Severn Estuary SAC and SPA: Intertidal Mudflats and Sandflats Condition Assessment 2012

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Performing Company:

Ecospan Environmental Ltd
Unit 8 Strashleigh View
Lee Mill
Devon
PL21 9GS

Tel: 01752 897198
Email: info@ecospan.co.uk
www.ecospan.co.uk

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Author: LA Curtis

Approved By: M D R Field

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1. Gavin Black — Natural England
2. Mike Field — Ecospan Environmental Ltd

EXECUTIVE SUMMARY

The Severn Estuary is the largest example of a coastal plain estuary in the United Kingdom. It has been designated as a Special Area of Conservation (SAC) under the EU Habitats Directive, a Special Protection Area (SPA) under the Birds Directive and as a Ramsar site under the Convention on Wetlands of International Importance. Natural England and the Countryside Council for Wales (CCW), now National Resource Wales (NRW) have a duty to monitor and assess the condition of the SAC's features once every six years. The primary focus of this study relates to monitoring the intertidal mudflats and sandflats feature of the Severn Estuary SAC by assessing the relevant attributes for the purpose of condition assessment. However, monitoring of prey availability within the Severn Estuary SPA was also a secondary objective.

The methods employed within this study were largely limited to Phase II sampling that was based on Phase I biotope maps from previous studies. However, if any obviously incorrect biotope boundaries were encountered or if any notable habitats or species were observed during the course of the surveys, then records were appropriately amended. Anthropogenic influences and negative indicators were also recorded where encountered.

A total of 9 littoral mudflat and sandflat sediment biotopes were identified throughout the Severn Estuary SAC and SPA during the course of the study, and their subsequent extent and distribution was mapped using GIS. The macrofaunal communities within two of the biotopes were found to vary geographically, depending on their distance from the head of the estuary.

Temporal comparisons of littoral sediment biotopes in the Severn Estuary SAC resulted in a number of apparent changes. However, no quantitative core data from previous surveys was received from either CCW or Natural England which made it difficult to draw any firm conclusions. Very broadly speaking the total number of littoral sediment biotopes does not appear to have altered greatly over time. The principal differences in biotopes were as a consequence of different versions of the Marine Habitat Classification for Britain and Ireland being used between studies. Notwithstanding the differences in classification used between studies, it is thought that a number of potentially real changes in biotope distributions elsewhere in the estuary are apparent. Most notably, differences include the absence of the polychaete *Arenicola marina* from the Welsh Grounds in the mid estuary and, in the lower estuary on both the Welsh and English shores (including those within Bridgewater Bay, Weston and Sand Bay), the polychaete *Nephtys hombergii* appears to have displaced *Hediste diversicolor*. The precise reasons for these temporal changes are unknown but a number of likely physical and biological contributory factors are discussed Over the survey area a number of negative indicators were observed including outfalls, evidence of netting and litter. The vast majority of water inputs were land drains. However, there were also several industrial pipelines and some sewers. A large number of these were clearly disused with many looking as if they had not been operational for several years.

Since previous relevant surveys within the study area have been limited to Phase I methods and quantitative data was not available, it has been impossible to draw definitive conclusions with regard to the condition of the measured attributes of the Severn Estuary SAC and SPA. The output from this study will however provide a comprehensive baseline from which a change in the condition of the attributes can be measured within any future condition assessments.

An evaluation of methods has been carried out and a number of recommendations have been made for future condition assessment of the Severn Estuary SAC and SPA. In summary, the

methods adopted within this study have cost effectively enabled the aims and objectives set out by Natural England to be met as far as practicably possible. Generally, a good level of sample replication was achieved within each of the biotopes, and the number of replicates was largely proportional and representative of the total area of each biotope; an exception was within the biotope - *Macoma balthica* and *Arenicola marina* in littoral muddy sand (LSa.MuSa.MacAre) which would have benefited from greater replication. It is recommended that the same station coordinates should be used in any future condition assessment, and sampling should be carried out at the same time of year to enable direct comparisons of communities to be made in future.

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1. INTRODUCTION

The Severn Estuary is the largest example of a coastal plain estuary in the United Kingdom and one of the largest estuaries in Europe. It has been designated as a Special Area of Conservation (SAC) under the EU Habitats Directive, a Special Protection Area (SPA) under the Birds Directive and as a Ramsar site under the Convention on Wetlands of International Importance. The overall area of the European and International conservation designations is 73,715.4 ha, of which, roughly two thirds is composed of sub-tidal habitats (stable sandbanks and shifting sediments of gravel, sand and mud) and one third is composed of intertidal habitats (tide washed mud and sand, saltmarshes and rocky shores).

A number of habitats and species have also been recognised through the designation of several Sites of Special Scientific Interest (SSSI) (most notably, the Upper Severn Estuary, Severn Estuary and Bridgwater Bay SSSIs in the 1980's) which underpin the European and international designations.

The intertidal part of the Severn Estuary supports extensive mudflats and sandflats. These cover an area of approximately 20,300 ha - the fourth largest area in a UK estuary and representing approximately 7% of the total UK resource of this habitat type (approximately 10% of the UK Natura 2000 resource for intertidal mudflats and sandflats, by area.)

The intertidal mudflats and sandflats of the Severn Estuary are representative of estuarine mudflats and sandflats influenced by strong tidal streams and extreme silt loading. As an SPA, the Severn Estuary is internationally important for assemblages of migratory passage and overwintering bird species. The intertidal mud and sandflats provide rich feeding areas for these species, with the less mobile, muddier areas being of greater value than the more mobile coarser sediment areas.

1.1 Condition Monitoring of the Intertidal mud and sandflats of the Severn Estuary SAC and SPA

Site Condition Monitoring (SCM) is undertaken to determine whether the status of the special interest features which underpin the designation of habitats or areas are being maintained, and to guide site management action where appropriate. Natural England and the Countryside Council for Wales (CCW), now National Resource Wales (NRW) have a duty to monitor and assess the condition of the SAC's features once every six years.

Natural England in association with other countryside agencies has established a series of common standards for the monitoring of sites of nature conservation interest. These common standards apply to a number of statutory designated sites, including SACs and SPAs, and ensure that a consistent approach is taken when monitoring such sites. Within the Severn Estuary SAC and SPA the intertidal special interest features which include the mudflats and sandflats fall under the Common Standards Monitoring (CSM) guidance produced for littoral sediment habitats[1].

For the purposes of monitoring, each feature has an associated series of attributes which are measurable indicators of the condition of the feature at the site. For each attribute a target is set which is considered to correspond to the favourable condition of the feature.

The primary focus of this study relates to the Severn Estuary SAC's intertidal mudflat and sandflat feature and monitoring its attributes. However, selected attributes of the Severn Estuary SPA are a secondary objective and as a result, are also considered within this study. Table 1 outlines those attributes and targets relating to the SAC and Table 2 outlines an additional attribute of the SPA.

Table 1. Attributes that, subject to natural variation, should be used to define the condition of the sandflat and mudflat features of the Severn Estuary SAC

SAC Attribute	Target
Extent and variety of the mudflat and sandflat communities comprising each sub-feature*	No decrease in the extent or range of types of intertidal mudflat and sandflat communities from an established baseline, subject to natural processes
Distribution of mudflat and sandflat communities*	Macro scale distribution of communities should not deviate significantly from an established baseline, subject to natural processes.
Community composition*	No decline in community quality due to changes in species composition or loss of typical species from an established baseline, subject to natural processes.
Sediment character Δ	Particle Size Analysis (PSA) - Mean PSA parameters should not deviate significantly from an established baseline. Reduction Oxidisation (REDOX) profile - Mean black layer depth should not deviate significantly from an established baseline.

*Phase I data from CCW/English Nature Intertidal Biotope Surveys 1995-2005 [2][3] are available as a limited baseline for this attribute

Δ This study will provide the baseline for future condition assessment of this attribute

Table 2. Attributes that, subject to natural variation, should be used to define the condition of the sandflat and mudflat features of the Severn Estuary SPA

SPA Attribute	Target
Prey availability (biomass and abundance of specified prey species) Δ	Presence and abundance of suitable prey species should not deviate significantly from an established baseline

Δ This study will provide the baseline for future condition assessment of this attribute

1.2 Existing Biotope Information

Habitat surveys of the English shores were carried out on behalf of Natural England in 2005. The methods used during the survey were generally limited to Phase I techniques, but on some occasions, sediment core samples and dig samples were collected and returned to marine laboratories for macrofaunal analysis confirmation of the field identification.

Phase I surveys were also carried out on the Welsh shores between 1996 and 2005 on behalf of CCW. The specific methods used during these surveys are unknown as only the GIS map outputs are available.

Figures 1, 2 and 3 below illustrate the distribution of the littoral sediment biotopes in the Severn Estuary SAC and SPA, as reported in 2006[3] on the English shores and between 1996 and 2005 on Welsh shores[2]. The sampled stations in 2012 have also been included on these maps to help make comparisons with the data collected in 2012.

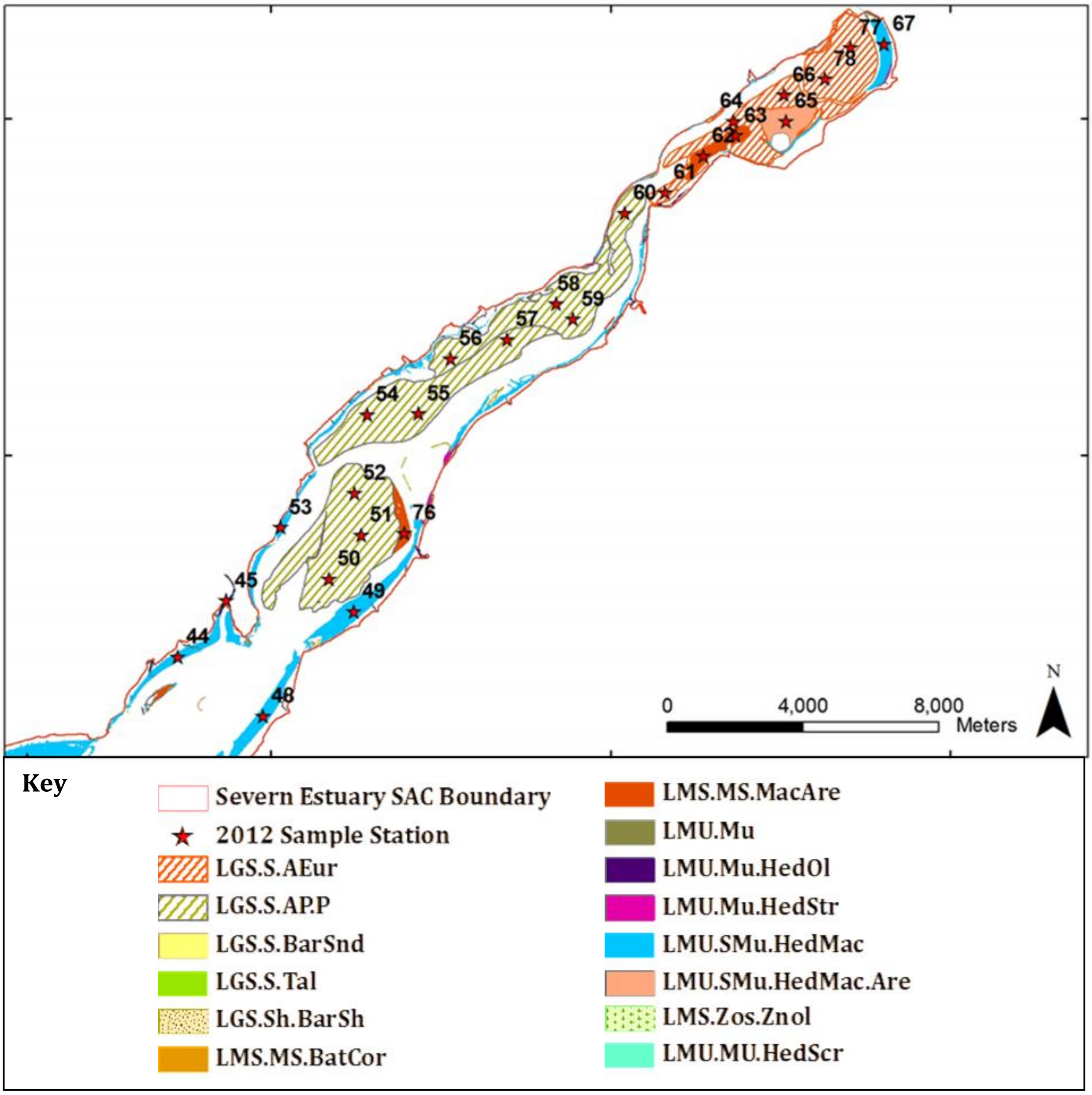

Figure 1. Upper Severn Estuary SAC and SPA littoral sediment biotope map 1996 - 2005

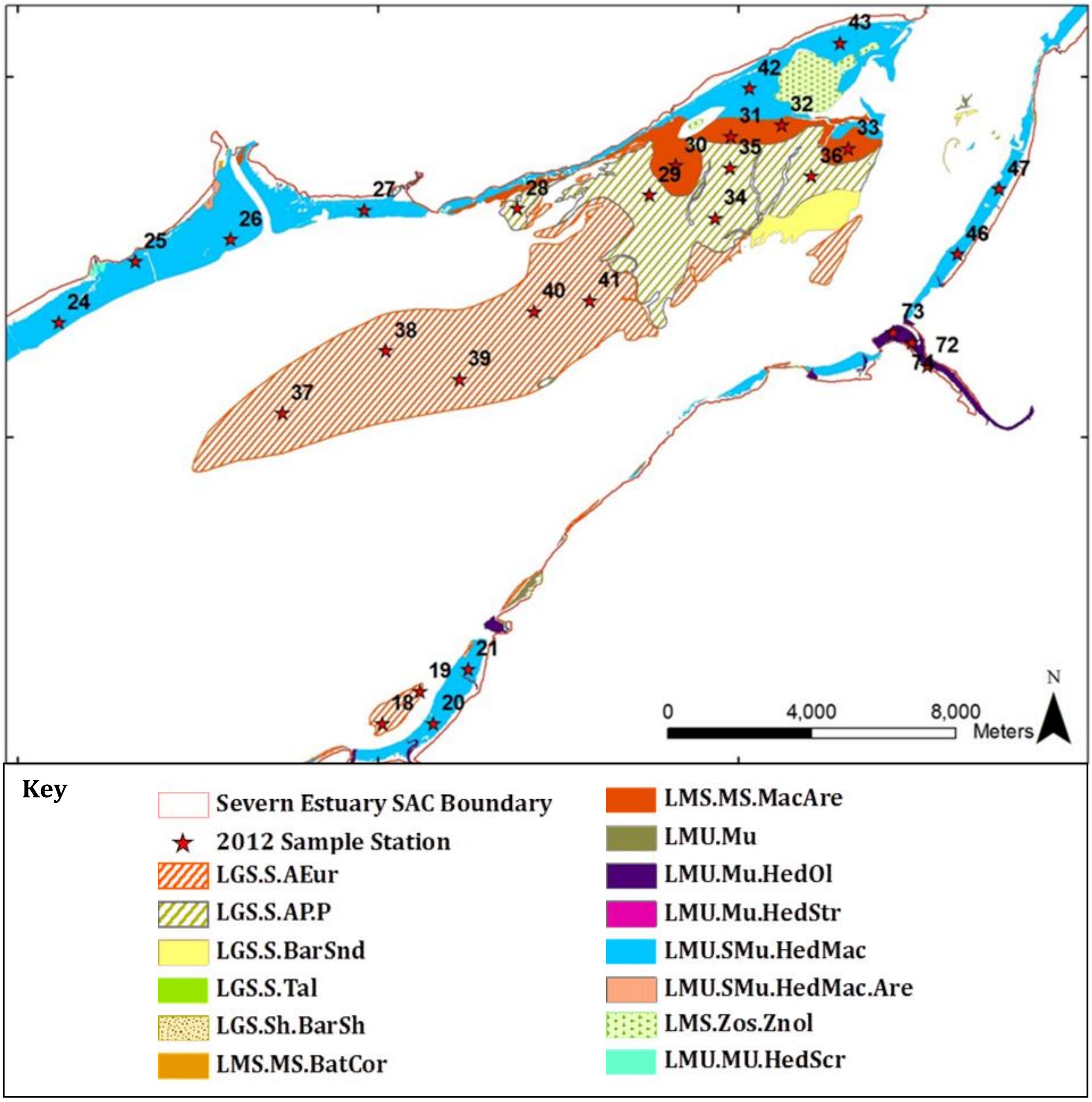

Figure 2. Mid Severn Estuary SAC and SPA littoral sediment biotope map 1996 - 2005

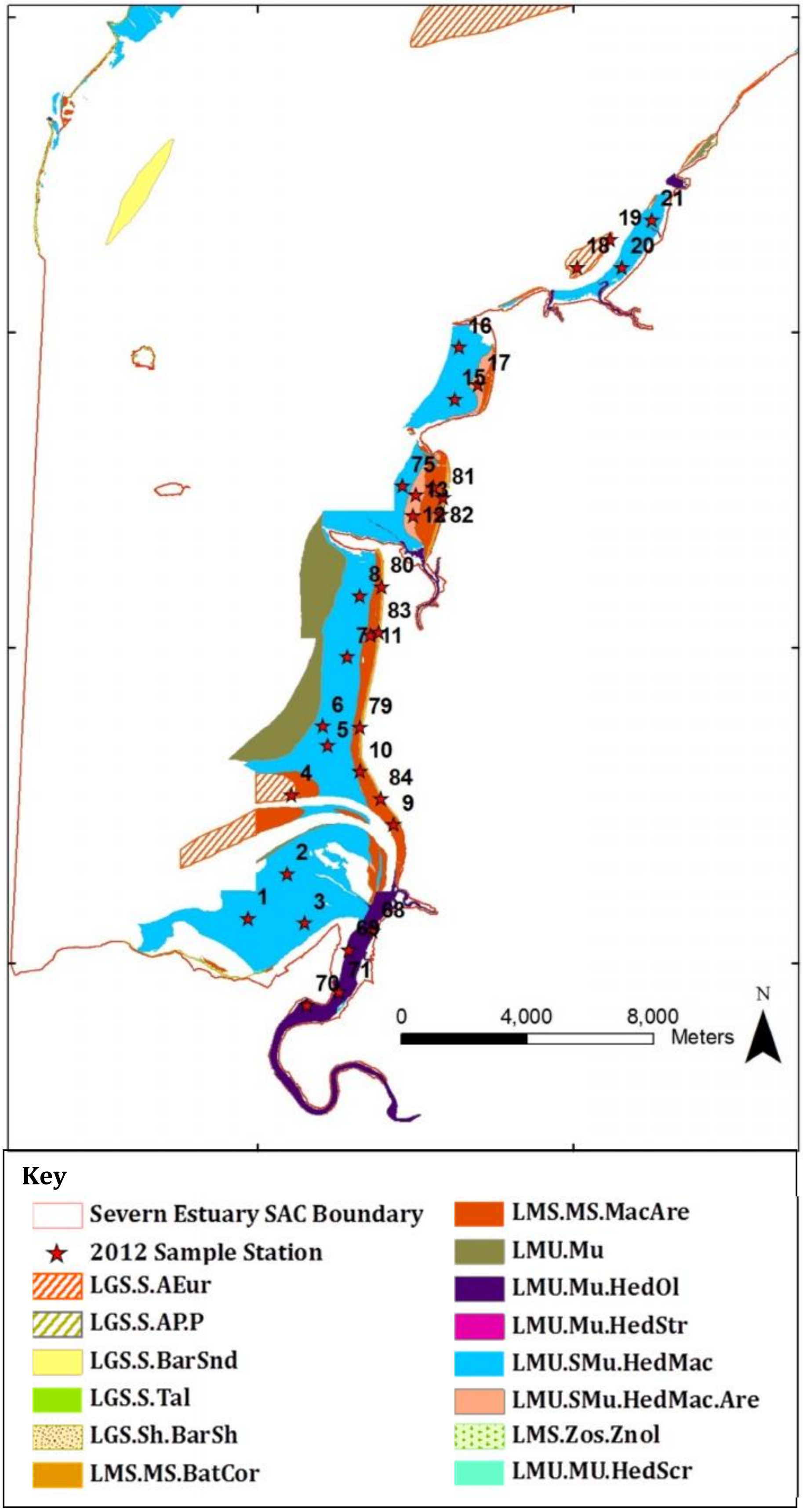

Figure 3. Lower Severn Estuary SAC and SPA littoral sediment biotope map 1996 – 2005

1.3 Objectives

The specific aims for this condition assessment of the intertidal sandflat and mudflat features within the Severn Estuary European Marine Site (EMS) as determined by Natural England were:

- To develop a cost effective sampling design to enable a measure of each sub-feature attribute to be obtained.
- To develop a sampling strategy that provides sufficient statistical power to determine a change in ecological condition over time and determine potential differences in particular attributes between otherwise similar communities subject to differing pressures.
- To undertake the necessary fieldwork and to analyse and interpret the resulting data. This will include appropriate statistical analyses to enable the hypotheses set out above to be tested as well as the quantitative characterisation of the condition of benthic communities. The range of intertidal habitats and associated fauna that exist within the area surveyed will also be described
- To identify and record the nature and location of any obvious human impacts identified during the survey within or near the sites (e.g. bait digging, fishing activities, coastal defence works, and damaging activities).
- To evaluate the effectiveness of data collection methods, techniques and technical equipment.
- To provide fully detailed 'standard operating protocols' for the work undertaken to ensure that these can be repeated in the future.
- To produce a concise technical report detailing the findings of the project and the condition of each attribute.
- To provide all data collected in the relevant Mapping European Seabed Habitats (MESH) Data Exchange Format and to add all data to Marine Recorder.

2. METHODS

2.1 Sampling Strategy

Ecospan Environmental Ltd would usually have recommended a two phased approach for undertaking surveys of this kind. The first phase would aim to determine the distribution and extent of littoral sediment biotopes, interest features, and species that are representative and/or notable within the study area. This would normally be achieved by examining geo-referenced aerial photography and subsequently ground-truthing defined habitats via field survey in order to establish the biotopes present. This stage would provide data on the extent and distribution of the various biotopes present in the study area.

However, due to the size of the study area and the fact that both sides of the Severn Estuary had been completely biotope mapped by EMU Ltd[3] and CCW[2] in the recent past, it was not considered that a further Phase I survey was required as this would add a significant cost to the project. It was therefore agreed, in consultation with Natural England's project officer, that the existing Phase I biotope maps should be used to provide the basis for a Phase II biotope survey.

Since the collection of these samples would also involve the transiting of large areas of the survey area, it was also agreed that Ecospan Environmental Ltd would alter the biotope maps if any obviously incorrect boundaries were encountered or any notable habitats or species observed.

The difference between this sampling strategy and the original one outlined in Natural England's tender specification was the use of target stations rather than transects. Ecospan Environmental Ltd has used both target station and the transect method in previous contracts with Natural England. Our experience indicates that the transect approach is useful in large areas of open coast where mudflats and sandflats tend to be more homogenous, but is the weaker method in more dynamic and complex estuarine systems.

The target stations were added to the biotope maps prior to the survey in consultation with Natural England. The number of stations (84) was pre-determined in the tender document. The approach used to determine the quantitative sampling positions was to examine the biotope maps produced following the 1995-2005 surveys[2][3] to sample each biotope in a proportional manner covering its entire geographical range within the estuary where possible, whilst simultaneously attempting to ensure adequate coverage in known bird feeding areas or other areas of interest. Areas that were thought to be barren and very small biotopes were excluded.

2.2 Access and Timing

All the necessary permissions were gained prior to the survey by Natural England and Ecospan Environmental Ltd. For reasons of efficiency and safety, all sampling was undertaken using Ecospan Environmental Ltd.'s 4 man MCA coded hovercraft Redshank. Since the Severn Estuary is probably one of the most dangerous in the U.K. having the third largest tidal range in the world, the hovercraft was also supported by our MCA Cat 3 coded RIB Pagrus for most of the survey. This also effectively extended the working range of the hovercraft offshore (due to coding limitations) and served as a mobile base for fuel, sample deposition etc. allowing optimal use of suitable weather and tide windows.

To gain access to many areas, spring tides were required. For this reason, the survey was undertaken in three blocks between the 13th October and 14th November 2012.

2.3 Station location

The exact sampling co-ordinates (OSGB36 BUG) are presented in Appendix 1. On arrival at each station and prior to sampling, the exact co-ordinates were recorded using differential GPS which is typically accurate to within 5 m. This was also used to record the hovercraft tracks during the survey (these are available within the GIS output of this contract).

2.4 Faunal Sampling

All sampling undertaken was consistent with ISO, Environment Agency and JNCC guidelines [4] [5] [6]. On arrival at the station, five replicate 0.01m^2 cores were taken to a depth of 15 cm following these guidelines and Ecospan Environmental Ltd. Standard Operating Procedure (SOP) SOP ES-087. Each fauna sample was labelled and stored separately in either bags or buckets until processing. A photograph of the sediment at the station and the general area was also taken (generally one up-shore and one down-shore, but it in some cases it was more relevant to take along-shore photographs). The fauna was subsequently separated from the sediment using a 0.5 mm sieve and preserved in uniquely labelled bottles containing 10% buffered formaldehyde and the vital stain Rose Bengal following SOP ES-028. Macrofauna samples were delivered to APEM Ltd for analysis.

2.5 Reduction-Oxidisation (Redox) Profile and Sediment Type

The depth of the Redox potential discontinuity (RPD) layer, a recognisable division zone between oxidized (sub-oxic) and reduced chemical conditions, was determined at each station. An *in situ* redox profile of the first 10 cm was taken at 2 cm intervals using a redox meter. The apparent depth of the redox discontinuity was also recorded following a visual assessment of depth of sediment colour change. The visual assessment was undertaken prior to the redox profile so that the accuracy of this subjective method could be determined. In some areas the sediment was too firm for the redox probe to penetrate without risk of breakage, and at one station the probe malfunctioned; in these areas a visual assessment only was recorded.

A second core was taken at each station for sediment granulometry (particle size analysis (PSA)). All samples were uniquely labelled. The sediment samples were delivered to the National Laboratory Service (NLS) at Starcross for PSA.

2.6 Determining the Extent and Distribution of Biotopes

The focus of this survey was to build on previous Phase I biotope surveys carried out by EMU [3] and CCW [2] to obtain quantitative macrofauna samples to enable condition assessment of the EMS. The biotope maps and target stations were overlaid onto aerial photography. These maps were then used in the field and the boundaries roughly checked when operating in each area. Additionally, when on a target station, a visual assessment was made of whether the biotope matched the description of the species and abiotic habitat features according to the biotope maps and the Marine Habitat Classification for Britain and Ireland (Vs 04.05) descriptions. If it was in a transitional area, or clearly in a different biotope, the position was moved to the correct biotope, if that biotope was available nearby. If no obviously correct biotope was available nearby, the sample was taken at the target position. Where significant variation or features of interest were observed, these were noted and the new boundary drawn using professional judgement.

2.7 Anthropogenic Influences and Negative Indicators

Anthropogenic influences and negative indicators were recorded where encountered in the survey area. Particular note was taken of outfalls that were clearly still in use and any areas where there were other evident pressures.

2.8 Univariate and Multivariate Analysis of Faunal Data

All faunal data was subjected to statistical analysis. The analysis is intended to establish a clearly defined quantitative baseline of faunal characteristics that could be used to facilitate a more robust condition assessment of the Severn Estuary EMS in the future.

Two statistical methods were used to interrogate the data, a univariate approach using species diversity statistics and a multivariate community analysis approach. The number of taxa per sample and number of individuals per sample were counted and the univariate indices (namely Shannon Wiener's diversity index, Margalef's species richness and Pielou's evenness) were calculated for each station. Community analysis in PRIMER 6[7] used the multivariate Bray-Curtis similarity statistic and multidimensional scaling (MDS) plots to assess the communities at each sampling site. MDS plots represent the sample points in three dimensions where the distances between points represent the differences between the samples. In order to reduce the influence of very abundant taxa on the analysis, the benthic invertebrate data set was subjected to a single square root transformation prior to fauna similarity analysis.

2.9 Quality Assurance

Ecospan Environmental Ltd has an ISO 9001 accredited quality management system to ensure that we work to the highest standards expected by our customers. We undertake all work in accordance with SOPs and recognised national and international guidelines.

3. RESULTS

3.1 Distribution of Biotopes

A total of 9 littoral sediment biotopes were sampled throughout the Severn Estuary SAC and SPA (Figures 4, 5 and 6). Where encountered, *Sabellaria alveolata* reefs on sand-abraded eulittoral rock (LS.LBR.Sab.Salv) were mapped, but this biotope was not targeted or sampled. The mapping of saltmarsh and *Zostera* beds was not an objective of the study but their distributions in certain areas have been mapped for clarity of the distribution of adjacent biotopes.

There do appear to be distributional patterns to biotopes related to geography (upper, mid and lower estuary) and some zonation relating to shore height, mainly in the mid-lower estuary. *Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand (LSa.MuSa.BatCare) and Barren or amphipod dominated mobile sand shores (LSa.MoSa) dominate the uppermost part of the estuary (above Lydney) until biotopes characterised by *Macoma balthica* (LSa.MuSa.MacAre and LMu.MEst.HedMac) become dominant in the mid-upper regions. As the estuary flows towards the sea LMu.MEst.HedMac remains present throughout the mid estuary on the mid and upper shores on both sides, but the vast high energy sandflats which extend out from the Welsh shores comprise mainly LSa.FiSa.Po communities in the more stable areas, and are barren (LSa.MoSa.BarSa) in areas where the sediment is most mobile.

