APPENDIX D

STATISTICAL BASIS FOR FISH TISSUE SAMPLING

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UPPER COLUMBIA RIVER RI/FS

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ACRONYMS AND ABBREVIATIONS

CV	coefficient of variation
COI	chemical of interest
UCR	Upper Columbia River
SD	standard deviation
UCL	upper confidence level

INTRODUCTION

The following appendix provides the statistical basis for selecting the number of samples to be collected in the 2009 fish tissue sampling program. The goals of this program are to collect fish tissues to analyze chemicals of interest (COI) to 1) evaluate spatial patterns of COI concentrations (between river reaches); 2) evaluate species-specific patterns of COI concentrations; and 3) to provide concentration data to be used in the exposure and risk assessments for fish, piscivorous wildlife, and human health.

A statistical analysis of the variability of the COI concentrations for fish collected by EPA in 2005 was conducted to inform the 2008 investigation. For concentrations of metals and dioxin found in fillet, offal, and whole body tissues of six species of fish common to the Upper Columbia River (UCR), samples sizes are calculated 1) for two-sample t-tests as a conservative estimate for Analysis of Variance (ANOVA) calculations and 2) such that confidence intervals do not exceed a maximum value. The definitions of the symbols used in the calculation of sample sizes in provided in Table D-1.

DATA

Data from the 2005 fish tissue sampling event were used in this analysis. Table D-2 shows the summary statistics used for calculating sample size. There are two to six composited samples of fish per reach, with a median of five.

SAMPLE SIZE – TWO SAMPLE T-TEST

Analysis of Variance (ANOVA) is proposed for testing null hypotheses of equal mean concentrations of COIs among the six reaches of the UCR (USEPA 2005). However, such statistical models become quite complex when estimating the potential variability among and between reaches. Therefore, sample size calculations are based on a two-tailed t-test. This is a conservative estimate as ANOVA includes more degrees of freedom, thereby requiring smaller sample sizes for achieving the same statistical power. Calculations of sample size are based on five fish per composite. The number of composited samples within a single reach is calculated. Thus, the total number of samples needed to compare two reaches is twice that calculated (Table D-3). (Note that the total number of samples to compare multiple reaches is not a linear function due to the increasing numbers of degrees of freedom).

Levels of Error

Following convention, a two-tailed Type 1 error (α) is set at 0.05 and Type 2 error (β) at 0.20 and 0.10, i.e. powers (1-β) of 0.80 and 0.90. The statistical literature documents the acceptance and common usage of two-tailed $\alpha = 0.05$. Similarly, power is frequently in the 0.80 to 0.90 range, Cohen (1988) suggests 0.80, Kraemer and Thiemann (1987) suggest

a range of 0.70 to 0.90, Snedecor and Cochran (1989) use 0.80 and 0.90 as do Armitage et al. (2002), and van Belle and Martin (1993) suggest power of 0.80.

Methods

Following USEPA (2005), sample size is based on coefficient of variation (CV) (van Belle and Martin 1993 Eq(2)),

$$n = \frac{1}{k}\left(\frac{\left(Z_{1-\alpha/2} + Z_{1-\beta}\right)^2 CV^2\left(f^2+1\right)}{\left(f-1\right)^2}\right) \quad (1)$$

Definitions of terms in Eq(1) are provided in Table D-1. Eq(1) tested correctly based on van Belle and Martin (1993) showed results similar to USEPA (2005; Figure 2). Means of composite concentrations were best approximated by the normal distribution, even though concentrations of samples making up composites may have been non-normally distributed, e.g., log-normal.

Results

Table D-3 shows sample sizes (n) for each reach at powers of 0.80 and 0.90, respectively, based on the CV, rounded up to the nearest whole number (as in van Belle and Martin 1993).

