Appendix D to Department of Ecology Publication 18-03-004

2004-2014 Puget Sound Marine Sediment Monitoring

Sediment Toxicity Data Summary

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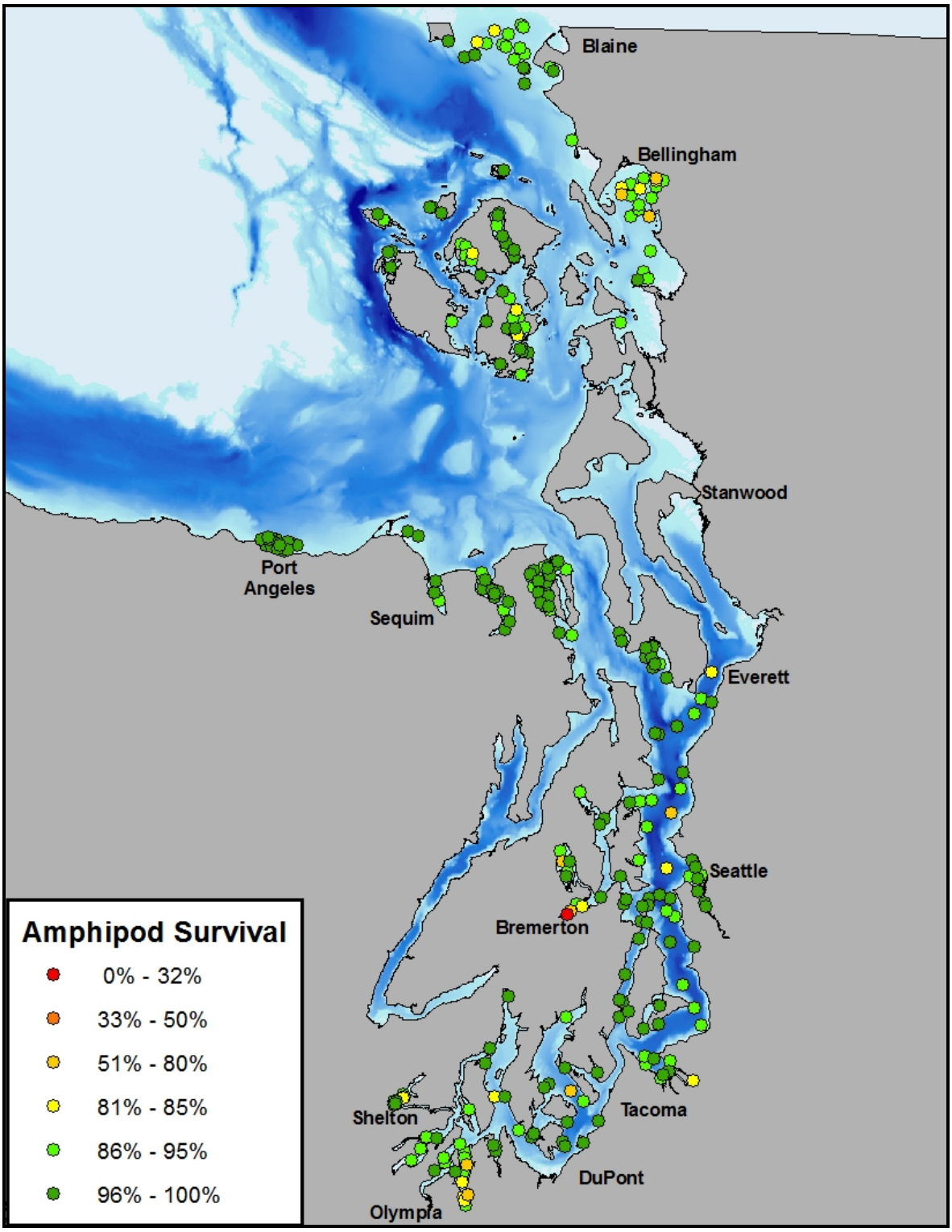
Results and Statistical Summaries

Summary results for amphipod survival tests from the 2004-2014 Puget Sound Sediment Monitoring Program.

Data are expressed as mean percent survival, percentage of control response. Tests were performed with *Eohaustorius estuarius*.

Region Stratum	Minimum	Maximum	Mean	Standard Deviation
Strait of Georgia	69.8	99	90.2	6.5
Basin	82	99	93.3	5.4
Harbor	76.5	85.7	82.3	5.1
Passage	69.8	99	89.4	8.6
Rural	83	97.9	90.4	5.2
Urban	79.6	94.8	89.2	5.5
San Juan Archipelago	84.2	100	95.1	3.9
Rural	84.2	100	95.1	3.9
Strait of Juan de Fuca	90.6	105.3	98.1	2.8
Harbor	96	99	97.8	1.3
Rural	90.6	105.3	98.4	3.3
Urban	95	100	97.4	1.7
Admiralty Inlet	88	101	97.1	3.4
Passage	94	101	98.5	2.1
Urban	88	101	96.5	3.6
Whidbey Basin	No results available			
Harbor				
Passage				
Rural				
Central	32	102	94.2	10.2
Basin	68	102	94.7	7.3
Harbor	32	101	87.3	18.4
Passage	97	100	98.7	1
Rural	92	100	98.5	2.6
Urban	57	100	93.4	9.8
Hood Canal	No results available			
Basin				
Rural				

South Sound	78	101.1	93.1	6.1
Basin	90.3	101.1	97.6	3.6
Harbor	79.4	96.9	90	6.7
Passage	90.9	100	97.8	3.4
Rural	79.4	101.1	92.6	5.8
Urban	78	95.96	89.3	5.9
Puget Sound	32	105.3	94.5	7.1
Basin	68	102	94.8	6.4
Harbor	32	101	89.4	13.2
Passage	69.8	101	96.5	5.6
Rural	79.4	105.3	95.3	4.9
Urban	57	101	94.3	6.5



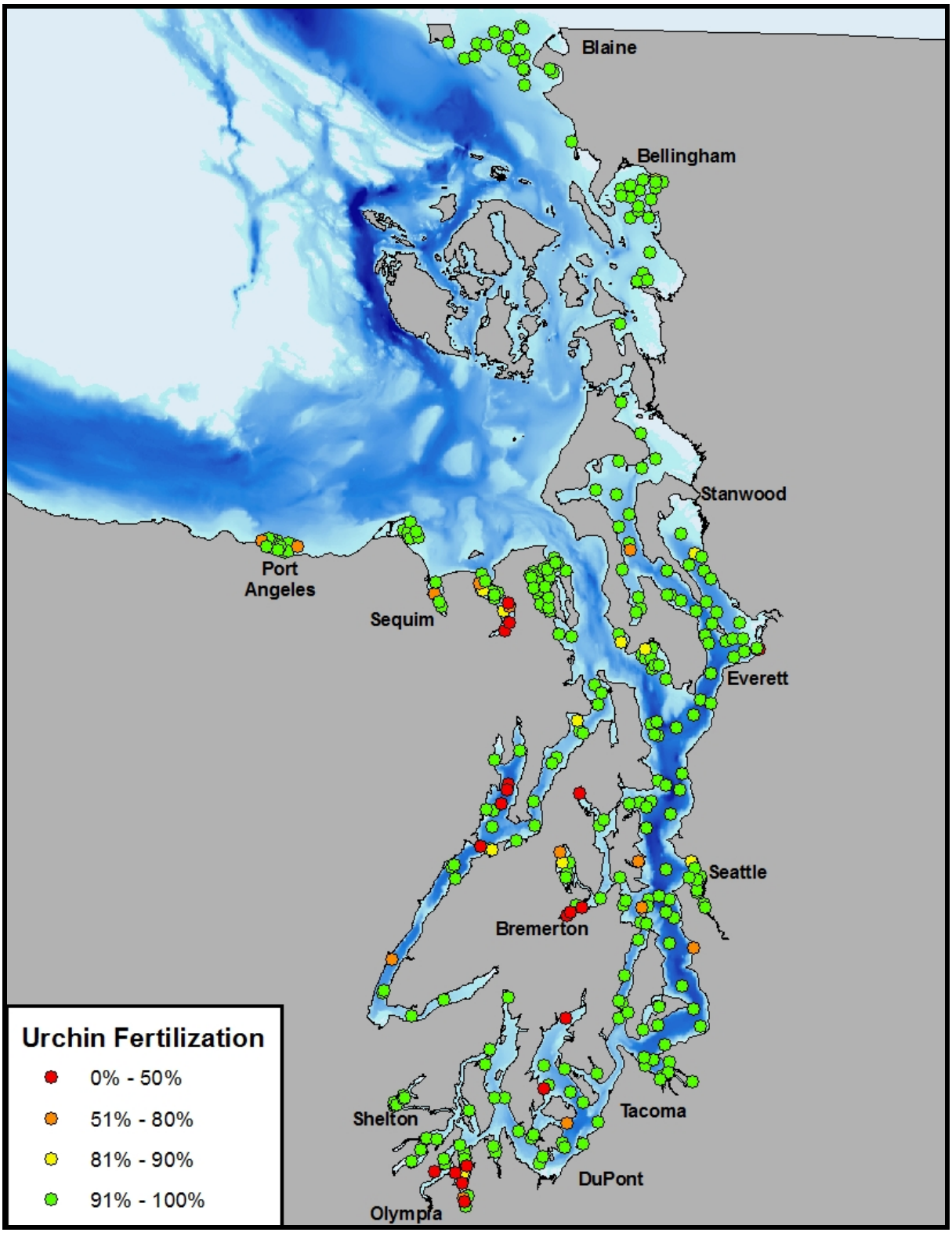
Spatial patterns in sediment toxicity determined with the amphipod *Eohaustorius estuarius* (control-corrected % survival) in the 2004-2014 Puget Sound Sediment Monitoring Program.

