Freshwater Fish Contaminant Monitoring Program

2016 Results

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Cover photo by author: Largemouth bass (*Micropterus salmoides*) from Riffe Lake.

Freshwater Fish Contaminant Monitoring Program

2016 Results

by

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Abstract

Ecology's Freshwater Fish Contaminant Monitoring Program collected fish at 11 sites from six areas in the Cowlitz River in 2016. Laboratory analyses were performed on 53 composite samples, which were created using 235 individual fish representing six species.

Goals were to characterize contaminant concentrations in fish and detect spatial and temporal patterns. Study results can be used in the next Water Quality Assessment and inform the Washington State Department of Health as they evaluate risks to humans from the consumption of contaminated fish that come from the Cowlitz River.

Chemicals frequently detected were mercury, PCBs, PBDEs, DDTs, and dioxins/furans. The highest concentrations of PCBs were found in whole largescale sucker (411 µg/kg) and fillets from northern pikeminnow (54 µg/kg). Mercury was highest in northern pikeminnow (566-1010 µg/kg) and largemouth bass (316-610 µg/kg).

Spatial trends appeared to be present, with concentrations of DDTs, PCBs, and PBDEs increasing from upstream to downstream sites. Spatial tends were not evident for mercury.

Detection of temporal trends for mercury, PCBs, PBDEs, and DDTs was confounded by small sample sizes and differences in the sizes and ages of fish across years. Concentrations of these pollutants in most fillets of cutthroat trout, mountain whitefish, and northern pikeminnow from the Cowlitz River near Vader appear to be lower than those sampled in 1995 and 2005. Concentrations of PCBs in whole largescale suckers appear to be the same for 1995 and 2016.

Study results support the current CWA 303(d) listings for the Cowlitz River and Mayfield Lake and suggest that the next Water Quality Assessment will find that several sites are not meeting standards for PCBs and mercury in fish.

Recommendations include sampling again for temporal trends in 10-15 years, targeting key species and size ranges, and collecting five to seven field replicates in order to increase the sensitivity of trend detection.

Introduction

Freshwater Fish Contaminant Monitoring Program

Since 2001, the Washington State Department of Ecology's (Ecology) Freshwater Fish Contaminant Monitoring Program (FFCMP)[1] has characterized persistent, bioaccumulative, and toxic chemicals (PBTs) in freshwater fish statewide with analyses of over 730 fish tissue samples from more than 170 sites. The FFCMP has two broad goals: (1) long-term monitoring for temporal trends and (2) exploratory monitoring to characterize the extent of contamination in areas where data are limited or non-existent.

Results from fish contaminant monitoring are used for a variety of purposes, such as water quality assessments, health risk assessments, determining total maximum daily load (TMDL) effectiveness, and evaluating spatial and temporal trends. Target analytes are most often mercury, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins and –furans (PCDD/Fs), chlorinated pesticides (CPs), such as dichloro-diphenyl-trichloroethane (DDT) and its breakdown products (DDD and DDE), and polybrominated diphenyl ethers (PBDEs). More information about these and other chemicals is available from Ecology[3].

Exposure to contaminants can have a variety of health effects on humans and wildlife, such as reproductive abnormalities, neurological problems, and behavioral changes. A primary route of exposure for people is through the consumption of contaminated fish. The Washington State Department of Health (Health) currently has a statewide fish consumption advisory (FCA) for mercury in bass and northern pikeminnow. There are also numerous site-specific advisories due to contamination of fish by various chemicals[2]. Results from the FFCMP enables Health to conduct the risk assessments which may lead to FCAs. For example, FFCMP data has led to FCAs or FCA revisions in watersheds such as the Spokane River, middle Columbia River, Wenatchee River, Snake River, Lake Washington, and Green Lake.

The 2016 sampling focused on the Cowlitz River basin in southwestern Washington. The Cowlitz River was chosen as a candidate site for the Long Term monitoring component of the FFCMP in the previous project plans (Seiders, 2009 and 2013 QAPPs) because of elevated levels of toxic contaminants in fish and the potential to detect changes in some contaminants over time.

The goal of the 2016 monitoring was to develop a robust data set in order to:

- Characterize spatial and temporal trends.
- Provide a baseline set of data for future trend monitoring work.
- Compare results to water quality standards.
- Support fish consumption risk assessments by health jurisdictions.
- Inform watershed management work related to toxic contaminants.

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[1] https://ecology.wa.gov/Research-Data/Monitoring-assessment/toxics-monitoring/Freshwater-fish-contaminant-monitoring
[2] www.doh.wa.gov/CommunityandEnvironment/Food/Fish.aspx.
[3] https://ecology.wa.gov/Waste-Toxics/Reducing-toxic-chemicals/Addressing-priority-toxic-chemicals.

Cowlitz River

The Cowlitz River basin is located in southwest Washington. This watershed of 2586 square miles drains the western slopes of the Cascade Mountains, including parts of Mount Rainier, Mount Adams, and Mount St. Helens. The Cowlitz River discharges to the Columbia River in Longview, WA.

The watershed is in the Cascades ecoregion and has a moist, temperate climate. Annual precipitation ranges from 120 inches in the Cascade Mountains to 40 inches in the lower Cowlitz Valley (Ecology, 2012). The average daily discharge is 9142 cubic feet per second (USGS, 2018). Land cover is predominately public and private forestry (>67%), with smaller amounts of agriculture (~5%) and urban/residential (<1%) (Lower Columbia Fish Recovery Board, 2004).

Most of the watershed lies within Lewis and Cowlitz counties, with smaller portions in Skamania and Yakima counties. Notable towns in the basin include Packwood, Randle, Morton, Mossyrock, Toledo, Winlock, Ryderwood, Vader, Castle Rock, Kelso, and Longview. There are three major dams on the river for electricity generation; from upstream to downstream they are Cowlitz Falls Project, Mossyrock Dam, and Mayfield Dam. The reservoirs are Lake Scanewa, Riffe Lake, and Mayfield Lake (respectively). The reservoirs allow for electricity generation, flood control, and recreation.

The Cowlitz River provides an important recreational fishery, especially for salmon and steelhead, of which several species are listed as Endangered or Threatened under the Endangered Species Act. Anglers can pursue hatchery-produced rainbow trout in the reservoirs and landlocked coho salmon in Riffe Lake. Cutthroat trout in the mainstem and warmwater species in the reservoirs are also popular fisheries. Multiple entities are involved in managing these fisheries, such as:

- Washington Department of Fish and Wildlife.
- Tacoma Power.
- Lewis County Public Utility District.
- Bonneville Power Administration.
- National Marine Fisheries Service.

Past studies of fish contaminants in the Cowlitz River were part of statewide screening-level studies (Davis, et al., 1998; Johnson et al., 2006; and Seiders et al., 2007). Only two sites were sampled: the mainstem near Vader and the Mayfield Lake impoundment. Table 1 summarizes historical results for key contaminants. A review of these and related historical data helped determine the species, analytes, and sample sizes needed to meet the goals of the 2016 monitoring effort. Figure 1 shows the location of the 2016 sampling sites, which are grouped into six areas. Appendix A gives more detail about each sample site.

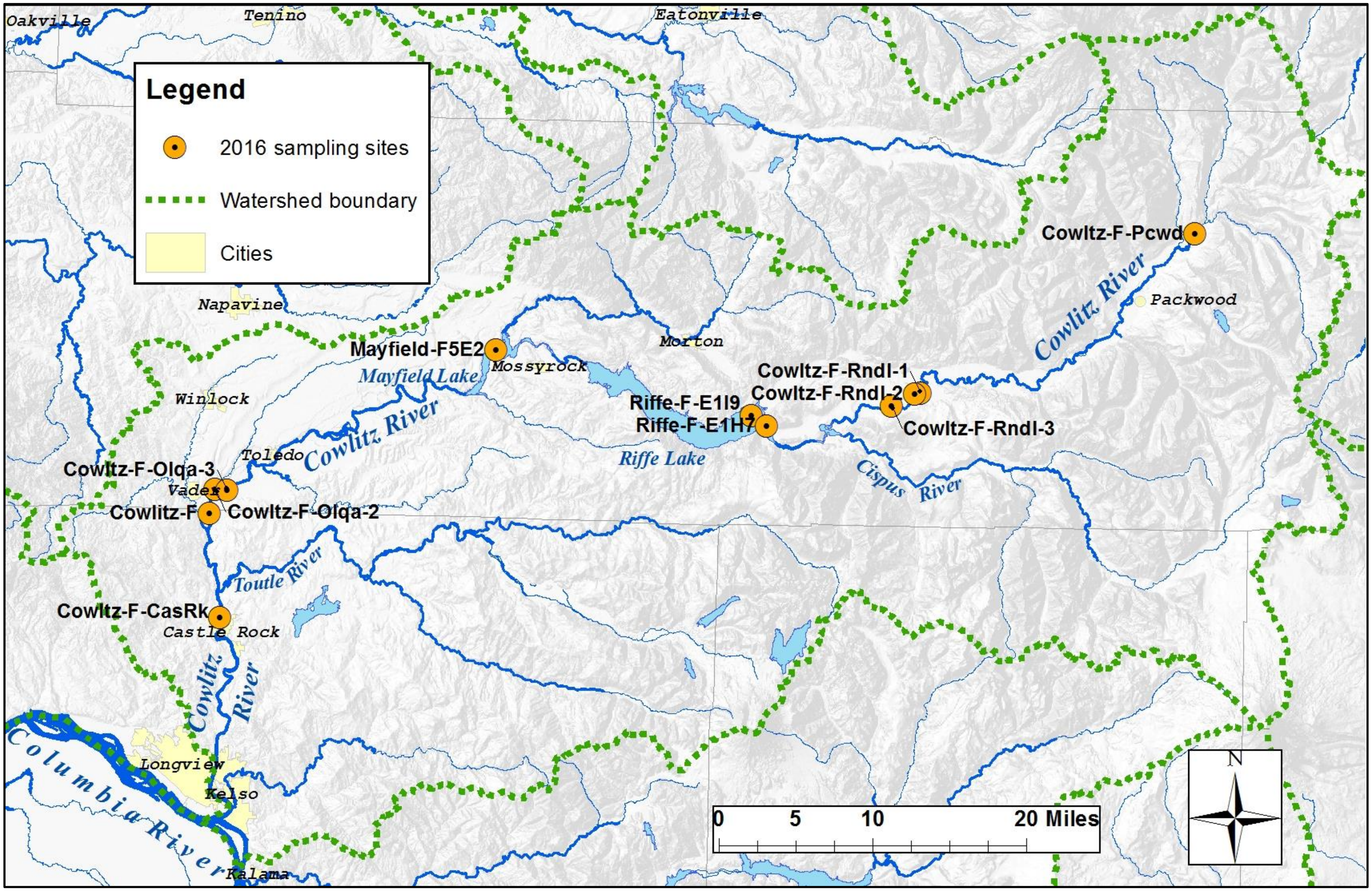

Figure 1. Fish collection sites in the Cowlitz River basin for the 2016 FFCMP.

Table 1. Results for key parameters from past sampling efforts in the Cowlitz River.

Site	Species and Sample Year	t-PCB (µg/kg)	TCDD (ng/kg)	TCDD TEQ (ng/kg)	t-PBDE (µg/kg)	4,4'-DDE (µg/kg)	Hg (µg/kg)	Lipid (%)	Mean Total Length (mm)	Mean Weight (g)	Mean Age (yr)
Cowlitz River near Vader	CTT-1995	**84** J				**43**		3.0	312	315	
	CTT-2005 (m)	**55**	**0.131**	0.303	5.0	21.5	87.0	4.7	360	493	3.0
	LSSw-1995	84 J				73		2.5	434	868	
	LSSw-1995	108 J				59		2.8	467	1036	
	MWF-1995	**47** J				13		6.0	350	403	
	MWF-1995	**60** J				10		5.8	382	611	
	MWF-2005	**46**			24	6.2	205	6.8	441	859	5.6
	NPM-2005	**92**	**0.124**	0.410	18	20.8	**859**	1.8	427	656	10.6
Mayfield Lake	LMB-2005	**5.5**	0.03 UJ	0.050 UJ	2.0	0.97 U	242	0.88	328	610	4.2
	LSS-2005				2.6 J			1.7	443	918	12.8
	NPM-2005	**8.9**	0.03 UJ	0.009	2.3	2.5	474	1.5	312	244	6.4
	YP-2005	5.0 U			0.38	1 U	84.0	0.52	237	164	4.0
Previous Water Quality Standard (FTEC)		5.3	0.065			32	775				

Bold values indicate results that did not meet Washington's previous water quality standards (FTECs).
FTEC = Fish Tissue Equivalent Concentration (see Glossary).
J = Estimated value.
M = results are the mean value from two field replicates.
U = Not detected at or above the reported value.
UJ = Not detected at or above the estimated reporting limit.

Species Codes:
CTT: Cutthroat trout
LMB: Largemouth bass
LSSw: Largescale sucker (whole fish)
MWF: Mountain whitefish
NPM: Northern pikeminnow
YP: Yellow perch

These fish tissue data were evaluated during Ecology's periodic assessment of data (Water Quality Assessment) to meet sections 303(d) and 305(b) of the Clean Water Act. The Water Quality Assessment process assigns water bodies to one of five categories. Category 5 applies to waters where data indicate that water quality standards are not consistently attained: waters in this category are included in the 303(d) list. Category 2 applies when data indicates possible impacts to designated uses. Assessment of monitoring data found concentrations of several chemicals in fish tissue that resulted in Category 5 or 303(d) listings for dioxin (2,3,7,8-TCDD), mercury, and PCBs (Table 2).

These 303(d) listings can affect how communities along the river manage their wastewater discharges to the river in order to meet regulatory permit limits, so the more comprehensive sampling effort in 2016 was crafted to also address questions about the extent of pollution in the river and its reservoirs.

Table 2. Current (July 2016) Category 5 and 2 listings for the Cowlitz Basin.

Water Body Name	Assessment Unit ID	Water Quality Assessment Parameter Name	Current Category	Species Not Meeting Standard	Listing ID
Cowlitz River	17080005000220 (same as 2016 site "Cowlitz-F")	PCBs	5	CTT, MWF, NPM	17164
		Mercury	5	NPM	52602
		2,3,7,8-TCDD (Dioxin)	5	CTT, NPM	51552
		2,3,7,8-TCDD TEQ	2	CTT, NPM	51605
Mayfield Lake	46122F5E3 (near 2016 site "Mayfield-F5E2")	PCBs	5	LMB, NPM	52669

Species Codes:
CTT: Cutthroat trout
LMB: Largemouth bass
MWF: Mountain whitefish
NPM: Northern pikeminnow

Monitoring and data analyses to measure statistically significant temporal changes have not been pursued in the Cowlitz River basin. Challenges for long-term monitoring programs include:

- Small sample sizes.
- High variability associated with fish tissue.
- High costs associated with laboratory analyses for organic contaminants.

Methods

Field and Laboratory Methods

Sample design, collection, preparation, and analytical methods followed those described in the project plan and Addendum 5 for the FFCMP (Seiders, 2013; Seiders and Deligeannis, 2016).

The sampling design was crafted to help reduce the effects of high variability of pollutant levels often seen in fish tissue. In general, the sampling design addresses sample representativeness, sample size, comparability of results to other studies, frequency of sampling, and other factors that can affect the usability of the data. For example, a sampling frequency of about 10 years allows for sampling a different generation of fish (for most species) than was historically sampled. Also, the use of multiple composite samples reduces sampling variability, which improves the strength of statistical tests to determine spatial or temporal trends.

Field

The collection, handling, and processing of fish tissue samples for analyses were guided by methods described by EPA (2000) and Ecology's standard operating procedures (Sandvik, 2018a, 2018b, and 2018c). The collection of fish by Ecology in 2016 adhered to these federal and state Scientific Collection Permits: USFWS # TE-058381-8, NOAA # 1386-8A, and WDFW # 12-298g.

Fish were collected at various sites using a 16' electrofishing boat and angling. Ecology staff performed the collections with help by staff from Lewis County PUD, Tacoma Power, and Washington Department of Fish and Wildlife.

After all fish were collected and preserved, individual fish were assigned to composite samples based on the sampling goals for individual sites. This involved grouping fish by size in order to match the sizes of fish used in historical samples and make use of available fish. To create multiple composite samples of similar sized fish (field replicates), individual fish meeting the size criteria were randomly assigned to composite samples. Most composite samples consisted of skin-on fillets from three to five individual fish of a similar size of the same species per site, except for largescale suckers, which were processed as whole fish. Samples of largescale suckers as whole fish were added to the 2016 effort as part of building a data set for this species, which will allow for statewide comparisons. Appendix B describes sample collection and processing in more detail.

Laboratory

The laboratory analytical methods are consistent with the most recent FFCMP monitoring events. Laboratory analyses of most samples were conducted by the Ecology Manchester Environmental Laboratory (MEL). Analyses for PCB congeners and dioxins/furans (PCDD/Fs) were done by Pacific Rim Laboratories in Surrey, BC. Table 3 shows the analytical methods and typical reporting limits for target parameters.

Table 3. Laboratory measurement methods for fish tissue samples, FFCMP 2016.

Parameter	Analytical Method	Typical Reporting Limits
Mercury	EPA 245.6 (CVAA)	17 µg/kg
Chlorinated pesticides	EPA 8081 (GC/ECD), MEL SOP	most 0.5 - 3.0 µg/kg
PCB Aroclors	EPA 8082 (GC/ECD), MEL SOP	1.1 - 5 µg/kg
PCB congeners	EPA 1668A, (HiRes GC/MS)	0.003-0.01 µg/kg
PCDD/Fs	EPA 1613B (HiRes GC/MS)	EQL 0.017 - 0.5 ng/kg
PBDEs	EPA 8270 (SIM); MEL SOP 730104	0.10 - 2.6 µg/kg; PBDE 209 1.9 - 4.3 µg/kg
Lipids	MEL SOP 730009 (Gravimetric)	0.10%

Fish tissue was analyzed for total mercury rather than methylmercury because it is easier and less costly to analyze as compared to methylmercury. More than 95% of the total mercury in fish fillet tissue is methylmercury where it is associated with muscle proteins (Bloom, 1995; Driscoll et al., 1994). Methylmercury is the bioaccumulative and toxic form of mercury in fish tissue. Even though the human health water quality standard for mercury is based on methylmercury, Ecology uses results from total mercury for comparison to water quality standards. Total mercury was the target analyte used in other fish tissue studies in Washington and in past water quality assessments.

