Lynher Estuary SSSI Intertidal Biotope Survey 2010

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1. Introduction

1.1 The Lynher Estuary SSSI

The Lynher Estuary is a Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981 (as amended). The Lynher Estuary SSSI forms the most western reaching component of the Tamar-Tavy-Lynher ria (drowned river valley) complex, that separates the counties of Devon and Cornwall. The majority of the total 672.63 Ha of area designated as SSSI is comprised of intertidal habitats (the focus of this study) with a proportion of subtidal and just 42.35 Ha terrestrial. The Lynher Estuary also lies within the Plymouth Sound and Estuaries Special Area of Conservation (SAC) and Tamar Estuaries Complex Special Protection Area (SPA) sites.

The upper part of the Lynher estuary has a very well developed estuarine gradient which has not been modified by the construction of locks or weirs. As a result the Lynher exhibits one of the finest examples of salinity graded communities in the UK, along which transitional marsh communities have developed that range from freshwater fen and willow carr to saltmarsh. Unusually for a ria system the Lynher Estuary encompasses relatively extensive saltmarsh. More commonly for such a system however the estuary also comprises highly productive mud flats. Combined, the saltmarshes and mudflats provide important feeding and roosting grounds for large populations of nationally and internationally important wintering wildfowl and wading birds (hence the designation of the area as a SPA). It is these habitats which are underpinned by the littoral sediments of the estuary, that constitute the intertidal components of the SSSI designated interest features of the Lynher Estuary.

1.2 Reasons for SSSI Notification[1]

A variety of salt marsh vegetation communities exist within the Lynher Estuary. These range from mid-upper marsh and transition fresh-water inundation communities, through lower-mid marsh with Common Saltmarsh-grass *Puccinellia maritima* and Sea-purslane *Halimione portulacoides,* to pioneer stands of Townsend's Cord-grass *Spartina townsendii* and Sea Aster *Aster tripolium* .

Within the most fresh-water influenced communities of the upper estuary small areas of Willow *Salix spp* carr lead on to wetland areas that sustain Fool's Water-cress *Apium nodiflorum*, Marsh Marigold *Caltha palustris*, Common Reed *Phragmites australis* and Bulrush *Typha latifolia*. The transition to saline influenced marshes then begins at which point the marshes become dominated by species such as the Creeping Bent *Argostis stolonifera,* with patches of Sea Aster and Sea Club-rush. However, important populations of the nationally rare Bulbous Foxtail *Alopecuru bulbosus* thrive here.

As salinity increases further down the estuary, the marshes become progressively more species rich. The largest and most diverse stands which exhibit a range of structural characteristics are the areas of mid-upper marsh which are found around Erth Island. Within these stands Common Saltmarsh-grasses including Sea Club-rush *Scirpus maritimus*, Saltmarsh Rush *Juncus gerardi* and English Scurvygrass *Cochlearia anglica* are frequent with more scattered distributions of Sea-milkwort *Glaux maritima*, Sea Plantain *Plantago matitima*, Sea Arrowgrass *Triglochin maritima* and Long-bracted Sedge *Carex extensa*.

The most elevated marshes are dominated by Sea rush *Juncus maritimus* and Red Fescue *Festuca rubra*; whilst Thrift *Armeria maritima* flourishes in old salt-pans. Of particular note is the presence of the locally distributed Parsley Water-dropwort *Oenanthe lachenalii*. Sea Couch *Elymus pycnanthus* is also found to form a distinct drift line and fresh water inlets support Yellow Iris *Iris pseudacorus* and Hemlock Waterdropwort *Oenanthe crocata*.

The entire Tamar-Tavy-Lynher complex is of national importance for its wintering populations of around 6,000 wildfowl and 10,000 waders. The saltmarsh system of the Lynher specifically however, provides important roosting areas for up to 5,000 Wigeon *Anas Penelope*, with Teal *Anas crecca*, Mallard *A. platyrhynchos*, Shelduck *Tadorna tadorna* and Pintail *Anas acuta* also occurring in high numbers. The soft mud flats attract 3–4% (up to 150 individuals) of the British wintering population a of Black-tailed Godwit *Limosa* limosa, a population which is considered to be nationally important. Other waders which feed on the mud flats include up to 5,000 Dunlin *Calidris alpina*, 800 Curlews *Numenius arquata*, 500 Oystercatchers *Haematopus ostralegus* and 200 Redshank *Tringa totanus*. Turnstone *Arcenaris interpres*, Grey Plover *Pluvialis squatarola*, Ringed Plover *Charadrius hiaticula* and Spotted Redshank *Tringa erythropus* also frequent the site. In addition there is a large gull roost of up to 4,000 Black-headed Gulls *Larus ridibundus* and the Mute Swan *Cygnus olor*, Grey Heron *Ardea cinerea*, Shelduck and Mallard are all known to breed within the Lynher.

1.3 Condition Monitoring of the Lynher Estuary SSSI

Site Condition Monitoring is (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 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 SSSIs, and ensure that a consistent approach is taken when monitoring such sites. Within the Lynher Estuary the intertidal special interest features which include the saltmarsh and mud flats fall under the Common Standards Monitoring guidance produced for littoral sediment habitats[2].

For the purposes of monitoring, each feature is represented by a series of attributes, which are measurable indicators of the condition of the feature at the site (see Table 1). For each attribute (e.g. extent of habitat or presence of representative/notable biotopes) a target is set which is considered to correspond to the favourable condition of the feature.

Table 1. Generic attributes that should be used to define the condition of littoral sediment features in site condition monitoring[3].

Attribute	Generic Target
Extent	No change in extent of littoral sediment
Biotope composition	Maintenance of the variety of biotopes
Sediment type	No change in sediment composition
Distribution of Biotopes	Maintenance if the distribution of biotopes
Extent of sub-feature	No change in extent of biotope
Species composition of specific biotope	No change in species composition or loss of notable species
Species population measures	E.g. Maintenance of presence or abundance of named positive indicator species.

Topography	No change in topography of littoral sediment
Carbon content	No increase in carbon content

Conservation objectives and site specific definitions of favourable condition of saltmarsh and mud flats within the Lynher Estuary SSSI have been developed[4].

1.4 Aims and Objectives

The purpose of the thus study is to:

- Establish a physical and biological baseline data set (where one does not exist) that will then facilitate an assessment of the favourable condition status of the littoral sediment habitats of the Lynher Estuary SSSI (therefore fulfilling Natural England's monitoring requirements for the SSSI for condition assessment).

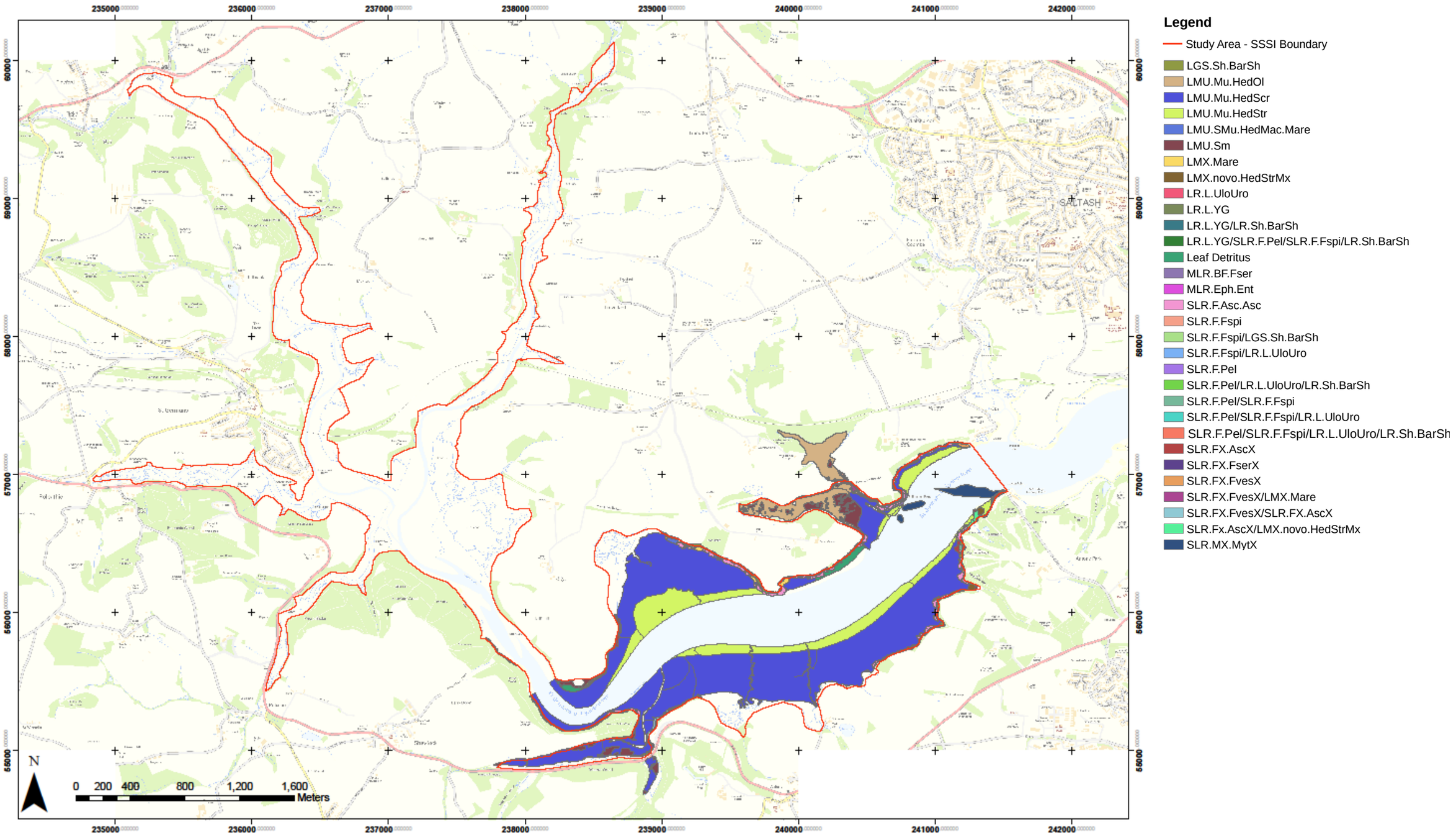
- Identify species and biotopes that are representative and/or notable within the Lynher Estuary.

1.5 Existing Biotope Information

The eastern end of the Lynher Estuary SSSI was the subject of a Phase I biotope survey that was carried out on behalf of Natural England in 2001[5]. This survey however focused on the supralittoral and littoral rock biotopes rather than the mudflats, and was not progressed to the Phase II stage. Therefore although the survey provided a comprehensive assessment of the supralittoral and littoral rock biotopes, the mud flat biotopes were less rigorously assessed; the lack of a hovercraft during survey meant that biotopes were observed principally from the shore.

The 2001 survey identified Hediste characterised biotopes to be dominant; on the lowest portions of the mudflats Hediste and the spionid *Streblospio shrubsolii* were observed, whilst on the mid and upper shores Hediste and the bivalve mollusc *Scrobicularia plana* occurred. Within the most upper reaches of Wivelscombe Creek on the northern shore of the estuary *Hediste diversicolor* and oligochaetes were reported.

Figure 1. Lynher 2001 survey biotope map



1.6 Anthropogenic Influences within the Lynher SSSI

Land use within the Lynher catchment is predominantly agricultural. 75% of the land is populated by dairy farms with a small number of beef, sheep and arable practices producing potatoes and maize.

There are a number of continuous and intermittent sewage discharges into the Lynher Estuary, including those from Landrake, St Germans, Sheviock and Anthony Sewage Treatment Works (STWs)[6]. An investigation into the impact of sewage discharges in the lower reaches of the Lynher is being funded within PR09. Driven by the Shellfish Waters Directive, Southwest Water is expected to complete the investigation by March 2012. The focus of the investigation will be primarily on microbiological parameters within the Lynher shellfish water, but it is also likely to provide a more general indication of the influence that these discharges have on the estuary as a whole.

Studies have shown that the Lynher Estuary has a tendency towards being eutrophic and is considered moderately vulnerable to nutrient enrichment[7]. Excess nutrient loading is thought to be primarily derived from diffuse agricultural pollution and to a lesser degree from sewage infrastructure; although the percentage contribution from each source changes with the seasons[9].

Biological disturbance via bait digging and peeler crab collection result in the selective extraction of species from the intertidal area. The extent of such impacts are unclear, but the placing of crab shelters on intertidal sediments introduces hard substrata for colonisation by rocky shore species, and may change sediment characteristics by affecting water and oxygen exchange and sedimentation rates[10]. The vulnerability of Plymouth Sound and its associated estuaries to peeler crab collection has been highlighted by previous studies[11,12].

Historical mining activities (particularly in the headwaters) have resulted in historical contamination of the Lynher waters and sediments to varying degrees by metalliferous compounds such as zinc and copper [8,13].

The total daily abstraction volume of the licences at full uptake is approximately 140,000 m^3/day. Of this volume, all but 10,000 m^3/day is returned to the system, representing an overall impact of around 2.5% of the naturalised flow at the saline limit. This level of impact is not thought to adversely affect the integrity of the Lynher's designations under the Habitats Directive[14].

2. Methods

A previous biotope survey within the Lynher Estuary SSSI was limited to the eastern end of the designated area; therefore in order to deliver the objectives set out by Natural England in the most efficient and cost effective manner, a two phased survey approach was implemented throughout the study area. Such an approach enabled more effective targeting of effort on intertidal interest features, species and biotopes that are representative and/or notable within the Lynher Estuary SSSI.

2.1 Phase I

The aim of the Phase I survey was to determine the distribution and extent of intertidal biotopes, interest features, and species that are representative and/or notable within the Lynher Estuary SSSI. This was achieved by examining geo-referenced aerial photography and subsequently ground-truthing defined habitats via field survey in order to establish the biotopes present (as per Procedural Guidelines 1-1 Inter-tidal resource mapping using aerial photographs in the Marine Monitoring Handbook). The littoral sediment habitats and communities present within the SSSI were determined using the JNCC Marine Habitat Classification for Britain and Ireland Version 04.05. A digitised map of the intertidal zone was then produced showing the spatial extent of the main biotopes. Target Notes were used to indicate the presence of noteworthy features and biotopes that existed in only very limited areas.

The Phase I component of the survey was carried out during the spring tides that occurred during the 13th and 14th of August 2010 (LW 0.6m and 0.8m above chart datum respectively).

2.1.1 Aerial Photographs

The aerial photographs which formed the basis of the intertidal biotope mapping were those that were collected during a 2007 survey carried out by the Channel Coastal Observatory[15]. The photographs were printed onto waterproof paper at an appropriate resolution to distinguish the features on the ground (The precise resolution varied depending on the complexity of the features in different areas of the estuary). Photographs covering the entire extent of the SSSI were then incorporated into the project field book and were annotated in the field. Specific attention was paid to determining whether the extent of the saltmarsh matched that within the photographs.

2.1.2 Use of hovercraft

For reasons of efficiency, quality and safety, all fieldwork was conducted from Ecospan Environmental Ltd's 4 man hovercraft.

The hovercraft can safely and efficiently cover large areas of mudflat and access areas in which safety considerations would have otherwise limited or prohibited access. When compared to point mapping and interpolating between points as would have been necessarily be the case if the same survey was undertaken on foot or by boat, much more comprehensive and accurate biotope mapping of the intertidal was possible. Therefore as well as significantly improving survey efficiency,

it is considered that that resulting quantity and quality of information gathered was superior to what would have otherwise been achievable.

A further advantage of using a hovercraft is that given that the craft rides upon a cushion of air, disturbance to the littoral sediment habitats being surveyed is minimal; tracks are not visible after one tide. In contrast, survey teams accessing littoral habitats from the shore may cause disturbance which is apparent following multiple tides.

