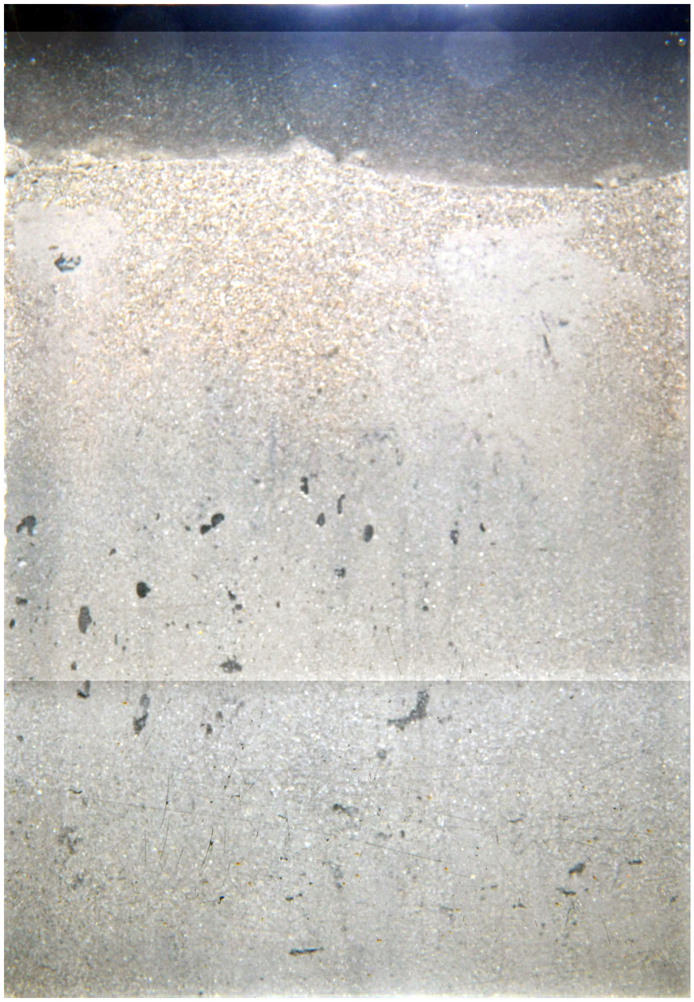
Benthic Biotope classification of subtidal sedimentary habitats in the Lower River Suir candidate Special Area of Conservation and the River Nore and River Barrow candidate Special Area of Conservation (July 2008).



Sediment Profile Image of station 42 in the Barrow estuary showing mobile sand overlying recently deposited mud. The holes in the mud layer are not gas bubbles, they are water filled voids caused by violent deposition events, similar to spoil dumping. There appears to be an older, relict layer of mud at depth in the image. Image width is 13.7cm, penetration depth is approx 18cm.

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Executive Summary

This report documents the findings of an inshore benthic survey of Waterford Harbour, the Lower River Suir cSAC and River Barrow and River Nore cSAC carried out for the NPWS by Atlantic RMS Ltd. Sampling took place in July 2008. 49 stations were sampled at approximately 800m spacing throughout the area. One 0.1 m^2 Day grab sample was taken at each station and used to determine macrofaunal and sediment distribution patterns in the area. Lack of replication and small sample size presented a challenge to producing habitat classifications. The Zero Adjusted Bray Curtis Similarity Coefficient, Hierarchical Cluster Analysis (HCA), the Similarity Percentages technique (SIMPER) and the Similarity Profiling test (SIMPROF) were used to classify the sites into groups, define the characterising species and test the significance of the groups.

The biotopes were classified using a modified JNCC Marine habitat classification scheme. They showed very good qualitative correspondence to established biotopes. The estuarine stations were generally characterised by low numbers of species and individuals. The most common biotope in the Suir and Barrow estuaries was the level 5 biotope infralittoral fluid mobile mud in variable salinity, occurring eleven times. Eight estuarine stations were assigned to *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay. Five stations were classified as oligochaetes in variable or reduced salinity infralittoral muddy sediment. Other stations in the Barrow estuary were classified as either Infralittoral mobile sand in variable salinity (estuaries) or Sublittoral coarse sediment in variable salinity (estuaries).

In the more seaward Harbour area south of Cheek Point the northern part was classified as *Nephtys hombergii* and *Macoma baltica* in infralittoral muddy sand. Three stations in the lower Suir and Barrow estuaries were also classified as NhomMac. The southern area of the Harbour was mostly classified as *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand.

It was necessary to be flexible in assigning the biotopes. There were several stations at which the fauna corresponded to a level 5 biotope that did not match the sediment type determined at the station. In this case, stations 6, 7 and 9 were characterised as *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay as determined by the faunal "bottom up" approach. Stations 38, 41 and 42 were classified as being part of the infralittoral fluid mobile mud in variable salinity group by faunal analyses, but were classified as Infralittoral mobile sand in variable salinity (estuaries) because of the very depauperate nature of the fauna and the sandy sediments at these stations. In this case, the "top down" approach was taken. There is evidence that some level 5 biotopes may be represent different successional states of the same community, and that some communities may extend over two or more sediment classes. Bottom up classification should be supplemented with top down analyses.

At the sampling effort used in this survey, it was possible to delineate the biotopes with statistical confidence that very closely resemble the JNCC / EUNIS biotopes. These biotopes will be robust to statistical testing in their own right, whether compared to the JNCC descriptions or not. The discriminatory power of future surveys would be improved by an increased sampling effort, particularly the inclusion of additional quantitative samples. Qualitative benthic data are generally not amenable to inferential statistical analyses and are likely to be of limited value in informing management decisions.

1. Introduction

Atlantic RMS Ltd. Was contracted by the National Parks and Wildlife Service (NPWS) to undertake a survey of the Lower River Suir candidate Special Area of conservation (cSAC) and the River Nore and River Barrow cSAC. The purpose of this survey was to perform habitat classification on the subtidal sediments of the Suir and Barrow estuaries and an area of Waterford Harbour. Benthic macrofauna, sediments samples for grain size and organic content, photographs and written descriptive notes were collected from each station.

NPWS requested that a classification of biotopes into significantly different classes be applied to the data set in addition to the JNCC Marine Habitat Classification. To that end, a modified JNCC classification was developed that was amenable to delineating significantly different groups of stations based on cluster analysis without replication.

This report outlines the sampling methods and data analyses, presents results and discusses the findings of the survey.

2. Materials & Methods

The overall sampling area extended from New Ross on the River Barrow to Waterford on the River Suir, and to a line between Creaden Head and Broomhill Point at the mouth of Waterford Harbour (Figure 1). Survey work was limited to soft sedimentary habitats.

2.1 Sampling Procedure

Station locations were recorded by differential GPS. At 49 stations (Figure 1) a 0.1 m^2 Day grab sample was retrieved. Following removal of a sub-sample for particle size distribution and organic content (LOI) analysis, the remaining sediment was preserved for macrofaunal identification.

All samples were labelled inside and outside so that each sample could be identified. All sediment samples were frozen (<-18°C) in screw top containers, labelled inside and outside, as soon as possible after acquisition. A digital image of each sample was taken on deck to include the sample code, date and scale identifier. Available ancillary in situ environmental observations were recorded for each sampling location including :

Co-ordinates (Lat/Long & national grid)
Ship Anchored (Y/N)
Time
Weather & Sea state
Exposure
Depth
Salinity
Sediment type
Sampler type
Sieve size
Sample photograph (Y/N and identifier code)

All data were entered into a Microsoft Excel database on an onboard laptop as the samples were processed. This was backed up on four solid state external storage devices.

On board, the faunal grab samples were photographed and rapidly visually assessed for bottom type. The penetration depth, texture and grain size of the sediments were visually determined and noted. Samples were emptied into a hopper and the grab rinsed thoroughly to avoid loss of the sample. The sample was sieved on a 0.5mm sieve as a sediment water suspension. Very stiff clay was fragmented by hand (with care). ·

All material retained on the sieve was flushed into a prelabelled 15l bucket, with water from below. All the samples were fixed in buffered 4% w/v buffered formaldehyde solution. In very organic mud, this concentration was increased to 10%. Formalin was added to the faunal samples obtained as soon as possible. The sample was completely covered by the fixative solution.

In addition, as part of an associated research program by Galway Mayo Institute of Technology which is funded by NPWS, two dredge samples were taken at each grab station using a 53cm diameter Rallier du Baty sampler with a 2mm mesh. The fauna was rapidly identified on board, preserved and subsequently reanalyzed in the laboratory. The Macrofaunal returns from the grab were very gently separated into 2 mm, 1 mm and 0.5 mm fractions at the laboratory, and identified separately. The data was forwarded to GMIT and NPWS in digital form and is not dealt with in this report. This report deals only with the >1mm fraction (material retained on 1mm and on 2mm sieves combined) of the macrofaunal grab returns.

Figure 1: Benthic grab sampling stations in Waterford Harbour, the Lower River Suir cSAC and River Barrow and River Nore cSAC in July 2008.

2.2 Sample processing

2.2.1 Sediment Organic Content

Sediment samples were dried to a constant weight at 105°C to determine dry weight. Following this, samples were heated in an oven to 550°C for 4 hours, and reweighed. While many temperature combinations have been used by various operators, this method produces the most reproducible results (Heiri et al 2001). The loss on ignition was taken as the labile organic content of the sediment. The returns of this technique include some organic nitrate and carbonate, as do all other standard techniques including chromic acid oxidation (CAOV). For this reason it is better to refer to this variable as organic content rather than organic carbon.

2.2.2 Sediment particle sizing

Samples were analysed using a Malvern Mastersizer X laser diffraction particle sizer, capable of sizing in the range of 1-2,000µm. The samples were sonicated and stirred in distilled water while being analysed. Two replicate runs of 1,000 sweeps of the samples were performed. The distribution of apparent diameters encountered by the laser in a sample sweep was used to calculate an equivalent sphere diameter particle size frequency distribution (in which the particles are represented as spheres with the same distribution of diameters as those measured by the laser). A cumulative frequency plot of the particle size distributions was constructed from a table of particle size distributions equivalent to a series of standard sieves based on the Wentworth Scale (Folk 1974). The following summary statistics developed by Folk (1974) were calculated for the surficial sediment samples.

