CORRIB OFFSHORE GAS FIELD DEVELOPMENT

ERRIS HEAD OUTFALL ENVIRONMENTAL SURVEY 2008

August 2009

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1 Introduction

The Corrib gas field lies in approximately 350m of water, approximately 65km off the coast of County Mayo. The gas in the field is to be brought ashore using a 20-inch-diameter pipeline, which will landfall at Dooncarton in Broadhaven Bay. From there, the pipeline will be routed to the terminal at Bellanaboy Bridge. The plan of development for the field was approved in 2002, subject to various conditions.

Processing of the gas at the terminal will result in the production of waste water, which will be discharged back to sea through a pipeline (consented under an IPPC licence).

The proposed discharge location lies approximately 2km north of Erris Head in water depths of approximately 70m below chart datum. A baseline survey of biological and chemical parameters in seawater and sediment was undertaken around the proposed Corrib outfall in June–August 2005 (EcoServe, 2006). In addition, a second baseline survey was undertaken in July 2007 (RSK, 2008). This report documents a third baseline survey of water and sediment around the outfall in summer 2008.

After the completion of the 2008 baseline survey, Shell agreed to route the produced water back through some spare umbilical cores, and toe release it in the Corrib field itself. The proposed outfall, which is the subject of this report, will be engaged solely for the discharge of treated surface water run-off from the terminal.

2 Methods

2.1 Vessel

Sampling operations were carried out from the M/V *Deepworker*, a 70-metre dynamically positioned salvage/survey/research vessel, licensed for survey operations in waters of the continental shelf.

Osiris Projects provided an onboard positioning package and helmsman display from which to position the vessel during survey operations. The following equipment was mobilised aboard the vessel for the survey: CSI dGPS Max receiver; high-specification navigation PC supporting Quincy V8 (spare PC); TSS Meridian gyro; Simrad HPR 400 subsea positioning system over-the-side mount and Simrad 60 series single-beam echo sounder. The vessel's existing Trimble dGPS navigation system was used as a secondary resource.

2.2 Personnel

SEPIL commissioned RSK Environment Ltd (RSK) to manage the environmental survey cruise. RSK contracted Osiris Projects to act as vessel operators for the offshore survey work and to provide navigational services for the duration of the project.

During the survey operations, the scientific crew aboard worked according to two 12-hour shifts to enable sampling operations to continue over 24 hours. Each watch comprised three scientists, the most senior being the dedicated shift leader.

2.3 Survey dates

Table 2.1 presents key dates of the survey.

Table 2.1: Dates of 2008 Erris Head environmental survey

Date (July 2008)	Task	Location
11	Mobilisation	Foynes
12–13	Depart/transit (30 hours), Navigation calibration	Foynes/en route
13–21	Survey operations (outwith this report)	Corrib field
21–22	**Survey operations**	**Erris Head outfall**
22–23	Survey operations (outwith this report)	Stations at 12nm limit alternative outfall
23–26	Transit (to Foynes), partial demobilisation, remobilisation, transit (to alternative outfall stations off Erris Head)	Foynes/en route/alternative stations off Erris Head
26–29	Survey operations (outwith this report)	Stations at alternative outfall off Erris Head
30	Transit, complete demobilisation	Alternative outfall, Foynes

*Partial demobilisation only. Survey continued to sample 'Alternative outfall' stations; see separate report.

2.4 Sampling locations

Twenty stations were planned for sampling and these are presented in. Stations included those both with sediment (S) and water (W) sampling elements (nine stations) and those with only water (eight stations) and only sediment (three stations) elements.

The target accuracy for benthic samples was within 30m of the position.

Table 2.2: Coordinates of sites (WGS84 datum)

Site	Latitude N	Longitude W
S1 and W1	54.294696	-10.183642
S2 and W2	54.320796	-10.017542
S4	54.328996	-10.023142
W4	54.324834	-9.998042
W6	54.326687	-9.989278
S5	54.333900	-9.987600
S5R	54.327996	-9.986942
S6 and W11	54.332500	-9.993100
S6R and W5	54.326596	-9.992442
W7	54.330676	-9.983941
S9 & W9	54.332296	-9.952242
S10 &W8	54.356496	-9.986242
W10	54.337643	-9.996132
S11 and W3	54.332496	-10.027042
W12	54.329328	-9.990907
W13	54.328220	-9.990162
W14	54.323598	-9.986581
S15 and W15	54.319296	-9.982042
W16	54.327586	-9.972536
S17 and W17	54.320696	-9.956342

Blank cell: sediment and water; Brown: sediment only; Blue: water only

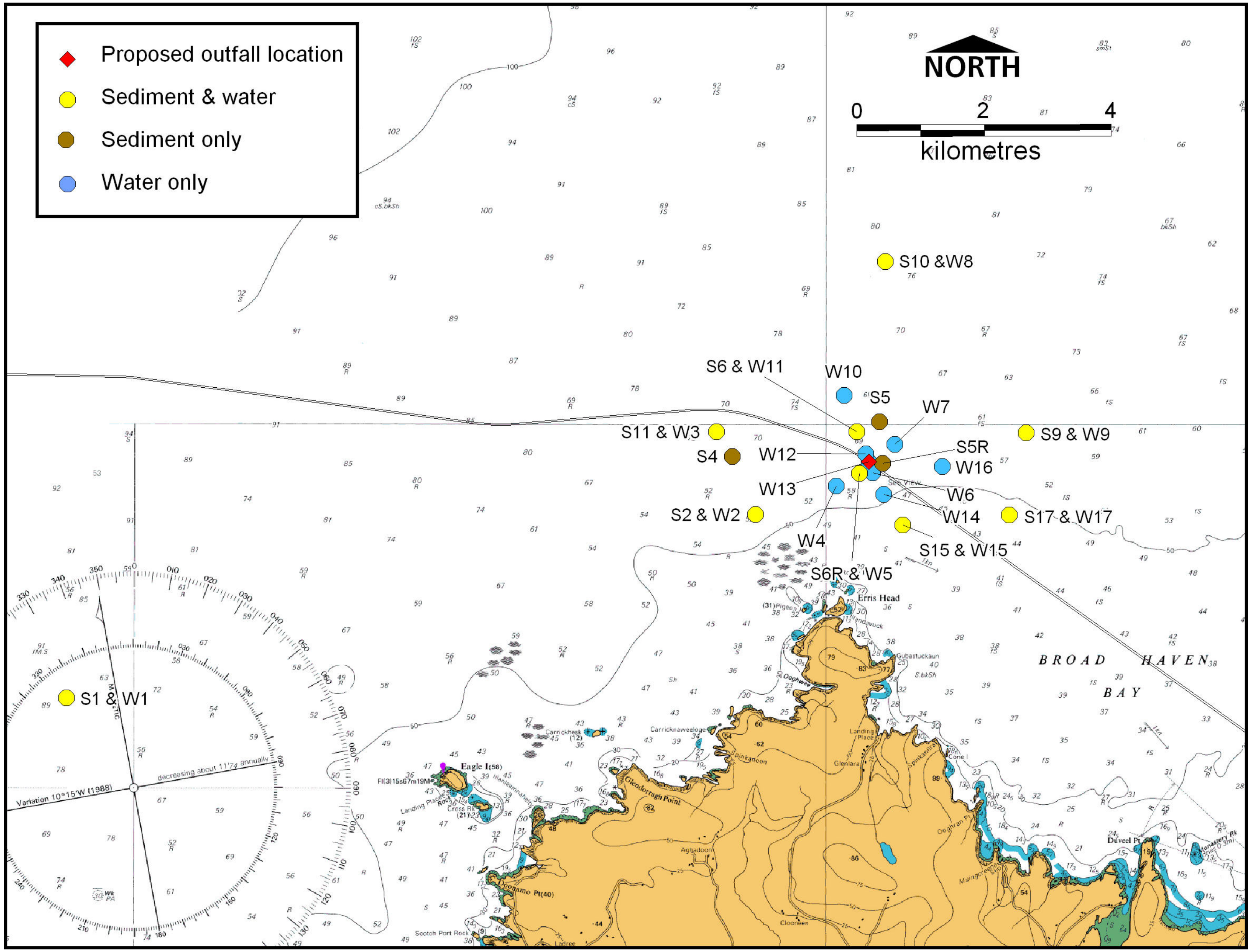

Figure 2.1: Planned sampling stations, Erris Head outfall survey (July 2008)

2.5 Sampling methods

Survey operations at the Erris Head outfall locations consisted of sampling:

a) **Water quality parameters:**
   a. Collection of surface and near-bottom samples for laboratory chemical analysis
   b. Measurement of parameters using a conductivity, temperature and depth (CTD) probe.

b) **Seabed sediments** using a grab sampler for:
   a. Physico-chemistry (particle size and total organic carbon, TOC)
   b. Chemistry (metals, hydrocarbons)
   c. Benthic macroinvertebrates.

2.5.1 Water quality

Surface water samples were obtained by means of a surface-deployed Winchester bottle using a 4.5m pole. The bottle was opened remotely at a depth of one metre. Once full, the bottle was recovered and transferred to subsample bottles for various analytes. A new Winchester bottle was used for each of the surface water stations.

For near-bottom water samples (including water column CTD profiling), a Richter and Weise Niskin bottle was deployed from the deck winch on a 4mm stainless steel wire along with a Valeport Monitor CTD profiler, both of which were positioned two metres above a sinker weight. The CTD was allowed to equilibrate in the surface waters for three minutes before it was lowered through the water column. When the weight at the bottom of the cable reached the seabed, the bottle-closing mechanism was triggered by a messenger sent down the cable. Upon retrieval of the Niskin bottle, subsamples were poured into appropriate containers from the release tap.

During all water quality sampling, care was taken to avoid any contamination from the survey vessel. Therefore, all vessel outlets (deck scupper, bilge pump, water maker outlets etc.) were identified and avoided during the water sampling operations.

2.5.2 Sediment

A double Van Veen grab comprising twin buckets, each sampling a surface area of $0.1m^2$, was used. The grab was constructed of stainless steel. The double Van Veen was used in place of ordinary single-grab samplers to reduce the number of deployments necessary at each station.

To limit cross-contamination and maximise consistency, all physico-chemical and chemical sediment samples were taken by the same surveyor on each watch, who wore a pair of nitrile gloves (disposed of after each station). Samples were taken from sediment that had not been in direct contact with the surface of the grab, and the grab was scrubbed clean and rinsed with seawater between each deployment.

2.6 Sample processing

2.6.1 Water quality processing and analysis

Processing and analysis details of water samples collected are present in Table 2.3.

Table 2.3: Water quality sample processing and analysis details

Parameter	No./Volume	Container	Preservation	Lab
Total suspended solids	1000ml	PET	-	Environment Agency
Ammoniacal N	125ml	Polypropylene	-	
Metals Cd, Cu, Pb, Ni, Zn, Ba, Cr	125ml	Polypropylene		
Arsenic	125ml	Polypropylene		
Mercury	125ml	Glass	1ml of 2.5% K-dichromate in 50% HNO_3	
Phenol	250ml	Glass	1 molar H_2SO_4	
BTEX	250ml	PET	-	

All samples were transferred to cold boxes containing ice packs at the end of the survey and couriered under chain-of-custody procedures to the analytical laboratory.

2.6.2 Metals in water QA/QC

A certified reference material (CRM) containing known levels of metals, was provided to the Environment Agency (EA) along with other samples in order to determine their analytical accuracy.

The CRM used was SLEW-3 specification (estuarine waters), produced by the National Research Council of Canada (NRCC).

Results of the analysis of the CRM by the EA are presented in 3.2.3.

2.6.3 Sediment processing & analysis

Details of sediment samples collected are presented in Table 2.4.

Table 2.4: Sediment sample processing and analysis details

Parameter	No./Volume	Container	Preservation	Lab
Benthic macro-invertebrates	3x1 complete (separate) grab buckets	Double-labelled plastic bucket	4–10% buffered formaldehyde solution	Hebog Environmental
Particle size analysis (PSA)	~1kg	Double-labelled plastic	Frozen	Environment Agency

Parameter	No./Volume	Container	Preservation	Lab
Total organic carbon (TOC)		tub/Ziploc bag		
Organics: total organic extract (TOE)	~300ml	Double-labelled aluminium tins/glass jars	Frozen	M-Scan (subcontractor to Benthic Solutions)
Organics: polycyclic aromatic hydrocarbons (2-6 ring EPA16 PAH and NPD (naphthalenes, phenanthrenes, dibenzothiophenes + alkylated homologues)				
Metals: Al, Ag, As, Ba, Cd, Cr, Cu, Fe, Hg, Li, Mn, Ni, Pb, Se, V, Zn	~1kg	Double-labelled plastic tub/Ziploc bag	Frozen	Environment Agency

At the end of the survey, samples were transferred to cold boxes containing ice packs (with the exception of benthic samples). All samples were then transferred under chain-of-custody procedures to analytical laboratories.

2.6.4 Metals in sediment QA/QC

To assess the accuracy of one of the analytical laboratories in determining levels of metals, a CRM of marine sediment containing certified levels of metals, was provided to the Environment Agency (EA) along with other samples.

The CRM used was the MESS-3 specification (marine sediment), produced by the National Research Council of Canada (NRCC).

Results of the analysis of the CRM by the EA are presented in 3.4.2.

2.6.5 Sediment macrofaunal analysis

After sieving over a 0.5mm-mesh sieve, macrofaunal invertebrates were identified and enumerated. These data were then used to collate a number of ecological indices as follows:

- *Species richness* (S): the number of species present;
- *Abundance* (N): the number of individuals present;
- *Diversity* (Shannon-Wiener, H'): an integrated index of species richness and relative abundance;
- *Evenness* (Pielou's, J'): evenness of the distribution of individuals amongst different species in each sample; and
- *Dominance* (Simpsons, λ): dominance, essentially the reverse of evenness.

In addition, numerical data were then used in multivariate analyses to calculate a number of indices. These were:

- *Cluster analysis*: determination of inherent groupings within species and station data. In this study Bray-Curtis similarity was calculated using the PRIMER statistical package;

- *Multi-dimensional scaling* (MDS): using similar data to cluster analysis, this presents groupings on a 2-D map;

- *SIMPER*: this identifies those species most responsible for the defining similarities in each group; output is given as a percentage of similarity/dissimilarity and ranks those species that contribute most to this value; and

- *BIOENV*: performed within PRIMER, this incorporates physical or chemical data from each station (e.g. water depth, sediment size fraction) to determine the degree of correlation between this and the communities present.

3 Results

3.1 Planned and actual sample collection

All planned samples were successfully taken; planned and actual samples are presented in Table 3.1. At 10 of the 12 grab sites, a minimum of two deployments was used to collect samples, and at only two sites (S1 and S10) were more than two required; these were due to the grab not firing. All grab samples were within 1.0–8.5m (mean 4.3m) of the target location.

All water samples were collected successfully and without issue.

Table 3.1: Planned and actual sediment and water samples taken

Station	Sediment				Water		
	Macrofauna	PSA/TOC	Chem	Organics	Surface water	Near-bottom water	CTD profile
S1 and W1	3	1+1	1	1+1	1	1	1
S2 and W2	3	1+1	1	1+1	1	-	-
S4	3	1+1	1	1+1	-	-	-
W4	-	-	-	-	1	1	1
W6	-	-	-	-	1	-	-
S5	3	1+1	1	1+1	-	-	-
S5R	3	1+1	1	1+1	-	-	-
S6 and W11	3	1+1	1	1+1	1	-	-
S6R and W5	3	1+1	1	1+1	1	-	-
W7	-	-	-	-	1	1	1
S9 and W9	3	1+1	1	1+1	1	1	1
S10 and W8	3	1+1	1	1+1	1	-	-
W10	-	-	-	-	1	-	-
S11 and W3	3	1+1	1	1+1	1	-	-
W12	-	-	-	-	1	-	-
W13	-	-	-	-	1	1	1
W14	-	-	-	-	1	-	-
S15 and W15	3	1+1	1	1+1	1	-	-
W16	-	-	-	-	1	-	-
S17 and W17	3	1+1	1	1+1	1	-	-
Planned	**36 (12x3)**	**12 + 12**	**12**	**12**	**17**	**5**	**5**
Actual	**36 (12x3)**	**12 + 12**	**12**	**12**	**17**	**5**	**5**
Not collected	**0**	**0**	**0**	**0**	**0**	**0**	**0**

3.2 Water quality

3.2.1 CTD profiles

3.2.1.1 Salinity

Salinity-depth profiles for the stations sampled are presented in Figure 3.1.