2.1.3 Target Stations

Pre-determined target stations were established at approximately 500m intervals throughout the study area. These stations were both added to the aerial photographs and loaded into a Garmin GPS 76 differential GPS which was used for all position fixing during the course of the survey.

The survey technique was to fly from one point to another via hovercraft. Where changes in biotope were observed, the perceived boundaries of the changes were marked on the aerial map. An additional target position representative of the new biotope was then added to the survey plan and attributes present (species, topography, redox and sediment type) recorded.

The positions of all target locations were recorded using GPS. The hovercraft speed was kept to ensure that changes were observed. In addition, where large expanses of mudflats were exposed, a 'zig zag' transect route between target positions was taken in order to maximise the area covered.

2.1.4 Topography, Reduction-Oxidisation (Redox) Profile & Sediment Type

The topography at each target location was determined using fixed viewpoint digital photography (Procedural guideline 1-2) as suggested in the Common Standards Monitoring Guidance[3]. The Redox discontinuity layer was determined by visual assessment. The sediment type was also determined visually and described using the Wentworth/Folk scale.

2.1.5 Assignment of Biotopes

Wherever possible, biotopes were assigned in the field by direct observation (i.e. spade sample inspection and species field signs). Where the species present and therefore resulting biotope was not obvious, a 0.01m^2 core of sediment was taken and sieved through a 0.5 mm sieve to enable closer examination and identification of benthic macrofauna present. In order to keep costs to a minimum, these samples were only processed to a level at which enabled the biotope to be determined (using the SACFOR scale and identification of characterising species only) rather than full faunal enumeration and identification. The macrofauna present and the method of observation was recorded at each sample point together with relevant target notes. All information gathered was then added to the digitised map on GIS using the attribute tables for each feature. Photographs of the littoral sediment habitats were also taken at each target location and were also added as a layer on the GIS.

Although the majority of survey effort was directed towards biotope mapping the Lynher Estuary SSSI littoral sediment habitats as required by the tender; the rocky shore biotopes were also identified and recorded *in situ*. However, since this was not a primary aim of the survey, target positions were not allocated to rocky shore habitats and fewer stops were made on these biotopes.

2.1.6 Mapping Saltmarsh Extent

The distribution and extent of saltmarsh in the Lynher Estuary SSSI was determined by cross-referencing the aerial photographs from the 2007 Coastal Observatory survey with observations made in the field. Specific attention was paid to determining whether the extent of the saltmarsh matched that within the photographs. Where there were larger swathes of saltmarsh, the hovercraft was used to fly around the perimeter and tracks were recorded on the DGPS. By then downloading the tracks onto GIS it was possible to determine any changes in the extent of saltmash since 2007. Any notable factors or negative impact indicators (such as signs of disturbance, smothering etc) were also recorded.

2.2 Phase II

In accordance with the relevant guidance (see section 2.2.1), the aim of the Phase II survey was to produce detailed descriptions of the biotopes present within the Lynher Estuary SSSI. These descriptions include floral and faunal species lists and abundance information, as well as detailed sediment character descriptions that include carbon content and sediment granulometry analysis results. The overall objective was to produce a comprehensive digitised map in GIS that both illustrates the distribution and extent of the biotopes identified within the Lynher Estuary SSSI, and outlines the detailed physical and biological data within the attribute layers.

The Phase II survey was undertaken during the springs tides on the 9th and 10th of September 2010 LW 0.6m and 0.5m above chart datum respectively).

2.2.1 Faunal Sampling

The information gathered during the Phase I survey was used to prepare a preliminary biotope map. This map was subsequently used to determine the locations of 30 intertidal cores which were intended to provide a representative sample of the fauna within each of the biotopes present. Adequate replication was also required; therefore the larger the area covered by each biotope, the greater the number of replicates assigned to that biotope.

Having accessed the target core locations via hovercraft, intertidal cores were taken using a standard 0.01 m^2 box corer which was placed to depth of 15 cm. Faunal samples were separated through a 0.5 mm sieve and preserved in a 10% buffered formalin solution containing the vital stain Rose Bengal. The faunal sampling and preservation was carried out in accordance with standard methodologies (ISO 16665:2005)[16] and according to Ecospan Environmental Ltd's standard operating procedures (ES-01, ES-02, ES-07 and ES-08). The benthic macrofauna present in the cores was subsequently identified to species level and enumerated in a laboratory setting and according to the National Marine Biological Analytical Quality Control Scheme guidelines following SOP ES-04.

As in the Phase I, the exact location of each sampling station was recorded using DGPS, and photographs taken of the littoral sediment.

2.2.2 Topography, Reduction-Oxidisation (Redox) Profile & Sediment Type

As in the Phase I survey, the topography at each target location was determined using fixed viewpoint digital photography (Procedural guideline 1-2) as outlined in the Common Standards Monitoring Guidance[3]. Sediment type was again assessed *in-situ* using the Wentworth scale, but in addition, a sediment sample was taken for more detailed and accurate particle size analysis (PSA). PSA was carried out using dry sieving and laser diffraction methods following SOP LAB-25. A second sediment sample was taken at each station for the determination of total carbon by Loss on Ignition (LOI) by a UKAs accredited laboratory.

2.2.3 Univariate and Multivariate Analysis of Faunal Data

Where more than one replicate core was taken within a defined biotope, the 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 Lynher Estuary SSSI in the future.

Two statistical methods were used to interrogate the data, a uni-variate approach using species diversity statistics and a multi-variate community analysis approach. The number of taxa per sample and number of individuals per sample were counted and the uni-variate statistics (namely Shannon Wiener's diversity index, Margalef's species richness and Pielou's evenness) were calculated for each station. Community analysis in PRIMER[17] used the multi-variate 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.

2.3 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 standard operating procedures and recognised national and international guidelines.

2.3.1 Benthic Invertebrate Analysis

A random 10% of samples were selected for re-analysis by a second operator following Ecospan Environmental's internal benthic analysis quality assurance process detailed in SOP ES-05. The second analysis checks the accuracy with which the detritus was sorted and confirms fauna identifications. The limit of error allowed is 10% dissimilarity according to the Bray Curtis measure. Ecospan Environmental also takes part in external quality assurance proceedings under the National Marine Biological Analytical Quality Control Scheme (NMBAQCS) and the Biological Effects Quality Assurance in Monitoring Programmes (BEQUALM).

3. Results

3.1 Phase I Survey

The results of the Phase I survey have been previously presented in Report ER10-111, and as such the results are not repeated here. However, the Phase I target locations and area covered via hovercraft are presented electronically within the GIS files supplied with this report.

3.2 Phase II Survey

A total of 11 littoral sediment biotopes and 5 littoral rock biotopes were identified throughout the Lynher Estuary SSSI. There do appear to be distributional patterns to biotopes related to geography (upper, mid and lower estuary) and shore height.

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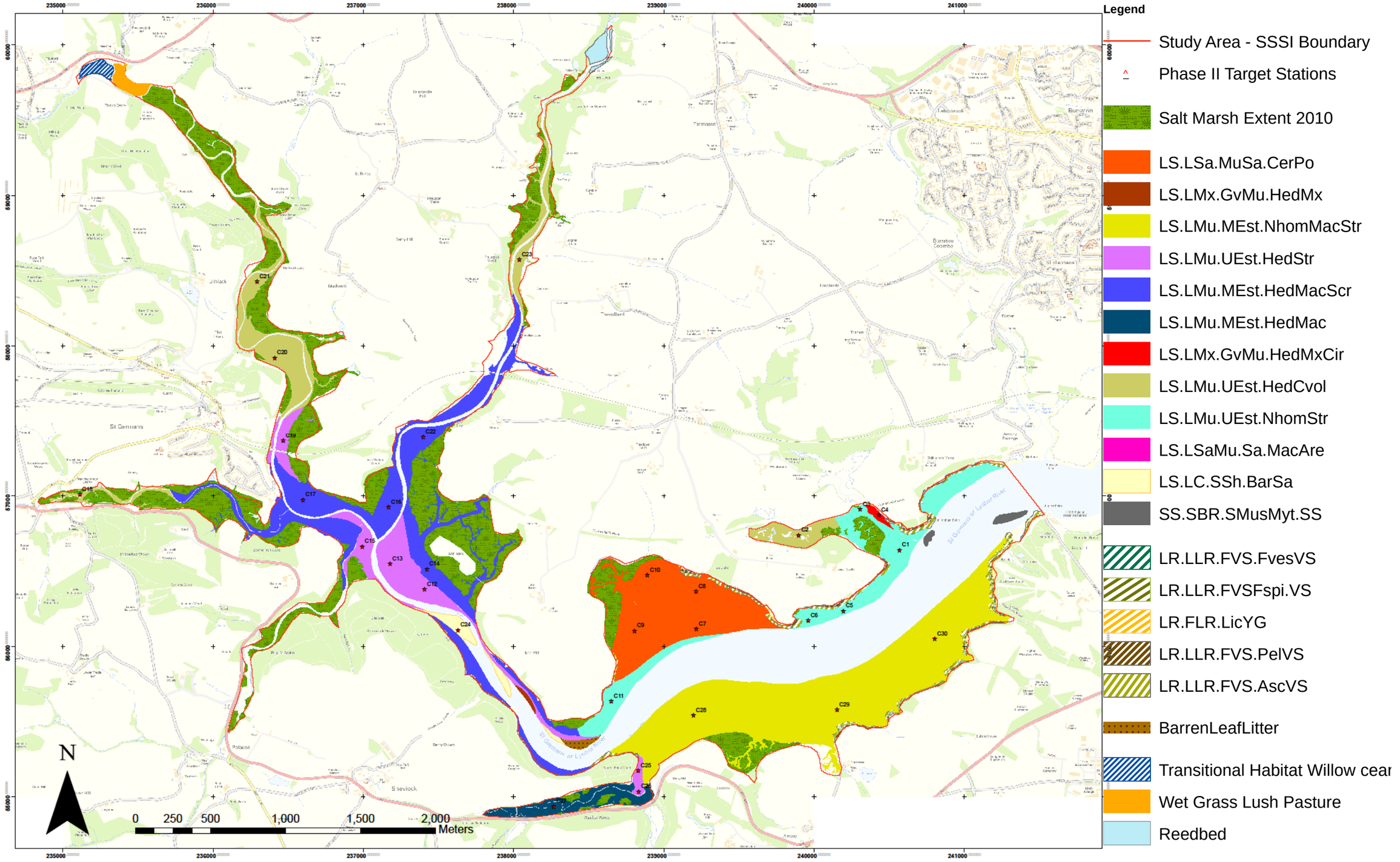
Figure 2. Distribution of Biotopes throughout the Lynher Estuary SSSI November 2010



3.3 Physical Characteristics

3.3.1 Particle Size Analysis

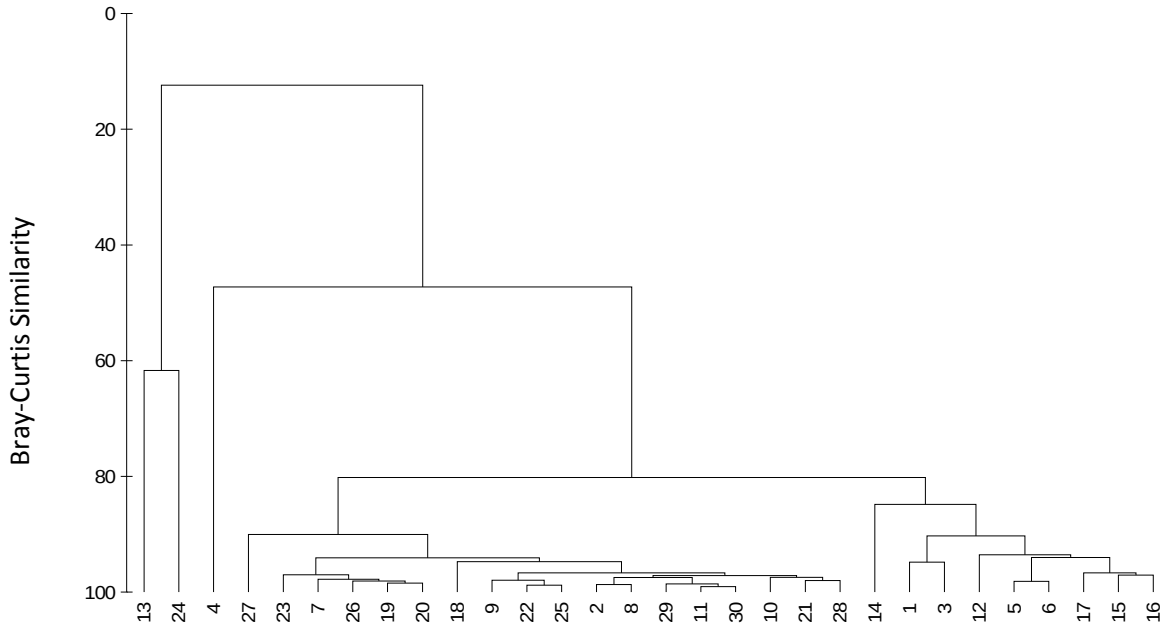
The particle size distributions (percentage distribution of sediments by weight) at each target station was summarised into 12 size bands following the Wentworth Scale.

Table 2. Particle size analysis results (Wentworth Scale)

Station	>4000 µm Pebbles	>2 <4 mm Granules	>1 <2 mm Very coarse sand	>0.5 <1 mm Coarse sand	250 <500 µm Medium sand	125 <250 µm Fine sand	63 <125 µm Very fine sand	>31 <63 µm Silt	>16 <31 µm Silt	>8 <16 µm Silt	>4 <8 µm Silt	<4 µm Clay
C1	0	0	0	1.6	3.6	8.1	17.8	22.8	15.5	11.3	9.4	10
C2	0	0	0	0	0	0.2	6.5	23.6	23.8	17.9	13.7	14.5
C3	0	0	0	1.7	1.1	8.2	21.9	23.6	14.1	10.7	8.6	10
C4	13.5	9.5	10.7	6.2	7.7	7	9.3	12	8.2	6	4.7	5.2
C5	0	0	0	0	1	4.5	14.8	27.6	19.5	12.6	9.6	10.5
C6	0	0	0	0	0.1	3.7	15.2	28.5	19.3	12.6	9.8	10.8
C7	0	0	0	0	0	1	10.5	27.3	21.8	15.1	11.5	12.8
C8	0	0	0	0	0	0	6.5	24.8	23.6	17.5	13.1	14.5
C9	0	0	0	0	0	0.2	7.6	26.8	24.3	16.6	11.5	13.1
C10	0	0	0	0	0.3	0.7	5.7	24.8	24.9	17.4	12.8	13.2
C11	0	0	0	0	0.4	1.3	7.3	24.6	22.6	16.5	13.1	14.1
C12	0	0	0	0	1.3	7.1	17.1	24.4	17	12.4	9.5	11.2
C13	0	0.3	0.8	3.7	42	39.3	9.1	1.1	0.9	0.8	0.9	1.1
C14	0	0	0	0	0.8	9.2	27.8	28.1	13.2	8	6.1	6.8
C15	0	0	0	0	0	4.9	19.7	27	16.8	11.8	9.5	10.3
C16	0	0	0	0	0.1	4.4	18.8	28.7	18	11.7	9	9.4
C17	0	0	0	0	0.1	5.9	20.6	28.2	16.9	11	8.6	8.7
C18	0	0	0	0	0	0	7.1	27.3	25.8	17.3	11.2	11.3
C19	0	0	0	0	0.1	2	10	25.6	21.8	15.8	11.8	13
C20	0	0	0	0	0.1	1.8	9.9	26.5	22.2	15.5	12	12
C21	0	0	0	0	0	0.8	8.1	24.1	23.4	17.7	12.4	13.4
C22	0	0	0	0	0	1	8.3	25.8	23.2	16.5	12.4	12.8
C23	0	0	0	0	0.1	1.3	9.7	27.7	23.2	15.6	10.7	11.7
C24	0.9	1.2	3.7	15.2	64.1	10.8	0.6	1	0.5	0.7	0.7	0.6
C25	0	0	0	0	0.1	0.9	7.5	25.8	23.7	16.7	12.1	13.2
C26	0	0	0	0	0	2.1	11.3	26.2	21.5	15.4	11.4	12
C27	0	0	0	0	0	0	3.9	20.9	24.7	20.2	14.8	15.5
C28	0	0	0	0	0	1.5	7	24.4	24	17.5	12.8	12.7
C29	0	0	0	0	0	0.4	7.8	24.8	22.6	16.7	13.3	14.4
C30	0	0	0	0	0.2	1.1	7.2	24.2	22.9	17	13.1	14.3

It is well documented that the particle size distribution of the sediment has an effect on the community structure of benthic communities[18]. Figure 3 overleaf illustrates that at all but three of the stations granulometry characteristics of the sediments are very similar.

