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

2004-2014 Puget Sound Marine Sediment Monitoring

Infaunal Community Data Summary

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Statistical Summaries of 9 Benthic Indices

Benthic infaunal indices calculated to characterize the infaunal invertebrate assemblages identified for the 2004-2014 survey of Puget Sound.

Infaunal index	Definition	Calculation
Total abundance	A measure of density equal to the total number of organisms per sample area	Sum of all organisms counted in each sample
Major taxa abundance (5 groups)	A measure of density equal to the total number of organisms in each major taxa group (Annelida, Mollusca, Echinodermata, Arthropoda, Miscellaneous Taxa) per sample area	Sum of all organisms counted in each major taxa group per sample
Taxa richness	Total number of taxa (taxa = lowest level of identification for each organism) per sample area	Sum of all taxa identified in each sample
Pielou's Evenness (J') (Pielou, 1966, 1974)	Relates the observed diversity in benthic assemblages as a proportion of the maximum possible diversity for the data set (the equitability (evenness) of the distribution of individuals among species)	$J' = H'/\log S$, where $H' = -\sum_{i=1}^{S} p_i \log p_i$, where p_i = the proportion of the assemblage that belongs to the i^{th} species ($p_i = n_i/N$, where n_i=the number of individuals in the i^{th} species and N= total number of individuals) and S = the total number of species (H' is the Shannon-Wiener diversity index)
Swartz Dominance Index (SDI) (Swartz et al., 1985)	The minimum number of taxa whose combined abundance accounted for 75 percent of the total abundance in each sample	Sum of the minimum number of taxa whose combined abundance accounted for 75 percent of the total abundance in each sample

Summary results for major taxa abundance calculated for the 2004-2014 Puget Sound Sediment Monitoring Program, by region and stratum.

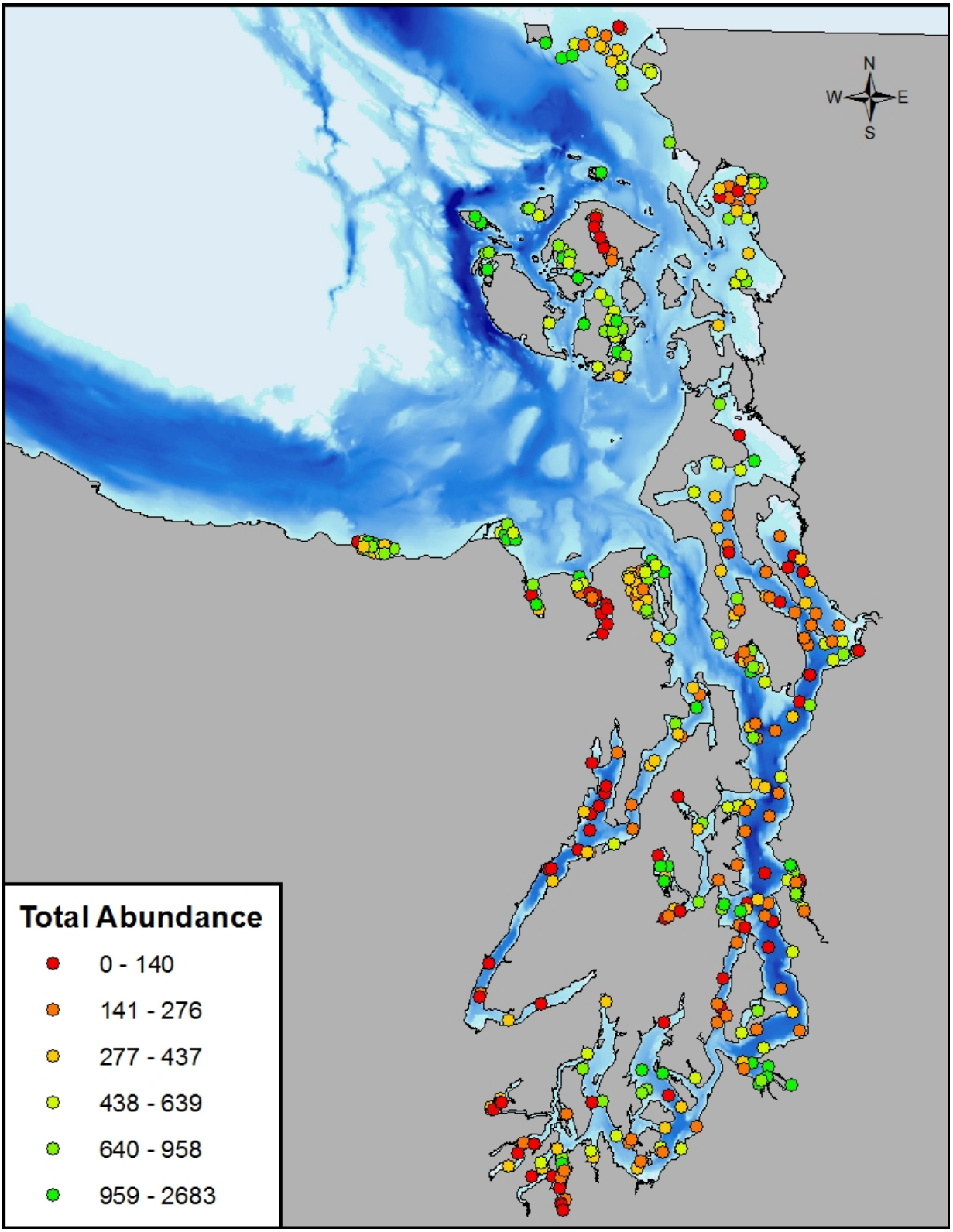
Region	Second Round																			
	Annelida				Mollusca				Arthropoda				Echinodermata				Miscellaneous taxa			
Stratum	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev
Strait of Georgia	36	1647	265.23	333.40	4	1822	146.45	298.12	0	286	77.18	70.61	0	183	33.50	44.05	0	51	5.83	9.15
Basin	37	904	261.00	301.11	40	1822	225.46	481.75	55	286	135.69	64.39	7	109	62.08	36.28	0	51	11.00	13.86
Harbor	414	1647	1074.00	621.09	6	24	14.33	9.07	0	21	10.00	10.54	0	6	2.00	3.46	0	18	6.33	10.12
Passage	81	498	205.38	135.11	14	333	166.88	119.65	5	123	65.38	44.62	0	183	49.00	67.12	0	5	2.88	1.64
Rural	36	183	93.86	60.55	33	594	195.43	216.09	17	224	97.71	66.64	0	42	17.14	16.62	0	10	4.14	4.02
Urban	67	332	188.22	97.20	4	56	20.11	20.48	2	30	9.56	8.80	0	14	1.67	4.64	0	10	2.11	3.06
San Juan Archipelago	27	1063	376.50	246.54	0	1310	229.80	262.71	0	893	107.85	186.69	0	54	3.08	9.76	0	95	8.63	16.09
Rural	27	1063	376.50	246.54	0	1310	229.80	262.71	0	893	107.85	186.69	0	54	3.08	9.76	0	95	8.63	16.09
E. Strait of Juan de Fuca	1	1576	378.38	334.70	1	1072	174.68	209.45	0	283	39.65	72.52	0	12	0.78	2.12	0	35	5.13	7.71
Harbor	58	817	365.80	279.78	12	134	69.80	57.00	1	68	16.20	29.02	0	1	0.20	0.45	1	3	1.40	0.89
Rural	1	1576	306.67	354.01	1	1072	188.67	252.46	0	277	35.00	72.17	0	4	0.54	1.14	0	35	5.92	9.21
Urban	165	969	540.55	275.66	30	434	191.82	130.02	0	283	60.45	85.97	0	12	1.55	3.67	0	19	5.09	5.28
Admiralty Inlet	41	1114	247.93	254.10	13	687	273.51	169.80	0	272	61.42	81.56	0	46	7.30	10.32	0	130	19.95	26.89
Passage	47	627	205.38	178.80	13	687	188.15	179.88	9	272	115.46	98.38	0	46	7.92	11.98	1	130	36.54	36.47
Urban	41	1114	266.37	281.28	108	656	310.50	153.90	0	260	38.00	61.27	0	41	7.03	9.73	0	77	12.77	17.88
Whidbey Basin	18	825	217.18	172.57	2	586	102.10	112.60	0	149	26.75	31.50	0	133	7.65	24.84	0	56	10.93	13.69
Harbor	22	640	383.33	322.02	15	238	127.67	111.52	1	149	66.33	75.51	0	9	5.00	4.58	0	24	14.33	12.66
Passage	44	825	245.60	201.88	2	259	68.33	65.46	4	91	26.87	29.20	0	22	2.87	5.79	0	23	6.87	7.58
Rural	18	420	175.14	109.02	10	586	121.64	134.89	0	73	21.27	21.82	0	133	11.27	33.03	0	56	13.23	16.60
Central	1	2134	232.45	323.29	0	854	164.31	195.10	0	455	64.65	81.97	0	87	8.90	16.67	0	50	9.00	9.79

Region	Second Round																			
	Annelida				Mollusca				Arthropoda				Echinodermata				Miscellaneous taxa			
Stratum	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev
Basin	4	348	103.37	93.23	12	412	103.83	85.15	15	455	62.90	79.46	0	15	2.97	3.73	0	50	9.70	12.92
Harbor	1	1116	288.08	296.13	0	854	217.92	282.07	0	423	74.46	115.93	0	32	5.92	11.46	0	20	5.69	6.79
Passage	17	380	159.30	98.15	18	406	91.00	126.80	9	126	46.00	38.93	0	87	9.80	27.22	4	22	12.20	7.00
Rural	56	566	197.60	153.53	6	677	271.40	245.94	10	236	96.00	67.61	0	66	24.40	23.90	0	31	9.00	9.32
Urban	8	2134	481.24	558.78	0	613	210.18	223.83	0	360	52.76	84.61	0	56	12.00	16.62	0	24	8.41	6.56
Hood Canal	19	266	106.80	72.94	1	405	94.57	104.85	0	405	54.03	83.23	0	10	2.10	3.18	0	69	11.03	17.99
Basin	19	266	109.62	72.66	1	405	117.90	112.96	3	405	74.19	92.75	0	10	2.90	3.49	0	69	14.52	20.45
Rural	19	263	100.22	77.57	1	177	40.11	56.44	0	18	7.00	7.05	0	2	0.22	0.67	0	14	2.89	4.62
South Sound	0	971	195.44	159.70	0	387	51.09	70.38	0	565	61.04	100.34	0	568	44.84	101.75	0	70	11.27	15.71
Basin	183	376	270.25	68.39	2	118	41.88	37.63	10	121	50.00	37.88	0	101	34.38	41.56	1	57	13.75	18.41
Harbor	0	269	145.78	99.09	0	90	27.33	28.04	0	60	22.22	21.10	0	17	4.89	6.47	0	16	4.56	6.13
Passage	93	434	269.14	137.60	11	387	93.29	133.80	2	565	132.71	211.83	0	120	23.57	42.84	2	55	24.00	16.57
Rural	27	971	176.57	210.39	1	238	60.74	71.61	0	340	49.22	79.49	0	176	27.48	51.82	0	70	10.13	16.45
Urban	71	364	166.25	91.45	0	68	22.38	24.12	5	230	87.00	94.65	0	568	168.75	216.58	0	41	8.50	13.98
Grand Total	0	2134	251.90	270.69	0	1822	154.01	201.06	0	893	62.09	97.90	0	568	14.55	46.06	0	130	10.19	15.65
Basin	4	904	152.19	161.57	1	1822	123.01	220.79	3	455	77.90	81.51	0	109	17.11	30.82	0	69	11.79	16.01
Harbor	0	1647	341.15	371.76	0	854	116.79	197.40	0	423	44.79	80.03	0	32	4.33	8.13	0	24	5.58	7.31
Passage	17	825	216.49	161.11	2	687	120.17	133.88	2	565	72.00	99.32	0	183	15.11	35.16	0	130	16.81	23.02
Rural	1	1576	250.88	246.21	0	1310	164.71	215.71	0	893	62.67	118.63	0	176	10.24	28.25	0	95	8.56	13.92
Urban	8	2134	335.23	359.72	0	656	204.77	186.56	0	360	46.45	72.69	0	568	23.96	84.19	0	77	8.92	13.11

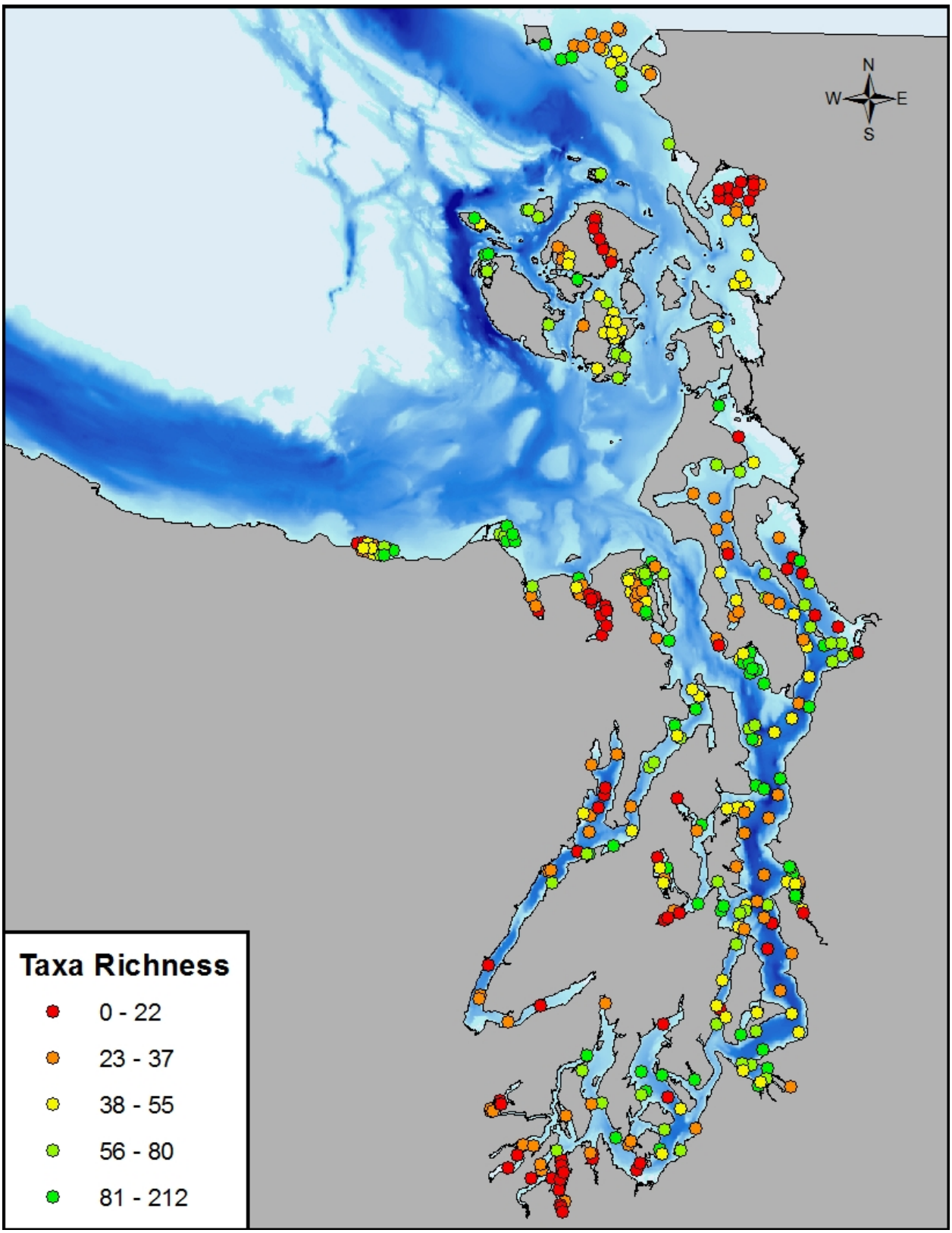
Summary results for total abundance, taxa richness, Pielou's evenness, and Swartz Dominance Index calculated for the 2004-2014 survey of Puget Sound, by region and stratum.

Region	Total Abundance (# organisms/0.1 m^2)				Taxa Richness (# taxa/0.1 m^2)				Pielou's Evenness (J')				Swartz Dominance (SDI) (# taxa)			
Stratum	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev
Strait of Georgia	77	2132	528.18	428.36	14	185	45.35	33.67	0.29	0.83	0.69	0.13	1	31	8.85	6.52
Basin	260	2132	695.23	529.87	32	185	73.62	43.96	0.44	0.81	0.73	0.10	3	31	14.23	8.21
Harbor	472	1681	1106.67	606.75	17	27	22.00	5.00	0.29	0.73	0.50	0.22	1	5	2.67	2.08
Passage	169	733	489.50	192.84	24	53	44.38	10.36	0.60	0.77	0.71	0.06	6	11	8.00	2.07
Rural	101	854	408.29	256.55	23	65	35.29	14.59	0.65	0.83	0.76	0.07	6	10	7.71	1.50
Urban	77	353	221.67	94.03	14	48	21.00	10.40	0.40	0.80	0.61	0.16	1	15	4.78	4.24
San Juan Archipelago	29	1847	725.85	453.96	1	182	53.95	39.13	0.18	0.85	0.63	0.15	1	40	9.05	8.23
Rural	29	1847	725.85	453.96	1	182	53.95	39.13	0.18	0.85	0.63	0.15	1	40	9.05	8.23
E. Strait of Juan de Fuca	4	1897	598.60	488.40	3	144	50.75	37.27	0.32	0.95	0.69	0.13	1	23	8.60	6.22
Harbor	75	955	453.40	326.11	20	46	32.00	12.10	0.59	0.78	0.70	0.08	4	9	6.20	1.92
Rural	4	1897	536.79	546.09	3	138	44.00	36.32	0.32	0.95	0.68	0.14	1	23	6.92	5.00
Urban	281	1275	799.45	371.15	34	144	74.00	38.01	0.52	0.85	0.71	0.12	3	22	13.36	7.57
Admiralty Inlet	149	1809	610.12	411.45	24	216	77.14	51.81	0.25	0.92	0.68	0.15	1	46	15.98	13.67
Passage	149	1106	553.46	305.59	24	189	92.23	56.83	0.25	0.92	0.74	0.19	1	46	24.85	17.18
Urban	225	1809	634.67	452.18	26	216	70.60	49.04	0.40	0.86	0.66	0.13	2	37	12.13	9.91
Whidbey Basin	38	984	364.60	268.31	11	120	47.65	27.31	0.44	0.88	0.72	0.10	3	29	10.80	7.27
Harbor	38	949	596.67	489.30	11	120	80.67	60.50	0.73	0.87	0.81	0.07	5	27	17.67	11.37
Passage	56	984	350.53	270.33	19	103	41.13	22.19	0.44	0.88	0.70	0.11	3	23	8.73	6.37
Rural	70	939	342.55	232.03	16	96	47.59	22.85	0.56	0.87	0.72	0.08	3	29	11.27	6.98
Central	1	2683	479.31	480.98	1	119	53.04	28.28	0.36	0.91	0.72	0.12	1	41	11.64	8.10
Basin	57	752	282.77	178.32	19	115	53.50	29.50	0.57	0.91	0.76	0.10	4	41	14.23	9.99
Harbor	1	2415	592.08	653.63	1	95	41.46	33.03	0.44	0.76	0.65	0.11	1	17	6.92	5.47
Passage	50	752	318.30	237.59	19	85	52.80	22.07	0.65	0.89	0.78	0.08	4	25	14.80	7.02
Rural	86	1111	598.40	334.49	36	95	60.90	20.96	0.54	0.86	0.70	0.11	4	18	11.20	4.89

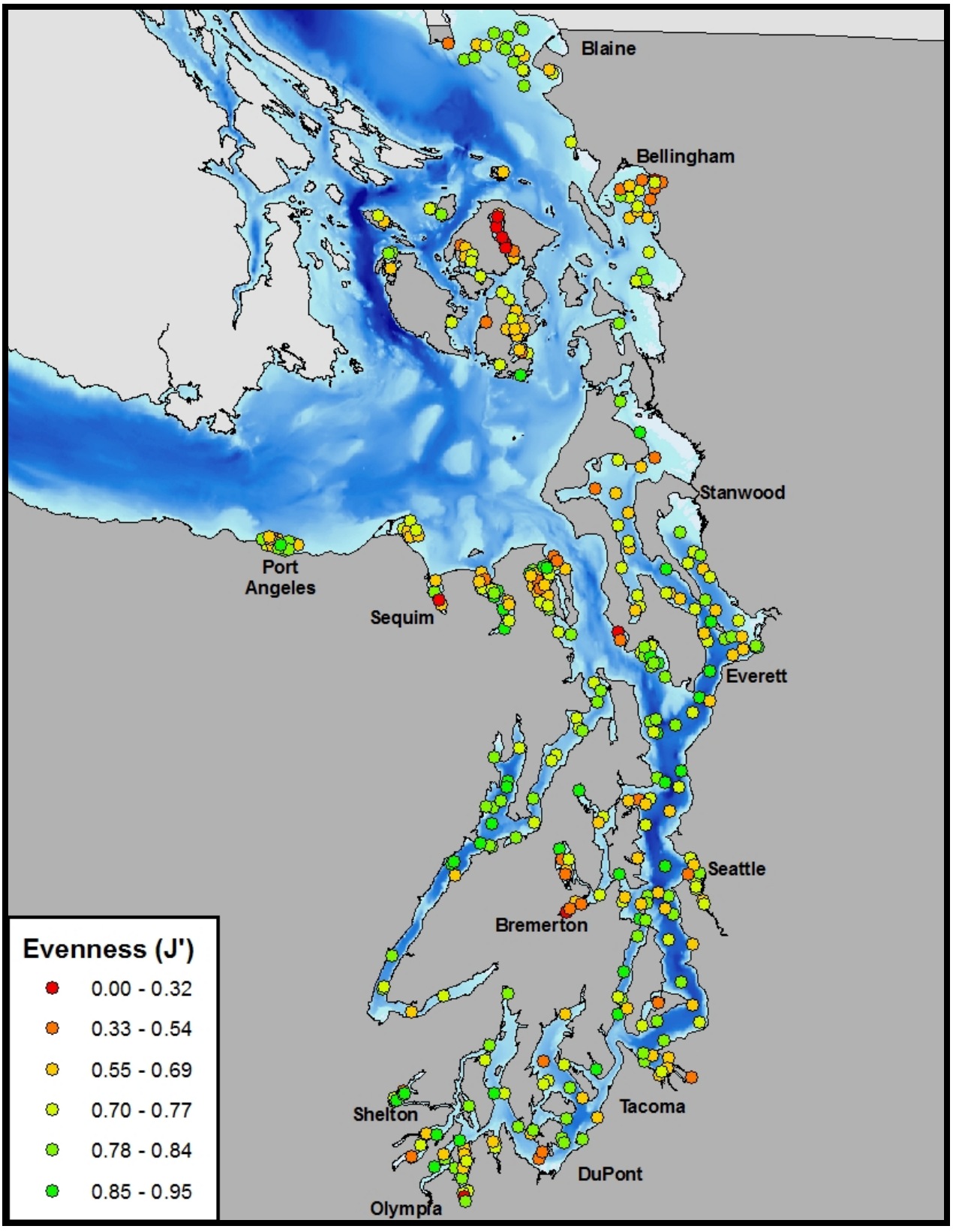
Region	Total Abundance (# organisms/0.1 m^2)				Taxa Richness (# taxa/0.1 m^2)				Pielou's Evenness (J')				Swartz Dominance (SDI) (# taxa)			
Stratum	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max	Mean	StdDev
Urban	8	2683	764.59	689.34	4	119	56.59	29.53	0.36	0.88	0.67	0.15	2	22	9.06	5.96
Hood Canal	20	1073	268.53	235.20	4	142	45.03	29.66	0.60	0.95	0.79	0.07	2	29	11.33	6.01
Basin	34	1073	319.14	256.91	14	142	54.24	29.81	0.68	0.95	0.79	0.06	6	29	13.43	5.67
Rural	20	337	150.44	114.50	4	55	23.56	15.03	0.60	0.87	0.77	0.09	2	14	6.44	3.47
South Sound	0	1451	363.67	291.08	0	116	39.13	27.92	0.40	0.88	0.72	0.11	0	29	9.11	6.39
Basin	227	638	410.25	145.06	16	116	57.38	37.46	0.42	0.81	0.69	0.15	2	29	13.13	10.03
Harbor	0	363	204.78	142.28	0	75	29.11	22.72	0.72	0.83	0.78	0.04	0	20	8.00	5.98
Passage	151	1451	542.71	463.06	24	86	59.71	28.23	0.69	0.84	0.77	0.06	6	24	13.43	6.19
Rural	32	1062	324.13	259.83	8	102	34.87	24.59	0.40	0.88	0.72	0.12	2	17	7.87	4.29
Urban	121	994	452.88	363.64	16	64	26.38	16.00	0.53	0.84	0.68	0.13	3	19	6.13	5.36
Grand Total	0	2683	492.74	421.59	0	216	51.55	35.83	0.18	0.95	0.70	0.13	0	46	10.74	8.42
Basin	34	2132	382.01	323.25	14	185	57.78	33.59	0.42	0.95	0.76	0.10	2	41	13.88	8.44
Harbor	0	2415	512.64	529.20	0	120	38.45	31.84	0.29	0.87	0.69	0.13	0	27	7.70	6.42
Passage	50	1451	440.58	301.52	19	189	58.81	38.43	0.25	0.92	0.73	0.12	1	46	14.34	11.64
Rural	4	1897	497.07	419.69	1	182	45.41	31.67	0.18	0.95	0.69	0.13	1	40	8.75	6.30
Urban	8	2683	619.33	496.94	4	216	57.25	41.70	0.36	0.88	0.66	0.13	1	37	10.09	8.20