For PCBs, all samples were analyzed for Aroclors while a subset of samples (30) were analyzed for all 209 congeners using EPA Method 1668c. Aroclor results were used for spatial and temporal trend analyses in this report because the Aroclor method was used for all 2016 samples and for samples from historical studies. The PCB congener analyses were done to help build a data set to evaluate the comparability of the Aroclor and congener methods and help determine the most appropriate use of either method in future monitoring projects.

A total of 53 samples of fish tissue were analyzed for some or all of these chemicals in the table above. All results were reported on a wet-weight basis. Table 4 shows the number of composite samples that were analyzed for each species and size class in each area. The six sampling areas are shown in order from downstream to upstream. All samples were prepared from fillet tissue except largescale suckers, which were prepared as whole fish.

Table 4. Sample areas, species, samples, and analyses of composite samples, FFCMP, 2016.

Sample collection area	Sample area code	Species and size code	Number of composite samples for each analysis: Mercury	CP, PCB Aroclors	PBDE, lipid	PCB congener	PCDD/F
Cowlitz River: near Castle Rock	6-CR	LSS		3	3		
		MWF	3	3	3	3	3
		NPM	1	1	1	1	1
Cowlitz River near Vader: Olequa Cr. to I-5 bridge	5-OL	CTT	3	3	3	3	3
		LSS		3	3		
		MWF	3	3	3	3	3
		MWF-L	3	3	3	3	3
		NPM	3	3	3	3	3
Mayfield Lake: central	4-ML	LSS		3	3		
		NPM	3	3	3	3	3
Riffe Lake: east end	3-RF	CTT-L	2	2	2	2	2
		CTT-S	1	1	1	1	1
		LMB	3	3	3		
		LSS		3	3		
		RBT-L	1	1	1		
		RBT-S	1	1	1		
Cowlitz River: below Randle	2-RN	LSS		3	3		
		MWF	2	2	2	2	2
		NPM	3	3	3	3	3
		RBT	3	3	3		
Cowlitz River - Clear Fork: near Mt. Rainier NP boundary	1-CF	MWF	3	3	3	3	3

Species codes:
CTT: Cutthroat trout
LMB: Largemouth bass
LSS: Largescale sucker (as whole fish)
MWF: Mountain whitefish
NPM: Northern pikeminnow
RBT: Rainbow trout

Relative size groups: L-large; S-small.

Data Quality Assessment

General

The quality of laboratory results from the 2016 study was assessed by reviewing laboratory case narratives and analytical results. Quality control procedures included a mixture of analyses such as method blanks, calibration and control standards, matrix spikes, matrix spike duplicates, surrogate recoveries, and laboratory duplicates.

All laboratory analyses were completed and no results were rejected. Some results from laboratory analyses (e.g., 4% of chlorinated pesticides and 11% of PBDEs) were qualified as estimated values, mostly because of analytical interferences from fats associated with the matrix of fish tissue. Overall, most of the 2016 data met measurement quality objectives such as bias and other data quality targets described in the project plans (Seiders, 2013 and 2016). All results were deemed usable as qualified.

The field sampling came close to meeting the original goal for completeness. Where targeted species were not found, alternative species were collected (e.g., largemouth bass used instead of smallmouth bass in Riffe Lake). As with many fish tissue studies, the sampling design used methods that resulted in fish that were collected from multiple locations and habitats within a river reach or a lake. The samples from these subareas were deemed to be representative of the larger river reach or lake.

Overall, adequate samples were collected to meet most project objectives. While larger sample sizes for some species at some sites would have improved the sensitivity of trends analyses, the need for greater spatial representation of the watershed was also an important consideration. Field replicate samples usually consisted of two or three samples of the same species of similar size range from the same area. Results from field replicate samples indicated that variability in pollutant concentrations in the population and resultant uncertainty were large in many cases. Appendix C reviews the nature of variability and resultant uncertainty for PCBs and mercury.

The quality and comparability of historical data were examined by reviewing the individual study reports with emphasis on field, laboratory, and quality assurance procedures. Results from all of the historical studies were in Ecology's Environmental Information Management (EIM) system: these data, as qualified, were deemed acceptable for comparisons to results from the 2016 sampling. Additional quality assurance information is available by contacting the authors of this report.

Data Reduction, Trends Analyses, Water Quality Standards

Data Reduction

Data reduction and management procedures followed practices described in the project plan for the FFCMP (Seiders, 2013). Results from some groups of target analytes were summed in order to account for their additive effects and for simplicity of comparison to various criteria and to other data. Summed values in this report are noted using the prefix "t-" as in t-PCB. Result values that were qualified as “non-detect” (U and N variants) were set to zero for summing. Procedures for summing followed Ecology’s internal guidance for the Water Quality Assessment process.

For dioxins and furans, a cumulative toxicity concentration for the 17 toxic dioxin and furan congeners was calculated following EPA (EPA, 2010) and the World Health Organization (Van den Berg et al., 2006). The cumulative toxicity is expressed as TCDD-TEQ, the toxicity equivalent (TEQ) to the single congener 2,3,7,8-TCDD, which is the most toxic congener. The TCDD-TEQ values can be used for comparisons to various values for the protection of human health, such as EPA Screening Values described later.

Contaminant concentrations in fish can be influenced by many factors, such as species, tissue type, size, age, lipid content, collection location, collection season, and analytical method (Exponent, 2003). When these factors correlate to contaminant concentrations, use of the relationships could potentially increase the sensitivity of statistical testing to detect differences among sites or between years. The results were plotted to examine relationships between each of three analytes (t-PCB, t-DDT, and mercury) to the factors of fish length, weight, age, and lipids. Simple linear regression showed that relationships among these parameters were non-existent, inconsistent, or too weak (coefficient of determination or $r^2 < 0.7$) to use in normalizing the data or performing other adjustments using co-variance.

Trends Analyses

The 2016 data were tested for spatial differences using the non-parametric Kruskal-Wallis single-factor ANOVA test (SYSTAT, 2012; Zar, 1984). The generalized null hypothesis was that data sets did not differ. For these tests, an alpha level of 0.05 was chosen, meaning that there was a low probability (5%) that the outcome was due to chance. For sample results that were reported as non-detect, the value of the detection limit was used in these tests.

Temporal trends in contaminant concentrations were examined only for the Cowlitz River near Vader and Mayfield Lake because these are the only two sites that have historical data. Table 5 shows the numbers of samples for the different species and sites over time. Sample sizes in the historical studies were smaller than in 2016 because they were screening level efforts.

Table 5. Numbers of samples potentially available for temporal trend analyses.

	Study:	Ecology WSPMP [1]	Ecology WSTMP [2,3]	Ecology FFCMP
	Sample Year:	1995	2005	2016
Location	Species	Number of samples analyzed		
Cowlitz River near Vader: same as 2016 site "Cowlitz-F"	CTT	1	1	3
	LSS	2		3
	MWF	2	1	6
	NPM		1	3
Mayfield Lake: is near 2016 site "Mayfield-F5E2"	NPM		1	3

All samples are composites of fillets except LSS, which were processed as whole fish.

References:
[1] Davis et al., 1998
[2] Johnson et al., 2006
[3] Seiders et al., 2007
Study Codes:
WSPMP: Washington State Pesticide Monitoring Program
WSTMP: Washington State Toxics Monitoring Program
FFCMP: Freshwater Fish Contaminant Monitoring Program
Species Codes:
CTT: Cutthroat trout; LSS: Largescale sucker (whole fish); MWF: Mountain whitefish; NPM: Northern pikeminnow.

The comparability of samples between years was evaluated qualitatively using two measures of fish size: total length and weight. Fish age was not available for all historical samples, but was reviewed where available. If the fish used in samples were of similar size, then they were considered to be comparable for purposes of detecting differences over time. For MWF and NPM, all samples within the site and sample year were pooled, even though they may have been designated as small or large size class during sampling. The differences in size were deemed to be minimal and were generally within acceptable size range guidance used during sample collection.

Results for DDE, mercury, PBDEs, and PCBs from the historical and 2016 projects were plotted to determine whether statistical testing for trends might be pursued. The historical data had too few samples for statistical testing, so qualitative indications of change over time were shown using boxplots in the Results and Discussion section below.

Water Quality Standards

Washington's water quality standards protect the health of people, fish, shellfish, and wildlife. These standards were revised in October 2017 (Ecology, 2017). The water quality standards "consist of water quality criteria, designated uses, and anti-degradation components. The water quality standards represent the chemical, physical, and biological conditions necessary to support the state designated uses of a water body" (Ecology, 2018).

For toxic substances, Washington's water quality standards employ both numeric and narrative criteria for both marine and fresh water. Numeric criteria are based on data and scientific assessment of adverse effects from specific chemicals or conditions. Narrative criteria are statements that describe the desired water quality goal, such as waters being "free from" pollutants like oil as well as other substances or conditions that can harm people or aquatic life. These criteria protect water bodies from pollutants for which numeric criteria are difficult to specify.

Fish tissue results from the 2016 study were evaluated using the methodology described in Ecology's Water Quality Program Policy 1-11, Chapter 1 (Ecology, 2018). This November 2018 revision of the policy describes how fish tissue data are used to determine if water quality standards are met. Appendix D shows the tissue exposure concentrations (TECs) for pollutants in fish tissue that are used in determining whether the designated use of fish and shellfish harvest is supported or whether the sampled water bodies are impaired. There can be two TEC values associated with each pollutant depending on the type of toxic effect produced: the TECc relates to carcinogenic effects, while the TECn relates to non-carcinogenic effects.

Appendix D also describes EPA's Screening Values (SV) for Subsistence and Recreational Fishers, Washington State Department of Health's (Health) Fish Consumption Advisory Screening Levels (FCASL), and Ecology's previously used Fish Tissue Equivalent Concentration (FTEC). Appendix E describes the different approaches used by Ecology and Health in evaluating risks to human health from exposure to contaminants in fish.

Results and Discussion

Results for each monitoring site are summarized and discussed below using several formats. All results are available from Ecology's Environmental Information Management database (EIM) at https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database under the Study ID FFCMP16.

Table 6 summarizes results for chemicals detected in fillets from five species collected in 2016 from the Cowlitz River system. These species include cutthroat trout (CTT), largemouth bass (LMB), mountain whitefish (MWF), northern pikeminnow (NPM), and rainbow trout (RBT). Because the data from fillets were pooled in Table 6, these statistics are not representative of any single species or site.

Table 6. Summary statistics for chemicals detected in fish fillet tissue from the Cowlitz River basin, FFCMP 2016.

Parameter	Number of Samples	Mean	Median	Min	Max	SD	95% CL	Detection Frequency
Mercury	38	191	86	19	1010	221	70	100%
t-PCBc	30	8.6	4.9	0.5	45.2	9.9	3.5	100%
t-PBDE	38	2.43	1.03	0.11	10.09	2.71	0.86	100%
t-PCBa	38	14.5	9.1	1.9	53.8	14.4	5.2	76%
t-DDT	38	7.38	2.82	0.78	32.67	9.83	3.78	68%
4,4'-DDE	38	6.55	2.93	0.78	27.50	8.15	3.20	66%
TCDD TEQ (ng/kg)	30	0.033	0.023	0.000	0.160	0.043	0.022	50%
t-Chlordane	38	1.27	1.08	0.65	2.01	0.54	0.47	13%
Hexachlorbenzene	38	0.49	0.49	0.49	0.49	0.00	0.00	3%
Lipids (%)	38	2.73	1.90	0.49	6.25	1.84	0.59	-
Mean Length (mm)	38	310.8	311.3	257.7	384.0	33.7	10.7	-
Mean Weight (g)	38	299.3	311.5	145.0	536.3	96.1	30.6	-
Mean Age (yr)	38	4.2	3.3	1.0	11.4	3.0	1.0	-

Values are in µg/kg unless otherwise specified.

t-PCBa = sum of PCB Aroclors

t-PCBc = sum of PCB congeners

SD = standard deviation

CL = confidence limit

Chemicals with high frequencies of detection in fillets were PCBs, dioxin/furans (as TCDD-TEQ), PBDEs, DDTs, and mercury. For example, PCB Aroclors were detected in 76% of the samples and 4,4'-DDE was detected in 66% of samples. Mercury was detected in all fillet samples. Chlordane and hexacholorbenzene were detected at low frequency while dieldrin was not detected.

Largescale suckers (LSS) were prepared as whole fish; results are summarized in Table 7. The contaminants 4,4'-DDE, PCBs, and PBDEs were detected in 100% of the samples. Mean concentrations of 4,4'-DDE, PBDEs, and PCBs in whole largescale suckers were about 3 to 5 times higher than those found in fillets from the other species.

Table 7. Summary statistics for chemicals detected in whole largescale suckers from the Cowlitz River basin, FFCMP 2016.

Parameter	Number of Samples	Mean	Median	Min	Max	SD	95% CL	Detection Frequency
t-PCBa	15	67.8	14.9	3.3	411.0	111.9	56.6	100%
t-PBDE	15	10.23	7.90	0.57	29.65	9.77	4.94	100%
t-DDT	15	38.27	5.21	1.46	201.1	58.17	29.44	100%
4,4'-DDE	15	29.20	4.63	1.46	122.0	39.91	20.19	100%
t-Chlordane	15	1.73	1.73	1.51	1.94	0.30	0.42	13%
HCB	15	1.03	1.03	1.03	1.03	-	-	7%
Lipids (%)	15	4.34	4.61	1.69	6.14	1.37	0.69	-
Mean Length (mm)	15	447.4	445.4	430.4	467.0	10.4	5.2	-
Mean Weight (g)	15	887.0	855.0	824.4	1029.6	74.5	37.7	-
Mean Age (yr)	15	11.5	11.2	7.0	15.8	2.6	1.3	-

Values are in µg/kg unless otherwise specified.

t-PCBa = sum of PCB Aroclors

SD = standard deviation

CL = confidence limit

Figure 2 shows the range of PCBs and mercury in fish from the Cowlitz River. These boxplots graphically summarize the data set using various statistical descriptors. The lower and upper ends of the box represent the lower and upper quartiles (i.e., the 25th and 75th percentile values), with the line dividing the box depicting the median, or 50th percentile. The whiskers extending beyond the box represent the range of observed values that fall within 1.5 times the interquartile range. A short horizontal line (e.g., for LMB in the t-PCB Aroclor plot below) indicates a single result or multiple results having the same value. Outliers are shown as asterisks – those values between 1.5 and 3 times the interquartile range, and open circles – those values greater than 3 times the interquartile range.

The highest concentrations of PCBs were found in whole largescale sucker (73.5–411 µg/kg) and fillets from northern pikeminnow (39.7–53.8 µg/kg). The highest levels of mercury were found in northern pikeminnow (566–1010 µg/kg) and largemouth bass (316–610 µg/kg). Largescale suckers were not analyzed for mercury. Boxplots for other contaminants and field data are in Appendix F.

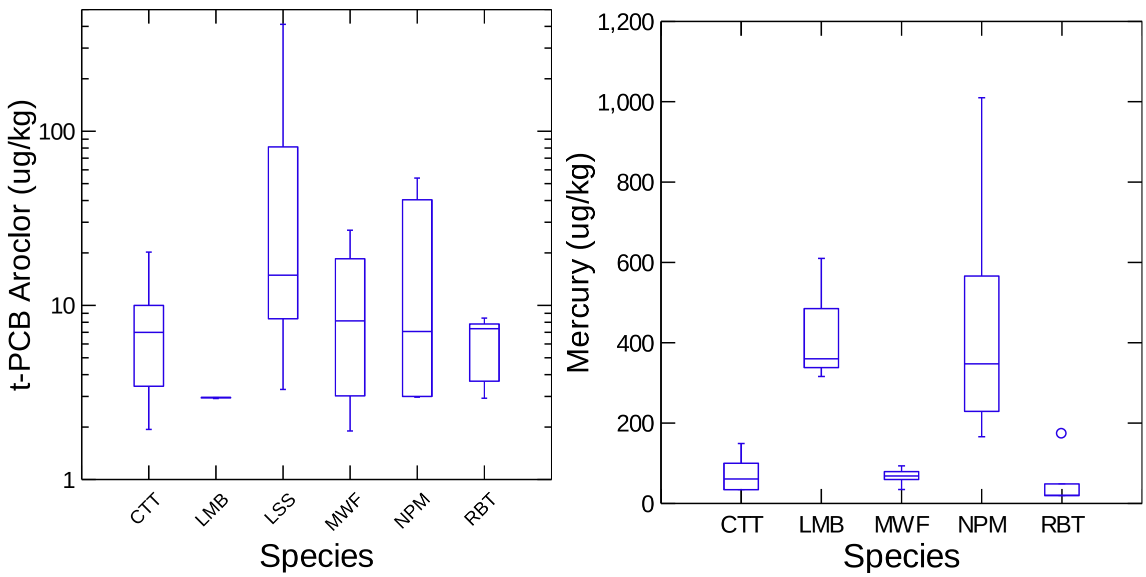

Figure 2. Boxplots for PCBs and mercury in Cowlitz River fish, FFCMP 2016.

Species codes:

CTT: Cutthroat trout

LMB: Largemouth bass

LSS: Largescale sucker (whole fish)

MWF: Mountain whitefish

NPM: Northern pikeminnow

RBT: Rainbow trout.

Figures 3–6 give general comparisons of Cowlitz River results to statewide results and thresholds for protecting human health. The figures show results for t-PCB, t-PBDE, mercury, and TCDD-TEQ in fillet tissue from multiple species of fish collected across Washington during the FFCMP since 2001. Results from 2016 for the Cowlitz River system are indicated with circles. Where multiple field replicates were taken, the symbols show the mean value of those replicates. In Figure 3 for PCBs, the gaps in the symbols around 1, 2, 5, and 10 µg/kg appear because results for some samples were reported at these same values. These values were often the reporting limit for the analytical method used for that sample, either EPA 8082 or EPA 1668. Figure 6 for TCDD-TEQ has a similar gap around 0.05 ng/kg, also because multiple samples had the same result value.

