wenatchee, where it becomes the Wenatchee River at the outlet and flows 53 miles (85 km) to the confluence with the Columbia River. The river traverses a number of biogeoclimatic zones, with the major transition taking place near Leavenworth when the topography becomes lower relief.

The geology of the basin is variable, comprising a number of different landforms ranging from the alpine and sub-alpine peaks of the Cascades to the low-lying Columbia plateau. The climate of the Wenatchee basin is continental with hot, dry summers and cold, wet winters. The hydrology of the Wenatchee River is nival-dominated (snow-dominated). Generally, discharge peaks in May-June and low flow occurs in September.

Sampling locations for this study were located from the City of Cashmere downstream to the confluence with the Columbia River (Figure 1). Specific sample locations can be found in Appendix A, Table A-1. Sample sites for water and biofilms focused on the two main areas of suspected PCB sources, near the City of Cashmere and near the confluence of the Wenatchee and Columbia Rivers. Sites that had been sampled previously by Hobbs and Friese (2016) were also included to document temporal variation.

Collections of fish took place in 2015 (MWF) and in 2016 (largescale suckers; LSS). In 2015, MWF were collected near the confluence with the Columbia River and between Leavenworth and Peshastin (Figure 1). Collections of MWF occurred in May and September. Collections of LSS occurred in September 2016 at the confluence with the Columbia River.

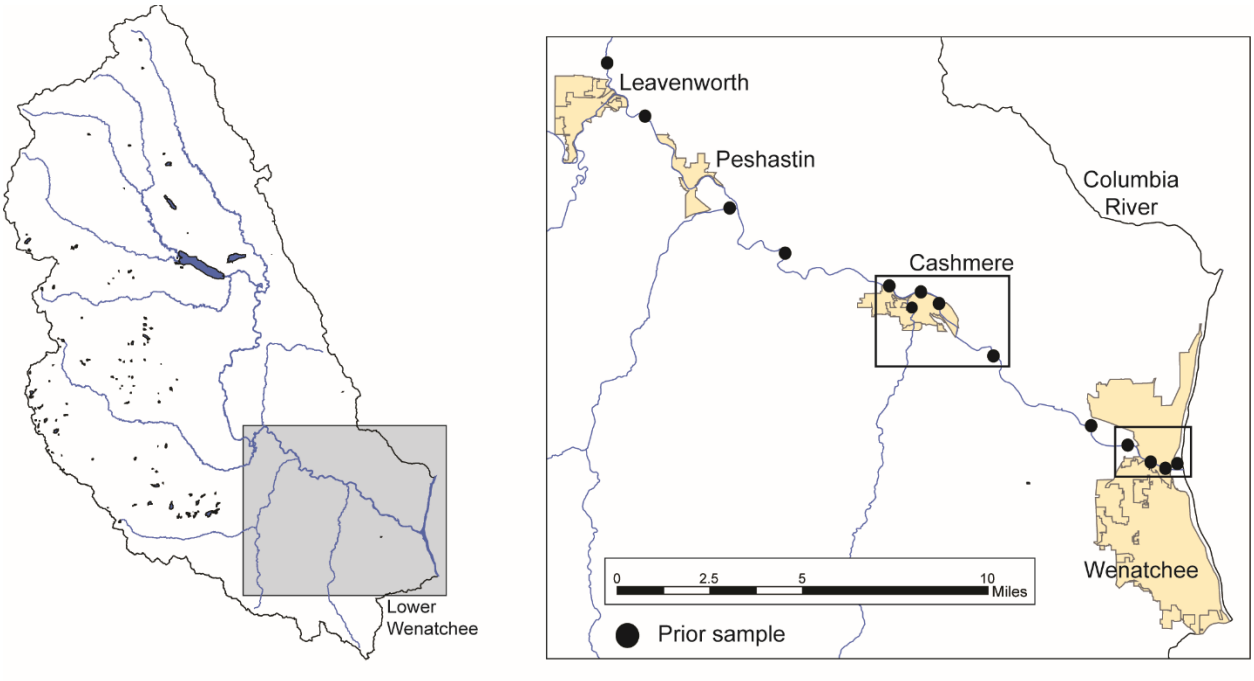

Figure 1: Map of the Wenatchee River Basin with the study areas highlighted.

Black dots represent locations of previous sampling

Sampling and Laboratory Methods

All sample preparation and laboratory methods used in the study are detailed in Table B-1

Water

Surface water grab samples were collected for the conventional parameters of suspended sediment concentrations (SSC), dissolved organic carbon (DOC) and total organic carbon (TOC). The parameters collected using grab approaches are used as ancillary data to help understand relationships between suspended matter and the organochlorine contaminants. Grab samples were collected using Ecology standard operating procedures (Joy, 2006).

Additional field parameters were measured *in situ* at the time of water sampling using a Hydrolab DataSonde (Swanson, 2007). Parameters included: temperature, pH, dissolved oxygen, and conductivity.

Semi-permeable membrane devices (SPMDs) are passive sampling devices and have been used by Ecology for a number of years (Seiders et al., 2012b). SPMDs are composed of a thin-walled, layflat polyethylene tube (91.4 cm x 2.5 cm x 70-95 um thickness) filled with 1 ml of triolein, a neutral lipid compound. After an approximate 28-day deployment, the membrane is removed, extracted, and analyzed for PCBs.

Performance reference compounds (PRCs) were spiked into the membranes in order to assess biofouling and the non-equilibrium uptake of the compounds of interest (Huckins et al., 2006). The use of PRCs is essentially an *in situ,* site-specific calibration technique based on the observation that the rate of PCB loss is proportional to the rate of PCB uptake. The PCB congeners PCB-14, PCB-31L, PCB-50, PCB-95L, and PCB-153L were used as PRCs, where "L" denotes a ^{13}C labeled compound. PRCs were added at a concentration of 2.5 ng per SPMD.

SPMDs were deployed using stainless steel canisters and spindle devices. Each site canister contained 5 membranes that were preloaded onto spindles and shipped in solvent-rinsed metal cans under argon gas. SPMDs were exposed for no more than 45 seconds at each site during deployment and retrieval. Nitrile gloves were used at all times.

A StowAway® TidbiT™ temperature logger was attached to the canister to continuously monitor the water temperature during deployment. A second datalogger was attached nearby to monitor air temperature. The data collected from the temperature loggers are used to confirm that the SPMD remained submerged during the sampling period.

SPMDs were deployed for approximately 28 days in August/September 2016 and March/April 2017. Following retrieval, SPMDs were sealed, cooled, and kept near freezing until arrival at AXYS Analytical for the extraction of the membranes (dialysis). Dissolved PCB congener concentrations were calculated from the mass extracted and measured from the SPMDs using the most recent USGS model (Alvarez, 2010; Alvarez, pers. comm.). The model is based on the octanol-water partition coefficient (MacKay et al., 1997), the physical properties of the SPMD, water temperature, PRC recoveries, and the length of deployment. Concentrations presented in this report are also adjusted for blank contamination by subtracting measurable congener-specific concentrations from the environmental samples.

Biofilms and Invertebrates

Biofilm refers to the mixture of periphyton, microbial biomass, and fine sediments. Periphyton is algae attached to the river bottom, rocks, or debris in the river. Biofilms were sampled at the end of SPMD deployment in September 2016 and April 2017. Samples were collected at sites with SPMDs and without to increase the spatial resolution of samples in the source identification areas.

Biofilm was scraped from rocks and collected in a stainless bowl for weighing in the field to confirm that sufficient biomass had been retrieved. Samples were transferred from the bowl to a cleaned glass jar. A sample to assess areal biomass (g dry weight / cm^2) was collected separately; each rock scraped for biofilm was measured by cutting a piece of aluminum foil tracing the sample area. The aluminum foil was then measured at Ecology using the Image J software (Schneider et al, 2012).

Biofilms were analyzed for PCBs, ash-free dry weight (to calculate areal biomass), and carbon (C) and nitrogen (N) abundance and stable isotope ratios. Stable isotopes are expressed as the ratio of the heavier isotope: lighter isotope relative to a standard (atmospheric N and Vienna Pee Dee Belemnite for C). The delta notation (δ) is used to express the very small variations in the isotopic ratios in parts per mil (‰), such that:

(1) $$\delta^{15}N\ (‰) = \left(\frac{^{15}N/^{14}N_{sample}}{^{15}N/^{14}N_{reference}} - 1\right) \times 1000$$

The same formula is used to express the $\delta^{13}C$ for the heavier ^{13}C isotope to the lighter ^{12}C. Prior to C and N analysis, biofilms were freeze-dried at Manchester Environmental Laboratory (MEL).

The PCB concentrations of the biofilms are expressed as total-PCBs (pg/g) and normalized to the organic carbon (OC) fraction of the sample. Normalization of the PCB concentrations is conducted by dividing by the % OC as a decimal.

Invertebrates were sampled in September 2016 at one location near the confluence of the Wenatchee River and the Columbia River. This was the same location as sampled in September 2015 (45WR01.1). The predominant prey of MWF (caddisflies and mayflies) was targeted for collection by picking individuals from rocks. Invertebrates were removed from their casings, and sufficient biomass for analysis was assessed in the field using a scale. Invertebrate tissues were analyzed for PCBs, C, and N.

Fish Tissue

MWF and LSS samples were collected using electrofishing techniques near the confluence and MWF were collected using hook and line at the upstream site near Leavenworth. Fish were collected for both composite fillet samples and individual whole fish to assess PCB concentrations. The stable C and N isotopic ratios of the fillet (muscle) tissues from individual fish were assessed. The isotopic ratios of the tissues are used to infer trophic position (Post, 2002) and assess feeding location. The $\delta^{13}C$ of tissues were adjusted for lipid content using the equations of Post et al. (2007). Lipid correction is necessary because the synthesis of lipids by an organism imparts a more negative or depleted ratio which can bias comparisons among organisms.

Previous studies on PCBs in MWF tissues in the Wenatchee River have focused on fillet composite samples (Era-Miller, 2004; Seiders et al., 2012a). The current fish consumption advisory also relies on fillet composite samples. Therefore, the fillet composites sampled in this study were used to compare to previous data and to compare to consumption thresholds. Individual whole fish were used in assessing bioaccumulation of PCBs in the food web of the Wenatchee River.

The gut contents of MWF from the Wenatchee River were previously assessed in Hobbs and Friese (2016). Samples of gut contents from LSS collected during this study were assessed for diet. Gut content samples were collected in the field prior to processing the tissue sample.

Numerical Methods

A principal components analysis (PCA) was used to explore the similarities among the PCB congener profiles for different media (SPMDs and fish tissue). PCA is an unconstrained, multivariate statistical analysis which considers each of the congener profiles for the samples of

interest and produces synthetic gradients (principal components) to best describe the differences among the sample sites. For the purposes of this study, the PCA is used as an exploratory tool to see which samples (or sites) have similar congener profiles and whether the congener profiles are similar to known PCB mixtures (aroclors). This allows us to infer something about geographic source area.

Quality Assurance

All quality assurance data are detailed in Appendix B. All laboratory recoveries, internal standards, data censoring, equipment performance, and laboratory narratives were reviewed by Ecology's Manchester Environmental Laboratory quality control officer, Ginna Grepo-Grove. A level 4 validation of the data was carried out for PCB congener results.

Blanks

For the PCB congener results analyzed by EPA method 1668c using high-resolution mass spectrometry (HRMS), associated lab method blanks were run with each sample batch. These method blanks were then used to censor the congener-specific results, where acceptable results in the sample needed to be greater than five times any lab blank contamination.

Blank samples are particularly relevant to the SPMD samples. These results are used to determine the level of background contamination in the equipment or in the field caused by exposure to the atmosphere. These blank samples are also used to quantify the suitable site-specific method detection limits (MDLs) and method quantitation limits (MQLs) for the SPMDs (Seiders and Sandvik, 2012). This estimation is based on the mean blank concentration plus three times the standard deviation among the blanks for MDLs and the mean plus ten times the standard deviation for MQLs (Seiders and Sandvik, 2012).

The blanks for the SPMDs comprised both field and manufacturing (day-zero) blanks. During the September 2016 SPMD sampling we calculated an MQL of 19.4 pg/L for PCBs (Appendix B, Table B-2). The April 2017 sampling had an MQL of 29.0 pg/L for PCBs. We used the MQLs to censor our estimates of water concentrations in the river. It should also be recognized that the variability among the SPMD blanks was low (~ 0.5 pg/L standard deviation).

In addition to using the blank samples to censor and screen the environmental samples, blank correction was carried out at each sample site. Blank correction is when the mean of the blank contamination is subtracted from the environmental sample. The mass of each PCB congener in the SPMD is corrected for blank contamination prior to the estimated water concentration being modeled.

Blank samples were also run in association with all other parameters and media to determine if the laboratory environment contributes any contamination. All results indicated no detectable contamination was present.

Precision

Precision is assessed by the analysis of sample replicates collected at the same time (Table B-3). Field replicates were collected during each sampling event at a frequency of no less than 10% of the total sample number per sampling event. All grab samples taken for conventional parameters met the MQOs for the study (Hobbs, 2016), with the exception of the three SSC samples from 2017. Relative percent differences were poor for each sampling event, which reflects the heterogeneous nature of this parameter at higher concentrations. Averages of the replicate samples are presented as the sample result.

The precision of the PCB results in SPMDs was excellent and met the study MQOs. The relative percent difference (RPD) between sample replicates of the estimated water concentrations (pg/L) was 10% and 13% for the two sampling events. Likewise the precision of the PCB results in tissues was very good (Table B-4). The biofilms had an RPD of 13 and 12%, the invertebrates were 5%, whole fish were 5 and 19% and a composite fish tissue sample was 10%. The low RPD of duplicate samples taken at the same site suggests good sample representation of the sample site.

The RPD of isotope samples taken as independent duplicate samples in the field were similarly low. Biofilm samples were 8 and 2% for $\delta^{15}N$ and 1 and 4% for $\delta^{13}C$. The RPD for invertebrate samples were 6% for $\delta^{15}N$ and 0.3% for $\delta^{13}C$.

Each isotope sample was run in duplicate giving an inter-sample RPD. The precision of these isotope samples was excellent (Table B-5). Inter-sample RPD for biofilms averaged 3% for $\delta^{15}N$ and 1% for $\delta^{13}C$. The inter-sample RPD for invertebrate tissues was 2 and 15% for $\delta^{15}N$ and 1% for $\delta^{13}C$. The inter-sample RPD for fish tissues averaged 1% for $\delta^{15}N$ and 0.5% for $\delta^{13}C$. The average of the inter-sample duplicates was used as the result.

Bias

Bias is assessed by measuring the recovery of analytes using laboratory spikes. All the specifications for PCB high resolution methods were met.

The recovery of spiked compounds is also used for the SPMDs to assess the rate of uptake of organic contaminants. These PRCs are introduced to the SPMDs during manufacturing and their recovery is measured following deployment. A range of PRCs with varying molecular weights are used and they are expected to attenuate from the SPMD during the deployment period. In general, only the lighter PCB-14 was found to reliably attenuate within the expected range (Table B-6). The higher weight PCBs did not attenuate below 90%. PRCs that did not show attenuation during deployment were not used in the model for water concentrations.

Sensitivity

Sensitivity is described by the estimated detection limit for each parameter and data are censored accordingly. Required detection and quantitation limits under the project plan (Hobbs, 2016) were met for all the parameters analyzed.

Results

Water

Discharge

Typically, the Wenatchee River experiences higher flows from April through July and the lowest flows from August through October (Figure 2). As discussed in Hobbs and Friese (2016), the 2014 water year was generally normal; however, the 2015 water year had higher than normal flows from January through March and lower than normal flows from May through September.

The 2016 water year had higher than normal flows from November through mid-January and from February through May. Flows during the September 2016 sampling were below normal but higher than in September 2015. The 2017 water year had higher than normal flows from November through December and mid-March through May, the latter overlapping with sampling for this project.

Figure 2: Hydrologic discharge in the Wenatchee River from 2014 through 2017.
SPMD sampling events are shown as gray shaded bars.

Conventional parameters

Conventional parameters are measured in association with SPMDs to provide some indication of the concentrations of suspended and dissolved organic carbon that may influence the total PCB concentrations. Generally, waters in the Wenatchee River during low flow are at or near detection capabilities for SSC, TOC and DOC (Table D-1). During higher flows the waters have higher SSC and measurable concentrations of TOC and DOC. Most of the TOC is present in dissolved form (i.e. <0.45µm). Relative to historical SSCs sampled since 1978, the samples taken in this study range up to the 97th percentile (Figure 3).

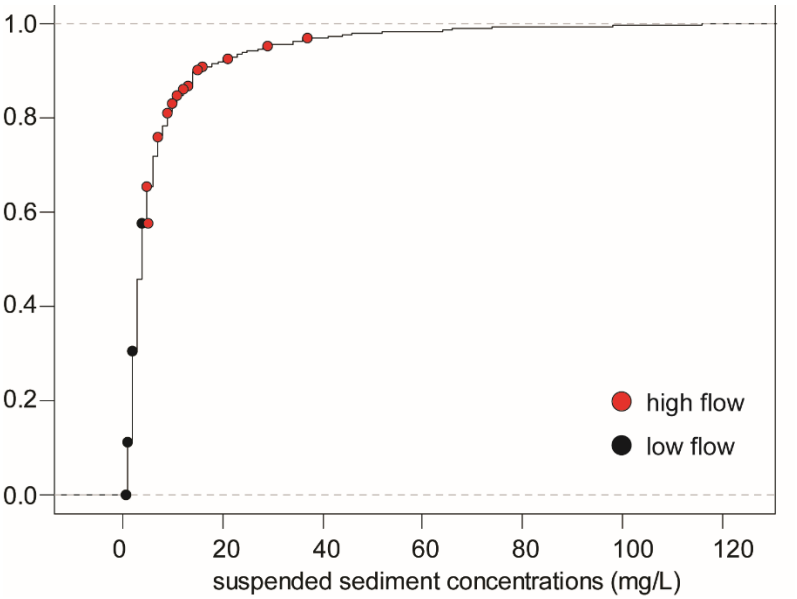

Figure 3: Empirical cumulative distribution function of suspended sediment concentrations in the Wenatchee River since 1978.

Sample location is near the site 45WR01.1 from the current study. Dots represent samples taken in this study.

SPMDs

Generally, SPMDs were recovered in good condition and remained submerged for the duration of deployment (Appendix C). An exception was at sample site 45CR468 during the March/April 2017 deployment. This location is heavily influenced by water level fluctuations driven by the dams on the Columbia River. The temperature loggers show periods when the air temperature logger was similar to the water temperature, suggesting the air logger was actually submerged. Furthermore, during retrieval the SPMD was found partially submerged in a location close to where it was deployed, suggesting that increased water levels had moved the anchor and buoy apparatus it was attached to. The results from SPMD 45CR468 should be interpreted cautiously.

Water concentrations estimated from the SPMDs during 2016 and 2017 deployments showed similar trends relative to suspected PCB sources in the Wenatchee River (Figure 4). Upstream background concentrations of PCBs were 28.2 pg/L during low flow and 41 pg/L during high flow. In the vicinity of the City of Cashmere, concentrations increased an order of magnitude above background, upstream of the Cotlets Way bridge. This occurred during low-flow and high- flow periods of sampling; however, concentrations were lower during high flow.

Unlike sampling events during 2014 and 2015, the concentrations of PCBs in water at low flow decreased from upstream (Cashmere) to downstream locations near the City of Wenatchee and the confluence with the Columbia River (Figure 4). However, new sample sites in 2017, collected during high flow, did show an increase in the PCB concentrations at the Columbia River (Figure 5).