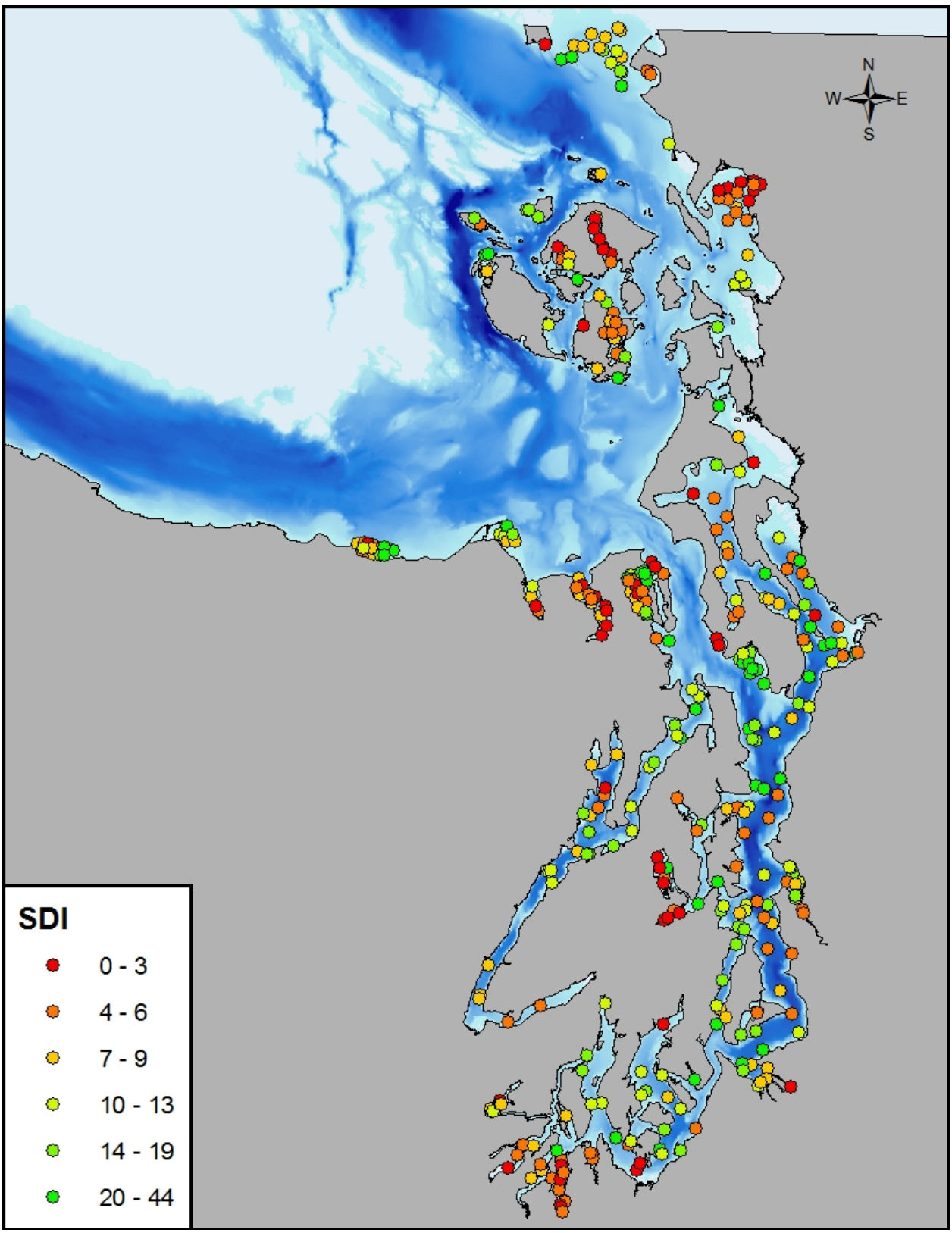
Spatial patterns in total benthic invertebrate abundance for the 2004-2014 Puget Sound sediment survey.



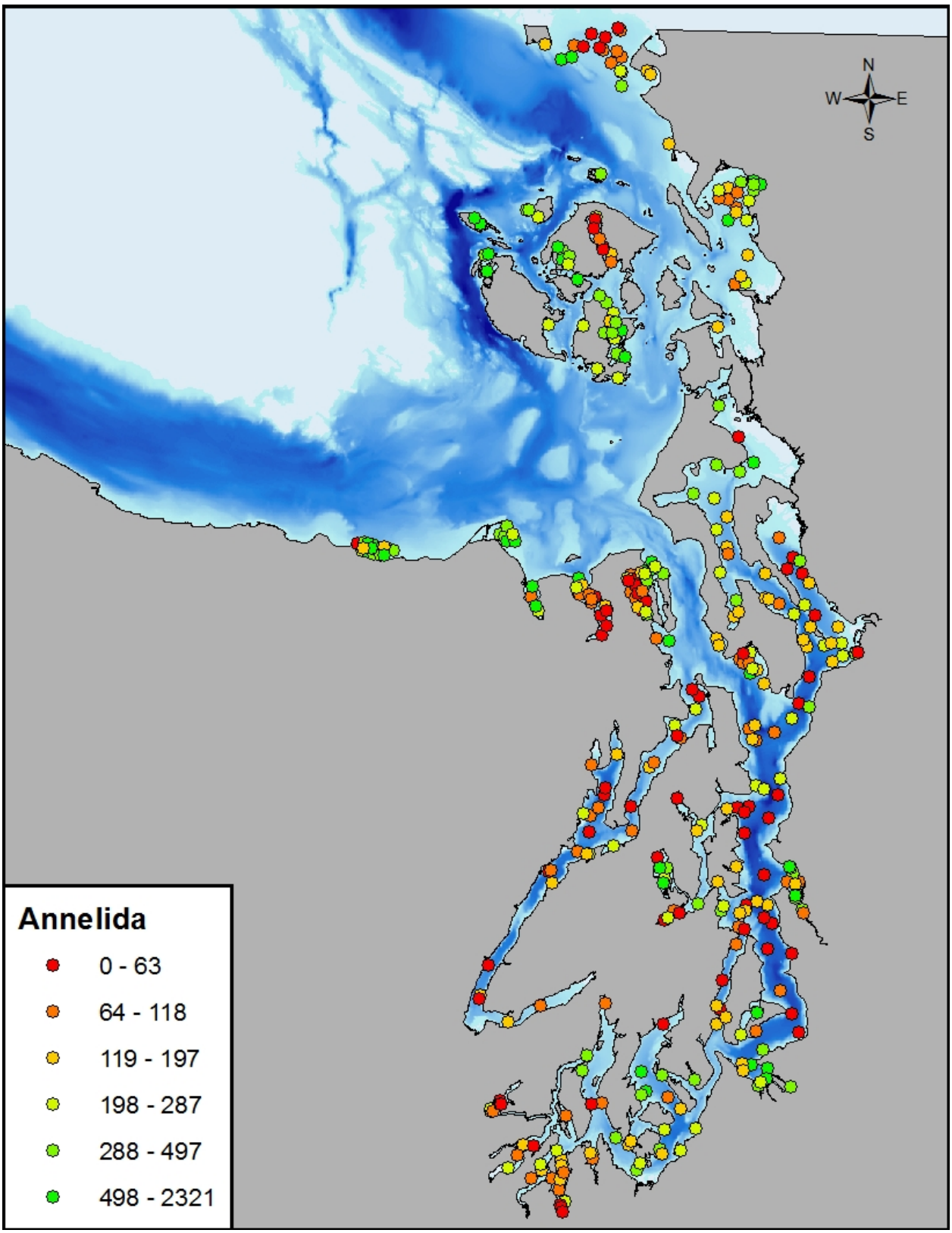
Spatial patterns in taxa richness for the 2004-2014 Puget Sound sediment survey.



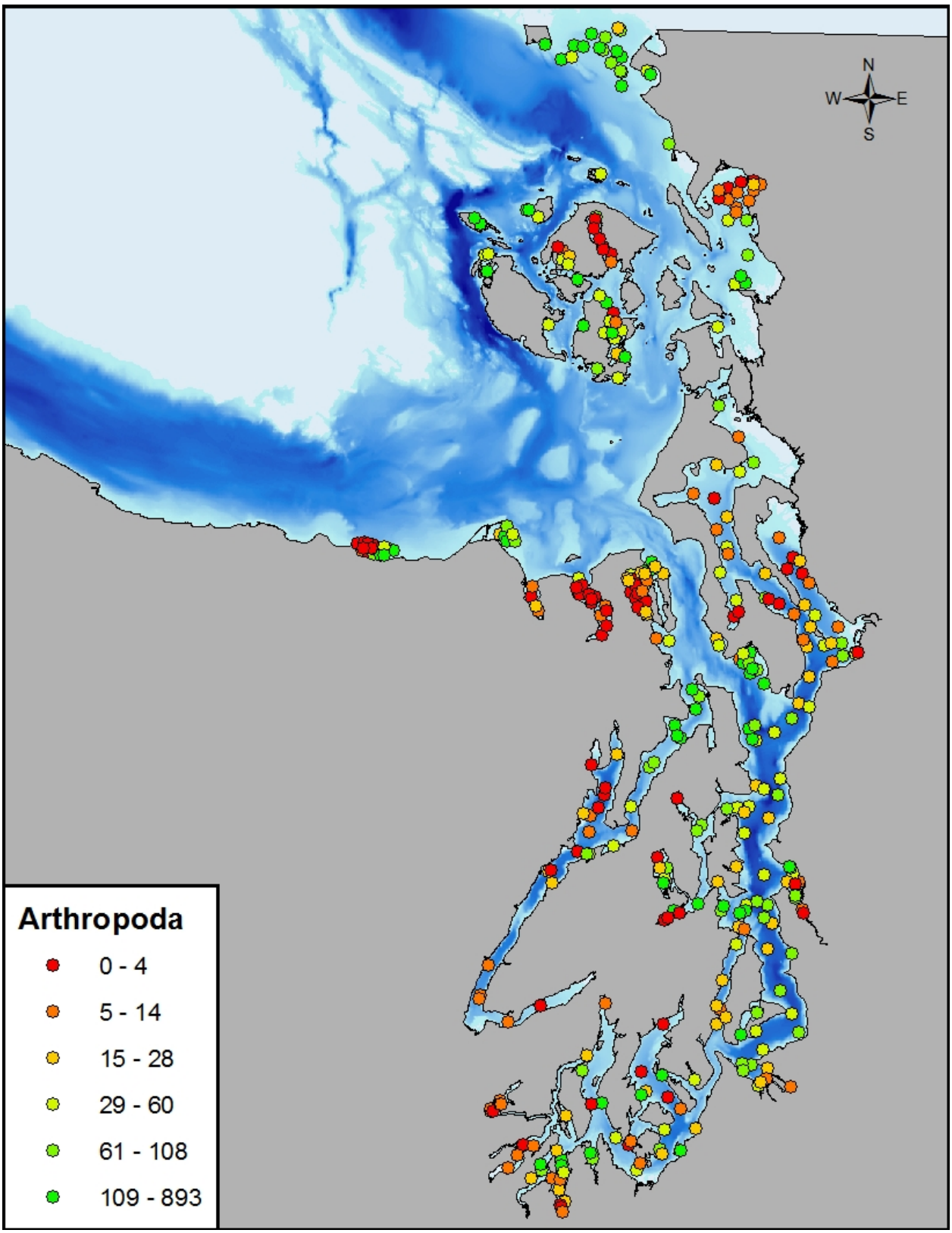
Spatial patterns in Pielou's Evenness (J') for the 2004-2014 Puget Sound sediment survey.



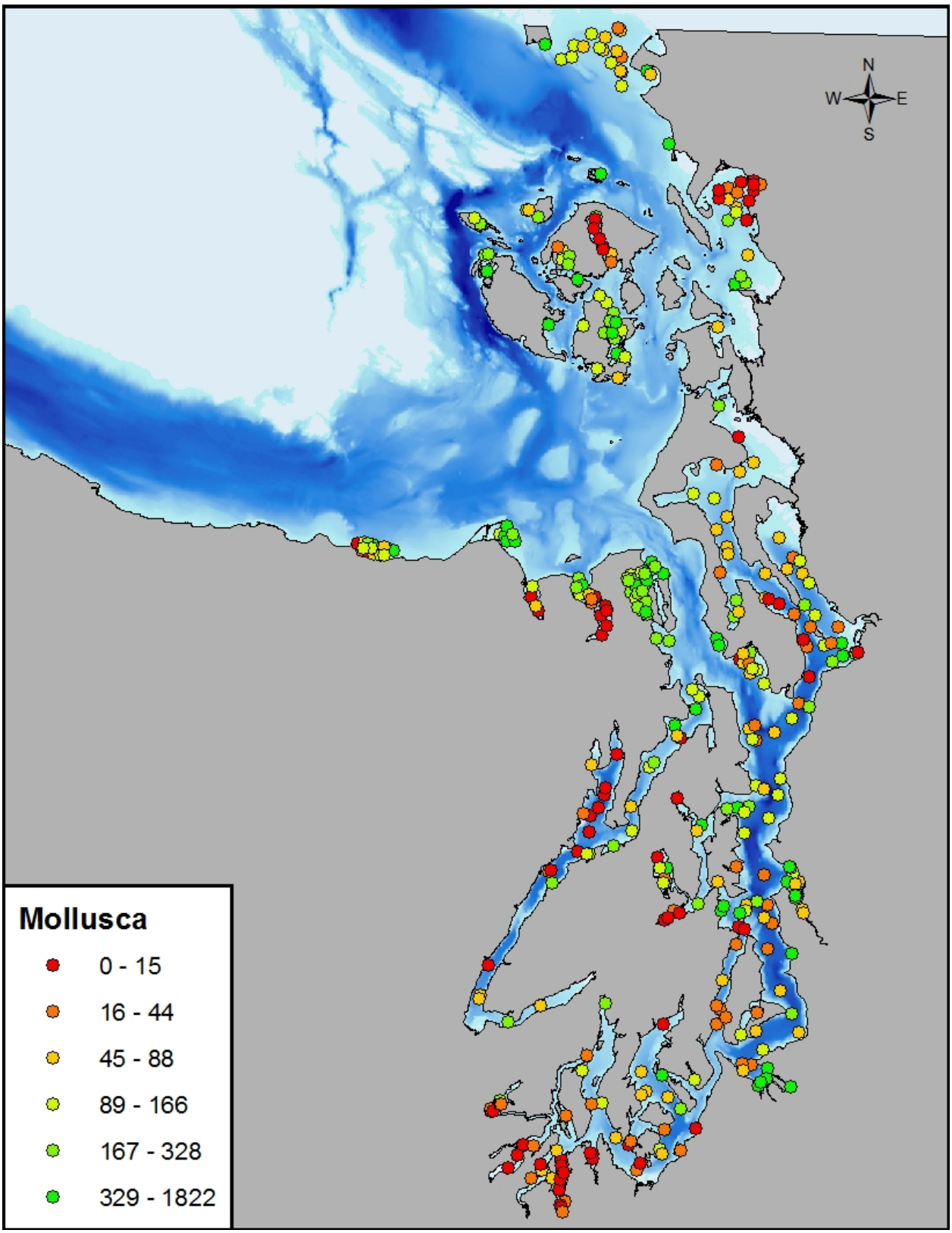
Spatial patterns in Swartz Dominance Index (SDI) for the 2004-2014 Puget Sound sediment survey.



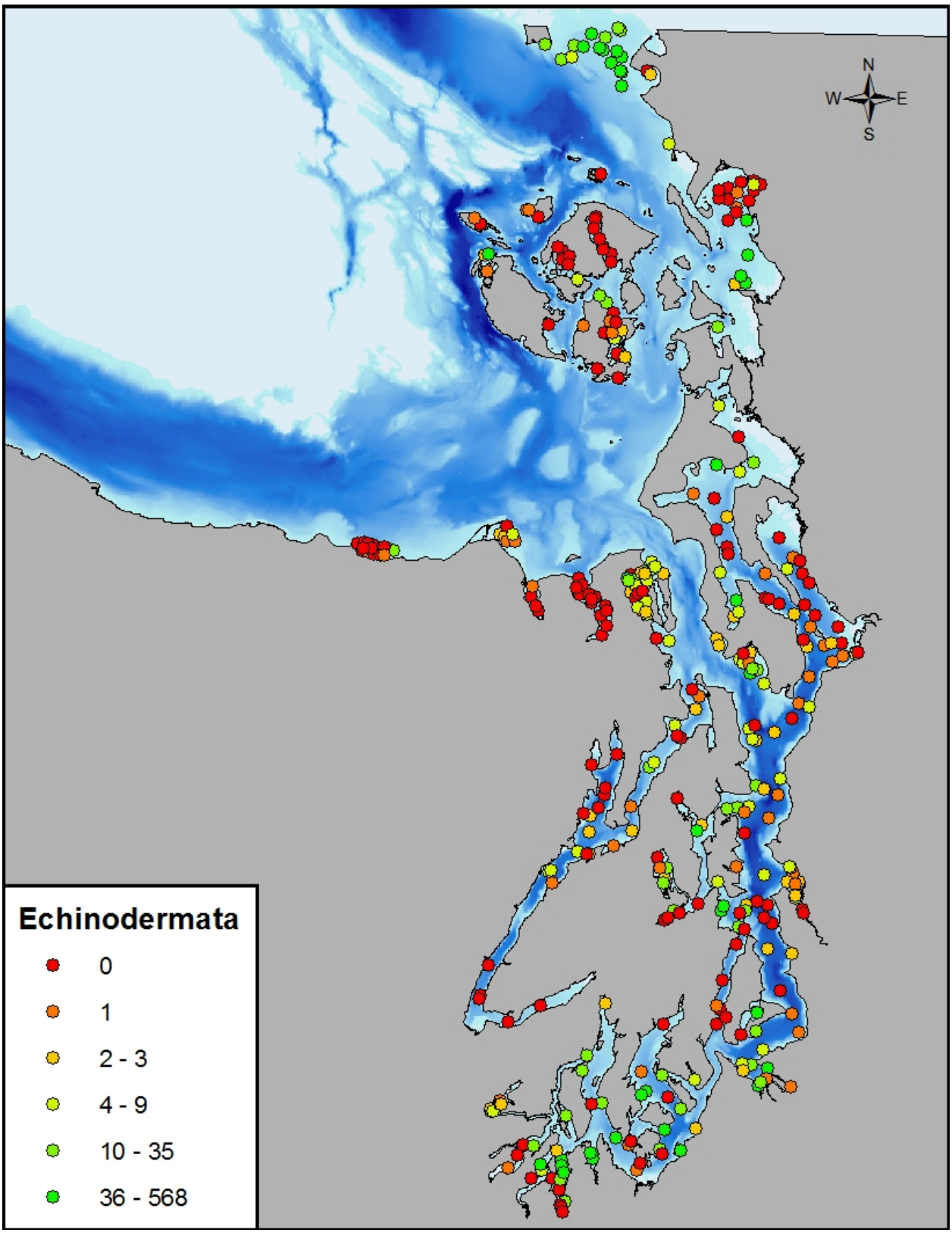
Spatial patterns in annelid abundance for the 2004-2014 Puget Sound sediment survey.



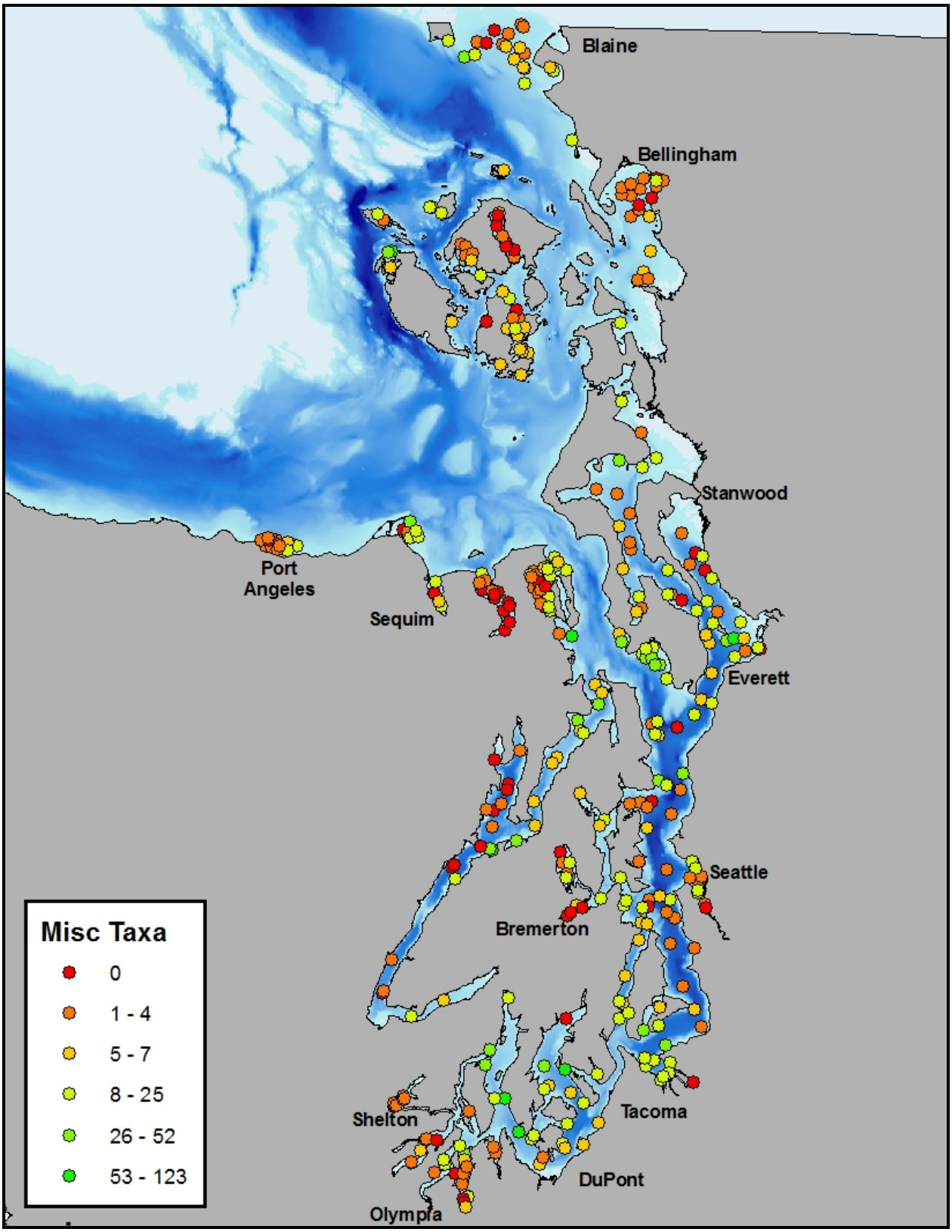
Spatial patterns in arthropod abundance for the 2004-2014 Puget Sound sediment survey.



Spatial patterns in mollusc abundance for the 2004-2014 Puget Sound sediment survey.



Spatial patterns in echinoderm abundance for the 2004-2014 Puget Sound sediment survey.



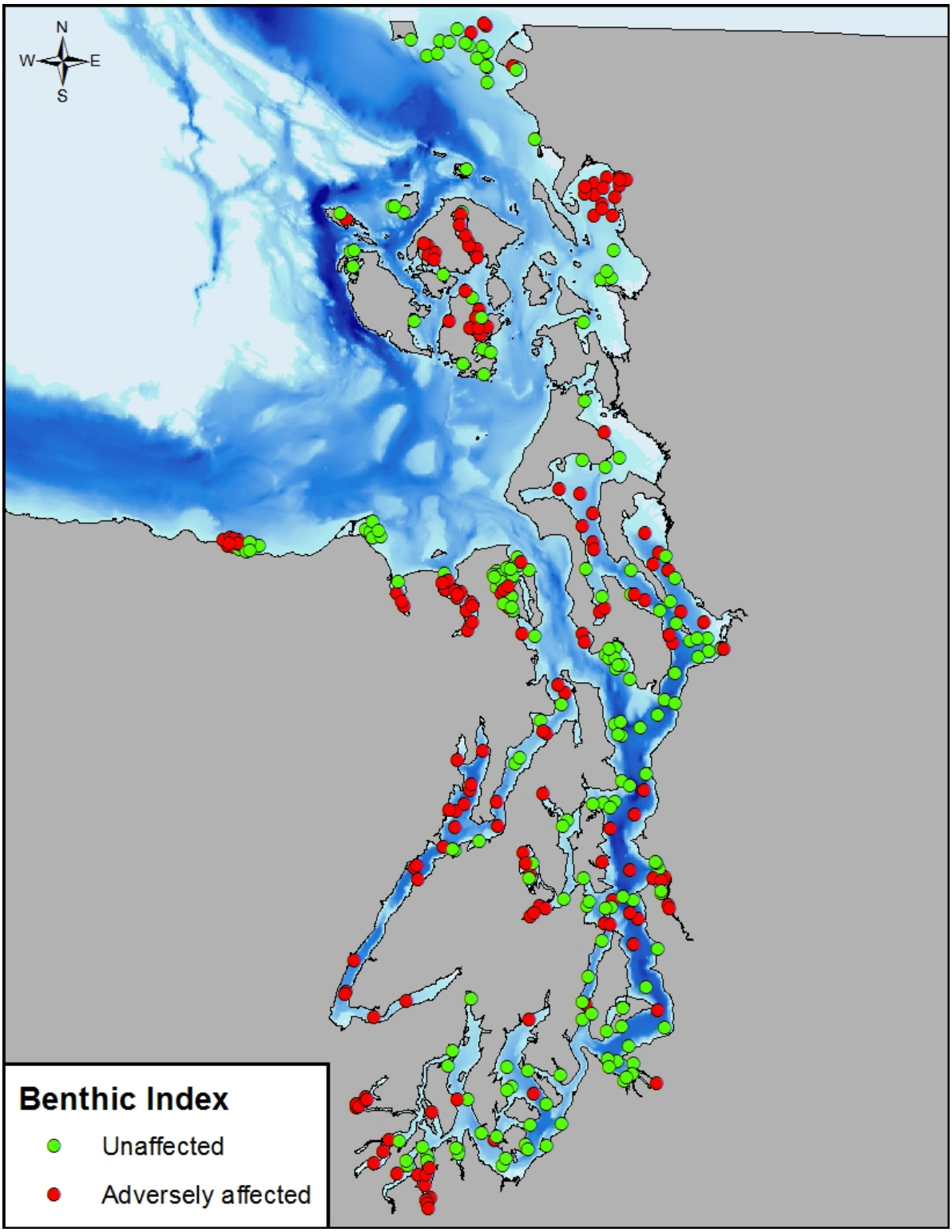
Spatial patterns in miscellaneous taxa abundance for the 2004-2014 Puget Sound sediment survey.