At the lower extent of the estuary on the Welsh side, the characterising polychaete *Hediste diversicolor* in LMu.MEst.HedMac is replaced by *Nephtys hombergii* and the resulting biotope LMu.MEst.NhomMacStr occupies the most western shores. On the English shores of the lower estuary LMu.MEst.HedMac is also largely replaced by LMu.MEst.NhomMacStr, though the two biotopes are found alongside each other in some places, with LSa.MuSa.MacAre and/or LSa.MoSa.BarSa frequently found in zones on the upper shore. Bridgewater Bay represents the most western extent of littoral habitats in the Severn Estuary SAC on the English side, and has the most diverse array of biotopes relative to the rest of the SAC. LSa.FiSa.Po.Ncir and LMu.MEst.NhomMacStr are found on the mid and low shores adjacent to Burnham-on-Sea, whilst LSa.MuSa.MacAre occupies the upper shore of these flats. LMu.MEst.HedMac communities are found to dominate the flats on the western side of the mouth of the River Parrett. LMu.Mest.NhomMacStr communities occupy the lowest stretches of the Parrett which then transition with LMu.Uest.Hed.Str communities further up the mouth to the river.

Table 2 provides figures for the estimated total area occupied by each biotope within the Severn Estuary SAC and SPA. The table shows that LMu.MEst.HedMac accounts for the largest area of littoral sediment mapped.

Table 2. Estimated total area (m^2) occupied by sand and mudflat biotopes within the SAC

Biotope	Area Covered by Biotope (m^2)	% of Total Area Mapped
LMu.MEst.HedMac	45,171,878	23%
LSa.MoSa.BarSa	34,499,410	17%
LSa.MuSa.BatCare	29,736,131	15%
LMu.MEst.NhomMacStr	29,144,169	15%
LSa.FiSa.Po	21,867,167	11%
LSa.MuSa.MacAre	14,118,090	7%
LSa.FiSa.PoNcir	11,206,468	6%
LSa.MoSa	9,392,057	5%
LMu.UEst.Hed.Str	2,075,395	1%
LS.LBR.Sab.Salv	1,019,595	<1%

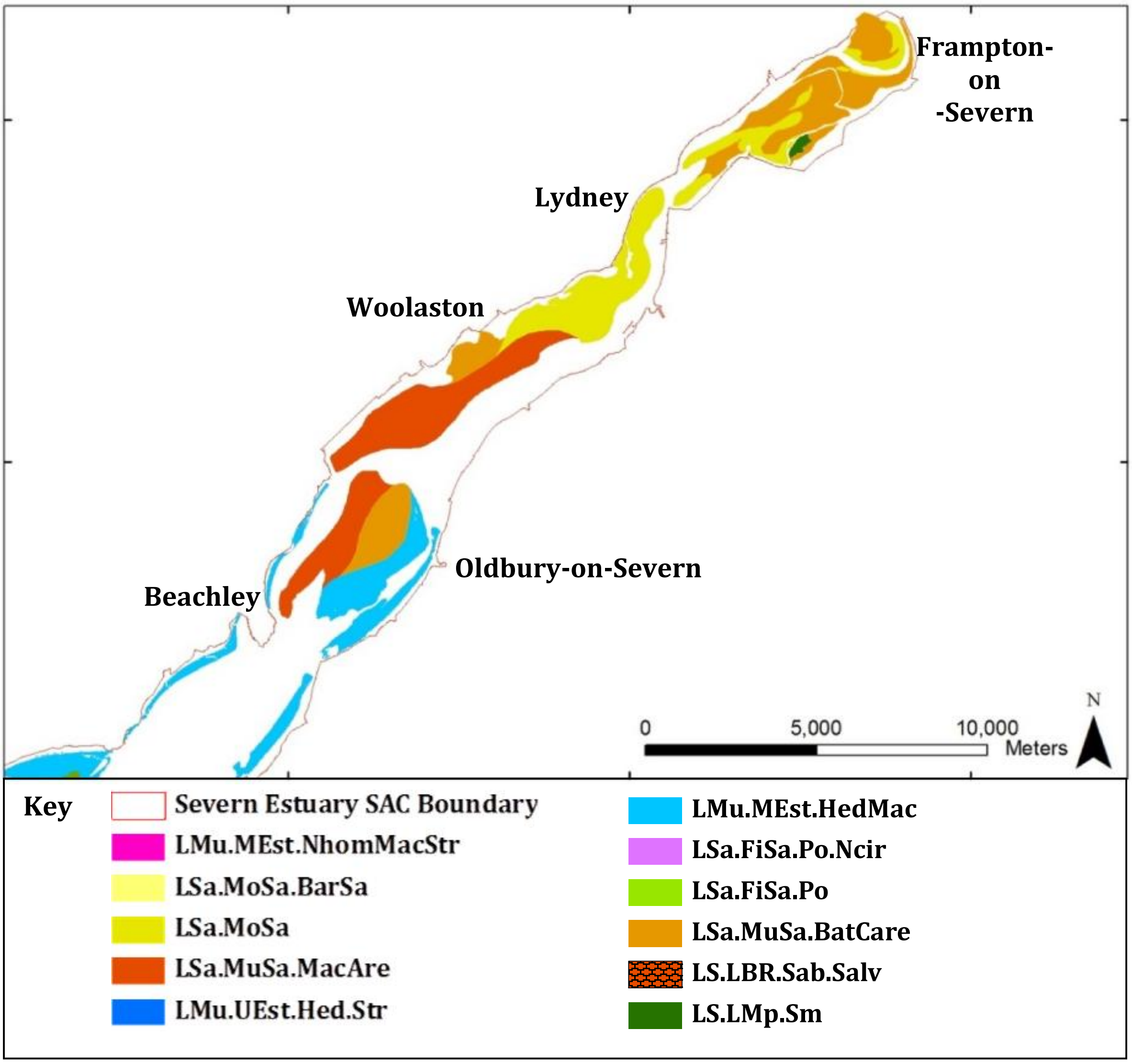

Figure 4. Distribution of sampled littoral sediment biotopes in the upper reaches of the Severn Estuary SAC.

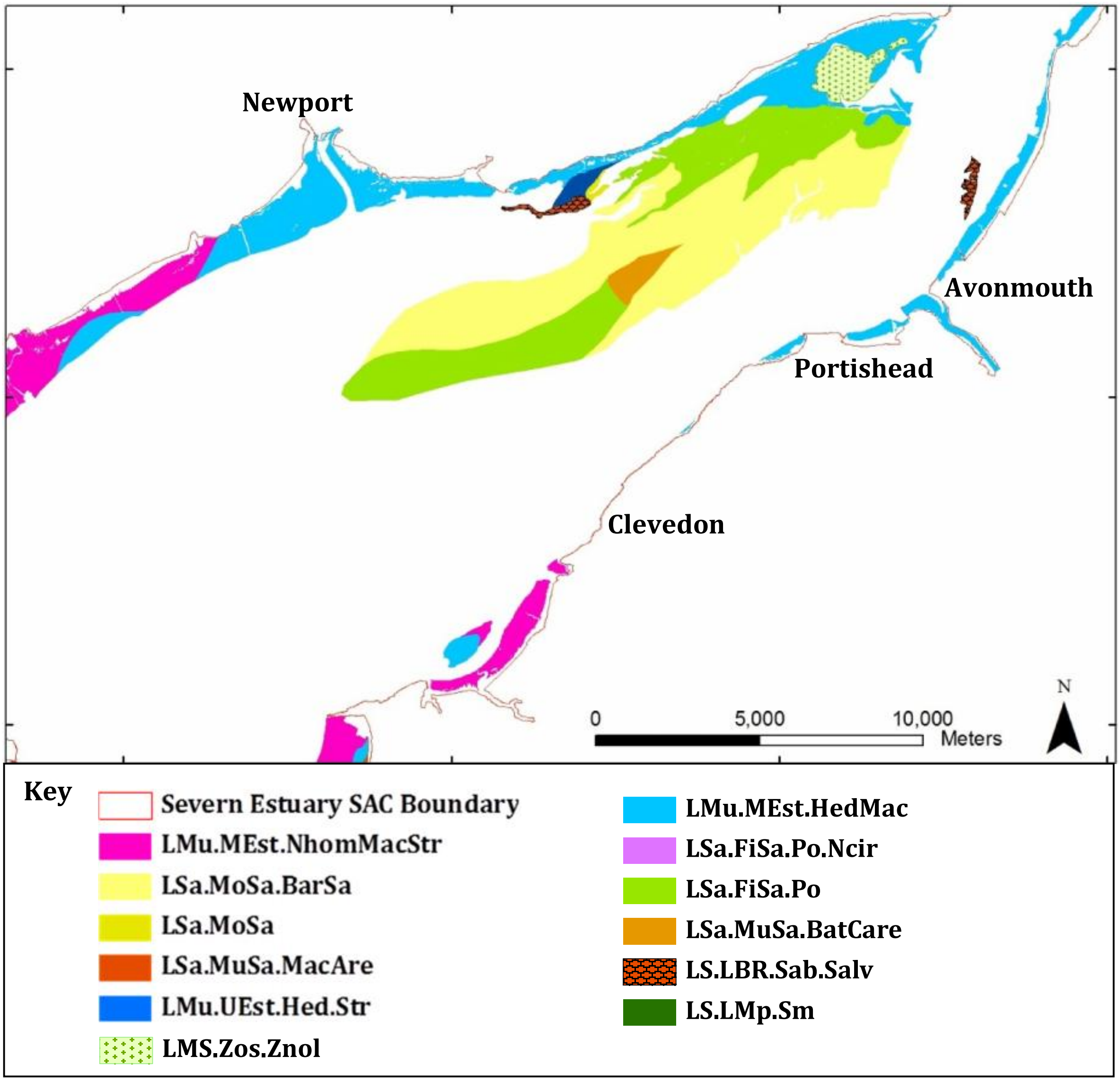

Figure 5. Distribution of sampled littoral sediment biotopes in the mid reaches of the Severn Estuary SAC.

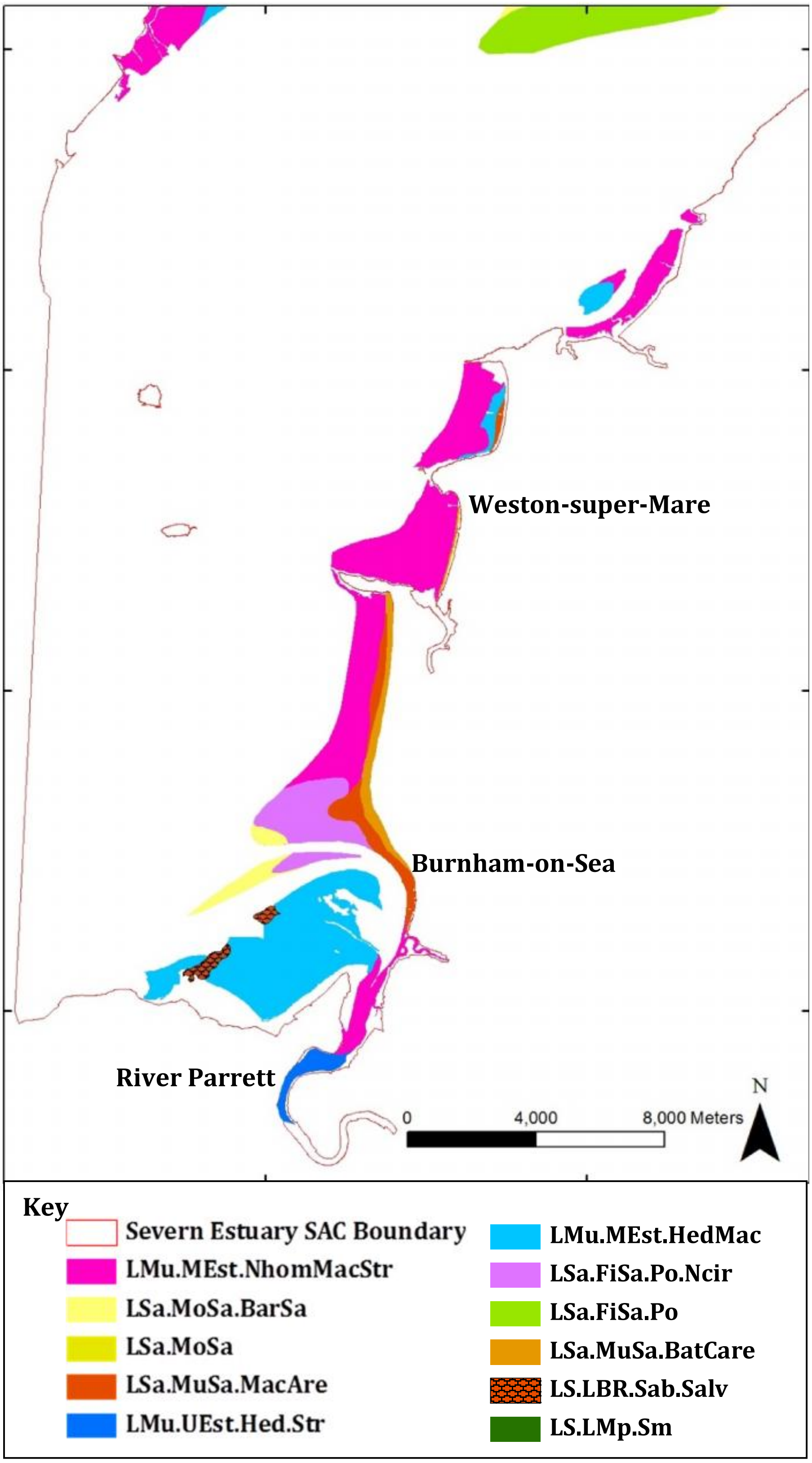

Figure 6. Distribution of sampled littoral sediment biotopes in lower Severn Estuary SAC.

3.2 Physical Characteristics

3.2.1 Particle Size Analysis

The particle size distributions (percentage distribution of sediments by weight) at each sampling station was summarised into 12 size bands following the Wentworth Scale and is shown in Table 3.

Table 3. PSA results (Wentworth Scale)

Biotope	Station	<3.91 µm Clay	3.91 to 7.81 µm Silt	7.81 to 15.6 µm Silt	15.6 to 31.3 µm Silt	31.3 to 62.5 µm Silt	62.5 to 125 µm Very fine sand	125 to 250 µm Fine sand	250 to 500 µm Medium sand	500 to 1000 µm Coarse sand	1000 to 2000 µm Very coarse sand	2000 to 4000 µm Granules	>4000 µm Pebbles
LMu.MEst.HedMac	1	21.73	28.4	26.5	13.55	5.72	2.76	1.02	0.36	0	0	0	0
	2	17.97	25.2	26.1	16.24	7.95	4.8	1.66	0	0	0	0	0
	3	21.05	26.4	25.5	15.42	7.48	3.17	0.89	0	0	0	0	0
	17	13.85	7.86	9.55	12.81	10.25	18.76	23.58	3.27	0	0	0	0
	18	0	0	0	0	0	1.92	67	31.01	0	0	0	0
	23	25.37	24.2	25	15.29	7.9	2.3	0.07	0	0	0	0	0
	25	20.48	23.7	23	14.77	7.6	5.32	3.24	1.93	0.01	0	0	0
	26	17.01	23.7	27.7	16.56	7.59	4.06	1.86	0.67	0.85	0	0	0
	27	21.64	19.23	21.9	16.84	10.74	5.87	2.57	1.3	0	0	0	0
	42	14.12	14.77	14.98	17.38	15.88	9.96	3.31	4.21	5.39	0	0	0
	43	14.76	15.26	16.99	21.04	18.26	8.73	4.73	0.16	0	0	0	0
	44	19.53	16.82	17.81	17.69	12.45	8.39	5.97	1.35	0	0	0	0
	45	17.59	14.62	15.77	21.09	17.91	9.03	3.55	0.47	0	0	0	0
	46	17.94	18.71	19.86	17.28	12.71	6.97	3.71	2.16	0.68	0	0	0
	47	16.29	22.9	22.9	16.34	8.85	5.95	6.34	0.38	0	0	0	0
	48	18.67	20.94	22	18.56	11.78	5.07	2.27	0.68	0	0	0	0
	49	22.94	19.32	18.49	16.38	10.86	6.58	4.73	0.69	0	0	0	0
	50	20.73	20.27	21.3	17.5	11.86	5.38	1.93	1.08	0.01	0	0	0
	53	13.89	19.5	21.5	19.9	14.52	6.34	3.73	0.66	0	0	0	0
	72	21.93	24	22.6	16.46	8.7	3.73	1.5	0.91	0.21	0	0	0
	73	17.95	21.26	21	19.6	13.94	4.49	1.59	0.15	0	0	0	0
	74	20.8	18.19	18.87	20.23	12.57	6.47	2.82	0	0	0	0	0
	76	0	0	0	0	0	5.84	76.8	17.27	0	0	0	0
	Mean	**17.23**	**18.49**	**19.10**	**15.69**	**10.24**	**6.17**	**9.78**	**2.99**	**0.31**	**0.00**	**0.00**	**0.00**
LMu.Mest.NhomMacStr	6	18.53	18.57	19.28	15.97	11.71	7.39	5.24	2.39	0.91	0	0	0
	7	18.42	13.26	15.87	22.9	17.8	7.23	3.18	1.25	0.02	0	0	0
	8	16.39	13.09	16.63	18.82	18.26	12.59	3.97	0.24	0	0	0	0
	12	11.89	11.42	12.4	17.42	13.68	10.05	18.46	4.7	0	0	0	0
	13	7.79	7.88	7.62	7.74	3.24	11.12	39.7	14.12	0	0	0	0.75
	14	0.3	0.68	0.04	0	0	9.28	70.3	17.48	0.06	0	0	0
	15	18.19	21.63	23.7	20.27	10.99	3.01	1.32	0.81	0.11	0	0	0
	16	22.88	21.6	20.46	15.82	10.87	5.74	2.79	0.12	0	0	0	0
	19	0.66	1.58	0.98	1.43	0.45	0.99	63.5	30.44	0.01	0	0	0
	20	19.69	23.8	23.4	17.55	10.08	3.7	0.96	0.85	0.01	0	0	0
	21	15.72	25.1	27.2	16.74	9.5	4.4	1.1	0.28	0	0	0	0
	22	22.52	28.8	26.8	14.28	5.19	2.25	0.21	0	0	0	0	0
	24	23.77	16.74	19.14	22.3	13.08	3.82	0.98	0.15	0	0	0	0
	68	18.7	20.49	19.75	12.14	7.91	8.91	8.84	3.17	0.11	0	0	0
	69	21.47	28	28.4	13.77	5.26	2.42	0.6	0.17	0	0	0	0
	71	20.59	32.7	31.3	11.4	2.74	1.22	0.08	0	0	0	0	0
	75	14.41	18.35	21.9	16.41	9.01	4.05	1.13	0.02	0	0.68	1.76	12.36
	Mean	**16.00**	**17.86**	**18.52**	**14.41**	**8.81**	**5.77**	**13.08**	**4.48**	**0.07**	**0.04**	**0.10**	**0.77**
LMu.UEst.Hed.Str	28	0	0	0	0	0	0	13.16	76.1	9.67	0.13	0.46	0.56
	70	20.26	26.2	27.3	14.63	6.36	3.14	1.8	0.37	0	0	0	0
	Mean	**10.13**	**13.1**	**13.65**	**7.315**	**3.18**	**1.57**	**7.48**	**38.235**	**4.835**	**0.065**	**0.23**	**0.28**
LSa.FiSa.Po	29	1.2	2.07	1.74	0.71	1.2	0	16.66	72.2	4.14	0	0	0
	30	0	0	0	0	0	0.14	35.5	61	3.35	0	0	0
	31	5.16	7.59	6.32	2.79	0.7	1.03	41.1	34.77	0.57	0	0	0
	32	0	0	0	0	0	1.88	47.2	48	2.95	0	0	0
	33	1.02	2.18	1.58	1.87	0.4	2.05	66.3	24.62	0	0	0	0
	35	0	0	0	0	0	2.74	54	42.1	1.19	0	0	0
	37	3.08	4.59	4.63	2.79	1.59	0.12	28.98	51	3.16	0	0	0
	39	0	0	0	0	0	0	19.44	71	9.64	0	0	0
	Mean	**1.31**	**2.05**	**1.78**	**1.02**	**0.49**	**1.00**	**38.65**	**50.59**	**3.13**	**0.00**	**0.00**	**0.00**

Table 3 Continued. PSA results (Wentworth Scale).

Biotope	Station	<3.91 µm Clay	3.91 to 7.81 µm Silt	7.81 to 15.6 µm Silt	15.6 to 31.3 µm Silt	31.3 to 62.5 µm Silt	62.5 to 125 µm Very fine sand	125 to 250 µm Fine sand	250 to 500 µm Medium sand	500 to 1000 µm Coarse sand	1000 to 2000 µm Very coarse sand	2000 to 4000 µm Granules	>4000 µm Pebbles
LSa.FiSa.PoNcir	4	0	0	0	0	0	1.2	63	35.79	0.03	0	0	0
	5	0	0	0	0	0	6.08	63.3	30.53	0.07	0	0	0
	Mean	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.64**	**63.15**	**33.16**	**0.05**	**0.00**	**0.00**	**0.00**
LSa.MoSa.BarSa	34	5.89	8.09	7.37	4.77	2.3	0.86	30.25	37.8	2.8	0	0	0
	36	0	0	0	0	0	0.38	51.4	47.9	0.38	0	0	0
	38	0	0	0	0	0	0.63	48.6	49.8	0.98	0	0	0
	40	0	0	0	0	0	0.39	45.9	52.7	1.08	0	0	0
	82	0	0	0	0	0	4.07	79.4	16.54	0	0	0	0
	Mean	**1.18**	**1.62**	**1.47**	**0.95**	**0.46**	**1.27**	**51.11**	**40.95**	**1.05**	**0.00**	**0.00**	**0.00**
LSa.MoSa	58	0	0	0	0	0	6.08	76.4	17.51	0	0	0	0
	59	0	0	0	0	0	4.09	66	29.95	0.05	0	0	0
	60	0	0	0	0	0	6.59	76.6	16.83	0	0	0	0
	61	0	0	0	0	0	12.92	67.3	19.87	0	0	0	0
	63	0	0	0	0	0	9.07	78.1	12.85	0	0	0	0
	66	0	0	0	0	0	8	71.2	20.81	0.01	0	0	0
	67	0	0	0	0	0	19.1	66.6	14.27	0	0	0	0
	Mean	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**9.41**	**71.74**	**18.87**	**0.01**	**0.00**	**0.00**	**0.00**
LSa.MuSa.BatCare	10	0	0	0	0	0	10.24	61.2	28.54	0.12	0	0	0
	41	0	0	0	0	0	0.44	36.32	57.2	5.85	0.11	0.09	0
	51	0	0	0	0	0	5.52	76.1	18.37	0	0	0	0
	56	0	0	0	0	0	9.56	66	24.45	0.04	0	0	0
	62	0	0	0	0	0	12.76	78.8	8.54	0	0	0	0
	64	0	0	0	0	0	8.22	77.5	14.33	0	0	0	0
	65	0	0	0	0	0	12.29	73.2	14.55	0	0	0	0
	77	0	0	0	0	0	6.7	76.3	17.01	0	0	0	0
	78	0	0	0	0	0	9.13	73.1	17.83	0	0	0	0
	79	7.21	5.54	8.76	12.75	4.69	4.8	42.9	13.34	0.01	0	0	0
	80	0	0	0	0	0	17.63	68.7	5.23	0	0	0	8.4
	81	0	0	0	0	0	4.73	74.2	21.11	0	0	0	0
	83	0	0	0	0	0	13.4	76.9	9.69	0	0	0	0
	84	0	0	0	0	0	2.5	69.4	28.09	0.01	0	0	0
	Mean	**0.52**	**0.40**	**0.63**	**0.91**	**0.34**	**8.42**	**67.90**	**19.88**	**0.43**	**0.01**	**0.01**	**0.60**
LSa.MuSa.MacAre	9	0	0	0	0	0	2.06	60	37.73	0.13	0	0	0
	11	0	0	0	0	0	19.02	74	5.63	0	0	0.17	1.24
	52	0	0	0	0	0	7.03	77.6	15.37	0	0	0	0
	54	0	0	0	0	0	10.05	66.8	23.12	0.01	0	0	0
	55	0.63	1.46	1.09	1.95	0.11	7.09	71.2	16.44	0	0	0	0
	57	0	0	0	0	0	10.75	72.6	16.69	0	0	0	0
	Mean	**0.11**	**0.24**	**0.18**	**0.33**	**0.02**	**9.33**	**70.37**	**19.16**	**0.02**	**0.00**	**0.03**	**0.21**

It is well documented that the particle size distribution of the sediment has an effect on the community structure of benthic communities [8]. The overall degree of similarity in the mean sediment particle size between each station has been determined using PRIMER 6[7] and is illustrated by the Principle Component Analysis (PCA) plot in Figure 6. Within the PCA plot the vectors represent proportions of each sediment size fraction. It can be seen that the station sediment granulometry results are separated predominantly into two groups on the basis of the proportion of silt and the proportion of sand. The two groups generally separate the littoral mud biotopes (LMu) from the littoral sand biotopes (LSa) but there are a few exceptions; LMu.Uest.Hed.Str stations are more similar in terms of sediment granulometry to the sandy sediment biotopes, and the sediment at three LMu stations contain a significant sand fraction.

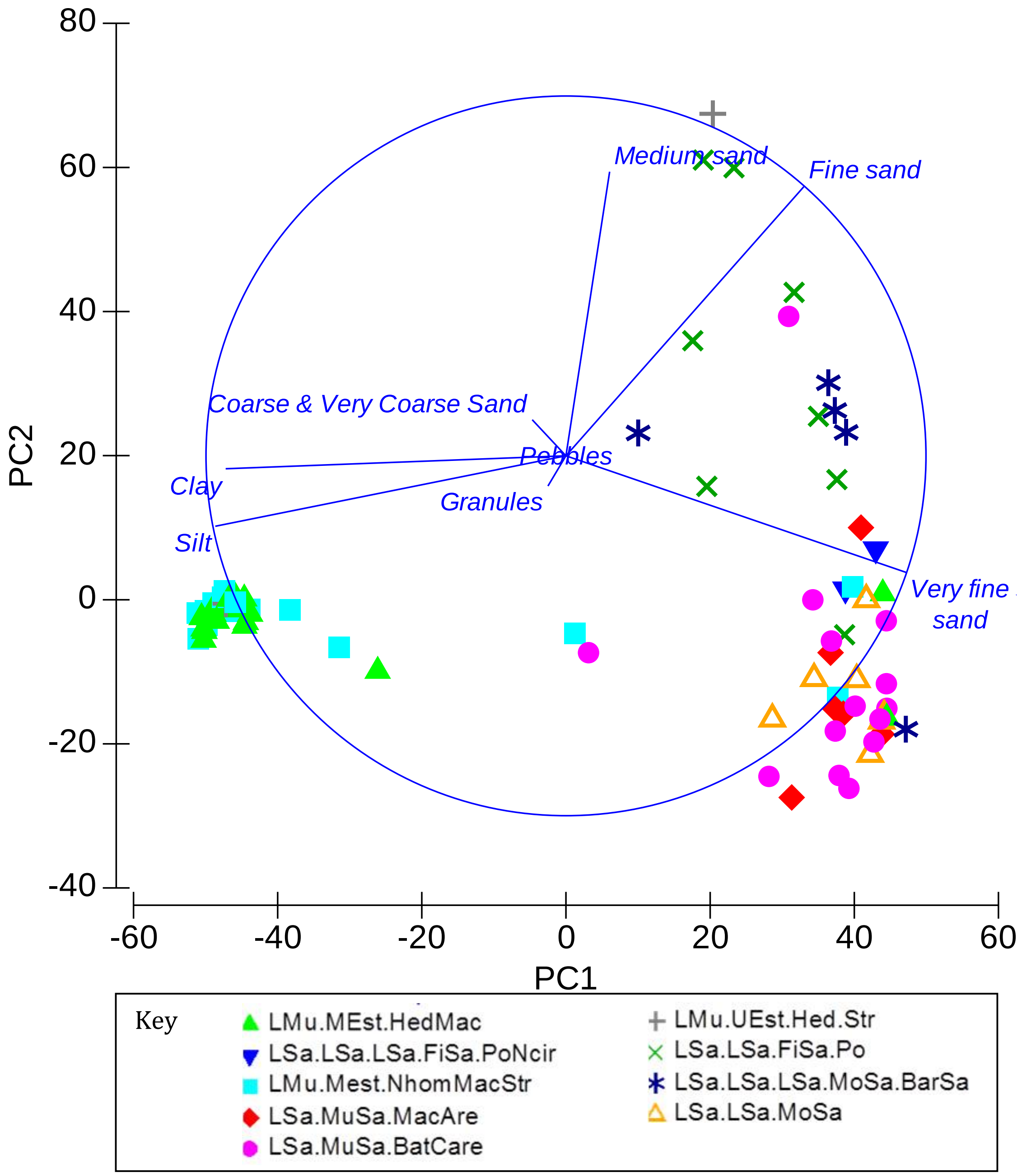

Figure 6. Principal component analysis (PCA) of station sediment granulometry similarities

3.2.2 Sediment Redox Profile

The results of the *in situ* redox measurements and visual assessments for each station are presented in Table 4.