1) Graphic Mean (Mz) is a measure of the average particle size of the sediment, given in a logarithmic scale.
2) Inclusive graphic standard deviation or sorting (δ_i) defines the degree of scatter of particle sizes about Mz.
3) Inclusive graphic skewness (Sk_i) characterises the asymmetry of the cumulative frequency curve.

Samples that were too coarse for laser particle sizing, (gravels rather than sands), were processed by wet sieving to remove the <63µm fraction, and dry sieving the remainder by mechanical shaker using a nest of sieves equivalent to the Wentworth Scale.

All sediment samples were classified using the simplified Folk classification of the EUNIS seabed sediment classification (Long 2006). This classification differs from the normal Folk triangle (Folk 1954) in that it defines boundary between mud and sandy mud (Mu) and sand and muddy sand (Sa) as a 4:1 ratio of sand to mud (Figure 2). A sediment may have 79.9% sand and 20.1% mud and still be classified as mud and sandy mud (Mu). To be classified as sand and muddy sand (Sa), the sediment must have a percentage of sand larger than 80%. Coarse sediments (CS) correspond to the normal Folk categories slightly gravelly sand, gravelly sand, sandy gravel and gravel. All other sediments are designated as mixed sediments (Mx).

Principal components analysis (PCA) was used to determine the distribution of sediment parameters in the area. PCA is a standard parametric ordination technique that plots station distributions in (usually) two dimensions based on linear combinations of variables. It is particularly suited to analysis of the environmental variables in this study as there are relatively few variables (far fewer than the number of species). Because of collinearity in these variables (for example organic content being high correlated with grain size) the data set was reduced before analysis.

2.2.3 Benthic macrofauna sample processing

Samples were analysed using standard analytical procedures as outlined below. These procedures meet the requirements of the National Marine Biological Analytical Quality Control Scheme (NMBAQC). For the purposes of this report the >1mm faunal fraction was analysed.

If not done previously by the field operatives, the samples were stained overnight with Eosin-briebrich scarlet to facilitate visual extraction of small individuals The sample contents were split into three fractions >2mm, 1 to 2mm and 0.5 to 1mm and refixed in 70% alcohol. Sieves were thoroughly washed between samples to avoid cross contamination. The fractions were clearly labeled including a permanent internal label in each container. The 0.5mm to 1mm fraction was not included in the analyses reported here as per tender specification. It was collected for the GMIT project.

The >2mm fraction was placed in an illuminated shallow white tray and sorted first by eye to remove large specimens, and the remainder sorted using a Nikon stereo microscope at 6 to 10 times magnification. The other two fractions were placed into Petri dishes, approximately one half teaspoon at a time and sorted using a Nikon binocular microscope at x25 magnification.

The fauna were split into five "taxa" in the first instance: molluscs, echinoderms, crustaceans, polychaetes and a miscellaneous grouping consisting of all other taxa, and maintained in stabilised 70% industrial methylated spirit (IMS). These groupings were subsequently identified to species level where practical using a Nikon binocular microscope, a Nikon compound microscope and the best available taxonomic keys. Species nomenclature was classified in accordance with Howson & Picton (1997).

After identification and enumeration, specimens were separated and stored to species where possible. All containers were clearly labelled on the outside stating site, date, replicate number, and name of who analysed the sample. A permanent internal label bearing the same information was also included with all containers. Specimens were stored in stabilised Industrial Methylated Spirits (IMS) in containers with adequate seals to comply with COSHH regulations that were labelled accordingly.

Residual detritus was kept in a separate container for each sample, labeled inside and outside. Sample residue was preserved in 10% formalin in containers with adequate seals to comply with COSHH regulations that were labelled accordingly.

2.2.4 Quality Control

Internal quality control was carried out in accordance with the NMBAQC guidelines. Internally, 5% of sample residues were resorted by another operative to ensure consistency in sorting procedures. 5% of identified specimens were re-identified by another operative to ensure that species identification was precise and consistent. The samples were included in our regular external QA procedure under the EU wide Biological Effects Quality Assurance In Monitoring Programmes (BEQUALM). The benthic element of BEQUALM is administered through the UK National Marine Biological Analytical Quality Control Scheme NMBAQCS. The macrofaunal dataset was sent to Unicomarine Ltd., the contractor for NMBAQC. Unicomarine chose three samples (6% of the total) for complete reanalysis including resorting of the residue. Some QA issues were identified during this process and all samples were resorted and re-identified. Subsequent testing under the Own Sample (OS) element of NMBACS resulted in a pass grade being awarded to the entire dataset.

2.2.5 Voucher Specimen Collection

A voucher collection of all species identified in this survey was created according to the specifications of the Natural History Museum, Dublin. This collection is in the process of being deposited to the NHM with the code NMINH:2009.22. The remaining fauna has been forwarded to the Galway Mayo Institute of Technology (GMIT) as part of their associated research program.

2.2.6 Benthic macrofaunal data analyses and biotope classification

Standard community parameters were calculated for each grab sample. These included:

1) Shannon-Wiener diversity index (H').
2) Pielou's Evenness index (J).
3) Margalef's species richness index (D).
4) Number of species (S)

All faunal and environmental data were input to data matrices and analysed using standard multivariate techniques in the program Primer 6.1.7 (Clarke and Warwick 2001, Clarke and Gorley 2006). To test for association between the faunal communities and the sediment data BioEnv analysis was performed. BioEnv is a technique for pattern matching in environmental and biological similarity matrices. BioEnv uses permutative Mantel testing to find the combination of environmental variables that best explains the distribution of fauna.

A modified data analysis procedure was used to classify the stations according to the JNCC Biotope scheme. This is explained in detail in Figures 2a and 2b. The faunal data matrix was square root transformed but not standardised. A Bray-Curtis similarity matrix was prepared using the Zero Adjusted Bray-Curtis similarity coefficient (Clarke et al 2006). This coefficient allows samples with zero abundance (number of individuals) to be similar to samples with very low numbers of individuals. The similarity matrix was used to classify the stations into groups of similar elements in a dendogram by higher agglomerative clustering (HAC) using group average linkage. The Similarity Profile (SimProf) test was used to determine significant difference between the clusters. This technique is a permutation test of the null hypothesis that a specified set of samples, that are not grouped *a priori*, do not differ in multivariate structure. The classification structure output by SimProf was used as the factor in a Similarity Percentages (SIMPER) analysis that determined the characterising species of each group of stations. The characterising species were compared to the JNCC comparative tables (Connor et al 2004) to determine the level 5 biotope classification. The levels higher than 5 (i.e. levels 2, 3 and 4) were assigned to match the level 5 biotope and field descriptions, but no discrimination was made between muds and muddy sands (Mu) and sands and sandy muds (Sa). Where the significant cluster produced by SimProf had only one element, the species abundance data for that station were compared directly to the biological comparative tables and the level 5 biotope was assigned.

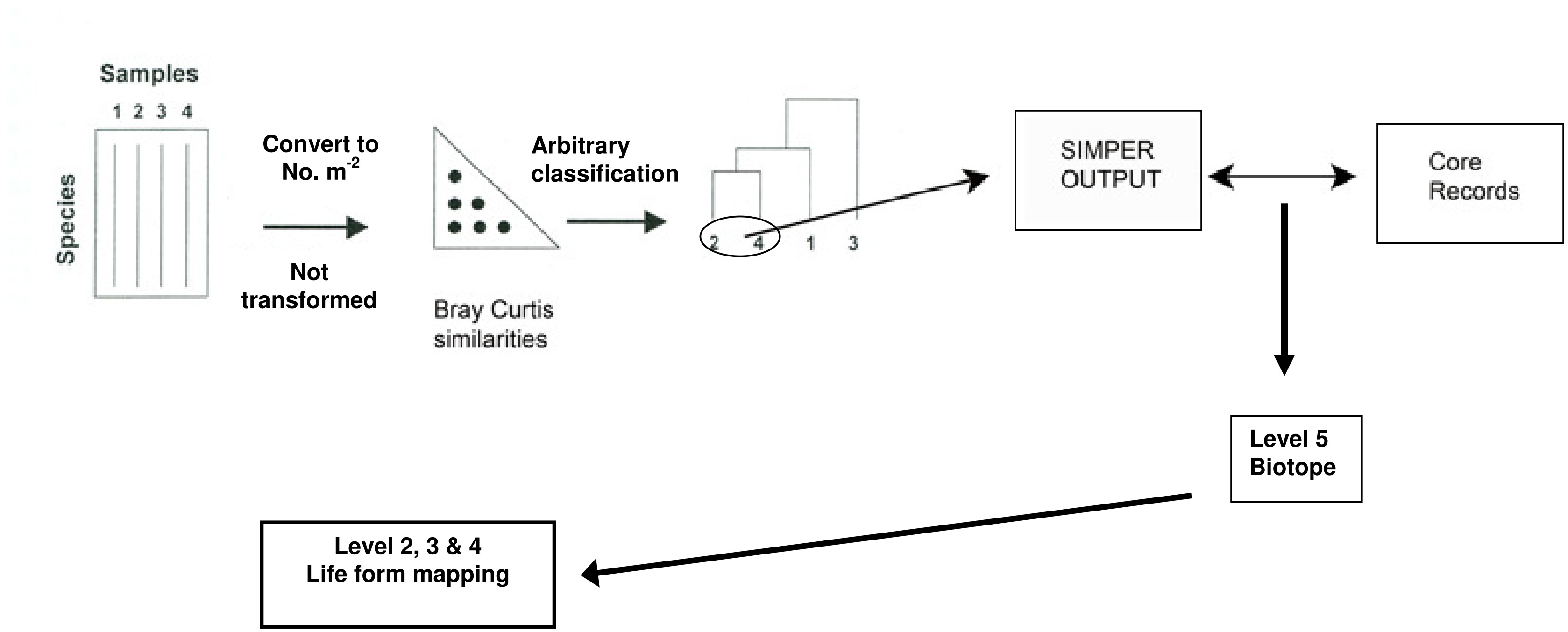

Figure 2a: EUNIS / JNCC biotope classification scheme of Connor et al 2004. Untransformed data are converted to numbers per square metre and used to calculate Bray Cutis similarity. The Bray Curtis similarity matrix is subjected to higher agglomerative clustering using group average linkage and groups are identified in the dendogram arbitrarily. These groups are analysed for characterising species using Simper analyses. The simper outputs are used to determine the level 5 biotope by comparison to the core macrofaunal records in conjunction with the core environmental records. Levels 2, 3 and 4 are usually determined by the mean environmental parameters, for example grain size, of the group. Where levels 4 and 5 do not correspond, usually the macrofaunal data are used for classification. This is a “bottom up” approach.