Adversely Affected Benthic Communities

Incidence and spatial extent of benthic community condition in eight sediment monitoring regions, 5 strata, and all of Puget Sound.

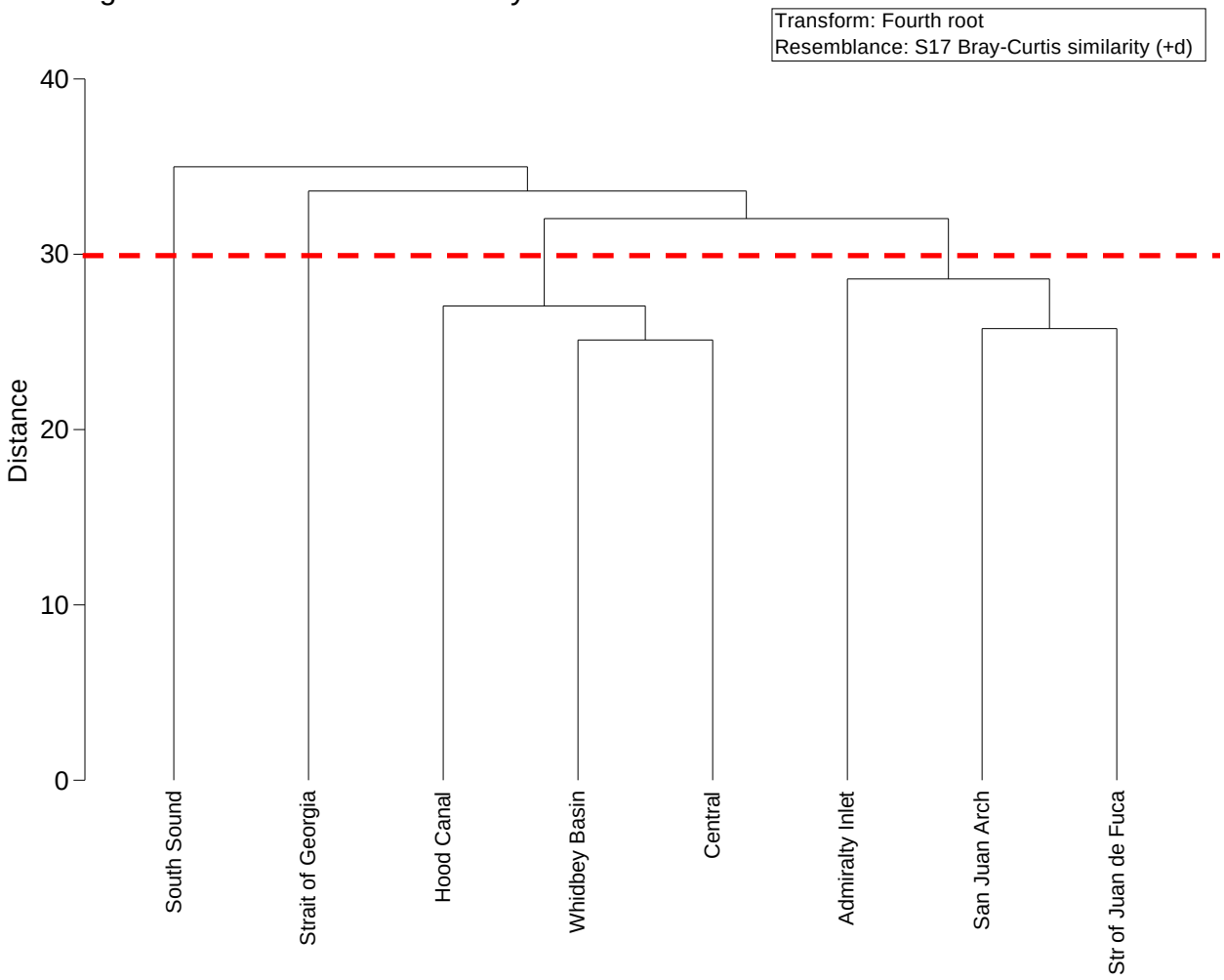
Region / Stratum	Adversely affected				Unaffected			
	Stations		Area		Stations		Area	
	No.	(%)	km^2	(%)	No.	(%)	km^2	(%)
Strait of Georgia	**19**	**(47.5)**	**159.1**	**(44.1)**	**21**	**(52.5)**	**201.6**	**(55.9)**
Basin	0	(0.0)	0.0	(0.0)	13	(100.0)	86.2	(100.0)
Harbor	3	(100.0)	1.4	(100.0)	0	(0.0)	0.0	(0.0)
Passage	4	(50.0)	62.0	(50.0)	4	(50.0)	62.0	(50.0)
Rural	4	(57.1)	66.2	(57.1)	3	(42.9)	49.6	(42.9)
Urban	8	(88.9)	29.5	(88.9)	1	(11.1)	3.7	(11.1)
San Juan Archipelago	**23**	**(57.5)**	**45.7**	**(57.5)**	**17**	**(42.5)**	**33.8**	**(42.5)**
Rural	23	(57.5)	45.7	(57.5)	17	(42.5)	33.8	(42.5)
Eastern Strait of Juan de Fuca	**25**	**(62.5)**	**43.7**	**(64.4)**	**15**	**(37.5)**	**24.2**	**(35.6)**
Harbor	4	(80.0)	2.8	(80.0)	1	(20.0)	0.7	(20.0)
Rural	16	(66.7)	36.5	(66.7)	8	(33.3)	18.2	(33.3)
Urban	5	(45.5)	4.3	(45.5)	6	(54.5)	5.2	(54.5)
Admiralty Inlet	**10**	**(23.3)**	**15.4**	**(23.2)**	**33**	**(76.7)**	**51.1**	**(76.8)**
Passage	3	(23.1)	**8.5**	(23.1)	10	(76.9)	28.2	(76.9)
Urban	7	(23.3)	7.0	(23.3)	23	(76.7)	22.9	(76.7)
Whidbey Basin	**20**	**(50.0)**	**185.6**	**(52.5)**	**20**	**(50.0)**	**167.7**	**(47.5)**
Harbor	1	(33.3)	0.3	(33.3)	2	(66.7)	0.5	(66.7)
Passage	9	(60.0)	103.7	(60.0)	6	(40.0)	69.1	(40.0)
Rural	10	(45.5)	81.7	(45.5)	12	(54.5)	98.0	(54.5)
Central	**27**	**(33.8)**	**186.8**	**(28.0)**	**53**	**(66.3)**	**480.6**	**(72.0)**
Basin	9	(30.0)	140.0	(30.0)	21	(70.0)	326.6	(70.0)
Harbor	8	(61.5)	7.9	(61.5)	5	(38.5)	5.0	(38.5)
Passage	1	(10.0)	8.6	(10.0)	9	(90.0)	77.7	(90.0)
Rural	2	(20.0)	10.9	(20.0)	8	(80.0)	43.7	(80.0)
Urban	7	(41.2)	19.4	(41.2)	10	(58.8)	27.7	(58.8)
Hood Canal	**23**	**(76.7)**	**230.2**	**(78.1)**	**7**	**(23.3)**	**64.6**	**(21.9)**
Basin	14	(66.7)	129.2	(66.7)	7	(33.3)	64.6	(33.3)
Rural	9	(100.0)	101.0	(100.0)	0	(0.0)	0.0	(0.0)
South Sound	**25**	**(45.5)**	**107.5**	**(33.8)**	**30**	**(54.5)**	**210.2**	**(66.2)**
Basin	0	(0.0)	0.0	(0.0)	8	(100.0)	75.4	(100.0)
Harbor	8	(88.9)	1.0	(88.9)	1	(11.1)	0.1	(11.1)
Passage	2	(28.6)	13.6	(28.6)	5	(71.4)	34.1	(71.4)
Rural	11	(47.8)	84.6	(47.8)	12	(52.2)	92.3	(52.2)

Region / Stratum	Adversely affected				Unaffected			
	Stations		Area		Stations		Area	
	No.	(%)	km^2	(%)	No.	(%)	km^2	(%)
Urban	4	(50.0)	8.3	(50.0)	4	(50.0)	8.3	(50.0)
Puget Sound	**172**	**(46.7)**	**974.0**	**(44.1)**	**196**	**(53.3)**	**1233.6**	**(55.9)**
Basin	23	(31.9)	269.2	(32.7)	49	(68.1)	552.8	(67.3)
Harbor	24	(72.7)	13.4	(68.1)	9	(27.3)	6.3	(31.9)
Passage	19	(35.8)	196.4	(42.0)	34	(64.2)	271.1	(58.0)
Rural	75	(55.6)	426.5	(56.0)	60	(44.4)	335.6	(44.0)
Urban	31	(41.3)	68.4	(50.2)	44	(58.7)	67.8	(49.8)

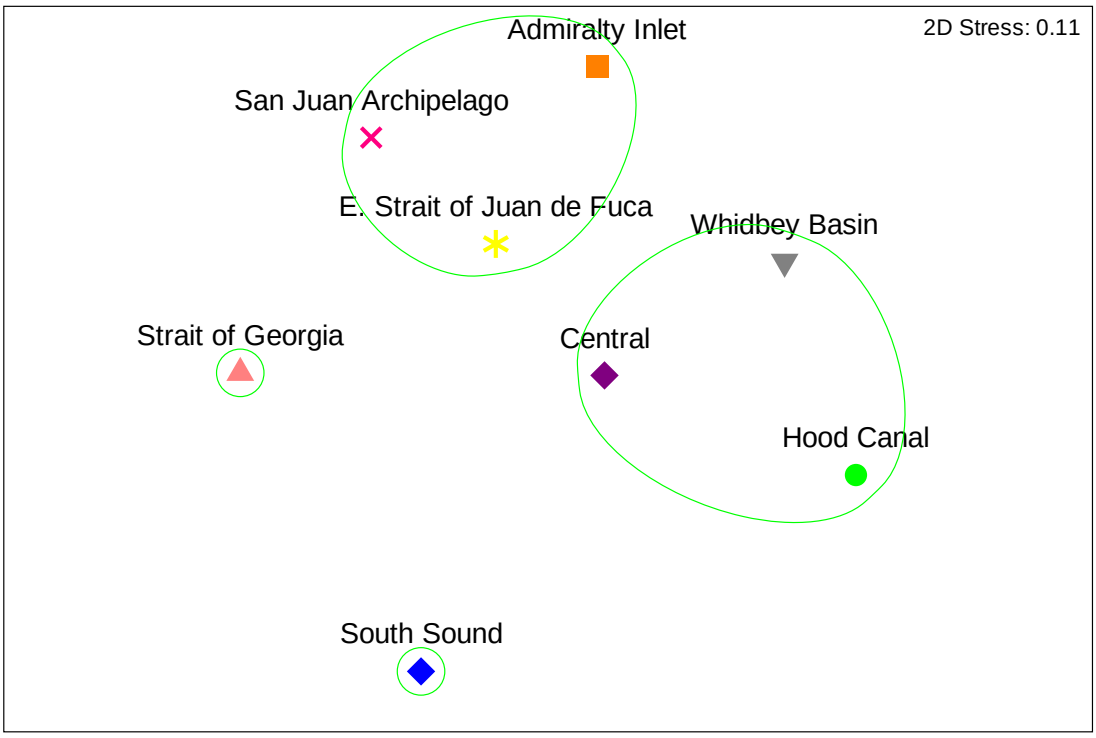


Spatial patterns in *adversely affected* benthic invertebrate assemblages for the 2004-2014 Puget Sound sediment survey.

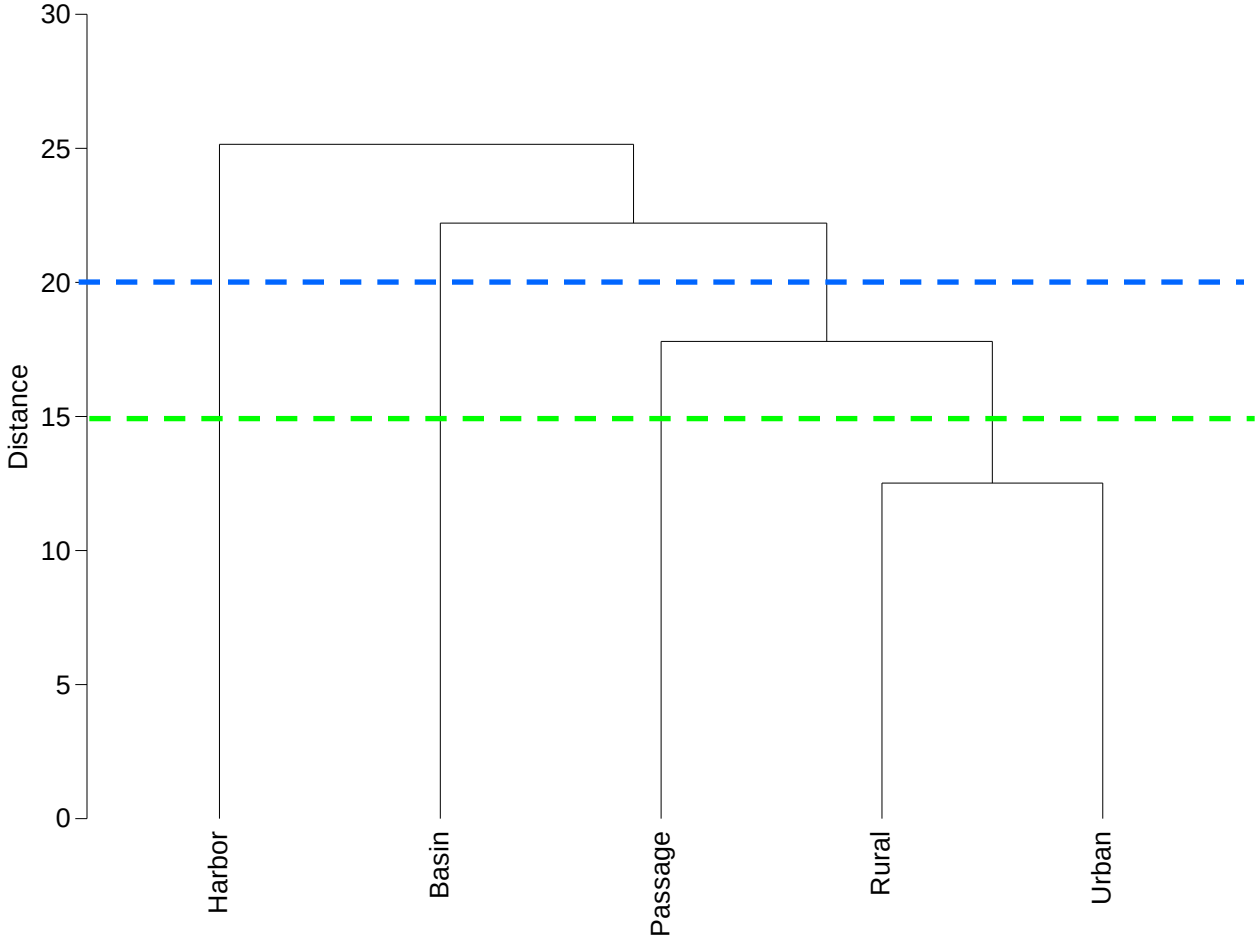
Cluster dendrogram of centroids of benthic invertebrate assemblages for the eight regions in the 2004-2014 Puget Sound Sediment Monitoring Program (Bray-Curtis similarities of 4th-root-transformed unweighted abundances, all species). The dendrogram is sliced at 30% similarity.



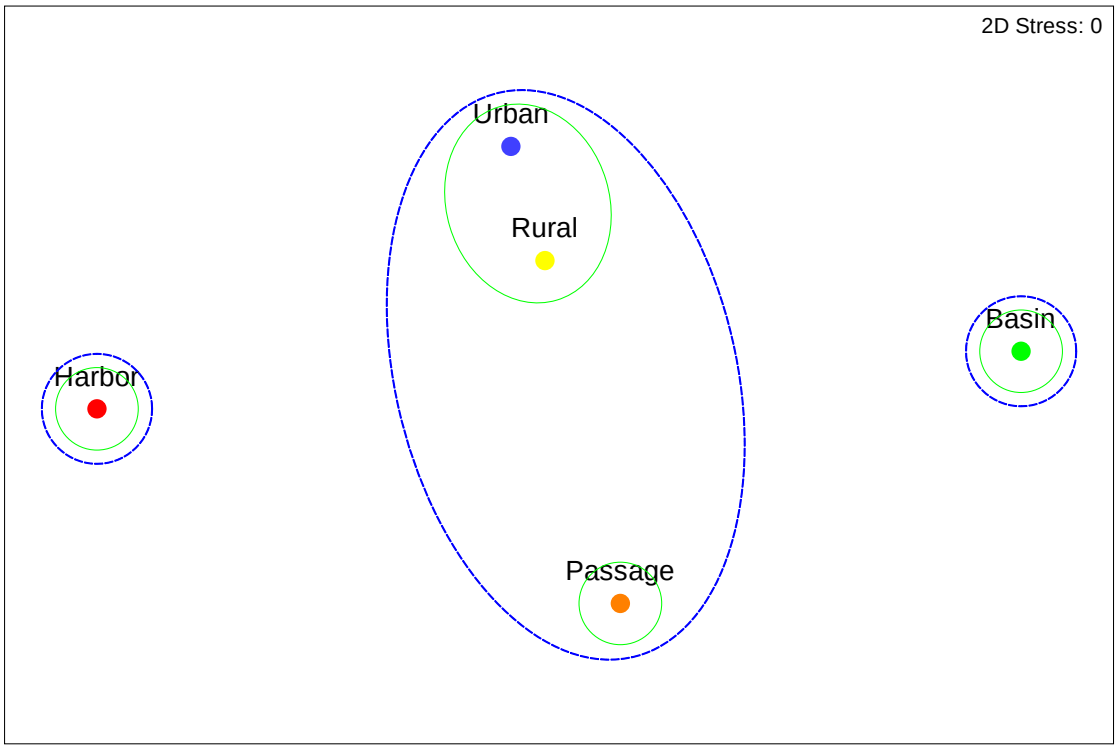
Nonmetric multidimensional scaling (MDS) diagram indicating relative similarities of centroids of benthic invertebrate assemblages for the eight regions in the 2004-2014 Puget Sound sediment survey (Bray-Curtis similarities of 4^{th}-root-transformed unweighted abundances, all species; 2D stress=0.11). The ellipses indicate assemblages with 30% or greater similarity, from the cluster dendrogram in the previous figure. The closer the symbols are in the diagram, the more similar their assemblages are.



Cluster dendrogram of centroids of the five stratum types in the 2004-2014 Puget Sound Sediment Monitoring Program (Bray-Curtis similarities of 4th-root-transformed unweighted abundances, all species). The dendrogram is sliced at 15% and 20% similarity.



Nonmetric multidimensional scaling (MDS) diagram indicating relative similarities of centroids of benthic invertebrate assemblages for 5 stratum types in the 2004-2014 Puget Sound sediment survey (Bray-Curtis similarities of 4th-root-transformed unweighted abundances, all species; 2D stress=0). The ellipses indicate assemblages with 15% or 20% or greater similarity, from the cluster dendrogram in the previous figure. The closer the symbols are in the diagram, the more similar their assemblages are.

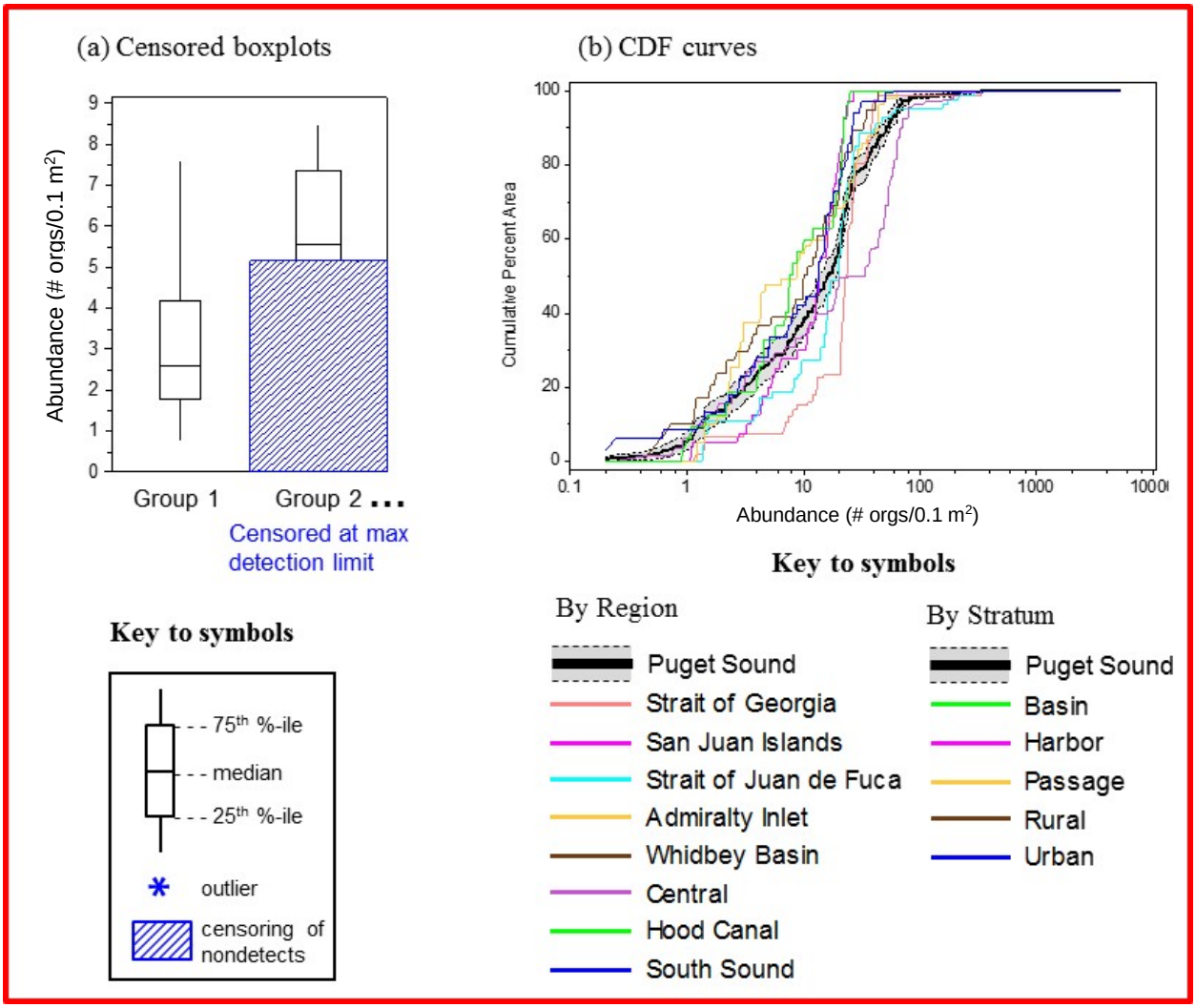


Comparisons between Regions and between Strata

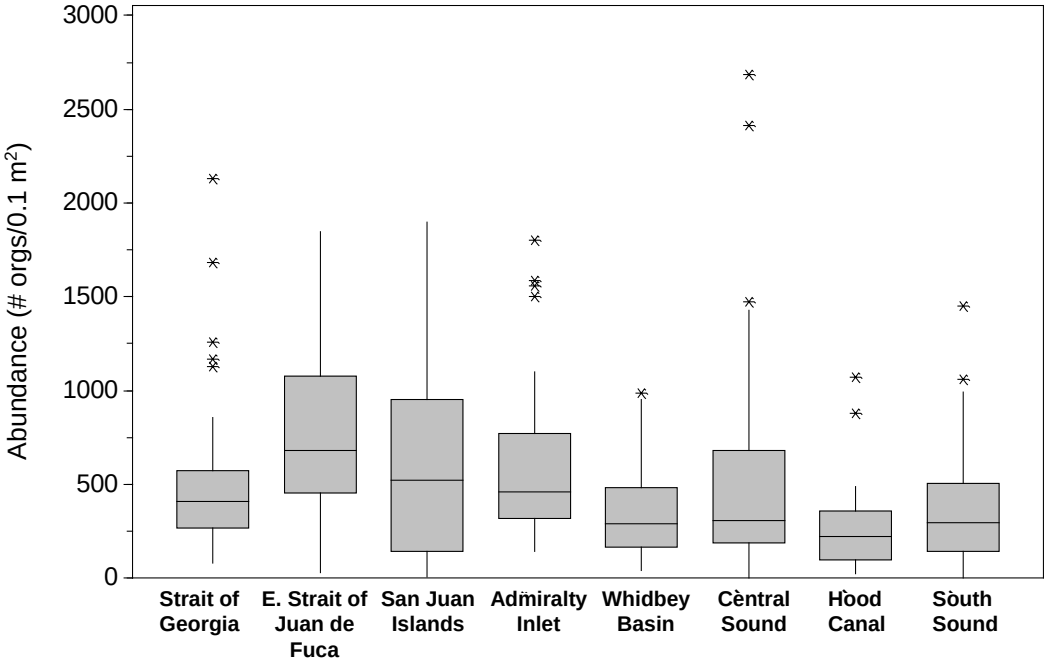
Comparison of infaunal indices calculated for Puget Sound sampling regions and strata. The graphical displays include two types of graphs:

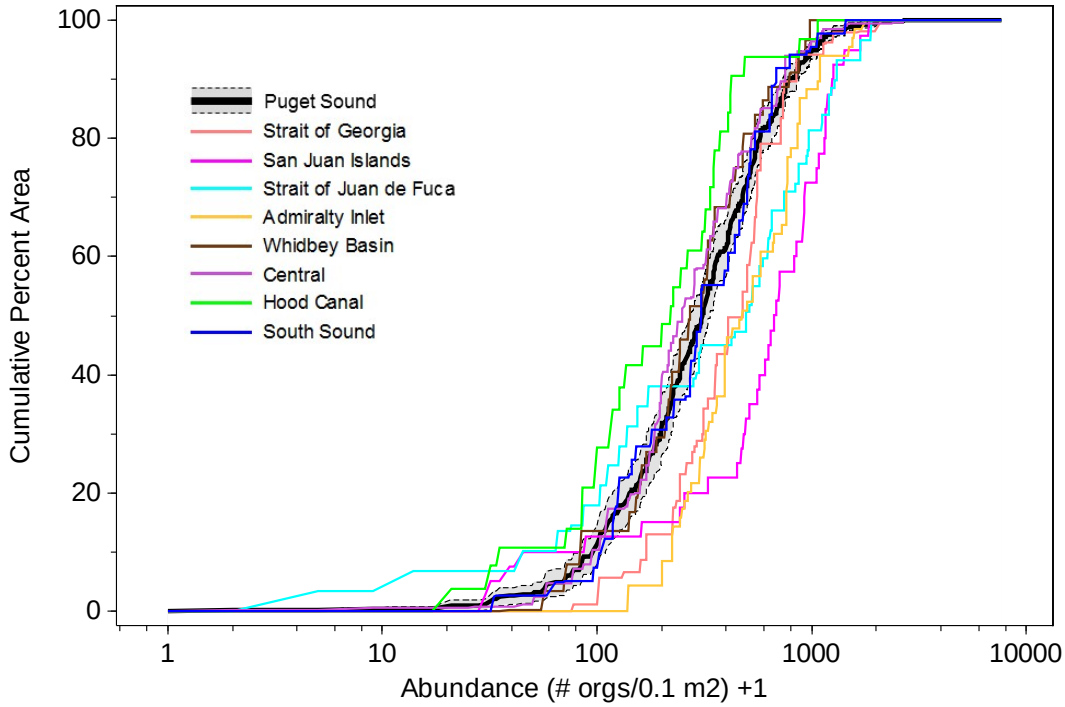
(a) Censored boxplots display the distributions of the data unweighted by sample area.

(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.

