

# **2015 Bainbridge Basin Marine Sediment Monitoring**



## **Infaunal Community Data Summary**

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## Results and Statistical Summaries

[Benthic infaunal results for the 2015 Bainbridge Basin survey.](#)

[Benthic infaunal species identified for the 2015 Bainbridge Basin survey.](#)

## Statistical Summaries of 5 Benthic Indices

Benthic infaunal indices calculated to characterize the infaunal invertebrate assemblages identified for the 2015 Bainbridge Basin survey.

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	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 $i^{\text{th}}$ species ( $p_i = n_i/N$ , where $n_i$ = the number of individuals in the $i^{\text{th}}$ species and $N$ = total number of individuals) and $S$ = the total number of species ( $H'$ is the Shannon-Wiener diversity index)
Swartz's 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

Total abundance, major taxa abundance, and major taxa percent abundance calculated for the 2015 Bainbridge Basin survey.

*Abundances are expressed in numbers of organisms per 0.1 m<sup>2</sup>.*

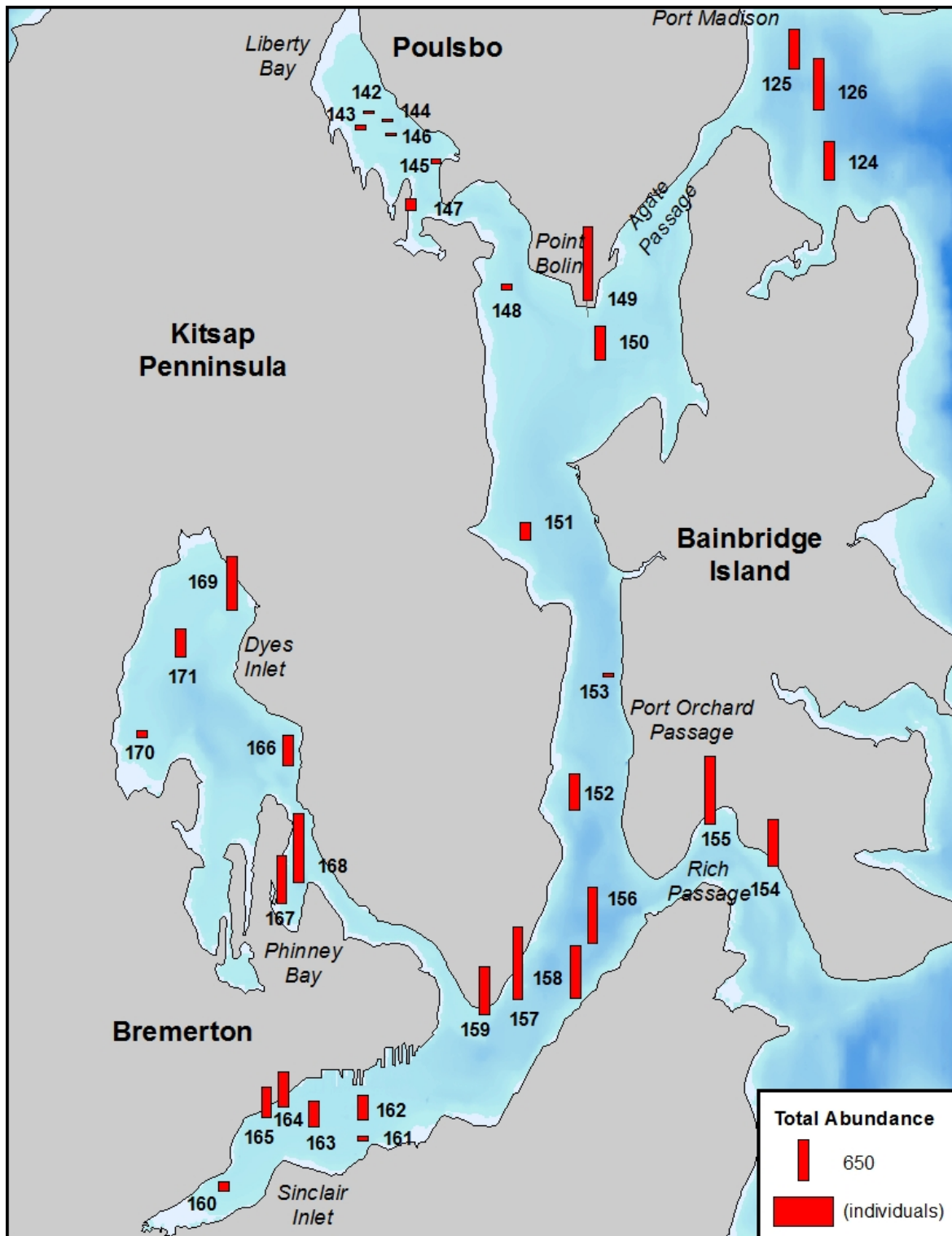
Station	Total abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Echino-dermata	Echinodermata % of total abundance	Mollusca	Mollusca % of total abundance	Misc. taxa	Misc. taxa % of total abundance
124	554	107	19.31	106	19.13	106	19.13	233	42.06	2	0.36
125	708	235	33.19	98	13.84	61	8.62	301	42.51	13	1.84
126	432	87	20.14	92	21.30	16	3.70	229	53.01	8	1.85
142	65	25	38.46	18	27.69	0	0.00	19	29.23	3	4.62
143	72	42	58.33	10	13.89	1	1.39	15	20.83	4	5.56
144	62	33	53.23	12	19.35	0	0.00	15	24.19	2	3.23
145	133	80	60.15	16	12.03	1	0.75	27	20.30	9	6.77
146	131	47	35.88	57	43.51	0	0.00	26	19.85	1	0.76
147	299	213	71.24	2	0.67	3	1.00	81	27.09	0	0.00
148	154	88	57.14	5	3.25	0	0.00	61	39.61	0	0.00
149	549	157	28.60	94	17.12	2	0.36	291	53.01	5	0.91
150	217	99	45.62	27	12.44	21	9.68	60	27.65	10	4.61
151	154	75	48.70	17	11.04	2	1.30	50	32.47	10	6.49
152	547	252	46.07	14	2.56	31	5.67	232	42.41	18	3.29
153	81	51	62.96	0	0.00	0	0.00	29	35.80	1	1.23
154	650	262	40.31	34	5.23	3	0.46	331	50.92	20	3.08
155	654	139	21.25	93	14.22	0	0.00	410	62.69	12	1.83
156	294	145	49.32	84	28.57	3	1.02	53	18.03	9	3.06
157	643	260	40.44	77	11.98	18	2.80	279	43.39	9	1.40
158	457	110	24.07	75	16.41	3	0.66	264	57.77	5	1.09
159	568	163	28.70	38	6.69	10	1.76	339	59.68	18	3.17

Station	Total abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Echino-dermata	Echinodermata % of total abundance	Mollusca	Mollusca % of total abundance	Misc. taxa	Misc. taxa % of total abundance
160	70	63	90.00	0	0.00	0	0.00	6	8.57	1	1.43
161	70	54	77.14	10	14.29	0	0.00	5	7.14	1	1.43
162	574	414	72.13	28	4.88	0	0.00	129	22.47	3	0.52
163	55	20	36.36	9	16.36	0	0.00	26	47.27	0	0.00
164	642	572	89.10	31	4.83	7	1.09	26	4.05	6	0.93
165	900	673	74.78	146	16.22	14	1.56	57	6.33	10	1.11
166	323	168	52.01	23	7.12	0	0.00	123	38.08	9	2.79
167	187	141	75.40	11	5.88	0	0.00	31	16.58	4	2.14
168	407	333	81.82	11	2.70	0	0.00	63	15.48	0	0.00
169	354	192	54.24	60	16.95	0	0.00	96	27.12	6	1.69
170	5	3	60.00	1	20.00	0	0.00	0	0.00	1	20.00
171	292	243	83.22	12	4.11	1	0.34	33	11.30	3	1.03
Mean	343	168	52.40	40	12.55	9	1.86	119	30.51	6	2.67
Median	299	139	52.01	23	12.44	1	0.36	60	27.65	5	1.69
Min	5	3	19.31	0	0.00	0	0.00	0	0.00	0	0.00
Max	900	673	90.00	146	43.51	106	19.13	410	62.69	20	20.00

Total abundance, taxa richness, Pielou's evenness, and Swartz Dominance Index calculated for the 2015 Bainbridge Basin survey.

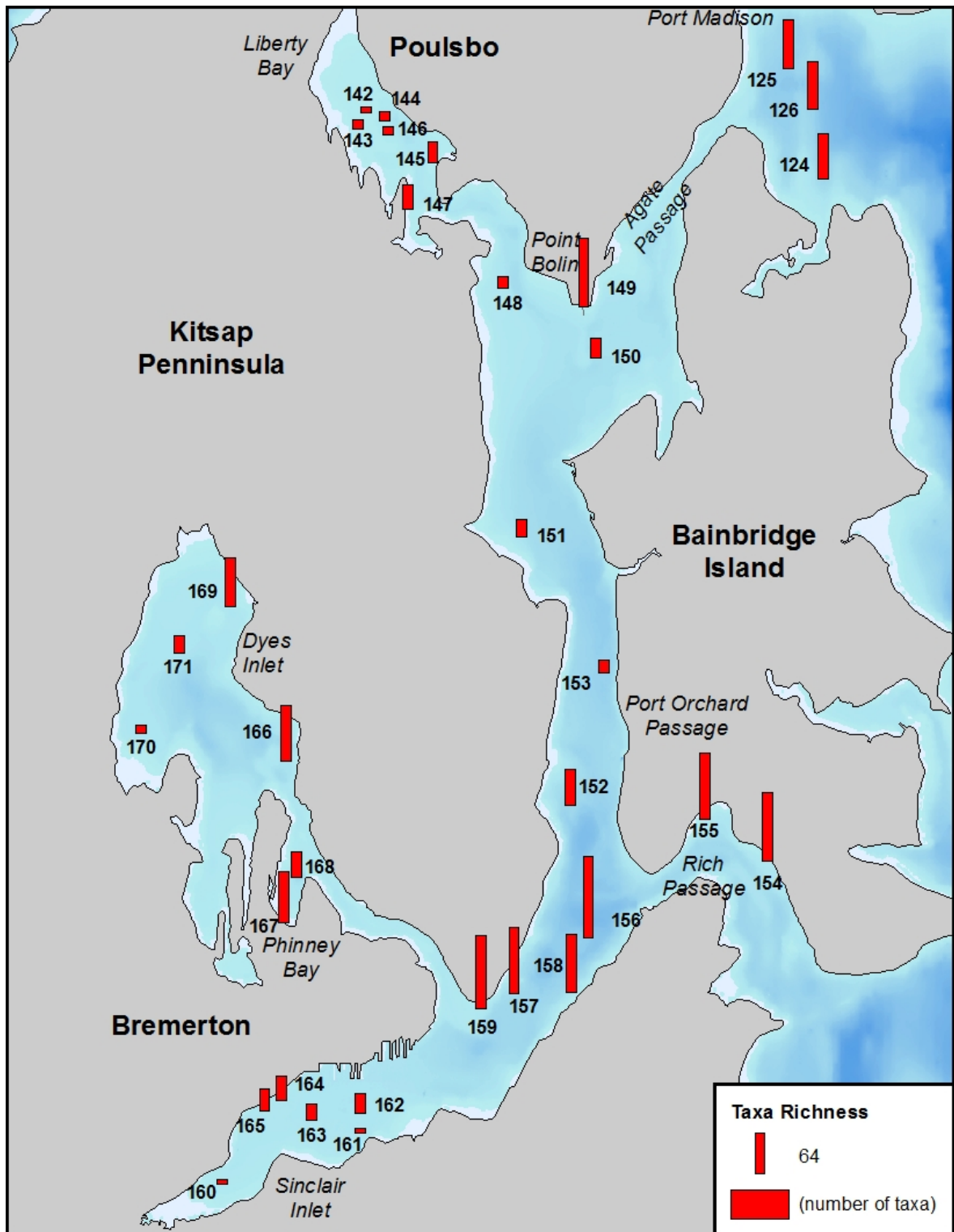
Station	Location	Total abundance (# org/0.1 m <sup>2</sup> )	Taxa richness (# taxa/0.1 m <sup>2</sup> )	Pielou's evenness (J')	Swartz Dominance Index (# taxa)
124	Port Madison	554	64	0.73	12
125	Port Madison	708	83	0.75	15
126	Port Madison	432	71	0.77	16
142	Liberty Bay	65	14	0.84	6
143	Liberty Bay	72	18	0.73	6
144	Liberty Bay	62	16	0.84	6
145	Liberty Bay	133	42	0.89	16
146	Liberty Bay	131	19	0.78	6
147	Liberty Bay	299	44	0.72	9
148	Southeast of Keyport	154	17	0.77	5
149	North Port Orchard Pt. Bolin	549	84	0.73	18
150	North Port Orchard	217	38	0.90	16
151	North Port Orchard E. of Brownsville	154	40	0.89	15
152	Port Orchard Illahee	547	74	0.74	15
153	Port Orchard	81	27	0.88	11
154	Rich Pass Pleasant Beach	650	95	0.81	22
155	Rich Pass Lynwood Center	654	76	0.73	17
156	South Port Orchard	294	89	0.84	31
157	South Port Orchard East Bremerton	643	115	0.81	26
158	South Port Orchard	457	72	0.77	16
159	South Port Orchard Pt. Herron	568	113	0.72	25
160	Sinclair Inlet	70	14	0.62	3
161	Sinclair Inlet	70	11	0.73	3
162	Sinclair Inlet	574	26	0.48	3
163	Sinclair Inlet	55	15	0.85	6
164	Sinclair Inlet	642	38	0.34	1
165	Sinclair Inlet	900	37	0.46	3
166	Dyes Inlet Tracyton	323	76	0.82	20
167	Phinney Bay	187	39	0.78	11
168	Phinney Bay	407	23	0.46	3
169	Dyes Inlet SE of Silverdale	354	69	0.81	19
170	Dyes Inlet North Chico Bay	5	5	1.00	4
171	Dyes Inlet	292	26	0.39	2
	Mean	343	48	0.74	12
	Median	299	39	0.77	11
	Min	5	5	0.34	1
	Max	900	115	1.00	31





