Freshwater Fish Contaminant Monitoring Program

2014 Results

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Cover photo: Northern pikeminnow (*Ptychocheilus oregonensis*) in our electrofishing boat's holding tank: this species was collected from three sites in the Yakima River basin for the FFCMP effort in 2014.

Freshwater Fish Contaminant Monitoring Program

2014 Results

by

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

WRIAs
- 37 – Lower Yakima
- 39 – Upper Yakima

HUCs
- 17030003 – Lower Yakima
- 17030001 – Upper Yakima

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Abstract

Ecology's Freshwater Fish Contaminant Monitoring Program sampled fish from the Yakima River basin in 2014. Results are highlighted for Keechelus Lake and three mainstem river sites: the canyon upstream of Roza Dam, the river near Prosser, and the Horn Rapids to Kiona reach. Goals were to characterize: (1) contaminant concentrations in fish tissue and (2) spatial and temporal patterns.

Contaminant concentrations in tissue for most of the chemicals analyzed were below Washington's Fish Tissue Equivalent Concentrations (FTEC). FTECs are used in Washington's Water Quality Assessment and 303(d) listing process to determine whether designated uses of the sampled water bodies are being met. FTECs were exceeded (indicating impairment) at each site for one or more of: 4,4'-DDE, dieldrin, toxaphene, t-PCBs, and dioxins/furans.

Spatial and temporal trends in Yakima River fish were seen for some contaminants. Spatially, concentrations of 4,4'-DDE increased in a downstream direction. This was true to a lesser extent for many other organic chemicals.

Temporal trends were seen in concentrations of 4,4'-DDE and PCBs in whole largescale suckers, yet not for fillet tissue from other species. Between the 1990s and 2014, median concentrations of 4,4'-DDE in whole suckers from the Canyon, Prosser, and Horn Rapids-Kiona sites, decreased by 73%, 56%, and 87%, respectively. Decreases in median concentrations of PCBs in suckers from these same sites were 41%, 41%, and 85%, respectively.

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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 analysis of over 550 fish tissue samples from 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 of interest.

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), 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 at www.ecy.wa.gov/programs/eap/toxics/chemicals_of_concern.html.

The accumulation of 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 food, particularly 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 16 site-specific advisories due to contamination of fish by various chemicals: www.doh.wa.gov/CommunityandEnvironment/Food/Fish.aspx.

Yakima River Basin Focus

Numerous fish tissue monitoring efforts in the Yakima River basin have been conducted since the 1980s. These efforts were primarily focused on characterizing levels of chlorinated pesticides that were associated with agriculture in the basin. The general locations, timeframes, and analytes that these studies targeted were tabulated in the project plan for this study (Seiders and Deligeannis, 2014).

These past efforts yielded information that supported key actions by state and local jurisdictions. These actions included:

- Fish Consumption Advisory in 1993 for DDT compounds (Health, 2009).
- Clean Water Act Section 303(d) listings for chlorinated pesticides beginning in 1996 (http://www.ecy.wa.gov/programs/wq/303d/index.html).
- TMDL efforts to address turbidity (which was associated with DDT compounds) in the lower and upper basins in 1998 and 2002 (Joy and Patterson, 1997; Joy, 2002).

[1] www.ecy.wa.gov/programs/eap/toxics/wstmp.html

More recent sampling also supported water quality improvement efforts. In 2006, Yakima River fish were sampled in order to compare findings to water quality standards and inform restoration work (Johnson et al., 2007). A more comprehensive water quality study was done in 2007-08 to aid in developing a TMDL to address 303(d) listings for chlorinated pesticides, PCBs, turbidity, and suspended solids (Johnson et al., 2010). The sampling included waters from the river and tributaries, wastewater treatment plant effluents, irrigation returns, and stormwater.

Collectively, the historical fish tissue data comprise a mix of sites, species, tissue types, collection seasons, and analytical methods. While Ecology has reported general impressions about changes in contaminant levels over time, we have not measured for statistically significant temporal changes. Challenges to such efforts have been small sample sizes, high variability associated with fish tissue, and high costs associated with laboratory analyses for organic contaminants.

The 2014 effort targeted sites and species that were sampled historically in order to gain a temporal perspective where possible. The goal of the 2014 monitoring was to develop a robust data set of contaminant levels in fish from the Yakima River to:

- Characterize temporal trends by comparisons to historical and future data.
- Characterize spatial trends among sites.
- Compare results to water quality standards.
- Support fish consumption risk assessments by health jurisdictions.
- Inform future efforts such as implementation of pollution controls and related effectiveness monitoring.

Review of historical data led to selection of sites, species, analytes, and sample sizes to meet the goals of the current project. The proposed sites and species were most recently sampled in 2006 (Johnson et al., 2007). The Columbia River Basin Fish Contaminant Survey from 1996-98 (EPA, 2002a) also evaluated many sites, species, and analytes. These studies provide the bulk of data that will be used for temporal comparisons. Some of these historical data are discussed later in this document. Ecology's FFCMP plans to sample this area again in about 10 years. Figure 1 shows the sample locations for 2014 and historical sampling efforts.

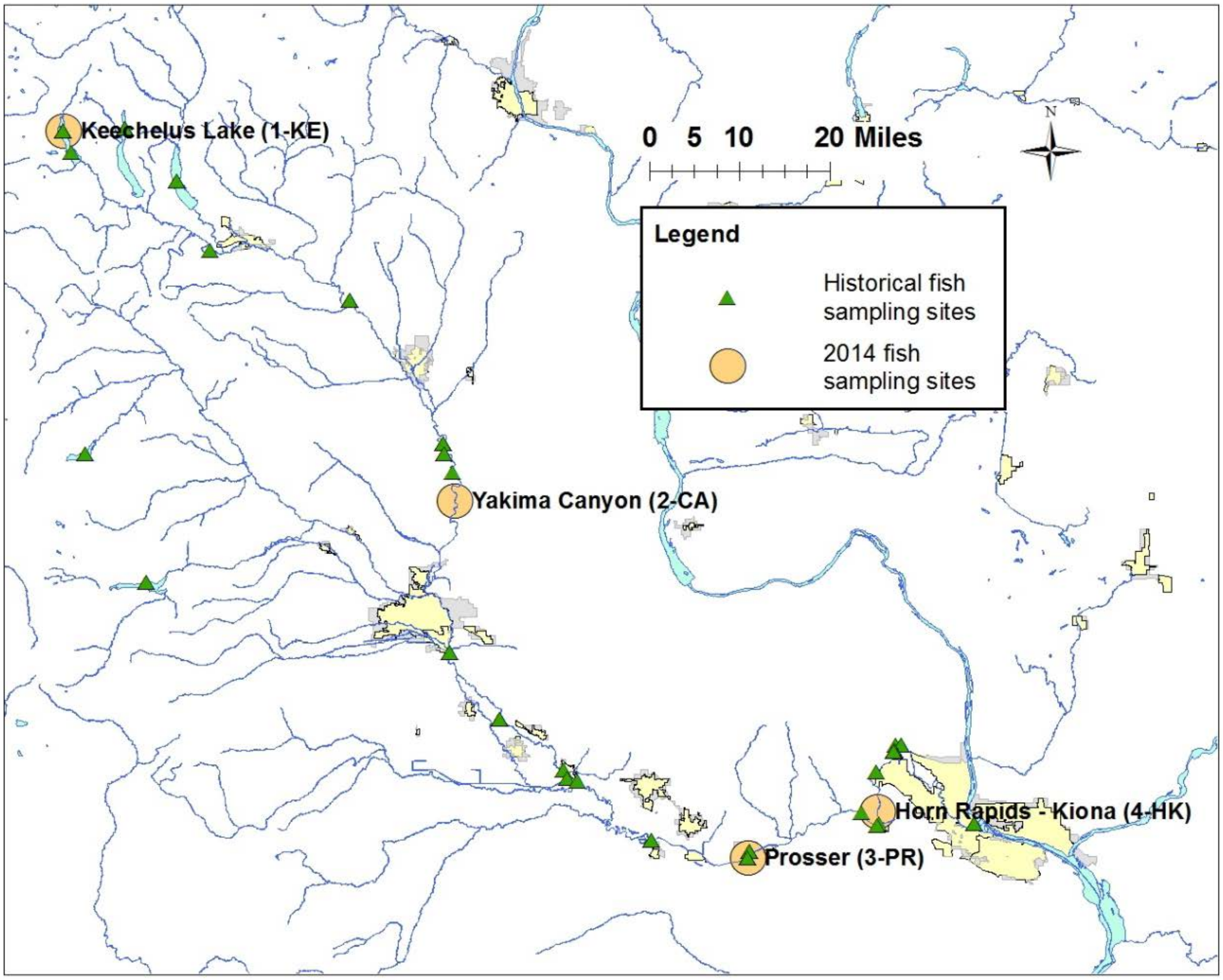

Figure 1. Sample locations for fish contaminant studies in the Yakima River basin.

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Methods

Field and Laboratory Methods

Sample collection, preparation, and analytical methods followed those described in the project plan and Addendum 2 for the FFCMP (Seiders, 2013; Seiders and Deligeannis, 2014). A total of 74 samples of fish tissue were analyzed for some or all of these chemicals: chlorinated pesticides, mercury, PBDEs, PCBs, and PCDD/Fs. All results were reported on a wet-weight basis.

Most composite samples consisted of skin-on fillets from five individual fish of a similar size of the same species per site, except for largescale suckers which were processed as whole fish. For most sites, multiple composite samples of the same species were collected in order to address sampling variability and improve the strength of statistical tests to determine spatial or temporal differences. Historical data informed the selection of species and fish sizes for collections in order to improve the spatial and temporal comparability of results among sites and studies. Appendix A describes sample collection and processing in more detail. Table 1 shows the number of composite samples that were analyzed for each species at each sampling area.

Table 1. Number of composite samples analyzed per fish species per site, 2014.

Site	LSS	NPM	MWF	CCP	SMB	KOK	CTT
1-KE: Keechelus Lake	3	5	3	-	-	3	1
2-CA: Yakima Canyon	7	6	6	-	-	-	-
3-PR: Prosser	7	3	-	5	4	-	-
4-HK: Horn Rapids-Kiona	7	3	3	5	3	-	-

Species codes: CCP: Common carp, CTT: Cutthroat trout, KOK: Kokanee, LSS: Largescale sucker, MWF: Mountain whitefish, NPM: Northern pikeminnow, SMB: Smallmouth bass.

Two different analytical methods were used for determining chlorinated pesticides and PCBs. For chlorinated pesticides, a subset of samples were analyzed using a very sensitive method: high resolution gas chromatography mass spectrometry (HRGC-MS). This method was used to obtain lower reporting limits than can be obtained with EPA Method 8080. The lower reporting limits for some analytes allow comparison of sample results to Washington's current water quality standards; as well as to standards that were proposed in 2014 but not adopted. The use of the HRGC-MS method for this study is described in Addendum 3 to the project plan (Seiders, 2015).