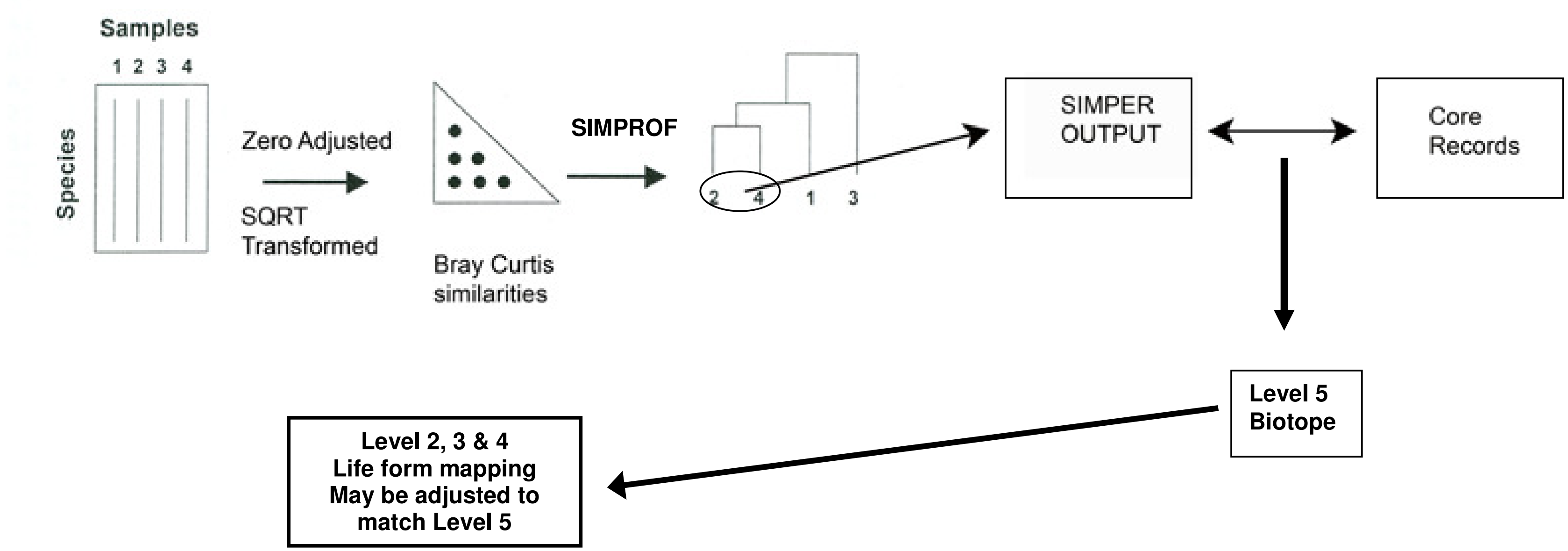

Figure 2b: Modified EUNIS / JNCC biotope classification scheme used in this survey. Square root tranbsformed data are used to Zero Adjusted Bray Cutis similarity. The Bray Curtis similarity matrix is subjected to higher agglomerative clustering using group average linkage and statistically significant groups are identified in the dendogram using a similarity profile test. These groups are analysed for characterising species using Simper analyses. The simper outputs are used to determine the level 5 biotope by comparison to the core macrofaunal records in conjunction with the core environmental records. Levels 2, 3 and 4 are usually determined by the mean environmental parameters, for example grain size, of the group. Where levels 4 and 5 do not correspond, usually the macrofaunal data are used for classification. This is a “bottom up” approach.

3 Results

3.1 Sediments

Sediment results for grain size and organic content analyses are summarised in Table 1 and given in more detail on the CD accompanying this report in MS Excel format. Figure 2 shows the PCA ordination of the sediment data. Stations to the right of the ordination are classified as being sands and muddy sand (upper right) or muds and sandy mud (lower right). Only stations 47 from the Barrow estuary, station 7 from the Suir estuary and station 19 from Waterford Harbour were coarser material. These stations were also outliers in the faunal data set. Organic content levels were normal for estuarine conditions (<10%) in all stations.

Bioenv analysis to determine which environmental variables produce the best pattern match to the macrofaunal distribution revealed that %gravel was the parameter that produced the best fit. At Rho=0.44, it accounted for a moderate amount of the pattern in the macrofaunal distribution, see Appendix 1.

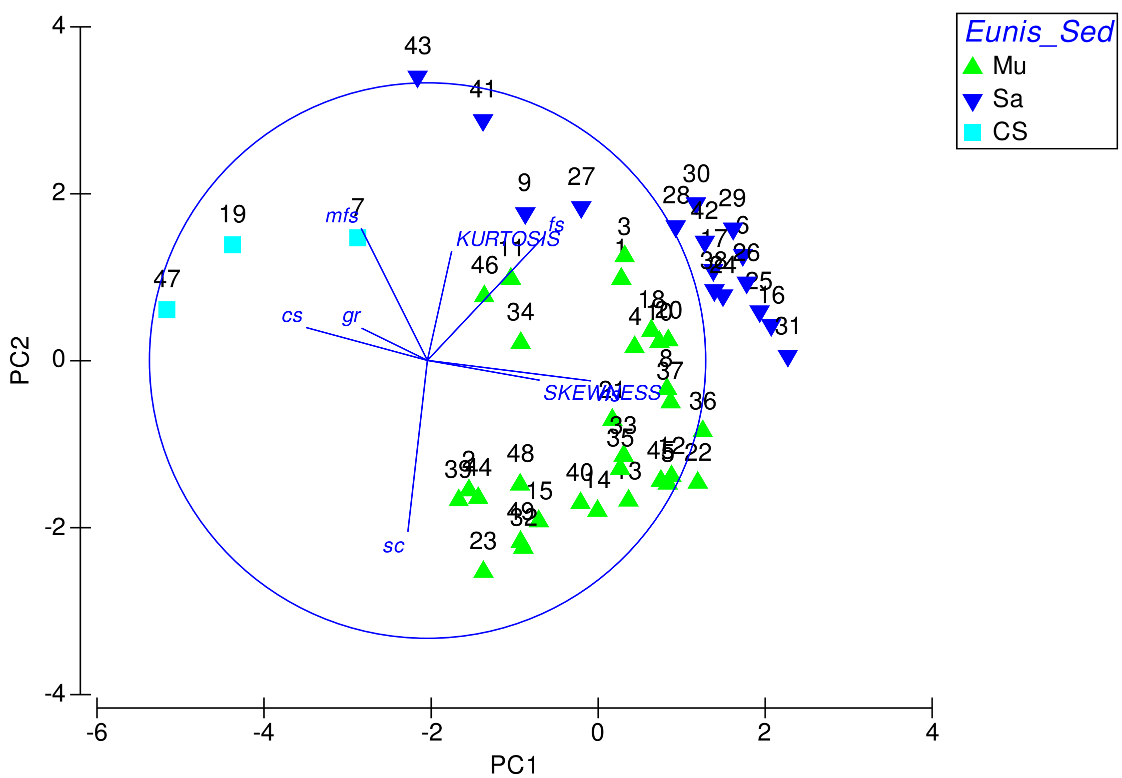

Figure 3: Principal components analysis (PCA) ordination of sediment data from Lower River Suir cSAC and River Nore and River Barrow cSAC and Waterford Harbour. For full results see Table 1. EUNIS sediment classifications: Mu= muds and sandy muds, Sa = sands and muddy sands, CS = coarse sediments. This ordination accounts for 57% of the variance in the data set and clearly separates the EUNIS sediment classes.

