2015 Bainbridge Basin Marine Sediment Monitoring

Sediment Chemistry Data Summary

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Parameter	N	# Detects	# ND	# ND > highest detect	Mean*	Std. Dev.*	Median*	Minimum*	Maximum (detected)	Max RL (ND)	Notes (see bottom)
Total Organic Carbon	33				1.729	1.397	1.67	0.17	4.49	4.49	1
Metals (mg/kg dry weight)											
Arsenic	33				6.708	3.645	6.53	1.86	14	14	1
Cadmium	33				0.938	0.67	1.01	0.127	2.32	2.32	1
Chromium	33				39.36	23.68	34.4	16.3	138	138	1
Copper	33				39.04	35.33	23.8	4.92	122	122	1
Lead	33				23.8	20.24	16.2	3.86	66.8	66.8	1
Mercury	33				0.1968	0.2111	0.107	0.0114	0.812	0.812	1
Nickel	33				30.47	11.39	30.7	14.2	48.3	48.3	1
Selenium	33				0.886	0.5375	0.898	0.253	1.78	1.78	1
Silver	33	19	14		0.3547	0.3161	0.228	0.0335	1.38	0.1	
Tin	33				2.126	1.77	1.26	0.3	6.09	6.09	1
Zinc	33				98.5	138.7	89.6	19.9	828	828	1
Organic Compounds (µg/kg dry weight)											
Polycyclic Aromatic Hydrocarbons (PAH)											
Low Molecular Weight PAH											
1-Methylnaphthalene	33				10.66	8.43	7.94	1.12	30.6	30.6	1
2,6-Dimethylnaphthalene	33				43.19	32.01	41.5	4.81	95.6	95.6	1
2-Methylnaphthalene	33				15.62	13.18	12	1.09	41.9	41.9	1
2-Methylphenanthrene	33	29	4		22.2	19.59	15.2	1.04	57	1.01	
Acenaphthene	33	27	6		5.316	3.518	4.98	1.48	15.3	2.03	

Parameter	N	# Detects	# ND	# ND > highest detect	Mean*	Std. Dev.*	Median*	Minimum*	Maximum (detected)	Max RL (ND)	Notes (see bottom)
Acenaphthylene	33	29	4		11.07	11.35	8.21	0.78	47.1	1.02	
Anthracene	33	32	1		25.29	24.54	21.6	0.54	103	0.974	
Biphenyl	33	20	13		6.854	2.968	5.112	3.95	14.4	5.09	
Dibenzofuran	33				10.31	7.51	6.98	1.38	23.9	23.9	1
Dibenzothiophene	33	30	3		5.283	4.091	4.46	0.732	12.9	0.995	
Fluorene	33	31	2		9.73	7.69	6.3	0.55	23.2	1.84	
Naphthalene	33	32	1		24.26	20.14	21.3	1.56	61.7	3.47	
Phenanthrene	33	27	6		53.85	41.99	49.2	6.17	138	7.55	
Retene	33				71.1	62.3	50.2	3	191	191	1
High Molecular Weight PAH											
Benzo(a)anthracene	33				64.7	64.1	54.5	1.2	248	248	1
Benzo(a)pyrene	33				91.3	95.8	69.9	1.5	376	376	1
Benzo(b)fluoranthene	33				94	86.4	78.5	2.6	255	255	1
Benzo(g,h,i)perylene	33				79.7	78	64.1	2.1	284	284	1
Benzo(k)fluoranthene	33				82.2	75.2	75.4	2.5	219	219	1
Benzo(e)pyrene	33				76.5	73.5	68.2	1.9	257	257	1
Chrysene	33				90.5	85.1	86	1.7	315	315	1
Dibenzo(a,h)anthracene	33	31	2		16.4	16.18	13.6	0.55	52.9	0.974	
Fluoranthene	33				123.5	106.9	123	4.1	355	355	1
Indeno(1,2,3-c,d)pyrene	33				59.6	57.5	48.3	1.5	199	199	1
Perylene	33				51.2	42.15	36.4	2.14	120	120	1
Pyrene	33				147	136.1	128	3.5	501	501	1
Base/Neutral/Acid (BNA) - all others not detected											
Semivolatile Compounds											
Miscellaneous Extractable Compounds											

Parameter	N	# Detects	# ND	# ND > highest detect	Mean*	Std. Dev.*	Median*	Minimum*	Maximum (detected)	Max RL (ND)	Notes (see bottom)
Biphenyl	20	13		6.854	2.968	5.112	3.95	14.4	5.09		20
Benzoic Acid	33				1113.6	572.4	1200	360	2200	2200	1
Carbazole	33	16	17		5.351	2.061	4.284	3.57	10.8	5.95	
Phenols											
4-Methylphenol	33	13	20		95.2	138.3	23.5	3.8	510	44	
Phthalate Esters											
Bis(2-ethylhexyl)phthalate	**33**	18	15		56.28	47.37	32.45	17	180	100	
Chlorinated Pesticides and herbicides - all others not detected											
4,4'-DDD	33	6	27		0.3029	0.4479	0.1335	0.0299	2.1	0.6	
4,4'-DDT	33	4	29		0.453	1.513	0.025	0	8.3	1.2	
Polychlorinated Biphenyls (PCB) - all others not detected											
PCB congeners											
PCB Congener 52	33	3	30		0.3455	0.4285	0.1843	0.0393	2.1	1.2	
PCB Congener 66	33	5	28		0.7311	0.2918	0.6431	0.3506	1.6	1.2	
PCB Congener 101	33	10	23		0.877	0.937	0.499	0.103	4.1	1.2	
PCB Congener 105	33	3	30		0.5966	0.28	0.5184	0.2568	1.5	1.2	
PCB Congener 118	33	11	22		1.045	0.963	0.63	0.159	4	1.2	
PCB Congener 138	33	10	23		1.085	1.431	0.474	0.065	6.1	1.2	
PCB Congener 153	33	12	21		1.331	1.82	0.468	0.063	7.9	1.2	
PCB Congener 170	33	4	29		0.4972	0.5017	0.2936	0.0791	2.3	1.2	
PCB Congener 180	33	4	29		0.462	0.607	0.214	0.042	2.8	1.2	
PCB Congener 187	33	6	27		0.635	0.613	0.382	0.103	2.8	1.2	
PCB Aroclors											
PCB Aroclor 1254	33	17	16		10.65	11.57	7.2	1.21	50	5.1	
PCB Aroclor 1260	33	11	22		7.1	10.14	2.53	0.46	44	6	

Parameter	N	# Detects	# ND	# ND > highest detect	Mean*	Std. Dev.*	Median*	Minimum*	Maximum (detected)	Max RL (ND)	Notes (see bottom)
Polybrominated Diphenylethers (PBDE) - all others not detected											
PBDE-47	33	22	11		0.2325	0.2589	0.2	0.057	1.6	0.41	
PBDE-99	33	8	25		0.2239	0.2241	0.1765	0.0777	1.4	0.48	