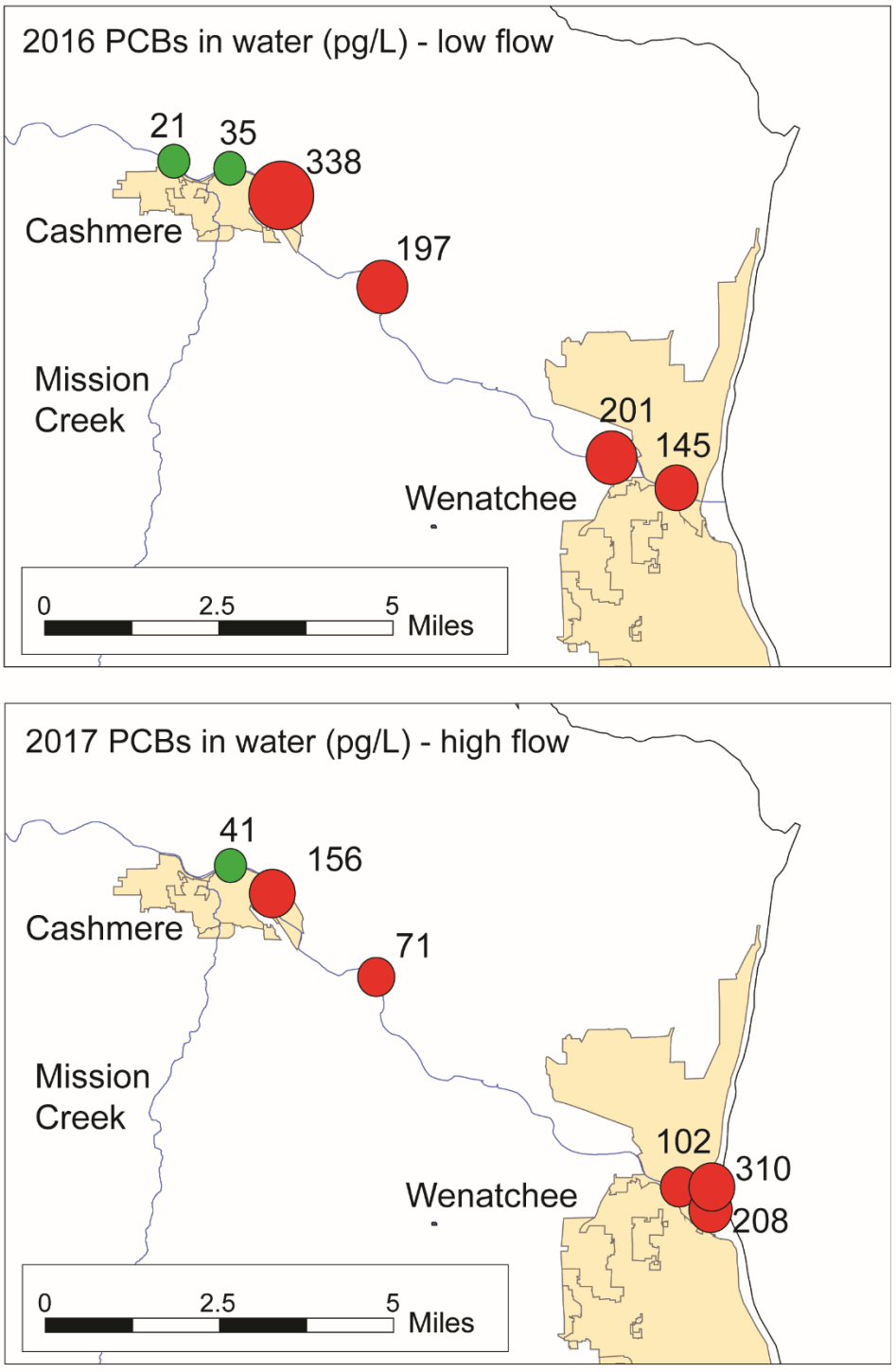

Figure 4: Estimated total PCB concentrations in water from SPMDs.

Green dots are not above the equipment background and red dots are scaled in size to the concentration. Concentrations are adjusted for blank contamination.

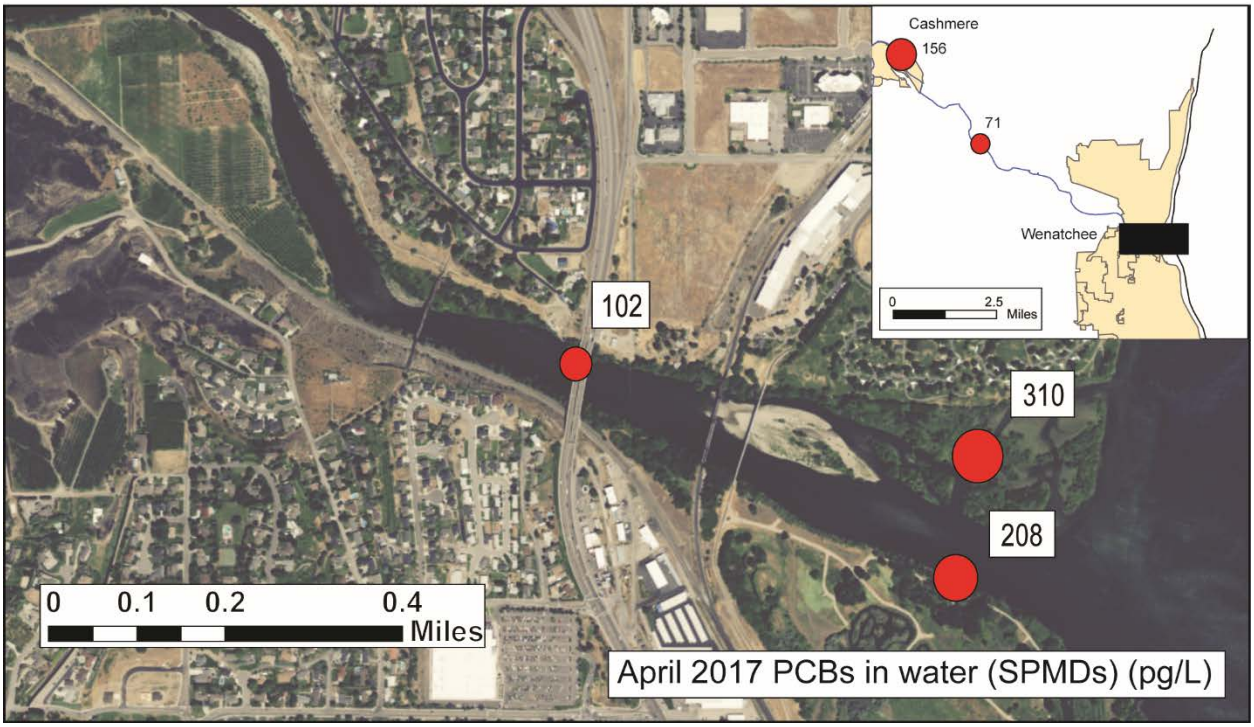

Figure 5: Detail of SPMD sites in 2017 near the confluence with the Columbia River.

In the previous sampling the congener profiles from the SPMDs were compared to the measured congener composition of the technical aroclor mixtures (Rushneck et al., 2004). Repeating the same multivariate analysis (principal components analysis) for the SPMD samples collected in 2016 and 2017, shows similar results to the previous sampling (Hobbs and Friese, 2016). In Figure 6, the closer the sample points are to the aroclor mixtures, the more similar they are. The grouping of samples is done subjectively. Samples collected at the downstream site, near the confluence resemble aroclor mixture 1248, while the upstream samples near the City of Cashmere resemble aroclor 1254. Also included in Figure 6 are the congener profiles that represent PCBs heavily influenced by microbial dechlorination from wastewater treatment plants and groundwater (Rodenburg et al., 2010; 2011; 2012; 2015). None of the SPMD samples from the Wenatchee River closely resemble these dechlorination profiles.

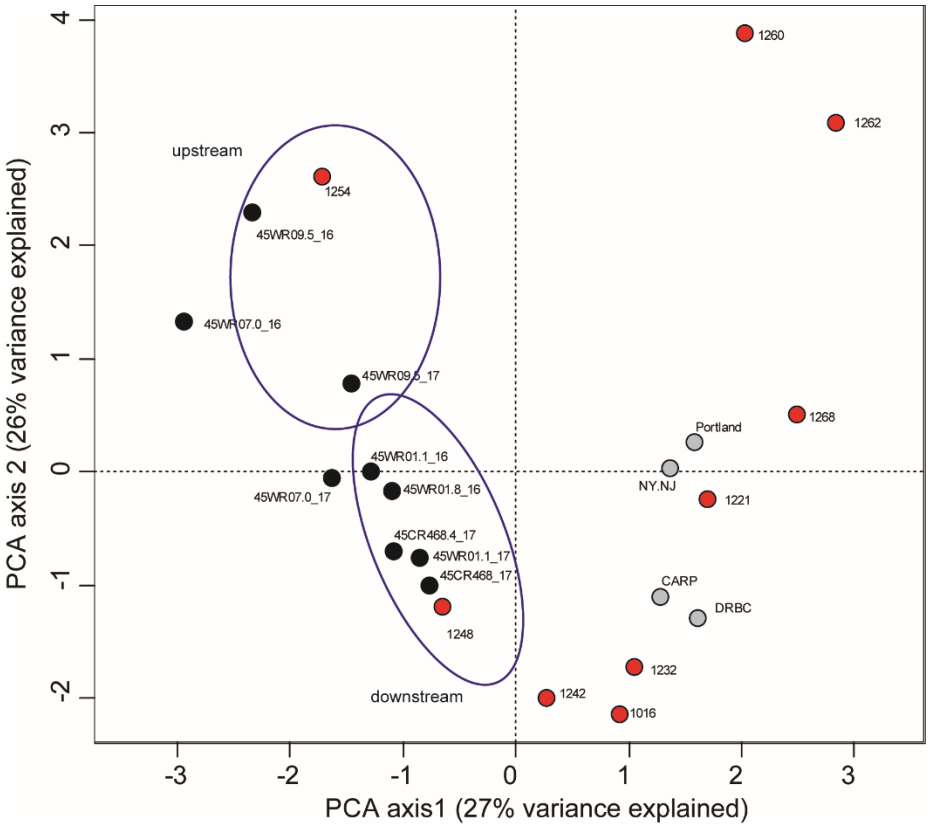

Figure 6: Principal components analysis (PCA) of the congener profiles for dissolved PCBs in water and aroclor mixtures.

Black dots are the SPMD samples; red dots are the aroclor mixtures (Rushneck et al., 2004); gray dots are congener profiles of known microbial dechlorination (Rodenburg et al., 2010; 2011; 2012; 2015); groupings represent upstream and downstream source areas.

Biofilms and Invertebrates

Results from this study further contributed to the highly significant relationship between total PCB concentrations in water and biofilms (Figure 7). As established in previous work, the total concentrations and congener distributions of PCBs in biofilms reflect the dissolved concentrations of PCBs in water (Hobbs and Friese, 2016).

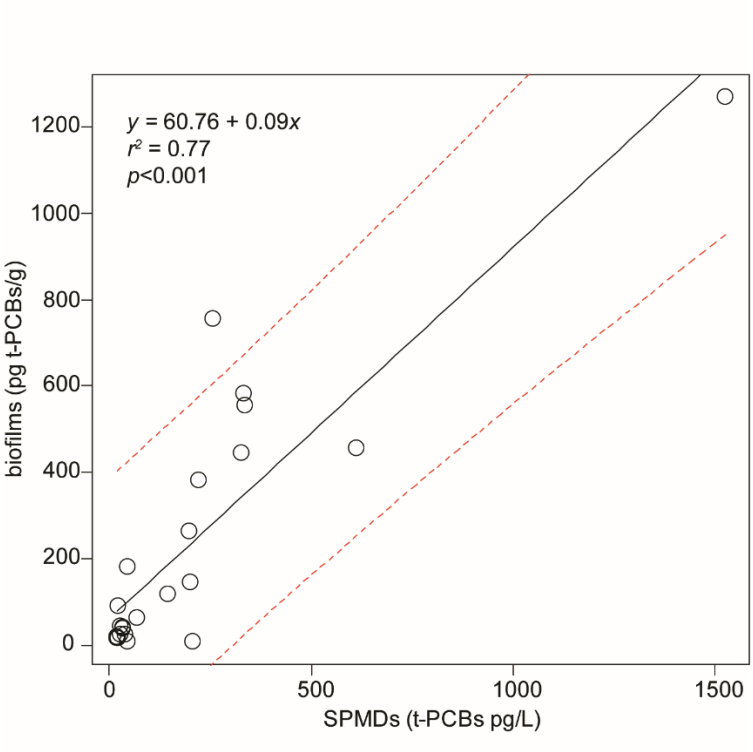

Figure 7: Linear relationship between PCBs in biofilms and dissolved water concentrations.

The stable isotopic ratios of N ($\delta^{15}N$) in the biofilms ranged from 6.74 to 8.92 ‰ during low-flow sampling and 3.88 to 4.39 ‰ during high-flow sampling (Table D-3). The stable C isotope ratio ($\delta^{13}C$) ranged from -15.37 to -13.15‰ during the low-flow period and -22.87 to -18.97‰ during the high-flow period.

Concentrations of PCBs in biofilms from background or upstream sites during the low-flow sampling (2016) averaged 20.2 pg/g. The site adjacent to Riverside Park in the City of Cashmere (formerly a landfill) showed an increase of an order of magnitude above the upstream background (Figure 8). Concentrations increased again further downstream near the Cotlets Way Bridge.

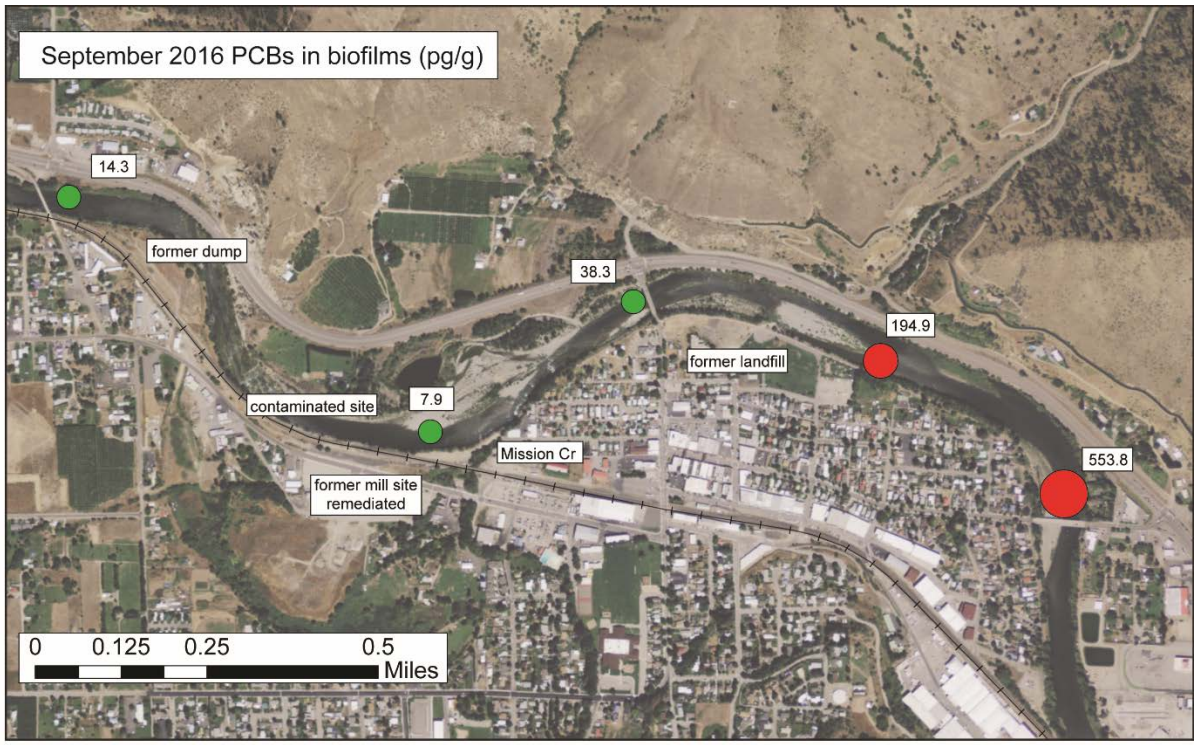

Figure 8: Detail of biofilm samples (2016) near the City of Cashmere.

Red dots are above background; green dots are background

The 2016 concentrations of PCBs in biofilms near the confluence of the Wenatchee and Columbia Rivers showed a very different trend than sampling in 2015. In 2016 there were no large differences in PCBs along the lower Wenatchee River (Figure 9). Concentrations were lower than the sites Riverside Park in the City of Cashmere and the Old Monitor Bridge, but remained above the upstream background concentrations.

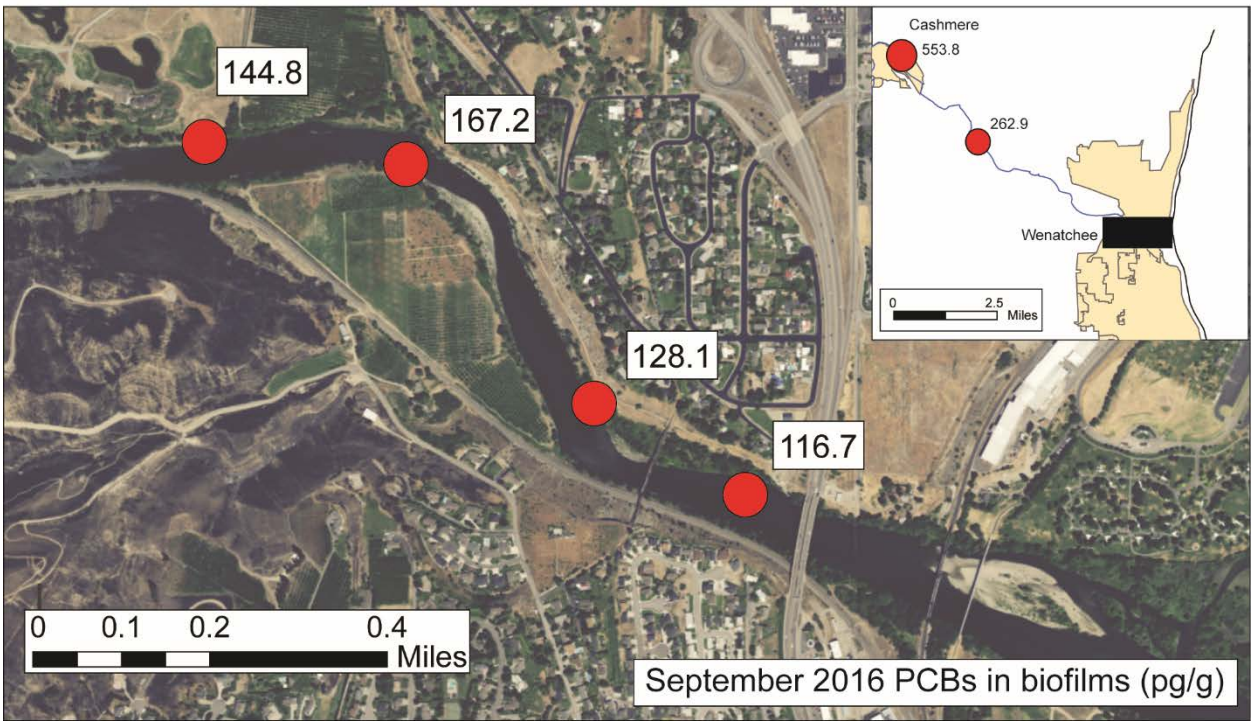

Figure 9: Detail of biofilm samples (2016) near the confluence with the Columbia River.

Red dots are above background; Inset detail shows upstream concentrations.

During the higher flow in April 2017, biofilm samples had much lower organic carbon due to the higher suspended material in the river and likely lower periphyton growth. Background concentrations of PCBs in biofilms were ~ 40 pg/g (Figure 10). Two additional sample locations were added during the April 2017 sampling to increase the frequency of samples adjacent to the city park. Concentrations were moderately low near the boat launch for the park (61 pg/g) and then increased at the downstream end of the park by an order of magnitude (492 pg/g). This is the same location where the initial increase was observed during low-flow sampling.