Station	Gravel %	Sand %	Mud %	Eunis Sed	Folk (1954)	LOI %	*Mz*	SORT	SKEW	KURT	Modality
1	0.0	73.4	26.6	Mu	Muddy Sand	2.9	3.5	2.0	0.3	1.7	Trimodal
2	0.0	37.1	62.9	Mu	Sandy Mud	8.0	4.8	2.2	-0.1	1.1	Trimodal
3	0.0	73.8	26.2	Mu	Muddy Sand	4.6	3.5	1.8	0.5	1.5	Trimodal
4	0.0	69.8	30.2	Mu	Muddy Sand	5.7	4.0	1.9	0.2	1.5	Bimodal
5	0.0	52.2	47.8	Mu	Muddy Sand	7.2	4.5	1.7	0.4	0.9	Bimodal
6	0.0	93.1	6.9	Sa	Sand	1.5	3.1	0.8	0.4	1.3	Bimodal
7	90.2	8.3	1.4	CS	Gravel	1.5	-1.2	0.3	0.3	2.0	Unimodal
8	0.0	67.4	32.6	Mu	Muddy Sand	3.4	4.1	1.7	0.4	1.1	Bimodal
9	0.0	83.8	16.2	Sa	Muddy Sand	2.0	2.8	1.7	0.1	1.4	Trimodal
10	0.0	70.9	29.1	Mu	Muddy Sand	3.9	4.0	1.7	0.3	1.3	Bimodal
11	0.0	73.2	26.8	Mu	Muddy Sand	3.1	3.3	2.1	0.3	1.2	Polymodal
12	0.0	55.1	44.9	Mu	Muddy Sand	3.4	4.4	1.7	0.4	0.9	Bimodal
13	0.0	48.5	51.5	Mu	Sandy Mud	3.5	4.6	1.8	0.4	0.8	Bimodal
14	0.0	44.7	55.3	Mu	Sandy Mud	4.9	4.7	1.8	0.3	0.8	Bimodal
15	0.0	38.5	61.5	Mu	Sandy Mud	5.1	4.9	1.8	0.1	0.8	Bimodal
16	0.0	96.2	3.8	Sa	Sand	1.4	3.1	0.5	0.5	0.6	Bimodal
17	0.0	80.4	19.6	Sa	Muddy Sand	2.1	3.6	1.3	0.3	1.7	Bimodal
18	0.0	70.9	29.1	Mu	Muddy Sand	3.9	4.0	1.7	0.4	1.2	Trimodal
19	13.3	85.9	0.8	CS	Gravelly Sand	1.6	0.4	1.2	0.1	0.6	Trimodal
20	0.0	71.3	28.7	Mu	Muddy Sand	2.6	4.0	1.8	0.3	1.5	Bimodal
21	0.0	60.0	40.0	Mu	Muddy Sand	3.1	4.3	2.0	0.2	1.1	Bimodal
22	0.0	55.3	44.7	Mu	Muddy Sand	4.2	4.5	1.7	0.5	0.9	Bimodal
23	0.0	22.1	77.9	Mu	Sandy Mud	2.2	5.5	1.6	0.0	0.8	Bimodal
24	0.0	86.3	13.7	Sa	Muddy Sand	1.4	3.4	0.9	0.1	1.5	Bimodal
25	0.0	94.2	5.8	Sa	Sand	1.4	3.1	0.7	0.3	1.1	Bimodal
26	0.0	93.9	6.1	Sa	Sand	1.5	3.1	0.8	0.3	1.2	Bimodal
27	0.0	95.7	4.3	Sa	Sand	1.5	2.8	1.1	-0.2	1.3	Trimodal
28	0.0	97.0	3.0	Sa	Sand	1.5	3.0	0.7	0.2	1.0	Trimodal
29	0.0	92.7	7.3	Sa	Sand	0.2	3.1	0.9	0.4	1.4	Bimodal
30	0.0	84.5	15.5	Sa	Muddy Sand	2.8	3.1	1.4	0.3	2.2	Bimodal
31	0.0	95.7	4.3	Sa	Sand	1.4	3.2	0.5	0.4	0.6	Bimodal
32	0.0	32.3	67.7	Mu	Sandy Mud	9.7	5.2	1.7	0.1	0.8	Bimodal
33	0.0	55.2	44.8	Mu	Muddy Sand	4.6	4.4	1.8	0.3	0.8	Bimodal
34	0.0	63.5	36.5	Mu	Muddy Sand	5.7	3.8	2.2	0.1	1.1	Trimodal
35	0.0	53.7	46.3	Mu	Muddy Sand	4.7	4.4	1.8	0.3	0.8	Bimodal
36	0.0	65.6	34.4	Mu	Muddy Sand	3.0	4.2	1.6	0.4	0.9	Bimodal
37	0.0	66.1	33.9	Mu	Muddy Sand	3.9	4.1	1.7	0.4	1.0	Bimodal
38	0.0	85.7	14.3	Sa	Muddy Sand	1.7	3.4	1.0	0.1	1.5	Bimodal
39	0.0	33.3	66.7	Mu	Sandy Mud	9.3	5.0	2.1	-0.1	1.1	Trimodal
40	0.0	44.1	55.9	Mu	Sandy Mud	4.4	4.7	1.8	0.2	0.8	Bimodal
41	0.0	98.1	1.9	Sa	Sand	1.4	2.5	0.7	-0.2	1.0	Trimodal
42	0.0	82.1	17.9	Sa	Muddy Sand	2.2	3.3	1.3	0.5	1.8	Trimodal
43	0.0	97.9	2.1	Sa	Sand	2.0	2.4	0.7	-0.3	1.1	Bimodal
44	0.0	35.6	64.4	Mu	Sandy Mud	5.3	4.9	2.1	-0.1	1.0	Bimodal
45	0.0	55.3	44.7	Mu	Muddy Sand	5.6	4.4	1.7	0.4	0.7	Bimodal
46	0.0	74.8	25.2	Mu	Muddy Sand	2.6	2.9	2.3	0.2	1.2	Polymodal
47	9.1	89.6	1.3	CS	Gravelly Sand	1.3	-0.1	0.7	-0.1	1.0	Unimodal
48	0.0	41.3	58.7	Mu	Sandy Mud	7.2	4.8	2.1	0.0	1.1	Bimodal
49	0.0	32.5	67.5	Mu	Sandy Mud	4.8	5.2	1.7	0.1	0.8	Bimodal

Table 1: Summary results of sediment analyses from Lower River Suir cSAC and River Nore and River Barrow cSAC and Waterford Harbour, July 2008. EUNIS Sed is the simplified sediment type under the EUNIS marine habitat classification. Folk (1954) is the sediment type under the classification of Folk (1954). LOI % is percentage organic content. Modality is the number of modes in the grain size distribution. *Sensu* Folk and Ward (1957) :*Mz* is graphic mean, SORT is the sorting coefficient, SKEW is Skewness, KURT is Kurtosis.

Station	Eunis Sed	Folk (1954)	Field sediment observation	Field faunal comment
1	Mu	Muddy Sand	Mud, gravel, cobbles, dredge spoil	none visible
2	Mu	Sandy Mud	Mud, algal detritus	none visible
3	Mu	Muddy Sand	Sandy mud, algal detritus	Small polychaetes
4	Mu	Muddy Sand	Sand over laminated clay, algal detritus	Small polychaetes
5	Mu	Muddy Sand	Sand over laminated clay, algal detritus	none visible
6	Sa	Sand	Sand	none visible
7	CS	Gravel	Mud, cobbles, gravel	Amphipods visible
8	Mu	Muddy Sand	Mud smelling of methane, algal detritus	Terrabellid worm and Macoma
9	Sa	Muddy Sand	Sand, cobbles, gravel	none visible
10	Mu	Muddy Sand	Clay, shells, cobbles, algal detritus	none visible
11	Mu	Muddy Sand	Sand over mud	Large polychaete and tellins
12	Mu	Muddy Sand	Sand over laminated clay, algal detritus	none visible
13	Mu	Sandy Mud	Sand over laminated clay, algal detritus	Nephtys
14	Mu	Sandy Mud	Sand over laminated clay, algal detritus	none visible
15	Mu	Sandy Mud	Sand over laminated clay, algal detritus	Polychaetes
16	Sa	Sand	Fine muddy sand	Nephtys
17	Sa	Muddy Sand	Sand over clay	Nephtys and tellins
18	Mu	Muddy Sand	Muddy fine sand	Tellins
19	CS	Gravelly Sand	Coarse sand, shell and shingle	none visible
20	Mu	Muddy Sand	Muddy fine sand, algal detritus	Polychaetes
21	Mu	Muddy Sand	Muddy fine sand	Lanice, Nephtys and Tellins
22	Mu	Muddy Sand	Muddy fine sand, algal detritus	Amphipods,polychaetes and Macoma
23	Mu	Sandy Mud	Mud, shell, gravel	Carcinus juv.
24	Sa	Muddy Sand	Fine sand with a lot of shell	Lanice, Nepthys and Abra
25	Sa	Sand	Muddy fine sand, algal detritus	Lanice, Nephtys and Tellins
26	Sa	Sand	Muddy fine sand, algal detritus	Lanice, Nephtys and Tellins
27	Sa	Sand	Muddy fine sand, algal detritus	Lanice and Tellins
28	Sa	Sand	Muddy fine sand, algal detritus	Lanice and Tellins
29	Sa	Sand	Muddy fine sand, algal detritus	Lanice and Tellins
30	Sa	Muddy Sand	Laminate clay, algal detritus	none visible
31	Sa	Sand	Muddy fine sand, algal detritus	Lanice,Tellins and Nephtys
32	Mu	Sandy Mud	Laminate clay, algal detritus	Polychaetes (Amphaeritide) and Abra
33	Mu	Muddy Sand	Sand over laminated clay	Abra and Macoma
34	Mu	Muddy Sand	Shell gravel, cobbles over clay, dredge spoil?	Nereis and Hydroids
35	Mu	Muddy Sand	Fine sand over laminated clay	Lanice and Tellins
36	Mu	Muddy Sand	Fine sand over laminated clay, shell gravel, algal detritus	polychaete
37	Mu	Muddy Sand	Muddy fine sand, terrestrial plant debris	Lanice and Macoma
38	Sa	Muddy Sand	Muddy fine sand, terrestrial plant debris	none visible
39	Mu	Sandy Mud	Clay, cobble, dead shell (mussel)	none visible
40	Mu	Sandy Mud	Muddy fine sand, terrestrial plant debris	none visible
41	Sa	Sand	Muddy fine sand, terrestrial plant debris	none visible
42	Sa	Muddy Sand	Muddy fine sand, terrestrial plant debris	none visible
43	Sa	Sand	Muddy fine sand, terrestrial plant debris	none visible
44	Mu	Sandy Mud	Fine and medium sand, silt and plant debris	none visible
45	Mu	Muddy Sand	Laminated clay	none visible
46	Mu	Muddy Sand	Sandy mud with plant debris	none visible
47	CS	Gravelly Sand	Very coarse sand	none visible
48	Mu	Sandy Mud	Muddy fine sand, terrestrial plant debris	none visible
49	Mu	Sandy Mud	Muddy fine sand over clay, terrestrial plant debris	none visible

Table 2: Summary results of sediment analyses, field sediment observations and field faunal comment from Lower River Suir cSAC and River Nore and River Barrow cSAC and Waterford Harbour, July 2008. EUNIS Sed is the simplified sediment type under the EUNIS marine habitat classification. Folk (1954) is the sediment type under the classification of Folk (1954).