For PCBs, all samples were analyzed for Aroclors while a subset of samples were analyzed for all congeners. Aroclor results were used in this report because the Aroclor method was used for all samples and in the historical studies. Results for total PCBs from the Aroclor and congener methods were similar. Results for congeners are not discussed in this report: these analyses were done to supplement data that can address interests that are broader than the scope of the FFCMP. These interests include informing statewide strategies for addressing PCB contamination in the environment and allowing comparisons to other fish samples (statewide) having PCB congener data.

Data Quality Assessment

The quality of laboratory results from the 2014 study was assessed by reviewing laboratory case narratives, analytical results, and field replicate data. Quality control procedures included a mixture of analyses such as method blanks, calibration and control standards, matrix spikes, matrix spike duplicates, surrogate recoveries, laboratory duplicates and field replicates. All laboratory analyses were completed and no data were rejected. Yet results were heavily qualified, which is common with the analytical interferences associated with the matrix of fish tissue. Overall, most of the 2014 data met measurement quality objectives, and all results were deemed usable as qualified.

The field effort did not meet original sampling goals because of challenges in getting enough samples of target species in desired size ranges at specific locations. No fish were collected from the Wapato-Toppenish area because of difficulty accessing this reach of the river. For the remaining sites, sample collection goals were met (100% completeness) for 10 of 15 of the site-species cases. Sample collection goals for the remaining 5 sites-species cases ranged from 20% to 67% completeness. In many cases, non-target species and size ranges were substituted in order to provide alternative information. Overall, adequate samples were collected to meet most project objectives.

The quality and comparability of historical data were examined by reviewing the individual study reports with emphasis on field, laboratory, and quality assurance procedures. Most of the historical studies were in Ecology's Environmental Information Management (EIM) system, and in most cases, data from historical studies were deemed acceptable as qualified for use in this report. Further assessment of data quality is beyond the scope of this report. Additional quality assurance information is available by contacting the authors of this report.

Data Reduction, Trends Analyses, Water Quality Criteria

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. Procedures for summing followed Ecology guidance for the Water Quality Assessment process (Ecology, 2012).

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. These factors were considered while choosing samples for various comparisons. The results were plotted to examine relationships between 4,4'-DDE (DDE) and mercury to fish length, weight, age, and lipids. DDE served as a surrogate for other organic contaminants in the first round of plots. Simple linear regression was used to help determine the existence and strength of relationships. These plots 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. Such adjustments could potentially increase the sensitivity of statistical tests for differences among sites or between years.

Trends Analyses

Analyses for trends proceeded by viewing data sets of interest and then performing statistical tests for selected data. Data sets representing cases of individual fish species, sites, and key analytes were defined for further use. Two examples of such cases are: DDE in common carp from the Prosser reach in 2014; and PCBs in suckers from Keechelus Lake in 2006. The various cases were then examined for spatial and temporal patterns using boxplots produced in SYSTAT (SYSTAT, 2012).

The boxplots used in this report graphically summarize the data set using various elements. 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. 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

Where boxplots suggested there might be statistically significant differences between cases of interest, statistical testing was pursued. Data sets usually failed assumptions for normal distribution or equality of variances, so parametric tests for comparisons were not pursued. Data were not transformed prior to conducting the statistical tests described below.

The 2014 data were tested for spatial differences using the non-parametric Kruskal-Wallis single-factor ANOVA (SYSTAT, 2012). 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, ½ the value of the detection limit was used in these tests as recommended by EPA (EPA, 2000).

Data sets from studies conducted between the 1990s and 2014 were tested for temporal differences using the non-parametric two-sample Mann-Whitney test. The generalized null hypothesis was that data sets did not differ. For these tests, alpha levels of 0.05, 0.10, and 0.20 were chosen, meaning that there was a 5%, or 10%, or 20% (respectively) chance that the outcome of the test was due to chance. These levels were used progressively in order to find cases where statistical significance was detected; that is, if no significance was found at alpha = 0.05, then the test was repeated using alpha = 0.10, and so on.

For sample results that were reported as non-detect, the value of the detection limit was used in these tests. Less information about the historical analyses was available to justify use of ½ the value of the detection limit.

Water Quality Standards

Results from the 2014 study were compared to Washington's Fish Tissue Equivalent Concentrations (FTEC). The FTEC is a tissue contaminant concentration used by Ecology to determine whether the designated uses of fishing and drinking from surface waters are being met. The FTEC is an interpretation of Washington's water quality criterion for a specific chemical for the protection of human health: the National Toxics Rule (40 CFR 131.36). Fish tissue sample concentrations that are lower than the FTEC suggest that the uses of fishing and drinking from surface waters are being met for that specific contaminant.

Washington's periodic Water Quality Assessment involves comparing the results from studies to water quality standards (for water samples) and FTECs (for tissue samples). Water bodies are then assigned to one of five categories that help guide the management of pollution problems. Where FTECs are not met (i.e., concentrations of a chemical in fish tissue is greater than the FTEC), that water body is then placed into Category 5, which is Washington's 303(d) list. This process and categories are described at www.ecy.wa.gov/programs/wq/303d/index.html.

For dioxins and furans, Washington's FTEC applies to two expressions of these compounds: the single congener 2,3,7,8-TCDD (the most toxic congener) and TCDD-TEQ, (the toxicity equivalent or TEQ to 2,3,7,8-TCDD. This TCDD-TEQ approach accounts for the cumulative toxicity of all dioxin and furan congeners and follows recommendations by EPA (EPA, 2010) and the World Health Organization (Van den Berg et al., 2006). In Washington's water quality assessment, TCDD-TEQ results that exceed the FTEC for 2,3,7,8-TCDD (0.065 ng/kg) are placed in Category 2 – "Segment is a Water of Concern", rather than in Category 5 – "Segment is on 303(d) List" (Ecology, 2012). Category 2 is used because TCDD-TEQ is not specifically listed in the National Toxics Rule, the basis for Washington's water quality standards for the protection of human health.

There are other water quality benchmark values that organizations use for evaluating the risks of consuming contaminated fish. Two of these are used for comparing this study's results to:
(1) Ecology's proposed changes to the water quality standards, which yields proposed FTECs, and
(2) EPA's Screening Values for Subsistence and Recreational Fishers. Appendix B describes these in more detail, along with other benchmark values such as EPA's Recommended Water Quality Criteria and Health's Screening Values. Appendix C describes the different approaches used by Ecology and Health in evaluating fish tissue data.

Results and Discussion

Results for the most frequently detected analytes in 2014 are described below. Results are also compared to Washington's FTECs in the following tables and figures. All results are available from Ecology's Environmental Information Management database (EIM) at http://www.ecy.wa.gov/eim under the Study ID FFCMP14.

Table 2 summarizes results for fillets from six species and whole tissue from largescale suckers. The statistics for fillet data are from results for six species (common carp, cutthroat trout, kokanee, mountain whitefish, northern pikeminnow, and smallmouth bass) from the four sample locations. Because the fillet data were pooled, these statistics are not representative of any single species, and also of limited use in comparing to the statistics from whole largescale suckers. No species were analyzed as both fillet tissue and whole fish tissue as had been done for some samples in previous studies. Statistics for whole fish are not compared to FTECs because the Washington's water quality standards apply only to fillet tissue.

Fillet tissue from common carp had some of the highest concentrations of pollutants measured in this study, such as for 4,4'-DDE, t-DDT, dieldrin, chlordane, and others. These values from fillet tissue were higher than those found in whole fish tissue from largescale sucker. As described previously, contaminant concentrations in fish can be influenced by many factors (e.g., species, tissue type, size, age, lipid content, life history and feeding, and collection location and season). These sources of variability need to be considered when comparing results between different data sets, such as results from carp fillets and results from whole largescale sucker.

Table 2. Summary of results from the FFCMP, 2014.

Tissue Type	Statistic	4,4'-DDE (ug/kg)	t-DDT (ug/kg)	Dieldrin (ug/kg)	t- Chlordane (ug/kg)	Toxaphene (ug/kg)	t-PCBa (ug/kg)	TCDD - TEQ (ng/kg)	2,3,7,8-TCDD (ng/kg)	t- PBDE (ug/kg)	Mercury (ug/kg)	Lipids (%)	Mean Total Length (mm)	Mean Weight (g)	Mean Age (yrs)
Fillet (most species)	Count	50	50	50	50	50	50	31	31	50	44	50	50	50	50
	Mean	**158**	166	**1.9**	1.6	7.4	**36.0**	**0.179**	0.047	14.6	263	3.7	401	1113	6.1
	Median	**34**	37	**1.30**	0.99	8.2	**15.9**	**0.121**	0.024	7.17	241	2.8	333	390	4.9
	Min	0.77	0.77	0.02	0.27	0.30	2.6	0.006	0.011	0.59	28	0.4	276	188	1.3
	Max	**1000**	1029	**6.7**	7.1	**22**	**167**	**0.971**	**0.211**	61.4	664	9.3	665	4284	18.0
	FTEC	31.6	-	0.65	8.3	9.8	5.3	0.065	0.065	-	770	-	-	-	-
	#>FTEC	27	-	32	0	9	37	17	7	-	0	-	-	-	-
	%>FTEC	54%	-	64%	0%	18%	74%	55%	23%	-	0%	-	-	-	-
Whole (LSS only)	Count	24	24	24	24	24	24	-	-	24	-	24	24	24	24
	Mean	122	142.7	2.7	-	-	29	-	-	12.8	-	8.50	451	1040	6.8
	Median	115	134	1.5	-	-	24	-	-	11.5	-	8.71	457	1006	6.0
	Min	3.3	3.3	0.75	0.76 U	15 U	11	-	-	4.2	-	2.16	411	788	3.2
	Max	290	327	4.7	5.0 U	62 U	66	-	-	39.8	-	12.5	484	1404	16.2

t-PCBa: total PCB Aroclors
Bold values are those above Washington's FTEC

Figure 2 shows boxplots for DDE concentrations in fish sampled in 2014. Results are ordered left to right by site from upstream (1-KE, Keechelus Lake) to downstream (4-HK, Yakima River from Horn Rapids to Kiona). These plots show that the highest concentrations of DDE in fillet tissue are in common carp from the Prosser and Horn Rapids-Kiona reaches, with median values of 520 and 730 ug/kg, respectively. Similarly, whole largescale suckers from the two downstream sites showed elevated levels with median values of 130 –210 ug/kg. The dashed lines help show how sample results compare to Washington's current and proposed FTECs. Appendix D shows boxplots for other parameters by site and species.