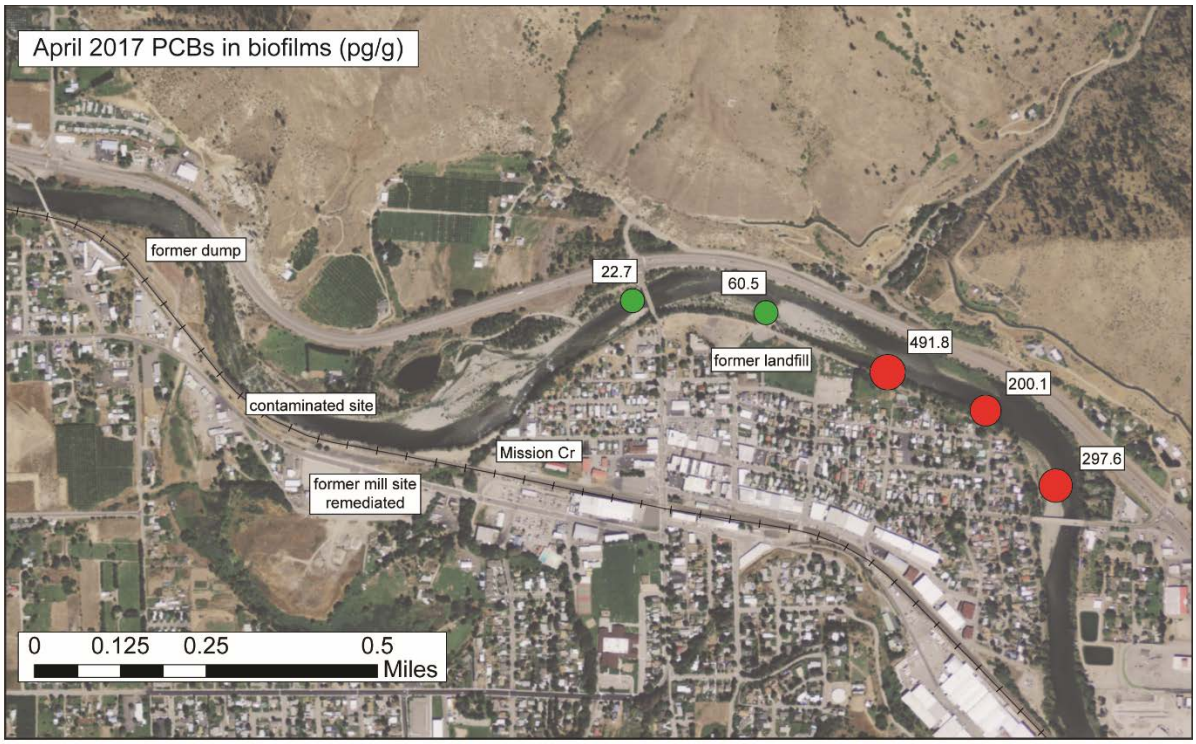

Figure 10: Detail of biofilm samples (2017) near the City of Cashmere.

Red dots are above background; green dots are background

During the higher flow period, there were few opportunities to collect biofilms due to habitat availability and site access. The furthest downstream site in the Wenatchee with no influence from Columbia River water had PCB concentrations above the upstream background, while the biofilm collected in the confluence was similar to background concentrations (Figure 11). The latter sample was very high in fines and low in OC and lipids, likely making it poor media for PCBs to bind to. It is also worth noting that the SPMD data contradict this low concentration of PCBs in the confluence area.

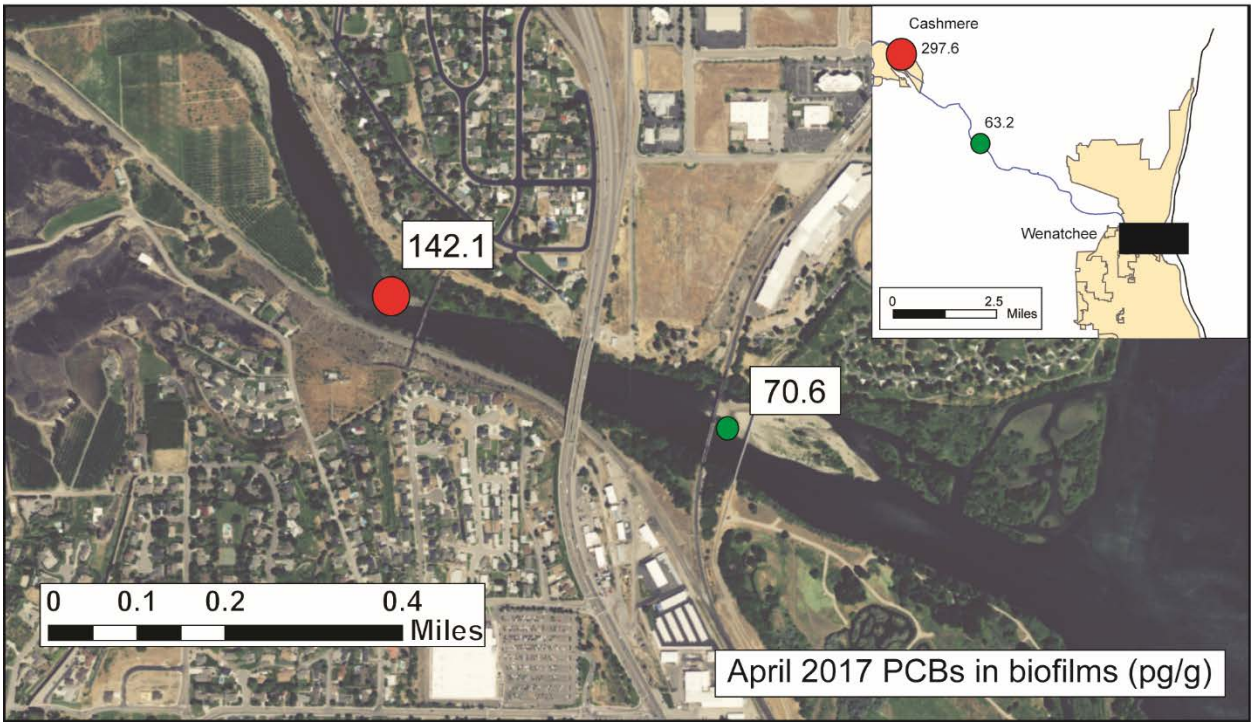

Figure 11: Detail of biofilm samples (2017) near the confluence with the Columbia River.

Red dots are above background; green dots are background; Inset detail shows upstream concentrations.

Similar to 2015, benthic macroinvertebrates that are the diet of the mountain whitefish (MWF) – caddis and mayflies – were picked in 2016 from one location in the lower Wenatchee near the confluence. In September 2015 the PCB concentrations in invertebrate tissues were 315 ng/g. In September 2016 the concentrations of duplicate samples (independent collections but approximately the same location) were 6.2 ng/g and 5.9 ng/g. The isotopic ratios of $\delta^{15}N$ and $\delta^{13}C$ are detailed in Table D-3.

Fish Tissue

Concentrations of PCBs in tissues of mountain whitefish (MWF) and largescale suckers (LSS) were analyzed in 2015/16 and 2016, respectively. Fillet composite samples and whole-fish were analyzed. Fillet composites were analyzed for PCB aroclors using EPA method 8082 similar to the previous work of Seiders et al. (2012a), making them directly comparable to the previous study. Whole fish samples were analyzed using HRMS for PCB congeners with EPA method 1668C. The stable isotopic ratios of N and C for the whole fish tissue samples are shown in Tables D-4 and D-5.

Fish tissue samples were last analyzed from the Wenatchee River using samples collected in 2010 and 2004 (Era-Miller, 2004; Seiders et al., 2012a). Generally the 2015 and 2016 samples were comparable to previous fish tissue samples (Figure 12). The vast majority of the recent samples are above the 75th percentile when compared to Ecology's dataset for PCBs in fish tissues statewide (n=788); with the exception of four MWF samples which were near the 50th percentile. The most recent collection of MWF tissues from the lower Wenatchee River included one composite fillet sample that has the highest measured PCB concentration statewide (3580 µg/kg).

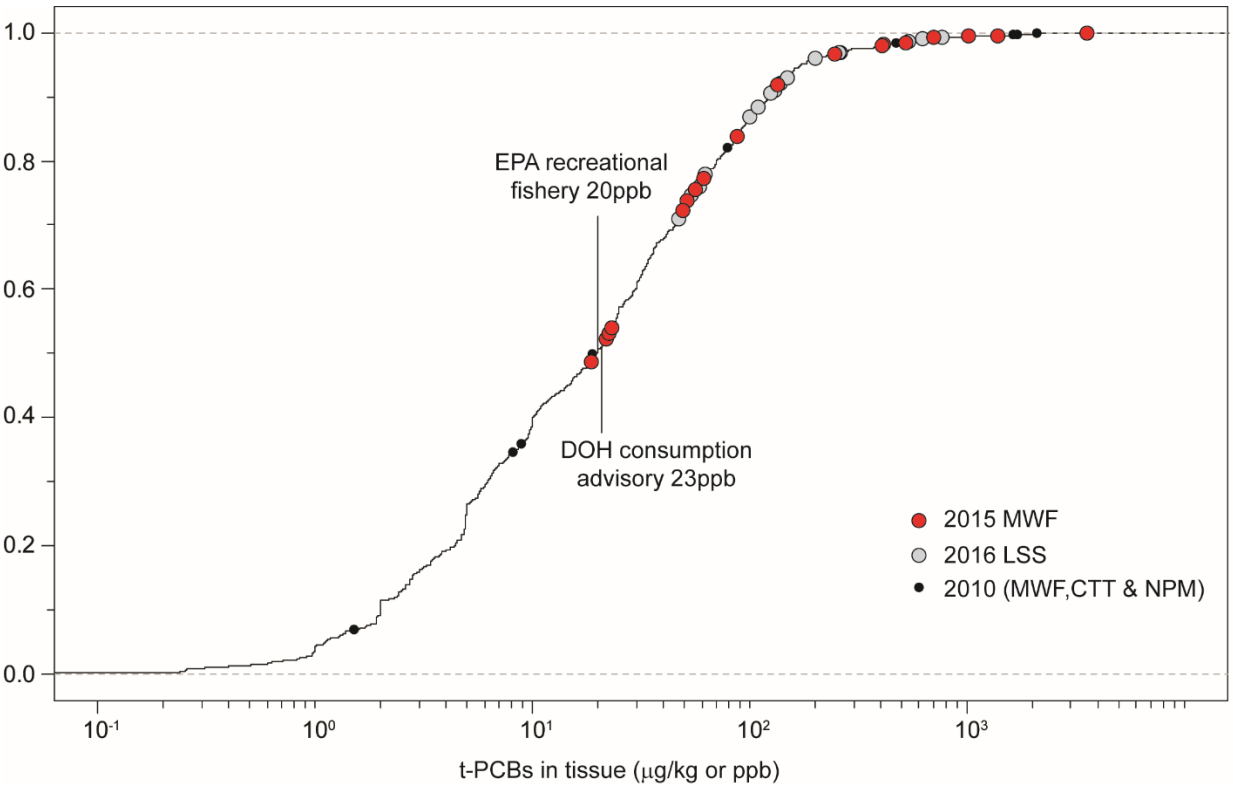

Figure 12: Empirical cumulative distribution function of PCBs in fish tissue in Washington State.

The black line is the concentrations of fish tissue statewide (n=788) (Seiders et al., 2015); red and gray dots are samples taken in 2015 and 2016, black dots were samples in the Wenatchee River from Seiders et al., 2012; y-axis is the percentile of the concentration and the x-axis is the PCB concentration on a logarithmic scale. DOH = Washington State Department of Health.

There are no human health criteria for fish tissue in Washington State, rather contaminant thresholds or screening levels for consumption of fish tissue are derived by Washington State Department of Health (DOH) toxicologists using human health risk models. Screening levels for fish tissues used by DOH and the Environmental Protection Agency (EPA) are highlighted on Figure 12. In general, the vast majority of fish collected from the Wenatchee River continue to be above screening levels for the protection of human health from consumption of tissue.

Whole fish tissue samples were analyzed for PCB congeners which allows us to compare the congener distribution or profile among the individuals. As a means to consider all fish tissue samples at the same time a principal components analysis was completed to observe the similarities in the congener profiles (Figure 13). MWF samples were collected at an upstream location near Leavenworth and a downstream location near the confluence with the Columbia River. The different sample locations are generally reflected in the PCB profile of the fish. LSS samples were collected only in the downstream location and their PCB profile generally reflects this. Lastly, total PCB concentrations are higher in the fish with a PCB profile indicative of the downstream area.

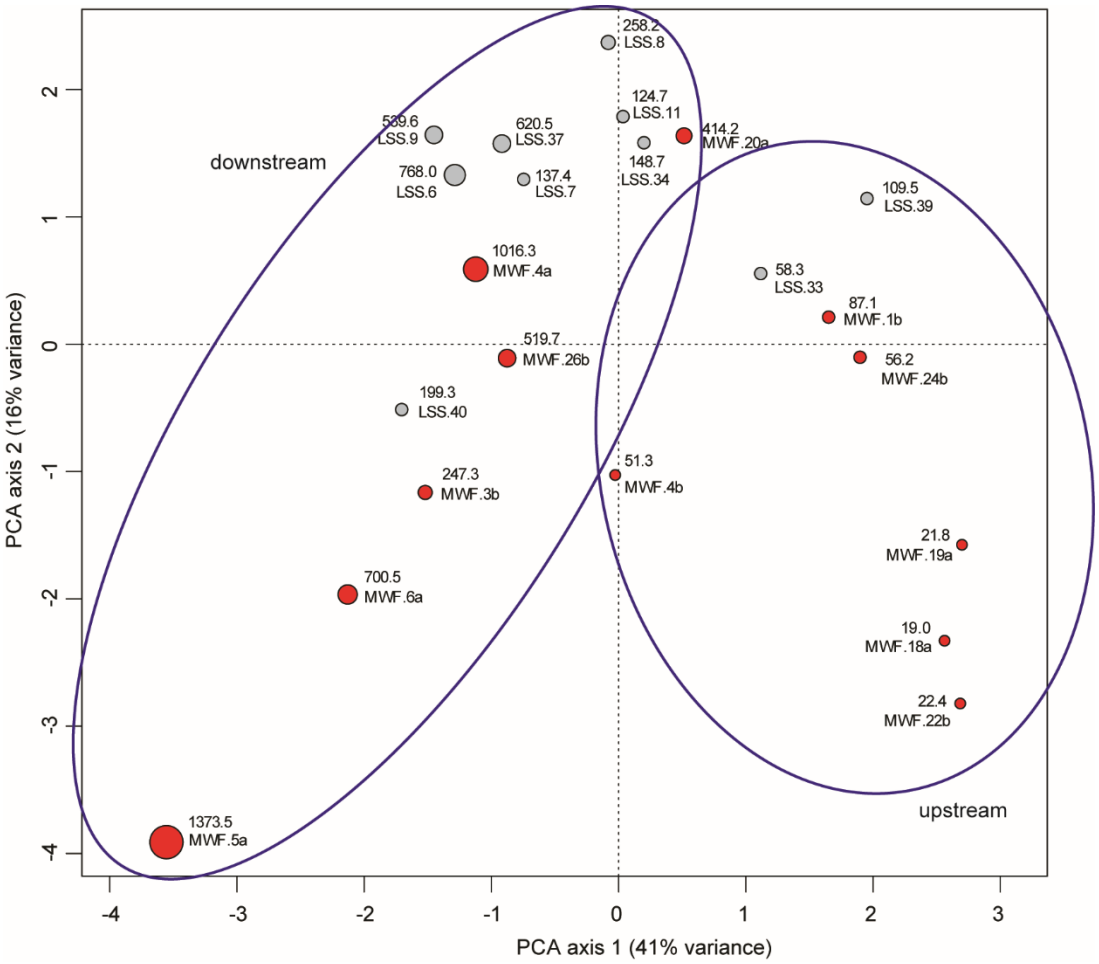

Figure 13: Principal components analysis (PCA) of the congener profiles for fish tissues.

Red dots are MWF samples; gray dots are LSS samples; the size of the dot is scaled to the total PCB concentration, which is shown in parts per billion (ppb) above the sample ID; the groupings are based on the congener profile of upstream and downstream source areas.

The MWF from downstream sites have a congener profile with a greater proportion of lighter weight (less chlorination) PCBs (Figure 14). The congener profiles are distinct enough between upstream and downstream sources that it's possible to identify fish caught in one location, but having a PCB profile that suggests it was actually residing near the other location. For example, MWF26b was caught near Leavenworth, but has a PCB profile more similar to the downstream fish, suggesting that PCBs were accumulated in this location; the opposite is true for MWF1b (Figure 13).

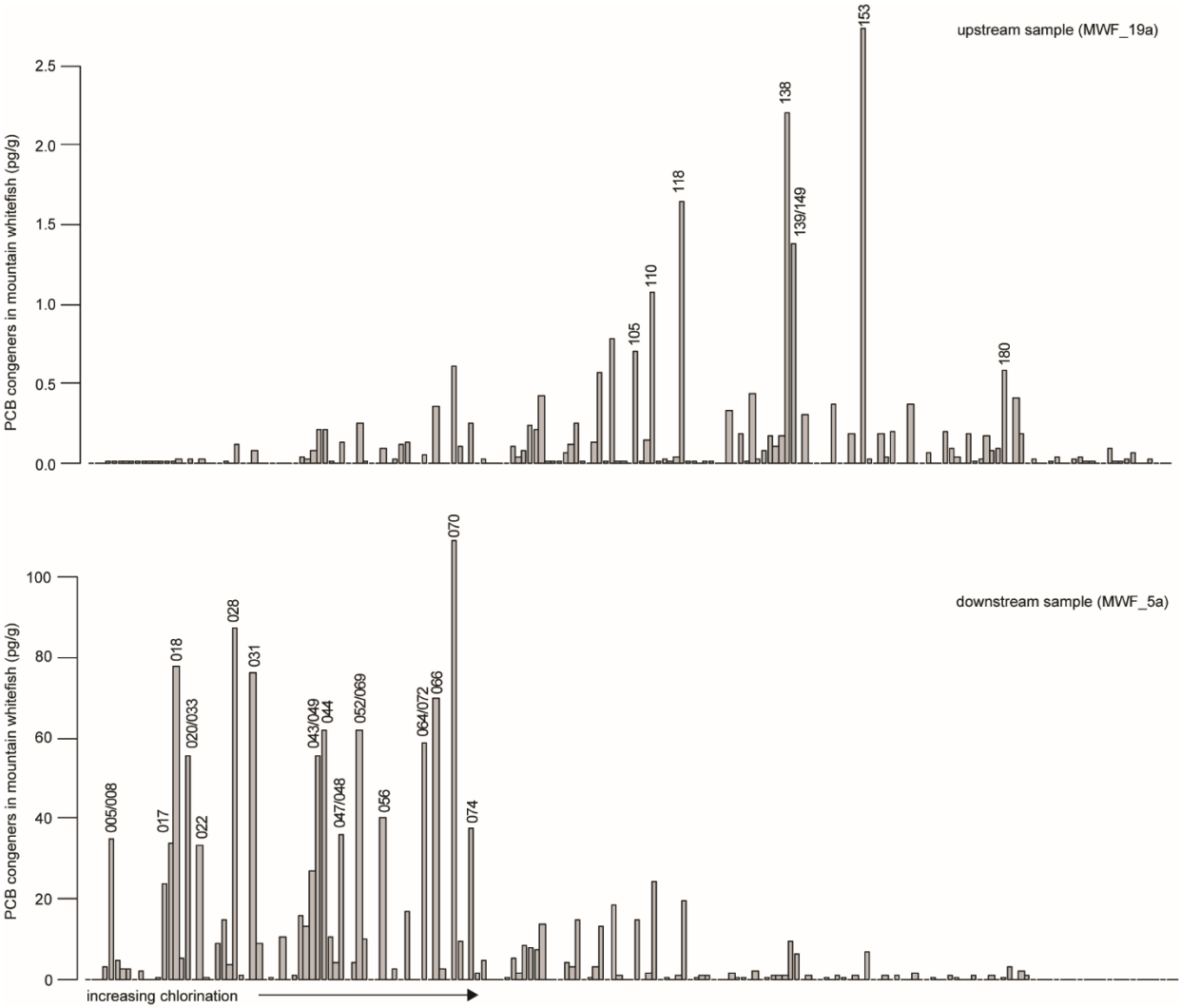

Figure 14: PCB congener profile of 3-year old MWF tissue at two locations.

The upper profile is from the upstream source near the City of Cashmere; the lower profile is from the downstream source near the confluence with the Columbia River; both fish are 3 years old.

Using the distinct PCB profiles for the two sources it becomes clear that the fish with a profile indicative of the downstream source have higher total PCB concentrations (Figure 15). Among the 209 potential PCB congeners present in the tissues there are a group of congeners that have a similar structure to polychlorinated dibenzodioxins (dioxins). Because dioxins have well-known toxicities, these 12 PCB congeners that are similar in structure are often seen as the most toxic (Ahlborg et al., 1994; Bhavsar et al., 2007). In the MWF tissue samples from the downstream location there is a greater mass of dioxin-like PCBs compared to the upstream source (Figure 15). However, the total PCB concentrations at the upstream location generally have a similar proportion of dioxin-like PCBs. The maximum proportion of dioxin-like PCBs is found in MWF20a with 27%, mainly PCB-118 (15% of the total PCBs).

