Marine Surveys of Two Irish Sandbank cSACs

Prepared For:
National Parks & Wildlife

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1 INTRODUCTION

Aqua-Fact International Services Ltd was contracted by the Department of the Environment, Heritage and Local Government (DEHLG) to undertake two discrete subtidal benthic surveys, one in the Irish Sea at the Long Bank and Holdens Bank, off Co. Wexford and the second at the mouth of the Shannon Estuary on the Ballybunion Bank and Turbot Bank.

2 METHODOLOGY

2.1 Sampling Procedure and Processing

To carry out the assessment of the Long Bank and Holdens Bank in the Irish Sea and the Ballybunnion Banks and Turbot Bank in the Shannon Estuary, Aqua-Fact International Services Ltd. sampled 11 stations at the Long Bank and Ballybunnion Bank and 4 stations at the Holdens Bank and Turbot Bank. The station locations for the Irish Sea and Shannon Estuary can be seen in Figures 1 and 2 respectively. The accompanying coordinates for these stations can be seen in Tables 1 and 2 respectively. For station numbering purposes, the following codes were used for the sandbanks; LB – Long Bank; HB – Holdens Bank; BB – Ballybunnion Bank and TB – Turbot Bank. The MESH Report on "Review of Standards and Protocols for Seabed Habitat Mapping" (Mitchell & Golding, 2007) was adhered to during sampling.

Sampling at the Long and Holdens Bank took place on the 31st July 2007 and sampling at the Ballybunnion and Turbot Bank took place on the 14th June 2007. Stations were located using DGPS and this positioning method is accurate to within c. 1m. A 0.1m^2 van Veen was used to collect the benthic samples. Five replicate samples were taken at each of the 30 stations at both locations. Measurements of sediment depth were taken in a diagonal transect across the grab surface using a clean plexiglass ruler. Data on each sample, e.g. station number, date, time, depth of sediment, surface features and visible macrofauna were logged in a field notebook. The data for each station can be seen in Appendix I. The faunal returns were sieved on a 1 mm mesh sieve, stained with Rhodamine dye, fixed with 10% buffered formalin and preserved in 70% alcohol. Samples were then sorted under a microscope (x 10 magnification), into four main groups: Polychaeta, Mollusca, Crustacea and others. The 'others' group consisted of echinoderms, nematodes, nemerteans, cnidarians and other lesser phyla. The taxa were then identified to species level where possible. The MESH methodology for evaluating biomass was used to determine the total biomass for each species. Faunal returns were blotted dry on absorbant paper prior to wet weighing. The Echinoidea and

Holothurioidea were punctured to facilitate this process. Wet weight was determined to two decimal places using a Sartorious balance. All gastropods and bivalves were weighed in their shells. All hermit crabs and tubicolous species were removed from their shells/tubes prior to weighing. Appendix II contains the Long Bank and Holdens Bank faunal abundances and biomass and Appendix III contains the Ballybunnion Bank and Turbot Bank faunal abundance and biomass data.

An additional sample was taken at each station and used for sedimentological analyses. The sediment samples were taken through the opening on the top of the grab. Two sub samples (c. 250g each) were collected from each sample, for organic carbon and granulometric analysis. Both sub-samples were collected using a plastic spoon and placed in labeled plastic bags. All samples were stored immediately in a cold room on board the vessel and were frozen at –20^{o}C on return to the lab.

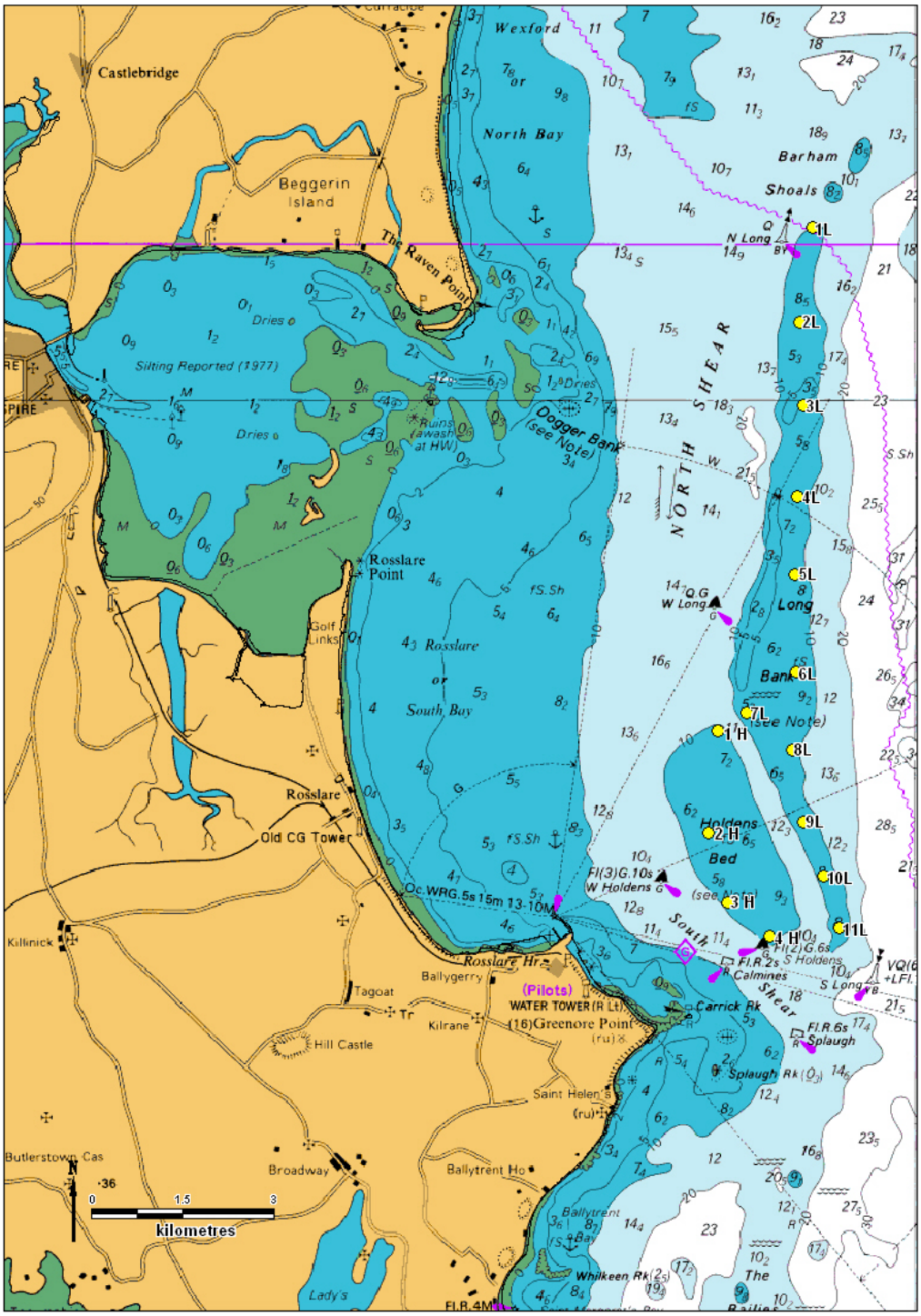

Figure 1: Station locations at the Long Bank and Holdens Bank sampled on the 31st July 2007.

Table 1: Station coordinates for the 15 stations sampled at the Long Bank and Holdens Bank on the 31st July 2006.

Station	Longitude	Latitude
1LB	6° 16.54′	52° 21.56′
2LB	6° 16.73′	52° 20.72′
3LB	6° 16.69′	52° 19.98′
4LB	6° 16.76′	52° 19.17′
5LB	6° 16.80′	52° 18.47′
6LB	6° 16.78′	52° 17.60′
7LB	6° 17.51′	52° 17.24′
8LB	6° 16.85′	52° 16.91′
9LB	6° 16.68′	52° 16.27′
10LB	6° 16.39′	52° 15.79′
11LB	6° 16.16′	52° 15.33′
1 HB	6° 17.92′	52° 17.08′
2 HB	6° 18.05′	52° 16.17′
3 HB	6° 17.77′	52° 15.55′
4 HB	6° 17.18′	52° 15.25′

