South West of England Regional Development Agency

Wave Hub

Appendix F to the Environmental Statement

June 2006

Halcrow

South West *of* England
Regional Development Agency

Wave Hub

Intertidal Studies

Final Report

October 2005
Report No. 03/J/1/03/0775/0503

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EXECUTIVE SUMMARY

A survey of the intertidal areas of Hayle Beach, North Cornwall was undertaken by Emu Ltd on behalf of Halcrow. The study was required as part of the planning issues required for the proposed development of a Wave Hub off the north Cornwall coast.

The aim of the study was to establish an ecological baseline of the biological communities of the intertidal area within the proposed corridor for the wave hub cable, against which any impacts resulting from the installation of the cable can be assessed.

The surveys comprised core sampling of the intertidal sediment along three transects within the proposed corridor for the hub cable and Phase I biotope mapping of the area within and peripheral to the proposed corridor. The methods employed for the intertidal biotope mapping were based on Marine Nature Conservation Review techniques. Full species lists together with ecological and physical observations and photographic records were also compiled.

The biotope "Barren or amphipods dominated mobile sand shores", code: **LS.LSa.MoSa**, was characteristic of the sandy beach extending from the dune/cliff to the low water mark. The biotope is typical of sandy areas characterised by high energy hydrodynamic regime. This causes accumulation of sandy substrate although is subject to redistribution by waves, tides and currents. Analysis of the core samples revealed a fauna comprising crustaceans (*Eurydice pulchra, Pontocrates arenarius*), polychaetes (*Ampharete lindstroemi*, Glyceridae sp, *Lumbrineris gracilis*, *Nephtys cirrosa, Nephtyis* sp), molluscs (Copepoda sp), echinoderms (*Amphiura* sp) and spring-tail insects (*Collembola* sp). Overall, the site showed an impoverished benthic community with ten species of invertebrates being recorded across the sampling stations in the present study. Some of these species can provide species prey for waders, wildfowl and marine predators such as fish.

Additional biotopes included: "*Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock", code: **LR.LLR.F.FvesFS,** recorded within an outcrop of fucoid population to the west of the survey area, at the mouth of the estuary.

Biotopes recorded on the bedrock cliff were typical of exposed rocky shores. An upper-shore band of yellow and grey lichens (biotope: Yellow and Grey lichens on supra-littoral rock, code: **LR.FLR.Lic.YG**) was recorded along the whole length of the cliff. Below this a band of *Verrucaria* (biotope "*Verrucaria maura* on very exposed to very sheltered upper eulittoral fringe rock" code: **LLR.FLR.Lic.VerVer**) occurred.

The presence of barnacle (biotope:*Chthamalus montagui* and *Chthamalus stellatus* on exposed upper eulittoral rock, code: **LR.HLR.MusB.ChtCht**), mussel (biotope: *Mytilus edulis* and barnacles on very exposed eulittoral rock **LR.HLR.MusB.MytB** code) and fucoid communities (biotope:*Fucus spiralis* on full salinity exposed to moderately exposed upper eulittoral, code: **LR.MLR.BF.FspiB**) was found to be discontinuous along the cliff and seemed dictated by the presence of continuously moist cracks/fissures in the rock as well as horizontal ledges which provided shelter from sand scouring thus allowing the establishment of such communities.

Green algae dominated upper shore rock pools (Green seaweeds (*Enteromorpha* spp and *Cladophora* spp.) in shallow upper-shore, code: **LR.FLR.Rkp.G**) occurred in depression within the ledges and small intertidal caves within the cliff supported the biotopes (*Verrucaria mucosa* and /or *Hildenbrandia rubra* on upper to mid shore cave walls code: **LR.FLR.Cv.Ov.VmucHil** and *Audouinella purpurea* and *Pilinia maritima* crusts on upper and mid shore cave walls and ceilings, code: **LR.FLR.Cv.Ov.AudPil**

1.0 Introduction

1.1 Background

The South West Regional Development Agency (SWRDA) is seeking alternatives for renewable energy generation. Following review from Metoc, it was concluded that the north Cornwall coast has high potential for the generation of electricity from offshore wave power. The development of a Wave Hub off the north Cornwall coast has been designed in order to support and encourage developers of wave energy devices, allowing them to install and operate arrays of devices in commercial scale conditions, and to bring the related industrial development and benefits to the south west.

Hayle has been identified as a potential location for the development because it already has a suitable National Grid connection point situated very close to the coast and because there is a viable route for the cable that does not pass through any nationally designated sites. Hayle is located in the far south west of Cornwall just to the east of St Ives on the north coast.