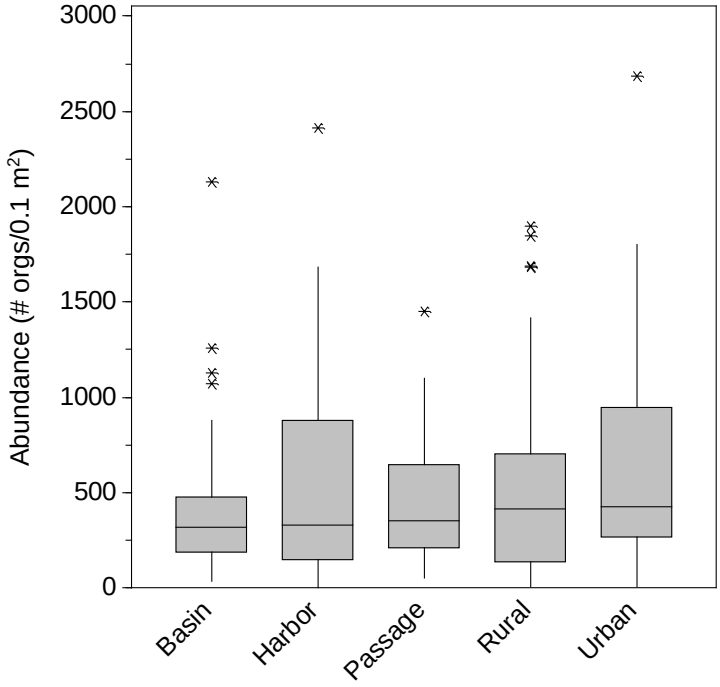


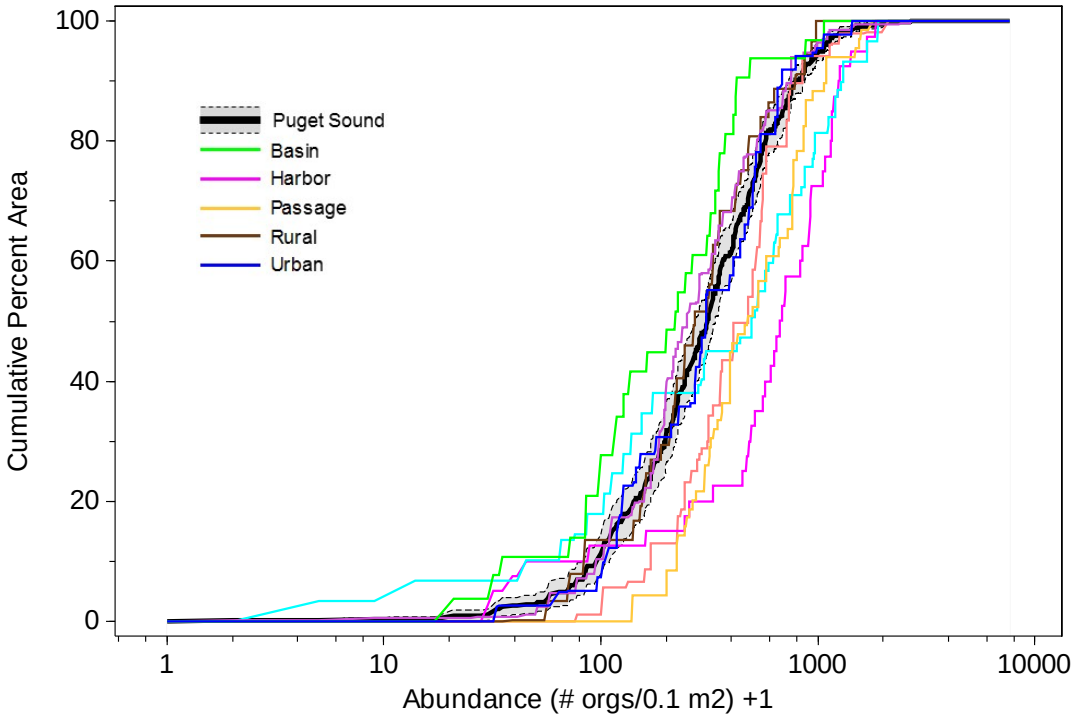
Total Abundance by Region



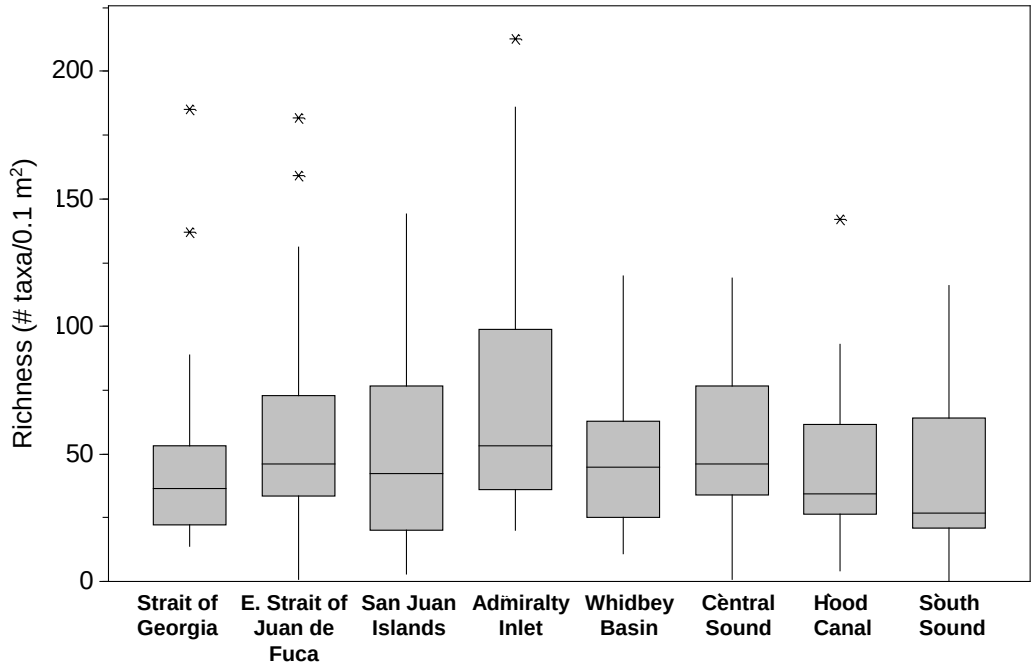


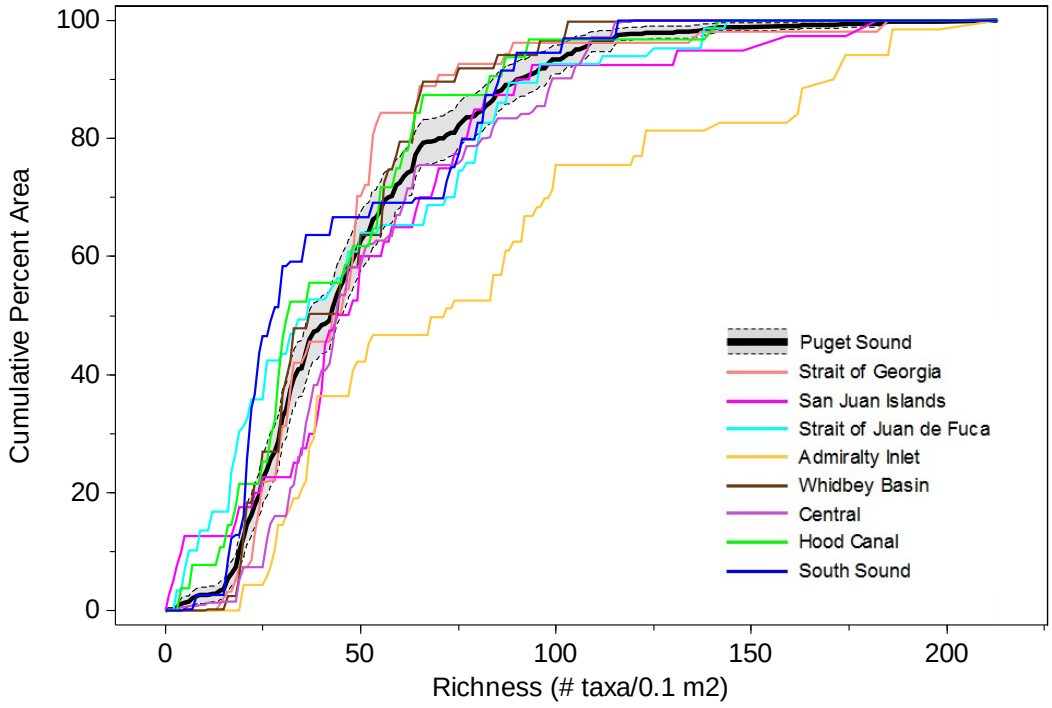
Total Abundance by Stratum



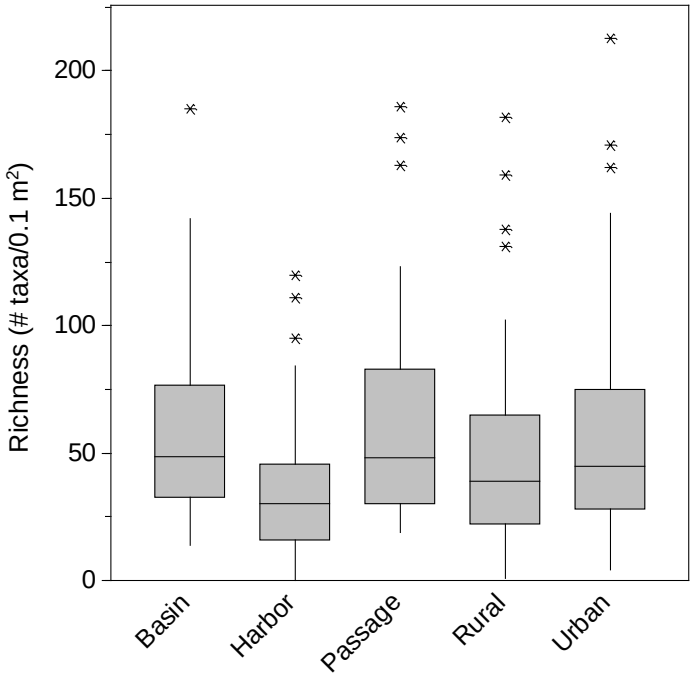


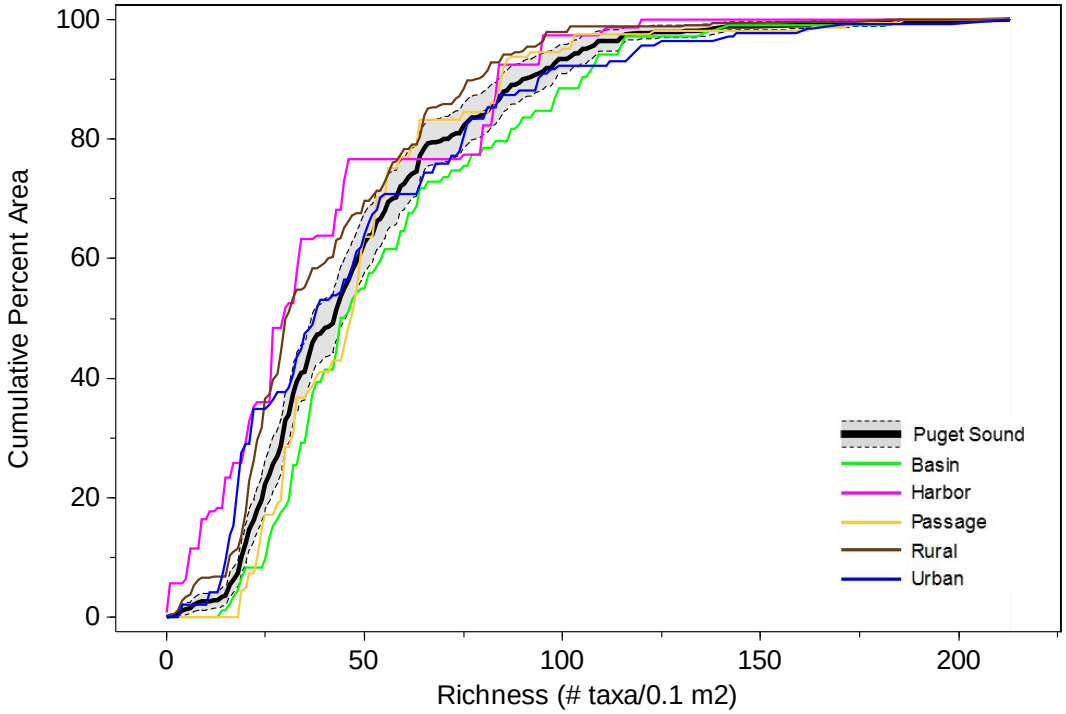
Taxa Richness by Region



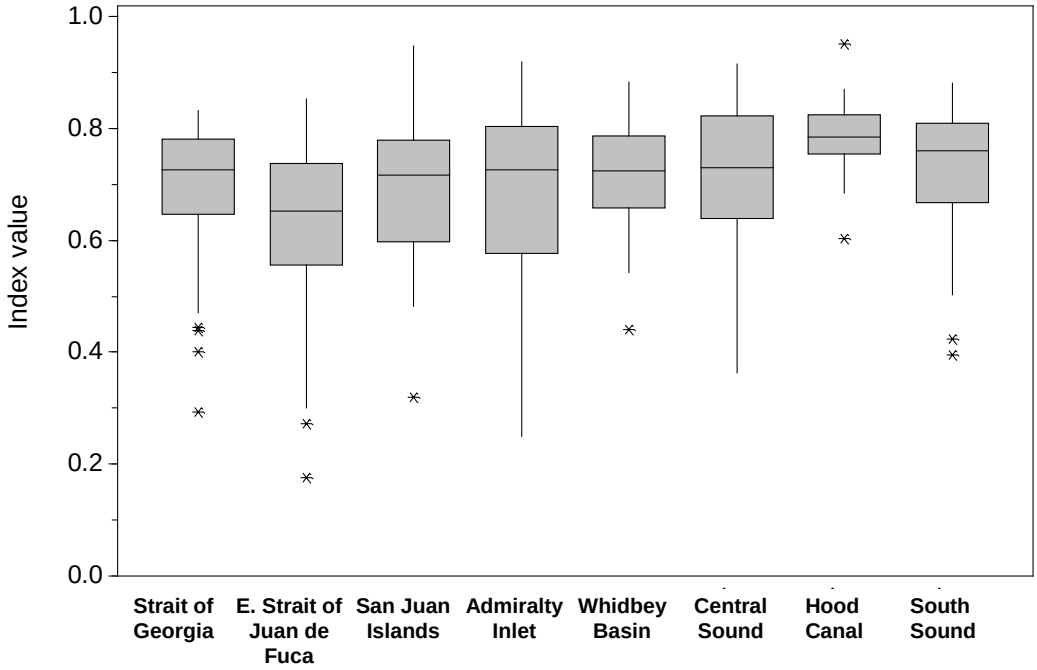


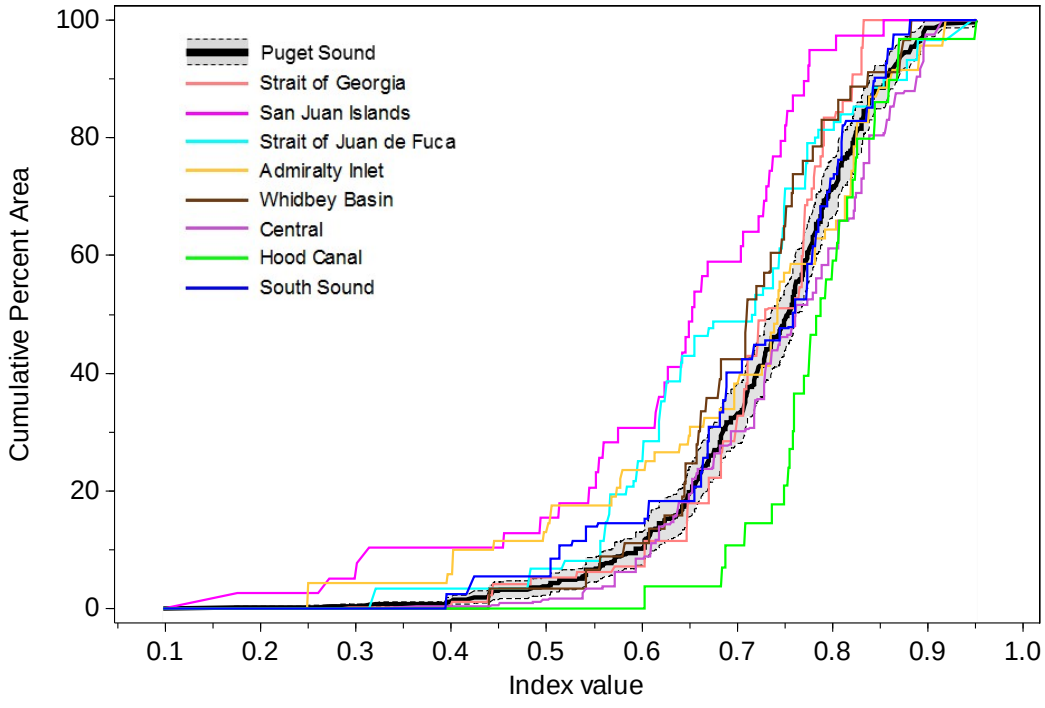
Taxa Richness by Stratum



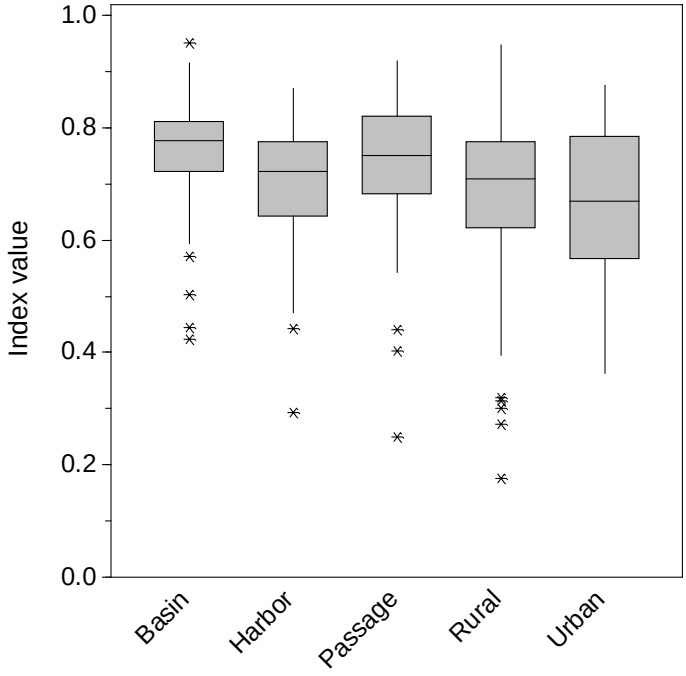


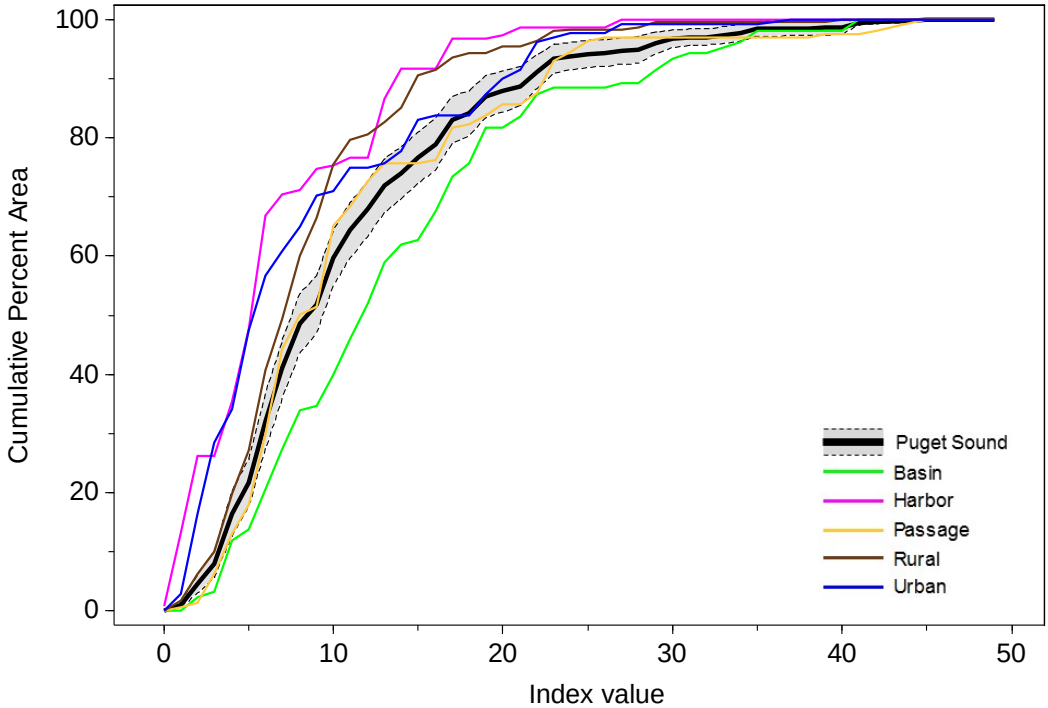
Pielou's Evenness (J')
by Region



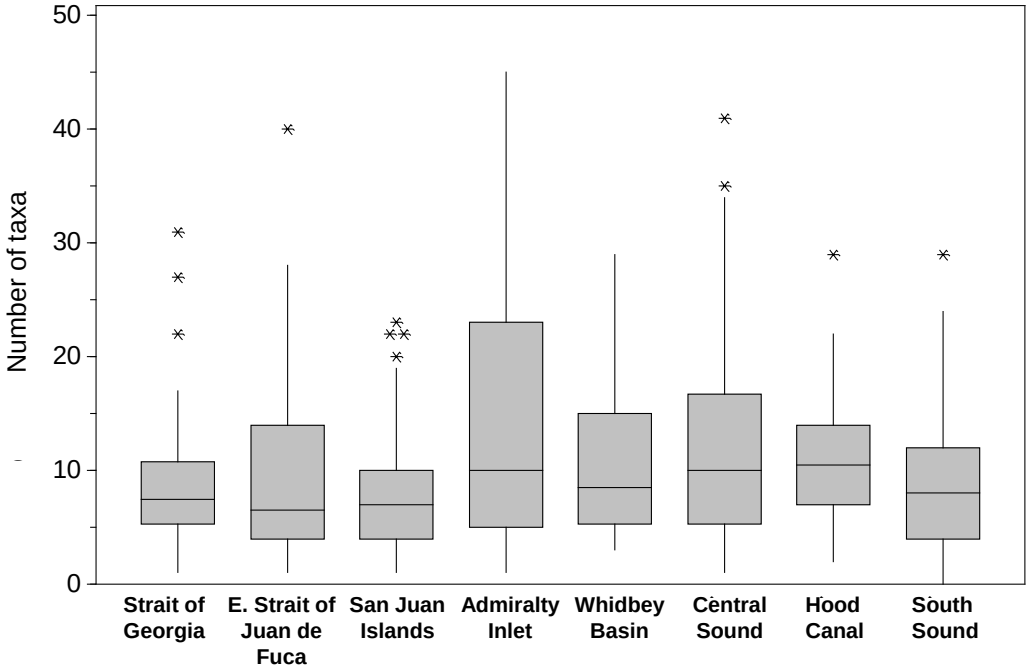


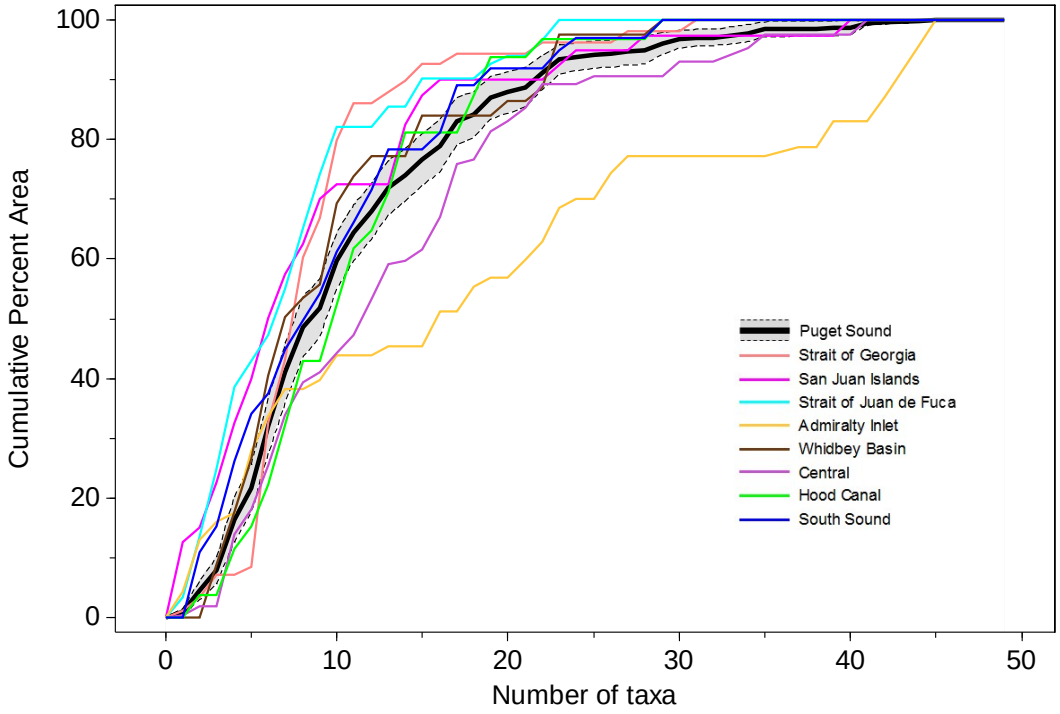
Pielou's Evenness (J') by Stratum



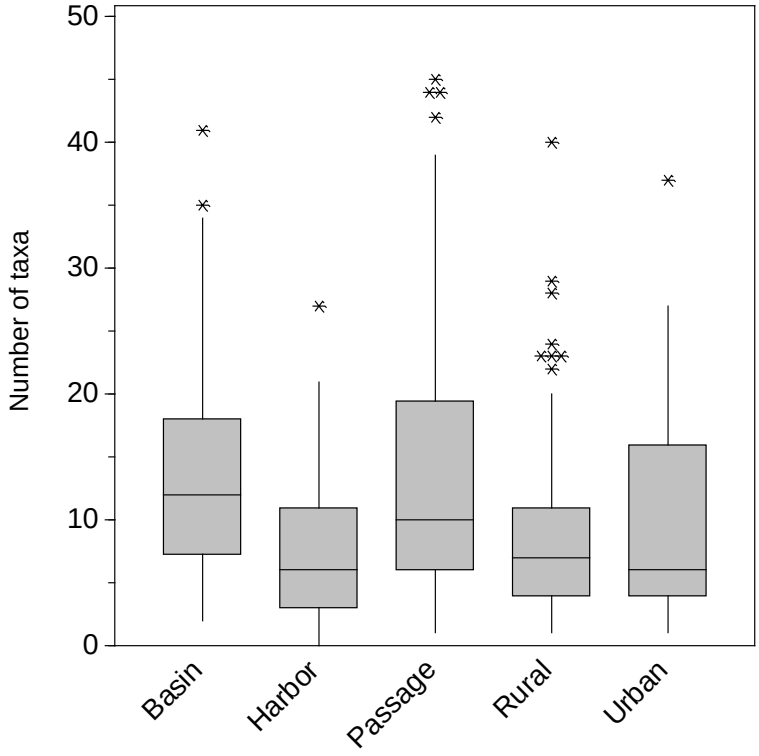


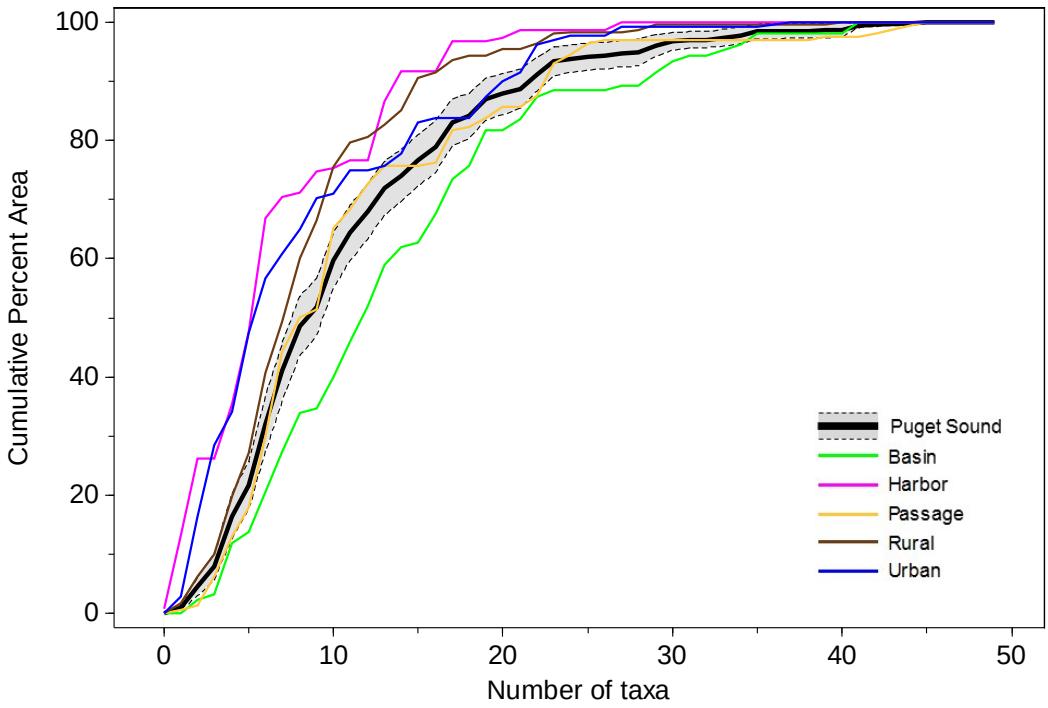
Swartz Dominance Index by Region



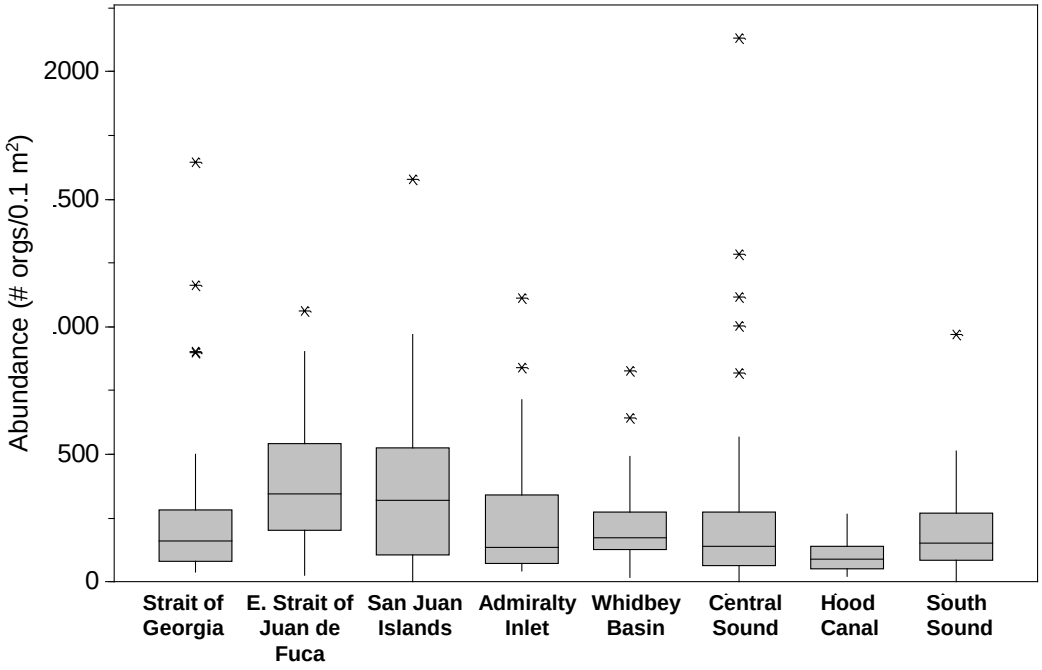


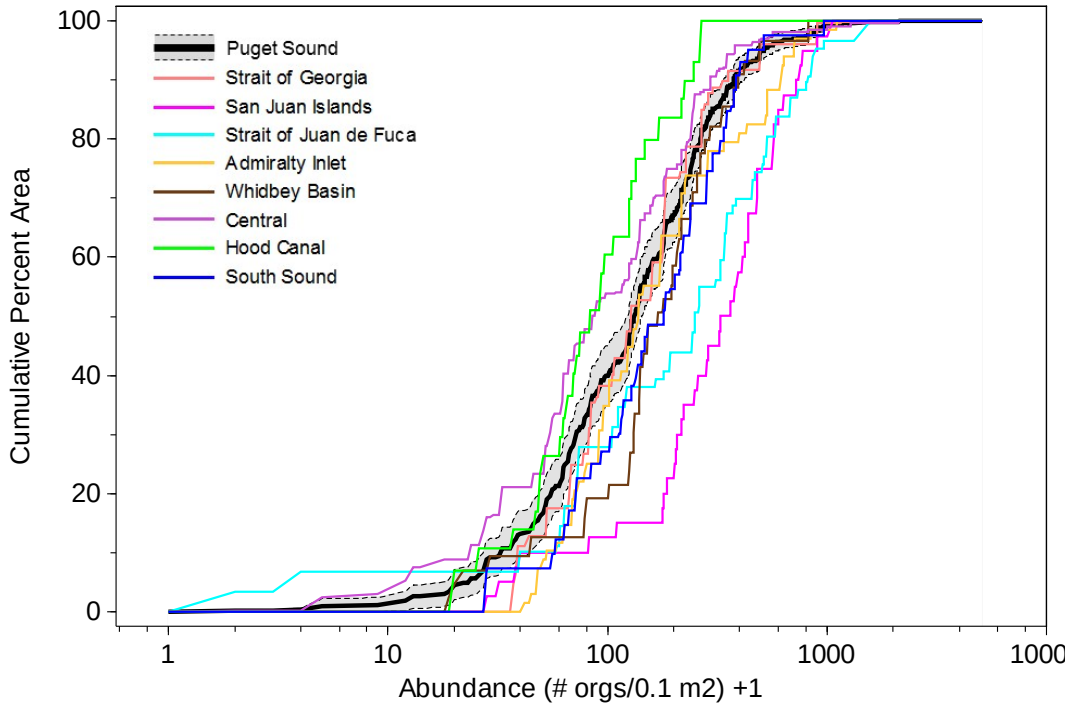
Swartz Dominance Index by Stratum



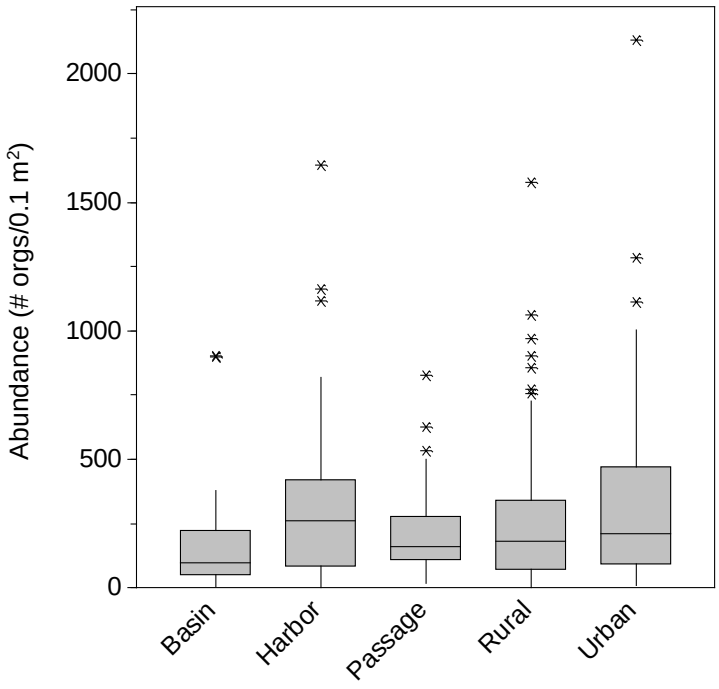


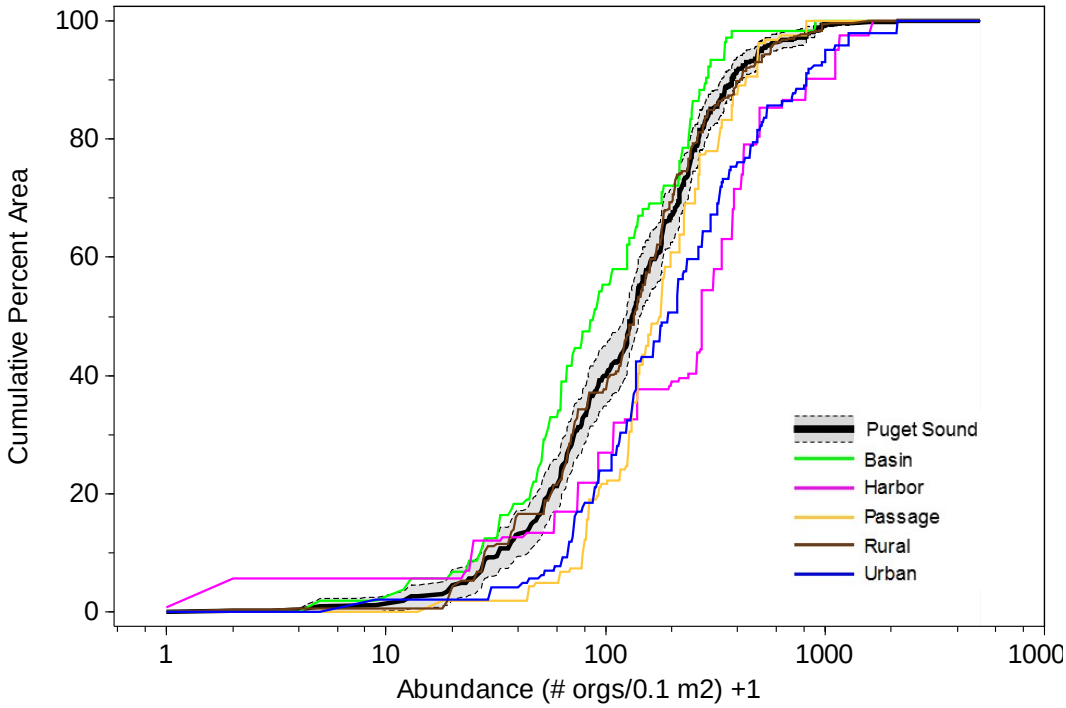
Annelid Abundance by Region



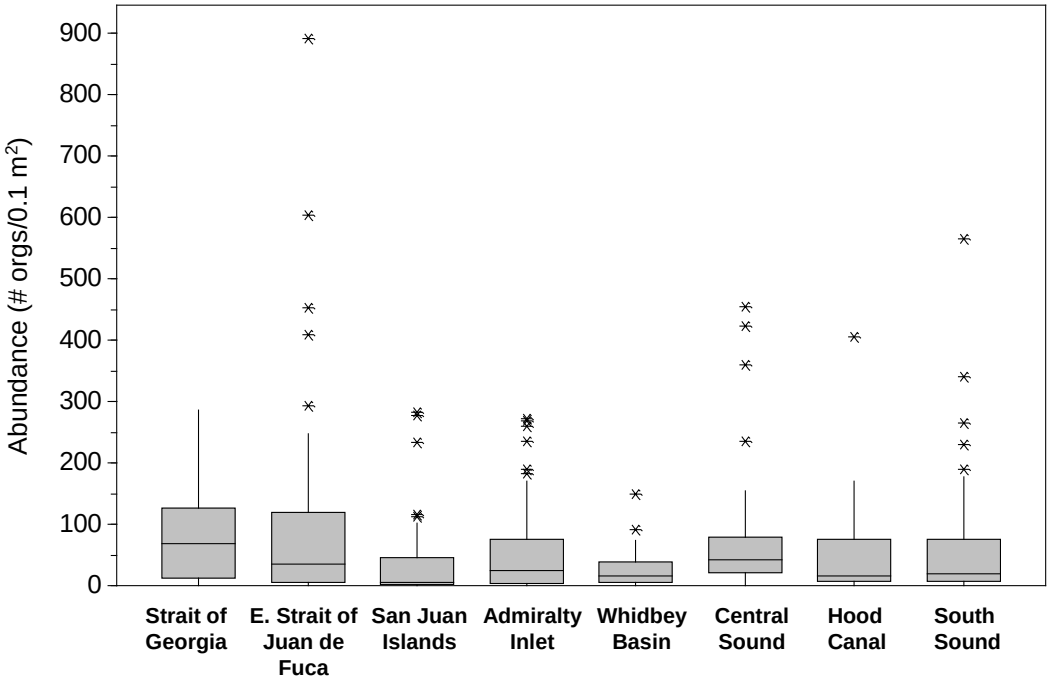