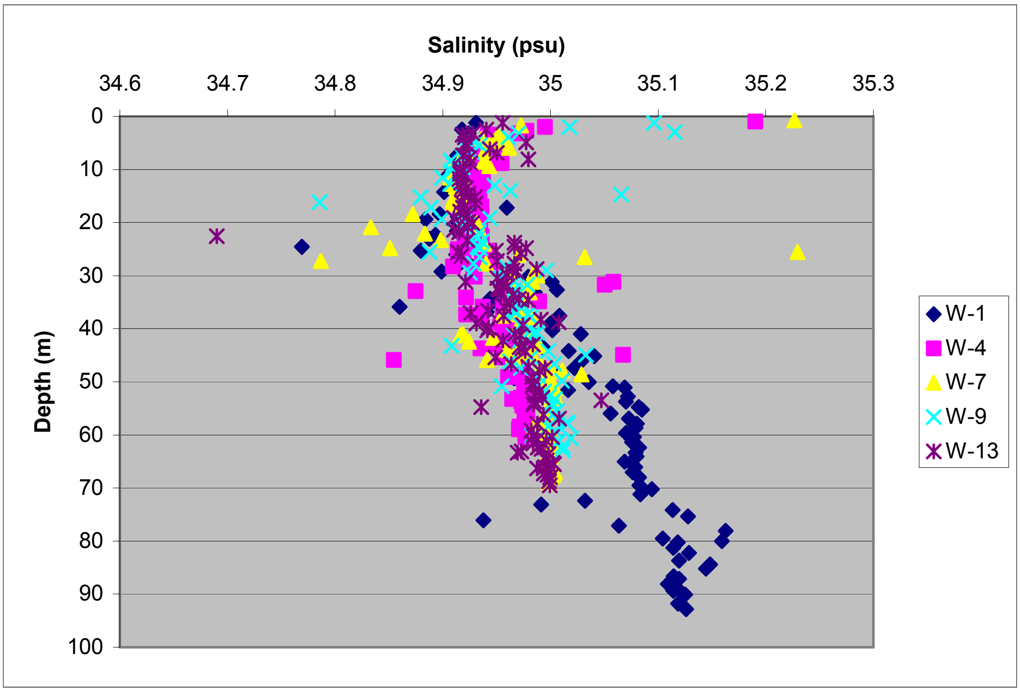

Figure 3.1: Salinity depth profiles

These data showed a gradual increase with salinity with depth, which was slightly more noticeable at reference station W1, the deepest station, located to the SW of the main survey area.

3.2.1.2 Temperature

A temperature-depth profile for the stations sampled is presented in Figure 3.2.

The overall range of temperatures recorded was approximately 3°C, ranging from *c*.11.34°C at 81m depth (W1) to *c*.14.23°C in surface waters at W9.

Recorded surface temperatures varied little, over a range of approximately 0.5°C from 13.81°C (W4) to 14.23°C. At depth, stations displayed a greater range of temperatures: at a comparable depth of 60m, five of the six stations were relatively similar (between 12.63 and 13.04°C), with station S1 marginally cooler than other stations, at 11.78°C.

All stations showed evidence of some degree of stratification throughout the water column. In general, there was a layer at the surface of a homogenous temperature (indicating mixing); this ranged in depth from *c*.13m at W9 to *c*.28m at W4. Below this, there was a gradual decrease in water temperature with water depth. A second layer of water of homogenous temperature was then recorded, commencing at around 50m depth. This continued to beyond 60m for shallower stations (W9, W4), and to 70m depth at the deeper stations

(W1, W7, W13). At the deepest station (W1), below this depth there was a further slight decrease in temperature (with the lowest recorded temperature, 11.34°C at around 85m depth). Temperatures beyond 85m were fairly homogenous and possibly slightly higher than those around 80–85m.

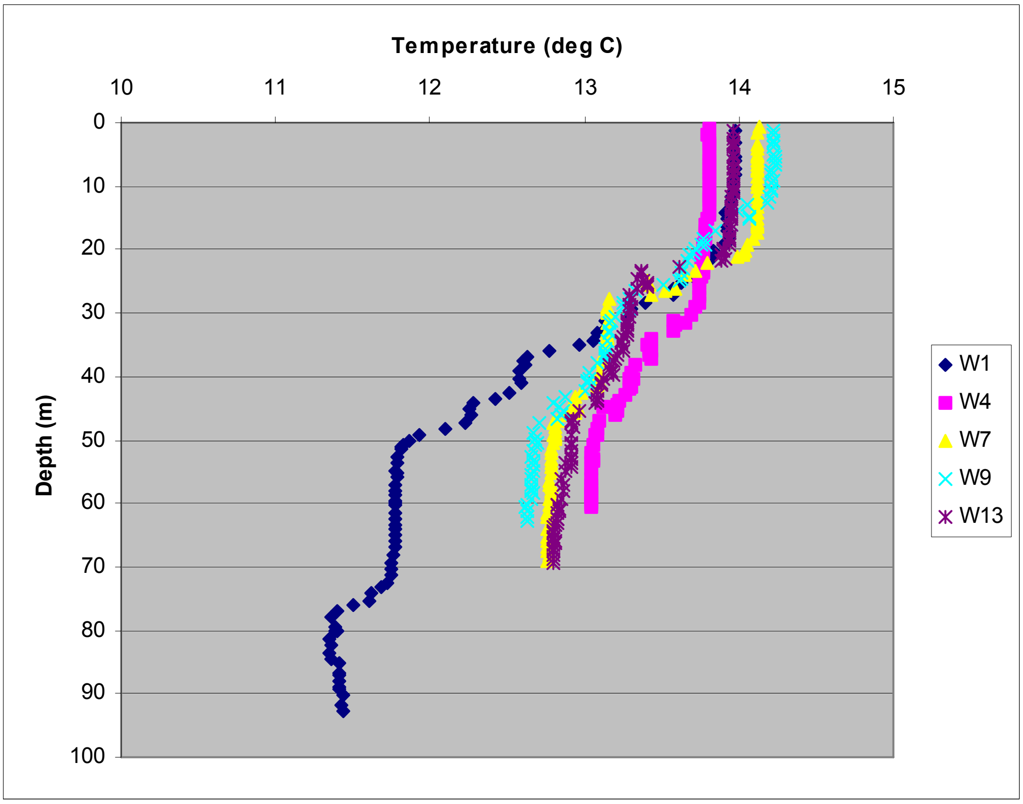

Figure 3.2: Temperature depth profile

3.2.2 Water samples

Results for suspended particulate matter (SPM) and ammoniacal nitrogen from discrete water samples are presented in Table 3.2.

Table 3.2: Suspended particulate matter (SPM) and ammoniacal nitrogen in seawater results

Station	Depth	Suspended particulate matter (SPM)	Ammoniacal nitrogen as N
		mg/l	
W1	Surface	<3.00	<0.01
	Bottom	<3.00	**0.022**
W2	Surface	<3.00	<0.01
W3	Surface	<3.00	<0.01
W4	Surface	<3.00	<0.01
	Bottom	<3.00	<0.01
W5	Surface	<3.00	<0.01
W6	Surface	<3.00	<0.01
W7	Surface	<3.00	<0.01
	Bottom	<3.00	<0.01
W8	Surface	<3.00	<0.01
W9	Surface	<3.00	<0.01

Station	Depth	Suspended particulate matter (SPM)	Ammoniacal nitrogen as N
		mg/l	
	Bottom	<3.00	<0.01
W10	Surface	<3.00	<0.01
W11	Surface	<3.00	<0.01
W12	Surface	<3.00	<0.01
W13	Surface	<3.00	<0.01
	Bottom	<3.00	<0.01
W14	Surface	<3.00	<0.01
W15	Surface	**4.00**	<0.01
W16	Surface	<3.00	<0.01
W17	Surface	<3.00	<0.01

3.2.2.1 Suspended particulate matter (SPM)

With the exception of a single station, all stations had SPM levels below that of the detection limit, i.e. <3.00mg/l. Station W15 recorded a value of 4mg/l, which is considered to be low.

3.2.2.2 Ammoniacal nitrogen

With the exception of a single sample (W1 bottom, 0.022mg/l), all stations had results below that of the detection limit, i.e. <0.01mg/l. The EQS for ammoniacal nitrogen is 0.021mg/l. Given that the other results were below the detection limit, it may be the case that the result from W1 is erroneous, though checks on the sampling and analytical procedure show no problems.

3.2.2.3 Metals

Results for metals in discrete seawater samples are presented in Table 3.3. Concentrations of barium, cadmium and chromium were all below their respective limits of detection.

Four of the readings for arsenic were below the detection limits and all samples had concentrations less than 1.45µg/l. No patterns in the distribution of concentrations of arsenic are evident.

Eight of the results for copper were below the limit of detection, and all samples contained less than 1.21µg/l. There is no apparent pattern in the distribution of copper concentrations, although the highest concentration was recorded at the most westerly sampling station.

Lead concentration range from 0.056 – 40.8µg/l. Four of the five samples taken from close to the seabed have concentrations >2µg/l, while only one of the other seventeen surface samples is above 0.14µg/l. There is no apparent reason for this difference between surface and seabed concentrations, sample dilution was investigated as a possible cause, but was eliminated. Notably, the highest concentration was again found in the most westerly sampling station.

Nickel concentrations were all below the limits of detection, except in those samples taken from site W1, which were marginally above the limit. The concentration at W1 close to the surface was greater than that close to the seabed. Site W1 is the most westerly station.

The range of zinc concentrations recorded was 1.39-29.5µg/l, with a tendency for lower concentrations to be found in samples taken close to the seabed rather than near the surface. Samples from the surface at stations W3 and W2 had the highest concentrations, these sites are located to the north west of Erris Head. The zinc concentration at site W4, located between W2 and W3 was close to the average for the other sites, indicating that there is unlikely to be a pattern in zinc concentrations.

Only four samples had mercury concentrations above the limit of detection. The maximum concentration, 0.019µg/l is less than twice the limit of detection, indicating that all concentrations are low. All positive readings were collected from surface samples, but no geographic pattern in the distribution of concentrations is evident.

Table 3.3: Metals in seawater results

Station		As	Cd	Cu	Pb	Ni	Zn	Ba	Hg	Cr
		µg/l								
W1	Surface	1.02	<0.0400	<0.200	0.082	0.350	11.0	<100	<0.010	<0.500
	Bottom	<1.00	<0.0400	1.21	40.8	0.320	8.72	<100	<0.010	<0.500
W2	Surface	1.31	<0.0400	0.200	0.138	<0.300	21.6	<100	<0.010	<0.500
W3	Surface	<1.00	<0.0400	0.670	0.251	<0.300	29.5	<100	<0.010	<0.500
W4	Surface	<1.00	<0.0400	0.300	0.067	<0.300	4.97	<100	<0.010	<0.500
	Bottom	1.27	<0.0400	<0.200	8.80	<0.300	1.39	<100	<0.010	<0.500
W5	Surface	1.06	<0.0400	0.400	0.088	0.300	7.32	<100	<0.010	<0.500
W6	Surface	1.00	<0.0400	<0.200	0.065	<0.300	3.26	<100	<0.010	<0.500
W7	Surface	<1.00	<0.0400	0.480	2.67	<0.300	1.63	<100	<0.010	<0.500
	Bottom	1.09	<0.0400	0.340	0.082	<0.300	4.00	<100	<0.010	<0.500
W8	Surface	1.25	<0.0400	<0.200	0.085	<0.300	5.44	<100	0.011	<0.500
W9	Surface	1.14	<0.0400	<0.200	0.056	<0.300	3.02	<100	0.016	<0.500
	Bottom	1.45	<0.0400	0.420	2.18	<0.300	2.15	<100	<0.010	<0.500
W10	Surface	1.20	<0.0400	<0.200	0.068	<0.300	4.81	<100	<0.010	<0.500
W11	Surface	1.26	<0.0400	0.210	0.063	<0.300	3.38	<100	0.019	<0.500
W12	Surface	1.24	<0.0400	<0.200	0.107	<0.300	4.27	<100	<0.010	<0.500
W13	Surface	1.15	<0.0400	0.240	0.087	<0.300	5.56	<100	<0.010	<0.500
	Bottom	1.36	<0.0400	<0.200	5.32	<0.300	2.16	<100	<0.010	<0.500
W14	Surface	1.02	<0.0400	0.210	0.065	<0.300	4.45	<100	<0.010	<0.500
W15	Surface	1.10	<0.0400	0.330	0.081	<0.300	3.11	<100	<0.010	<0.500
W16	Surface	1.08	<0.0400	0.560	0.077	<0.300	3.32	<100	<0.010	<0.500
W17	Surface	1.09	<0.0400	0.320	0.095	<0.300	5.64	<100	0.014	<0.500

Orange: highest result; green: lowest result

3.2.3 Metals in water QA/QC

Results from the EA analytical laboratory as compared to the pre-determined levels in the SLEW-3 CRM are presented in Table 3.4. All differences between certified and EA laboratory results are less than 12.5%, with the exception of zinc, where EA results were much higher than the certified value.

Discussions with the EA laboratory have revealed that all of the quality checks were passed during the analytical run for the zinc samples, including measurements of the internal laboratory standard. The zinc reading was close to the minimum reporting value (detection limit), around which any "uncertainty of measure" is at it's maximum. This uncertainty decreases as the concentrations of a metal move more into the centre of the analytical working range (between the minimum and maximum reporting values). The readings from the field samples were all much higher than the CRM, and therefore subject to less uncertainty than the CRM result. All results for zinc were lower than the EQS for marine waters.

Table 3.4: Comparison of analytical results for metals in seawater from EA laboratory against Certified Reference Material (CRM) values

Metal	EA result	CRM value	%difference
Ag	<1.00	0.003	N/A
As	1.52	1.36	11.76
Cd	0.054	0.048	12.50
Cr	<0.5	0.183	N/A
Cu	1.36	1.55	-12.26
Ni	1.18	1.23	-4.07
Pb	<0.04	0.009	N/A
Zn	0.86	0.201	327.86

3.2.4 Organics

Results for organic compounds in seawater are presented in Table 3.5. The majority of results are reported as less than the minimum reporting value. Of the 46 compounds tested for, only four were detected (phenol; 1,2-di-methylbenzene {o-Xylene}; di-Mebenzene 13+14; and ethylbenzene), although these were only present in low concentrations.

Table 3.5: Organic compounds in seawater (S=Surface, B=near-bottom)

Compound	Station												
	W1 S	W1 B	W2 S	W3 S	W4 S	W4 B	W5 S	W6 S	W7 S	W7 B	W8 S	W9 S	W9 B
Acenaphthene	<0.0100	<0.0120	0.0150	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Acenaphthylene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Anthracene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
B(a)anthracene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
B(a)pyrene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
B(b)fluoranthene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
B(ghi)perylene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
B(k)fluoranthene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Chrysene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
DiB(ah)anthracene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Fluoranthene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Fluorene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Indeno123cdPyrene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Naphthalene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Phenanthrene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
Pyrene	<0.0100	<0.0120	<0.0120	<0.0110	<0.0120	<0.0110	<0.0120	<0.0120	<0.0110	<0.0110	<0.0110	<0.0110	<0.0110
2,3,5,6-Tetrachlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,3-Dichlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,3-Dimethylphenol {2,3-Xylenol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,4,5-Trichlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,4,6-Trichlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,4-Dichlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,4-Dimethylphenol {2,4-Xylenol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,5-Dichlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100

Compound	Station												
	W1 S	W1 B	W2 S	W3 S	W4 S	W4 B	W5 S	W6 S	W7 S	W7 B	W8 S	W9 S	W9 B
2,5-Dimethylphenol {2,5-Xylenol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,6-Dichlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2,6-Dimethylphenol {2,6-Xylenol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2-Chlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2-Ethylphenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
2-Methylphenol {o-Cresol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
3,4-Dimethylphenol {3,4-Xylenol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
3,5-Dimethylphenol {3,5-Xylenol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
3-Chlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
3-Methylphenol {m-Cresol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
4-Chloro-2-methylphenol {p-Chloro-o-cresol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
4-Chloro-3,5-dimethylphenol {PCMX}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
4-Chloro-3-methylphenol {p-Chloro-m-cresol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
4-Chlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
4-Methylphenol {p-cresol}	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Pentachlorophenol	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Phenol	<0.200	<0.200	**0.207**	<0.200	<0.200	**0.222**	<0.200	<0.200	**0.220**	**0.340**	**0.293**	<0.200	<0.200
1,2-Dimethylbenzene {o-Xylene}	<0.100	**0.103**	<0.100	<0.100	<0.100	**0.127**	**0.103**	**0.142**	**0.119**	<0.100	<0.100	<0.100	**0.104**
Benzene	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Di-Mebenzene 13+14	<0.200	**0.282**	**0.213**	<0.200	<0.200	**0.578**	**0.569**	**0.645**	**0.601**	**0.411**	**0.454**	**0.405**	**0.569**
Ethylbenzene	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Toluene {Methylbenzene}	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00

Orange=highest value

Compound	W10 S	W11 S	W12 S	W13 S	W13 B	W14 S	W15 S	W16 S	W17 S
Acenaphthene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Acenaphthylene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Anthracene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
B(a)anthracene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
B(a)pyrene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
B(b)fluoranthene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
B(ghi)perylene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
B(k)fluoranthene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Chrysene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
DiB(ah)anthracene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Fluoranthene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Fluorene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Indeno123cdPyrene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Naphthalene	0.0150	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Phenanthrene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
Pyrene	<0.0100	<0.0130	<0.0120	<0.0110	<0.0110	<0.0120	<0.0110	<0.0110	<0.0110
2,3,5,6-Tetrachlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,3-Dichlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,3-Dimethylphenol {2,3-Xylenol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,4,5-Trichlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,4,6-Trichlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,4-Dichlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,4-Dimethylphenol {2,4-Xylenol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,5-Dichlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,5-Dimethylphenol {2,5-Xylenol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,6-Dichlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2,6-Dimethylphenol {2,6-Xylenol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200

Compound	W10 S	W11 S	W12 S	W13 S	W13 B	W14 S	W15 S	W16 S	W17 S
2-Chlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2-Ethylphenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
2-Methylphenol {o-Cresol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
3,4-Dimethylphenol {3,4-Xylenol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
3,5-Dimethylphenol {3,5-Xylenol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
3-Chlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
3-Methylphenol {m-Cresol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
4-Chloro-2-methylphenol {p-Chloro-o-cresol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
4-Chloro-3,5-dimethylphenol {PCMX}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
4-Chloro-3-methylphenol {p-Chloro-m-cresol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
4-Chlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
4-Methylphenol {p-cresol}	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
Pentachlorophenol	<0.100	<0.100	<0.100	<0.200	<0.100	<0.100	<0.0200	<0.0200	<0.0200
Phenol	<0.200	<0.200	<0.200	<0.400	**0.544**	<0.200	**0.102**	**0.069**	**0.239**
1,2-Dimethylbenzene {o-Xylene}	<0.500	<0.100	<0.100	<0.100	**0.144**	<0.100	<0.100	<0.100	<0.100
Benzene	<0.500	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Di-Mebenzene 13+14	<0.500	**0.427**	**0.365**	**0.401**	**0.588**	**0.426**	**0.389**	**0.343**	**0.343**
Ethylbenzene	<0.500	**0.365**	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Toluene {Methylbenzene}	<10.0	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00

Orange=highest value

3.3 Sediment physico-chemistry

Summary results for particle size analysis (PSA) and total organic carbon (TOC) are presented in Table 3.6. Full PSA results are presented in Appendix 1.