Table 4. Sediment redox depth data (green highlights oxic conditions and red highlights anoxic conditions)

Biotope	Station	Apparent Depth of Redox Layer (cm)	Measured Redox (mv)					
			0cm	2cm	4cm	6cm	8cm	10cm
LMu.MEst.HedMac	1	6	183	184	-172	-186	-196	-204
	2	4	132	-134	-164	-187	-192	-193
	3	2-4	105	-103	-150	-155	-159	-174
	17	Not visible	113	64	-11	-59	-128	-129
	18	>15	43	92	75	81	62	57
	23	2	4	-108	-216	-233	-219	-226
	25	1	-73	-180	-176	-181	-193	-194
	26	4	89	-100	-115	-113	-132	-139
	27	1	25	-27	-141	-20	-247	-280
	42	2	201	165	56	17	-143	-142
	43	2	249	-12	-78	-115	-125	-149
	44	4	289	216	177	-54	-112	-162
	45	5	208	274	168	43	-34	-72
	46	2	39	-92	-147	-139	-142	-145
	47	4	62	-6	-150	-182	-138	-133
	48	5	157	162	55	-94	-97	-110
	49	2	126	80	4	-46	-108	-115
	50	Not visible	58	-20	-107	-131	-154	-155
	53	>15	Probe malfunction					
	72	3-4	200	-50	-63	-101	-95	-112
	73	3-4	128	-17	-85	-113	-122	-151
	74	4	95	-127	-149	-155	-164	-162
	76	>15	111	94	61	59	60	35
LMu.Mest.NhomMacStr	6	4-6	215	214	135	-84	-139	-159
	7	8-10	192	193	157	7	-26	-74
	8	4-6	198	74	-17	-79	-121	-119
	12	4-6	156	94	83	60	52	35
	13	8	178	187	197	100	98	98
	14	>15	217	273	217	207	166	-14
	15	4-6	258	141	162	-112	-137	-143
	16	4-6	129	9	-62	-89	-79	-129
	19	>15	38	22	36	95	87	97
	20	3	75	-10	-68	-123	-117	-108
	21	2	82	-125	-154	-137	-130	-128
	22	2	212	-58	-150	-139	-154	-193
	24	2	134	-78	-147	-167	-175	-171
	68	4	154	148	87	-72	-92	-108
	69	6	108	17	-89	-109	-115	-153
	71	8	159	177	154	-87	-100	-140
	75	2	98	-29	-62	-97	-106	-101
LMu.UEst.Hed.Str	28	>15	141	147	154	152	155	144
	70	4-6	85	40	110	113	50	-40
LSa.LSa.FiSa.Po	29	>15	231	228	220	223	215	208
	30	>15	246	233	225	210	217	214
	31	>15	183	186	172	157	154	113
	32	>15	227	181	175	168	162	141
	33	>15	212	309	298	291	245	198
	35	>15	188	185	179	171	158	152
	37	>15	127	87	91	82	51	29
	39	>15	192	198	152	124	164	159

Table 4 Continued. Sediment redox depth data (green highlights oxic conditions and red highlights anoxic conditions)

Biotope	Station	Apparent Depth of Redox Layer (cm)	Measured Redox (mv)					
			0cm	2cm	4cm	6cm	8cm	10cm
LSa.LSa.LSa.FiSa.PoNcir	4	>15	212	-	-	-	-	-
	5	>15	209	251	248	166	155	89
LSa.LSa.LSa.MoSa.BarSa	34	>15	211	206	197	186	189	183
	36	>15	130	99	70	87	92	86
	38	>15	165	146	197	200	201	198
	40	>15	153	136	113	140	138	132
	82	>15	205	-	-	-	-	-
LSa.LSa.MoSa	58	>15	158	149	118	131	121	183
	59	>15	139	146	142	147	139	144
	60	>15	180	150	150	130	133	110
	61	>15	139	123	142	145	153	160
	63	>15	126	96	110	130	140	150
	66	>15	247	250	253	254	255	251
	67	>15	233	250	233	239	236	292
LSa.MuSa.BatCare	10	>15	212	195	-	-	-	-
	41	>15	88	97	110	88	99	83
	51	>15	76	71	35	101	55	44
	56	>15	297	301	280	245	205	179
	62	>15	136	140	159	158	160	154
	64	>15	255	256	257	260	258	259
	65	>15	139	156	152	154	116	102
	77	>15	236	215	226	237	247	239
	78	>15	239	220	205	195	197	179
	79	>10	150	192	206	184	156	55
	80	>15	99	79	80	-	-	-
	81	>15	-	-	-	-	-	-
	83	>15	261	263	259	-	-	-
	84	>15	-	-	-	-	-	-
LSa.MuSa.MacAre	9	>15	255	216	242	229	8	-61
	11	>15	165	131	114	93	90	61
	52	>15	88	106	119	142	147	91
	54	>15	200	223	256	272	227	249
	55	>15	271	244	242	252	236	248
	57	>15	132	145	145	150	157	169

Anoxic conditions were generally found at depths of between 2 and 10 cm from the sediment surface in littoral mud biotopes throughout the Severn Estuary SAC and SPA, though the anoxic layer was not found within 15cm at a few of these stations often where sand accounted for a larger proportion of the sediment granulometry than silt. At the stations where sediment granulometry does not account for the differences in redox conditions observed, a number of confounding variables may be responsible, such as differences in abundances and types of infauna (which introduce oxygen into the sediments via burrowing and feeding), and/or different levels of organic matter within the sediments.

The redox discontinuity layer was only observed at one littoral sand biotope station where it was between 8 and 10 cm, the sediment at the remainder of the sandy sediment stations was oxygenated to at least 15 cm depth. The lack of anoxic conditions in sandier sediments is expected given the greater mobility of the sandy sediments in parts of the estuary exposed to more high energy wave and/or tidal conditions.

3.3 Biotope Descriptions

Those species referred to as characteristic within this chapter are characteristic as defined by The Marine Habitat Classification for Britain and Ireland (Vs 04.05)[9].

Those figures in italics within the tables of species composition represent numbers of species which were not specifically named within the Marine Habitat Classification for Britain and Ireland (Vs 04.05), but which are likely to occupy the ecological niche of taxa specifically listed e.g. The oligochaete *Tubificoides benedii* may be listed as a characteristic species but only *Tubificoides pseudogaster* may be identified within the sample and therefore numbers of this species instead is presented in italics.

3.3.1 LMu.MEst.HedMac

The LMu.MEst.HedMac biotope (*Hediste diversicolor* and *Macoma balthica* in littoral sandy mud) is the most widespread biotope in the Severn Estuary SAC and SPA and accounts for 23% of the total area of littoral sediment mapped during this study. A photograph of a typical area of this biotope is presented in Plate 1. The biotope is only absent from the uppermost stretches of the estuary, above Lydney (Figure 7).

Plate 1. A typical LMu.MEst.HedMac biotope in the Severn Estuary SAC and SPA (photograph taken at Station 2).

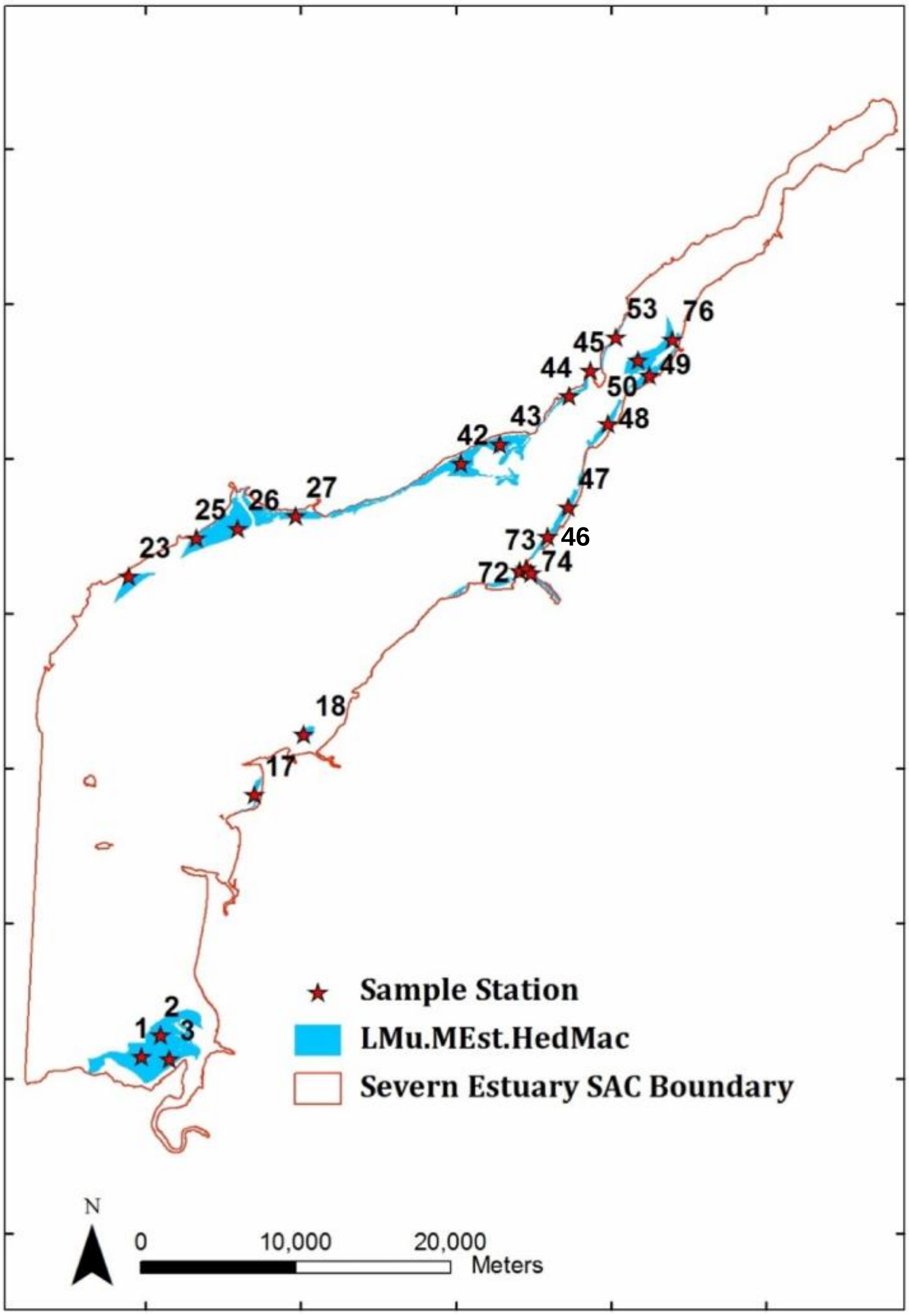

Figure 7. Extent and distribution of LMu.MEst.HedMac in the Severn Estuary SAC and SPA

The sediments at stations within the LMu.MEst.HedMac biotope are predominantly comprised of clay and silt fractions (Table 3). Though at stations 18 and 76 (which are more exposed to tidal energy) the clay and silt fractions are absent and sediments are entirely very fine to medium sand. Sediments at station 17 are a mixture clay and sand.

The redox discontinuity layer is present within 2 cm of the sediment surface at over half of the stations (Table 4). Elsewhere within the biotope the anoxic layer occurs at between 2 and 8 cm from the sediment surface, with the exception of stations 18 and 76 where no redox layer was detected within 15 cm of the surface.

The mean similarity of faunal communities between all stations is 45% (derived using SIMPER analysis in PRIMER 6[7]). Those species which provide the highest percentage contribution to similarity are listed in table 5 below where it can be seen that the most frequently occurring species at stations (apart from the common gastropod *Peringia ulvae*) is *Hediste diversicolor*, which is the main characterising polychaete species for the biotope.

Table 5. Species % contribution in the Severn Estuary SAC and SPA LMu.MEst.HedMac biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Peringia ulvae	26.0	14.7	48.2
Hediste diversicolor	16.7	10.9	35.5
Macoma balthica	4.7	3.1	10.2
Corophium volutator	5.6	0.5	1.6
Nephtys juv.	1.3	0.4	1.2
Streblospio shrubsolii	0.7	0.3	1.02
Gammaridae	0.2	0.2	0.6
Cyathura carinata	0.5	0.1	0.4
NEMATODA	0.2	0.1	0.4
Pygospio elegans	0.4	0.1	0.4
Nephtys hombergii	0.6	0.1	0.3
Retusa obtusa	0.1	0.06	0.2
Dolichopodidae	0.1	0.03	0.1
Bathyporeia pilosa	0.04	0.03	0.09

The communities at stations within the LMu.MEst.HedMac biotope have been plotted using MDS, see Figure 8.

The MDS plot demonstrates a link between the faunal communities and distance of stations from the head of the estuary. Further investigation in PRIMER 6[7] using BEST analysis (a procedure which finds the 'best' match between the multivariate among-sample patterns of an assemblage and that from environmental variables associated with those samples) found that the highest correlation between faunal communities and measured biotic variables was best explained by the distance from the head of the estuary, and resulted in a correlation coefficient of 0.5. Those communities found in the highest reaches of the estuary (i.e. stations 50, 53, 76, 44, 45 and 49) have grouped at the bottom and left of the plot, whilst those from Bridgewater Bay in the lower estuary (stations 1, 2 and 3) have grouped to the top right corner of the plot. These correlations are unsurprising given the environmental variables to which the communities are exposed over the wide geographical area that the biotope is distributed (i.e. different salinity ranges, and wave and tidal exposures and regimes).

Avonmouth sewage treatment works discharge was identified as the most substantial discharge identified during the survey, and is located approximately 100 m east of station 46. Stations 47 and 48 are located 2 km and 8 km respectively further along the coast to the northeast of station 46 but are grouped closely with station 46 on the MDS plot. This would suggest that the outfall is not having a detectable impact on the faunal communities at station 46, although a more detailed ecological survey would be required to confirm this.

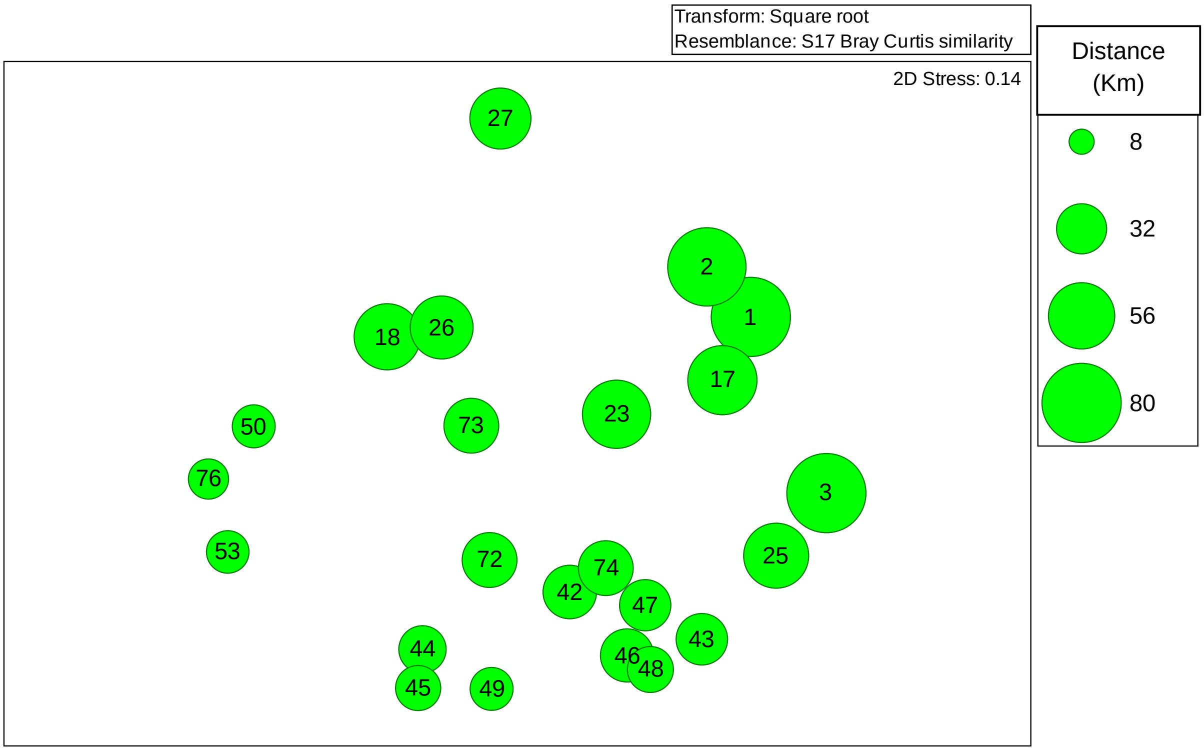

Figure 8. MDS bubble plot of LMu.MEst.HedMac communities sampled from the Severn Estuary SAC and SPA in relation to distance in kilometres from the head of the estuary. The bubbles represent sample stations and the distances between bubbles represent the dissimilarities between the faunal communities at those stations. The bubble sizes correspond to distance from the head of the estuary.

Species diversity, evenness and richness are variable throughout the LMu.MEst.HedMac biotope (Table 6) and do not show any clear correlation with distance down the estuary. The mean number of individuals per core however is linked with distance down the estuary, with fewer numbers per core found in the upper reaches (Figure 9).

Table 6. Severn Estuary SAC and SPA LMu.MEst.HedMac biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
1	11	500	1.609	0.3396	0.8143	0.3389
2	9	341	1.372	0.5135	1.128	0.5461
3	11	500	1.609	0.3396	0.8143	0.3389
17	10	438	1.48	0.3233	0.7444	0.3008
18	6	31	1.456	0.484	0.8672	0.4
23	7	193	1.14	0.4021	0.7824	0.3657
25	10	776	1.353	0.4626	1.065	0.5731
26	8	62	1.696	0.7805	1.623	0.7583
27	8	611	1.091	0.2897	0.6024	0.2657
42	8	274	1.247	0.4536	0.9433	0.4745
43	12	483	1.78	0.5614	1.395	0.7052
44	6	100	1.086	0.5133	0.9198	0.4248
45	8	134	1.429	0.3197	0.6647	0.2618
46	10	301	1.577	0.6493	1.495	0.7447
47	8	389	1.174	0.5209	1.083	0.6019
48	10	377	1.517	0.6205	1.429	0.7221
49	6	167	0.9769	0.6317	1.132	0.5688

50	4	16	1.082	0.5931	0.8223	0.4417
53	9	25	2.485	0.8526	1.873	0.8333

Table 6 continued. Severn Estuary SAC and SPA LMu.MEst.HedMac biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
72	7	169	1.17	0.5423	1.055	0.5611
73	10	72	2.104	0.8506	1.959	0.8392
74	10	280	1.597	0.4719	1.087	0.5826
76	4	13	1.17	0.8691	1.205	0.7179

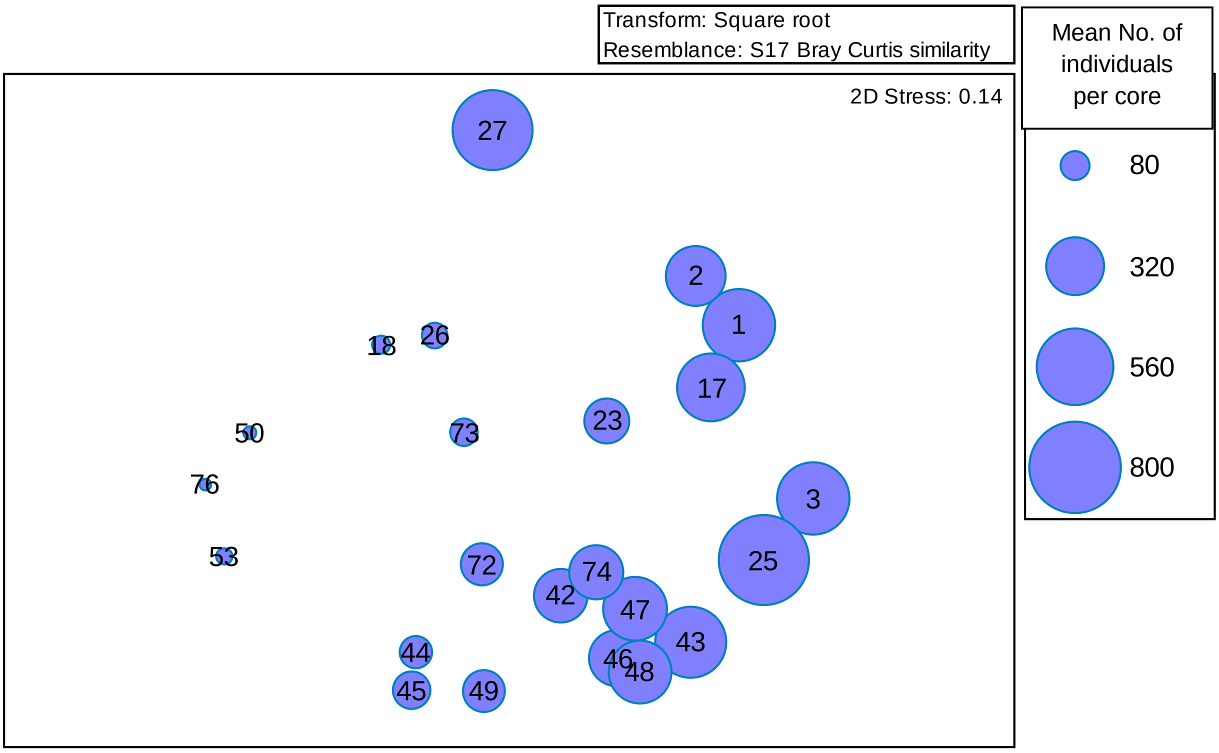

Figure 9. MDS bubble plot of LMu.MEst.HedMac communities sampled from the Severn Estuary SAC and SPA in relation to the mean number of individuals per core.

Table 7. Severn Estuary SAC and SPA LMu.MEst.HedMac species composition

Species	Average Abundance per m² at Stations																							Biotope Characterising Species Abundance (No. m²)
	1	2	3	17	18	23	25	26	27	42	43	44	45	46	47	48	49	50	53	72	73	74	76	
Eteone longa agg.	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	111
Hediste diversicolor	140	40	6160	140	20	360	5540	40	20	3800	3400	1500	2300	1640	3900	2260	2060	40	20	2080	320	2500	40	1168
Nephtys hombergii	520	220	480	20	0	0	0	0	0	0	0	0	0	60	0	40	0	0	20	0	100	0	0	27
Nephtys juv.	720	1580	120	20	60	40	0	160	0	0	0	0	0	0	0	60	0	0	40	0	120	20	0	*27*
Pygospio elegans	40	0	240	340	0	0	20	0	100	20	120	40	0	20	0	0	0	0	0	20	40	0	0	679
Streblospio shrubsolii	0	0	0	0	0	0	120	0	0	0	60	160	20	700	20	240	180	0	80	0	40	60	0	1084
Enchytraeidae	0	0	0	0	0	0	40	0	0	20	0	0	60	0	0	0	0	0	0	0	0	0	0	*1082 - 4396*
Tubificoides pseudogaster agg.	0	0	0	0	0	0	0	40	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	*1082 - 4396*
Macoma balthica	120	180	1000	380	20	320	520	60	160	260	2220	80	80	1440	740	2100	700	20	180	20	160	140	80	784
Corophium volutator	0	0	0	280	0	0	660	420	10420	100	20	0	60	0	140	20	20	0	0	640	20	60	0	3488
Corophiidae juv.	0	0	0	0	0	0	0	0	660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*3488*
Peringia ulvae	8080	4300	10520	7300	480	3040	8460	420	820	1140	3320	180	100	2020	2900	2500	260	240	40	560	400	2620	120	1539
Dolichopodidae	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0	120	20	40	0	
NEMERTEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	
NEMATODA	40	0	40	0	0	20	60	0	0	0	80	0	40	60	20	20	0	0	80	20	0	0	0	
Dipolydora coeca	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Fabricia stellaris	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	
COPEPODA	260	320	60	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	
Eusarsiella zostericola	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	
Pontocrates arenarius	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Hyalidae	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Bathyporeia pelagica	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	20	0	
Bathyporeia pilosa	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	20	0	0	0	20	
Gammaridae	20	20	0	20	20	0	0	60	0	0	0	0	0	40	0	0	0	20	0	40	200	80	0	
Cyathura carinata	0	0	0	240	0	0	0	0	20	120	320	40	0	0	20	280	120	0	0	0	0	0	0	
Jaera sp.	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Diastylis rathkei	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
GASTROPODA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0	
Littorina juv.	20	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	20	0	0	0	0	
Retusa obtusa	0	120	0	20	0	60	0	40	0	20	20	0	0	0	0	0	0	0	0	0	40	0	0	

The stations assigned as LMu.MEst.HedMac correspond reasonably well with the LMu.MEst.HedMac biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05). The biotope in the Severn Estuary SAC and SPA does however occur in more exposed conditions and with considerably more tidal stream than might be expected and as a result the sediments at three of the stations lack the mud content usually present in this biotope.

At all stations assigned as LMu.MEst.HedMac the two main characterising species *Hediste diversicolor* and *Macoma balthica* are present, though the abundance of these species is variable ranging from an order of magnitude or two less than expected for the biotope at some stations, to an order of magnitude greater at others (Table 7). A number of non-characterising faunal species were captured in samples; the most frequently occurring is an unidentified species of Gammaridae.

The disparity observed in the fauna recorded at LMu.MEst.HedMac stations in the Severn Estuary SAC and SPA when compared to that described in the Marine Habitat Classification are most likely to be attributable to the high degree of local and regional environmental variability found in estuarine environments (i.e. salinity, wave exposure, carbon matter, nutrient input and pollution); the Severn Estuary in particular is unique in its geographic scale and extraordinary tidal energy.

3.3.2 LSa.MoSa.BarSa

The LSa.MoSa.BarSa biotope (barren littoral coarse sand) accounts for the second largest area covered by a single biotope in the Severn Estuary SAC and SPA. The distribution of this biotope is mainly limited to the most mobile parts of the vast high energy sandflats known as the Middle Grounds which extend out from the Welsh shores. A small area of the biotope is also found to occupy a narrow strip of the upper shore within Weston Bay (adjacent to Weston-super-Mare). The extent and distribution of the biotope is shown in Figure 9 and a photograph of a typical area of the biotope is shown in Plate 2.

Plate 2. A typical LSa.MoSa.BarSa biotope in the Severn Estuary SAC and SPA (photograph taken at Station 36).

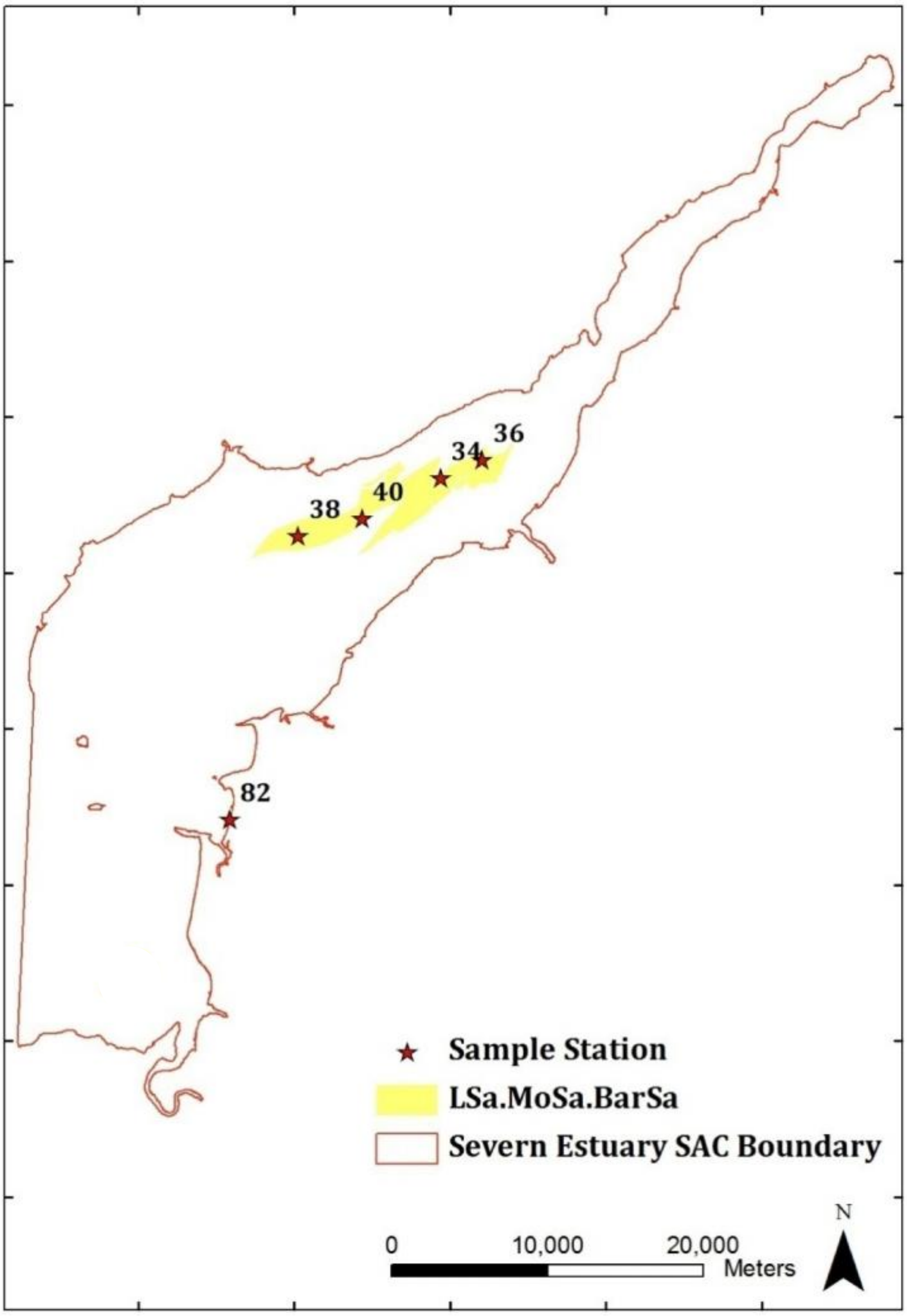

Figure 9. Extent and distribution of LSa.MoSa.BarSa in the Severn Estuary SAC and SPA

The sediments at stations within the LSa.MoSa.BarSa biotope are predominantly comprised of very fine to medium sand with a very small proportion of coarse sand (Table 3). Station 34 also has an additional small silt and clay fraction, whilst station 82 in Weston Bay lacks the coarse sand fraction. No redox discontinuity layer was observed within the first 15 cm of sediment at any station (Table 4). At station 82 the sediment was too firm for the redox probe to penetrate, but a spade inspection revealed no visible redox layer.

The similarity between faunal communities at stations has been calculated using SIMPER analysis in PRIMER 6 [7]. Due to the lack of macrofaunal community the mean similarity of fauna between all stations is low at 12.77%; only stations 36, 38 and 40 resulted in any similarity to each other which resulted primarily from the presence of the isopod *Eurydice pulchra* (Table 9).

Table 8. Species % contribution in the Severn Estuary SAC and SPA LSa.MoSa.BarSa biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Eurydice pulchra	0.5	10.3	80.9
Bathyporeia pelagica	0.2	2.4	19.1

An MDS plot of the communities sampled in the LSa.MoSa.BarSa biotope is presented as Figure 10; the large distances between stations within the plot demonstrate the loose resemblance between the communities recorded at the stations.