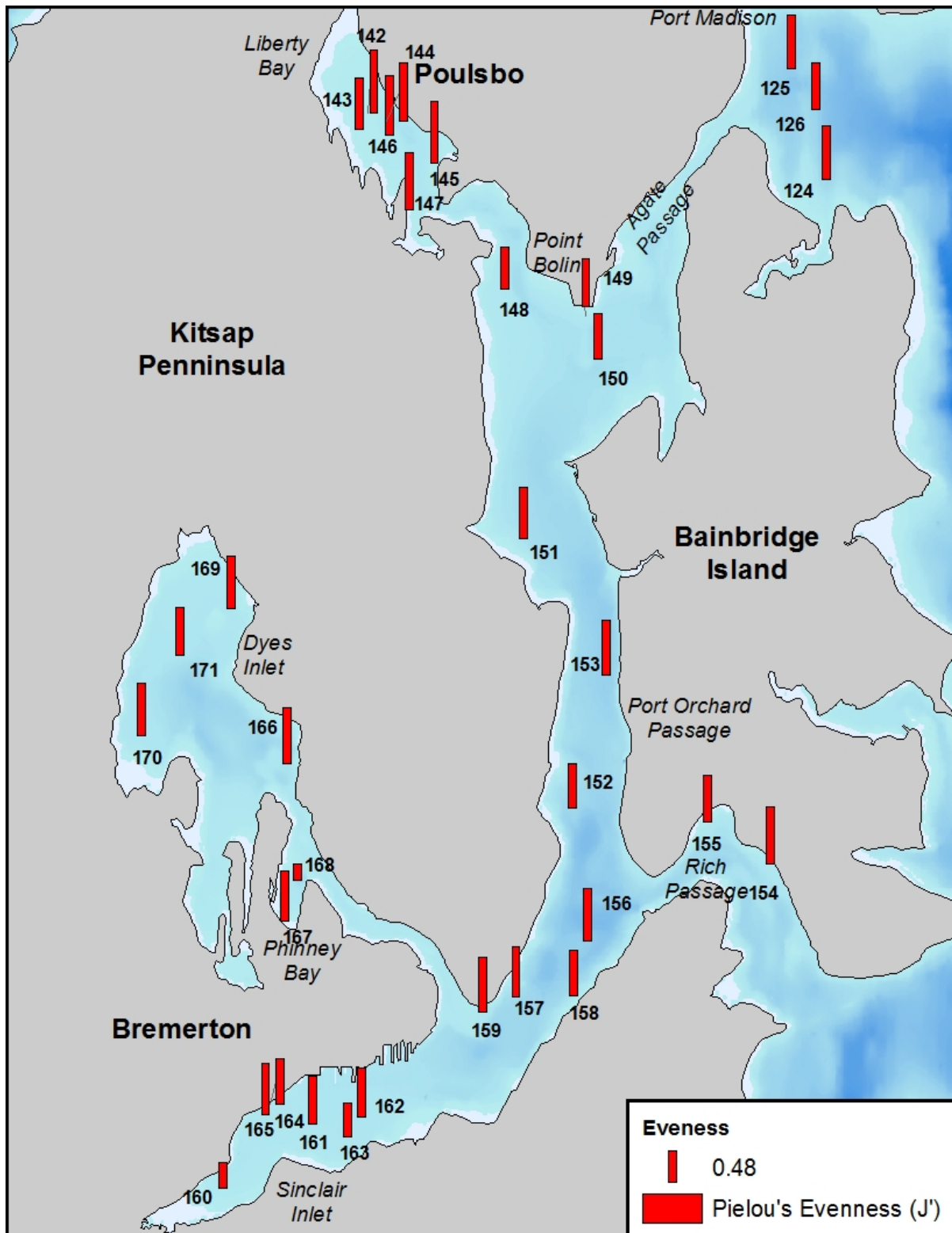
Spatial patterns in total benthic invertebrate abundance (number of individuals per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

*The numbers on the map are the station identifications.*

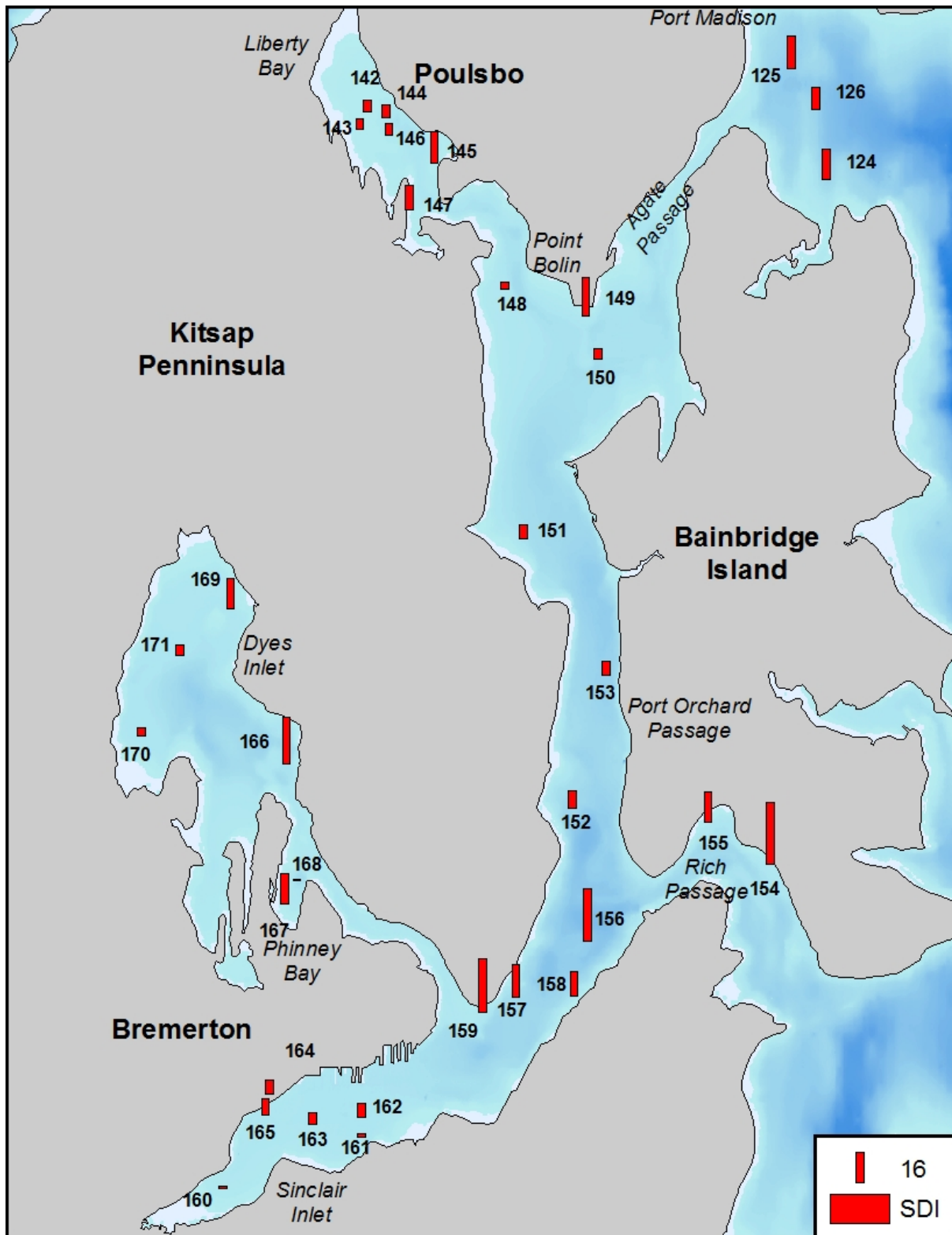


Spatial patterns in taxa richness (number of taxa per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