Table 3.6: Sediment particle size and total organic carbon results

Station	%			Grain size (mm)		Sediment description (Udden Wentworth)	Total organic carbon (%)
	Gravel	Sand	Mud	Median	Mean		
S1	15.0	85.0	0.0	0.957	1.007	Coarse sand	1.63
S2	6.5	93.0	0.5	1.069	1.089	Very coarse sand	0.96
S4	2.4	97.6	0.0	0.440	0.361	Medium sand	3.03
S5	33.0	66.3	0.6	1.075	1.495	Very coarse sand	0.6
S5R	2.3	97.7	0.0	0.882	0.777	Coarse sand	2.56
S6	0.9	99.1	0.0	0.578	0.520	Coarse sand	2.9
S6R	23.3	76.8	0.0	1.486	1.381	Very coarse sand	1.52
S9	0.0	100.0	0.0	0.419	0.367	Medium sand	2.79
S10	0.0	96.4	3.6	0.223	0.196	Fine sand	0.45
S11	0.7	99.3	0.0	0.404	0.352	Medium sand	0.52
S15	0.3	99.7	0.0	0.548	0.485	Coarse sand	0.47
S17	0.3	99.7	0.0	0.415	0.364	Medium sand	0.45

Sand is the dominant sediment type, ranging from very coarse (S2, S5, S6R) to fine (S10), with medium and coarse sand both being the most frequently occurring classification. In most samples, the gravel fraction was not important, although it comprised a significant component at stations S5 (33%), S6R (23%) and to a lesser extent at S1 and S2. Fine sediment fractions (<63µm) were absent at all but three stations, with a maximum of 3.6% at S10.

TOC ranged from 0.45–3.03%. There was no clear pattern in the distribution of TOC levels, with for example stations with relatively high levels (S4, S6) adjacent to stations with lower levels (S11 and S5, respectively). There appeared to be no clear correlation between levels of TOC and grain size.

Together, the particle size and TOC data are consistent with a high-energy marine environment with no significant terrestrial (i.e. estuarine) inputs.

3.4 Sediment chemistry

3.4.1 Metals

Results are presented in Table 3.7, which indicate that no single station completely dominated in terms of relatively high, or low, levels of metals. Although there was considerable inter-station variability in levels of some metals (e.g. by more than an order of magnitude for arsenic), others varied within a relatively small range (e.g. copper). Samples and replicates from sites S5 and S6 show the local heterogeneity of the sediment metal concentrations too.

Aluminium concentrations ranged from 2850mg/kg to 33800mg/kg, indicating a wide range in sediment grain sizes across the survey sites. Aluminium is often used as a surrogate for grain size, with high concentrations indicating low grain sizes. Finer grained sediments have higher numbers of binding sites to which metal ions can attached, hence it is normal that finer grained sediments have higher concentrations of many metals than coarser sediments which have been exposed to the same metal inputs. Site S1, with an Al concentration of 33800mg/kg, also has highest concentrations of arsenic, iron, lithium, manganese, nickel and vanadium.

Sites S10 and S15, which had 3rd and 5th highest concentrations of aluminium respectively, between them had the highest concentrations of cadmium, chromium, copper, lead and zinc.

Conversely, highest concentrations of barium, mercury and selenium were recorded from site S5, from which the lowest concentration of aluminium was recorded. S5 also had the lowest level of organic carbon (0.6%), which also indicates that the number of potential binding sites for metals was low.

No highly elevated outliers, indicative of localised anthropogenic contamination, were recorded.

Comparison of the concentrations recorded against previous data from the outfall area, and international standards can be found in section 4.3.1.

Table 3.7: Sediment metals results

Station	Al	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Li	Mn	Ni	Pb	Se	V	Zn
	mg/kg															
S1	33800	<10.0	17.1	12.7	0.058	8.69	2.91	9650	0.0032	7.95	354	6.96	12.4	<0.1	21.7	18.0
S2	8950	<10.0	1.76	16.6	0.061	4.82	1.96	3170	<0.001	4.57	158	2.21	3.47	<0.1	8.25	10.9
S4	14700	<10.0	3.50	8.6	0.031	6.02	1.88	3790	0.001	5.08	101	1.16	4.92	<0.1	7.44	11.2
S5	2850	<10.0	6.15	19.9	0.105	7.84	1.52	3340	0.0034	4.99	286	2.95	7.38	0.134	12.1	8.9
S5R	15900	<10.0	1.97	14.8	0.056	8.17	4.11	3260	0.0019	5.54	134	0.78	9.44	<0.1	7.78	16.8
S6	12400	<10.0	9.58	12.8	0.050	11.3	2.01	5550	0.0021	4.96	255	2.17	6.15	<0.1	16.5	10.7
S6R	14200	<10.0	0.43	15.7	0.045	3.84	2.61	3560	0.0018	4.02	128	0.93	6.65	0.115	7.77	11.6
S9	22400	<10.0	1.78	10.7	0.053	10.4	3.32	5090	0.0014	4.94	107	1.50	12.2	<0.1	9.06	16.2
S10	22700	<10.0	3.17	7.1	0.050	31.7	3.46	8270	0.0024	7.89	159	4.75	19.3	<0.1	13.7	19.0
S11	18000	<10.0	2.62	6.7	0.077	24.8	3.12	9470	0.0020	6.66	120	2.00	6.64	<0.1	14.7	14.3
S15	20700	<10.0	0.45	12.6	0.128	12.3	4.36	5960	<0.001	4.65	104	0.96	19.5	<0.1	10.5	18.1
S17	23600	<10.0	0.74	11.7	0.052	7.78	3.34	3830	0.0014	5.17	85	1.08	7.53	<0.1	7.37	17.9

Green: lowest result; Orange: highest result

3.4.2 Metals in sediment QA/QC

Table 3.8 presents the certified concentration data for the MESS-3 marine sediment CRM from the NRCC, together with the results of the analysis performed on the sample by the EA's National Laboratory Service.

The similarity between the certified and measured results shows confidence in the EA analysis of sediment samples at the Corrib alternative outfall sites. The sample analyses that do stand out, however, are the differences recorded for cadmium and vanadium.

The degree of error that is observed between the certified result and the EA laboratory result for cadmium is believed to be due to interference from tin oxide in the reference material. The EA has recently carried out an investigation into this issue and has determined that it appears to affect only the CRM, and can be overcome by analysing for the 114 isotope of cadmium only. Their investigations (using various spikes etc, also show that field samples tend to be unaffected by the tin oxide effects). Hence, it is not appropriate to use the CRM for quality checking the cadmium concentrations.

The degree of error observed in the results for vanadium are because the EA laboratory prepares its sediment samples for analysis using an aqua regia digestion, rather than a hydrofluoric acid digestion. Aqua regia is a significantly less vigorous digestion technique that achieves lower recoveries than hydrofluoric acid digestion, which is what the reference values for the CRM are based. The EA have stated that the reason they use aqua-regia is that it releases only the vanadium which is biologically available, rather than all of the metal in the sediment. Hence the results from the field samples reflect the biologically available vanadium.

Table 3.8: Analyses of marine sediment CRM

	Analysis of Marine Sediment CRM (MESS-3) (mg/kg)		
Determinand	**2008 EA results**	**NRCC Reference value**	**Difference (%)**
Ag	<10.0	0.18	N/A
Al	97,100	85,900	13.04%
As	22.1	21.2	4.25%
Cd	0.322	0.24	34.17%
Cr	98.3	105	-6.38%
Cu	37.5	33.9	10.62%
Fe	41,800	43,400	-3.69%
Hg	0.1004	0.091	10.29
Li	75.3	73.6	2.31%
Mn	325	324	0.31%
Ni	41.2	46.9	-12.15%
Pb	23.3	21.1	10.43%
Se	0.607	0.72	-15.69%
Vn	103	243	-57.61%
Zn	157	159	-1.26%

3.4.3 Hydrocarbons

3.4.3.1 Total organic extracts (TOE)/saturates

Results from analysis of TOE/saturates are presented in Table 3.9. They show that station S10 had a TOE concentration approximately three times greater than the next highest site. While the concentration at S10 is elevated above the other sites, it is generally within the background of concentrations recorded in and around the Corrib Field. Interestingly, S10 also had highest concentrations of TOE in the 2007 survey.

Ecomul, Ecosol and Esterkleen are components of drilling muds historically used in the Corrib field itself.

Table 3.9: Sediment TOE results

Station	TOE	Ecomul	Ecosol	Esterkleen
	µg/g; ppm			
S1	1.6	<0.1	<0.1	<0.01
S2	4.6	<0.1	<0.1	<0.01
S4	4.1	<0.1	<0.1	<0.01
S5	4.4	<0.1	<0.1	<0.01
S5R	1.3	<0.1	<0.1	<0.01
S6	1.4	<0.1	<0.1	<0.01
S6R	2.3	<0.1	<0.1	<0.01
S9	1.6	<0.1	<0.1	<0.01
S10	14	<0.1	<0.1	<0.01
S11	2.2	<0.1	<0.1	<0.01
S15	0.93	<0.1	<0.1	<0.01
S17	1.1	<0.1	<0.1	<0.01

Green: lowest result; Orange: highest result

3.4.3.2 Polycyclic aromatic hydrocarbons (PAHs)

Results are presented in Table 3.10. The majority of PAHs tested for were either not detected at all (i.e. dibenzothiophenes) or only detected at a few stations and in low concentrations. Naphthalenes were the only group that were detected at every station.

Table 3.10: PAHs in sediment results

Parameter	Station											
	S1	**S2**	**S4**	**S5**	**S5R**	**S6**	**S6R**	**S9**	**S10**	**S11**	**S15**	**S17**
	µg/kg (ppb); dry weight basis											
Naphthalene	0.12	0.11	0.08	0.17	0.34	0.19	0.31	0.29	0.27	0.22	0.12	0.49
C1-Naphthalenes	0.16	0.05	0.01	0.29	0.13	0.04	0.22	0.22	0.2	0.14	0.08	0.23
C2- Naphthalenes	0.22	0.21	0.28	0.24	0.06	0.25	0.51	0.19	2.7	0.23	0.12	0.24
C3- Naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C4- Naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Naphthalenes	0.5	0.37	0.37	0.7	0.53	0.48	1.00	0.7	3.2	0.59	0.32	0.96
Phenanthrene	0.01	<0.01	0.02	0.04	<0.01	0.02	<0.01	<0.01	0.01	<0.01	0.02	<0.01
C1-Phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2- Phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3- Phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Phenanthrenes	0.01	<0.01	0.02	0.04	<0.01	0.02	<0.01	<0.01	0.01	<0.01	0.02	<0.01
Dibenzothiophene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-Dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-Dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Parameter	Station											
	S1	S2	S4	S5	S5R	S6	S6R	S9	S10	S11	S15	S17
C3-Dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total DBT	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total NPD	0.51	0.37	0.39	0.74	0.53	0.5	1.00	0.7	3.3	0.59	0.34	0.96
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	0.01	<0.01	<0.01	0.06	<0.01	<0.01	0.01	<0.01	0.05	<0.01	<0.01	<0.01
Pyrene	0.08	<0.01	0.02	0.06	<0.01	<0.01	0.01	<0.01	0.04	0.01	0.02	<0.01
C_1-Fluoranthenes/Pyrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C_2-Fluoranthenes/Pyrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C_3-Fluoranthenes/Pyrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C_1-Benanthracenes/Chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C_2-Benanthracenes/Chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(b)fluoranthene	0.02	<0.01	<0.01	0.1	<0.01	<0.01	<0.01	<0.01	0.18	<0.01	<0.01	<0.01
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C_1-Benzofluoranthenes/Benzpyrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C_2-Benzofluoranthenes/Benzpyrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Indeno(1,2,3-cd)pyrene	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	0.13	<0.01	<0.01	<0.01
Dibenzo(a,h)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(ghi)perylene	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	0.13	<0.01	<0.01	<0.01
Total EPA 16	0.24	0.11	0.12	0.52	0.34	0.21	0.33	0.29	0.81	0.23	0.16	0.49

Orange=highest result

3.5 Sediment macrofauna

This section contains summary information on the analysis of benthic macrofauna samples. Full details are available in Appendix 2.

3.5.1 Diversity indices

Summary results for a range of univariate parameters, and percentage contribution of each phyla per station (replicates pooled), are presented in Table 3.11. Note that these data do not include encrusting species.

Table 3.11: Summary per-station sediment macrofauna results: univariate indices and taxonomic composition

Station	Species richness	Abundance	Evenness (Pielou's)	Diversity (Shannon-Wiener)	Dominance (Simpson's)	% abundance				
	S	N (m^{-2})	J'	H'	λ	Annelids	Crust.	Molluscs	Echino.	Other
S1	119	5,070	0.74	3.51	0.06	64.23	7.43	4.47	3.68	20.18
S2	104	10,540	0.58	2.70	0.14	89.06	3.86	3.07	0.92	3.10
S4	90	1,720	0.75	3.39	0.08	62.33	22.14	2.52	9.51	3.50
S5	135	11,590	0.59	2.88	0.14	51.38	3.62	7.02	7.16	30.81
S5R	83	9,580	0.55	2.42	0.18	73.84	2.50	3.44	2.16	18.05

Station	Species richness	Abundance	Evenness (Pielou's)	Diversity (Shannon-Wiener)	Dominance (Simpson's)	% abundance				
	S	N (m^{-2})	J'	H'	λ	Annelids	Crust.	Molluscs	Echino.	Other
S6	115	6,150	0.72	3.40	0.06	67.46	6.89	7.16	4.93	13.56
S6R	141	13,390	0.57	2.78	0.16	52.69	4.68	5.38	1.87	35.38
S9	74	1,460	0.83	3.55	0.04	28.47	28.47	26.42	11.85	4.78
S10	120	6,760	0.71	3.38	0.09	63.53	7.34	14.93	3.84	10.35
S11	79	1,170	0.83	3.64	0.04	54.42	16.24	11.68	12.54	5.13
S15	60	3,510	0.61	2.50	0.18	48.62	4.75	5.70	2.66	38.27
S17	59	1,050	0.87	3.55	0.03	39.05	33.33	10.16	16.19	1.27

Green: lowest result; Orange: highest result. Crust=crustaceans; echino=echinoderms
S: Species richness; **N**: abundance; J': evenness; H': Diversity

Species richness (S) was high for all sites, ranging from 59 species (station S17) to 141 per station (S6R).

Total abundance (N) was moderate throughout the dataset, but over 10,000 individuals per m^2 were found at S2, S5 and S6R.

