Addendum to the Deschutes River Estuary Restoration Study

Analysis and Summary of Benthic Invertebrates from Selected Benthic Cores

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Introduction

This study was undertaken as an addendum to the Deschutes River Estuary Restoration Feasibility Study, which was completed in September 2006. In the September study, we found that a restored Capitol Lake will most likely be dominated by mud and sand flats. Predicted salinities will range from fresh to marine, and sediments will be dominated by silty loams. The community was interested to learn what sort of organisms may inhabit the mud and sand flats of a restored Capitol Lake and what the ecological roles of those organisms may be.

Estuaries typically have large numbers of "benthic infauna." The benthic infauna are organisms that live in the soft bottoms of freshwater lakes and in estuaries. Organisms may be visible to the naked eye or microscopic in size. Benthic infauna include organisms such as crustaceans, several types of worms, and mollusks, all of which are invertebrates. Most of these animals burrow into the sediment of the estuary floor.

Others travel up and down through the water column. These invertebrates are an important food source for several fish and bird species found in estuaries.

Methods

Field Methods

As described in the September report, we selected five southern Puget Sound estuaries for characterization. These five estuaries were Woodard Bay, Ellis Cove, and Mud Bay/Eld Inlet of Thurston County, as well as Kennedy Creek of Totten Inlet and Little Skookum Bay, both in Mason County. Within each estuary, sampling occurred within predefined regions or areas that were referred to as riverine, brackish, and marine. The riverine region was the innermost region of the estuary located near the mouth of the stream/ inlet feeding the estuary, the marine region was near the mouth of the estuary, and the brackish was between the two located midway through the estuary. Sampling points where site characterization occurred were distributed throughout these three regions within each estuary. See the September 2006 report for more information.

As part of the site characterization, we collected benthic invertebrate samples during the late summer of 2005 by coring sediments using a transparent coring cylinder (8.2 cm interior diameter, 316.7 cm^3). The cylinder contents were transferred to a container and preserved with 10% buffered formalin. Only one benthic invertebrate core was collected from each site[1] and sample sites were selected haphazardly within each subestuary. The haphazard nature of sample site selection limits the types of statistical comparisons that can be made.

In addition to benthic invertebrate cores, biological and physical data were also collected at all sampling points.

Laboratory Methods

We washed sediment and debris from benthic core samples using a 500 micrometer (#35) sieve and tap water. Contents of the core that remained on the sieve were transferred to vials and preserved with 70% ethyl alcohol and a small amount of rose bengal. Rose bengal is a stain that is commonly used to visualize biological samples.

We then hand picked invertebrates from the remaining debris, and identified individuals to varying taxonomic levels using 20-80x dissecting microscopes. To identify organisms, we used the following taxonomic references: Light's Manual of Intertidal Invertebrates of the Central Californian Coast (Smith and Carlton 1989), Marine Invertebrates of the

[1] We collected 90 benthic invertebrate cores as part of the September 2006 study; however, we only identified the invertebrates from 44 of those cores. We focused on benthic cores from silt and mud dominated Mud Bay and Kennedy Creek sites since the restored Capitol Lake would likely be similar.

Pacific Northwest (Kozloff 1996), other Pacific Northwest manuals, and online taxonomic keys. We then counted organisms by taxon and entered data into a spreadsheet. Those benthic organisms that were retained as voucher specimens were stored in labeled vials with 70% ethyl alcohol.

Statistical Methods

We made the following comparisons of the mean number of organisms using JMP (Version 5.1): sediment classes (loamy sand vs. silty loam vs. sandy loam vs. loam); subestuary (Ellis Cove vs. Kennedy Creek vs. Mud Bay vs. Little Skookum vs. Woodard Bay); sampling areas of each subestuary (riverine, brackish, and marine; see field methods September report); and the combination of subestuary and sampling areas. Analysis of variance was selected because it is a fairly robust statistical test that is relatively insensitive to unbalanced designs and departures from normal distributions. We did not transform data prior to analysis. All pairs of means were compared using Tukey-Kramer HSD.

We used site by taxon data matrices to conduct an indirect gradient analysis. Indirect gradient analysis uses ordination and correlation analysis performed in PC-ORD software (Version 4.28). Ordinations are multivariate statistical procedures used to find patterns in complex data sets. In this case, we used ordination to visualize patterns in the site by taxon data matrix in two or three dimensions, i.e., on a graph. Correlations were then made between the site scores, given by the ordination, and the environmental variables collected during our field work. This statistical procedure, indirect gradient analysis, is an analysis commonly used in ecology to look for environmental factors that may be responsible for the patterns observed in the abundance and distribution of organisms (Gauch 1982).

Results & Discussion

This addendum is possible because additional resources were available to identify and analyze some but not all of the benthic invertebrate samples collected in 2005. We selected cores from the reference subestuaries that most resembled predicted substrate and habitat types of the restored Deschutes River Estuary/ Capitol Lake. We focused on cores from Mud Bay and Kennedy Creek.

We identified 7,346 individual organisms from 44 benthic cores (Table 1). We identified 46 taxa, most individuals to species. We focused on Amphipods, Polychaetes, and some marine Arthropods. Individuals from the phyla Nematoda and Nemertea and the classes Oligochaeta, Nematoda, Gastropoda, and Insecta were identified to higher taxonomic levels primarily due to the limited amount of ecological information their further identification would provide, as well as time and resource limitations (Appendix I).

The gastropods identified were all of one type and 533 of the 535 were found at one site, Kennedy Creek Riverine #7. The 533 gastropods were the only organisms found in this benthic core. The other two gastropods of the same type were found in Mud Bay Riverine #1 and Ellis Cove Brackish #3.

Almost 99% of the individual collected belong to twenty taxa (Table 2). Included in these twenty taxa are the gastropods (7.3%) which, as we mentioned above, are mostly from a single sample. Nematodes (8.2%) are also in the twenty most abundant taxa. However, it is important to keep in mind with nematodes that those identified were extremely small and small enough to pass through the 500 micrometer sieve used to sort organisms from debris. Therefore, the nematode count may only represent a small fraction of the total number actually present in the benthic core before sieving.

Table 1. Taxonomic resolution of benthic invertebrates identified in 44 benthic cores from South Puget Sound Subestuaries. Shown are number of individuals identified to various taxonomic levels and the proportion of the total collection.

		No. Ind.	%
Phylum		616	8.4
Class		2153	29.3
Order		496	6.8
Family		914	12.4
Genus		207	2.8
Species		2960	40.3
Total		7346	100

Oligochaetes (20.4%), Spionid: *Streblospio benedicti* (19.8%), Capitellids (9.4%), and Cumacea (6.6%) are organisms representing greater than 5% of the total organisms. *Streblospio benedicti* was found consistently throughout all samples except those from Kennedy Creek Riverine area. This Spionid (polychaete) is associated with Dethiers' estuarine intertidal sand: open; estuarine intertidal mixed fines: partly enclosed; and marine intertidal mud: protected habitat classifications (Dethier 1990).

	Table 2. Top twenty taxa from benthic invertebrate cores collected in South Puget Sound Subestuaries in 2005. Shown are the total number of individuals for each taxon, the percent of the total number of individuals for this study (7,346), and the cumulative percent of the total.								
Rank	**Phylum**	**Class**	**Order**	**Family**	**Genus**	**Species**	Total	% of Total	Cum %
1	Annelida	Oligochaeta					1497	20.4%	20.4%
2	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	1453	19.8%	40.2%
3	Annelida	Polychaeta		Capitellidae			689	9.4%	49.5%
4	Nematoda						600	8.2%	57.7%
5	Mollusca	Gastropda					535	7.3%	65.0%
6	Arthropoda	Malacostraca	Cumacea				487	6.6%	71.6%
7	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne	310	4.2%	75.8%
8	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum	282	3.8%	79.7%
9	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis	246	3.3%	83.0%
10	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina	182	2.5%	85.5%
11	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa	169	2.3%	87.8%
12	Annelida	Polychaeta	Aciculata	Nereidae			129	1.8%	89.6%
13	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.	120	1.6%	91.2%
14	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum	103	1.4%	92.6%
15	Arthropoda	Ostracoda					100	1.4%	94.0%
16	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae			88	1.2%	95.2%
17	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.	82	1.1%	96.3%
18	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta	77	1.0%	97.3%
19	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica	75	1.0%	98.3%
20	Nemertea						16	0.2%	98.6%

Analysis of Variance/ Comparison of Means

Benthic invertebrates feed on decomposing plant and animal material (detritus), bacteria, plants, and animals. These invertebrates are, in turn, eaten by other organisms within the estuary thereby forming an important link in the estuarine food web. One ecological function of estuarine habitat is food web support. Numbers of invertebrates per unit area, in this case the total number of invertebrates in the 316.7 cm^3 benthic core, are a crude measure of estuarine productivity and therefore a measure of how much energy is available for fish and wildlife. We compared total productivity among sediment classes, subestuaries, sampling areas, and sampling areas within each subestuary.