For comparisons to values for protecting human health, the plots also show Washington's current thresholds used in the narrative criteria (10x TECc and TECn) as well as Washington's previous thresholds used in narrative criteria: the Fish Tissue Equivalent Concentration (FTEC), Health's Fish Consumption Advisory Screening Levels (FCASL), and EPA's Screening Values (SV). These terms are described in Appendix D.

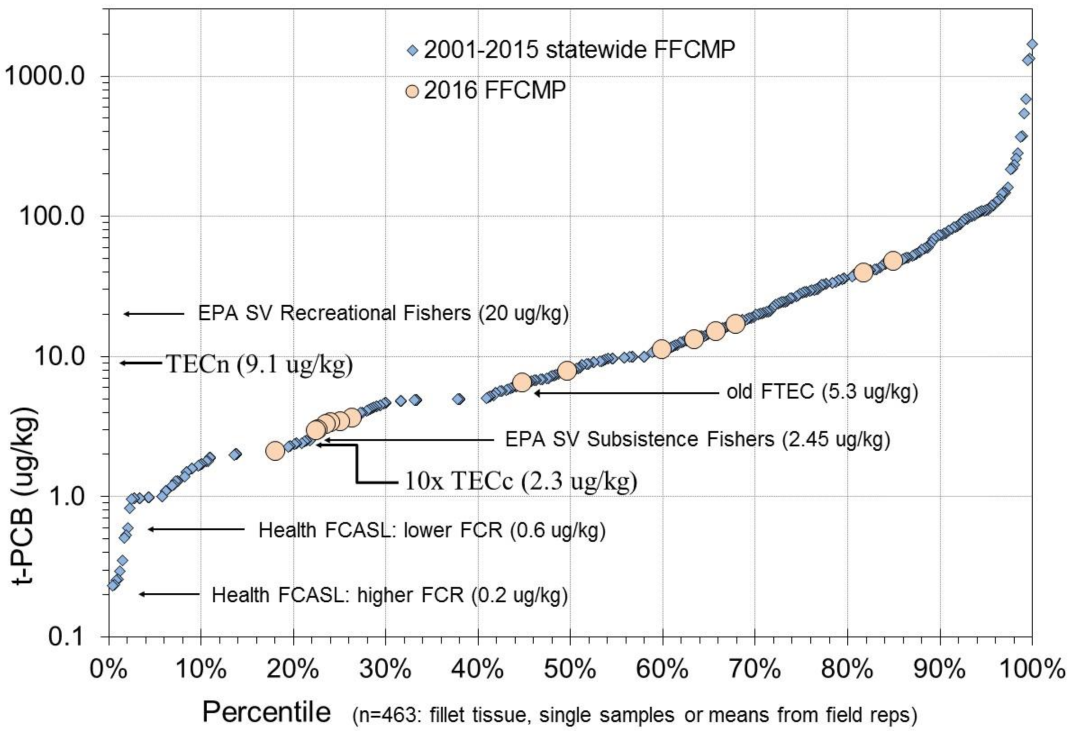

Figure 3. Cumulative frequency distributions for t-PCB in fillet tissue from Washington between 2001 and 2016.

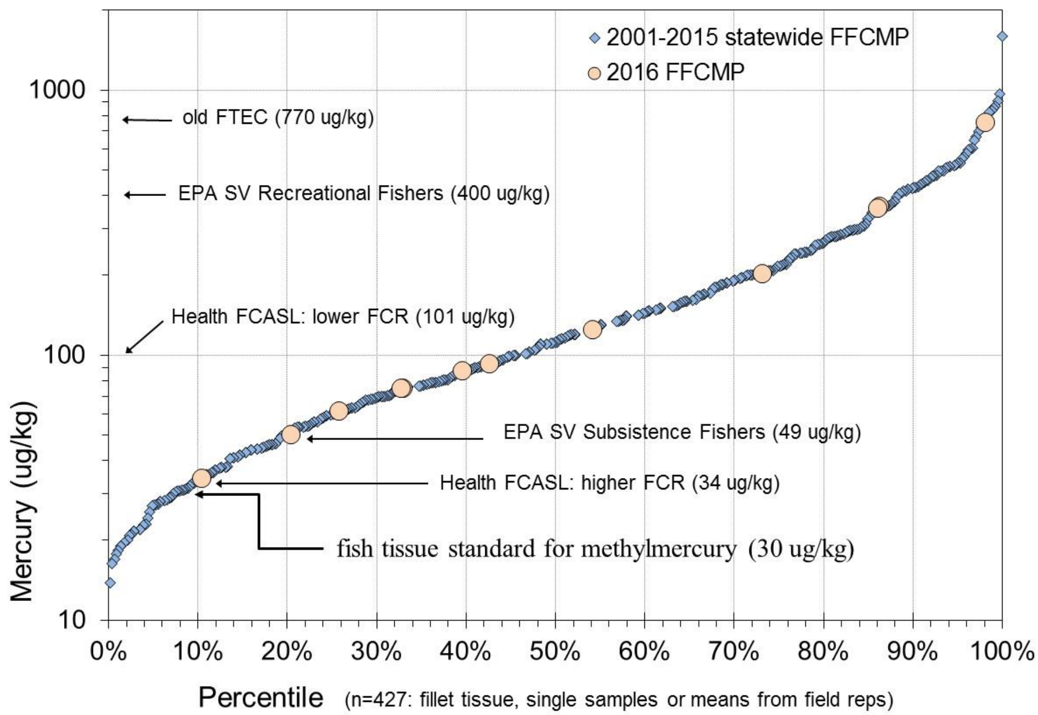

Figure 4. Cumulative frequency distributions for mercury in fillet tissue from Washington between 2001 and 2016.

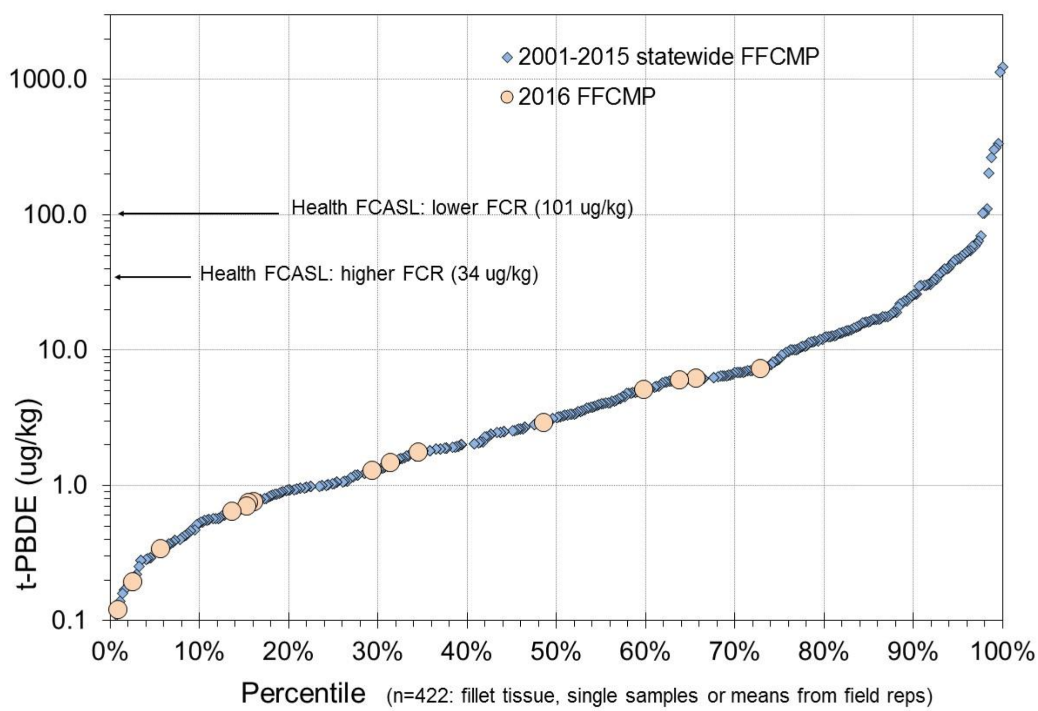

Figure 5. Cumulative frequency distributions for t-PBDE in fillet tissue from Washington between 2001 and 2016.

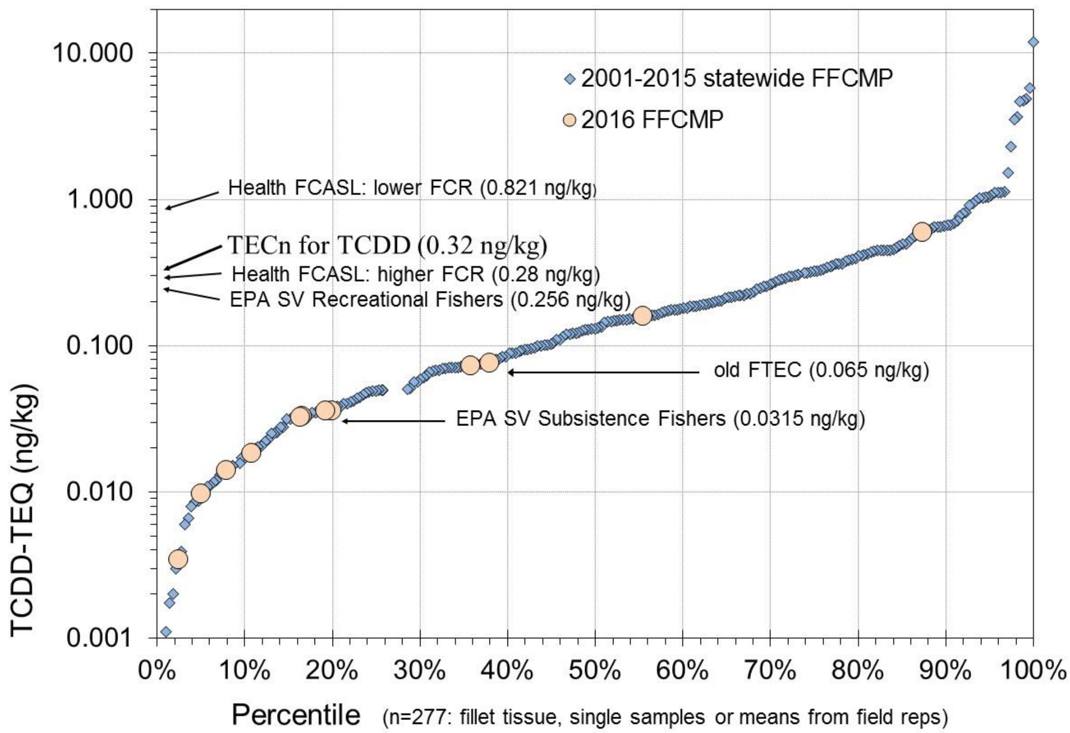

Figure 6. Cumulative frequency distributions for TCDD-TEQ in fillet tissue from Washington between 2001 and 2016.

Figures 3–6 indicate that the range of contaminant concentrations seen in Cowlitz River fish from 2016 are similar to the ranges found in fish from across Washington sampled during the FFCMP from years 2001 through 2016. Levels of PCBs in Cowlitz River fish ranged from the 18^{th} to 85^{th} percentile of the statewide range, which corresponds to 2.1–48 µg/kg. Concentrations of PCBs in fish at the upstream sites (Clear Fork near Mount Rainier National Park and the Cowlitz River near Randle) were relatively low (<10 µg/kg) and comparable to levels seen in water bodies deemed to have little apparent human impact (Johnson et al., 2010). Mercury concentrations in 2016 ranged from the 10^{th} to 98^{th} percentile while PBDEs ranged up to the 73^{rd} percentile. Dioxins and furans, as TCDD-TEQ, ranged from the 3^{rd} to the 88^{th} percentile. Comparisons to Washington's water quality standards for PCBs and mercury are described in a separate section below.

Spatial Trends

Concentrations of selected contaminants and field measurements were plotted to see whether differences might be discerned among sites. Tests for spatial differences were then conducted using the non-parametric Kruskal-Wallis single-factor ANOVA test as described in the Methods section. This test determines only that at least one sampled area is different from the others, yet it does not identify which areas are different from each other. Additional testing between areas was not pursued because of likely confounding factors, which are discussed following the plots below.

Figures 7–9 show boxplots for t-PCBs, t-PBDEs, and t-DDTs in three species from the sampled sites. The plots are ordered left to right by site from upstream (1-CF) to downstream (6-CR). The site codes in the plots refer to the areas that were sampled:

1-CF: Cowlitz River, Clear Fork near Mt. Rainier NP boundary.
2-RN: Cowlitz River below Randle.
3-RF: Riffe Lake, east end.
4-ML: Mayfield Lake, central area.
5-OL: Cowlitz River near Vader, Olequa Creek to I-5 bridge.
6-CR: Cowlitz River near Castle Rock.

Generally, fish from upstream sites had lower levels of the three chemicals than did fish from downstream sites. These differences ranged up to two orders of magnitude for t-DDTs (e.g., 2–3 µg/kg in LSS from the Randle and Mayfield Lake areas to 100–200 µg/kg in LSS from the Castle Rock area). Differences of about one order of magnitude were seen for t-PCBs and t-PBDEs between upstream and downstream sites.

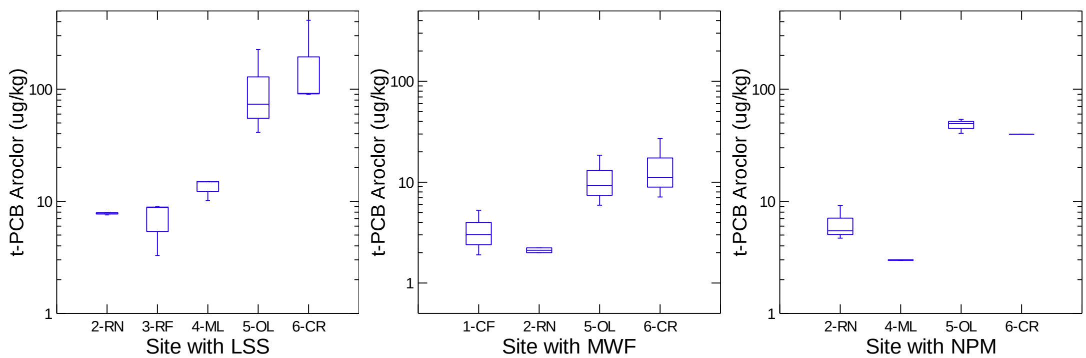

Figure 7. Boxplots for t-PCB Aroclors in Cowlitz River basin whole largescale suckers (LSS) and fillets of mountain whitefish (MWF) and northern pikeminnow (NPM).

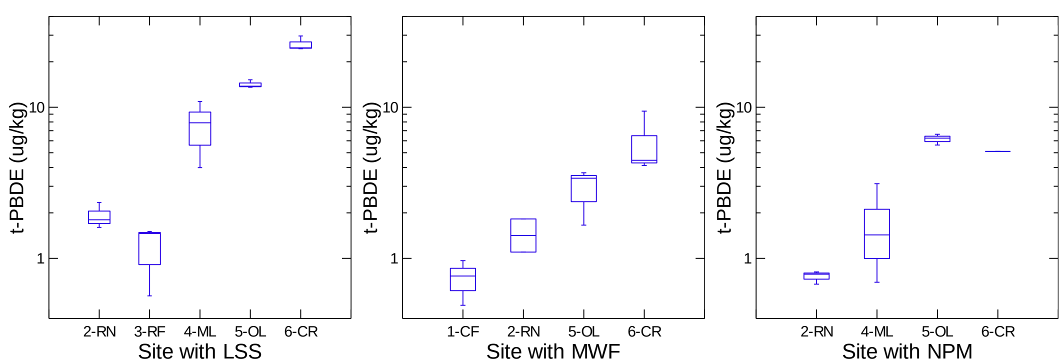

Figure 8. Boxplots for t-PBDEs in Cowlitz River basin whole largescale suckers (LSS) and fillets of mountain whitefish (MWF) and northern pikeminnow (NPM).

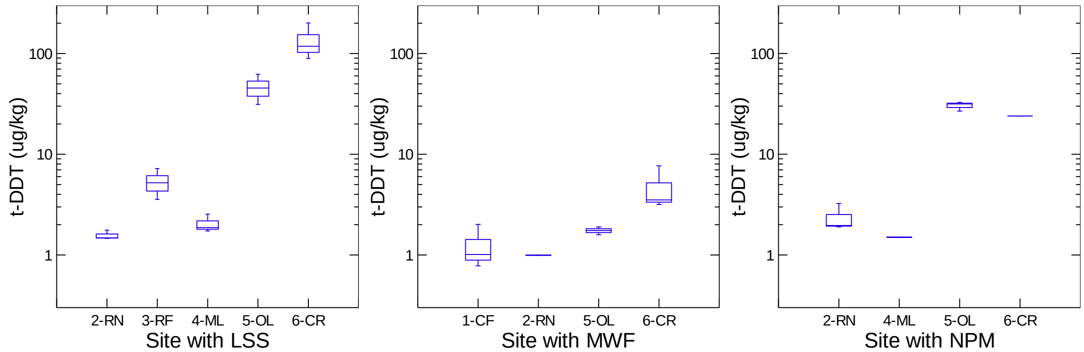

Figure 9. Boxplots for t-DDT in Cowlitz River basin whole largescale suckers (LSS) and fillets of mountain whitefish (MWF) and northern pikeminnow (NPM).

Spatial patterns for mercury in two species did not show a similar upstream-downstream gradient (Figure 10), yet there were differences among sampled areas, especially for NPM. Levels of mercury in MWF ranged from 35 to 93 µg/kg and were similar among all areas. For NPM, concentrations ranged from 166 to 1010 µg/kg across all areas. The samples collected from the area below Randle (2-RN) had higher concentrations (566–1010 µg/kg) than those from Mayfield Lake (166–229 µg/kg), the mainstem near Vader (318–425 µg/kg), and a single composite sample from the mainstem near Castle Rock (362 µg/kg). The NPM from Mayfield Lake had lower concentrations of mercury than NPM from the mainstem river, yet there is too little information to determine the reasons for this difference; potential reasons could be methylmercury dynamics associated with some reservoirs or fish size and age. Whole LSS were not analyzed for mercury.