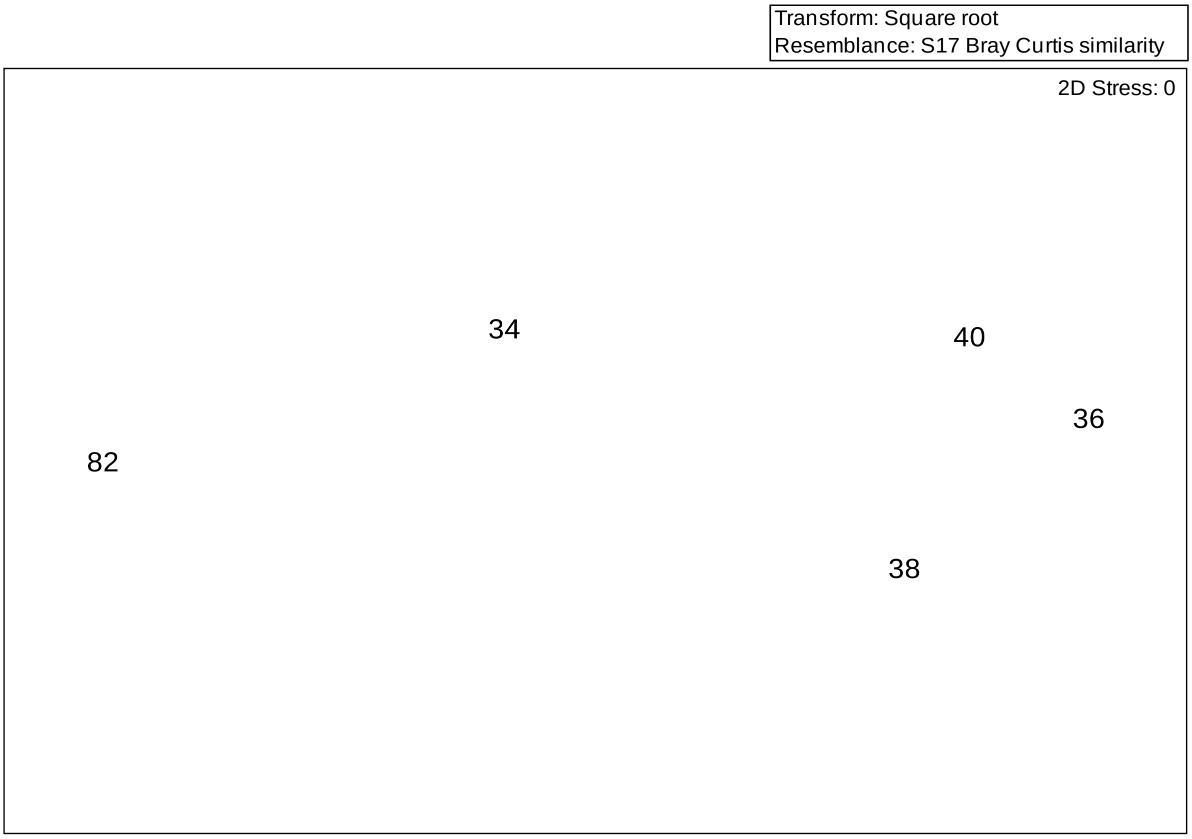

Figure 10. MDS plot of LSa.MoSa.BarSa communities sampled from the Severn Estuary SAC and SPA

As expected the species diversity, evenness and richness throughout the biotope is low (Table 10). The greatest diversity and richness (although still low) is found at station 82 within Weston Bay, where the narrow stretch of the biotope on the shore appears to have been influenced by adjacent biotopes.

Table 9. Severn Estuary SAC and SPA LSa.MoSa.BarSa biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
34	2	2	1.443	1	0.6931	1
36	3	5	1.243	0.865	0.9503	0.7
38	1	1	-	-	0	-
40	2	13	0.3899	0.3912	0.2712	0.1538
82	3	6	1.116	0.9206	1.011	0.7333

Table 10. Severn Estuary SAC and SPA LSa.MoSa.BarSa species composition

Species	Mean Abundance per m² at Stations					Biotope Characterising Species Abundance (No. m²)
	34	36	38	40	82	
Eurydice pulchra	0	20	20	240	0	6
Nephtys juv.	0	0	0	0	40	
COPEPODA	20	0	0	0	20	
Bathyporeia pelagica	0	60	0	20	0	
Haustorius arenarius	20	0	0	0	0	
Peringia ulvae	0	0	0	0	60	
Nuculidae juv.	0	20	0	0	0	

The absence of *Oligochaetes* and/or *Scolelepis* at stations 34, 36, 38, 40 and 82 has resulted in their allocation as LSa.MoSa.BarSa rather than LS.LSa.MoSa.AmSco or LS.LSa.MoSa.AmSco.Eur. Although the stations have a low similarity to each other, they correspond well with the LSa.MoSa.BarSa biotope described within The Marine Habitat Classification[1]; minor deviations being in the sediment granulometry at station 34, the presence of *Nephtys* juveniles at station 82, and the greater than expected number of *Eurydice pulchra* at station 40. The presence of *Nephtys* juveniles at station 82 is thought to be due to temporary colonisation from the adjacent LMu.MEst.NhomMacStr biotope at that location.

3.3.3 LSa.MoSa

The LSa.MoSa biotope (barren or amphipod dominated mobile sand shores) is limited to the upper stretches of the Severn Estuary SAC and SPA above Woolaston, where it appears to occupy more mobile areas alongside the more stable LSa.MuSa.BatCare communities (Figure 11). A photograph of a typical area of the biotope is shown in Plate 3.

Plate 3. A typical LSa.MoSa biotope in the Severn Estuary SAC and SPA (photograph taken at Station 59).

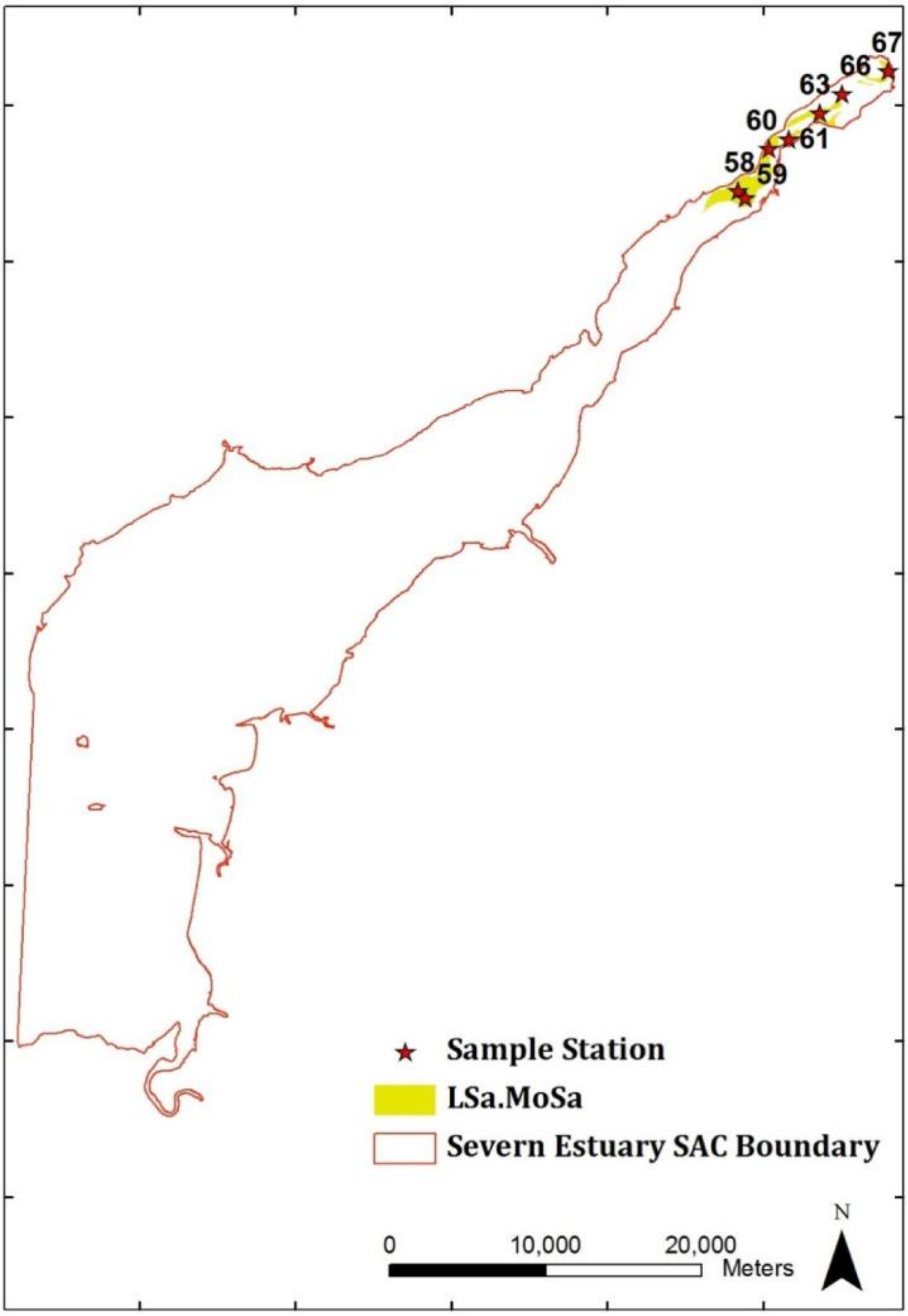

Figure 11. Extent and distribution of LSa.MoSa in the Severn Estuary SAC and SPA

The sediments at the stations within the LSa.MoSa biotope are almost entirely comprised of very fine to medium sands; just two of the stations have a coarse sand component amounting to less than 1%, and all stations are void of any clay or silt fractions (Table 3). The redox discontinuity layer was not present within the first 15 cm at any of the stations (Table 4).

In terms of benthic macrofaunal communities, the mean similarity between stations is 48%. Between 1 and 5 taxa were found in samples from the seven stations sampled within the biotope. The level of exposure to tidal scouring and sediment mobility is reflected in the faunal communities present and subsequent richness, diversity and evenness indices (Table 11). At stations 61, 66 and 67 in particular, only the burrowing amphipod *Bathyporeia pilosa* is present. *Bathyporeia pilosa* is the most abundant species throughout the biotope and accounts for 97% of the similarity between the faunal communities at stations (Table 13).

Table 11. Severn Estuary SAC and SPA LSa.MoSa biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
58	2	81	0.2276	0.0960	0.0665	0.0247
59	2	15	0.3693	0.3534	0.2449	0.1333
60	5	13	1.559	0.6485	1.044	0.5385
61	1	2	0	-	0	0
63	3	17	0.7059	0.6171	0.6779	0.4044
66	1	190	0	-	0	0
67	1	35	0	-	0	0

Table 12. Species % contribution in the Severn Estuary SAC and SPA LSa.MoSa biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Bathyporeia pilosa	2.6	46.7	97.1
Cyathura carinata	0.1	2.3	1.7
Haustorius arenarius	0.1	0.2	1.2

The communities categorised as LSa.MoSa have been plotted using MDS (Figure 12). The bubbles represent the stations and the size of the bubbles represents the mean number of *Bathyporeia pilosa* per core. The greater dissimilarities in communities at stations 61 and 63 are as a result of the relatively low number of *Bathyporeia pilosa* at station 61, and the relatively high abundance of *Bathyporeia* juveniles at station 63. The difference in communities at these two stations is unknown but is not associated with sediment granulometry variations.

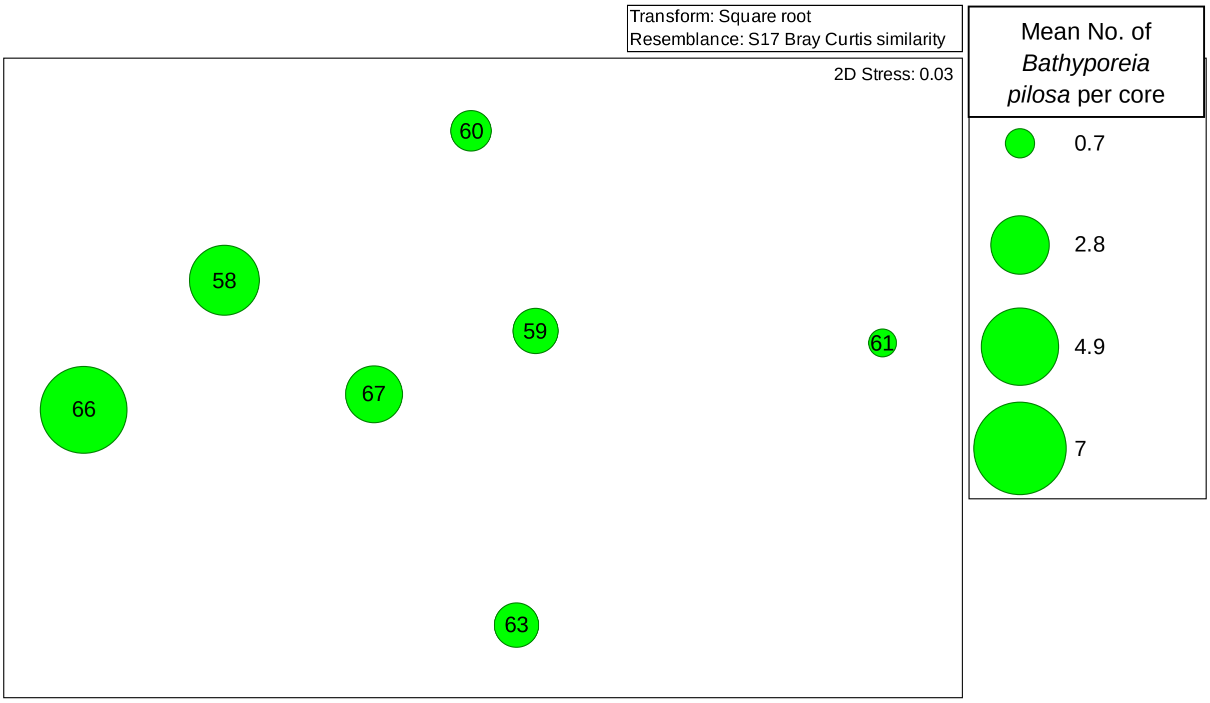

Figure 12. MDS plot of LSa.MoSa communities sampled from the Severn Estuary SAC and SPA

Table 13. Severn Estuary SAC and SPA LSa.MoSa species composition

Species	Average Abundance per m^2 at Stations							Biotope Characterising Species Abundance (No. m^2)
	58	59	60	61	63	66	67	
Bathyporeia juv.	0	0	0	0	60	0	0	*54 - 114*
Bathyporeia pilosa	1600	280	180	40	260	3800	700	114
Haustorius arenarius	20	0	20	0	0	0	0	23
NEMATODA	0	0	20	0	0	0	0	
Streblospio shrubsolii	0	0	20	0	0	0	0	
Cyathura carinata	0	20	20	0	0	0	0	
Peringia ulvae	0	0	0	0	20	0	0	

The station characteristics correspond largely with the LS.LSa.MoSa biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05). The main difference is in the sediment character; the sediments of the biotope in the Severn Estuary SAC and SPA have larger fine sand and smaller coarse sand fractions than expected. The sands are clean and rippled as a result of wave action, a feature which is expected within the biotope.

With regard to the faunal communities, *Bathyporeia pilosa,* which is one of the characterising species for the biotope, is more abundant than expected at all but station 61 (Table 13). Station 61 is also devoid of any other species, probably owing to the extreme tidal energy and mobility of the environment at the narrows of the estuary. The absence of species such as *Eurydice pulchra*, *Scolelepis* sp., *Pontocrates arenarius* and oligochaetes has prevented assignment of the communities beyond LSa.MoSa to sub-biotope level. The absence of these species may be as a result of the unique tidal conditions within the Severn Estuary SAC and SPA; however it may also be associated to the unusually poor weather of the summer months preceding the collection of samples which may have washed these species out of sediments temporarily.

3.3.4 LSa.MuSa.BatCare

It can be seen from Figure 12 that the greatest area of the LSa.MuSa.BatCare biotope (*Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand) is found in the upper region of the Severn Estuary SAC and SPA, but the biotope also occurs in isolated patches in the mid and lower estuary on upper and mid-shore flats. The biotope is always present adjacent to LSa.MoSa biotopes in more wave and tide-sheltered areas. A typical photograph of the biotope is shown in Plate 4.

Plate 4. A typical LSa.MuSa.BatCare biotope in the Severn Estuary SAC and SPA (photograph taken at Station 84).

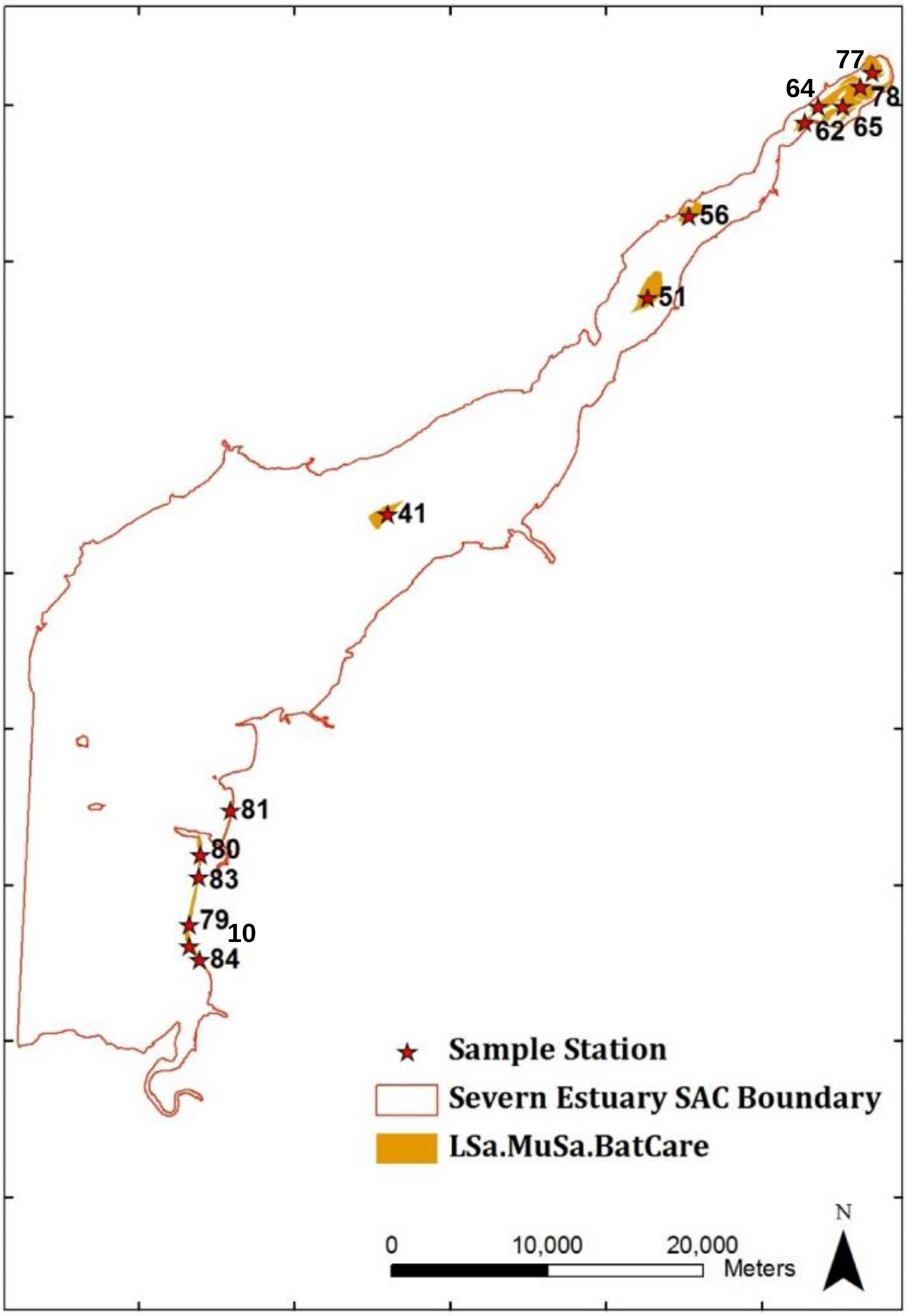

Figure 12. Extent and distribution of LSa.MuSa.BatCare in the Severn Estuary SAC and SPA

The sediments at stations within the biotope are mainly comprised of very fine to medium sand, a few stations having a coarse sand fraction of <1% (Table 3). Station 79 however has an additional clay and silt fraction which accounts for almost 40% of the sediment. Station 41 also has a substantially larger medium sand fraction and small fine sand fraction than the other stations. No redox discontinuity layer was observed within the first 15 cm of sediment (Table 4).

The mean similarity of faunal communities between all stations is 32%. This is relatively low and is likely to be a result of the distribution of the biotope over an extensive geographical area within the estuarine system, resulting in inconsistent environmental parameters between stations.

Those species which provide the highest percentage contribution to similarity are listed in table 14 below. The presence of one of the two main characterising species, *Bathyporeia pilosa*, is responsible for 70% of the similarity of fauna between stations.

Table 14. Species % contribution in the Severn Estuary SAC and SPA LSa.MuSa.BatCare biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Bathyporeia pilosa	13.8	16.1	70.3
Peringia ulvae	1.4	3.9	16.9
Corophium volutator	0.6	1.5	6.7
Macoma balthica	0.8	1.2	5.04
Gammaridae	0.04	0.2	0.8
Bathyporeia juv.	6.9	0.03	0.1
Pygospio elegans	0.1	0.02	0.1

Species richness, diversity and evenness vary substantially throughout the biotope (Table 15). The communities displaying the lowest values in terms of the diversity indices are generally those located at the head of the estuary and in the middle of the main channel in the mid estuary region. However, the greatest diversity is found at stations 56 and 79. Species richness within the biotope tends to be greater at those stations in Bridgewater Bay.

Table 15. Severn Estuary SAC and SPA LSa.MuSa.BatCare biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
10	8	120	1.462	0.6884	1.431	0.7048
41	4	122	0.6245	0.1287	0.1784	0.0646
51	4	52	0.7593	0.3422	0.4743	0.2164
56	5	11	1.668	0.9122	1.468	0.8182
62	2	33	0.286	0.3298	0.2286	0.1174
64	2	18	0.346	0.5033	0.3488	0.2092
65	3	285	0.3538	0.3062	0.3363	0.1785
77	4	27	0.9102	0.3397	0.4709	0.2137
78	4	35	0.8438	0.509	0.7057	0.3849
79	7	25	1.864	0.8688	1.691	0.8167
80	10	1049	1.294	0.374	0.8612	0.5294
81	3	16	0.7213	0.756	0.8305	0.5417
83	4	24	0.944	0.7068	0.9798	0.5616
84	6	15	1.846	0.7698	1.379	0.7048

The communities within the biotope have been plotted using MDS, see Figure 13.

The MDS plot demonstrates a clear correlation between the faunal communities within the LSa.MuSa.BatCare biotope and the distance from the head of the estuary. The correlation has been investigated fully in PRIMER 6[7] using BEST analysis and resulted in a correlation coefficient of 0.7 (the greatest of all the biotic variables measured). Those communities found in the highest reaches of the estuary (i.e. stations 62, 64, 65, 77 and 78) are set apart to the left of the plot, whilst those from Bridgewater Bay and Weston Bay in the lower estuary (stations 80, 83, 79, 81, 84, 10 and 41) have grouped to the right of the plot. The bubbles representing stations 51 and 56 (which are located in the mid estuary) are situated between the lower and upper estuarine stations in the middle of the plot, and represent a continuum in the community characteristics from the lower estuary to the upper estuary.

Stations at the top of the estuary are in very tide swept and mobile conditions, whereas those stations in Bridgewater Bay are located at the top of banks; the tidal energy is therefore far less at those stations in the lower estuary and may account for the differences in communities observed. Station 41 however sits apart from all the other stations as a result of the complete absence of *Bathyporeia pilosa* and high abundance of *Bathyporeia pelagica*. The difference in fauna at this station is likely to be a result of the immense tidal regime which characterises the Middle Grounds as well as the resulting different sediment granulometry at that location.

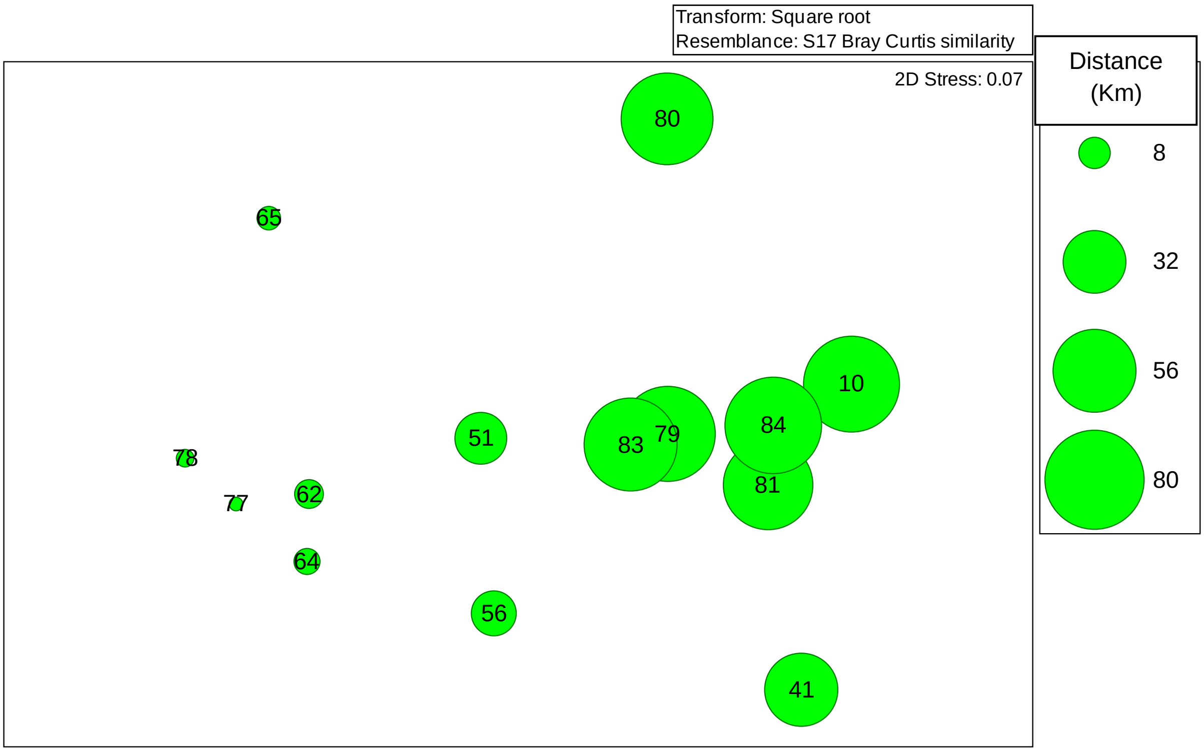

Figure 13. MDS bubble plot of LSa.MuSa.BarCare communities sampled from the Severn Estuary SAC and SPA in relation to distance in kilometres from the head of the estuary. The bubbles represent sample stations and the bubble sizes correspond to distance from the head of the estuary.

Table 16. Severn Estuary SAC and SPA LSa.MuSa.BatCare species composition

Species	Average Abundance per m² at Stations														Biotope Characterising Species Abundance (No. m²)
	10	41	51	56	62	64	65	77	78	79	80	81	83	84	
Bathyporeia pilosa	0	0	920	80	620	320	5,140	480	540	160	10,800	0	300	0	2644
Corophium volutator	20	0	60	0	0	0	540	20	20	100	0	100	20	20	1144
Peringia ulvae	980	0	40	20	0	0	0	20	0	120	280	200	120	160	1591
NEMERTEA	20	0	0	0	0	0	0	0	0	0	0	0	0	0	
NEMATODA	0	0	0	0	0	0	0	0	0	0	140	0	0	60	
Hediste diversicolor	0	20	0	0	0	0	0	0	0	0	0	0	0	0	
Pygospio elegans	140	0	0	0	0	0	0	0	0	20	40	0	0	0	
Capitella	0	0	0	60	0	0	0	0	0	0	0	0	0	0	
Paranais litoralis	0	0	0	0	0	0	0	0	0	0	20	0	0	0	
CIRRIPEDIA	0	0	0	0	0	0	0	0	0	0	40	0	0	0	
COPEPODA	220	0	0	0	0	0	0	0	0	40	80	20	40	20	
Bathyporeia juv.	20	0	0	0	0	0	0	0	120	0	9,520	0	0	0	
Bathyporeia pelagica	0	2,360	0	0	0	0	0	0	0	0	0	0	0	0	
Bathyporeia sarsi	180	0	0	0	0	0	0	0	0	0	0	0	0	0	
Haustorius arenarius	0	0	20	0	0	0	0	0	0	0	0	0	0	0	
Gammaridae	0	0	0	20	0	0	0	0	20	0	0	0	0	20	
Eurydice pulchra	0	20	0	0	0	0	0	0	0	0	20	0	0	0	
Lekanesphaera monodi	0	0	0	0	0	0	0	0	0	0	0	0	0	20	
Nuculidae juv.	0	0	0	0	0	0	0	0	0	0	20	0	0	0	
Kurtiella bidentata	0	0	0	0	0	0	0	0	0	20	0	0	0	0	
Macoma balthica	820	20	0	40	40	40	20	20	0	40	60	0	0	0	

The LSa.MuSa.BatCare biotope in the Severn Estuary SAC ad SPA corresponds reasonably well with the description given in The Marine Habitat Classification[7], though there are components of the faunal communities which deviate from that expected for the biotope, and these also vary depending on the location within the estuary.

Most notably, one of the main characterising species, *Corophium arenarium* is absent. However, *Corophium volutator*, also a characterising species, is present at 9 of the 14 stations (Table 16). The characterising species *Bathyporeia pilosa* is also absent from a number of stations, though the occasional high abundance of other *Bathyporeia* species at these stations may suggest some ecological niche substitution, perhaps in areas where the tidal streams within the Severn estuary are weaker. The abundance of all characterising species is substantially lower than expected for the biotope, with the exception of *Bathyporeia pilosa* at station 80 where numbers are an order of magnitude greater than expected. Although the Baltic tellin *Macoma balthica* is not listed as a characterising species for LSa.MuSa.BatCare, the description of the biotope in the Marine Habitat Classification includes the species presence, and is consistent with the fauna at stations assigned LSa.MuSa.BatCare in the Severn Estuary SAC and SPA.