Summary results for sea urchin fertilization tests in undiluted porewaters from the 2004-2014 Puget Sound Sediment Monitoring Program.

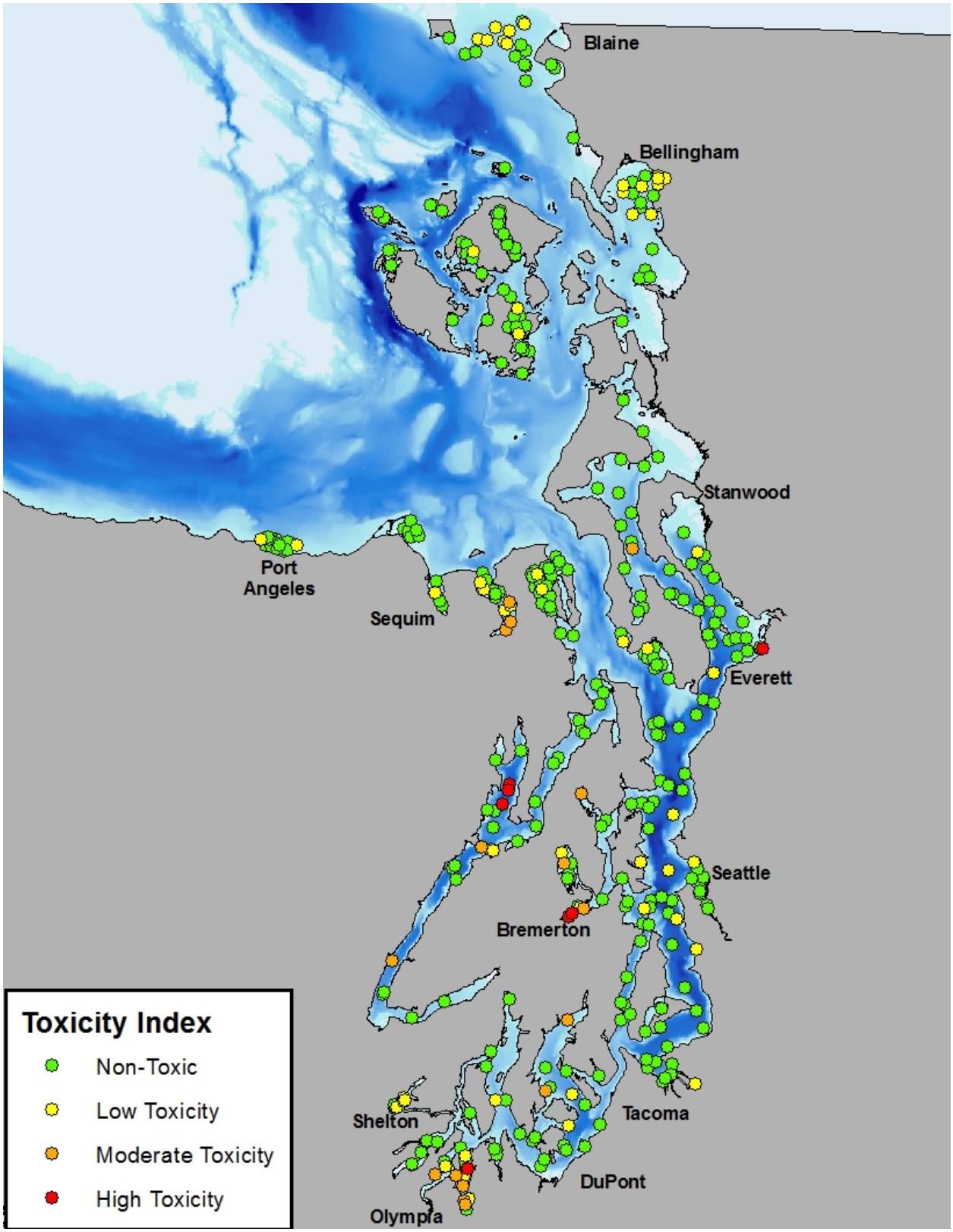
Data are expressed as mean percent fertilization, percentage of control response. Test performed with *Strongylocentrotus purpuratus*.

Region Stratum	Minimum	Maximum	Mean	Standard Deviation
Strait of Georgia	89.6	111.4	107.9	4.5
Basin	108.0	111.4	110.8	0.9
Harbor	89.6	108.3	97.0	9.9
Passage	106.7	108.2	107.5	0.5
Rural	107.6	108.2	107.9	0.2
Urban	100.1	111.4	107.5	3.7
San Juan Archipelago	No results available			
Rural				
Strait of Juan de Fuca	0.0	107.9	86.7	28.0
Harbor	68.8	101.0	92.7	13.8
Rural	0.0	107.9	82.1	34.6
Urban	65.9	100.4	94.0	9.7
Admiralty Inlet	82.6	101.2	98.5	3.4
Passage	82.6	101.2	96.8	5.4
Urban	93.9	101.0	99.2	1.7
Whidbey Basin	3.3	116.1	103.6	18.2
Harbor	3.3	103.7	70.1	57.8
Passage	74.8	115.9	103.4	9.0
Rural	86.7	116.1	108.3	7.5
Central	1.2	100.7	93.1	21.8
Basin	56.2	100.6	98.6	8.0
Harbor	1.4	100.5	76.2	39.0
Passage	99.0	100.7	100.1	0.6
Rural	60.0	100.5	96.0	12.7
Urban	1.2	100.7	90.7	26.0
Hood Canal	0.0	99.4	83.7	29.8
Basin	47.4	99.4	91.6	13.2
Rural	0.0	99.4	65.4	47.4
South Sound	0.0	100.4	86.0	28.5
Basin	53.0	98.6	92.1	15.8
Harbor	0.0	100.2	82.4	34.4
Passage	35.8	100.0	89.3	23.6
Rural	0.0	100.4	91.8	23.4

Region Stratum	Minimum	Maximum	Mean	Standard Deviation
Urban	0.0	100.2	64.8	42.2
Puget Sound	0.0	116.1	94.1	23.0
Basin	47.4	111.4	98.0	12.1
Harbor	0.0	108.3	81.7	34.2
Passage	35.8	115.9	99.9	11.1
Rural	0.0	116.1	92.3	28.6
Urban	0.0	111.4	93.8	21.4



Spatial patterns in sediment toxicity determined with the *Strongylocentrotus purpuratus* (control-corrected % survival) in the 2004-2014 Puget Sound Sediment Monitoring Program.



Spatial patterns of toxicity in the 2004-2014 Puget Sound Sediment Monitoring Program as measured with the Toxicity Index (Dutch et al., 2014).

Comparisons between Regions, Strata, and Surveys

Incidence and spatial extent of toxicity in the eight sediment monitoring regions and all of Puget Sound, by survey.

Monitoring Region	Year(s) sampled	Numbers of Samples	Sea Urchin Fertilization Test		Amphipod Survival Test		
			Incidence (% of stations)	Spatial Extent (% of area)	Test Species	Incidence (% of stations)	Spatial Extent (% of area)
Strait of Georgia	1997	61	8.2	2.5	*Ampelisca abdita*	0.0	0.0
	2006	40	0.0	0.0	*Eohaustorius estuarius*	7.5	5.5
San Juan Islands	2002-2003	30	3.3	3.3	*Eohaustorius estuarius*	3.3	3.3
	2012	No urchin test results for 2012			*Eohaustorius estuarius*	0.0	0.0
Eastern Strait of Juan de Fuca	2002-2003	30	16.7	22.1	*Eohaustorius estuarius*	0.0	0.0
	2013	40	20.0	22.5	*Eohaustorius estuarius*	0.0	0.0
Admiralty Inlet	1998-2003	30	6.7	11.1	*Ampelisca abdita*, *Eohaustorius estuarius*	0.0	0.0
	2014	43	0.0	0.0	*Eohaustorius estuarius*	0.0	0.0
Whidbey Basin	1997	39	25.6	6.0	*Ampelisca abdita*	0.0	0.0
	2007	40	5.0	3.3	No amphipod test results for 2007		
Central Puget Sound	1998-1999	128	7.8	0.6	*Ampelisca abdita*	0.8	0.2
	2008-2009	80	10.0	4.6	*Eohaustorius estuarius*	5.0	3.0
Hood Canal	1999	21	14.3	11.7	*Ampelisca abdita*	0.0	0.0
	2004	30	16.7	17.7	No amphipod test results for 2004		
South Puget Sound	1999	42	9.5	3.0	*Ampelisca abdita*	0.0	0.0
	2011	55	16.4	12.0	*Eohaustorius estuarius*	5.5	3.1
All of Puget Sound	1997-2003	381	10.5	4.7	*Ampelisca abdita*, *Eohaustorius estuarius*	0.5	0.2
	2004-2014	368	8.7	6.7	*Eohaustorius estuarius*	2.7	2.3

Incidence and spatial extent of toxicity in the five sediment monitoring strata and all of Puget Sound in the Baseline (1997-2003) and Second Round (2004-2014) surveys.