Sediment Class

We compared the mean number of invertebrates per core by sediment class[2]. We found that loamy sand sediments had significantly more invertebrates in them than silt loams, sandy loam, or loam sediments (Table 3). This indicates that loamy sand substrates may be more valuable for fish and wildlife habitat because of the available prey than the other sediment classes examined. However, the sample size for loamy sand samples was very small. Sandy loam and Silt loam sediments were the next most productive sites based on the mean number of organisms.

We examined the data for differences in individual taxa according to sediment class. At a cursory level, there appear to be higher numbers of Corophiid amphipods in the loamy sand and sandy loam sediments compared to samples with silt loam and loam sediments. We recommend that this relationship be investigated in future studies.

Table 3. Comparison of the Mean Number of Benthic Invertebrates by Sediment Class in South Puget Sound Subestuaries. Shown are the number of samples in each sediment class (n), the mean number of organisms for samples within each sediment class, and the groups resulting from the comparison of means.

	n	**Mean**	**Significantly Different**	
Loamy Sand	3	445.0	A	
Silt Loam	28	156.8		B
Sandy Loam	5	149.8		B
Loam	8	109.0		B

Levels not connected by the same letter are significantly different using Tukey-Kramer HSD Means Comparison (alpha = 0.05)

[2] In ecological studies, the number of organisms is generally expressed as number per unit area (e.g., per m^2) or per unit volume (e.g., per m^3). In our study, we collected invertebrates using the same coring device at all sites. Therefore, the volume of each sample was the same and we can make comparisons between the number of organisms per core.

Subestuary

We also considered that some subestuaries may be more productive than others. We urge caution on the interpretation of these results because the sampling design of the original study was not designed to make between estuary comparisons. In other words, the haphazard nature (i.e., not random) of our sample points limits our confidence in this comparison. In addition, the cores processed and data analyzed do not represent similar levels of effort in sampling each subestuary (i.e., the number of samples ranged from three to 17 for the five sites, Table 4). We offer this analysis as an example of what could be done if more of the benthic samples are processed in the future and to provide managers with some information to guide future studies.

Table 4. Comparison of the Mean Number of Benthic Invertebrates by South Puget Sound Subestuaries. Shown are the number of samples within each subestuary (n), the mean number of organisms for samples within each subestuary, and the groups resulting from the comparison of means.

Subestuary	**n**	**Mean**	**Significantly Different**		
Woodard Bay	3	388.33	A		
Mud Bay	17	199.94		B	
Kennedy Creek	11	175.91		B	C
Little Skookum	9	65.78			C
Ellis Cove	4	63.75		B	C

Levels not connected by the same letter are significantly different using Tukey-Kramer HSD Means Comparison (alpha = 0.05)

We found that Woodard Bay had a significantly greater number of benthic organisms than the other sites (Appendix I). Mud Bay and Kennedy Creek samples have mean numbers of benthic invertebrates intermediate to Little Skookum and Ellis Cove subestuaries. This indicates that there are differences in the productivity of Southern Puget Sound subestuaries. Additional work to understand the relationship between the landscape setting and within estuary habitat types is warranted and can be accomplished through the analysis of the remaining 46 samples.

Within Subestuary Differences

We were interested to see if areas within each of the subestuaries were more productive than others. See the September 2006 report for details on how each subestuary was partitioned. Although there was a general decline in the mean number of benthic organisms moving from the more riverine-influenced sites to the marine sites, this trend was not statistically significant (Table 5). We recommend that this be re-examined if additional information from the remaining benthic cores becomes available.

Table 5. Comparison of the Mean Number of Benthic Invertebrates by three sampling areas of five South Puget Sound Subestuaries. Shown are the number of samples within each sampling area (n), the mean number of organisms for samples within each sampling area, and the groups resulting from the comparison of means.			
Region	**n**	**Mean**	**Significantly Different**
Riverine	12	222.67	A
Brackish	23	144.87	A
Marine	9	149.11	A
Levels not connected by the same letter are significantly different using Tukey-Kramer HSD Means Comparison (alpha = 0.05)			

We were also interested if there were differences between cores collected from the specific sampling areas within each of the subestuaries, i.e. Kennedy Creek Brackish vs. Woodard Bay Riverine vs. Little Skookum Marine, etc. Again, we urge caution in the interpretation of these results because of the relatively small sample sizes and the limited number of samples with which we had to work. We found that the mid-region (brackish) Woodard Bay had significantly greater numbers of benthic invertebrates than other sites, including the riverine sites from Woodard Bay. However, only one core sample was processed from Woodard Bay Brackish for this study. The high numbers of organisms in this Woodard Bay Brackish sample come from nematodes, *Americorophium salmonis*, *Monocorophium acherusicum*, and other amphipod species (Appendix I). The lowest numbers of invertebrates were observed at both regions within Ellis Cove. Riverine regions at most subestuaries were among the most productive[3].

Table 6. Comparison of the Mean Number of Benthic Invertebrates for sampling areas within five South Puget Sound Subestuaries. Shown are the number of samples within each subestuary sampling area (n), the mean number of organisms for samples within each subestuary sampling area, and the groups resulting from the comparison of means.							
Subestuary	Region	**n**	**Mean**	**Significantly Different**			
Woodard Bay	**Brackish**	1	783.00	A			
Woodard Bay	**Riverine**	2	191.00		B	C	D
Mud Bay	**Riverine**	4	208.75		B	C	
Mud Bay	**Brackish**	8	193.50			C	
Mud Bay	**Marine**	5	203.20		B	C	
Kennedy Creek	**Riverine**	4	331.25		B		
Kennedy Creek	**Brackish**	7	87.14			C	D
Little Skookum	**Brackish**	5	53.20				D
Little Skookum	**Marine**	4	81.50			C	D
Ellis Cove	**Riverine**	2	65.00			C	D
Ellis Cove	**Brackish**	2	62.50			C	D
Levels not connected by the same letter are significantly different using Tukey-Kramer HSD Means Comparison (alpha = 0.05)							

[3] No Riverine samples were collected from Little Skookum subestuary.

Indirect Gradient Analysis

We used detrended correspondence analysis (DCA) and correlations to explore the patterns in the site by taxa data matrix. DCA is a type of ordination. Ordinations, like PCA (used in the September 2006 report) and DCA, are descriptive statistical techniques used to visualize patterns in large data sets. During ordinations of site by taxa data matrices, sites that share similar taxonomic compositions appear near each other in ordination space. Sites that are dissimilar appear far apart. Similarity can be affected by numeric abundance and community composition. Indirect gradient analysis involves taking the ordination axis scores generated by ordination of the primary data matrix and correlating those axis scores with environmental variables. In this study, the primary data matrix contained the numeric abundance values for each of the 46 taxonomic groups found at each site. The secondary data matrix contained site classification and environmental variables.

We performed a Beals smoothing operation on the primary data matrix. Beals smoothing is designed for data sets with a large number of zeros and acts to enhance the pattern in the data by reducing noise (PC-ORD 1999). We set the software to downweight rare species, to rescale the derived axes, and for 26 segments. These decisions were based on the characteristics of the primary matrix.

We found that the first two axes of the ordination explained 88.8% of the variability of the primary data matrix. This is satisfactory for biological data sets; therefore, we concluded that enough information was retained by the ordination to continue interpretation.

We found that the ordination grouped most of the sites at relatively low values of DCA Axis I and II (Fig. 1) with the exception of the Kennedy Creek Riverine and Woodard Bay Brackish sites. This indicates that the benthic communities of the Kennedy Creek Riverine and Woodard Bay Brackish sites are most unlike the remaining sites. The differences may be due, in part, to the differences in productivity previously described (Tables 4 and 6, Appendix I).