3.3.5 LMu.MEst.NhomMacStr

The distribution of the LMu.MEst.NhomMacStr biotope (*Nephtys hombergii*, *Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud) within the Severn Estuary SAC and SPA is limited to the lower half of the estuary, west of Newport on the Welsh shores and Clevedon on the English shores. A map of the Severn Estuary showing the distribution of the biotope is shown in Figure 14, and a photograph of a typical area of this biotope is shown in Plate 5.

Plate 5. A typical LMu.MEst.NhomMacStr biotope in the Severn Estuary SAC and SPA (photograph taken at Station 12).

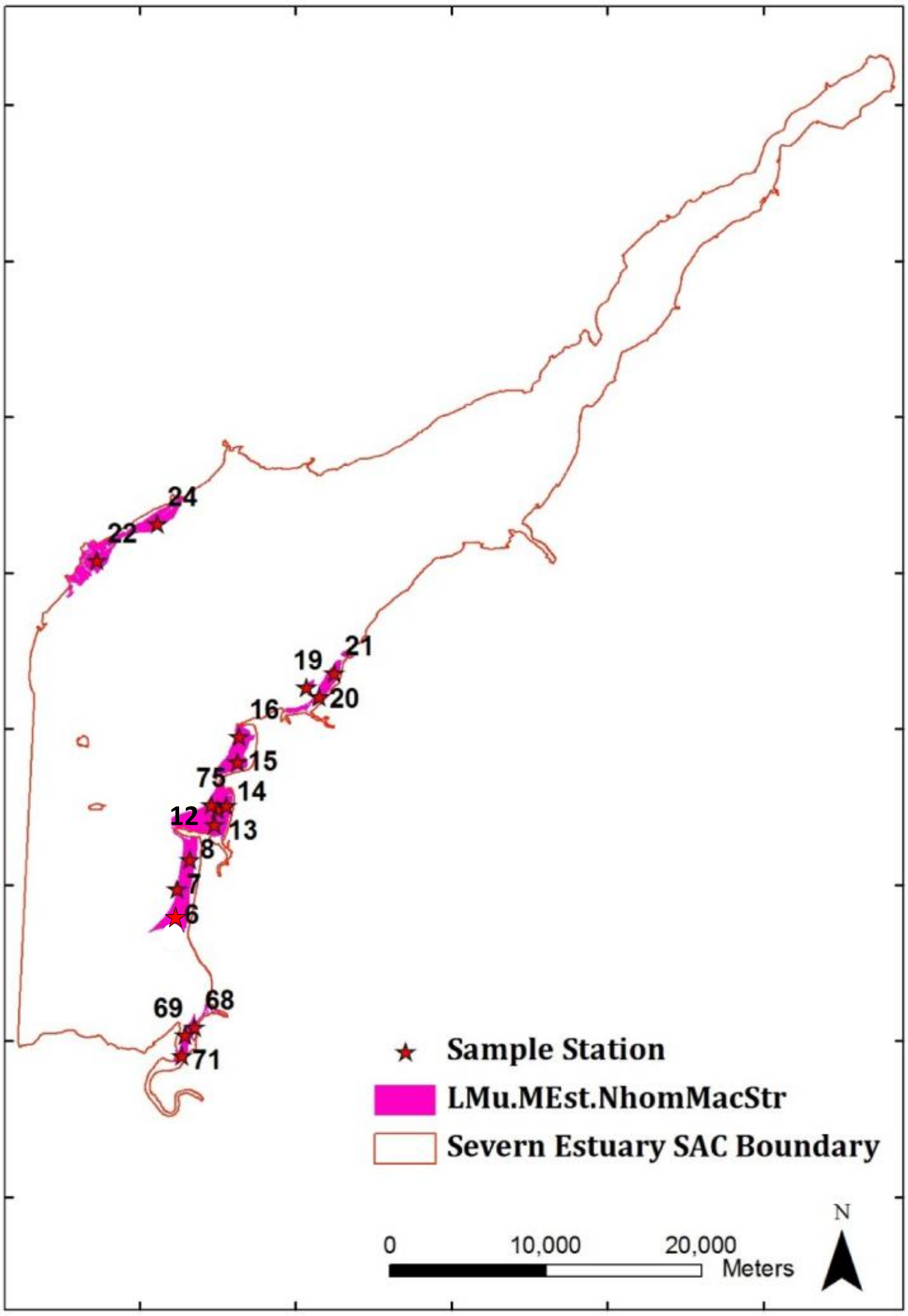

Figure 14. Extent and distribution of LMu.MEst.NhomMacStr in the Severn Estuary SAC and SPA

The sediments at most of the stations within the LMu.MEst.NhomMacStr biotope are predominantly comprised of clay and silt fractions with some fine to medium sand (Table 3). Almost half of the stations have an additional very small fraction of coarse sand. Those stations in Weston Bay display slightly different sediment granulometry than stations of the biotope elsewhere in the Severn Estuary; stations 13 and 75 contain a proportion of pebbles, whilst station 14 has a much lower proportion of clay and silt and lacks the larger silt fractions altogether.

The redox discontinuity layer is present within 2 cm of the sediment surface at almost half of the stations (Table 4). Elsewhere within the biotope the redox layer occurs at between 2 and 8 cm from the sediment surface, with the exception of stations 12, 13 and 19 where no redox layer was detected within 15 cm of the surface.

The mean similarity of faunal communities between all stations is the highest of all the biotopes sampled within the Severn Estuary SAC and SPA at 61%. Those species which provide the highest percentage contribution to similarity are listed in Table 17. The most frequently occurring species at stations (apart from the common gastropod *Peringia ulvae*) is juvenile *Nephtys* which are expected to develop into *Nephtys hombergii*, the main characterising polychaete species for the biotope. The next most abundant species is the main characterising bivalve species for the biotope, *Macoma balthica*.

Table 17. Species % contribution in the Severn Estuary SAC and SPA LMu.MEst.NhomMacStr biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Peringia ulvae	63.7	38.5	78.6
Nephtys juv.	5.5	6.4	13.08
Macoma balthica	4.2	3.2	6.6
Nephtys hombergii	1.05	0.5	0.9
Corophium volutator	0.2	0.09	0.2
Gammaridae	0.3	0.08	0.2
Pygospio elegans	0.5	0.08	0.2
Hediste diversicolor	0.4	0.05	0.09
NEMATODA	0.2	0.02	0.05
Streblospio shrubsolii	0.2	0.02	0.04

From Figure 15 it can be seen that at the three stations located at the mouth of the Parrett (68, 69 and 71), the faunal communities are different to those found elsewhere in the biotope. The precise environmental variables responsible for these differences are unknown, but they do not appear to be linked to sediment granulometry or redox conditions. Freshwater influence, different tidal regimes and lower exposure to wave action are however likely to be key factors.

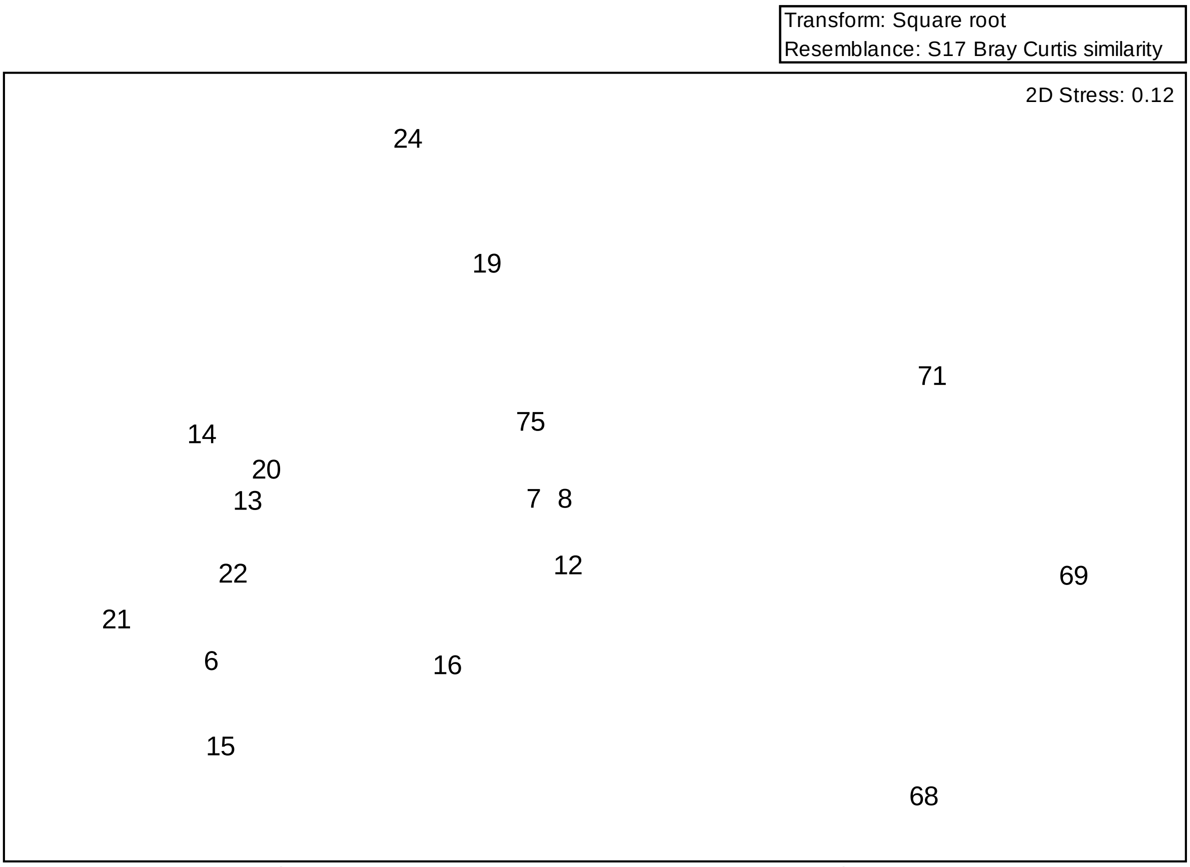

Figure 15. MDS plot of LMu.MEst.NhomMacStr communities sampled from the Severn Estuary SAC and SPA

Species diversity, evenness and richness are variable throughout the biotope (Table 18), though these indices are broadly similar between stations which are geographically closest to each other, supporting suggestions that the environmental variability within different parts of the estuary (i.e. different shore heights, salinity ranges, and wave and tidal exposures) are having localised effects on communities.

Table 18. Severn Estuary SAC and SPA LMu.MEst.NhomMacStr biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
6	11	500	1.609	0.3396	0.8143	0.3389
7	11	500	1.609	0.3396	0.8143	0.3389
8	8	222	1.296	0.4257	0.8852	0.444
12	6	216	0.9302	0.4631	0.8297	0.4499
13	6	505	0.8033	0.175	0.3136	0.125
14	8	463	1.14	0.2928	0.6088	0.2429
15	8	1040	1.008	0.1941	0.4035	0.1551
16	7	363	1.018	0.3448	0.671	0.3497
19	7	153	1.193	0.3376	0.657	0.2647
20	6	457	0.8164	0.2193	0.3928	0.1609
21	8	944	1.022	0.2635	0.5479	0.2428
22	8	599	1.095	0.2596	0.5399	0.235
24	9	238	1.462	0.2113	0.4642	0.175
68	8	86	1.571	0.6552	1.362	0.6544
69	8	56	1.739	0.6047	1.257	0.5675
71	9	95	1.757	0.7683	1.688	0.7843
75	9	186	1.531	0.347	0.7624	0.3312

At all stations assigned as LMu.MEst.NhomMacStr the two main characterising species *Nephtys hombergii* and *Macoma Balthica* are present (Table 19). The abundance of these species is variable. However, where present, *Nephtys hombergii* is in numbers from approximately half to more than five times than that expected (*Nephtys* juveniles expected to develop into *Nephtys hombergii* are present in hundreds at all but one station but are likely to be only temporarily abundant). The numbers of *Macoma balthica* are broadly in line with those expected but are notably more abundant at stations 6, 7 21 and 22.

A number of non-characterising crustacea species are recorded within the biotope though rarely in any large abundance; the most frequently occurring is *Corophium volutator*.

Table 19. Severn Estuary SAC and SPA LMu.MEst.NhomMacStr species composition

Species	Average Abundance per m^2 at Stations																	Biotope Characterising Species Abundance (No. m^2)
	6	7	8	12	13	14	15	16	19	20	21	22	24	68	69	71	75	
Hediste diversicolor	0	0	0	0	0	0	0	20	0	0	180	0	360	0	20	20	0	124
Nephtys hombergii	600	0	0	80	0	100	280	100	100	60	100	220	0	0	60	0	80	133
Nephtys juv.	800	800	660	1,020	300	180	740	1,260	100	180	320	480	40	920	720	440	360	*133*
Streblospio shrubsolii	0	0	0	0	0	0	20	0	0	0	0	0	0	40	0	200	0	593
Tubificoides pseudogaster agg.	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	*662-999*
Peringia ulvae	11,620	3,160	3,220	3,040	9,440	8,040	19,100	5,720	2,620	8,360	16,340	10,440	3,040	380	60	620	3,020	5093
Macoma balthica	940	600	440	120	280	420	220	40	60	440	1,680	760	320	100	160	420	140	*373*
NEMATODA	340	0	0	0	0	0	0	0	20	0	0	0	20	0	20	0	0	
Pygospio elegans	0	0	0	0	0	240	360	20	80	80	20	0	0	20	0	0	0	
CIRRIPEDIA	0	0	0	0	0	0	0	0	0	0	0	0	0	40	320	340	0	
Elminius modestus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	
COPEPODA	280	120	40	0	0	0	0	0	0	0	0	0	0	200	40	100	40	
Eusarsiella zostericola	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	
Hyalidae	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	20	
Bathyporeia juv.	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	
Bathyporeia pilosa	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	20	
Bathyporeia sarsi	0	20	0	0	40	220	0	0	0	0	0	0	0	0	0	0	0	
Gammaridae	20	0	0	0	0	0	0	0	80	20	220	20	0	0	40	40	0	
Gammarus salinus	0	0	20	0	0	20	0	0	0	0	0	0	0	0	0	40	0	
Corophium volutator	40	0	20	40	20	0	60	100	0	0	0	0	0	40	0	0	20	
Jaera	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	
Diastylis rathkei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	
Crangonidae	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	
Crangon crangon	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	
Retusa obtusa	0	20	0	20	0	0	20	0	0	0	0	0	60	0	0	0	0	
Nuculidae juv.	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Cardiidae juv.	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	

The stations assigned as LMu.MEst.NhomMacStr correspond reasonably well with that described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), the main deviation being the lack of dominance by the spionid polychaete *Streblospio shrubsolii* which was only present at 3 of the 17 stations. The biotope in the Severn Estuary SAC and SPA also occurs in more exposed conditions than expected.

The disparity observed in the fauna recorded at LMu.MEst.NhomMacStr stations when compared to that described in the Marine Habitat Classification are most likely to be attributable to the high degree of local and regional environmental variability found in estuarine environments (i.e. salinity, wave exposure, carbon matter, nutrient input and pollution); the Severn Estuary in particular is characterised by its extraordinary tidal energy. The low presence of the spionid *Streblospio shrubsolii* in particular may be as a result of the higher energy conditions than usually found in this biotope. Given that spionids are interface feeders (capturing particles at the sediment surface)[10] the potentially lower organic content at the surface of sediments in the Severn Estuary may be a reason for their lower abundance here. The extraordinarily high sediment loading may also be a contributing factor.

3.3.6 LSa.FiSa.Po

The LSa.FiSa.Po (Polychaetes in littoral fine sand) biotope is found in the middle reaches of the Severn Estuary SAC and SPA alongside LSa.MoSa.BarSa on the vast high energy Middle Grounds and Welsh Grounds which extend out from the Welsh shores (Figure 16). LSa.FiSa.Po occupies the more stable areas of these flats such as those shown in Plate 6.

Plate 6. A typical LSa.FiSa.Po biotope in the Severn Estuary SAC and SPA (photograph taken at Station 31).

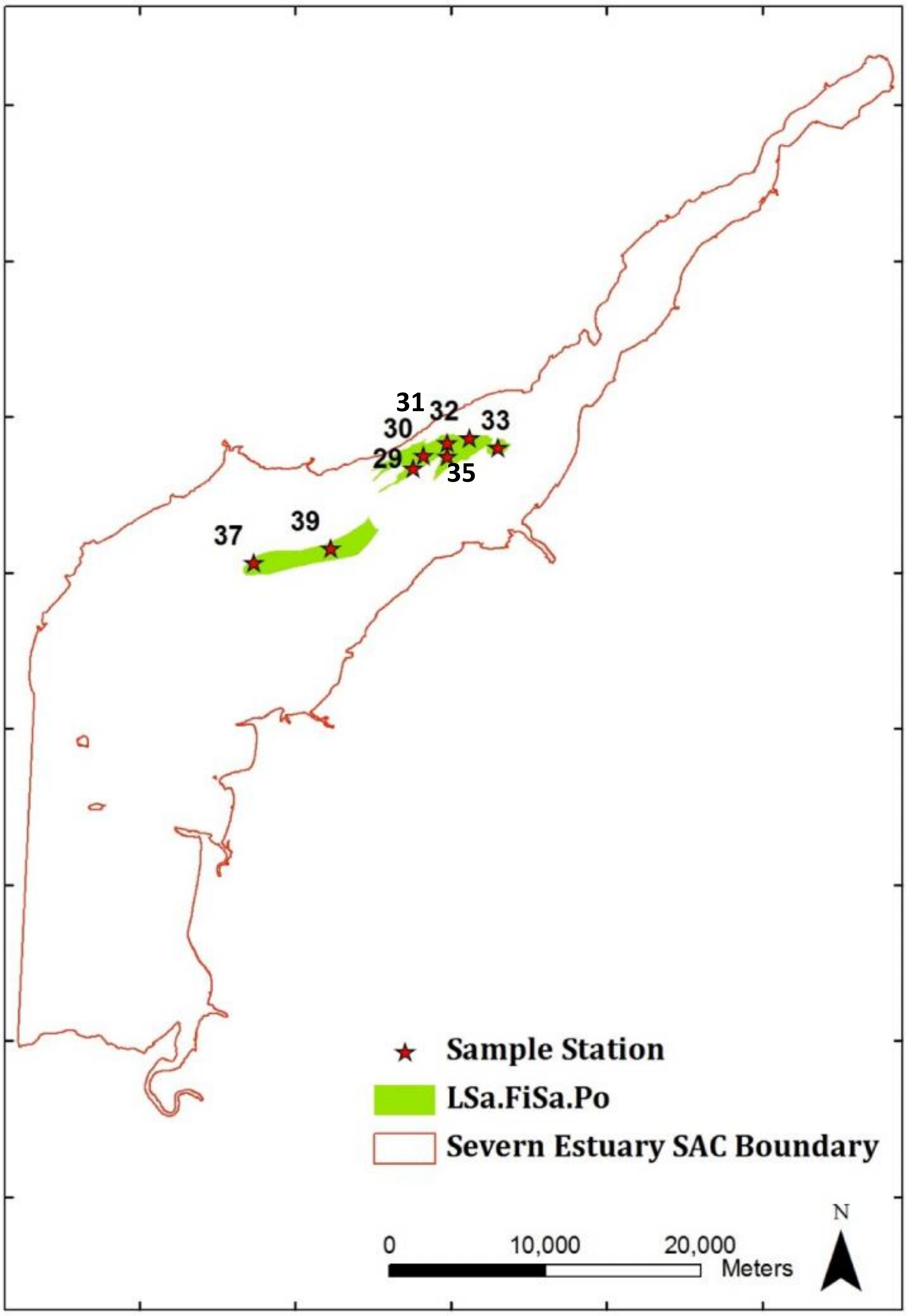

Figure 16. Extent and distribution of LSa.FiSa.Po in the Severn Estuary SAC and SPA

The sediments at the stations within the LSa.FiSa.Po biotope are dominated by very fine to medium sands (Table 3). Half of the stations also have a small fraction of clay and silt, but these fractions are otherwise absent. With the exception of station 33, all sediments sampled also have a small coarse sand fraction. The redox discontinuity layer was not detected within the first 15 cm at any of the stations (Table 4). Sediments were recorded as being mobile and thixotrophic at stations 29, 32, 35, 37 and 39.

The mean similarity between the benthic faunal communities at stations is 36.5%. The level of exposure to tidal scouring and sediment mobility is reflected in the fauna present; the burrowing amphipod *Bathyporeia pelagica* is frequently dominant throughout the biotope and accounts for 68% of the similarity between the faunal communities at stations (Table 20). Figure 17 shows how the similarity between stations is influenced by the mean number of *Bathyporeia pelagica*.

Table 20. Species % contribution in the Severn Estuary SAC and SPA LSa.FiSa.Po biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Bathyporeia pelagica	6.7	17.4	67.6
Hediste diversicolor	0.4	5.7	22.02
Peringia ulvae	0.3	1.4	5.3
Nephtys cirrosa	0.1	0.7	2.9
Cyathura carinata	0.05	0.3	1.2
Macoma balthica	0.1	0.2	0.8
Lekanesphaera monodi	0.05	0.04	0.2

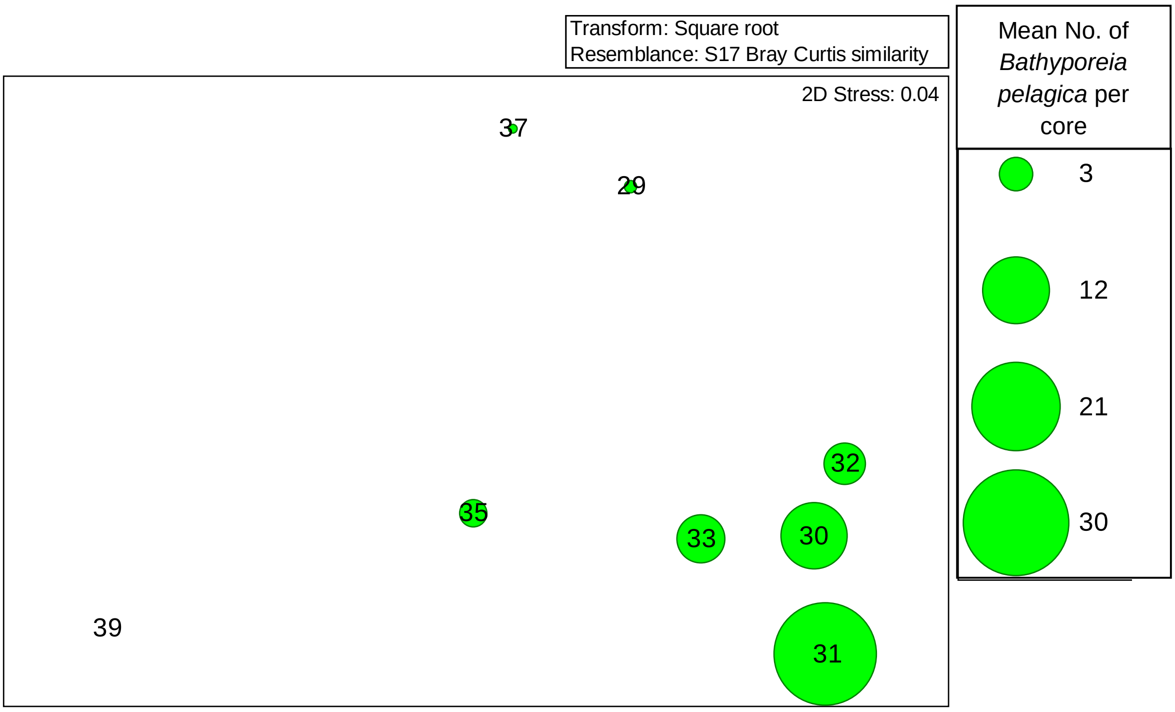

Figure 17. MDS bubble plot of LSa.FiSa.Po communities sampled from the Severn Estuary SAC and SPA in relation to mean number of *Bathyporeia pelagica*.

Between 3 and 7 taxa were found at the eight stations sampled within the biotope, and as has been found in many of the other biotopes within the Severn Estuary SAC and SPA, the richness, diversity and evenness of the communities is variable (Table 21). Evenness and diversity of communities is skewed frequently by the high numbers of *Bathyporeia pelagica*, though these indices are high at station 39 where just a few individuals of five species are recorded.

Table 21. Severn Estuary SAC and SPA LSa.FiSa.Po biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
29	4	7	1.542	0.9212	1.277	0.8095
30	3	61	0.4865	0.152	0.167	0.0650
31	7	153	1.193	0.2007	0.3905	0.1498
32	6	33	1.43	0.5968	1.069	0.5076
33	5	37	1.108	0.4094	0.6589	0.2988
35	6	18	1.73	0.7273	1.303	0.6667
37	3	8	0.9618	0.6696	0.7356	0.4643
39	5	5	2.485	1	1.609	1

Table 22. Severn Estuary SAC and SPA LSa.FiSa.Po species composition

Species	Average Abundance per m² at Stations								Biotope Characterising Species Abundance (No. m²)
	29	30	31	32	33	35	37	39	
Nephtys cirrosa	0	0	20	0	20	20	0	20	42
Nephtys juv.	0	0	0	0	0	20	0	0	*42*
Bathyporeia unident.	0	0	0	0	40	0	0	0	*260*
Bathyporeia juv.	20	0	0	0	0	0	0	0	*260*
Bathyporeia pelagica	40	1180	2820	460	620	200	20	0	*260*
Hediste diversicolor	60	0	20	0	20	80	120	20	
Capitella	0	0	0	20	0	0	0	0	
COPEPODA	0	0	40	40	0	0	0	0	
Pontocrates arenarius	0	0	0	0	0	0	0	20	
Haustorius arenarius	0	0	20	0	0	0	0	0	
Cyathura carinata	0	0	0	0	0	20	0	20	
Eurydice pulchra	0	0	0	0	0	0	0	20	
Sphaeromatidae	0	20	0	0	0	0	0	0	
Lekanesphaera monodi	0	0	20	0	0	20	0	0	
Littorina juv.	0	0	0	20	0	0	0	0	
Peringia ulvae	20	20	120	60	0	0	20	0	
Macoma balthica	0	0	0	60	40	0	0	0	

The absence of species such as *Angulus tenuis* and *Paraonis fulgens,* and a lack of dominance by *Nephtys cirrosa* made further sub-categorisation of stations assigned as LSa.FiSa.Po impossible. The stations assigned as the more broad level LSa.FiSa.Po biotope in the Severn Estuary SAC ad SPA largely correspond with the description in The Marine Habitat Classification for Britain and Ireland (Vs 04.05) particularly in terms of the physical characteristics they display (though again this biotope occurs in more exposed conditions than expected). However, the faunal communities are less well matched. Most notably the diversity and abundance of polychaete species is lower than expected and there is an absence of spionid polychaetes altogether (Table 22). The characterising species *Nephtys cirrosa* is present at half of all stations, though in much lower abundance than expected. The characterising amphipod *Bathyporeia pelagica* is present at seven of the total of eight stations, four of which it is present in much higher abundance than expected. A number of non-characterising species, mainly crustacea, are occasionally present.

The LSa.FiSa.Po biotope is known to be affected significantly by seasonal changes in the degree of wave exposure[9] and this is thought to be a contributory factor (together with the immense tidal regime) for the differences observed between the LSa.FiSa.Po biotope assigned within the Severn Estuary SAC and SPA and that described in the Marine Habitat Classification. Sampling was carried out in the autumn following a poor summer and unusually stormy weather; it is therefore likely that the sediments within the biotope were de-stabilised during the poor weather resulting in a loss of some faunal species that are less well adapted to mobile conditions. This assumption is supported by observations in the field where mobile and thixotrophic conditions were recorded at 5 of the 8 stations.

3.3.7 LSa.FiSa.PoNcir

The biotope LSa.FiSa.PoNcir (*Nephtys cirrosa* dominated littoral fine sand) is found in just one location within the Severn Estuary SAC and SPA, within Bridgewater Bay where it fringes the channel cut by the flow from the mouth of the River Parrett (Plate 7 and Figure 17).