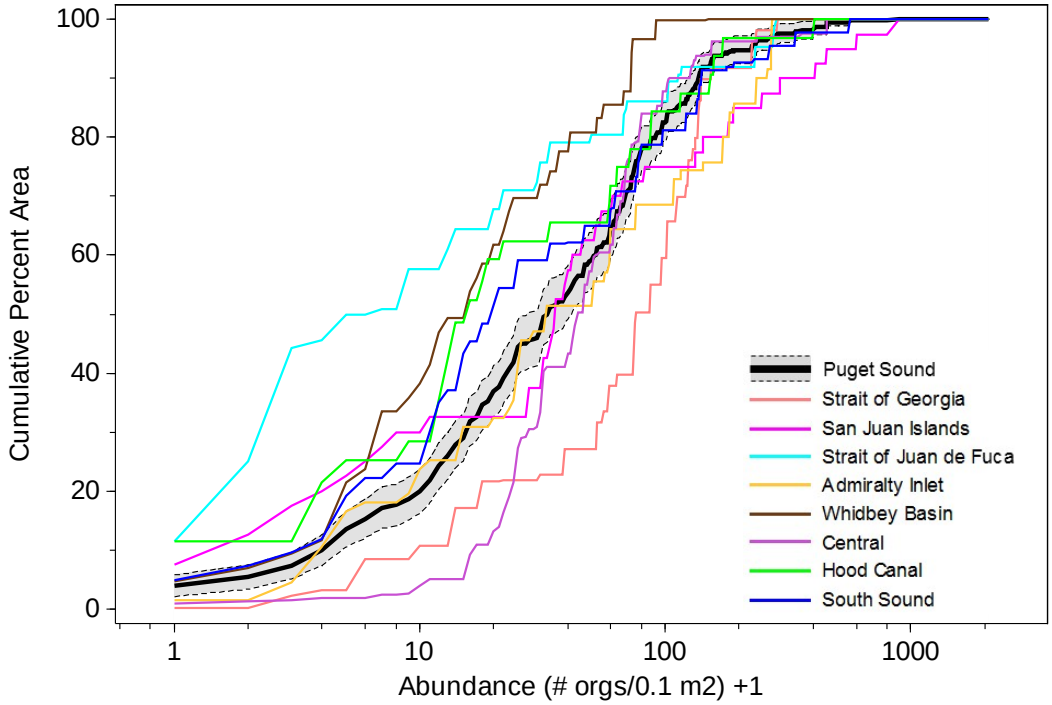
Annelid Abundance by Stratum



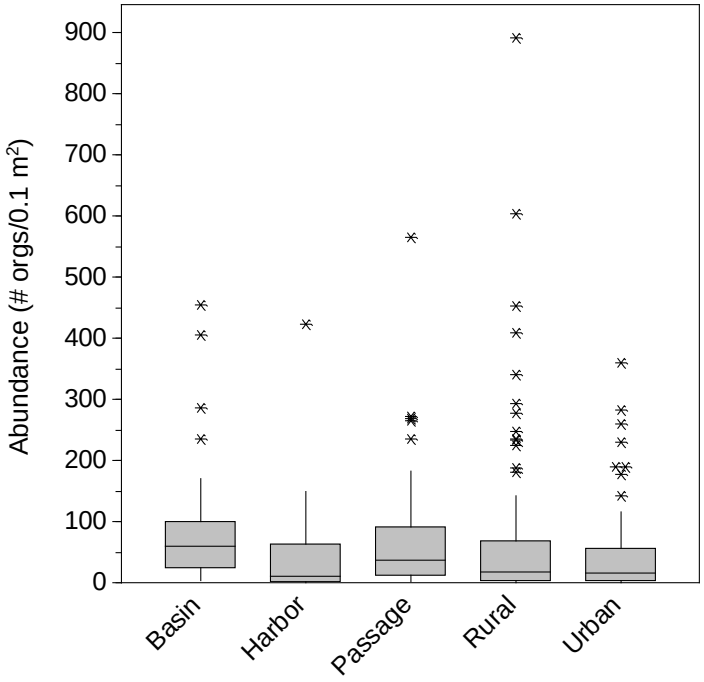


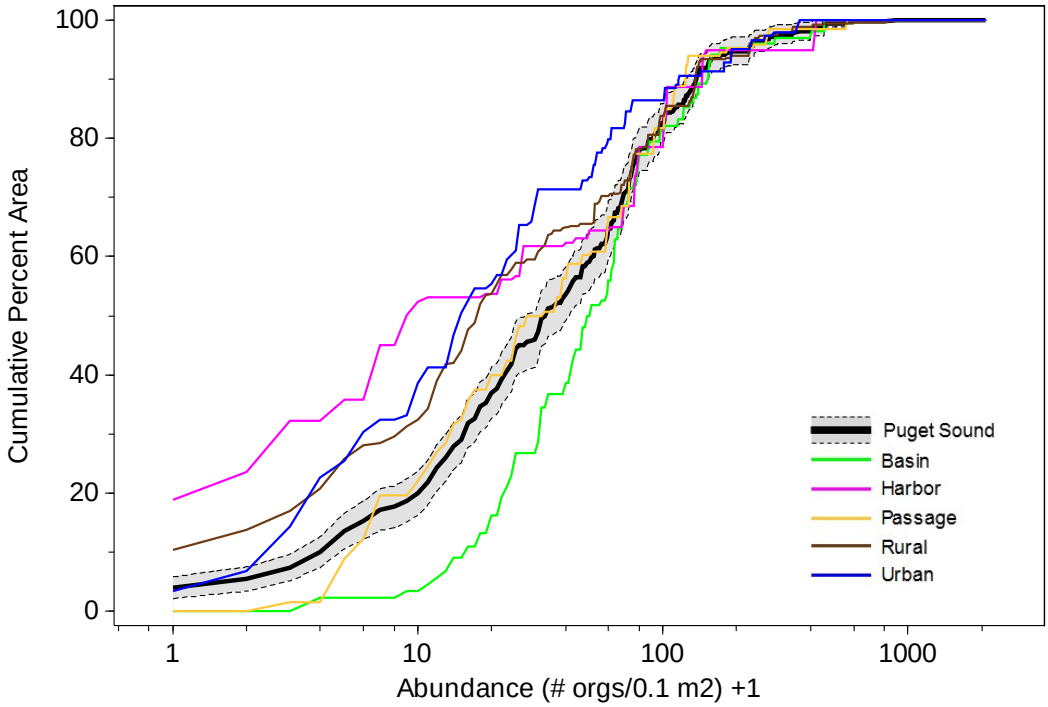
Arthropod Abundance by Region



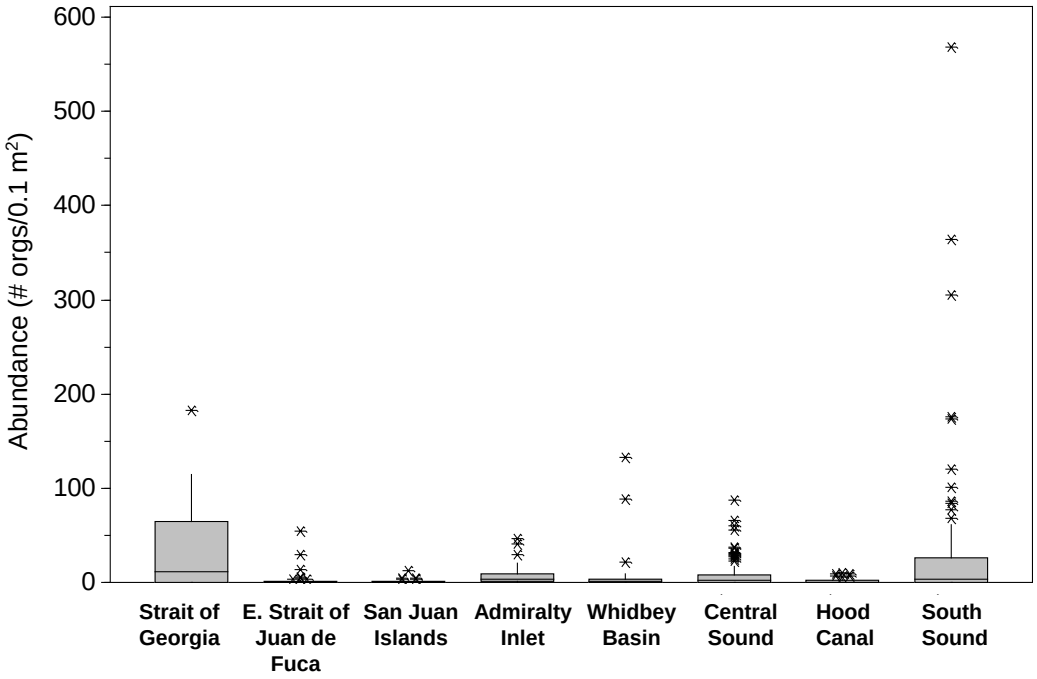


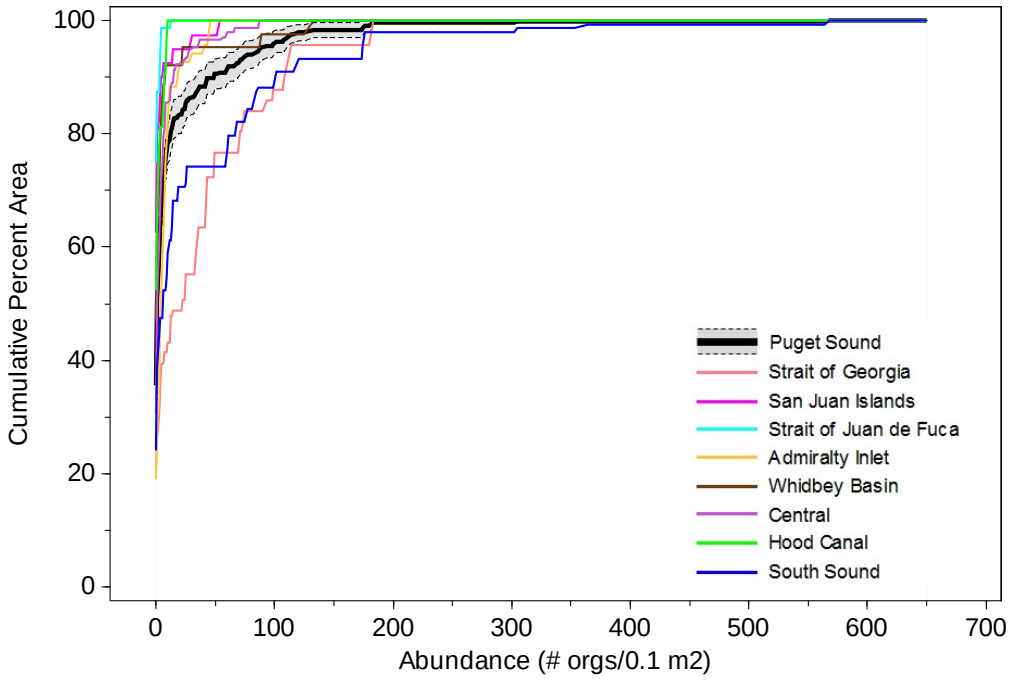
Arthropod Abundance by Stratum



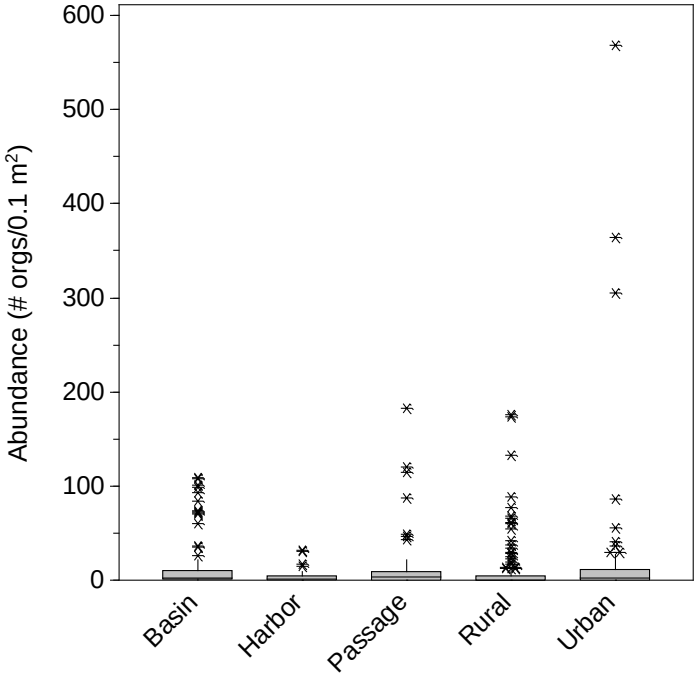


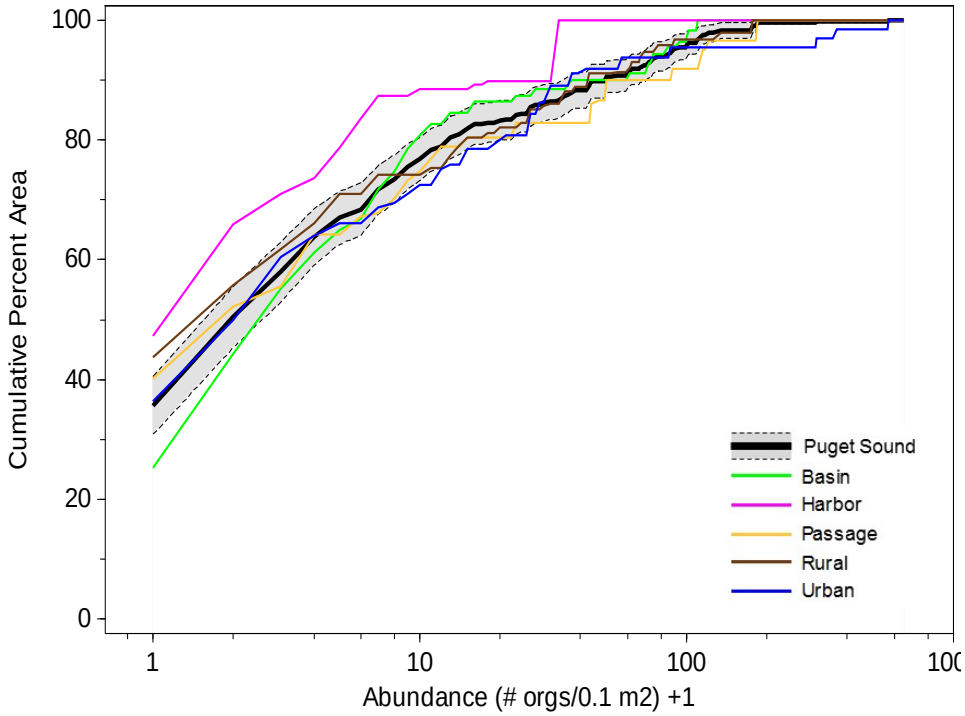
Echinoderm Abundance by Region



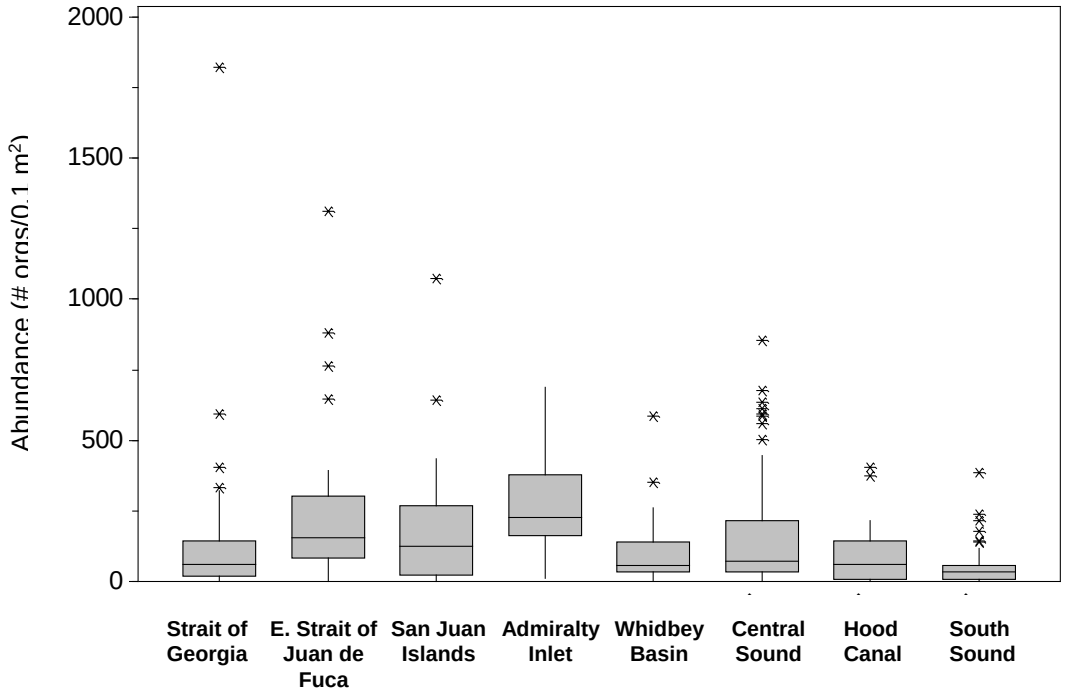


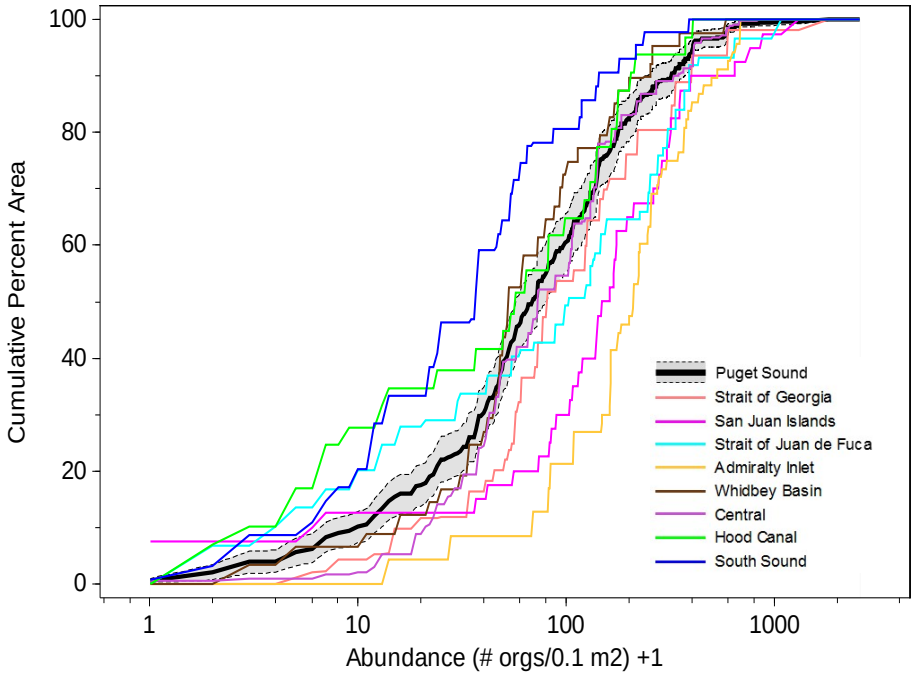
Echinoderm Abundance by Stratum



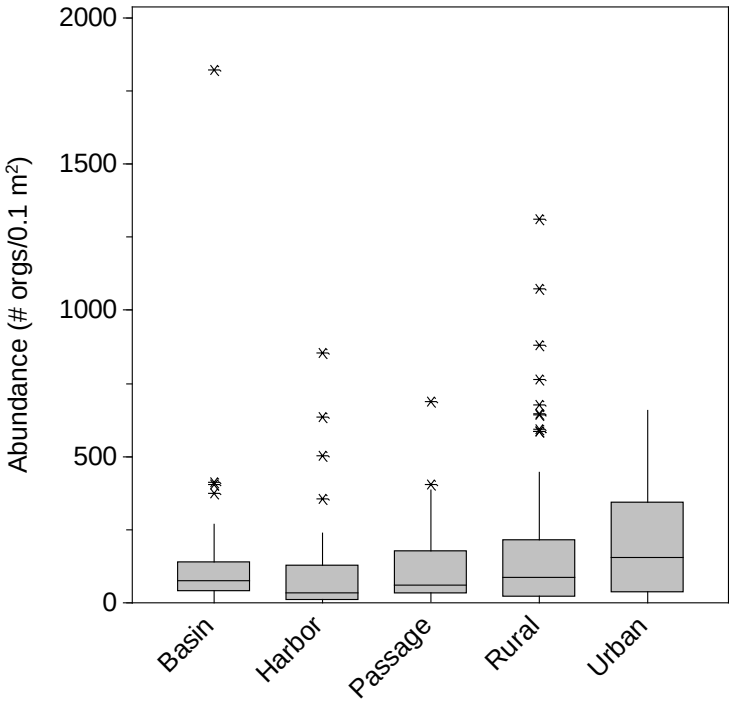


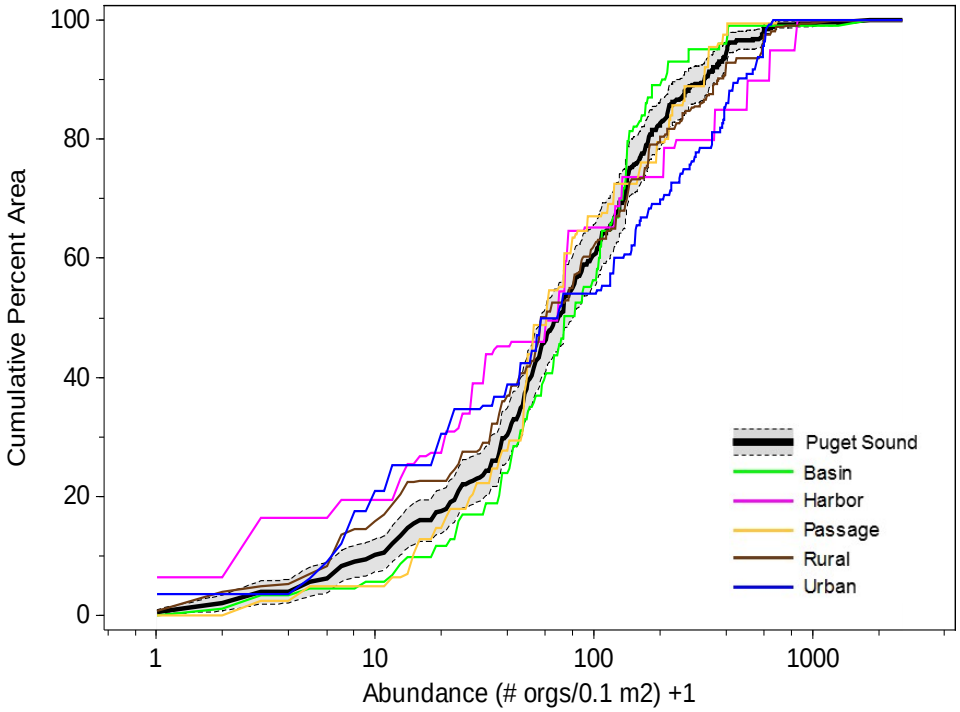
Mollusc Abundance by Region



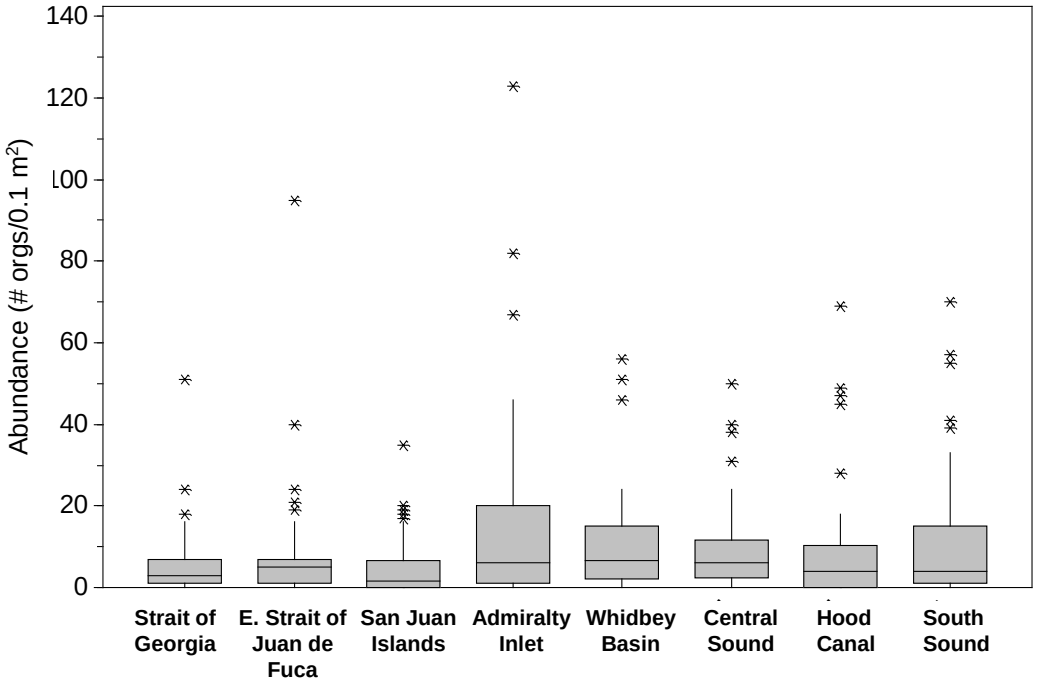


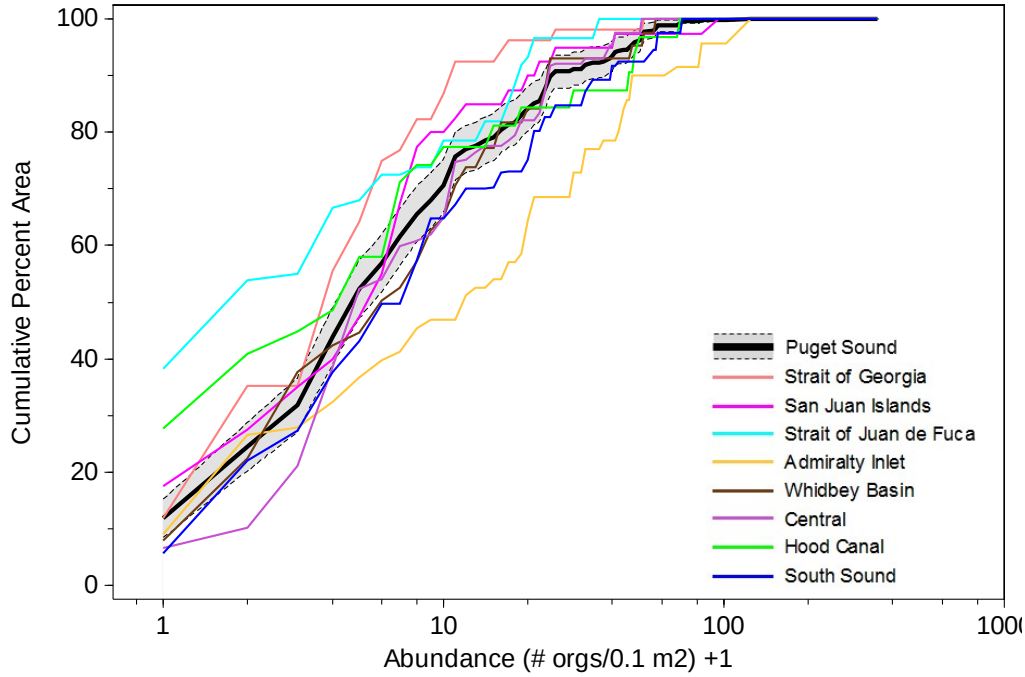
Mollusc Abundance by Stratum



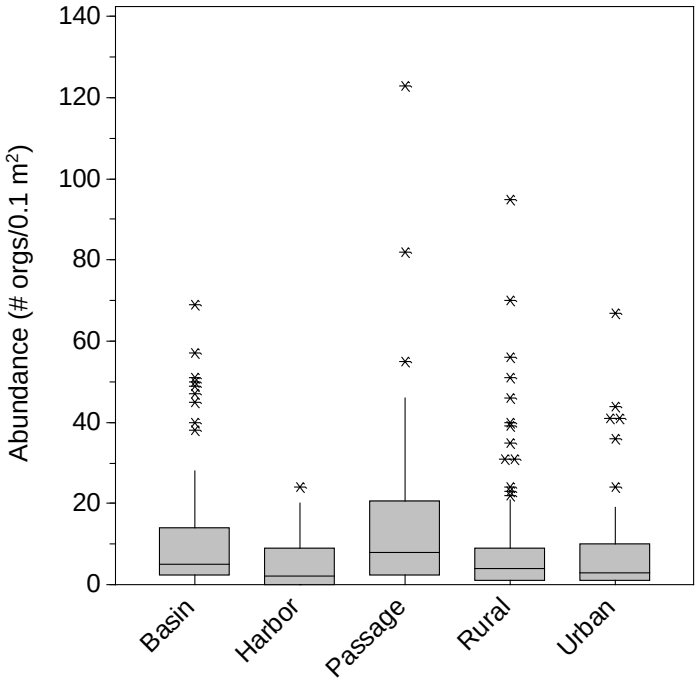


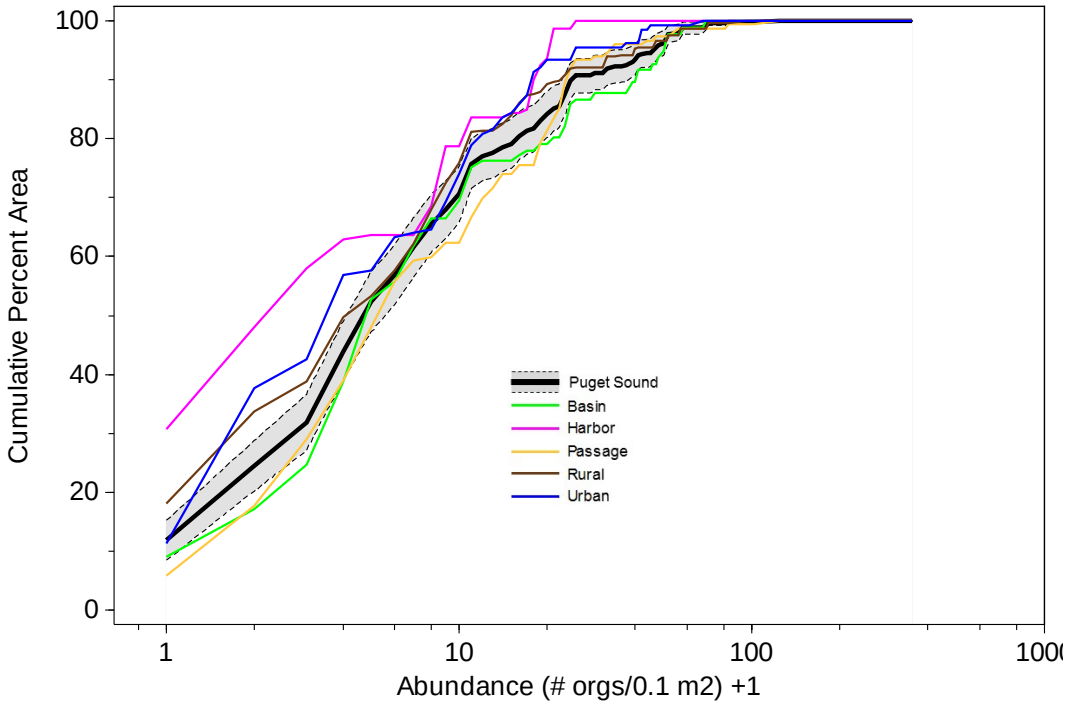
Miscellaneous Taxa Abundance by Region





Miscellaneous Taxa Abundance by Stratum





Comparison with Baseline

Changes[1,2] in benthic invertebrate measures calculated for the 1997-2003 and 2004-2014 surveys of Puget Sound.