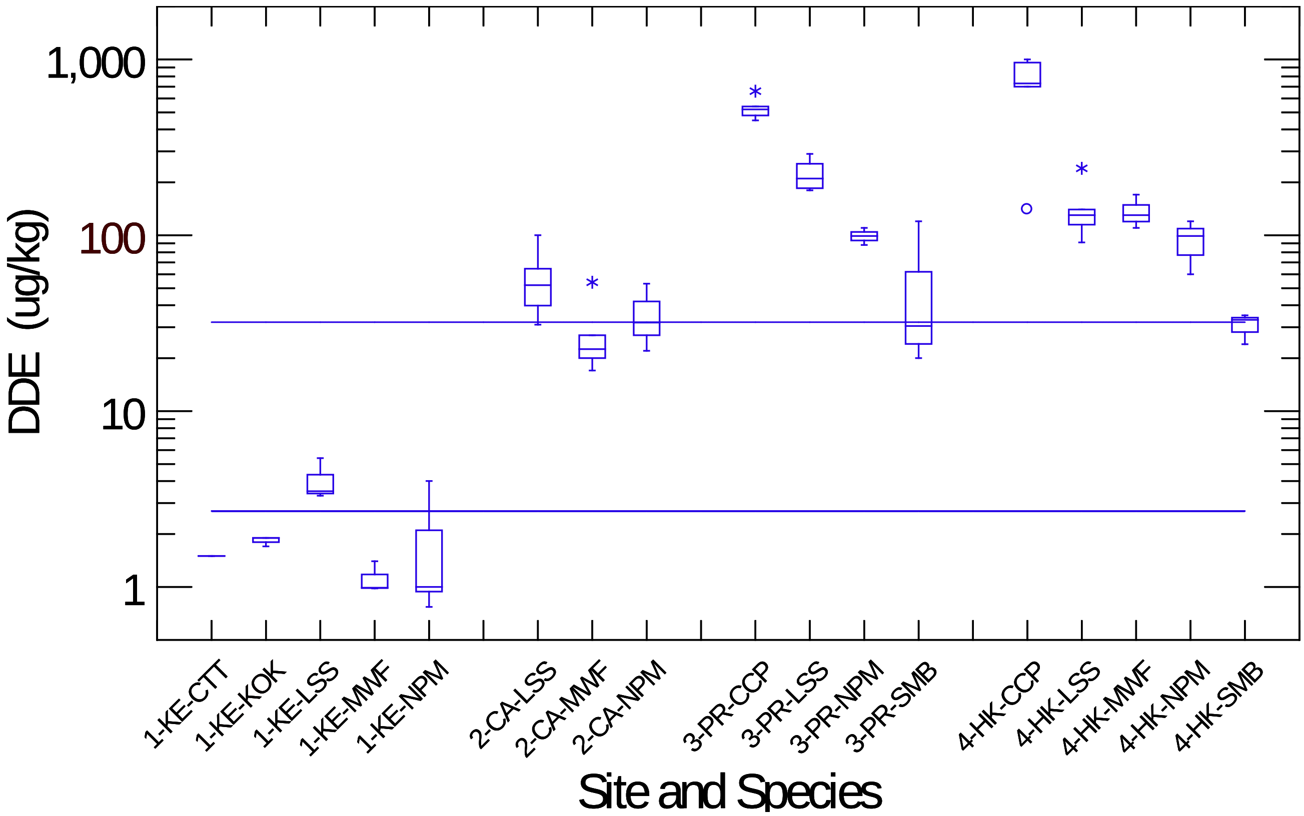

Figure 2. Boxplots of DDE in fillet tissue from six species and whole tissue from largescale suckers from the Yakima River basin in 2014.

Dashed line = current FTEC (32 ug/kg); dotted line = proposed FTEC (2.73 ug/kg).

Site codes and species codes: 1-KE: Keechelus Lake. 2-CA: Yakima River canyon (upstream of Roza Dam). 3-PR: Yakima River at Prosser (upstream of dam). HK: Yakima River section from Horn Rapids to Kiona. CCP: Common carp. CTT: Cutthroat trout. KOK: Kokanee. LSS: Largescale sucker. MWF: Mountain whitefish. NPM: Northern pikeminnow. SMB: Smallmouth bass.

Figure 3 shows results for t-DDT, t-PCBs, TCDD-TEQ, and t-PBDEs in fillet tissue from multiple species of fish collected across Washington during the FFCMP since 2001. Results from 2014 are also indicated, along with values that can be used for assessing health risks to humans consuming contaminated fish. These are (1) the U.S. EPA Screening Values (SVs) for Subsistence and Recreational Fishers (EPA, 2000) and (2) Washington's current FTECs. Because there is no FTEC for t-DDT, the chart uses the FTEC for both 4,4'-DDE and 4,4'-DDT (the FTEC for 4,4'-DDD is 44 ug/kg). Screening values and regulatory thresholds have not yet been established for PBDEs.

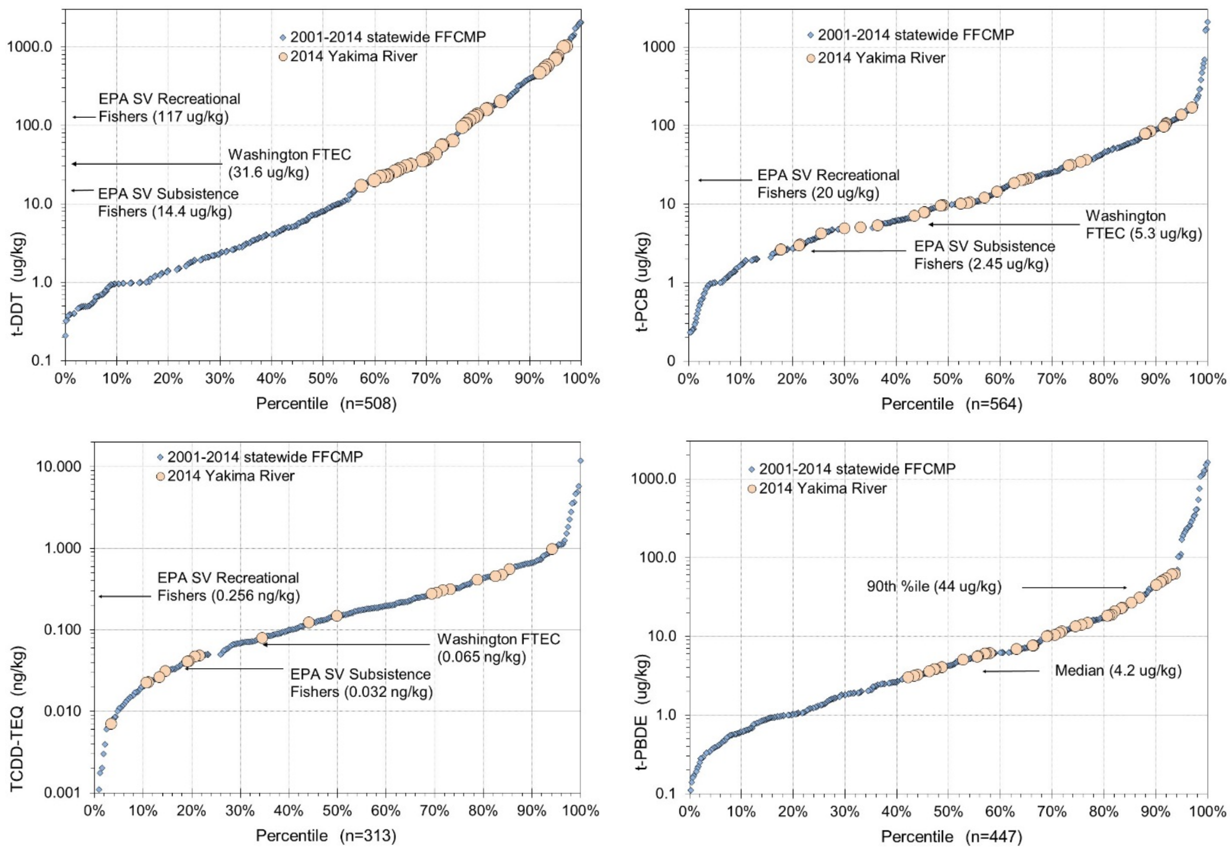

Figure 3. Cumulative frequency distributions for t-DDT, t-PCB, TCDD-TEQ, and t-PBDE in fillet tissue from Washington.

For these four contaminants, the 2014 results are generally representative of statewide values, except for t-DDT. Nearly all Yakima River fish are above the 60th percentile for t-DDT. Common carp from the lower river have some of the highest levels of t-DDT in the state, with 9 of the 10 samples being above the statewide 90th percentile. For t-PBDEs, most of the Yakima River fish are higher than the statewide median, with most of the carp exceeding the 90th percentile. Results for t-PCBs and TCDD-TEQ span the range of values found statewide. Most of the 2014 results shown in Figure 4 are above what are considered "background" levels for Washington as described by Johnson and others (Johnson et al, 2010; Johnson and Friese, 2013).

Figure 4 shows concentrations of dieldrin in fish fillets from four locations sampled in 2014. Labels on the x-axis indicate the site, species, and field sample identifier for each sample. Sites are arranged left to right from upstream to downstream. Within the site groups, samples from the same species are grouped together. A subset of samples were analyzed for some chlorinated pesticides using a more sensitive analytical method as described in Addendum 3 (Seiders, 2015) and are plotted as diamonds.

The plot shows that most sample results from the mainstem Yakima River do not meet Washington's current FTEC of 0.65 ug/kg (dotted line). The highest levels were found in common carp and mountain whitefish. Dieldrin was not detected in any samples from Keechelus Lake using low resolution methods. No samples met Washington's proposed FTEC of 0.028 ug/kg (not shown in chart) except for one of the northern pikeminnow samples from Lake Keechelus.

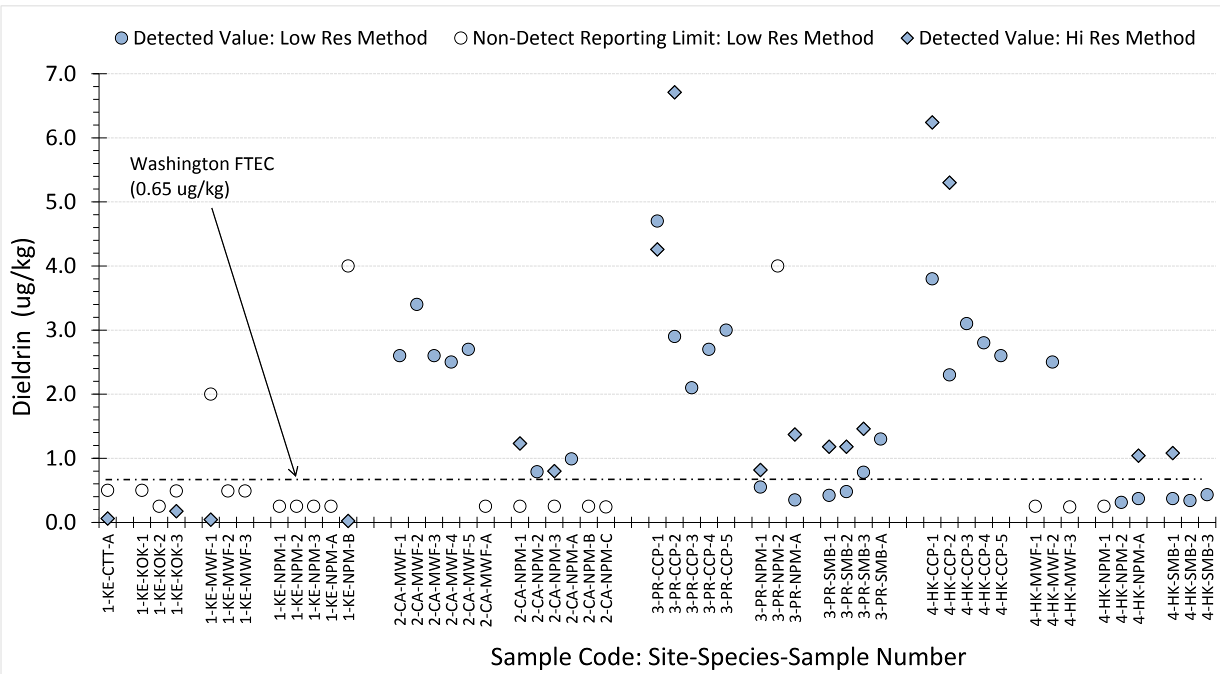

Figure 4. Results for dieldrin in fillet tissue from different species from four locations sampled in 2014.