Parameters
Rank correlation method: Weighted Spearman
Method: BIOENV
Maximum number of variables: 5
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

Variables
1 gr
2 cs
3 mfs
4 fs
5 vfs
6 sc
7 SKEWNESS
8 KURTOSIS

Best results

No.Vars	Corr.	Selections
1	0.436	1
4	0.266	2,4,6,7
5	0.256	2-4,6,7
3	0.255	2,6,7
5	0.255	2,4-7
5	0.255	1,2,4,6,7
4	0.252	1,2,6,7
5	0.247	2,4,6-8
3	0.245	2,4,7
4	0.245	2,5-7

Table 3: Results of BioEnv analysis to select the environmental parameters that produce the best pattern match to the macrofaunal distribution. gr = gravel, cs = coarse sand, mfs = medium fine sand, fs= fine sand, sc=silt/clay.

3.2 Benthic Macrofauna

The full listing of species found in the study is given in the digital appendix to the report in MS Excel format. Table 4 shows species diversity measures from all stations. The number of species and individuals ranged from moderately low in the Harbour to very low in the upper reaches of the estuaries, particularly the Barrow. This is typical for shallow infralittoral sediments that are exposed to wind driven and tidal disturbance and also for estuarine sediments.

3.3 Biotope Classification

Classification by the JNCC Biotope scheme indicated that the biotopes were those normally found in estuaries and infralittoral fine sediments (See Table 6 and Figure 6).

The estuarine stations were generally characterised by low numbers of species and individuals. The stations were almost all characterized to level 5. Eight stations, mostly in the Suir estuary, (3, 4, 6, 7, 9, 10, 12, 34) were assigned to *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay. Station 8 in the Suir and stations 46, 48 and 49 in the Barrow estuary were classified as the biotope Oligochaetes in variable or reduced salinity infralittoral muddy sediment.

Seven stations from the Barrow estuary (35-37, 39, 40, 44, 45) and four from the Suir (1, 2, 5, 14) were classified as the level 5 biotope infralittoral fluid mobile mud in variable salinity because of field observations that there was laminated mud or sand layers deposited on the mud at most of these stations (Table 2). Stations 38, 41-43 were assigned to Infralittoral mobile sand in variable salinity (estuaries) because of field observations of mobile sediments at these stations. Station 43 was a singleton in the faunal dendogram, while stations 38, 41 and 42 were part of the mobile mud group in the dendogram. They were separated from the mobile mud group because of the very high sand content of these stations, average sand content of the mobile sand group was 90.9%.

The remaining station in the Barrow estuary, station 47, was classified as Sublittoral coarse sediment in variable salinity (estuaries).

In the more seaward Harbour area south of Cheek Point the northern part (15-18, 20- 22, 30) was classified as *Nephtys hombergii* and *Macoma baltica* in infralittoral muddy sand. This biotope was also found at two stations in the Suir estuary, 11 and 13. The southern area of the Harbour (24-29, 31) was classified as *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand. Other biotopes found were *Mytilus edulis* on subtidal sediments at stations 23, and *Hesionura elongata* and *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand at station 19. Table 5 lists the characterizing species for each group.

Station	EUNIS Sed	S	N	d	J	H’
1	Mu	6	7	2.57	0.98	1.75
2	Mu	1	3	0.00		0.00
3	Mu	9	51	2.03	0.80	1.76
4	Mu	3	10	0.87	0.94	1.03
5	Mu	3	9	0.91	0.85	0.94
6	Sa	5	40	1.08	0.83	1.34
7	CS	14	204	2.44	0.72	1.90
8	Mu	12	239	2.01	0.47	1.16
9	Sa	16	245	2.73	0.63	1.73
10	Mu	10	73	2.10	0.85	1.96
11	Mu	10	61	2.19	0.60	1.37
12	Mu	9	31	2.33	0.79	1.74
13	Mu	4	12	1.21	0.90	1.24
14	Mu	4	4	2.16	1.00	1.39
15	Mu	5	12	1.61	0.82	1.31
16	Sa	5	16	1.44	0.78	1.25
17	Sa	16	36	4.19	0.85	2.36
18	Mu	6	13	1.95	0.85	1.52
19	CS	8	331	1.21	0.42	0.88
20	Mu	2	2	1.44	1.00	0.69
21	Mu	14	47	3.38	0.84	2.22
22	Mu	11	130	2.05	0.47	1.13
23	Mu	35	499	5.47	0.65	2.31
24	Sa	23	91	4.88	0.84	2.64
25	Sa	19	83	4.07	0.73	2.14
26	Sa	20	77	4.37	0.81	2.42
27	Sa	15	63	3.38	0.76	2.06
28	Sa	12	64	2.64	0.66	1.65
29	Sa	7	34	1.70	0.82	1.59
30	Sa	4	24	0.94	0.71	0.98
31	Sa	15	97	3.06	0.57	1.55
32	Mu	4	17	1.06	0.66	0.92
33	Mu	7	90	1.33	0.39	0.76
34	Mu	12	62	2.67	0.73	1.82
35	Mu	4	8	1.44	0.88	1.21
36	Mu	1	1			0.00
37	Mu	8	21	2.30	0.86	1.79
38	Sa	4	5	1.86	0.96	1.33
39	Mu	0	0			0.00
40	Mu	2	2	1.44	1.00	0.69
41	Sa	4	4	2.16	1.00	1.39
42	Sa	1	1			0.00
43	Sa	3	86	0.45	0.16	0.17
44	Mu	4	4	2.16	1.00	1.39
45	Mu	3	3	1.82	1.00	1.10
46	Mu	7	15	2.22	0.91	1.77
47	CS	6	132	1.02	0.46	0.83
48	Mu	5	49	1.03	0.41	0.66
49	Mu	4	94	0.66	0.33	0.46

Table 4: Univariate diversity parameters measured at grab sampling stations in Lower River Suir cSAC and River Nore and River Barrow cSAC and Waterford Harbour, July 2008. Eunis Sed is the simplified sediment type under the EUNIS marine habitat classification. S is the number of species, N is the number of individuals, d is Margalef Species Richness, J is Pielou’s Evenness, H’ is Shannon-Weaver diversity.

SS.SMu.SMuVS.MoMu and SS.SSa.SSaVS.MoSaVS Average similarity: 9.59 Stns 1,2,5,14,35-45					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Scrobicularia plana	0.6	4.44	0.37	46.3	46.3
Tubificoides pseudogaster	0.32	1.52	0.24	15.79	62.1
Malacoceros fuliginosus	0.21	0.95	0.18	9.87	71.97
Corophium volutator	0.21	0.76	0.18	7.91	79.87
Streblospio shrubsolii	0.4	0.62	0.18	6.49	86.36
Crangon crangon	0.21	0.47	0.18	4.87	91.23
SS.SMu.SMuVS.PolCvol: Average similarity: 34.37 Stns: 3, 4, 6, 7, 9, 10, 12, 34					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Polydora cornuta	2.98	8.2	1.22	23.85	23.85
Gammarus salinus	2.95	5.87	0.88	17.07	40.92
Hediste diversicolor	1.57	4.74	0.8	13.8	54.72
Corophium volutator	1.66	3.66	0.75	10.63	65.35
Scrobicularia plana	1.38	2.35	0.7	6.83	72.18
Tubificoides pseudogaster	1.48	2.29	0.7	6.68	78.86
Capitella	0.93	1.59	0.66	4.63	83.49
Cyathura carinata	1.82	1.45	0.48	4.21	87.69
Streblospio shrubsolii	1.11	1.15	0.47	3.36	91.05
SS.SMu.SMuVS.OlVS: Average similarity: 35.01 Stns 8, 33, 46, 48, 49					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tubificoides pseudogaster	7.67	26.27	1.44	75.05	75.05
Tubificoides amplivasatus	1.22	3.62	0.56	10.33	85.38
Nematoda	0.55	0.82	0.32	2.35	87.73
Psammoryctides barbatus	0.48	0.82	0.32	2.35	90.08
SS.SSa.ISaMu.NhomMac: Avg similarity: 26.52 Stns 11, 13, 15-18, 20-22, 30					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Nephtys hombergii	2.09	12.71	1.45	47.91	47.91
Macoma balthica	1.06	5.17	0.78	19.49	67.4
Tubificoides pseudogaster	0.97	2.62	0.45	9.89	77.29
Pygospio elegans	0.82	1.54	0.44	5.8	83.09
Cerastoderma edule	0.36	1.09	0.33	4.12	87.21
Capitella	0.84	0.84	0.33	3.16	90.37
SS.SSa.IMuSa.FfabMag: Average similarity: 43.74 Stns 24-29, 31					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Fabulina fabula	4.85	15.4	3.58	35.2	35.2
Nephtys hombergii	3.14	9.86	3.82	22.55	57.75
Owenia fusiformis	2.42	4.7	1.46	10.76	68.51
Magelona johnstoni	1.13	1.99	0.89	4.54	73.05
Mactra stultorum	0.88	1.54	0.92	3.53	76.58
Magelona filiformis	0.9	1.45	0.62	3.33	79.9
Sigalion mathildae	0.69	1.26	0.58	2.89	82.79
Ampelisca brevicornis	1.34	1.07	0.4	2.45	85.24
Perioculodes longimanus	0.77	1.01	0.61	2.32	87.56
Glycera tridactyla	0.63	0.95	0.62	2.17	89.73
Abra alba	0.63	0.9	0.61	2.06	91.78

Table 5: Output of SIMPER analysis of macrobenthic grab data to determine species characterizing groups from the Lower River Suir cSAC and River Nore and River Barrow cSAC. The factor is classification using a SIMPROF significance test, see Figure 2b.