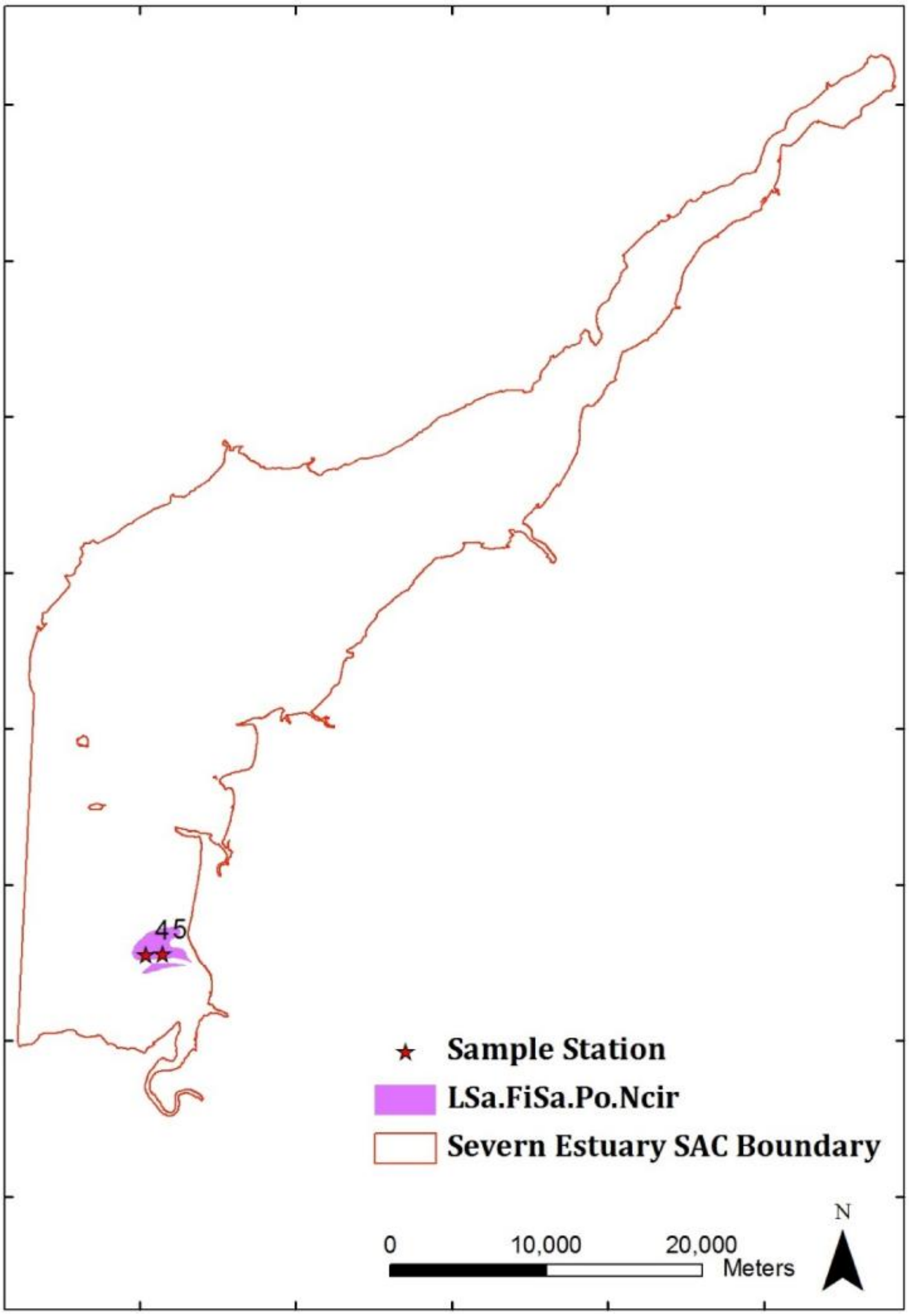

Figure 18. Extent and distribution of LSa.FiSa.PoNcir in the Severn Estuary SAC and SPA

Plate 7. A typical LSa.FiSa.Po.Ncir biotope in the Severn Estuary SAC and SPA (photograph taken at Station 4).

Fine sand fractions accounted for 63% of the sediments at both stations within this biotope, 30-35% was medium sand and the remainder was very fine sand with <1 % coarse sand (Table 3). Anoxic conditions were not detected within 15 cm from the sediment surface (Table 4). At station 4 the sediment was too firm for the redox probe to penetrate the sediment beyond 2 cm but a visual inspection resulted in no detection of a redox layer.

The mean similarity of target stations is 33.4%. With the exception of the gastropod *Peringia ulvae* (which is common to most of the biotopes in the Severn Estuary SAC and SPA), those species which contribute most to the similarity of the two stations are the burrowing amphipod *Bathyporeia pelagica* and the main characterising species *Nephtys cirrosa* which account for 16.7% similarity contribution equally (Table 23).

Between 7 and 8 taxa were recorded at the 2 stations that were sampled. Species diversity, richness and abundance are comparable between stations (Table 24). Species richness within the biotope is the highest of all the biotopes sampled within the Severn Estuary SAC and SPA. Evenness in communities at stations is reduced by the high numbers of *Bathyporeia pelagica* at station 4, and *Peringia ulvae* and Copepods at station 5.

Table 23. Species % contribution in the Severn Estuary SAC and SPA LSa.FiSa.PoNcir biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Peringia ulvae	2.6	12.3	66.7
Nephtys cirrosa	0.4	3.08	16.7
Bathyporeia pelagica	2.2	3.08	16.7

Table 24. Severn Estuary SAC and SPA LSa.FiSa.PoNcir biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
4	8	6	3.232	0.6123	1.191	0.6412
5	7	7	2.65	0.6095	1.092	0.6147

Table 25. Severn Estuary SAC and SPA LSa.FiSa.PoNcir species composition

Species	Mean Abundance per m² at Stations		Biotope Characterising Species Abundance (No. m²)
	4	5	
Nephtys cirrosa	20	60	79
Spio martinensis	0	20	279
Bathyporeia pelagica	420	20	*13-48*
Gammaridae	0	20	*13-48*
NEMATODA	20	0	
Pygospio elegans	60	0	
Elminius modestus	20	0	
COPEPODA	40	280	
Corophium volutator	20	0	
Peringia ulvae	80	440	
Macoma balthica	0	100	

The station characteristics correspond well with the LSa.FiSa.PoNcir biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), but deviations do exist in the faunal component. The characterising species which are present are variable in numbers compared to those expected (Table 25), some are far in excess, some broadly in-line, whilst others such as *Paraonis fulgens* and *Magelona mirablis* are absent altogether. A number of non-characterising species such as *Macoma balthica* and *Corophium volutator* are present and these species may represent some transition with adjacent biotopes in Bridgewater Bay.

3.3.8 LSa.MuSa.MacAre

The LSa.MuSa.MacAre biotope (*Macoma balthica* and *Arenicola marina* in littoral muddy sand) is distributed in two regions within the Severn SAC and SPA. The largest extent of the biotope is in the upper stretches of the estuary between Beachley and Lydney on the Welsh side, where it occupies broad swathes of sandflats. More limited bands of the biotope are also found in the lower estuary on the English side in Bridgewater Bay, Weston Bay and Sand Bay, on the same shores as LMu.MEst.NhomMacStr (Figure 18).

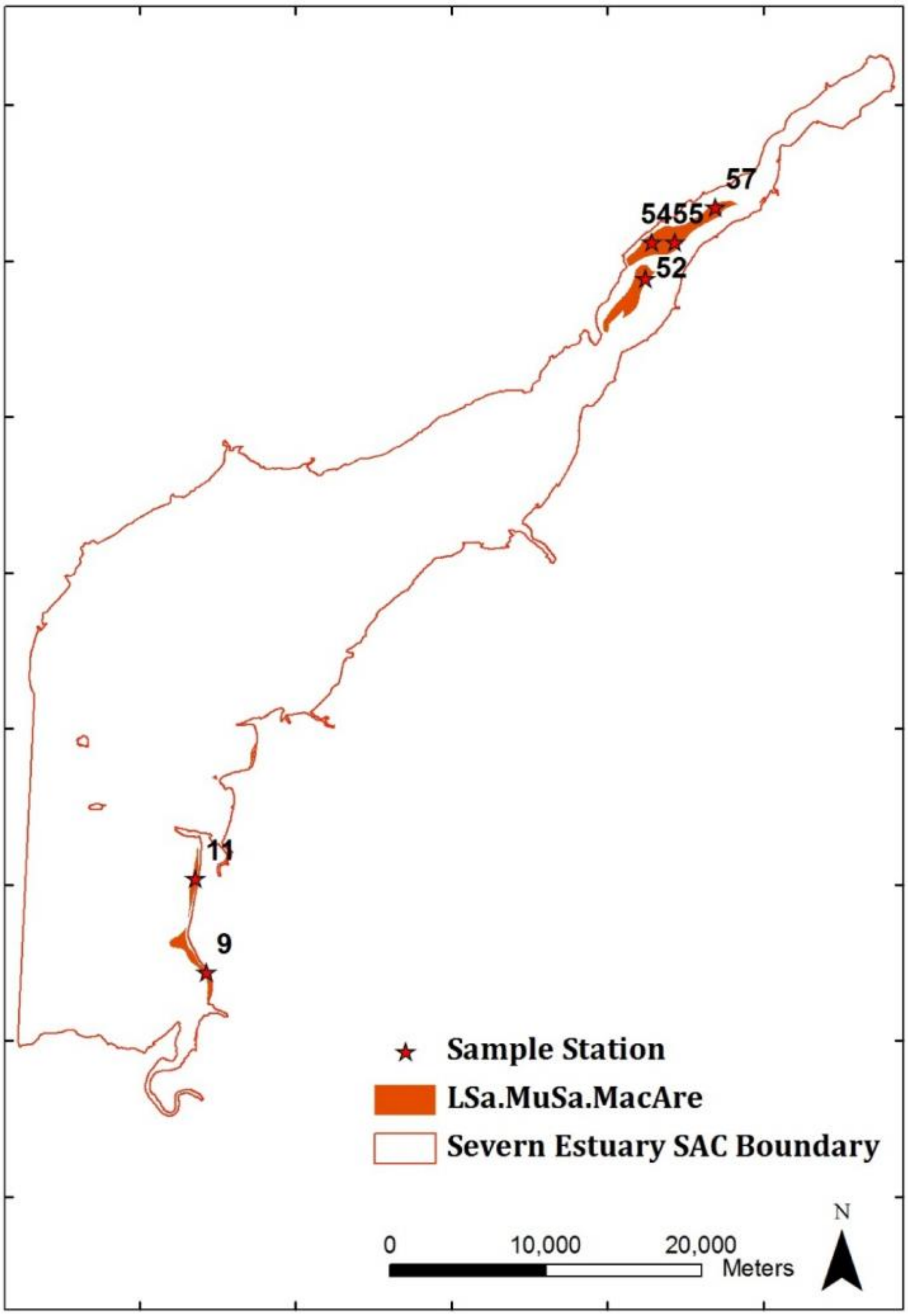

Figure 19. Extent and distribution of LSa.MuSa.MacAre in the Severn Estuary SAC and SPA

Plate 8. A typical LSa.MuSa.MacAre biotope in the Severn Estuary SAC and SPA (photograph taken at Station 55).

The sediment within the biotope is predominantly very fine to medium sand (Table 3 and Plate 8). Station 55 has an additional clay and silt fraction which accounts for approximately 5% of the sediment in total, and station 11 has an additional granule and pebble fraction amounting to less than 2% in total. The redox discontinuity layer was only detected at station 9 where a value of -61 mV was recorded at 10 cm depth (Table 4).

The mean similarity of the faunal communities between stations is 35.8%. However, the confidence in assignment of the communities as LSa.MuSa.MacAre has been underpinned by field observations of *Arenicola marina* casts (one of the two main characterising species) which are not accounted for in the replicate cores (*Arenicola marina* are often not captured in samples because the species quickly retreat into burrows which are often deeper than the core). The similarity between communities is therefore under-represented at least to some degree.

The main characterising bivalve species *Macoma balthica* accounts for 46.7% of the similarity between communities within the biotope and is followed by the non-characterising species *Bathyporeia pilosa*, which accounts for 39.2% similarity (Table 26).

Table 26. Species % contribution in the Severn Estuary SAC and SPA LSa.MuSa.MacAre biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Macoma balthica	1.4	12.2	46.7
Bathyporeia pilosa	0.8	10.3	39.2
Peringia ulvae	8.1	2.02	7.7
Pygospio elegans	10.7	1.5	5.7
Capitella	0.1	0.04	0.2
NEMATODA	0.5	0.04	0.1
Hediste diversicolor	0.2	0.04	0.1
NEMERTEA	0.2	0.02	0.08

An MDS bubble plot of the communities similarities within the biotope show that stations in the upper estuary are grouped together at the right hand side of the plot whilst stations 9 and 11 in Bridgewater Bay are located on the left hand side of the plot (Figure 19).

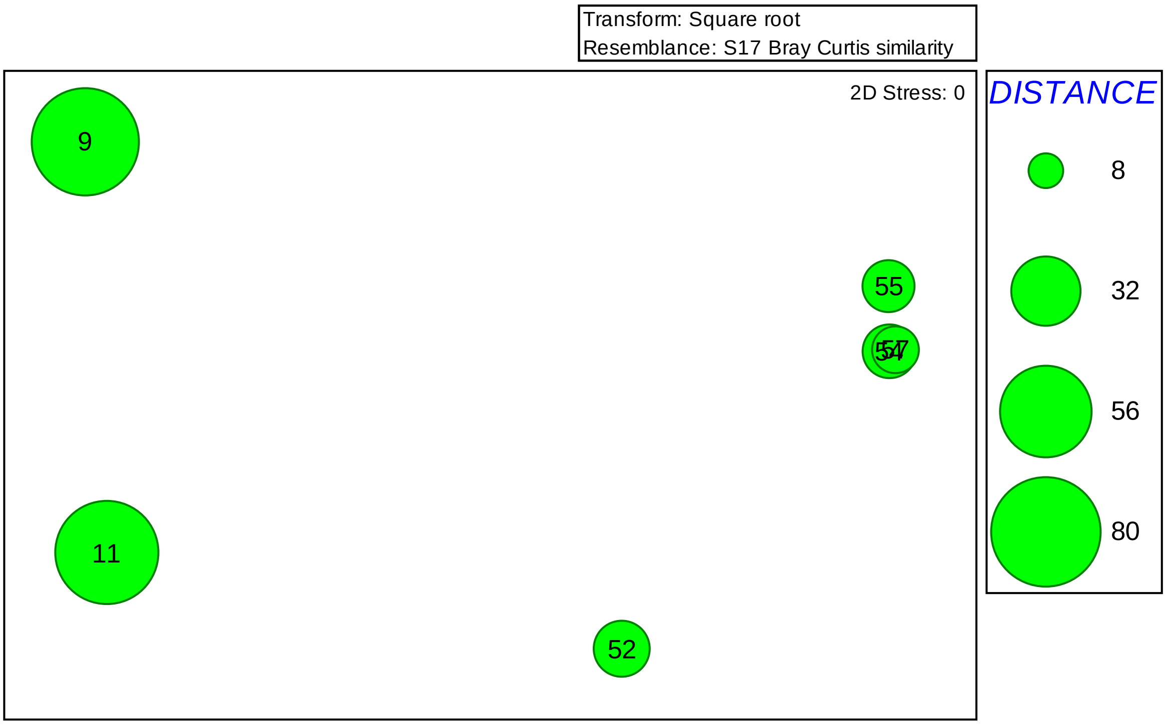

Figure 20. MDS plot of LSa.MuSa.MacAre communities sampled from the Severn Estuary SAC and SPA in relation to distance in kilometres from the head of the estuary

Community richness, evenness and diversity are variable throughout the biotope (Table 27). Evenness is relatively low at stations 9 and 11 in the lower estuary, which are strongly dominated by the characterising spionid *Pygospio elegans* which is absent from the replicates in the upper estuary. Replicates in the lower estuary contain more species; stations 9 and 11 contain 10 and 12 species respectively, whilst all other stations located in the upper reaches of the estuary contain between 2 and 7 species.

If measured redox can be used as an indication of the organic matter content in sediments as suggested by Natural England, the differences in communities observed between the upper and lower estuary may be linked to the potentially higher levels of organic matter in the lower estuary sediments, which would favour colonisation by deposit feeders and detritivores.

Table 27. Severn Estuary SAC and SPA LSa.MuSa.MacAre biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
9	10	335	1.548	0.4281	0.9856	0.4248
11	12	319	1.908	0.4869	1.21	0.5578
52	7	27	1.82	0.7468	1.453	0.7236
54	2	8	0.4809	0.9544	0.6616	0.5357
55	3	6	1.116	0.7897	0.8676	0.6
57	4	10	1.303	0.8427	1.168	0.7111

Table 28. Severn Estuary SAC and SPA LSa.MuSa.MacAre species composition

Species	Average Abundance per m² at Stations						Biotope Characterising Species Abundance (No. m²)
	9	11	52	54	55	57	
Pygospio elegans	5,020	1,440	0	0	0	0	58
Arenicola marina	0	0	0	0	0	20	24
Macoma balthica	400	160	60	60	80	60	248
NEMERTEA	80	20	0	0	0	0	
NEMATODA	280	0	20	0	0	0	
Hediste diversicolor	120	0	20	0	0	0	
Nephtys cirrosa	0	20	0	0	0	0	
Capitella spp.	60	0	0	0	20	0	
COPEPODA	20	180	0	0	0	0	
Bathyporeia	0	0	20	0	0	0	
Bathyporeia juv.	20	260	0	0	0	0	
Bathyporeia pilosa	0	100	160	100	20	100	
Bathyporeia sarsi	0	60	0	0	0	0	
Gammaridae	0	0	20	0	0	0	
Corophium volutator	60	0	0	0	0	0	
Sphaeromatidae	0	20	0	0	0	0	
Cumopsis goodsir	0	120	0	0	0	0	
Peringia ulvae	640	3,980	240	0	0	20	
Retusa obtusa	0	20	0	0	0	0	

The stations assigned as LSa.MuSa.MacAre correspond reasonably well with the LSa.MuSa.MacAre biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05). However, as detailed below, there are some discrepancies in both the physical and biological components of the biotope in the Severn Estuary SAC and SPA.

The sediment had a larger proportion of medium sands and smaller proportion of mud than expected, and as such sediments were not found to be anoxic within the first 5 cm as described in the Marine Habitat Classification. This may indicate that the sediments are subject to higher energy and are more mobile than usual for the biotope, which would not be surprising given the tidal characteristics of the Severn estuary compared to other estuaries in the UK.

In terms of the biological components of the biotope, the two main characterising species (*Macoma balthica* and *Arenicola marina*) were present at all stations assigned as LSa.MuSa.MacAre though *Arenicola marina* is under-represented in cores (Table 28). The subsidiary characterising species *Scoloplos armiger*, *Cerastoderma edule* and oligochaetes were absent altogether. A number of non-characterising species are present, particularly at stations 9 and 11, adding to the overall diversity and richness of those communities considerably. Most notable within the biotope is the abundance and contribution to similarity of the non-characteristic amphipod *Bathyporeia pilosa*.

3.3.9 LMu.UEst.Hed.Str

The LMu.UEst.Hed.Str biotope (*Hediste diversicolor* and *Streblospio shrubsolii* in littoral sandy mud) was found at two stations within the Severn Estuary SAC and SPA. In the course of other biotopes being targeted, each area is relatively limited in extent. One of the areas is on the Welsh coast on the upper shores of the Welsh Grounds, and the other is on the English side of the estuary within the mouth of the River Parrett (Figure 20).

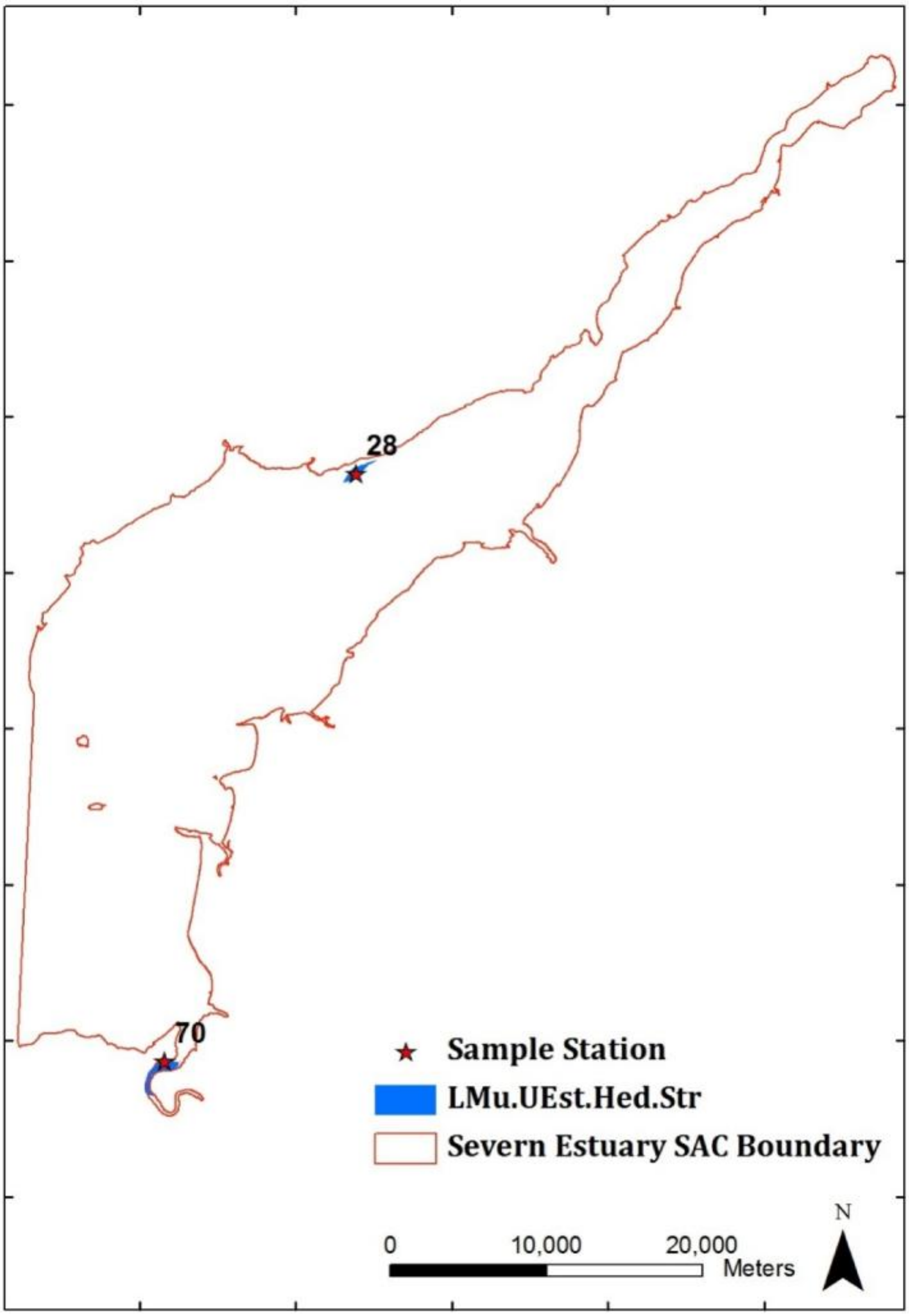

Figure 21. Extent and distribution of LMu.UEst.Hed.Str in the Severn Estuary SAC and SPA

Plate 9. A typical LMu.UEst.Hed.Str biotope in the Severn Estuary SAC and SPA (photograph taken at Station 70).

The sediments within the cores taken from this biotope are quite different between the two stations sampled; station 28 is mainly fine and medium sand with a 10% proportion of course sand and approximately 1% of the largest particle sizes (Table 3). In contrast station 70 is dominated by clay and silt fractions with a small proportion of fine and medium sands (Plate 9). Consequently the redox properties are also variable and the redox discontinuity layer was not observed at station 28, but was present at 8-10 cm at station 70 where a value of -40 mV was recorded (Table 4).

In terms of faunal communities the mean similarity between stations is low at 19.8% (this is not surprising given the different substrate properties between stations). With the exception of *Peringia ulvae*, the presence of *Hediste diversicolor* and *Streblospio shrubsolii* account for the largest similarities in fauna between stations, contributing 43% and 29% respectively (Table 29). These species are the two principal characterising species for the LMu.UEst.Hed.Str biotope and it is the abundance of these species that has formed the basis for the assignment of these stations as LMu.UEst.Hed.Str despite some obvious discrepancies in the physical characteristics.

Diversity indices vary between the stations owing to the greater number of species and much larger abundances at station 70 (Table 30).

Table 29. Species % contribution in the Severn Estuary SAC and SPA LMu.UEst.Hed.Str biotope

Species	Mean Abundance Per Core	Mean Similarity	% Contribution
Hediste diversicolor	16.6	1.8	42.9
Streblospio shrubsolii	1.3	1.2	28.6
Peringia ulvae	13.7	1.2	28.6

Table 30. Severn Estuary SAC and SPA LMu.UEst.Hed.Str biotope community analysis

Station	Total No. Taxa Per Station (x5 Cores) S	Mean No. Individuals Per Core N	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'
28	6	12	2.012	0.9757	1.748	0.8939
70	9	326	1.382	0.4779	1.05	0.5782

Table 31. Severn Estuary SAC and SPA LMu.UEst.Hed.Str species composition

Species	Average Abundance per m² at Stations 28	70	Biotope Characterising Species Abundance
Hediste diversicolor	60	3260	2020
Streblospio shrubsolii	40	220	3033
Paranais litoralis	0	20	*6592*
Corophium volutator	40	0	2897
Dolichopodidae	20	0	
NEMATODA	0	180	
Nephtys juv.	0	20	
Capitella	40	0	
Elminius modestus	0	80	
Gammaridae	0	20	
Sphaeromatidae	20	0	
Peringia ulvae	40	2700	
Macoma balthica	0	20	

The characteristics of the LMu.UEst.Hed.Str biotope in the Severn Estuary SAC and SPA correspond broadly with that described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05). Assignment of the biotope is based primarily on the relative abundance of the two main characterising species. The main differences are the lack of silt and clay components in the sediments at station 28 and the lower numbers of all characterising species, except for *Hediste diversicolor* at station 70 (Table 31). The presence of *Macoma balthica* at station 70 is also not expected for the biotope but the presence of this species is thought to be a result of transition with the adjacent LMu.MEst.NhomMacStr biotope; in effect station 70 is transitional between the two biotopes.

3.3.10 LS.LBR.Sab.Salv

The mapping of the extent and distribution of LS.LBR.Sab.Salv (*Sabellaria alveolata* reefs on sand-abraded eulittoral rock, previously LR.MLR.Sab.Salv) in the Severn Estuary SAC and SPA was not a key objective within this study, but where this biotope was observed it was noted and subsequently mapped. Figures 21 and 22 show the extent and distribution of *Sabellaria alveolata* that was surveyed between 1996 and 2005 [2][3] together with that which was recorded during the course of the 2012 Phase II survey.

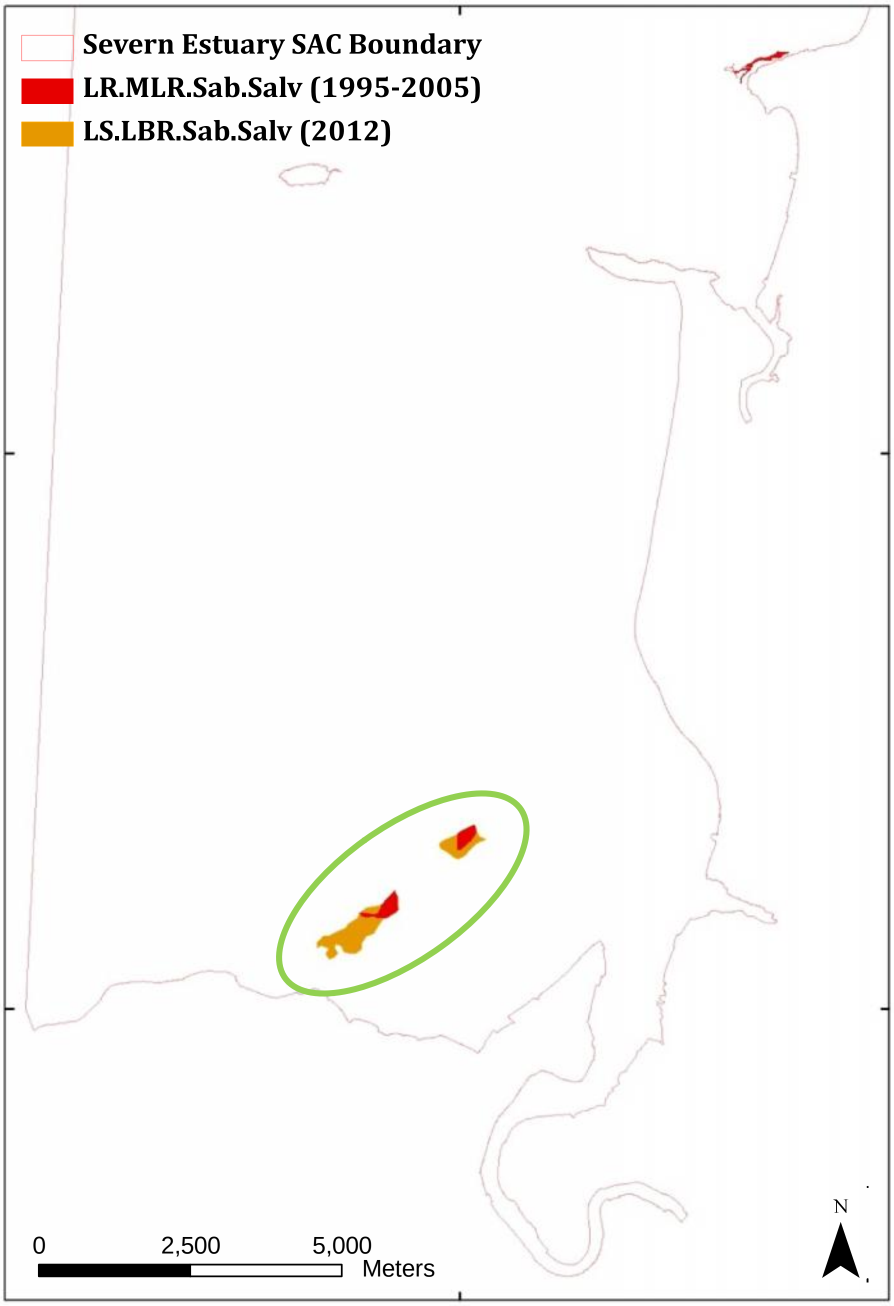

Figure 22. Extent and distribution of LS.LBR.Sab.Salv in the lower reaches of the Severn Estuary SAC and SPA (the *Sabellaria* reef at Hinkley point is circled in green).