Diversity (H') was high throughout the sampling area, ranging from 2.42 (S5R) to 3.64 (S11). Stations that had relatively lower diversity were generally those with a comparatively low evenness (J') and slightly higher dominance (λ) score, indicating a few dominant species present in the community. For example, S5R, where diversity was 2.42 and the lowest evenness of 0.55 was observed, the polychaete *Spio filicornis* numerically dominated the community.

3.5.2 Taxonomic composition

Throughout the sampling area, communities were found to be typical of subtidal sands, ranging from species characteristic of stable, fine sand to those species found in more exposed coarse sand with gravel.

At a broad taxonomic level, annelid polychaetes were the most dominant phyla at all sites with the maximum abundance recorded at S2 (89%). Crustaceans, molluscs and echinoderms made up small proportions of the fauna observed at most sites, on average comprising less than 25% of the community. However, at S4, S9 and S17 crustaceans made up more than 20% of the community. Additionally, molluscs were found to be abundant at S9 where they also made up more than 20% of the community. Tellinid bivalves such as *Moerella pygmaea* and *Abra pristmatica* were common throughout the sampling sites. Nematode worms were important at S5, S6R and S15 where they represented 30% or more of the community found there.

3.5.3 Community clustering

3.5.3.1 Within stations

Variability was low within stations, with a similarity of around 45% or more, indicating that each replicate at a station sampled a relatively similar community. Further details of this are presented in Appendix 3.

3.5.3.2 Between stations

Results of the group-average clustering analysis using Bray Curtis similarity (per station) are presented in Figure 3.3.

The fauna was dominated by two main communities, which were themselves split into two sub-groups. The first main group (clusters 1 and 2) was characterised by species typical of coarser sand and gravelly sediments. The second main group (clusters 3 and 4) was more typical of sandy sediments.

- **Cluster 1**: (S15): species typical of communities in a medium to coarse sand and gravelly sand. Nematode worms dominated, with contributions from syllid polychaetes such as *Streptosyllis bidentata* and *Opistodonta pterochaeta*.
- **Cluster 2:** (S1, S2, S5, S5R, S6 and S6R) a similar community composition to cluster 1; nematodes and the polychaetes *Pisione remota, Polygordius*, *Hesionura elongata* and *Glycera lapidum* were found to contribute highly to the similarity between these stations.
- **Cluster 3**: (S10) dominated by the spionid polychaetes *Spiophanes bombyx* and *Spio decorata*, and tellinid bivalves.
- **Cluster 4**: (S4, S9, S11 and S17) characterised by lower faunal abundance but higher diversity. Species that significantly contributed to community similarity were those associated with medium to fine sand sediments such as the amphipod *Bathyporeia elegans*, echinoids and spionid polychaetes such as *Aonides pauchibranchiata* and *Spiophanes bombyx.*

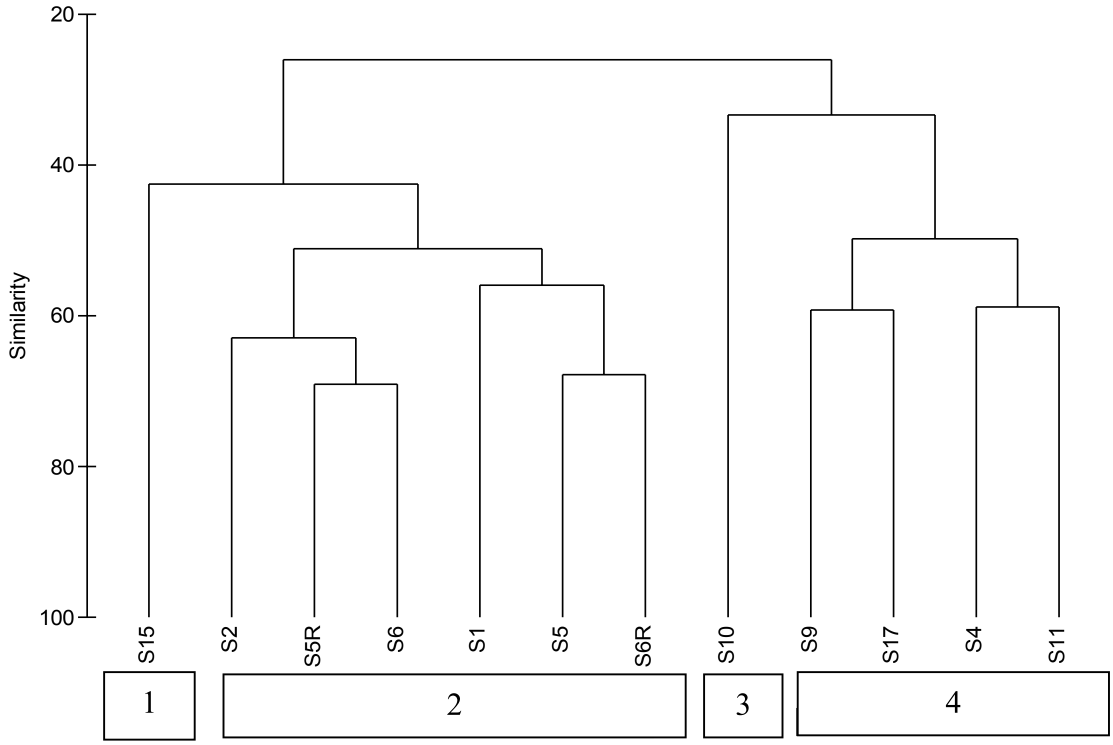

Figure 3.3: Dendrogram representation of clustering of benthic macrofauna communities (per station, replicates pooled)

Clusters were separated very discretely, with, for example, a similarity of less than 30% between clusters 2 and 3. Characterising species for each cluster were rare or absent in other clusters.

3.5.4 Environmental factors

Details of BIO-ENV analysis are presented in Appendix 3. In summary, BIO-ENV analysis showed that:

- No particular measured environmental variable was responsible for the observed variation between sites, although some strong correlations were found.
- Sediment grain size was found to be an important environmental variable for all the observed communities.
- Water depth was also important in explaining community variability. However, this relationship was not clearly defined.

Bubble plots showing the levels or concentrations of various environmental variables at each site, overlaying the MDS plots, are also included in Appendix 3.

4 Discussion

4.1 Water quality

4.1.1 CTD profiles

4.1.1.1 Salinity

The small level of variation in recorded salinity, and the minor increase in salinity with depth in the water column, is consistent with a fully marine environment, with little freshwater influence. Slightly reduced salinity levels at the surface are likely to be due to the natural buoyancy of freshwater, such as that from the small input of local rivers (e.g. the Sruwaddacon) or recent rain.

4.1.1.2 Temperature

Minor variation in temperature profiles across the survey area is likely to be due to the presence of different water masses moving through the area, and the influence of different tidal currents and water depths. Temperature differences may have also been influenced by sampling at different times of the day, and in different weather and tidal conditions.

Temperature profiles were sampled over similar dates (late July/early August) in 2007 and 2008 data, allowing comparison. In 2007, the highest temperature recorded (15.82°C at W1 surface) was around 1.5°C greater than the highest value recorded in 2008 (14.23°C, W9, surface), although such variations are to be expected as a result of diurnal temperature fluctuations (i.e. time of day of sampling) and the effect of other factors such as wind, tidal state and rainfall. Data for both 2007 and 2008 show stratification at around 50m water depth, most notably at station W1 (the deepest station), and both are typical for summer in temperate waters. The lowest temperature recorded in 2008 (11.34°C) was around 0.7°C lower than the lowest recorded in 2007 (12.13°C), both of which were near the seabed in around 90m at W1. This natural variation is likely to be a result of the movement of water masses and/or tidal streams.

4.1.2 Water samples

4.1.2.1 Suspended particulate matter

The non-detectable and low levels of SPM at all stations are indicative of the high clarity of the relatively deep coastal Atlantic waters sampled, with little local freshwater (and/or fine sediment) input.

4.1.2.2 Ammoniacal nitrogen

This parameter was non-detectable (i.e. <0.01mg/l) at all but one of the sampling points. The single detectable value from near-bottom water at station W2 (0.022mg/l) marginally exceeds the environmental quality standard (0.021mg/l); given the non-detectable levels throughout the survey area (indicating no anthropogenic influence, from, for example, fertiliser run-off), this is somewhat anomalous, and not a cause for concern.

4.1.2.3 *Metals*

Results from the 2007 and 2008 surveys were similar with no major discrepancies for any of the metals observed. A comparison of the results shows that the maximum levels recorded were lower in 2008 for arsenic, copper and nickel, while there were increases in the maxima for mercury, lead and zinc

Although the reported values are above the very low levels reported for oceanic waters by a number of academic and governmental organisations, in no instance were any concentrations observed that would give rise to concern, all being significantly less than the respective EQSs (with the exception of lead – discussed below). At many sites, however, the results for copper, and to a lesser extent for zinc, and lead exceed the provisional OSPAR Ecotoxicological Assessment Criteria. Assessments made using current EACs, however, should be treated with extreme caution (UKNMMP, 2004). (It should be noted that OSPAR is reviewing these guidelines, which have been renamed 'environmental assessment criteria'.)

Lead exceeded it's EQS at a single station. With measurement at such low detection limits, and even with stringent precautions, inadvertent contamination of samples may have occurred. This is the most likely explanation of anomalous results, such as that for lead from W12 (bottom), i.e. 40.8µg/l.

Table 4.1: 2008 Comparison of observed metals in water data with international standards

Metal	Outfall station ranges	EQS	BRC	EAC
	µg/l			
As	<1.00–1.45	25	No data	1–10
Cd	<0.0400	2.5	0.004–0.025	0.01–0.10
Cr	<0.500	15	0.09–0.12	1.0–10
Cu	<0.200–1.21	5	0.05–0.36	0.005–0.05
Hg	<0.010–0.019	0.3	0.0001–0.0005	0.005–0.05
Ni	<0.30–0.35	30	0.16–0.26	0.1–1.0
Pb	0.056–40.8	25	0.005–0.02	0.5–5.0
Zn	1.39–29.5	40	0.03–0.45	0.5–5.0

(EQS: EU Environmental Quality Standard for Dangerous Substances; BRC: OSPAR Background Reference Concentrations; EAC: OSPAR Ecotoxicological Assessment Criteria)

4.1.2.4 *Organics*

Whilst some persistent organic compounds were detected, these give no cause for concern at such low concentrations.

4.2 Sediment physico-chemistry

Comparison of results from 2008 with 2007 data shows that several stations retained the same classification (S2, S4, S5, S5R, S17), while others became slightly finer (S1: very coarse to coarse sand; S10: medium to fine sand; S11: coarse to medium sand) or slightly more coarse (S6: medium to coarse sand; S9: fine to medium sand; S15: medium to coarse sand). One station, S6R, increased from medium to very coarse sand. As no construction activities had taken place between the 2007 and 2008 surveys, these slight variations reflect natural variability over time, patchiness of sediment and slight differences in the area sampled by the grab.

4.3 Sediment chemistry

4.3.1 Metals

Metals in sediment results for both 2007 and 2008 were very similar and low, as would be expected in an area with minimal anthropogenic activity.

To determine the degree of any anthropogenic contamination in marine sediments, it is useful to compare observed metal concentrations in sediment with the following values:

- OSPAR (Northeast Atlantic)
  - Background Reference (**BC**)
  - Ecotoxicological Assessment Criteria (**EAC**), with lower and upper limits.
- Environment Canada
  - Threshold effects level (**TEL**): the concentration above which metals may start to be harmful to organisms; and
  - Predicted effects level (**PEL**): the concentration above which metals are likely to become harmful to organisms.

Metal concentrations from the 2008 survey in comparison to these values are presented in Table 4.2.

Table 4.2: Comparison of observed sediment metals data to international standards

Metal	2008 Outfall station range	OSPAR			Upper limit exceeded?	Environment Canada		PEL exceeded?
		BC	EAC limits: Lower	EAC limits: Upper		TEL	PEL	
	mg/kg dry weight							
As	0.43–17.1	15	1	10	Yes	7.24	41.6	No
Cd	0.031–0.128	0.2	0.1	1	No	0.676	4.21	No
Cr	3.84–31.7	60	5	50	No	52.3	160	No
Cu	1.52–4.36	20	5	50	No	18.7	108	No
Hg	<0.001–0.0034	0.05	0.05	0.5	No	0.13	0.7	No
Ni	0.78–6.96	30	5	50	No	15.9	42.8	No
Pb	3.47–19.5	25	5	50	No	30.3	112	No
Zn	8.9–19	90	10	100	No	124	271	No

It is also informative to compare observed values with reference data available from the UK. These data are presented in Table 4.3.

Table 4.3 Comparison of observed sediment metals data to UK data

Metal	Outfall station range	Liverpool Bay[1]	Cumbrian coast[2]	Scottish Minches[3]	North Sea[4]
	mg/kg dry weight				
As	0.43–17.1	No data	No data	4.3	1.2–33 (mean 11)
Cd	0.031–0.128	0.3–2.1	0.007–0.46	0.018	0.01–0.38– (mean 0.05)
Cr	3.84–31.7	0.5–35.9	10.7–85.8	57	No data
Cu	1.52–4.36	1.8–33.7	1.8–49.4	7.3	0.1–87 (mean 14)
Hg	<0.001–0.0034	0.01–1.44	0.005–0.17	0.05	75% <0.025
Ni	0.78–6.96	1.2–16.5	No data	6.4	1.5–113 (mean 23)
Pb	3.47–19.5	6.9–101	10.3–69.7	24	1.7–288 (mean 21)
Zn	8.9–19	9.4–327	22.4–129.4	45	3–510 (mean 39)

Sources: [1] Taylor, 1986; [2] Nixon, 1985; [3] FRS/SEPA, 1998; [4] NSTF, 1993

Sediment metal results from the survey can be summarised as follows:

- Results reflect what would be expected for an area with both little or no anthropogenic impact and low levels of fine material (with which many metals are generally associated).
- Results are generally well below concentrations that could potentially give rise to any biological effects, and hence give no cause for concern.
- Arsenic levels at a single station (S1) exceed the OSPAR EAC upper limit, although this does not exceed the PEL. This result is not unexpected and is likely to reflect naturally elevated levels of this element present in Donegal Bay. Elevated levels of arsenic have also been found in intertidal sediment in Sruwaddacon Bay. As such, these data are not cause for concern;
- In general, results were either at the lower end of, or similar to, the ranges encountered around the UK coast;
- The results reflect a pristine environment with little evidence for departures from typical background levels.

4.3.2 Hydrocarbons

4.3.2.1 TOE/saturates

In general, the observed concentrations were consistent with the previous year's results, if anything, perhaps slightly lower. The concentration at station S10 (14.0µg/kg) was somewhat higher than nearby locations, a pattern that was also seen in 2007. There was no evidence of anthropogenically derived hydrocarbons.

4.3.2.2 *Polycyclic aromatic hydrocarbons (PAHs)*

Results from the present study are compared against reference criteria in Table 4.4. In most cases, PAH concentrations were below detection limits; where positive results were recorded, these were well below any levels of potential concern. Together these data indicate a pristine environment with little or no anthropogenic influence.

Table 4.4: Comparison of observed sediment PAH data to international standards

PAH	Environment Canada		OSPAR*		Outfall station max.
	TEL	PEL	*BC*	*BAC*	
	µg/kg				
Acenaphthene	6.7	88.9	-	-	-
Acenaphthylene	5.9	128	-	-	-
Anthracene	46.9	245	3	5	-
Benz(a)anthracene	74.8	693	9	16	-
Benzo(a)pyrene	88.8	763	15	30	-
Benzo(b)fluoranthene	No data	No data	-	-	0.22
Benzo(g,h,i)perylene	No data	No data	45	80	0.13
Benzo(k)fluoranthene	No data	No data	-	-	-
Chrysene	108	846	11	20	-
Dibenz(a,h)anthracene	6.2	135	-	-	-
Fluoranthene	113	1,494	20	39	0.05
Fluorene	21.2	144	-	-	-
Indeno(1,2,3,cd)pyrene	No data	No data	50	103	0.13
Naphthalene	34.6	391	5	8	0.49
Phenanthrene	86.7	544	17	32	0.04
Pyrene	153	1,398	13	24	0.08

*Note the BC and BAC sediment figures are listed as a dry weight normalised to 2.5% organic carbon, whereas the Corrib outfall samples were not normalised, however the majority of the data have organic carbons of <1%

(**TEL** = threshold effects level, **PEL** = probable effects level, **BC** = background concentration, **BAC** = background assessment concentration)

4.4 Sediment macrofauna

While there were differences in the community composition at stations throughout the sampling area, a degree of homogeneity was observed as sites did not initially separate below a similarity level of 25% (Figure 3.3). The species found were typical of a subtidal sandy habitats, ranging from those found in coarse sand and gravel to those preferring more stable fine sand.