Prior to the implementation of the project, ecological studies need to be conducted in order to gain baseline data of the present ecological status of the area against which any impacts deriving from the proposed scheme can be assessed. As part of this process, Emu Ltd was commissioned by Halcrow to undertake an intertidal survey of the onshore site, e.g. the site of the proposed cable corridor for the hub.

1.2 Objectives

The aims of the present study were to undertake core sampling of the intertidal sediment along transects, within the proposed cable route and a MNCR Phase I biotope mapping survey of the area within and peripheral to the proposed cable corridor. The study was designed to establish the current status of the intertidal biological communities within and peripheral to the proposed cable route, against which any changes following the implementation of the project can be assessed.

1.3 Survey dates

The intertidal survey was conducted on 12th and 13th March 2005 during spring low water tides to allow maximum access of the shore line.

2.0 Methodology

2.1 Field methods

2.1.1 Biotope mapping Phase I

Geo-referenced Ordnance Survey (OS) maps of the survey area were prepared at a scale of approximately 1:3,000 for field mapping purposes. Emu Ltd intertidal mapping recording forms were used in the field. These included polygon log form, waypoint log form, photo log form and a target note log form. The methodology employed followed the JNCC procedural guidelines for intertidal mapping (1.1, 3.1 and 3.2 in: Davies *et al*., 2001).

The position of boundaries of each intertidal polygon were gained by using a hand held GPS (Garmin 12XL), as well as distance and bearing from permanent visual markers on the shore, and plotted onto the field map. All GPS survey positions were derived in OSGB 36 Datum, with positions recorded in British National Grid format. Sketches of the shore were also made to aid mapping, where necessary. Polygon boundaries were identified by a change in the dominance or occurrence of conspicuous species or communities in combination with changes in physical characteristics of the habitat.

For each polygon the following information was noted:

- Physical characteristics, such as substrate type, presence/depth of anoxic layer, stability and topographic features (sand ripples, area of standing water, scouring etc.)
- Species present and their SACFOR abundances (Table 2.1)
- Detail of any anthropogenic activities observed to occur within the polygon
- Detail of specimen samples taken from sites within the polygon.

Each waypoint marked with the GPS was noted on the waypoint log form along with the following information:

- Waypoint number
- A description of what the way point represented
- The British National Grid easting and northing
- Any photo numbers associated with each waypoint

Digital photographs were taken during the survey, in order to illustrate the location of polygon boundaries in relation to adjacent polygons and features on the shore. Panoramic and close up frames of each habitat were also taken to aid data interpretation as well as to provide visual information on the condition of each habitat against which gross change may be assessed. The position of each photograph was determined using the GPS, distance and bearing from visual markers on the shore and recorded on the field map together with the following information:

- Photo number
- Direction of view
- Frame type (view, habitat, close-up)
- Date and description of the view

Target notes were made for polygons less than 5x5m (e.g. artificial substrates, pipelines, etc.) as well as for not mappable structure (e.g. vertical seawalls) and recorded in the target note log including the following information:

- Polygon number within each target note
- Size of target note feature and position

- Physical description
- Associated species

Qualitative dig-overs were carried out to assess substrate type and anoxic condition and to identify conspicuous sediment infauna *in-situ*. Flora and fauna were identified *in-situ* and their relative abundance estimated using the SACFOR scale. Where species could not be readily identified, specimens were collected for subsequent identification at Emu Laboratories.

2.1.2 Sediment coring

Prior to site visit, sampling stations were marked on the field map. Sampling stations were established to include upper-shore, mid-shore and lower shore sediment samples along three transects, perpendicular to the shore line and within the proposed area of the cable corridor. Samples were taken using a 11.3cm diameter stainless steel core at a depth of 15cm.

Triplicate faunal samples were undertaken at each sampling site with an additional core sample taken for particle size analysis (PSA). PSA samples were stored into labelled plastic bags and refrigerated at Emu's laboratories prior to analysis. The macrofaunal samples were stored into labelled plastic buckets and fixed in buffered 4% formal saline solution. All samples were returned to Emu Laboratories for registration and processing.

2.2 Laboratory methods

2.2.1 Particle Size Analysis

Particle size analysis (PSA) was undertaken at Emu Ltd's UKAS accredited Laboratory, employing Emu Ltd's In House Methods (MET/01) for the Determination of Particle Size Distribution (based on BS1377, part two; 1990), and Emu Ltd's In house methods for the determination of particle size distribution by Malvern Microsizer Laser Diffraction (MET/02). The latter method does not fall under UKAS accreditation.