Site and species codes: 1-KE: Keechelus Lake. 2-CA: Yakima River canyon (upstream of Roza Dam).
3-PR: Yakima River at Prosser (upstream of dam). HK: Yakima River section from Horn Rapids to Kiona.
CCP: Common carp, CTT: Cutthroat trout, KOK: Kokanee, MWF: Mountain whitefish, NPM: Northern pikeminnow, SMB: Smallmouth bass.

Results from all samples were compared to Washington's current FTECs. Table 3 summarizes the sites, species, and contaminants where FTECs in samples were exceeded. No sites met water quality standards because of elevated levels of various contaminants in one or more species of fish. All sites are recommended for Category 5 (the 303[d] List) and Category 2 (Waters of Concern) assignments as appropriate for the contaminants shown below.

Table 3. Sites and species not meeting Washington's current FTECs.

Site	4,4'-DDE (Category 5)	Dieldrin (Category 5)	Toxaphene (Category 5)	t-PCB (Category 5)	2,3,7,8-TCDD (Category 5)	TCDD-TEQ (Category 2)
1-KE: Keechelus Lake	-	-	KOK, MWF	KOK, NPM	-	CTT, KOK, MWF, NPM
2-CA: Yakima Canyon	MWF, NPM	MWF, NPM	MWF	NPM	-	NPM
3-PR: Prosser	CCP, NPM, SMB	CCP, SMB	-	CCP, NPM, SMB	CCP	CCP, NPM
4-HK: Horn Rapids-Kiona	CCP, MWF, NPM, SMB	CCP, MWF	MWF	CCP, MWF, NPM, SMB	CCP, MWF	CCP, MWF, NPM

Species codes: CCP: Common carp, KOK: Kokanee, MWF: Mountain whitefish, NPM: Northern pikeminnow, SMB: Smallmouth bass.

Spatial Trends

Concentrations of some contaminants were plotted to see whether differences could be discerned among sites. Figure 5 shows boxplots for DDE in three species from the sampled sites. Results are ordered left to right by site from upstream (1-KE, Keechelus Lake) to downstream (4-HK, Yakima River from Horn Rapids to Kiona).

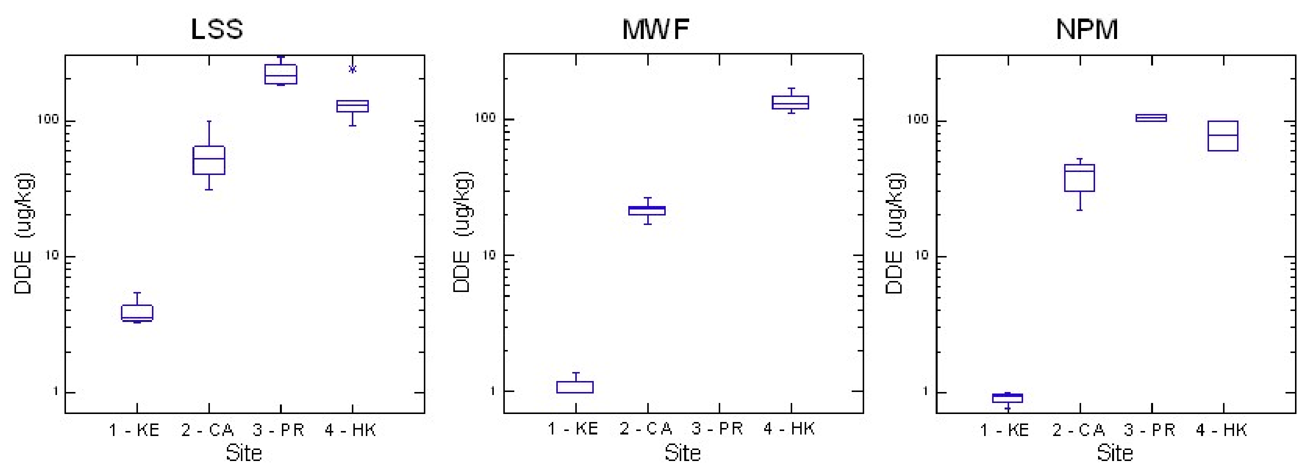

Figure 5. Boxplots for DDE in Yakima River basin whole largescale suckers (LSS) and fillets of mountain whitefish (MWF) and northern pikeminnow (NPM).

Site and species codes: 1-KE: Keechelus Lake. 2-CA: Yakima River canyon (upstream of Roza Dam). 3-PR: Yakima River at Prosser (upstream of dam). HK: Yakima River section from Horn Rapids to Kiona. LSS: Largescale sucker, MWF: Mountain whitefish, NPM: Northern pikeminnow.

Figure 5 shows a similar pattern in DDE concentrations from upstream to downstream for each species: low levels in Keechelus Lake (perhaps due mainly to atmospheric inputs), an increase into the Yakima Canyon area (reflecting inputs from upstream agricultural land use), and highest levels at Prosser and Horn-Rapids-Kiona reaches (downstream of most agricultural land use). The Kruskal-Wallis ANOVA tests for these three species showed statistically significant differences in contaminant concentrations among sites.

In general, concentrations of PCBs, PBDEs, and PCDD/Fs in these species also increased in a downstream direction. However, the patterns for other chemicals were weaker and more variable than is seen with DDE.

Mercury in fish followed no spatial patterns within species. Northern pikeminnow and carp had the highest concentrations (167-664 ug/kg) among all species. Concentrations of mercury in 8 of the 17 samples of northern pikeminnow were greater than 400 ug/kg. This concentration corresponds to Health's statewide consumption advisory for northern pikeminnow: to consume no more than two meals per month.

Temporal Trends

Results from 2014 and historical studies were examined for clues to changes in concentrations of contaminants in fish over time. Few chemicals had data records that could be evaluated, yet DDE showed the most promise for further evaluation, partly because of its relatively high levels. For DDE, several sets of site-species groups of data were examined further for determining changes over time.

The 2006 study (Johnson et al, 2007) provided the best data set for temporal trend analyses because two or three samples of a single species per site were analyzed. Most of the data from historical studies are results from single samples, so variability could not be characterized, which makes detection of trends unlikely. Future efforts to detect trends should be more powerful because of the larger sample sizes collected in this study.

Figure 6 shows results from 2014 and 2006 for fillet tissue from 3 site-species groups. These boxplots suggest that there's no difference between the 2006 and 2014 results for DDE in fillet tissue. Temporal trends appear to be absent for these site-species groups, so statistical testing was not pursued. Any difference in the DDE in smallmouth bass from the Horn Rapids-Kiona site between 2006 and 2014 was attributed to differences in fish size rather than a temporal trend. The 2006 fish were 2.7 times heavier than the fish collected in 2014 (median weight of 897 g vs 332 g) and 1.3 times longer (median total length of 379 mm vs 296 mm). Figure 6 also shows that most of the 2014 samples are above the current FTEC for DDE (31.6 ug/kg) and that DDE in carp fillets are more than 10 times higher than the current FTEC.

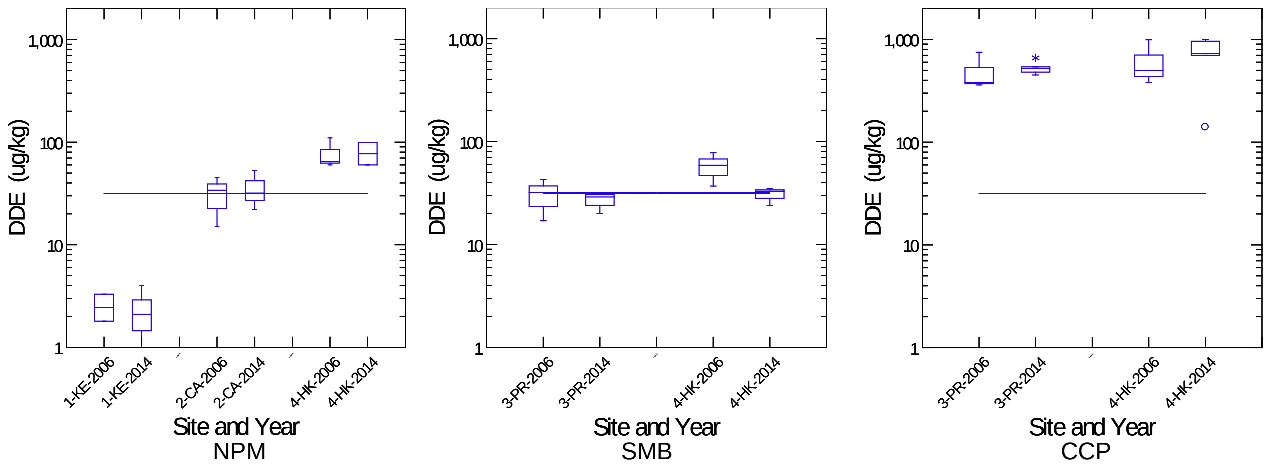

Figure 6. Boxplots for DDE in fillets of northern pikeminnow (NPM), smallmouth bass (SMB), and common carp (CCP) from 2006 to 2014 for multiple sites.
Line=current FTEC of 31.6 ug/kg.

Site and species codes: 1-KE: Keechelus Lake. 2-CA: Yakima River canyon (upstream of Roza Dam).
3-PR: Yakima River at Prosser (upstream of dam). HK: Yakima River section from Horn Rapids to Kiona.
LSS: Largescale sucker, NPM: Northern pikeminnow, SMB: smallmouth bass.

Figure 7 summarizes results for DDE and PCBs in samples of either largescale or bridgelip suckers. Past studies sampled one species or the other, or combined individuals from both species when forming composite samples. Results from the two species were pooled in order to create a larger data set for analyses of temporal trends. Each plot contains groups of results for 3 sites from 3 different study periods spanning from 1992 to 2014, depending on the site and analyte.