The DCA ordination also showed little separation in the Mud Bay and Little Skookum Marine site indicating that their communities are somewhat similar. Finally, samples from Ellis Cove and Little Skookum Marine appear spread out on DCA Axis I and Axis II, more so than many of the other sites expect for Kennedy Creek Riverine. This suggests that these communities are somewhat variable.

We then compared the patterns in the DCA ordination (Fig. 1) with some of the environmental variables in the secondary matrix. We found the following relationships: a positive correlation between DCA Axis I and elevation; a positive correlation between DCA Axis II and percent sand and dry bulk density; and negative correlations between percent clay and percent organic matter (Table 7 and Fig. 2).

Sites along DCA Axis I are structured by elevation while sites along DCA Axis II are structured by percent sand, percent clay, percent organic matter, and bulk density.

Table 7. Correlations between DCA Axis 1, 2 and 3 and environmental variables collected at 44 sample sites in five South Puget Sound Subestuaries in 2005. Shown are elevation (NAVDF), percent organic matter (OMPERCEN), percent sand (SAND), percent silt (SILT), percent clay (CLAY) and dry bulk density (DBDRY). See the 2006 report for details.

Axis:		**1**			**2**			**3**
	r	**r-sq**		**r**	**r-sq**		**r**	**r-sq**
NAVDFT	0.498	0.248		-0.205	0.042		0.027	0.001
OMPERCEN	0.270	0.073		-0.557	0.310		0.135	0.018
SAND	0.079	0.006		0.483	0.233		0.406	0.165
SILT	-0.099	0.01		-0.428	0.183		-0.380	0.144
CLAY	0.054	0.003		-0.623	0.388		-0.418	0.175
DBDRY	0.076	0.006		0.525	0.276		0.221	0.049

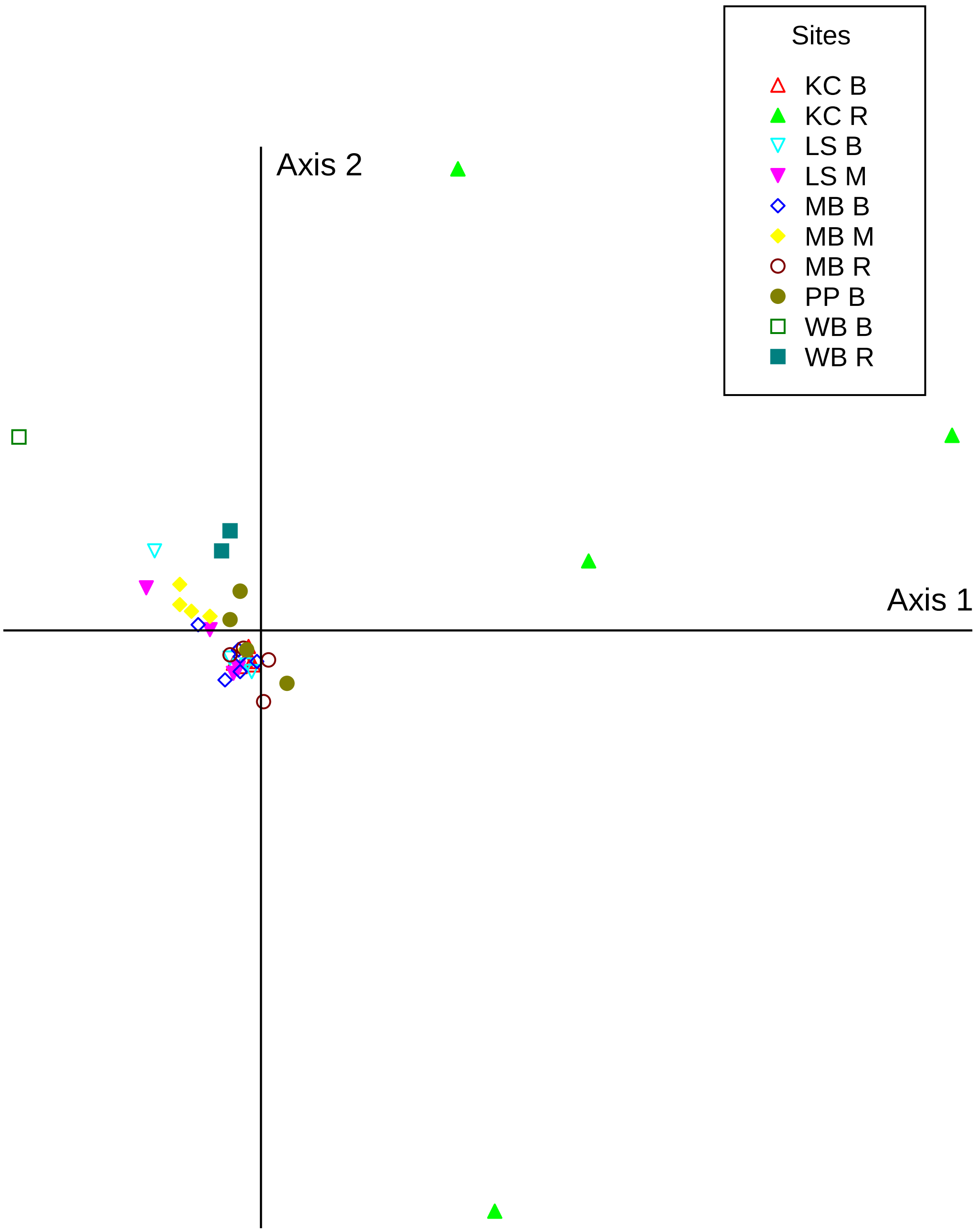

Figure 1. Detrended Correspondence Analysis (DCA) ordination of 44 benthic core samples from Southern Puget Sound. Sites are coded by subestuary and region within each subestuary. KC B= Kennedy Creek Brackish, KC R = Kennedy Creek Riverine; LS B= Little Skookum Brackish, LS M= Little Skookum Marine; MB B = Mud Bay Brackish, MB M = Mud Bay Marine; MB R = Mud Bay Riverine; PP B= Ellis Cove Brackish, WB B= Woodard Bay Brackish, and WB R= Woodard Bay Riverine.