RL = reporting limit; ND = nondetect; CDF = cumulative distribution function
*: Estimated by ROS when nondetects present.
1: All values detected (no nondetects).
2: All nondetect.
3: Nondetects higher than the maximum detect are set to missing values.
4: All nondetects are higher than the maximum detect.
5: Too few detected observations for regression.
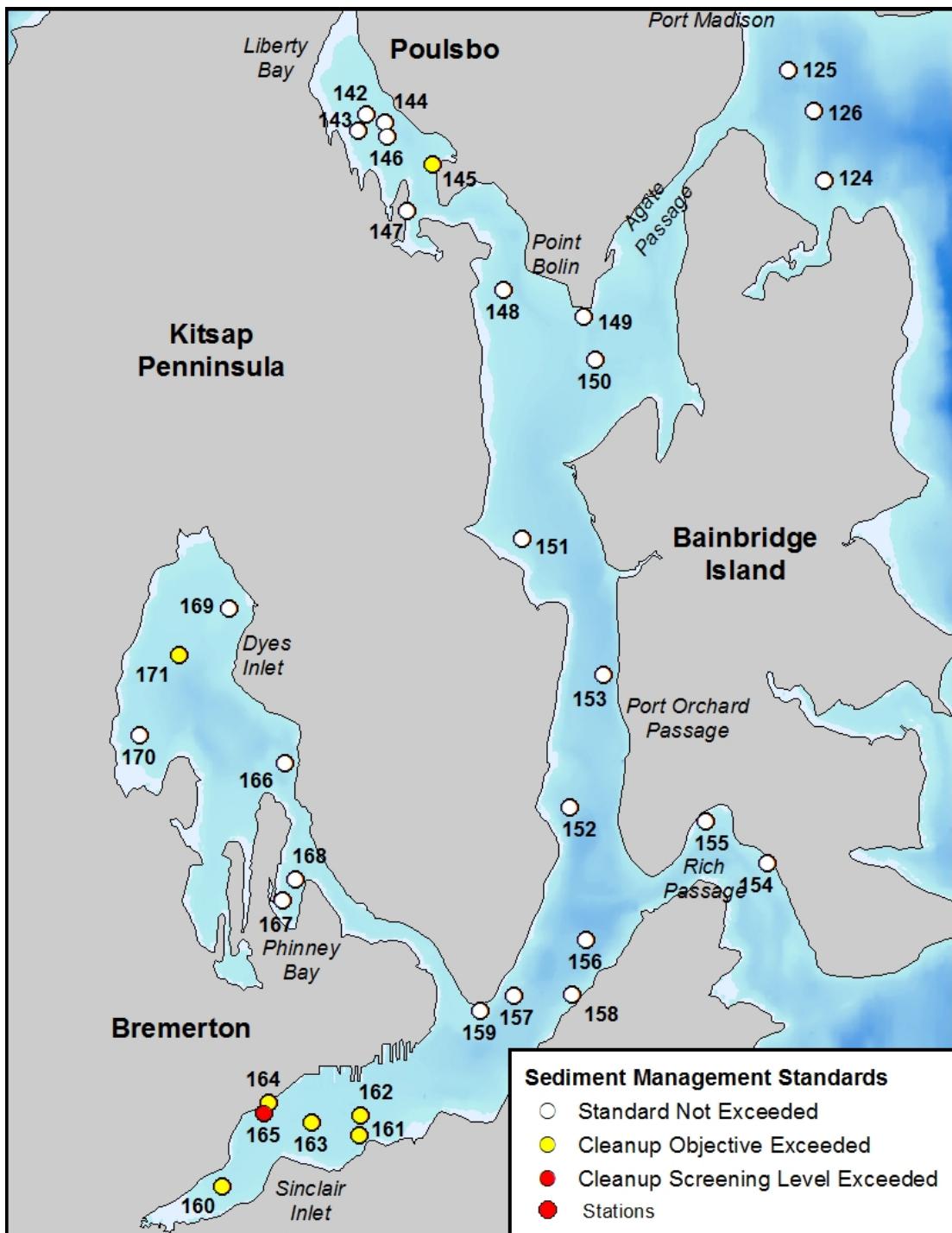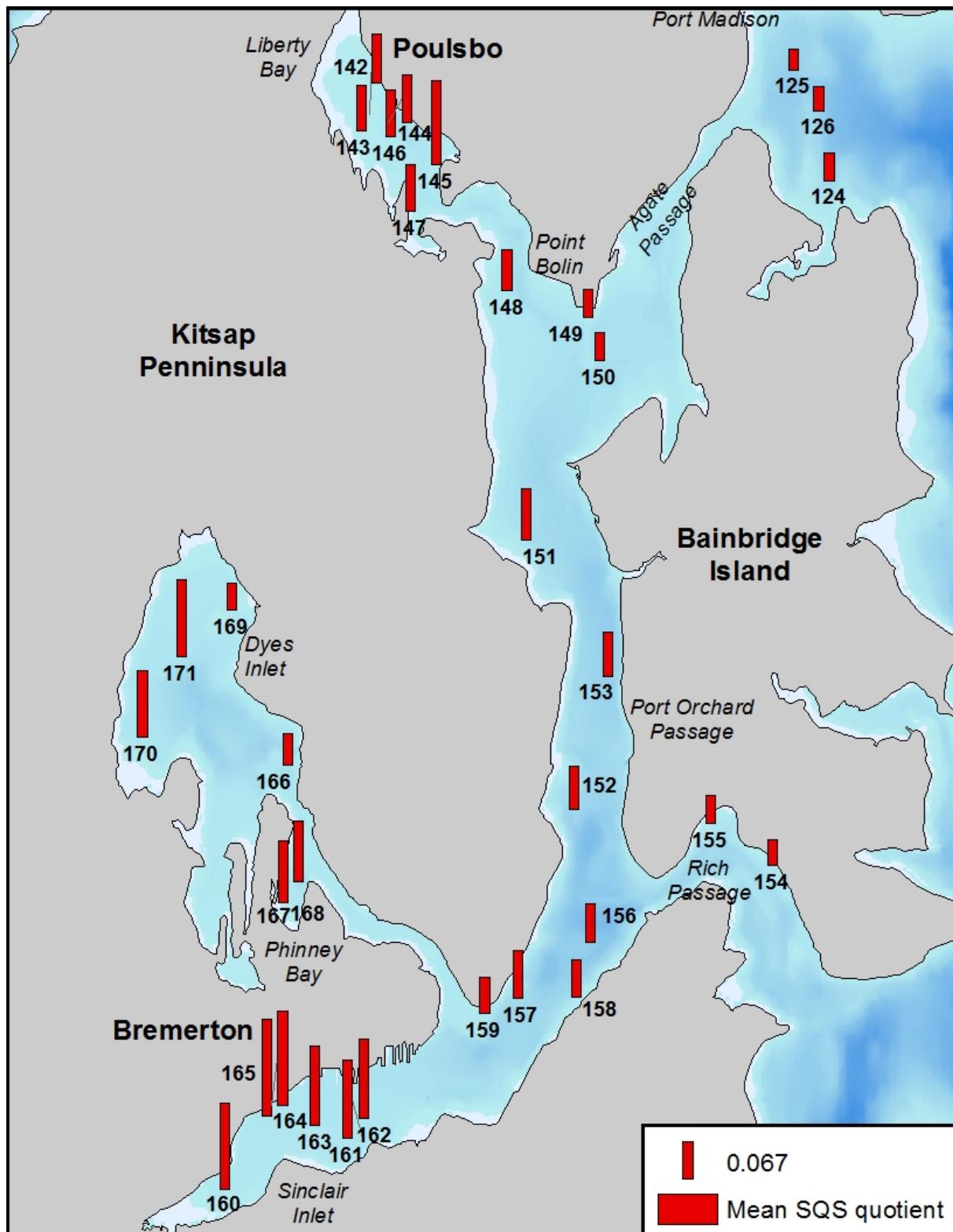
Chemical Contamination

Spatial patterns of stations with chemicals exceeding the Washington State Sediment Management Standards criteria in the 2015 Urban Bays Monitoring Program sediment survey.

The numbers on the map are the station identifiers.

Spatial patterns for mean SQS quotients (SQSq) in the 2015 Urban Bays Monitoring Program sediment survey.

The numbers on the map are the station identifiers.

Number of 2015 Urban Bays Monitoring Program sediment study samples exceeding Washington State sediment-quality standards[a] and estimated spatial extent of chemical contamination.

Total sampling area = 81.85 km^2.

Parameter	Criterion	> SQS[b]				Criterion	> CSL[b]			
		No.	Area (km^2)	% of Total area	Station number		No.	Area (km^2)	% of Total area	Station number
Trace Metals (ppm dry weight)										
Arsenic	57					93				
Cadmium	5.1					6.7				
Chromium	260			No criteria exceeded		270			No criteria exceeded	
Copper	390					390				
Lead	450					530				
Mercury	0.41	7	10.28	12.56	160-165, 171	0.59	1	1.13	1.38	165
Silver	6.1			No criteria exceeded		6.1				
Zinc	410	1	0.99	1.21	145	960			No criteria exceeded	
Organic Compounds										
LPAH (ppm organic carbon)										
2-Methylnaphthalene	38									
Acenaphthene	16									
Acenaphthylene	66									
Anthracene	220			No criteria exceeded					No criteria exceeded	
Fluorene	23									
Naphthalene	99									
Phenanthrene	100									
Total LPAH (ppm organic carbon)										
Sum of 6 LPAH	370			No criteria exceeded		780			No criteria exceeded	

| Parameter | Criterion | > SQS[b] | | | | Criterion | > CSL[b] | | | |
		No.	Area (km²)	% of Total area	Station number		No.	Area (km²)	% of Total area	Station number
HPAH (ppm organic carbon)										
Benzo(a)anthracene	110					270				
Benzo(a)pyrene	99					210				
Benzo(g,h,i)perylene	31					78				
Chrysene	110					460				
Dibenzo(a,h)anthracene	12			No criteria exceeded		33			No criteria exceeded	
Fluoranthene	160					1200				
Indeno(1,2,3-c,d)pyrene	34					88				
Pyrene	1000					1400				
Total Benzofluoranthenes	230					450				
Total HPAH (ppm organic carbon)										
Sum of 9 HPAH	960			No criteria exceeded		5300			No criteria exceeded	
Phenols (ppb dry weight)										
Pentachlorophenol	360			No criteria exceeded		690			No criteria exceeded	
Phthalate Esters (ppm organic carbon)										
Bis(2-ethylhexyl)phthalate	47					78				
Butylbenzylphthalate	4.9					64				
Diethylphthalate	61			No criteria exceeded		110			No criteria exceeded	
Dimethylphthalate	53					53				
Di-N-Butyl Phthalate	220					1700				
Di-N-Octyl Phthalate	58					4500				
Total PCB (ppm organic carbon)										
Total Aroclors	12			No criteria exceeded		65			No criteria exceeded	

Parameter	Criterion	> SQS[b]				Criterion	> CSL[b]			
		No.	Area (km²)	% of Total area	Station number		No.	Area (km²)	% of Total area	Station number
Miscellaneous Compounds (ppm organic carbon)										
1,2-Dichlorobenzene	2.3					2.3				
1,2,4-Trichlorobenzene	0.81					1.8				
1,4-Dichlorobenzene	3.1					9				
Dibenzofuran	15			No criteria exceeded		58			No criteria exceeded	
Hexachlorobenzene	0.38					2.3				
Hexachlorobutadiene	3.9					6.2				
N-Nitrosodiphenylamine	11					11				

[a] Excluding Benzoic Acid, Benzyl Alcohol, Phenol, 2-Methylphenol, 4-Methylphenol, and 2,4-Dimethylphenol.

[b] SQS = Sediment Quality Standard, CSL = Cleanup Screening Levels (Washington State Sediment Management Standards - Chapter 173-204 WAC).
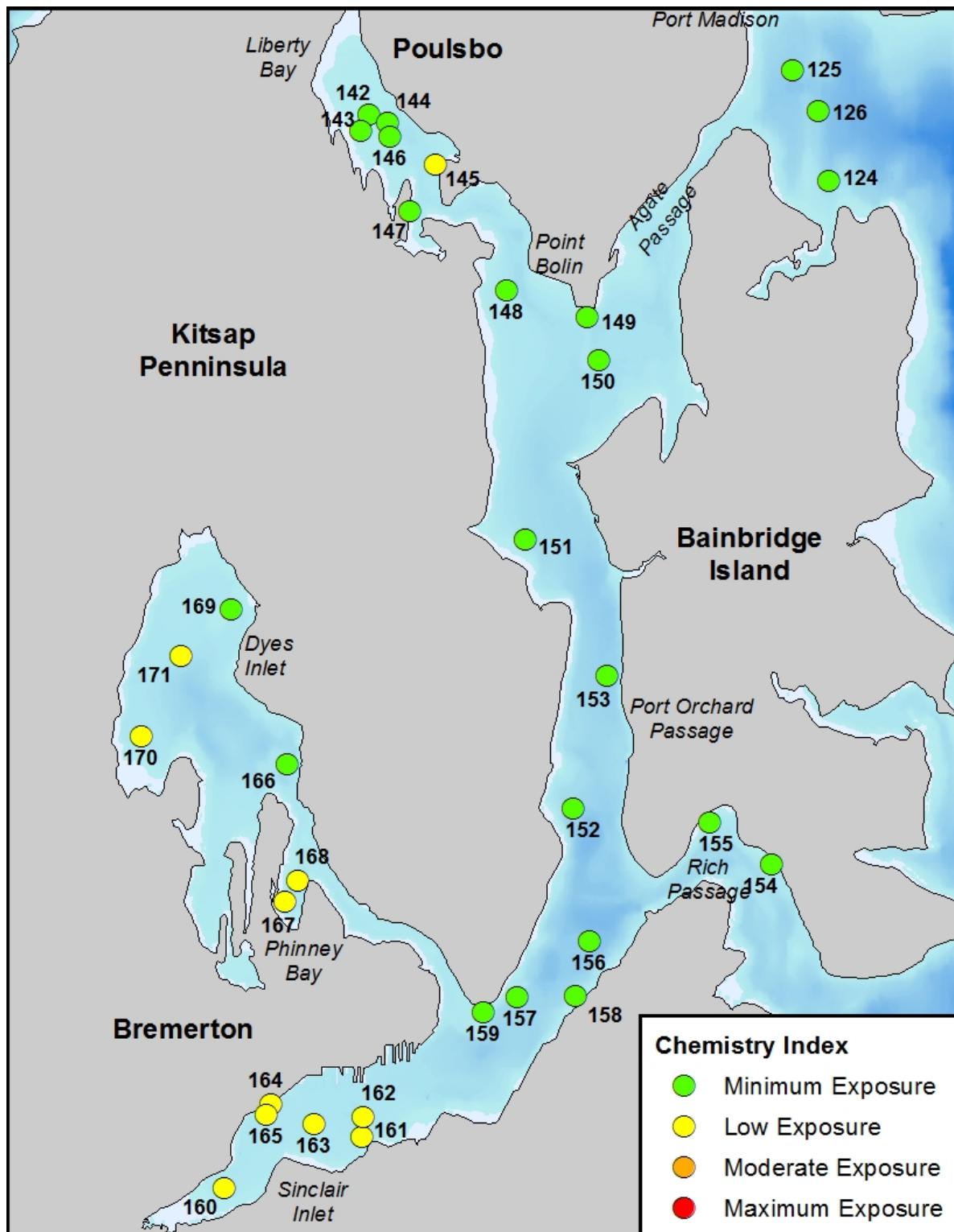
Samples from the 2015 Urban Bays Monitoring Program sediment study in which Washington State sediment quality standards[a] were exceeded.