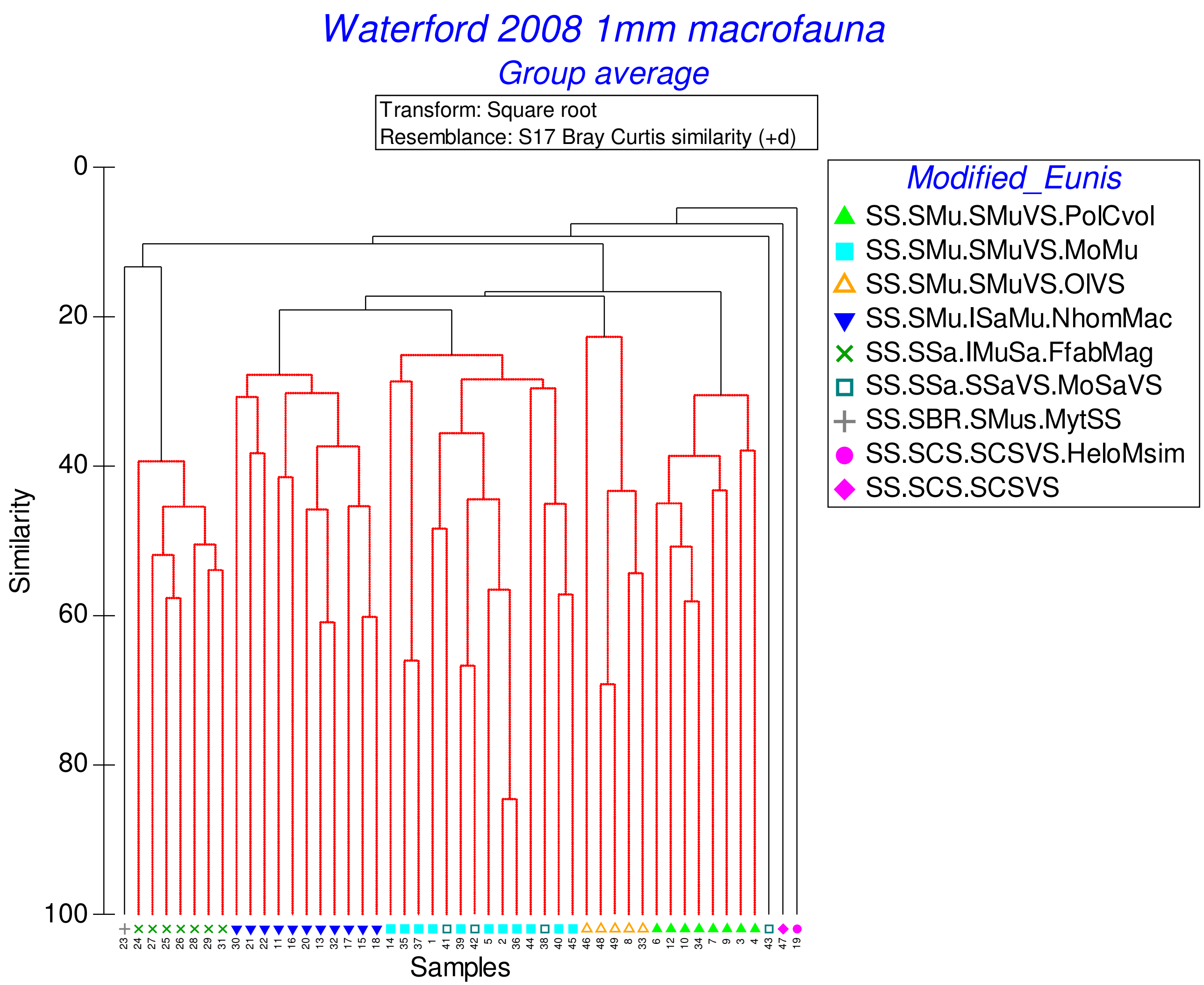

Figure 4: Dendogram of hierarchical agglomerative clustering output to classify square root transformed zero adjusted Bray Curtis similarities between station from the Lower River Suir cSAC and River Nore and River Barrow cSAC. The labeling factor is level 5 EUNIS classification assigned using a SIMPROF significance test and SIMPER analysis. Groups of samples joined by red lines are not significantly different, while groups joined by black lines are significantly different.

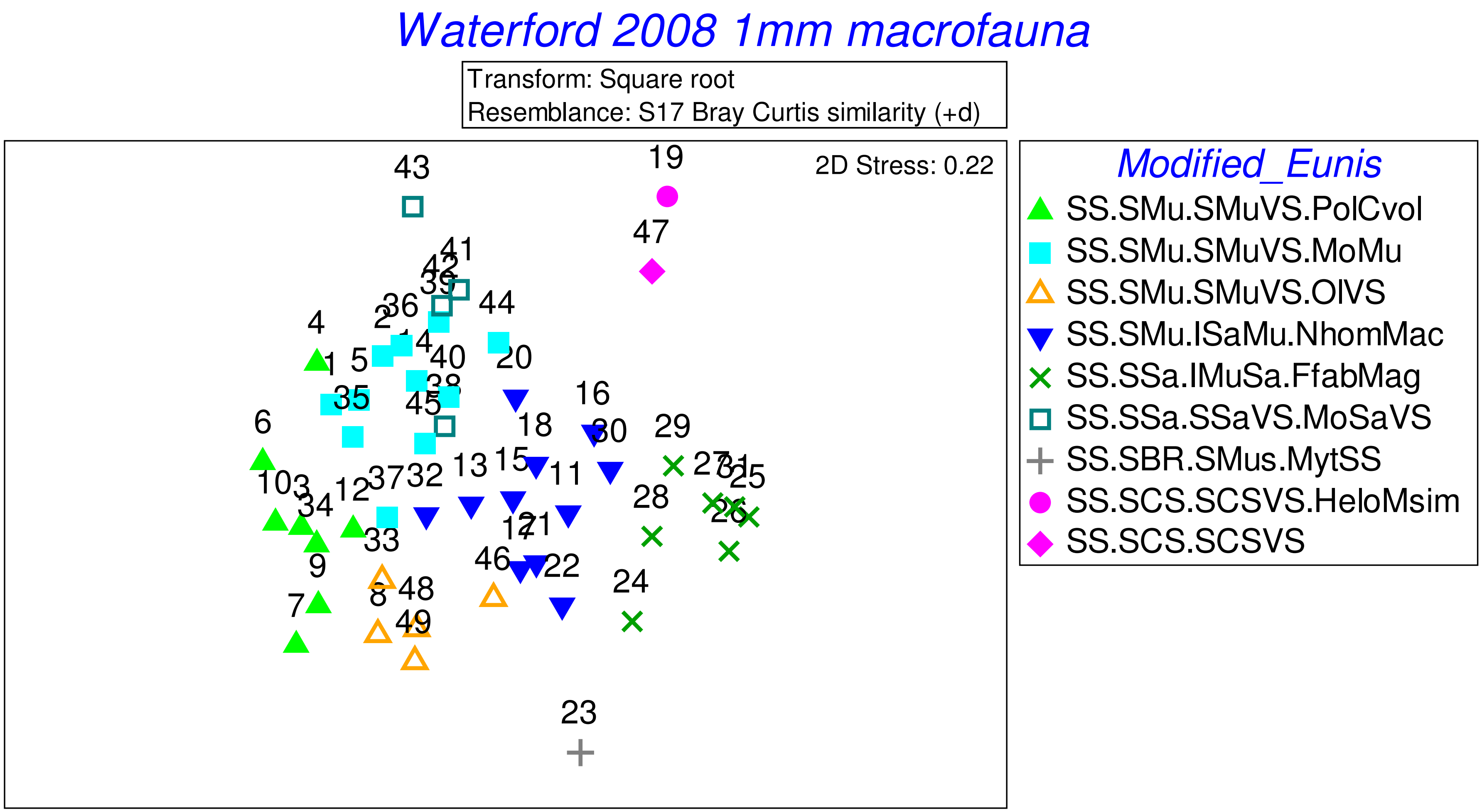

Figure 5: Multidimensional scaling (MDS) plot of square root transformed zero adjusted Bray Curtis similarities between stations in Lower River Suir cSAC and River Nore and River Barrow cSAC. The labeling factor is level 5 EUNIS classification assigned using a SIMPROF significance test and SIMPER analysis.

Station	Eunis Sed	Mobility	Lev2	Lev3	Lev4	Lev5
1	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
2	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
3	Mu	0	SS	SMu	SMuVS	SS.SMu.SMuVS.PolCvol
4	Mu	0	SS	SMu	SMuVS	SS.SMu.SMuVS.PolCvol
5	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
6	Sa	0	SS	SSa	SSaVS	SS.SMu.SMuVS.PolCvol
7	CS	0	SS	SCS	SCSVS	SS.SMu.SMuVS.PolCvol
8	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.OlVS
9	Sa	0	SS	SSa	SSaVS	SS.SMu.SMuVS.PolCvol
10	Mu	0	SS	SMu	SMuVS	SS.SMu.SMuVS.PolCvol
11	Mu	0	SS	SMu	ISaMu	SS.SMu.ISaMu.NhomMac
12	Mu	0	SS	SMu	SMuVS	SS.SMu.SMuVS.PolCvol
13	Mu	0	SS	SMu	ISaMu	SS.SMu.ISaMu.NhomMac
14	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
15	Mu	0	SS	SMu	ISaMu	SS.SMu.ISaMu.NhomMac
16	Sa	0	SS	SSa	ISaMu	SS.SMu.ISaMu.NhomMac
17	Sa	0	SS	SSa	ISaMu	SS.SMu.ISaMu.NhomMac
18	Mu	0	SS	SMu	ISaMu	SS.SMu.ISaMu.NhomMac
19	CS	0	SS	SCS	SCSVS	SS.SCS.SCSVS.HeloMsim
20	Mu	0	SS	SMu	ISaMu	SS.SMu.ISaMu.NhomMac
21	Mu	0	SS	SMu	ISaMu	SS.SMu.ISaMu.NhomMac
22	Mu	0	SS	SMu	ISaMu	SS.SMu.ISaMu.NhomMac
23	Mu	0	SS	SBR	SMus	SS.SBR.SMus.MytSS
24	Sa	0	SS	SSa	IMuSa	SS.SSa.IMuSa.FfabMag
25	Sa	0	SS	SSa	IMuSa	SS.SSa.IMuSa.FfabMag
26	Sa	0	SS	SSa	IMuSa	SS.SSa.IMuSa.FfabMag
27	Sa	0	SS	SSa	IMuSa	SS.SSa.IMuSa.FfabMag
28	Sa	0	SS	SSa	IMuSa	SS.SSa.IMuSa.FfabMag
29	Sa	0	SS	SSa	IMuSa	SS.SSa.IMuSa.FfabMag
30	Sa	0	SS	SSa	ISaMu	SS.SMu.ISaMu.NhomMac
31	Sa	0	SS	SSa	IMuSa	SS.SSa.IMuSa.FfabMag
32	Mu	0	SS	SMu	SMuVS	SS.SMu.ISaMu.NhomMac
33	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.OlVS
34	Mu	0	SS	SMu	SMuVS	SS.SMu.SMuVS.PolCvol
35	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
36	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
37	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
38	Sa	1	SS	SSa	SSaVS	SS.SSa.SSaVS.MoSaVS
39	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
40	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
41	Sa	1	SS	SSa	SSaVS	SS.SSa.SSaVS.MoSaVS
42	Sa	1	SS	SSa	SSaVS	SS.SSa.SSaVS.MoSaVS
43	Sa	1	SS	SSa	SSaVS	SS.SSa.SSaVS.MoSaVS
44	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
45	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.MoMu
46	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.OlVS
47	CS	0	SS	SCS	SCSVS	SS.SCS.SCSVS
48	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.OlVS
49	Mu	1	SS	SMu	SMuVS	SS.SMu.SMuVS.OlVS