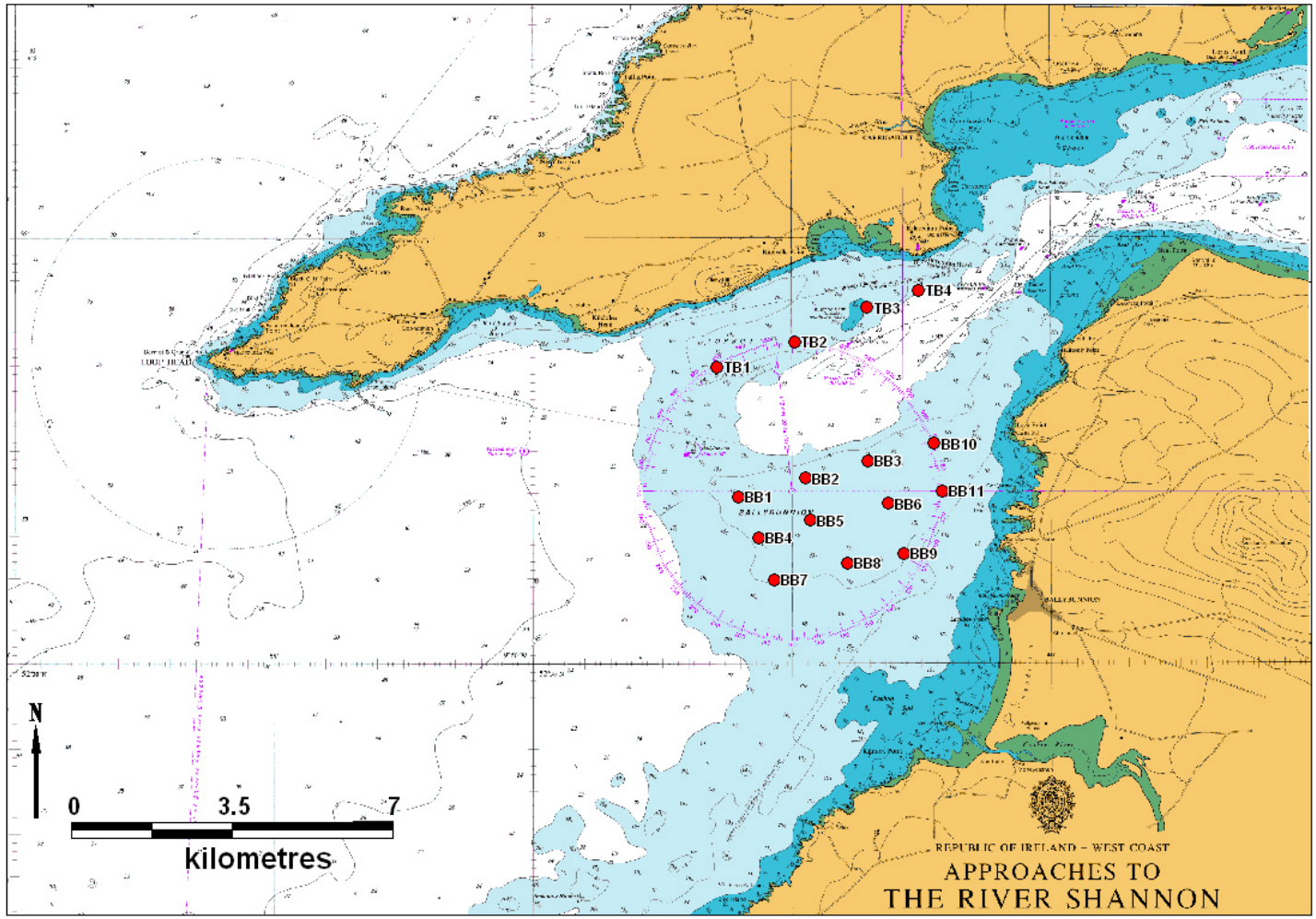

Figure 2: Station locations at the Ballybunnion Bank and Turbot Bank sampled on the 14th June 2006.

Table 2: Station coordinates of the 15 stations sampled at the Ballybunnion Bank and Turbot bank on the 14th June 2006.

Station	Longitude	Latitude
1BB	9°46.1′	52°32.0′
2BB	9°44.8′	52°32.2′
3BB	9°43.6′	52°32.4′
4BB	9°45.7′	52°31.5′
5BB	9°44.7′	52°31.7′
6BB	9°43.2′	52°31.9′
7BB	9°45.4′	52°31.0′
8BB	9°44.0′	52°31.2′
9BB	9°42.9′	52°31.3′
10BB	9°42.3′	52°32.6′
11BB	9°42.15′	52°32.04′
1 TB	9°46.5′	52°33.5′
2 TB	9°45.0′	52°33.8′
3 TB	9°43.6′	52°34.2′
4 TB	9°42.6′	52°34.4′

Particle size analysis was carried out using the traditional granulometric approach, which involved the dry sieving of approximately 100g of sediment using a series of Wentworth graded sieves. The process involved the separation of the sediment fractions by passing them through a series of sieves. Each sieve retained a fraction of the sediment, which were later weighed and a percentage of the total was calculated. Table 3 shows the classification of sediment particle ranges into size classes. Sieves, which corresponded to the range of particle size (Table 3) were used in the analyses.

Table 3: The classification of sediment particle size ranges into size classes (adapted from Buchanan, 1984).

Range of Particle Size	Classification	Phi Unit
<63 µm	Silt/Clay	>4 Ø
63-125 µm	Very Fine Sand	4 Ø, 3.5 Ø
125-250 µm	Fine Sand	3 Ø, 2.5 Ø
250-500 µm	Medium Sand	2 Ø, 1.5 Ø
500-1000 µm	Coarse Sand	1 Ø, 0.5 Ø
1000-2000 µm	Very Coarse Sand	0 Ø, -0.5 Ø
>2000 µm	Gravel	-1 Ø, -1.5 Ø, -2 Ø, -3 Ø, -4 Ø

Organic carbon analysis was carried out by OMAC labs, using the Chromic Acid Oxidation method described by Walkley & Black (1934). This involved oven drying the sediment to a constant weight, grinding the sample and titrating the sample with chromic acid. Results are presented as percentage organic carbon, chromic acid oxidation values (CAOV).

2.2 Data processing

2.2.1 Fauna

All faunal replicates were combined to give a total for each station. Data matrices of all the faunal data were compiled and later used for statistical analyses using the Primer ® (Plymouth Routines in Multivariate Ecological Research) programme.

Univariate statistics in the form of diversity indices were calculated. The following diversity indices were calculated:
1) Margalef's species richness index (D), (Margalef, 1958).

$$D = \frac{S-1}{\log_2 N}$$

where: N is the number of individuals
S is the number of species

2) Pielou's Evenness index (J), (Pielou, 1977).

$$J = \frac{H'(observed)}{H'_{max}}$$

where: H'_{max} is the maximum possible diversity, which could be achieved if all
species were equally abundant (= $\log_2 S$)

3) Shannon-Wiener diversity index (H'), (Pielou, 1977).

$$H' = -\sum_{i=1}^{S} p_i(\log_2 p_i)$$

where: p_I is the proportion of the total count accounted for by the i^{th} taxa

Species richness is a measure of the total number of species present for a given number of individuals. Evenness is a measure of how evenly the individuals are distributed among different species. The diversity index incorporates both of these parameters. Richness ranges from 0 (low richness) to 12 (high richness), evenness ranges from 0 (low evenness) to 1 (high evenness), diversity ranges from 0 (low diversity) to 5 (high diversity).

The PRIMER ® programme (Clarke & Warwick, 2001) was used to carry out multivariate analyses on the station-by-station faunal data. This was done for all surveys individually and on the combined survey data. All species/abundance data were fourth root transformed and used to prepare a Bray-Curtis similarity matrix in PRIMER ®. The fourth root transformation was used in order to down-weigh the importance of the highly abundant species and to allow the mid-range and rarer species to play a part in the similarity calculation. The similarity matrix was then used in classification/cluster analysis. This aim of this analysis was to find "natural

groupings' of samples, i.e. samples within a group that are more similar to each other, than they are similar to samples in different groups (Clarke & Warwick, *loc. cit.*). The PRIMER ® programme CLUSTER carried out this analysis by successively fusing the samples into groups and the groups into larger clusters, beginning with the highest mutual similarities then gradually reducing the similarity level at which groups are formed. The result is represented graphically in a dendrogram, the x-axis representing the full set of samples and the y-axis representing similarity levels at which two samples/groups are said to have fused.

The Bray-Curtis similarity matrix was also subjected to a non-metric multi-dimensional scaling (MDS) algorithm (Kruskal & Wish, 1978), using the PRIMER ® programme MDS. This programme produces an ordination, which is a map of the samples in two- or three-dimensions, whereby the placement of samples reflects the similarity of their biological communities, rather than their simple geographical location (Clarke & Warwick, 2001). With regard to stress values, they give an indication of how well the multi-dimensional similarity matrix is represented by the two-dimensional plot. They are calculated by comparing the interpoint distances in the similarity matrix with the corresponding interpoint distances on the 2-d plot. Perfect or near perfect matches are rare in field data, especially in the absence of a single overriding forcing factor such as an organic enrichment gradient. Stress values increase, not only with the reducing dimensionality (lack of clear forcing structure), but also with increasing quantity of data (it is a sum of the squares type regression coefficient). Clarke and Warwick (*loc. cit.*) have provided a classification of the reliability of MDS plots based on stress values, having compiled simulation studies of stress value behaviour and archived empirical data. This classification generally holds well for 2-d ordinations of the type used in this study. Their classification is given below:

Stress value < 0.05: Excellent representation of the data with no prospect of misinterpretation.
Stress value < 0.10: Good representation, no real prospect of misinterpretation of overall structure, but very fine detail may be misleading in compact subgroups.
Stress value < 0.20: This provides a useful 2-d picture, but detail may be misinterpreted particularly nearing 0.20.
Stress value 0.20 to 0.30: This should be viewed with scepticism, particularly in the upper part of the range, and discarded for a small to moderate number of points such as < 50.
Stress values > 0.30: The data points are close to being randomly distributed in the 2-d ordination and not representative of the underlying similarity matrix.

Each stress value must be interpreted both in terms of its absolute value and the number of data points. In the case of this study, the moderate number of data points indicates that the stress value can be interpreted more or less directly. While the above classification is arbitrary, it does provide a framework that has proved effective in this type of analysis.

2.2.2 *Sediment*

A procedure similar to multi-dimensional scaling (MDS) was carried out on the sediment data. The procedure is known as principal component analysis (PCA) and it is a 2D/3D ordination. Like MDS, it is based on an underlying (dis)similarity matrix; however in this case it is a Euclidean distance dissimilarity matrix not a Bray-Curtis similarity matrix. The data matrix used for PCA included all of the environmental parameters, i.e. sediment particle size percentage distributions (% sand, %silt-clay etc) and sediment organic carbon concentrations. This dataset was transformed to prevent any outliers having a disproportionate influence on the results. The organic carbon values were $\log_{10}$ transformed. The sediment particle size percentage distributions were square-root transformed. If any significant (pairwise correlation >0.95) correlations existed between variables, only one variable from that correlated group was included in the analysis, to prevent the correlation being exaggerated in the analysis. Following the transformations, the data were normalised to equalise the variance and standardise the contributory importance of each variable. The resulting data matrix was subjected to a correlation based PCA using the PRIMER® program PCA (Clarke & Warwick, 1994), to identify the parameters that accounted for a large proportion of the variance in the original data set. The variances of the principal components (eigen values), the proportion and cumulative proportion of the total variance, explained by each principal component, and the coefficients for each principal component (eigen vectors) were calculated. A two-dimensional PCA ordination of the data was constructed. The PCA plot defined the positions of samples in relation to each axes, which represented the full set of variables. Each station acquired a place on this graph and the location depended on a number of variables significant to that station and which set it apart from all the rest.