Sample	Sample location	Area (km²)	Number of SQS[b] exceeded	Chemicals exceeding SQSs	Number of CSL[b] exceeded	Chemicals exceeding CSLs
124	Port Madison	5.56				
125	Port Madison	5.56				
126	Port Madison	5.56				
142	Liberty Bay	0.62				
143	Liberty Bay	0.62				
144	Liberty Bay	0.62				
145	Liberty Bay	0.99	1	Zinc		
146	Liberty Bay	0.99				
147	Liberty Bay	0.99				
148	Southeast of Keyport	4.32				
149	North Port Orchard, Pt. Bolin	4.32				
150	North Port Orchard	4.32				
151	North Port Orchard, E. of Brownsville	3.40				
152	Port Orchard, Illahee	3.40				
153	Port Orchard	3.40				
154	Rich Pass, Pleasant Beach	3.34				
155	Rich Pass, Lynwood Center	3.34				
156	South Port Orchard	3.34				
157	South Port Orchard, East Bremerton	1.98				
158	South Port Orchard	1.98				
159	South Port Orchard, Pt .Herron	1.98				
160	Sinclair Inlet	1.00	1	Mercury		

Sample	Sample location	Area (km²)	Number of SQS[b] exceeded	Chemicals exceeding SQSs	Number of CSL[b] exceeded	Chemicals exceeding CSLs
161	Sinclair Inlet	1.00	1	Mercury		
162	Sinclair Inlet	1.00	1	Mercury		
163	Sinclair Inlet	1.13	1	Mercury		
164	Sinclair Inlet	1.13	1	Mercury		
165	Sinclair Inlet	1.13	1	Mercury	1	Mercury
166	Dyes Inlet, Tracyton	1.06				
167	Phinney Bay	1.06				
168	Phinney Bay	1.06				
169	Dyes Inlet, SE of Silverdale	3.89				
170	Dyes Inlet, North Chico Bay	3.89				
171	Dyes Inlet	3.89	1	Mercury		

[a] Excluding Benzoic Acid, Benzyl Alcohol, Phenol, 2-Methylphenol, 4-Methylphenol, and 2,4-Dimethylphenol.

[b] SQS = Sediment Quality Standard, CSL = Cleanup Screening Levels (Washington State Sediment Management Standards - Chapter 173-204 WAC).

Spatial patterns in Sediment Chemistry Index in the 2015 Urban Bays Monitoring Program sediment survey.

The numbers on the map are the station identifiers.

Incidence and spatial extent of chemical contamination in the 2015 Urban Bays Monitoring Program sediment survey, as measured with the Sediment Chemistry Index.

Chemistry Index Category	Stations		Area	
	No.	(%)	km^2	(%)
Bainbridge Basin	33	(100.0)	81.9	(100.0)
Minimal exposure	22	(66.7)	64.6	(78.9)
Low exposure	11	(33.3)	17.3	(21.1)
Moderate exposure	0	(0.0)	0.0	(0.0)
High exposure	0	(0.0)	0.0	(0.0)

Comparisons over Time

Summary of pairwise statistical comparisons[1,2] of 1998 PSAMP/NOAA, 2009 Urban Waters, and 2015 Urban Waters chemical parameters.

↓ = decrease; ↑ = increase; -- = no change; n.a. = not applicable

Parameter	Change from 1998 to 2009	Change from 1998 to 2015	Change from 2009 to 2015
Organic Carbon Content			
Total organic carbon	--	--	--
Priority Pollutant Metals			
Arsenic	--	--	--
Cadmium	--	↑	--
Chromium	↑	--	--
Copper	--	--	--
Lead	--	--	--
Mercury	--	--	--
Nickel	--	--	--
Selenium	--	--	--
Silver	--	--	--
Zinc	--	--	--
Trace Elements			
Tin	n.a.	n.a.	n.a.
Organic Compounds			
Polynuclear Aromatic Hydrocarbons (PAHs)			
Low Molecular Weight PAHs			
1,6,7-Trimethylnaphthalene	--	--	--
1-Methylnaphthalene	--	--	--
2,6-Dimethylnaphthalene	--	--	--
2-Methylnaphthalene	--	--	--
1-Methylphenanthrene	--	--	--
2-Methylphenanthrene	↑	--	↓
Acenaphthene	↑	↑	--
Acenaphthylene	--	--	--
Anthracene	--	--	--
Biphenyl	--	--	--
Dibenzothiophene	--	--	--
Fluorene	--	--	--
Naphthalene	--	--	--

| Parameter	Change from 1998 to 2009	Change from 1998 to 2015	Change from 2009 to 2015
Phenanthrene	--	--	--
Retene	--	--	--
Total LPAH (sum of 6 compounds)	--	--	↓
High Molecular Weight PAHs			
Benzo(a)anthracene	--	--	--
Benzo(a)pyrene	--	--	--
Benzo(b)fluoranthene	--	--	--
Benzo[e]pyrene	--	--	--
Benzo(g,h,i)perylene	--	--	--
Benzo(k)fluoranthene	--	--	--
Chrysene	--	--	--
Dibenzo(a,h)anthracene	--	--	--
Fluoranthene	--	--	--
Indeno(1,2,3-c,d)pyrene	--	--	--
Perylene	--	--	--
Pyrene	--	--	--
Total Benzofluoranthenes	--	--	--
Total HPAH (sum of 9 compounds)	--	↓	↓
Miscellaneous Extractable Compounds			
Carbazole	--	--	--
Dibenzofuran	↑	--	↓
Polychlorinated Biphenyls (PCBs)			
PCB Aroclor 1254	--	--	--
Total PCB Aroclors	↓	↓	--
All other PCB congeners and Aroclors	--	--	--
Polybrominated Diphenyl Ethers (PBDEs) - not measured in 1998			
PBDE congener 47	n.a.	n.a.	n.a.
PBDE congener 99	n.a.	n.a.	n.a.
PBDE congener 209	n.a.	n.a.	n.a.
All other PBDE congeners	n.a.	n.a.	n.a.
All other organic compounds – too few detected values			
Sediment Chemistry Index			
Chemistry Index	--	↑	--

[1] Medians (unweighted) compared by Kruskal-Wallis test when all results detected, or by the Generalized Wilcoxon test when nondetects present ($\alpha = 0.05$).
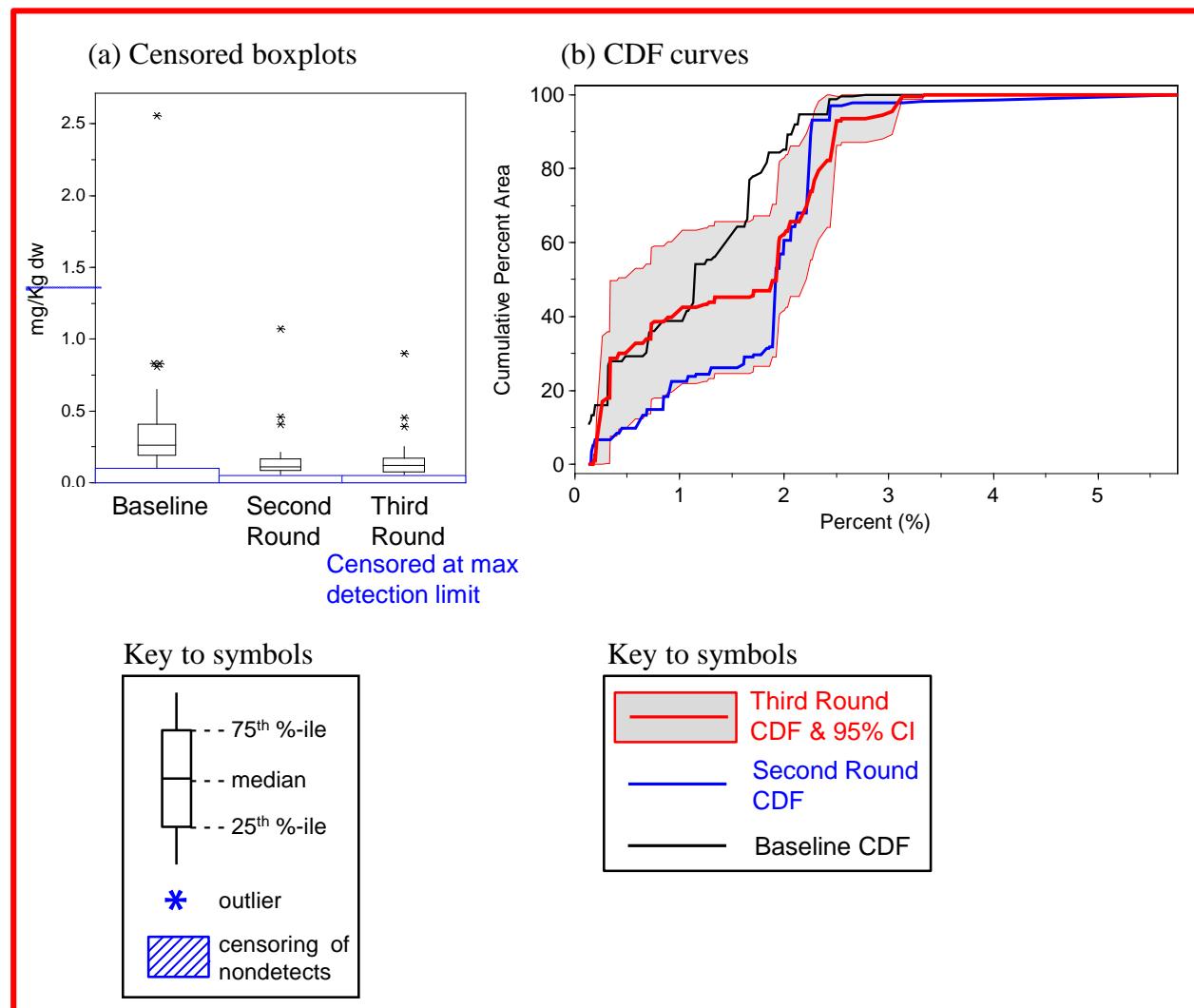
[2] CDFs (weighted) compared by Wald F test ($\alpha = 0.05$).