Table 6: Habitat classification of benthic stations in Lower River Suir cSAC and River Nore and River Barrow cSAC and Waterford Harbour, July 2008. For complete legend, see next page. **= a biotope described from one sample. Stations labeled in red show difference between the level three biotope determined by grain size analysis and that determined by faunal analyses.

Table 6: Habitat classification of benthic stations in Lower River Suir cSAC and River Nore and River Barrow cSAC and Waterford Harbour, July 2008. **= a biotope described from one sample.

SS.SMu.SMuVS = sublittoral mud in variable salinity (estuaries)

SS.SMu.SMuVS.OlVS = Oligochaetes in variable or reduced salinity infralittoral muddy sediment

SS.SMu.SMuVS.MoMu = infralittoral fluid mobile mud in variable salinity

SS.SMu.SMuVS.PolCvol = *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay

SS.SSa.SSa.VS = Sublittoral sand in variable salinity (estuaries)

SS.SSa.SSa.VS.MoSaVS = Infralittoral mobile sand in variable salinity (estuaries)

SS.SMu.ISaMu.NhomMac = *Nephtys hombergii* and *Macoma baltica* in infralittoral sandy mud

SS.SSa.IMuSa.FfabMag = *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand

SS.SCS.SCSVS = Sublittoral coarse sediment in variable salinity (estuaries)

SS.SCS.SCSVS.HeloMsim** = *Hesionura elongata* and *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand

SS.SBR.SMus.MytSS** = *Mytilus edulis* on subtidal sediments

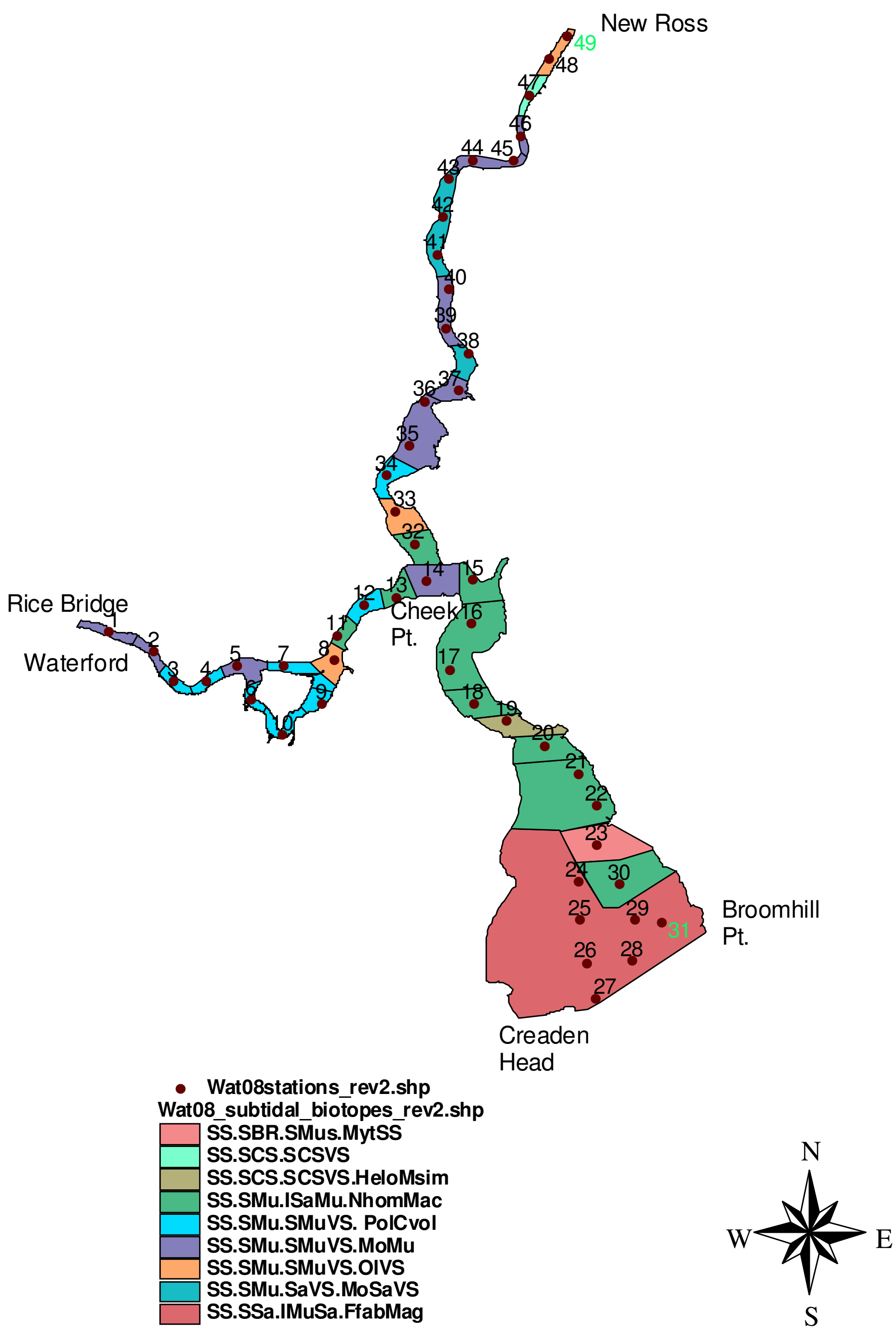

Figure 6: Subtidal benthic JNCC biotopes sensu Connor et al (2004) in Waterford Harbour, the Lower River Suir cSAC and River Barrow and River Nore cSAC as determined by analyses of Day grab samples taken in July 2008.

4. Discussion

The sediment data was largely classified as sandy mud and muddy sand with a small amount of coarser stations. The coarse stations were outliers in terms of macrofauna also. Principal components analysis (PCA) was effective in separating out the EUNIS sediment classes, indicating that these classes are meaningful in terms of sediment distribution. However, the faunal groups overlapped the EUNIS sediment classes, indicating that the level 5 biotopes can only be effectively classified from "the bottom up" *sensu* Connor et al 2004. There appears to be an association between sand and the SS.SSa.IMuSa.FfabMa biotope and mud at the SS.SMu.IMuSa.NhomMac in the Harbour area. Bioenv analysis revealed that the distribution of gravel had the most explanatory power of the sediment parameters in terms of the macrofaunal distribution. The organic content of the sediment was normal for estuarine conditions and there was no indication of excessive organic enrichment.

The estuarine fauna was very depauperate, most likely due to the stress of the variable salinity, shallow water depth and associated resuspension of sediments by wind and tidal disturbance. The fauna was poorest in the Barrow estuary. This may be linked to several factors:

- The sampling effort reached further into the estuarine reaches of the Barrow than the Suir.
- There may be an effect of heavy shipping causing bottom disturbance in the very narrow and shallow Barrow estuary.
- The topography of the Barrow may have an effect. It is very exposed to the south and may funnel the wind along its length.
- Most stations sampled in the Barrow showed evidence of sediment mobility. Highly mobile sediments in variable salinity are a habitat that very few macrofaunal species are robust enough to tolerate.

Connor et al (2004) state that some biotopes for example mobile mud in variable salinity can only be determined with the aid of field notes. In this study, field sediment observations indicated that there was mobile sediment overlying the clay at many stations in the Barrow and some in the Suir. It is difficult to determine if these field observations are reliable. Grab samplers are not designed to maintain the stratigraphy of the sediments they sample. In the case of this survey, field observations do provide evidence at some stations of sediment mobility and layering. In conjunction with observations of the sediment load in the water column this may be sufficient to classify a station as having mobile sediments. More detailed and reliable assessment of the stratigraphy of the sediment could be obtained from a small core.