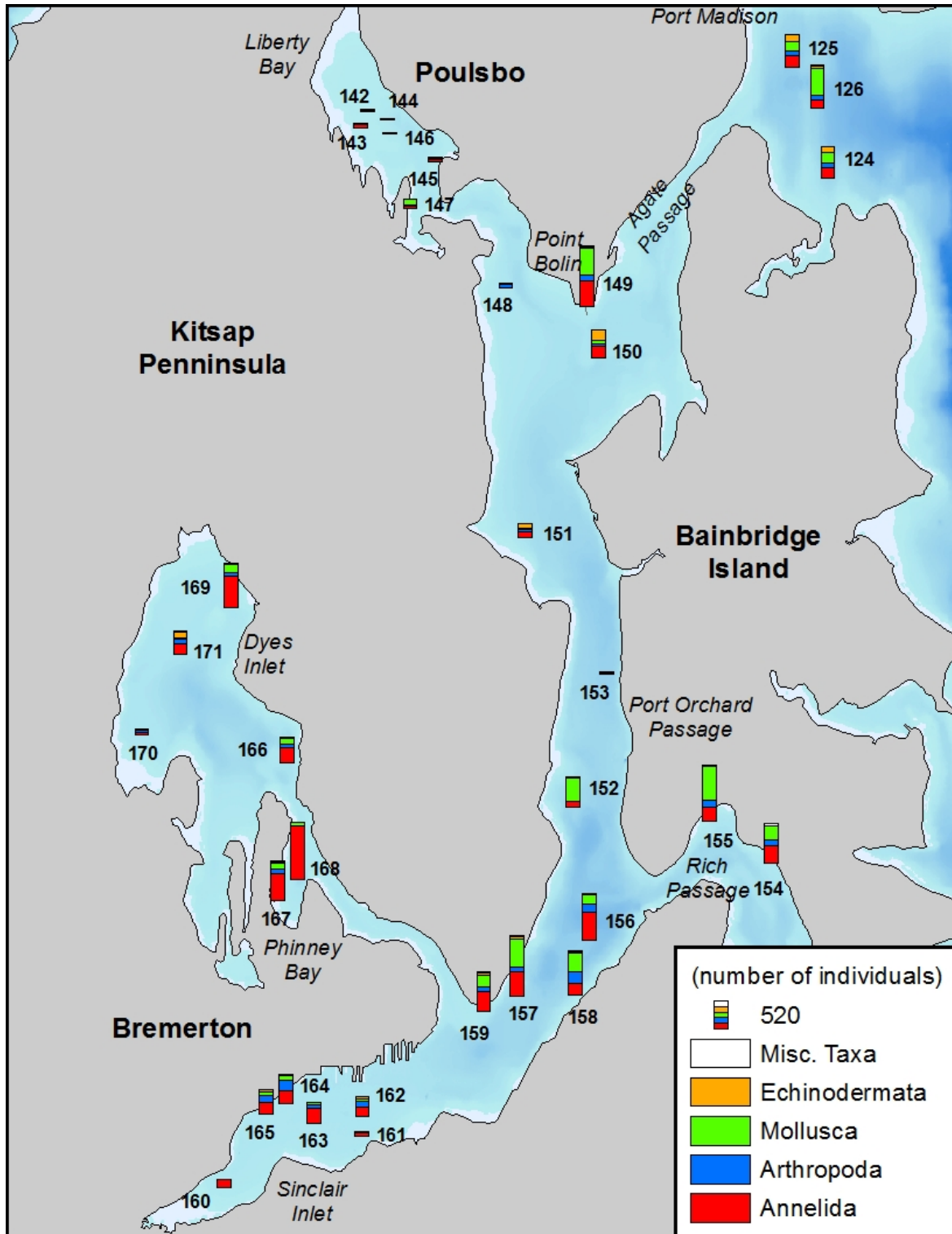
*The numbers on the map are the station identifications.*



Spatial patterns in Pielou's Evenness (J') in the 2015 Bainbridge Basin survey. *The numbers on the map are the station identifications.*

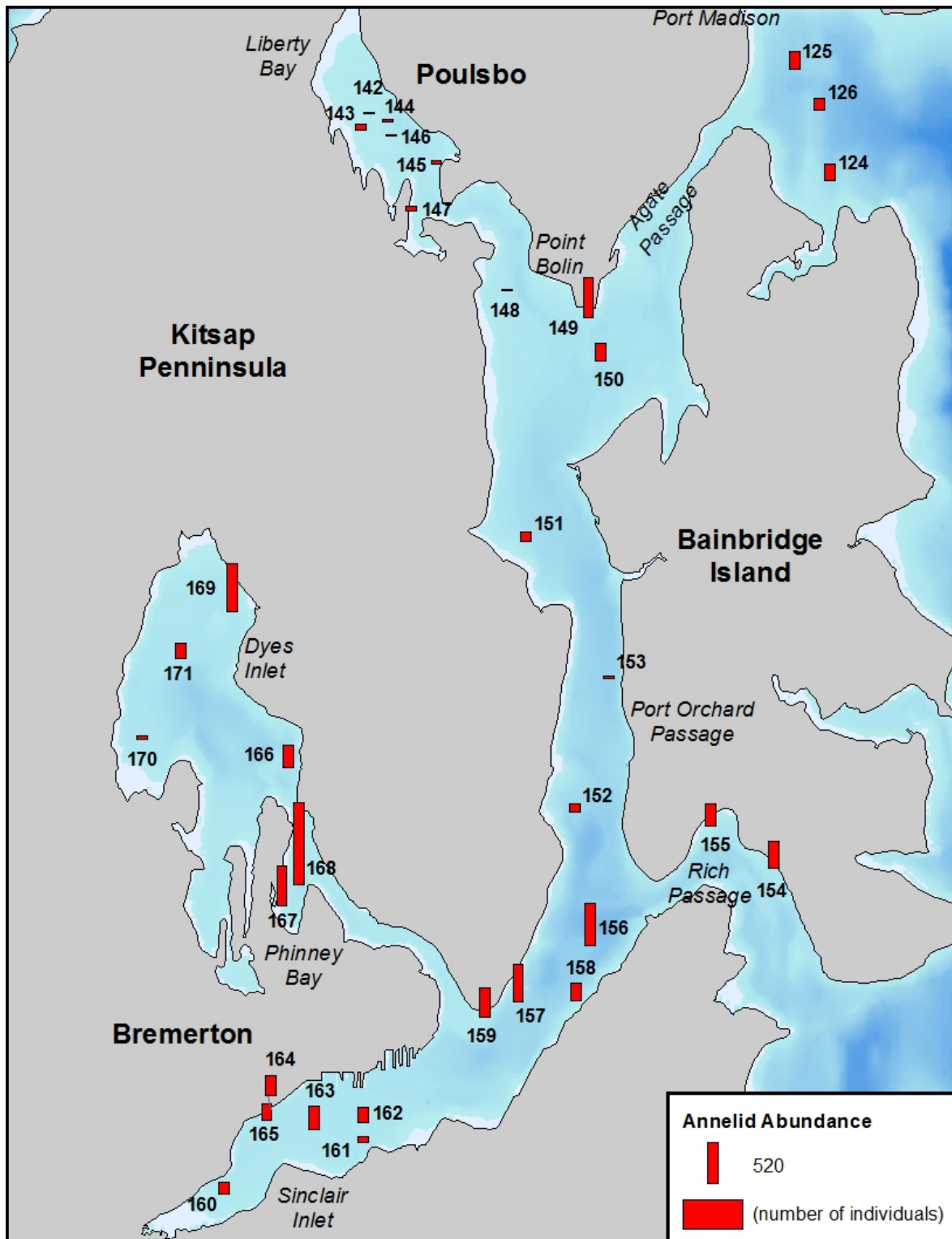


Spatial patterns in Swartz Dominance Index (SDI) in the 2015 Bainbridge Basin survey. *The numbers on the map are the station identifications.*



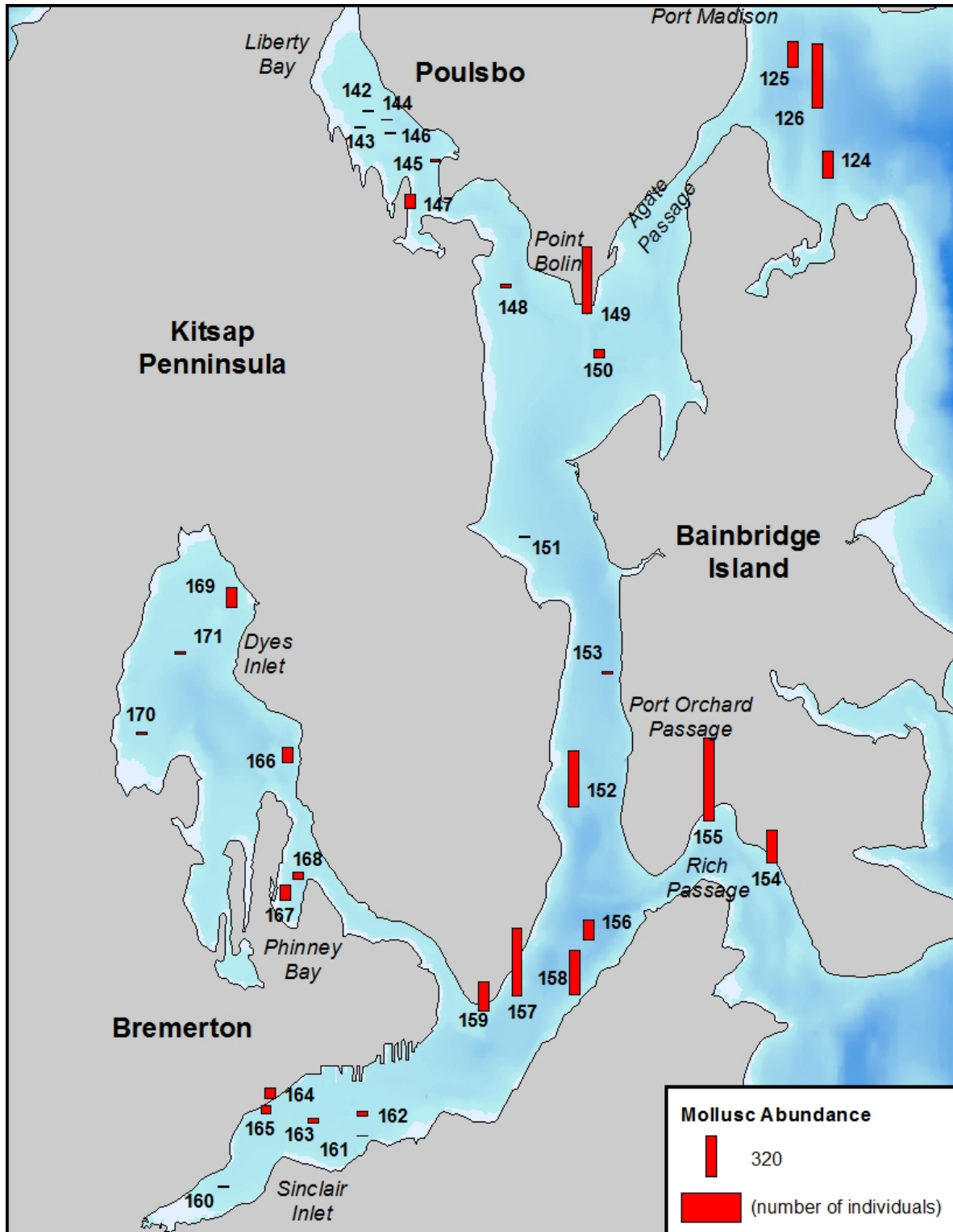
Spatial patterns in abundance of major benthic taxonomic groups (number of individuals per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