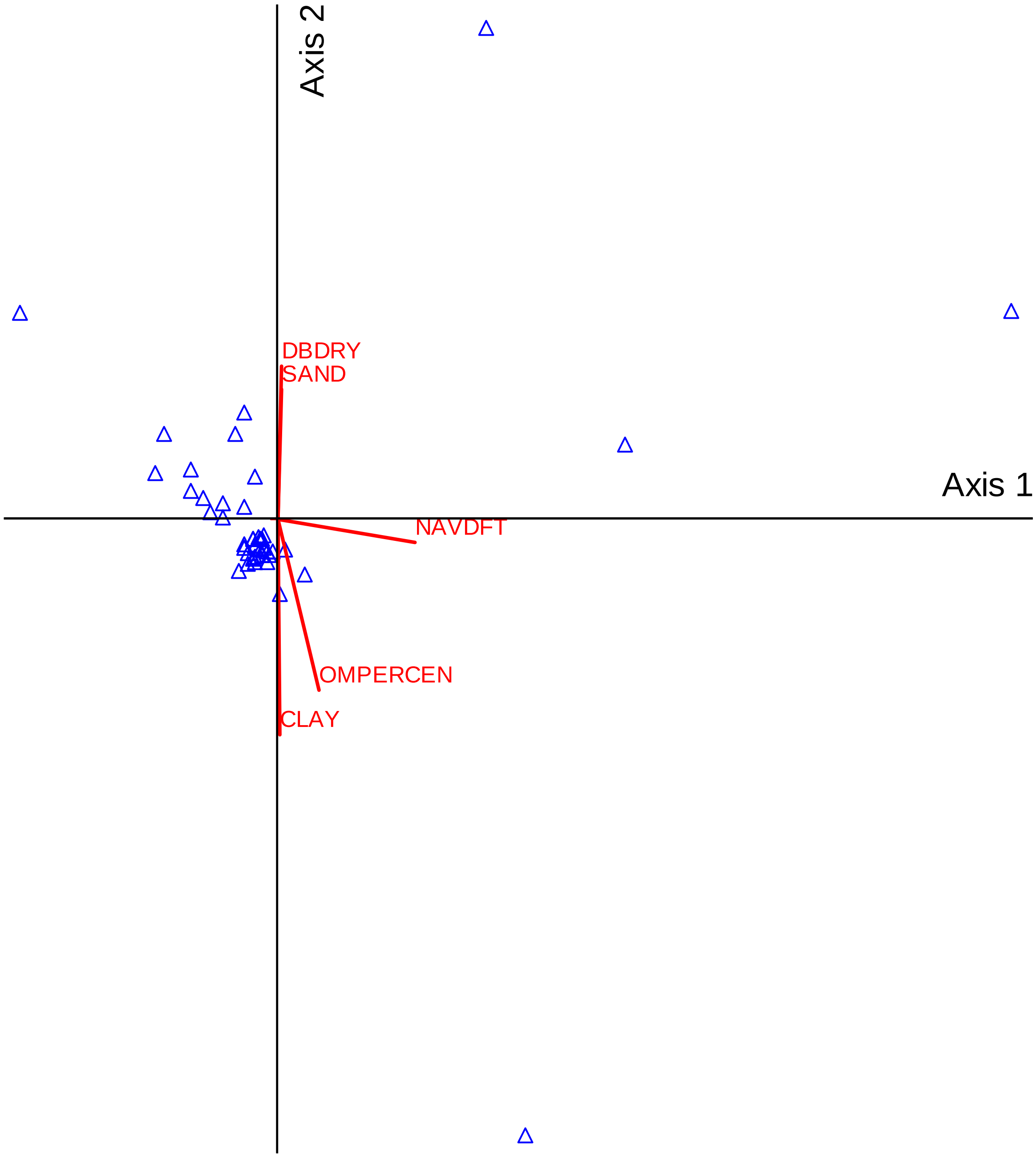

Figure 2. DCA ordination of 44 benthic invertebrate samples and the environmental variables correlated to ordination axis scores. Shown are elevation (NAVDF), percent organic matter (OMPERCEN), percent sand (SAND), percent silt (SILT), percent clay (CLAY), and dry bulk density (DBDRY). See the 2006 report for details.

Ecological and Distribution Information

Ecological and distribution information for some of the major taxonomic groups identified in the reference estuary samples is presented below. Information is organized according to phylum.

Phylum Nematoda:
Nematodes are small, unsegmented worms that typically occupy a significant component of benthic community of many aquatic ecosystems. They feed on bacteria, algae, and protozoans (Thorp and Covich 1991). The nematodes found in the reference estuaries were extremely small and therefore may have easily passed through the 500 micrometer sieve. Therefore, the number of nematodes is likely an under-representation of the true number within a sample.

Phylum Nemertea:
Nemertea, also called ribbon worms, are soft, unsegmented worms with a long proboscis that is used for collecting the numerous prey items it feeds upon. Many are free-living and bottom-dwelling (Smith and Carlton 1989).

Phylum Annelida:

Class Oligochaeta

Oligochaetes are annelid worms that are common prey for many invertebrate and vertebrate predators. Abundant in aquatic ecosystems, oligochaetes feed on benthic algae, epiphytic organisms, and also ingest sediments.

Class Polychaeta

Polychaete worms, which are also in the Phylum Annelida with Oligochaetes, were common in study samples. Families of polychaetes found in reference estuary samples are Sabellidae, Spionidae, Syllidae, Hesionidae, Nereidae, Nephtyidae, Cirratulidae, Capittelidae, Goniadidae, Glyceridae, Opheliidae, and Phyllodocidae.

Capitellids (Family **Capitellidae**) were found in all but four of the reference estuary samples. We did not identify Capitellids to species level but one common Capitellid is *Capitellid capitata.* This species is a mud-dwelling polychaete typically in temperate waters that feeds on direct deposits (Rudy and Rudy 1983). *C. capitata* can tolerate low salinity levels and sulfourous sediments, and are found in mudflats of muddy sand and those of pure mud. This species can indicate high pollution levels if found in high numbers with very few other invertebrates (Rudy and Rudy 1983).

The **Sabellid *Manayunkia aestuarina*** was found in nine of 44 samples and four of five reference estuaries. *M. aestuarina* are very small (6 mm), tube-building polychaetes typical in brackish water. Tubes built from the sand and mud of estuaries are often two times the length of its body. It feeds on surface deposits.

Spionids (Family **Spionidae)** are also tube-building polychaetes that can feed by sweeping their tentacles across the surface of substrate and collecting the particles that are released (Rudy and Rudy 1983). This group is one of the most common across all samples from the five reference estuaries, as well as being the most diverse polychaete in our samples. The species of Spionids identified are ***Streblospio benedicti***, ***Polydora cornuta*** (formerly *P. ligni*), ***Pseudopolydora kempi***, ***Prionospio lighti*** (also called *P. cirrifera*), ***Boccardia proboscidea***. *Prionospio lighti* is common in silty mud sediments (Smith and Carlton 1989). *Streblospio benedicti* and *Polydora cornuta* are associated with mud flats of estuaries, whereas *Pseudopolydora kempi* is considered to be more common in sandy mud sediments of bays (Smith and Carlton 1989). *Boccardia proboscidea*, common in sandy mudflats, has also been observed in many other niches such as tide pools and rocky shales. It is known for a great tolerance to temperature and salinity variation (Rudy and Rudy 1983). *B. proboscidea* feed on copepods, algae, and other small animals while burrowing.

Nereidae are typically large, long, active polychaete worms with a distinctive look that feed upon fresh animal food (Rudy and Rudy 1983). The only species identified in our samples was ***Nereis vexillosa***. This polychaete can grow up to 30cm in length in Puget Sound (Johnson 1943). It is associated with marine salinities, colder waters, intertidal and shallow water, among heavy algae, eelgrass, under rocks with muddy sand or sandy substrate (Johnson 1943). It has also been observed with mussel beds or barnacle clusters on intertidal pilings (Rudy and Rudy 1983). This Nereid has a wide geographical range and is abundant. This species was observed in samples from all of the study sites except for those from Woodard Bay (Appendix I).

Nephtys cornuta (Family **Nephtyidae**), represented in Mud Bay Marine and Woodard Bay Brackish samples, is found in muddy sediments (Smith and Carlton 1989)

Spaerosyllis californiensis is a **Syllidae** polychaete and is associated with silt and mud sediments (Smith and Carlton 1989).

Goniadidae polychaetes are found in a variety of sediments including muddy and mixed sand flats, and mud (Rudy and Rudy 1983). They are typically intertidal and can be associated with eelgrass. They have a large proboscis used for feeding. The species of Goniadidae identified in reference estuary samples was ***Glycinde picta*** (previously referred to as *G. polygnatha*) and is associated with sandy mud sediments (Smith and Carlton 1989).

Polychaetes in the family **Opheliidae** are typically burrowers that feed on deposits (Rudy and Rudy 1983). The species collected in the southern Puget Sound reference estuaries is ***Armandia brevis***. *A. brevis* burrows into sandy mud and silt while feeding on deposits (Rudy and Rudy 1983, Smith and Carlton 1989).

Phyllodocidae are polychaetes found in intertidal muddy sand and large open muddy areas. ***Eteone californica*** is one of the species encountered in our samples which is associated with sandy mud (Smith and Carlton 1989). Other unidentifiable *Eteone* species were also present in reference estuary samples. In Tillamook Bay on the Oregon Coast, *Eteone* species are prey for smelt and English sole in 10-30 o/oo salinity waters over large areas of muddy sediments (Rudy and Rudy 1983).

Phylum Arthropoda

Class Malacostraca

Order Amphipoda

Amphipods in the family **Corophiidae** are a common and important prey in estuarine environments. The species identified are *Monocorophium acherusicum*, *M. insidiosum*, *Americorophium spinicore*, and *A. salmonis*. In our results, higher numbers of Corophiids were observed in loamy sand and sandy loam sediments.

M. acherusicum may be the most widely distributed corophiid amphipod in temperate-tropical waters of the world that most likely originated from the eastern North Atlantic (Bousfield and Hoover 1997). This species builds tubes that are attached to algae and to debris on the mud bottom, and are also associated with harbor pilings (Rudy and Rudy 1983). ***M. insidiosum*** is thought to have spread to the North Pacific from the North Atlantic via commercial vessels (Bousfield and Hoover 1997). It is said to be a common species from the Strait of Georgia and Puget Sound, south to California in temperate and warm-temperate waters (Bousfield and Hoover 1997). This species also builds tubes that it attaches to debris on the mud bottoms of estuaries and can be found around harbor pilings (Rudy and Rudy 1983).