SAMPLE SIZE – CONFIDENCE LIMITS

The sample size needed such that the 95 percent (and alternately, 99 percent) upper confidence limit (UCL) of the mean does not exceed some maximum value is calculated. Maximum is defined as any observation above the 99th quantile. For a normal distribution the 99th quantile of the data is 2.34 σ above the mean

Using the t-distribution to estimate the UCL, $2.34\sigma \succ t_{1-\alpha}\ se$ and since $se = \sigma / \sqrt{n}$, then we want *n* such that

$$2.34 \succ \frac{t_{1-a}}{\sqrt{n}} \quad (2)$$

Solving Eq(2) for *n*,

95% CL (α = .05) $n = 3$

99% CL (α = .01) $n = 4$

For a maximum that occurs no more than 99 percent of the time, the one-tailed UCLs will exceed the maximum less than 5 percent and 1 percent of the time for $n \geq 3$ and 4, respectively. Because no decision is being made (i.e., no hypothesis is being tested), Type 2 error (the probability of not rejecting the null hypothesis when it is false; a false negative) is not considered.

RECOMMENDATIONS

For observational studies the guidelines provided by van Belle and Martin (1993) are useful, "A standard prescription for sample size calculations specifies $\alpha = 0.05$ and $\beta = 0.20$, or power = 0.80, and a two-sided test." Power = 0.90 is usually reasonable only for designed experiments where the treatment is randomized among subjects and factors affecting the outcome (in our case concentrations of metals) are controlled. A power 0.90 is usually impractical for observational studies, where factors affecting outcomes are many, uncontrollable and, mostly, unknown. Similarly an f-fold difference in means (defined in Table D-1) of 1.25 is difficult to achieve for observational studies, again given all the uncontrollable natural factors; an f-fold difference of 2 is reasonable for planning purposes.

In most cases a sample size of 1 (number of composites) is calculated for a power of 0.80 and a difference in means between 1.5 and 2.0 (Table D-3), with a maximum of 15 samples. The chance for a new maximum occurs each time more data is taken. Three and four composite samples (for 95 percent and 99 percent UCL) provide adequate assurance that confidence limits will not exceed the maximum concentration observed. A sample size of four composites (five fish per composite) is adequate to evaluate the differences among river reaches of the UCR for COIs, based on the data available from 2005. The 2009 sampling effort intends to collect additional fish species and COIs not previously evaluated in 2005. To provide additional data for species and COIs not previously examined, a composite size of six will be adopted in 2009. Therefore, for each river reach, six composite samples for each fish species and each size range will be collected to provide adequate data to allow for statistical comparisons among reaches.

REFERENCES

Armitage, P., G. Berry, and J.N.S. Mathews. 2002. Statistical methods in medical research. Blackwell Sciences. Malden, Massachusetts, USA.

Cohen, J. 1988. *Statistical power analysis for the behavioral sciences*. Second edition. Lawrence Freeman and Associates, Hillsdale, New Jersey, USA.

Kraemer, H.C. and S. Thiemann. 1987. *How many subjects?* Sage Publications, Newbury Park, California, USA.

Snedecor, G.W. and W.G. Cochran. 1989. *Statistical methods*, 8th edition. Iowa State University Press, Ames, Iowa, USA.

USEPA. 2005. Phase I fish tissue sampling quality assurance project plan - Upper Columbia River site CERCLA RI/FS. Prepared by CH2M Hill. Prepared for USEPA Region 10, Seattle, Washington.

van Belle, G. and M.C. Martin. 1993. Sample size as a function of coefficient of variation and ratio of means. *The American Statistician.* Vol 47, No. 3.

TABLES

Table D-1. Symbols used for calculating sample size.