Figure 3. **Sediment granulometry Bray-Curtis Plot**



At stations 13, 24 and 4 the sediments have a gravel component which is absent from all other stations; as such, the faunal component of the biotopes at these stations have a higher dissimilarity value than at those stations where sediment characteristics are more similar. For example, although the LS.LMxGvMu.HedMx.Cir biotope occurs on the same shore as LS.LMu.Uest.NhomStr, it is 73.56% dissimilar, principally because of the dissimilar granulometry component within the sediment (though a number of confounding variables will also have an influence on the faunal communities).

3.3.2 Sediment Carbon Content

Using loss on Ignition techniques, the carbon content of sediment samples was determined.

Table 3. Sediment organic carbon content (%)

Target Station	Organic Content (%)	Target Station contd.	Organic Content (%)
1	10.5	**16**	6.44
2	6.9	**17**	7.6
3	4.32	**18**	9.59
4	5.43	**19**	9.92
5	7.63	**20**	9.01
6	8.54	**21**	8.92
7	8	**22**	10.15
8	9.89	**23**	10.08
9	9.65	**24**	1.12
10	8.28	**25**	9.21
11	9.88	**26**	8.12
12	10.12	**27**	9.09
13	1.52	**28**	9.14
14	6.06	**29**	9.33
15	5.4	**30**	9.91

The sediment organic carbon content is relatively high at many of the target stations within the study area. The highest levels appear to be present at those stations which are influenced by the main Lynher River channel, particularly in areas of leaf litter deposition.

Previous studies have found that the organic carbon content of sediment samples from the main Tamar is largely dependent on the proportion of fine sediment within the sample[19]. As may therefore be expected, the lowest organic carbon levels were found in those sediments with the least silt and clay content due their exposure to tidal currents and scouring.

3.3.3 Sediment Redox Profile

The depth of the Redox potential discontinuity (RPD) layer, a recognizable division zone between oxidized (sub-oxic) and reduced chemical conditions, is represented by the transition of positive to negative mV values.

Table 4. Sediment redox profile (mV)

Target	Redox (mV)					
Station	Surface	1cm	4cm	6cm	8cm	10cm
C1	85	46	-99	-136	-157	-158
C2	105	114	112	-11	-98	-106
C3	25	15	-3	-60	-109	-117
C4	135	56	-45	-82	-155	-161
C5	135	80	75	-76	-142	-160
C6	80	100	-64	-104	-120	-128
C7	48	-13	-78	-110	-136	-139
C8	135	-15	-78	-119	-164	-163
C9	129	168	-96	-112	-137	-143
C10	109	18	-157	-189	-199	-199
C11	112	-65	-113	-130	-144	-139
C12	146	134	-23	-126	-146	-146
C13	135	122	122	121	117	115
C14	137	33	-83	-119	-136	-140
C15	139	123	76	-68	-107	-114
C16	145	45	-7	-60	-108	-112
C17	132	33	-45	-83	-131	-140
C18	135	140	102	106	-62	-100
C19	122	36	21	-10	-20	-98
C20	34	19	-16	-64	-114	-120
C21	135	91	89	-2	-13	-42
C22	135	85	13	-91	-145	-160
C23	140	85	87	24	-54	-75
C24	146	135	115	127	107	116
C25	75	25	-71	-125	-128	-124
C26	88	-11	52	-106	-135	-139
C27	80	-49	-92	-113	-130	-136
C28	88	-76	-145	-159	-165	-163
C29	108	-74	-83	-96	-116	-119
C30	59	50	-80	-90	-110	-110

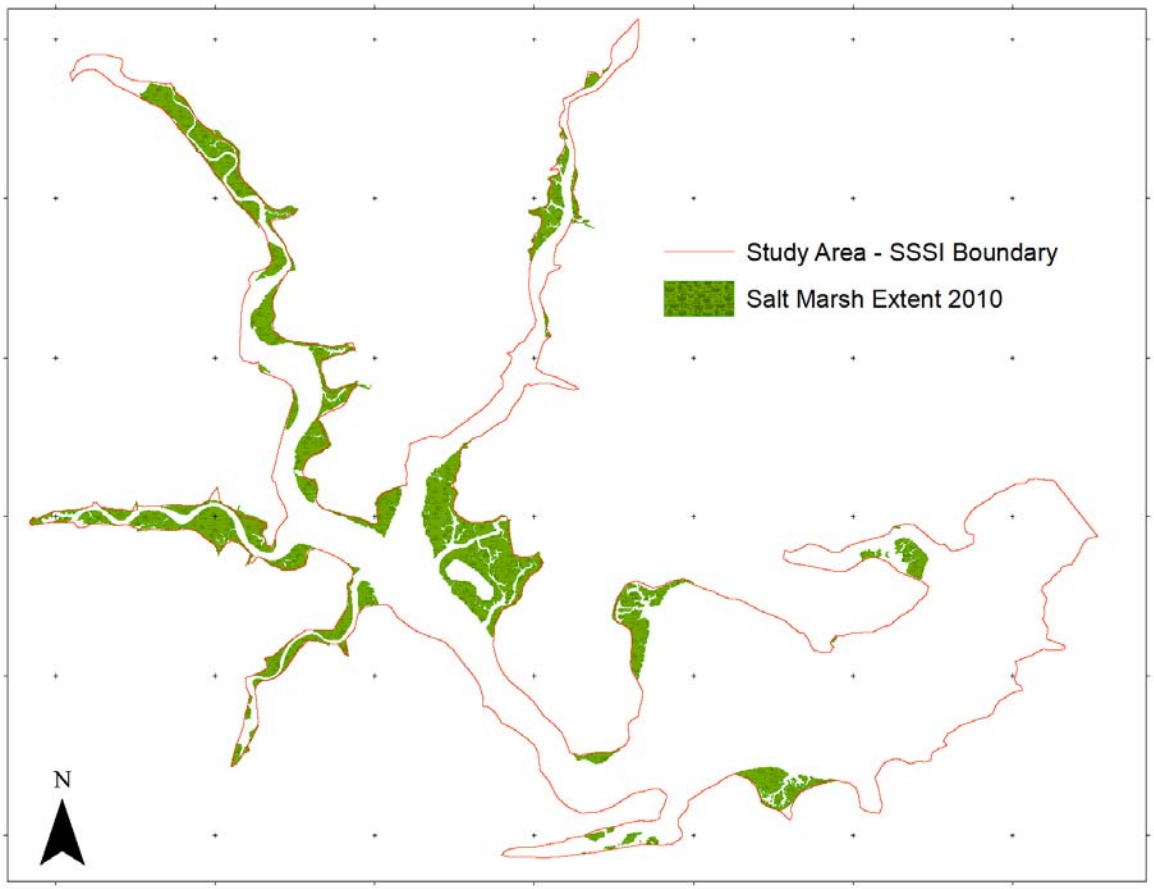
Highly anoxic conditions are observed mostly in the lower stretches of the Lynher Estuary SSSI, both north and south of the main channel. The increasing anoxic conditions towards the mouth of the Lynher is likely to be as a result of the opportunistic algal mats, principally *Ulvae* species, which were observed in swathes on the lower estuary shores.

The mid and upper stretches of the tributaries are less anoxic. The difference in the redox conditions of the mid and upper estuary is probably as a result of a number of confounding variables. The different numbers and types of infaunal species found in the upper estuary for example may display different behavioural characteristics (e.g. burrows, tubes and feeding voids) which introduce oxygen into the sediments. The finer sediments of the upper reaches are also exposed to regular intratidal resuspension and transport during high tides with little time available for consolidation following deposition during slack-water periods as in the lower estuary[19]; a factor which may also contribute to alleviating the anoxic conditions of the upper estuary[19].

3.4 Saltmarsh Extent and Distribution

Field observations determined that no saltmarsh accretion was occurring obviously anywhere within the Lynher. Erosion however was apparent, indicated by undercut, steeply sloping or exposed sediment banks bordering the Saltmarsh at numerous points throughout the estuary. The extent of such erosion was not at a scale which was detectable when compared to the Coastal Observatory aerial photography from the 2007 survey using DGPS, and therefore it is difficult to discern whether the 1% threshold of loss in extent has occurred since 2007.

Figure 4. Extent and distribution of saltmarsh 2010 (Graticules represent 1km^2)

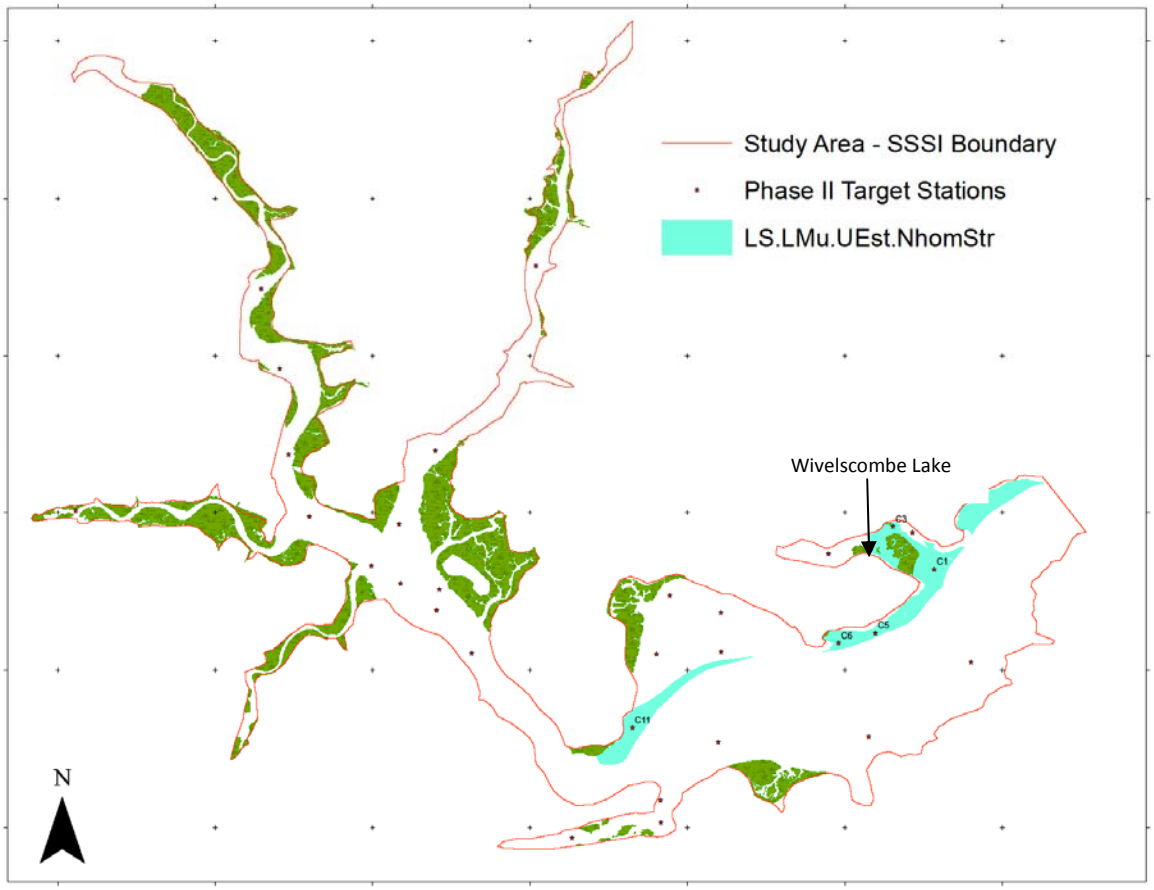


3.5 Biotopes Identified within the Lynher Estuary SSSI

3.5.1 LS.LMu.UEst.NhomStr

The biotope LS.LMu.UEst.NhomStr (*Nephtys hombergii* and *Streblospio shrubsolii* in littoral mud) is restricted to the northern shore within the Lynher Estuary SSSI; within Wivelscombe Lake and on the lower shores to the west and east of the mouth of the lake.

Figure 5. Extent and distribution of LS.LMu.UEst.NhomStr (Graticules represent 1km^2)



The sediments within the cores taken are described mainly as muddy sand (very fine sand mixed with very course silt), with the exception being the sediment sample taken at the most western distribution of the biotope (C11) which is described as mud (very fine silt). The carbon content within sediment samples ranged from 4.32% to 10.50%. The anoxic layer is present within the first 6cm at all but one of the core stations, with the exception again being at station C11 where the anoxic layer occurs within 1cm of the surface.

The most abundant and frequently occurring species within the replicate cores is the oligochate *Tubicoides benedenii*, followed by the polychaete species *Nephtys hombergii*. Species diversity, eveness and richness is broad ranging within the biotope. The most impoverished communities occur at the mouth of Wiveslcombe Lake, whilst the most diverse, rich and even communities occur at the most upper estuarine extent of the biotope.

Table 5. Lynher LS.LMu.UEst.NhomStr biotope community analysis

Station	No. Taxa Per Core	No. Individuals	Margalef's Species	Pielou's Evenness	Shannon Wiener	Simpson diversity
	s	Per Core n	Richness d	J'	Index H'(log10)	Index 1-Lambda'
C1	4	67	0.7135	0.4323	0.2603	0.3116
C3	11	191	1.904	0.5432	0.5657	0.5948
C5	6	35	1.406	0.6049	0.4707	0.5193
C6	9	25	2.485	0.8969	0.8559	0.87
C11	14	541	2.066	0.5929	0.6796	0.725

The average similarity between stations is 43.74 %. Those species which provide the highest % contribution to similarity are listed in Table 6 below.

Table 6. Species % contribution in Lynher LS.LMu.UEst.NhomStr biotope

Species	Average Abundance	Average Similarity	% Contribution
Hydrobia ulvae	43.75	14.76	33.74
Tubificoides benedii	13.50	8.70	19.88
Tharyx A	8.75	7.57	17.30
Nephtys Sp. Juv.	2.75	4.24	9.69
Nephtys hombergii	2.25	3.39	7.75
Parvicardium scabrum	1.75	2.70	6.16

The characteristics at stations correspond reasonably well with the LS.LMu.UEst.NhomStr biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), although there is some deviation from the location and faunal component. All but one of the cores is located on the mid or lower shore as is outlined within the biotope description, with one occurring on the upper shore.

Perhaps the most notable difference in the faunal component at stations is the absence of the cirratulid polychaete *Aphelochaeta marioni*. However, the closely related cirratulid *Tharyx 'A'* is abundant in all but the most upper shore core, which may imply some type of ecological niche substitution by the *Tharyx 'A'* species.