Connor et al (2004) allude to the possibility that some biotopes such as SS.SSa.SSa.VS.MoSaVS, which is largely azoic, are transitory and can only be determined at slack water because animals are carried in as bedload at other times. Other biotopes such as SS.SMu.SMuVS.MoMu may appear as reduced diversity versions of other biotopes such as SS.SMu.SMuVS.OlVS or SS.SMu.SMuVS.PolCvol. In the case of this survey, OlVS and PolCvol were found adjacent to MoMu in both the Barrow and Suir estuaries, and were determined based on numbers of species and individuals obtained from a single grab sample per station. Replicate grab samples from these stations may have led to a different classification. Connor et al (2004) yield that it is not always possible to clearly delineate between biotopes, but in this case there is a clear possibility that OlVS and MoMu in the Barrow are essentially the same biotope at stations that have experienced different recent levels of sediment mobility. Similar issues exist for PolCvol and MoMu in the Suir estuary. There are also similar issues for NhomMac at stations 11 and 13, MoMu at stations 14 and PolCvol at stations 10 and 12. Management objectives set for these types of biotopes should presumably be set at level 4 to account for the possibility of an area changing from one level 5 biotope to another over time. There is an extensive scientific literature describing the nature of succession on the soft seafloor (Pearson & Rosenberg 1978, Rhoads 1978, Kaiser et al 2006). Johnson (1971, 1972) suggests that communities are temporal and spatial mosaics "parts of which are at different levels of succession .... in this view the community is a collection of relics of former disasters" caused by local disturbance, rather than a uniform passive reflection of environmental parameters. The level 5 biotopes in the physically disturbed shallow estuarine areas may simply represent tiles in the mosaic. A greater quantitative sampling effort would aid in clarifying the situation. Qualitative samples such as dredging have several disadvantages including the capture of epifauna, unknown sample volume and unknown sample location that make them unsuitable for inferential statistical analyses.

There are a minority of stations in this survey where the level 5 biotope derived from the macrofaunal analyses do not match the level 3 biotopes derived from grainsize analyses. Stations 6, 7 and 9 in the Suir estuary were classified as the muddy biotope SS.SMu.SMuVS.PolCvol, despite being characterised as sand (6 and 9) or coarse sediment (7) by the EUNIS sediment classification scheme. The EUNIS sediment scheme is a very simplified version of the Folk triangle (Folk and Ward 1957) devised to allow for clearer classification of habitats than the original scheme would allow for. In the case of these stations, they are classified as sand (6), gravel (7) and muddy sand (9) by the Folk triangle. Other stations in the PolCvol group were classified as Mu by EUNIS and muddy sand by Folk and Ward 1957. The mud / sand boundary is rather arbitrary in the EUNIS scheme, as acknowledged by O'Connor et al 2004. Reclassifying stations 6 and 9 as mud rather than sand based appears to be a reasonable action. Reclassifying station 7 from coarse sediment warrants further discussion. There is no doubt that the faunal data from station 7 is clearly grouped with stations 6, 9, 10 and 12. In a framework where biotopes are derived from the "bottom up", i.e. primarily from faunal analyses, there will always be cases in which there is mismatch between the fauna and sediment groupings. This is because other factors such as salinity variation, organic content, water depth, aspect, exposure, current speed etc. can have pronounced effects on macrofaunal communities either as main effects or as interactions with grain size. This can mean that where a station is in an estuary and its recent disturbance history (such as sediment mobility) can have as great an effect on the macrofaunal community structure (Level 5 biotope) as the grain size distribution. A top down approach using grain size in conjunction with other environmental variables to determine biotopes before assessing the successional status of the macrofaunal communities within these biotopes may be a useful strategy in managing coastal and estuarine conservation areas. This is an area of active research across the EU at the time of writing this report, see *inter al.* Galvan et al 2010, Ducrotoy 2010,Valesini et al 2010.

In the Barrow estuary, the discontinuity between the faunal and the sediment classifications occurred again. Stations 38 and 41-43 were classified as SS.SSa.SSaVS.MoSaVS, while stations 36, 37, 39, 40, 44, 45 were classified as SS.SMu.SMuVS.MoMu, despite all stations from 36-45 forming a single cluster in the SimProf analysis. Both SS.SMu.SMuVS.MoMu and SS.SSa.SSaVS.MoSaVS are essentially near azoic communities on mobile mud or mobile sand respectively. These stations were settled by the same early stage opportunistic species *e.g.* Capitellid polychaetes, amphipods in the genus *Bathyporeia*. These species are known to show little substrate preference for settlement (Bolam & Fernandes 2003, Shull 1997, Hannan 1981) utilising available space when larvae being dispersed. Here, the principle reason for splitting the 36-45 faunal group into two was for greater correspondence to the EUNIS scheme. It may have been equally valid to classify the entire group as MoMu as there were more MoMu stations than MoSa. This is another area of uncertainty that may possibly be resolved by a top down classification approach.

In this survey, a modified EUNIS classification scheme was employed to compensate for low sampling effort. Using best current practise (square root transformation, Zero adjusted Bray Curtis similarity, similarity profile tests) a robust classification was derived for this area that appears to be qualitatively comparable to the JNCC core records. It should be noted however, that this classification is different to the standard EUNIS scheme of O'Connor et al 2004. While performing exploratory analyses on this data set it became very clear that the data processing techniques used would have a marked effect on the output of the analyses. In particular, the choice of transformation and use of zero adjusted Bray Curtis similarity had very strong effects on the final classification derived. Similar effects can be expected from different levels of taxonomic resolution. Evidence from Ireland (Kennedy et al 2002) and elsewhere (Olsgard et al 1997) indicates that the effect of transformation and taxonomic level on the output of multivariate analyses can be very pronounced. It is important therefore that the same data processing techniques be applied to future comparable studies in Ireland if inter-site comparison is needed between conservation areas, including the standardisation of taxonomic resolution.

5. Conclusion

The benthic habitats of the Suir and Barrow estuaries and Waterford Harbour can be shown to be statistically significant and to conform qualitatively to normal biotopes as defined by Connor et al 2004, using a modified classification scheme. In some cases, the level 5 biotopes assigned did not match the level 3 biotope determined by grain size analysis. The spatial distribution of these biotopes in relation to mobile sediments and salinity variability indicates that these level 5 biotopes may represent successional stages of the same biotope. If statistical confidence is required in the biotope classification, management measures should be made at EUNIS level 4 for the estuarine areas in this survey. An improved habitat classification would result from a greater quantitative sampling effort. The use of top down classification techniques may remove some of the subjectivity from the modified EUNIS scheme, and provide a more robust management tool.

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Appendix 1: Principal components analysis (PCA) of sediment data from Lower River Suir cSAC and River Barrow cSAC.

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	2.46	30.7	30.7
2	2.15	26.9	57.6
3	1.4	17.5	75.1
4	0.845	10.6	85.7
5	0.568	7.1	92.8

Eigenvectors

(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
gravel	−0.237	0.116	0.696	0.099	−0.293
coarse sand	−0.437	0.119	−0.010	−0.697	0.361
medium fine sand	−0.238	0.476	−0.359	0.188	−0.428
fine sand	0.418	0.447	−0.243	0.039	−0.030
very fine sand	0.588	−0.073	−0.028	−0.189	0.250
silt clay	−0.071	−0.617	−0.090	0.374	0.041
SKEWNESS	0.404	−0.070	0.371	−0.371	−0.479
KURTOSIS	0.087	0.395	0.425	0.393	0.552

Principal Component Scores

Sample	SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
1	0.278	0.979	0.587	0.426	0.553
2	−1.55	−1.56	−0.405	0.938	0.848
3	0.319	1.25	0.253	0.287	−0.941
4	0.438	0.161	0.384	0.167	0.949
5	0.835	−1.47	0.21	−0.316	−0.576
6	1.73	1.27	0.213	−0.376	8.23E−2
7	−2.88	1.47	6.78	1.28	−1.19
8	0.826	−0.342	0.127	−0.304	−0.184
9	−0.87	1.77	−0.526	0.453	−2.16E−2
10	0.736	0.222	0.201	9.34E−3	−8.41E−2
11	−1.04	0.979	−0.441	0.172	−0.986
12	0.88	−1.39	0.3	−0.443	−0.4
13	0.364	−1.68	0.124	−0.272	−0.398
14	−6.62E−3	−1.8	−9.26E−2	4.5E−2	−0.276
15	−0.708	−1.93	−0.396	0.464	−0.11
16	2.07	0.427	−0.427	−1.51	−0.995
17	1.38	1.09	0.563	0.519	0.878
18	0.639	0.359	0.109	6.26E−2	−0.368
19	−4.37	1.39	−0.577	−2.05	−1.19
20	0.842	0.241	0.45	0.172	0.771
21	0.173	−0.709	8.21E−4	6.42E−2	0.193
22	1.19	−1.46	0.373	−0.468	−0.374
23	−1.37	−2.53	−0.516	1.16	0.109
24	1.5	0.782	0.115	0.207	1.43
25	1.93	0.591	−6.38E−2	−0.95	0.322
26	1.78	0.934	−2.78E−2	−0.632	0.173
27	−0.201	1.84	−1.06	0.635	0.951
28	0.93	1.61	−0.696	−0.244	−0.484
29	1.62	1.58	0.286	−0.206	−0.118
30	1.17	1.88	1.16	0.714	1.59
31	2.27	5.76E−2	−0.473	−1.51	−0.523
32	−0.894	−2.24	−0.354	0.515	−1.62E−4
33	0.308	−1.14	−0.132	−0.238	−0.645
34	−0.924	0.211	−0.493	0.368	−0.191
35	0.266	−1.3	−9.15E−2	−0.323	−0.543
36	1.25	−0.845	0.203	−0.626	−0.459
37	0.869	−0.499	9.51E−2	−0.338	−0.318
38	1.39	0.842	0.115	0.242	1.31
39	−1.67	−1.67	−0.486	1.09	0.893

40	−0.208	−1.71	−0.209	0.147	−0.344
41	−1.38	2.88	−2.34	1.07	−0.732
42	1.28	1.42	0.882	9.83E−2	0.135
43	−2.16	3.4	−2.62	1.65	−0.796
44	−1.43	−1.65	−0.516	0.925	0.586
45	0.753	−1.44	4.97E−2	−0.543	−0.744
46	−1.36	0.772	−0.477	0.217	−0.604
47	−5.15	0.611	0.425	−3.95	2.05
48	−0.932	−1.49	−0.188	0.577	0.857
49	−0.926	−2.17	−0.404	0.63	−9.05E−2