3 RESULTS

3.1 Long Bank and Holdens Bank

3.1.1 *Fauna*

The taxonomic identification of the benthic infauna across all 15 stations sampled in the Long and Holdens Bank survey yielded a total count of 125 species, comprising 2589 individuals, ascribed to 12 phyla. A complete listing of these species abundance is provided in Appendix II. Of the 125 species enumerated, 59 were polychaetes (segmented worms), 32 were crustaceans (crabs, shrimps, prawns), 16 were molluscs (mussels, cockles, snails etc.), 4 species were echinoderms (brittlestars, sea cucumbers), 5 species were pycnogonids (sea spiders), 1 species was a chaetognath (arrow worms) and 3

species were chordates (animals with a backbone). Five phyla were grouped as others; this group consisted of porifera (sponges), cnidarians (jellyfish, corals), nemerteans (ribbon worms), nematodes (round worms) and tunicates (sea squirts).

UNIVARIATE ANALYSES

Univariate statistical analyses were carried out on the combined replicate station-by-station faunal data. The following parameters were calculated and can be seen in Table 4; species numbers, number of individuals, richness, evenness and diversity. Biomass has also being included in this table. Species numbers ranged from 7 (LB7 and HB4) to 87 (LB3). Number of individuals ranged from 14 (HB1) to 1729 (LB3). Richness ranged from 1.65 (LB11) to 11.54 (LB3). Evenness ranged from 0.57 (LB6) to 0.96 (HB1). Diversity ranged from 1.98 (LB6) to 4.54 (LB3). Biomass ranged from <0.01 (LB5) to 22.72 (LB3).

Table 4: Diveristy indices for all 15 stations sampled at the long Bank and Holdens bank.

Station	Species Numbers	Number of Individuals	Richness	Evenness	Diversity	Biomass (g)
LB1	15	136	2.85	0.65	2.54	0.68
LB2	12	64	2.64	0.81	2.90	0.87
LB3	87	1729	11.54	0.71	4.54	22.72
LB4	9	21	2.63	0.84	2.68	1.76
LB5	10	23	2.87	0.87	2.89	<0.01
LB6	11	92	2.21	0.57	1.98	2.9
LB7	7	45	1.58	0.82	2.31	1.46
LB8	16	116	3.16	0.68	2.73	1.7
LB9	18	111	3.61	0.64	2.66	0.39
LB10	12	81	2.50	0.59	2.12	0.42
LB11	8	69	1.65	0.75	2.25	2.82
HB1	9	14	3.03	0.96	3.04	1.32
HB2	12	37	3.05	0.79	2.85	1.05
HB3	10	31	2.62	0.90	2.98	3.91
HB4	7	20	2.00	0.89	2.50	0.87

MULTIVARIATE ANALYSES

The dendrogram and the MDS plot can be seen in Figures 3 and 4 respectively. In the coastal environment, groups formed below a 40% are usually statistically meaningless. The groupings identified were based on a >40% similarity level. The classification analyses delineated two distinct groupings, with one group having 2 sub-groups, arbitrarily labeled:

- Group I (LB1 and LB2);
- Group II (HB3, LB4, LB11, HB4, LB10, LB7, HB1, LB8, LB5, LB6 and HB2);
    - Group IIa (LB11, HB4, LB10, LB7 and HB1)
    - Group IIb (LB8, LB5, LB6 and HB2)

Station LB3 separated from all the other stations at a similarity level of 7.52%. This station grouped alone due to the high number of species and individuals returned compared with the other stations. Station LB9 grouped alone due to the fact that the amphipod *Urothoe brevicornis* was the only species recorded in appreciable numbers. . Groups I and II separated at a similarity level of 29.09%. Group I had a similarity level of 53.49%. Group II had a similarity level of 44.65%. Within Group II, Group IIa formed at a similarity level of 56.34% and Group IIb formed at a similarity level of 49.4%. Station HB3 separated from Groups IIa and IIb at a similarity level of 44.65%. Station LB4 separated from Group IIa and IIb at a similarity level of 45.03%.

These delineations were also preserved in the MDS plot. The stress value of the MDS ordination is 0.07; this is a good representation of the data with no real prospect of misinterpretation of the overall structure, but very fine detail may be misleading in compact subgroups. Station LB3 (blue circle in Figure 4) grouped separately from the other stations. Stations LB1 and LB2 (Group I; red circle in Figure 4) grouped together. Station LB9 (yellow circle in Figure 4) grouped separately to Group II. Group II can be seen within the black line in Figure 4, within this Groups IIa (green circle) and IIb (pink circle) can be identified.

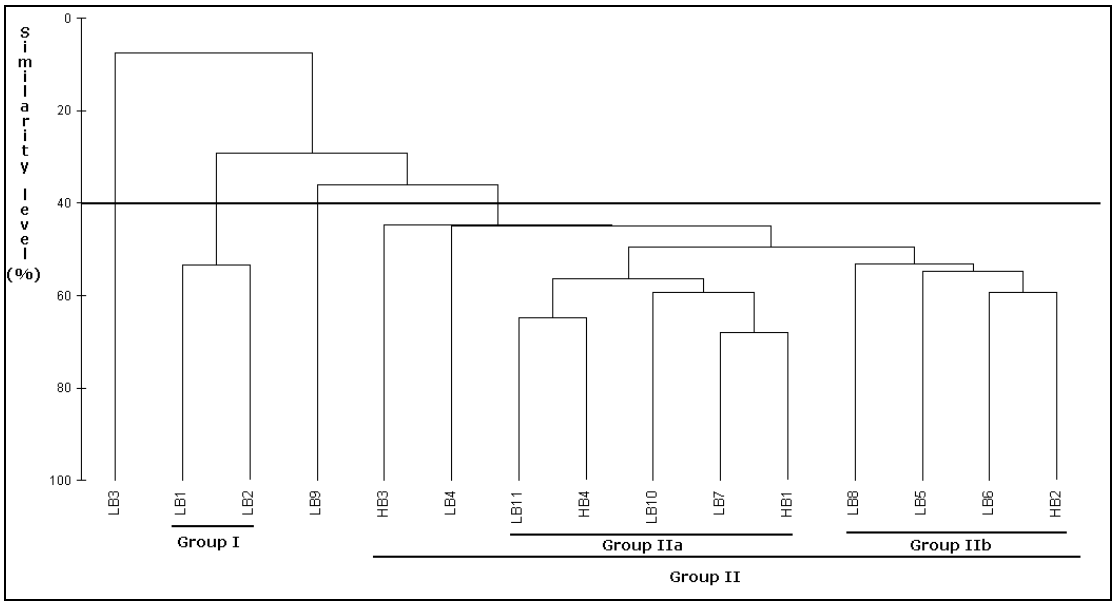

Figure 3: Dendrogram showing the 15 stations sampled at the Long Bank and Holdens Bank on the 31st July 2007.

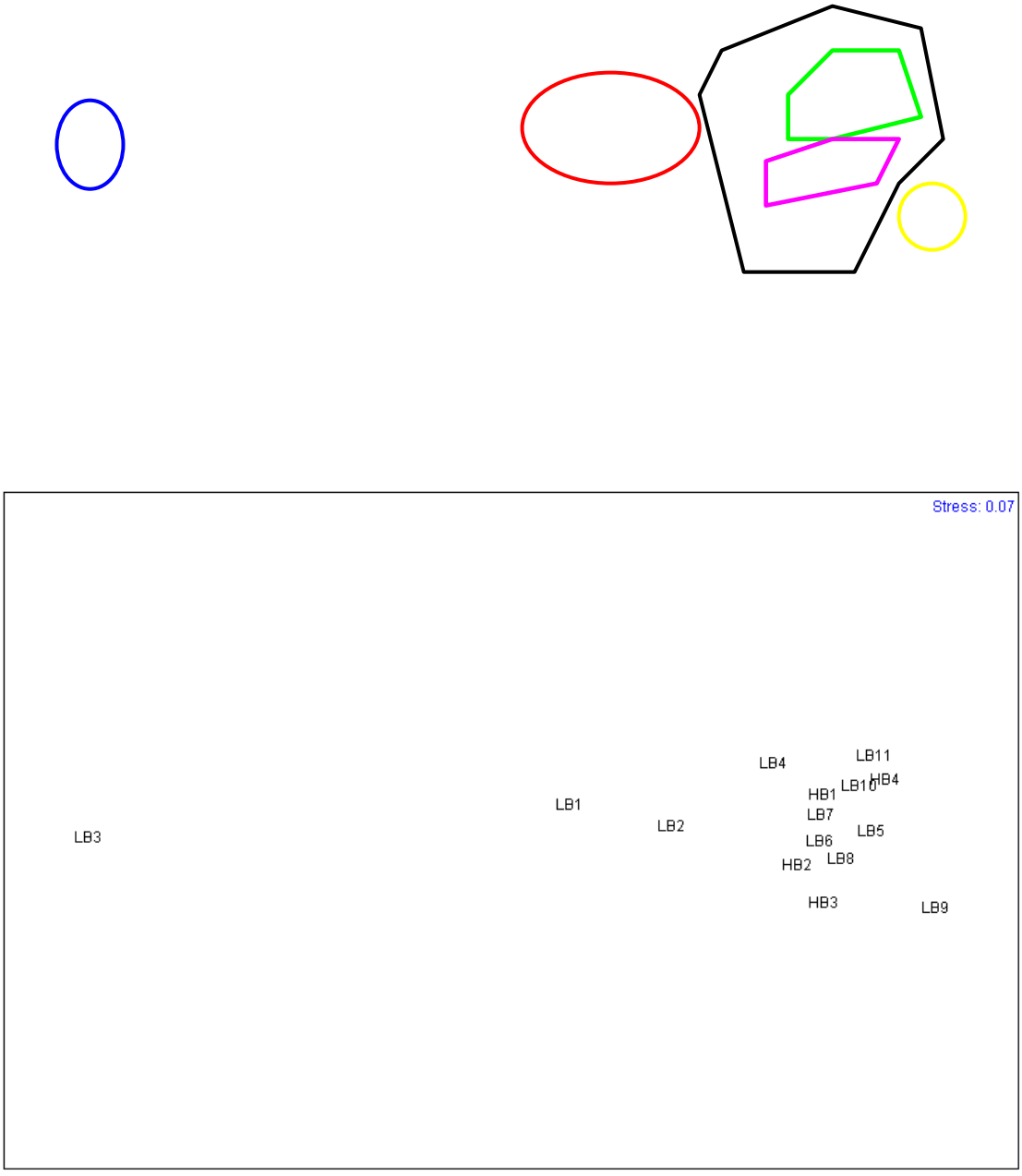

Figure 4: MDS plot of all 15 stations sampled at the Long Bank and Holdens Bank on the 31st July 2007.