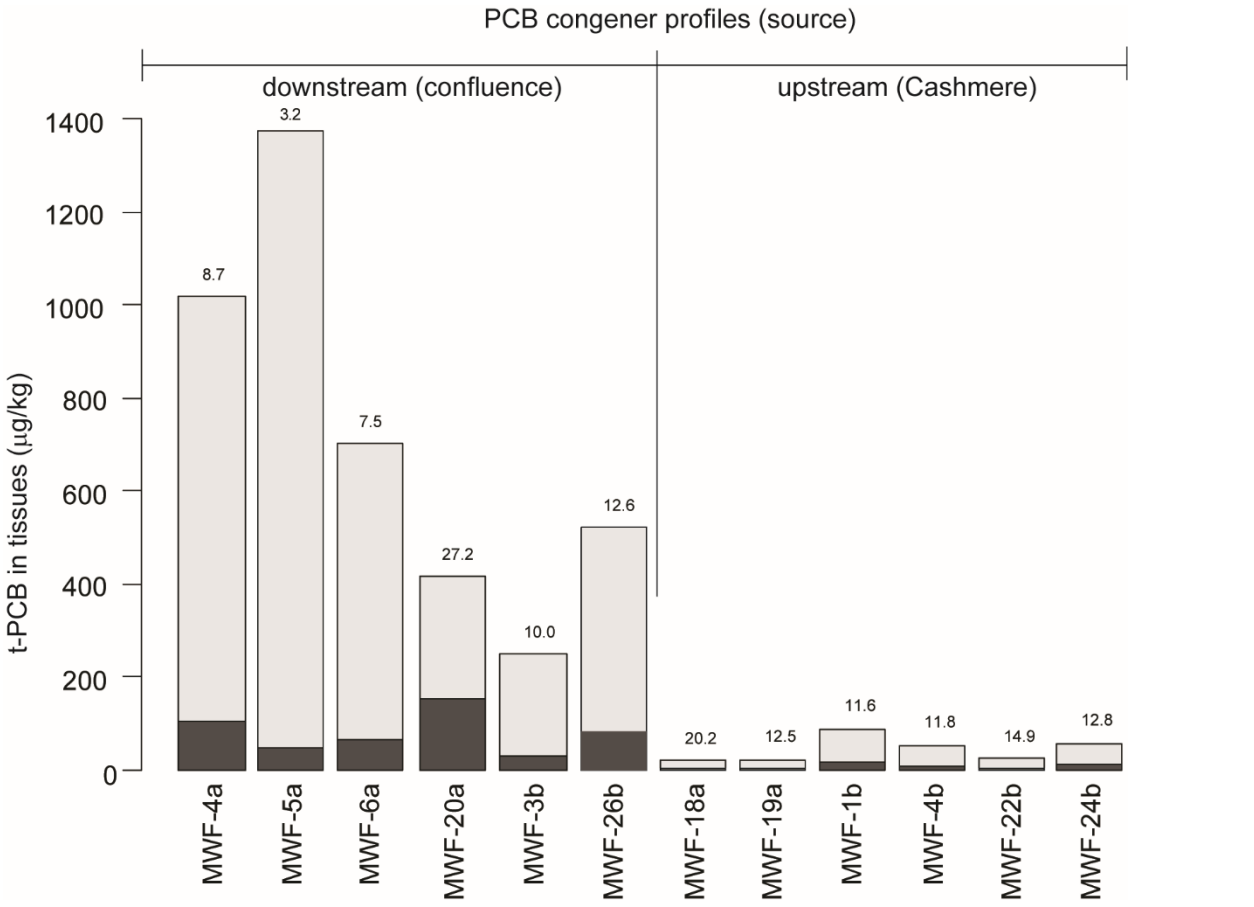

Figure 15: Total PCBs for whole fish (MWF) from both sources in the Wenatchee River.

Light gray bars are the total PCBs, dark gray bars are the total dioxin-like PCBs; the percent of dioxin-like congeners of the total are shown above the bars.

The LSS samples generally have a PCB profile that reflects the downstream location they were collected in; however, there are two notable exceptions, LSS33 and LSS39 (Figure 13). The congener profile for these fish contain a larger proportion of heavier (more chlorinated) congeners, similar to the MWF from the upstream location (Figure 16). Therefore, the PCB profile for LSS33 and LSS39 suggests they spent more time accumulating PCBs upstream of the confluence.

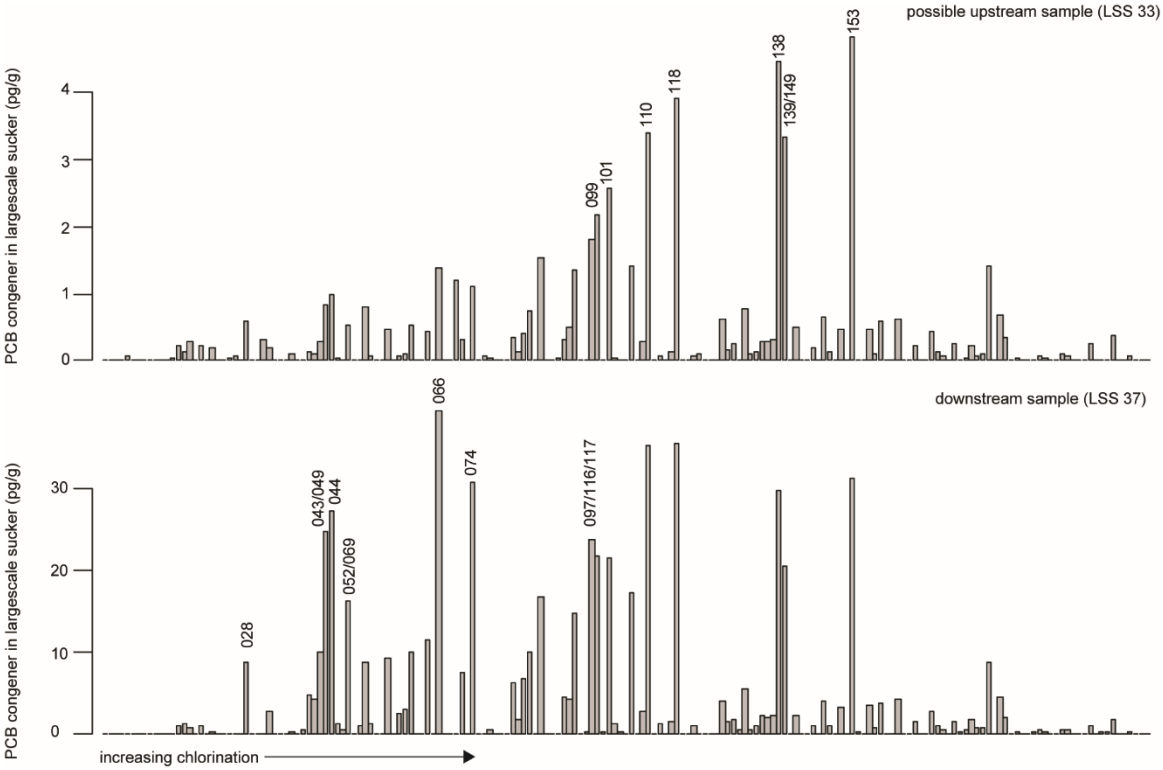

Figure 16: PCB congener profile of LSS tissue.

The upper profile is thought to be from the upstream source near the City of Cashmere; the lower profile is from the downstream source near the confluence with the Columbia River; both fish are 12 years old and have a lipid content of 1.8%.

The proportion of dioxin-like PCBs in the LSS samples were generally similar to the MWF fish at the downstream (confluence) source (Figure 17). The proportion was also similar in the fish with a congener profile that suggests they spent more time feeding upstream of the confluence source (LSS 33 and LSS39). The proportion of total dioxin-like PCBs in LSS was fairly consistent among the fish with a mean of 10.7% (± 1.2% standard deviation).

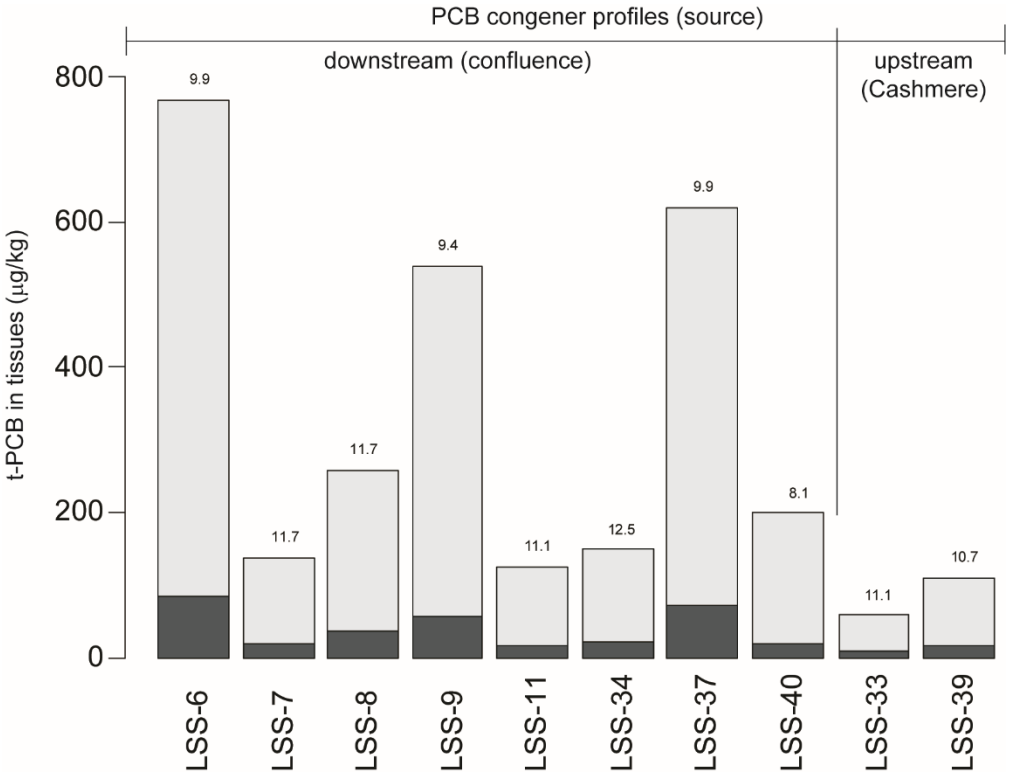

Figure 17: Total PCBs for whole fish (LSS) from both sources in the Wenatchee River.

Light gray bars are the total PCBs, dark gray bars are the total dioxin-like PCBs; the percent of dioxin-like congeners of the total are shown above the bars.

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Discussion

PCB Sources

The 2016 and 2017 sampling of the suspected PCB source areas provided further confirmation that there are indeed two different PCB sources to the Wenatchee River. The different congener profiles of the two PCB sources are evident in the water, biofilms, and fish tissue sampled during 2016 and 2017.

Cashmere source

Looking at the congener profile in water from the suspected source near the City of Cashmere shows a consistent profile over time (station 45WR09.5; Figure 18). The consistency in the profile over periods of low flow and high flow also suggests there is an ongoing source to the river that is not controlled by stormwater or runoff, which influence periods of high flow. Groundwater is a possible pathway for this PCB source into the river that deserves further investigation.

As shown previously in the multivariate analysis of PCB congeners from this area (Figure 6), the profile resembles aroclor 1254. A number of congeners and co-elutions dominate the PCB congener profile, mainly PCB-52, PCB-61/70/74/76, PCB-90/101/113, PCB-110/115, PCB-118 (Figure 18). These congeners have not been highlighted in other studies as products of microbial dechlorination (Imamoglu et al., 2004; Rodenburg et al., 2015).

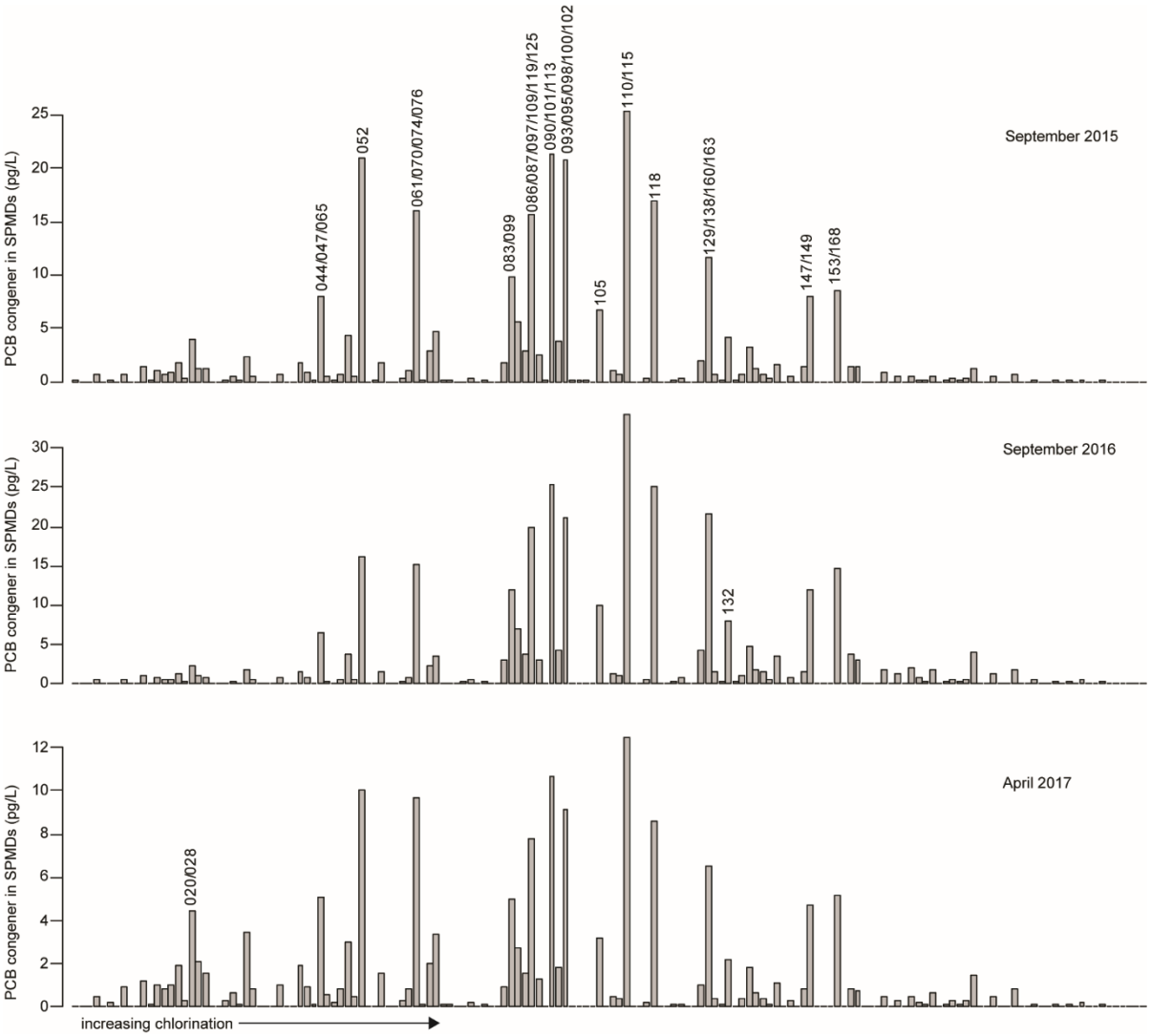

Figure 18: Congener profile of dissolved PCBs from SPMDs over time at the upstream source (45WR09.5).

The PCB congener number is listed above the dominant congeners in the upper profile, only new congeners are labeled in the middle and bottom profiles; the "upstream source" is near the City of Cashmere.

Of concern in the congener composition of the PCB source are the dioxin-like congeners PCB-105 and PCB-118. Bhavsar et al. (2007) noted that these congeners (PCB-105 and -118) are typically the most common of the dioxin-like found in fish tissue (n=912), with a median of 1.3% and 4.3% of the total PCBs, respectively. In the MWF samples from the upstream source there is a mean of 3.7% (PCB-105) and 8.3% (PCB-118), double the finding from Bhavsar et al., (2007). The dioxin-like congeners seem to make up a fairly consistent proportion of the total PCBs, regardless of source areas.

The location of the upstream source near the City of Cashmere has been isolated to between the approximate river miles 9.7 and 9.9, along the right bank of the river adjacent to the downstream end of Riverside Park in the City of Cashmere. Riverside Park was constructed on a former landfill which would be a logical starting point for further investigations into upland sources. It would be particularly useful to discern whether groundwater monitoring wells exist in this area.

Confluence source

Similar to the upstream source, the downstream PCB source near the confluence with the Columbia River has shown consistent congener profiles in water over time during both low- and high-flow sample periods (Figure 19). This congener profile is dominated by many lighter or less chlorinated congeners and resembles the aroclor 1248 mixture. Unlike the upstream source, there is a presence of congeners that suggest dechlorination is occurring; PCB-4 and PCB-44/47/65. Dechlorination from groundwater or river sediments has been observed in the lower Columbia River (Rodenburg et al., 2015) and other contaminated sites in the US (Imamoglu et al., 2004). The dechlorination process is likely occurring in an anaerobic environment within the sediments or groundwater, altering the PCB congener profile of the contamination to the river. The congener profiles also show the presence of the upstream PCB source.

The proportion of the dioxin-like PCBs in the samples from the downstream source are consistent with the upstream source. PCB 105 and PCB-118 are the dominant dioxin-like congeners, accounting for 3.0% and 6.3% of the total PCB mass.

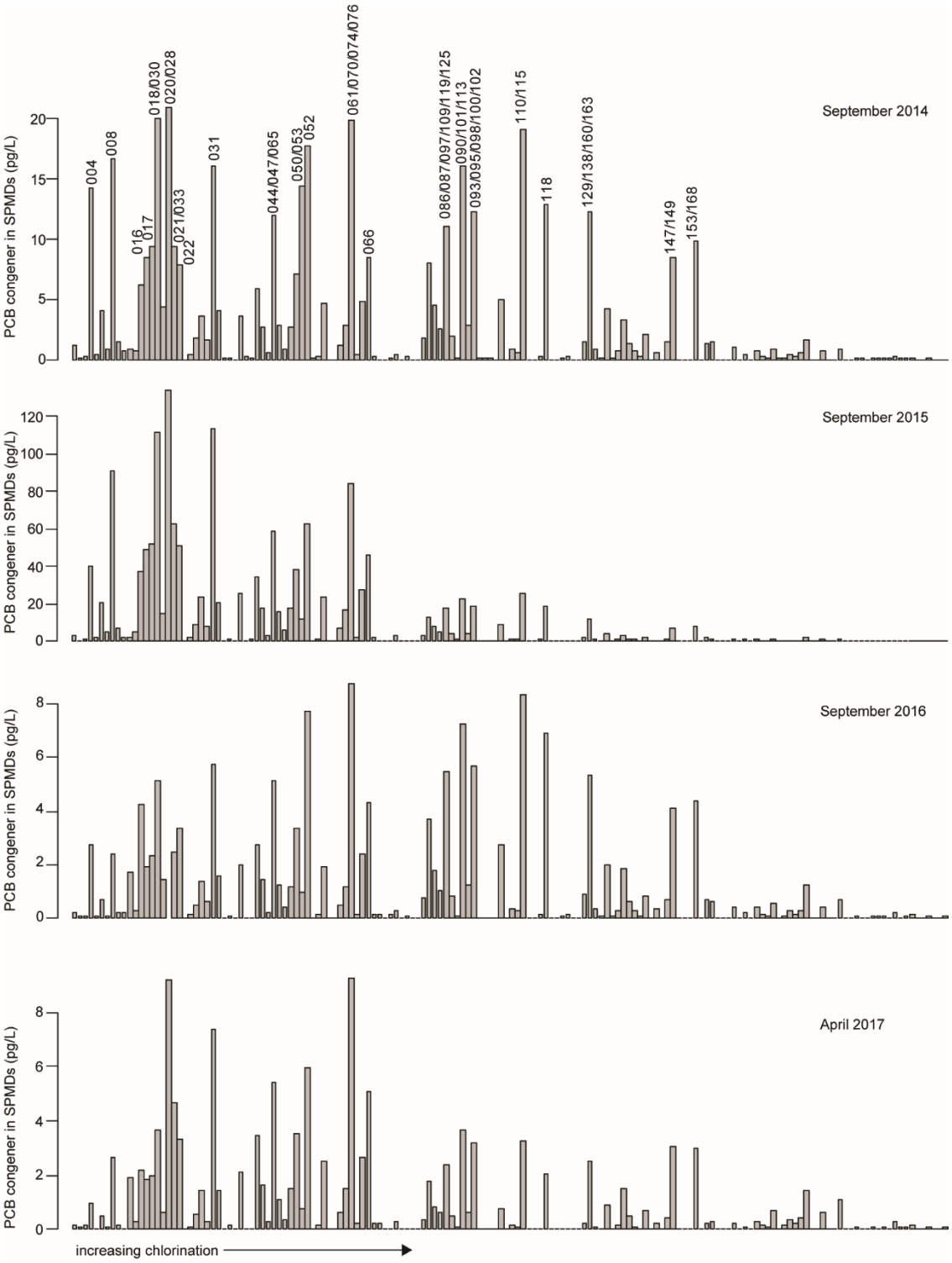

Figure 19: Congener profile of dissolved PCBs from SPMDs over time at the downstream source.