Monitoring Strata	Sampling Event	Numbers of Samples	Total Area	Sea Urchin Fertilization Test		Amphipod Survival	
				Incidence (% of stations)	Spatial Extent (% of area)	Incidence (% of stations)	Spatial Extent (% of area)
Basin	Baseline	42	890.5	0.0	0.0	0.0	0.0
	Second Round	72	822.0	5.6	5.3	1.4	1.9
Harbor	Baseline	63	21.2	30.2	18.8	0.0	0.0
	Second Round	33	19.7	24.2	26.2	12.1	13.1
Passage	Baseline	61	491.7	4.9	1.8	1.6	0.2
	Second Round	53	467.5	3.8	3.9	1.9	3.3
Rural	Baseline	129	750.5	11.6	12.3	0.8	0.4
	Second Round	135	762.2	8.9	8.9	0.7	1.0
Urban	Baseline	86	140.3	3.5	1.4	0.0	0.0
	Second Round	75	136.2	8.0	9.3	4.0	6.3
Puget Sound	Baseline	381	2294.6	10.2	4.5	0.3	0.1
	Second Round	368	2207.6	8.7	6.7	2.7	2.3

Incidence and spatial extent of toxicity, as measured with the Toxicity Index (Dutch et al., 2014), in eight sediment monitoring regions and all of Puget Sound, for each the Baseline (1997-2003) and Second Round (2004-2014) surveys.

Sediment Toxicity Index Category	Baseline				Second Baseline			
	Stations		Area		Stations		Area	
	No.	(%)	km^2	(%)	No.	(%)	km^2	(%)
Strait of Georgia	61	(100.0)	386.9	(100.0)	40	(100.0)	360.6	(100.0)
Non-Toxic	56	(91.8)	377.4	(97.5)	24	(60.0)	237.3	(65.8)
Low Toxicity	2	(3.3)	4.8	(1.2)	16	(40.0)	123.3	(34.2)
Moderate Toxicity	3	(4.9)	4.8	(1.2)	0	(0.0)	0.0	(0.0)
High Toxicity	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)
San Juan Archipelago	30	(100.0)	80.7	(100.0)	40	(100.0)	79.5	(100.0)
Non-Toxic	28	(93.3)	75.4	(93.3)	37	(92.5)	73.5	(92.5)
Low Toxicity	1	(3.3)	2.7	(3.3)	3	(7.5)	6.0	(7.5)
Moderate Toxicity	1	(3.3)	2.7	(3.3)	0	(0.0)	0.0	(0.0)
High Toxicity	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)
E. Strait of Juan de Fuca	30	(100.0)	61.8	(100.0)	40	(100.0)	67.8	(100.0)
Non-Toxic	25	(83.3)	48.1	(77.9)	30	(75.0)	48.0	(70.8)
Low Toxicity	3	(10.0)	8.2	(13.3)	7	(17.5)	13.0	(19.1)
Moderate Toxicity	2	(6.7)	5.5	(8.8)	3	(7.5)	6.8	(10.1)
High Toxicity	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)
Admiralty Inlet	30	(100.0)	69.2	(100.0)	43	(100.0)	66.5	(100.0)
Non-Toxic	28	(93.3)	61.5	(88.9)	39	(90.7)	58.9	(88.5)
Low Toxicity	1	(3.3)	3.8	(5.5)	4	(9.3)	7.6	(11.5)
Moderate Toxicity	1	(3.3)	3.84	(5.5)	0	(0.0)	0.0	(0.0)
High Toxicity	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)
Whidbey Basin	39	(100.0)	338.1	(100.0)	40	(100.0)	353.3	(100.0)
Non-Toxic	29	(74.4)	317.8	(94.0)	37	(92.5)	333.4	(94.2)
Low Toxicity	3	(7.7)	19.7	(5.8)	1	(2.5)	8.2	(2.3)
Moderate Toxicity	7	(17.9)	0.6	(0.2)	1	(2.5)	11.5	(3.3)
High Toxicity	0	(0.0)	0.0	(0.0)	1	(2.5)	0.3	(0.1)
Central	128	(100.0)	683.9	(100.0)	80	(100.0)	667.4	(100.0)
Non-Toxic	113	(88.3)	677.8	(99.1)	64	(80.0)	568.9	(85.2)
Low Toxicity	11	(8.6)	3.6	(0.5)	11	(13.8)	89.9	(13.5)
Moderate Toxicity	4	(3.1)	2.5	(0.4)	3	(3.8)	6.5	(1.0)
High Toxicity	0	(0.0)	0.0	(0.0)	2	(2.5)	2.0	(0.3)
Hood Canal	21	(100.0)	331.7	(100.0)	30	(100.0)	294.8	(100.0)
Non-Toxic	18	(85.7)	293.0	(88.3)	24	(80.0)	233.5	(79.2)
Low Toxicity	1	(4.8)	1.4	(0.4)	1	(3.3)	9.2	(3.1)
Moderate Toxicity	2	(9.5)	37.4	(11.3)	2	(6.7)	18.5	(6.3)
High Toxicity	0	(0.0)	0.0	(0.0)	3	(10.0)	33.7	(11.4)
South Sound	42	(100.0)	341.6	(100.0)	55	(100.0)	317.7	(100.0)
Non-Toxic	38	(90.5)	331.3	(97.0)	36	(65.5)	221.5	(69.7)
Low Toxicity	1	(2.4)	5.7	(1.7)	11	(20.0)	67.5	(21.3)

Sediment Toxicity Index Category	Baseline				Second Baseline			
	Stations		Area		Stations		Area	
	No.	(%)	km^2	(%)	No.	(%)	km^2	(%)
Moderate Toxicity	3	(7.1)	4.6	(1.3)	7	(12.7)	26.6	(8.4)
High Toxicity	0	(0.0)	0.0	(0.0)	1	(1.8)	2.1	(0.7)
Total Study Area	381	(100.0)	2294.1	(100.0)	368	(100.0)	2207.5	(100.0)
Non-Toxic	335	(87.9)	2182.3	(95.1)	291	(79.1)	1774.9	(80.4)
Low Toxicity	23	(6.0)	49.84	(2.2)	54	(14.7)	324.75	(14.7)
Moderate Toxicity	23	(6.0)	61.93	(2.7)	16	(4.3)	69.94	(3.2)
High Toxicity	0	(0.0)	0	(0.0)	7	(1.9)	37.96	(1.7)

Incidence and spatial extent of toxicity, as measured with the Toxicity Index (Dutch et al., 2014), in five sediment monitoring strata and all of Puget Sound, for each the Baseline (1997-2003) and Second Round (2004-2014) surveys.