A. spinicorne is said to be the most commonly encountered estuarine corophiid of the NE Pacific region because of its distribution in many intertidal habitats (Bousfield and Hoover 1997). The diverse habitats include stream run-offs, mud flats, beach and log booms, areas of heavy silting, as well as sand in fresh and brackish waters (Bousfield and Hoover 1997, Rudy and Rudy 1983). This species builds tubes that are attached to debris and is a favorite prey item of Chinook (Rudy and Rudy 1983, Smith and Carlton 1989). ***A. salmonis*** is more common in higher salinity estuarine waters with muddy bottoms where it feeds on detritus (Rudy and Rudy 1983). This species is also sometimes associated with algae, especially *Ulva* spp. (Rudy and Rudy 1983). Like *A. spinicorne*, this species is preyed upon by young Chinook.

Other Amphipod species collected are ***Eogammarus confervicolus*** (**Family Anisogammaridae)** and ***Grandidierella japonica*** **(Family Aoridae).** *E. confervicolus* is recorded to be associated with sedges, eelgrass, *Salicornia*, algae, other marsh vegetation, and deposits of wood chips on muddy substrates (Rudy and Rudy 1983, Smith and Carlton 1989, Kozloff 1996). This amphipod can be estuarine, intertidal, subtidal and from full salt to brackish water (Rudy and Rudy 1983). It is an important prey item for fish and birds. *G. japonica* is an introduced species from Japan that is abundant in estuaries and builds tubes that are partially inserted into mud bottoms (Smith and Carlton 1989).

Order Cumacea

Cumacea are very small arthropods that inhabit the surface layer of sediments, especially of intertidal habitats (Smith and Carlton 1989). They can swim through the water column and burrow into the sediment while feeding by cleaning individual grains of sediment or directly eating surface deposits (Smith and Carlton 1989).

Conclusions

If tidal flow is restored to Capitol Lake, we expect the restored estuary to be dominated by intertidal mud flats, with mixed sand and mud flats interspersed (Figure 25 in 2006 report). We also predict sand flats near the edges of the main channel and higher energy areas, sand in the main channel of the North and Middle Basins, with vegetated marsh dispersed along the periphery of the Lake (Figure 25 in the 2006 report). Salinity will vary from fresh to salt water depending on tidal and seasonal flow patterns. We hypothesize that the restored Deschutes Estuary/ Capitol Lake will share similarities with the mud flats of Kennedy Creek and Mud Bay reference subestuaries.

This study has shown that the Mud Bay benthic invertebrate samples are very similar to one another regardless of what region of the subestuary they were taken from (Table 6 and Figure 1) and that the Kennedy Creek Brackish samples are more similar to the Mud Bay samples than they were to the Kennedy Creek Riverine samples (Figure 1).

Aside from the Woodard Bay samples, the Mud Bay samples had the highest mean number of organisms of all the sites sampled (Table 4). This suggests that the restored Deschutes Estuary/ Capitol Lake has the potential to be as productive as Mud Bay. However, the Ellis Cove sites, which had the lowest mean number of organisms (Table 4), also appeared similar to Mud Bay in DCA ordination space (Figure 1). Additional study is needed to determine the environmental factors that may affect these two subestuaries and their productivity. One possible effect on productivity at Ellis Cove is the location of the Cascade Pole and Lumber Company SuperFund site on the tip of the peninsula dividing the west and east bays of Budd Inlet. Cascade Pole was a 17 acre wood preservation and treatment facility that operated since the early 1940 through 1990 using creosote and pentachlorophenol (PCP) (WADH 2000). Upland and marine sediment investigation and remediation of contaminants has occurred including dredging and containment cell construction (WADH 2000). Contaminants detected include dioxins, furans, carcinogenic polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), other semivolatile organic compounds (SVOCs), volatile, organic compounds (VOCs), and metals (WADH 2000). These contaminants can have detrimental effects on benthic invertebrates and many other organisms. The affected area may extend to the southern edge of the mouth of Ellis Cove (WADH 2000).

The environmental factors driving the patterns observed in the benthic invertebrate communities were predominantly characteristics of the substrate. We found that elevation explained patterns along DCA Axis I and percent sand and clay explained patterns along DCA Axis II (Figure 2).

In this study, loamy sand benthic cores had the highest productivity. However, the sample size for loamy sand samples was very small. Sandy loam and silt loam sediments were the next most productive sites based on the mean number of organisms. These sediment types were the most common encountered in all reference estuary sampling (90 total samples) and the most common for those predicted in a restored Deschutes Estuary. In addition, silt loam sediments dominate the Mud Bay and Kennedy Creek samples processed in this study. Silt loam sediments are comprised mainly of clay and silt, with small percentages of sand. Silt loam and other fine sediment types can support many invertebrates. Dethier (1990) describes the diverse flora and fauna associated with these sediment types and habitat classes in more detail.

Table 8 also lists organisms associated with habitat types recognized by Dethier (1990). We have highlighted some of the organisms that may be useful as indicator organisms because they may only appear in the habitats that are expected to develop in a restored Deschutes Estuary/ Capitol Lake. Table 8 also lists the organisms that were found in the samples processed from the reference subestuaries and their associated Dethier (1990) habitat type. In addition, *Americorophium salmonis* and *A. spinicorne* may be indicators of fresh to brackish areas while *A. brevis*, *Monocorophium insidiosum* and *M. acherusicum* may be more common in marine settings (J. Cordell, personal communication). Other potential indicator organisms may be apparent in the data set generated by this study (Appendix I). It is important to note the diversity of organisms associated with the habitat types predicted for a restored Deschutes Estuary. These organisms include many polychaete species and diverse amphipods.

There may be other interesting trends in the raw data which are not evident in statistical tests (comparison of means) or the ordination. Our comparison of means was hampered by the relatively small sample sizes.

We recommend that biological diversity and community similarity values be calculated from the existing data. For example, taxonomic richness appears to be fairly high in Woodard Bay especially considering the relatively small volume of the benthic core of mud.

Results from this study are also encouraging for those with concerns of the possible development of mud and sand flats in the restored Deschutes Estuary/ Capitol Lake. If the habitats develop as predicted, the restored Deschutes Estuary should support a diverse and productive benthic community. Researchers at PNW universities are beginning to look at the energetic relationships between the need of juvenile salmonids and their prey. Although salmon concerns are not a primary driver for the proposed restoration project, the mud and sand flats have the potential to support them, along with other fish and wildlife. We recommend that data from this report be evaluated for fish and wildlife food quality.

In summary, we have the following recommendations should addition funds or resources become available from the Deschutes Estuary Feasibility Study or other sources:

- We recommend processing remaining core samples because we believe there is an interesting story here to tell but we are missing a few of the pieces to tell it with confidence;

- We recommend additional community analysis, i.e., calculating community similarities and diversity indices.

Table 8. Habitat types (Dethier 1990) and associated benthic organisms. Benthic organisms that were identified in reference estuary samples, or those in the same family or genus, are presented according to the Dethier habitat type they are associated with. Habitat types shaded in gray are those predicted for the restored Deschutes Estuary.