The IUPAC PCB number is listed above the dominant congeners in the upper profile, only new congeners are labeled in the remaining profiles; the "downstream source" is near the confluence with the Columbia River.

In the previous study by Hobbs and Friese (2016), the PCB source near the confluence was thought to be outside the influence of Columbia River water, which flows into the confluence area with the Wenatchee River (Figure 20) (Carroll et al., 2006). The 2016 and 2017 sampling, showed that in fact the water from the Columbia River is indeed influencing this PCB source area. PCB concentrations of the biofilm samples collected in 2016 and 2017 did not vary in the lower section of the Wenatchee River, then in 2017 the SPMDs showed that PCBs in water were higher closer to the Columbia River (Figure 20).

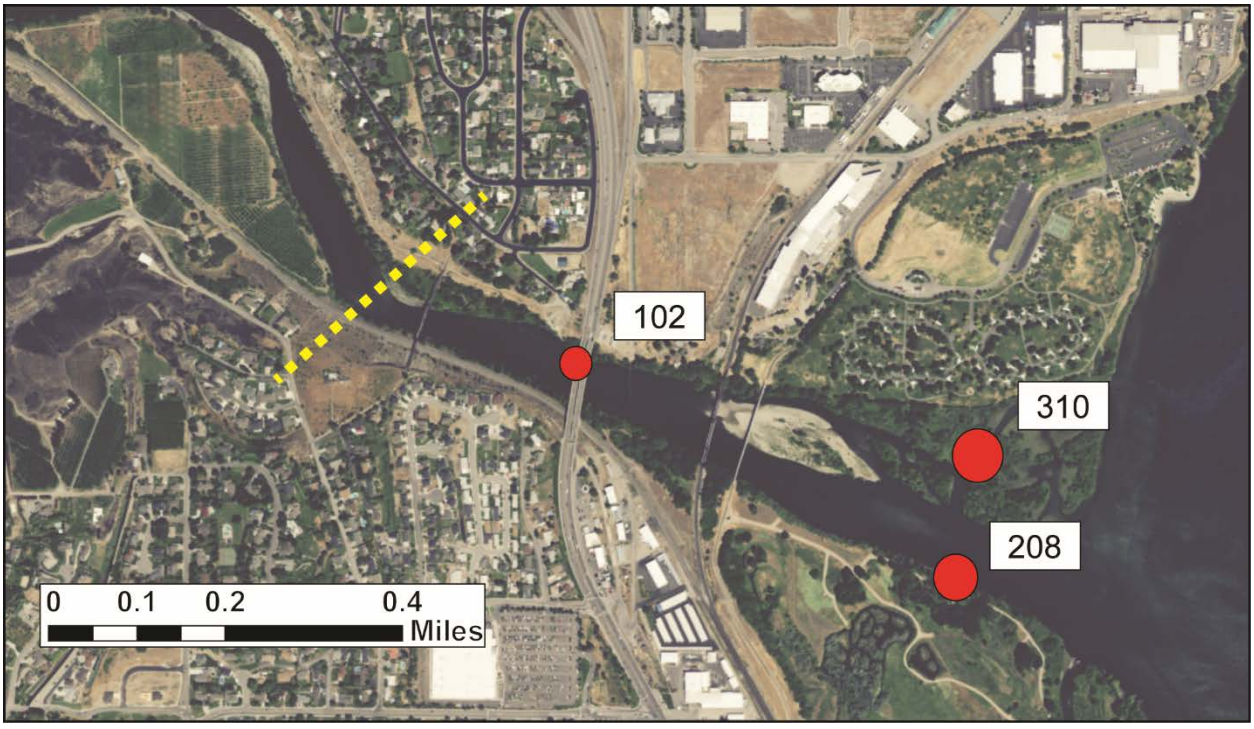

Figure 20: Detail of extent of Columbia River water influence into the lower Wenatchee River.

Dashed yellow line represents the extent of influence from Columbia River water (Carroll et al., 2006); red dots are the SPMD sites in 2017.

The highest concentrations of PCBs in water, biofilms and invertebrate tissues that we have measured in this source area was during 2015, when the discharge of the Wenatchee River was near record lows. During this time PCB concentrations were one to two orders of magnitude higher in water, biofilms and invertebrate tissues. It is likely that there was a greater influence of the Columbia River water simply because there was less water flowing down the Wenatchee River. Indeed the lighter congeners present in the 2015 sample have much higher concentrations compared to the heavier congeners which are more representative of the upstream source.

PCB concentrations of the sediments in the confluence area were measured on one sample during 2015. Measurable concentrations of PCBs were found, but not above the freshwater sediment management standards (WAC 173-204). Given the results in 2016 and 2017, further investigation of the sediments and water in the backwater areas at the confluence would help determine if this area is the PCB source.

PCB Loading

During the 2014 sampling using SPMDs, a few of the sites were situated in concert with gauging stations which allows us to calculate a PCB load[1] at points in the river. Follow-up investigations that have focused on the lower Wenatchee River only have one USGS gauging station that can be used to calculate PCB load. The station at the Old Monitor Bridge (USGS 12462500) is located just upstream of the town of Monitor. The loads calculated at this station do not account for the PCB source downstream near the confluence.

PCB loads from 2014 through 2017 at the Old Monitor station have varied by ~ 300 mg/day (Figure 21). The highest load was calculated for the high-flow period in April 2017. The lowest load was for the low-flow period in 2015. Load calculations are largely driven by the discharge at the time of sampling.

While load calculations are a nice standardized way to assess contributions of contaminants under different flow regimes in different locations, they do not account for exposure concentrations of bioaccumulative toxics at the base of the food web. For instance, the concentrations measured in the biofilms at the Old Monitor station, at the same time as the water concentrations used in the PCB load, show a very different trend (Figure 21). The highest concentrations in the biofilms were measured during the 2015 low-flow period. Given that the biofilms are the base of the food web in the river, these high concentrations in 2015 have the greatest potential to lead to higher PCB accumulation in the fish of the river.

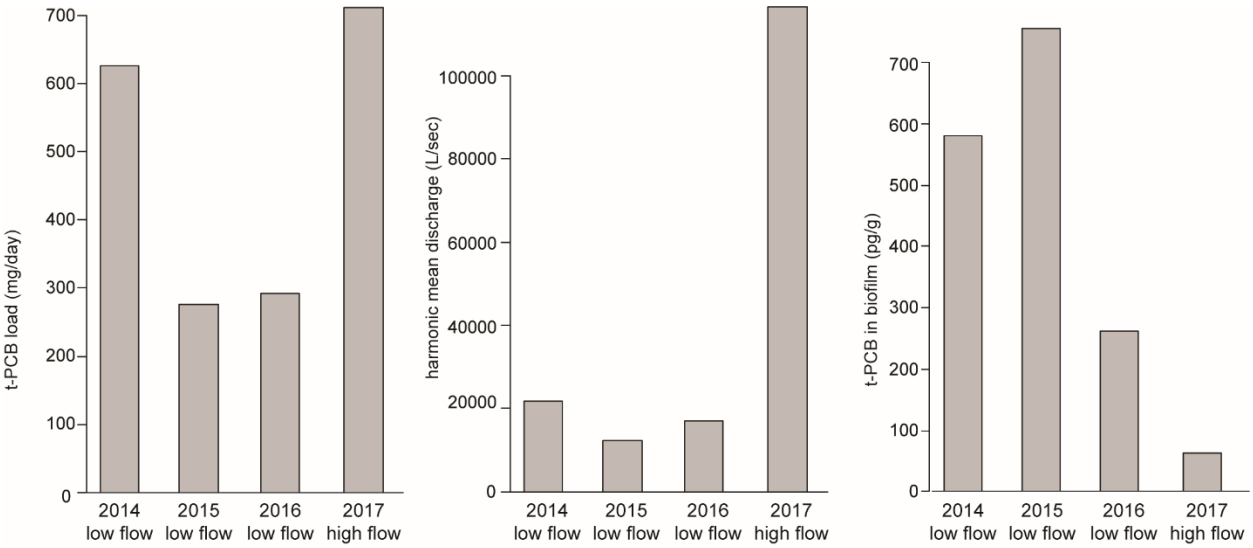

Figure 21: Bar plots of PCB load, discharge and PCB in biofilms over time at the Monitor gauging station.

(left) PCB load at the Old Monitor gauging station (USGS 12462500); (middle) harmonic mean discharge for the period of SPMD deployment at the Old Monitor station; (right) PCB burden in biofilms at the Old Monitor station.

[1] The load is PCB concentration in water (pg/L) x the harmonic mean discharge (L/s) x a unit conversion

Wenatchee Food Web

In the previous study of the Wenatchee River (Hobbs and Friese, 2016) the stomach contents of MWF were examined to confirm the suspected diet of caddis flies and mayflies, and the occasional midge larvae. In this study LSS were collected and a similar investigation of the intestinal contents was conducted. Dauble (1986) has reported on LSS diets from the Columbia River and shown that mature adults consume largely periphyton and some benthic invertebrates (mainly midge larvae). The analysis of intestines from 10 individuals, confirmed a diet of biofilms (periphyton) and the occasional benthic invertebrate (caddis fly or midge larvae).

Stable isotopes and trophic position

In the previous work of Hobbs and Friese (2016), the isotopic ratios of carbon (C) and nitrogen (N) were useful in inferring the general structure of the food web in the lower Wenatchee River (Figure 22). Generally, the N isotopic ratio will increase by ~ 3.4 ‰ with each trophic level, due to the excretion of the lighter isotope, ^{14}N, over time (Cabana and Rasmussen, 1996; Post, 2002).

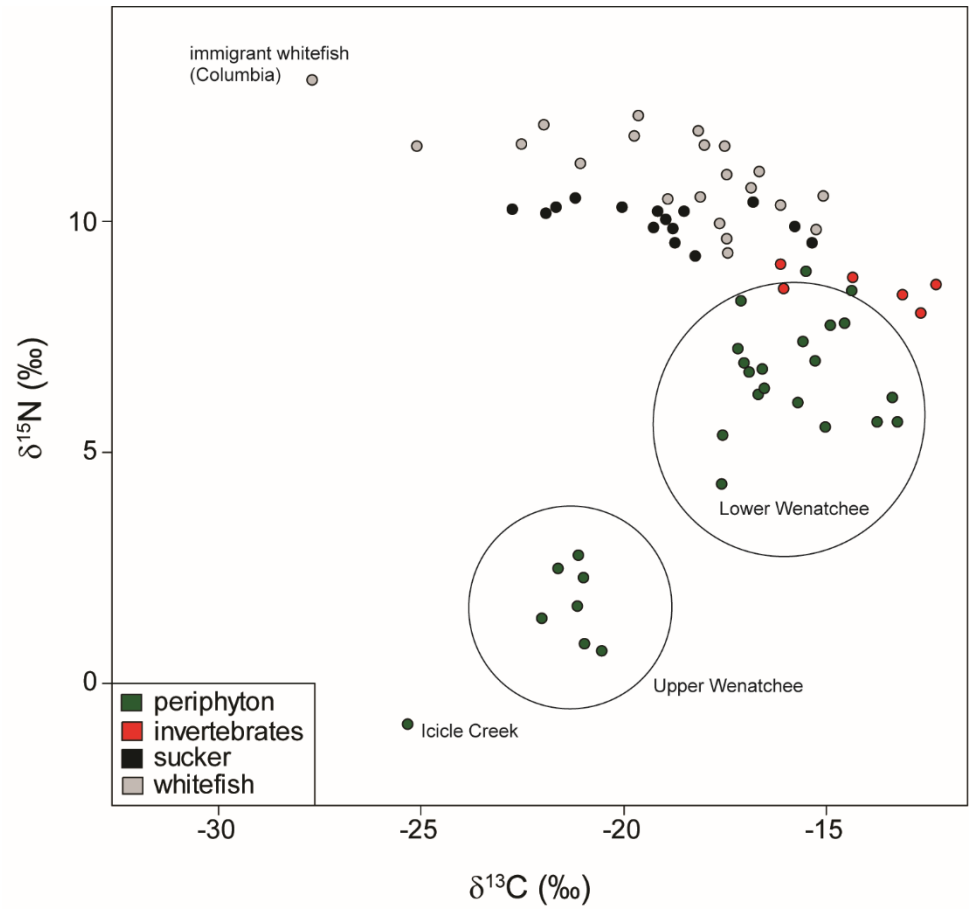

Figure 22: Isotope biplot of the Wenatchee River food web.

Stable N and C isotope ratios of biofilms (green), invertebrates (red), LSS (black), and MWF (gray) tissues; geographical groupings of the biofilms are shown; suspected immigrant MWF from the Columbia River are highlighted.

We now have a decent understanding of the food web in the lower Wenatchee River that is relevant to MWF and LSS. Biofilms (periphyton) occupy the base of the food web and are consumed by caddis flies and mayflies which are collector-filterers, meaning they filter material out of the overlying water and graze on biofilm and periphyton such as diatoms. Biofilms are also directly consumed by LSS, which places them at a trophic level between invertebrates and MWF. The MWF feed exclusively on benthic invertebrates and occupy the top of the food web in the lower Wenatchee River.

Stable isotopes and fish migration

The isotopic ratios of carbon (C) and nitrogen (N) were also useful for inferring the general range of the MWF (Figure 23); where a heavier N isotope was more indicative of a downstream range or location (Hobbs and Friese, 2016). This is due to the lower trophic levels of the food web (i.e. the diet of the fish) having a heavier N isotope ratio from differences in N inputs to the river downstream (Figure 22). Pastor et al. (2013) have shown how the N-isotope ratios of periphyton accurately reflect changes in the primary N source. In the lower Wenatchee River both the LSS and MWF do not appear to migrate into the upper Wenatchee (up Tumwater Canyon) to feed. This observation is based on the ~3‰ enrichment in N isotopes of the organisms from the biofilms in the lower Wenatchee River, not the upper Wenatchee River (Figure 22).

The MWF in the Wenatchee River are key organism in the food web because there is a consumption advisory due to PCBs in the tissues. The multivariate analysis based on PCB congener profiles in MWF tissues presented earlier (Figure 13), suggests that it is possible to decipher where an individual MWF has accumulated PCBs based on the chemical signature of the tissues. Plotting the isotopic ratios of the MWF gives a similar indication of where the individuals have been feeding (Figure 23). In general, the MWF that are more enriched in N-isotopes are feeding near the confluence with the Columbia River. The chemical signatures also allow us to decipher when an individual was caught in one location, but appears to be feeding in another location. For example, MWF-26b was caught upstream near Leavenworth but has a PCB profile and isotopic signature that would suggest it was predominantly feeding at the downstream location.

Two individuals do not fit the interpretations of the chemical signatures (MWF-1b and MWF-24b). These fish have PCB congener profiles that suggest they were feeding near the upstream location, but an isotopic signature that would suggest a different location. It is possible that these individuals were migrating to other locations in the river or tributaries (e.g. Icicle Cr.), or spending most of their time in the Columbia River upstream of the confluence with the Wenatchee River.

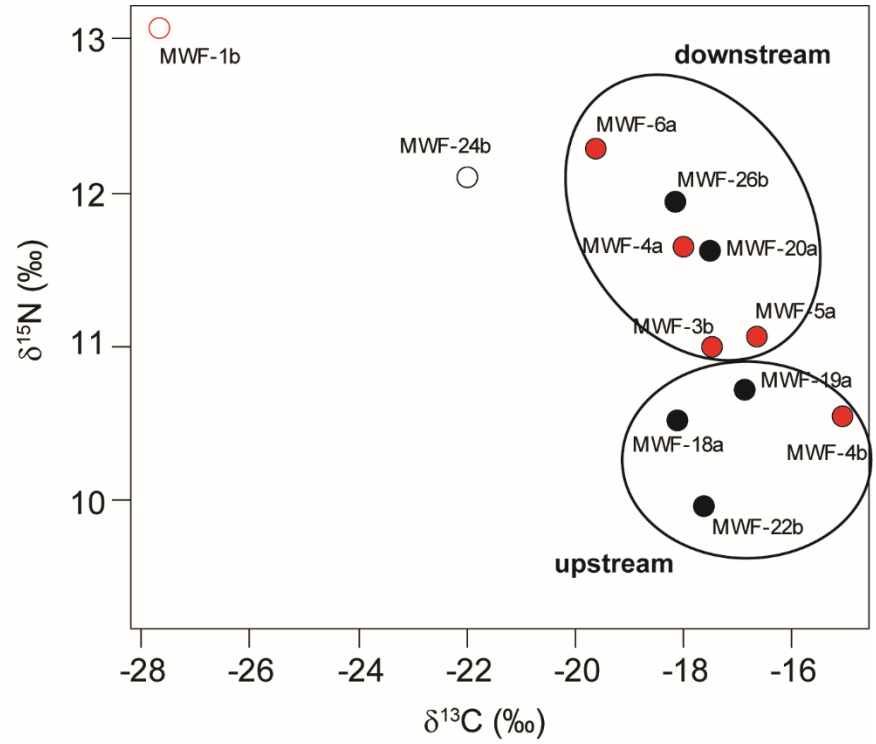

Figure 23: Isotope biplot of individual mountain whitefish tissues.

Stable N and C isotope ratios of MWF tissues collected from near the confluence (red dots) and upstream near Leavenworth (black dots); groupings are based on similarities of PCB profile; the unfilled dots do not fit the chemical signature of the others.

PCB Bioaccumulation

It appears that the bioaccumulation of PCBs in the Wenatchee River is taking place mainly downstream of the City of Cashmere to the confluence with the Columbia River. The downstream source area near the confluence is likely contributing a greater amount of PCBs to the MWF in the Wenatchee River. MWF and LSS with chemical signatures that indicate feeding is taking place in the downstream location, have higher total PCB burdens in the tissues (Figure 24), although not statistically higher.

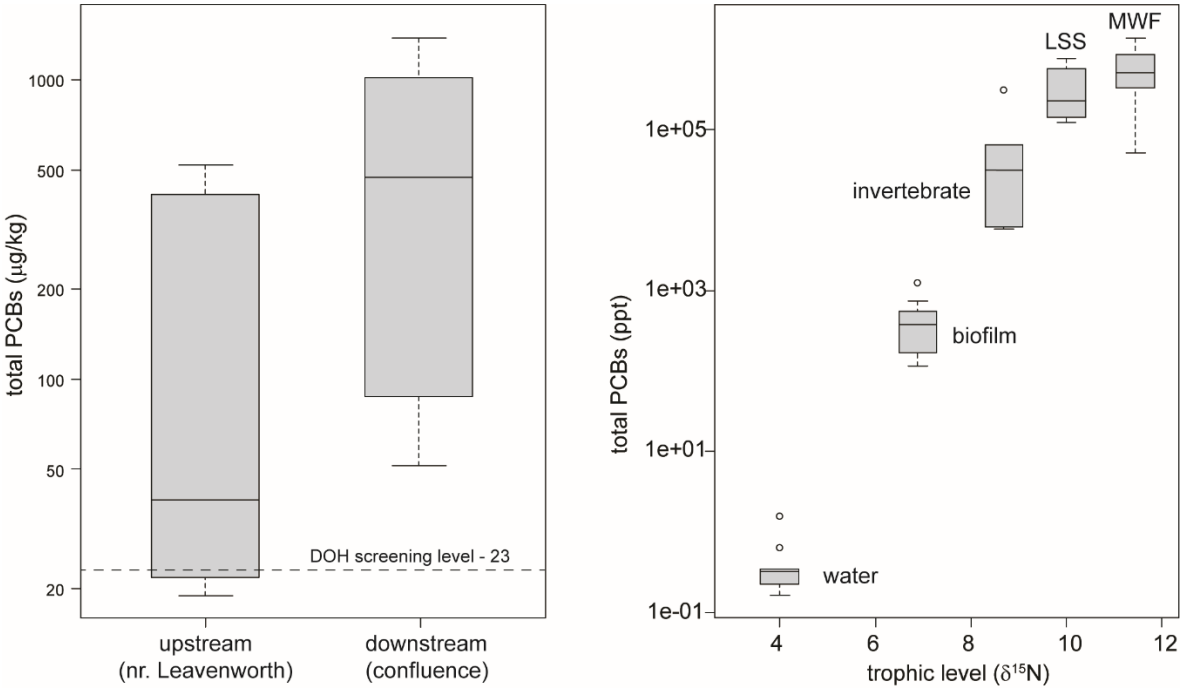

Figure 24: Boxplots of PCBs in mountain whitefish tissues (left) and biomagnification of PCBs in the lower Wenatchee River food web (right).