Group I (LB1 and LB2) contained 20 species comprising 264 individuals. Eight species were present twice or less. This group was dominated by the bivalve molluscs *Donax vittatus* and *Fabulina fabula,* the polychaete *Nephtys cirrosa*, the amphipod *Bathyporeia elegans* and the polychaete *Spiophanes bombyx*. The biotope found here resembles the SS.SSA.IMuSa.FfabMag *Fabulina fabula* and

Magelona mirabilis with venerid bivalves and amphipods in infralittoral compacted fine muddy sand.

Group II (HB3, LB4, LB11, HB4, LB10, LB7, HB1, LB8, LB5, LB6 and HB2) contained 36 species comprising 549 individuals. Eighteen species were present twice or less. This group was dominated by the amphipod crustacean *Bathyporeia elegans*, the mysid crustacean *Gastrosaccus spinifer,* the polychaete *Nephtys cirrosa,* the amphipod *Urothoe brevicornis,* the polychaete *Spio filicornis* and the amphipod *Pseudocuma longicornis.* The biotope here resembles a mosaic of SS.SSA.IFiSa.IMoSa Infralittoral mobile clean sand with sparse fauna biotope and the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope.

Group IIa (LB11, HB4, LB10, LB7 and HB1) contained 18 species comprising 229 individuals. Nine species were present twice or less. This group was dominated by the mysid crustacean *Gastrosaccus spinifer,* the amphipods *Urothoe brevicornis* and *Bathyporeia elegans* and the polychaete *Nephtys cirrosa.* The biotope here resembles a mosaic of SS.SSA.IFiSa.IMoSa Infralittoral mobile clean sand with sparse fauna biotope and the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope.

Group IIb (LB8, LB5, LB6 and HB2) contained 24 species comprising 268 individuals. Twelve species were present twice or less. This group was dominated by the amphipod *Bathyporeia elegans,* the polychaete *Nephtys cirrosa,* the mysid *Gastrosaccus spinifer* and the polychaete *Spio filicornis.* The biotope here resembles a mosaic of the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope and the SS.SSA.IFiSa.IMoSa Infralittoral mobile clean sand with sparse fauna biotope.

Two other stations HB3 and LB4 formed part of Group II but were excluded from Groups IIa and IIb. Station HB3 contained 10 species comprising 31 individuals. Five species were present twice or less. This station was dominated by the polychaetes *Ophelia limacine, Nephtys cirrosa* and *Spio filicornis.* This station contained elements of the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope. Station LB4 contained 9 species comprising 21 individuals. Seven species were present twice or less. This station was dominated by the polychaete *Nephtys cirrosa* and the amphipod *Bathyporeia elegans.* The biotope found at this station resembles the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope.

The following stations grouped alone. Station LB3 contained 87 species comprising 1729 individuals. Thirty-seven species were present twice or less. This station was dominated by the polychaetes *Eumida bahusiensis, Polygordius* sp., *Pisione remota, Saccocirrus papillocerus*, the bivalve *Modiolula phaseolina* and the polychaete *Polygordius lacteus.* This station shows elements of the SS.SCS.CCS.Blan *Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel biotope. It should be noted here that his station had a very large number of species and individuals.

Station LB9 contained 18 species comprising 111 individuals. Twelve species were present twice or less. This station was dominated by the amphipods *Urothoe brevicornis* and *Bathyporeia elegans.* The biotope here resembles a mosaic of the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope and the SS.SSA.IFiSa.IMoSa Infralittoral mobile clean sand with sparse fauna biotope.

3.1.2 Sediment

The results from the traditional granulometric analysis can be seen in Table 5. The sediment sampled during along the Long Bank and Holdens Bank ranged from medium to fine sand. Out of the 15 stations sampled, 8 were dominated by fine sand (Stations LB1, LB2, LB3, LB6, LB7, LB8, HB1 and HB2) and the remaining 7 by medium sand (LB4, LB5, LB9, LB10, LB11, HB3 and HB4). Station LB4 contained the highest percentage of gravel (11.5%), station HB3 contained the highest percentage of very coarse sand (3.5%). Station LB10 contained the highest percentage of coarse sand (27.9%). Station LB11 contained the highest percentage of medium sand (84%). Station LB7 contained the highest percentage of fine sand (77.7%). Station LB1 contained the highest percentage of very fine sand (20.8%) and station LB2 contained the highest proportion of silt-clay (2.3%). Figure 5 shows the sediment type at each station sampled.

The results from the organic carbon analysis can be seen in Table 6. Organic carbon values at the Long Bank ranged from 0.03% (Station LB7) to 0.27% (Station LB2). Organic carbon values at the Holdens Bank ranged from 0.03% (Stations HB2 and HB4) to 0.05% (Station HB1).

Table 5: Granulometry results for the 15 stations sampled at the Long Bank and Holdens Bank on the 31st July 2007.

	Gravel (%)	Very Coarse Sand (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Very Fine Sand (%)	Silt-Clay (%)
LB1	0.7	0.8	2.5	36.4	38.5	20.8	0.2
LB2	6.6	3.1	6.3	26.7	47.9	7.1	2.3
LB3	6.5	2.8	5.4	28.1	51.7	4.4	1
LB4	11.5	2.5	5.4	60.3	20.2	0.2	0
LB5	1	1.4	7.8	62.3	27.1	0.4	0
LB6	0.9	0.1	1.7	43.5	53.3	0.4	0
LB7	0	0.1	1.2	20.2	77.7	0.7	0
LB8	0	0	0.5	33.3	65.3	0.8	0
LB9	0	0.1	1.2	59.3	39	0.3	0
LB10	0.9	0.5	27.9	49.7	20.9	0.1	0
LB11	0.3	0.3	2.1	84	13.2	0.1	0
HB1	0	0.2	1.8	47.6	50.2	0.1	0
HB2	0.5	0.3	23.2	26.8	48.7	0.5	0
HB3	2.4	3.5	10.8	82.9	0.3	0.1	0
HB4	0.4	0.7	4.7	72.1	22	0.1	0

Table 6: Total organic carbon results (%) for the 15 stations sampled at the Long and Holdens Banks on the 31st July 2007.

Station	TOC (%)
LB1	0.08
LB2	0.27
LB3	0.18
LB4	0.05
LB5	0.05
LB6	0.05
LB7	0.03
LB8	0.05
LB9	0.04
LB10	0.04
LB11	0.05
HB1	0.05
HB2	0.03
HB3	0.04
HB4	0.03

Faunal Group I (LB1 and LB2) were dominated by fine sand with a relatively high very fine sand component. Station LB2 had the highest organic carbon value.

Group II (HB3, LB4, LB11, HB4, LB10, LB7, HB1, LB8, LB5, LB6 and HB2) was dominated by medium and fine sand with low coarse and silt-clay contents for the most part. Stations HB3 and LB4 had relatively high gravel and coarse sand components. Organic carbon levels were low.

Group IIa (LB11, HB4, LB10, LB7 and HB1) was dominated by medium and fine sand with low coarse and silt-clay contents. Organic carbon levels were low.

Group IIb (LB8, LB5, LB6 and HB2) was dominated by medium and fine sand with low coarse and silt-clay contents. Organic carbon levels were low.

Station LB3 was dominated by fine sand with a relatively high gravel component compared to most other stations. Organic carbon levels at this station were high compared to the other stations.

Station LB9 was dominated by medium sand with a relatively high fine sand component. Organic carbon levels at this station were low.