2.2.2 Macrobenthic analysis

The current study focuses on macrofaunal and macro-floral communities only; meiofauna and micro-flora were not considered and were therefore excluded from the study. Prior to laboratory processing, the general stain, Rose Bengal, was add to each faunal core sample to aid the subsequent sorting process. The core samples were then gently sieved on a 0.5mm mesh size to remove fine sediment material, preservative and stain.

Biological material retained on the mesh was then sorted from the sediment by elutriation, with the remaining sediment sorted by hand under a stereo-microscope. Following sorting, residual sediment fractions were retained for quality control as detailed in Emu Ltd's (MET/07) for the processing and Analysis of Macro-invertebrate Samples (Emu Ltd, 1998b).

Macro-invertebrates from core samples were identified to species level, where possible and enumerated. All biological material was stored in 70% Industrial Methyladed Spirit (IMS). A faunal reference collection was prepared with individuals of all species identified retained. This will allow future checks on taxonomic classification to be made in assessing comparative monitoring data. Colonial sessile epifauna were identified to species level where possible and were recorded as presence/absence only. Emu Ltd. undertook Quality Control checks on a representative number of whole samples as well as the entire reference collection in compliance with internal analytical quality control criteria.

2.2.3 Biomass analysis

Biomass analysis was undertaken by Emu Ltd following identification and enumeration. The infauna from each sample was sorted into 5 groups (Polychaeta, Crustacea, Mollusca, Echinodermata and Others) and biomass analysis conducted using the wet blotted method. Infaunal taxa were weighted to constant weight (4 decimal places) on a tared balance. Subsequently, the appropriate standard corrections were applied to his data to provide equivalent dry weight biomass data (after Eletheriou & Basford, 1989) as detailed in Emu Ltd's In-house methods (MET/07) for the processing and analysis of macro invertebrate samples. (Emu Ltd. 1998b). The conversion factors applied are given below:

Polychaeta :	15.5%
Crustacea :	22.5%
Echinodermata :	8.0%
Mollusca :	8.5%
Others	15.5%.

2.3 Data analysis and interpretation

Upon return from field all field data (polygon boundaries, waypoints, photo and target note logs) were cross checked prior to data processing. All photographic images relating to species or habitat information were reviewed and cross checked with the field records to verify the *in-situ* species data and biotope assignation.

Following this, biotopes were assigned to all polygons identified and any biotopes assigned in the field were reviewed. Biotopes were assigned by reviewing biological images and written records (which were amended where appropriate with additional data from image review and the lab analysis of any hand collected specimens). Biotope classification followed that of Connor *et al* (2004). Where biotopes/features did not perfectly match those published, a description of the variation in the biotope has been provided.

The data set from the core sampling was subject to a series of univariate community structure measures. These included Margalef's index of Richness, Pielou's Eveness index, the Shannon-Weiener Diversity index and Simpson's index of Dominance. Richness is a measure of the number of species present relative to the number of individuals, evenness is a measure of species dominance and diversity is a measure of the distribution of individuals between species. Full methods for the application of the univariate analysis are given in Clarke and Warwick (1994)

2.3.2 Map production

All geographic data collected in the field was converted into a digital format MapInfo 7.5. Polygons boundaries were digitised on screen over the top of the geo-referenced Ordnance Survey Landline data. Maps, indicating biotope code/s recorded within each polygon were produced at a scale of 1: 1,000.

Table 2.1 Abundance Scale used for both Littoral and Sublittoral Taxa from 1990 Onwards.

Growth Form			Size of individuals/colonies				
%cover	**Crust/Meadow**	**Massive/Turf**	**<1cm**	**1-3cm**	**3-15cm**	**>15cm**	**Density**
>80%	S		S				>1/0.001m^2
40-79%	A	S	A	S			1-9/0.001m^2
20-39%	C	A	C	A	S		1-9/0.01 m^2
10-19%	F	C	F	C	A	S	1-9/.0.1 m^2
5-9%	O	F	O	F	C	A	1-9/ m^2
1-5%	R	O	R	O	F	C	1-9/10 m^2
<1% density		R		R	O	F	1-9/100 m^2
					R	O	1-9/1000 m^2
						R	<1/1000 m^2

Key: S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare
P = present (Used when the abundance of an organism could not be estimated accurately