↑ = increase, ↓ = decrease, -- = no change, ? = significant only at α = 0.10.

Benthic invertebrate measure	Change over time
Total abundance	↓
Taxa richness	↓
Pielou's Evenness (J')	--
Swartz Dominance Index (SDI)	--
SDI standardized by Richness	--
Annelid abundance	--
Arthropod abundance	--
Echinoderm abundance	↓
Mollusc abundance	--
Abundance of miscellaneous taxa	--
Overall condition of assemblage (as determined with the Benthic Index)	↓

[1] Medians (unweighted) compared by Kruskal-Wallis test (α = 0.05).

[2] CDFs (weighted) compared by Wald F test (α = 0.05).

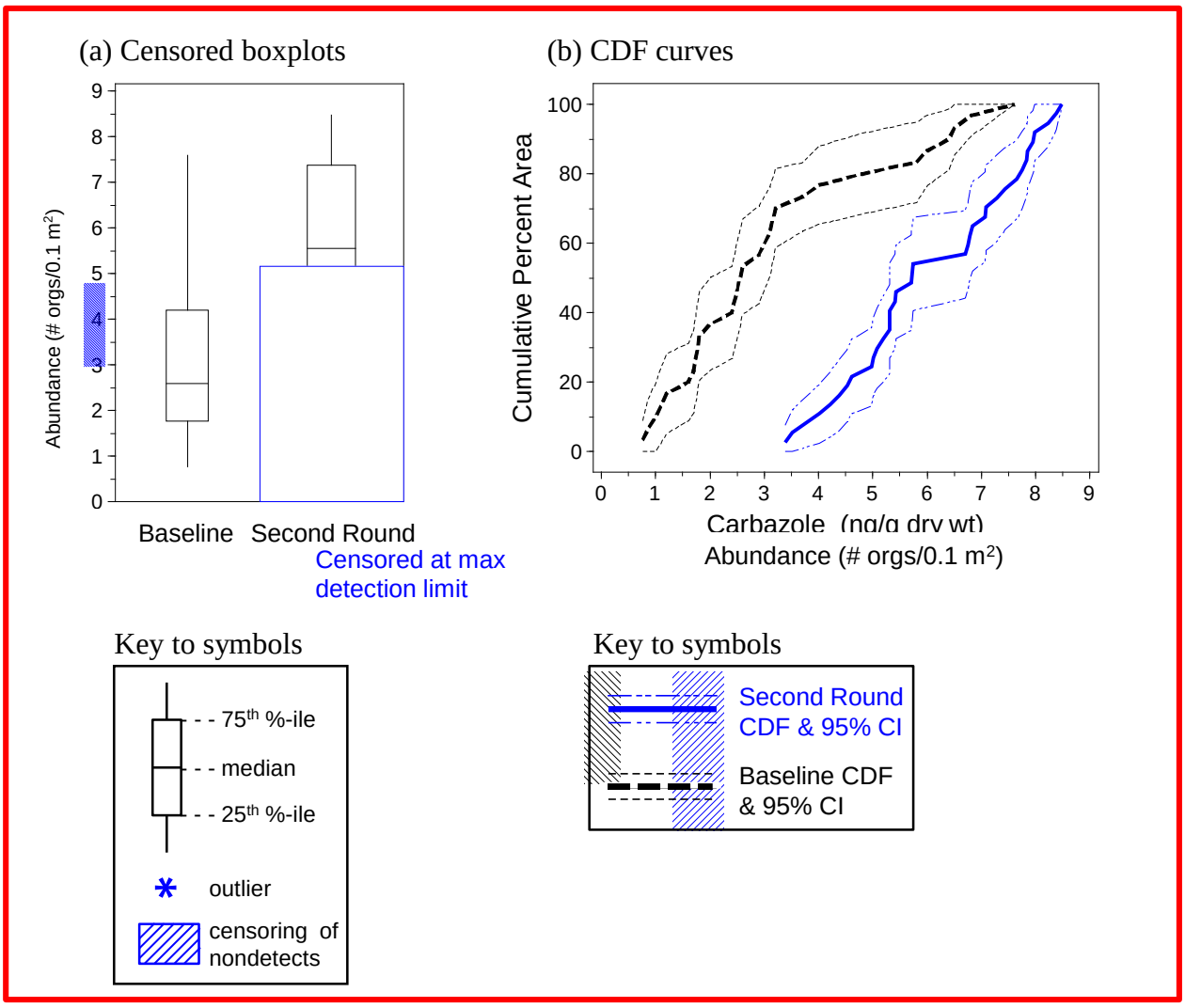
Comparisons of Surveys

Comparison of infaunal indices calculated for Puget Sound, Baseline (1997-2003) vs. Second Round (2004-2014).

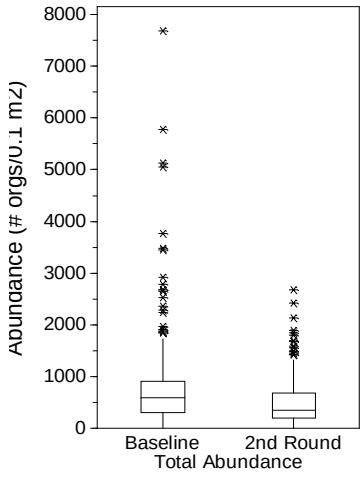
(a) Boxplots display the distributions of the data unweighted by sample area.

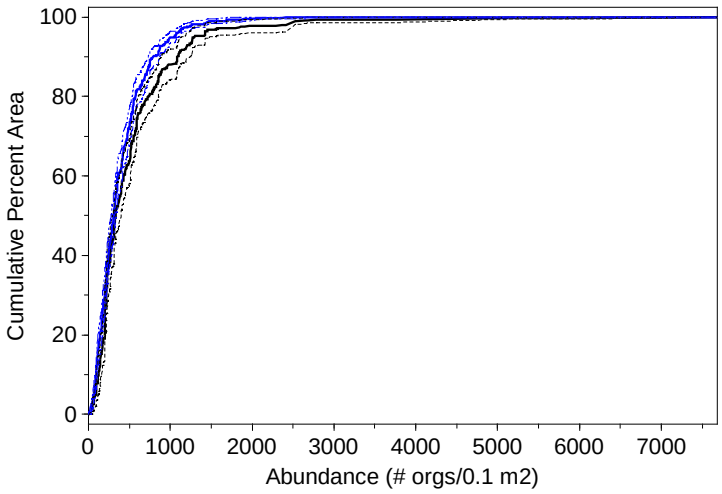
(b) Cumulative distribution function (CDF) curves display the cumulative distributions of the data weighted by sample area.

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

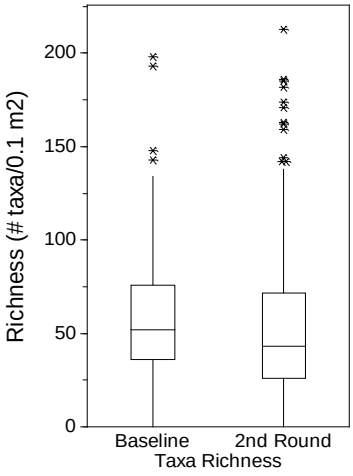


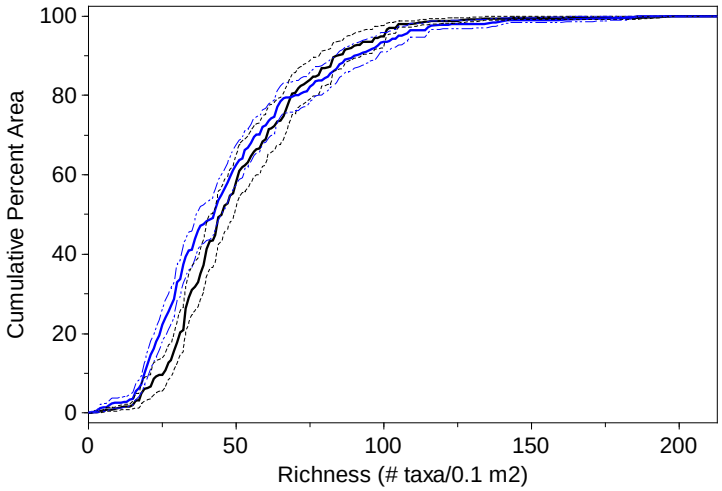
Total Abundance



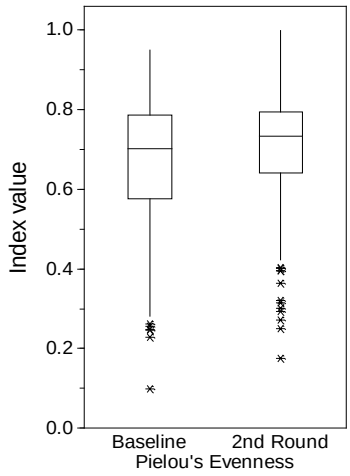


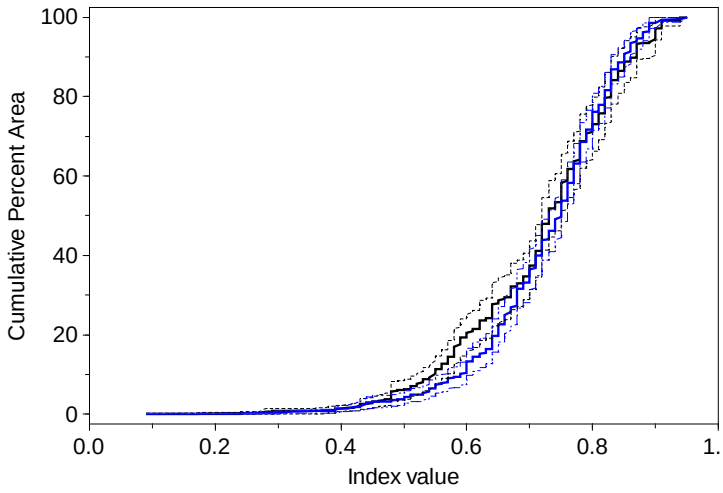
Taxa Richness



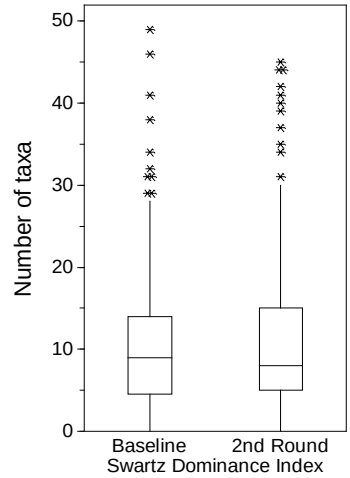


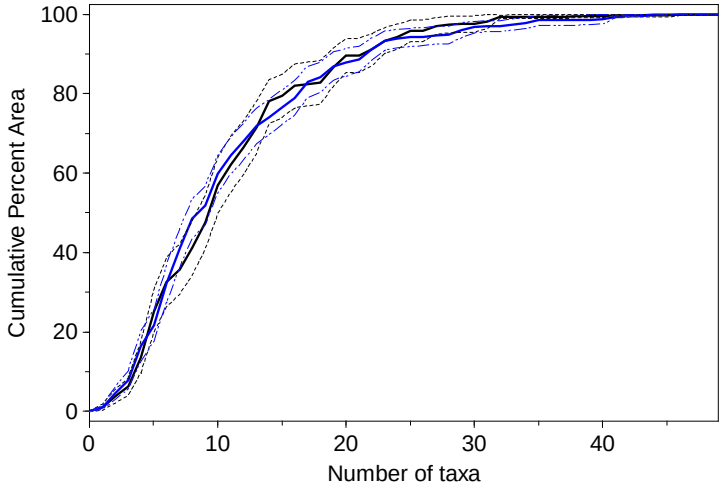
Pielou’s Evenness (J')



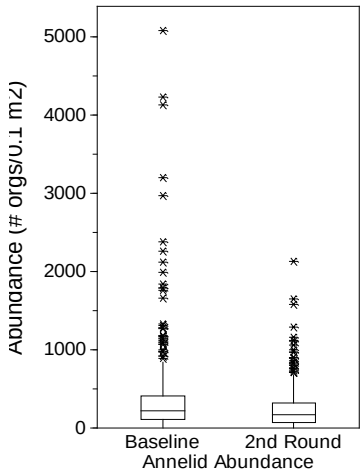


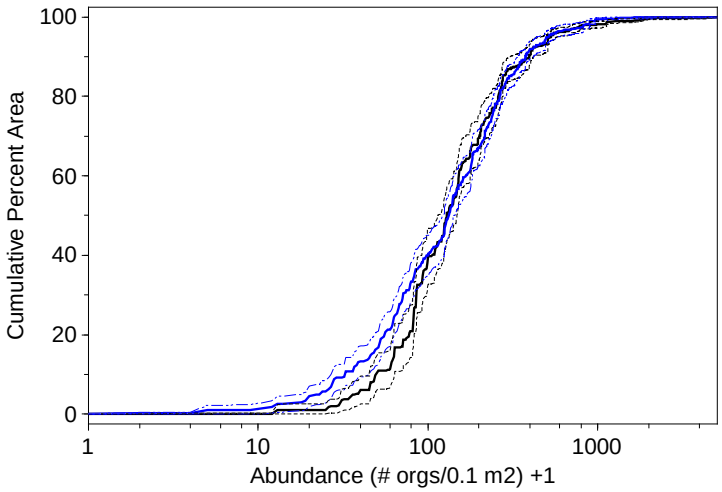
Swartz Dominance Index (SDI)



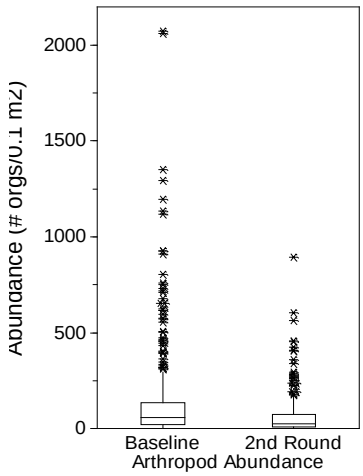


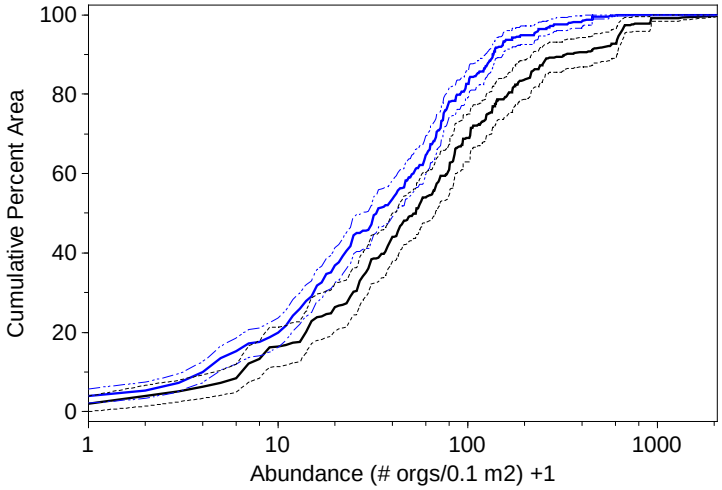
Annelid Abundance



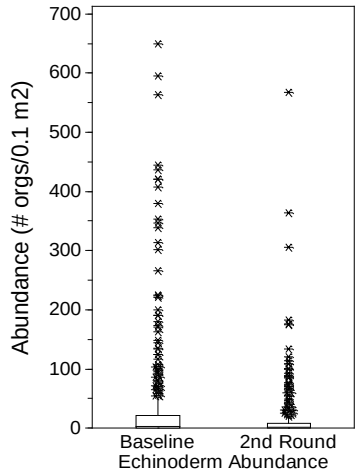


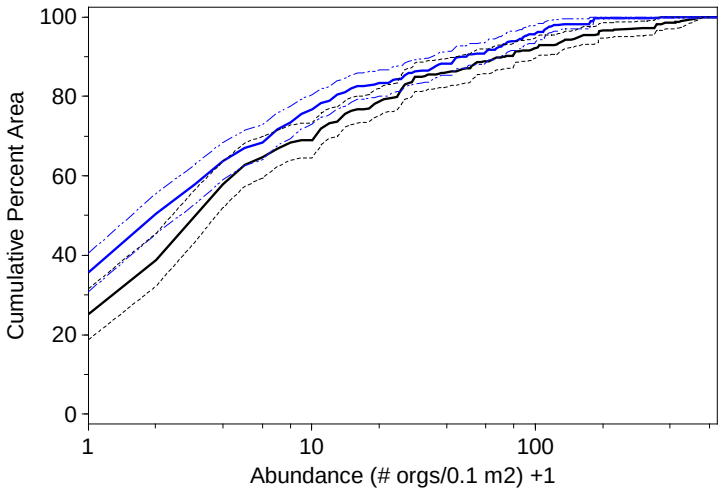
Arthropod Abundance



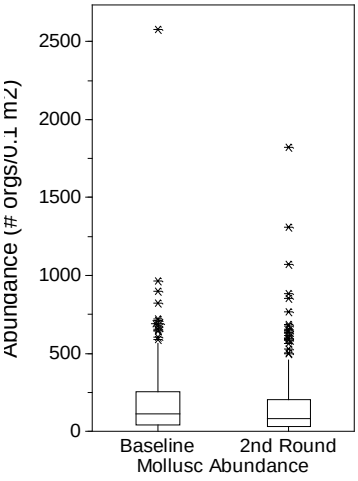


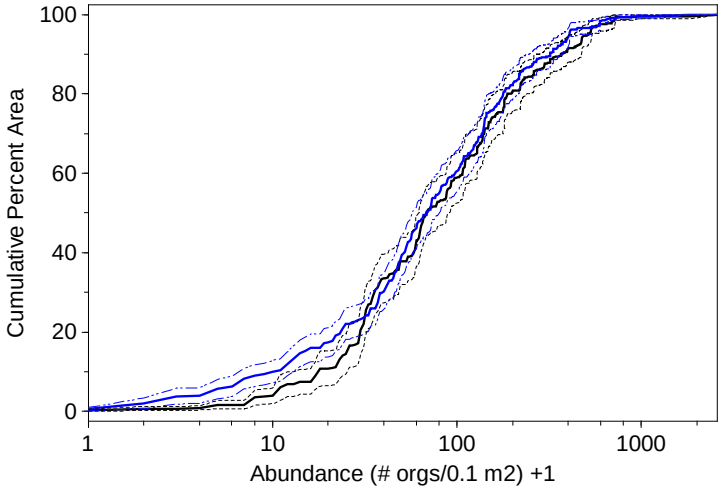
Echinoderm Abundance



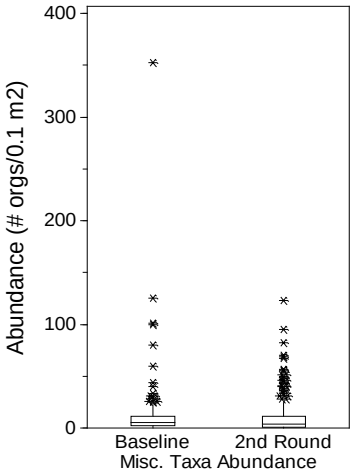


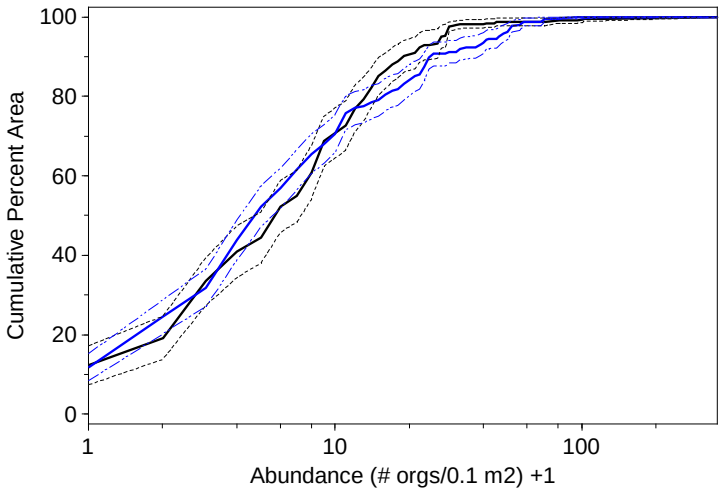
Mollusc Abundance





Abundance of Miscellaneous Taxa





Summary statistics for benthic indices in Puget Sound for the Baseline (1997-2003) and Second Round (2004-2014) surveys.

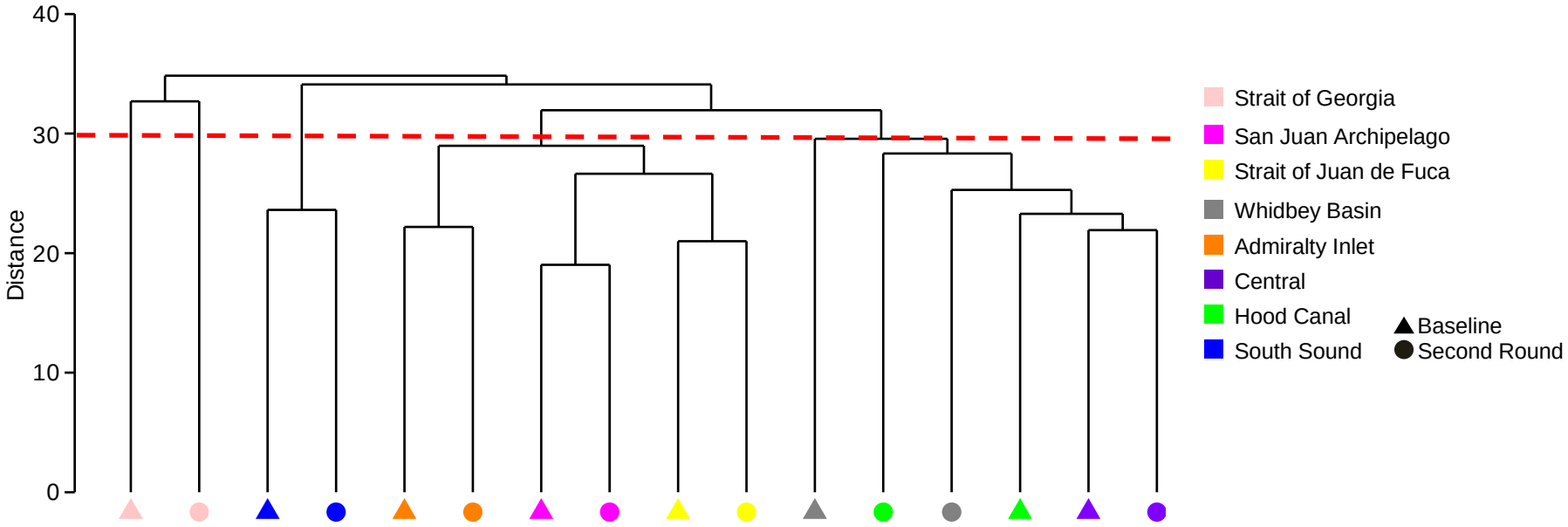
		Region	Strait of Georgia	San Juan Archi-pelago	E. Strait of Juan de Fuca	Admiralty Inlet	Whidbey Basin	Central	Hood Canal	South Sound	**Puget Sound**
Second Round	Total Abundance (# orgs/0.1 m^2)	Min	77	29	4	149	38	1	20	0	0
		Max	2132	1847	1897	1809	984	2683	1073	1451	2683
		Mean	528.18	725.85	598.60	610.12	364.60	479.31	268.53	363.67	492.74
		StdDev	428.36	453.96	488.40	411.45	268.31	480.98	235.20	291.08	421.59
	Taxa richness (# taxa/0.1 m^2)	Min	14	1	3	24	11	1	4	0	0
		Max	185	182	144	216	120	119	142	116	216
		Mean	45.35	53.95	50.75	77.14	47.65	53.04	45.03	39.13	51.55
		StdDev	33.67	39.13	37.27	51.81	27.31	28.28	29.66	27.92	35.83
	Pielou's Evenness (J')	Min	0.29	0.18	0.32	0.25	0.44	0.36	0.60	0.40	0.18
		Max	0.83	0.85	0.95	0.92	0.88	0.91	0.95	0.88	0.95
		Mean	0.69	0.63	0.69	0.68	0.72	0.72	0.79	0.72	0.70
		StdDev	0.13	0.15	0.13	0.15	0.10	0.12	0.07	0.11	0.13
	Swartz Dominance (SDI) (# taxa)	Min	1	1	1	1	3	1	2	0	0
		Max	31	40	23	46	29	41	29	29	46
		Mean	8.85	9.05	8.60	15.98	10.80	11.64	11.33	9.11	10.74
		StdDev	6.52	8.23	6.22	13.67	7.27	8.10	6.01	6.39	8.42
Baseline	Total Abundance (# orgs/0.1 m^2)	Min	54	27	16	227	24	114	26	0	0
		Max	7684	1558	1107	2367	1159	3764	3479	1070	7684
		Mean	1353.57	618.83	501.83	814.63	415.36	780.38	705.14	340.57	750.20
		StdDev	1456.70	362.37	341.87	423.54	301.55	563.59	813.73	255.30	787.58
	Taxa richness (# taxa/0.1 m^2)	Min	11	2	4	41	4	21	15	0	0
		Max	111	148	133	198	80	143	101	105	198
		Mean	51.03	54.50	60.10	84.93	40.10	64.54	50.00	43.45	57.22
		StdDev	20.63	39.84	38.42	39.79	19.73	24.24	27.05	27.32	30.27
	Pielou's Evenness (J')	Min	0.2	0.1	0.6	0.5	0.2	0.3	0.3	0.4	0.1
		Max	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9	0.9
		Mean	0.63	0.63	0.72	0.70	0.68	0.66	0.68	0.73	0.67
		StdDev	0.15	0.18	0.08	0.10	0.13	0.14	0.18	0.14	0.14
	Swartz Dominance (SDI) (# taxa)	Min	1	1	1	4	1	1	1	0	0
		Max	27	41	28	46	25	49	23	25	49
		Mean	8.00	10.23	12.43	15.83	7.87	11.04	9.29	10.36	10.48
		StdDev	5.79	10.25	8.05	9.80	5.11	8.32	5.93	7.33	7.96

Summary statistics for infaunal indices at stations with *adversely affected* and *unaffected* benthos in the Baseline (1997-2003) and Second Round (2004-2014) surveys of Puget Sound.