Symbol	Definition
n	The calculated number of composites sample per reach.
Z	The Z statistic for the standard normal distribution, e.g., $Z_{1-\alpha/2} = 1.96$ for $\alpha = .05$. Normality among composites means is assumed.
μ_1, μ_2	The two means being compared. The convention for calculating sample size: $\mu_1 > \mu_2$.
f	The ratio of means, $f = \mu_1 / \mu_2$. Sample size calculated for f = 1.25 (25% increase or 20% decrease), f= 1.5 (50% increase or 33% decrease), and f= 2 (100% increase or 50% decrease).
CV	The coefficient of variation: the standard deviation divided by the mean. $CV = \sigma/\mu$. CV is independent of sample size.
k	The number of fish per composite, where there are n composites per reach. k is set at 5 fish per composite. k is used as the compositing correction factor for calculating sample size using Eq(2) from van Belle and Martin (1993), where for composite (c) and fish-to-fish (f) variances are related by $s^2_c = \sigma^2_f / k$ (see also USEPA 2005, p 4)

Table D-2. Median statistics over reaches. CV and SD symbolize coefficient of variation and standard deviation. Mean, min and max are not used in analyses, and are presented for perspective[a].

Common Name	Tissue	Contaminant	Number of Reaches Sampled	Median				
				CV	SD	Mean	Min	Max
Burbot	Whole body	2,3,7,8-TCDF	5	0.1740	0.0008	0.0041	0.0031	0.0049
Burbot	Whole body	Antimony	5	0.0430	3.57	83.14	79.04	88.92
Burbot	Whole body	Arsenic	5	0.1248	103.50	804.24	668.04	941.42
Burbot	Whole body	Cadmium	5	0.2469	11.27	40.92	22.88	47.84
Burbot	Whole body	Copper	5	0.2012	203.95	1108.30	938.95	1396.95
Burbot	Whole body	Lead	5	0.1425	13.48	88.03	65.72	109.18
Burbot	Whole body	Mercury	5	0.1967	35.45	189.20	134.00	230.00
Burbot	Whole body	Zinc	5	0.0694	857.39	12347.24	11310.20	13228.80
Lake Whitefish	Whole body	2,3,7,8-TCDF	5	0.1567	0.0008	0.0062	0.0048	0.0075
Lake Whitefish	Whole body	Antimony	5	0.0394	4.82	130.13	126.40	136.80
Lake Whitefish	Whole body	Arsenic	5	0.1112	30.87	249.64	218.88	290.70
Lake Whitefish	Whole body	Cadmium	5	0.1921	3.60	18.73	15.85	23.45
Lake Whitefish	Whole body	Copper	5	0.1592	81.95	633.80	537.20	726.60
Lake Whitefish	Whole body	Lead	5	0.3943	21.98	66.62	41.04	81.36
Lake Whitefish	Whole body	Mercury	5	0.0848	5.87	59.78	52.10	69.80
Lake Whitefish	Whole body	Zinc	5	0.0619	778.57	12576.72	11850.00	13816.80
Largescale Sucker	Whole body	2,3,7,8-TCDF	6	0.2515	0.0008	0.0035	0.0021	0.0041
Largescale Sucker	Whole body	Antimony	6	0.0475	5.15	106.06	96.52	113.08
Largescale Sucker	Whole body	Arsenic	6	0.1514	24.92	186.50	153.52	207.28
Largescale Sucker	Whole body	Cadmium	6	0.1502	48.54	303.00	268.69	341.40
Largescale Sucker	Whole body	Copper	6	0.1648	158.09	895.15	715.41	1063.08
Largescale Sucker	Whole body	Lead	6	0.3246	486.30	2280.19	1580.27	2788.19
Largescale Sucker	Whole body	Mercury	6	0.0985	26.21	228.05	207.50	254.00

Table D-2. Median statistics over reaches. CV and SD symbolize coefficient of variation and standard deviation. Mean, min and max are not used in analyses, and are presented for perspective[a].