3.0 Results

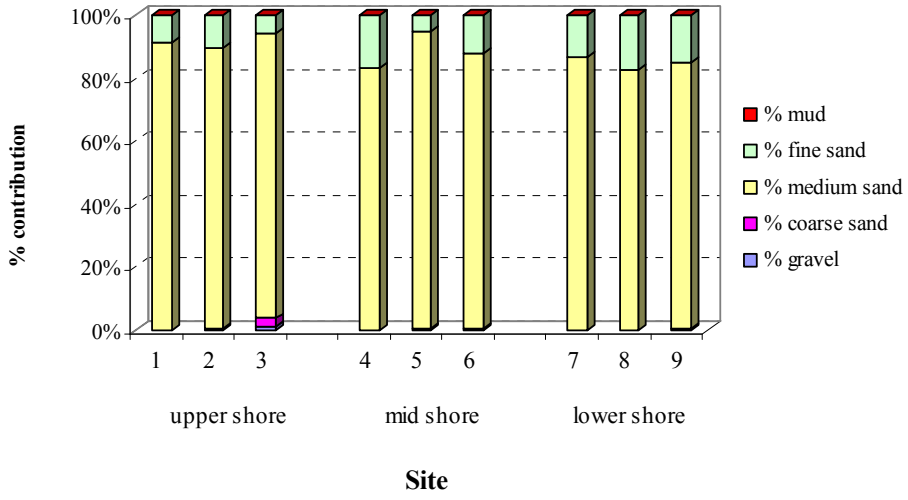
Results of the present study are presented and discussed in conjunction with the physical (PSA analysis) and biological (macrobenthic analysis) characteristics of the survey area as well as the description and extent of biotopes within the survey area (see Figure 3.3).

3.1 Particle Size Analysis

Full results from PSA analysis are presented in Appendix VII

Figure 3.1 shows a summary of the main sediment fractions characterising the upper- mid and lower shore.

Figure 3.1 Particle size distribution of sediment from sampling stations



Results from the PSA analysis showed that sand constituted the greatest percentage of sediment at all sites. Specifically, medium sand (grain size between 0.25 and 1mm) accounted for over 80% of the sediment at all sites, with coarse sand accounting for less than 3% at core site 3. Mud represented a negligible fraction of the sediment at all sites (all values ≤0.03%). Figure 3.1 shows the particle size distribution of sediment across the sampling stations.

3.2 Macrobenthic analysis

A complete species list of invertebrates is presented in Appendix V

Table 3.1 presents the results of the univariate analysis undertaken on the fauna data set from the core samples and Figure 3.2 shows the macro-fauna distribution across the sampling stations.

Average abundances per square metre of individual species per site are given in Table 3.2.

The biomass (as wet weight per square meter) of the main taxonomic groups of macrobenthic fauna is presented in Table 3.3. Raw data of biomass is presented in Appendix VI

Table 3.1 Results of Univariate Analysis of macro-fauna from core samples

	Site	No of species	No of Individuals	Species richness	Eveness	Shannon-Wiener	Simpson
Upper shore	1a	1	1	-	-	-	-
	1b	0	0	-	-	-	-
	1c	0	0	-	-	-	-
	2a	0	0	-	-	-	-
	2b	0	0	-	-	-	-
	2c	0	0	-	-	-	-
	3a	0	0	-	-	-	-
	3b	0	0	-	-	-	-
	3c	0	0	-	-	-	-
Mid shore	4a	0	0	-	-	-	-
	4b	5	9	1.82	0.89	1.4	0.8
	4c	0	0	-	-	-	-
	5a	0	0	-	-	-	-
	5b	0	0	-	-	-	-
	5c	0	0	-	-	-	-
	6a	1	1	-	-	-	-
	6b	0	0	-	-	-	-
	6c	0	0	-	-	-	-
Low shore	7a	1	1	-	-	-	-
	7b	1	1	-	-	-	-
	7c	2	2	1.44	1	0.69	1
	8a	1	1	-	-	-	-
	8b	1	1	-	-	-	-
	8c	0	0	-	-	-	-
	9a	0	0	-	-	-	-
	9b	2	4	0.72	0.81	0.56	0.5
	9c	2	2	1.44	1	0.69	1

Ten species of invertebrates were recorded across the sampling stations in the present study, including 5 species of polychaetes (*Ampharete lindstroemi*, Glyceridae sp, *Lumbrineris gracilis*, *Nephtys cirrosa* and *Nephtyis* sp), 2 species of crustaceans (*Eurydice pulchra* and *Pontocrates arenarius*), molluscs (Copepoda sp), echinoderms (*Amphiura* sp) and spring-tail insect (*Collembola* sp).