4.4.1 Comparison between 2007 and 2008

The comparison between data from 2007 and 2008 can be summarised as follows:

- For all but one of the stations (S11), there was no notable difference in community composition between 2007 and 2008, with some sites demonstrating a very high degree of similarity (Figure 4.1).

- Between the two years, stations clustered in a similar pattern.
- Station S11 was unusual in that it shifted from a community of species typical of coarse sand/gravel (*Polygordius* and *Pisione remota*) to one more typical of finer sand (spionid polychaetes and echinoids); sediment composition had changed at this station.

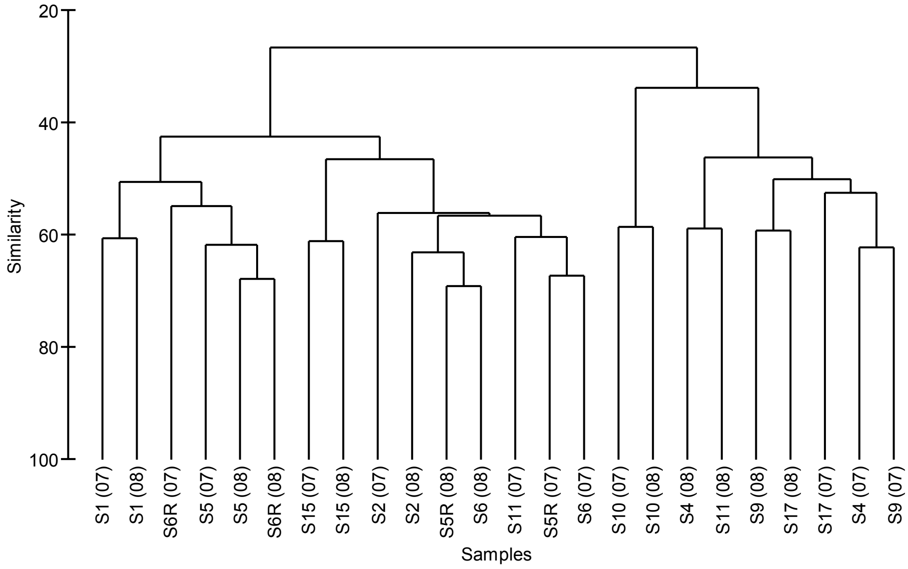

Figure 4.1: Dendrogram showing clustering of communities using pooled replicate (per site) data taken from sites around the proposed outfall in 2007 and 2008.

5 Summary

The summer 2008 outfall area survey was completed successfully, with data collected for water and sediment quality and macrofaunal diversity and abundance. The methods were the same as those used previously, and therefore the data are comparable with those collected in 2007.

5.1 Physico-chemical

5.1.1 Sediments

Typically, the sediments collected in the area around the outfall consist of varying grades of sand, with four sites being medium sand, and the others being coarse or very coarse, with the exception of one site that had fine sand. Whilst overall these results are almost identical to those from 2007, several individual results have changed.

Total organic carbon concentrations were generally low, and this is related to the coarse nature of the sediments.

Trace metal and organic chemical concentrations are generally low, and similar to those from 2007, reflecting the coarse nature of the sediments in the area, and the lack of anthropogenic influences. Arsenic was present at one site at a concentration above the EAC, however, this metal is known to be present at naturally relatively high levels throughout Donegal Bay.

5.1.2 Water

Profiles of salinity and temperature were taken at five water sampling stations and reveal a relatively well-mixed water body in the area. Evidence from these sites showed that a weak thermocline existed; with water temperature at the surface of around 14^{o}C, falling to less than 12^{o}C at the deepest site (W1), and to 13^{o}C at the other, shallower, sites.

Salinity levels increased very slightly with depth; the highest salinities being recorded at around 80m depth at site W1.

Water temperatures and salinities recorded were generally in line with expectations for the area and the time of year.

Trace metal, organics and nutrient concentrations were generally relatively low, however, the sample from close to the seabed at site W1 did contain a high concentration of lead. This appears to be a single anomalous result, and may have been the result of sample contamination.

5.2 Macrofauna

The benthic macrofaunal communities present at the sites sampled had moderate to high diversity, generally with moderate abundance and a high degree of evenness, with low dominance by single species, indicating a stable seabed ecosystem. No species of particular conservation value were recorded.

6 References

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Taylor, D. (1986). Changes in the distribution patterns of trace metals in sediments of the Mersey Estuary in the last decade. *Science of the Total Environment.* **49**, 257–295.

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Appendix 1: Raw sediment particle-size data

Aperture (mm)	8.000	4.000	2.000	1.000	0.710	0.500	0.355	0.250	0.180	0.125	0.090	0.063	0.044	0.032	0.022	0.016	0.011	0.008	0.006	0.004	0.002	0.001	<0.001
Grade	>8000	fine gravel	v fine gravel	v coarse sand	coarse sand		medium sand		fine sand		v. fine sand	med & coarse silt					clay & fine silt						
Station	**8.000**	**4.000**	**2.000**	**1.000**	**0.710**	**0.500**	**0.355**	**0.250**	**0.180**	**0.125**	**0.090**	**0.063**	**0.044**	**0.032**	**0.022**	**0.016**	**0.011**	**0.008**	**0.006**	**0.004**	**0.002**	**0.001**	**<0.001**
S1	4.89	4.52	5.64	31.46	23.93	16.94	7.37	2.75	1.35	0.91	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2	0.00	0.25	6.24	47.99	26.15	13.17	2.96	0.13	0.67	1.24	0.64	0.05	0.00	0.08	0.18	0.17	0.06	0.00	0.00	0.00	0.00	0.00	0.00
S4	0.00	0.14	2.21	3.54	6.63	13.52	21.46	25.56	18.17	8.27	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S5	0.25	4.24	28.56	32.30	18.64	10.07	2.74	0.46	0.59	0.84	0.47	0.21	0.15	0.16	0.17	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00
S5R	0.00	0.26	2.09	24.84	25.04	25.05	15.92	6.16	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S6	0.00	0.01	0.88	6.52	16.78	27.39	27.12	16.53	4.53	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S6R	0.55	4.96	17.74	38.34	23.01	11.42	2.42	0.15	0.45	0.72	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S9	0.00	0.00	0.00	0.00	4.49	18.06	29.32	28.88	15.06	4.12	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S10	0.00	0.00	0.00	0.00	0.00	0.13	4.44	20.05	32.75	29.48	8.92	0.64	0.00	0.20	1.16	0.91	0.38	0.21	0.29	0.30	0.14	0.00	0.00
S11	0.00	0.04	0.62	1.53	4.71	14.03	25.78	29.83	17.91	5.48	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S15	0.00	0.14	0.17	2.95	14.79	28.69	30.06	18.36	4.71	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S17	0.00	0.00	0.27	0.19	4.76	16.75	28.73	29.75	15.70	3.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 2: Raw benthic invertebrate data

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
	Porifera																																					
C0001	Porifera																						P															
	Cnidaria																																					
D0240	*Leuckartiara octona*																				P				P													
D0277	*Podocoryne carnea*													P																								
D0343	*Phialella quadrata*																										P											
D0618	*Virgularia mirabilis*	juvs																								2												
D0632	*Cerianthus lloydii*																						1	1			1		1		1							
D0662	Actiniaria																																					
D0759	Edwardsiidae	juvs			2											1		2	1	1				2		3	37	34	37	1	1				1		1	
D0776	Scleractinia	indet											P																									
	Platyhelminthes																																					
F0002	*Turbellaria*						1		1						1				1						1	1	1	1	2									
	Nemertea																																					
G0001	Nemertea		4	1	9	18	17	21			3	7	1	3	4	5	2	5	6			1	6		2	2	17	11	9	3	4		2		3			
G0034	*Tubulanus polymorphus*		5		4	4	4	6	2	4	2				4	5	3	2	4	8	1	2			2	1	4	5	3	3	1					1		1
G0039	*Cerebratulus*					1								1	1																							1
	Nematoda																																					
HD001	Nematoda		42	115	119	924	844	632			2	355	237	463	255	118	120	106	103	5	535	421	453	2		2						1	2	388	7			
	Chaetognatha																																					
L0001	Chaetognatha																																					
	Sipuncula																																					
N0001	Sipuncula	juvs	1		1	1						1																										
N0028	*Thysanocardia procera*																																					
N0034	*Phascolion strombus*			1		1														1																		
N0047	*Aspidosiphon muelleri*																	1			1																	
	Annelida																																					
P0015	*Pisione remota*		21	45	42	177	146	122	1		1	45	70	68	73	72	58	52	27	52	173	93	55							1			4	4	4			
P0017	Aphroditidae	juvs																																				
P0025	Polynoidae	juvs/scale-less	2	16	21	6	8	5			4	71	18	51	3	3	2	9	8	3	53	113	95			2	4	1							1			
P0052	*Harmothoe ?antilopes*																												1									
-	*Malmgreniella arenicolae*							1			1		1							1	1			1	1				1							1		
P0062	*Malmgreniella glabra*																	1																			1	
P0065	*Harmothoe impar*			2	2						1		1															3	3									
P0066	*Malmgreniella ?ljungmani*																									1												
P0094	*Pholoe inornata (sensu petersen)*					1						1																										
P0105	*Sigalion squamosus*							1																														
P0109	*Sthenelais limicola*									1						1								1	4	2		1	1	2					1		1	2
P0118	*Eteone longa*	agg																												1								
P0122	*Hesionura elongata*		7	18	22	102	47	57	10	2	2	6	28	2	19	22	28	19	45	43	24	25	15							5	2	3	7	36	16	1	6	
P0124	*Hypereteone foliosa*																															1						
P0130	*Mystides caeca*					19	3	5				1	1								1	2																
P0139	*Anaitides*	juvs/damaged																3											2		1					1		
P0142	*Anaitides lineata*		1	1	1		1	1	1				1		4	1		3		3				1	1		2			1	1	1			1	1	3	
P0144	*Anaitides maculata*					1	1	2							1		1									3										1		
P0146	*Anaitides rosea*							1			1													2			10	5	4									
P0150	*Eulalia*		1		1																																	

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
P0155	*Eulalia mustela*		4	13	20	4	3	2				4	4	7	1	4	2	5	3	6	19	11	17															
P0156	*Eulalia ornata*	small							1	2																												
P0163	*Eumida*	juvs				3	3	5			1			1	1	2	1	1					1				3	2	1						1			
P0164	*Eumida bahusiensis*																											2										
P0167	*Eumida sanguinea*			1							1	1	2									1																
P0195	*Lacydonia miranda*											3	3	6							2	3																
P0255	*Glycera*	juvs	8				5					10					3		5	5	17		17												10			
P0256	*Glycera alba*																										2		1			1						
P0257	*Glycera celtica*				1																																	
P0260	*Glycera lapidum*		3	26	25	18	11	23				34	56	51	11	10	10	23	29	15	87	63	24					1				1		3	2			
P0262	*Glycera oxycephala*		14	1	1	17	20	10	3		2	5	8	3	6	6	8	6	7	3	6	3	47	1	2	1				4	4	2	12	7	3	1	5	1
P0265	*Glycera tridactyla*										1																											
P0266	Goniadidae	juvs																																				
P0268	*Glycinde nordmanni*		1							1					2	4	1			2							1				1							
P0271	*Goniada maculata*																										1	1	1									
P0275	*Goniadella bobretzkii*		4	7	14	3	12	6				6	7	8	10	8	7	10	8	14	10	9	12															
P0282	*Ephesiella peripatus*											9	3	5																								
P0288	*Sphaerodoropsis minuta*							2					2					1																				
P0291	*Sphaerodorum gracilis*																						1															
P0305	*Psamathe fusca*		1	4	9	3	4	4				10	4	4				1		2	5	7	4															
P0319	*Podarkeopsis capensis*													3						1		1	1				3	1				1						
P0340	*Glyphohesione klatti*																																					
P0349	*Syllis cornuta*			1																																		
P0362	*Trypanosyllis coeliaca*			1	3	1	2					7	1	5						1	1	10	11															
P0365	*Syllis armillaris*																																					
-	*Syllis* "species E"				1	1															1		3															
-	*Syllis* "species D"			1	2	14	2	2					2	5	1			1		3		5	6															
-	*Syllis* "species H"		4	9	4	18	16	8				4	19	27	4	7	4	4	1	6	30	31	38											1				
P0377	*Dioplosyllis cirrosa*																			1	1	1																
P0380	*Eusyllis blomstrandi*																						3				1		1									
P0388	*Odontosyllis gibba*				1							9		6									4															
P0390	*Opisthodonta*				2		3																															
P0391	*Opisthodonta pterochaeta*		12	12	10	28	27	24				1	1	2	11	17	18	16	11	22	1		2	1	2						2		26	8	14	1		
P0394	*Palposyllis prosostoma*		2	1				1							1	2																						
P0400	*Pionosyllis pulligera*				5																																	
P0403	*Streptosyllis bidentata*					3	8	3							11	23	18	17	32	30	1	5								1	2	3	36	49	50			
P0405	*Streptosyllis websteri*		3	5	1					1																										1	1	
P0421	*Exogone hebes*								1	3					1				4	1					1					2			2		4		1	
P0422	*Exogone naidina*						1	5				3	3	1						1		15	6				1											
P0423	*Exogone verugera*								1																													
P0425	*Sphaerosyllis bulbosa*		9	4	15	11	5					28	60	40		2	2			1	41	27	12															
P0430	*Sphaerosyllis taylori*		1	5	4	1	1		1		1	7		10	2	1	1	7	14	8	6	3	3							1								
P0458	*Nereididae*	juvs																																				
P0475	*Nereis longissima*		1	1	2		1							1							1	1																
P0493	*Aglaophamus rubella*		1		1																																	
P0494	*Nephtys*	juvs							4	6	10				4		2		1			1		1		3	2			2	1	1	5	6	8	9	8	
P0495	*Nephtys assimilis*																										1	1										
P0498	*Nephtys cirrosa*								3	2	1				2			1	1					2	2	1	2			1	3	2	1	3	2	2	2	4

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
S0528	*Euphrosine foliosa*											3	1	5								1																
P0539	*Aponuphis bilineata*		3	3	8	1			1		1	2	2	3		1			1	1	2		5	1							1							
P0545	*Nothria conchylega*																												1									
P0554	*Eunice*	juvs											1	2																								
P0563	*Marphysa*	juvs																					1															
P0564	*Marphysa bellii*																																					
P0573	*Lumbrineris agastos*				1	1						1	3		1	2	1		2	4			1										2					
P0577	*Scoletoma fragilis*											6	1																									
P0579	*Lumbrineris gracilis*				1															1							6	1	5									
P0633	*Parougia caeca*												1																									
P0638	*Protodorvillea kefersteini*		7	2	17	91	32	31				20	12	12	13	4	3	6	4	12	55	38	24															
P0661	*Orbinia*	juvs																							1	1											2	
P0665	*Orbinia sertulata*																															1				2		
P0672	*Scoloplos armiger*								2	1	4													2	1		9	13	16									
P0678	*Aricidea wassi*																										3	3	2									
P0684	*Aricidea catherinae*																																					
P0685	*Aricidea cerrutii*		1					1	3						1	3	2	3		4		1			1	2	2	1		6	7	3	6	8	9			
P0688	*Aricidea simonae*																																					
P0699	*Paradoneis lyra*			1																1				1					1									
P0711	*Apistobranchus tenuis*																																					
P0718	*Poecilochaetus serpens*		2	2	2	2		2	1		2					2	1		1	1	1				1		5	9	16				1					
P0721	*Aonides*	juvs							1																													
P0722	*Aonides oxycephala*												1																									
P0723	*Aonides paucibranchiata*		12	11	35	16	10	6	17	16	15	11	15	11	6	35	11	16	12	14	12	24	27	18	13	8	29	24	27	15	27	7	2	5	2	4	5	10
P0732	*Laonice*	juvs																					1															
P0733	*Laonice bahusiensis*			1	3									4							2	2																
P0747	*Minuspio cirrifera*			2	5	3	1			4	3	3	6	2								5	15	2	1		15	11	8	1	1				1			
P0751	*Polydora caulleryi*			2																																		
P0763	*Prionospio*		2			6	1	6	5						5			4	2		4		10					3	3									
P0765	*Prionospio fallax*																										19	13	15									
P0773	*Pseudopolydora paucibranchiata*																											1										
P0779	*Scolelepis bonnieri*									1	1													1			1			2							1	
-	*Scolelepis gilchristi*		1		1									1									1		1					1								
P0787	*Spio*	damaged										1																										
P0789	*Spio decorata*				1				46	14	67				6	9	3	3	3	7				4	2	6	25	58	78	11	4	8		1				
P0790	*Spio filicornis*		28	8	1	266	277	337				8	8		387	386	238	58	67	34	8	3	3					4			5			3	1			
P0794	*Spiophanes bombyx*								3	3	9			1					1					2	2		172	151	196	5	3	4	1			5	2	1
P0796	*Spiophanes kroyeri*																	1									7	13	33									
P0804	*Magelona alleni*																										1	3										
P0805	*Magelona filiformis*									2																	42	38	65					2		1	1	
P0807	*Magelona mirabilis*								1	2																												
-	*Magelona johnstoni*																															1						
P0810	Chaetopteridae	juvs					1	1													3	10	2															
P0824	*Aphelochaeta* "species A"				1					1																1					1	1						
-	*Chaetozone christiei*								1																		2	1		1								
P0829	*Caulleriella alata*												1							1			1															
P0828	*Caulleriella*	sp. indet.																														1						
-	*Caulleriella viridis*																																					