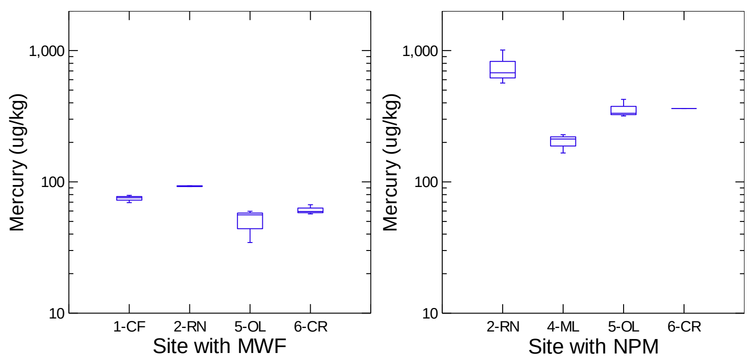

Figure 10. Boxplots for mercury in Cowlitz River basin fillets of mountain whitefish (MWF) and northern pikeminnow (NPM).

The Kruskal-Wallis ANOVA tests for each of these three species (LSS, MWF, and NPM) and analyte in each species (t-PCBs, t-PBDEs, t-DDT, and mercury) showed that there were spatial differences in contaminant concentrations among the areas sampled. Likewise, the ANOVA testing also showed differences in length, age, and lipids measurements for each of these species among sites, except for age in MWF.

While the differences between upstream and downstream concentrations could be due to the different availability of a pollutant at a site, certain characteristics of fish might explain some of the differences. Size, age, and lipid content are factors that can influence accumulation of contaminants. However, sample sizes were too small to quantify the influence of each of these factors.

Qualitative observations (Appendix G) suggest that differences in lipids and age contributed largely to the upstream-downstream differences in concentrations observed, while lengths and weights were less influential. The plots for fish age show differences among sites for the same species, especially for LSS. The plots for lipids in LSS show a wide range among sites, while lipids in MWF increase in a downstream direction. The length of the fish used in the samples was more consistent for each species except for MWF, where the fish from the downstream sites near Vader (5-OL) and Castle Rock (6-CR) were slightly larger than those collected upstream. The weights of fish among sampled sites were relatively consistent, except perhaps for the larger range of MWF from the site near Vader (5-OL).

However, the nearly ten-fold difference for PCBs in LSS between upstream and downstream sites is so large that it seems to be more likely influenced by true differences between upstream and downstream environments, and less influenced by differences in the size, age, or lipids of the fish.

Temporal Trends

Several data sets from the Cowltiz River near Vader (the Olequa reach) and Mayfield Lake were selected for temporal trends evaluation for key parameters because data were available from the sampling conducted in 1995, 2005, and 2016. Some of these data sets had multiple samples (field replicates) of individual fish species that were of similar sizes among years. Parameters examined were mercury, t-PCB, t-PBDE, and t-DDT. Physical measurements of the fish (length, weight, age, and lipids) were also evaluated (Appendix G) because of their potential influence on contaminant concentrations. Quantitative statistical testing was not performed because the historical data had too few samples.

Figures 11–14 show boxplots for mercury, t-PCBs, t-PBDE, and t-DDT in fish from the Cowlitz River near Vader. Samples from the three reaches sampled in this area (sites Cowlitz-F, Cowltz-F-Olequa-2, and Cowltz-F-Olequa-3 in Figure 1) were pooled for trends analyses. This pooling helps to increase the sensitivity of trend detection by using larger sample sizes. The fish from these reaches were also collected near each other and deemed to be representative of this section of the river.

Figure 11 suggests that mercury for three species is lower in 2016 than in past studies. Figure 12 suggests that t-PCBs for three species is lower in 2016 than in past studies, yet there appears to be no difference between years for whole largescale sucker. For PBDEs, Figure 13 suggests lower concentrations in 2016 than in 2005; yet like mercury, the single sample available for 1995 gives little information about the range of concentrations in that year. Figure 14 shows that concentrations of t-DDT are lower in 2016 than in previous years for three species, yet for northern pikeminnow, the 2016 results were higher than those in 2005.

While these plots are suggestive of changes over time, high variability leads to large uncertainties in the true mean or median values of these populations, thus hampering efforts to detect true trends. Future sampling efforts should collect larger numbers of samples to allow a stronger assessment of temporal trends.

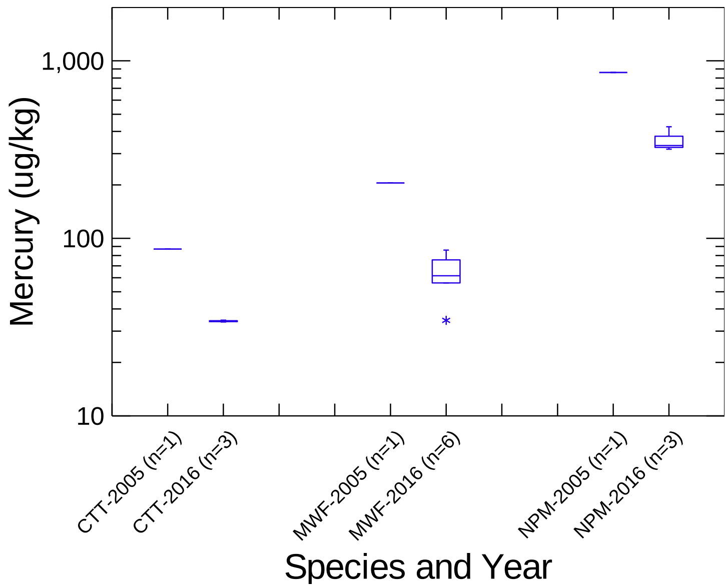

Figure 11. Boxplots comparing mercury concentrations among years in cutthroat trout (CTT), mountain whitefish (MWF), and northern pikeminnow (NPM) from the Cowlitz River near Vader.

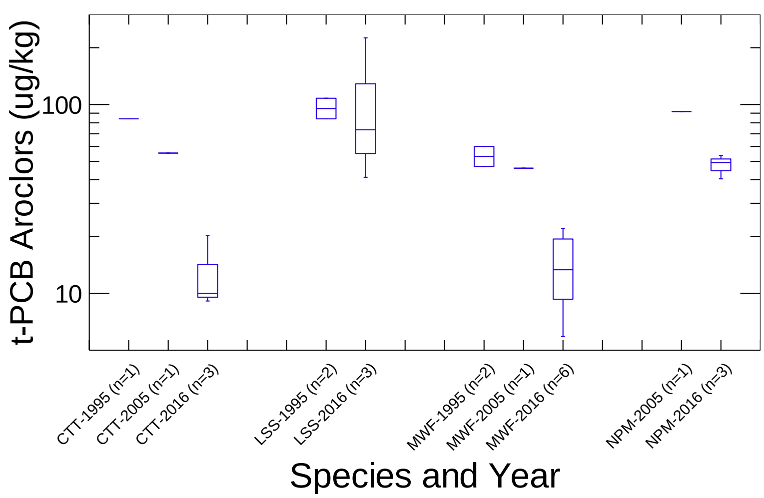

Figure 12. Boxplots comparing PCB concentrations among years 1995, 2005, and 2016 in cutthroat trout (CTT), whole largescale sucker (LSS), mountain whitefish (MWF), and northern pikeminnow (NPM) from the Cowlitz River near Vader.

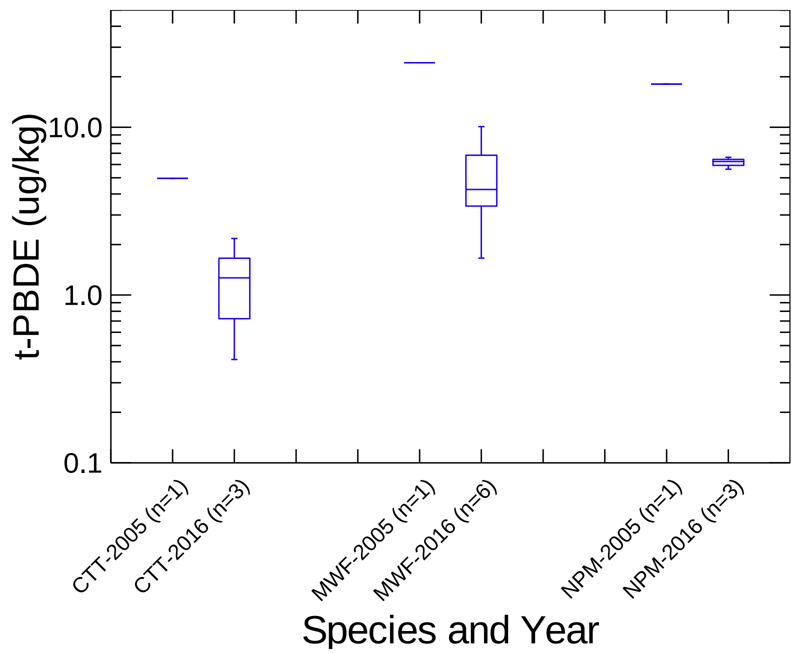

Figure 13. Boxplots comparing PBDE concentrations between years 2005 and 2016 in cutthroat trout (CTT), mountain whitefish (MWF), and northern pikeminnow (NPM) from the Cowlitz River near Vader.

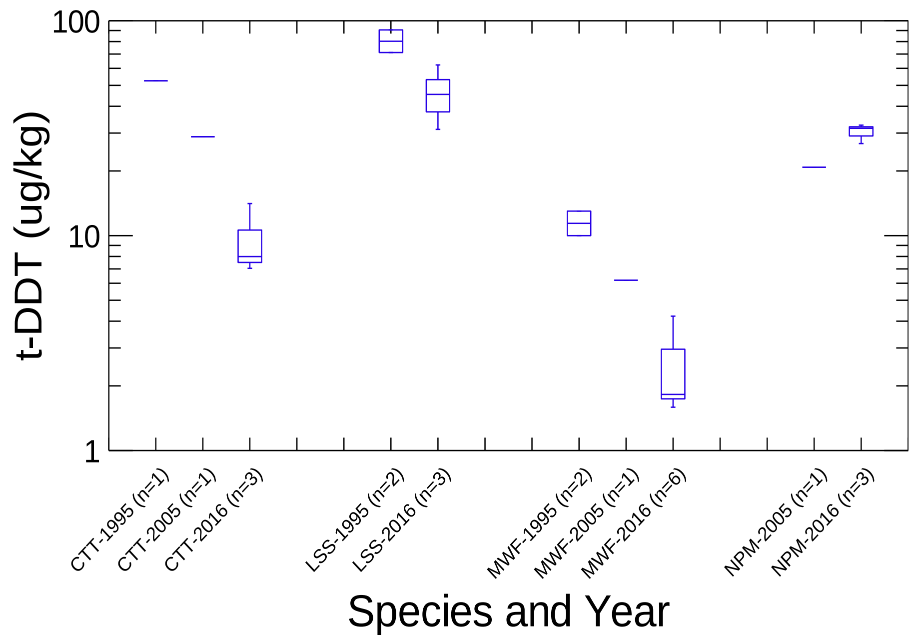

Figure 14. Boxplots comparing t-DDT concentrations among years 1995, 2005, and 2016 in cutthroat trout (CTT), whole largescale sucker (LSS), mountain whitefish (MWF), and northern pikeminnow (NPM) from the Cowlitz River near Vader.

Water Quality Standards Comparison

The fish tissue results from this study were analyzed using the methods described in the November 2018 revision of Policy 1-11 (Ecology, 2018) for determining if the beneficial use of fish harvest is impaired.

Results for PCBs were compared to thresholds related to tissue exposure concentrations (TEC), which represent a tissue consumption exposure route for pollutants. Results for mercury were compared to the numeric criterion in the water quality standards. These preliminary determinations were conducted to help inform Cowlitz River water quality managers and interested parties of river segments that may not meet water quality standards. The next statewide Water Quality Assessment will use these data to determine if water quality standards are met. Appendix D describes how Washington's water quality standards are applied to toxics substances.

Policy 1-11 describes many conditions that the sample data must meet in order to be used in the assessment. The process essentially compares the median value of multiple composite samples from a sampling location, also termed an Assessment Unit (AU), to thresholds related to the TECs. If the thresholds are exceeded, then the beneficial uses are likely not being met in that AU. According to Policy 1-11, a Clean Water Act Section 303(d) listing (water body does not meet water quality standards) will result for carcinogenic substances when the TECc is exceeded by a factor of 10 or greater, and for non-carcinogenic substances when the TECn is exceeded by any amount. The results from this study will be used in the next assessment of data, expected to begin in 2019.

Tables 8 and 9 show the evaluation of mercury and PCB results for the sampled water bodies. Only results from mercury and PCBs were evaluated because they were found in samples at frequencies and concentrations that were high enough to indicate that water quality standards might not be met in sections of the Cowlitz River. Concentrations of other pollutants, (e.g., pesticides and degredates, dioxins/furans) and their samples sizes were unlikely to exceed (not meet) narrative water quality standards. Each table shows the key information that is used in reducing the sample results in a sequential manner to arrive at:

- The site-specific median value for each species.
- The number of samples used in calculating the median for each site/species pairing.
- The number of samples used in medians from the site that exceed the numeric or narrative criteria for the parameter.
- The likelihood that the site will meet water quality standards for the parameter.

This data reduction process is described in Policy 1-11 supporting documentation and will be used in automated data processing steps for the next Water Quality Assessment.

Table 8. Evaluation of mercury results to determine impairment, FFCMP 2016.

Site	Reach Code (AU)	Species	MEL Sample ID	# Fish in Sample	Sample Result (µg/kg)	Median for Species (µg/kg)	Median Exceed WQS of 30 µg/kg?	# Samples Used in Median for Species	# Samples Used in Medians from AU Which Are >WQS	AU Likely to Meet Water Quality Standards?
Cowltz-F-Pcwd	17080004000293	MWF	1701015-51	5	75.7	75.7	Yes	3	3	No
			1701015-53	5	69.5					
			1701015-52	5	79					
Cowltz-F-Rndl-1	17080004005729	MWF	1701015-43	3	93.4	93.4	Yes	1	2	Insufficient data
		NPM	1701015-45	5	1010	1010	Yes	1		
		RBT	1701015-48	5	19.3	19.3	No	1		
Cowltz-F-Rndl-2	17080004000212	NPM	1701015-46	5	566	566	Yes	1	2	Insufficient data
		RBT	1701015-49	5	20.3	20.3	No	1		
		MWF	1701015-44	3	92.1	92.1	Yes	1		
Cowltz-F-Rndl-3	17080004002615	NPM	1701015-47	5	678	678	Yes	1	1	Insufficient data
		RBT	1701015-50	4	19.1	19.1	No	1		
Riffe-F-E1I9	46122E1I9, 17080005000915	CTT	1701015-29	3	100	100	Yes	3	5	No
			1701015-31	3	86.7					
			1701015-30	3	149					
		RBT	1701015-38	3	173	110.8	Yes	2		
			1701015-39	3	48.5					
Riffe-F-E1H7	46122E1H7, 17080005000915	LMB	1701015-33	4	316	360	Yes	3	3	No
			1701015-32	4	360					
			1701015-34	4	610					
Mayfield-F5E2	46122F5E4, 17080005000913	NPM	1701015-27	5	229	212	Yes	3	3	No
			1701015-28	5	166					
			1701015-26	5	212					

Site	Reach Code (AU)	Species	MEL Sample ID	# Fish in Sample	Sample Result (µg/kg)	Median for Species (µg/kg)	Median Exceed WQS of 30 µg/kg?	# Samples Used in Median for Species	# Samples Used in Medians from AU Which Are >WQS	AU Likely to Meet Water Quality Standards?
Cowltz-F-Olqa-3	17080005000222	CTT	1701015-10	5	33.8	33.8	Yes	1	4	No
		MWF	1701015-19	3	63.4	49.0	Yes	2		
			1701015-16	5	34.5					
		NPM	1701015-22	3	425	425	Yes	1		
Cowltz-F-Olqa-2	17080005000221	CTT	1701015-09	5	34.6	34.6	Yes	1	4	No
		MWF	1701015-18	3	85.9	72.8	Yes	2		
			1701015-15	5	59.7					
		NPM	1701015-21	3	333	333	Yes	1		
Cowlitz-F	17080005000220	CTT	1701015-08	5	34.1	34.1	Yes	1	4	No
		MWF	1701015-17	3	75.6	65.9	Yes	2		
			1701015-14	5	56.1					
		NPM	1701015-20	3	318	318	Yes	1		
Cowltz-F-CasRk	17080005000069	MWF	1701015-06	5	59.5	59.5	Yes	3	4	No
			1701015-04	5	67					
			1701015-05	5	57					
		NPM	1701015-07	5	362	362	Yes	1		

Species Codes:

CTT: Cutthroat trout

LMB: Largemouth bass

MWF: Mountain whitefish

NPM: Northern pikeminnow

RBT: Rainbow trout

For mercury, it is likely that eight of eleven areas in the Cowlitz River basin are not meeting water quality standards. While some of the samples in the other three areas had concentrations above the numeric criterion for mercury, there were not enough samples in each area to determine if the assessment unit was not meeting standards. Also, there were not enough samples (at least 10) to determine that the standard for mercury was being met in each area.

Table 9. Evaluation of PCB results to determine impairment, FFCMP 2016.