Comparison of contaminant concentrations in sediments sampled in the 1998, 2009, and 2015 surveys of the Bainbridge Basin.
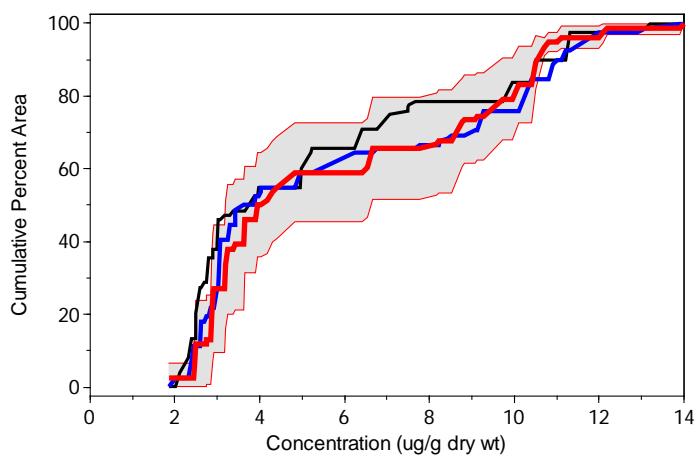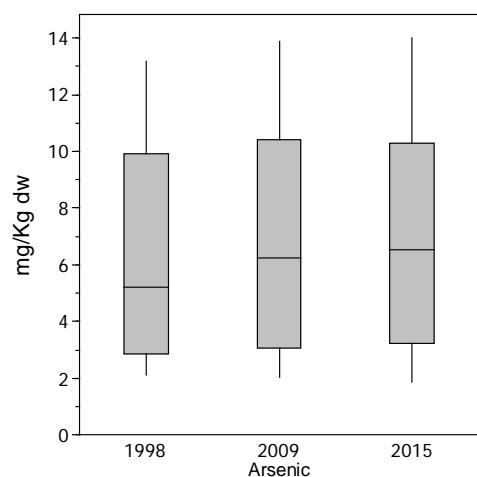
Graphical displays are given below for metals, PAHs, and the Sediment Chemistry Index.

The graphical displays include two types of graphs:
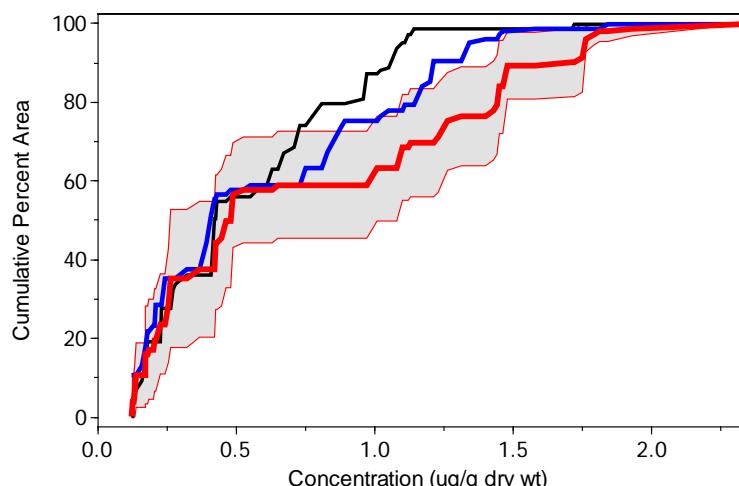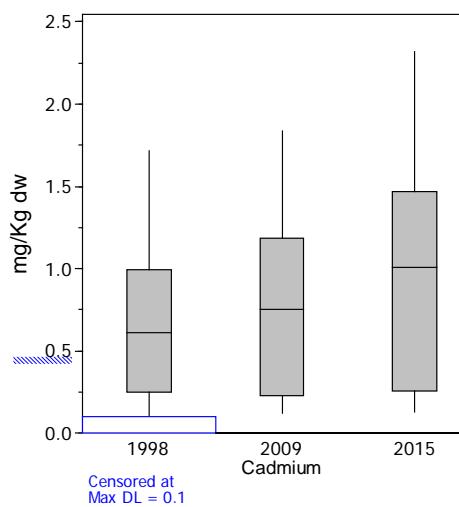
    (a) Censored boxplots display the distributions of the data unweighted by sample area.

    (b) Cumulative distribution function (CDF) curves display the cumulative distributions of the data weighted by sample area. Confidence intervals are shown for the 2015 CDF curves only.