Organism:	Estuarine Intertidal Mixed Coarse: Open	Estuarine Intertidal Gravel: Open	Estuarine Intertidal Sand: Open	Estuarine Intertidal Sand or Mixed Fine: Lagoon, Hyperhaline, and Euhaline	Estuarine Intertidal Mixed Fines: Partly Enclosed	Estuarine Intertidal Mud: Partly Enclosed and Enclosed	Estuarine Intertidal Mixed Fines and Mud: Channel/ Slough	Esutarine Subtidal Mixed-Coarse: Open, Deep	Estuarine Subtidal Mud: Partly-Enclosed, Shallow	Estuarine Subtidal Mud: Partly-Enclosed, Deep	Estuarine Subtidal Sand and Mud: Channels	Marine Intertidal Sand: Exposed and Partially Exposed	Marine Intertidal Mud: Protected	Marine Subtidal Mud and Mixed Fines: Low Energy and Shallow	Marine Subtidal Mud: Low Energy and Deep
Americorophium brevis [1]	X														
*Americorophium salmonis**					X	X	X		X		X				
Ampharetids								X							
Armandia brevis		X		X					X					X	
Capitella capitata [1]		X				X			X		X		X		
Capitellids*										X					
chironomid larvae*							X								
Cirratulids*									X	X					
Crangon spp.											X	X			
*Eogammarus confervicolus**					X										
Eogammarus spp.*							X				X				
Eteone longa [1]					X								X		
*Eteone pacifica** [1]									X						
Eteone spp.*											X				
*Glycera capitata** [1]										X					
Glycerids*									X						
Glycinde picta		X				X			X	X			X		
*Manayunkia aestuarina**					X	X	X								
Nematodes*										X					
Nemertean worms												X			
Nephtys cornuta										X					X
Nepthys spp.			X		X				X			X			
Nereis limnicola [1]					X										
Nereis spp.	X														
Polydora kempi japonica [2]					X	X							X		
Polydora ligni [1]				X											
Sabellids								X						X	
Spionids*											X				
Streblospio benedicti			X		X								X		

Footnotes: * Indicates groups or species that may be considered important in future monitoring of a restored Deschutes Estuary because of their presence solely within Dethier (1990) habitat types predicted for the Deschutes Estuary. 1. Species not identified in reference estuary samples but in the same genus as those that were identified. 2. Also referred to as *Psuedopolydora kempi* .

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Appendix I

Data collected from 44 benthic cores taken from five South Puget Sound subestuaries in 2005.

Code	Phylum	Class	Order	Family	Genus	Species	KCB1	KCB2	KCB3	KCB5	KCB7	KCB8	KCB9
TODE	Nematoda						1	7			4		
NEMR	Nemertea												
OLIG	Annelida	Oligochaeta					25	8	19	7	31	21	11
CAPIT	Annelida	Polychaeta		Capitellidae			4	9	17	5	122	9	4
CIRRAT	Annelida	Polychaeta	Canalipalpata	Cirratulidae									
GlyNa	Annelida	Polychaeta	Aciculata	Glyceridae	Glycera	nana							
GlyPi	Annelida	Polychaeta	Aciculata	Goniadidae	Glycinde	picta							
NEREID	Annelida	Polychaeta	Aciculata	Nereidae			4	4	5	6	1		
NerVex	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa	8	3	1	5	1	2	6
Ner_spp	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.	3	2	2	2			2
NepCor	Annelida	Polychaeta	Aciculata	Nephtyidae	Nephtys	cornuta							
MicDub	Annelida	Polychaeta	Aciculata	Hesionidae	Micropodarke	dubia							
SphCal	Annelida	Polychaeta	Aciculata	Syllidae	Sphaerosyllis	californiensis							
StrBen	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	44	28	60	29	15	11	20
Polcor	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta		1		1			
PseKem	Annelida	Polychaeta	Canalipalpata	Spionidae	Pseudopolydora	kempi							
PriLig	Annelida	Polychaeta	Canalipalpata	Spionidae	Prionospio	lighti							
BocPro	Annelida	Polychaeta	Canalipalpata	Spionidae	Boccardia	proboscidea							
MaAe	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina			1				
EteCal	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	californica							
Ete_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	spp.							
Phyl_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Phyllodoce	spp.							
ArmBre	Annelida	Polychaeta		Opheliidae	Armandia	brevis							
AmeSpi	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne							
AmeSal	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis							
MonIns	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum							
MonAch	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum							
Mon_spp	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.							
EogCon	Arthropoda	Malacostraca	Amphipoda	Anisogammaridae	Eogammarus	confervicolus							
GraJap	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica			1				
CUMA	Arthropoda	Malacostraca	Cumacea				2		7	23	4		1
ISO_Ase	Arthropoda	Malacostraca	Isopoda										
ISO_Sph	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae									
OSTRA	Arthropoda	Ostracoda						1					
COP_Harp	Arthropoda	Copepoda											
DECA	Arthropoda	Malacostraca	Decapoda										
CIRR	Arthropoda	Cirripedia	Thoracica										
GASTRO	Mollusca	Gastropda											
MyaAre	Mollusca	Bivalvia			Mya	arenaria							
BIVALV	Mollusca	Bivalvia											
COLEOP	Arthropoda	Insecta	Coleoptera										
CERAT	Arthropoda	Insecta	Diptera	Ceratopogonidae									
SCIOM	Arthropoda	Insecta	Diptera	Sciomyzidae									
TIPUL	Arthropoda	Insecta	Diptera	Tipulidae									
HEMIP	Arthropoda	Insecta	Hemiptera										
COL_Anu	Arthropoda	Insecta	Collembola	Hypogastruridae	Anurida								
						Total	91	63	113	78	178	43	44

Code	Phylum	Class	Order	Family	Genus	Species	KCR1	KCR3	KCR4	KCR7	LSB1	LSB2	LSB3	LSB4
TODE	Nematoda							159	4					
NEMR	Nemertea													
OLIG	Annelida	Oligochaeta					1	1	5		3	7	2	4
CAPIT	Annelida	Polychaeta		Capitellidae				70			3	1	4	1
CIRRAT	Annelida	Polychaeta	Canalipalpata	Cirratulidae										
GlyNa	Annelida	Polychaeta	Aciculata	Glyceridae	Glycera	nana								
GlyPi	Annelida	Polychaeta	Aciculata	Goniadidae	Glycinde	picta								
NEREID	Annelida	Polychaeta	Aciculata	Nereidae							1	3	4	
NerVex	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa			3		7	3	4	6
Ner_spp	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.					1	3	2	2
NepCor	Annelida	Polychaeta	Aciculata	Nephtyidae	Nephtys	cornuta								
MicDub	Annelida	Polychaeta	Aciculata	Hesionidae	Micropodarke	dubia								
SphCal	Annelida	Polychaeta	Aciculata	Syllidae	Sphaerosyllis	californiensis								
StrBen	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti					12	14	18	13
Polcor	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta							2	
PseKem	Annelida	Polychaeta	Canalipalpata	Spionidae	Pseudopolydora	kempi								
PriLig	Annelida	Polychaeta	Canalipalpata	Spionidae	Prionospio	lighti								
BocPro	Annelida	Polychaeta	Canalipalpata	Spionidae	Boccardia	proboscidea								
MaAe	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina		137						
EteCal	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	californica								
Ete_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	spp.								
Phyl_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Phyllodoce	spp.								
ArmBre	Annelida	Polychaeta		Opheliidae	Armandia	brevis								
AmeSpi	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne			310					
AmeSal	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis								
MonIns	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum								
MonAch	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum								
Mon_spp	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.								
EogCon	Arthropoda	Malacostraca	Amphipoda	Anisogammaridae	Eogammarus	confervicolus			5					
GraJap	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica								
CUMA	Arthropoda	Malacostraca	Cumacea									8		
ISO_Ase	Arthropoda	Malacostraca	Isopoda				1							
ISO_Sph	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae					88					
OSTRA	Arthropoda	Ostracoda						1						
COP_Harp	Arthropoda	Copepoda												
DECA	Arthropoda	Malacostraca	Decapoda											
CIRR	Arthropoda	Cirripedia	Thoracica								1			
GASTRO	Mollusca	Gastropda								533				
MyaAre	Mollusca	Bivalvia			Mya	arenaria								
BIVALV	Mollusca	Bivalvia												
COLEOP	Arthropoda	Insecta	Coleoptera					1						
CERAT	Arthropoda	Insecta	Diptera	Ceratopogonidae				1						
SCIOM	Arthropoda	Insecta	Diptera	Sciomyzidae			2							
TIPUL	Arthropoda	Insecta	Diptera	Tipulidae			1	1						
HEMIP	Arthropoda	Insecta	Hemiptera						1					
COL_Anu	Arthropoda	Insecta	Collembola	Hypogastruridae	Anurida								1	
						Total	5	371	416	533	28	39	37	26