Figure 3.2 shows the number of species and individuals recorded by core sampling at individual sites.

The upper shore sites supported no marine infauna, the only invertebrate recorded at core site 1 being a species of spring tail insect (Collembola).

Of the mid shore sites only replicate b from core sites 4 supported macrobenthic fauna. Fauna recorded included 4 species of polychaetes (*Nephtys* sp, *Lumbrineris gracilis*, *Glyceridae* sp, *Ampharete lindstroemi*) and 1 species of echinoderm (*Amphiura* sp). A spring tail insect (Collembola) was the only other invertebrate recorded at core site 6.

The highest number of species and individuals was recorded across the low shore site, which accounted for a total of 4 species and 12 individuals. Crustaceans were numerically dominant, with *Pontocrates arenarius* occurring at all three sites and *Eurydice pulcra* recorded at core site 9, the latter also accounting for species of Copepoda. The polychaete *Nephthys cirrosa* was recorded at 2 sites.

Figure 3.2 Macrofauna distribution from sampling stations

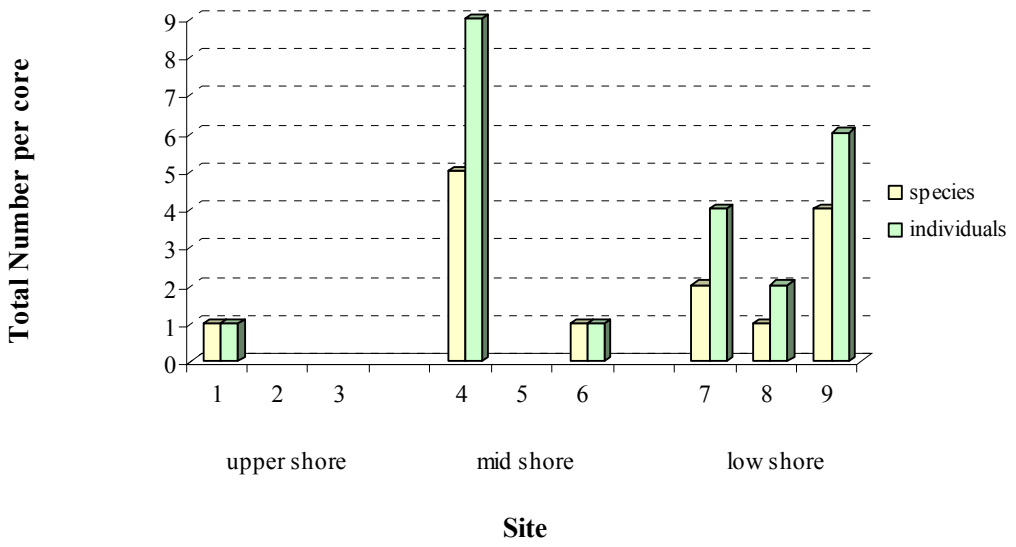


Table 3.2 Average abundance (/m^2) of invertebrate species from sampling stations

Location	Upper shore			Mid shore			Low shore		
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Species Name	**Abundance /m^2**								
Ampharete lindstroemi	0	0	0	66.7	0	0	0	0	0
Amphiura sp. indet.	0	0	0	33.3	0	0	0	0	0
Collembola	33.3	0	0	0	0	33.3	0	0	0
Copepoda	0	0	0	0	0	0	0	0	33.3
Eurydice pulchra	0	0	0	0	0	0	0	0	1
Glyceridae sp. indet. (juv.)	0	0	0	33.3	0	0	0	0	0
Lumbrineris gracilis	0	0	0	33.3	0	0	0	0	0
Nephtys cirrosa	0	0	0	0	0	0	33.3	0	33.3
Nephtys sp. indet. (juv.)	0	0	0	133	0	0	0	0	0
Pontocrates arenarius	0	0	0	0	0	0	100	66.7	33.3

Table 3.3 Biomass (wet weight/m^2) of the main taxonomic groups of macrobenthic fauna from core sites

Location	Mid shore			Low shore								
Site	**4a**	**4b**	**4c**	**7a**	**7b**	**7c**	**8a**	**8b**	**8c**	**9a**	**9b**	**9c**
Species Name	**Biomass Wet weight (g)/m^2**											
Polychaeta	-	0.288	-	-	-	0.011	-	-	-	-	0.21	-
Crustacea	-	-	-	0.014	0.011	0.007	0.009	0.020	-	-	0.158	-
Echinodermata	-	0.029	-	-	-	-	-	-	-	-	-	-
Insecta	-	-	-	-	-	-	-	-	-	-	-	-
Total		**0.317**		**0.014**	**0.011**	**0.018**	**0.009**	**0.020**			**0.365**	

Correlation analysis was undertaken using the Pearson's correlation coefficient in order to identify relationships between physical and biological variables within the data set derived from the survey.