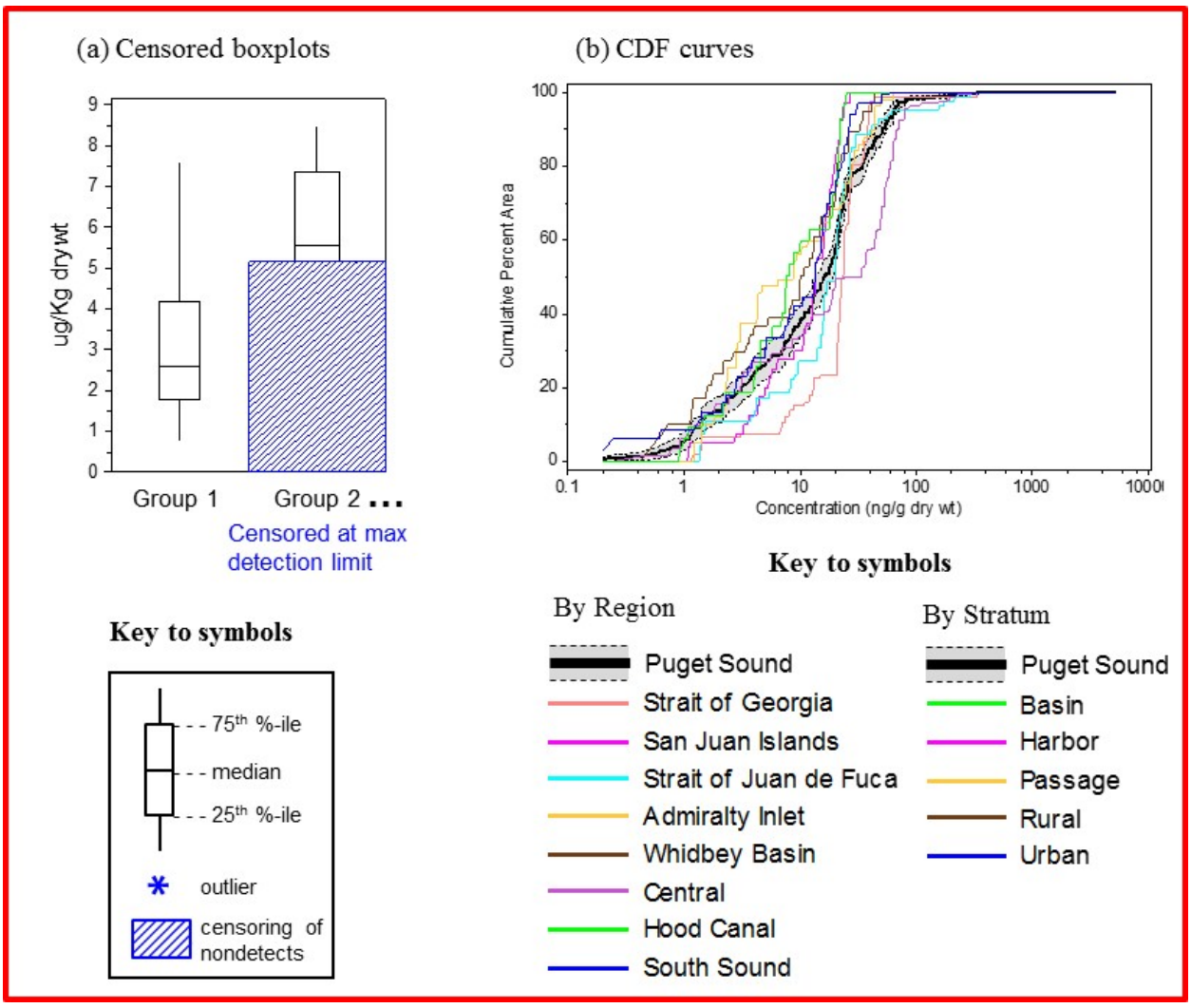
Sediment Toxicity Index Category	Baseline				Second Round			
	Stations		Area		Stations		Area	
	No.	(%)	km^2	(%)	No.	(%)	km^2	(%)
Basin	42	(100.0)	890.5	(100.0)	72	(100.0)	822.0	(100.0)
Non-Toxic	42	(100.0)	890.5	(100.0)	59	(81.9)	680.6	(82.8)
Low Toxicity	0	(0.0)	0.0	(0.0)	11	(15.3)	122.9	(15.0)
Moderate Toxicity	0	(0.0)	0.0	(0.0)	2	(2.8)	18.5	(2.2)
High Toxicity	0	(0.0)	0.0	(0.0)	0	(0.0)	0.0	(0.0)
Harbor	63	(100.0)	21.2	(100.0)	33	(100.0)	19.7	(100.0)
Non-Toxic	41.00	(65.1)	16.6	(78.3)	18	(54.5)	10.0	(50.9)
Low Toxicity	10.00	(15.9)	2.0	(9.4)	9	(27.3)	6.2	(31.5)
Moderate Toxicity	12.00	(19.0)	2.6	(12.1)	3	(9.1)	1.3	(6.3)
High Toxicity	0	(.0)	0.0	(.0)	3	(9.1)	2.2	(11.3)
Passage	61	(100.0)	491.7	(100.0)	53	(100.0)	467.5	(100.0)
Non-Toxic	57.00	(93.4)	481.8	(98.0)	47	(88.7)	412.5	(88.2)
Low Toxicity	2.00	(3.3)	4.9	(1.0)	4	(7.5)	36.7	(7.8)
Moderate Toxicity	2.00	(3.3)	4.9	(1.0)	2	(3.8)	18.3	(3.9)
High Toxicity	0.0	(.0)	0.0	(.0)	0	(0.0)	0.0	(0.0)
Rural	129	(100.0)	750.5	(100.0)	135	(100.0)	762.2	(100.0)
Non-Toxic	113.00	(87.6)	655.3	(87.3)	107	(79.3)	571.8	(75.0)
Low Toxicity	9.00	(7.0)	42.3	(5.6)	20	(14.8)	134.4	(17.6)
Moderate Toxicity	7.00	(5.4)	52.9	(7.0)	5	(3.7)	22.2	(2.9)
High Toxicity	0	(0.0)	0.0	(0.0)	3	(2.2)	33.7	(4.4)
Urban	86	(100.0)	140.2	(100.0)	75	(100.0)	136.2	(100.0)
Non-Toxic	82	(95.3)	138.0	(98.4)	61	(81.3)	103.7	(76.1)
Low Toxicity	2	(2.3)	0.7	(.5)	9	(12.0)	20.8	(15.3)
Moderate Toxicity	2	(2.3)	1.6	(1.1)	4	(5.3)	9.7	(7.1)
High Toxicity	0	(0.0)	0.0	(0.0)	1	(1.3)	2.1	(1.5)
Puget Sound	381	(100.0)	2294.1	(100.0)	368	(100.0)	2207.6	(100.0)
Non-Toxic	335	(87.9)	2182.3	(95.1)	291	(79.1)	1774.9	(80.4)
Low Toxicity	23	(6.0)	49.8	(2.2)	54	(14.7)	324.7	(14.7)
Moderate Toxicity	23	(6.0)	61.9	(2.7)	16	(4.3)	69.9	(3.2)
High Toxicity	0	(0.0)	0.0	(0.0)	7	(1.9)	38.0	(1.7)

Comparisons between Regions and between Strata

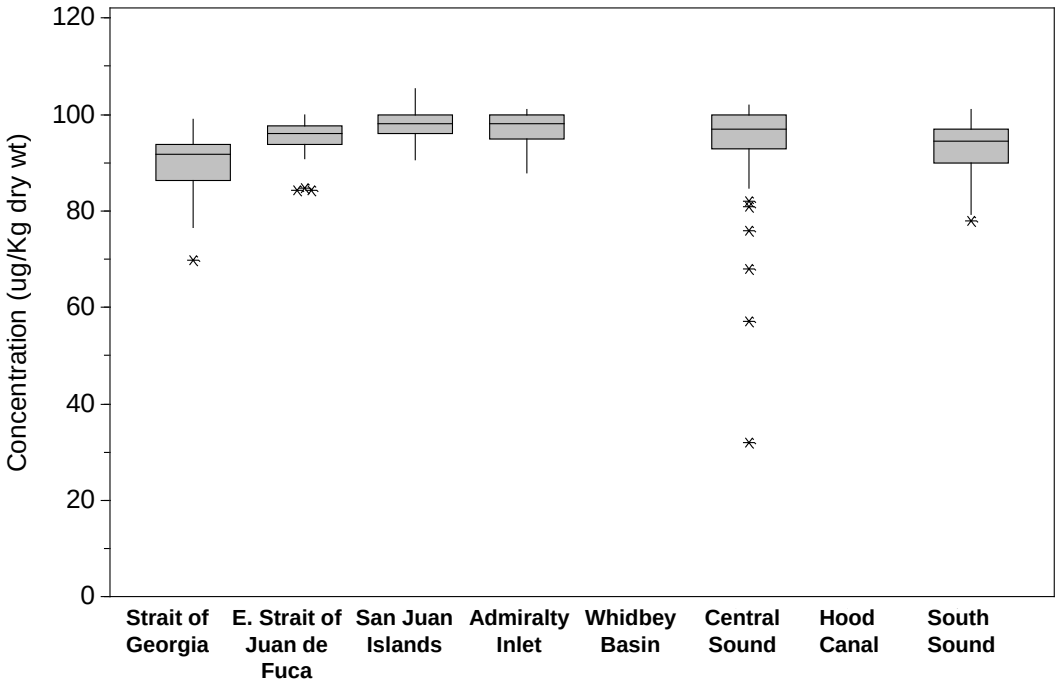
Comparison of amphipod survival and sea urchin fertilization toxicity test results and Toxicity Index values in the 2004-2014 Puget Sound sampling regions and strata. The graphical displays include two types of graphs:

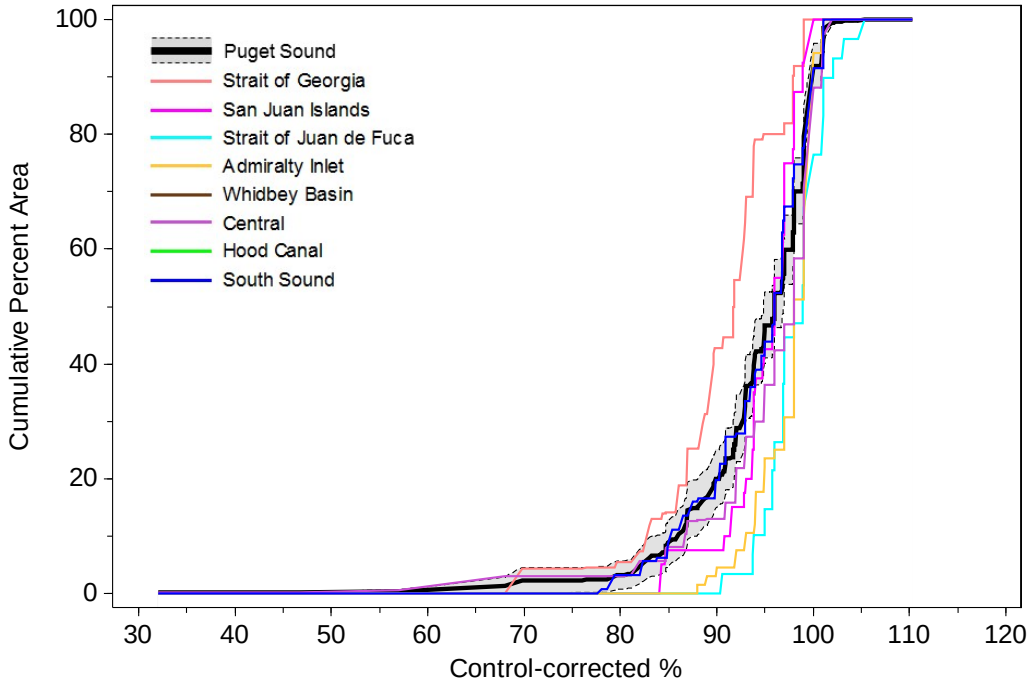
(a) Censored boxplots display the distributions of the data unweighted by sample area.

(b) Cumulative distribution function (CDF) curves display the cumulative distributions of the data weighted by sample area. A 95% confidence interval is given for the whole-Sound CDF. CDFs are not given when there were too few detected values.