*The numbers on the map are the station identifications.*



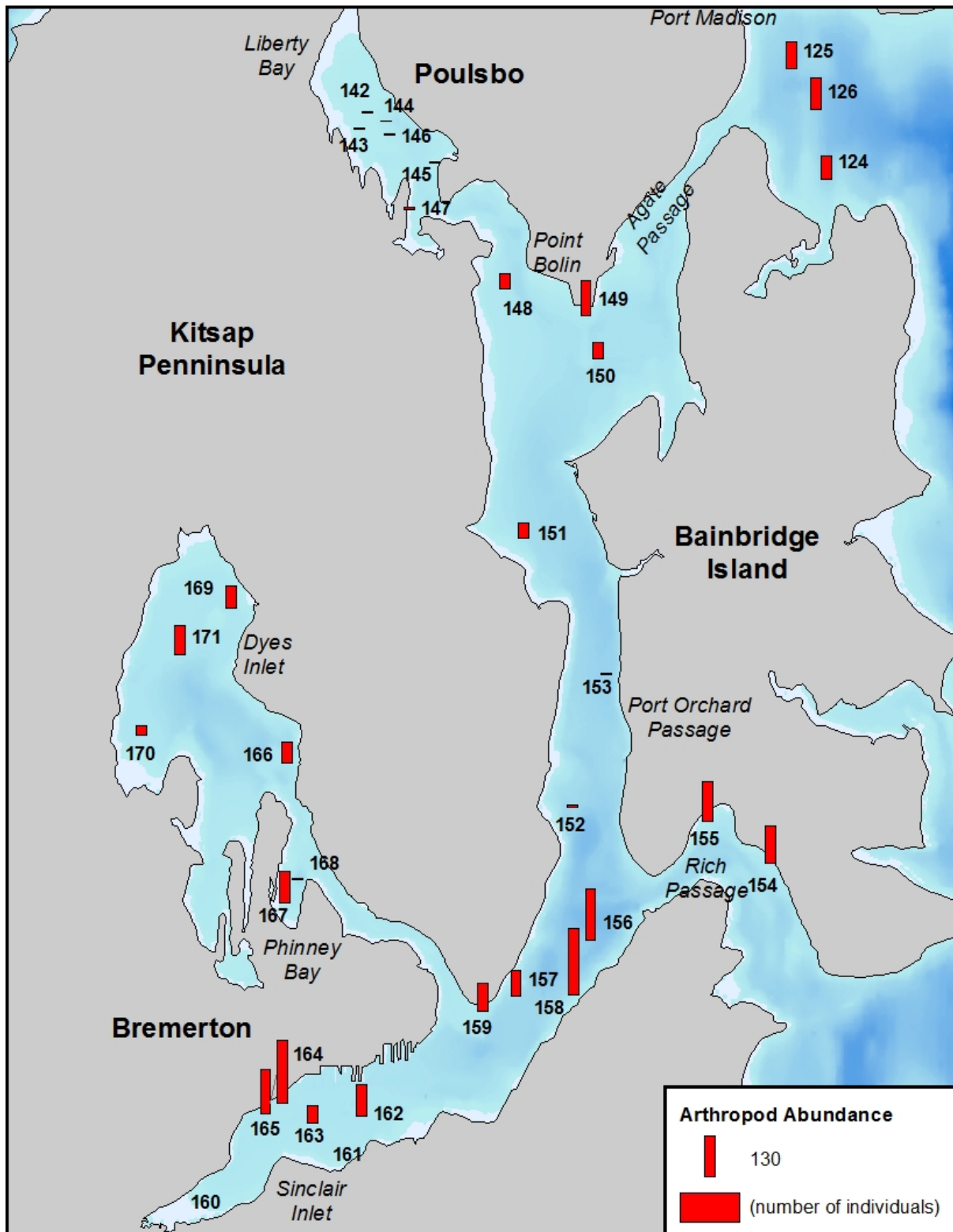
Spatial patterns in Annelid abundance (number of individuals per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

*The numbers on the map are the station identifications.*



Spatial patterns in Mollusc abundance (number of individuals per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

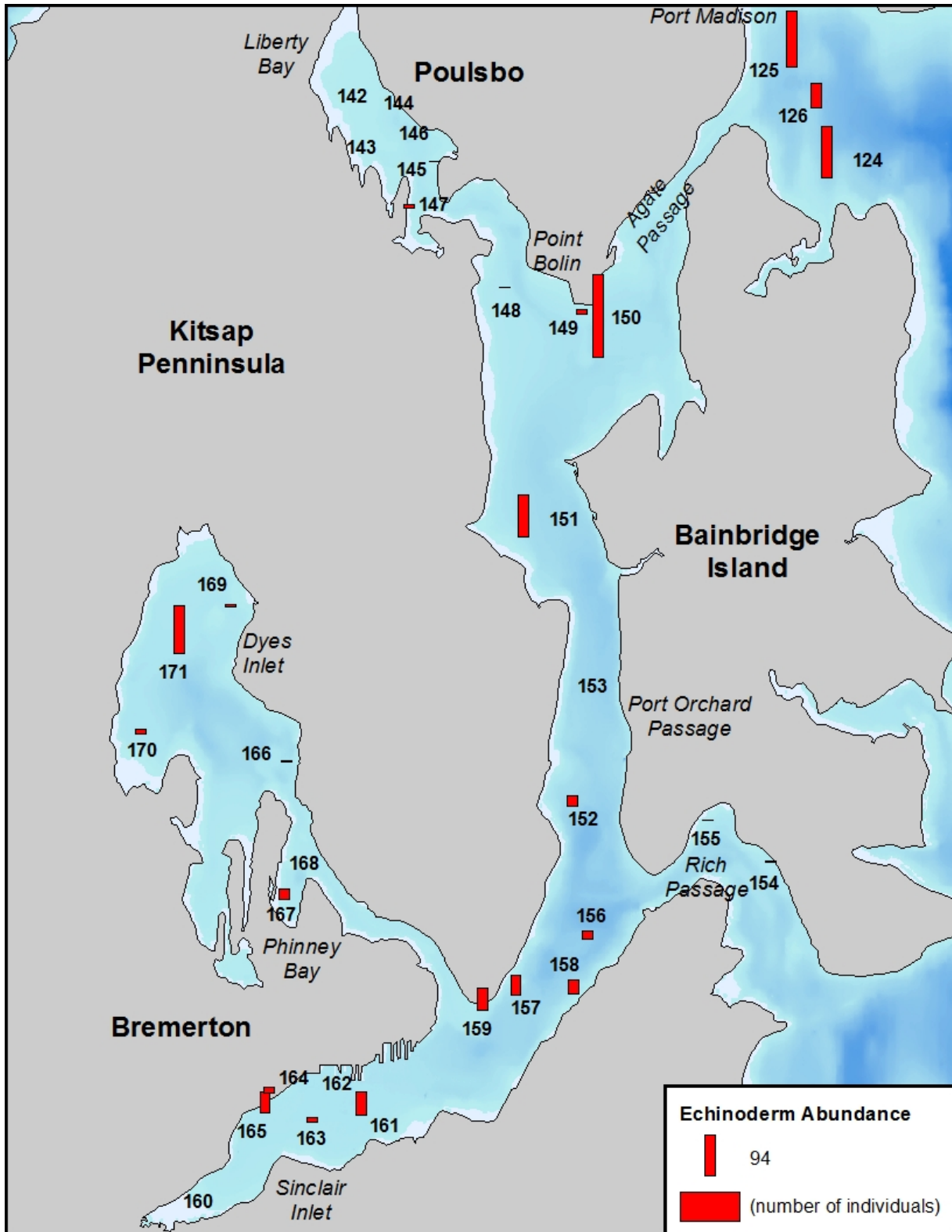
*The numbers on the map are the station identifications.*



Spatial patterns in Arthropod abundance (number of individuals per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

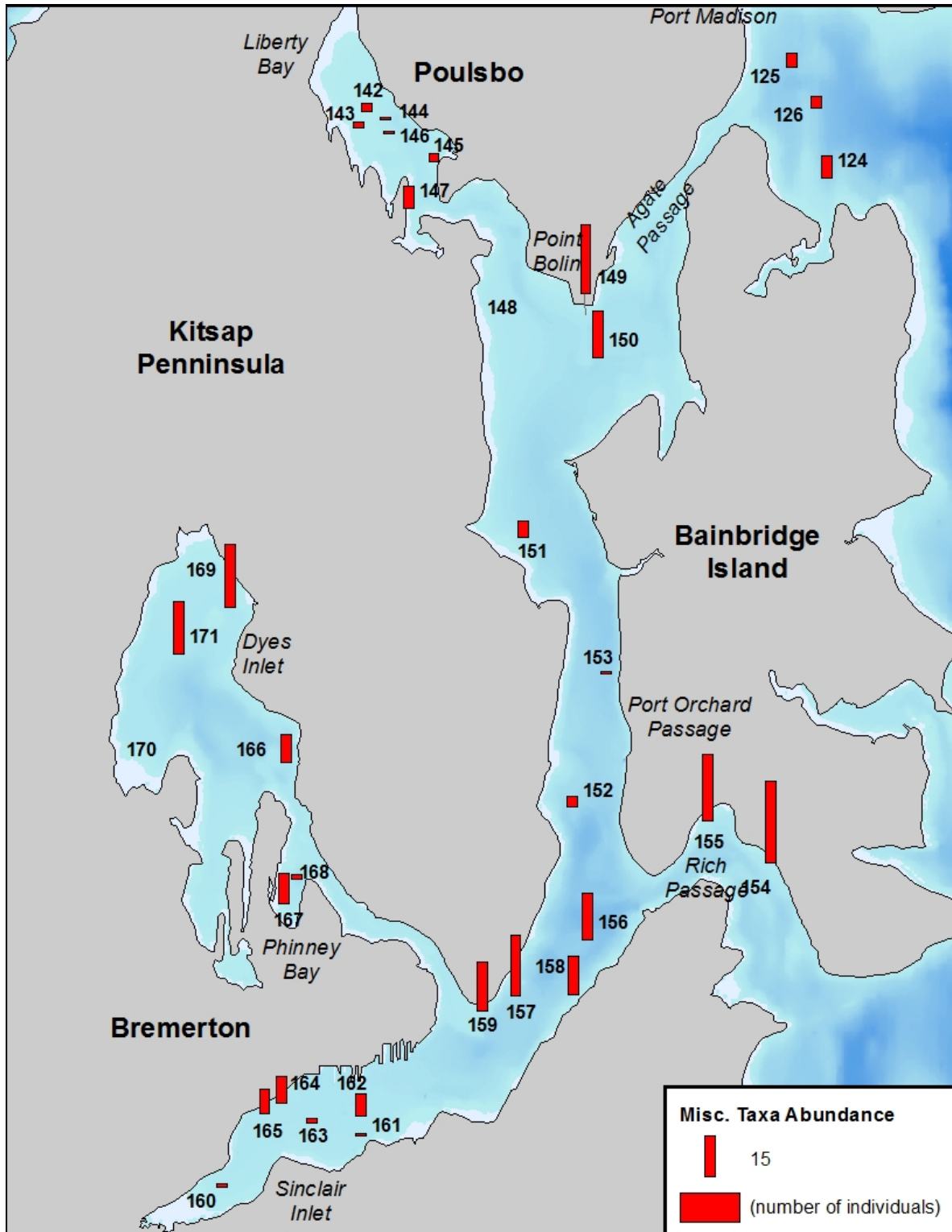
*The numbers on the map are the station identifications.*





Spatial patterns in Echinoderm abundance (number of individuals per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

*The numbers on the map are the station identifications.*



Spatial patterns in miscellaneous taxa abundance (number of individuals per 0.1 m<sup>2</sup>) in the 2015 Bainbridge Basin survey.