Arsenic

Cadmium

Censored at
Max DL = 0.1
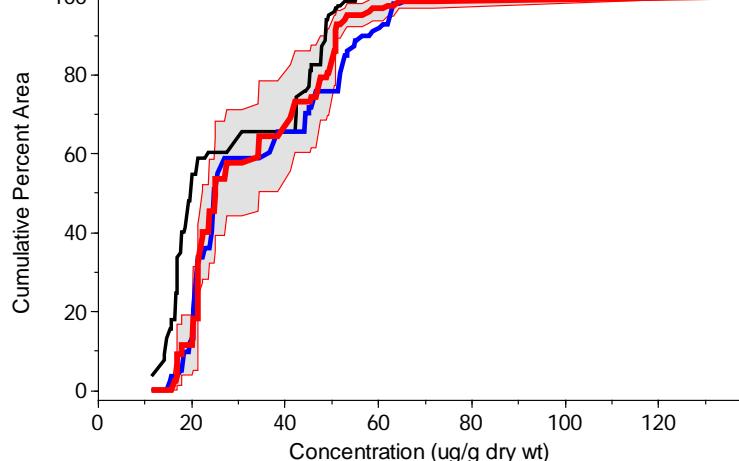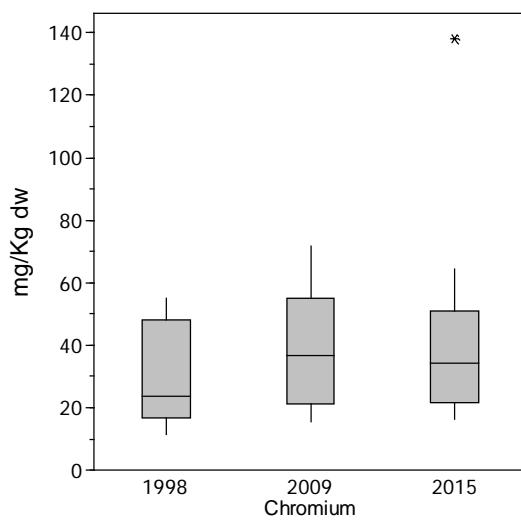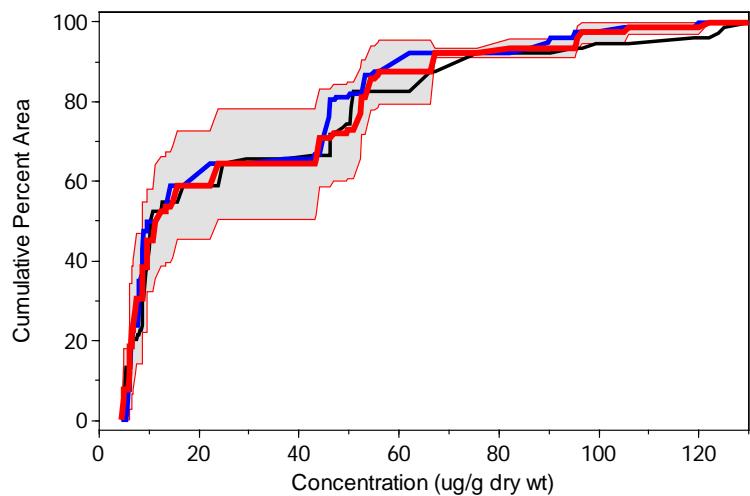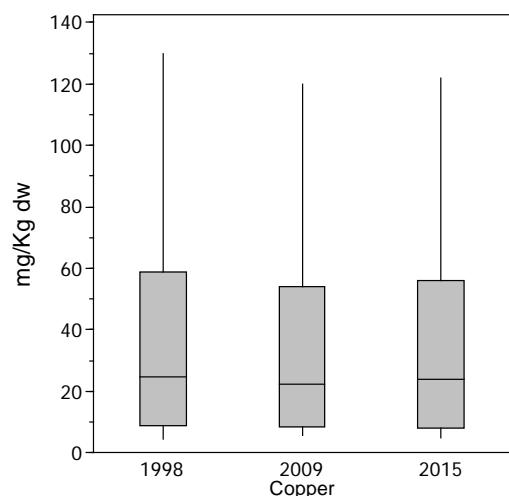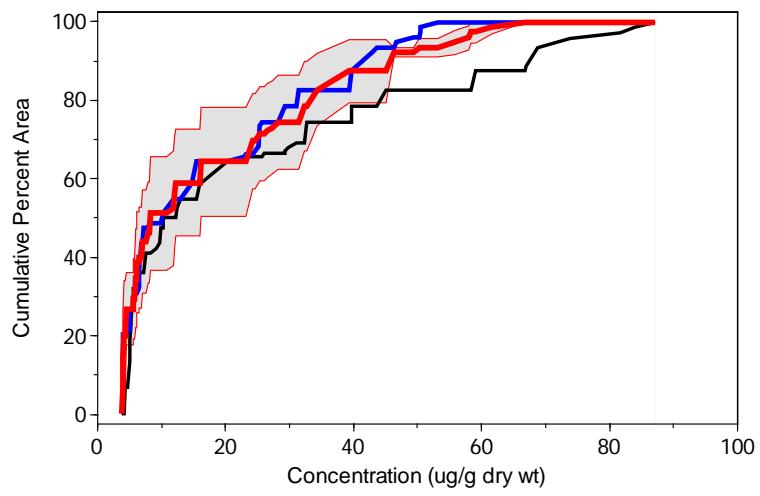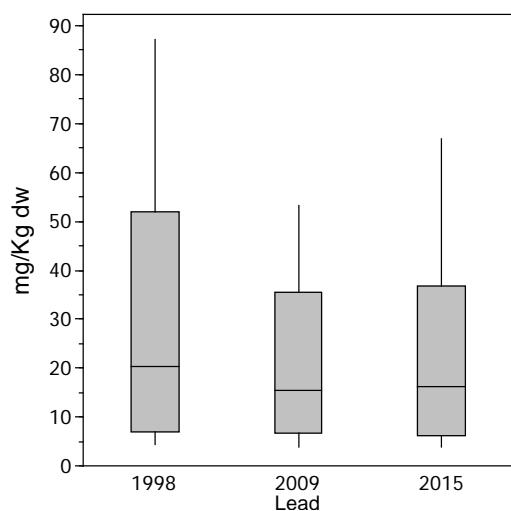
Chromium
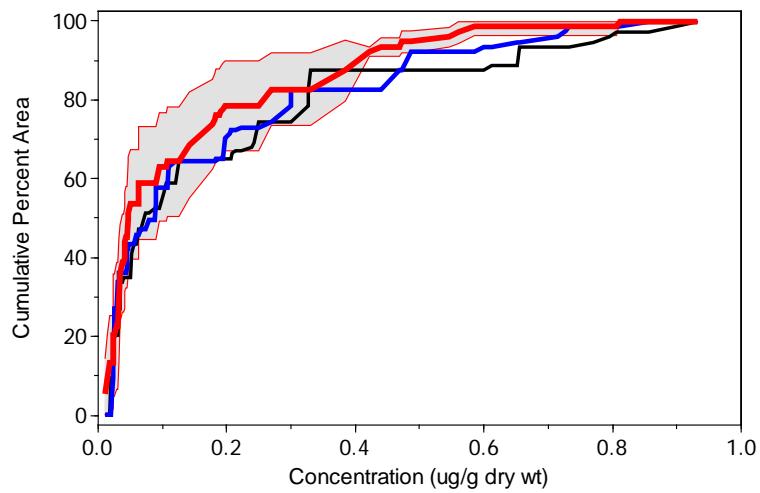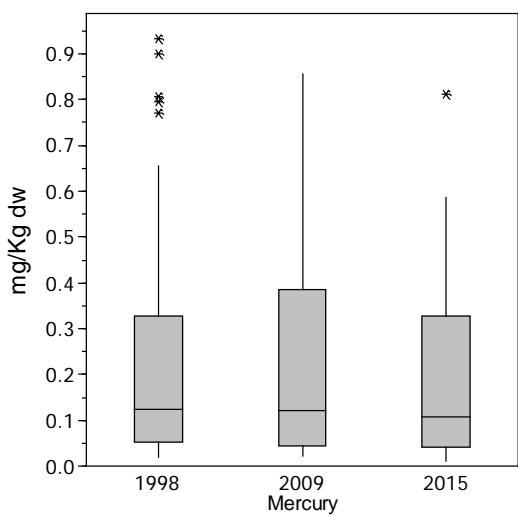
Copper
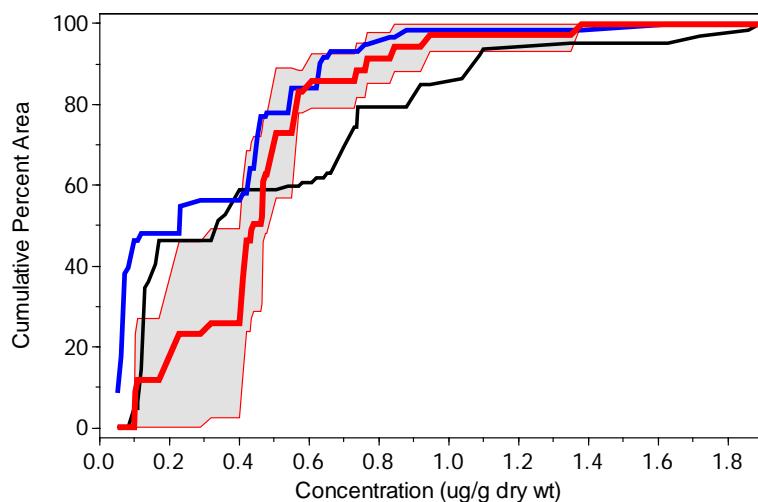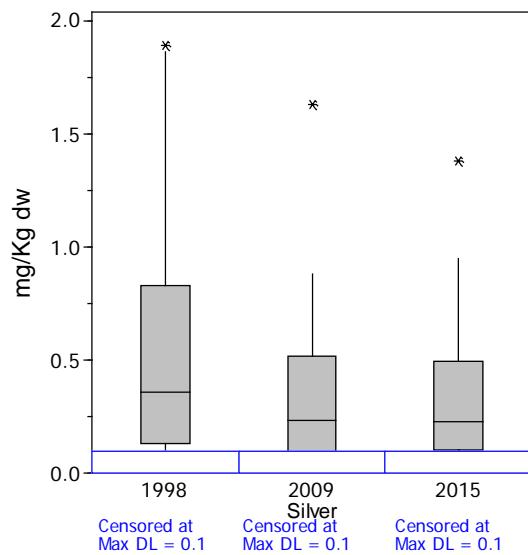
Lead
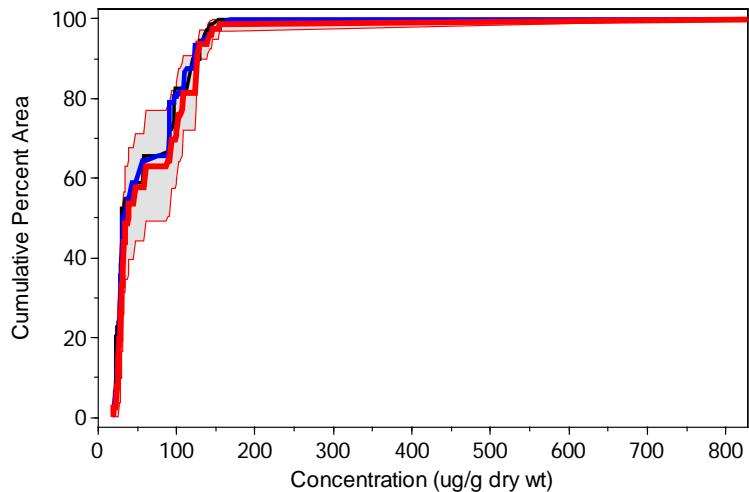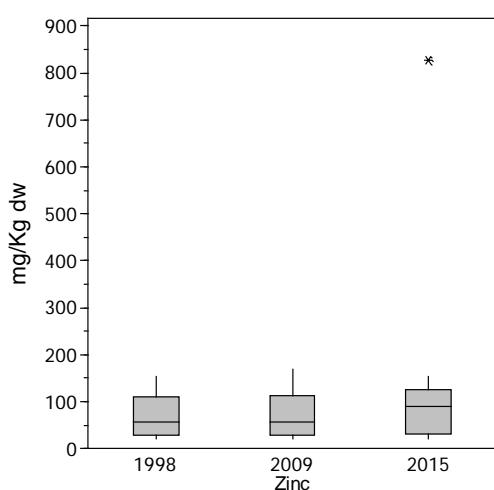
Mercury
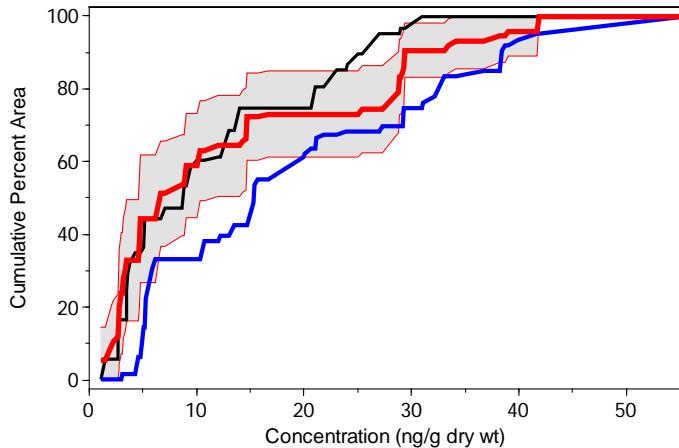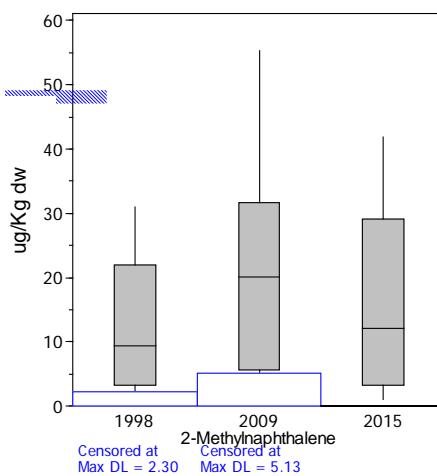
Silver
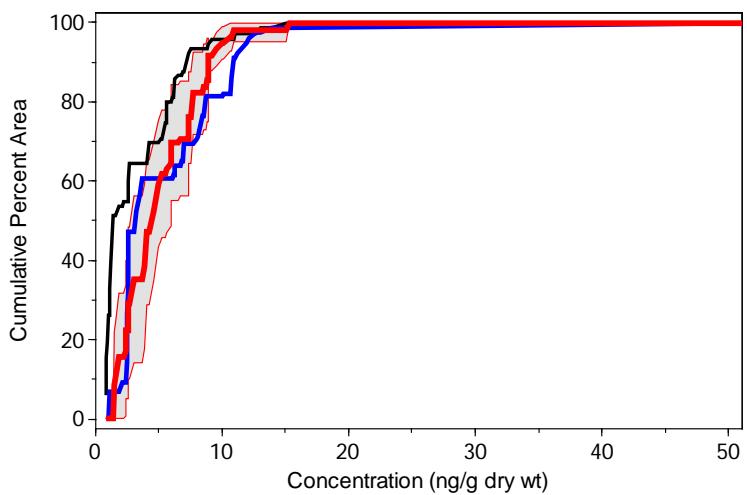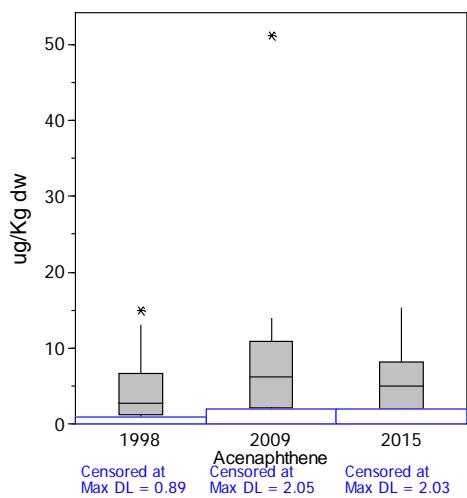
Zinc
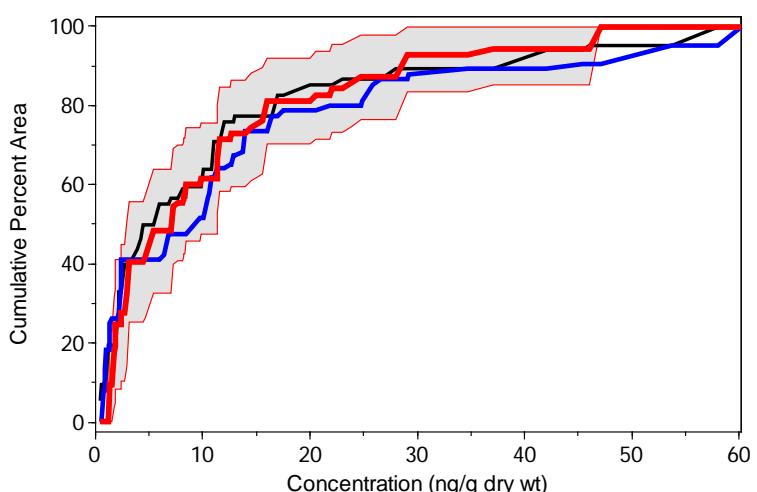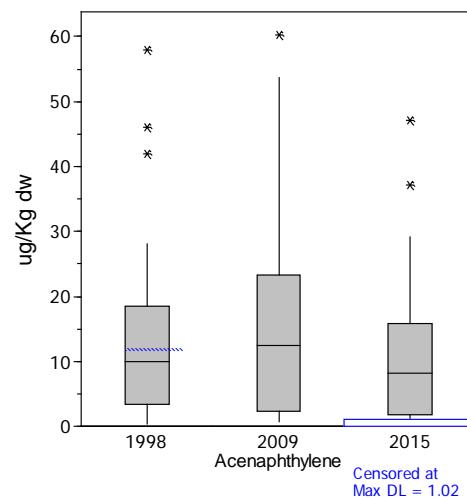
2-Methylnaphthalene