Whilst most of the other biotope characterising species are present in three of the total five replicates, there is a greater degree of infaunal community variation between two the replicates and the communities described as characteristic for the biotope. Where characterising species are present, their abundance is generally in-line with that outlined in the biotope description. However, at the most upper shore station the abundance of *Nephtys hombergii* (and *Nephtys* species juveniles) and *Tubificoides benedii* is 4 times that expected for the biotope (See table 7 below).

Table 7. Lynher LS.LMu.UEst.NhomStr replicate core species composition

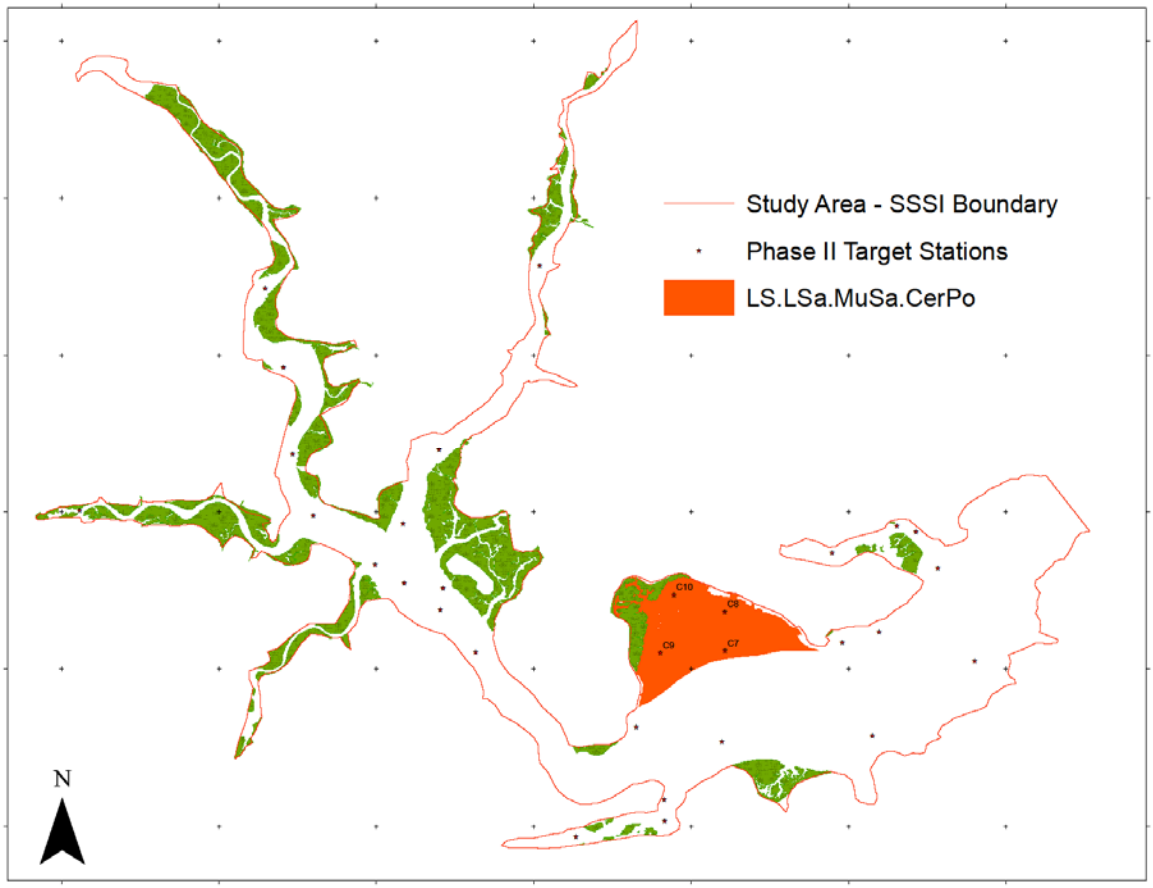
Species		C1 No. m²	C3 No. m²	C5 No. m²	C6 No. m²	Biotope Characterising Species Abundance
Nephtys hombergii		0	400	100	600	*108*
Streblospio shrubsolii		0	200	0	600	*483*
Aphelochaete marioni		0	0	0	0	*2790*
Tubificoides benedii		200	4700	300	200	*1259*
Nephtys	sp. Juv.	0	500	400	0	
Pygospio elegans		0	100	0	0	
Tharyx A		900	0	2400	200	
Melinna palmata		100	700	0	0	
Sphaeromatidae	sp.juv.	0	0	0	100	
Hydrobia ulvae		5500	11200	200	600	
Cardiacea	sp. Juv.	0	500	100	100	
Mya	Sp. Juv.	0	400	0	0	

The variations observed 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). However, the differences observed in the fauna of the most westerly core probably represent a transition to the LS.LSa.MuSa.CerPo biotope that borders LS.LMu.UEst.NhomStr at that location.

3.5.1 LS.LSa.MuSa.CerPo

The biotope LS.LSa.MuSa.CerPo (*Cerastoderma edule* and polychaetes in littoral muddy sand) occurs in one area within the Lynher Estuary SSSI where it covers the mid and upper shores of an embayment on the northern shore.

Figure 6. Extent and distribution of LS.LSa.MuSa.CerPo (Graticules represent 1km^2)



The sediment can be described as sandy mud at the lower shore station and mud on the mid and upper shore stations (very fine sand to coarse silt). The carbon content within sediments was similar between stations and ranged from 8.00% to 9.65%. The redox discontinuity layer was more variable and ranged from <1cm to < 4cm.

Excluding *Cerastoderma edule*, *the* most abundant and frequently occurring species is the oligochate *Tubicoides benedenii*, followed by the spionid polychaetes *Pygospio elegans* and *Streblespio shrubsolli* and the gastropod *Hydrobia ulvae*. Between 10 and 11 taxa were encountered at all 4 stations; species richness and diversity increases with distance up the shore, whilst overall abundance decreases.

Table 8. Lynher LS.LSa.MuSa.CerPo biotope community analysis

Station	No. Taxa Per Core S	No. Individuals Per Core n	Margalef's Species Richness D	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson diversity Index 1-Lambda'
C7	11	357	1.701	0.4052	0.4219	0.4326
C8	10	265	1.613	0.6052	0.6052	0.6527
C9	11	166	1.956	0.6414	0.6679	0.6926
C10	11	127	2.064	0.6195	0.6452	0.6339

The average similarity between stations is 52.76%. Those species which provide the highest % contribution to similarity are listed in Table 9 below.

Table 9. Species % contribution in Lynher LS.LSa.MuSa.CerPo biotope

Species	Average Abundance	Average Similarity	% Contribution
Tubificoides benedii	101.40	15.79	29.93
Hydrobia ulvae	101.00	12.91	24.47
Pygospio elegans	18.20	7.64	14.49
Streblospio shrubsolii	27.20	6.31	11.96
Nephtys hombergii	2.80	2.48	4.70
Tharyx A	15.80	1.88	3.57
Macoma balthica	1.00	1.69	3.21

The cores correspond reasonably well with the LS.LSa.MuSa.CerPo biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), although there is some deviation from the sediment character and faunal component. Only the sediments of the lower shore proportion of the biotope contained a sand component, the remainder were described as coarse or very coarse silt.

The most notable difference between the cores and the faunal communities described as characteristic for the biotope, is that at all stations, only 4 of the total 11 characterising species were present. *Crangon crangon* and *Cerastoderma edule* were not expected to be consistently captured in cores due to the method of sampling and/or core size rather than the absence of the species. Where *Cerastoderma edule* were not present in cores, the species was observed in the field and therefore determined present for the purposes of assigning a biotope to the target station.

Where characterising species are present however, their abundance is generally far greater than that outlined in the biotope description (with the exception of *Macoma balthica*). In particular, the abundance of the spionid *Pygospio elegans* is more than four times greater than expected, whilst the gastropod *Hydrobia ulvae* is up to three orders of magnitude more abundant.

A number of non-characterising species are also present, and these contribute greatly to the species diversity at stations and to exposing the inter-replicate variations. For example, at the most upper shore station (C10) the abundance of *Tharyx 'A'* increased significantly, whilst the abundance of spionids and *Tubificoides* species reduced. The remaining three stations which were located on the mid and lower shores were more similar in their species composition and abundance.

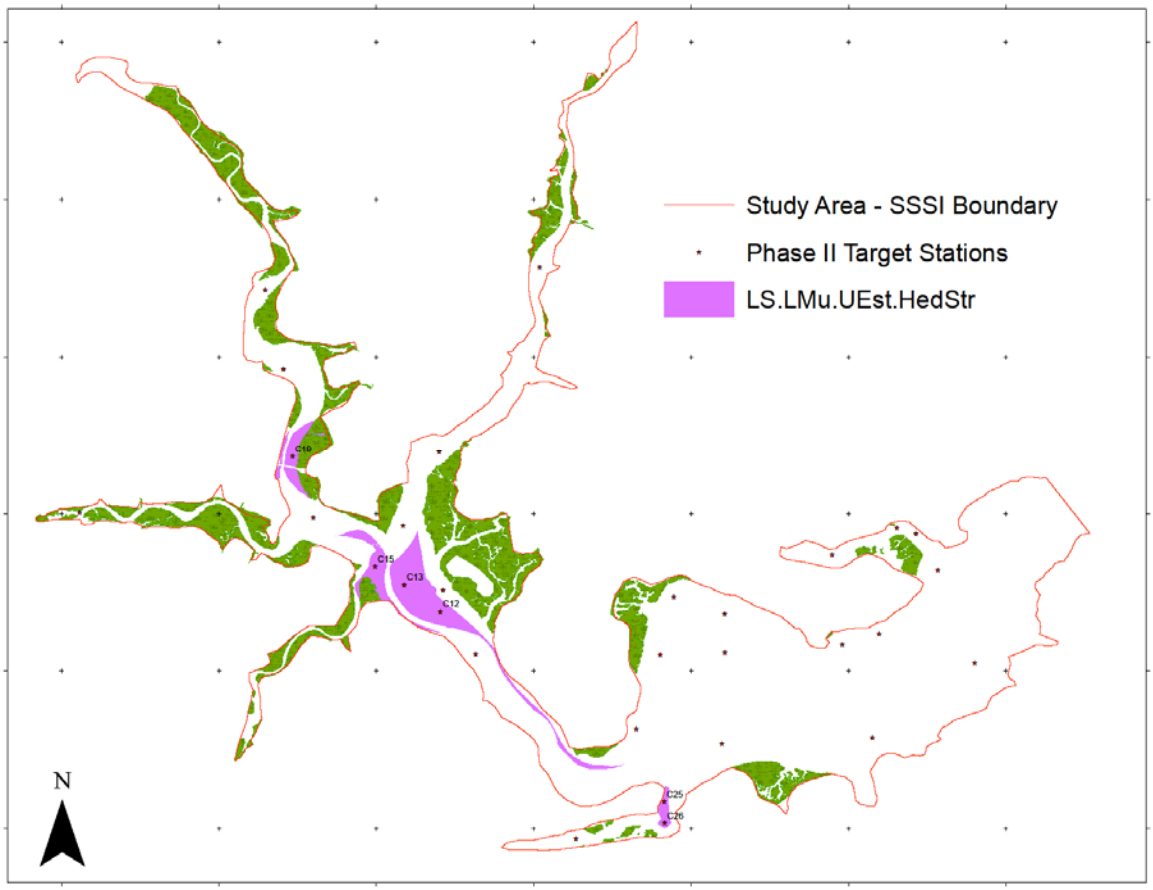
Table 10. Lynher LS.LSa.MuSa.CerPo replicate core species composition

Species		C7 No. m²	C8 No. m²	C9 No. m²	C10 No. m²	Biotope Characterising Species Abundance
Pygospio elegans		1700	3500	1200	400	*832*
Crangon crangon		0	0	100	0	*57*
Hydrobia ulvae	sp. Juv.	26400	4900	3400	700	*25*
Cardiacea		1000	0	0	0	*715*
Cerastoderma edule		0	300	0	200	*715*
Macoma balthica		100	100	100	200	*574*
Diptera	Unident	100	0	0	0	
Nematoda	Sp. Juv.	0	0	0	600	
Nereidae	Sp. Juv.	0	0	0	0	
Nephtys		300	0	0	0	
Nephtys hombergii	sp.juv.	400	300	300	0	
Polydora		0	0	0	0	
Streblospio shrubsolii		700	2000	1600	200	
Tharyx A		0	200	200	7400	
Notomastus spp.	Sp. Juv.	0	0	0	1500	
Melinna palmata		0	0	200	0	
Melinna palmata		100	800	0	0	
Ampharete grubei	Unident	0	0	0	100	
Terebellidae		0	0	100	0	
Manayunkia aestuarina	Unident	0	100	1100	0	
Oligochaeta		100	0	0	0	
Tubificoides benedii		4800	14300	8300	1300	
Cyathura carinata	Sp. Juv.	0	0	0	100	
Mya		0	0	0	0	

3.5.2 LS.LMu.UEst.Hed.Str

The biotope LS.LMu.UEst.Hed.Str (*Hediste diversicolor* and *Streblospio shrubsolii* in littoral sandy mud) is distributed in patches throughout mid section of the Lynher Estuary SSSI, often on the same shores as LS.LMu.MEst.HedMacScr, but restricted to the lower and mid shores.

Figure 7. Distribution and extent of LS.LMu.UEst.Hed.Str biotope in Lynher SSSI



The sediments varied between stations and ranged from being described as mud, to slightly gravelly sand (very course silt to slightly very fine gravelly medium sand). The carbon content within sediment samples was also variable, ranging from 5.40% to 9.92%. The anoxic layer was present within the first 1cm in the muddy sediments, and within 4-6 cm in the sandy mud sediments; the exception was at station C13 where no redox discontinuity layer was reached.

The most frequently occurring and abundant species at stations is the oligochate *Tubificoides benedii*, followed by the polychaetes *Streblospio shrubsolii* and *Hediste diversicolor*. Between 5 and 15 taxa were encountered within the 6 replicate cores that were taken. Species richness, diversity and evenness is generally quite high within the biotope with the exception of that at station C13, where communities are influenced by the more mobile, high energy conditions of the main channel.

Table 11. Lynher LS.LMu.UEst.Hed.Str biotope community analysis

Station	No. Taxa Per Core S	No. Individuals Per Core n	Margalef's Species Richness D	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson diversity Index 1-Lambda'
C12	13	64	2.885	0.7794	0.8682	0.7951
C13	5	26	1.228	0.5888	0.4115	0.4985
C19	14	292	2.29	0.7803	0.8944	0.8391
C15	15	332	2.412	0.7843	0.9224	0.8514
C25	12	586	1.726	0.4886	0.5273	0.6056
C26	12	176	2.127	0.5514	0.595	0.6534

The average similarity between stations is 40.46%. Those species which provide the highest % contribution to similarity are listed in Table 12 below.

Table 12. Species % contribution in Lynher LS.LMu.UEst.Hed.Str biotope

Species	Average Abundance	Average Similarity	% Contribution
Streblospio shrubsolii	29.17	11.94	29.53
Tubificoides benedii	66.67	7.32	18.10
Hydrobia ulvae	76.00	6.78	16.78
Pygospio elegans	19.00	3.22	7.96
Melinna palmata	2.33	2.11	5.23
Nereidae Sp. Juv	8.33	1.99	4.92
Hediste diversicolor	3.00	1.88	4.64
Heterochaeta costata	6.50	1.29	3.18

The cores correspond reasonably well with the LS.LMu.UEst.Hed.Str biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), although there is some deviation from the sediment character and faunal component. The sediment at station C13 contained a slight very fine gravel component; the remainder were described as mud or sandy mud in agreement with the biotope description.