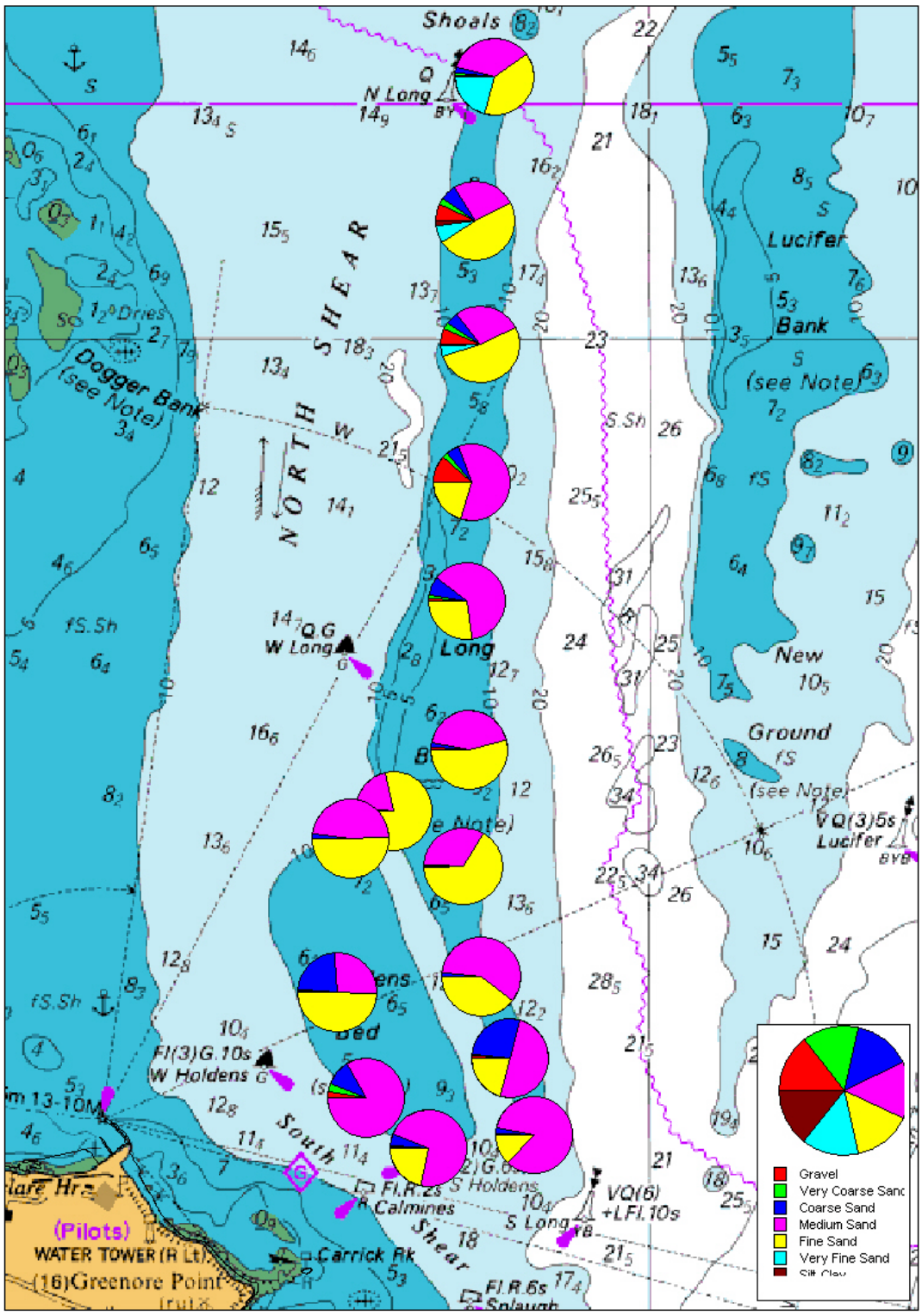

Figure 5: Sediment type at each station in the Long Bank and Holdens Bank.

Figure 6 shows the PCA ordination of the sediment data analysed from the Long and Holdens Banks. The variation seen in this 2-D ordination accounted for 74.9% of the overall variation, PC1 accounted for 38.9% of the variation, whereas PC2 accounted for 36.0% of the variation. The stations characterized by medium sand are outlined in red in Figure 6 and the stations characterized

by fine sand are outlined in blue in Figure 6. Station LB9, while dominated by medium sand is located lower down the plot that the other medium sand stations, this was due to the high occurrence of fine sand at this station also. Station HB3, while dominated by medium sand also had the highest percentage of very coarse sand and relatively high levels of gravel and coarse sand. Station LB4 groups further away from the other stations due to this station having the highest gravel content. Within the fine sand grouping, stations LB2 and LB3 grouped to the left of the plot because of their relatively high gravel content and organic carbon content. Station LB1 is located in the centre of the fine sand grouping because of its high very fine sand content. The remaining stations in this group were characterised by their high fine sand content.

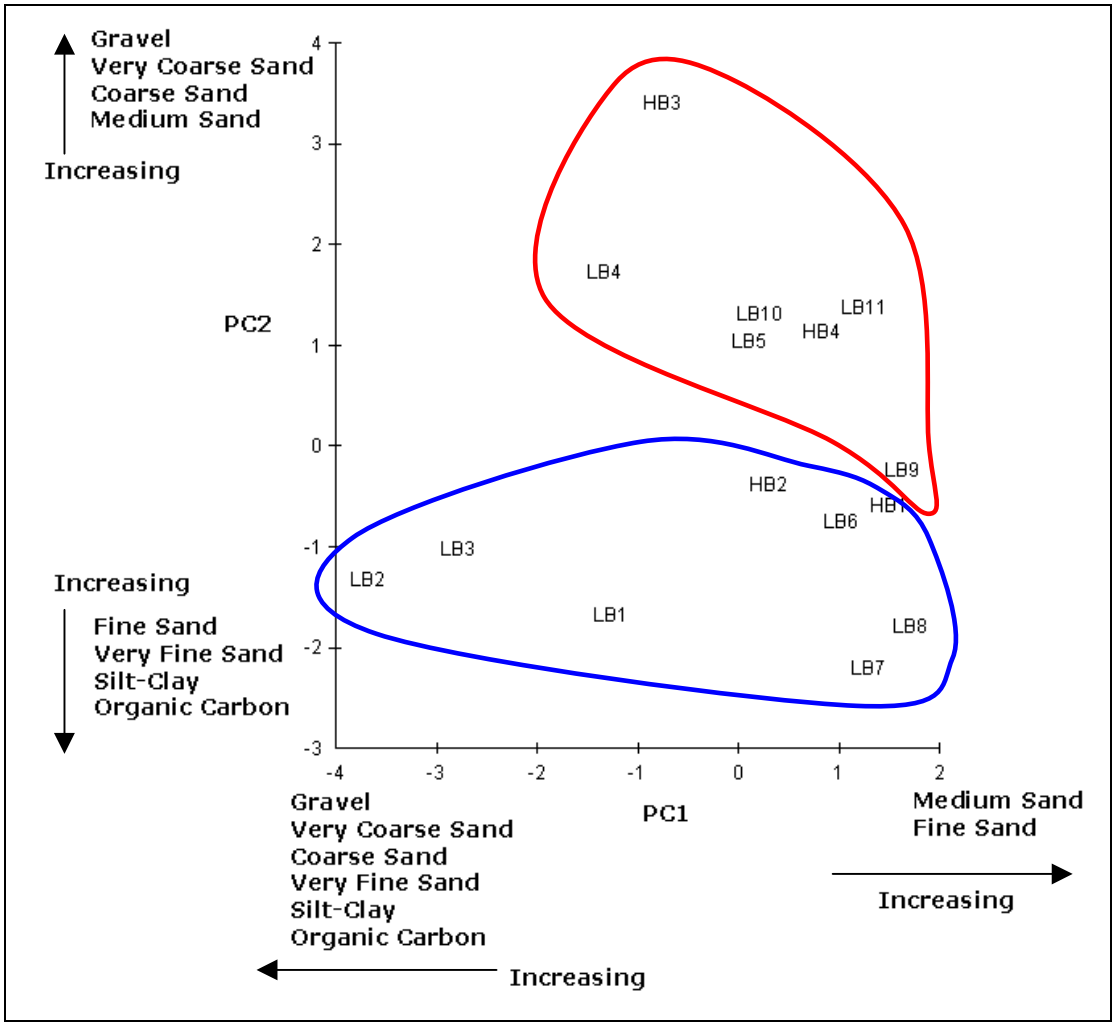

Figure 6: PCA ordination of the environmental data sampled at theLong and Holdens Banks on the 31st July 2007.

3.2 Ballybunnion Bank and Turbot Bank

3.2.1 Fauna

The taxonomic identification of the benthic infauna across all 15 stations sampled in the Ballybunnion and Turbot Bank survey yielded a total count of 81 species, comprising 3059 individuals, ascribed to 8 phyla. A complete listing of these species abundance is provided in Appendix III. Of the 81 species enumerated, 29 were polychaetes (segmented worms), 32 were crustaceans (crabs, shrimps, prawns), 11 were molluscs (mussels, cockles, snails etc.), 2 species were echinoderms (brittlestars, sea cucumbers) and 2 species were chordates (animals with a backbone). Two phyla were grouped

as others; this group consisted of cnidarians (jellyfish, corals) and sipunculida (unsegmented worms).

UNIVARIATE ANALYSES

Univariate statistical analyses were carried out on the averaged replicate station-by-station faunal data. The following parameters were calculated and can be seen in Table 7; species numbers, number of individuals, richness, evenness and diversity. Biomass has also being included in this table. Species numbers ranged from 10 (TB4) to 23 (BB8 and BB9). Number of individuals ranged from 20 (TB4) to 1626 (TB3). Richness ranged from 1.49 (TB3) to 4.79 (BB6). Evenness ranged from 0.42 (TB2) to 0.87 (TB4). Diversity ranged from 1.73 (TB2) to 3.69 (BB6). Biomass ranged from 0.22g (BB3) to 10.63g (BB4).

Table 7: Diveristy indices for all 15 stations sampled at the long Bank and Holdens bank.