Acenaphthene

Censored at Max DL = 0.89 (1998)
Censored at Max DL = 2.05 (2009)
Censored at Max DL = 2.03 (2015)

Acenaphthylene

Censored at Max DL = 1.02

Anthracene

Censored at Max DL = 0.974
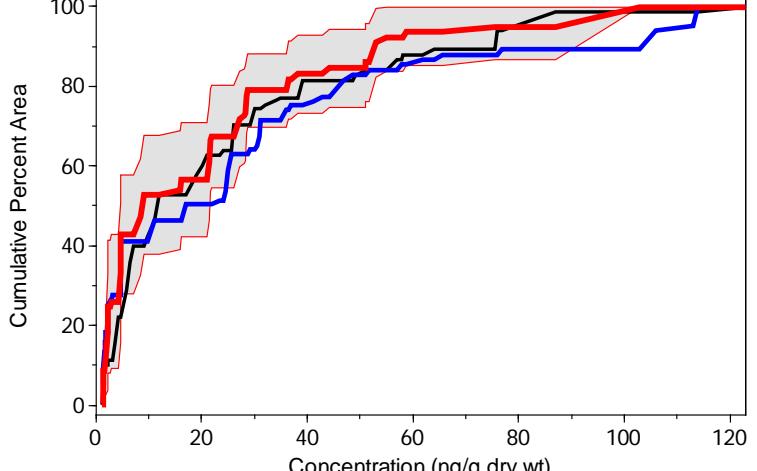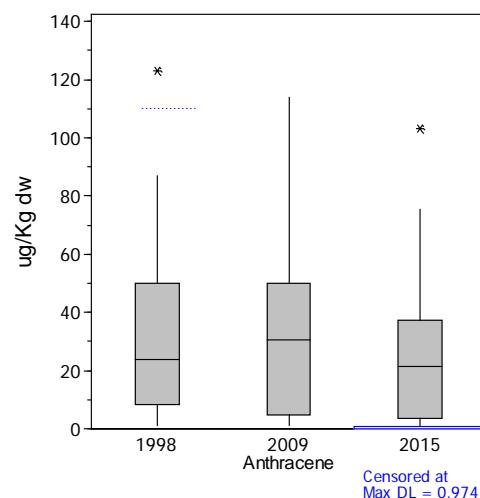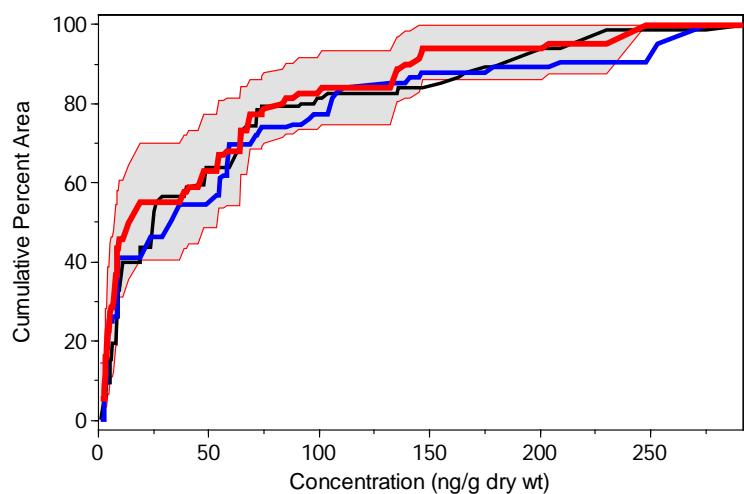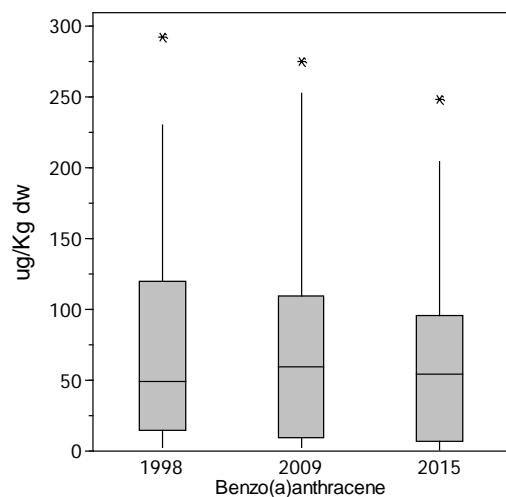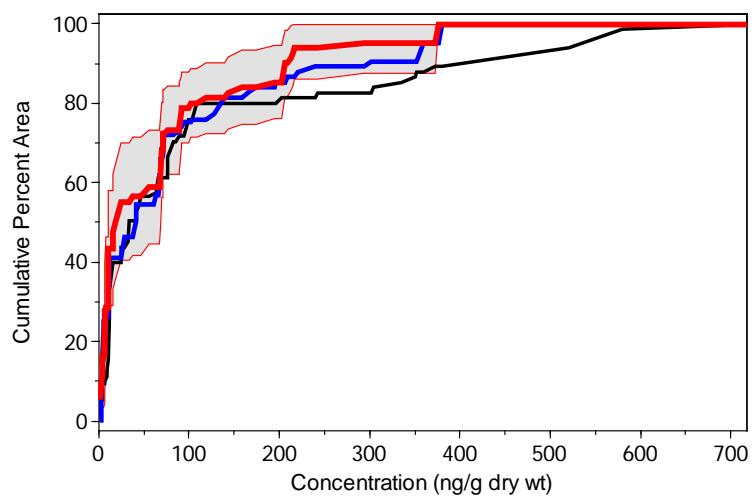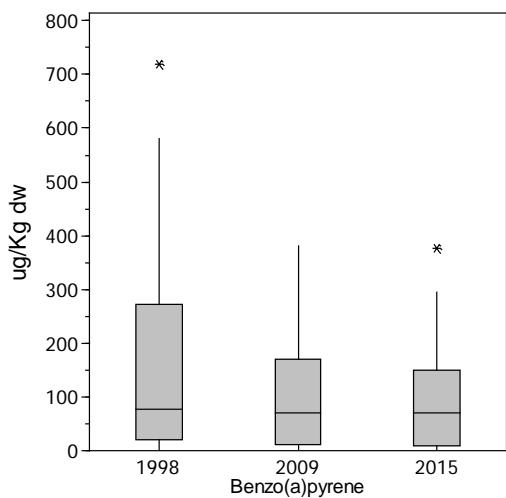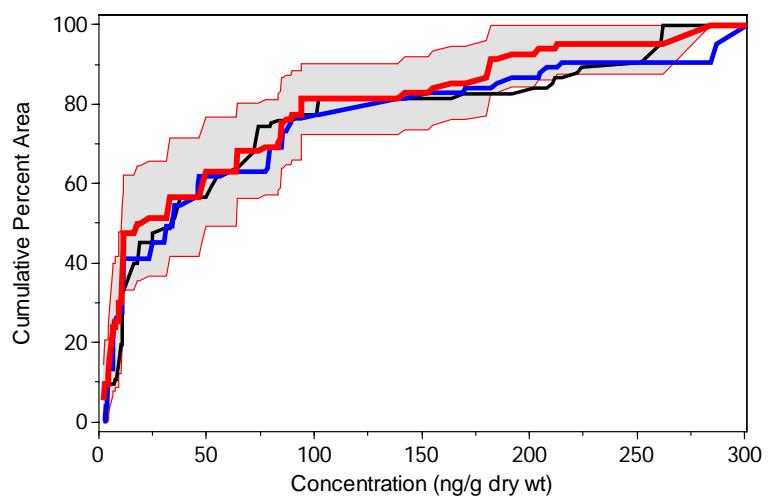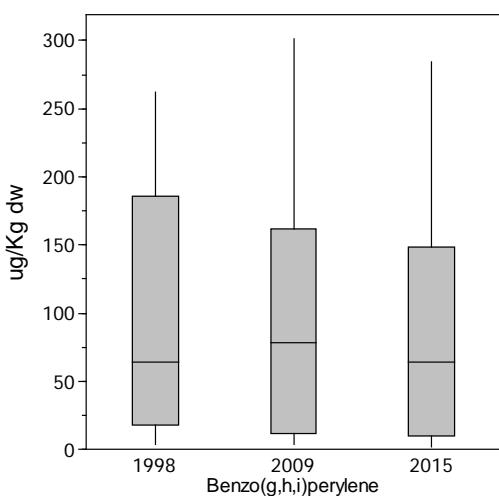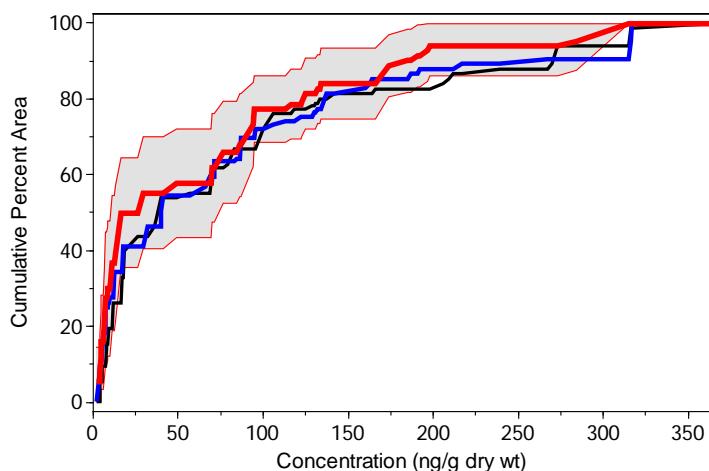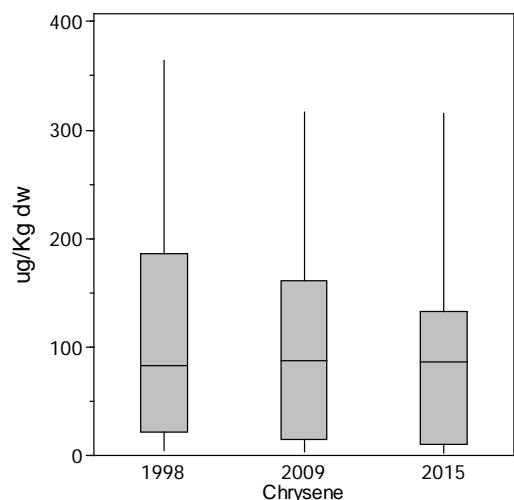
Benzo(a)anthracene
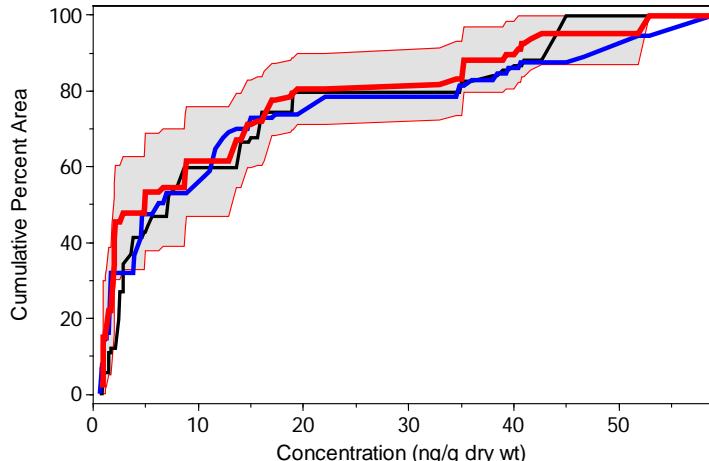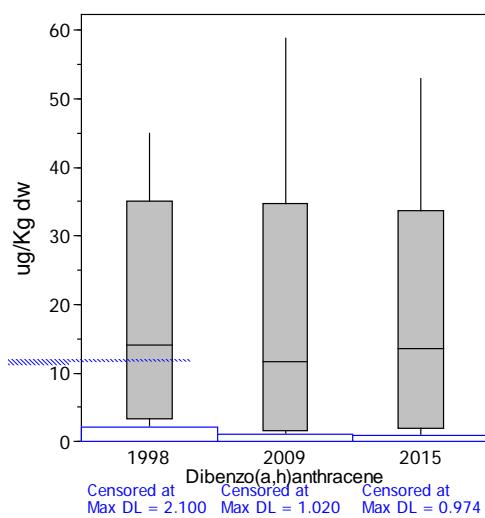
Benzo(a)pyrene