			Number of	Median				
Common Name	Tissue	Contaminant	Reaches Sampled	CV	SD	Mean	Min	Max
Largescale Sucker	Whole body	Zinc	6	0.0873	1899.93	21354.73	19191.55	23701.90
Mountain Whitefish	Whole body	2,3,7,8-TCDF	1	0.3354	0.0013	0.0039	0.0026	0.006
Mountain Whitefish	Whole body	Antimony	1	0.0233	3.28	140.96	138.00	146.40
Mountain Whitefish	Whole body	Arsenic	1	0.1241	18.36	147.93	119.68	169.05
Mountain Whitefish	Whole body	Cadmium	1	0.1658	18.33	110.51	91.52	128.39
Mountain Whitefish	Whole body	Copper	1	0.3277	400.87	1223.32	563.20	1533.74
Mountain Whitefish	Whole body	Lead	1	0.3124	104.78	335.36	176.00	448.50
Mountain Whitefish	Whole body	Mercury	1	0.1115	8.62	77.30	63.30	84.00
Mountain Whitefish	Whole body	Zinc	1	0.2416	7241.04	29967.86	20134.40	40128.00
Rainbow Trout Hatchery	Fillet	2,3,7,8-TCDF	2	0.3910	0.0003	0.0008	0.0005	0.0012
Rainbow Trout Hatchery	Fillet	Antimony	2	0.0128	1.25	98.10	97.20	99.60
Rainbow Trout Hatchery	Fillet	Arsenic	2	0.0838	5.49	63.76	60.75	71.80
Rainbow Trout Hatchery	Fillet	Cadmium	2	0.0128	0.16	12.26	12.15	12.45
Rainbow Trout Hatchery	Fillet	Copper	2	0.0966	31.24	303.89	279.45	336.65
Rainbow Trout Hatchery	Fillet	Lead	2	0.0128	0.16	12.26	12.15	12.45
Rainbow Trout Hatchery	Fillet	Mercury	2	0.1534	13.49	82.11	71.40	98.05
Rainbow Trout Hatchery	Fillet	Zinc	2	0.0941	677.28	7163.76	6467.00	7828.85
Rainbow Trout Hatchery	Offal	2,3,7,8-TCDF	2	0.2126	0.0004	0.0008	0.0005	0.0012
Rainbow Trout Hatchery	Offal	Antimony	2	0.0116	1.36	113.53	111.60	114.60
Rainbow Trout Hatchery	Offal	Arsenic	2	0.1207	16.54	138.46	118.49	154.71
Rainbow Trout Hatchery	Offal	Cadmium	2	0.1570	15.01	100.58	83.47	113.75
Rainbow Trout Hatchery	Offal	Copper	2	0.1645	488.89	2303.93	1730.90	2605.85
Rainbow Trout Hatchery	Offal	Lead	2	0.4115	81.45	163.13	70.43	218.86
Rainbow Trout Hatchery	Offal	Mercury	2	0.1132	7.07	54.35	49.05	64.15

Table D-2. Median statistics over reaches. CV and SD symbolize coefficient of variation and standard deviation. Mean, min and max are not used in analyses, and are presented for perspective[a].