*The numbers on the map are the station identifications.*

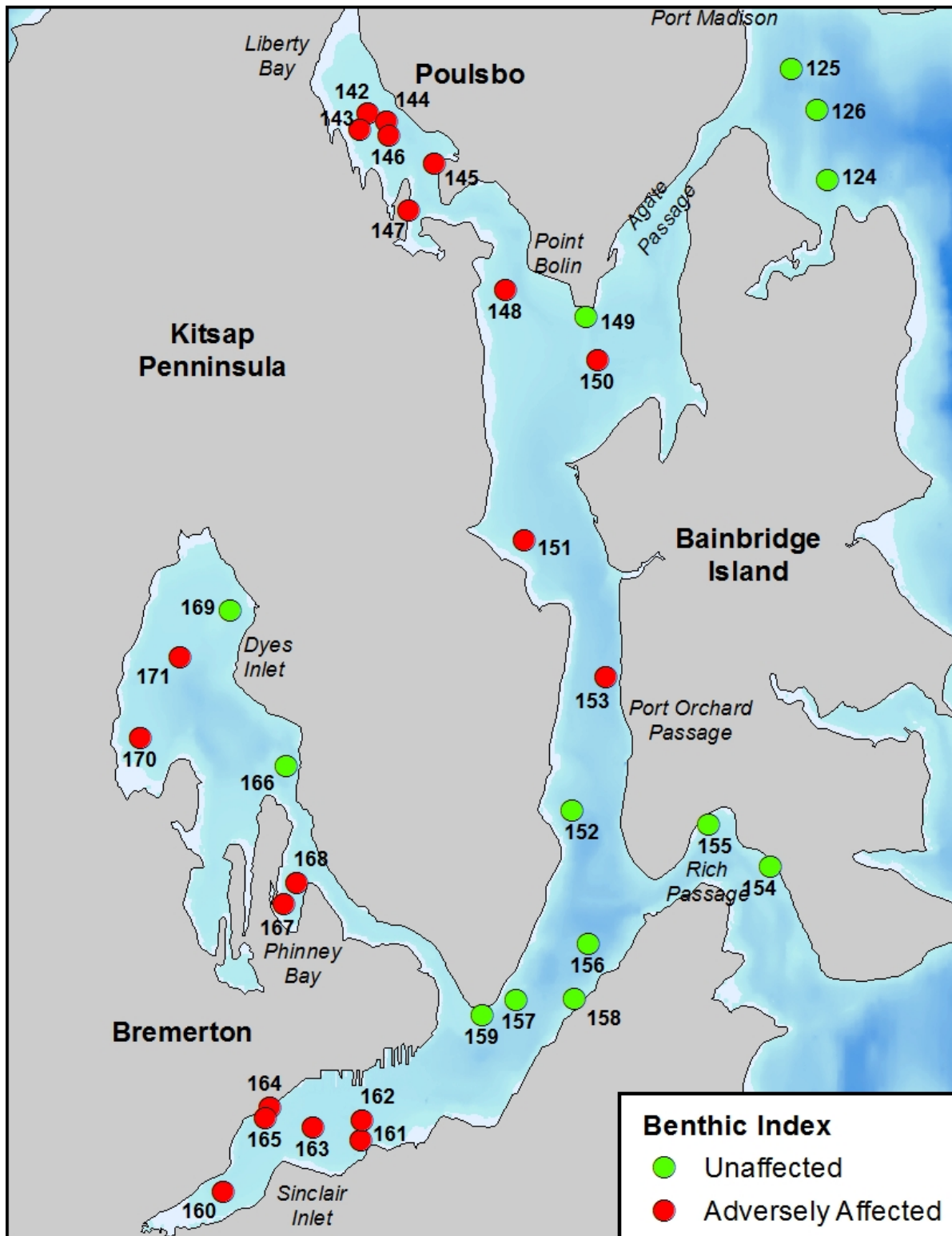
## Adversely Affected Benthic Communities

Samples from the 2015 Bainbridge Basin survey with unaffected and adversely affected benthos.

Station	Location	Condition of benthos
124	Port Madison	Unaffected
125	Port Madison	Unaffected
126	Port Madison	Unaffected
142	Liberty Bay	Adversely Affected
143	Liberty Bay	Adversely Affected
144	Liberty Bay	Adversely Affected
145	Liberty Bay	Adversely Affected
146	Liberty Bay	Adversely Affected
147	Liberty Bay	Adversely Affected
148	Southeast of Keyport	Adversely Affected
149	North Port Orchard Pt. Bolin	Unaffected
150	North Port Orchard	Adversely affected
151	North Port Orchard E. of Brownsville	Adversely affected
152	Port Orchard Illahee	Unaffected
153	Port Orchard	Adversely Affected
154	Rich Pass Pleasant Beach	Unaffected
155	Rich Pass Lynwood Center	Unaffected
156	South Port Orchard	Unaffected
157	South Port Orchard East Bremerton	Unaffected
158	South Port Orchard	Unaffected
159	South Port Orchard Pt. Herron	Unaffected
160	Sinclair Inlet	Adversely Affected
161	Sinclair Inlet	Adversely Affected
162	Sinclair Inlet	Adversely Affected
163	Sinclair Inlet	Adversely Affected
164	Sinclair Inlet	Adversely Affected
165	Sinclair Inlet	Adversely Affected
166	Dyes Inlet Tracyton	Unaffected
167	Phinney Bay	Adversely Affected
168	Phinney Bay	Adversely Affected
169	Dyes Inlet SE of Silverdale	Unaffected
170	Dyes Inlet North Chico Bay	Adversely Affected
171	Dyes Inlet	Adversely Affected

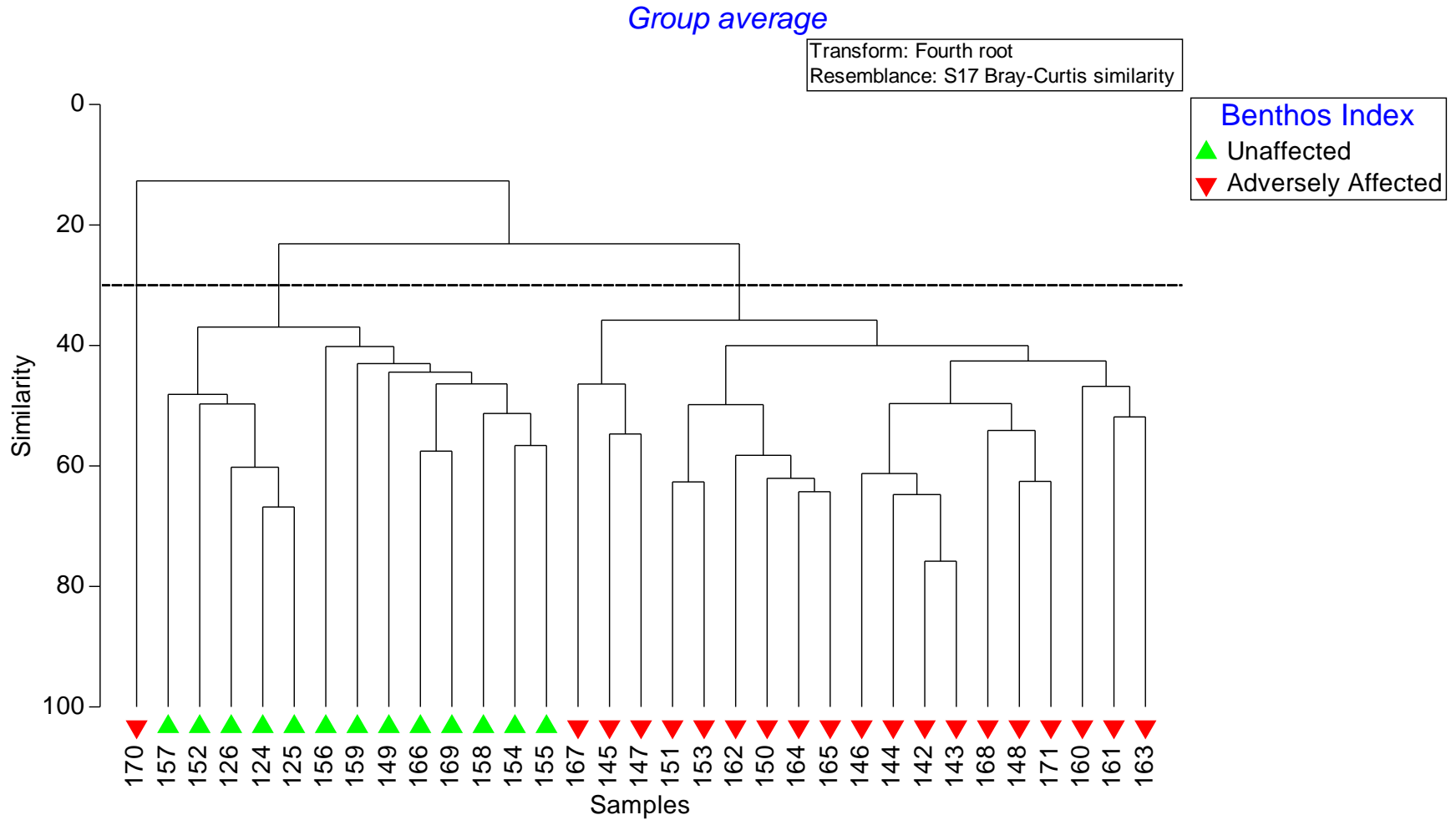
Mean and median benthic indices at stations with adversely affected and unaffected benthos in the 2015 Bainbridge Basin survey.

Benthic index	Adversely affected benthos		Unaffected benthos	
	Mean	Median	Mean	Median
Number of stations	20		13	
Total abundance (# orgs/0.1 m <sup>2</sup> )	228.50	143.50	517.92	549.00
Taxa richness (# taxa/0.1 m <sup>2</sup> )	25.45	24.50	83.15	76.00
Pielou's Evenness (J')	0.72	0.77	0.77	0.77
Swartz Dominance Index (# taxa)	6.75	6.00	19.38	18.00
Annelid abundance	163.45	77.50	175.15	163.00
Arthropod abundance	21.15	11.50	68.31	77.00
Mollusc abundance	37.95	28.00	244.69	264.00
Echinoderm abundance	2.50	0.00	19.46	3.00
Abundance of misc. taxa	3.45	2.50	10.31	9.00