(left) MWF tissues are grouped according to the similarity with the upstream or downstream PCB profile; (right) trophic level is implied from N-isotope ratios, where the $\delta^{15}N$ of water was assigned.

The bioaccumulation of PCBs in the Wenatchee River food web generally follows a predictable biomagnification (Figure 24). The greatest bioaccumulation or bioconcentration is taking place between the water and the biofilms. There is considerable overlap in the PCB concentrations for LSS and MWF which may be attributable to diet or age of the fish, where older fish would accumulate greater amounts of PCBs; MWF averaged 4.5 years, while LSS averaged 12 years. The PCB data in water and tissues collected from 2014 to 2017 will contribute to a future bioaccumulation model for the lower Wenatchee River.

The bioconcentration of PCBs from the water to the base of the food web (biofilms) is described using a bioconcentration factor (BCF), which is the ratio of PCBs in the biofilm:water. The BCF assumes that bioaccumulation between the water and biofilm is at equilibrium. The BCF based on collections from the Wenatchee River varies with location. The upstream location which is dominated by heavier PCB congeners has a significantly higher BCF (Table 1). This is likely due to the greater log K_{ow}[2] of the heavier congeners found at this location. A higher log K_{ow} means that the chemicals have a stronger affinity to remain bound to lipids or organic carbon (biofilms). In fact the bioaccumulation of chemicals in algae has been found to be proportional to the log K_{ow} if there is an equilibrium reached between the media (Stange and Swackhamer, 1994).

Table 1: Summary of bioconcentration factors between water and biofilms for the Wenatchee River PCB source areas.

Site	Site ID	Date	Biofilm PCB (pg/g)	Water (pg/ml)	Bioconcentration factor (BCF)
Upstream source					
Hwy 285 bridge (2014)	45WR01.1	9/16/2014	455.85	0.63	729
Hwy 285 bridge (2015)	45WR01.1	9/21/2015	1270.12	1.55	817
Hwy 285 bridge (2016)	45WR01.1	9/14/2016	116.73	0.17	707
Hwy 285 bridge (2017)	45WR01.1	4/18/2017	142.07	0.13	1104
				mean ± sd	***839 ± 183***
Downstream source					
Cotlets Way (2015)	45WR09.5	9/23/2015	380.78	0.23	1634
Cotlets Way (2016)	45WR09.5	9/14/2016	553.78	0.35	1597
Cotlets Way (2017)	45WR09.5	4/18/2017	297.63	0.17	1784
				mean ± sd	***1672 ± 99***

In the water samples collected between 2014 and 2017 from the two source areas, we know that the congener profile changes very little. As a result, the collections of water and biofilm samples in the two main source areas have shown a fairly consistent BCF (Table 1).

The 2015 sample year was one instance when the concentrations of PCBs and the congener profile varied somewhat at the downstream (confluence) location. As a result the bioaccumulation of PCBs from biofilms to the benthic macroinvertebrates varied (Figure 25). Despite the slight differences in congener profiles of the biofilm from 2015 to 2016, invertebrates sampled at the same location and grazing on the biofilms, retained a very similar congener profile to their food source (Figure 25). This inter-annual variability in PCB congener profiles and total concentrations would then be passed on to MWF.

[2] The log K_{ow} is the octanol/water partition coefficient and describes a chemical's physical-chemical properties which control the affinity to move from water to fats (lipids) or carbon.

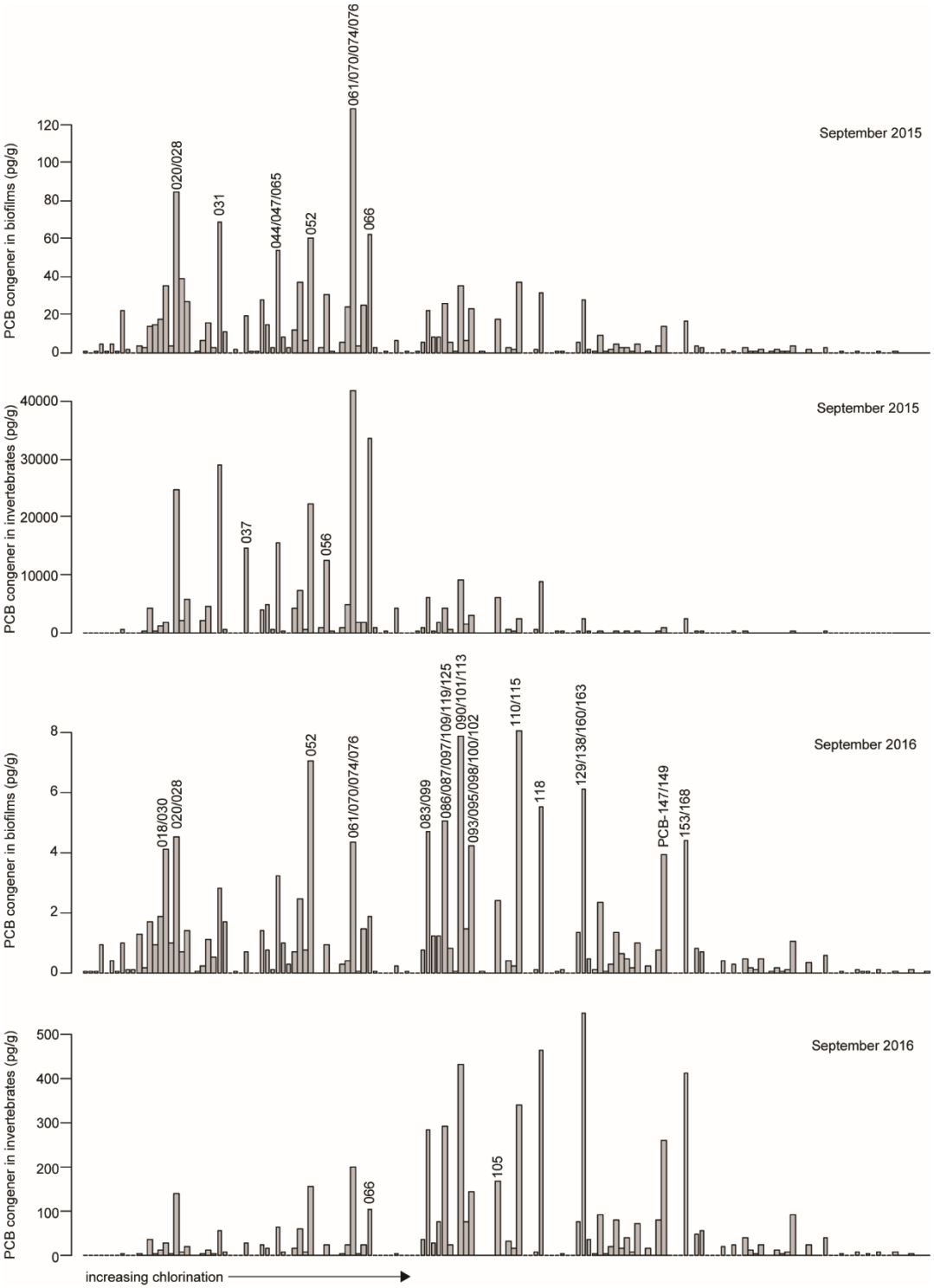

Figure 25: Congener profiles for biofilms and invertebrates in 2015 and 2016.

Samples are taken near the confluence with the Columbia River at the same location in 2015 and 2016; The IUPAC PCB number is listed above the dominant congeners in the upper profile, only new congeners are labeled in the remaining profiles.

Conclusions

As a result of the sampling in 2016 and 2017, the following conclusions can be made:

- We confirmed that two chemically-distinct PCB sources are impacting the Wenatchee River: Upstream near the City of Cashmere and downstream near the confluence with the Columbia River.
  - The upstream (Cashmere) source has been isolated to 500 feet (150 m) of river bank adjacent to Riverside Park. The PCB source has a congener profile similar to the technical mixture aroclor 1254 and is likely entering the river through groundwater.
  - The location of the downstream (confluence) source is less certain. There seems to be an influence of Columbia River water flowing back into the lower Wenatchee River. It is possible that sediments in the backwater channels in this confluence area are contributing PCBs. The PCB source in this area resembles aroclor 1248 and contains congeners indicative of microbial dechlorination.
- Dioxin-like PCB congeners are present in consistent proportions among fish tissues from both source areas. PCB-105 and PCB-118 are the most predominant dioxin-like congeners.
- Concentrations of PCBs in fish feeding near the downstream (confluence) source are higher than from the upstream source. Concentrations in the water and biofilms are higher during low-flow periods; however, the PCB load is lower during this time.
- PCB loads over the period 2014 to 2017 have been variable. However, the chemical profile of each PCB source is consistent over time and also between high- and low-flow periods.
- The bioconcentration of PCBs from water to biofilms is occurring by a factor (BCF) of 839 ± 183 at the downstream source and 1672 ± 99 at the upstream source. This difference in BCF is likely due to the difference in congener composition between the source areas.

Recommendations

Based on the findings from the 2016 and 2017 sampling, the following recommendations can be made:

- Begin to investigate possible upland PCB sources at the upstream (Cashmere) source area.
  - Complete a historical investigation of the former landfill area.
  - Continue to sample water and biofilms in the source area to further delineate the area of entry into the Wenatchee River.
  - During low flow, complete a detailed survey of the source area for debris (e.g. old transformers) that may be an instream source.
  - Sample groundwater seeps, install temporary piezometers, or sample existing groundwater wells within the footprint of the former landfill area.
  - Investigate groundwater-surface water interactions in the source area.
- Investigate the extent of contamination at the downstream (confluence) source area.
  - Complete a historical investigation of the reclamation of agricultural lands near the confluence area, including investigating whether sediment or soils were imported during the construction of Confluence State Park.
  - Continue to sample water and biofilms in the source area.
  - Complete an intensive sediment survey of the backchannel areas at the confluence.
  - Consider sampling sediment-dwelling organisms in the backchannel areas.
- Work with Washington Department of Fish and Wildlife and the Yakama First Nation to conduct a tagging study of mountain whitefish. This basic understanding of the life history of these fish is important to confirm periods of PCB exposure in the lower Wenatchee River.

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Appendices

Appendix A. Sample site locations

Table A-1: Study site locations.

Site ID	Site name	Lat	Long	Notes
45CR468.4	Confluence SP	47.45756	-120.32854	Wenatchee R – Columbia R confluence in north bank backwater
45CR468	Confluence rt bnk	47.45564	-120.32822	Wenatchee R – Columbia R confluence on the right bank
45WR00.5	Ped Bridge	47.45773	-120.33183	Wenatchee R – Columbia R confluence below the pedestrian bridge
45WR01.1	Hwy 285 bridge	47.45874	-120.33646	Wenatchee R under Hwy 285 bridge
45WR01.4	Pipeline	47.46138	-120.34282	Wenatchee Rec pipeline
45WR01.6	Orchard	47.46489	-120.34597	Wenatchee mainstem downstream of Highline
45WR01.8	Wenatchee mainstem	47.46487	-120.35120	Wenatchee R upstream of Highline canal input
45WR07.0	Old Monitor	47.50070	-120.42571	Wenatchee R under Old Monitor bridge
45WR09.5	Cotlets Way	47.52158	-120.45765	Wenatchee R upstream of Cotlets Way bridge
45WR09.7	Douglas	47.52278	-120.45973	Wenatchee R, right bank at the end of Douglas St, Cashmere
45WR09.9	Riverside	47.52417	-120.4638	Riverside Park, Cashmere
45WR10.0	Boat Launch	47.52496	-120.46663	The boat launch at Riverside Park, Cashmere
45WR10.2	Aplets Way	47.52537	-120.47048	Aplets Way Bridge, Cashmere
45WR10.5	Old Mill	47.52285	-120.48103	Wenatchee mainstem upstream of Mission Cr
45WR11.4	Goodwin Br	47.52735	-120.48940	Wenatchee R under downstream side of Goodwin bridge

Appendix B. Laboratory methods and quality assurance

Table B-1: Measurement methods (laboratory).

Analyte	Sample Matrix	Reporting Limit	Sample Prep Method	Analytical (Instrumental) Method
PCB congeners	Biofilm and invertebrates	4 pg g^{-1} w/w per congener	EPA 1668C	EPA 1668C
Lipids	Biofilm, invertebrates, and fish	0.10%	N/A	MEL SOP 730009[†]
Ash-free dry mass	Biofilm	1.00%	N/A	SM 10300C
C:N and isotopes	Biofilm, invertebrates and fish	0.10%	N/A	[‡] stable isotopes of N and C
PCB congeners	Invertebrates and fish	4 pg g^{-1} w/w per congener	EPA 1668C	EPA 1668C
PCB congeners	SPMD extract	0.5 pg/S per congener	dialysis; EPA 1668C	EPA 1668C
PCB aroclors	Fish	1.1 – 5 µg Kg^{-1}	EPA 8082 (GC/ECD); MEL SOP	EPA 8082 (GC/ECD); MEL SOP
SSC	Surface water	0.5 mg L^{-1}	N/A	EPA 160.2
TOC	Surface water	1 mg L^{-1}	N/A	SM 5310B
DOC	surface water	1 mg L^{-1}	N/A	SM 5310B

SSC = suspended sediment concentrations; TOC = total organic carbon; DOC = dissolved organic carbon

[†] Manual of Analytical Methods for the Analyses of Pesticides in Humans and Environmental Samples. EPA-600 8-80-038.

[‡] Costech Elemental Analyzer, Conflo III, MAT253.

Table B-2: SPMD blanks and calculated reporting limits.

Site	Sample Date	Lab ID	t-PCBs (pg/S)	t-PCBs (pg/L)	MDL (pg/L)	MQL (pg/L)
Field Blank (Cashmere)	9/14/2016	1609055-15	2.7	15.1		
Field Blank (confluence)	9/15/2016	1609055-16	2.7	14.9		
Day-0 Blank		1609055-17	2.6	14.2	16.1	19.4
Field Blank (Cashmere)	4/18/2017	1704025-15	1.7	17.8		
Field Blank (confluence)	4/18/2017	1704025-16	1.8	19.3		
Day-0 Blank		1704025-17	1.6	17.2	21.4	29.0

Table B-3: Sample precision for conventional parameters.

Site ID	Site name	Lab ID	Sample date	SSC (mg/L)	RPD	DOC (mg/L)		RPD	TOC (mg/L)		RPD	t-PCBs (ng/S)	RPD	t-PCBs (pg/L)	RPD
Grab samples															
45WR01.1	Hwy 285 bridge	1608058-01	8/16/2016	1	0%	1	U	0%	1	U	0%				
45WR01.1 dup	Hwy 285 bridge	1608058-07	8/16/2016	1		1	U		1						
45WR07.0	Old Monitor	1609042-04	8/30/2016	4	0%	1.1		0%	1.2		0%				
45WR07.0 dup	Old Monitor	1609042-05	8/30/2016	4		1.1			1.2						
45WR01.1	Hwy 285 bridge	1609055-06	9/15/2016	2	0%	1.2		18%	1.1		0%				
45WR01.1 dup	Hwy 285 bridge	1609055-07	9/15/2016	2		1	U		1.1						
45WR01.1	Hwy 285 bridge	1703029-04	3/21/2017	37	**85%**	1.79		3%	1.86		2%				
45WR01.1 dup	Hwy 285 bridge	1703029-05	3/21/2017	15		1.84			1.89						
45WR01.1	Hwy 285 bridge	1704024-03	4/3/2017	29	**105%**	2.26		10%	2.47		4%				
45WR01.1 dup	Hwy 285 bridge	1704024-04	4/3/2017	9		2.5			2.57						
45WR01.1	Hwy 285 bridge	1704025-04	4/18/2017	10	**35%**	2.03		5%	2.15		0%				
45WR01.1 dup	Hwy 285 bridge	1704025-05	4/18/2017	7		2.13			2.16						
SPMD samples															
45WR01.1	Hwy 285 bridge	1609055-13	9/15/2016									21.1	0%	173.1	10%
45WR01.1REP	Hwy 285 bridge	1609055-14	9/15/2016									21.0		157.0	
45WR01.1	Hwy 285 bridge	1704025-11	4/18/2017									13.4	27%	137.3	13%
45WR01.1 dup	Hwy 285 bridge	1704025-12	4/18/2017									17.5		120.1	

Table B-4: Sample precision for tissues.

Site name	Site ID	Lab ID	Date	Biomass (gOC/cm^2)	RPD	%lipids	RPD	t-PCBs (pg/g)	RPD	t-PCBs (pg/g OC)	RPD
Biofilms											
Hwy 285 bridge	45WR01.1	1609055-27	9/14/2016	0.00056	19%	0.23	36%	129.9	23%	896.6	32%
Hwy 285 bridge	45WR01.1 rep	1609055-28	9/14/2016	0.00047		0.16		103.6		651.9	
Cotlets Way	45WR09.5	1704025-22	18/4/2017	0.00039	47%	0.14	157%	266.5	21%	12396.0	52%
Cotlets Way	45WR09.5 rep	1704025-29	18/4/2017	0.00062		1.16		328.7		21209.7	
Invertebrates											
Hwy 285 bridge	45WR01.1	1609055-29	9/14/2016	na		1.56	4%	5915.6	5%	na	
Hwy 285 bridge	45WR01.1_rep	1609055-30	9/14/2016	na		1.63		6204.5		na	
Fish											
Confluence	LSS-6	1611039-7	9/14/2016	na		2.26	14%	768.0	5%	na	
Confluence	LSS-6 rep	1611039-19	9/14/2016	na		2.6		805.2		na	
Confluence	LSS-37	1611039-14	9/14/2016	na		1.79	18%	620.5	19%	na	
Confluence	LSS-37 rep	1611039-20	9/14/2016	na		1.49		513.3		na	
Confluence	LSS-Wen-5	1611039-5	9/14/2016	na		1.42	40%	130.5	10%	na	
Confluence	LSS-Wen-5 rep	1611039-17	9/14/2016	na		2.14	40%	144.0	10%	na	

Table B-5: Sample precision for stable isotopes in tissues.