Site	Reach Code (AU)	Species	MEL Sample ID	# Fish in Sample	PCB Aroclor Result (µg/kg)	PCB Congener Result (µg/kg)	Median for Species (µg/kg)	Median Exceed 10x TECc (2.3 µg/kg)?	Median Exceed TECn (9.1 µg/kg)?	# Samples Used in Median for Species	# Samples Used in Medians from AU Which Are > 10xTECc	# Samples Used in Medians from AU Which Are > TECn	AU Likely to Meet Water Quality Standards?
Cowltz-F-Pcwd	17080004000293	MWF	1701015-51	5	1.9 J	*1.02*	1.66	No	No	3	na	na	Insufficient data
			1701015-53	5	5.27 J	*1.66*							
			1701015-52	5	3.02 J	*1.88*							
Cowltz-F-Rndl-1	17080004005729	MWF	1701015-43	3	2.23 J	*1.46*	1.46	No	No	1	2	na	Insufficient data
		NPM	1701015-45	5	9.19 J	*3.51*	3.51	Yes	No	1			
		RBT	1701015-48	5	*7.82 J*		7.82	Yes	No	1			
Cowltz-F-Rndl-2	17080004000212	NPM	1701015-46	5	4.69 J	*4.88*	4.88	Yes	No	1	3	na	No
		RBT	1701015-49	5	*8.45 J*		8.45	Yes	No	1			
		MWF	1701015-44	3	2 U	*2.64*	2.64	Yes	No	1			
Cowltz-F-Rndl-3	17080004002615	NPM	1701015-47	5	5.45 J	*4.31*	4.31	Yes	No	1	2	na	Insufficient data
		RBT	1701015-50	4	*7.34 J*		7.34	Yes	No	1			
Riffe-F-E1I9	46122E1I9, 17080005000915	CTT	1701015-29	3	5.37 J	*1.14*	1.14	No	No	3	1	na	Insufficient data
			1701015-31	3	3.43 J	*1.53*							
			1701015-30	3	1.94 U	*0.50*							
		RBT	1701015-38	3	*2.93 U*		3.30 (TECn) 3.67 (TECc)	Yes	No	2 (TECn) 1 (TECc)			
			1701015-39	3	*3.67*								
Riffe-F-E1H7	46122E1H7, 17080005000915	LMB	1701015-33	4	*2.92 U*		2.96 (TECn) na (TECc)	na	No	3	na	na	Insufficient data
			1701015-32	4	*2.96 U*								
			1701015-34	4	*2.96 U*								
Mayfield-F5E2	46122F5E4, 17080005000913	NPM	1701015-27	5	2.97 U	*1.50*	1.66	No	No	3	na	na	Insufficient data
			1701015-28	5	2.99 U	*1.79*							
			1701015-26	5	3 U	*1.66*							

Site	Reach Code (AU)	Species	MEL Sample ID	# Fish in Sample	PCB Aroclor Result (µg/kg)	PCB Congener Result (µg/kg)	Median for Species (µg/kg)	Median Exceed 10x TECc (2.3 µg/kg)?	Median Exceed TECn (9.1 µg/kg)?	# Samples Used in Median for Species	# Samples Used in Medians from AU Which Are > 10xTECc	# Samples Used in Medians from AU Which Are > TECn	AU Likely to Meet Water Quality Standards?
Cowltz-F-Olqa-3	17080005000222	CTT	1701015-10	5	9.11	*7.56*	7.56	Yes	No	1	4	3	No
		MWF	1701015-19	3	19.4 J	*12.56*	9.90	Yes	Yes	2			
			1701015-16	5	5.91 J	*7.24*							
		NPM	1701015-22	3	53.8 J	*45.15*	45.15	Yes	Yes	1			
Cowltz-F-Olqa-2	17080005000221	CTT	1701015-09	5	20.22 J	*11.26*	11.26	Yes	Yes	1	4	2	No
		MWF	1701015-18	3	22.07 J	*11.97*	8.11	Yes	No	2			
			1701015-15	5	9.31 J	*4.25*							
		NPM	1701015-21	3	40.4 J	*24.20*	24.20	Yes	Yes	1			
Cowlitz-F	17080005000220	CTT	1701015-08	5	10	*8.24*	8.24	Yes	No	1	4	1	No
		MWF	1701015-17	3	9.6 J	*5.00*	7.48	Yes	No	2			
			1701015-14	5	18.51 J	*9.96*							
		NPM	1701015-20	3	49.3 J	*24.71*	24.71	Yes	Yes	1			
Cowltz-F-CasRk	17080005000069	MWF	1701015-06	5	11.18 J	*8.28*	8.28	Yes	No	3	4	1	No
			1701015-04	5	27 J	*18.27*							
			1701015-05	5	7.13 J	*7.38*							
		NPM	1701015-07	5	39.7 J	*23.53*	23.53	Yes	Yes	1			

Species Codes:
CTT: Cutthroat trout
LMB: Largemouth bass
MWF: Mountain whitefish
NPM: Northern pikeminnow
RBT: Rainbow trout.
Italicized result values are the ones used in calculating medians: PCB Aroclor data are used only if PCB congener data are not available.

For PCBs, it is likely that five of the eleven areas in the Cowlitz River basin are not meeting the narrative criteria in the water quality standards. As with the mercury results, some of the samples in the other areas had concentrations above the TEC-related threshold for PCBs, but there were not enough samples in each area that were above the threshold to determine if the assessment unit was not meeting standards. Also, there were not enough samples (at least 10) to determine that the narrative criteria for PCBs were being met in each area.

The broader spatial extent of the 2016 sampling will allow the next Water Quality Assessment to evaluate many more sections (n=11) of the river and reservoirs than was done in previous assessments (n=2). The next assessment will make the final determination on whether the sampled areas meet or do not meet Washington's water quality standards.

Summary and Conclusions

Results of this 2016 study support the following conclusions:

- Toxic contaminants were characterized in six species of fish collected from eleven locations in six areas of the Cowlitz River basin in 2016. Fish from nine of these locations in four areas had not been sampled previously.

- Chemicals with high frequencies of detection in fillets were mercury, PCBs, PBDEs, DDTs, and dioxin/furans. Some samples exceeded Washington's Water Quality Assessment TEC-related thresholds, Washington State Department of Health's Screening Levels, or EPA Screening Values for these chemicals.

- The highest concentrations of PCBs were found in whole largescale sucker (411 µg/kg) and fillets from northern pikeminnow (53.8 µg/kg). The highest levels of mercury were found in northern pikeminnow (566–1010 µg/kg) and largemouth bass (316–610 µg/kg) fillets.

- The ranges of concentrations in fish fillets from the Cowlitz River for four chemicals are similar to the ranges found in fish from across Washington sampled during the FFCMP from years 2001 to 2016.

    - Levels of PCBs in Cowlitz River fish fillets ranged from 2.1 to 53.8 µg/kg, which is within the 18^{th} to 85^{th} percentile of the statewide range.
    - PBDEs ranged from non-detect to 10 µg/kg, which is up to the 73^{rd} percentile.
    - Mercury ranged from 19 to 1,010 µg/kg, with the 10^{th} to 98^{th} percentile of statewide results.
    - Dioxins and furans, as TCDD-TEQ, ranged from non-detect to 0.160 ng/kg, which is within the 3^{rd} to the 88^{th} percentile of statewide values.

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- Spatial trends appeared to be present. Concentrations of organic contaminants such as DDTs, PCBs, and PBDEs tended to increase from upstream to downstream sites. However, physical differences in the fish making up the samples, such as size and age, probably contribute to the observed differences in contaminant concentrations. Mercury did not show the upstream-downstream pattern seen with organic pollutants, and there was inadequate information to determine whether the lower concentrations of mercury in northern pikeminnow from Mayfield Lake were due to methylmercury dynamics associated with some reservoirs or other factors such as size and age.

- Temporal trends were detected in some species. Concentrations of PCBs, PBDEs, DDTs, and mercury in fillets of cutthroat trout, mountain whitefish, and northern pikeminnow from the

Cowlitz River near Vader appear to be lower than those sampled in 1995 and 2005 (except for DDTs in northern pikeminnow). Concentrations of PCBs in whole largescale suckers from the Cowlitz River near Vader appear to be the same for 1995 and 2016, while levels of DDT appear to be lower in 2016 than in 1995. Detection of temporal trends for PCBs, DDTs, PBDEs, and mercury was confounded by small sample sizes, high variability, and the potential influence of differences in the sizes and ages of fish used in the historical and 2016 samples.

- The current CWA 303(d) listings for the Cowlitz River and Mayfield Lake remain in effect until a new Water Quality Assessment is performed. Data from this report indicate that many of the areas sampled in 2016 will not meet water quality standards for PCBs and mercury in the next water quality assessment.

Recommendations

Results of this 2016 study support the following recommendations:

- Results of this study should be included in the next Water Quality Assessment conducted by Ecology. Future CWA 303(d) listings that result from this study will be prioritized for future TMDLs or alternative clean up actions for this area.
- Results of this study should be reviewed by Washington State Department of Health to determine the need for a Fish Consumption Risk Assessment, particularly for mercury and PCBs.
- Based on contaminant concentrations and the ages of fish sampled in 2016, re-sampling fish at a frequency of about 10–15 years seems appropriate for temporal trends analyses.
- Future sampling of fish for temporal trends analyses should focus on sites and analytes where a change might be detectable, such as for PCBs and mercury in the lower reaches of the river. The sampling effort should strive to sample the sites, species, and fish size ranges that are comparable to the 2016 study.
- Fish species of greatest value in detecting temporal trends would be those that are abundant in each segment (which allows larger sample sizes) and known to accumulate target contaminants (which allows greater chance of detecting change). The use of multiple species helps increase the weight of evidence for true trends (i.e., true signals from the environment rather than false signals that could be due to sampling or analytical procedures). These species would vary by segment and include a mix of largescale suckers, northern pikeminnow, mountain whitefish, cutthroat trout, and largemouth bass.

Larger sample sizes, such as five to seven field replicate composite samples of a single fish species per site, will likely be needed in future monitoring where the goal is detection of temporal trends. Larger sample sizes help reduce sampling variability and decrease the uncertainty associated with measures of central tendency, such as the mean concentration of a chemical.

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Appendices

Appendix A. Sample location descriptions for FFCMP 2016

Table A-1. Sample location descriptions, coordinates, and codes.

EIM Location ID	EIM Location Description	Latitude	Longitude	HUC Reach Code and Grid #	Prefix for Sample Field IDs
Mayfield-F5E2	Location is the centroid of fish collection sites for this sample. Sample represents entire lake. Centroid is approx. 1 mile NNE of County Park boat ramp.	46.54543	-122.54842	46122F5E4, 17080005000913	ML-
Cowltz-F-CasRk	Location is the centroid of fish collection sites for this sample. Sample represents fish collected from RM 17.3 to RM 19.5. Centroid is approx. 1 mile upstream of Hwy 411 bridge in Castle Rock.	46.28622	-122.91380	17080005000069	CR-
Cowlitz-F	Cowlitz R, 8 mi N of Castle Rock, near Olequa Creek, RM 24-27	46.38360	-122.93230	17080005000220	OL-
Cowltz-F-Olqa-2	Location is the centroid of fish collection sites for this sample. Sample represents fish collected from RM 27.6 to RM 28.4. Centroid is approx. 2 miles downstream of I-5 bridge.	46.40635	-122.92558	17080005000221	OL-
Cowltz-F-Olqa-3	Location is the centroid of fish collection sites for this sample. Sample represents fish collected from RM 28.4 to RM 29.9. Centroid is approx. 1 mile downstream of I-5 bridge.	46.40618	-122.90962	17080005000222	OL-
Cowltz-F-Pcwd	Location is the centroid of fish collection sites for this sample. Sample represents fish collected from RM 132.7 to RM 133.5. Centroid is at RM 133.1; approx. 0.5 mile upstream of FS road 1270; about 6 mi upstream of Packwood.	46.66746	-121.59646	17080004000293	CF-
Riffe-F-E1I9	Location is the centroid of fish collection sites for this sample. Sample represents east end of lake. Centroid is approx. 1.7 mile WNW of low water boat ramp at Taidnapam Park.	46.48896	-122.19791	46122E1I9, 17080005000915	RF-

EIM Location ID	EIM Location Description	Latitude	Longitude	HUC Reach Code and Grid #	Prefix for Sample Field IDs
Riffe-F-E1H7	Location is the centroid of fish collection sites for this sample. Sample represents east end of lake. Centroid is approx. 0.5 mile WNW of low water boat ramp at Taidnapam Park.	46.47963	-122.17653	46122E1H7, 17080005000915	RF-
Cowltz-F-Rndl-1	Location is the centroid of fish collection sites for this sample. Sample represents fish collected from RM 99.4 to RM 99.7. Centroid is approx. 3 miles downstream of Hwy 131 bridge in Randle.	46.51323	-121.96768	17080004005729	RN-
Cowltz-F-Rndl-2	Location is the centroid of fish collection sites for this sample. Sample represents fish collected from RM 97.8 to RM 99.4. Centroid is approx. 3.5 miles downstream of Hwy 131 bridge in Randle.	46.51270	-121.97600	17080004000212	RN-
Cowltz-F-Rndl-3	Location is the centroid of fish collection sites for this sample. Sample represents fish collected from RM 95.7 to RM 97.4. Centroid is approx. 6.5 miles downstream of Hwy 131 bridge in Randle.	46.50091	-122.00725	17080004002615	RN-

Appendix B. Field Collection and Preservation Methods

The collection, handling, and processing of fish tissue samples for analyses were guided by methods described by EPA (2000) and Ecology's standard operating procedures (SOPs) (Sandvik, 2018a, 2018b, and 2018c). The collection of fish by Ecology in 2016 adhered to these federal and state Scientific Collection Permits: USFWS # TE-058381-8, NOAA # 1386-8A, and WDFW # 12-298g.

Fish Collection

Information from historical work helped determine the sampling goals for each site. Goals for each site consisted of specific fish species and specific size ranges of fish (i.e., length and weight). The 2016 monitoring aimed to increase the number of samples (compared to historical work) available for analyses in order to reduce variability and improve the ability to detect spatial and temporal trends. Fish were collected from late August to early September in order to match the timeframes in which fish were collected in previous studies.

Fish were collected using a 16' electrofishing boat (at most sites) and angling (near Mt. Rainier park boundary). Ecology staff performed the collections with help from staff at Lewis County PUD, Tacoma Power, and Washington Department of Fish and Wildlife.

Captured fish were identified to species, and target species were retained, while non-target species were released. Retained fish were inspected to ensure that they were acceptable for further processing (e.g., proper size – smallest fish at least 75% the length of largest fish in the sample, no obvious damage to tissues, skin intact).

Field preservation of each retained fish involved assigning a unique identification code, measuring length and weight, wrapping in foil and zip-sealed bags or large plastic bags, and placing on ice for transport to freezer for storage at -20° C. Fish were processed at a later date to form samples that were sent to the laboratory for analysis.

Sample Preparation

Frozen fish were processed at Ecology's headquarters several months after collection. Individual fish were first assigned to composite samples based on the sampling goals for individual sites. This involved grouping fish by size, usually by total length, to match sizes of fish used in historical samples and to make use of available fish. To create multiple composite samples of similar sized fish, individual fish meeting the size criteria were randomly assigned to composite samples. For example, where three composite samples of five fish each were to be created, each of the 17 individual fish that were collected was randomly assigned to one of the three composite samples.

Most composite samples consisted of skin-on fillets from five individual fish of the same species per site of a similar size (i.e., the smallest fish was at least 75% the length of the largest fish in the composite sample). Fillets of largescale suckers were not used; all samples of this species were processed as whole fish. For fish (species or size) that did not match historical collections, composite samples were created using fish of similar size. Composite samples were used because they reduce the variability in contaminant levels that are often seen in individual fish, and they provide adequate tissue material for varied laboratory analyses.

Individual fish selected for a specific composite sample were processed at the same time. Fish were partially thawed before further processing. For fillet samples, fillets were removed and cut into smaller pieces. One or both fillets were removed from the fish, depending on the fish size and sample mass required for laboratory analysis. Pieces of fillet tissue were then passed through a Kitchen-Aid food processer into a stainless steel bowl three times in order to grind and homogenize the tissue sample (Figure B-1). Whole fish were passed through a larger, commercial-grade Hobart meat grinder in a similar fashion. Equal amounts of the ground and homogenized tissue from each fish were then combined and homogenized to form a single composite sample. This composite was then passed once again through the grinder.

Figure B-1. Left: grinding fish fillet tissue. Right: removing otolith to determine age.

An aliquot (30–90 grams) of the homogenized composite tissue was put in pre-cleaned jars (I-Chem 200 or 300) labeled for specific analyses and stored frozen until transport to the Ecology/EPA Manchester Environmental Laboratory (MEL).

For fillet samples, the abdominal cavity of the fish was opened to determine gender after fillets were removed from the fish. Fish scales, otoliths, opercula, or other structures were removed for age determination by Washington Department of Fish and Wildlife (WDFW) biologists in Olympia, WA. All utensils used for tissue processing were cleaned between samples to minimize contamination. The cleaning procedure involved soap and water washes followed by acid and solvent rinses. Sample collection and processing details are described in SOPs (Sandvik, 2018a, 2018b, and 2018c).

Appendix C. Environmental Variability of PCBs and Mercury

In the context of this study, environmental variability is the variation of the pollutant levels that are measured among units of the population being sampled (Gilbert, 1987). A challenge for sampling programs is to obtain reliable measurements of each parameter to characterize the sampled population in order to detect trends or inform decisions about protecting the consumers of fish (i.e., people and wildlife). While part of this variation comes from the laboratory analytical process, the largest source of this variation is often within the population being measured. While the laboratory analyses met goals for analytical variability in this study (as determined from repeated analyses of the same sample to estimate analytical precision) the environmental variability (or sampling precision) was often more variable than that from laboratory analyses.

Contaminant concentrations in individual fish can be influenced by many factors such as size, age, trophic position, diet, lipid content, sex, exposure to contaminants, and sample preparation and analysis. Commonly used strategies to reduce variability include the use of composite samples and analysis of multiple samples. Generally, as one increases both the number of fish used in composite samples and the number of composite samples, one reduces the uncertainty of measurements used to characterize the population, such as the mean or average concentration.

Results from multiple field replicate samples from the 2016 study indicate that variability in pollutant concentrations in the population can be large, which can lead to large uncertainty in characterizing the population. One way to estimate the uncertainty associated with a sample statistic (e.g., the mean) is to calculate the confidence interval. Di Stefano (2004) argues that the confidence interval is an informative way of characterizing sampling precision, especially where uncertainty may complicate important decisions to be made using the data. The confidence interval is based on the mean value, the standard error, and the critical t-value associated with the desired level of confidence.