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
P0831	*Chaetozone zetlandica*				2						1																				1							
P0833	*Chaetozone gibber*																												1									
P0840	*Dodecaceria*																										2		1									
P0844	*Monticellina dorsobranchialis*																																					
P0846	*Tharyx killariensis*																																					
P0878	*Diplocirrus glaucus*			2																								2	2									
P0881	*Flabelligera affinis*											1															1											
P0889	*Macrochaeta helgolandica*											1	2									1																
P0907	*Capitella*	spp complex					1			1	6																1	3										
P0919	*Mediomastus fragilis*			1	6			1												1		9	19								1							
P0921	*Notomastus*		2	14	10	2	6	1		1		1		2	1	1	1	1	1	3	6	2	5	1	1	1				1								
P0925	*Peresiella clymenoides*																										8	5	12									
P0938	Maldanidae	no tail																																				
P0955	*Clymenura*	no tail											2																									
P0958	*Clymenura johnstoni*											3	5	2																								
P0973	*Praxillella praetermissa*																																					
-	*Isocirrus planiceps*																											1	1									
P0993	Opheliidae	juvs			2																								1									1
P1007	*Travisia forbesii*									1																			1		1	2						
P1011	*Armandia polyophthalma*														1																		1					
P1014	*Ophelina acuminata*																											1										
P1027	*Scalibregma inflatum*				1																																	
P1062	*Polygordius*		54	55	86	106	251	219	3			90	534	78	120	164	94	89	83	119	242	259	216									1	20	32	46			
P1063	*Polygordius appendiculatus*		46			68					1												14							1								
P1093	*Galathowenia oculata*																												1									
P1095	*Myriochele danielsseni*																										4	2	4									
P1098	*Owenia fusiformis*										1	1	1	1	1	1			1	11	1			1		1					4		1		1	2		
P1100	Pectinariidae	juvs																																				
P1102	*Amphictene auricoma*																										6	4	4									
P1106	*Lagis koreni*																					1					1	3	6									
P1118	*Ampharetidae*	juvs/damaged																			2																	
P1139	*Ampharete lindstroemi*												2														1	4	7									
P1142	*Amphicteis gunneri*																																					
P1160	*Sabellides octocirrata*			2																	2	1	1															
P1167	*Sosane sulcata*																																					
P1175	*Terebellides stroemi*																																					
P1179	Terebellidae	juvs																																				
P1185	*Amphitritides gracilis*			1																	1																	
P1190	*Eupolymnia nesidensis*			2								2								1																		
P1195	*Lanice conchilega*																	1	1																			
P1213	*Paramphitrite tetrabranchia*										1																											
P1216	*Pista*	juvs									3									2							1				1							
P1217	*Pista cristata*																																					
P1218	*Pistella lornensis*			1																																		
P1233	*Lysilla loveni*																																					
P1235	*Polycirrus*	juvs																		3										2				2				14
P1242	*Polycirrus medusa*		3	8	2	17	6	4			1	13	12	8	3	3	3	13	12	10	5	17	15	3	5	3	1				2	1			4	8	8	
P1249	*Parathelepus collaris*		8	7	6																1	1	1															

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
P1260	*Bispira*	juvs																				1	1															
P1269	*Chone filicaudata*		1					2										1		1	9	8	5				4		1									
P1289	*Jasmineira caudata*					1			1							1			1			1						1										
P1329	*Ditrupa arietina*																																					
P1425	Tubificidae															4					1																	
P1501	Enchytraeidae			1	6	4	4	7	2			3	8		29	35	49	22	19	11	4	6	5	1						1	1		6	17	11	1	1	
	Chelicerata																																					
Q0044	*Anoplodactylus petiolatus*																																					
	Crustacea																																					
R0077	*Balanus crenatus*				P																																	
R0142	Copepoda				1	3			1		1	7	11		1			2			12	7			2	4		3			1			1			3	2
R2412	Ostracoda						1		3	1	3									1	2	2	1				1		2	1								
S0005	*Nebalia*										1																											
S0011	*Sarsinebalia typhlops*								5		1																											
S0041	*Gastrosaccus lobatus*		2								2								1	1											2	1						
S0048	*Erythrops elegans*																	1	1		1			1														
S0087	*Schistomysis ?ornata*													1																						1	1	
S0125	*Monoculodes carinatus*					1																																
S0131	*Perioculodes longimanus*								1															1			1	1	2			1				2		2
S0135	*Pontocrates arenarius*		2			2					1		2		1						1														1			
S0138	*Synchelidium maculatum*						1	1	1	2	2						1	1	2					2		1	1	1		4	3	3				2	1	
S0140	*Westwoodilla caecula*																																					
S0154	*Amphilochoides boecki*		1													1																						
S0159	*Amphilochus neapolitanus*																																					
S0164	*Gitana sarsi*			1	7																1		5															
S0170	*Paramphilochoides odontonyx*										1																1	1	3									
S0173	*Peltocoxa brevirostris*																					1																
S0177	*Leucothoe incisa*																																					
S0213	*Stenothoe marina*			1	1															1																		
S0248	*Urothoe elegans*																																					
S0254	*Harpinia antennaria*																										4		4									
S0265	*Parametaphoxus fultoni*			1								1										1																
S0274	*Acidostoma nodiferum*																																					
S0296	*Hippomedon denticulatus*					1		1	6	6	4			1	1	1		2	1	1				12	2	1				1	1	1			1	17	2	1
S0301	*Lepidepecreum longicorne*										1		1					1	4	1				1	1	2										1	2	
S0330	*Socarnes erythrophthalmus*																					26	43															
S0347	*Tryphosites longipes*																																					
S0360	*Argissa hamatipes*			1				1			1													2	4	3	2	1										2
S0399	*Listriella mollis*											3	2																									
S0409	*Atylus*	juvs	2				2		1		1		1							4	2									2	1							
S0410	*Atylus falcatus*					8	2	4							6	6	12	1	1	2	1		1		1									4	6		1	
S0413	*Atylus vedlomensis*			5	2	9	6	6			2	2	7	2	1	1	3	1	11	3	2	5	1															
S0418	*Guernea coalita*			7	3	9	4					20	31	11	2		1	1	5		11	17	13															
S0423	*Ampelisca*	juvs							1											1		1						3	6		1							
S0427	*Ampelisca brevicornis*					1					1								1						1	1	1										1	
S0438	*Ampelisca spinipes*			2		1																	2					3										
S0440	*Ampelisca tenuicornis*																										1	4	3									
S0442	*Ampelisca typica*																																					

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
S0451	*Bathyporeia*	juvs	1						20	2	9					1					1			8	3	5	3	7		4		8				2	3	
S0452	*Bathyporeia elegans*								13	8	8											1		1	5		5	2	6	7	6	18	2			10	4	9
S0456	*Bathyporeia pelagica*																											2	1									
S0489	*Megaluropus agilis*								1															2		1												
S0493	*Melphidippella macra*								2			1	1								1						3		2									
S0502	*Ceradocus semiserratus*																						1															
S0503	*Cheirocratus*	females/juvs	2		3																											1						
S0519	*Maera othonis*			1	3																																	
S0539	*Gammaropsis cornuta*		5	5	6	9	10	6	2		2	3	3	3		1	2	6	3	5		3					1	1	3		1	1						
S0561	*Ericthonius punctatus*					1																																
S0577	Aoridae	females/juvs								1	2																2	1	11		1							
S0588	*Leptocheirus hirsutimanus*					2	9	1				1										1	1															
S0618	*Siphonoecetes kroyeranus*																								1	1							1	2	3	2	7	2
S0619	*Siphonoecetes striatus*								1		1																5	2	3									
S0639	Caprellidae	no legs																					2															
S0651	*Pariambus typicus*																											1										
S0657	*Phtisica marina*																																					
S0793	*Gnathia*	praniza/females												1													2											
S0796	*Gnathia oxyuraea*																																					
S0854	*Eurydice pulchra*											1	1																									
S0856	*Eurydice truncata*		3	1	1	4	2	7	2	1	1		1	1	8	11	6	19	22	13					3	1				4	1	3	7	4	12	5	4	4
S0911	*Paramunna bilobata*											11		5																								
S0955	*Astacilla longicornis*		1								1																											
S1099	Tanaidacea				3				1			12		4							2							4	6	1				1				
S1196	*Bodotria pulchella*																														1							
S1197	*Bodotria scorpioides*																		1	2																		
S1224	*Cumella pygmaea*		1		1							8		4							2	1	2															
S1236	*Pseudocuma longicornis*							1		1															2													
S1237	*Pseudocuma similis*						1		6	3	3					1	2	1	1	1				26	13	11	3	2	6	1		1			2	1	4	4
S1247	*Diastylis*	juvs																																				
S1248	*Diastylis bradyi*																																	1				
S1251	*Diastylis laevis*																										1											
S1254	*Diastylis rugosa*																										1	1	2	1	1							1
S1257	*Diastyloides biplicata*																																					
S1361	Processidae	damaged															1																					
S1374	*Pandalina brevirostris*				1							1																										
S1386	*Philocheras bispinosus*																											1										
S1445	Paguridae	juvs										1	1															1										
S1462	*Pagurus prideaux*				1																							4	1									
S1569	Portunidae	damaged/juvs					1																										1			1		
S1472	*Galathea intermedia*			13	22	1						4		4	1							2	2				1	1										
S1482	*Pisidia longicornis*											1																										
S1504	*Ebalia*	damaged												1									1															
S1506	*Ebalia granulosa*																											1										
S1535	*Eurynome*	juvs										1									1	1																
S1537	*Eurynome ?spinosa*																						1															
S1552	*Corystes cassivelaunus*																											1										
S1555	*Atelecyclus rotundatus*											1																										

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
S1582	*Liocarcinus marmoreus*					1		1					1									1													1			
S1584	*Liocarcinus pusillus*																				1																1	
-	Decapoda	megalopa				1																																
-	Decapoda	zoea																		1	1																	
	Mollusca																																					
W0029	Neomenia				1							5	3	8							3	2																
W0046	Polyplacophora	juvs			1																																	
W0088	Gastropoda	damaged	1	1									1	3					1		3	1	2															
W0157	*Gibbula*	juvs		1	2							2									1	32	11															
W0324	Rissoidae	juvs												1																								
W0418	*Caecum glabrum*											22	12	21				1			1	10	3															
W0488	*Polinices*	juvs										3																1										
W0491	*Polinices pulchellus*					1		2			1			2							1		1															
W0553	*Epitonium trevelyanum*																																					
W0603	*Eulima bilineata*																						1															
W0702	Buccinidae	juvs																																				
W0771	Turridae	juvs																																				
W0959	*Ondina diaphana*												1																									
W1006	*Acteon tornatilis*																											1										
W1019	*Scaphander lignarius*														2										1													
W1028	*Cylichna cylindracea*																	1									28	27	26									
W1036	*Philine*	juvs																								1												
W1044	*Philine quadrata*					5	4	2							2	2	1				2	1		3	7	7	2	2	3				1	1	2	3	6	2
W1045	*Philine scabra*																							1			26	16	15							1	1	
W1059	*Diaphana minuta*												1		1	1																					1	
W1077	*Retusa obtusa*				1	1						1	2	3	4				1	2	2	1	2															
W1243	Nudibranchia	juvs/indet										43	7					2	1	1		7																
W1414	Aeolidaiacea												2	4																								
W1519	*Antalis entalis*																																					
W1560	Pelecypoda	damaged/juvs																																	1			
W1688	*Glycymeris glycymeris*											1									1																	
W1695	*Mytilus edulis*	juvs																					1													1		
W1703	*Modiolula phaseolina*	juvs												1							1	3	2															
W1746	*Limatula subauriculata*		1	1	1	1	1					1	2		1		1	1		2	2	2	1															
W1785	*Palliolum striatum*		3	4	1						1	3		2								1	2															
W1803	*Similipecten similis*																																					
W1829	*Lucinoma borealis*																										2		4									
W1837	*Thyasira flexuosa*																										8	7	11									
W1866	Galeommatacea	juvs																	1																			
W1892	*Montacuta substriata*												1							8																		
W1902	*Tellimya ferruginosa*					1						4	7	1						3	1																	
W1906	*Mysella bidentata*																												1									
W1911	*Epilepton clarkiae*																														2							
W1929	*Goodallia triangularis*					3	1	1				4	2	2					1														1					
W1940	*Acanthocardia*	juvs										1									1		6		1		4	3	7									
W1959	*Laevicardium crassum*	juvs												1	1	1								1														
W1973	*Spisula*	juvs			18	17	2	2				5	5	5		2		2	4	4	8	7	1											2				
W1975	*Spisula elliptica*		1			6	2	1			1		3	1	3	6	8	2	5	3	3		1		3	4				1			1		5			1

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
W1983	*Lutraria angustior*				1		3									1	1	1		2			1															
W1995	Pharidae	juvs																									1		2									
W1999	*Ensis ensis*					1	1	1									2			1														1	2			1
W2008	Tellinidae	juvs		5	3	3				1		2	5	3				4		4	1																	
W2015	*Arcopagia crassa*						1														1																	
W2023	*Moerella pygmaea*					6	5	14		2	1				16	4	30	22	18	15	1	2	7	1	1	6				3		1	2	18	20	3		2
W2044	*Gari*	juvs										2	4							1		29	10															
W2046	*Gari depressa*				1		1	2				1	2	8	2	1				1	12	1	2															
W2049	*Gari tellinella*																	1		1																		
W2058	*Abra*	juvs												1		1								16	27	8	18	11	7	5	19	1						3
W2062	*Abra prismatica*					1				4	2							2	9					2	11	5	11	19	10	3	2	2						
W2086	Veneridae	juvs												3								1																
W2095	*Gouldia minima*											2										1	1															
W2098	*Chamelea striatula*			1															1							1	1		3									
W2100	*Clausinella fasciata*											1		2							1	1																
W2104	*Timoclea ovata*													1		1					1	2											1					
W2126	*Dosinia*	juvs																			1										1							
W2131	*Dosinia lupinus*					1	1						1		1		1		1	1	1			2			4	3	5							1		2
W2157	*Corbula gibba*																											1	1									
W2166	*Hiatella arctica*																					1	1															
W2226	Thraciidae	juvs			17									1			1				2			2														
W2233	*Thracia villosiuscula*			1	1	2	1					2		4	1					1	3		1							1					1			
W2239	*Cochlodesma praetenue*																								3	2	6	1	5						1	3		1
W2247	*Lyonsia norwegica*																																					
W2277	*Cuspidaria*	juvs																																				
W2280	*Cuspidaria ?cuspidata*																																					
	Bryozoa																																					
Y0027	Tubulipora			P																																		
Y0054	*Entalophoroecia deflexa*			P																																		
Y0057	*Hornera lichenoides*																																					
Y0066	*Disporella hispida*			P																																		
Y0076	*Alcyonidium diaphanum*																					P																
Y0154	*Aetea anguina*																																			P		
Y0162	*Scruparia chelata*													P																								
Y0178	*Electra pilosa*																																		P			
Y0474	*Schizomavella linearis*			P																																		
Y0480	*Microporella ciliata*			P																																		
	Phoronida																																					
ZA003	Phoronis	indet								1		1															8	9	18	1	1							
	Echinodermata																																					
ZB018	Asteroidea	juvs		2	1									1		2		1	1	1				2		1		1		1					1			1
ZB105	Ophiuroidea	juvs		6	13			1				126	80	111					1		12		25				2	2	3									
ZB154	*Amphiura filiformis*													1														3										
ZB157	*Amphiura securigera*											3	2								1																	
ZB161	*Amphipholis squamata*											47	20	70					2		4	5	1															
ZB167	*Ophiocten affinis*			l		1							2		1			1	2										2									
ZB181	Echinoidea	smashed/juvs		9	2	2	1		19	22	19	6	5	1	3	1		8	2	1		4	10	11	15	6	11	6	7	10	4	9	3	8	5	1	9	8
ZB212	*Echinocyamus pusillus*			6	14	4	1	4	7	4	24	10	15	18	14	21	9	12	15	16	6	2	2		2	9	1	5	11	5	9	3	1	3	2	9	6	3

MCS Code			S1-a	S1-b	S1-c	S2-a	S2-b	S2-c	S4-a	S4-b	S4-c	S5-a	S5-b	S5-c	S5R-a	S5R-b	S5R-c	S6-a	S6-b	S6-c	S6R-a	S6R-b	S6R-c	S9-a	S9-b	S9-c	S10-a	S10-b	S10-c	S11-a	S11-b	S11-c	S15-a	S15-b	S15-c	S17-a	S17-b	S17-c
ZB219	*Spatangus purpureus*																		1	2					2													
ZB224	*Echinocardium flavescens*					5	2	1	3	2	3				2	2	6	8	13	4				10	5	14	5	13	6		2	1	2		3	1	12	
ZB225	*Echinocardium pennatifidum*							1																														
ZB257	*Pseudothyone raphanus*																																					
ZB262	*Thyone fusus*				1	2	3						1		1						1	1																
ZB297	*Leptosynapta minuta*				1	1																																
ZB298	*Labidoplax*	juvs																						1												1		
ZB299	*Labidoplax buskii*																						1															
ZB300	*Labidoplax digitata*																								1													
	Hemichordata																																					
ZC001	Hemichordata	indet									3								1								5	3	4	1								
	Tunicata																																					
ZD109	*Cnemidocarpa mollis*																	1		1																		
	Cephalachordata																																					
-	*Branchiostoma lanceolatum*		3										2																									
	Pisces																																					
ZG007	Teleostei																	1																				
	Astrorhiza																																					
	No. Species		53	72	84	76	65	60	46	37	62	85	84	80	62	58	49	65	69	84	89	84	87	45	47	44	82	85	79	46	48	38	31	30	44	40	36	28
	No. Individuals		351	493	677	2082	1855	1628	212	130	254	1175	1402	1223	1083	1034	785	620	657	593	1499	1432	1382	160	164	142	643	625	788	132	144	102	160	621	272	111	118	86

Appendix 3: Benthic invertebrate statistical analysis

Table 1. Univariate Indices by replicate for sample sites around the proposed outfall.