			Number of	Median				
Common Name	Tissue	Contaminant	Reaches Sampled	CV	SD	Mean	Min	Max
Rainbow Trout Hatchery	Offal	Zinc	2	0.0586	2370.39	41203.33	38864.50	43480.50
Rainbow Trout Hatchery	Whole body	2,3,7,8-TCDF	2	0.1624	0.0002	0.0013	0.0009	0.0015
Rainbow Trout Hatchery	Whole body	Antimony	2	0.0413	4.65	112.37	107.64	119.40
Rainbow Trout Hatchery	Whole body	Arsenic	2	0.1780	21.16	120.86	95.83	147.15
Rainbow Trout Hatchery	Whole body	Cadmium	2	0.2496	11.00	44.86	29.82	55.63
Rainbow Trout Hatchery	Whole body	Copper	2	0.2342	148.19	634.73	496.00	875.35
Rainbow Trout Hatchery	Whole body	Lead	2	0.1499	2.31	15.16	13.63	19.19
Rainbow Trout Hatchery	Whole body	Mercury	2	0.1050	6.77	64.27	57.55	72.95
Rainbow Trout Hatchery	Whole body	Zinc	2	0.0811	1885.63	23222.30	20535.00	25367.50
Rainbow Trout Wild	Fillet	2,3,7,8-TCDF	3	0.5012	0.0005	0.0008	0.0006	0.0008
Rainbow Trout Wild	Fillet	Antimony	3	0.0330	3.39	98.80	96.80	100.80
Rainbow Trout Wild	Fillet	Arsenic	3	0.1507	12.28	79.92	68.04	79.92
Rainbow Trout Wild	Fillet	Cadmium	3	0.4928	11.38	12.35	12.10	12.60
Rainbow Trout Wild	Fillet	Copper	3	0.0346	11.70	333.20	321.60	338.80
Rainbow Trout Wild	Fillet	Lead	3	0.0826	1.25	12.35	12.10	12.60
Rainbow Trout Wild	Fillet	Mercury	3	0.1618	13.27	86.66	68.40	108.00
Rainbow Trout Wild	Fillet	Zinc	3	0.0343	268.90	6405.40	6327.00	6485.60
Rainbow Trout Wild	Offal	2,3,7,8-TCDF	3	0.3448	0.0007	0.0014	0.0014	0.0015
Rainbow Trout Wild	Offal	Antimony	3	0.0249	3.08	108.87	107.64	110.20
Rainbow Trout Wild	Offal	Arsenic	3	0.0895	18.09	204.24	204.24	214.52
Rainbow Trout Wild	Offal	Cadmium	3	0.1753	9.71	81.53	72.50	85.56
Rainbow Trout Wild	Offal	Copper	3	0.2473	530.66	1907.35	1635.60	2179.10
Rainbow Trout Wild	Offal	Lead	3	0.0887	19.68	51.57	50.94	52.20
Rainbow Trout Wild	Offal	Mercury	3	0.1494	7.84	55.52	47.80	64.00

Table D-2. Median statistics over reaches. CV and SD symbolize coefficient of variation and standard deviation. Mean, min and max are not used in analyses, and are presented for perspective[a].

			Number of	Median				
Common Name	Tissue	Contaminant	Reaches Sampled	CV	SD	Mean	Min	Max
Rainbow Trout Wild	Offal	Zinc	3	0.0568	2446.76	43633.60	40136.00	49680.00
Rainbow Trout Wild	Whole body	2,3,7,8-TCDF	2	0.4028	0.0013	0.0025	0.0017	0.0033
Rainbow Trout Wild	Whole body	Antimony	2	0.0557	6.72	121.36	117.84	125.04
Rainbow Trout Wild	Whole body	Arsenic	2	0.2012	24.89	149.51	137.79	167.16
Rainbow Trout Wild	Whole body	Cadmium	2	0.1674	6.43	52.09	49.09	57.01
Rainbow Trout Wild	Whole body	Copper	2	0.1849	293.12	1074.47	915.95	1244.46
Rainbow Trout Wild	Whole body	Lead	2	0.2269	22.37	56.96	40.12	65.27
Rainbow Trout Wild	Whole body	Mercury	2	0.1457	6.27	56.26	52.75	60.45
Rainbow Trout Wild	Whole body	Zinc	2	0.0494	1058.57	21593.64	20906.75	22230.25
Walleye	Fillet	2,3,7,8-TCDF	3	0.2048	0.0001	0.0004	0.0003	0.0004
Walleye	Fillet	Antimony	3	0.0225	1.88	83.92	81.20	86.40
Walleye	Fillet	Arsenic	3	0.2206	20.92	111.61	96.82	125.86
Walleye	Fillet	Cadmium	3	0.0225	0.24	10.49	10.15	10.80
Walleye	Fillet	Copper	3	0.0812	18.28	213.49	203.84	241.20
Walleye	Fillet	Lead	3	0.8484	18.15	21.39	10.30	52.78
Walleye	Fillet	Mercury	3	0.1908	43.35	240.60	201.00	281.00
Walleye	Fillet	Zinc	3	0.0587	427.05	6421.00	6220.80	6730.90
Walleye	Offal	2,3,7,8-TCDF	3	0.2464	0.0004	0.0019	0.0018	0.0021
Walleye	Offal	Antimony	3	0.0379	4.58	118.72	114.40	122.00
Walleye	Offal	Arsenic	3	0.2365	29.32	158.24	122.18	191.36
Walleye	Offal	Cadmium	3	0.1746	5.92	33.88	25.76	39.65
Walleye	Offal	Copper	3	0.0595	27.95	464.12	383.60	538.20
Walleye	Offal	Lead	3	0.2400	10.25	55.79	37.18	65.52
Walleye	Offal	Mercury	3	0.1630	19.04	115.80	86.00	135.00