Combined, the replicates encompassed all of the species described as characteristic for the biotope. However, individually, the cores captured between 2 and 6 of the total 7 characteristic species. Both of the principal characterising species *Hediste diversicolor* and *Streblospio shrubsolii* occurred at all but station C13. The abundance of characterising species however is generally lower than expected, with the exception of *Streblospio shrubsolii* and *Tubificoides benedii* which are present in significantly greater numbers than expected at one and three stations respectively.

A number of non-characterising species contribute considerably to the overall species diversity at most stations.

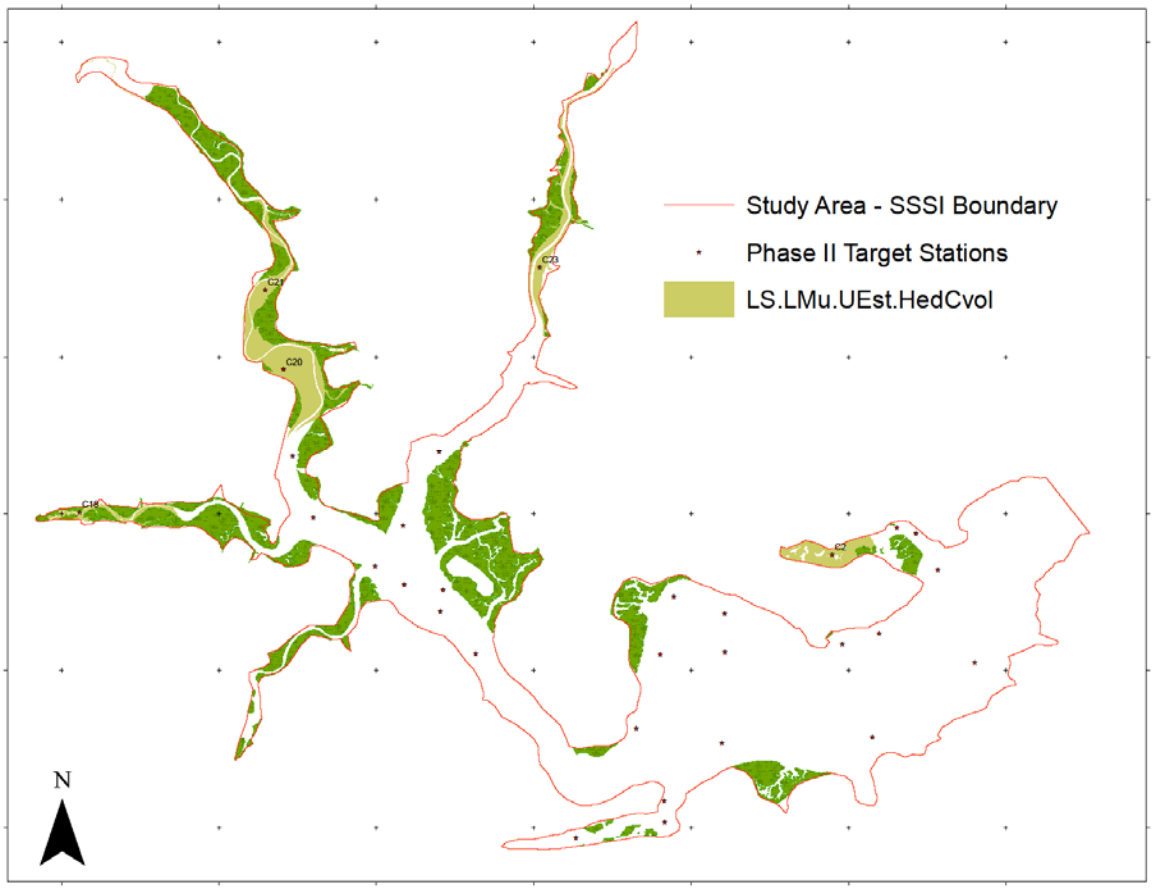
Table 13. Lynher LS.LMu.UEst.Hed.Str replicate core species composition

Species		C12	C13	C15	C19	C25	C26	Biotope Characterising Species Abundance
		No. m²	No. m²	No. m²	No. m²	No. m²	No. m²	
Hediste diversicolor		100	0	700	600	300	100	*2020*
Streblospio shrubsolii		2700	1800	6900	3000	1700	1400	*3033*
Manayunkia aestuarina			0	0	600	1400	200	*4526*
Oligochaeta	unident	200	0	0	0	0	0	*6592*
Heterochaeta costata			500	1000	2400	0	0	*2386*
Tubificoides	sp		0	0	0	0	0	
Tubificoides benedii		300	0	4500	8700	10400	6100	*4557*
Corophium	Sp. Juv.		0	0	100	0	0	
Corophium volutator		300	0	0	0	100	0	*2897*
Diptera			0	100	200	0	0	
Nematoda	Unident	100	0	0	0	0	0	
Nereidae	Sp. Juv.	500	100	2900	1500	0	0	
Nephtys	Sp. Juv.		0	0	0	0	200	
Nephtys hombergii			0	100	0	1500	200	
Polydora cornuta		400	0	1900	5100	0	0	
Pygospio elegans		700	100	8400	0	2000	200	
Capitellidae	sp. Juv.	100	0	1400	0	0	0	
Capitellidae	unident		0	0	0	0	100	
Capitella capitata	agg.		100	0	100	0	0	
Notomastus spp.			0	1900	0	0	0	
Melinna palmata		300	0	100	500	200	300	
Cyathura carinata		100	0	0	3100	100	0	
Crangon crangon			0	0	0	0	400	
Hydrobia ulvae		600	0	3000	3200	30500	8300	
Cerastoderma edule			0	0	0	100	0	
Macoma balthica			0	100	0	0	0	
Abra tenuis			0	0	0	300	0	
Mya	Sp. Juv.		0	200	100	0	100	

3.5.3 LS.LMu.Uest.HedCvol

The biotope LS.LMu.Uest.HedCvol (*Hediste diversicolor* and *Corophium volutator* in littoral mud) occurs in the most upper reaches of each tributary of the Lynher Estuary SSSI, except for within Waker Lake on the south bank. The biotope is frequently found adjacent to main channels of reduced salinity water, fringed by saltmarsh on the upper shore.

Figure 8. Extent and distribution of LS.LMu.Uest.HedCvol (Graticules represent 1km^2)



The sediments at stations range from being described as mud to sandy mud (coarse silt to very fine sand). The carbon content within sediments is relatively broad ranging from 6.90% to 10.08%. The depth of the redox discontinuity layer is relatively deep compared to other biotopes within the study area, ranging from <4cm to <8cm.

As might be expected for the biotope the most abundant and frequently occurring species is the amphipod *Corophium volutator*, followed by the polychaete *Hediste diversicolor*. Oligochaete species including *Heterochaeta costata* and *Tubificoides* were also common or abundant within all but one of the cores. Between 6 and 10 taxa were found at the five stations; species richness, diversity and evenness was relatively broad ranging between replicates.

Table 14. Lynher LS.LMu.Uest.HedCvol biotope community analysis

Station	No. Taxa Per Core S	No. Individuals Per Core n	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson diversity Index 1-Lambda'
C2	9	238	1.462	0.4198	0.4006	0.459
C20	7	43	1.595	0.9156	0.7738	0.835
C21	10	102	1.946	0.6549	0.6549	0.6915
C23	8	195	1.328	0.6765	0.6109	0.691
C18	6	205	0.9393	0.6987	0.5437	0.6077

The average similarity between stations is relatively low at 33.43%. Those species which provide the highest % contribution to similarity are listed in Table 15 below.

Table 15. Species % contribution in Lynher LS.LMu.Uest.HedCvol biotope

Species	Average Abundance	Average Similarity	% Contribution
C2	9	238	1.462
C20	7	43	1.595
C21	10	102	1.946
C23	8	195	1.328
C18	6	205	0.9393

The cores correspond well with the LS.LMu.UEst.Hed.Cvol biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), although there is some minor deviation from the sediment character and elements of the faunal component. The sediment analysis at stations determined that 3 of the 5 cores had no sand component as would be expected within the biotope.

The two characterising species were present at all replicate core stations; where *Hediste diversicolor* was not present in cores, the species was observed in the field and therefore determined as present for the purposes of assigning a biotope to the area. The abundance of all characterising species is generally lower than that outlined in the biotope description. Exceptions include stations C23 and C18 where the abundance of *Corophium volutator* is two to three times greater than expected. The high abundance of this burrowing faunal species may account for the redox discontinuity layer being deeper than expected for the biotope, as the activity of the species results in oxygen being introduced into sediments via burrows and feeding voids.

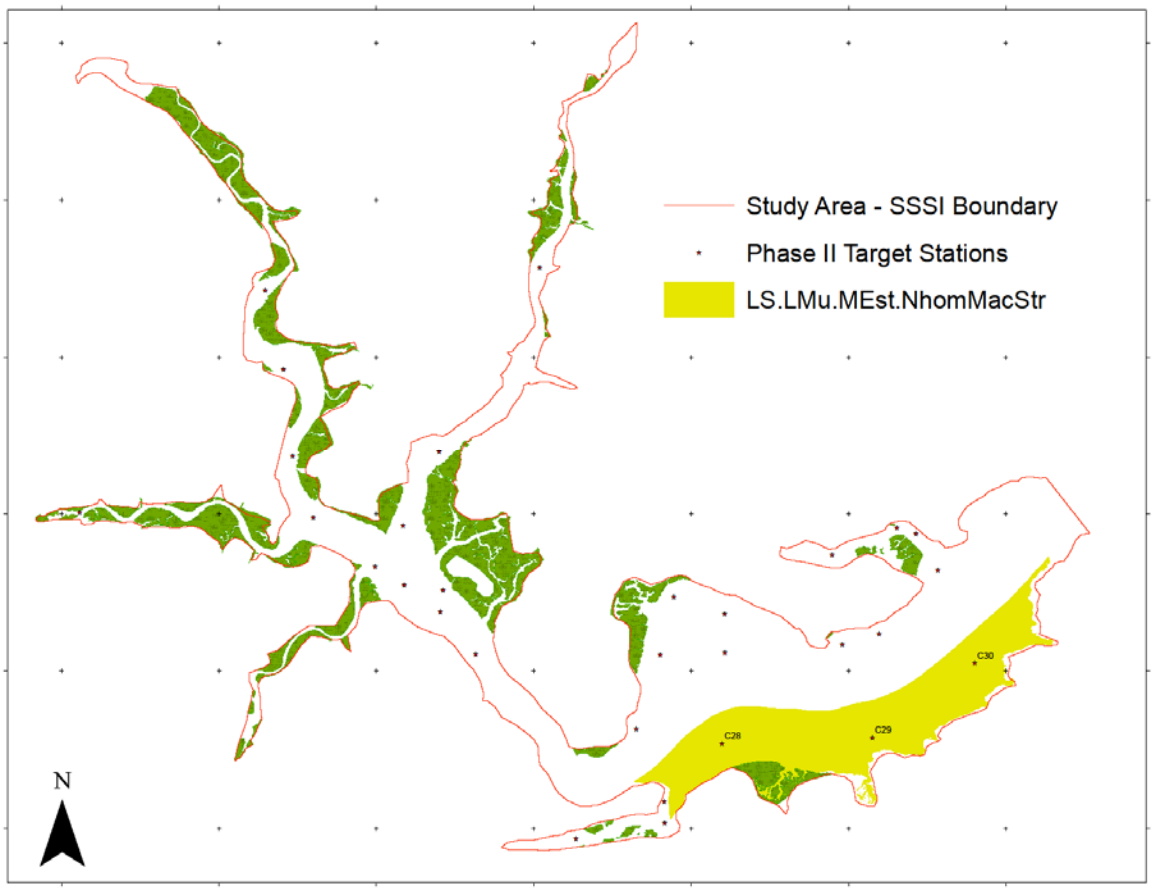
Table 16. Lynher LS.LMu.Uest.HedCvol replicate core species composition

Species		C20 No. m²	C21 No. m²	C23 No. m²	C2 No. m²	Biotope Characterising Species Abundance
Hediste diversicolor		700	300	2500	0	*1783*
Corophium	Sp. Juv.	0	0	1900	0	*4257*
Corophium volutator		600	5100	9200	200	*4257*
Nereidae	Sp. Juv.		2000		100	
Nephtys hombergii					200	
Pygospio elegans		1100			400	
Streblospio shrubsolii		500	500	200		
Tharyx A		100			100	
Melinna palmata					100	
Manayunkia aestuarina				100		
Oligochaeta	unident			500		
Heterochaeta costata			100	4900		
Tubificoides benedii			100		4900	
Cyathura carinata		1000	1500	200		
Hydrobia ulvae		300	400		16800	
Cardiacea	sp. Juv.		100			
Macoma balthica			100			
Abra tenuis					1000	

3.5.4 LS.LMu.MEst.NhomMacStr

The biotope LS.LMu.MEst.NhomMacStr (*Nephtys hombergii*, *Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud) is found on the southern bank of the lower stretches of the Lynher Estuary SSSI, where it spans from the lower shore to the upper shore.

Figure 9. Extent and distribution of LS.LMu.MEst.NhomMacStr (Graticules represent 1km^2)



The sediments at stations range from being described as mud (course silt to very coarse silt). The carbon content within sediment samples ranged from 9.14% to 9.91%. The redox discontinuity layer was present at <1cm at stations C28 and C29, and at <4cm at C30.

The most abundant and frequently occurring species within the biotope is the gastropod *Hydrobia ulvae*. The most abundant and frequently occurring infaunal species however are the polychaetes *Hediste diversicolor* and *Streblospio shrubsolii*, followed by the bivalve *Macoma Balthica*. Between 6 and 16 taxa were recorded at the 3 stations. Species richness is significantly greater at station whilst faunal abundance is significantly greater at station C28.

Table 17. Lynher LS.LMu.MEst.NhomMacStr biotope community analysis

Station	No. Taxa Per Core S	No. Individuals Per Core n	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson diversity Index 1-Lambda'
C28	14	529	2.073	0.34	0.3897	0.447

C29	6	25	1.553	0.804	0.6256	0.7533
C30	18	98	3.708	0.6381	0.8009	0.693

The average similarity between stations is relatively low at 35.33%. Those species which provide the highest % contribution to similarity are listed in Table 18 below.

Table 18. Species % contribution in Lynher LS.LMu.MEst.NhomMacStr biotope

Species	Average Abundance	Average Similarity	% Contribution
Hydrobia ulvae	144.33	11.85	33.53
Nephtys hombergii	5.33	6.28	17.78
Streblospio shrubsolii	4.33	4.97	14.08
Macoma balthica	1.00	3.45	9.77
Nephtys Sp. Juv.	2.67	3.45	9.77
Pygospio elegans	5.33	2.16	6.12

The station characteristics correspond reasonably well with the LS.LMu.MEst.NhomMacStr biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), although there is some deviation from the sediment character and faunal component. The sediments at all stations lack a sand component as expected for the biotope.

All species described as characteristic for the biotope were present at all three stations with the exception of *Tubificoides benedii* which was absent at two of the stations. The abundance of characterising species was somewhat variable however; some were present in far greater numbers than expected, whilst others were far fewer. *Nephtys hombergii* was consistently present in greater numbers at all stations.

Only a few additional non-characterising species are present in cores, with the exception of station C30 where species richness was the highest of all stations in the estuary.