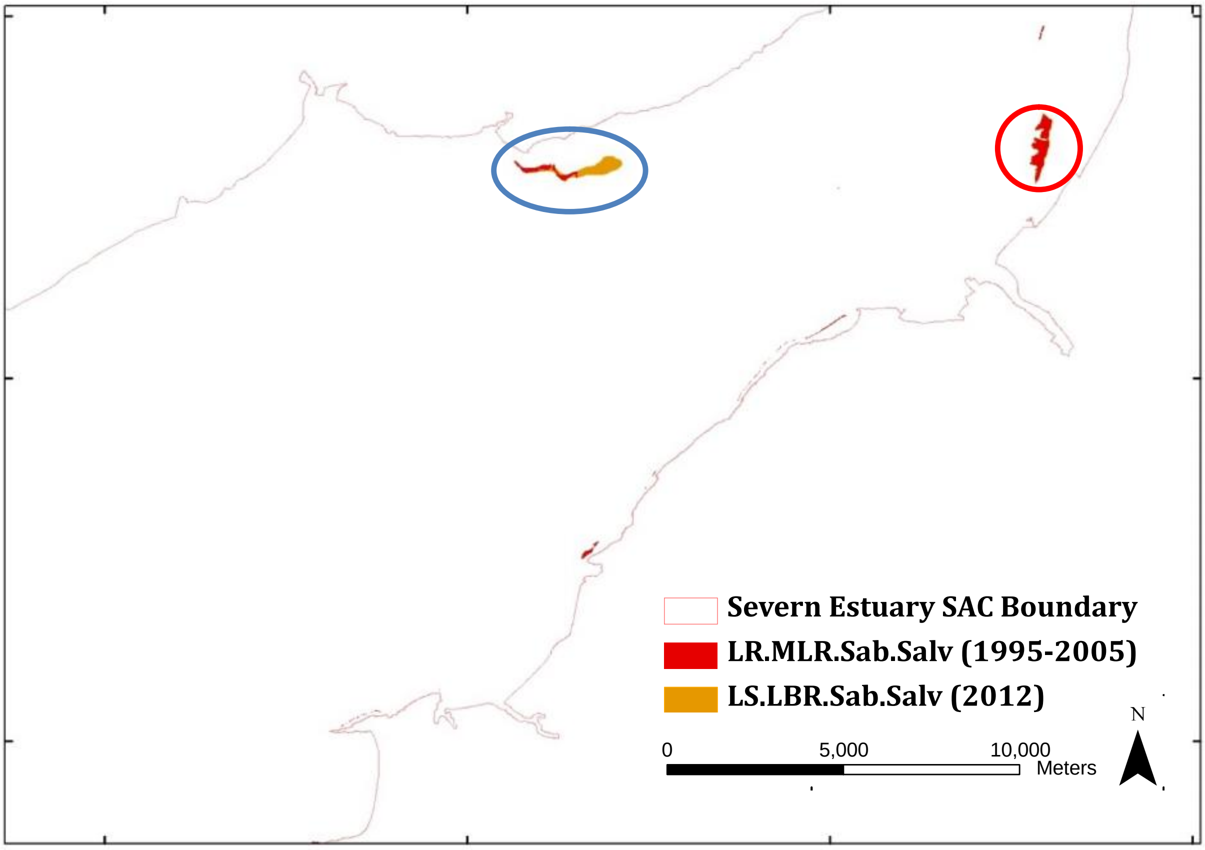

Figure 23. Extent and distribution of LS.LBR.Sab.Salv in the mid reaches of the Severn Estuary SAC and SPA (the *Sabellaria* reef at Usk patch is circled in blue, and that at Avonmouth is circled in red).

Figures 22 and 23 suggest that the extent of the biogenic reefs have increased since 1995-2005 at Hinkley Point (circled in green in Figure 22) and at Usk Patch (circled in blue in Figure 23). However, the biotope is found at extreme low water and therefore unless these areas were visited within an hour either side of low water then it is unlikely that the full extent of the biotope would be exposed. The change in extent is therefore likely to be an artefact of the state of the tide during survey. It was unclear whether the areas of reef observed extend into the subtidal (and can therefore be considered as part of the reef feature of the SAC), but it is likely that this is the case at least in some places.

An extensive area of reef is located on the English shores northeast of Avonmouth (circled in red in Figure 23), the extent of this reef was reported to be largely the same as that which was reported in 2006[3]. All other distributions of the biotope recorded between 1995 and 2005 which are mapped in Figures 21 and 22 were not observed during the course of this survey (those reefs adjacent to Clevedon, south of Avonmouth, and at Sand Point and Braen Down). This is not to say that the reefs were not present, but again may be an artefact of the tidal state at the time surveyors were in the area. Also, given that the 2012 survey was limited to Phase II methods, some of these areas were not traversed in the course of sample stations being targeted.

3.4 Faunal Biomass

The intertidal mudflats and sandflats are key supporting habitats to the bird communities of the Severn Estuary SPA. Bird communities are highly mobile and exhibit patterns of activity related to a number of factors including prey availability. Different bird species exploit different parts of the intertidal flats and different prey species, changes in the habitat may therefore affect different species in different ways.

In recognition of the fact that bird populations within the Severn Estuary SPA may change in response to changes in the mudflat and sandflat communities, objectives to maintain these aspects of bird interest in favourable condition are found within Natural England and CCW's conservation objectives for the SPA (Section 1.1). A specific target of the conservation objectives is that the biomass and abundance of suitable prey species should not deviate significantly from an established baseline. Measurement of this target is a secondary objective within this study, but in the absence of any baseline data with which to compare, this study will provide a baseline with which to make future comparisons. This section therefore describes the main faunal species which account for the biomass within the intertidal sandflat and mudflat biotopes of the Severn Estuary SAC and SPA.

It should be noted that some species i.e. *Arenicola marina* are under-represented by the cores as explained in section 3.3.8, and therefore the contributing biomass of this species will be underestimated.Table 32 lists the top three species that contribute most to biomass within cores from each of the sandflat and mudflat biotopes within the Severn Estuary.

Table 32. Top 3 species contributing to biomass within each biotope

Biotope	Species	Mean Biomass Per Core (g)	% Contribution
LMu.MEst.HedMac	*Macoma balthica*	0.23	47.71
	Hediste diversicolor	0.18	39.66
	Peringia ulvae	0.05	11.45
LSa.MoSa.BarSa	*Eurydice pulchra*	<0.01	95.13
	Bathyporeia pelagica	<0.01	3.34
	COPEPODA	<0.01	1.53
LSa.MoSa	*Bathyporeia pilosa*	<0.01	98.61
	Haustorius arenarius	<0.01	1.05
	Cyathura carinata	<0.01	0.34
LSa.MuSa.BatCare	*Bathyporeia pilosa*	0.02	44.83
	Macoma balthica	0.05	23.53
	Peringia ulvae	<0.01	20.87
LMu.MEst.NhomMacStr	*Macoma balthica*	0.25	57.71
	Peringia ulvae	0.12	28.92
	Nephtys juv.	0.02	10.71
LSa.FiSa.Po	*Nephtys cirrosa*	0.01	61.92
	Bathyporeia pelagica	<0.01	25.98
	Hediste diversicolor	<0.01	9.75
LSa.FiSa.PoNcir	*Nephtys cirrosa*	0.01	77.73
	Peringia ulvae	<0.01	20.52
	Bathyporeia pelagica	<0.01	1.31
LSa.MuSa.MacAre	*Macoma balthica*	0.11	95.27
	Pygospio elegans	0.01	1.54
	Bathyporeia pilosa	<0.01	1.4
LMu.UEst.Hed.Str	*Peringia ulvae*	0.03	87.05
	Hediste diversicolor	0.44	9.35
	Streblospio shrubsolii	<0.01	3.6

A few species re-occur as a significant contributor to biomass within the sand and mudflat biotopes of the Severn Estuary SAC and SPA (Table 33). Species of burrowing amphipods occur most frequently within the table, namely *Bathyporeia pelagica* and *Bathyporeia pilosa*. The tiny gastropod *Peringia ulvae* is the second most frequently occurring species and is followed by the bivalve *Macoma balthica* and the polychaetes *Hediste diversicolor* and *Nephtys cirrosa* respectively.

Table 34. Mean total biomass of fauna within cores collected from each biotope sampled

Species	Mean Biomass Per Core (g)	% of total area of littoral sediment mapped in 2012
LMu.MEst.HedMac	0.47186	23%
LSa.MoSa.BarSa	0.00164	17%
LSa.MuSa.BatCare	0.07269	15%
LMu.MEst.NhomMacStr	0.41389	15%
LSa.FiSa.Po	0.03451	11%
LSa.MuSa.MacAre	0.13358	7%
LSa.FiSa.PoNcir	0.10322	6%
LSa.MoSa	0.00407	5%
LMu.UEst.Hed.Str	0.47619	1%

Table 34 shows that LMu.MEst.HedMac, LMu.UEst.Hed.Str and LMu.MEst.NhomMacStr have the largest mean total biomass per core. The species contributing most to the biomass within two of these three biotopes is (LMu.MEst.HedMac and LMu.MEst.NhomMacStr) is *Macoma balthica*. Given that LMu.MEst.HedMac and LMu.MEst.NhomMacStr account for large proportions of the total mapped sandflat and mudflat communities within the Severn Estuary SAC and SPA (23% and 15% of the total area respectively) arguably *Macoma balthica* may be considered as a significant species in terms of prey availability for birds within the Severn Estuary SPA.

Given the large area and high mean biomass within the LMu.MEst.HedMac and LMu.MEst.NhomMacStr biotopes, these biotopes may be considered to be the most important biotopes within the Severn Estuary in terms of providing a food source for birds. In support of this statement, the extent and distribution of these biotopes appears to relate to the mean number of all waterfowl species recorded in the winters of 1987/1988 to 1991/1992, and in 2002/2003 (from British Trust for Ornithology (BTO) low tide count data from across the Severn Estuary SPA[13]). During the winters from 1987 to 2003 the greatest densities of birds were recorded on the flats between Newport and Cardiff (Figure 24), and in 2002/2003 the greatest densities were recorded and on the southern flats of Bridgewater Bay (Figure 25). Both of these areas are dominated by the LMu.MEst.HedMac and LMu.MEst.NhomMacStr biotopes.

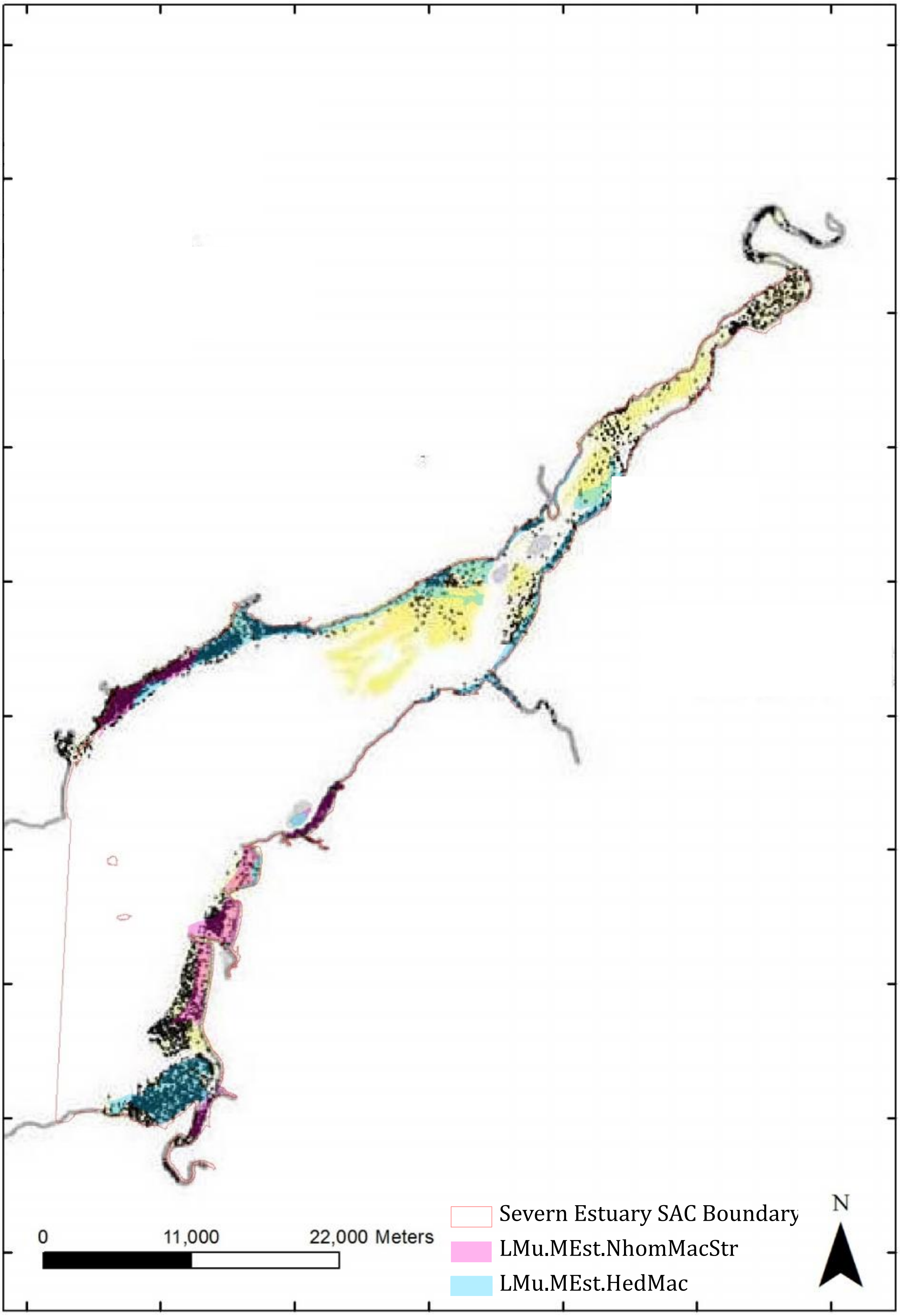

Figure 24. Mean number of all waterfowl species recorded between 1987 and 1992 (taken from BTO low tide count data as presented in the Severn Estuary Regulation 33 document where 1 dot = 10 birds) [13], overlaid with extent and distribution of LMu.MEst.HedMac and LMu.MEst.NhomMacStr in 2012.

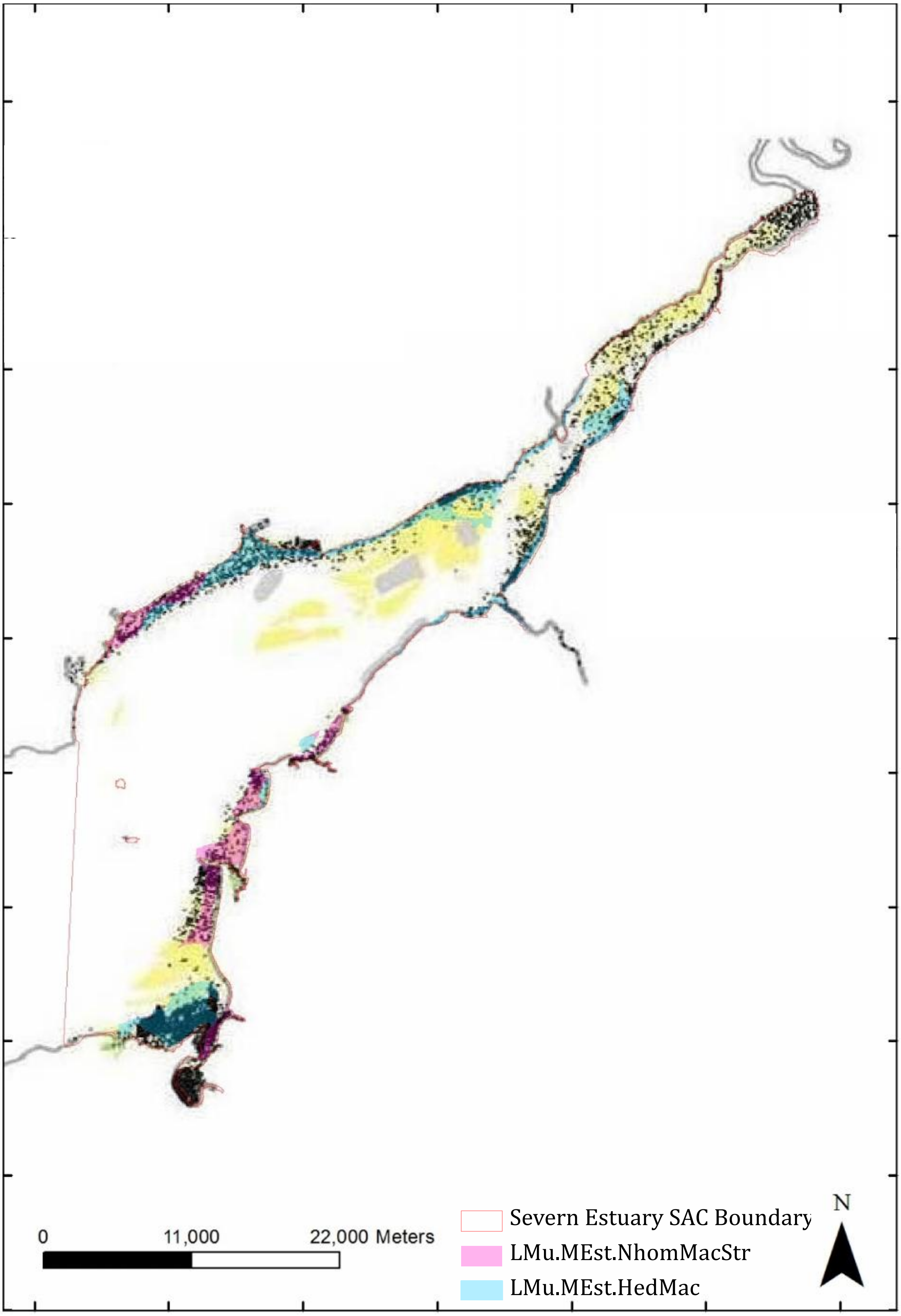

Figure 25. Mean number of all waterfowl species recorded in 2002/2003 (taken from BTO low tide count data as presented in the Severn Estuary Regulation 33 document where 1 dot = 10 birds [13]), overlaid with extent and distribution of LMu.MEst.HedMac and LMu.MEst.NhomMacStr in 2012.

3.5 Multivariate Analysis of All Biotope Fauna

The results of the univariate analysis have been incorporated into the relevant sections in Chapter 3 above.

Community analysis in PRIMER[7] used the multivariate Bray-Curtis similarity statistic and multidimensional scaling (MDS) to assess the communities at each target station. The MDS plot in Figure 25 represents the sample stations (within each biotope) in two dimensions, where the distances between points represent the dissimilarities between the faunal communities at those stations. In order to reduce the influence of very abundant taxa on the analysis, the benthic invertebrate data set was subjected to a single square root transformation prior to fauna similarity analysis.

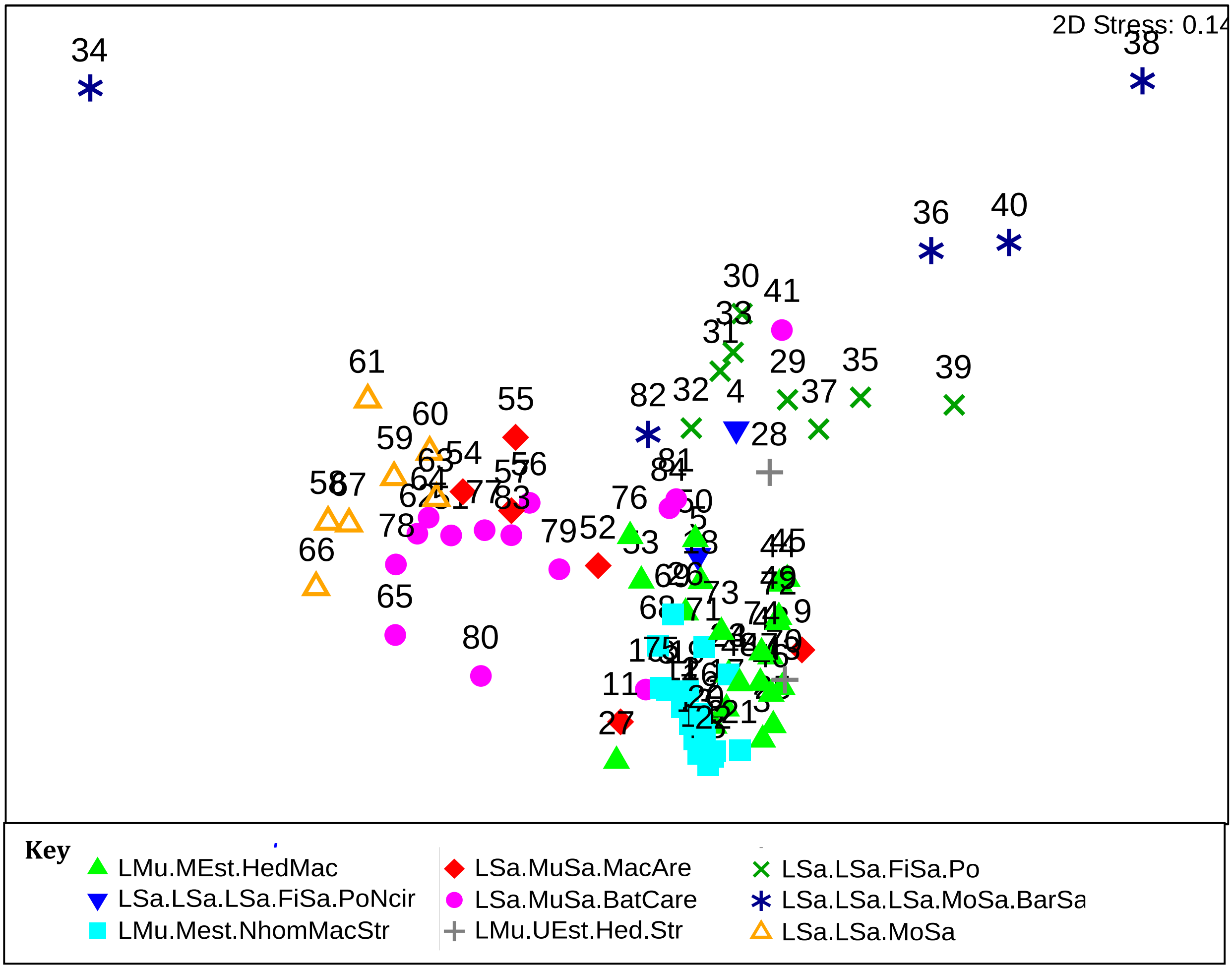

Figure 26. Two dimensional MDS plot of all communities sampled within the Severn Estuary SAC and SPA (the distances between points represent the dissimilarities between the faunal communities at stations).

Figure 26 demonstrates a reasonably good similarity and therefore grouping of replicates from the same biotopes, particularly given the large geographical area over which a number of the biotopes are distributed. Some biotopes do however demonstrate better Bray-Curtis similarity values than others. The LMu.MEst.NhomMacStr biotope for example has the highest Bray-Curtis value of 61% whilst the LSa.MoSa.BarSa biotope has the lowest value at 13%.

The distribution of LMu.MEst.NhomMacStr is limited to one location within the estuary; therefore the communities within the biotope are not exposed to a broad range of environmental variables as is the case for a number of the other biotopes that are distributed over an extensive geographical area within the estuary. The weaker similarities observed within the LSa.MoSa.BarSa biotope replicates are a consequence of the lack of macrofaunal community within the biotope.

4. DISCUSSION

4.1 Condition Assessment

4.1.1 Temporal Comparisons

A comparison of the previous distribution of intertidal mudflat and sandflat biotopes in the Severn Estuary SAC[2][3] with those identified within this study reveals a number of temporal changes. However, it should be noted that the apparent differences described here have resulted from looking at the results of previous studies where only Phase I methods were applied, and comparing those with the results of the current study where only Phase II methods were applied. No quantitative core data was received from either CCW or Natural England which has made it difficult to draw any firm conclusions. Very broadly speaking, the diversity of biotopes does not appear to have changed significantly over time.

The principal differences in biotopes are as a consequence of different versions of the Marine Habitat Classification for Britain and Ireland being used between studies. Version 97.06 was used to assign biotopes identified in the studies carried out between 1996 and 2005, and version 04.05 was used to assign biotopes within this study (2012). Two biotopes which accounted for a large proportion of the total area mapped in 1995-2005 [2][3] (LS.LGS.S.AEur and LS.LGS.S.AP.P) have been removed from the updated version of the Marine Habitat Classification for Britain and Ireland (Vs 04.05), and records elsewhere in the country have since been reassigned mostly to LSa.FiSa.Po, LS.LSa.MoSa.AmSco and LS.LSa.MoSa.AmSco.Eur which are considered to be broadly equivalent.

Due to the absence of *Scolelepis* spp. from stations in 2012, the faunal communities do not fit well with LS.LSa.MoSa.AmSco and LS.LSa.MoSa.AmSco.Eur descriptions in which *Scolelepis* spp. are a principal characterising species. Mudflats and sandflats previously categorised as LGS.S.AEur and LGS.S.AP.P in the Severn Estuary SAC and SPA have therefore been assigned as a number of different biotopes in 2012 and include LSa.FiSa.Po, LSa.MoSa, LSa.MoSa.BarSa, LSa.MuSa.BatCare and LSa.MuSa.MacAre.

Burrowing amphipods (mainly *Bathyporeia pilosa* and *Bathyporeia pelagica*) are common within areas that have been assigned as LSa.FiSa.Po, LSa.MoSa, LSa.MoSa.BarSa, LSa.MuSa.BatCare or LSa.MuSa.MacAre, and often appear in samples as additional species that are not characterising in the associated biotope descriptions. It is therefore likely that had the LS.LGS.S.AEur and LS.LGS.S.AP.P biotopes been continued in Version 04.05 of the Marine Habitat Classification for Britain and Ireland then many of the areas assigned as LSa.FiSa.Po, LSa.MoSa, LSa.MoSa.BarSa, LSa.MuSa.BatCare or LSa.MuSa.MacAre in 2012 would have better fitted the biotope descriptions for LS.LGS.S.AEur or LS.LGS.S.AP.P. As a result, from an initial glance at results it could appear that temporal changes have occurred in areas previously assigned as LS.LGS.S.AEur and LS.LGS.S.AP.P, however, changes in these biotopes are principally as a result of the discontinuation of previous biotope codes.

Notwithstanding the differences in classification used between the surveys, it is thought that a number of potentially real changes in biotope distributions elsewhere in the estuary are apparent. Differences include the absence of the polychaete *Arenicola marina* from the Welsh Grounds and the bank adjacent to the main channel at Oldbury-on-Severn, and subsequent re-assignment of the LSa.MuSa.MacAre biotope in those areas to LSa.FiSa.Po and LS.LM.Mu.HedMac respectively. In the lower estuary on both the Welsh and English shores (including those within Bridgewater Bay, Weston and Sand Bay) LS.LMu.SMu.HedMac has been largely replaced by LS.LMu.MEst.NhomMacStr (the polychaete *Nephtys hombergii* appears to have displaced *Hediste diversicolor*). In addition, LS.LSa.FiSa.PoNcir (*Nephtys cirrosa* dominated littoral fine sand) is now also found within Bridgewater Bay. LS.LMu.Mu.HedOl has also been replaced both within the mouth of the River Parrett and the River Avon by LS.LMu.MEst.NhomMacStr and LS.LMu.UEst.Hed.Str and LS.LMu.Smu.HedMac respectively.

The loss of *Arenicola marina* as described above may be a result of the unseasonably poor weather and storm events in the summer which preceded sampling in 2012, or due to differences in the time of year that surveys were undertaken. The species is known to be vulnerable to being washed out of sediments as a result of increases in sediment mobility during storminess and wave action[10]. Given the thixotrophic nature of sediments noted in the area where *Arenicola marina* were previously recorded, the loss of sediment stability and subsequent loss of the species as a result of increased sediment mobility is a possible scenario. Another explanation however maybe that fewer casts indicating the presence of *Arenicola marina* were observed because of the fasting behaviour following spawning which is exhibited particularly by females. The breeding season of *Arenicola marina* coincides with, or is preceded by, the first major fall in air temperatures[14]. After spawning males have been shown to fast for 2 days while females fast for 3-4 weeks, presumably to avoid ingesting eggs and larvae[15]. Fasting of the females is therefore likely to have coincided with the time of survey; this does not account for the apparent absence of the species altogether in areas where it was previously recorded, but nevertheless it may be a contributing factor.

Nephtys hombergii is known to be more tolerant of a range of physical and biological factors than *Hediste diversicolor*[11], but without further investigation the factors responsible for the apparent substitution of *Hediste diversicolor* by *Nephtys* spp. within communities in the lower estuary cannot be determined. The cause of the replacement of LS.LMu.Mu.HedOl from the mouths of the Rivers Parrett and Avon is also unknown and cannot be determined here.

4.1.2 Identification of Anthropogenic Impacts and Negative Indicators

Over the survey area a number of negative indicators were observed including outfalls, evidence of netting and litter. The vast majority of water inputs were land drains. However, there were several industrial pipelines and some sewers. A large number of these were clearly disused with many looking as if they had not been operational for several years.

As this survey was primarily a Phase II assessment, we did not achieve 100% coverage of the intertidal area. However, as can be seen from the hovercraft tracks (on the associated GIS files), coverage of the area was considerable (over 500km traversed) which resulted in many outfalls, areas of fishing activity and debris (such as wrecks) being identified. Since the focus of the survey was intertidal sediments, it is likely that some inputs on the rockier areas of the shoreline may have been missed.

Sewers and Outfalls

Since the previous hovercraft surveys[2][3] which were carried out from 1996-2004, there has been a considerable reduction in the number of operational industrial and Sewage Treatment Works (STW) outputs into the Severn Estuary. There remain a large number of land drains in addition to these outfalls. Larger drains which exited via a pipe were more likely to be noted than those which discharge at the high water mark as these will appear like gullies to the survey staff when on the mudflat. The positions and the current status/use of each of the outfalls identified (where known) are shown in Table 34 and their position in Figure 23.