Table D-2. Median statistics over reaches. CV and SD symbolize coefficient of variation and standard deviation. Mean, min and max are not used in analyses, and are presented for perspective[a].

			Number of	Median				
Common Name	Tissue	Contaminant	Reaches Sampled	CV	SD	Mean	Min	Max
Walleye	Offal	Zinc	3	0.0587	994.76	16937.66	15525.80	18001.80
Walleye	Whole body	2,3,7,8-TCDF	4	0.1473	0.0002	0.0019	0.0014	0.002
Walleye	Whole body	Antimony	4	0.0221	2.30	104.33	103.00	106.00
Walleye	Whole body	Arsenic	4	0.2040	31.72	166.79	137.94	192.92
Walleye	Whole body	Cadmium	4	0.2308	5.68	21.07	16.57	30.16
Walleye	Whole body	Copper	4	0.1351	45.66	343.85	306.60	389.25
Walleye	Whole body	Lead	4	0.3675	34.10	54.43	18.87	104.22
Walleye	Whole body	Mercury	4	0.1635	28.99	184.43	134.50	216.50
Walleye	Whole body	Zinc	4	0.0776	987.26	12753.69	11482.80	13636.75

[a] Source: EPA (2005) Phase 1 Fish Tissue Data

Table D-3. Number of samples (rounded up) per reach for a two-sample t-test based on powers of 0.80 and 0.90, and the f-fold difference in means.

			Power = 0.80 f-fold difference in means			Power =0.90 f-fold difference in means		
Common Name	Tissue	Contaminant	1.25	1.50	2.00	1.25	1.50	2.00
Burbot	Whole body	2,3,7,8-TCDF	2	1	1	3	1	1
Burbot	Whole body	Antimony	1	1	1	1	1	1
Burbot	Whole body	Arsenic	2	1	1	2	1	1
Burbot	Whole body	Cadmium	4	2	1	6	2	1
Burbot	Whole body	Copper	3	1	1	4	2	1
Burbot	Whole body	Lead	2	1	1	2	1	1
Burbot	Whole body	Mercury	3	1	1	4	2	1
Burbot	Whole body	Zinc	1	1	1	1	1	1
Lake Whitefish	Whole body	2,3,7,8-TCDF	2	1	1	3	1	1
Lake Whitefish	Whole body	Antimony	1	1	1	1	1	1
Lake Whitefish	Whole body	Arsenic	1	1	1	2	1	1
Lake Whitefish	Whole body	Cadmium	3	1	1	4	2	1
Lake Whitefish	Whole body	Copper	2	1	1	3	1	1
Lake Whitefish	Whole body	Lead	11	4	2	14	5	2
Lake Whitefish	Whole body	Mercury	1	1	1	1	1	1
Lake Whitefish	Whole body	Zinc	1	1	1	1	1	1
Largescale Sucker	Whole body	2,3,7,8-TCDF	5	2	1	6	2	1
Largescale Sucker	Whole body	Antimony	1	1	1	1	1	1
Largescale Sucker	Whole body	Arsenic	2	1	1	2	1	1
Largescale Sucker	Whole body	Cadmium	2	1	1	2	1	1
Largescale Sucker	Whole body	Copper	2	1	1	3	1	1
Largescale Sucker	Whole body	Lead	7	3	1	10	3	2
Largescale Sucker	Whole body	Mercury	1	1	1	1	1	1

Table D-3. Number of samples (rounded up) per reach for a two-sample t-test based on powers of 0.80 and 0.90, and the f-fold difference in means.