Table 19. Lynher LS.LMu.MEst.NhomMacStr replicate core species composition

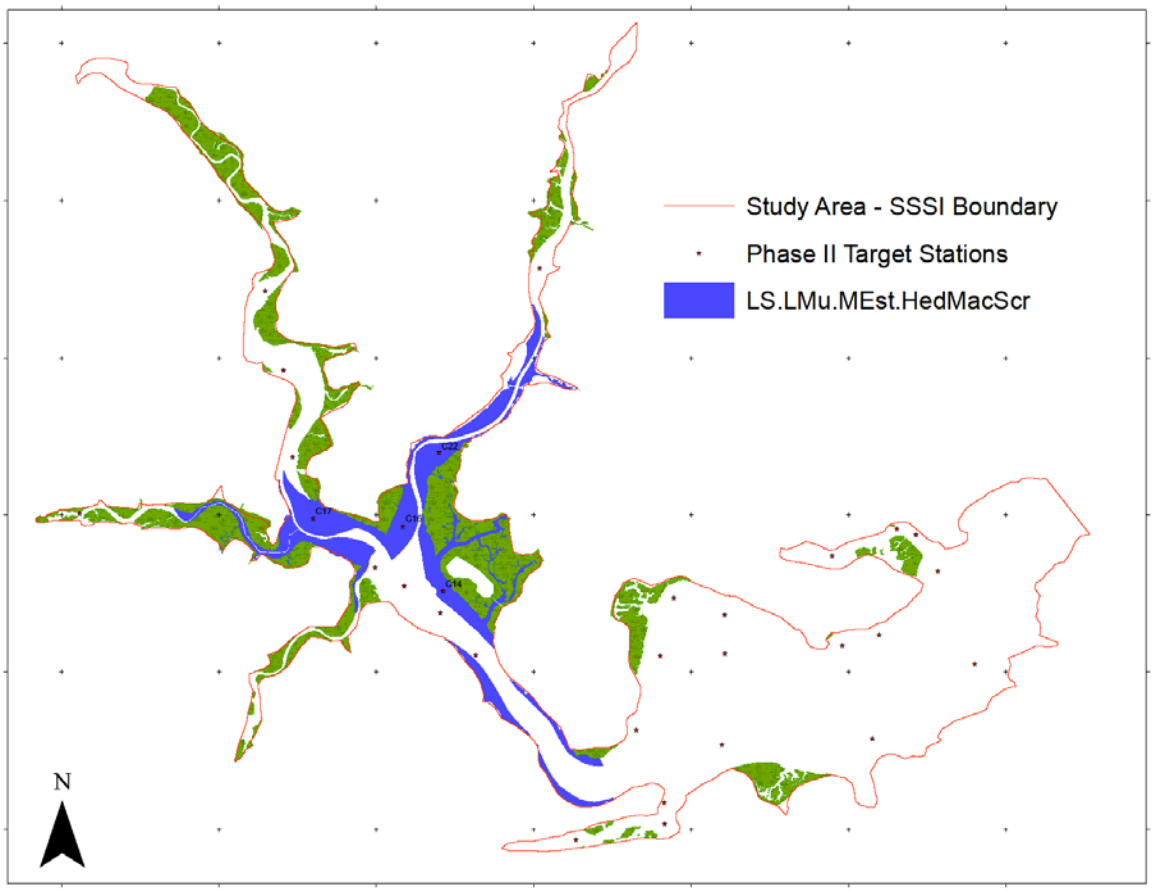
Species		C28 No. m²	C29 No. m²	C30 No. m²	Biotope Characterising Species Abundance
Nephtys	Sp. Juv.	100	100	600	*133*
Nephtys hombergii		400	900	300	*133*
Streblospio shrubsolii		100	800	400	*593*
Tubificoides benedii		11900	0	0	*999*
Hydrobia ulvae		37500	500	5300	*5093*
Macoma balthica		100	100	100	*373*
Exogone	sp.	0	0	100	
Pygospio elegans		900	0	700	
Tharyx A		0	0	800	
Cossura	sp.	0	0	200	

Capitellidae	sp. Juv.	0	0	100
Notomastus spp.		0	0	100
Melinna palmata		0	100	400
Manayunkia aestuarina		800	0	100
Oligochaeta	unident	0	0	100
Heterochaeta costata		500	0	0
Cyathura carinata		0	0	100
Sphaeromatidae	sp.juv.	0	0	100
Idotea chelipes		100	0	0
Carcinus maenus		100	0	0

3.5.5 LS.LMu.MEst.HedMacScr

The biotope LS.LMu.MEst.HedMacScr (*Hediste diversicolor*, *Macoma balthica* and *Scrobicularia plana* littoral sandy mud shores) is situated mainly where the tributaries of the the Lynher Estuary SSSI join at the estuary's mid section.

Figure 10. Extent and distribution of LS.LMu.MEst.HedMacScr (Graticules represent 1km^2)



The sediments at stations were mostly sandy mud (very fine sandy very coarse silt); one core which was taken at the most upper estuary extent of the biotope (C22) lacked the sand component. The carbon content within sediment samples ranged broadly from 6.06% to 10.15%. The anoxic layer was present within the first 4cm in the sandy mud sediments, and within 6cm in the mud sediments.

The most abundant and frequently occurring species within the biotope is the oligochate *Tubificoides benedii*, followed by the spionids *Streblospio shrubsolii* and *Pygospio elegans*, although *Scrobicularia plana* were observed to be abundant in the field. Between 10 and 17 taxa were encountered within the 4 replicate cores that were taken. Species diversity, richness and abundance within replicates were generally high compared to other biotopes within the SSSI.

Table 20. Lynher LS.LMu.MEst.HedMacScr biotope community analysis

Station	No. Taxa Per Core S	No. Individuals Per Core n	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson diversity Index 1-Lambda'
C14	17	719	2.432	0.6628	0.8155	0.8049
C16	14	181	2.501	0.8149	0.934	0.8497
C22	10	133	1.84	0.6688	0.6688	0.7086
C17	14	246	2.361	0.8693	0.9964	0.8885

The average similarity of target stations is 49.79%. Those species which provide the highest % contribution to similarity are listed in Table 21 below. Note that *Scrobicularia plana* is also likely to contribute significantly to the assignment of the biotope but due to the core size and relatively low number of replicates, the species was not captured in cores.

Table 21. Species % contribution in Lynher LS.LMu.MEst.HedMacScr biotope

Species	Average Abundance	Average Similarity	% Contribution
Hydrobia ulvae	52.00	7.60	15.27
Streblospio shrubsolii	72.25	7.14	14.33
Nereidae Sp. Juv	23.50	6.93	13.92
Heterochaeta costata	17.25	4.50	9.05
Tubificoides benedii	52.00	4.24	8.51
Hediste diversicolor	5.50	3.59	7.22
Cyathura carinata	7.50	3.51	7.04
Notomastus spp.	18.25	3.34	6.70
Pygospio elegans	38.00	2.91	5.84
Polydora sp.juv.	14.00	2.83	5.69

Table 22. Lynher LS.LMu.MEst.HedMacScr replicate core species composition

Species		C14 No. m²	C16 No. m²	C17 No. m²	C22 No. m²	Biotope Characterising Species Abundance
Hediste diversicolor		100	500	1000	600	*798*
Pygospio elegans		12500	1800	900	0	*929*
Streblospio shrubsolii		20400	5300	2900	300	*392*
Tharyx A		800	0	0	0	*537*
Heterochaeta costata		1400	1700	3700	100	*1677*
Tubificoides	**Sp**	0	0	0	600	
Tubificoides benedii		16600	200	3700	300	*2699*
Hydrobia ulvae		12200	200	3900	4500	*4118*
Macoma balthica		0	500	100	0	*438*
Nematoda	Unident	100	0	0	0	
Nereidae	Sp. Juv.	900	1200	1800	5500	
Nephtys	Sp. Juv.	300	200	0	0	
Nephtys hombergii		0	0	100	0	
Polydora	sp.juv.	0	3200	2200	200	
Polydora cornuta		500	0	0	0	
Notomastus spp.		3400	1100	2800	0	
Melinna palmata		900	400	500	0	
Manayunkia aestuarina		100	0	200	0	
Corophium	Sp. Juv.	0	0	0	0	
Corophium volutator		0	100	0	1000	
Cyathura carinata		300	1700	800	200	
Crangon crangon		0	0	0	0	
Abra tenuis		1000	0	0	0	
Mya arenaria		400	0	0	0	

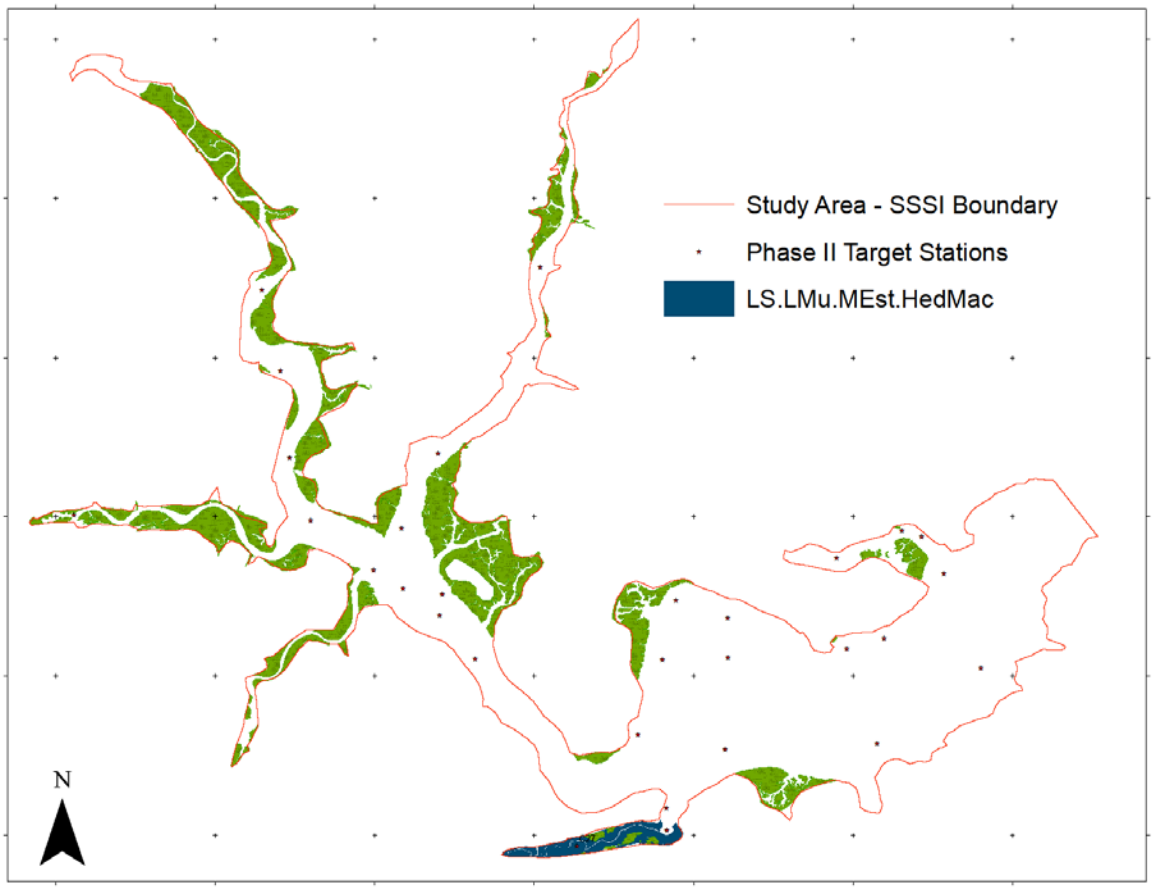
The station characteristics correspond well with the LS.LMu.MEst.HedMacScr biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), although there is some minor deviation from the faunal component. All characterising species are present within the cores (or in the case of *Scrobicularia plana*, the distinctive 'crow's foot' pattern on the sediment surface was observed in abundance at all stations), with the exception of the cirratulid *Tharyx killariensis* which was absent.

Abundance of species are broadly in-line with that expected for the biotope, however the station nearest the mouth of the estuary displays very high abundances for all species except *Hediste diversicolor* which is low in abundance. In particular, the abundance of *Streblospio shrubsolii*, *Pygospio elegans* and *Tubificoides benedii* are two orders of magnitude greater. A number of non-characterising species are also present, generally doubling the overall species diversity within cores.

3.5.6 LS.LMu.MEst.HedMac

The biotope LS.LMu.MEst.HedMac (*Hediste diversicolor* and *Macoma balthica* in littoral sandy mud) occurs in one relatively small area in the Lynher Estuary SSSI, within Wacker Lake on the southern bank.

Figure 11. Extent and distribution of LS.LMu.MEst.HedMac (Graticules represent 1km^2)



The sediment within the biotope is mud (coarse silt), with an carbon content of 9.09%. The sediment is highly anoxic with redox discontinuity level occurring within 1cm of the sediment surface.

Given the limited extent of this biotope only target station was assigned. A total of 12 species was present within the core; *Hydrobia ulvae*, *Hediste diversicolor* and *Abra tenuis* are the most abundant.

Table 23. Lynher LS.LMu.MEst.HedMac biotope community analysis

Station	No. Taxa Per Core s	No. Individuals Per Core n	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson diversity Index 1-Lambda'
C27	12	217	2.045	0.654	0.7057	0.7544

Table 24. Lynher LS.LMu.MEst.HedMac replicate core species composition

Species	C27 No. m²	Biotope Characterising Species Abundance
Hediste diversicolor	5400	*1168*
Nephtys hombergii	100	*27*
Pygospio elegans	200	*679*
Aphelochaete marioni	2300	*3457*
Capitella capitata agg.	300	*483*
Hydrobia ulvae	8200	*1539*
Abra tenuis	3800	*379*
Mya arenaria	100	*333*
Polydora cornuta	1000	
Melinna palmata	100	
Cyathura carinata	100	

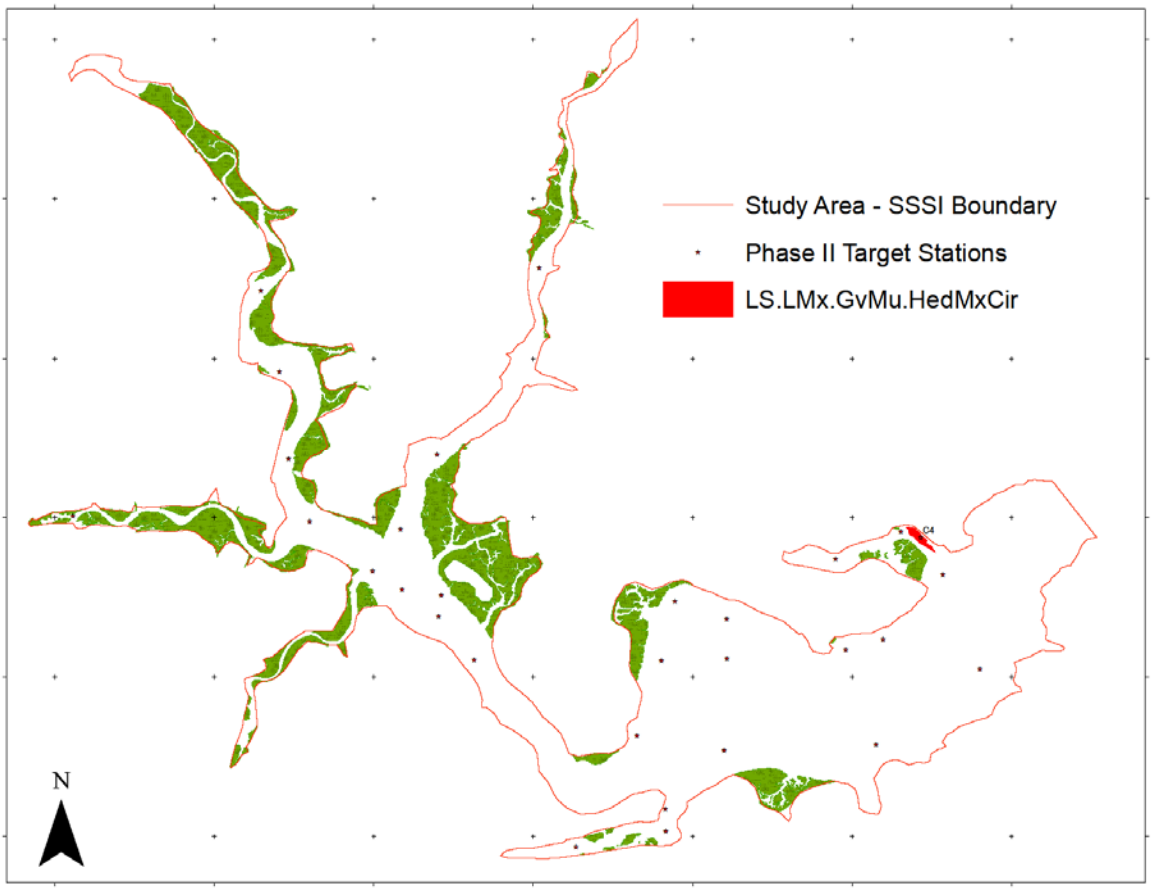
The station characteristics correspond reasonably well with the LS.LMx.GvMu.HedMx.Cir biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), the only deviation being aspects of the faunal component. The most obvious difference is the absence of the principle characterising species *Macoma balthica*. Despite the species absence in cores, it is thought likely that the species was present but was not captured in the limited sampling effort that was carried out within the biotope. Furthermore, the bivalve *Abra tenuis* which was present in abundance at the station is often found to occupy the same habitats as *Macoma balthica*.