Site name	Site ID	Date	% N	RPD	$\delta^{15}N$ (permil)	RPD	% C	RPD	$\delta^{13}C$ (permil)	RPD
Biofilms										
Hwy 285 bridge	45WR01.1	9/14/2016	1.4	10%	7.09	0%	13.9	8%	-14.04	3%
Hwy 285 bridge	45WR01.1	9/14/2016	1.6		7.08		15.1		-14.44	
Hwy 285 bridge	45WR01.1_rep	9/14/2016	1.6	5%	7.64	2%	15.4	6%	-14.26	1%
Hwy 285 bridge	45WR01.1_rep	9/14/2016	1.6		7.76		16.4		-14.42	
Pipeline	45WR01.4	9/15/2016	0.8	55%	6.95	1%	7.8	60%	-14.00	4%
Pipeline	45WR01.4	9/15/2016	1.5		7.02		14.5		-13.52	
Orchard	45WR01.6	9/15/2016	0.8	6%	7.21	1%	8.5	4%	-15.18	2%
Orchard	45WR01.6	9/15/2016	0.9		7.29		8.8		-15.53	
Highline	45WR01.8	9/15/2016	1.0	2%	6.72	1%	9.9	4%	-15.33	1%
Highline	45WR01.8	9/15/2016	1.0		6.76		10.4		-15.41	
Old Monitor	45WR07.0	9/14/2016	0.8	13%	6.89	1%	7.1	10%	-14.95	2%
Old Monitor	45WR07.0	9/14/2016	0.7		6.98		6.4		-15.30	
Cotlets Way	45WR09.5	9/14/2016	0.9	3%	8.25	1%	9.7	2%	-14.96	1%
Cotlets Way	45WR09.5	9/14/2016	0.9		8.32		9.5		-15.14	
Riverside	45WR09.9	9/13/2016	1.4	23%	9.08	4%	13.0	25%	-13.44	0%
Riverside	45WR09.9	9/13/2016	1.1		8.75		10.0		-13.43	
Aplets Way	45WR10.2	9/13/2016	1.9	4%	7.77	1%	16.6	1%	-13.45	3%
Aplets Way	45WR10.2	9/13/2016	2.0		7.72		16.8		-13.85	
Old Mill	45WR10.5	9/13/2016	1.9	1%	7.84	1%	17.0	1%	-13.26	1%
Old Mill	45WR10.5	9/13/2016	1.9		7.76		16.8		-13.36	
Goodwin	45WR11.4	9/13/2016	2.2	0%	8.17	8%	19.4	2%	-13.03	2%
Goodwin	45WR11.4	9/13/2016	2.2		8.85		19.7		-13.26	
Ped Bridge	45WR00.5	18/4/17	0.1	19%	3.69	11%	0.9	4%	-21.82	1%
Ped Bridge	45WR00.5	18/4/17	0.1		4.12		0.9		-22.09	
Pipeline	45WR01.4	18/4/17	0.2	8%	3.67	11%	1.4	2%	-19.61	0%

Site name	Site ID	Date	% N	RPD	$\delta^{15}N$ (permil)	RPD	% C	RPD	$\delta^{13}C$ (permil)	RPD
Pipeline	45WR01.4	18/4/17	0.2		4.08		1.5		-19.66	
Old Monitor	45WR07.0	19/4/17	0.1	25%	3.87	11%	0.9	5%	-22.88	0%
Old Monitor	45WR07.0	19/4/17	0.1		4.33		0.8		-22.85	
Cotlets Way	45WR09.5	18/4/17	0.3	3%	4.41	1%	2.3	16%	-20.68	1%
Cotlets Way	45WR09.5	18/4/17	0.3		4.37		2.0		-20.80	
Cotlets Way	45WR09.5 rep	18/4/17	0.2	23%	4.24	2%	1.7	21%	-19.83	0%
Cotlets Way	45WR09.5 rep	18/4/17	0.2		4.34		1.4		-19.83	
Douglas	45WR09.7	17/4/17	0.2	9%	4.30	0%	1.3	19%	-21.72	0%
Douglas	45WR09.7	17/4/17	0.2		4.31		1.6		-21.77	
Riverside	45WR09.9	17/4/17	0.2	0%	3.97	5%	1.2	14%	-21.62	0%
Riverside	45WR09.9	17/4/17	0.2		4.16		1.1		-21.73	
Boat Launch	45WR10.0	17/4/17	0.2	35%	3.81	4%	2.0	36%	-19.60	2%
Boat Launch	45WR10.0	17/4/17	0.2		3.95		1.4		-20.09	
Aplets Way	45WR10.2	17/4/17	0.5	16%	3.84	5%	3.9	10%	-18.89	1%
Aplets Way	45WR10.2	17/4/17	0.4		4.04		3.5		-19.05	
Invertebrates										
Hwy 285 bridge	45WR01.1	9/15/2016	8.1	11%	9.01	2%	42.4	12%	-18.75	1%
Hwy 285 bridge	45WR01.1	9/15/2016	7.3		9.15		37.6		-18.61	
Hwy 285 bridge	45WR01.1_rep	9/15/2016	8.1	3%	9.18	15%	40.8	5%	-18.58	1%
Hwy 285 bridge	45WR01.1_rep	9/15/2016	8.4		7.89		42.9		-18.68	
Fish										
Confluence	LSS-10	9/14/2016	13.1	8%	10.48	1%	43.5	9%	-16.84	0%
Confluence	LSS-10	9/14/2016	14.2		10.37		47.6		-16.79	
Confluence	LSS-11	9/14/2016	14.2	2%	10.32	0%	47.4	2%	-21.76	0%
Confluence	LSS-11	9/14/2016	14.5		10.30		48.4		-21.70	
Confluence	LSS-12	9/14/2016	14.0	2%	10.27	0%	46.8	2%	-20.08	0%
Confluence	LSS-12	9/14/2016	13.8		10.32		45.7		-20.07	
Confluence	LSS-33	9/14/2016	14.5	0%	9.21	1%	47.6	1%	-18.53	0%

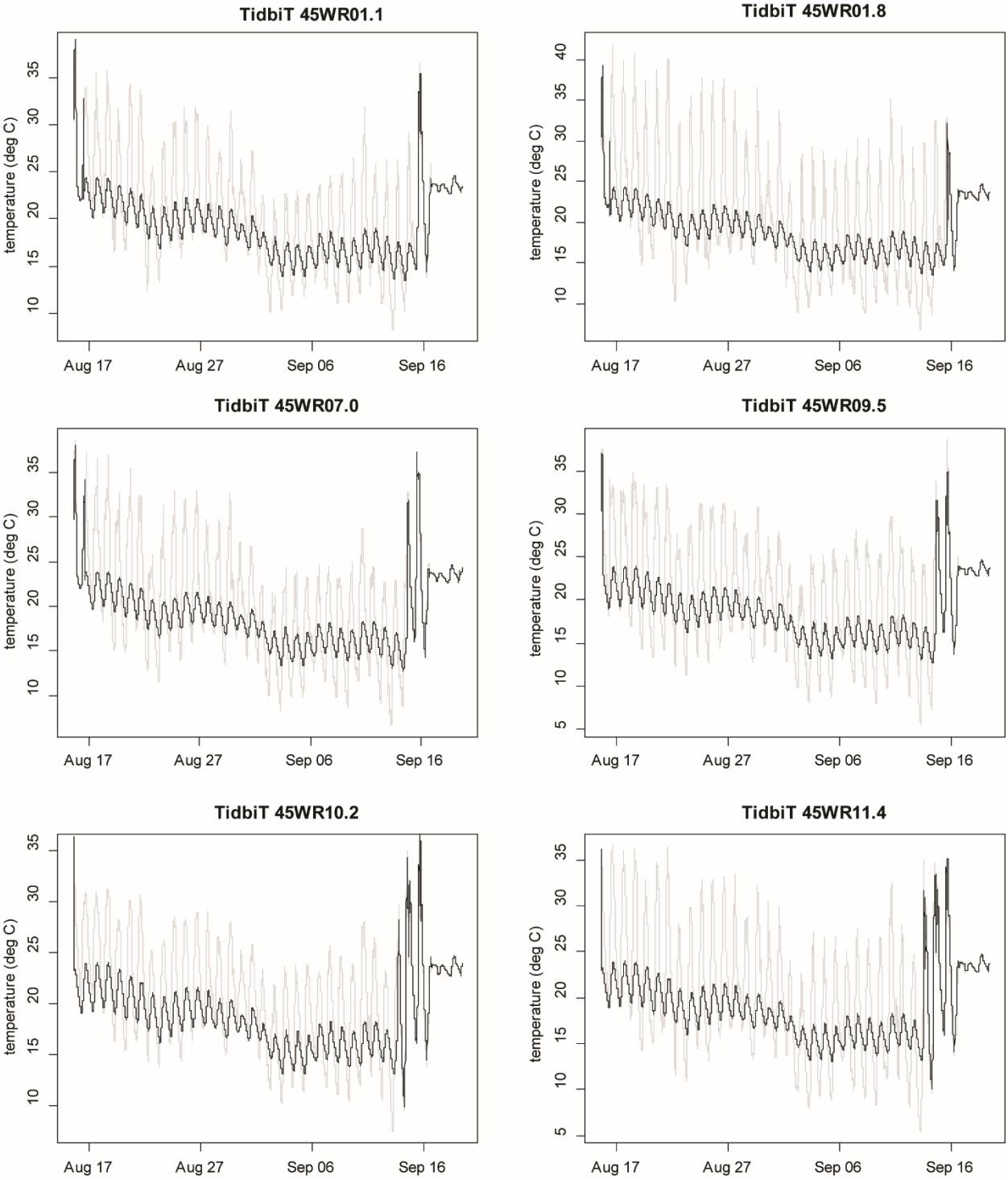
Site name	Site ID	Date	% N	RPD	$\delta^{15}N$ (permil)	RPD	% C	RPD	$\delta^{13}C$ (permil)	RPD
Confluence	LSS-33	9/14/2016	14.6		9.28		47.9		-18.55	
Confluence	LSS-34	9/14/2016	13.7	0%	9.82	1%	45.2	1%	-19.00	0%
Confluence	LSS-34	9/14/2016	13.7		9.88		45.8		-18.91	
Confluence	LSS-35	9/14/2016	13.8	6%	10.30	1%	48.8	7%	-23.08	1%
Confluence	LSS-35	9/14/2016	13.0		10.23		45.5		-22.94	
Confluence	LSS-36	9/14/2016	14.2	1%	10.11	1%	47.6	3%	-19.22	1%
Confluence	LSS-36	9/14/2016	14.3		9.97		48.8		-19.08	
Confluence	LSS-37	9/14/2016	14.5	1%	10.19	0%	48.6	0%	-22.06	0%
Confluence	LSS-37	9/14/2016	14.4		10.16		48.7		-22.02	
Confluence	LSS-38	9/14/2016	13.7	2%	9.87	0%	45.2	3%	-19.43	0%
Confluence	LSS-38	9/14/2016	13.9		9.86		46.5		-19.40	
Confluence	LSS-39	9/14/2016	14.7	6%	10.04	3%	46.4	1%	-18.88	3%
Confluence	LSS-39	9/14/2016	13.8		10.40		46.8		-19.40	
Confluence	LSS-40	9/14/2016	14.1	1%	10.51	0%	46.2	2%	-21.10	0%
Confluence	LSS-40	9/14/2016	14.3		10.49		46.9		-21.12	
Confluence	LSS-6	9/14/2016	13.6	4%	9.54	0%	43.8	4%	-18.81	1%
Confluence	LSS-6	9/14/2016	14.1		9.54		45.8		-18.94	
Confluence	LSS-7	9/14/2016	14.8	0%	9.57	1%	48.8	1%	-15.60	0%
Confluence	LSS-7	9/14/2016	14.7		9.49		49.2		-15.64	
Confluence	LSS-8	9/14/2016	13.6	7%	10.00	2%	45.1	8%	-15.96	0%
Confluence	LSS-8	9/14/2016	14.6		9.76		48.8		-15.90	
Confluence	LSS-9	9/14/2016	13.8	2%	10.23	0%	45.1	2%	-18.46	0%
Confluence	LSS-9	9/14/2016	14.1		10.21		45.9		-18.54	

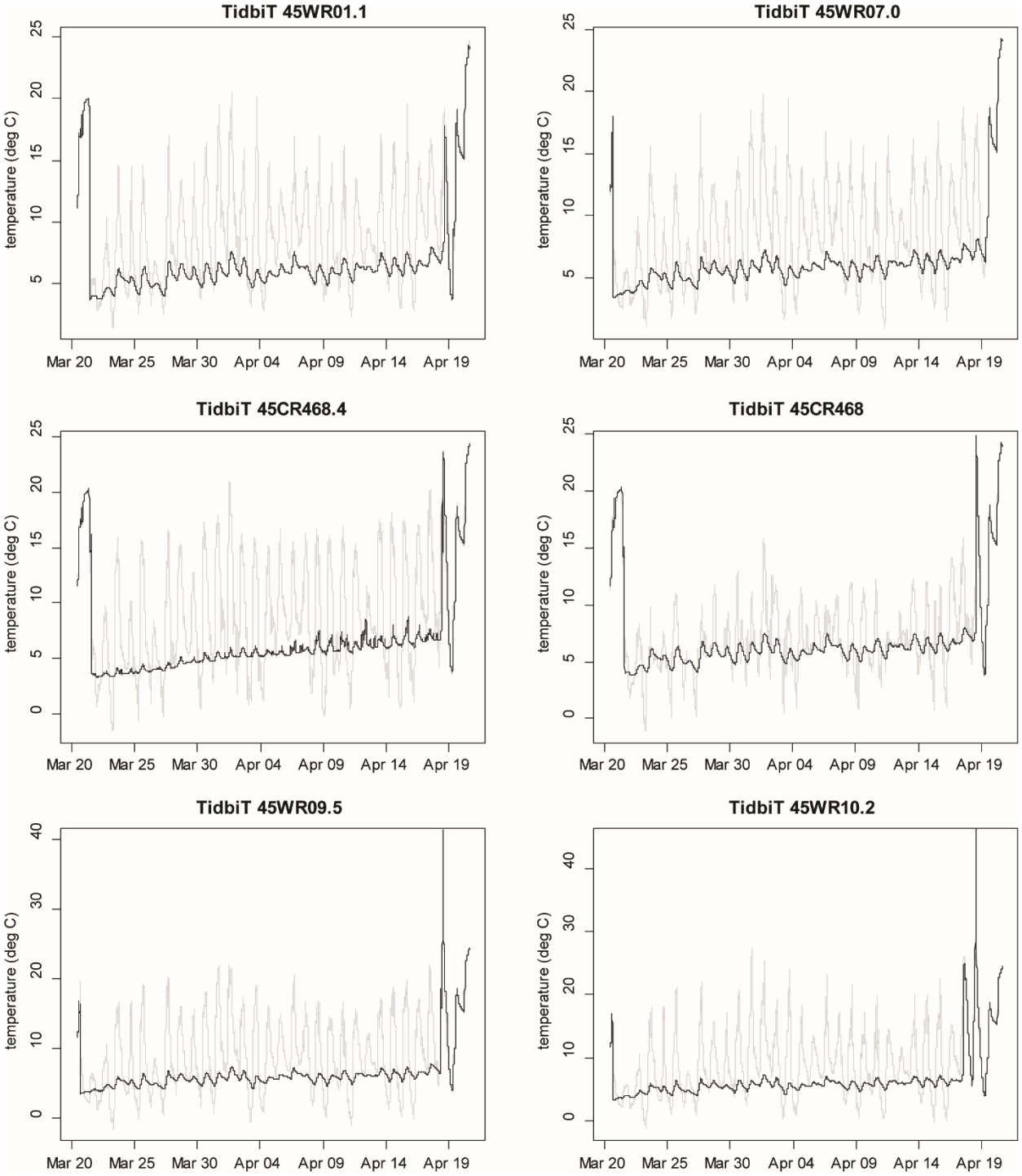
Table B-6: Sample bias for the SPMDs – recovery of performance reference compounds.

Site	Site name	Lab ID	Deployment time (days)	PCB-14 (ng/S)	PCB-14 (%)	PCB-31L (ng/S)	PCB-31L (%)	PCB-95 (ng/S)	PCB-95 (%)	PCB-153 (ng/S)	PCB-153 (%)
September 2016											
45WR01.1	Hwy 285 bridge	1609055-13	29.8	2.8	79%	2.05	87%	2.094	102%	2.58	108%
45WR01.1 dup	Hwy 285 bridge	1609055-14	29.8	2.74	78%	2.02	85%	2.134	104%	2.62	109%
45WR01.8	Wenatchee mainstem	1609055-12	30.2	2.2	62%	1.85	78%	2.118	103%	2.44	102%
45WR07.0	Old Monitor	1609055-11	29.2	2.76	78%	1.98	83%	1.9994	97%	2.31	96%
45WR09.5	Cotlets Way	1609055-10	29.8	1.992	56%	1.67	71%	1.7538	85%	2.22	92%
45WR10.2	Aplets Way	1609055-9	29.0	2.54	72%	1.91	81%	1.9676	96%	2.37	99%
45WR11.4	Goodwin Br	1609055-8	28.9	2.78	79%	1.97	83%	1.7928	87%	2.23	93%
	Field Blank (Cashmere)	1609055-15		3.62		2.42		2.05		2.42	
	Field Blank (Confluence)	1609055-16		3.52		2.38		1.9728		2.36	
	Day-0 Blank	1609055-17		3.46		2.31		2.156		2.42	
April 2017											
45CR468	Columbia	1704025-14	28.0	2.86	90%	1.71	89%	2.14	101%	2.46	113%
45CR468.4	Confluence	1704025-13	28.0	2.88	91%	1.94	101%	2.08	98%	2.38	109%
45WR01.1	Hwy 285 bridge	1704025-11	28.3	2.64	83%	1.94	101%	2.2	104%	2.46	113%
45WR01.1 dup	Hwy 285 bridge	1704025-12	28.3	2.38	75%	1.84	96%	2	95%	2.32	106%
45WR07.0	Old Monitor	1704025-10	29.7	1.912	60%	1.67	87%	2.1	99%	2.38	109%
45WR09.5	Cotlets Way	1704025-9	28.8	1.99	63%	1.69	88%	2.08	98%	2.32	106%
45WR10.2	Aplets Way	1704025-8	28.0	2.3	72%	1.65	86%	2	95%	2.06	94%
	Field Blank (Cashmere)	1704025-15		3.2		1.90		2.08		2.28	
	Field Blank (Confluence)	1704025-16		3.08		1.84		2.1		2.14	
	Day-0 Blank	1704025-17		3.24		2.04		2.16		2.12	

Appendix C. Continuous temperature data

Air temperature is the gray line and water temperature is the black line.




TidbiT 45WR01.1
TidbiT 45WR07.0
TidbiT 45CR468.4
TidbiT 45CR468
TidbiT 45WR09.5
TidbiT 45WR10.2
temperature (deg C)
Mar 20
Mar 25
Mar 30
Apr 04
Apr 09
Apr 14
Apr 19

Appendix D. Analytical results

Table D-1: Results for conventional parameters in water.