The confidence interval is the range within which the true mean of the population would be expected to be found in 95% of repeated sampling efforts. As can be seen in Figure C-1, the high variability in some field replicates leads to large confidence intervals. For example, the 95% confidence interval for t-PCBs from the three replicates in “OL-NPM” yielded 95% confidence limits of 31 and 65 µg/kg t-PCB, around a mean of 48 µg/kg. Smaller confidence intervals are present for other replicate groups. For example, the replicates in group “RN-MWF” yielded 95% confidence limits of 0.65 and 3.6 µg/kg t-PCB, with a mean of 2.1 µg/kg. The confidence intervals around samples RN-LSS and ML-NPM are so small that they barely show in Figure 2.

Figure C-1 shows the mean values for selected field replicates of t-PCBs along with the 95% confidence interval around each mean.

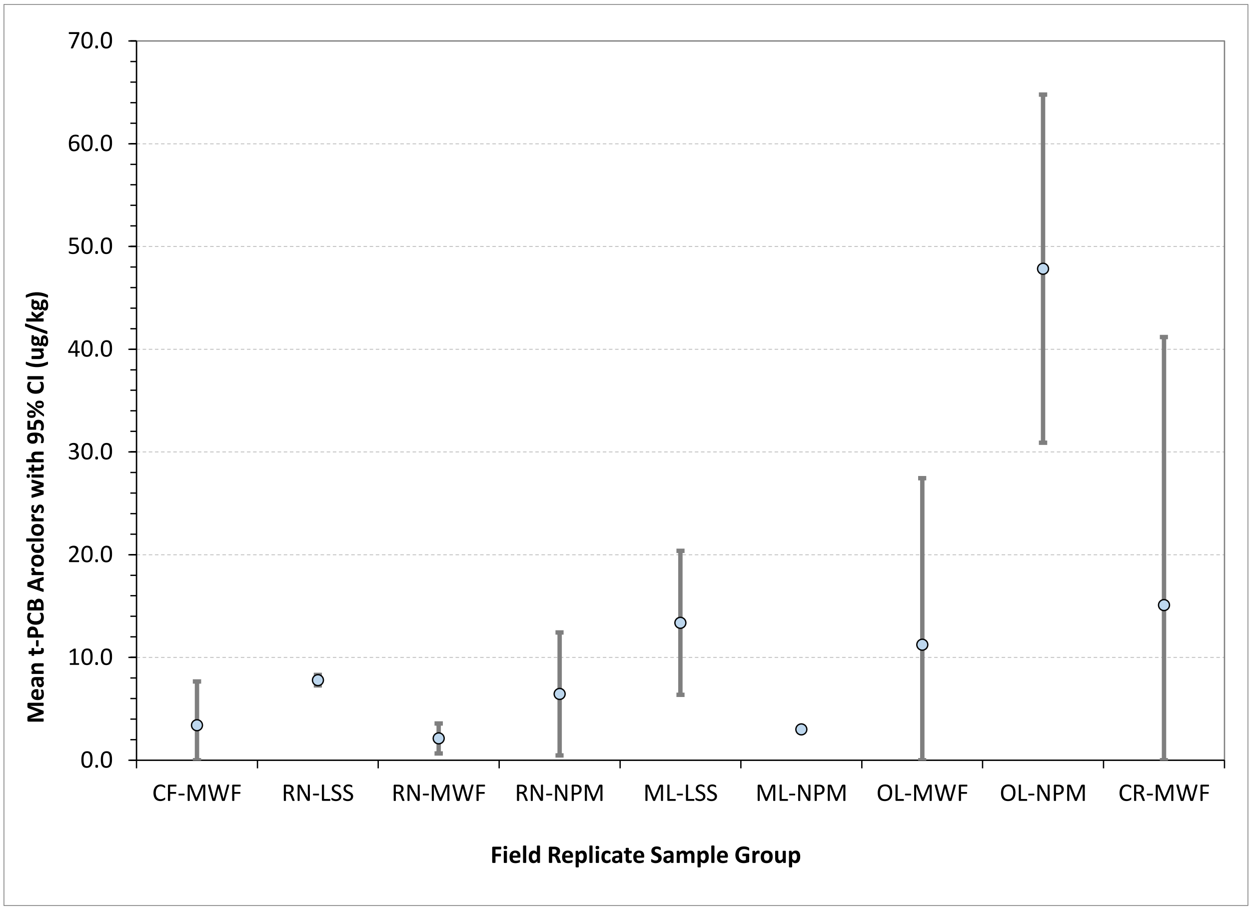


Figure C-1. Mean and 95% confidence intervals for t-PCB from selected field replicate samples.

Site codes:
CF – Clear Fork
RN – Cowlitz River near Randle
RF – Riffe Lake
ML – Mayfield Lake
OL – Cowlitz River above Olequa Creek
CR – Cowlitz River above Castle Rock

Species codes:
CTT - Cutthroat trout
LSS - Largescale sucker (whole)
MWF - Mountain whitefish
NPM - Northern pikeminnow

Figure C-2 shows the mean values for selected field replicates of mercury along with the 95% confidence interval around each mean. As with PCBs, the environmental variability ranges from small to large for mercury in fish.

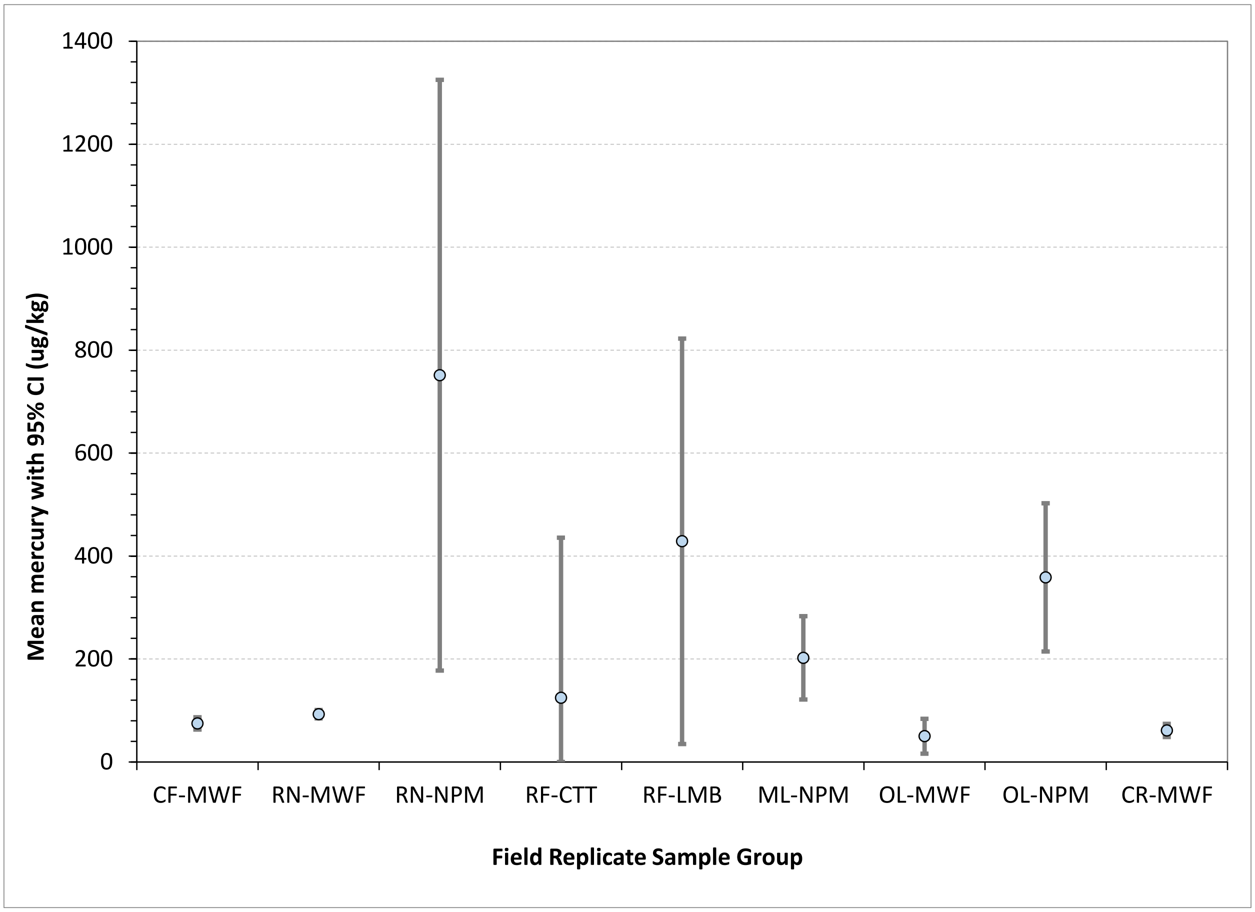


Figure C2. Mean and 95% confidence intervals for mercury from selected field replicate samples.

Site codes:
CF – Clear Fork
RN – Cowlitz River near Randle
RF – Riffe Lake
ML – Mayfield Lake
OL – Cowlitz River above Olequa Creek
CR – Cowlitz River above Castle Rock

Species codes:
CTT - Cutthroat trout
LMB - Largemouth bass
MWF - Mountain whitefish
NPM - Northern pikeminnow

Appendix D. Water Quality Standards and other Thresholds

Various fish tissue contaminant concentration thresholds for the protection of human health exist because of evolving knowledge about the toxic effects of chemicals and society's responses to estimate risks and protect consumers of fish. These thresholds are often based on various assumptions used in determining risk, such as daily consumption rates, toxicological data used in calculations, and risk levels. Thresholds that are relevant in the state of Washington are:

- Washington's water quality standards.
- Washington Department of Health screening levels.
- EPA's fish tissue screening values.

Washington's Water Quality Standards

Washington's water quality standards protect the health of people, fish, shellfish, and wildlife and were revised in October 2017 (Ecology, 2017). These standards are codified in Washington Administration Code Chapter 173-201A.

The water quality standards "consist of water quality criteria, designated uses, and anti-degradation components. The water quality standards represent the chemical, physical, and biological conditions necessary to support the state designated uses of a water body." (Ecology, 2018). Ecology's Water Quality Program Policy 1-11 (Ecology, 2018) describes the methodologies for using environmental data to assess the health of surface waters by determining whether water quality standards are met.

For toxic substances, Washington's water quality standards employ both numeric and narrative criteria for both marine and fresh water.

Numeric criteria are based on data and scientific assessment of adverse effects from specific chemicals or conditions. A typical numeric criterion for protecting aquatic life usually contains a concentration and averaging period. For example, the aquatic life chronic criterion for cyanide is 5.2 µg/L as a 4-day average concentration. The numeric criteria found in WAC 173-201A-240 (Ecology, 2017) were developed to protect both aquatic life and human health from toxic chemicals at given concentrations in the water column (µg/L). An exception is for methylmercury (MeHg), which is expressed as a fish tissue concentration (30 µg/kg).

Narrative criteria are statements that describe the desired water quality goal, such as waters being "free from" pollutants like oil and other substances or conditions that can harm people or aquatic life. These criteria protect water bodies from pollutants for which numeric criteria are difficult to specify. Narrative criteria for toxic substances are rooted in WAC 173-201A-260(2)(a), which protects existing and designated uses for fresh and marine water (Ecology, 2017):

> *(2) Toxics and aesthetics criteria. The following narrative criteria apply to all existing and designated uses for fresh and marine water:*

(a) Toxic, radioactive, or deleterious material concentrations must be below those which have the potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health (see WAC 173-201A-240, toxic substances, and 173-201A-250, radioactive substances).

The narrative criteria for toxic pollutants are also described in Ecology's WQP Policy 1-11, Section 1E, which states that "Ecology will consider the assessment of narrative criteria that demonstrates the impairment of a designated use":

Assessment of Studies to Determine Impairment based on Narrative Standards

Parts 2 and 3 of this policy describe the methodology for assessing specific water and sediment quality parameters. Most of the parameter sections focus on evaluations based on numeric criteria. However, Ecology also evaluates the attainment of designated uses based on narrative criteria. For example, narrative criteria are applied for the bioassessment parameter (to protect aquatic life uses), and for human health toxics parameters (to protect fish and shellfish harvesting and domestic water supply uses). Ecology may use narrative criteria in conjunction with numeric criteria as described in the parameter sections.

The narrative criteria incorporate factors such as a chemical-specific tissue exposure concentration (TEC) and environmental data requirements (e.g., sample size, species and tissue types analyzed, and sample results), to help determine whether the designated use of fish and shellfish harvest is supported in a water body.

Tissue Exposure Concentration

The Tissue Exposure Concentration (TEC) is a tissue concentration that was developed by Ecology using parts of the EPA's human health criteria equations. The TEC is intended to represent exposure to a potentially harmful level of a pollutant through the consumption of fish or shellfish. When the concentration of a pollutant in composite samples of fish or shellfish is greater than a threshold related to the TEC, the designated use of harvest is considered impaired, indicating that the water body may not be meeting water quality standards for the state of Washington, and may be placed on the Clean Water Act 303(d) list.

Ecology's WQP Policy 1-11, Section 2I(2) describes this approach:

Assessment of harvest use support will rely upon tissue exposure concentrations (TEC) for pollutants. The TECs are rooted in the human health criteria equations, but expressed as a tissue consumption exposure threshold. They do not represent a water quality criteria because they have not been adopted into Chapter 173-201A WAC, except for methylmercury. TEC thresholds for carcinogenic and non-carcinogenic effects differ *because the underlying assumptions associated with the two types of health effects are different.*

- *For chemicals that have non-carcinogenic effects (TECn):*
  (Reference dose) x (Body weight) ÷ Fish consumption rate = TECn
- *For chemicals that have a carcinogenic effect level (TECc):*
  (Risk level) x (Body weight) ÷ (Cancer slope factor) x (Fish consumption rate) = TECc

The thresholds used to determine whether the narrative water quality criteria are not met are unique to each chemical. For carcinogens, the threshold is ten times the TECc while for non-carcinogens, the threshold is the TECn. Ecology will determine that a water body is impaired (does not meet water quality standards) when the data meet either of the following conditions:

- *"The median composite sample value(s) from one or more resident species exceeds the TECc by a factor of 10 or more. A minimum of 3 composite samples is required."*
- *"The median composite sample value(s) from one or more resident species exceeds the TECn. A minimum of 3 composite samples is required."*

Sample results from environmental monitoring activities are used to assess the health of water bodies from which the samples were collected. The data are reviewed and reduced using methods in Policy 1-11 and its supporting documentation to determine whether water quality standards are met. Where water quality standards are not met, the water body is placed on the Clean Water Act Section 303(d) list, which means that the pollution problem will need to be addressed.

More information about Ecology's Policy 1-11 is available at https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-policy-updates

Fish Tissue Equivalent Concentration

The Fish Tissue Equivalent Concentrations (FTECs) were narrative criteria used by Ecology to determine whether water quality standards were being met during assessments prior to the 2018 revisions to Ecology's Water Quality Program Policy 1-11. Fish tissue contaminant concentrations that were lower than the contaminant-specific FTEC implied water quality standards were being met in the water body where fish samples were collected. Where concentrations were greater than the FTEC, the water body was considered to not meet standards and was placed on the 303(d) list.

The FTEC was calculated by multiplying the contaminant-specific bio-concentration factor (BCF) times the contaminant-specific water quality criterion found in the National Toxics Rule (NTR). For example, the water quality criterion in the NTR for PCBs was 0.00017 µg/L. The BCF for PCBs is 32,000. The resulting FTEC was 0.00017 µg/L x 32,500 = 5.3 µg/kg.

Washington's previous water quality standards for toxic contaminants were issued to the state by EPA through the 1992 National Toxics Rule (NTR) in 40 CFR 131.36 as described in the

Federal Register Vol. 57 No. 246 pp. 60848, 1992, and Vol. 64 No. 216 pp. 61182 1999. The FTECs were narrative criteria derived from the NTR criteria. The BCFs for toxic pollutants were taken from EPA's Ambient Water Quality Criteria development documents from the early 1980's archived at https://nepis.epa.gov.

Washington State Department of Health Screening Levels

The Washington Department of Health (Health) also developed Screening Levels (SLs) for the carcinogenic or non-carcinogenic effects of toxic substances to help determine whether a risk assessment is needed where fish show elevated concentrations of chemical. Sampling results that show fish tissue contaminant levels higher than these SLs may lead to Fish Consumption Advisories for a specific site and species (McBride, 2018).

Health calculates two SLs in order to address risks to the public and risks to populations who eat larger amounts of fish. Two different fish consumption rates are used, and these consumption rates are expressed in both grams per day (g/d) and meals per month. The daily consumption rate is used in risk assessment equations, whereas the meals per month expression is determining meal limits for communicating risks to the public. The lower consumption rate of 59.7 g/d corresponds to 8 meals per month and is used for assessing risks to the public. The higher consumption rate of 175 g/day corresponds to 23 meals per month and is more characteristic of high consuming populations.

Ecology and Health evaluate fish tissue data a bit differently in order to address different needs, and this is described in more detail in Appendix E.

More information about the health benefits of eating fish and fish consumption advisories in Washington are at Health's website:
https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish

EPA Screening Values

In 1988, the EPA and the American Fisheries Society identified the need for standard approaches to evaluating risks and developing fish consumption advisories for the public. EPA then developed guidance to help state, local, regional, and tribal jurisdictions address the problems of contaminated fish using more comparable ways than were being practiced. The resulting documents were volumes 1–4 of "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories" (EPA, 2000).

While the guidance provides standardized approaches, flexibility is provided so that risk assessors can incorporate circumstances that are unique to their jurisdictions. The guidance is neither prescriptive nor regulatory in nature. Both Ecology and Health reference EPA's guidance in their development of thresholds to protect human health.

For jurisdictions that choose not to conduct their own risk assessments, the guidance developed Screening Values for carcinogenic and non-carcinogenic effects of substances that could be used to help prioritize areas that may present risks to humans from fish consumption. A Screening

Value (SV) is the concentration of a chemical in fish tissue that constitutes a potential public health concern; this concentration can be used as a threshold value for comparing results from fish that were collected from the environment. The SVs were developed for two broad groups having different fish consumption rates: Recreational Fishers and Subsistence Fishers.

The SVs were developed using EPA-recommended risk-based methods, the approach also used by EPA in developing water quality criteria (EPA 2000a). The risk assessment process for any chemical uses information about the hazard, dose-response, exposure, and risk characterization. Risk-based SVs were derived from general models, which incorporate the factors relevant to assessing risks.