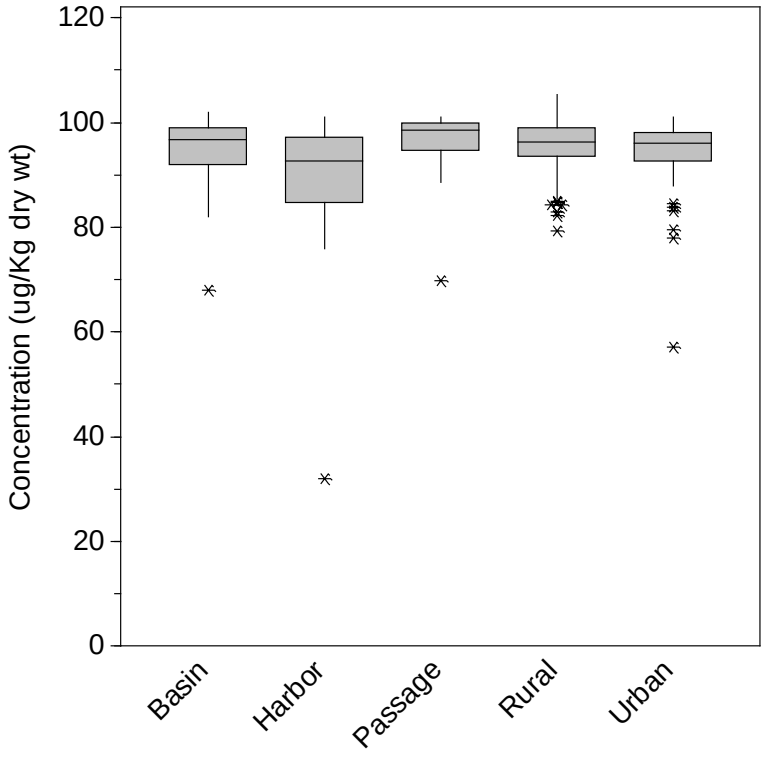


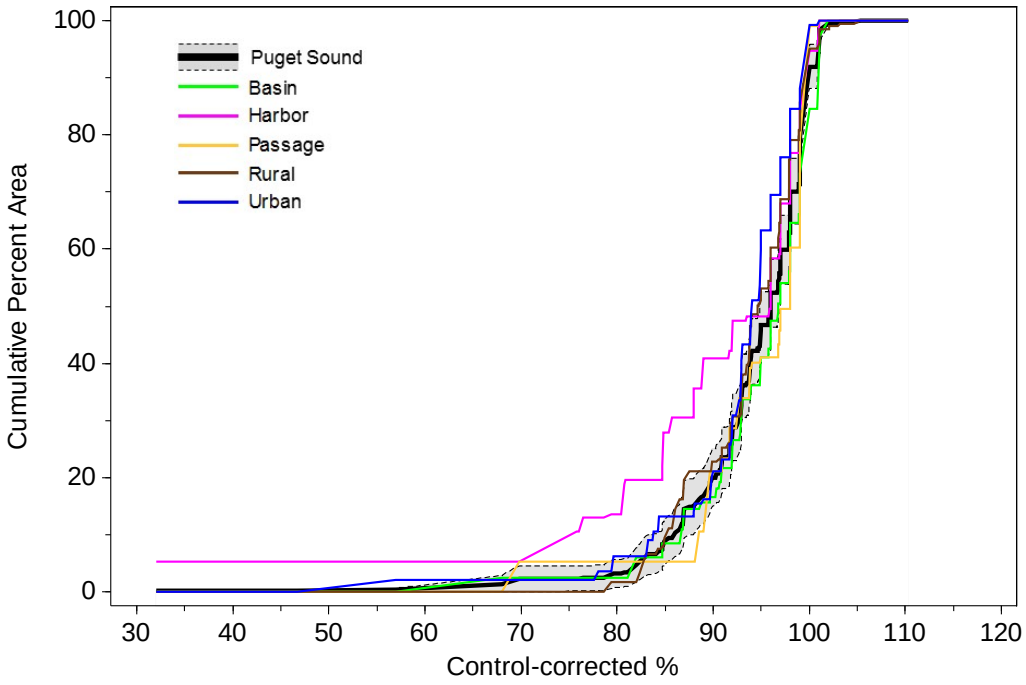
Amphipod Survival by Region



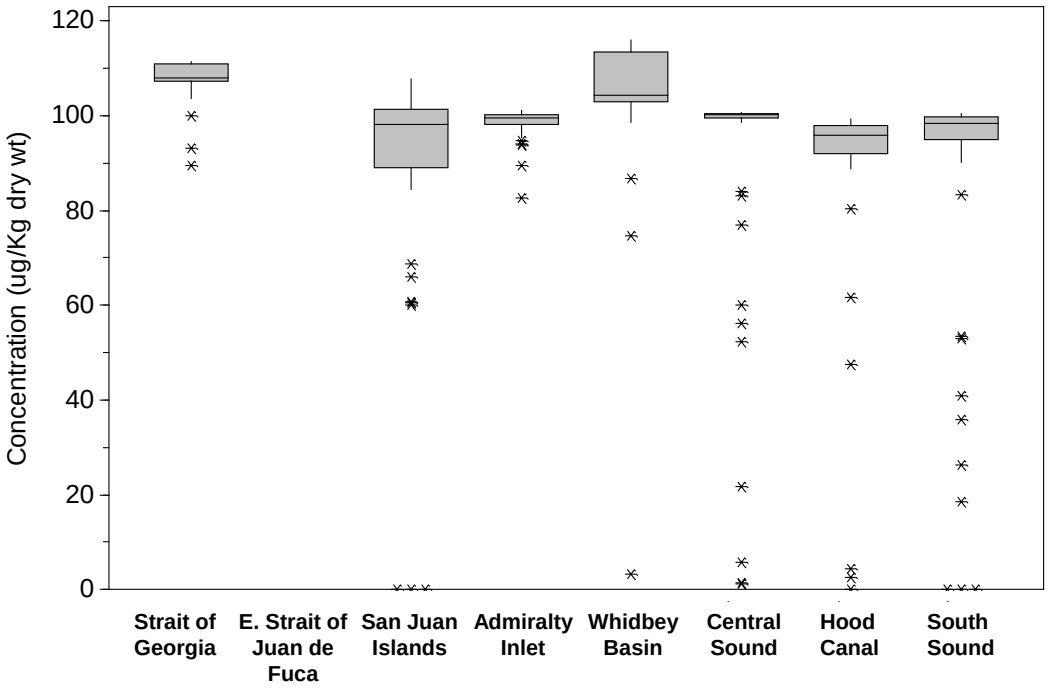


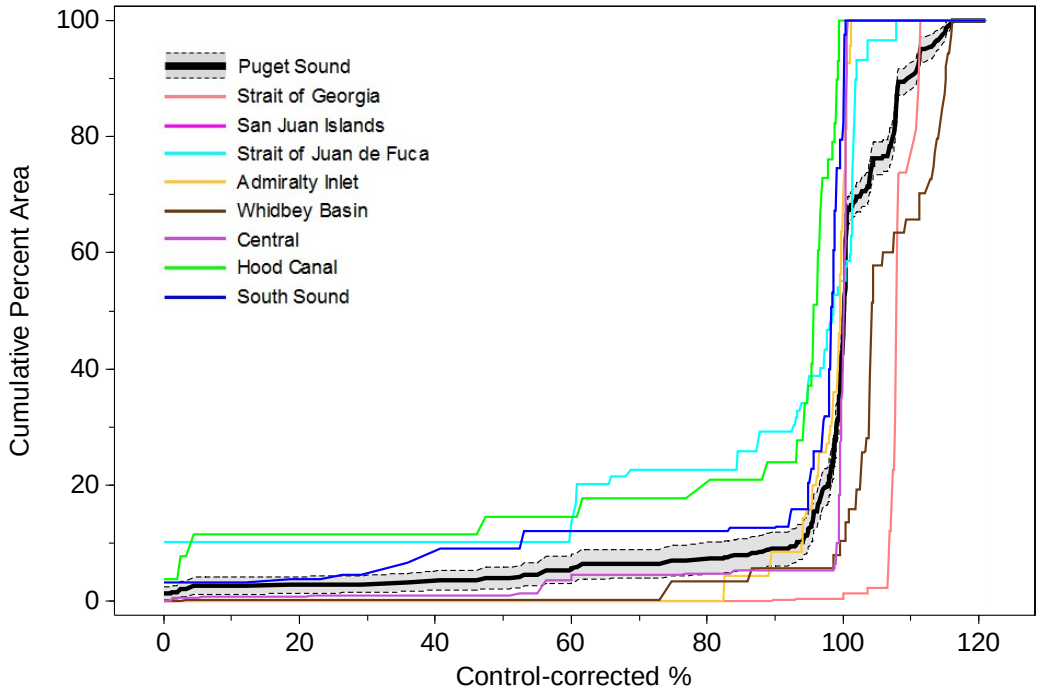
Amphipod Survival by Stratum



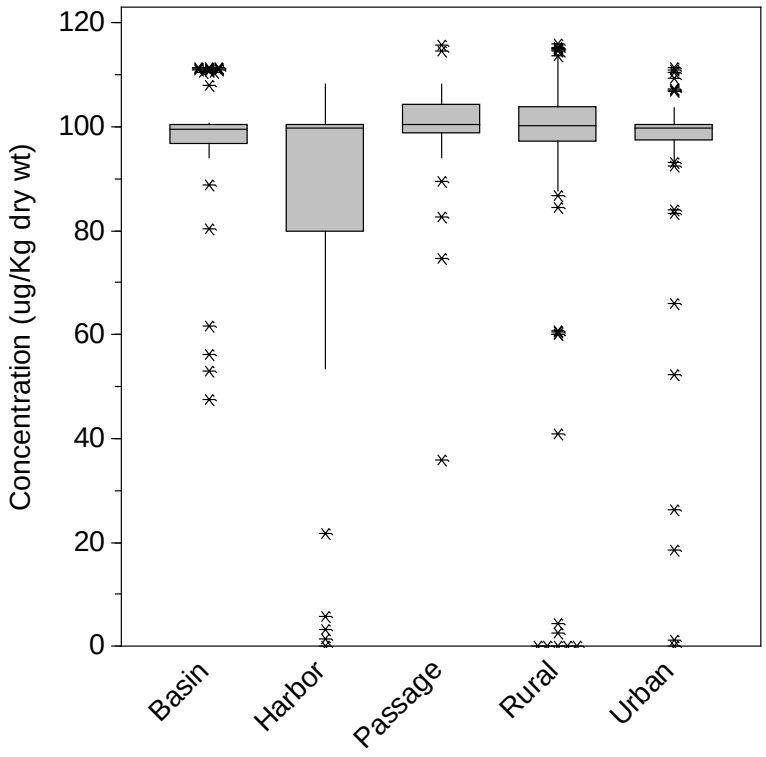


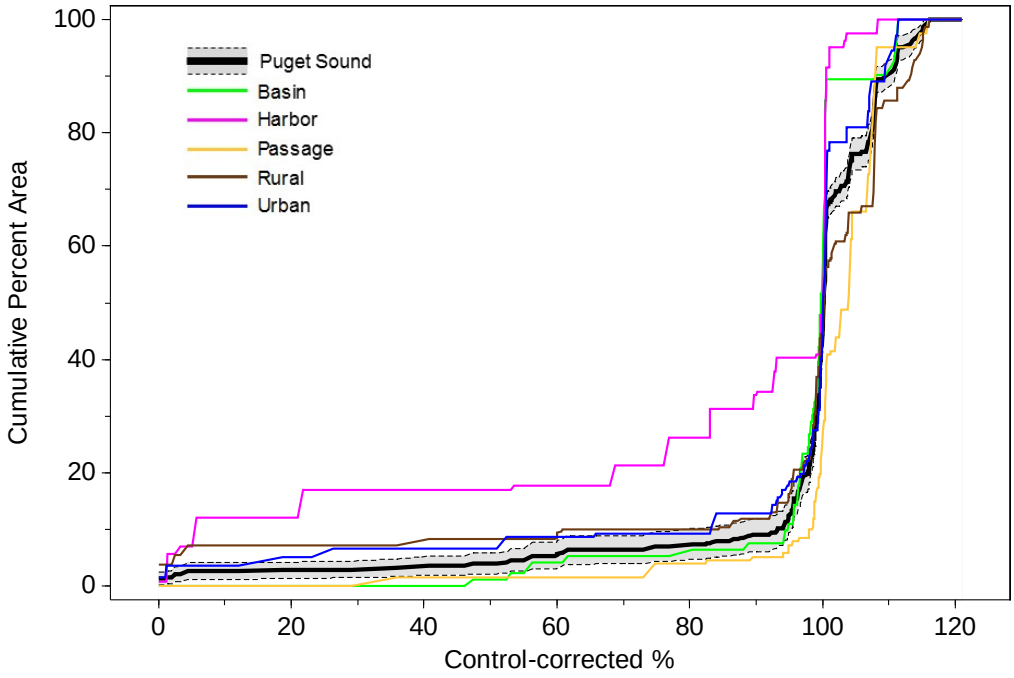
Urchin Fertilization by Region



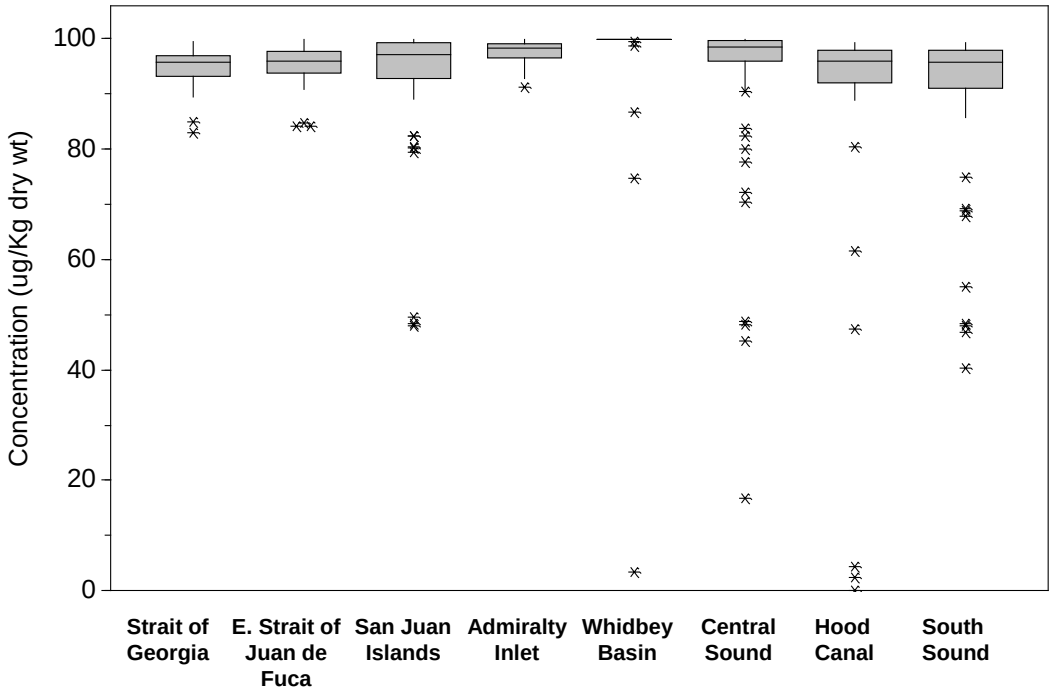


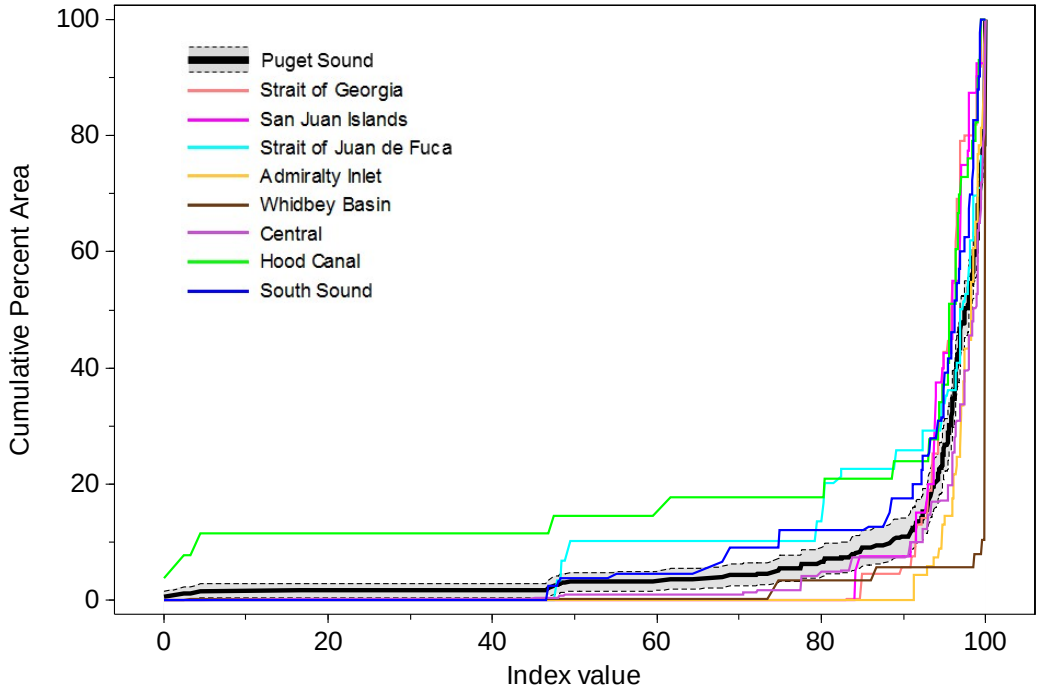
Urchin Fertilization by Stratum



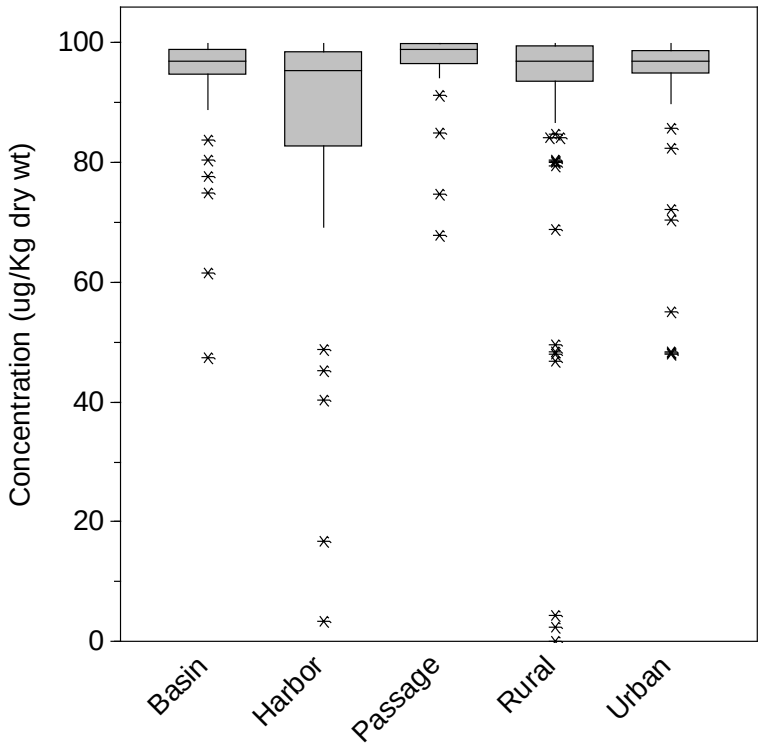


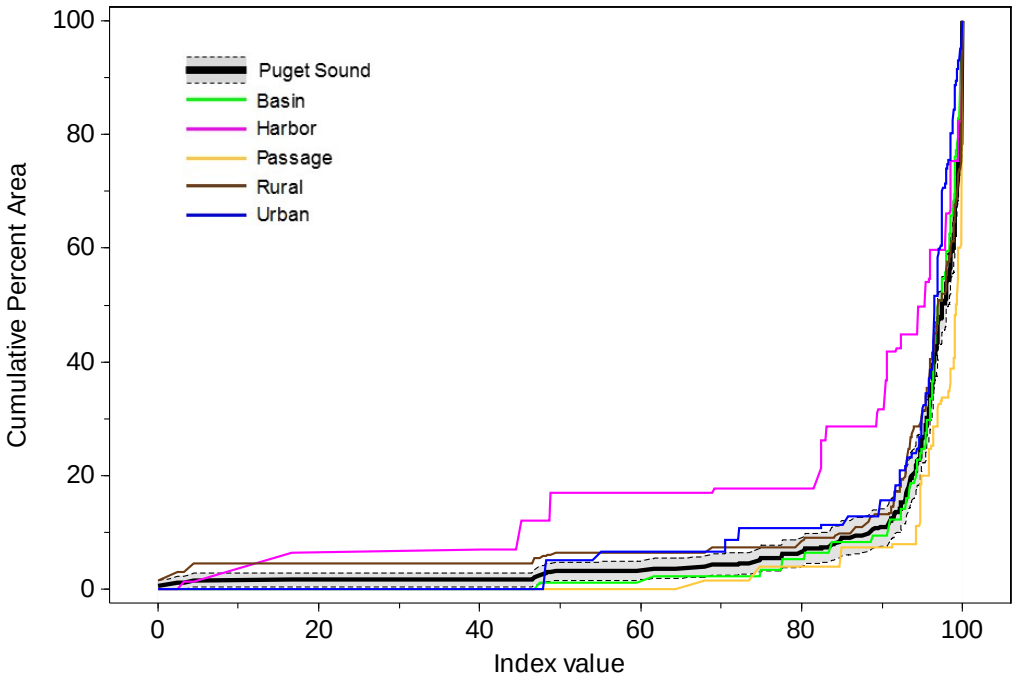
Toxicity Index by Region





Toxicity Index by Stratum





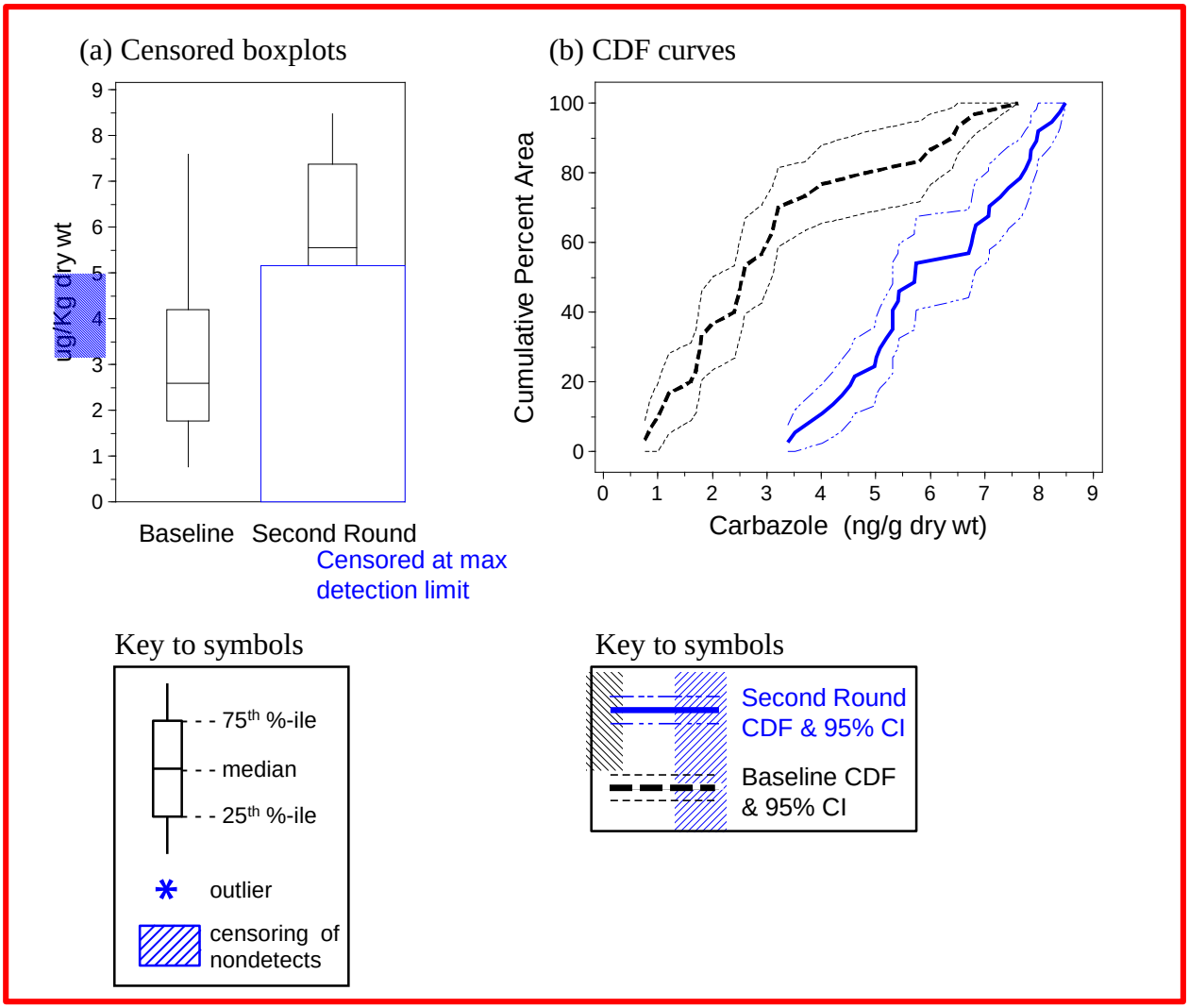
Comparisons of Surveys