			Power = 0.80 f-fold difference in means			Power =0.90 f-fold difference in means		
Common Name	Tissue	Contaminant	1.25	1.50	2.00	1.25	1.50	2.00
Largescale Sucker	Whole body	Zinc	1	1	1	1	1	1
Mountain Whitefish	Whole body	2,3,7,8-TCDF	8	3	1	10	4	2
Mountain Whitefish	Whole body	Antimony	1	1	1	1	1	1
Mountain Whitefish	Whole body	Arsenic	1	1	1	2	1	1
Mountain Whitefish	Whole body	Cadmium	2	1	1	3	1	1
Mountain Whitefish	Whole body	Copper	7	3	1	10	3	2
Mountain Whitefish	Whole body	Lead	7	2	1	9	3	2
Mountain Whitefish	Whole body	Mercury	1	1	1	2	1	1
Mountain Whitefish	Whole body	Zinc	4	2	1	6	2	1
Rainbow Trout Hatchery	Fillet	2,3,7,8-TCDF	10	4	2	14	5	2
Rainbow Trout Hatchery	Fillet	Antimony	1	1	1	1	1	1
Rainbow Trout Hatchery	Fillet	Arsenic	1	1	1	1	1	1
Rainbow Trout Hatchery	Fillet	Cadmium	1	1	1	1	1	1
Rainbow Trout Hatchery	Fillet	Copper	1	1	1	1	1	1
Rainbow Trout Hatchery	Fillet	Lead	1	1	1	1	1	1
Rainbow Trout Hatchery	Fillet	Mercury	2	1	1	3	1	1
Rainbow Trout Hatchery	Fillet	Zinc	1	1	1	1	1	1
Rainbow Trout Hatchery	Offal	2,3,7,8-TCDF	3	1	1	4	2	1
Rainbow Trout Hatchery	Offal	Antimony	1	1	1	1	1	1
Rainbow Trout Hatchery	Offal	Arsenic	1	1	1	2	1	1
Rainbow Trout Hatchery	Offal	Cadmium	2	1	1	3	1	1
Rainbow Trout Hatchery	Offal	Copper	2	1	1	3	1	1
Rainbow Trout Hatchery	Offal	Lead	11	4	2	15	5	2

Table D-3. Number of samples (rounded up) per reach for a two-sample t-test based on powers of 0.80 and 0.90, and the f-fold difference in means.

			Power = 0.80 f-fold difference in means			Power =0.90 f-fold difference in means		
Common Name	Tissue	Contaminant	1.25	1.50	2.00	1.25	1.50	2.00
Rainbow Trout Hatchery	Offal	Mercury	1	1	1	2	1	1
Rainbow Trout Hatchery	Offal	Zinc	1	1	1	1	1	1
Rainbow Trout Hatchery	Whole body	2,3,7,8-TCDF	2	1	1	3	1	1
Rainbow Trout Hatchery	Whole body	Antimony	1	1	1	1	1	1
Rainbow Trout Hatchery	Whole body	Arsenic	3	1	1	3	1	1
Rainbow Trout Hatchery	Whole body	Cadmium	5	2	1	6	2	1
Rainbow Trout Hatchery	Whole body	Copper	4	2	1	5	2	1
Rainbow Trout Hatchery	Whole body	Lead	2	1	1	2	1	1
Rainbow Trout Hatchery	Whole body	Mercury	1	1	1	1	1	1
Rainbow Trout Hatchery	Whole body	Zinc	1	1	1	1	1	1
Rainbow Trout Wild	Fillet	2,3,7,8-TCDF	17	6	2	22	7	3
Rainbow Trout Wild	Fillet	Antimony	1	1	1	1	1	1
Rainbow Trout Wild	Fillet	Arsenic	2	1	1	2	1	1
Rainbow Trout Wild	Fillet	Cadmium	16	5	2	21	7	3
Rainbow Trout Wild	Fillet	Copper	1	1	1	1	1	1
Rainbow Trout Wild	Fillet	Lead	1	1	1	1	1	1
Rainbow Trout Wild	Fillet	Mercury	2	1	1	3	1	1
Rainbow Trout Wild	Fillet	Zinc	1	1	1	1	1	1
Rainbow Trout Wild	Offal	2,3,7,8-TCDF	8	3	1	11	4	2
Rainbow Trout Wild	Offal	Antimony	1	1	1	1	1	1
Rainbow Trout Wild	Offal	Arsenic	1	1	1	1	1	1
Rainbow Trout Wild	Offal	Cadmium	2	1	1	3	1	1
Rainbow Trout Wild	Offal	Copper	4	2	1	6	2	1