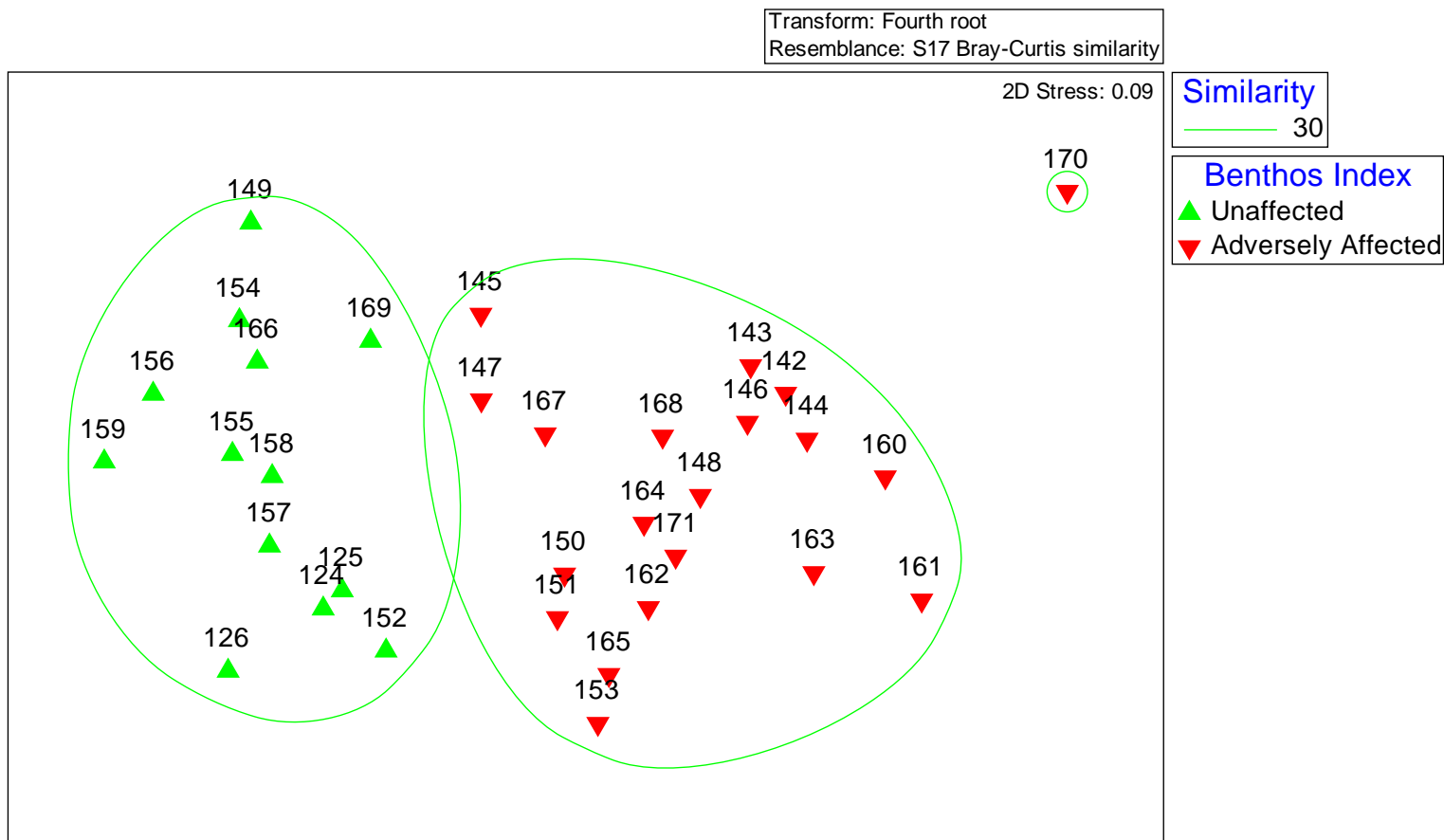
Spatial patterns in unaffected and adversely affected benthic invertebrate assemblages in the 2015 Bainbridge Basin survey.

*The numbers on the map are the station identifications.*



Cluster dendrogram of unaffected and adversely affected benthic invertebrate assemblages in the 2015 Bainbridge Basin survey (Bray-Curtis similarities of 4<sup>th</sup>-root-transformed abundances, all species).

*The dendrogram is sliced at 30% similarity (dashed line).*



Nonmetric multidimensional scaling (MDS) diagram indicating relative similarities of unaffected and adversely affected benthic invertebrate assemblages in the 2015 Bainbridge Basin sediment survey (Bray-Curtis similarities of 4<sup>th</sup>-root-transformed abundances, all species; 2D stress=0.09).

*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. The numbers on the diagram are the station identifications.*

## Comparisons over Time

Condition of the benthic invertebrate communities in the Bainbridge Basin surveys.

Station	Location	Condition of benthos		
		1989	2009	2015
124	Port Madison	Unaffected	Unaffected	Unaffected
125	Port Madison	Unaffected	Unaffected	Unaffected
126	Port Madison	Unaffected	Unaffected	Unaffected
142	Liberty Bay	Unaffected	Adversely affected	Adversely Affected
143	Liberty Bay	Unaffected	Adversely affected	Adversely Affected
144	Liberty Bay	Unaffected	Adversely affected	Adversely Affected
145	Liberty Bay	Unaffected	Adversely affected	Adversely Affected
146	Liberty Bay	Unaffected	Adversely affected	Adversely Affected
147	Liberty Bay	Unaffected	Adversely affected	Adversely Affected
148	Southeast of Keyport	Unaffected	Adversely affected	Adversely Affected
149	North Port Orchard Pt. Bolin	Unaffected	Unaffected	Unaffected
150	North Port Orchard	Unaffected	Unaffected	Adversely affected
151	North Port Orchard E. of Brownsville	Unaffected	Unaffected	Adversely affected
152	Port Orchard Illahee	Unaffected	Unaffected	Unaffected
153	Port Orchard	Unaffected	Adversely affected	Adversely Affected
154	Rich Pass Pleasant Beach	Unaffected	Unaffected	Unaffected
155	Rich Pass Lynwood Center	Unaffected	Unaffected	Unaffected
156	South Port Orchard	Unaffected	Unaffected	Unaffected
157	South Port Orchard East Bremerton	Unaffected	Unaffected	Unaffected
158	South Port Orchard	Unaffected	Unaffected	Unaffected
159	South Port Orchard Pt. Herron	Unaffected	Unaffected	Unaffected
160	Sinclair Inlet	Adversely affected	Adversely affected	Adversely Affected
161	Sinclair Inlet	Adversely affected	Adversely affected	Adversely Affected
162	Sinclair Inlet	Adversely affected	Adversely affected	Adversely Affected
163	Sinclair Inlet	Adversely affected	Adversely affected	Adversely Affected
164	Sinclair Inlet	Adversely affected	Adversely affected	Adversely Affected
165	Sinclair Inlet	Adversely affected	Adversely affected	Adversely Affected
166	Dyes Inlet Tracyton	Unaffected	Unaffected	Unaffected
167	Phinney Bay	Unaffected	Unaffected	Adversely Affected
168	Phinney Bay	Adversely affected	Adversely affected	Adversely Affected
169	Dyes Inlet SE of Silverdale	Unaffected	Unaffected	Unaffected
170	Dyes Inlet North Chico Bay	Unaffected	Adversely affected	Adversely Affected
171	Dyes Inlet	Unaffected	Unaffected	Adversely Affected



Summary of pairwise statistical comparisons<sup>1,2</sup> of 1998 PSAMP/NOAA, 2009 and 2015 Urban Bays benthic invertebrate measures.

↓ = decrease; ↑ = increase; -- = no change

Parameter	Change from 1998 to 2009	Change from 1998 to 2015	Change from 2009 to 2015
<b>Calculated Indices</b>			
Total Abundance	↓	↓	↓
Taxa Richness	--	--	--
Pielou's Evenness	↑	↑	--
Swartz' Dominance	--	--	--
SDI standardized by Richness	--	--	--
<b>Abundance of Major Taxa</b>			
Annelid Abundance	--	↓	--
Arthropod Abundance	↓	↓	↓
Echinoderm Abundance	↓	↓	↓
Mollusc Abundance	--	--	--
Abundance of Misc. Taxa	--	--	--

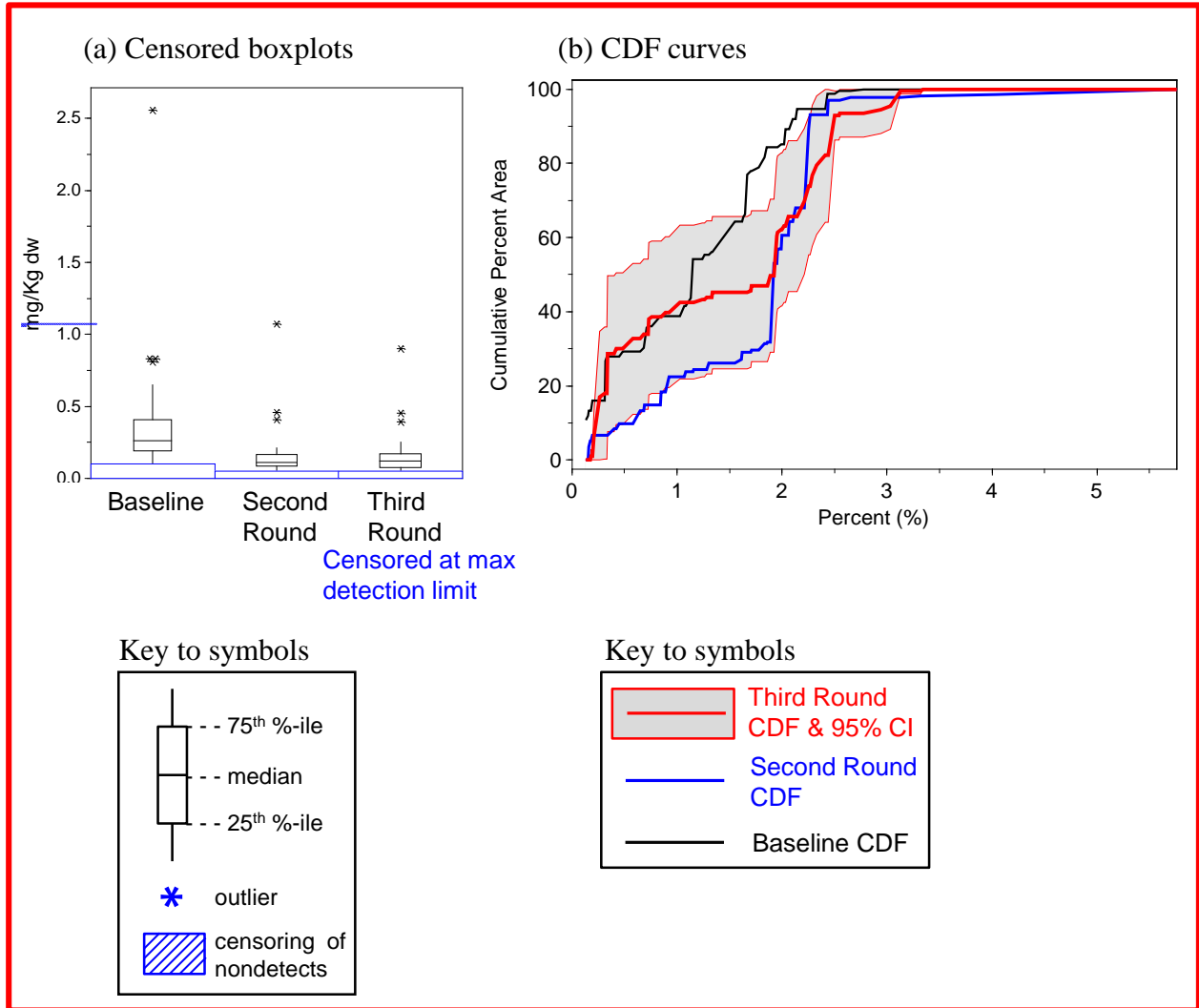
<sup>1</sup> Medians (unweighted) compared by Kruskal-Wallis test ( $\alpha = 0.05$ ).

<sup>2</sup> CDFs (weighted) compared by Wald F test ( $\alpha = 0.05$ ).