Benzo(g,h,i)perylene

Chrysene

Dibenzo(a,h)anthracene

Censored at Max DL = 2.100   Censored at Max DL = 1.020   Censored at Max DL = 0.974

Censored at Max DL = 2.100   Censored at Max DL = 1.020   Censored at Max DL = 0.974

Fluoranthene

Fluorene

Censored at Max DL = 0.87

Censored at Max DL = 1.84
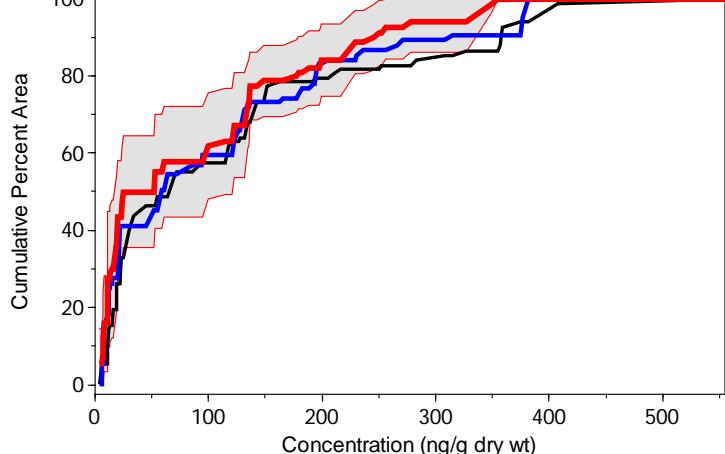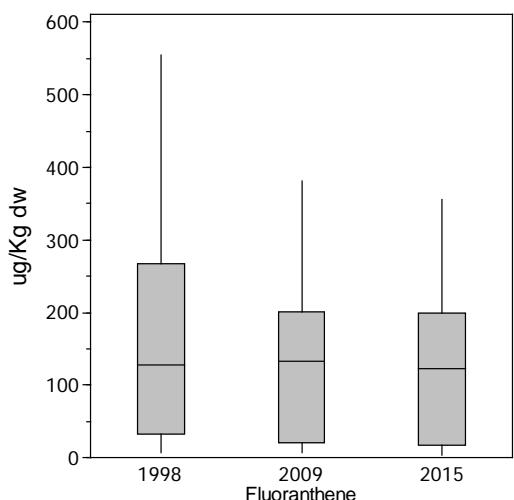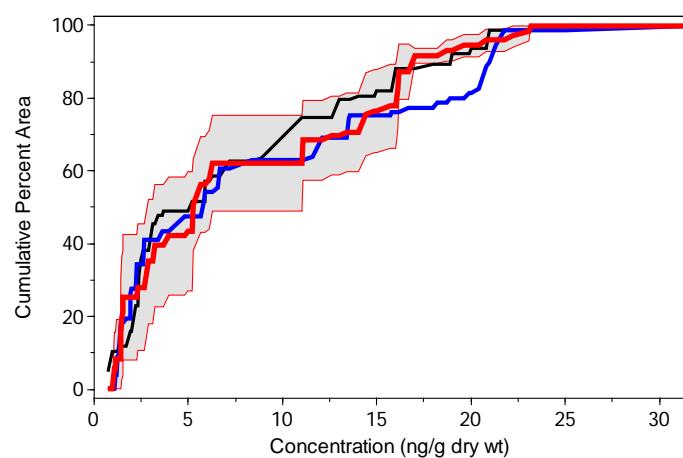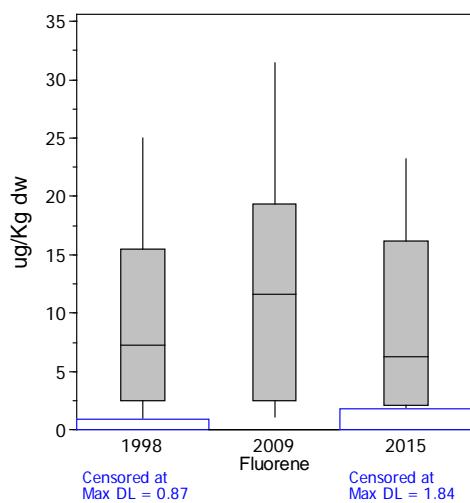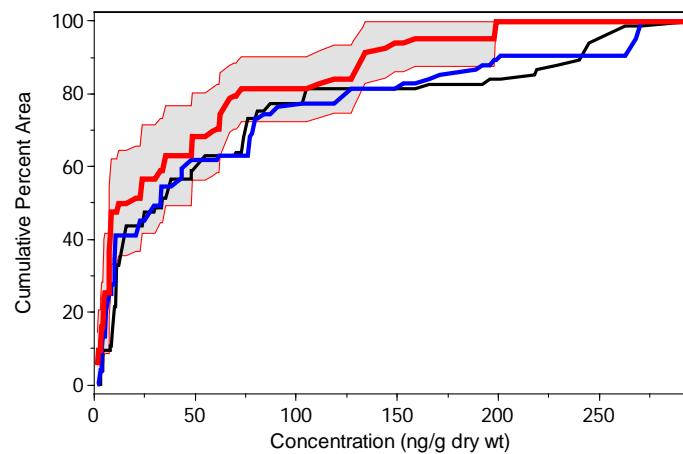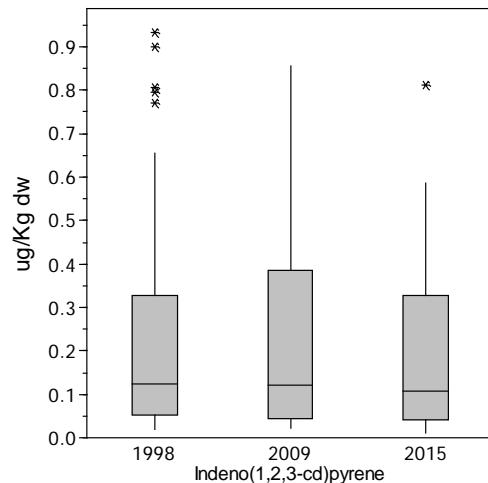
Indeno(1,2,3-c,d)pyrene