Table D-3. Number of samples (rounded up) per reach for a two-sample t-test based on powers of 0.80 and 0.90, and the f-fold difference in means.

			Power = 0.80 f-fold difference in means			Power =0.90 f-fold difference in means		
Common Name	Tissue	Contaminant	1.25	1.50	2.00	1.25	1.50	2.00
Rainbow Trout Wild	Offal	Lead	1	1	1	1	1	1
Rainbow Trout Wild	Offal	Mercury	2	1	1	2	1	1
Rainbow Trout Wild	Offal	Zinc	1	1	1	1	1	1
Rainbow Trout Wild	Whole body	2,3,7,8-TCDF	11	4	2	14	5	2
Rainbow Trout Wild	Whole body	Antimony	1	1	1	1	1	1
Rainbow Trout Wild	Whole body	Arsenic	3	1	1	4	2	1
Rainbow Trout Wild	Whole body	Cadmium	2	1	1	3	1	1
Rainbow Trout Wild	Whole body	Copper	3	1	1	3	1	1
Rainbow Trout Wild	Whole body	Lead	4	2	1	5	2	1
Rainbow Trout Wild	Whole body	Mercury	2	1	1	2	1	1
Rainbow Trout Wild	Whole body	Zinc	1	1	1	1	1	1
Walleye	Fillet	2,3,7,8-TCDF	3	1	1	4	2	1
Walleye	Fillet	Antimony	1	1	1	1	1	1
Walleye	Fillet	Arsenic	4	1	1	5	2	1
Walleye	Fillet	Cadmium	1	1	1	1	1	1
Walleye	Fillet	Copper	1	1	1	1	1	1
Walleye	Fillet	Lead	47	15	6	63	20	8
Walleye	Fillet	Mercury	3	1	1	4	1	1
Walleye	Fillet	Zinc	1	1	1	1	1	1
Walleye	Offal	2,3,7,8-TCDF	4	2	1	6	2	1
Walleye	Offal	Antimony	1	1	1	1	1	1
Walleye	Offal	Arsenic	4	2	1	5	2	1
Walleye	Offal	Cadmium	2	1	1	3	1	1

Table D-3. Number of samples (rounded up) per reach for a two-sample t-test based on powers of 0.80 and 0.90, and the f-fold difference in means.

			Power = 0.80 f-fold difference in means			Power =0.90 f-fold difference in means		
Common Name	Tissue	Contaminant	1.25	1.50	2.00	1.25	1.50	2.00
Walleye	Offal	Copper	1	1	1	1	1	1
Walleye	Offal	Lead	4	2	1	5	2	1
Walleye	Offal	Mercury	2	1	1	3	1	1
Walleye	Offal	Zinc	1	1	1	1	1	1
Walleye	Whole body	2,3,7,8-TCDF	2	1	1	2	1	1
Walleye	Whole body	Antimony	1	1	1	1	1	1
Walleye	Whole body	Arsenic	3	1	1	4	2	1
Walleye	Whole body	Cadmium	4	2	1	5	2	1
Walleye	Whole body	Copper	2	1	1	2	1	1
Walleye	Whole body	Lead	9	3	2	12	4	2
Walleye	Whole body	Mercury	2	1	1	3	1	1
Walleye	Whole body	Zinc	1	1	1	1	1	1