	S	N	J'	H(loge)	λ
S1-a	53	351	0.79	3.14	0.07
S1-b	72	493	0.76	3.18	0.08
S1-c	84	677	0.77	3.41	0.06
S2-a	76	2082	0.53	2.29	0.23
S2-b	65	1855	0.49	2.05	0.26
S2-c	60	1628	0.52	2.12	0.22
S4-a	46	212	0.80	3.07	0.08
S4-b	37	130	0.85	3.08	0.06
S4-c	62	254	0.77	3.18	0.09
S5-a	85	1175	0.68	3.01	0.12
S5-b	84	1402	0.58	2.58	0.18
S5-c	80	1223	0.62	2.71	0.17
S5R-a	62	1083	0.55	2.28	0.20
S5R-b	58	1034	0.59	2.39	0.19
S5R-c	49	785	0.65	2.54	0.14
S6-a	66	621	0.75	3.16	0.07
S6-b	69	657	0.76	3.23	0.07
S6-c	84	593	0.78	3.44	0.07
S6R-a	89	1499	0.57	2.53	0.17
S6R-b	84	1432	0.63	2.78	0.14
S6R-c	87	1382	0.64	2.85	0.14
S9-a	45	160	0.83	3.15	0.06
S9-b	47	164	0.85	3.26	0.06
S9-c	44	142	0.91	3.43	0.04
S10-a	82	643	0.75	3.30	0.09
S10-b	85	625	0.75	3.35	0.08
S10-c	79	788	0.75	3.27	0.09
S11-a	46	132	0.90	3.44	0.04
S11-b	48	144	0.84	3.26	0.06
S11-c	38	102	0.87	3.16	0.06
S15-a	31	160	0.79	2.70	0.10
S15-b	30	621	0.49	1.66	0.40
S15-c	44	272	0.80	3.00	0.08
S17-a	40	111	0.87	3.19	0.05
S17-b	36	118	0.91	3.26	0.04
S17-c	28	86	0.88	2.93	0.06

S = Number of species (including encrusting species)
N = Number of individuals
J' = Pielou's Evenness
H'= Shannon-Weiner Diversity ($\log_e$)
λ = Simpson's Dominance index

Table 2: SIMPER output of those species that contribute (top 30%) to the similarity between sites around the proposed outfall using Bray-Curtis similarity on standardised square root transformed data (see Figure 2). The columns shown give the average abundance, the average contribution to the similarity, the percentage contribution to overall similarity and the cumulative contribution to similarity.

Cluster 1 (Site 15)				
Average similarity:	100			
Species	Av. Abund	Av. Sim.	Contrib%	Cum%
Nematoda	132.34	-	37.61	37.61
Cluster 2 (Sites 1,2,5,5R,6,6R)				
Average similarity:	55.64			
Species	Av. Abund	Av. Sim.	Contrib%	Cum%
Polygordius	12.29	5.17	9.28	9.28
Nematoda	12.35	3.98	7.16	16.44
Pisione remota	7.49	2.99	5.38	21.82
Spio filicornis	8.46	2.19	3.93	25.75
Hesionura elongata	5.18	2.11	3.78	29.53
Glycera lapidum	4.79	1.67	2.99	32.53
Cluster 3 (Site 10)				
Average similarity:	100			
Species	Av. Abund	Av. Sim	Contrib%	Cum%
Spiophanes bombyx	173	-	25.21	25.21
Spio decorata	54	-	7.87	33.09
Cluster 4 (Sites 4,9,11,17)				
Average similarity:	52.88			
Species	Av. Abund	Av. Sim	Contrib%	Cum%
Aonides paucibranchiata	3.54	3.75	7.09	7.09
Echinocyamus pusillus	2.54	2.62	4.96	12.04
Hippomedon denticulatus	2.03	1.97	3.72	15.77
Echinoidea juveniles	1.98	1.87	3.54	19.31
Bathyporeia elegans	2.11	1.83	3.46	22.77
Spiophanes bombyx	1.76	1.76	3.33	26.10
Echinocardium flavescens	1.96	1.69	3.19	29.30
Nephtys juveniles	1.82	1.65	3.12	32.41

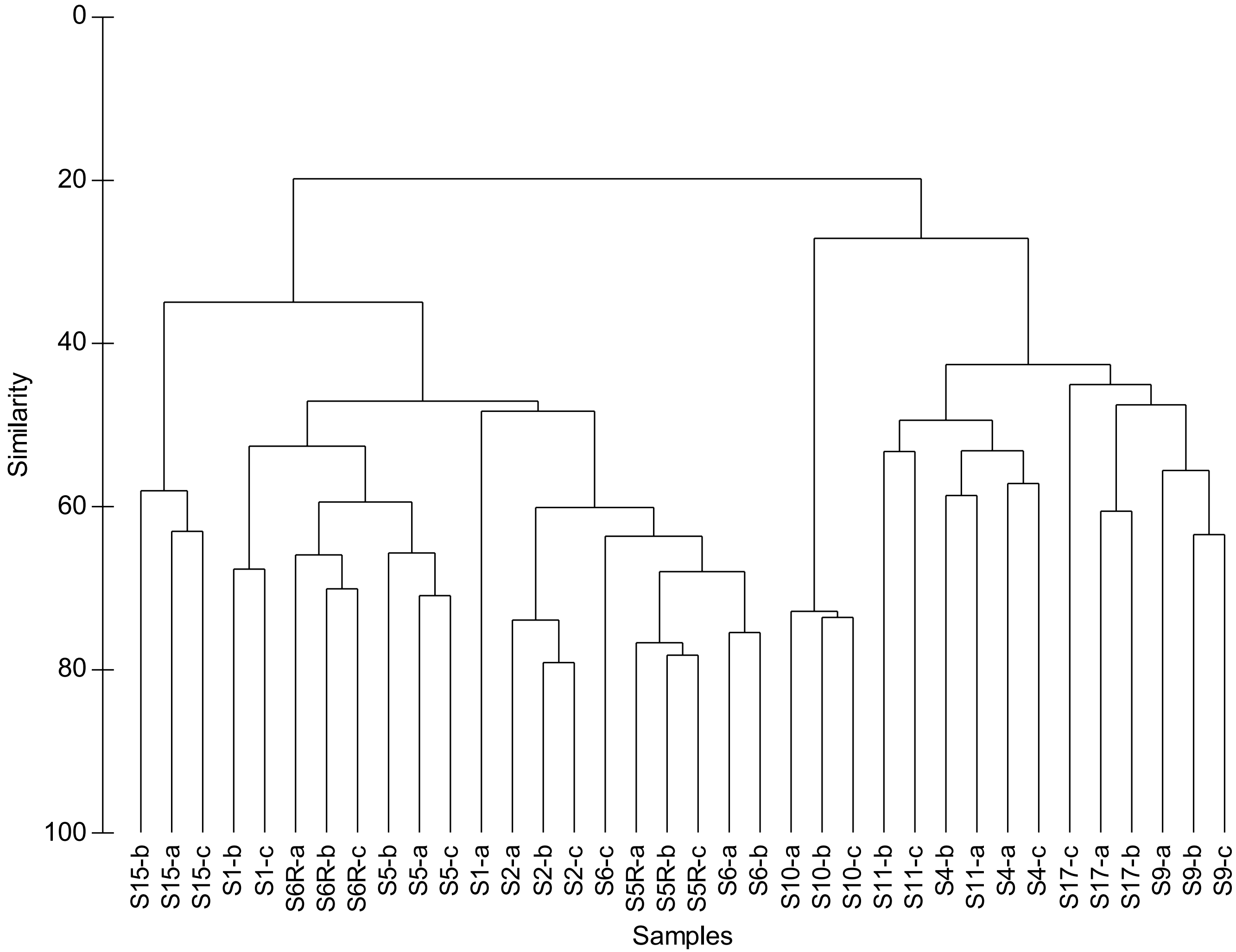

Figure 1. Dendrogram showing clustering of communities using per replicate sample data from sites around the proposed outfall.

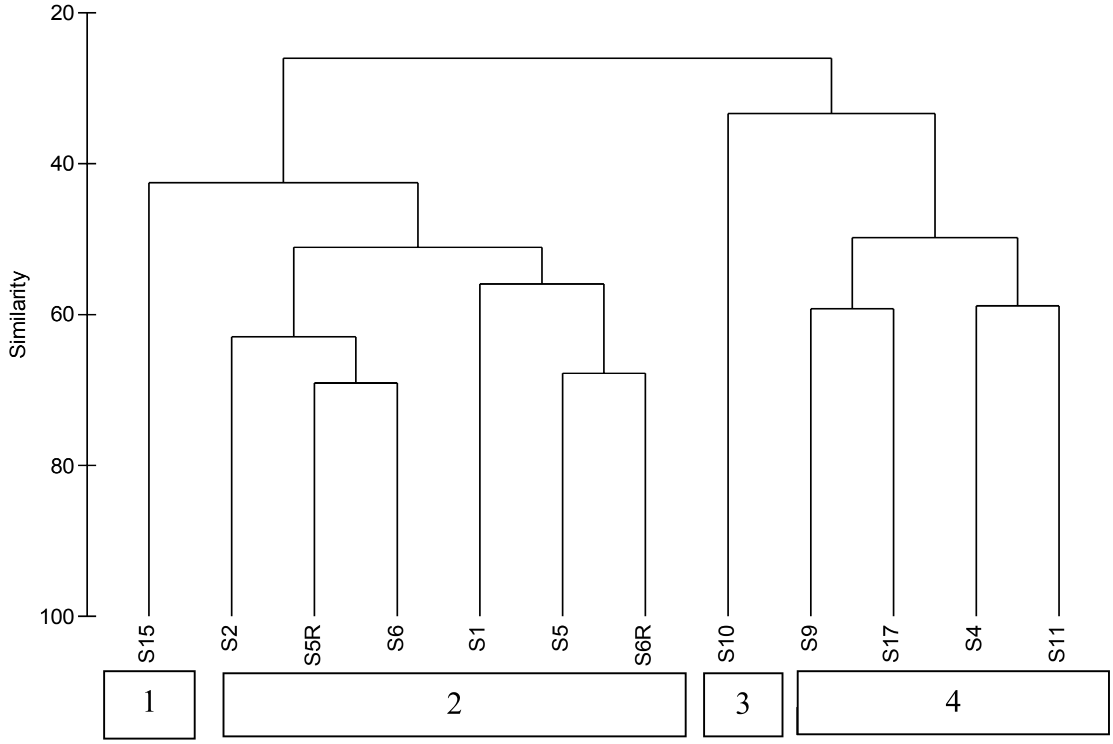

Figure 2: Dendrogram representation of clustering of benthic macrofauna communities (per station, replicates pooled)

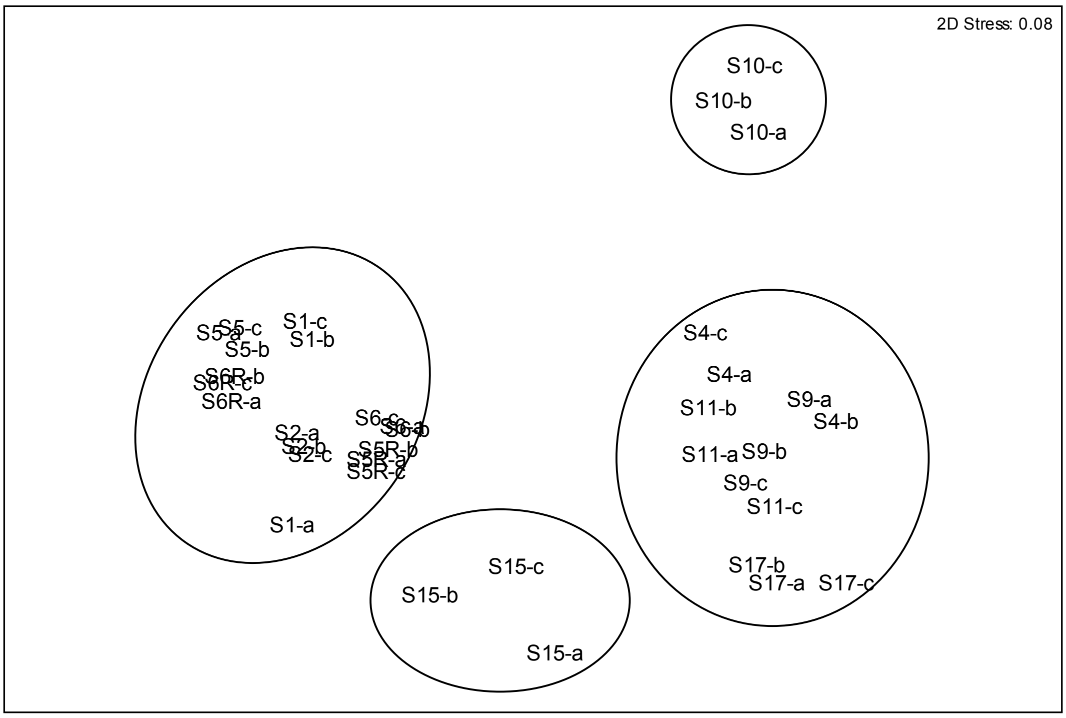

Figure 3. MDS plot of sample sites (per replicate data) around the proposed outfall with superimposed bubbles showing the four clusters.

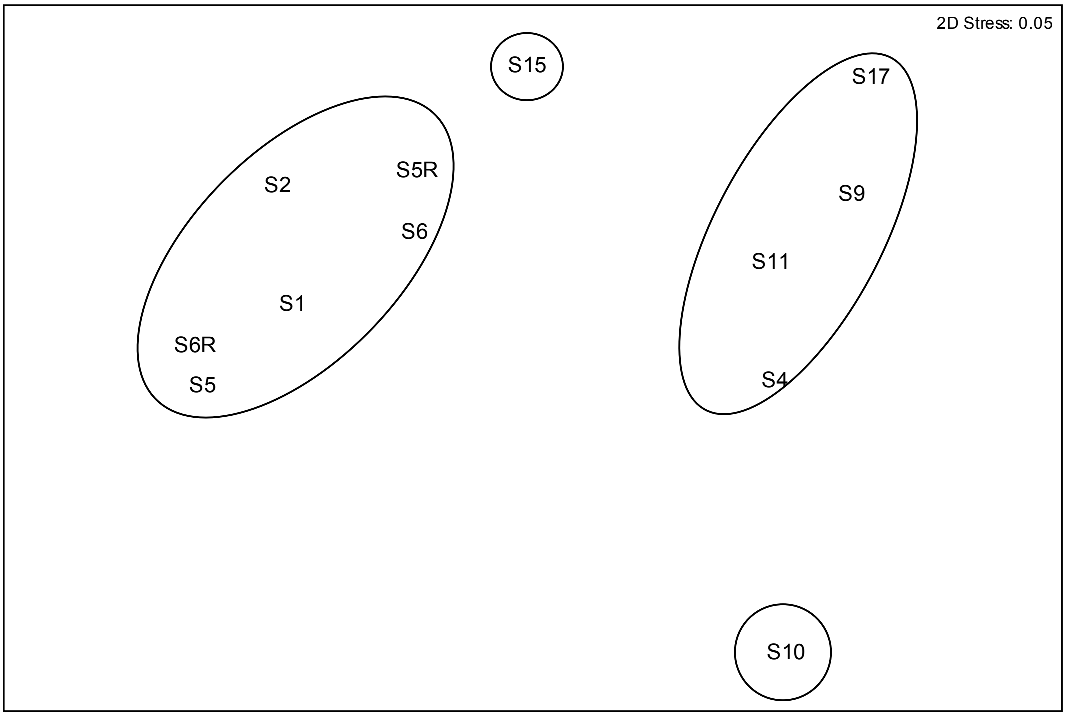

Figure 4. MDS plot of sample sites around the proposed outfall with superimposed bubbles showing the four clusters.