Index	Statistic	Baseline		Second Round	
		Adversely affected	Unaffected	Adversely affected	Unaffected
Total Abundance (# orgs/0.1 m^2)	Min	0	114	0	94
	Max	3764	7684	1690	2683
	Mean	580.31	860.52	315.64	648.15
	StdDev	624.17	861.04	330.17	432.40
Taxa richness (# taxa/0.1 m^2)	Min	0	20	0	16
	Max	116	198	66	216
	Mean	39.01	69.03	27.55	72.62
	StdDev	21.82	29.14	13.51	36.08
Pielou's Evenness (J')	Min	0.10	0.25	0.18	0.40
	Max	0.95	0.91	0.95	0.92
	Mean	0.63	0.70	0.68	0.73
	StdDev	0.17	0.12	0.15	0.10
Swartz' Dominance Index (# taxa)	Min	0	1	0	2
	Max	25	49	22	46
	Mean	6.25	13.23	5.85	15.02
	StdDev	4.14	8.62	3.53	9.11
Annelid Abundance (# orgs/0.1 m^2)	Min	0	30	0	32
	Max	3202	5084	1647	2134
	Mean	400.79	372.50	196.78	300.28
	StdDev	530.29	579.64	273.51	259.36
Arthropod Abundance (# orgs/0.1 m^2)	Min	0	4	0	0
	Max	459	2075	893	605
	Mean	40.40	206.57	24.44	95.12
	StdDev	65.37	303.10	73.81	104.48
Mollusc Abundance (# orgs/0.1 m^2)	Min	0	0	0	0
	Max	688	2581	687	1822
	Mean	128.79	215.20	88.12	211.82
	StdDev	157.33	240.76	115.12	239.31
Echinoderm Abundance (# orgs/0.1 m^2)	Min	0	0	0	0
	Max	105	650	183	568
	Mean	5.96	54.08	3.49	24.26
	StdDev	16.52	109.89	16.02	59.70
Misc. Taxa Abundance (# orgs/0.1 m^2)	Min	0	0	0	0
	Max	125	353	25	130
	Mean	4.37	12.17	2.80	16.67
	StdDev	10.97	25.88	3.89	18.90

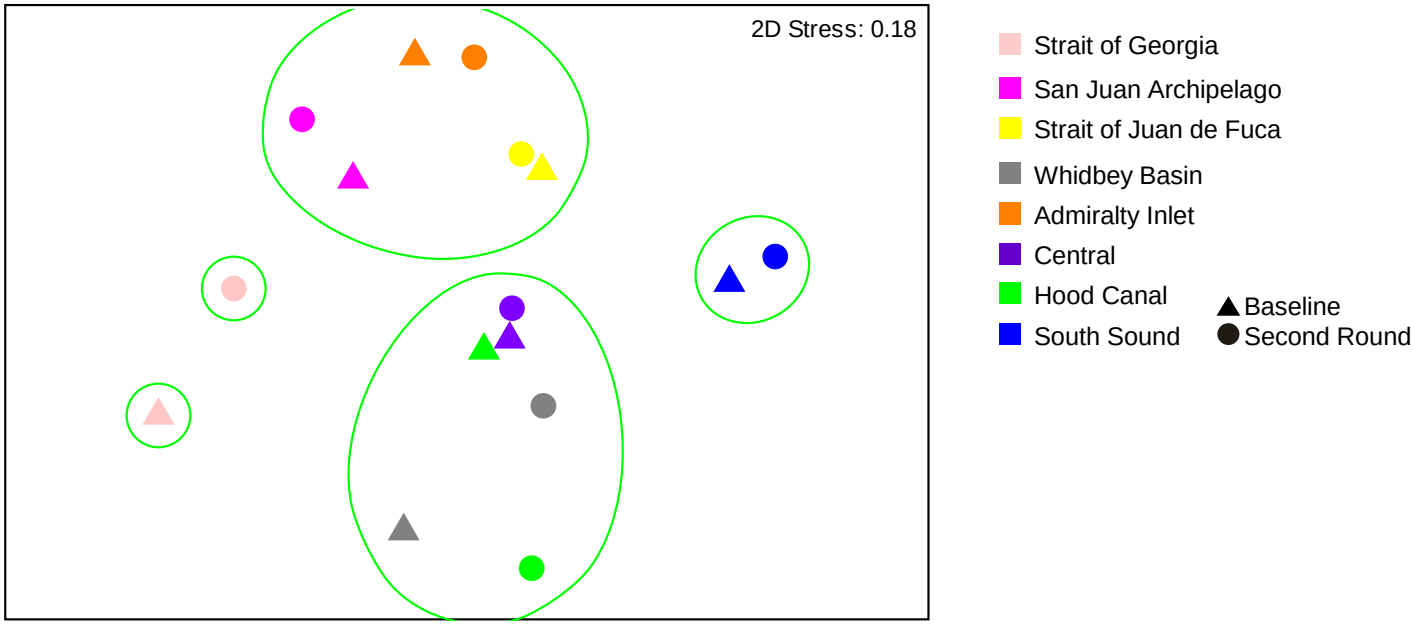
Cluster dendrogram indicating similarities of the centroids of the benthic invertebrate assemblages for the eight sediment monitoring regions in the Baseline (1997-2003) and Second Round (2004-2014) surveys of Puget Sound

(Bray-Curtis similarities of 4th-root-transformed unweighted abundances, all species).
The dendrogram is sliced at 30% similarity.



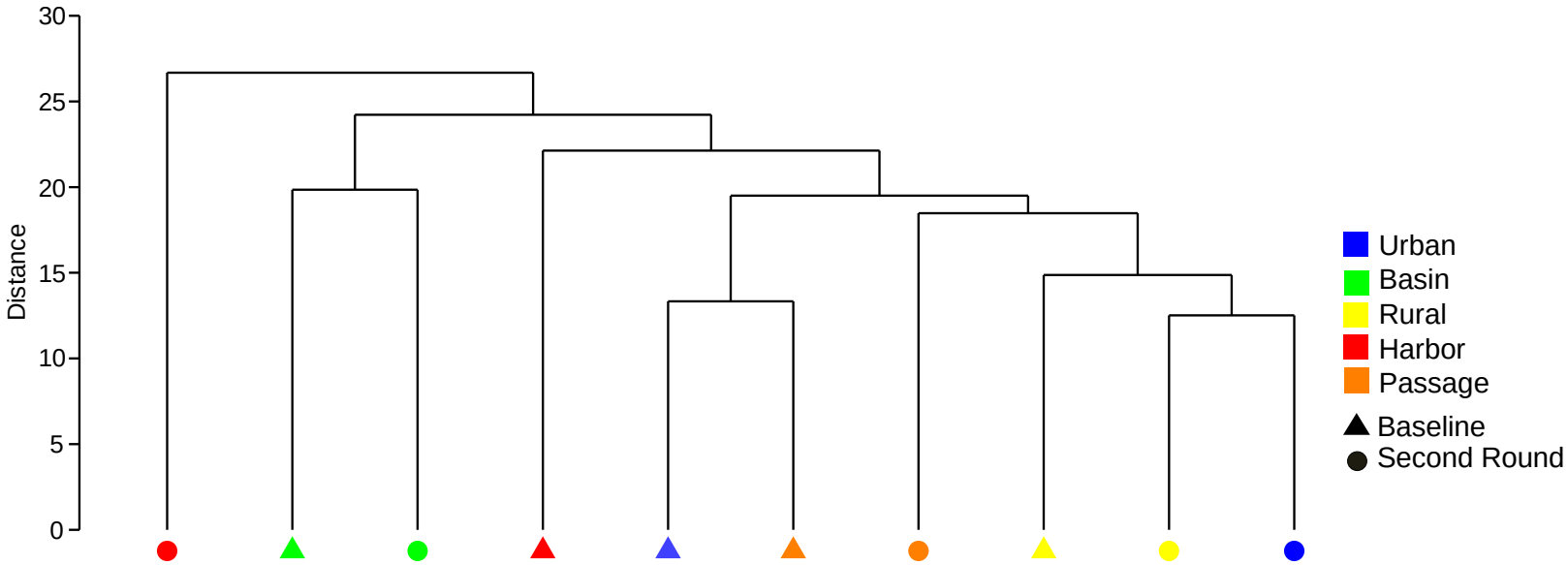
Nonmetric multidimensional scaling (MDS) diagram indicating relative similarities of the centroids of the benthic invertebrate assemblages for the eight regions in each of the two surveys.

(Bray-Curtis similarities of *4th-root-transformed unweighted abundances, all species; 2D stress=0.18).*
The ellipses indicate assemblages with 30% or greater similarity, from the cluster dendrogram in the previous figure.
The closer the symbols are in the diagram, the more similar their assemblages are.



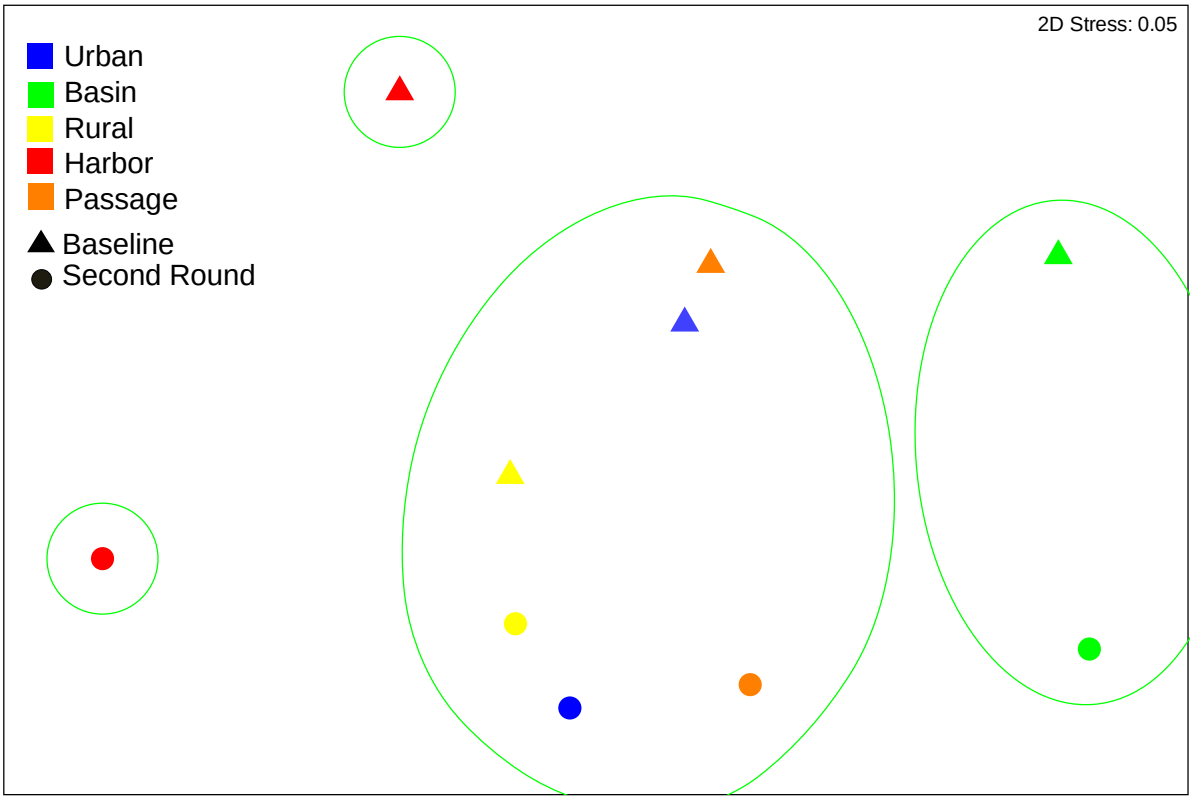
Cluster dendrogram indicating similarities of the centroids of the benthic invertebrate assemblages for the five sediment monitoring strata in each of the two surveys.

(Bray-Curtis similarities of *4th-root-transformed unweighted abundances, all species; 2D stress=0.05).*
The dendrogram is sliced at 20% similarity.



Nonmetric multidimensional scaling (MDS) diagram indicating relative similarities of the centroids of the benthic invertebrate assemblages for the five sediment monitoring strata and two surveys.

(Bray-Curtis similarities of 4th-root-transformed unweighted abundances, all species; 2D stress=0.05).
The ellipses indicate assemblages with 20% or greater similarity, from the cluster dendrogram in the previous figure.
The closer the symbols are in the diagram, the more similar their assemblages are.



Comparisons of Regions, Strata, and Surveys

Incidence and spatial extent of benthic condition in eight regions, five strata, and all of Puget Sound, for both the Baseline (1997-2003) and Second Round (2004-2014) sediment surveys.

Region / Stratum	Baseline								Second Round							
	Adversely affected				Unaffected				Adversely affected				Unaffected			
	Stations		Area		Stations		Area		Stations		Area		Stations		Area	
	No.	(%)	km²	(%)	No.	(%)	km²	(%)	No.	(%)	km²	(%)	No.	(%)	km²	(%)
Strait of Georgia	**10**	**(16.4)**	**59.4**	**(15.4)**	**51**	**(83.6)**	**327.5**	**(84.6)**	**19**	**(47.5)**	**159.1**	**(44.1)**	**21**	**(52.5)**	**201.6**	**(55.9)**
Basin	0	(0.0)	0.0	(0.0)	7	(100.0)	92.8	(100.0)	0	(0.0)	0.0	(0.0)	13	(100.0)	86.2	(100.0)
Harbor	1	(16.7)	0.3	(16.1)	5	(83.3)	1.6	(83.9)	3	(100.0)	1.4	(100.0)	0	(0.0)	0.0	(0.0)
Passage	1	(11.1)	18.7	(13.4)	8	(88.9)	120.9	(86.6)	4	(50.0)	62.0	(50.0)	4	(50.0)	62.0	(50.0)
Rural	2	(9.5)	12.1	(10.5)	19	(90.5)	103.6	(89.5)	4	(57.1)	66.2	(57.1)	3	(42.9)	49.6	(42.9)
Urban	6	(33.3)	28.3	(76.8)	12	(66.7)	8.5	(23.2)	8	(88.9)	29.5	(88.9)	1	(11.1)	3.7	(11.1)
San Juan Arch	**20**	**(66.7)**	**53.8**	**(66.7)**	**10**	**(33.3)**	**26.9**	**(33.3)**	**23**	**(57.5)**	**45.7**	**(57.5)**	**17**	**(42.5)**	**33.8**	**(42.5)**
Rural	20	(66.7)	53.8	(66.7)	10	(33.3)	26.9	(33.3)	23	(57.5)	45.7	(57.5)	17	(42.5)	33.8	(42.5)
Eastern Strait of Juan de Fuca	**15**	**(50.0)**	**39.4**	**(63.8)**	**15**	**(50.0)**	**22.4**	**(36.2)**	**25**	**(62.5)**	**43.7**	**(64.4)**	**15**	**(37.5)**	**24.2**	**(35.6)**
Harbor	0	(0.0)	0.0	(0.0)	4	(100.0)	3.5	(100.0)	4	(80.0)	2.8	(80.0)	1	(20.0)	0.7	(20.0)
Rural	14	(77.8)	38.3	(77.8)	4	(22.2)	10.9	(22.2)	16	(66.7)	36.5	(66.7)	8	(33.3)	18.2	(33.3)
Urban	1	(12.5)	1.1	(12.5)	7	(87.5)	7.9	(87.5)	5	(45.5)	4.3	(45.5)	6	(54.5)	5.2	(54.5)
Admiralty Inlet	**2**	**(6.7)**	**3.1**	**(4.4)**	**28**	**(93.3)**	**66.1**	**(95.6)**	**10**	**(23.3)**	**15.4**	**(23.2)**	**33**	**(76.7)**	**51.1**	**(76.8)**
Passage	0	(0.0)	0.0	(0.0)	10	(100.0)	38.4	(100.0)	3	(23.1)	**8.5**	(23.1)	10	(76.9)	28.2	(76.9)
Urban	2	(10.0)	3.1	(10.0)	18	(90.0)	27.7	(90.0)	7	(23.3)	7.0	(23.3)	23	(76.7)	22.9	(76.7)
Whidbey Basin	**29**	**(74.4)**	**233.3**	**(69.0)**	**10**	**(25.6)**	**104.8**	**(31.0)**	**20**	**(50.0)**	**185.6**	**(52.5)**	**20**	**(50.0)**	**167.7**	**(47.5)**
Harbor	9	(100.0)	0.7	(100.0)		(0.0)		(0.0)	1	(33.3)	0.3	(33.3)	2	(66.7)	0.5	(66.7)
Passage	7	(58.3)	112.0	(64.8)	5	(41.7)	60.9	(35.2)	9	(60.0)	103.7	(60.0)	6	(40.0)	69.1	(40.0)
Rural	13	(72.2)	120.6	(73.3)	5	(27.8)	44.0	(26.7)	10	(45.5)	81.7	(45.5)	12	(54.5)	98.0	(54.5)
Central	**42**	**(32.8)**	**47.4**	**(6.9)**	**86**	**(67.2)**	**636.5**	**(93.1)**	**27**	**(33.8)**	**186.8**	**(28.0)**	**53**	**(66.3)**	**480.6**	**(72.0)**
Basin	1	(4.3)	22.9	(4.7)	22	(95.7)	459.2	(95.3)	9	(30.0)	140.0	(30.0)	21	(70.0)	326.6	(70.0)

Region / Stratum	Baseline								Second Round							
	Adversely affected				Unaffected				Adversely affected				Unaffected			
	Stations		Area		Stations		Area		Stations		Area		Stations		Area	
	No.	(%)	km²	(%)	No.	(%)	km²	(%)	No.	(%)	km²	(%)	No.	(%)	km²	(%)
Harbor	26	(68.4)	10.5	(75.5)	12	(31.6)	3.4	(24.5)	8	(61.5)	7.9	(61.5)	5	(38.5)	5.0	(38.5)
Passage	1	(4.8)	1.1	(1.2)	20	(95.2)	85.3	(98.8)	1	(10.0)	8.6	(10.0)	9	(90.0)	77.7	(90.0)
Rural	1	(11.1)	3.5	(6.4)	8	(88.9)	51.1	(93.6)	2	(20.0)	10.9	(20.0)	8	(80.0)	43.7	(80.0)
Urban	13	(35.1)	9.5	(20.2)	24	(64.9)	37.6	(79.8)	7	(41.2)	19.4	(41.2)	10	(58.8)	27.7	(58.8)
Hood Canal	**14**	**(66.7)**	**225.6**	**(68.0)**	**7**	**(33.3)**	**106.1**	**(32.0)**	**23**	**(76.7)**	**230.2**	**(78.1)**	**7**	**(23.3)**	**64.6**	**(21.9)**
Basin	3	(50.0)	128.7	(55.8)	3	(50.0)	102.0	(44.2)	14	(66.7)	129.2	(66.7)	7	(33.3)	64.6	(33.3)
Rural	11	(73.3)	96.9	(95.9)	4	(26.7)	4.1	(4.1)	9	(100.0)	101.0	(100.0)	0	(0.0)	0.0	(0.0)
South Sound	**18**	**(42.9)**	**130.4**	**(38.2)**	**24**	**(57.1)**	**211.2**	**(61.8)**	**25**	**(45.5)**	**107.5**	**(33.8)**	**30**	**(54.5)**	**210.2**	**(66.2)**
Basin	0	(0.0)	0.0	(0.0)	6	(100.0)	84.9	(100.0)	0	(0.0)	0.0	(0.0)	8	(100.0)	75.4	(100.0)
Harbor	6	(100.0)	1.1	(100.0)	0	(0.0)	0.0	(0.0)	8	(88.9)	1.0	(88.9)	1	(11.1)	0.1	(11.1)
Passage	0	(0.0)	0.0	(0.0)	9	(100.0)	54.4	(100.0)	2	(28.6)	13.6	(28.6)	5	(71.4)	34.1	(71.4)
Rural	11	(61.1)	123.8	(67.1)	7	(38.9)	60.8	(32.9)	11	(47.8)	84.6	(47.8)	12	(52.2)	92.3	(52.2)
Urban	1	(33.3)	5.5	(33.3)	2	(66.7)	11.0	(66.7)	4	(50.0)	8.3	(50.0)	4	(50.0)	8.3	(50.0)
Puget Sound	**150**	**(39.4)**	**792.5**	**(34.5)**	**231**	**(60.6)**	**1501.6**	**(65.5)**	**172**	**(46.7)**	**974.0**	**(44.1)**	**196**	**(53.3)**	**1233.6**	**(55.9)**
Basin	4	(9.5)	151.6	(17.0)	38	(90.5)	738.9	(83.0)	23	(31.9)	269.2	(32.7)	49	(68.1)	552.8	(67.3)
Harbor	42	(66.7)	12.7	(59.8)	21	(33.3)	8.5	(40.2)	24	(72.7)	13.4	(68.1)	9	(27.3)	6.3	(31.9)
Passage	9	(14.8)	131.8	(26.8)	52	(85.2)	359.9	(73.2)	19	(35.8)	196.4	(42.0)	34	(64.2)	271.1	(58.0)
Rural	72	(55.8)	449.0	(59.8)	57	(44.2)	301.5	(40.2)	75	(55.6)	426.5	(56.0)	60	(44.4)	335.6	(44.0)
Urban	23	(26.7)	47.5	(33.9)	63	(73.3)	92.7	(66.1)	31	(41.3)	68.4	(50.2)	44	(58.7)	67.8	(49.8)

Incidence and spatial extent of *adversely affected* benthos in eight sediment monitoring regions and all of Puget Sound, by survey.

Monitoring Region	Year(s) sampled	Numbers of Samples	Percent of Stations with Adversely Affected Benthos	Percent of Area with Adversely Affected Benthos
Strait of Georgia	1997	61	16.4	15.4
	2006	40	47.5	44.1
San Juan Archipelago	2002-2003	30	66.7	66.7
	2012	40	57.5	57.5
Eastern Strait of Juan de Fuca	2002-2003	30	50	63.8
	2013	40	62.5	64.4
Admiralty Inlet	1998-2003	30	6.7	4.5
	2014	43	23.3	22.3
Whidbey Basin	1997	39	74.4	69
	2007	40	50	52.5
Central	1998-1999	128	32.8	6.9
	2008-2009	80	33.8	28
Hood Canal	1999	21	66.7	68
	2004	30	76.7	78.1
South Sound	1999	42	42.9	38.2
	2011	55	50	33.8
All of Puget Sound	1997-2003	381	39.4	34.5
	2004-2014	368	46.7	44.0

Comparison of Benthic Index Categories by Year

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

The differences between sampling events are statistically significant, as indicated by the difference confidence intervals *not* containing the value zero.

Interim Sediment Benthic 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	
Unaffected	55.88	51.15	60.61	65.45	60.25	70.65	-9.58	-16.61	-2.54	*
Adversely affected	44.12	39.39	48.85	34.55	29.35	39.75	9.58	2.54	16.61	*