Comparison of amphipod survival and sea urchin fertilization toxicity test results and Toxicity Index values in Puget Sound, Baseline vs. Second Round.

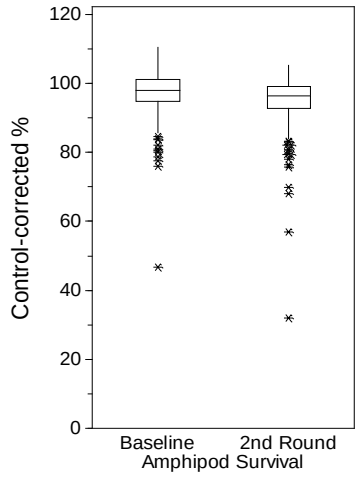
(a) Boxplots display the distributions of the data unweighted by sample area.

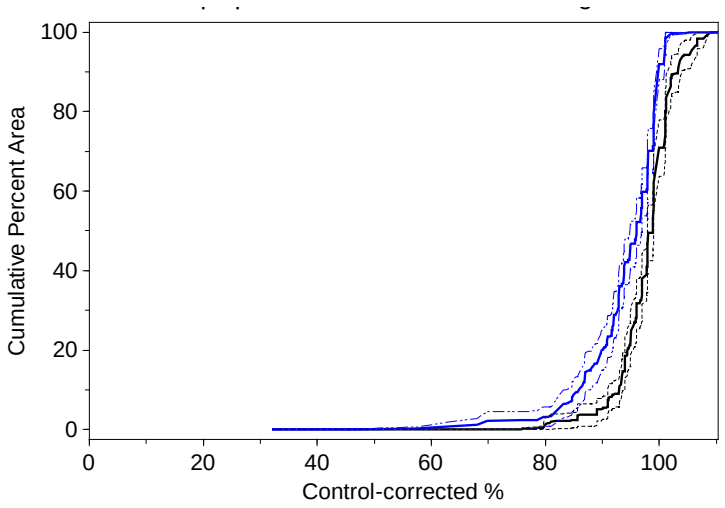
(b) Cumulative distribution function (CDF) curves display the cumulative distributions of the data weighted by sample area.

Note: 95% confidence intervals (CI) are shown in both graph types. Non-overlapping confidence intervals indicate statistically significant differences.

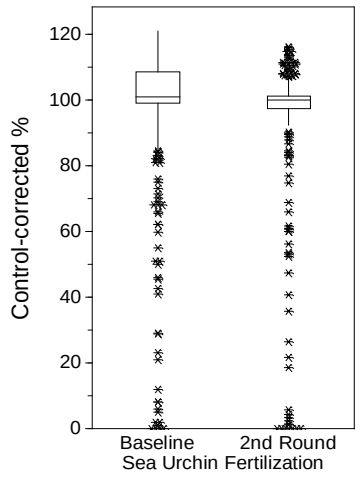


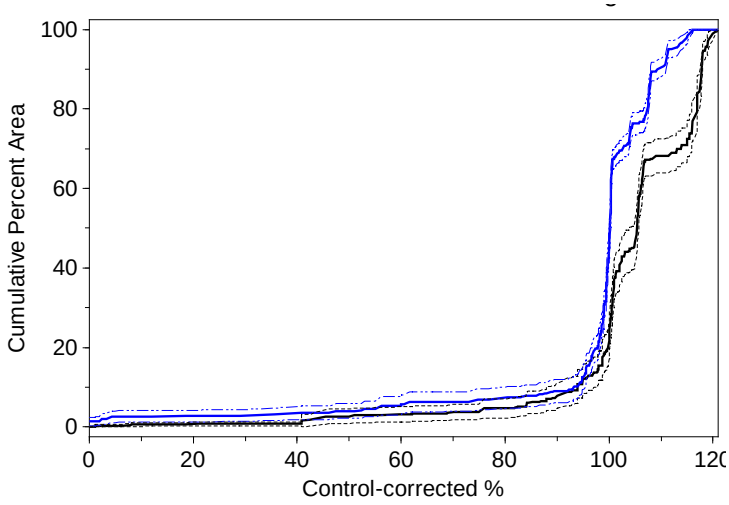
Amphipod Survival



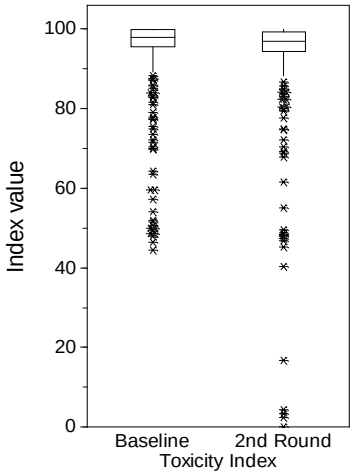


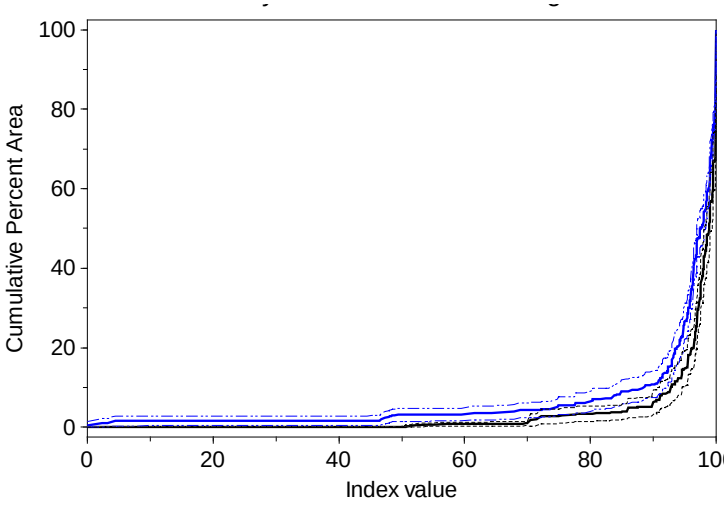
Urchin Fertilization





Toxicity Index





Comparison of Toxicity Index Categories by Survey

Estimated spatial extent (percent of area) and 95% confidence intervals for each of the Toxicity Index categories (Dutch et al., 2014) in the Baseline (1997-2003) and Second Round (2004-2014) surveys.

Sediment Toxicity Index Category	Baseline			Second Round			Difference			* = significantly different (Kincaid, 2015, α = 0.05)
		Confidence Limit			Confidence Limit			Confidence Limit		
	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper	
Non-Toxic	95.13	92.70	97.56	80.04	76.66	85.01	-15.09	-19.12	-9.46	*
Low Toxicity	2.17	0.60	3.75	14.7	10.55	18.00	12.53	8.05	16.14	*
Moderate Toxicity	2.70	0.86	4.54	3.17	1.47	4.86	0.47	-2.03	2.97	
High Toxicity	0.00	n.a.	n.a.	1.72	0.48	2.96	1.72	n.a.	n.a.