Station	Species Numbers	Number of Individuals	Richness	Evenness	Diversity	Biomass
BB1	22	88	4.69	0.81	3.62	1.41
BB2	17	66	3.82	0.81	3.32	2.46
BB3	16	38	4.12	0.82	3.27	0.22
BB4	22	140	4.25	0.70	3.10	10.63
BB5	15	86	3.14	0.79	3.11	8.66
BB6	22	80	4.79	0.83	3.69	3.41
BB7	20	204	3.57	0.70	3.04	0.81
BB8	23	198	4.16	0.74	3.36	2.81
BB9	23	142	4.44	0.81	3.66	0.93
BB10	11	42	2.68	0.65	2.24	0.36
BB11	19	73	4.20	0.80	3.39	1.26
TB1	19	105	3.87	0.85	3.60	0.58
TB2	18	151	3.39	0.42	1.73	1.26
TB3	12	1626	1.49	0.54	1.95	7.95
TB4	10	20	3.00	0.87	2.90	0.95

MULTIVARIATE ANALYSES

The dendrogram and the MDS plot can be seen in Figures 7 and 8 respectively. In the coastal environment, groups formed below a 40% are usually statistically meaningless. The groupings identified were based on a >40% similarity level. The classification analyses delineated one distinct group, having 3 sub-groups, arbitrarily labeled:

- Group I (BB10, BB2, BB8, BB9, TB1, BB6, BB1, BB5, BB11, BB4 and BB7);
    - Group Ia (BB10)
    - Group IIb (BB2, BB8, BB9, TB1, BB6, BB1, BB5 and BB11)
    - Group Ic (BB4 and BB7)

Stations TB3 and TB4 separated away from all the other stations at a similarity level of 8.38%. These two stations separated from each other at a similarity level of 24.71%. Station TB3 grouped alone due to the very high number of individuals found at this station. Station TB4 grouped alone due to the low faunal returns from this station. Station TB2 grouped alone due to the polychaete *Pisione remota* being the only species recorded in appreciable numbers; it separated from the other stations at a similarity level of 23.91%. Station BB3 grouped alone due to dominance of the cumacean *Cumopsis* sp.; it separated from the other stations at a similarity level of 35.16%. Group I formed a group at a similarity level of 45.06%. Group Ia (Station BB10) separated from the other Group I stations at this level due to the poor faunal diversity compared with the Groups Ib and Ic. Group Ib (BB2, BB8, BB9, TB1, BB6, BB1, BB5 and BB1) separated from Group Ic at a similarity level of 54.26%. Group Ib had a similarity level of 61.61%. group Ic had a similarity level of 60.89%. Groups Ib and Ic separated due to the varying dominance of some species within the groups.

These delineations were also preserved in the MDS plot. The stress value of the MDS ordination is 0.05; this is an excellent representation of the data with no prospect of misinterpretation. Stations TB2 (blue circle in Figure 8), TB3 (red circle in Figure 8), TB2 (green circle in Figure 8) and BB3 (yellow circle in Figure 8) all grouped alone. Group I is outlined in black in Figure 8, the subgroups can be seen within this; Ia (pink circle), Ib (orange circle) and Ic (purple circle).

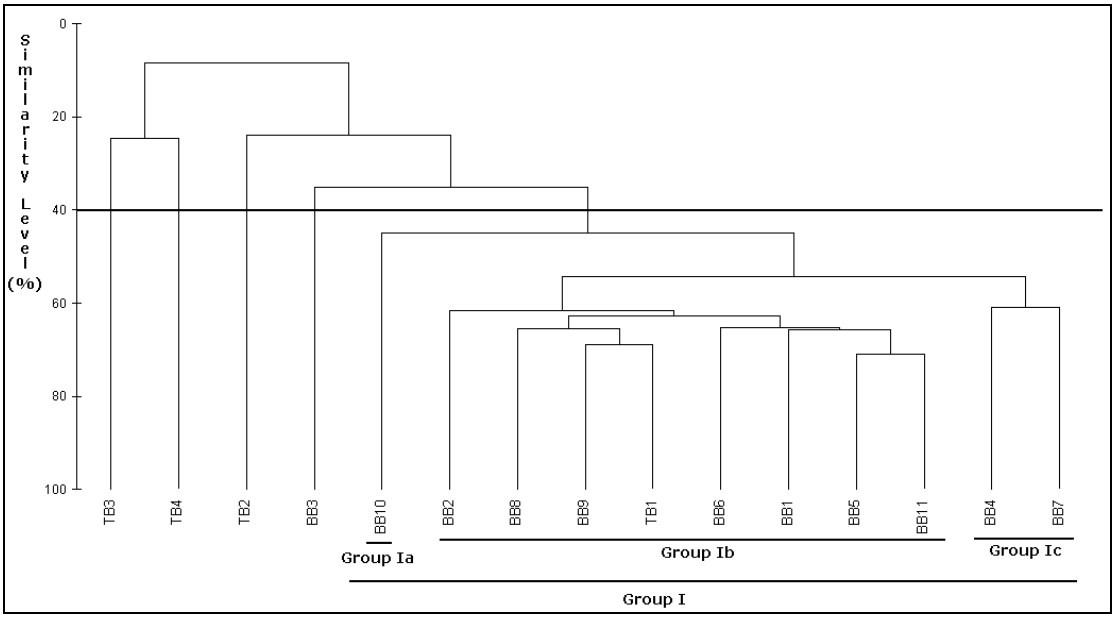

Figure 7: Dendrogram of all 15 stations sampled at the Ballybunnion Bank and Turbot Bank on the 14th June 2007.

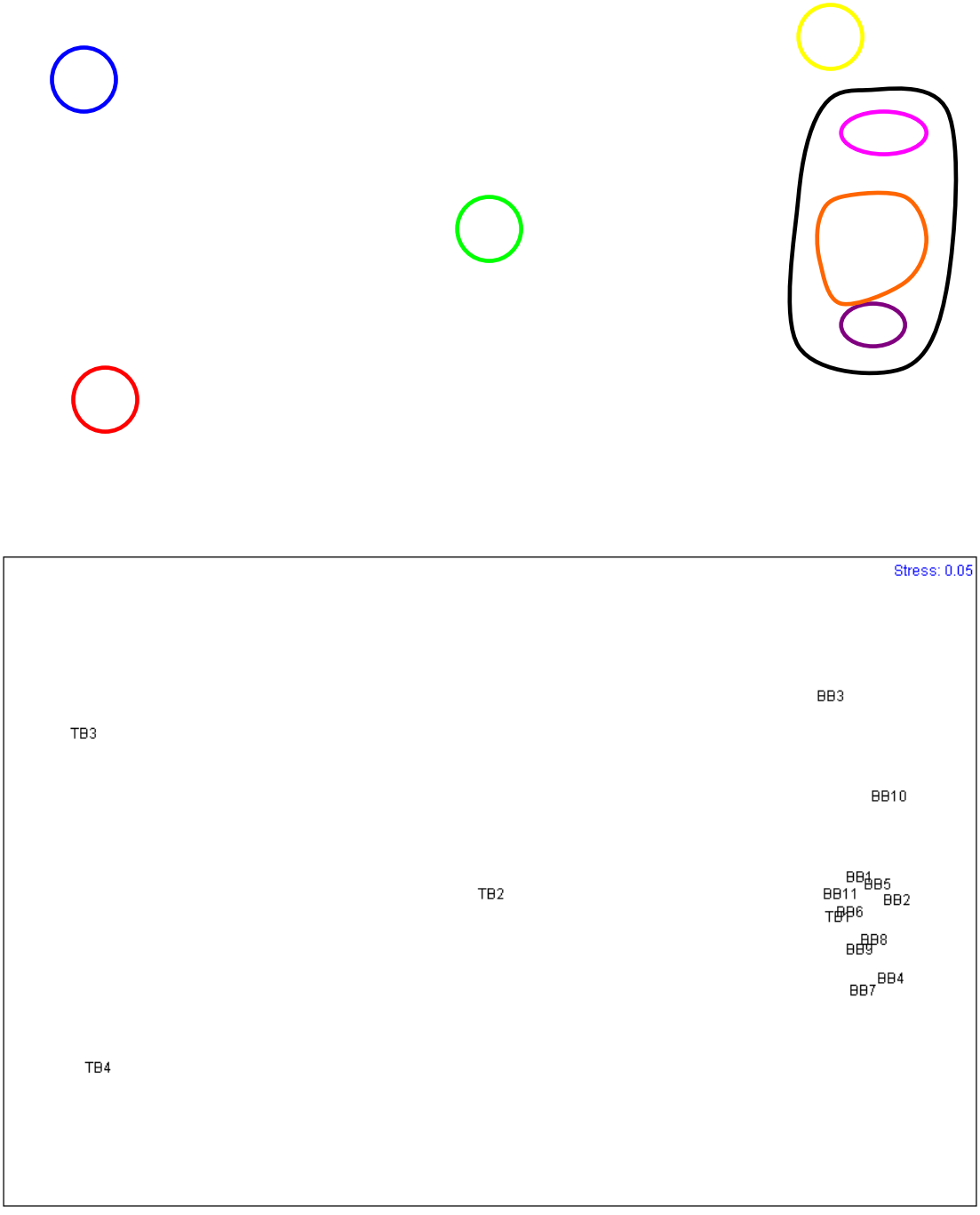

Figure 8: Dendrogram of all 15 stations sampled at the Ballybunnion Bank and Turbot Bank on the 14th June 2007.

Group I (BB10, BB2, BB8, BB9, TB1, BB6, BB1, BB5, BB11, BB4 and BB7) contained 56 species comprising 1224 individuals. Twenty-six species were present twice or less. The dominants of this group were the polychaete *Magelona mirabilis* and *Nephtys cirrosa,* the amphipods *Bathyporeia elegans, Pontocrates altamarinus, Pseudocoma longicornis,* the bivalves *Fabulina fabula, Donax vittatus,* the cumacean *Cumopsis fagei*, the polychaetes *Glycera lapidum,*

Caulleriella zetlandica and *Spiophanes bombyx*. The biotope encountered here resembles the SS.SSA.IMuSa.FfabMag *Fabulina fabul*a and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand.

Group Ia (BB10) contained 11 species comprising 42 individuals. Eight species were present twice or less. The dominant of this group/station was the polychaete *Nephtys cirrosa*. The biotope at this station contained elements of the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope.

Group Ib (BB2, BB8, BB9, TB1, BB6, BB1, BB5 and BB11) contained 47 species comprising 838 individuals. Twenty species were present twice or less. The dominants of this group were the polychaetes *Magelona mirabilis* and *Nephtys cirrosa,* the amphipods *Bathyporeia elegans, Pontocrates altamarinus, Pseudocuma longicornis,* the bivalves *Donax vittatus* and *Fabulina fabula* and the cumacean *Cumopsis fagei.* The biotope encountered here resembles the SS.SSA.IMuSa.FfabMag *Fabulina fabul*a and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand.