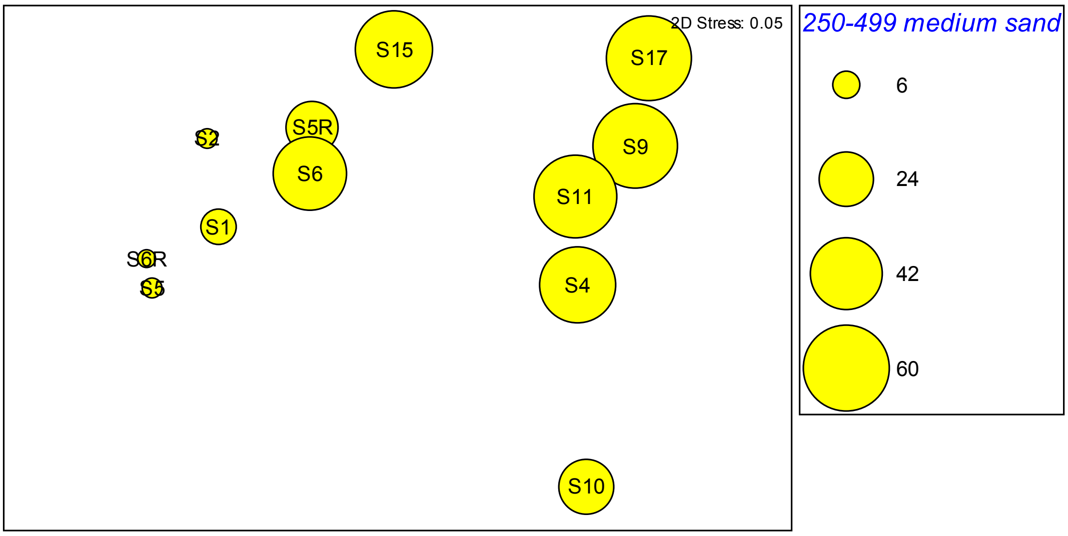

Figure 5. MDS plot of sites around the proposed outfall with superimposed bubbles representing the percent of sediment fraction 250-499µm (medium sand) at each site.

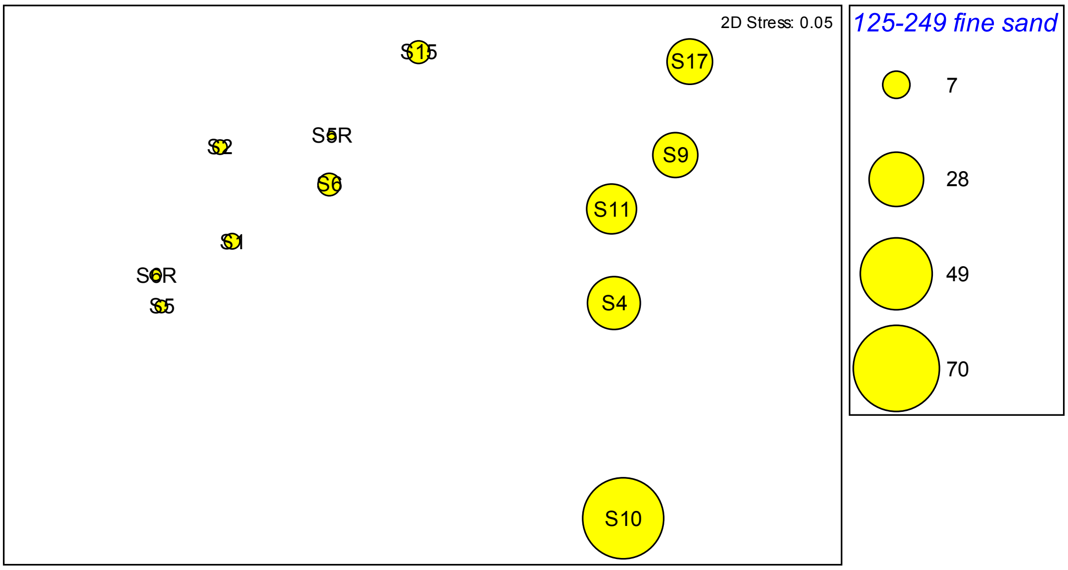

Figure 6. MDS plot of sites around the proposed outfall with superimposed bubbles representing the percent of sediment fraction 125-249µm (fine sand) at each site.

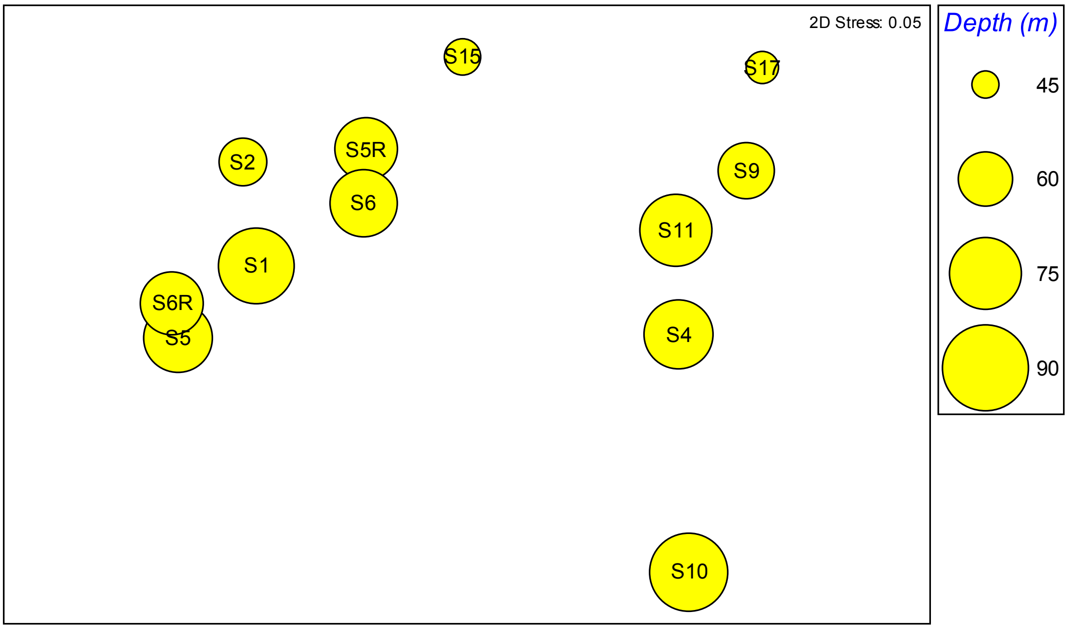

Figure 7. MDS plot of sites around the proposed outfall with superimposed bubbles representing the depth (m) at each site.

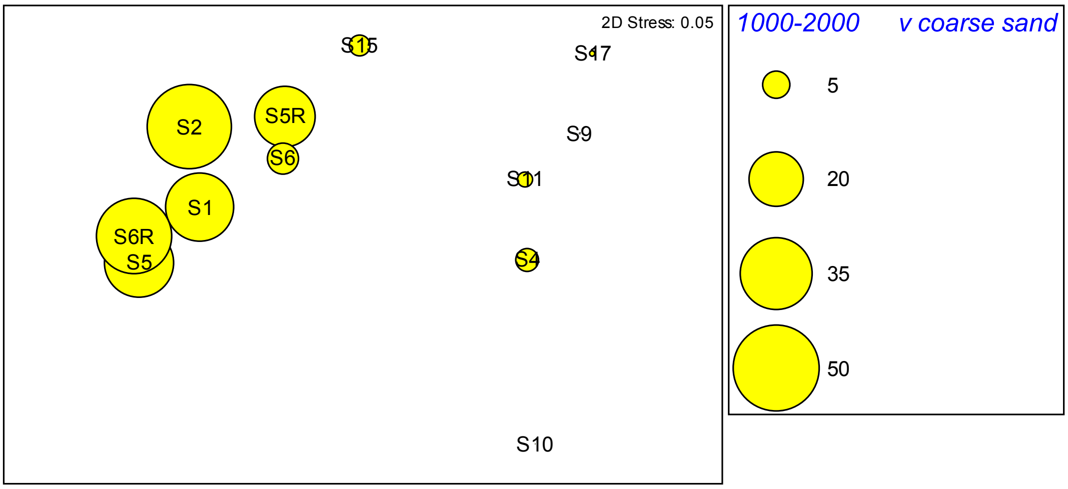

Figure 8. MDS plot of sites around the proposed outfall with superimposed bubbles representing the percent of sediment fraction 1000-2000µm (v coarse sand) at each site.

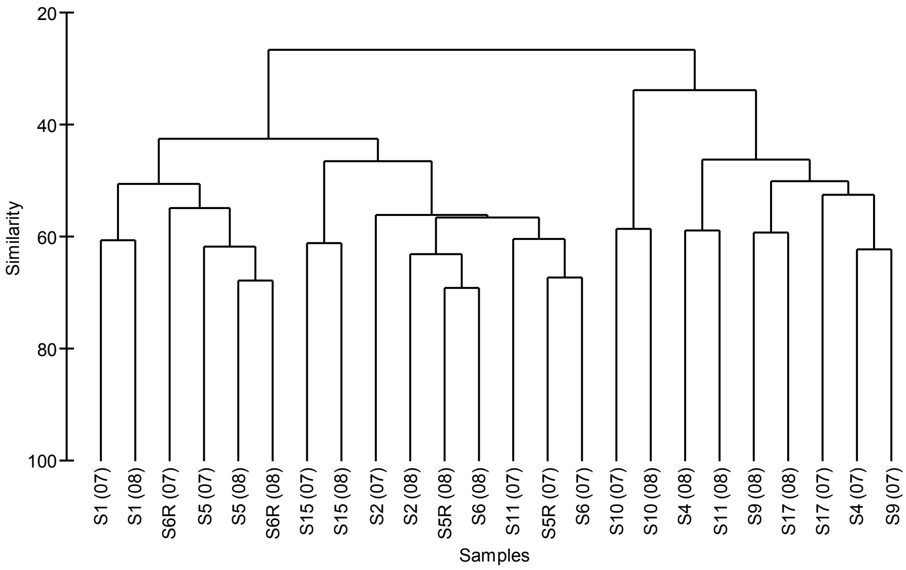

Figure 9. Dendrogram showing clustering of communities using pooled replicate (per site) data taken from sites around the proposed outfall in 2007 and 2008.

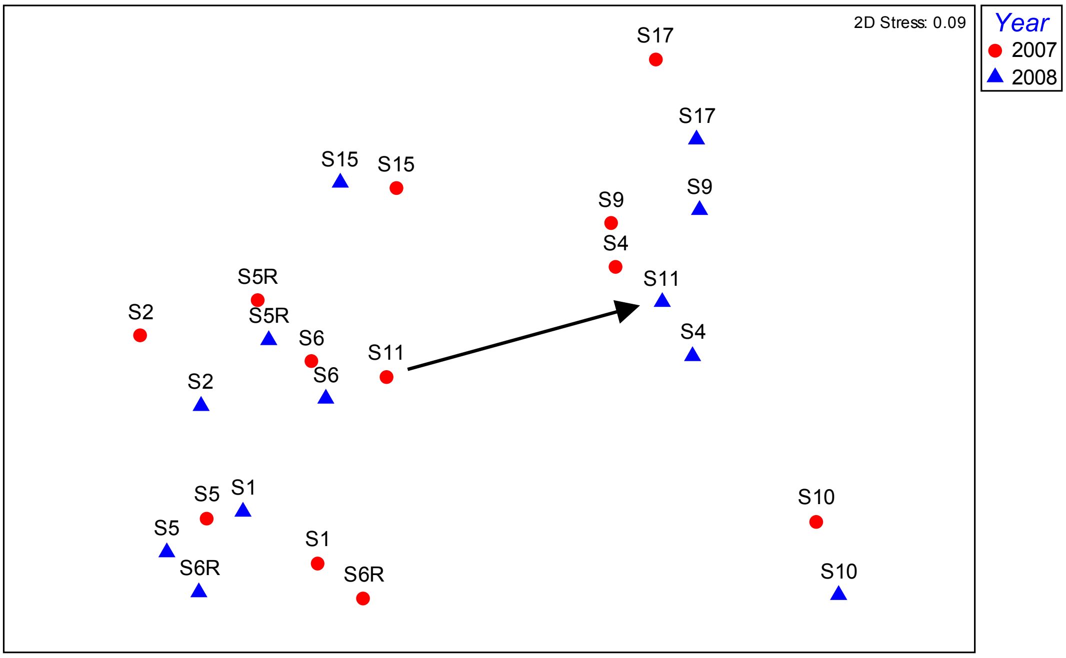

Figure 10. MDS plot of sample sites (per replicate data) around the proposed outfall in 2007 and 2008. The arrow indicates the movement of site 11.

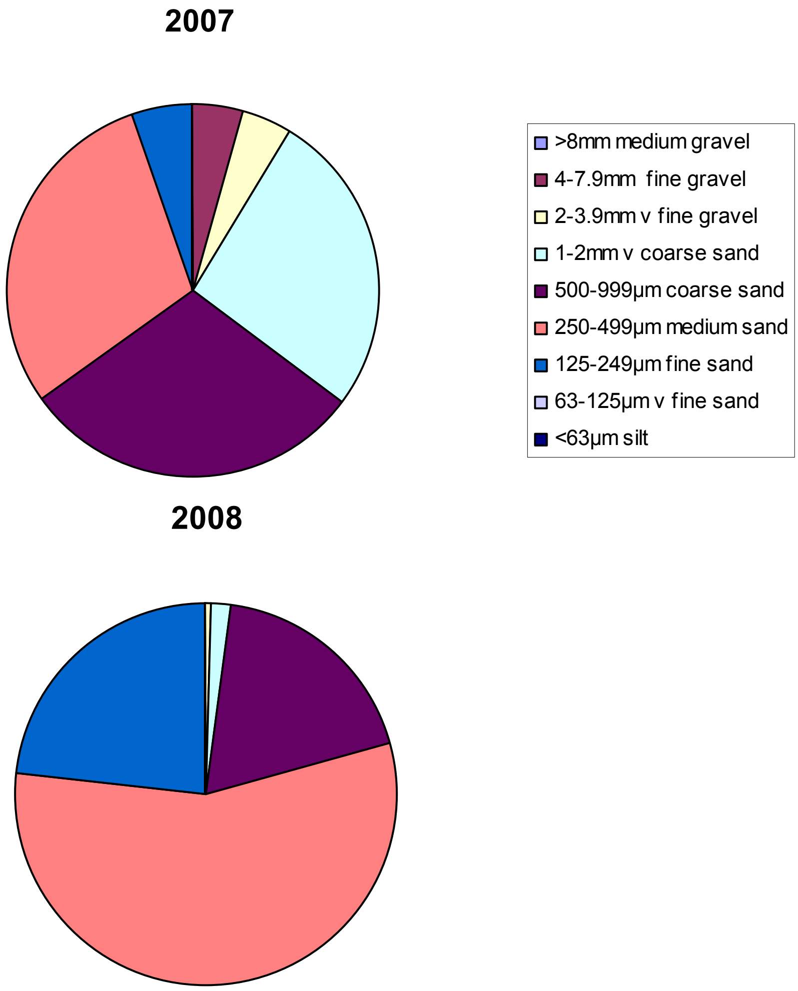

Figure 11. Pie charts showing the sediment composition at site 11 in 2007 and 2008.

Table 3. Ranked taxa list for site 11 in 2007 and 2008 based on average abundances per 0.1m^{2}.

2007		**2008**	
Polygordius	22	*Aonides pauchibranchiata*	16
Copepoda	21	*Bathyporeia elegans*	10
Nematoda	20	*Abra* juveniles	8
Pisione remota	18	*Spio decorata*	8
Protodorvillea kefersteini	15	*Echinoidea* juveniles	8
Aonides pauchibranchiata	10	*Echinocyamus pusillus*	6
Hesionura elongata	10	*Aricidea cerruti*	5
Spio filicornis	9	*Spiophanes bombyx*	4
Polygordius appendiculatus	9	*Bathyporeia* juveniles	4
Echinocyamus pusillus	8	*Hesionura elongata*	3
		Glycera oxycephala	3
		Synchelidium maculatum	3