Species richness at stations is relatively limited compared to that expected for the biotope, only 8 of the 18 characteristic species are present, with just 4 additional non-characterising species. The abundance of species are broadly in-line with that expected for the biotope, though there are some exceptions: *Abra tenuis* is ten times more abundant than expected whilst other species including *Pygospio elegans* and *Mya arenaria* are present in numbers only a third of that expected.

3.5.7 LS.LMx.GvMu.HedMx.Cir

The biotope LS.LMx.GvMu.HedMx.Cir (*Hediste diversicolor*, Cirratulids and *Tubificoides spp*. in littoral gravelly sandy mud) occurs in a small isolated patch within an inlet on the northern shore of the Lynher Estuary SSSI.

Figure 12. Extent and distribution of LS.LMx.GvMu.HedMx.Cir (Graticules represent 1km^2)



The sediment within the biotope is gravelly muddy sand (fine gravelly very coarse silty very coarse sand), with a relatively low carbon content of 5.43%. The redox discontinuity level occurs within 4cm of the sediment surface.

Given the limited extent of this biotope only one target station was assigned. A total of 17 species was present within the core; the most abundant species was the oligochate *Tubificoides benedii*, closely followed by the cirratulid *Tharyx 'A'*.

Table 25. Lynher LS.LMx.GvMu.HedMxCir biotope community analysis

Station	No. Taxa Per Core s	No. Individuals Per Core n	Margalef's Species Richness d	Pielou's Evenness J'	Shannon Wiener Index H'(log10)	Simpson diversity Index 1-Lambda'
C4	17	506	2.57	0.6032	0.7422	0.7416

Table 26. Lynher LS.LMx.GvMu.HedMxCir replicate core species composition

Species		C4 No. m²	Biotope Characterising Species Abundance
Nematoda	Unident	1200	*166*
Hediste diversicolor		600	*1040*
Pygospio elegans		1100	*15*
Streblespio shrubsolii		4300	*984*
Heterochaeta costata		400	*47*
Tubificoides benedii		20300	*106*
Nemerta	Undent	300	
Nephtys hombergii		100	
Polydora cornuta		100	
Tharyx A		14000	
Capitella capitata	agg.	100	
Notomastus spp.		5800	
Melinna plamata		100	
Cyathura carinata		1100	
Hydrobia ulvae		500	
Cardiacea	Spp. Juv.	500	
Abra tenuis		100	

The station characteristics correspond reasonably well with the LS.LMx.GvMu.HedMx.Cir biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), the only deviation being aspects of the faunal component.

The principal characterising species Cirratulids (*Tharyx 'A'*) and *Tubificoides spp.* (*Tubificoides benedii*) are present in superabundance. However, the ragworm *Hediste diversicolor* is only found at half the expected density. Four of the total nine characterising species listed are not present. The presence of the cirratulid *Tharyx 'A'* and not the characterising cirratulids species *Tharyx killariensis* may imply some type of ecological niche substitution by the *Tharyx 'A'* species, as also suggested within the LS.LMu.UEst.NhomStr biotope described in this study.

A number of non-characterising species are also present, significantly adding to the overall species diversity observed within the core.

Most notable within the biotope is the abundance of both characteristic and non-characteristic species. *Heteromastus filiformis* for example is present in abundance whilst many of the characterising species are present in numbers an order of magnitude greater than would be

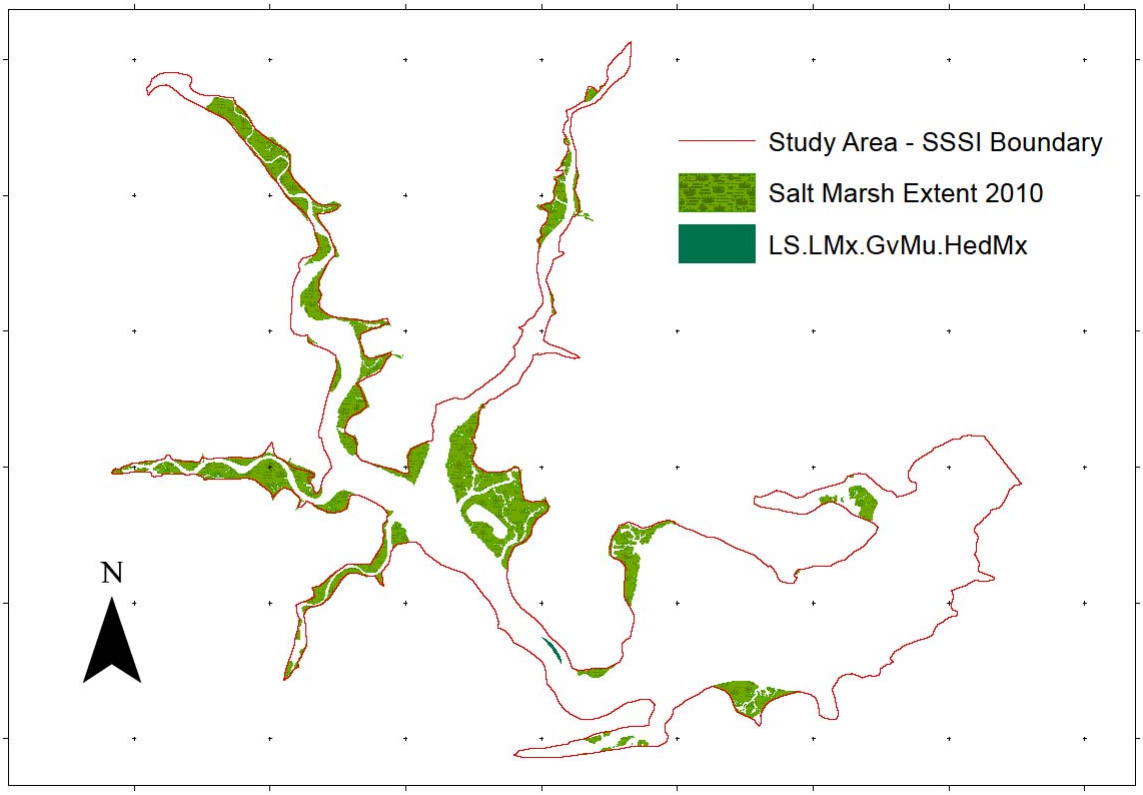
expected. Exceptionally, *Tubificoides benedii*, *Tharyx 'A'* and *Streblospio shrubsolii* are present in numbers two orders of magnitude greater than expected.

Sections 3.8 to 3.10 describe biotopes where no faunal cores, PSA or LOI were taken but which were assigned accordingly based on field observations.

3.5.8 LS.LMx.GvMu.HedMx

This biotope occurs in one isolated area in the mid Lynher Estuary SSSI, on the lower shore of the northern bank below HedMacScr.

Figure 13. Extent and distribution of LS.LMx.GvMu.HedMx (Graticules represent 1km^2)



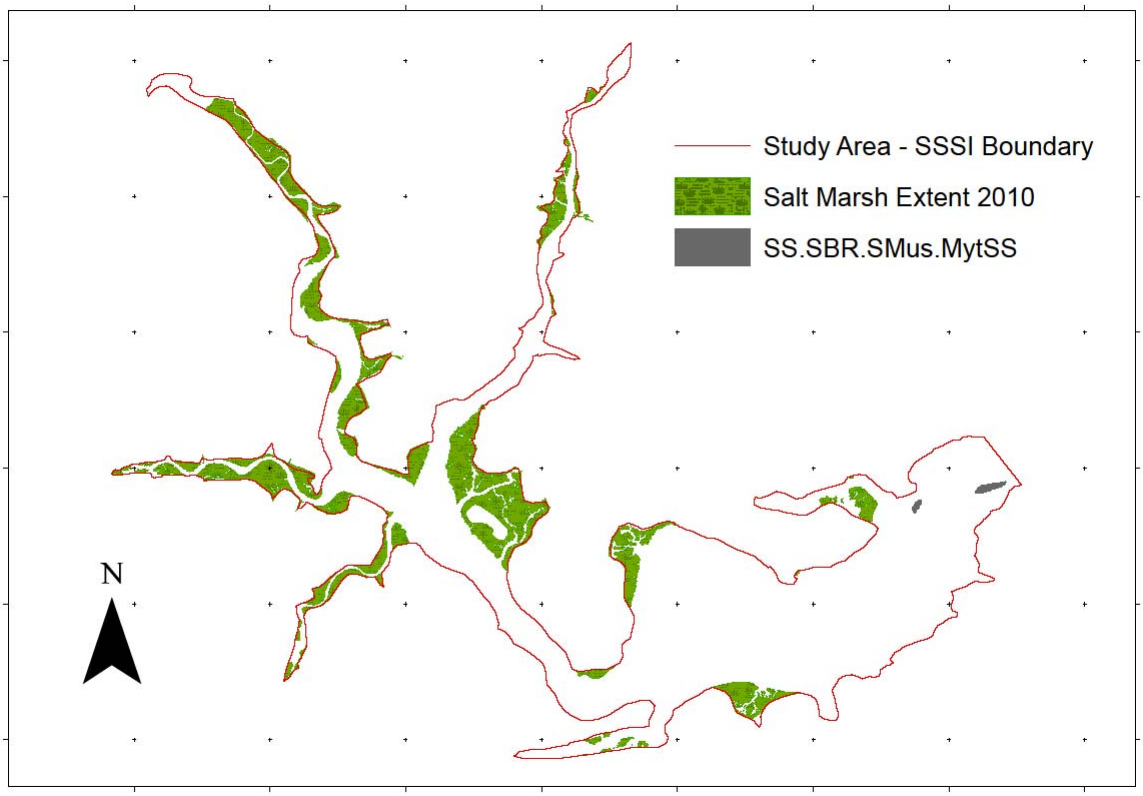
Field observations determined the sediment to be sandy mud. The fauna was dominated by abundant numbers of the polychaete *Hediste diversicolor*, no other species were observed and therefore further identification of the biotope was not possible.

The station characteristics correspond reasonably well with the LS.LMx.GvMu.HedMx biotope described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05), the only deviation being the faunal component where no species other than *Hediste diversicolor* were observed.

3.5.9 SS.SBR.SMus.MytSS

This biotope occurs in the lower reaches of the Lynher Estuary SSSI, and is only exposed by the tide during extreme low water springs hence the assignment of a subtidal biotope.

Figure 14. Extent and distribution of SS.SBR.SMus.MytSS (Graticules represent 1km^2)



The fauna was dominated by *Mytilus edulis* with frequent presence of the native oyster *Ostrea edulis*. Significantly in terms of notable species within the Lynher SSSI, *Ostrea edulis* is a UK National and Local Biodiversity Action Plan (BAP) species. Other species present include Crepidula fornicata, orange and green sponges and anemones.

The biotope fits reasonably well with the SS.SBR.SMus.MytSS biotope described in The Marine Habitat Classification for Britain and Ireland (Vs 04.05), though many of the species listed within the description were not observed; this is thought to be because relatively few records are available for the biotope.

3.5.10 Littoral Rock Biotopes

The littoral rock biotopes (LR.LLR.FVSFvesVS, LR.LLR.FVS.FspiVS, LR.FLR.LicYG, LR.LLR.FVS.PelVS, LR.LLRFVS.AscVS) are restricted to the higher energy more exposed environments of the mid and lower stretches of the Lynher Estuary SSSI.

Figure 15. Extent and distribution of littoral rock biotopes (Graticules represent 1km^2)

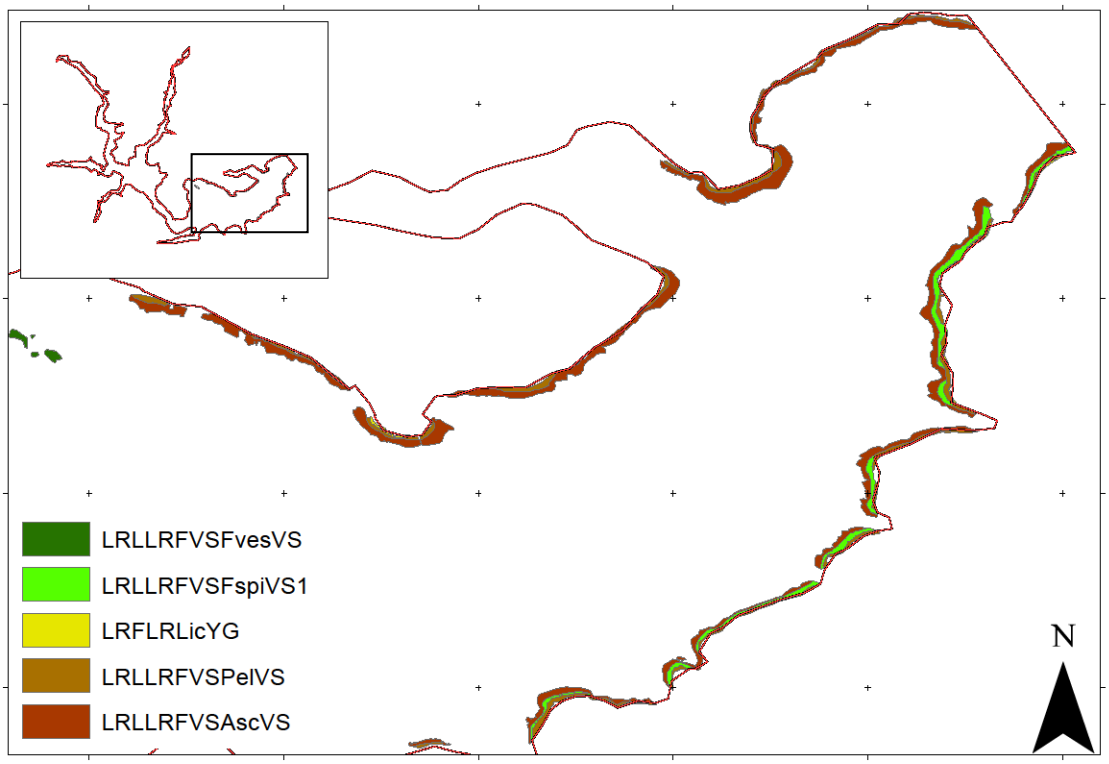


Figure 16. Distribution and extent of littoral rock biotopes (Graticule represents 1km^2)

The rock biotopes all correspond well with those described within The Marine Habitat Classification for Britain and Ireland (Vs 04.05).