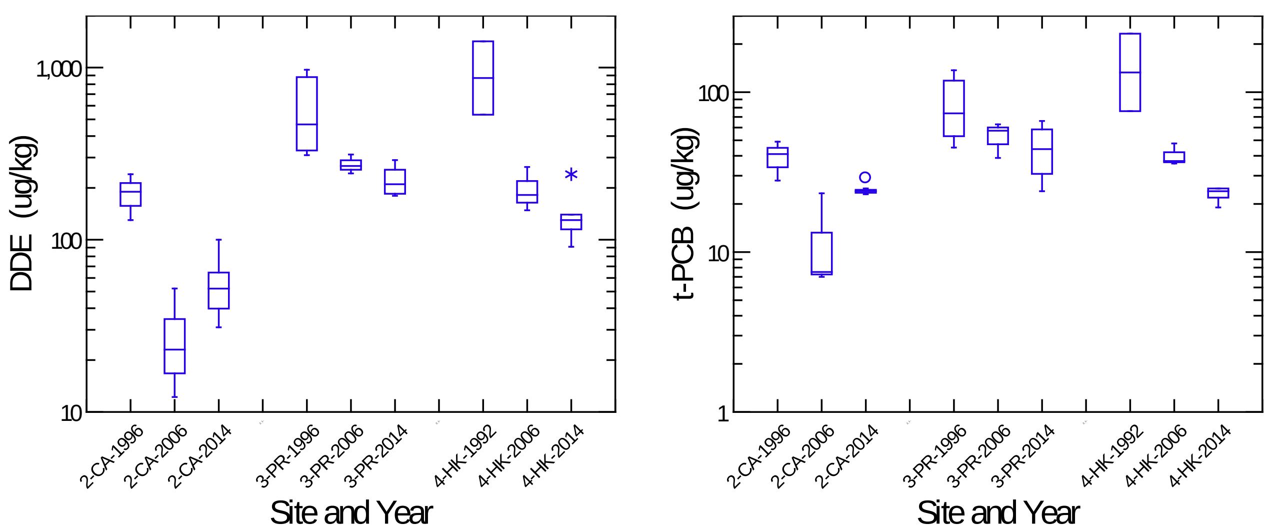

Figure 7. Boxplots for DDE and PCBs in whole largescale suckers from 1996 to 2014 for three sites.

In the boxplots for DDE, results from the different studies suggest a continuing decrease over time at the Prosser (3-PR) and Horn Rapids-Kiona (4-HK) sites. At the Prosser site, the 1996 median was 475 ug/kg, 268 ug/kg in 2006, and then 210 ug/kg in 2014. The Horn Rapids-Kiona data show a larger decline, with median values ranging from 976 ug/kg in 1992, then 182 ug/kg in 2006, and finally 130 ug/kg in 2014.

Results for DDE in suckers from the Yakima Canyon site (2-CA) show an initial decrease, followed by an increase. For these fish, the 1996 median was 190 ug/kg, then 23 ug/kg in 2006, and finally higher at 52 ug/kg in 2014. This pattern may be due to poor comparability among these data sets because of differing fish size. The 1996 fish were 1.5 times larger than the 2006 fish (median total lengths of 516 mm vs 342 mm). Fish sizes for the other sites across years were more similar, which improves comparability.

The Mann-Whitney test was used to determine whether differences in DDE between years were statistically significant at alpha = 0.05, 0.10 and 0.20. In most cases, there were no significant differences between adjacent studies (e.g., 1996 and 2006). While the plots suggest there might be significant differences between the 1992 and 2006 results from the Horn Rapids-Kiona site, the lack of difference is attributed to the very high variability from the 1992 results which only had two samples. However, between results from the 1990s and the 2014 studies for the Canyon, Prosser, and Horn Rapids-Kiona sites, significant differences represent decreases in the median DDE concentration in whole suckers of 73%, 56%, and 87%, respectively.

The boxplots for PCBs show patterns that are similar to those for DDE: declines of PCBs over time in suckers from the Prosser and Horn Rapids-Kiona locations, while fish from the Canyon site suggest a decline only between 1996 and 2006. Outcomes of Mann-Whitney tests applied to the PCB results were similar to those for DDE results: no significant differences between adjacent studies, yet significant differences between results from the 1990s and 2014 studies. For the Canyon, Prosser, and Horn Rapids-Kiona sites these differences represent decreases in the median concentration of PCBs in whole suckers of 41%, 41%, and 85%, respectively.

For temporal trends of mercury in the Yakima River, bass are sampled every five years from the Horn Rapids area as part of Ecology’s statewide effort to measure mercury trends in freshwater fish. Results for smallmouth bass from the Horn Rapids area were last reported by Meredith and Friese (2011). No changes in mercury concentrations were detected at this site between 2005 and 2010. Results from their 2015 sampling will be reported later this year. Temporal trends in mercury for other sites or species in the Yakima River basin were not examined as part of the FFCMP because of a lack of historical data.

Conclusions

As a result of this 2014 study, the following conclusions are made:

- Fish from three Yakima River sites continue to show elevated concentrations of organic contaminants. Fish from Keechelus Lake continue to show much lower concentrations.
- No sites met Washington's water quality standards for one or more of the following contaminants: DDE, dieldrin, toxaphene, t-PCBs, 2,3,7,8-TCDD, and TCDD-TEQ.
- Other pesticides that were detected in fish include: aldrin, alpha-BHC, chlordanes, DDT metabolites, endosulfans, endrin, gamma-BHC (Lindane), heptachlor epoxide, methoxychlor, and mirex.
- PBDEs were detected in all samples, and fish from the lower river had concentrations that were in the highest 10% of t-PBDE levels found in Washington.
- Mercury was found in all samples at concentrations typically seen across Washington.
- Spatial trends were evident in the 2014 results. Levels of organic contaminants in fish generally increased from upstream to downstream sites. The highest concentrations were found in fish from the lower reaches at Prosser and Horn-Rapids-Kiona.
- Temporal trends were found in DDE and PCBs between the 1990s and 2014 only in whole suckers. Median concentrations of DDE in whole suckers from the Yakima River sites (Canyon, Prosser, and Horn Rapids-Kiona) showed decreases of 73%, 56%, and 87%, respectively. The median concentrations of PCBs in whole suckers at these same sites showed decreases of 41%, 41%, and 85%, respectively.
- Small samples sizes from the historical data sets limited the ability to detect trends in many cases. Where trends were detected, they were often statistically weak. Future trend detection efforts should benefit from the larger samples sizes (n=7 or 5) collected during this study.

Recommendations

As a result of this 2014 study, the following recommendations are made:

- Results should be reviewed by state and local health agencies to determine whether the current Fish Consumption Advisory for the Yakima River should be revised.
- Results should be included in the next section 303(d) Water Quality Assessment conducted by Ecology.
- Based on contaminant concentrations and the ages of fish sampled in 2014, re-sampling fish at a frequency of about 10 years seems appropriate for temporal trends analyses.
- Future sampling of Yakima River fish for spatial and temporal trend analyses should focus on the sites, species, and fish size ranges that are comparable to the 2014 samples.
- Species of greatest value in detecting spatial and temporal trends would be those that are more widespread and abundant, such as: largescale or bridgelip sucker, northern pikeminnow, mountain whitefish, and perhaps smallmouth bass at the lower sites. The use of multiple species support a "weight of evidence" approach in discerning true trends from sampling variability.
- 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 efforts where the goal is detection of temporal trends. The appropriate sample size should be estimated when sampling plans are developed.

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Appendices

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Appendix A. 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, 2006 a, b, c).

Fish Collection

Historical sampling efforts helped determine the sampling goals for each site. Goals for each site consisted of specific fish species and specific size ranges of fish (length and weight. The 2014 effort 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. Most fish were collected during late summer and fall in attempts to match the timeframe in which fish were collected in previous studies.

Fish were collected using an 18' electrofishing boat and adhered to federal and state Scientific Collection Permits (USFWS # TE-058381-8, NOAA # 1386-7A, and WDFW # 12-298e). 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 unique identification code, measuring length and weight, wrapping in foil and Ziploc bags, and placing on ice for transport to freezer for storage at -20°C at Ecology headquarters in Olympia, WA. 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, most often total length, to match sizes of fish used in historical samples. To create multiple composite samples of similar sized fish, individual fish meeting the size criteria were randomly assigned to composite samples. For example, where five composite samples of five fish each were to be created, each of the 25 individual fish was randomly assigned to one of the five 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, and 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. Equal amounts of the ground and homogenized tissue from each fillet were then combined and homogenized to form a single composite sample. This composite was then passed once again through the grinder. 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).

After fillets were removed from the fish, the abdominal cavity of the fish was opened to determine gender. Fish scales, otoliths, 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 to prevent contamination of the samples. The cleaning procedure involved soap and water washes followed by acid and solvent rinses. Sample collection and processing details are described in SOPs. (Sandvik, 2006 a, b, c).

Appendix B. Water Quality Criteria and Screening Values

Various criteria for the protection of human health exist because of changing knowledge about the toxic effects of chemicals and subsequent risks to consumers of fish. These different criteria and screening values are often based on different assumptions used in determining risk, such as daily consumption rates, toxicological data used in calculations, and risk levels. The criteria summarized below are Washington's current water quality standards criteria (which reference 40 CFR 131.36, also known as the National Toxics Rule), Washington's proposed water quality standards, EPA's recommended criteria, and EPA's screening values.

Ecology is in the process of revising water quality standards for toxic chemicals. For many contaminants, the numerical criteria being proposed are more protective of human health than Washington's current criteria. The proposed criteria may be adopted in 2016. More information is available at http://www.ecy.wa.gov/water/standards/.

Washington's current criteria are one set of numerical values that are used in gauging the potential for human health risks from eating contaminated fish. EPA developed more recent criteria and guidance values. These are described below under *EPA Recommended Water Quality Criteria* and *EPA Screening Values.* These recommended criteria and screening values can be used by state, tribal, and local health jurisdictions in evaluating risks to human health from the consumption of contaminated fish.

Table B-1 shows Washington's current criteria, Ecology's proposed criteria, and other EPA criteria and screening values for the most frequently detected contaminants in the 2014 study. Appendix C describes how Ecology and Health evaluate fish tissue data.

Washington's Current Water Quality Standards (i.e., National Toxics Rule)

Washington's water quality standards for toxic substances (WAC 173-201A-040[5]) define human health-based water quality criteria by referencing 40 CFR 131.36, also known as the National Toxics Rule (NTR). EPA issued the NTR criteria in 1992 to all states that had not adopted their own criteria. These criteria are designed to minimize the risk of adverse effects occurring to humans from chronic (lifetime) exposure to toxic substances through the ingestion of drinking water and contaminated fish and shellfish obtained from surface waters. The NTR criteria are regulatory threshold values used by Ecology for a number of different purposes, including permitting wastewater discharges and assessing when water bodies are adversely impacted by contaminants.

Table B-1. Water Quality Standards Criteria and Guidelines Used for the Protection of Human Health for Contaminants Detected in Fish Tissue.