Fish Tissue Thresholds and Risk Assessment Inputs

Table D-1 shows Washington's Policy 1-11 tissue exposure concentrations, or TECs, along with Health's and EPA's threshold values for contaminants frequently detected in fish across Washington.

Approaches for addressing several contaminants differ among Ecology, Health, and EPA. As seen in Table D-1, Health has Screening Levels for PBDEs, whereas Ecology and EPA have not yet adopted protections for this group of chemicals. For dioxin/furans, Ecology uses the single congener TCDD (tetrachlorodibenzo-p-dioxin) for evaluating risks while EPA uses the dioxin/furan Toxic Equivalent (TCDD-TEQ) value. Another difference is for the pesticide DDT and its breakdown products: Ecology and Health use three individual analogs (DDD, DDE, and DDT) while EPA uses the sum of all DDT analogs and breakdown products. Health will also use the sum of analogs when they are available.

Table D-2 shows the key inputs into risk assessment equations used by evaluators for protecting consumers of contaminated fish. Differences in several inputs are reasons why threshold values developed by Ecology, Health, and EPA are different. For example, Ecology and Health use a Risk Level of 10^{-6} while the EPA SVs use a less protective Risk Level of 10^{-5}. The Risk Level is an acceptance threshold for which 10^{-6} means that an increased risk of harm in one in a million cases of exposure is acceptable. Ecology's TECs use a Body Weight of 80 kg while Health and EPA use 70 kg. The Consumption Rates used also differ among the agencies. Of particular note is that Ecology began using a much higher Consumption Rate (175 g/d) in 2018 than was used in the past (6.5 g/d).

Table D-1. Thresholds used by Ecology, Health, and EPA for protecting human health from contaminants in fish tissue.

Analyte (ppb ww)[1]	Ecology's Thresholds used in Narrative Criteria			Health's Screening Levels (2018)		EPA's Screening Values (2000)			
						Subsistence Fishers		Recreational Fishers	
	TECn (2018)	10x TECc (2018)	Old FTEC (1996–2016)	FCASL: Higher FCR	FCASL: Lower FCR	Non-carcinogens	Carcinogens	Non-carcinogens	Carcinogens
2,3,7,8-TCDD [3]	0.32	-	0.065	0.28	0.821	-	-	-	-
2,3,7,8-TCDD TEQ [3,4]	0.32	-	-	0.28	0.821	-	0.0315	-	0.256
4,4'-DDD	230	19	44	2	5	-	-	-	-
4,4'-DDE	230	27	32	1.2	3	-	-	-	-
4,4'-DDT	230	13	32	1.2	3	-	-	-	-
Total DDT [5]	-	-	-	1.2	3	245	14.4	2000	117
Beta-BHC	-	2.5	1.8	-	-	-	-	-	-
Chlordane [6]	230	13	8	1.1	3	245	14	2000	114
Dieldrin	23	0.29	0.65	0.03	0.07	24	0.307	200	2.5
gamma-BHC (Lindane)	2100	-	2.5	120	352	147	3.78	1200	30.7
Hexachlorobenzene	370	4.5	6.5	0.25	0.7	393	3.07	3200	25
Mercury [7]	30	-	770	34	101	49	-	400	-
Total PBDEs	-	-	-	34	101	-	-	-	-
Total PCBs [2]	9.1	2.3	5.3	0.2	0.6	9.83	2.45	80	20
Toxaphene	160	4.2	9.6	0.4	1.1	122	4.46	1000	36.3

FCASL: Fish Consumption Advisory Screening Level.
FCR: Fish Consumption Rate.
FTEC: Fish Tissue Equivalent Concentration (old water quality narrative standard).
TEC: Tissue Exposure Concentration; c=for carcinogenic effect; n=for non-carcinogenic effects.

1 - Values in parts per billion wet-weight (µg/kg ww) unless otherwise noted.
2 - Total PCBs is sum of Aroclors or congeners.
3 - Values in parts per trillion wet-weight (ng/kg ww).
4 - The cumulative toxicity of a mixture of congeners in a sample can be expressed as a TEQ to 2,3,7,8-TCDD. EPA (2010) states that the criterion for dioxin is expressed in terms of 2,3,7,8-TCDD and should be used in conjunction with the international convention of TEFs and TEQs to account for the additive effects of other dioxin-like compounds. When the TEQ is used, the toxicity of the single congener 2,3,7,8-TCDD is incorporated.
5 - Total DDT is typically the sum of the 2,4'- and 4,4'- isomers of DDD, DDE, and DDT. DDD: 4,4'-dichlorodiphenyldichloroethane. DDE: 4,4'-dichlorodiphenyldichloroethylene. DDT: 4,4'-dichlorodiphenyltrichloroethane. Where data for the 2,4' isomers are lacking, the sum of the 4,4'- isomers is used.
6 - The criterion for chlordane is interpreted as the sum of five chlordane components; these can be individually quantified through laboratory analyses while chlordane cannot. The EPA screening values are for "Total Chlordanes" which is the sum of five compounds: cis- and trans- chlordane, cis- and trans-nonachlor, and oxychlordane.
7 - The criterion for methylmercury is a true numeric criterion for fish tissue as opposed to a narrative criterion, which incorporates a TEC. The interpretation of tissue methylmercury results uses the TECn pathway described in Policy 1-11. Fish tissue was analyzed for total mercury, which has been deemed to adequately represent the concentration of methylmercury.

Table D-2. Summary of key inputs into risk assessment equations used for protecting people from consumption of contaminated fish.

Term	Ecology TECc 2018	Ecology TECn 2018	Ecology FTEC/NTR 1996-2016	Health (FCASL) 2018	EPA SV Subsistence 2000	EPA SV Recreational 2000
Risk Level	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-5}	10^{-5}
Exposure Time	70 yr	7-70 yr	70 yr	30/70 yr*	70 yr	70 yr
Body Weight	80 kg	80 kg	70 kg	70 kg**	70 kg	70 kg
Consumption Rate	175 g/d	175 g/d	6.5 g/d	175 g/d	142.4 g/d	17.5 g/d
Cancer Slope Factor	a	a	a	a	a	a
Reference Dose	a	a	a	a	a	a

* 30 years used for non-carcinogenic effects, 70 years used for carcinogenic effects
** 60 kg used for methylmercury and PBDEs
a = Specific to each chemical evaluated; and may also vary among evaluators.
FCASL = Fish Consumption Advisory Screening Level.
FTEC/NTR = Fish Tissue Equivalent Concentration based on National Toxics Rule water column criteria.
SV = Screening Value

Appendix E. Fish Tissue Evaluation: Ecology and Health

Several state and federal agencies collect and evaluate fish tissue data in Washington State. These include Ecology, Health, Washington Department of Fish and Wildlife, the U.S. Environmental Protection Agency (EPA), and the U.S. Geological Survey. Tissue data are evaluated differently by these agencies because their mandates and roles are varied. These different evaluations often lead to confusion and misunderstandings between agencies and the public on how fish tissue data are used and interpreted. Adding to potential confusion are the numerous thresholds derived by different agencies to provide guidance for determining the risks of consuming contaminated fish and protecting public health.

Most tissue contaminant data from Washington fish and shellfish, regardless of who conducted the study, make their way to Health for evaluation regarding the safety of consuming fish. Health provides information about the heathy benefits of fish as well as advice regarding Fish Consumption Advisories at: www.doh.wa.gov/CommunityandEnvironment/Food/Fish.aspx.

The fish tissue data collected for the FFCMP and many other Ecology studies are evaluated primarily to determine (1) if the waterbodies are supporting designated uses as defined in the water quality standards and (2) use in determining whether a fish consumption advisory is warranted.

Ecology determines whether water quality standards are met through the Policy 1-11 listing methodologies. Ecology then prioritizes the CWA 303(d) listings to determine where to begin correcting problems where standards are not met. Health and local health departments are responsible for weighing the potential risks to human health and developing fish consumption advisories in Washington. There is some overlap in these evaluations because the water quality standards that fish tissue data are compared to were developed to protect the beneficial uses of fish and shellfish harvest.

The following is an overview of how Ecology and Health evaluate fish tissue data to meet different needs.

Washington State Water Quality Standards

Washington's water quality standards for the protection of human health from toxic contaminants were originally issued to the state through EPA's 1992 National Toxics Rule (NTR) codified in 40 Code of Federal Regulations 131.36. Ecology revised the water quality standards in October 2017 (Ecology, 2017). For toxic contaminants, Water Quality Program Policy 1-11 describes how numeric and narrative criteria are used to minimize the risk of health effects from exposure to contaminants in water and fish/shellfish obtained from surface waters.

Ecology is responsible for assessing water bodies in the state to meet federal requirements for an integrated report under Sections 303(d) and 305(b) of the Clean Water Act. Policy 1-11, Chapter 1, describes the methods for determining whether water quality standards are met and beneficial uses are protected. The assessed waters are grouped into categories that describe the status of water quality. Category 5 represents the 303(d) list, which comprises those waters that are in the polluted water category, for which beneficial uses—such as drinking, recreation, aquatic habitat, and industrial use—are impaired by pollution. Water bodies in Category 5 require development of a water cleanup plan (such as a Total Maximum Daily Load, or TMDL). The water cleanup plan identifies the sources of pollution and a public involvement process which identifies actions to correct the sources of pollution. Ecology uses the TMDL program to control sources of the particular pollutant in order to bring the water body back into compliance with the water quality standards.

Risk Management Decisions for Fish Advisories

Health uses an approach similar to that in EPA's Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories Vol. 1–4 for assessing contaminants (EPA, 2000). These guidance documents provide a framework from which states can evaluate fish tissue data to develop fish consumption advisories. The framework is based on sound science and established risk management concepts such as:

- **Risk Assessment** involves calculating allowable meal limits based on known fish contaminant concentrations. These calculations are conducted for both non-cancer and cancer criteria using the appropriate Reference Dose or Cancer Slope Factor, if available. These initial calculations are the starting point for evaluating contaminant data to determine whether a fish advisory is warranted. Additionally, known or estimated fish consumption rates help determine the potential magnitude of exposure and highlight the sensitive groups or populations that may exist due to elevated consumption rates.

- **Risk Management** includes (but is not limited to) consideration of contaminant background concentrations, reduction in contaminant concentrations through preparation and cooking techniques, known health benefits from fish consumption, contaminant concentrations, health risks associated with replacement foods, and cultural importance of fish. Other considerations are the possible health criteria associated with a contaminant, the strength or weakness of the supporting toxicological or sampling data, and whether effects are transient or irreversible.

- **Risk Communication** is the outreach component of the fish advisory. The interpretation of the data from the risk assessment and risk management components drives how and when the fish advisory recommendations are issued to the public, dependent on whether the message is targeted toward a sensitive group, a population, or the general public. Health's dual objective is (1) how best to provide guidance to the public to increase fish consumption of fish low in contaminants to gain the benefits of eating fish, while (2) steering the public away from fish that have high levels of health-damaging contaminants.

Appendix F. Boxplots for Selected Parameters from Cowlitz River Fish, 2016

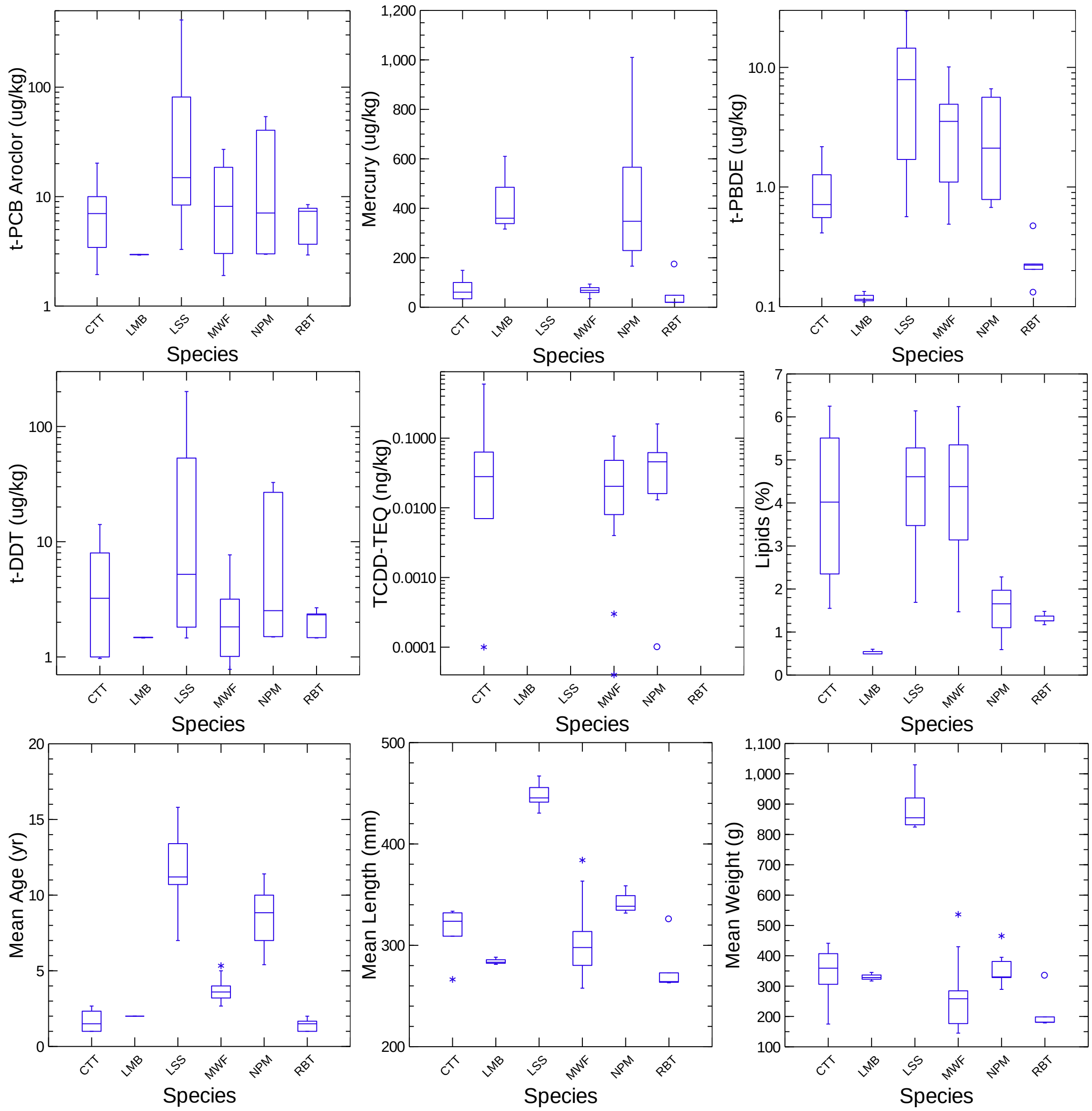


Figure F-1. Boxplots for selected parameters for Cowlitz River Fish, 2016. (LSS was not analyzed for mercury; dioxin/furan analyses were done only on CTT, MWF, and NPM).

Species codes:
CTT: Cutthroat trout
LMB: Largemouth bass
LSS: Largescale sucker (whole fish)
MWF: Mountain whitefish
NPM: Northern pikeminnow
RBT: Rainbow trout

Appendix G. Boxplots of Length, Weight, Age, and Lipids for Three Species Used for Spatial Trend Determination

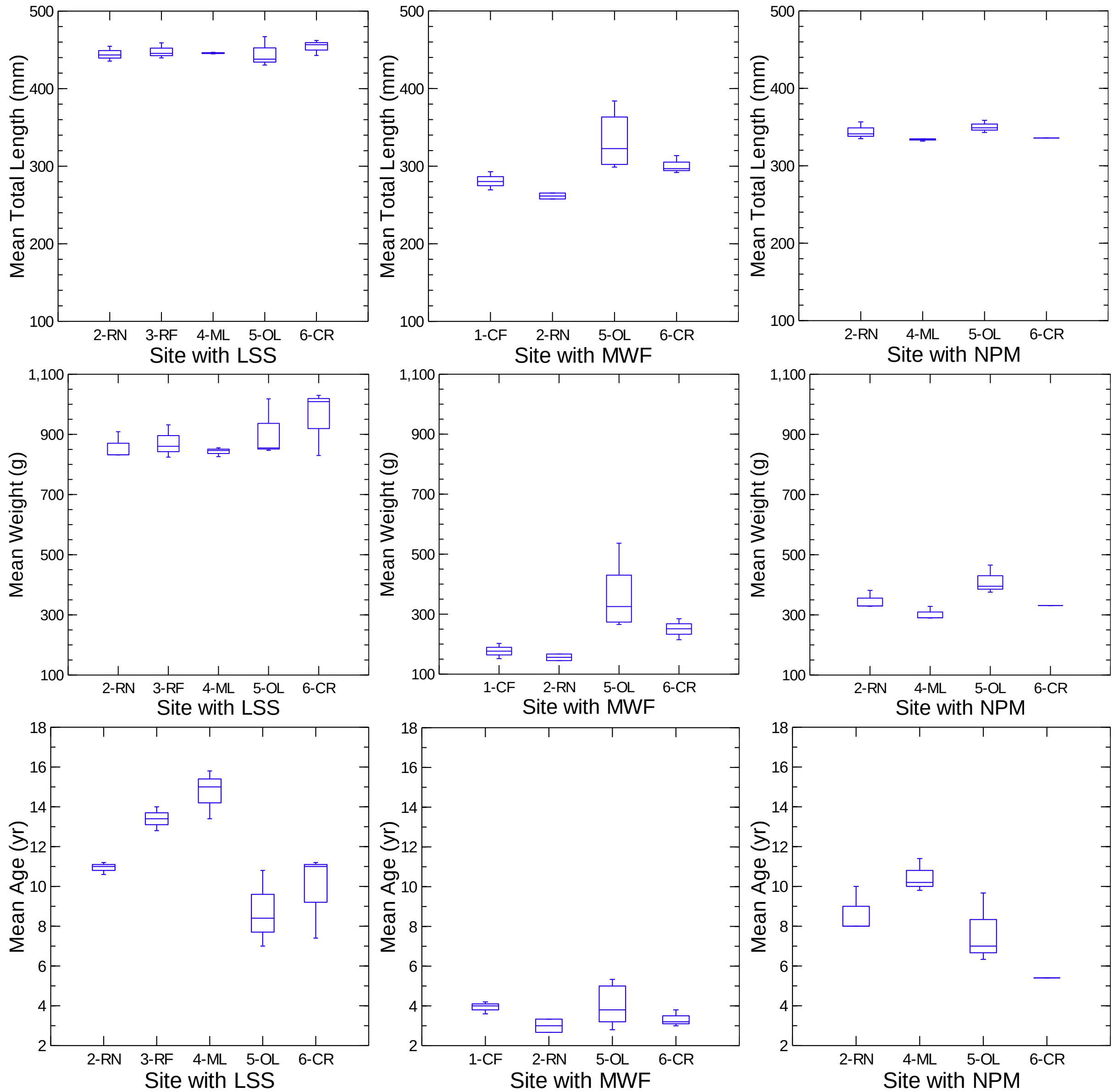


Figure G-1. Boxplots of length, weight, age, and lipids for three species used for spatial trend determination.