Group Ic (BB4 and BB7) contained 30 species comprising 344 individuals. Eighteen species were present twice or less. The dominants of this group were the polychaete *Magelona mirabilis,* the amphipods *Bathyporeia elegans, Pontocrates altamarinus,* the polychaete *Nephtys cirrosa* and the bivalve *Fabulina fabula.* The biotope encountered here resembles the SS.SSA.IMuSa.FfabMag *Fabulina fabul*a and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand.

The following stations grouped alone. Station BB3 contained 16 species comprising 38 individuals. Thirteen species were present twice or less. The dominants of this station were the cumacean *Cumopsis* sp. and the polychaete *Nephtys cirrosa.* This station contained elements of the SS.SCS.ICS.CumCset Cumaceans and *Chaetozone setosa* in infralittoral gravelly sand biotope and the SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand biotope.

Station TB2 contained 18 species comprising 151 individuals. Twelve species were present twice or less. The dominant of this group was the polychaete *Pisione remota.*This station resembles a mosicac of the SS.SCS.ICS.Glap *Glycera lapidum* in impoverished infralittoral mobile gravel and sand biotope and the SS.SCS.ICS.CumCset Cumaceans and *Chaetozone setosa* in infralittoral gravelly sand.

Station TB3 contained 12 species comprising 1626 individuals. Four species were present twice or less. The dominants of this station were the polychaetes *Polygordius lacteus, Saccocirrus papillocerus*, *Pisione remota, Syllides longocirrata, Glycera lapidum, Sphaerosyllis bulbous* and the amphipod *Atylus falcatus.* This station shows elements of the SS.SCS.CCS.Blan *Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel biotope. It is worth noting that this station contained an enormous number of individuals for the 12 species present.

Station TB4 contained 10 species comprising 20 individuals. Eight species were present twice or less. The dominant of this group was the polychaete *Pisione remota.* This station shows elements of the SS.SCS.ICS.Glap *Glycera lapidum* in impoverished infralittoral mobile gravel and sand.

3.2.2 Sediment

The results from the traditional granulometric analysis can be seen in Table 8. The sediment sampled along the Ballybunnion Bank was all classified at fine sand. The sediment sampled along the Turbot Bank varied between gravel , coarse sand, medium sand and fine sand. Station TB3 contained the highest percentage of gravel (55.7%), station TB2 contained the highest percentage of very coarse sand (14.5%) and coarse sand (42.8%). Station TB4 contained the highest percentage of medium sand (70.6%). Station BB2 contained the highest percentage of fine sand (91.7%). Station BB7 contained the highest percentage of very fine sand (28.7%) and station TB1 contained the highest proportion of silt-clay (0.8%). Figure 9 shows the sediment type at each station.

The results from the organic carbon analysis can be seen in Table 9 Organic carbon values at the Ballybunnion Bank ranged from 0.08% (Station BB10) to 0.18% (Stations BB7 and BB9). Organic carbon values at the Turbot Bank ranged from 0.17% (Station TB1) to 0.31% (Station TB3).

Table 8: Granulometry results for the 15 stations sampled at the Ballybunnion Bank and Turbot Bank on the 14th June 2007.

Station	Gravel (%)	Very Coarse Sand (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Very Fine Sand (%)	Silt-Clay (%)
BB1	0	0.1	0.2	2.5	87.2	9.9	0.2
BB2	0	0	0	4.2	91.7	3.9	0.2
BB3	0	0	0.1	14.4	83.5	2	0.1
BB4	0.2	0.1	0.2	1.1	82.3	15.8	0.3
BB5	0	0	0.1	1.1	87.9	10.4	0.4
BB6	0	0	0.1	3.2	89	7.5	0.2
BB7	0	0	0	0.3	70.4	28.7	0.5
BB8	0.2	0.1	0.1	0	81.3	17.8	0.4
BB9	0	0	0.2	0.9	81.2	17.3	0.4
BB10	0	0	0.7	12.1	85	2.1	0.1
BB11	0	0	0.3	2.1	90.3	7.1	0.1
TB1	0.5	0	0.2	3.9	68.9	25.6	0.8
TB2	5	14.5	42.8	34.4	2.3	1	0.1
TB3	55.7	28	9.7	4.7	1.2	0.8	0.1
TB4	0.1	1.5	26.9	70.6	0.8	0.1	0

Table 9: Total organic carbon (%) results from the Ballybunnion and Turbot Banks on the 14th June 2007.

Station	TOC (%)
BB1	0.09
BB2	0.10
BB3	0.11
BB4	0.12
BB5	0.10
BB6	0.11
BB7	0.18
BB8	0.12
BB9	0.18
BB10	0.08
BB11	0.10
TB1	0.17
TB2	0.23
TB3	0.31
TB4	0.20

Faunal Group I (BB10, BB2, BB8, BB9, TB1, BB6, BB1, BB5, BB11, BB4 and BB7) was dominated by fine sand with a low gravel, coarse sand and silt-clay component. This group had a low organic carbon level.

Station BB3 was dominated by fine sand with a relatively low organic carbon content. Station TB2 was dominated by coarse sand with a relatively high concentration of very coarse sand and medium sand. Organic carbon was high at this station compared to the other stations sampled. Station TB3 was dominated by gravel with a high percentage of very coarse sand and a low fines component. This station had the highest organic carbon level of all stations sampled. Station TB4 was dominated by medium sand with a high coarse sand component. Organic carbon at this station was relatively high.

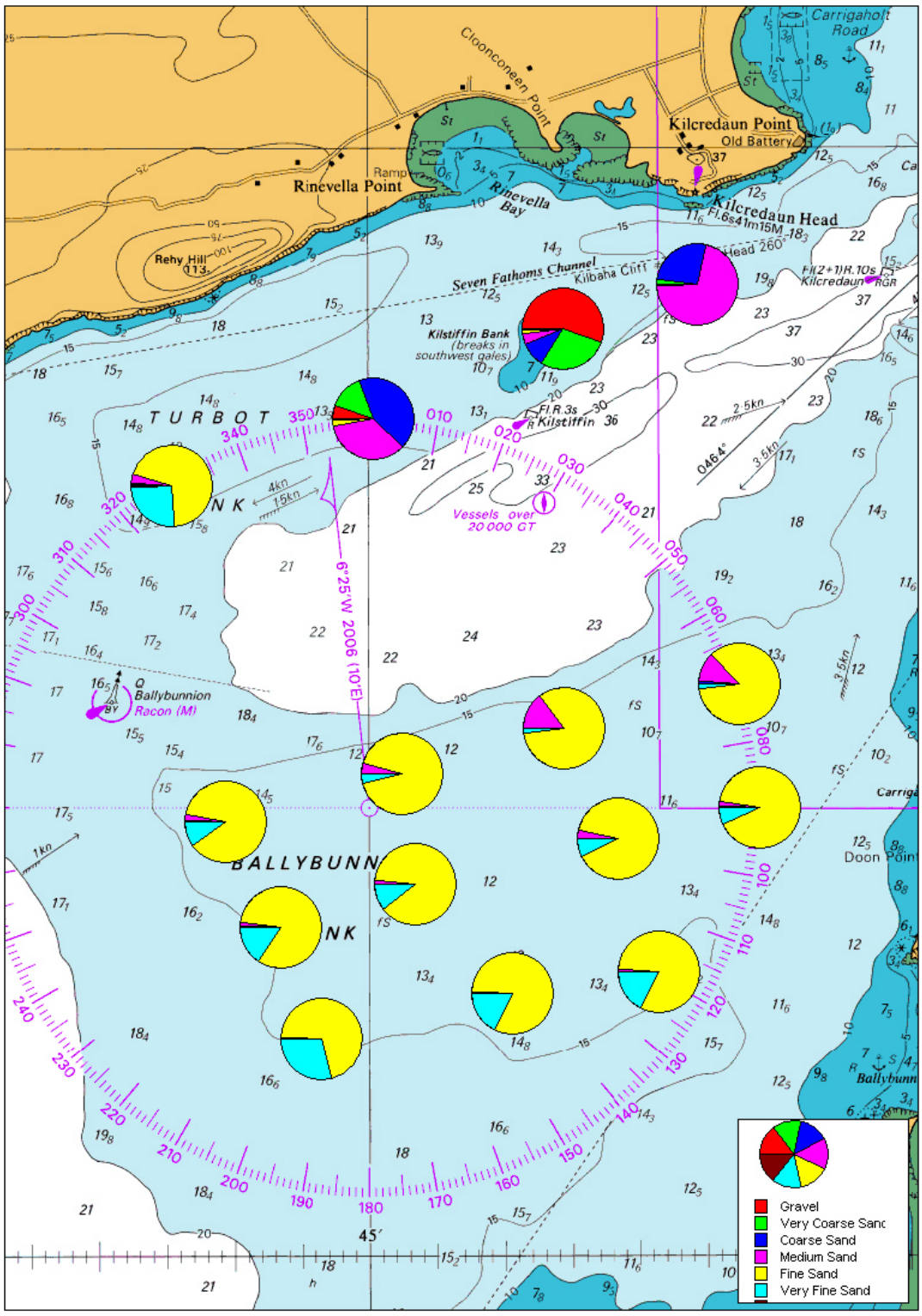

Figure 9: Sediment type at each station sampled in the Ballybunnion Bank and Turbot Bank.

Figure 10 shows the PCA ordination of the sediment data analysed from the Ballybunnion and Turbot Banks. The variation seen in this 2-D ordination accounted for 88.0% of the overall variation, PC1 accounted for 65.0% of the

variation, whereas PC2 accounted for 23.1% of the variation. The stations characterised by fine sand are outlined in blue in Figure ?, the variation seen along the length of PC2 is due to their varying levels of organic carbon. Stations TB4, TB2 and TB3 grouped individually. Station TB4 (red circle) was dominated by medium sand, station TB2 (green circle) was dominated by coarse sand and station TB3 (black circle) was dominated by gravel and had the highest organic carbon level.