Site ID	Site name	Lab ID	Sample date	SPMD stage	SSC (mg/L)		DOC (mg/L)		TOC (mg/L)		pH	Temp	Conduc-tivity
2016 Low-flow sampling													
45WR01.1	Hwy 285 bridge	1608058-01	8/16/2016	SPMD deploy	1		1	U	1	U	7.8	22.2	88.0
45WR01.1 dup	Hwy 285 bridge	1608058-07	8/16/2016	SPMD deploy	1		1		1				
45WR01.8	Wenatchee mainstem	1608058-02	8/16/2016	SPMD deploy	2		1	U	1	U	7.6	21.2	93.0
45WR07.0	Old Monitor	1608058-03	8/16/2016	SPMD deploy	2		1		1		8.2	23.1	68.0
45WR09.5	Cotlets Way	1608058-04	8/15/2016	SPMD deploy	2		1		1	U	8.8	23.5	74.9
45WR10.2	Aplets Way	1608058-05	8/15/2016	SPMD deploy	2		1		1	U	8.7	22.9	63.0
45WR11.4	Goodwin Br	1608058-06	8/15/2016	SPMD deploy	1		1		1	U	8.4	23	105.4
45WR01.1	Hwy 285 bridge	1609042-07	8/30/2016	SPMD midpoint	1		1	U	1.2		-	-	-
45WR01.8	Wenatchee mainstem	1609042-06	8/31/2016	SPMD midpoint	2		1	U	1.1		-	-	-
45WR07.0	Old Monitor	1609042-04	8/30/2016	SPMD midpoint	4		1.1		1.2		-	-	-
45WR07.0 dup	Old Monitor	1609042-05	8/30/2016	SPMD midpoint	4		1.1		1.2				
45WR09.5	Cotlets Way	1609042-03	8/30/2016	SPMD midpoint	2		1.1		1.3		-	-	-
45WR10.2	Aplets Way	1609042-02	8/30/2016	SPMD midpoint	2		1.1		1.2		-	-	-
45WR11.4	Goodwin Br	1609042-01	8/30/2016	SPMD midpoint	1		1.1		1.2		-	-	-
45WR01.1	Hwy 285 bridge	1609055-06	9/15/2016	SPMD retrieval	2		1.2		1.1		8.1	14.81	104.5
45WR01.1 dup	Hwy 285 bridge	1609055-07	9/15/2016	SPMD retrieval	2		1	U	1.1				
45WR01.8	Wenatchee mainstem	1609055-05	9/15/2016	SPMD retrieval	2		1	U	1.4		8.9	18.26	103.0
45WR07.0	Old Monitor	1609055-04	9/14/2016	SPMD retrieval	1		1	U	1.1		8.9	16.82	90.1
45WR09.5	Cotlets Way	1609055-03	9/14/2016	SPMD retrieval	1		1	U	1		8.7	16.13	94.4
45WR10.2	Aplets Way	1609055-02	9/13/2016	SPMD retrieval	1		1	U	1	U	8.6	17.04	82.5
45WR11.4	Goodwin Br	1609055-01	9/13/2016	SPMD retrieval	0.8		1	U	1		8.5	16.15	80.3

Site ID	Site name	Lab ID	Sample date	SPMD stage	SSC (mg/L)		DOC (mg/L)		TOC (mg/L)		pH	Temp	Conduc-tivity
2017 High-flow sampling													
45CR468	Columbia	1703029-07	3/21/2017	SPMD deploy	4		2.0		1.8		7.3	4.47	73.8
45CR468.4	Confluence	1703029-06	3/21/2017	SPMD deploy	4		1.3		1.4		7.4	4.12	137.7
45WR01.1	Hwy 285 bridge	1703029-04	3/21/2017	SPMD deploy	37		1.8		1.9		7.4	4.25	74.7
45WR01.1 dup	Hwy 285 bridge	1703029-05	3/21/2017	SPMD deploy	15		1.8		1.9				
45WR07.0	Old Monitor	1703029-03	3/20/2017	SPMD deploy	13		1.9		2.3		7.8	3.91	72.6
45WR09.5	Cotlets Way	1703029-02	3/20/2017	SPMD deploy	21		1.9		2.1		8.7	3.85	77.8
45WR10.2	Aplets Way	1703029-01	3/20/2017	SPMD deploy	5		1.8		1.9		7.3	3.75	66.4
45CR468	Columbia	1704024-02	4/3/2017	SPMD midpoint	5		2.2		2.6		7.6	5.77	87.7
45CR468.4	Confluence	1704024-01	4/3/2017	SPMD midpoint	7		1.9		2.2		7.5	5.92	143.6
45WR01.1	Hwy 285 bridge	1704024-03	4/3/2017	SPMD midpoint	29		2.3		2.5		7.7	6.31	92.6
45WR01.1 dup	Hwy 285 bridge	1704024-04	4/3/2017	SPMD midpoint	9		2.5		2.6				
45WR07.0	Old Monitor	1704024-05	4/3/2017	SPMD midpoint	12		2.3		2.6		-	-	-
45WR09.5	Cotlets Way	1704024-06	4/4/2017	SPMD midpoint	11		2.2		2.6		-	-	-
45WR10.2	Aplets Way	1704024-07	4/4/2017	SPMD midpoint	5		2.1		2.4		7.3	4.84	87.8
45CR468	Columbia	1704025-07	4/18/2017	SPMD retrieval	16		2.1		2.2		7.3	8.01	91.2
45CR468.4	Confluence	1704025-06	4/18/2017	SPMD retrieval	11		2.4		2.5		7.2	7.68	143.6
45WR01.1	Hwy 285 bridge	1704025-04	4/18/2017	SPMD retrieval	10		2.0		2.2		7.7	8.78	87.3
45WR01.1 dup	Hwy 285 bridge	1704025-05	4/18/2017	SPMD retrieval	7		2.1		2.2				
45WR07.0	Old Monitor	1704025-03	4/19/2017	SPMD retrieval	10		2.1		2.2		-	-	-
45WR09.5	Cotlets Way	1704025-02	4/18/2017	SPMD retrieval	15		2.2		2.2		6.8	6.46	90.9
45WR10.2	Aplets Way	1704025-01	4/17/2017	SPMD retrieval	7		2.7		2.3		7.7	7.73	65.5

Table D-2: Results of PCBs in the SPMDs.

SPMD results were corrected for blank contamination by subtracting the mean of the blank PCB concentrations for each congener.

Site	Site name	Lab ID (MEL)	Lab ID (AXYS)	Deployment time (days)	Not corrected		Blank corrected	
					t-PCBs (ng/S)	t-PCBs (pg/L)	t-PCBs (ng/S)	t-PCBs (pg/L)
September 2016								
45WR01.1	Hwy 285 bridge	1609055-13	L25855-6	29.8	21.1	173.1	18.5	152.7
45WR01.1 dup	Hwy 285 bridge	1609055-14	L25855-7	29.8	21.0	157.0	18.3	138.4
45WR01.8	Wenatchee mainstem	1609055-12	L25855-5	30.2	46.3	212.7	43.7	201.0
45WR07.0	Old Monitor	1609055-11	L25855-4	29.2	20.7	222.9	18.0	197.8
45WR09.5	Cotlets Way	1609055-10	L25855-3	29.8	83.2	346.9	80.6	337.7
45WR10.2	Aplets Way	1609055-9	L25855-2	29.0	6.6	38.9	4.3	35.0
45WR11.4	Goodwin Br	1609055-8	L25855-1	28.9	5.3	33.9	3.2	21.3
	Field Blank (Cashmere)	1609055-15	L25855-8		2.7	15.1		
	Field Blank (Confluence)	1609055-16	L25855-9		2.7	14.9		
	Day-0 Blank	1609055-17	L25591-1		2.6	14.2		
April 2017								
45CR468	Columbia	1704025-14	L27188-9	28.0	13.4	238.4	11.6	208.1
45CR468.4	Confluence	1704025-13	L27188-8	28.0	17.5	341.7	15.8	310.1
45WR01.1	Hwy 285 bridge	1704025-11	L27188-6	28.3	13.4	137.3	11.2	117.8
45WR01.1 dup	Hwy 285 bridge	1704025-12	L27188-7	28.3	17.5	120.1	12.6	87.0
45WR07.0	Old Monitor	1704025-10	L27188-5	29.7	13.8	80.4	12.1	70.7
45WR09.5	Cotlets Way	1704025-9	L27188-4	28.8	25.7	166.8	23.9	156.4
45WR10.2	Aplets Way	1704025-8	L27188-3	28.0	7.7	52.9	6.0	41.4
	Field Blank (Cashmere)	1704025-15	L27188-1		1.7	17.8		
	Field Blank (Confluence)	1704025-16	L27188-2		1.8	19.3		
	Day-0 Blank	1704025-17	L26887-2		1.6	17.2		

Table D-3: Results for isotopes and PCBs in biofilms and invertebrates.

Site ID	Site name	MEL ID	date	area (cm^2)	dry mass (g)	biomass (gOC/cm^2)	%OC	$\delta^{15}N$	$\delta^{13}C$	%lipids	t-PCBs (pg/g)	t-PCBs (pg/g OC)
Low-flow 2016 sampling - biofilms												
45WR01.1	Hwy 285 bridge	1609055-27	9/14/2016	787	3.1	0.0039	14.49	7.08	-14.24	0.23	129.9	896.6
45WR01.1 rep		1609055-28	9/14/2016	889	2.6	0.0029	15.89	7.70	-14.34	0.16	103.6	651.9
45WR01.4	Pipeline	1609055-26	9/15/2016	816	2.5	0.0030	11.14	6.98	-13.76	0.23	128.1	768.6
45WR01.6	Orchard	1609055-25	9/15/2016	495	3.4	0.0068	8.68	7.25	-15.36	0.22	167.2	1150.2
45WR01.8	Highline	1609055-24	9/15/2016	1073	4.5	0.0042	10.14	6.74	-15.37	0.18	144.8	1925.9
45WR07.0	Old Monitor	1609055-23	9/14/2016	1553	9.3	0.0060	6.71	6.94	-15.13	0.15	262.9	1427.9
45WR09.5	Cotlets Way	1609055-22	9/14/2016	1121	3.6	0.0032	9.62	8.29	-15.05	0.22	553.8	3916.8
45WR09.9	Riverside	1609055-21	9/13/2016	942	1.7	0.0018	11.50	8.92	-13.44	0.15	194.9	5757.1
45WR10.2	Aplets Way	1609055-20	9/13/2016	675	2.2	0.0033	16.68	7.75	-13.65	0.24	38.3	1695.6
45WR10.5	Old Mill	1609055-19	9/13/2016	929	2.2	0.0024	16.95	7.80	-13.31	0.17	7.9	229.8
45WR11.4	Goodwin	1609055-18	9/13/2016	1625	3.3	0.0020	19.55	8.51	-13.15	0.30	14.3	46.5
Low-flow 2016 sampling - benthic invertebrates												
Hwy 285 bridge	45WR01.1	1609055-29	09/15/2016	-	-	-	40.00	9.08	-18.68	1.56	5915.6	-
Hwy 285 bridge	45WR01.1 REP	1609055-30	09/15/2016	-	-	-	41.86	8.53	-18.63	1.63	6204.5	-
High-flow 2017 sampling - biofilms												
45WR00.5	Pedestrian bridge	1704025-25	18/4/17	801	22.6	0.028	0.93	3.90	-21.95	0.08	70.6	7587.1
45WR01.4	Pipeline	1704025-28	18/4/17	710	26.8	0.038	1.44	3.88	-19.64	1.27	142.1	9865.9
45WR07.0	Old Monitor	1704025-23	19/4/17	943	52.8	0.056	0.86	4.10	-22.87	0.08	63.2	7350.8
45WR09.5	Cotlets Way	1704025-22	18/4/17	1513	27.2	0.018	2.15	4.39	-20.74	0.14	266.5	12396.0
45WR09.5 rep	Cotlets Way	1704025-29	18/4/17	804	32.2	0.040	1.55	4.29	-19.83	1.16	328.7	21209.7
45WR09.7		1704025-21	17/4/17	1167	33.7	0.029	1.44	4.30	-21.74	0.09	200.1	16088.2
45WR09.9	Riverside	1704025-20	17/4/17	1556	47.8	0.031	1.17	4.06	-21.68	0.15	491.8	13896.5
45WR10.0	Boat Ramp	1704025-19	17/4/17	918	16.6	0.018	1.65	3.88	-19.85	0.10	60.5	42036.8
45WR10.2	Aplets Way	1704025-18	17/4/17	675	26.0	0.039	3.74	3.94	-18.97	0.39	22.7	3667.9

Table D-4: Results for isotopes and PCBs in mountain whitefish tissues.

All fish part of the composite were fillet samples, those that were not are whole fish.

ID	Sample date	MEL ID	Weight (g)	Length (mm)	Sex	Age	Fillet composite	$\delta^{15}N$	$\delta^{13}C$	%lipids	t-PCBs (ug/kg)
MWF-1a	5/18/2015		261	315	M	3		11.7	-22.5		
MWF-2a	5/18/2015		248	312	F	3					
MWF-3a	5/18/2015		191	285	M	3		11.9	-19.5		
MWF-4a	5/18/2015	1601009-77	413	354	M	7		11.7	-18.0	7.7	1016.3
MWF-5a	5/18/2015	1601009-79	237	295	F	3		11.1	-16.7	5.2	1373.5
MWF-6a	5/18/2015	1601009-80	891	484	F	6		12.3	-19.0	6.5	700.5
MWF-7a	5/18/2015	1601009-69	169	278	F	2	MWF-Conf-1			3.5	408
MWF-8a	5/18/2015		159	275	F	2					
MWF-9a	5/18/2015		275	323	F	5					
MWF-10a	5/18/2015		251	295	F	3					
MWF-11a	5/18/2015		195	285	M	3					
MWF-12a	5/18/2015	1601009-70	554	389	F	8	MWF-Conf-2			4.45	3580
MWF-13a	5/18/2015		425	354	F	7					
MWF-14a	5/18/2015		329	341	F	4					
MWF-15a	5/18/2015		547	397	F	8					
MWF-16a	5/18/2015		325	335	F	4					
MWF-17a	5/19/2015		433	350	F	7		10.5	-19.2		
MWF-18a	5/19/2015	1601009-81	391	344	F	5		10.5	-18.5	6.7	19.0
MWF-19a	5/19/2015	1601009-82	108	242	M	3		10.7	-16.9	2.4	21.8
MWF-20a	5/19/2015	1601009-83	607	405	F	16		11.6	-17.7	4.4	414.2
MWF-21a	5/20/2015	1601009-71	497	381	F	7	MWF-Osprey-1			4.27	23.2
MWF-22a	5/20/2015		571	400	F	9					
MWF-23a	5/20/2015		342	344	M	6					
MWF-24a	5/20/2015		495	384	F	6					
MWF-1b	9/21/2015	1601009-75	528	381	F	3		13.1	-27.4	9.9	87.1
MWF-2b	9/21/2015		351	313	F	2		11.6	-29.4		

ID	Sample date	MEL ID	Weight (g)	Length (mm)	Sex	Age	Fillet composite	$\delta^{15}N$	$\delta^{13}C$	%lipids	t-PCBs (ug/kg)
MWF-3b	9/21/2015	1601009-76	306	356	F	4		11.0	-17.5	4.3	247.3
MWF-4b	9/21/2015	1601009-78	128	232	M	2		10.5	-15.5	7.0	51.3
MWF-5b	9/21/2015		105	228	M	2		10.3	-17.9		
MWF-6b	9/21/2015	1601009-72	232	307	F	3	MWF-Conf-3	11.3	-21.2	4.85	60.9
MWF-7b	9/21/2015		202	290	F	2					
MWF-8b	9/21/2015		190	277	M	2					
MWF-9b	9/21/2015		201	279	M	2					
MWF-10b	9/21/2015		315	292	F	3					
MWF-11b	9/22/2015	1601009-73	163	290	F	2	MWF-Osprey-2			3.32	49.1
MWF-12b	9/22/2015		260	313	F	3					
MWF-13b	9/22/2015		182	285	F	2					
MWF-14b	9/22/2015		113	234	F	2					
MWF-15b	9/22/2015		213	286	F	3					
MWF-16b	9/22/2015	1601009-74	297	330	F	5	MWF-Osprey-3			3.69	134
MWF-17b	9/22/2015		340	356	M	5					
MWF-18b	9/22/2015		425	370	F	6					
MWF-19b	9/22/2015		418	377	M	6					
MWF-20b	9/22/2015		447	390	M	7					
MWF-21b	9/22/2015		167	277	F	3		9.3	-18.3		
MWF-22b	9/22/2015	1601009-84	527	414	F	7		10.0	-18.3	2.0	22.4
MWF-23b	9/22/2015		236	300	F	3		9.6	-18.1		
MWF-24b	9/22/2015	1601009-85	228	312	F	4		12.1	-21.5	1.8	56.2
MWF-25b	9/22/2015		100	225	M	2		9.8	-15.6		
MWF-26b	9/22/2015	1601009-86	453	399	F	7		11.9	-18.6	7.1	519.7

Table D-5: Results for isotopes and PCBs in largescale sucker tissues.

All fish part of the composite were fillet samples, those that were not are whole fish.

ID	Sample date	MEL ID	Weight (g)	Length (mm)	Sex	Age	Composite	$\delta^{15}N$	$\delta^{13}C$	%lipids	t-PCBs (ug/kg)
LSS-1	9/14/2016	1611039-1	1328	515	F	15	LSS-Wen-1			2.19	260.0
LSS-2	9/14/2016		1156	505	M	12					
LSS-3	9/14/2016		1208	520	F	15					
LSS-4	9/14/2016		1230	510	F	15					
LSS-5	9/14/2016		962	485	F	16					
LSS-6	9/14/2016	1611039-7	1061	475	F	14		9.54	-18.87	2.26	768.0
LSS-7	9/14/2016	1611039-8	935	470	F	13		9.53	-15.62	1.87	137.4
LSS-8	9/14/2016	1611039-9	1012	510	F	13		9.88	-15.93	1.35	258.2
LSS-9	9/14/2016	1611039-10	1054	510	F	15		10.22	-18.50	1.54	539.6
LSS-10	9/14/2016		998	515	F	17		10.43	-16.81		
LSS-11	9/14/2016	1611039-11	1025	500	F	15		10.31	-21.73	2.02	124.7
LSS-12	9/14/2016		955	475	F	15		10.30	-20.08		
LSS-13	9/14/2016	1611039-2	781	430	M	12	LSS-Wen-2			1.05	99.8
LSS-14	9/14/2016		756	420	M	8					
LSS-15	9/14/2016		715	445	M	9					
LSS-16	9/14/2016		803	440	M	10					
LSS-17	9/14/2016		745	447	F	10					
LSS-18	9/14/2016	1611039-3	754	440	F	13	LSS-Wen-3			0.9	46.9
LSS-19	9/14/2016		848	470	M	18					
LSS-20	9/14/2016		747	435	M	14					
LSS-21	9/14/2016		785	445	M	11					
LSS-22	9/14/2016		804	430	M	14					
LSS-23	9/14/2016	1611039-4	624	415	M	12	LSS-Wen-4			0.94	53.9
LSS-24	9/14/2016		627	430	M	10					
LSS-25	9/14/2016		649	420	M	11					
LSS-26	9/14/2016		686	420	M	11					

ID	Sample date	MEL ID	Weight (g)	Length (mm)	Sex	Age	Composite	$\delta^{15}N$	$\delta^{13}C$	%lipids	t-PCBs (ug/kg)
LSS-27	9/14/2016		705	430	F	8					
LSS-28	9/14/2016	1611039-5	739	455	F	13	LSS-Wen-5			1.42	130.5
LSS-29	9/14/2016		733	440	M	10					
LSS-30	9/14/2016		840	445	M	14					
LSS-31	9/14/2016		895	450	M	12					
LSS-32	9/14/2016		819	435	M	12					
LSS-33	9/14/2016	1611039-12	751	420	F	12		9.24	-18.54	1.82	58.3
LSS-34	9/14/2016	1611039-13	705	428	M	12		9.85	-18.95	1.37	148.7
LSS-35	9/14/2016		713	435	-	9		10.26	-23.01		
LSS-36	9/14/2016		721	442	M	14		10.04	-19.15		
LSS-37	9/14/2016	1611039-14	872	460	M	13		10.17	-22.04	1.79	620.5
LSS-38	9/14/2016		723	455	F	12		9.87	-19.41		
LSS-39	9/14/2016	1611039-15	771	460	F	11		10.22	-19.14	0.88	109.5
LSS-40	9/14/2016	1611039-16	834	445	F	7		10.50	-21.11	3.19	199.3
LSS-41	9/14/2016	1611039-6	644	405	M	8	LSS-Wen-6			1.14	62.1
LSS-42	9/14/2016		596	415	M	9					
LSS-43	9/14/2016		595	385	F	7					
LSS-44	9/14/2016		701	425	F	12					
LSS-45	9/14/2016		531	395	M	6					
LSS-Wen-5 rep		1611039-17								2.14	144.0
LSS-Wen-6 rep		1611039-18								1.19	
LSS-6 rep		1611039-19								2.6	805.2
LSS-37 rep		1611039-20								1.49	513.3

Appendix E. Glossary, acronyms, and abbreviations

Glossary

Anthropogenic: Human-caused.

Bioaccumulation: the process in which a chemical substance is absorbed in an organism by all routes of exposure as occurs in the natural environment (i.e. dietary and ambient environmental sources) (Arnot and Gobas, 2006). Expressed as a bioaccumulation factor (BAF); the ratio of the chemical concentration in an organism to the dissolved and bioavailable concentration in the water phase.

Bioconcentration: the process by which a chemical substance is absorbed by an organism from the ambient environment only through its respiratory and dermal surfaces (i.e. chemical exposure through diet is not included) (Arnot and Gobas, 2006). Expressed as a bioconcentration factor (BCF); in upper trophic level organisms (i.e. fish), BCFs can only be calculated in the lab where dietary intake is not included.

Biomagnification: the process in which the thermodynamic activity of the chemical in an organism exceeds that of its diet (Arnot and Gobas, 2006). Expressed as the biomagnification factor (BMF); the ratio of the chemical concentration in an organism to that of its diet at steady state or equilibrium.

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.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Congener: similar chemical compounds related to each other by origin, structure and function, but having slightly different composition. PCB congeners all have 2 biphenyl (benzene) rings with 1 to 10 chlorine atoms; however, the chlorine and benzene rings are in different positions yielding a total of 209 possible congeners. Congeners are sometimes referred to as isomers.

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

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

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

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

C	Carbon
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
MEL	Manchester Environmental Laboratory
N	Nitrogen
RM	River mile
RPD	Relative percent difference
SOP	Standard operating procedures
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
dw	dry weight
ft	feet
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
mg/d	milligrams per day
pg/g	picograms per gram (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
µg/Kg	micrograms per kilogram (parts per billion)
µS/cm	microsiemens per centimeter, a unit of conductivity