4. Univariate and Multivariate Analysis

The results of the univariate analysis have been incorporated into the relevant chapters in Section 3 above.

Community analysis in PRIMER[17] used the multi-variate Bray-Curtis similarity statistic and multidimensional scaling (MDS) plots to assess the communities at each target station. MDS plots represent the sample points in three dimensions where the distances between points represent the dissimilarities 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.

The MDS output in figures 17 and 18 below represent the replicate cores from all biotopes in which more than one replicate was taken (the plot therefore excludes those biotopes of limited size and/or distribution, as well as rock biotopes).

Figure 17. Three dimensional MDS plot

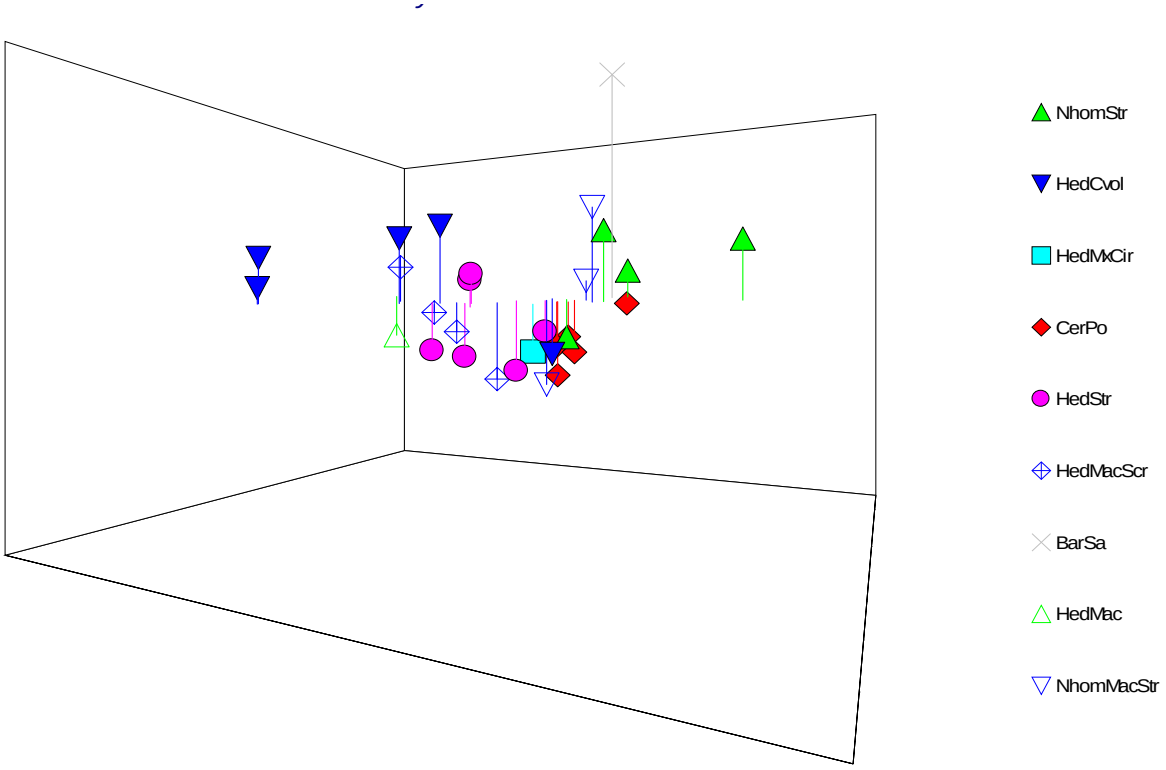
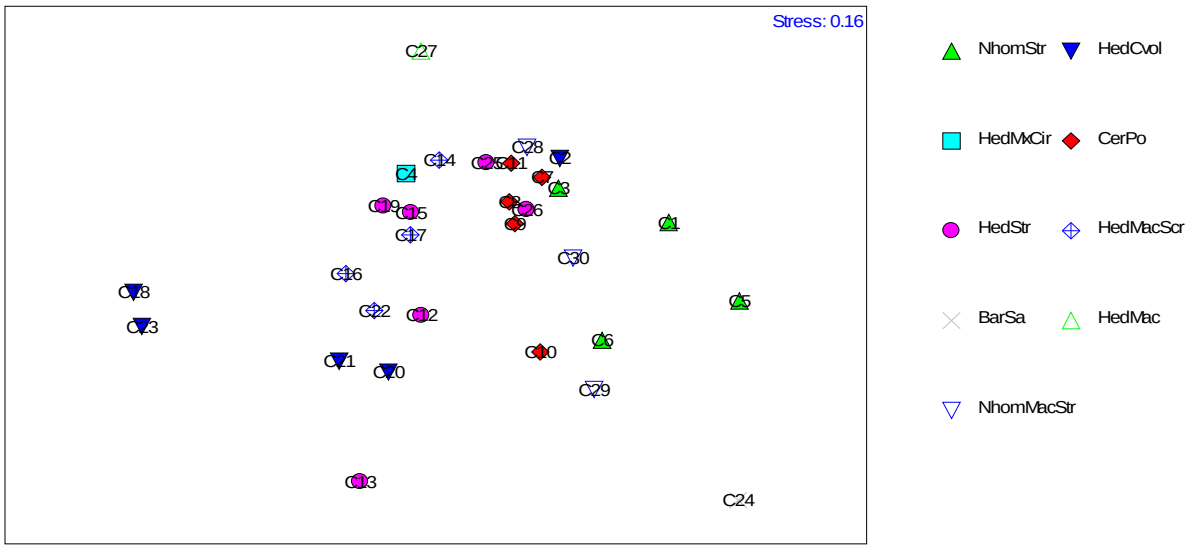


Figure 18. Two dimensional MDS plot



The plots demonstrate a reasonably good similarity and therefore grouping of replicates from the same biotopes. Some biotopes do however demonstrate better Bray-Curtis similarity values than others. The LS.LSa.MuSa.CerPo biotope for example has the highest Bray-Curtis value of 52.76%, whilst the LS.LMu.Uest.HedCvol biotope has the lowest value at 33.43%.

The weaker similarities observed within the LS.LMu.Uest.HedCvol biotope replicates may be associated with the fact that the biotope is widely distributed throughout the estuary, whilst LS.LSa.MuSa.CerPo is limited to one isolated location.

5. Discussion

5.1 Condition Assessment

5.1.1 Saltmarsh

In terms of condition assessment of the Saltmarsh, many of the site-specific standards that are intended for defining favourable condition of the Saltmarsh in the Lynher Estuary SSSI[4] were not within the scope of this study i.e. width of vegetation zones, vegetation structure and composition. These aspects of condition assessment are being carried out independently by Natural England.

The Saltmarsh habitat extent objectives were however within the scope of this study. Field observations determined that no saltmarsh accretion was occurring obviously anywhere within the Lynher. Erosion however was apparent, indicated by undercut, steeply sloping or exposed sediment banks bordering the Saltmarsh at numerous points throughout the estuary. The extent of such erosion was not at a scale which was detectable when compared to the Coastal Observatory aerial photography from the 2007 survey using DGPS, and therefore it is difficult to discern whether the 1% threshold of loss in extent has occurred since 2007.

However, importantly with respect to condition assessment, the cause of erosion is not thought to be due to significant anthropogenic influence as boat activity, tracks/access points or trampling was not observed. Instead, natural change is thought to be responsible for the effects of erosion. The dynamic nature of physical processes within estuarine systems (including wave exposure, riverine floods, tidal surges or storm events), including those within the Lynher, means that the gross distribution of habitats can be expected to change over time naturally to some extent.

Therefore, given that natural process are thought to be the primary cause of erosion of the Saltmarsh, based on **habitat extent objectives only** the Saltmarsh within the Lynher Estuary SSSI is considered to be in a **favourable condition**.

5.1.2 Coastal Flats

Although a previous biotope survey was carried out in a portion of the Lynher Estuary SSSI in 2001, the methods used and focus of the survey was different to that carried out here. The 2001 survey primarily focused on the littoral rock biotopes rather than the littoral sediment biotopes (where access and observations were restricted by the methods used). Furthermore the 2001 survey did not incorporate a Phase II study and therefore was considerably less comprehensive that that which was carried out here. Consequently, the biotopes identified during the 2001 survey are somewhat different to those identified during this study. The differences observed are therefore suspected not to be representative of temporal changes but as a result of different survey methods and sampling efforts employed. As a result, in terms of condition assessment, comparison of the two studies is not considered to be a useful approach. Instead, professional judgment has been used based to determine the condition of the Lynher Estuary SSSI based on observations and information gathered during the survey. This study will however provide a comprehensive baseline which can be implemented within any future condition assessments.

In respect of the current condition of the interest features, the Lynher Estuary has been identified as moderately vulnerable to nutrient enrichment[8] and at least historically having a tendency towards being eutrophic[19]; observations made during the study, namely the presence of the green algae's *Ulvae* and *Enteromorphae* on both the north and south banks suggest that this is potentially still the case within the SSSI.

There is also some evidence of biological disturbance through the selective extraction of species, namely the presence of peeler crab traps at Warren point on the south bank, and observations of bait digging in Wivelscombe Lake. The extent of impacts from such activity is likely to be only minor, particularly as it is limited to one relatively small area; but the placing of crab traps on intertidal sediments may change sediment characteristics by affecting water and oxygen exchange and sedimentation rates [10]. The vulnerability of Plymouth Sound and its associated estuaries to peeler crab collection has been highlighted by previous studies[11,12].

There was no evidence of adverse anthropogenic impact within the Lynher Estuary SSSI in terms of:

- Removal of estuarine habitats
- Increased siltation of the estuary bed or intertidal communities
- Abrasion of the estuarine habitats
- Increased synthetic and/or non-synthetic toxic contamination
- Increases in turbidity

Despite the potentially negative influences within the Lynher Estuary SSSI from selective extraction of species, at present such activity is not thought to be at a scale which threatens the overall condition of the intertidal designated features of interest. As such the Lynher Estuary SSSI coastal flats are deemed to be in a **favourable condition**.

5.2 Notable Biotopes and Communities

None of the littoral sediment or littoral rock biotopes identified within the Lynher estuary SSSI can be considered rare on a national or local scale, nor do they appear to be particularly good examples of their type or offer unusual features of conservation interest. The importance lies in the provision of invertebrates for the internationally and nationally aggregations of non-breeding birds including the Black Tailed Godwit (*Limosa limosa*).

One community of a notable species does exist within the Lynher estuary SSSI however, that is the Native Oytster *Ostrea edulis* which is a UK National and Local BAP species. The National and Local BAP targets for *Ostrea edulis* include:

T1 Maintain the existing geographical distribution of the native oyster within UK inshore waters.
T2 Expand the existing geographical distribution of the native oyster within UK inshore waters, where biologically feasible.
T3 Maintain the existing abundance of the native oyster within UK inshore waters.
T4 Increase the abundance of the native oyster within UK inshore waters, where biologically feasible.

5.3 Application of Biotope Methods

A degree of infaunal community variation both between replicates, and between the replicates and the communities described as characteristic for the biotope was observed for all biotopes. These 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[20] (i.e. salinity, wave exposure, carbon matter, nutrient input and pollution), highlighting some of the weaknesses of biotope mapping. However, variations are likely to also be attributable to the presence of transitional areas between biotopes.

5.4 Recommendations

Given the ambiguity associated with biotopes within the Lynher Estuary SSSI in terms of their fitting with those outlined in The Marine Habitat Classification for Britain and Ireland (Vs 04.05), it is suggested that in future condition assessments, where finance permits, more qualitative faunal assessment should be carried out within each biotope.

By implementing these recommendations it is considered that a more comprehensive, statistically sound qualitative assessment of the designated interest features can be made. Results from such studies would provide a better foundation from which to base scientifically robust conclusions regarding any temporal changes that may observed in the future, whether positive or negative in terms of conservation targets.

6. Glossary

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).
Multi-variate	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
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
Uni-variate	Statistics that describe the fauna in terms of a single number
Wentworth scale	Recognised 12 band scale of sediment particle size

References

[1]Natural England (1991). Citation: Site Name: Tamar-Tavy Estuary http://www.sssi.naturalengland.org.uk/citation/citation_photo/1005917.pdf

[2]JNCC (2004)Common Standards Monitoring Guidance for Littoral Sediment Habitats http://www.jncc.gov.uk/PDF/CSM_marine_littoral_sediment.pdf

[3]Anon. (1998). A Statement on Common Standards Monitoring. Peterborough: JNCC.

[4]Natural England (2010). Conservation Objectives: Lynher Estuary SSSI v2. Truro: Natural England.

[5]Bunker, F. & Bunker, A. R. (2001). Biotope survey of the intertidal of Plymouth Sound and Estuaries European Marine Site. A report to the Natural England from MarineSeen.

[6]Environment Agency (2009). Tamar Shellfish Water pollution Reduction Plan. Tidal Waters Report.

[7]Parr, W., & Wheeler, M., (1996) Trends in nutrient enrichment of Sensitive Marine Areas in England, Report to English Nature from the Water Resources Council (WRc Report No. C04055/1)

[8]Connolly, K., Hudson. R., P., Jonas (2004) Plymouth Sound and Estuaries cSAC / Tamar Estuaries Complex SPA: Tidal Waters Assessment. Environment Agency Report

[9]Environment Agency (2004). Plymouth Sound and Estuaries Tidal Waters Quality Report No: TWQ/96/07

[10]Natural England (2000) Plymouth Sound and Estuaries European Marine Site English Nature's advice given under Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations 1994. Natural England Report

[11]Godden, N., (1995) Crab trapping in the south Devon Estuaries (Primarily around Plymouth). Honors project Plymouth University Institute of Marine Studies, unpublished.

[12]Fowler, S., (1999) Guidelines for managing the collection of bait and other shoreline animals within UK marine Special Areas of Conservation. The Nature Conservation Bureau Ltd, Newbury (UK Marine SACs Project)

[13]Cornwall Rivers Project (No date). River catchments Lynher and Tiddy. http://www.cornwallriversproject.org.uk/geography/lynher.htm

[14]Bunting. B., Hancock. W., Prince. E., & Pennington J. (2004) Plymouth Sound and Estuaries cSAC / Tamar Estuaries Complex SPA Habitats Directive Stage 3 Water Resources Assessment - Version 6. Environment Agency Report.

[15]Channel Coastal Observatory (2007). Map viewer and data catalogue. http://www.channelcoast.org/data_management/online_data_catalogue/

[16]International Organisation for Standardisation (2005) ISO 16665:2005 Water quality - Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna. http://www.iso.org/iso/catalogue_detail.htm?csnumber=32348

[17]Clarke, K., and Warwick, R.M., (1994). Change in marine communities: an approach to statistical analysis and interpretation. 2nd edition, NERC, UK.

[18]Rhoads D C (1974). Organism-sediment relations on the muddy sea floor. Annual Reviews. Oceanogr. & Mar. Biol., 12, 263-300.

[19] Stephens, J., Uncles, R., Barton, M., Fitzpatrick, F. (1992). Bulk properties of intertidal sediments in a muddy, macrotidal estuary. Marine Geology 103: 445-460

[20]Ducrotoy, J., (2010) The use of biotopes in assessing the environmental quality if tidal estuaries in Europe. Estuarine, Coastal and Shelf Science 86: 317-321

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