Table 33. Positions and use of outfalls identified in the Severn Estuary

Waypoint No.	Co-ordinates (OSGB)		Comments
	Easting	Northing	
1	321561.6	175644.8	Pipeline on Orchard ledges, unknown use
2	322062.5	176137.8	Pipeline on Orchard ledges, unknown use
3	323379.2	177475.2	Pipeline NE of Rhymney river, disused
4	325678.8	178238.6	Large broken pipeline on Peterson Fields, disused
5	329286.1	180739.6	Pipeline west of river Usk, unknown use STW?
6	334419.2	182087.6	Pipeline on the Usk patch, looks operational unknown use
7	339737.9	182755.9	Old Llanwern Steelworks outfall pipe, disused since 2009
8	340998.4	183134.7	Large land drain at Redwick
9	343772.4	184579.9	STW outfall
10	348077.5	186821.3	Operational STW outfall
11	350142.6	187066.7	Sudbrook mill outfall, disused since 2006
12	350885.2	187473.6	Large freshwater outfall from the Severn Tunnel
13	365773.7	199781.9	Berkley Power Station (closed) outfall and lagoon
14	359401.9	195386.7	Oldbury Power station outfall and lagoon
15	353435.8	184527.0	Severnside outfall, unknown origin but now disused
16	352951.5	183860.0	AstraZeneca and Terra Outfall (Terra outfall no longer used)
17	351924.5	180709.7	Main Avonmouth sewer (now treated)
18	340125.1	171766.5	STW outfall
19	328320.4	156875.4	Huntspill STW outfall

It can be seen from Figure 23 that the majority of the outfalls identified are on the Welsh side of the estuary below the bridges. Although the majority of these are STW outfalls, some were industrial and several were evidently non-operational (Plate 10). It is known that two of the major industrial inputs that were present during the previous surveys (Llanwern Steelworks and Sudbrook Paper Mill outfalls) are no longer operating

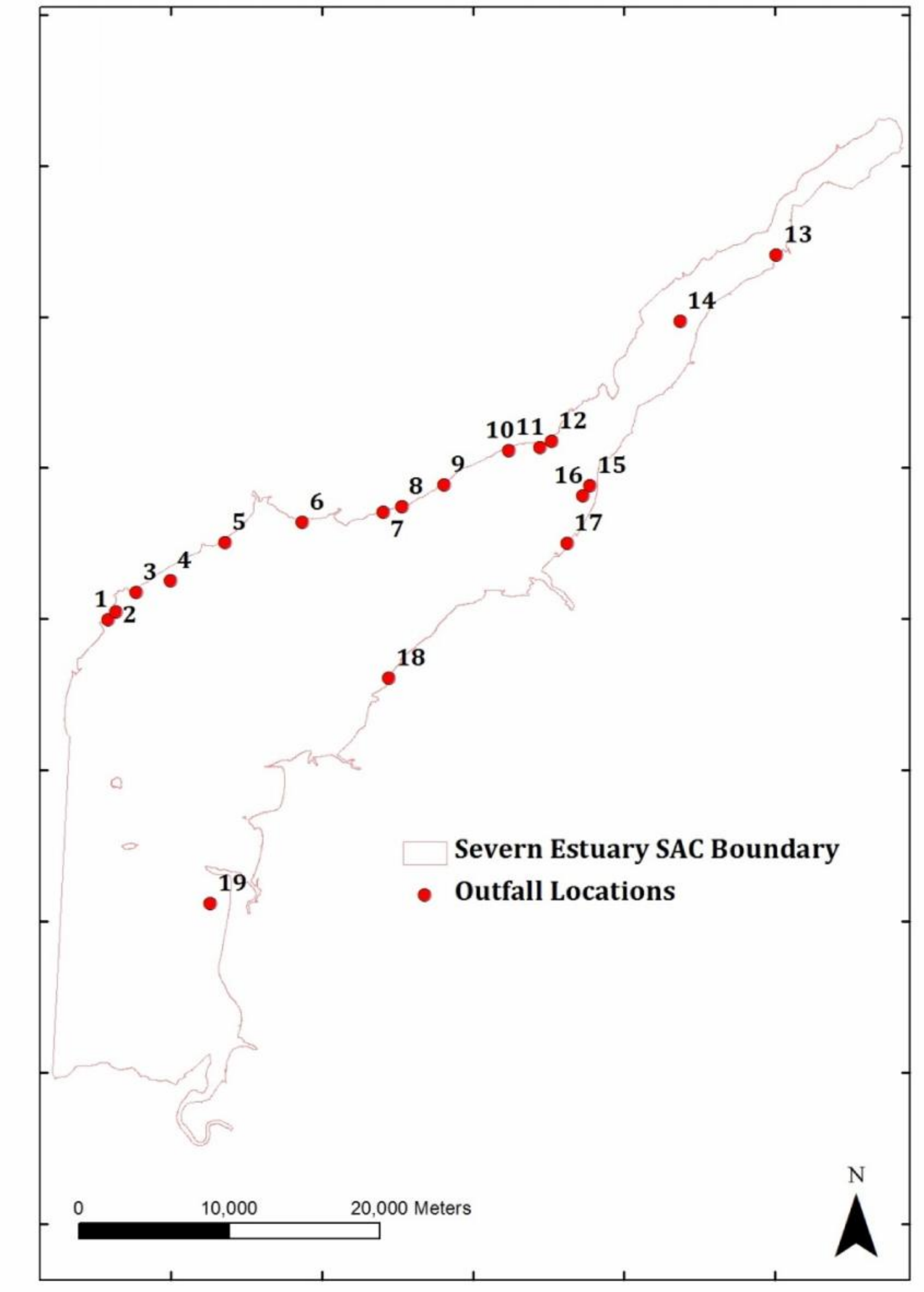

Figure 27. Map of outfall locations in the Severn Estuary SAC and SPA

Plate 10. A large disused outfall on the Peterson Flats between Newport and Carfdiff

Probably the two largest inputs into the Severn that were identified are the STW outfall at Avonmouth (waypoint 17) and the freshwater that is pumped from the Severn tunnel prior to being discharged at Sudbrook Point (waypoint 12). Although the outfall from the tunnel will be unchanged, the STW outfall at Avonmouth has been considerably improved by much better treatment since the late 1990's. Many of the other outfalls noted were also seen in previous surveys and although it is hard to definitively establish which are operational and which are not, it seems probable that, at worst, the number of these that are still in use remains unchanged. It is likely that some have stopped being used since the previous surveys. With respect to point source inputs, it is therefore considered that the estuary has improved since 2004.

Fishing Activity

It appears that the fishing effort using static intertidal nets attached to stakes has decreased since 2004. This is based on the observations of the hovercraft pilot (all hovercrafting for the EMU and CCW surveys was carried out by the same person who piloted the hovercraft for the vast majority of the 2012 survey) rather than any empirical data as this was not a primary focus of the previous surveys.

Very few nets were observed with the exception of an area at Hinkley Point, and also on the mudflats between Newport and Cardiff. In addition to these, there were many areas that looked as if they had been used for fish netting in the past (also particularly evident near Cardiff see Plate 11), but looked to be in disrepair. There were a few lines of posts (at Goldcliff, upstream of the Bridges SW of Lydney and at Frampton Sands/the Noose area) that did however look in reasonable repair and may still be in use. Since the survey was carried out later in the year than the surveys by EMU and CCW, it is not possible to make any definite conclusions about the level of fishing activity in 2012 compared to 2004, but it is tentatively suggested, based on the reduction of observed nets in use, that the fishing effort has declined. No other form of fishing other than angling was observed during this survey. No bait digging was observed at any point during the survey.

Plate 11. Net stakes (predominantly not in use) on the mudflats near Cardiff

Litter and Wreckage

Litter was encountered sporadically during the course of the survey, and was highest close to the coastal towns. However, the amount of litter observed was generally quite low (this may be due to the time of year and the absence of holidaymakers in the resorts) with the notable exception being the mudflats between Newport and Cardiff. The level of litter in some parts of these mudflats was very high and in the lower part of the Usk, the bottom was almost carpeted in litter and debris (including a car). It is not known if this level is higher than that observed in the past.

The Severn Estuary poses a significant hazard to navigation due to a combination of extremely large tides and shallow water. For this reason there are quite a number of old shipwrecks that can be seen intertidally. Some of these wrecks are relatively small, some wooden and some large steel wrecks. Of particular note are two wrecks on the Langford Grounds at Clevedon (Plate 12) as well as two wrecks which collided with each other prior to hitting the old Severn rail crossing (which was later demolished, the footings of which are still visible). These vessels later exploded prior to sinking nearby. Whether the wreckage is considered a negative factor probably depends on your point of view, as they are of considerable interest to those people with an historical bent. In any event, all the wrecks observed were old (probably at least 40 years) and are colonised to a varying degree by fauna and flora.

Plate 12. Two large steel shipwrecks taken from the Langford Grounds.

4.1.3 Preliminary Condition Assessment

Based on the temporal comparisons described above in section 4.1.1, a preliminary condition of the attributes has been made where a suitable baseline exists to make recommendations possible.

Table 34. Condition Recommendation of attributes that, subject to natural variation, define the condition of the sandflat and mudflat features of the Severn Estuary SAC

SAC Attribute	Target	Condition Recommendation
Extent and variety of the mudflat and sandflat communities comprising each sub-feature	No decrease in the extent or range of types of intertidal mudflat and sandflat communities from an established baseline, subject to natural processes.	Some changes in these attributes have been observed (i.e. apparent replacement of biotopes characterised by the presence of *Hediste diversicolor* by those characterised by *Nephtys* spp. in the lower estuary, loss of LS.LMu.Mu.HedOl from the mouths of the River Parrett and Avon, and loss of *Arenicola marina* (and therefore the LSa.MuSa.MacAre biotope) from the Welsh Grounds.
Distribution of mudflat and sandflat communities	Macro scale distribution of communities should not deviate significantly from an established baseline, subject to natural processes.	It cannot be determined whether the changes observed are as a consequence of different survey methods employed between studies or as a result of natural estuarine processes (or a combination of both). However, given that anthropogenic activities appear to have reduced in the Severn estuary, it is unlikely that the changes are a result of negative human pressures, but until water quality data over recent years has been reviewed then the condition of these attributes must be assessed as **unknown** [Δ].
Community composition	No decline in community quality due to changes in species composition or loss of typical species from an established baseline, subject to natural processes.	Changes in the species present within areas of the estuary have been observed (i.e. apparent replacement of biotopes characterised by the presence of *Hediste diversicolor* by those characterised by *Nephtys* spp. in the lower estuary, and loss of *Arenicola marina* from the Welsh Grounds). It is not known whether these changes are long term (indicating long term changes in physical variables within the estuary) or short term and therefore part of the natural process of the estuary. Lack of previous quantitative data makes a direct comparison of species composition more problematic. Furthermore, the measure of quality of the communities (e.g. richness and diversity) was not within the remit of previous studies and therefore no baseline with which to compare current results is available. Consequently change in the quality of communities cannot be determined.

		The condition of this attribute is therefore **unknown** [Δ].

Table 35 Continued. Condition Recommendation of attributes that, subject to natural variation, define the condition of the sandflat and mudflat features of the Severn Estuary SAC

SAC Attribute	Target	Condition Recommendation
Sediment character	PSA - Mean PSA parameters should not deviate significantly from an established baseline. REDOX - Mean black layer depth should not deviate significantly from an established baseline.	No suitable baseline exists with which to compare the current results. The condition of this attribute is therefore **unknown** [Δ].

[Δ] This study will provide a comprehensive baseline for condition assessment of this attribute

Table 36. Condition Recommendation of attributes that, subject to natural variation, define the condition of the sandflat and mudflat features of the Severn Estuary SPA

SPA Attribute	Target	Condition Recommendation
Prey availability (biomass and abundance of specified prey species)	Presence and abundance of suitable prey species should not deviate significantly from an established baseline	No suitable baseline exists with which to compare the current results. The condition of this attribute is therefore **unknown** [Δ].

[Δ] This study will provide a comprehensive baseline for condition assessment of this attribute

4.2 Evaluation of Methods

The methods adopted within this study have enabled the aims and objectives set out by Natural England (See Sections 1.1 and 1.3) to be met as far as practicably possible. Since previous relevant surveys within the study area have been limited to Phase I methods, it has been impossible to draw definitive conclusions with regard to the condition of attributes. The output from this study will however provide a comprehensive baseline from which a change in the condition of the attributes can be measured within any future condition assessments.

The cumulative number of species has been plotted against the number of stations sampled in each biotope (Figure 27). Generally a good level of sample replication was achieved within the biotopes of the Severn Estuary SAC and SPA, and the number of replicates was largely proportional and representative of the total area of each biotope. An exception was within the LSa.MuSa.MacAre biotope where the number of species does not reach a plateau as the number of replicates increases. This is due to the low number of replicates within the biotope which are geographically distributed over a large area resulting in two 'sub-communities' within the biotope (see the MDS plot of the LSa.MuSa.MacAre communities in Figure 19, Section 3.3.8). The number of species within mobile sand biotopes (LSa.MoSa and LSa.MoSa.BarSa) also fail to plateau, but this is a result of the inherent nature of the biotopes which have a low species diversity and low abundance of species, rather than a case of inadequate replication.

The LS.LSa.FiSa.PoNcir and LS.LMuUest.Hed.Str biotopes were sampled in the course of other biotopes being targeted and as a result only two sample stations represent each of these. To make statistical comparisons of the communities within these biotopes more robust in future, a minimum of three (preferably five) sample stations could be assigned to each. However, given the very limited extent of both of these biotopes this is not essential.

A degree of infaunal community variation both between stations within a biotope, and between the stations and the communities described as characteristic for the biotope was observed for all biotopes. This highlights some of the inherent weaknesses of biotope mapping. The variations are most likely to be attributable to the high degree of natural fluctuations that are found at both a local and regional scale in estuarine environments[12] (e.g. salinity, wave exposure, carbon matter, nutrient input and pollution). The Severn Estuary in particular is unique in its geographic scale and extraordinary tidal energy. Variations are also likely to be attributable to the presence of transitional areas between biotopes and seasonal influences on the communities present.

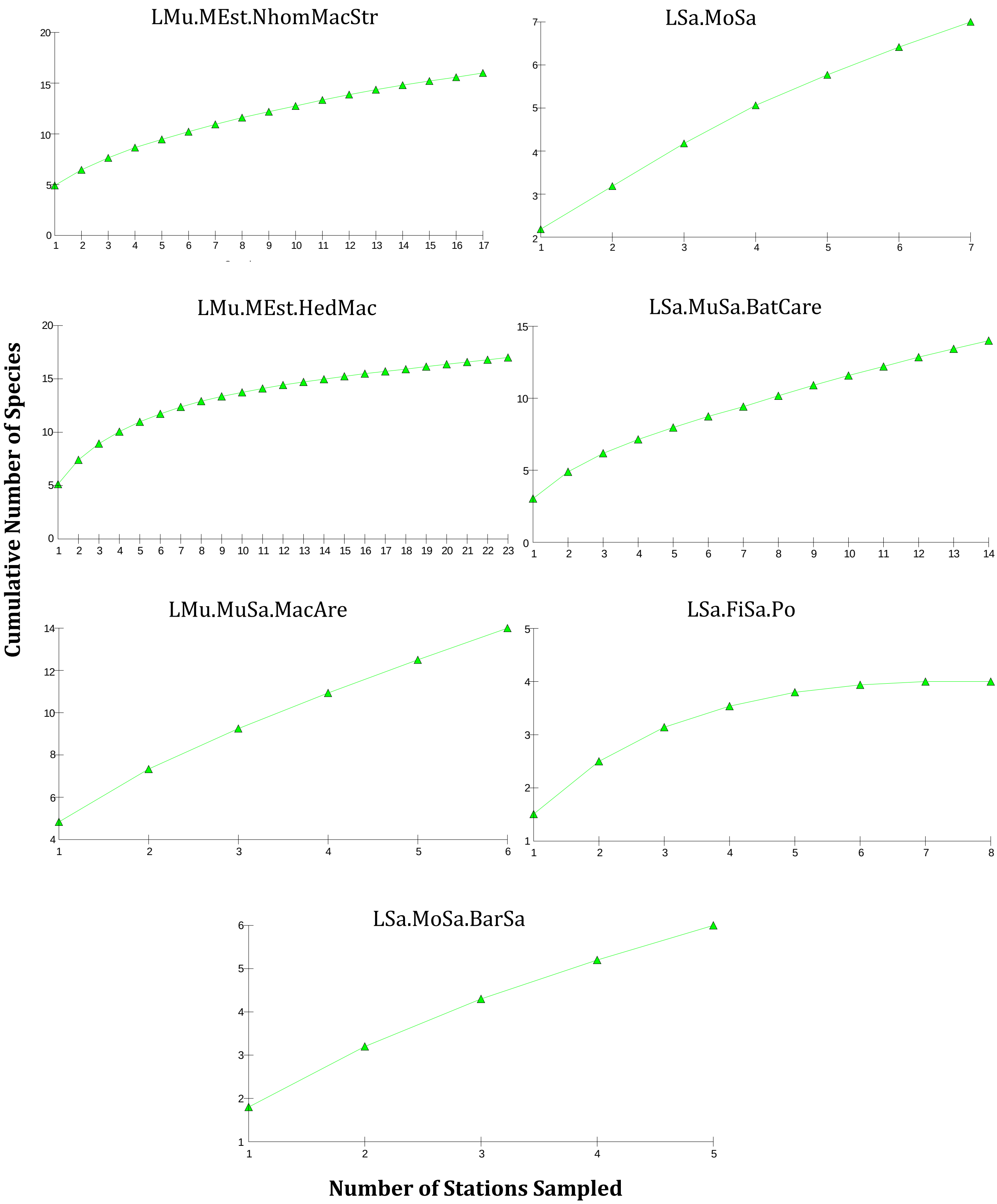

Figure 28. Cumulative number of species plotted against number of stations sampled within each biotope in the Severn Estuary SAC

Adequacy of Replication

The level of replication at each sampling station has been examined using Bray-Curtis similarity analysis for the purpose of assessing the adequacy of replication at stations. The average Bray-

Curtis value within each biotope has subsequently been calculated (together with the minimum and maximum Bray-Curtis values) and is presented in Table 37.

The average similarity observed between replicates was generally found to be greatest in the littoral mud biotopes, though there are exceptions. The average similarity within LS.LMuUest.Hed.Str stations was lowered by station 28 where replicates were just 10% similar (the low similarity at station 28 is an effect of very low numbers of just seven species, most of which were present in just two of the five replicates). Conversely, the average similarity within the LSa.MoSa.BarSa biotope was raised as a result of the sparse but consistent communities present (more specifically, the abundance of *Bathyporeia pilosa* accounted for 97% of the similarity between stations).

A good level of replication at each station was generally achieved within the littoral mud biotopes (with the exception of LS.LMuUest.Hed.Str as explained above); given this and the higher average similarities within the biotope it is suggested that the number of replicates within littoral mud communities could be lowered from five to three. However, within the littoral sand, fine sand and muddy sand biotopes the level of replication at each station should probably be maintained at five per station. The reason for this is that the sparse nature of the communities within these higher energy biotopes increases the risk of inadequate sampling. This assumption is supported by the lower average Bray-Curtis similarities between replicates within these biotopes.

By reducing the number of replicates within the littoral mud biotopes a total of 82 replicates will be made available. The surplus sampling effort should be used to increase the number of stations within biotopes (particularly those with less than five stations previously) as this will enable more statistically robust and representative sampling and analysis of biotope communities in the future, yet within the same sampling budget.

A number of cumulative species plots have been created from the replicate data at stations, the results of which were variable. The plots did seem to indicate that the additional data achieved by sampling an extra two replicates might not necessarily warrant the extra sampling effort, particularly within the muddy biotopes. Taken together with the data from the Bray-Curtis similarity matrices, this suggests that more statistical rigour might therefore be achieved by increasing the number of stations (true replicates) and reducing the number of station replicates (pseudo-replicates).

Table 37. Average, minimum and maximum Bray-Curtis similarity values between replicates at stations within each biotope.

Biotope	Sediment Type	Bray-Curtis Similarity (%)	
LMu.MEst.HedMac	Mud	Average	65
		Max	85
		Min	15
LMu.UEst.Hed.Str		Average	43
		Max	75
		Min	10
LMu.MEst.NhomMacStr		Average	74
		Max	87
		Min	47
LSa.MuSa.MacAre	Muddy Sand	Average	38
		Max	75
		Min	13
LSa.MuSa.BatCare		Average	56
		Max	89
		Min	0
LSa.FiSa.PoNcir	Fine sand	Average	49
		Max	55
		Min	41
LSa.FiSa.Po		Average	41
		Max	76
		Min	0
LSa.MoSa.BarSa	Sand	Average	23
		Max	55
		Min	0
LSa.MoSa		Average	64
		Max	95
		Min	22

4.3 Recommendations for Future Condition Assessment

In order to carry out future condition assessments the results presented here should be used as a baseline from which to compare the attributes and targets outlined in Tables 1 and 2 in Section 1.1.

Given the large geographical spread of the biotopes within the SAC, and the variation that has been observed between stations within the same biotope that are distant from each other, it is considered that it is essential to re-visit the same sample locations (+/- 10m). Not only will this avoid the potential for an erroneous indication of temporal change as a function of different sampling locations, but this will also, over time, enable any directional changes of condition status to be identified.

The number of replicates within the LSa.MuSa.MacAre biotope should be increased slightly to at least 10 to ensure that the communities are adequately represented in future. If future condition assessments are required to be carried out within the same sampling budget, then the additional replicates could be taken from the LMu.Mest.HedMac biotope without significantly compromising the representativeness of the data within that biotope. However, in view of the importance of LMu.MEst.HedMac for birds and given its wide distribution through the whole estuary it may be advisable to maintain the existing replication in this biotope.

Natural England should consider increasing the number of stations (true replicates) and reducing the number of station replicates (pseudo-replicates), so that more statistical rigour may be achieved.

Future sampling for the purposes of condition assessment should be carried out at the same time of year as this study (i.e. October to November). Although the weather conditions during these months are less than ideal for surveying, this is a necessary measure, as it will eliminate the introduction of variability in faunal communities as a result of seasonal fluctuations. It also reduces the influence of variable juvenile recruitment on the results. Such variability may otherwise falsely indicate temporal changes in communities and reduce the robustness of the data for subsequent condition assessment.

It is recommended that redox is determined using a redox meter rather than using subjective visual inspection methods. This will provide objective data from which more robust conclusions can be drawn.

As in the current study, the biotopes present should be determined in accordance with the most up-to-date Marine Habitat Classification for Britain and Ireland (currently Vs 04.05). The distribution, extent and variety of biotopes will be most efficiently compared using GIS software to map and measure the attributes area. Biomass analysis should accompany all faunal data for each biotope sampled.

The community composition should be described relative to the Marine Habitat Classification, and particular emphasis should be placed on macrofaunal community structures using a combination of univariate and multivariate statistics, as these measures are most likely to show any temporal changes caused by natural or anthropogenic factors. By plotting community data from this survey alongside future survey data, temporal trends in community assemblages should become apparent. Any directional changes in these plots could indicate anthropogenic stressors, particularly if the changes are not reflected at other stations within a biotope.

By implementing these recommendations, results from future studies would provide a sound foundation from which to base scientifically robust conclusions regarding any temporal changes that may be observed in the Severn Estuary EMS. However, the dynamic nature of physical processes within estuarine systems and particularly within an extensive high energy system such as the Severn Estuary EMS, means that the gross distribution of habitats and species can be expected to change over time naturally at least to some extent. Therefore, it will be necessary to discern whether any changes observed (e.g. loss in extent of a particular biotope) is attributable to anthropogenic factors as opposed to natural factors. This distinction is necessary to determine the condition of the SAC and SPA given that attribute targets stipulate changes 'subject to natural processes'. If it is not possible to derive the information to make such distinctions from the information available, then further work outside the remit if the initial condition assessment may be necessary.

GLOSSARY

CCW	Countryside Council for Wales
Abundance	Total number of all animals (individuals) in a sample
Benthic	"Bottom dwelling", pertaining to the sea bed or estuary bed
Bray Curtis similarity	Statistic that compares fauna samples in terms of abundance and number of taxa
Community	A collection of fauna (or flora) cohabiting in and characteristic of an area of the environment
Community analysis	Statistical technique used to identify areas with a similar biological community
Diversity	The range of animals (taxa) in a sample
Infauna	Animals that live within the sediment
MDS	Multi-Dimensional Scaling, a statistical manipulation used to identify groups of distinct fauna (communities).
Multivariate	Statistics which can be applied to a complete taxa abundance data matrix without any loss of information i.e. not requiring reduction of the data to a single number or index
Margalef's species richness	A measure of the variety of species present.
Pielou's evenness	A measure of the relative abundance of each species
Shannon Wiener diversity index	An index (single number) of fauna diversity, increases with fauna diversity
Simpson's diversity index	An index of fauna diversity, increases with fauna diversity
STW	Sewage Treatment Works
Taxon	A grouping of the fauna, may be a species or, if different species are indistinguishable, it may be based on a higher taxonomic group such as the genus, family or phylum
Univariate	Statistics that describe the fauna in terms of a single number
Wentworth scale	Recognised 12 band scale of sediment particle size
LMu.MEst.HedMac	*Hediste diversicolor* and *Macoma balthica* in littoral sandy mud
LSa.MoSa.BarSa	Barren littoral coarse sand
LSa.MoSa	Barren or amphipod dominated mobile sand shores
LSa.MuSa.BatCare	*Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand
LMu.MEst.NhomMacStr	*Nephtys hombergii*, *Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud

LSa.FiSa.Po	Polychaetes in littoral fine sand
LSa.FiSa.PoNcir	*Nephtys cirrosa* dominated littoral fine sand
LSa.MuSa.MacAre	*Macoma balthica* and *Arenicola marina* in littoral muddy sand
LS.LMu.UEst.Hed.Str	*Hediste diversicolor Streblospio shrubsolii* in littoral sandy mud
LS.LBR.Sab.Salv	*Sabellaria alveolata* reefs on sand-abraded eulittoral rock
LS.LSa.MoSa.AmSco	*Eurydice pulchra* in littoral mobile sand
LS.LSa.MoSa.AmSco.Eur	*Scolelepis spp.* in littoral mobile sand

APPENDIX 1

Coordinates of sampled stations including assigned biotope

Station	East	North	Biotope
1	325382	147086	LMu.MEst.HedMac
2	326624	148492	LMu.MEst.HedMac
3	327171	146939	LMu.MEst.HedMac
4	326761	150992	LSa.LSa.LSa.FiSa.PoNcir
5	327902	152554	LSa.LSa.LSa.FiSa.PoNcir
6	327740	153176	LMu.Mest.NhomMacStr
7	328525	155368	LMu.Mest.NhomMacStr
8	328926	157300	LMu.Mest.NhomMacStr
9	329976	150057	LSa.MuSa.MacAre
10	328921	151744	LSa.MuSa.BatCare
11	329264	156050	LSa.MuSa.MacAre
12	330608	159846	LMu.Mest.NhomMacStr
13	330696	160516	LMu.Mest.NhomMacStr
14	331247	160760	LMu.Mest.NhomMacStr
15	331938	163546	LMu.Mest.NhomMacStr
16	332066	165187	LMu.Mest.NhomMacStr
17	332662	164011	LMu.MEst.HedMac
18	335799	167722	LMu.MEst.HedMac
19	336831	168614	LMu.Mest.NhomMacStr
20	337211	167722	LMu.Mest.NhomMacStr
21	338168	169229	LMu.Mest.NhomMacStr
22	322952	176481	LMu.Mest.NhomMacStr
23	324630	177731	LMu.MEst.HedMac
24	326810	178850	LMu.Mest.NhomMacStr
25	328934	180549	LMu.MEst.HedMac
26	331582	181164	LMu.MEst.HedMac
27	335298	181973	LMu.MEst.HedMac
28	339542	182019	LMu.UEst.Hed.Str
29	343208	182393	LSa.LSa.FiSa.Po
30	343935	183207	LSa.LSa.FiSa.Po
31	345466	184018	LSa.LSa.FiSa.Po
32	346879	184338	LSa.LSa.FiSa.Po
33	348730	183687	LSa.LSa.FiSa.Po
34	345029	181747	LSa.LSa.LSa.MoSa.BarSa
35	345441	183146	LSa.LSa.FiSa.Po
36	347702	182913	LSa.LSa.LSa.MoSa.BarSa
37	333010	176335	LSa.LSa.FiSa.Po
38	337938	177274	LSa.LSa.LSa.MoSa.BarSa
39	335892	178072	LSa.LSa.FiSa.Po
40	339998	179154	LSa.LSa.LSa.MoSa.BarSa
41	341555	179454	LSa.MuSa.BatCare
42	345975	185349	LMu.MEst.HedMac
43	348502	186607	LMu.MEst.HedMac
44	352930	189686	LMu.MEst.HedMac
45	354352	191353	LMu.MEst.HedMac
46	351755	180750	LMu.MEst.HedMac
47	352915	182554	LMu.MEst.HedMac
48	355447	187924	LMu.MEst.HedMac
49	358117	191034	LMu.MEst.HedMac
50	357383	191997	LMu.MEst.HedMac
51	358320	193309	LSa.MuSa.BatCare
52	358126	194547	LSa.MuSa.MacAre
53	355957	193528	LMu.MEst.HedMac
54	358510	196883	LSa.MuSa.MacAre
55	360005	196909	LSa.MuSa.MacAre
56	360965	198546	LSa.MuSa.BatCare
57	362614	199114	LSa.MuSa.MacAre
58	364069	200179	LSa.LSa.MoSa
59	364563	199722	LSa.LSa.MoSa
60	366086	202878	LSa.LSa.MoSa
61	367261	203484	LSa.LSa.MoSa
62	368400	204579	LSa.MuSa.BatCare
63	369348	205181	LSa.LSa.MoSa
64	369348	205181	LSa.MuSa.BatCare
65	370828	205603	LSa.MuSa.BatCare
66	370765	206382	LSa.LSa.MoSa
67	373704	207896	LSa.LSa.MoSa
68	329311	146676	LMu.Mest.NhomMacStr
69	328574	146081	LMu.Mest.NhomMacStr
70	327242	144342	LMu.UEst.Hed.Str
71	328248	144753	LMu.Mest.NhomMacStr
72	350926	177645	LMu.MEst.HedMac
73	349965	178578	LMu.MEst.HedMac
74	350487	178304	LMu.MEst.HedMac
75	330265	160789	LMu.Mest.NhomMacStr
76	359598	193366	LMu.MEst.HedMac
77	372726	207787	LSa.MuSa.BatCare
78	371969	206864	LSa.MuSa.BatCare
79	328923	153129	LSa.MuSa.BatCare
80	329614	157592	LSa.MuSa.BatCare
81	331564	160409	LSa.MuSa.BatCare
82	331485	159885	LSa.LSa.LSa.MoSa.BarSa
83	329513	156153	LSa.MuSa.BatCare
84	329574	150871	LSa.MuSa.BatCare

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