Code	Phylum	Class	Order	Family	Genus	Species	LSB5	LSM3	LSM4	LSM7	LSM8	MBB1	MBB2
TODE	Nematoda						1						12
NEMR	Nemertea												
OLIG	Annelida	Oligochaeta					3	23	36	5		4	57
CAPIT	Annelida	Polychaeta		Capitellidae			5	12	8	1	9	6	6
CIRRAT	Annelida	Polychaeta	Canalipalpata	Cirratulidae					1				
GlyNa	Annelida	Polychaeta	Aciculata	Glyceridae	Glycera	nana							
GlyPi	Annelida	Polychaeta	Aciculata	Goniadidae	Glycinde	picta							
NEREID	Annelida	Polychaeta	Aciculata	Nereidae			4	7	8	7	3	1	5
NerVex	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa	2	9	2	5	5	2	4
Ner_spp	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.	11	15	7	1	1	1	3
NepCor	Annelida	Polychaeta	Aciculata	Nephtyidae	Nephtys	cornuta							
MicDub	Annelida	Polychaeta	Aciculata	Hesionidae	Micropodarke	dubia							
SphCal	Annelida	Polychaeta	Aciculata	Syllidae	Sphaerosyllis	californiensis							
StrBen	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	12	26	18	30	17	15	94
Polcor	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta	11	5	14				3
PseKem	Annelida	Polychaeta	Canalipalpata	Spionidae	Pseudopolydora	kempi	2		1				
PriLig	Annelida	Polychaeta	Canalipalpata	Spionidae	Prionospio	lighti			1				
BocPro	Annelida	Polychaeta	Canalipalpata	Spionidae	Boccardia	proboscidea							
MaAe	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina							
EteCal	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	californica							
Ete_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	spp.	1						
Phyl_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Phyllodoce	spp.							
ArmBre	Annelida	Polychaeta		Opheliidae	Armandia	brevis							
AmeSpi	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne							
AmeSal	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis							
MonIns	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum	15	1	4				
MonAch	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum	44		3				
Mon_spp	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.	12						
EogCon	Arthropoda	Malacostraca	Amphipoda	Anisogammaridae	Eogammarus	confervicolus							
GraJap	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica	10		2			1	
CUMA	Arthropoda	Malacostraca	Cumacea				1	19	11	2	7	2	80
ISO_Ase	Arthropoda	Malacostraca	Isopoda										
ISO_Sph	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae									
OSTRA	Arthropoda	Ostracoda					1						
COP_Harp	Arthropoda	Copepoda											
DECA	Arthropoda	Malacostraca	Decapoda										
CIRR	Arthropoda	Cirripedia	Thoracica										
GASTRO	Mollusca	Gastropda											
MyaAre	Mollusca	Bivalvia			Mya	arenaria						4	
BIVALV	Mollusca	Bivalvia					1						
COLEOP	Arthropoda	Insecta	Coleoptera										
CERAT	Arthropoda	Insecta	Diptera	Ceratopogonidae									
SCIOM	Arthropoda	Insecta	Diptera	Sciomyzidae									
TIPUL	Arthropoda	Insecta	Diptera	Tipulidae									
HEMIP	Arthropoda	Insecta	Hemiptera										
COL_Anu	Arthropoda	Insecta	Collembola	Hypogastruridae	Anurida								
						Total	136	117	116	51	42	36	264

Appendix I

Code	Phylum	Class	Order	Family	Genus	Species	MBB3	MBB4	MBB6	MBB7	MBB8	MBB9	MBM1
TODE	Nematoda						3	6	12	27		4	36
NEMR	Nemertea								1				2
OLIG	Annelida	Oligochaeta					44	39	42	107	45	40	28
CAPIT	Annelida	Polychaeta		Capitellidae			32	34	19	11	27	6	5
CIRRAT	Annelida	Polychaeta	Canalipalpata	Cirratulidae									
GlyNa	Annelida	Polychaeta	Aciculata	Glyceridae	Glycera	nana							
GlyPi	Annelida	Polychaeta	Aciculata	Goniadidae	Glycinde	picta							1
NEREID	Annelida	Polychaeta	Aciculata	Nereidae			20	6	1	6	6	3	1
NerVex	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa	17	5	4	6	3	1	15
Ner_spp	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.	9	3	2	6	10	4	3
NepCor	Annelida	Polychaeta	Aciculata	Nephtyidae	Nephtys	cornuta							1
MicDub	Annelida	Polychaeta	Aciculata	Hesionidae	Micropodarke	dubia							
SphCal	Annelida	Polychaeta	Aciculata	Syllidae	Sphaerosyllis	californiensis							1
StrBen	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	87	37	104	150	32	12	65
Polcor	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta	3	1	5	3	1		9
PseKem	Annelida	Polychaeta	Canalipalpata	Spionidae	Pseudopolydora	kempi							
PriLig	Annelida	Polychaeta	Canalipalpata	Spionidae	Prionospio	lighti							
BocPro	Annelida	Polychaeta	Canalipalpata	Spionidae	Boccardia	proboscidea							
MaAe	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina					1		
EteCal	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	californica							
Ete_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	spp.							
Phyl_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Phyllodoce	spp.							
ArmBre	Annelida	Polychaeta		Opheliidae	Armandia	brevis							
AmeSpi	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne							
AmeSal	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis							
MonIns	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum							
MonAch	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum						1	
Mon_spp	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.							
EogCon	Arthropoda	Malacostraca	Amphipoda	Anisogammaridae	Eogammarus	confervicolus							
GraJap	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica	1			2			
CUMA	Arthropoda	Malacostraca	Cumacea				116	15	12	34	2	6	10
ISO_Ase	Arthropoda	Malacostraca	Isopoda										
ISO_Sph	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae									
OSTRA	Arthropoda	Ostracoda					6	1		1			2
COP_Harp	Arthropoda	Copepoda											1
DECA	Arthropoda	Malacostraca	Decapoda										
CIRR	Arthropoda	Cirripedia	Thoracica										
GASTRO	Mollusca	Gastropda											
MyaAre	Mollusca	Bivalvia			Mya	arenaria			4				
BIVALV	Mollusca	Bivalvia											
COLEOP	Arthropoda	Insecta	Coleoptera										
CERAT	Arthropoda	Insecta	Diptera	Ceratopogonidae									
SCIOM	Arthropoda	Insecta	Diptera	Sciomyzidae									
TIPUL	Arthropoda	Insecta	Diptera	Tipulidae									
HEMIP	Arthropoda	Insecta	Hemiptera										
COL_Anu	Arthropoda	Insecta	Collembola	Hypogastruridae	Anurida								
						Total	338	147	206	353	127	77	180

Code	Phylum	Class	Order	Family	Genus	Species	MBM2	MBM3	MBM5	MBM6	MBR1	MBR3
TODE	Nematoda						12	68	7	7	3	1
NEMR	Nemertea											
OLIG	Annelida	Oligochaeta					20	47	184	31	20	187
CAPIT	Annelida	Polychaeta		Capitellidae			3	17	44	11	5	9
CIRRAT	Annelida	Polychaeta	Canalipalpata	Cirratulidae								
GlyNa	Annelida	Polychaeta	Aciculata	Glyceridae	Glycera	nana						
GlyPi	Annelida	Polychaeta	Aciculata	Goniadidae	Glycinde	picta						
NEREID	Annelida	Polychaeta	Aciculata	Nereidae			3	6	2	1	2	2
NerVex	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa	10	7	3	3	4	4
Ner_spp	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.	5	2	1	3	6	
NepCor	Annelida	Polychaeta	Aciculata	Nephtyidae	Nephtys	cornuta	2	1				
MicDub	Annelida	Polychaeta	Aciculata	Hesionidae	Micropodarke	dubia						
SphCal	Annelida	Polychaeta	Aciculata	Syllidae	Sphaerosyllis	californiensis						
StrBen	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	75	148	37	24	67	52
Polcor	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta	5	1	8	2		
PseKem	Annelida	Polychaeta	Canalipalpata	Spionidae	Pseudopolydora	kempi						
PriLig	Annelida	Polychaeta	Canalipalpata	Spionidae	Prionospio	lighti			1			
BocPro	Annelida	Polychaeta	Canalipalpata	Spionidae	Boccardia	proboscidea						
MaAe	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina		1				
EteCal	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	californica						
Ete_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	spp.						
Phyl_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Phyllodoce	spp.		1				
ArmBre	Annelida	Polychaeta		Opheliidae	Armandia	brevis						
AmeSpi	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne						
AmeSal	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis			5			
MonIns	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum		1				
MonAch	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum						
Mon_spp	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.						
EogCon	Arthropoda	Malacostraca	Amphipoda	Anisogammaridae	Eogammarus	confervicolus						
GraJap	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica	2	1	1			1
CUMA	Arthropoda	Malacostraca	Cumacea				9	2	4	3	2	10
ISO_Ase	Arthropoda	Malacostraca	Isopoda									
ISO_Sph	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae								
OSTRA	Arthropoda	Ostracoda					1			1		14
COP_Harp	Arthropoda	Copepoda										
DECA	Arthropoda	Malacostraca	Decapoda									
CIRR	Arthropoda	Cirripedia	Thoracica									
GASTRO	Mollusca	Gastropda									1	
MyaAre	Mollusca	Bivalvia			Mya	arenaria						
BIVALV	Mollusca	Bivalvia					2		1			
COLEOP	Arthropoda	Insecta	Coleoptera									
CERAT	Arthropoda	Insecta	Diptera	Ceratopogonidae								
SCIOM	Arthropoda	Insecta	Diptera	Sciomyzidae								
TIPUL	Arthropoda	Insecta	Diptera	Tipulidae								
HEMIP	Arthropoda	Insecta	Hemiptera									
COL_Anu	Arthropoda	Insecta	Collembola	Hypogastruridae	Anurida							
						Total	149	303	298	86	110	280