Analyte (ppb ww)[1]	Washington's Water Quality Standard for Freshwater Fish (FTEC)		National Recommended Water Quality Criteria [2]	EPA Screening Values			
				Subsistence Fishers		Recreational Fishers	
	Current	Proposed		Non-carcino-gens	Carcino-gens	Non-carcino-gens	Carcino-gens
2,3,7,8-TCDD [4]	0.065	0.320	0.025	-	-	-	-
2,3,7,8-TCDD TEQ [4, 5]	-	-	0.025 [5]	-	0.0315	-	0.256
4,4'-DDD	44	1.93	17	-	-	-	-
4,4'-DDE	32	2.73	12	-	-	-	-
4,4'-DDT	32	1.34	12	-	-	-	-
Total DDT [6]	-	-	-	245	14.4	2000	117
Aldrin	0.61	0.03	-	-	-	-	-
Alpha-BHC	0.5	0.07	0.64	-	-	-	-
Beta-BHC	1.8	0.2	2.2	-	-	-	-
Chlordane [7]	8.0	1.3	11	245	14.0	2000	114
Chlorpyriphos	-	-	-	147	-	1200	-
Dieldrin	0.65	0.029	0.24	24	0.307	200	2.5
Endosulfan Sulfate	251	2619	24000	-	-	-	-
Endrin	3017	135	230	147		1200	
gamma-BHC (Lindane)	2.5	1950	127	147	3.78	1200	30.7
Heptachlor Epoxide	1.1	0.08	0.44	6.39	0.54	52	4.39
Hexachlorobenzene	6.5	0.44	2.4	393	3.07	3200	25.0
Mercury	770	770	300	49	-	400	-
Mirex	-	-	-	98	-	800	-
PBDEs	-	-	-	-	-	-	-
Total PCBs [3]	5.3	5.3	2.0	9.83	2.45	80	20
Toxaphene	9.6	0.42	3.7	122	4.46	1000	36.3

FTEC: Fish Tissue Equivalent Concentration.

1 - Values in parts per billion wet-weight (ug/kg ww) unless otherwise noted.
2 - EPA, 2009. www.epa.gov/waterscience/criteria/wqctable/index.html
3 - Total PCBs is sum of Aroclors or congeners.
4 - Values in parts per trillion wet-weight (ng/kg ww).
5 - The cumulative toxicity of a mixture of congeners in a sample can be expressed as a TEQ to 2,3,7,8-TCDD. EPA (2002) 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.
6 - Total DDT is the sum of 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.
7 - The NTR 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.

The NTR criteria values are based on a daily fish consumption rate of 6.5 grams/day and a risk level of 10^{-6}. A risk level is an estimate of the number of cases of adverse health effects (e.g., cancer) that could be caused by exposure to a specific contaminant. At a risk level of 10^{-6}, one person in a million would be expected to contract cancer due to long-term exposure to a specific contaminant.

The NTR gives two sets of criteria for the protection of human health. One set is for *consumption of water and organisms* and the other is for *consumption of organisms only*. The criteria for *consumption of water and organisms* are used when evaluating contaminant levels in freshwater fish while the *consumption of organisms only* criteria are used for evaluating salt water fish.

For fish tissue, the NTR criteria are expressed as Fish Tissue Equivalent Concentrations (FTECs). The FTEC is the concentration of a contaminant in edible fish tissue that equates to the NTR criterion for the protection of human health from that contaminant. The FTEC is calculated by multiplying the bio-concentration factor (BCF) for each analyte by the respective water quality standard criterion. The BCFs for specific contaminants are found in EPA's 1980 Ambient Water Quality Criteria documents (EPA, 1980). Fish tissue sample concentrations that are lower than the FTEC indicate that water quality standards are being met for that specific contaminant.

These standards are used to help assess whether the designated uses of fishing and drinking surface waters are being met in ambient waters. Washington's periodic Water Quality Assessment compares sample results from studies to water quality standards for specific pollutants. These comparisons then leads to water bodies being assigned to one of five categories that help guide the management of pollution problems. Where water quality standards are not met (i.e. concentrations of a chemical in fish tissue is greater than the FTEC), that water body is then placed into Category 5, which is Washington's 303(d) list. This process and categories are described at www.ecy.wa.gov/programs/wq/303d/index.html.

Washington's Proposed Water Quality Criteria

Ecology has proposed adopting new human health-based water quality standards for toxic substances. The proposed criteria would replace those from the NTR and may be adopted in late 2016. The proposed criteria are based on a daily fish consumption rate of 175 grams/day and a risk level of 10^{-6}. For fish tissue, the FTECs will be calculated the same way as described above. The FTEC for many contaminants will be lower than the current FTECs; others will remain unchanged. More details can be found at http://www.ecy.wa.gov/water/standards/.

EPA Recommended Water Quality Criteria

EPA publishes *National Recommended Water Quality Criteria* for many pollutants such as mercury and pesticides (EPA, 2001, 2002b, 2003, and 2009). These criteria are periodically updated to incorporate the latest scientific knowledge. EPA recommends these criteria be used by states and Indian tribes to establish water quality standards and ultimately provide a basis for controlling discharges or releases of pollutants. Yet these EPA-recommended criteria are not regulatory levels. Most of EPA's *Recommended Water Quality Criteria* are based on a daily fish consumption rate of 17.5 grams/day and a risk level of 10^{-6}.

EPA Screening Values

EPA developed screening values (SVs) for carcinogenic and non-carcinogenic effects of substances to help prioritize areas that may present risks to humans from fish consumption. The EPA SVs are considered guidance only; they are not regulatory thresholds (EPA, 2000). The approach in developing EPA SVs was similar to the approach used for developing the NTR, yet the SVs differ in two key assumptions:

- A cancer risk level of 10^{-5}.
- Two consumption rates: 17.5 grams/day for Recreational Fishers, and 142.4 grams/day for Subsistence Fishers.

A difference between the EPA SVs and NTR relating to PCDD/Fs is that the SVs use the dioxin/furan TEQ value while Ecology uses the single congener (TCDD) for 303(d) assessments (Ecology, 2012).

Washington State Department of Health (Health) Screening Levels

Screening levels (SLs) for the carcinogenic effect of toxic substances were developed by Health to help determine whether a full risk assessment is needed. Such risk assessments may or may not lead to a fish consumption advisory for a specific site and species. More information about the health benefits of eating fish and fish consumption advisories in Washington are at Health's website: www.doh.wa.gov/ehp/oehas/fish/.

Appendix C. Fish Tissue Data Evaluation by Ecology and Health

Several state and federal agencies collect and evaluate fish tissue data in Washington State. These include the Ecology, Health, and 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 multiple evaluations often lead to confusion and misunderstanding among agencies and the public on how fish tissue data are used and interpreted. Adding to potential confusion are the numerous criteria or screening values derived to provide guidance for determining the risks of consuming contaminated fish and protecting public health.

Most fish tissue contaminant data from Washington fish, regardless of who conducted the study, make their way to Health for evaluation regarding the safety of consuming fish. Appendix I has information about health benefits of eating fish and potential risks from consuming contaminated fish. The following is an overview of how Ecology and Health evaluate fish tissue data to meet different needs.

For the FFCMP and many other Ecology studies, fish tissue data are evaluated primarily to determine if (1) Washington State water quality standards are being met, and (2) potential risks to human health from consuming contaminated fish warrant further study and/or development of a fish consumption advisory. Ecology's role is to determine whether water quality standards are met and to begin the process to correct problems where standards are not met. Health and local health departments are responsible for 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 for the protection of human health.

Washington State Water Quality Standards

Washington's water quality standards criteria for toxic contaminants were issued to the state in EPA's 1992 National Toxics Rule (NTR) (40CFR131.36). The human health-based NTR criteria are designed to minimize the risk of effects occurring to humans from chronic (lifetime) exposure to substances through the ingestion of drinking water and consumption of fish obtained from surface waters. The NTR criteria, if met, will generally ensure that public health concerns do not arise and that fish advisories are not needed.

The NTR criteria are thresholds that, when exceeded, may lead to regulatory action. When water quality criteria are not met, the federal Clean Water Act requires that the water body be put on a list and that a water cleanup plan be developed for the pollutant causing the problem. This list is known as the 303(d) list, and the water cleanup plan results from a Total Maximum Daily Load (TMDL) study and public involvement process. 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

While Health supports Ecology's use of the NTR criteria for identifying problems and controlling pollutant sources so that water quality will meet standards, Health does not use the NTR criteria to establish fish consumption advisories (McBride, 2006).

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 mercury, PCBs, and other 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 procedures in risk assessment, risk management, and risk communication. Neither the NTR criteria nor the screening values found in the EPA guidance documents described above incorporate the varied risk management decisions essential to developing fish consumption advisories.

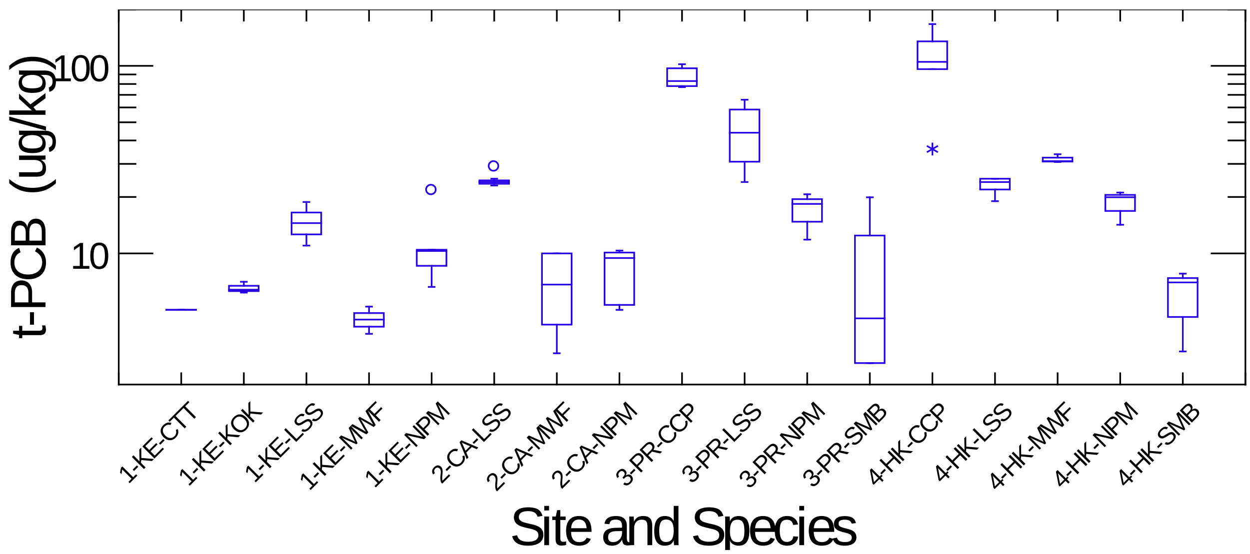
Risk management concepts include:

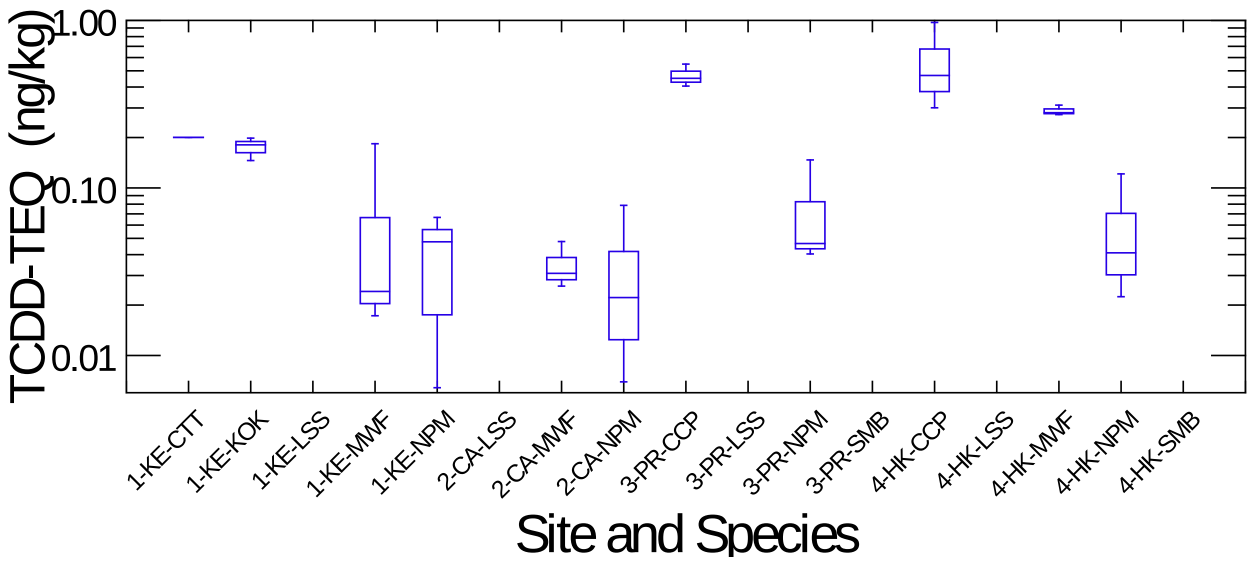
- **Risk Assessment** involves calculating allowable meal limits based on known fish contaminant concentrations. These calculations are conducted for both non-cancer and cancer criteria using the appropriate Reference Dose (RfD) or Cancer Slope Factor (CSF), if available. These initial calculations are 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.

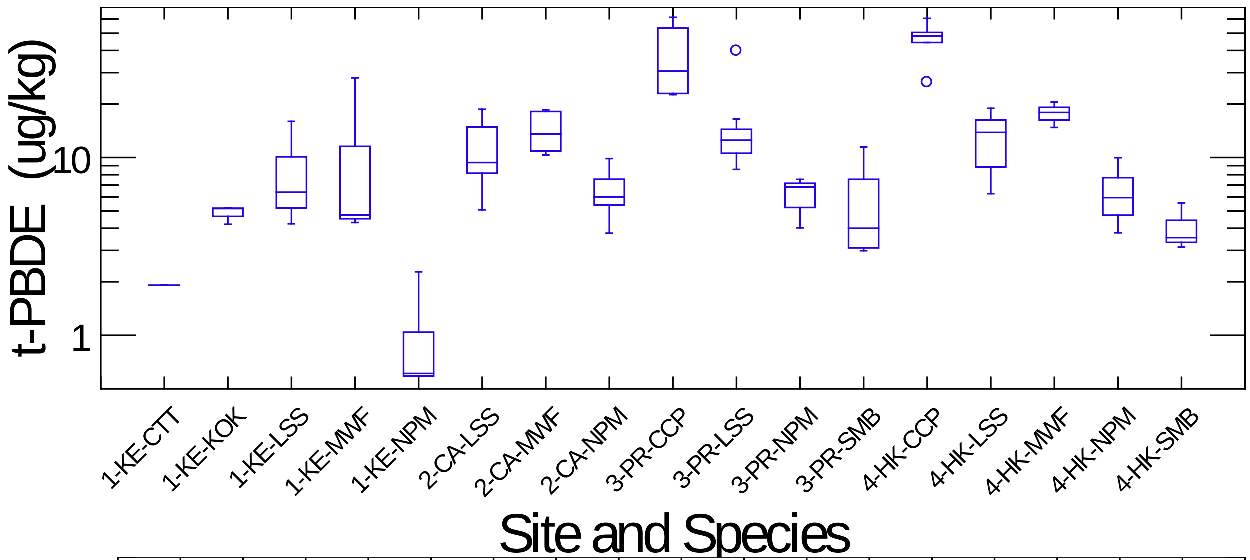
- **Risk Management** includes (but is not limited to) consideration of contaminant background concentrations, reduction in contaminant concentrations through preparation and cooking techniques, known health benefits from fish consumption, contaminant concentrations, health risks associated with replacement 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.

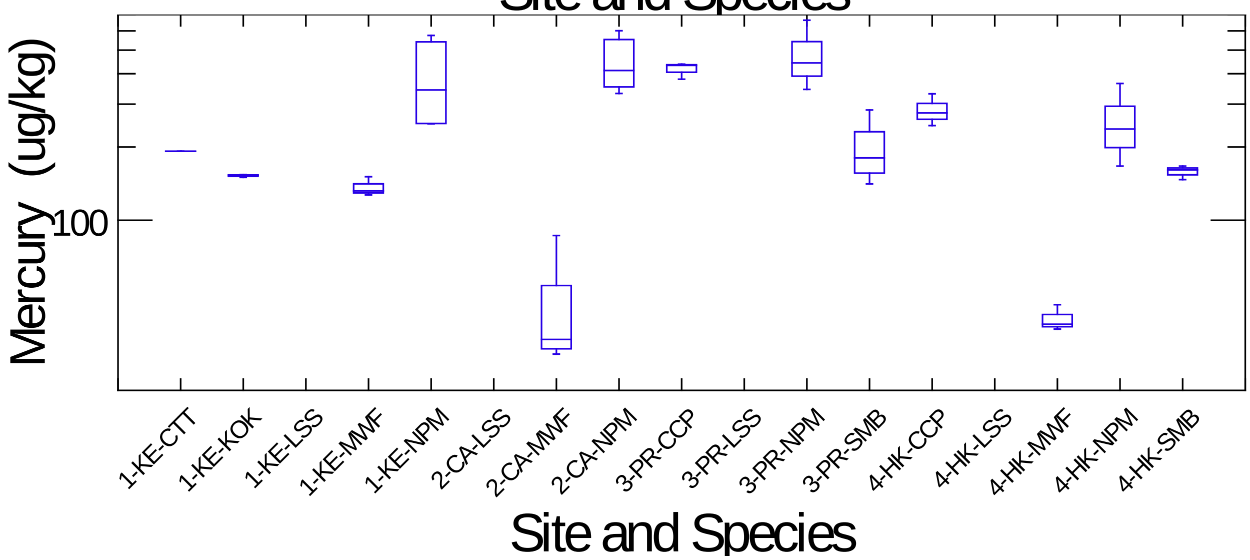
- **Risk Communication** is the outreach component of the fish advisory. The interpretation of the data from the risk assessment and risk management components drives how and when the fish advisory recommendations are issued to the public, dependent on whether the message is targeted toward a sensitive group or 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.

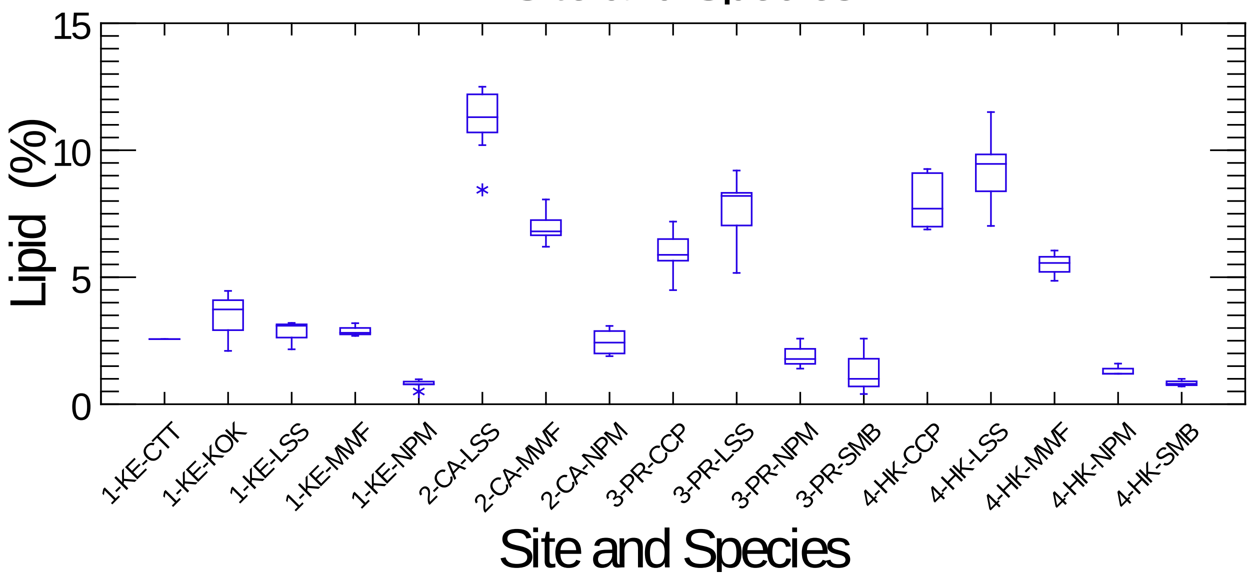
Appendix D. Boxplots for Sample Results from Selected Parameters.