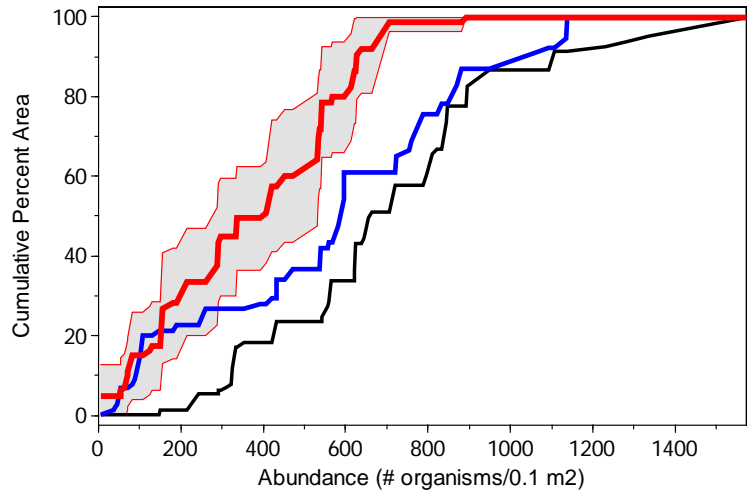
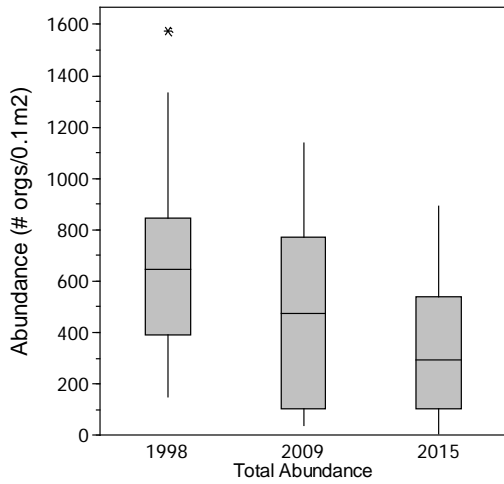
Comparison of benthic invertebrate community indices calculated for the 1998, 2009, and 2015 surveys of the Bainbridge Basin.

The graphical displays include two types of graphs:

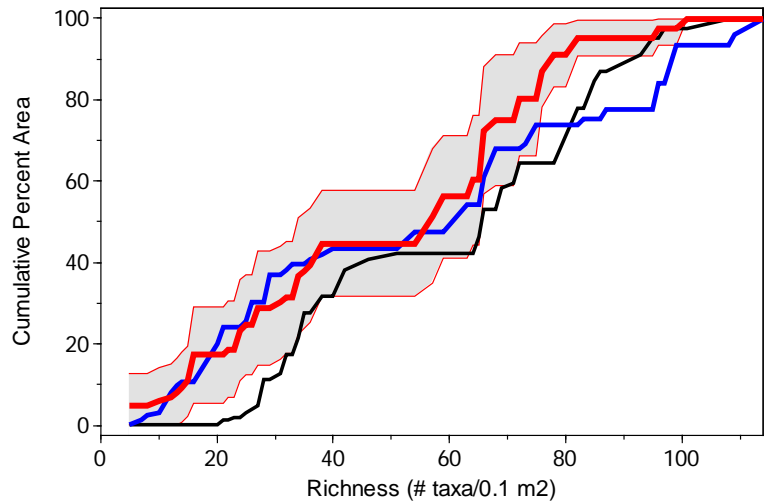
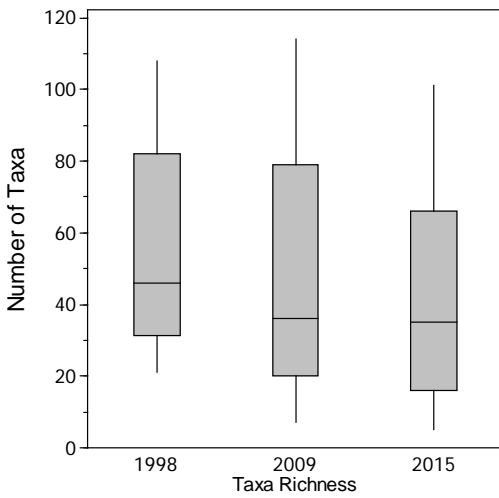
- (a) Censored boxplots display the distributions of the data unweighted by sample area.
- (b) Cumulative distribution function (CDF) curves display the cumulative distributions of the data weighted by sample area. Confidence intervals are shown for the 2015 CDF curves only.



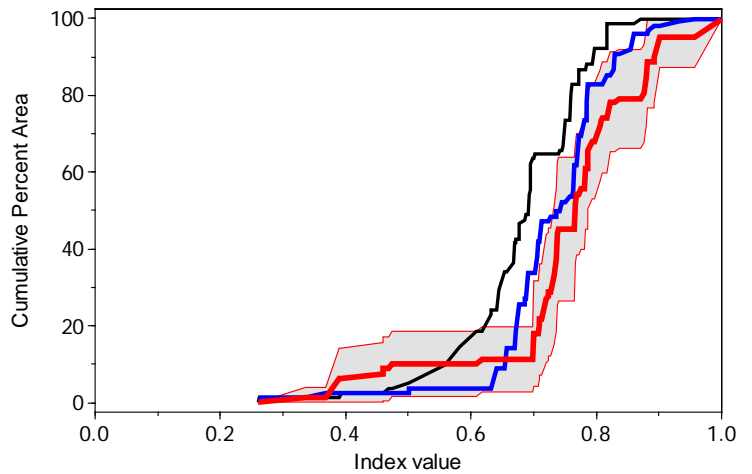
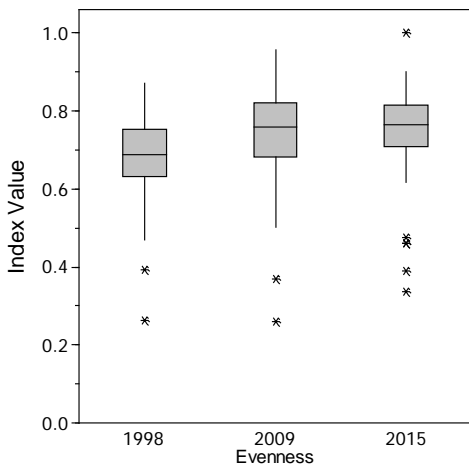
## Total Abundance



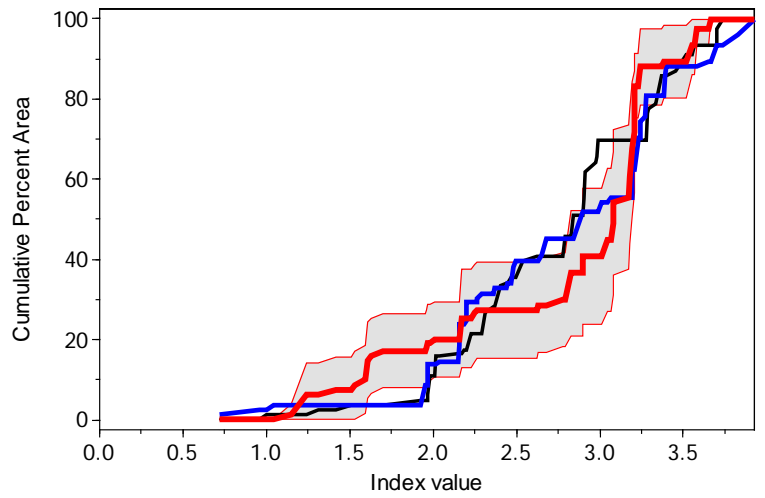
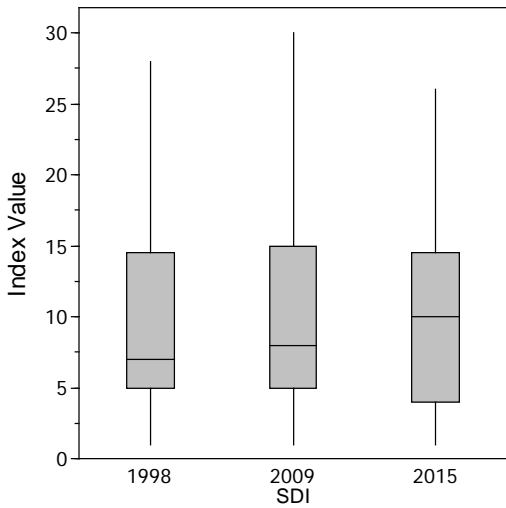
## Taxa Richness



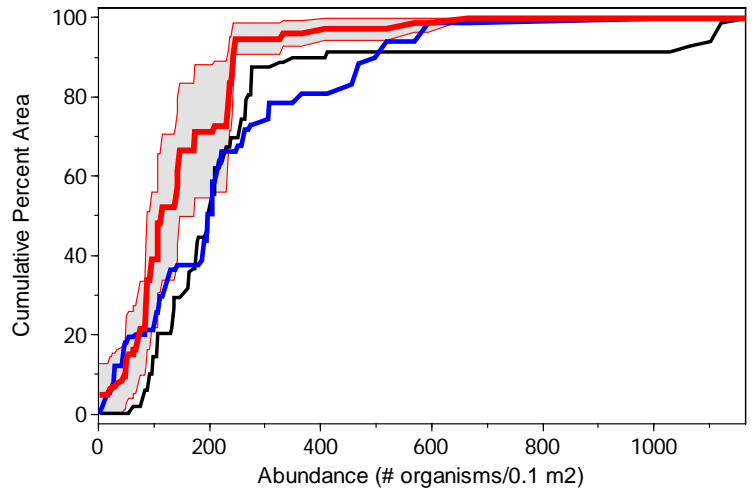
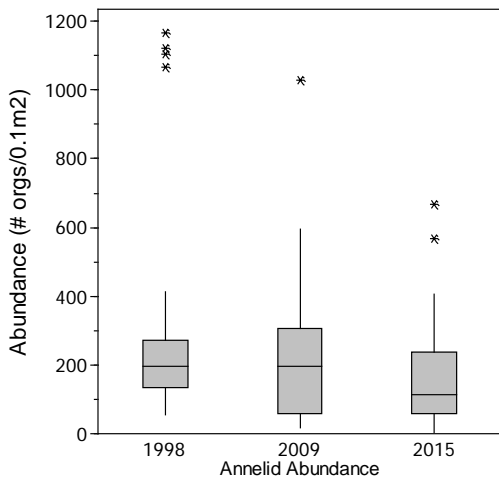
## Pielou's Evenness (J')



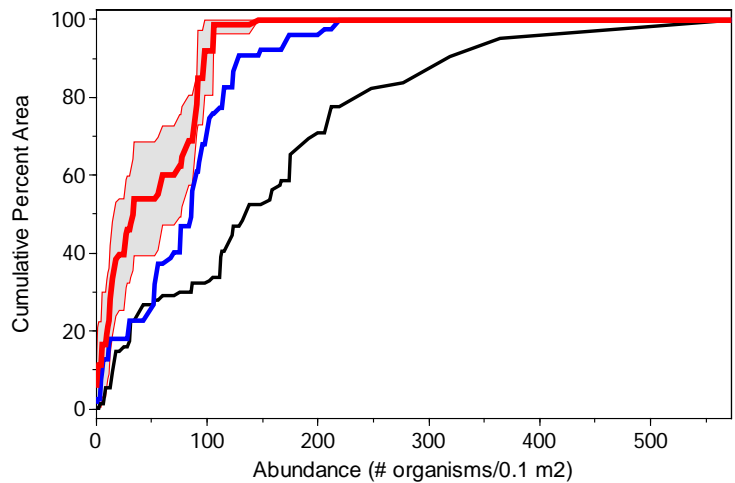
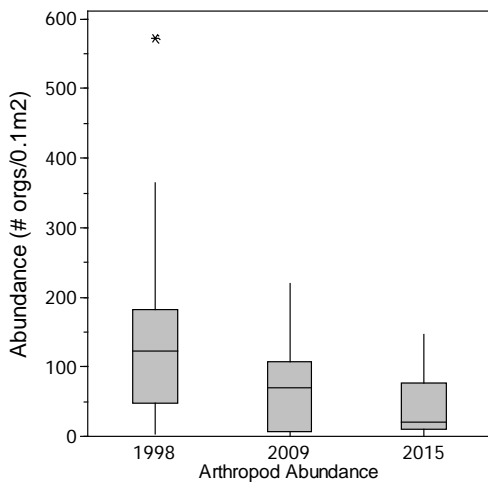
## Swartz Dominance Index (SDI)