Code	Phylum	Class	Order	Family	Genus	Species	MBR4	MBR5	PPB3	PPB6	PPR2	PPR3	WBB6
TODE	Nematoda						7	2	10		2		164
NEMR	Nemertea								8	4			
OLIG	Annelida	Oligochaeta					241	26	45	8	10	19	9
CAPIT	Annelida	Polychaeta		Capitellidae			32		25	3	2	7	1
CIRRAT	Annelida	Polychaeta	Canalipalpata	Cirratulidae						2			
GlyNa	Annelida	Polychaeta	Aciculata	Glyceridae	Glycera	nana							1
GlyPi	Annelida	Polychaeta	Aciculata	Goniadidae	Glycinde	picta							1
NEREID	Annelida	Polychaeta	Aciculata	Nereidae			3	3					
NerVex	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa		5		2	1	1	
Ner_spp	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.	3	4					
NepCor	Annelida	Polychaeta	Aciculata	Nephtyidae	Nephtys	cornuta							3
MicDub	Annelida	Polychaeta	Aciculata	Hesionidae	Micropodarke	dubia							6
SphCal	Annelida	Polychaeta	Aciculata	Syllidae	Sphaerosyllis	californiensis							
StrBen	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	23	37	2	1	1	5	2
Polcor	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta	1						
PseKem	Annelida	Polychaeta	Canalipalpata	Spionidae	Pseudopolydora	kempi							
PriLig	Annelida	Polychaeta	Canalipalpata	Spionidae	Prionospio	lighti							
BocPro	Annelida	Polychaeta	Canalipalpata	Spionidae	Boccardia	proboscidea							
MaAe	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina		3	2		19		
EteCal	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	californica							
Ete_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	spp.							
Phyl_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Phyllodoce	spp.							
ArmBre	Annelida	Polychaeta		Opheliidae	Armandia	brevis							16
AmeSpi	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne							
AmeSal	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis					2	7	108
MonIns	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum							66
MonAch	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum							234
Mon_spp	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.							69
EogCon	Arthropoda	Malacostraca	Amphipoda	Anisogammaridae	Eogammarus	confervicolus							
GraJap	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica	1		1		1	39	11
CUMA	Arthropoda	Malacostraca	Cumacea				47	7	1			4	30
ISO_Ase	Arthropoda	Malacostraca	Isopoda										
ISO_Sph	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae									
OSTRA	Arthropoda	Ostracoda							7	2	2	6	46
COP_Harp	Arthropoda	Copepoda									2		8
DECA	Arthropoda	Malacostraca	Decapoda										4
CIRR	Arthropoda	Cirripedia	Thoracica							1			
GASTRO	Mollusca	Gastropda							1				
MyaAre	Mollusca	Bivalvia			Mya	arenaria							
BIVALV	Mollusca	Bivalvia											4
COLEOP	Arthropoda	Insecta	Coleoptera										
CERAT	Arthropoda	Insecta	Diptera	Ceratopogonidae									
SCIOM	Arthropoda	Insecta	Diptera	Sciomyzidae									
TIPUL	Arthropoda	Insecta	Diptera	Tipulidae									
HEMIP	Arthropoda	Insecta	Hemiptera										
COL_Anu	Arthropoda	Insecta	Collembola	Hypogastruridae	Anurida								
						Total	358	87	102	23	42	88	783

Code	Phylum	Class	Order	Family	Genus	Species	WBUR1	WBUR2	Total
TODE	Nematoda						19	22	600
NEMR	Nemertea						1		16
OLIG	Annelida	Oligochaeta					17	15	1497
CAPIT	Annelida	Polychaeta		Capitellidae			60	40	689
CIRRAT	Annelida	Polychaeta	Canalipalpata	Cirratulidae					3
GlyNa	Annelida	Polychaeta	Aciculata	Glyceridae	Glycera	nana			1
GlyPi	Annelida	Polychaeta	Aciculata	Goniadidae	Glycinde	picta			2
NEREID	Annelida	Polychaeta	Aciculata	Nereidae			1		129
NerVex	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	vexillosa			169
Ner_spp	Annelida	Polychaeta	Aciculata	Nereidae	Nereis	spp.	1		120
NepCor	Annelida	Polychaeta	Aciculata	Nephtyidae	Nephtys	cornuta			7
MicDub	Annelida	Polychaeta	Aciculata	Hesionidae	Micropodarke	dubia			6
SphCal	Annelida	Polychaeta	Aciculata	Syllidae	Sphaerosyllis	californiensis			1
StrBen	Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	1	15	1453
Polcor	Annelida	Polychaeta	Canalipalpata	Spionidae	Polydora	cornuta		1	77
PseKem	Annelida	Polychaeta	Canalipalpata	Spionidae	Pseudopolydora	kempi		2	5
PriLig	Annelida	Polychaeta	Canalipalpata	Spionidae	Prionospio	lighti			2
BocPro	Annelida	Polychaeta	Canalipalpata	Spionidae	Boccardia	proboscidea	8		8
MaAe	Annelida	Polychaeta	Canalipalpata	Sabellidae	Manayunkia	aestuarina	12	6	182
EteCal	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	californica		1	1
Ete_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Eteone	spp.		2	3
Phyl_spp	Annelida	Polychaeta	Aciculata	Phyllodocidae	Phyllodoce	spp.			1
ArmBre	Annelida	Polychaeta		Opheliidae	Armandia	brevis			16
AmeSpi	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	spinicorne			310
AmeSal	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Americorophium	salmonis	40	84	246
MonIns	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum	5	11	103
MonAch	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum			282
Mon_spp	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium	spp.	1		82
EogCon	Arthropoda	Malacostraca	Amphipoda	Anisogammaridae	Eogammarus	confervicolus	1		6
GraJap	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella	japonica			75
CUMA	Arthropoda	Malacostraca	Cumacea				1	5	487
ISO_Ase	Arthropoda	Malacostraca	Isopoda						1
ISO_Sph	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae					88
OSTRA	Arthropoda	Ostracoda					3	5	100
COP_Harp	Arthropoda	Copepoda					2		13
DECA	Arthropoda	Malacostraca	Decapoda						4
CIRR	Arthropoda	Cirripedia	Thoracica						2
GASTRO	Mollusca	Gastropda							535
MyaAre	Mollusca	Bivalvia			Mya	arenaria			8
BIVALV	Mollusca	Bivalvia							8
COLEOP	Arthropoda	Insecta	Coleoptera						1
CERAT	Arthropoda	Insecta	Diptera	Ceratopogonidae					1
SCIOM	Arthropoda	Insecta	Diptera	Sciomyzidae					2
TIPUL	Arthropoda	Insecta	Diptera	Tipulidae					2
HEMIP	Arthropoda	Insecta	Hemiptera						1
COL_Anu	Arthropoda	Insecta	Collembola	Hypogastruridae	Anurida				1
						Total	173	209	7346