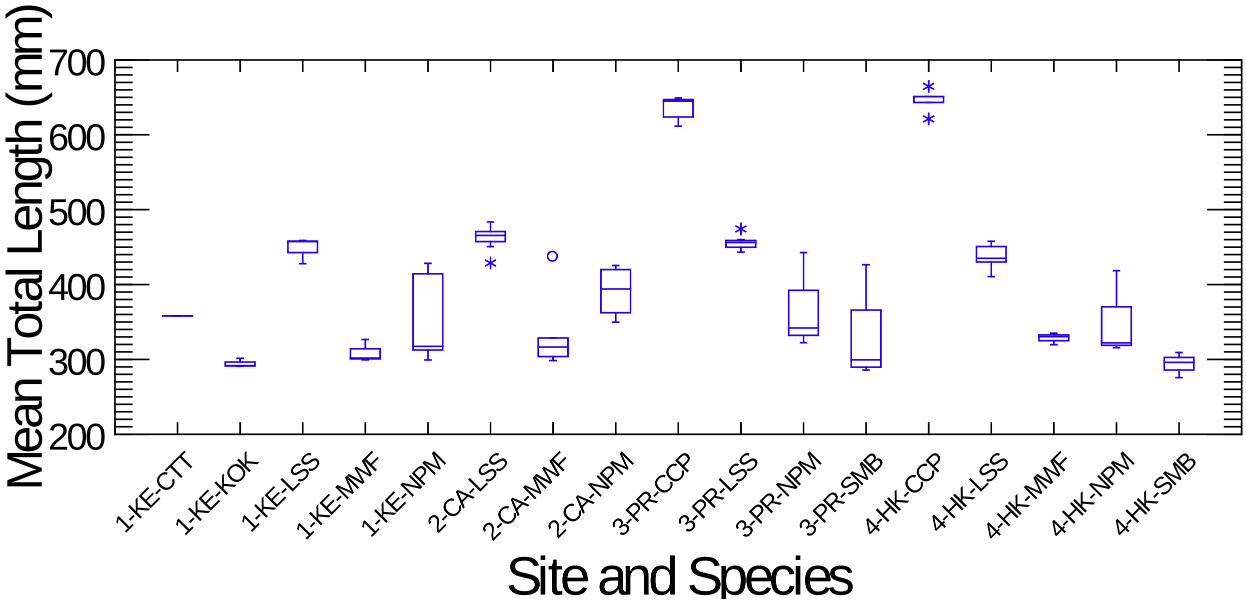


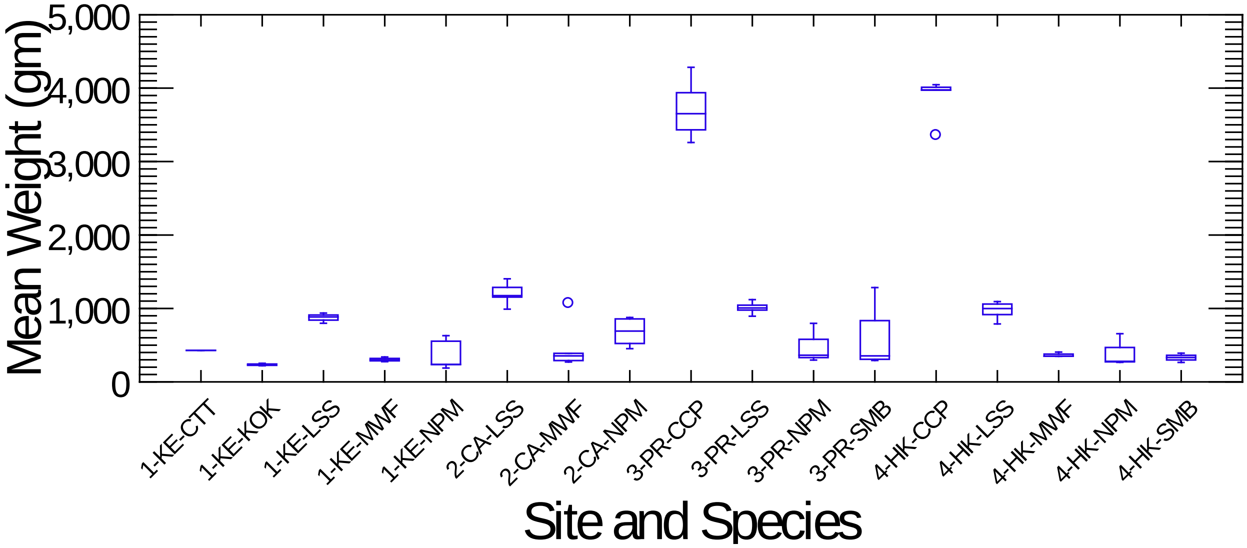


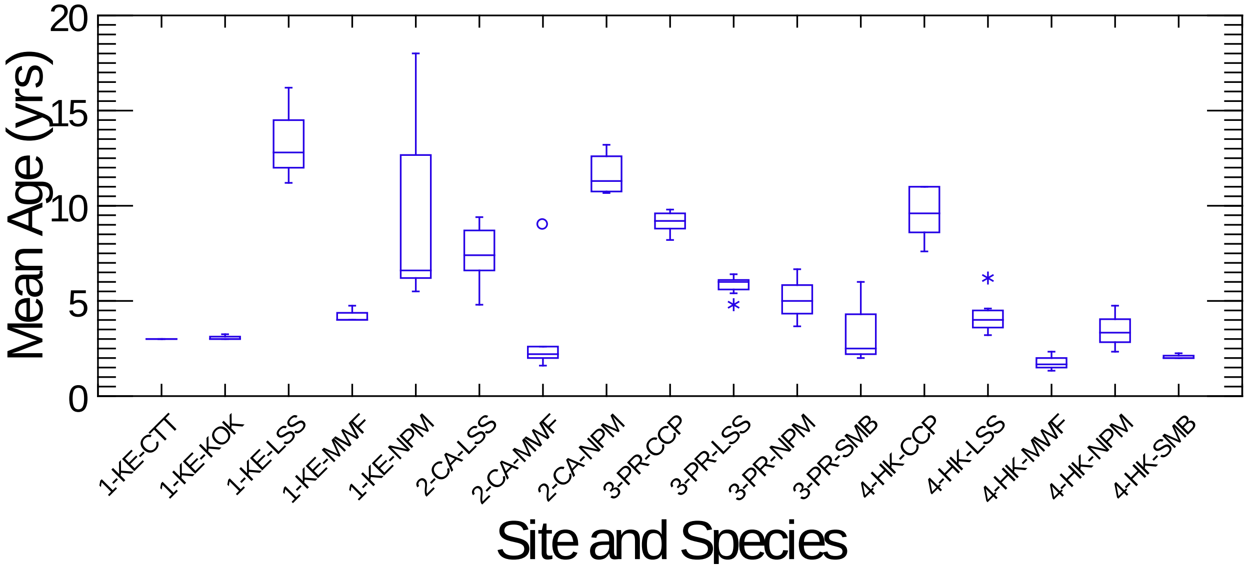

t-PBDE (ug/kg)
1
10
1-KE-CTT
1-KE-KOK
1-KE-LSS
1-KE-MWF
1-KE-NPM
2-CA-LSS
2-CA-MWF
2-CA-NPM
3-PR-CCP
3-PR-LSS
3-PR-NPM
3-PR-SMB
4-HK-CCP
4-HK-LSS
4-HK-MWF
4-HK-NPM
4-HK-SMB
Site and Species


Mercury (ug/kg)
100
1-KE-CTT
1-KE-KOK
1-KE-LSS
1-KE-MWF
1-KE-NPM
2-CA-LSS
2-CA-MWF
2-CA-NPM
3-PR-CCP
3-PR-LSS
3-PR-NPM
3-PR-SMB
4-HK-CCP
4-HK-LSS
4-HK-MWF
4-HK-NPM
4-HK-SMB
Site and Species


Lipid (%)
0
5
10
15
1-KE-CTT
1-KE-KOK
1-KE-LSS
1-KE-MWF
1-KE-NPM
2-CA-LSS
2-CA-MWF
2-CA-NPM
3-PR-CCP
3-PR-LSS
3-PR-NPM
3-PR-SMB
4-HK-CCP
4-HK-LSS
4-HK-MWF
4-HK-NPM
4-HK-SMB
Site and Species


Mean Total Length (mm)
700
600
500
400
300
200
1-KE-CTT
1-KE-KOK
1-KE-LSS
1-KE-MWF
1-KE-NPM
2-CA-LSS
2-CA-MWF
2-CA-NPM
3-PR-CCP
3-PR-LSS
3-PR-NPM
3-PR-SMB
4-HK-CCP
4-HK-LSS
4-HK-MWF
4-HK-NPM
4-HK-SMB
Site and Species


Mean Weight (gm)
5,000
4,000
3,000
2,000
1,000
0
1-KE-CTT
1-KE-KOK
1-KE-LSS
1-KE-MWF
1-KE-NPM
2-CA-LSS
2-CA-MWF
2-CA-NPM
3-PR-CCP
3-PR-LSS
3-PR-NPM
3-PR-SMB
4-HK-CCP
4-HK-LSS
4-HK-MWF
4-HK-NPM
4-HK-SMB
Site and Species


Mean Age (yrs)
20
15
10
5
0
1-KE-CTT
1-KE-KOK
1-KE-LSS
1-KE-MWF
1-KE-NPM
2-CA-LSS
2-CA-MWF
2-CA-NPM
3-PR-CCP
3-PR-LSS
3-PR-NPM
3-PR-SMB
4-HK-CCP
4-HK-LSS
4-HK-MWF
4-HK-NPM
4-HK-SMB
Site and Species

Appendix E. 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.

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 establishes the TMDL program.

Congener: In chemistry, congeners are related chemicals. For example, polychlorinated biphenyls (PCBs) are a group of 209 molecules that are related by a similar structure and are called congeners. Laboratory analysis for all PCB congeners is complex and expensive.

Fish Tissue Equivalent Concentration (FTEC): The FTECs is a tissue contaminant concentration used by Ecology to determine whether the designated uses of fishing and drinking from surface waters are being met. The FTEC is an interpretation of Washington's water quality criterion for a specific chemical for the protection of human health: the National Toxics Rule (40 CFR 131.36). Fish tissue sample concentrations that are lower than the FTEC suggest that the uses of fishing and drinking from surface waters are being met for that specific contaminant. Where a FTEC is not met (i.e., concentration of a chemical in fish tissue is greater than the FTEC), that water body is then placed into Category 5 during Washington's periodic Water Quality Assessment (www.ecy.wa.gov/programs/wq/303d/index.html). Category 5 listings become part of Washington's 303(d) list during the assessment process. The FTEC is calculated by multiplying the contaminant-specific Bio-Concentration Factor (BCF) times the contaminant-specific Water Quality Criterion found in the National Toxics Rule.

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

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. This assessment meets the 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. The 303(d) list 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.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

Acronyms and Abbreviations

ANOVA	Analysis of Variance
CCP	Common carp (*Cyprinus carpio*)
CTT	Cutthroat trout *(Oncorhynchus clarki)*
DDE	Dichloro-diphenyl-dichloroethylene
DDT	Dichloro-diphenyl-trichloroethane
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FCA	Fish Consumption Advisory
FFCMP	Freshwater Fish Contaminant Monitoring Program
FTEC	Fish tissue equivalent concentration
Health	Washington State Department of Health
J	estimated value
KOK	Kokanee *(Oncorhynchus nerka)*
LSS	Largescale sucker (*Catostomus macrocheilus*)
MEL	Manchester Environmental Laboratory
MWF	Mountain whitefish (*Prosopium williamsoni*)
NOAA	National Oceanic and Atmospheric Administration
NPM	Northern pikeminnow (*Ptychocheilus oregonensis*)
NTR	National Toxics Rule
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PCDD/F	Polychlorinated dibenzo-p-dioxin and -furan
SMB	Smallmouth bass (*Micropterus salmoides*)
SV	Screening value
t-DDT	Total DDTs
t-PCBs	Total PCBs
t-PBDEs	Total PBDEs
TCDD	2,3,7,8-tetra-chlorinated dibenzo-p-dioxin
TEQ	Toxicity equivalent
TMDL	Total Maximum Daily Load

U	Not detected at the reported value
UJ	Undetected at the estimated reported value
USFWS	United States Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area

Units of Measurement

=	equal to
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
mg	milligram
mm	millimeter
ng/kg	nanograms per kilogram (parts per trillion)
ug/kg	micrograms per kilogram (parts per billion)