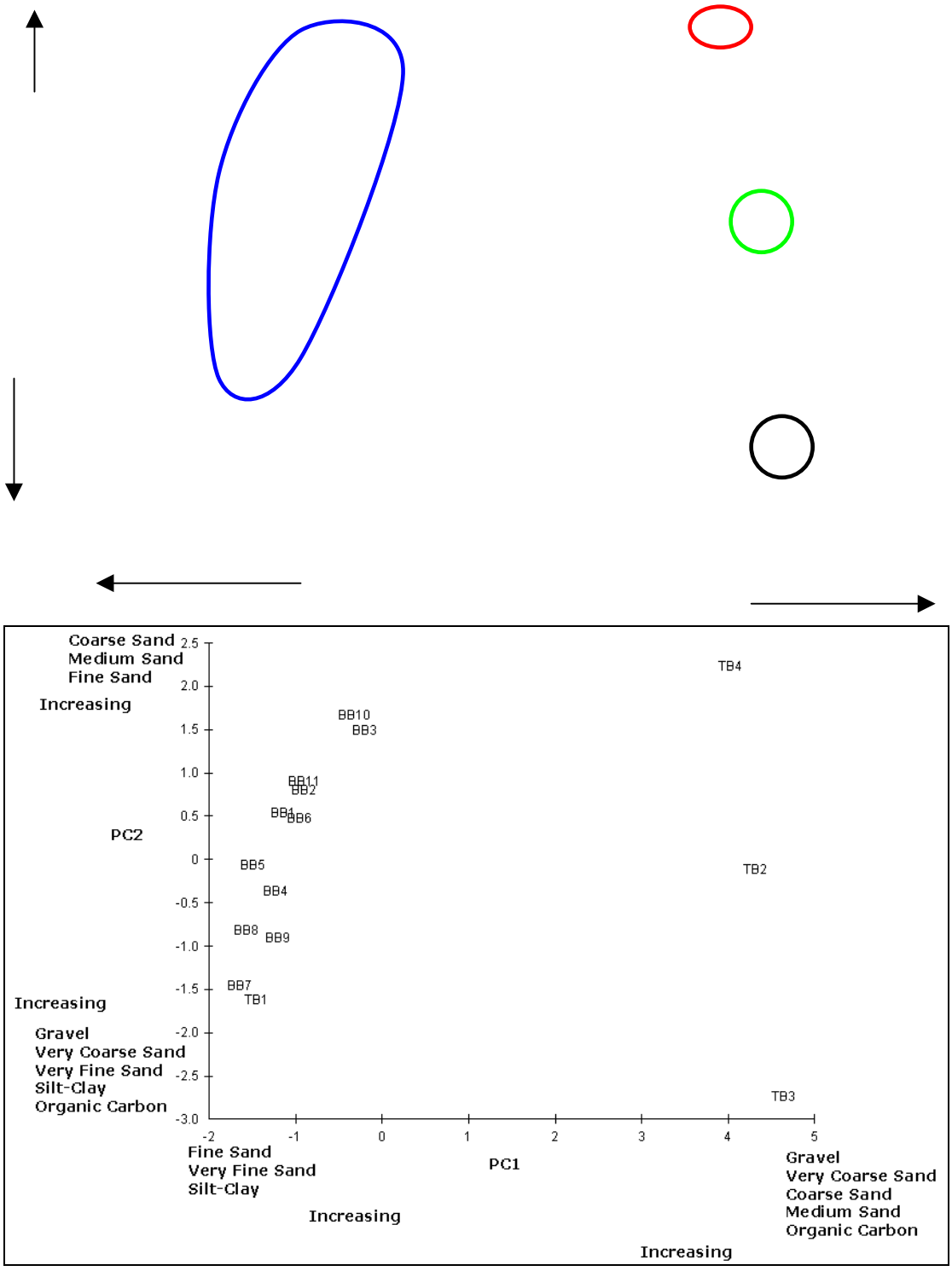

Figure 10: PCA ordination of the environmental data sampled at the Ballybunnion and Turbot Banks on the 14st June 2007.

4 DISCUSSION

4.1 Long Bank and Holdens Bank

Keegan *et al.,* (1987) described regions of the western Irish Sea as being characterised by polychaetes such as *N. cirrosa, O. borealis* and *Lanice conchilega* and the bivalve *S. elliptica.* Mackie *et al.* (1995) have shown that areas in the locality of the Long Bank and Holdens Bank have been characterised as a "Shallow *Venus*" community. This community occurs at depths of 5-40m in nearshore sands. Often such localities are in areas subjected to strong currents and the sand formations consist of sand banks or sand wave systems. Two sub-communities related to preferred sand grades/stability are recognised. The *Tellina* sub-community occurs in fine stable sands and typical species include the bivalve *Tellina fabula* (syn. *Fabulina fabula*) and the polychaetes *Magelona mirabilis*. The *Spisula* sub-community occurs in medium to coarse sands subject to disturbance and typical species include the bivalve *Spisula elliptica* and the polychaetes *Nephtys cirrosa*. The shallow Venus community is widely distributed around the Irish Sea coastline.

The Long Bank itself, was surveyed by Aqua-Fact (1989). The sediments here were classified as being medium sands with very low values of organic carbon. The findings of this report indicated an area of high hydrodynamic activity with strong, tidally induced currents speeds operating. Such currents would not allow for the settling out of finer particles of both organic and inorganic matter. This type of current regime would also tend to make the sediments quite mobile with material being transported over some distances during strong phases of the tidal cycle. This area was also characterised by low species numbers and densities. The low species numbers and densities in such a habitat were more likely due to the inhospitable nature of the environment, i.e. mobile sands, which demands a specialised lifestyle to allow the animals either cope with or escape from sand abrasion (Tyler & Shackley, 1980; Keegan *et al.,* 1987). Wheeler *et al.* (2000), with the use of side scan sonar also revealed evidence of seabed mobility on and adjacent to the Bank. They also found that sand waves increased in amplitude towards the edge of the Bank suggesting that currents were highest closest to the Bank.

Aqua-Fact has carried out similar studies on sandbanks in the Irish Sea. In 2005, Aqua-Fact sampled 12 stations along the Kish and Blackwater banks respectively (Aqua-Fact, 2005). The Kish bank was dominated by sands, which ranged from medium to very fine sand. The organic carbon concentrations in the area were low. A number of faunal biotopes were

identified on the Kish Bank; "*Glycera lapidum* in impoverished infralittoral mobile gravel and sand" (SS.SCS.ICS.Glap); "*Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand" (SS.SSA.CFiSa.ApriBatPo); "*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand" (SS.SSa.IFiSa.NcirBat); "*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment" (SS.SSa.CMuSa.AalbNuc)'

The Blackwater bank was dominated by fine sands (Aqua-Fact, 2005) with a low organic carbon concentration. A number of faunal biotopes were identified on the Blackwater Bank; "Infralittoral mobile clean sand with sparse fauna" (SS.SSA.IMoSa) and "*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand" (SS.SSA.IFiSa.NcirBat).

The current survey of the Long Bank and Holdens Bank revealed a sandy substratum ranging from medium to fine sands. Organic carbon results in the area were low. A number of biotopes, typical of sandy habitats were identified in the area: "SS.SSA.IMuSa.FfabMag *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand"; "SS.SSA.IFiSa.IMoSa Infralittoral mobile clean sand with sparse fauna"; "SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand" and "SS.SCS.CCS.Blan *Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel".

The faunal species identified from the Long Bank and Holdens Bank are typical of sandy environments and are similar to the assemblages from the Kish and Blackwater Banks located further north. The low organic carbon and silt-clay levels in the area are due to high hydrodynamic activity in the area, which prevents fines settling out of the water column.

4.2 Ballybunnion Bank and Turbot Bank

Aqua-Fact (1998) described the Ballybunnion Bank as being a highly dynamic environment where the substrate comprised compact sands underlain by gravel. The biotopes in the area are known to be low in species numbers and individuals.

The current survey of the Ballybunnion Bank and Turbot Bank revealed tat the Ballybunnion Bank was dominated by fine sands. The sediment sampled along the Turbot Bank varied between gravel, coarse sand, medium sand and fine sand. Organic carbon values were higher in the Turbot Bank than the Ballybunnion Bank, however overall levels were low.

A number of biotopes, typical of sandy habitats were identified in the area: "SS.SSA.IMuSa.FfabMag *Fabulina fabul*a and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand"; "SS.SSA.IFiSa.NcirBat *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand"; "SS.SCS.ICS.CumCset Cumaceans and *Chaetozone setosa* in infralittoral gravelly sand"; "SS.SCS.ICS.Glap *Glycera lapidum* in impoverished

infralittoral mobile gravel and sand" and "SS.SCS.CCS.Blan *Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel".

These biotopes are typical of a sandbank community and are similar to other sandbanks surveyed in the Irish Sea. The low organic carbon and silt-clay fractions are indicative of a high level of hydrodynamic activity in the area preventing fines from settling out of the water column.

4.3 Comparison of the Two Sandbank Sites

The Long Bank and Holdens Bank had more species, more taxa and more phyla that the Ballybunnion Bank and Turbot Bank but fewer individuals. The Ballybunnion and Turbot Banks were less diverse than the Long and Holdens Banks. The sediments at the Long and Holdens Banks were predominantly fine and medium sand. At the Ballybunnion and Turbot Banks fine sand dominated most of the stations, with 10 stations having a fine sand component of >80%. All the fine sand stations were in the Ballybunnion Bank whereas the Turbot Bank sediments were coarser. The sediments between the two sites were similar and therefore it was expected that the faunal species encountered would be similar and they were. Typical dominant species were the polychaetes *Magelona mirabilis* and *Nephtys cirrosa,* the amphipods *Bathyporeia elegans, Urothoe elegans*, the mysid crustacean *Gastrosaccus spinifer,* and the mollusc *Fabulina fabula.,*

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