Naphthalene

Censored at Max DL = 2.80

Censored at Max DL = 3.47

Phenanthrene

Censored at
Max DL = 7.55
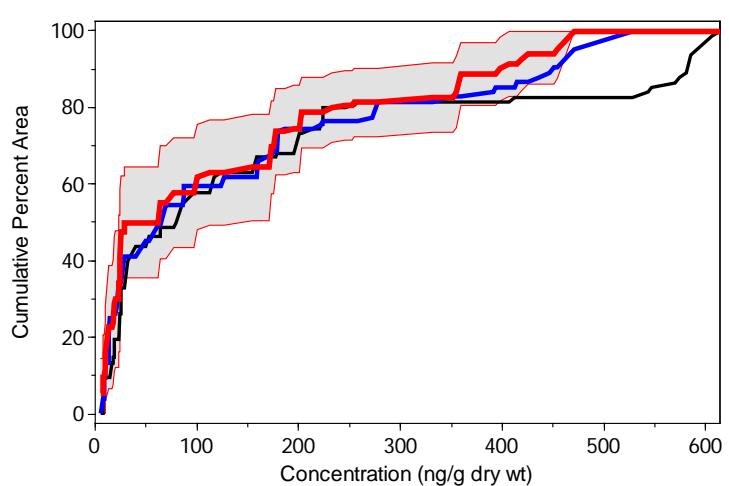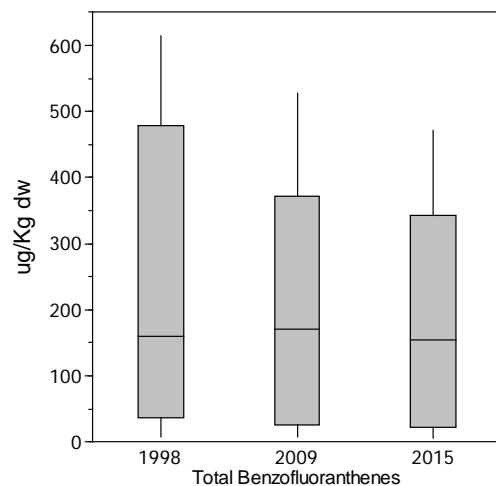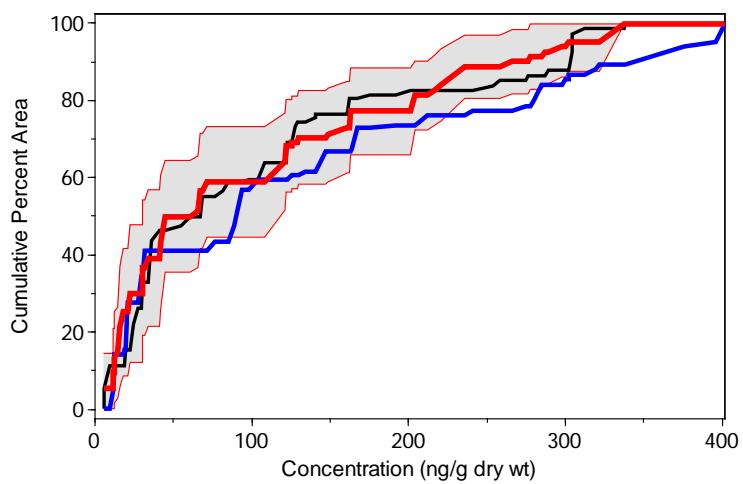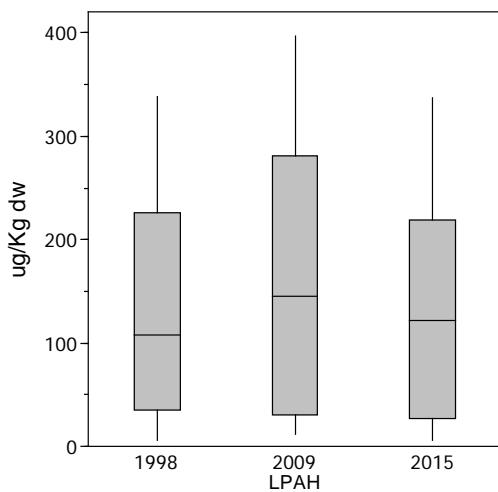
Pyrene
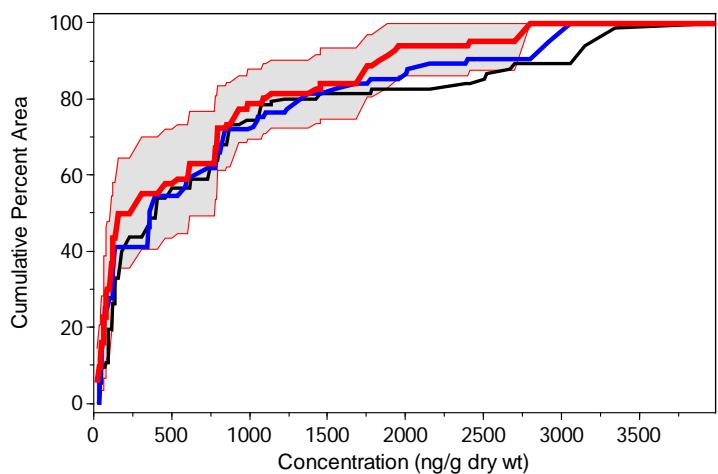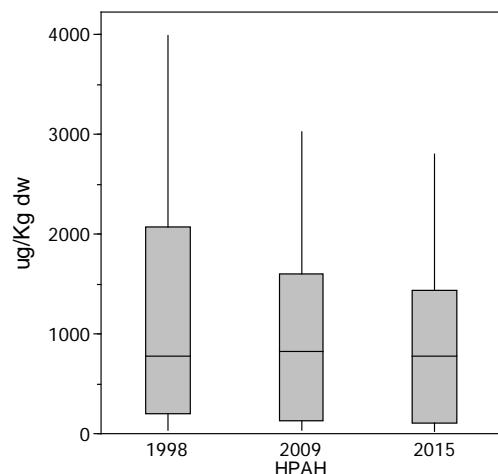
# Total Benzofluoranthenes

Total LPAH

Total HPAH

Dibenzofuran

Sediment Chemistry Index (SCI)
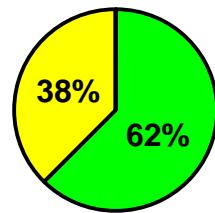
Comparison of Sediment Chemistry Index Categories by Year
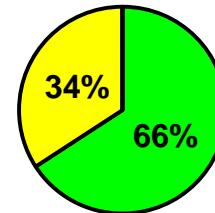
Estimated spatial extent (percent of area) and 95% confidence intervals for each of the SCI categories for the Bainbridge Basin in 2015, compared to 1998 and 2009.

There were no statistically significant differences in spatial extent between the three years (Kincaid, 2015, α = 0.05).
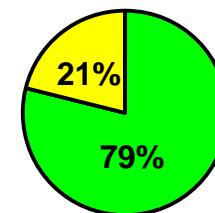
Sediment Chemistry Index Category	1998			2009			2015		
		Confidence limit			Confidence limit			Confidence limit	
	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Minimum exposure	62.44	39.25	62.99	65.82	42.48	65.30	78.89	56.32	72.86
Low exposure	37.56	18.01	43.49	34.18	17.04	38.92	21.11	9.59	24.97
Moderate exposure	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum exposure	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1998   **2009**   **2015**[*]

Spatial and temporal patterns in spatial extent (percent of area, shown in pie charts) for the Chemistry Index categories in the Bainbridge Basin.

[*]Statistically significant different in spatial extent between 1998 and 2015 (Kincaid, 2015, α = 0.05).

Comparisons with the Region

Incidence and spatial extent of chemical contamination among Bainbridge Basin, Central Sound monitoring region, and all of Puget Sound, as measured by chemical concentrations exceeding applicable Washington State Sediment Quality Standards.

Monitoring Region	Year(s) sampled	Numbers of Samples	Percent of samples > SQS	Percent of area (km^2) > SQS
Bainbridge Basin	1998	33	24.2	16.6
	2009	33	24.2	17.3
	2015	33	24.2	13.8
Central Puget Sound	1998-1999	128	32.0	4.0
	2014-2009	80	21.3	11.1
All of Puget Sound	1997-2003	381	15.5	4.7
	2004-2014	368	5.7	3.9

Incidence and spatial extent of chemical contamination in Bainbridge Basin, Central Puget Sound, and all of Puget Sound, as measured with the Sediment Chemistry Index.

Sediment Chemistry Index Category	Baseline				Second Round				Third Round			
	Stations		Area		Stations		Area		Stations		Area	
	No.	(%)	km²	(%)	No.	(%)	km²	(%)	No.	(%)	km²	(%)
Bainbridge Basin	33	(100.0)	81.9	(100.0)	33	(100.0)	81.9	(100.0)	33	(100.0)	81.9	(100.0)
Minimum exposure	19	(57.6)	51.1	(62.4)	18	(54.5)	53.9	(65.8)	22	(66.7)	64.6	(78.9)
Low exposure	14	(42.4)	30.75	(37.6)	15	(45.5)	28.0	(34.2)	11	(33.3)	17.3	(21.1)
Moderate exposure	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)
High exposure	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)
Central Sound	128	(100.0)	683.9	(100.0)	80	(100.0)	667.4	(100.0)				
Minimum exposure	54	(42.2)	569.5	(83.3)	58	(72.5)	583.2	(87.4)				
Low exposure	46	(35.9)	105.1	(15.4)	21	(26.3)	68.6	(10.3)				
Moderate exposure	19	(14.8)	7.8	(1.1)	1	(1.3)	15.6	(2.3)				
High exposure	9	(7.0)	1.5	(0.2)	0	(0.0)	0.0	(0.0)				
Total Study Area	381	(100.0)	2294.1	(100.0)	368	(100.0)	2207.5	(100.0)				
Minimum exposure	269	(70.6)	2087.0	(91.0)	325	(88.3)	2078.3	(94.1)				
Low exposure	80	(21.0)	187.36	(8.2)	42	(11.4)	113.7	(5.2)				
Moderate exposure	22	(5.8)	18.15	(0.8)	1	(0.3)	15.6	(0.7)				
High exposure	10	(2.6)	1.57	(0.1)	0	(0.0)	0.0	(0.0)				

Chemistry Case Narratives

General Chemistry

PSEMP Urban Waters_GChem_1505061.pdf

Metals

PSEMP Urban Waters_Metals-1505061.pdf

BNAs

PSEMP Urban Waters_BNASQS-1505061.pdf

PAHs

PSEMP Urban Waters_PAHNOAA-1505061.pdf

PBDEs

PSEMP Urban Waters-2015_PBDE-1505061-1to36.pdf

PCBs and Pesticides

PSEMP Urban Waters_PCLNOAA-1505061.pdf

PPCP - PFAS

AXYS narrative from PFC 1505061-01thru09,19-21,23,24,29,34,35,36
PSEMP_DPWG51651.pdf

AXYS narrative from PFC 1505061-10thru18,22,25,27,31,32,33
PSEMPDPWG51381.pdf

PPCP1 narrative from 1505061-10thru18,22,25,27,31,32,33 PSEMP DPWG51657-4.pdf

PPCP2 narrative from 1505061-01thru09,19-21,23,24,29,34,35,36 PSEMP_DPWG51619.pdf