Species codes:

CTT: Cutthroat trout
LMB: Largemouth bass
LSS: Largescale sucker (whole fish)
MWF: Mountain whitefish
NPM: Northern pikeminnow
RBT: Rainbow trout

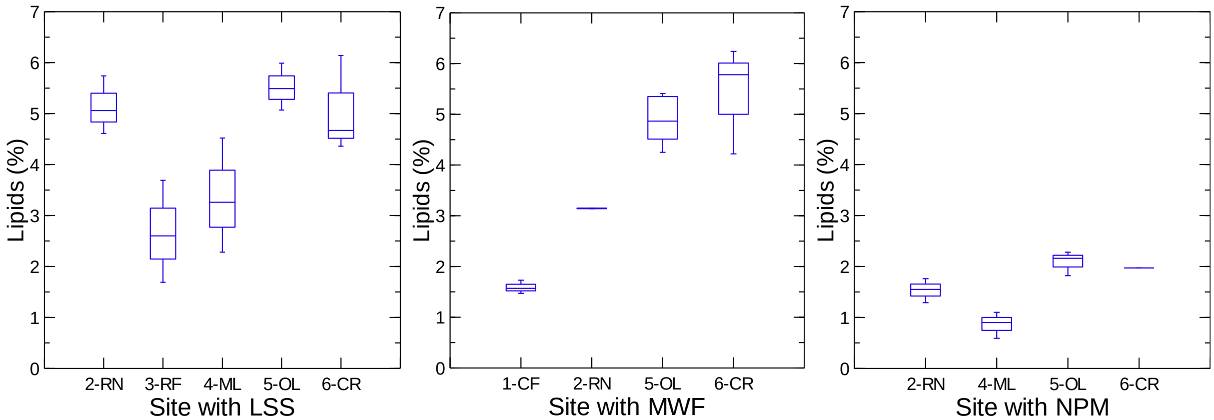
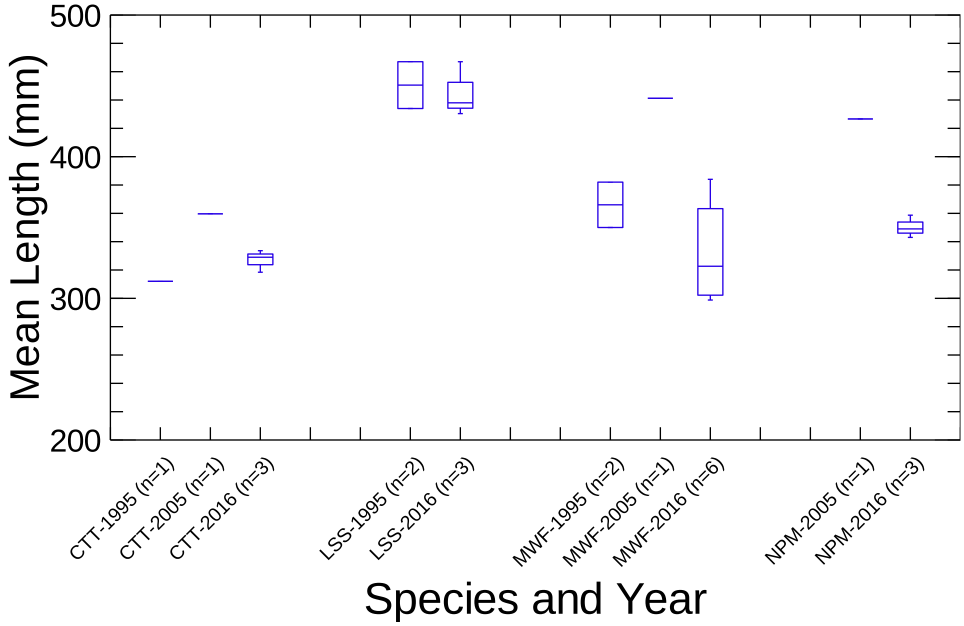


Figure G-1 (continued).

Appendix H. Boxplots Comparing Results from Different Years for Ancillary Parameters from the Cowlitz River



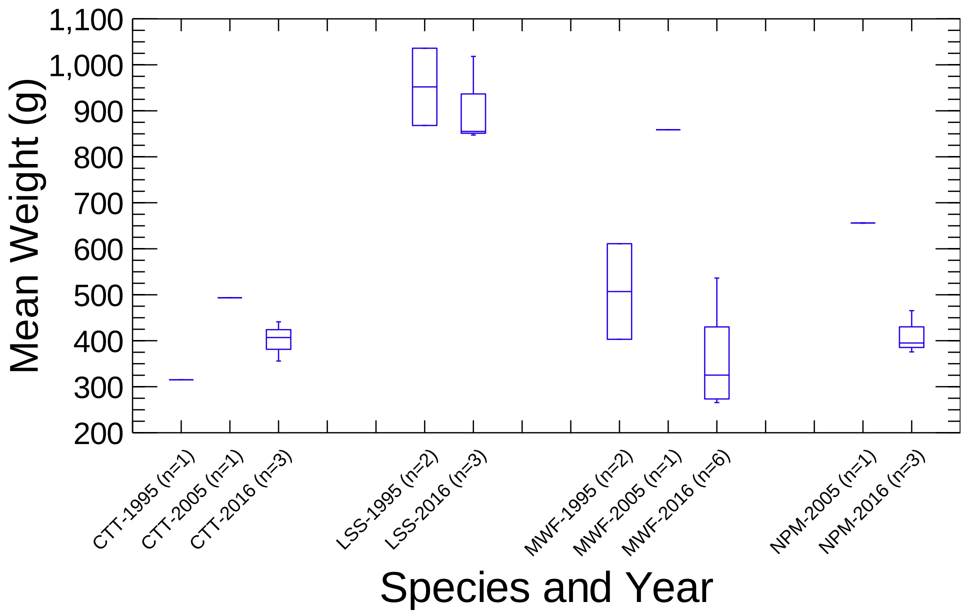


Figure H-1. Boxplots comparing results for ancillary parameters measured in fish from the Cowlitz River near Vader over time.

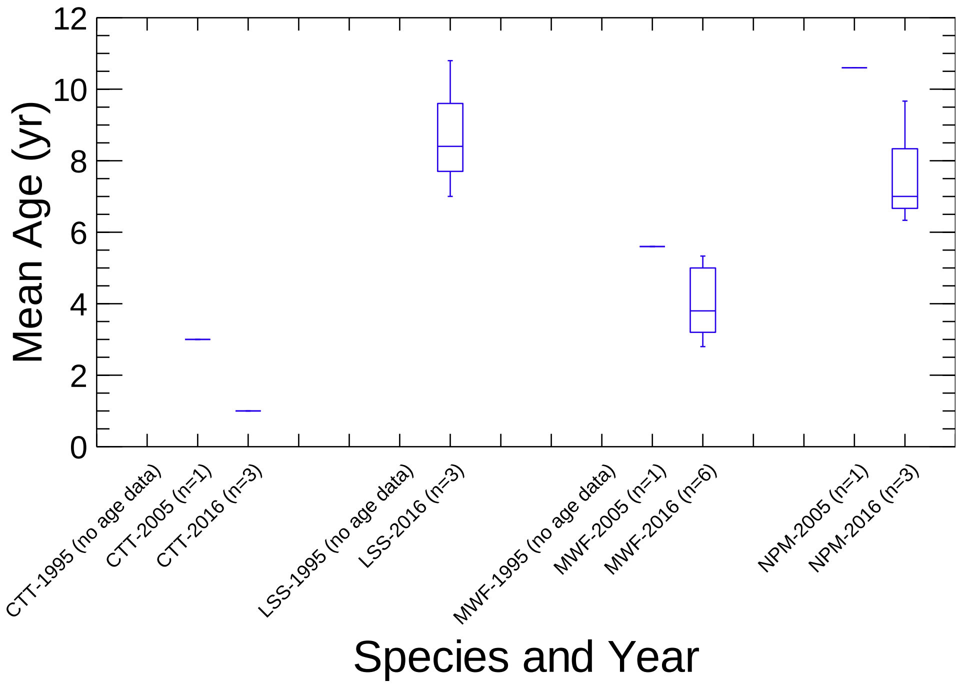
Species codes:

CTT: Cutthroat trout

LSS: Largescale sucker (whole fish)

MWF: Mountain whitefish

NPM: Northern pikeminnow



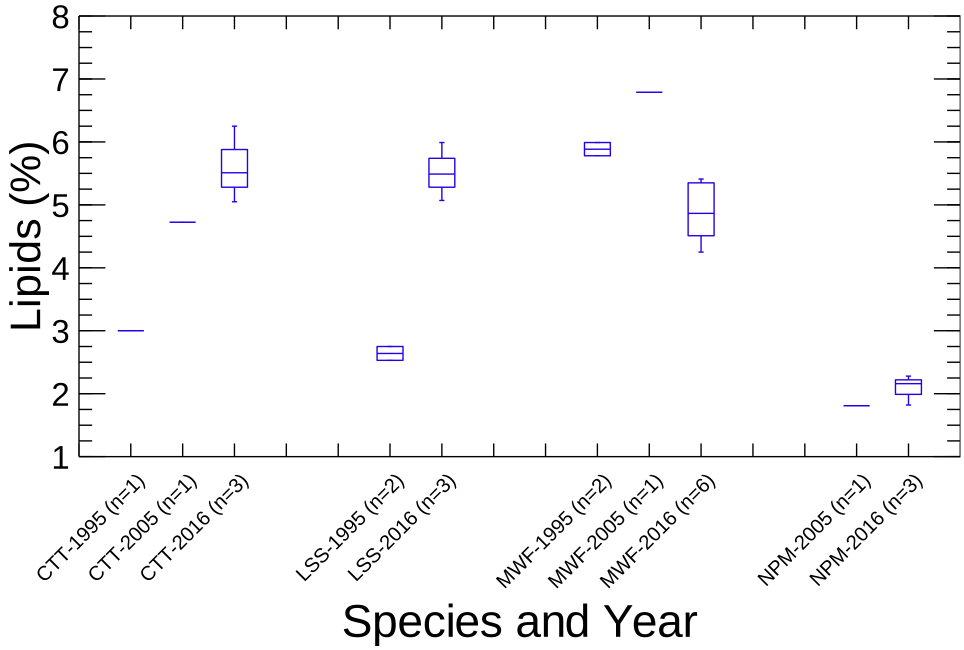


Figure H-1 (continued).

Appendix I. Glossary, Acronyms, and Abbreviations

Glossary

Analyte: A substance or constituent being measured in an analytical procedure (parameter). A physical, chemical, or biological property whose measured value help determine the characteristics of something of interest.

Anthropogenic: Human-caused.

Aroclor: A trade name under which a commercial mixture of individual PCB congeners was marketed by Monsanto Company in North America. Different mixtures, or Aroclors, were used for different applications. Aroclors are the most common form of PCBs targeted in laboratory analyses.

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 required states to identify impaired waters and established the TMDL program to mitigate sources of pollution.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Effectiveness Monitoring: An effectiveness monitoring evaluation is an essential component of TMDLs and Water Cleanup Plans because it determines to what extent the actions to control pollution have attained the goals of watershed restoration. Formal effectiveness monitoring evaluation addresses four fundamental questions with respect to restoration or implementation activity: (1) Is the restoration or implementation work achieving the desired objectives or goals? (2) How can restoration or implementation techniques be improved? (3) Is the improvement sustainable? (4) How can the cost-effectiveness of the work be improved?

Fish Tissue Equivalent Concentration (FTEC): The FTEC was a tissue pollutant concentration previously used by Ecology to determine whether surface water human health criteria were being met. The FTEC was an interpretation of Washington's older surface water quality criterion for a specific chemical for the protection of human health (National Toxics Rule: Federal Register Vol. 57 No. 246 pp. 60848, 1992; Federal Register Vol. 64 No. 216 pp. 61182 1999). Fish tissue sample concentrations that were lower than the FTEC suggested that criteria for a specific contaminant were being met. Where a FTEC was not met (i.e., concentration of a chemical in fish tissue is greater than the FTEC), that water body was then placed into Category 5 during Washington's periodic Water Quality Assessment (https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d). These Category 5 listings became part of Washington's 303(d) list during previous assessments. The FTEC was calculated by multiplying the contaminant-specific Bio-Concentration Factor (BCF) times the contaminant-specific Water Quality Criterion found in the National Toxics Rule.

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

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

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

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Riparian: Relating to the banks along a natural course of water.

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

Spatial: Relating to space, location, and distance, such as between two sampling sites.

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

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

TEC: Tissue Exposure Concentration.

The TEC is a tissue concentration that was developed by Ecology using parts of the EPA's human health criteria equations. The TEC is intended to represent exposure to a potentially harmful level of a pollutant through the consumption of fish or shellfish. When the concentration of a pollutant in composite samples of fish or shellfish is greater than a threshold related to the TEC, the designated use of harvest is considered impaired, indicating that the water body may not be meeting water quality standards for the State of Washington, and may be placed on the Clean Water Act 303(d) list.

The TECs for carcinogenic (TECc) and non-carcinogenic (TECn) effects of pollutants differ because of differences in the underlying assumptions associated with exposure, toxicity, and risk/hazard with the two types of health effects. For example, the TECc assumes a daily exposure over a 70-year period while the TECn assumes a daily exposure over a 7–70 year period, depending on the pollutant. Some carcinogens also have non-cancer health effects above certain concentrations, so these chemicals will have both TECc and TECn values. Calculation of TECs:

- TECc = (Risk level) x (Body weight) ÷ (Cancer slope factor) x (Fish consumption rate).
- TECn = (Reference dose) x (Body weight) ÷ Fish consumption rate.

The TEC-related thresholds used to determine whether water quality standards *are not* being met are unique to each chemical. For carcinogens, the threshold is ten times the TECc (10x TECc) while for non-carcinogens, the threshold is the TECn.

The TEC-related thresholds used to determine whether water quality standards *are* being met are a bit different. For carcinogens, the threshold is the TECc. For non-carcinogens the threshold is still the TECn.

Temporal: Relating to time, such as between one year and another.

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

Trend: A meaningful change or difference that can be measured and differentiated from measurement error. Often used in the context of time (temporal trend) or space (spatial trend).

Water Quality Assessment (WQA): Washington's Water Quality Assessment lists the water quality status for water bodies in the state to meet federal requirements for an integrated report under Sections 303(d) and 305(b) of the Clean Water Act. The assessed waters are grouped into categories that describe the status of water quality. Category 5 represents the 303(d) list, which comprises those waters that are in the polluted water category, for which beneficial uses—such as drinking, fishing, recreation, aquatic habitat, and industrial use—are impaired by pollution.

Water Quality Standards: Water quality standards consist of designated uses, numeric and narrative criteria, and anti-degradation components. These components work together to protect the health of surface waters in Washington.

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 all states to periodically prepare a list of all surface waters for which beneficial uses of the water—such as for drinking, fishing, recreation, aquatic habitat, and industrial use—are impaired by pollutants. These are water-quality-limited estuaries, lakes, and streams that fall short of the state's surface water quality standards and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Acronyms and Abbreviations

ANOVA	Analysis of Variance
BMP	Best management practice
CCT	Cutthroat trout (*Oncorhynchus clarki*)
CP	Chlorinated pesticide
DDE	Dichloro-diphenyl-dichloroethylene
DDT	Dichloro-diphenyl-trichloroethane
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FCA	Fish Consumption Advisory
FFCMP	Freshwater Fish Contaminant Monitoring Program
FTEC	Fish tissue equivalent concentration
GIS	Geographic Information System software
Health	Washington State Department of Health
J	estimated value
LMB	Largemouth bass (*Micropterus salmoides*)
LSS	Largescale sucker (*Catostomus macrocheilus*)
MEL	Manchester Environmental Laboratory
MS/MSD	Matrix Spike / Matrix Spike Duplicate
MWF	Mountain whitefish (*Prosopium williamsoni*)
NJ	The analysis indicates the presence of the analyte, has been tentatively identified and the associated numerical value is the approximate concentration. Identification needs further confirmation.
NPDES	(See Glossary above)
NPM	Northern pikeminnow (*Ptychocheilus oregonensis*)
NTR	National Toxics Rule
PBDE	Polybrominated diphenyl ether
PBT	persistent, bioaccumulative, and toxic substance
PCB	Polychlorinated biphenyl
PCDD/F	Polychlorinated dibenzo-p-dioxin and -furan
RBT	Rainbow trout (*Oncorhynchus mykiss*)
RCW	Revised Code of Washington
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
t-PCB	Total PCBs
t-PBDE	Total PBDEs
SOP	Standard Operating Procedure
SV	Screening value
t-DDT	Total DDTs
t-PCB	Total PCBs
t-PBDE	Total PBDEs

TCDD	2,3,7,8-tetra-chlorinated dibenzo-p-dioxin
TECc	Tissue Exposure Concentration for carcinogenic effects
TECn	Tissue Exposure Concentration for non-carcinogenic effects
TEQ	Toxicity equivalent
TMDL	(See Glossary above)
U	Not detected at the reported value
UJ	Undetected at the estimated reported value
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

=	equal to
>	greater than
<	less than
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
mg	milligram
mm	millimeters
ng/Kg	nanograms per kilogram (parts per trillion)
µg/Kg	micrograms per kilogram (parts per billion)