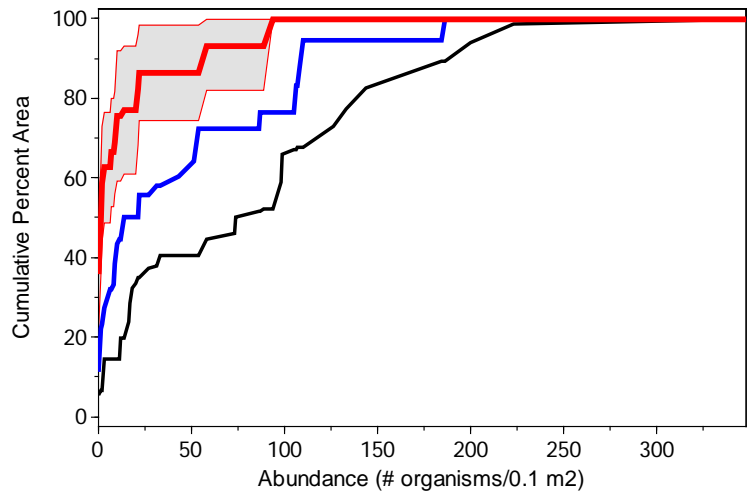
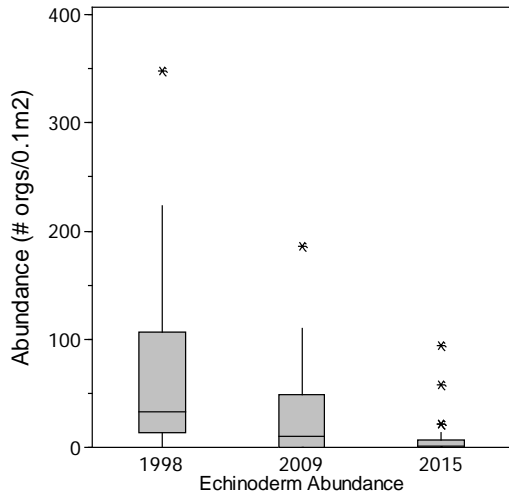
## Annelid Abundance



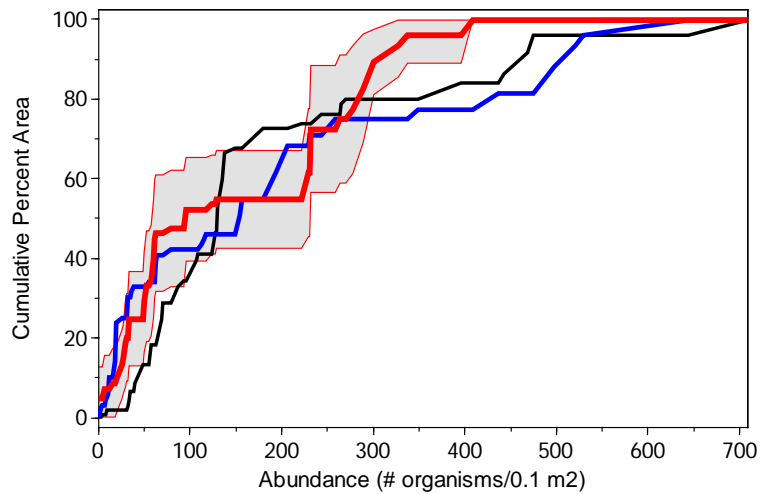
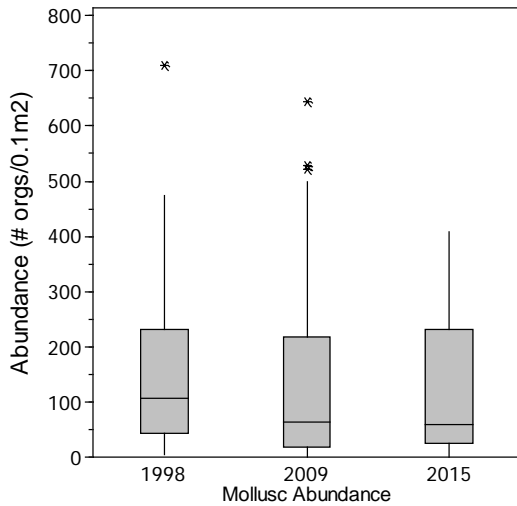
## Arthropod Abundance



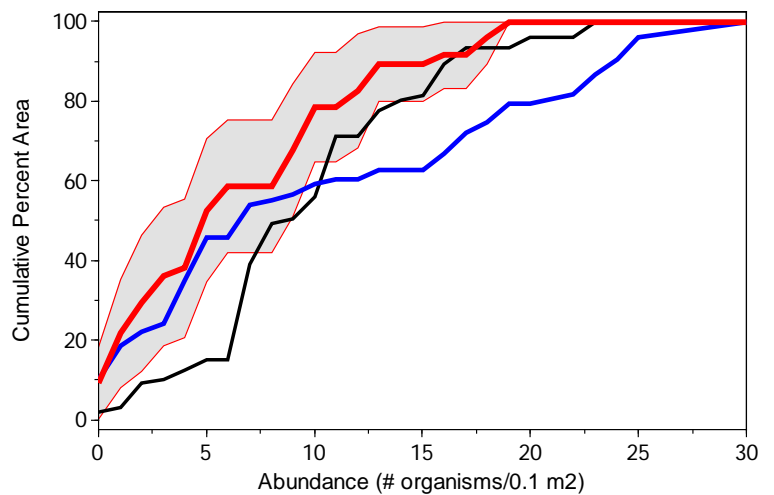
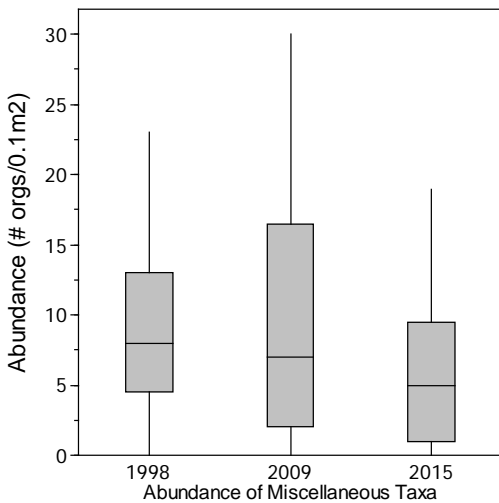
## Echinoderm Abundance



## Mollusc Abundance



## Abundance of Miscellaneous Taxa





Summary statistics for benthic indices in the 1998, 2009, and 2015 surveys of the Bainbridge Basin.

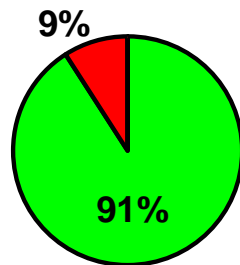
Benthic index		Total abundance (# orgs/0.1 m <sup>2</sup> )	Taxa richness (# taxa/0.1 m <sup>2</sup> )	Pielou's Evenness (J')	Swartz Dominance (SDI) (# taxa)	Annelid abundance (# orgs/0.1 m <sup>2</sup> )	Arthropod abundance (# orgs/0.1 m <sup>2</sup> )	Mollusc abundance (# orgs/0.1 m <sup>2</sup> )	Echinoderm abundance (# orgs/0.1 m <sup>2</sup> )	Abundance of misc. taxa (# orgs/0.1 m <sup>2</sup> )
2015	Mean	342.52	48.18	0.74	11.73	168.06	39.73	119.39	9.18	6.15
	StDev	245.21	31.66	0.15	7.94	152.33	39.13	122.41	21.32	5.57
	Median	299.00	39.00	0.77	11.00	139.00	23.00	60.00	1.00	5.00
	Min	5.00	5.00	0.34	1.00	3.00	0.00	0.00	0.00	0.00
	Max	900.00	115.00	1.00	31.00	673.00	146.00	410.00	106.00	20.00
2009	Mean	495.45	51.88	0.74	11.06	235.24	67.12	152.06	31.67	9.36
	StDev	361.48	37.19	0.14	7.69	216.44	60.06	183.37	45.74	8.66
	Median	475.00	38.00	0.76	8.00	197.00	67.00	64.00	10.00	8.00
	Min	35.00	7.00	0.26	1.00	17.00	0.00	1.00	0.00	0.00
	Max	1153.00	127.00	0.96	31.00	1030.00	213.00	644.00	187.00	30.00
1998	Mean	690.33	59.18	0.67	10.67	303.58	139.52	163.18	75.09	8.97
	StDev	339.02	28.50	0.13	7.54	316.78	119.36	165.46	80.64	5.85
	Median	650.00	48.00	0.69	7.00	199.00	122.00	107.00	46.00	8.00
	Min	149.00	21.00	0.26	1.00	56.00	3.00	4.00	0.00	0.00
	Max	1575.00	113.00	0.87	29.00	1165.00	574.00	709.00	353.00	24.00

## Comparison of Interim Sediment Benthic Index Categories by Year

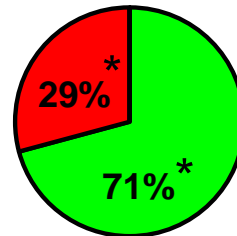
Estimated spatial extent (percent of area) and 95% confidence intervals for each of the Interim Sediment Benthic Index categories for the Bainbridge Basin in 2015, compared to 1998 and 2009.

\* = significantly different from 1998 (Kincaid, 2015,  $\alpha = 0.05$ )

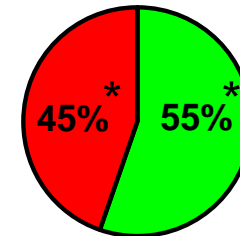
Interim Sediment Benthic Index Category	1998			2009			2015		
	Estimate	Confidence limit		Estimate	Confidence limit		Estimate	Confidence limit	
		Lower	Upper		Lower	Upper		Lower	Upper
Unaffected	90.90	66.70	82.14	70.82	46.64	69.32	55.34	34.31	56.31
Adversely affected	9.10	5.58	9.32	29.18	12.89	34.89	44.66	25.06	48.06



1998



2009\*



2015\*

Spatial and temporal patterns in estimated spatial extent (percent of area, shown in pie charts) for the Interim Sediment Benthic Index in the Bainbridge Basin.

\* = significantly different from 1998 (Kincaid, 2015,  $\alpha = 0.05$ )



## Comparison to the Region

Incidence and spatial extent of adversely affected benthos for the Bainbridge Basin, Central Puget Sound, and all of Puget Sound.

Region	Year(s) sampled	Numbers of samples	Percent of stations with Adversely Affected benthos	Percent of area with Adversely Affected benthos
Bainbridge Basin	1998	33	21.2	9.1
	2009	33	48.5	29.2
	2012	33	60.6	44.7
Central Puget Sound	1998-1999	128	32.8	6.9
	2014-2009	80	33.8	28.0
All of Puget Sound	1997-2003	381	39.4	34.5
	2004-2014	368	46.7	44.0