Results are given in Table 3.4

Table 3.4 Correlation analysis between physical and biological variables.

	% gravel	% coarse sand	% medium sand	% fine sand	total species	total individual
% gravel	1					
% coarse sand	**0.7953**	1				
% medium sand	0.3130	0.3147	1			
% fine sand	-0.5131	-0.5312	-0.9695	1		
% mud	-0.0090	-0.1082	-0.5072	0.4670		
total species	-0.4985	-0.3038	**-0.6918**	**0.7123**	1	
total individual	-0.4859	-0.2913	**-0.7178**	**0.7320**	**0.9860**	1

r=0.5822 @ p<0.10; **r=0.6664 @ p<0.05;** r=0.7498 @ p<0.02; r=0.7977 @ p<0.01; r=0.8982 @p<0.001

Results show a strong positive correlation between the percentage of medium and fine sand and the total number of species and individuals. However, given the small number of total species and individuals, results of the correlation analysis are of little significance.

3.3 Biotope mapping

Hayle Estuary lies at the southern most part of St Ives Bay in Cornwall and is regarded as one of the most beautiful bays, boasting some 3 miles of golden beach.

The survey area included the intertidal shore to the east of the estuary, extending from the Caves (westernmost boundary) (Table 3.7 Photos 1 & 2) to approximately 500m to the east of Black Cliff (eastern most boundary) (Table 3.7 Photos 3 & 4).

The width of the beach varied approximately from 800m at the mouth of the estuary to 350m at the eastern boundary of the survey area. Here the upper-shore beach met a steep-near vertical bedrock cliff (Photo 5) which extended for ca 500m to the west before giving way to sand dunes (Table 3.7 Photo 6).

Figure 3.3 illustrates the results from the biotope mapping exercise. The sampling stations are highlighted on the map.

A list of Biotopes identified in the present study is presented in Table 3.5

Table 3.5 List of Biotopes identified at Hayle Estuary and beach

	Biotope Code	Biotope name	Importance (From MarLIN) (www.marlin.ac.uk)
Littoral Sediment Biotopes	**LS.LSa.MoSa**	Barren or amphipods dominated mobile sand shores	National Importance: Common Listed under: UK Biodiversity Action Plan EU Habitat Directive (Annex 1 feature)
Littoral Rock Biotopes	**LLR.FLR.Lic.YG**	Yellow and Grey lichens on supra-littoral rock.	National Importance: widespread Listed under: UK Biodiversity Action Plan EU Habitat Directive (Annex 1 feature)
	LLR.FLR.Lic.VerVer	*Verrucaria maura* on very exposed to very sheltered upper eulittoral fringe rock	Not available
	LR.HLR.MusB.ChtCht	*Chthamalus montagui* and *Chthamalus stellatus* on exposed upper eulittoral rock	National Importance: widespread Listed under: UK Biodiversity Action Plan EU Habitat Directive (Annex 1 feature)
	LR.HLR.MusB.MytB	*Mytilus edulis* and barnacles on very exposed eulittoral rock	National Importance: widespread Listed under: UK Biodiversity Action Plan EU Habitat Directive (Annex 1 feature)
	LR.MLR.BF.FspiB	*Fucus spiralis* on full salinity exposed to moderately exposed upper eulittoral	National Importance: widespread Listed under: UK Biodiversity Action Plan EU Habitat Directive
	LR.FLR.Rkp.G	Green seaweeds (*Enteromorpha* spp and *Cladophora* spp) in shallow upper-shore rock pools	National Importance: widespread Listed under: UK Biodiversity Action Plan EU Habitat Directive (Annex 1 feature)
	LR.LLR.F.FvesFS	*Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock	National Importance: widespread Listed under: UK Biodiversity Action Plan EU Habitat Directive
	LR.FLR.Cv.Ov.VmucHil	*Verrucaria mucosa* and /or *Hildenbrandia rubra* on upper to mid shore cave walls	Not available
	LR.FLR.Cv.Ov.AudPil	*Audouinella purpurea* and *Pilinia maritima* crusts on upper and mid shore cave walls and ceilings	Not available

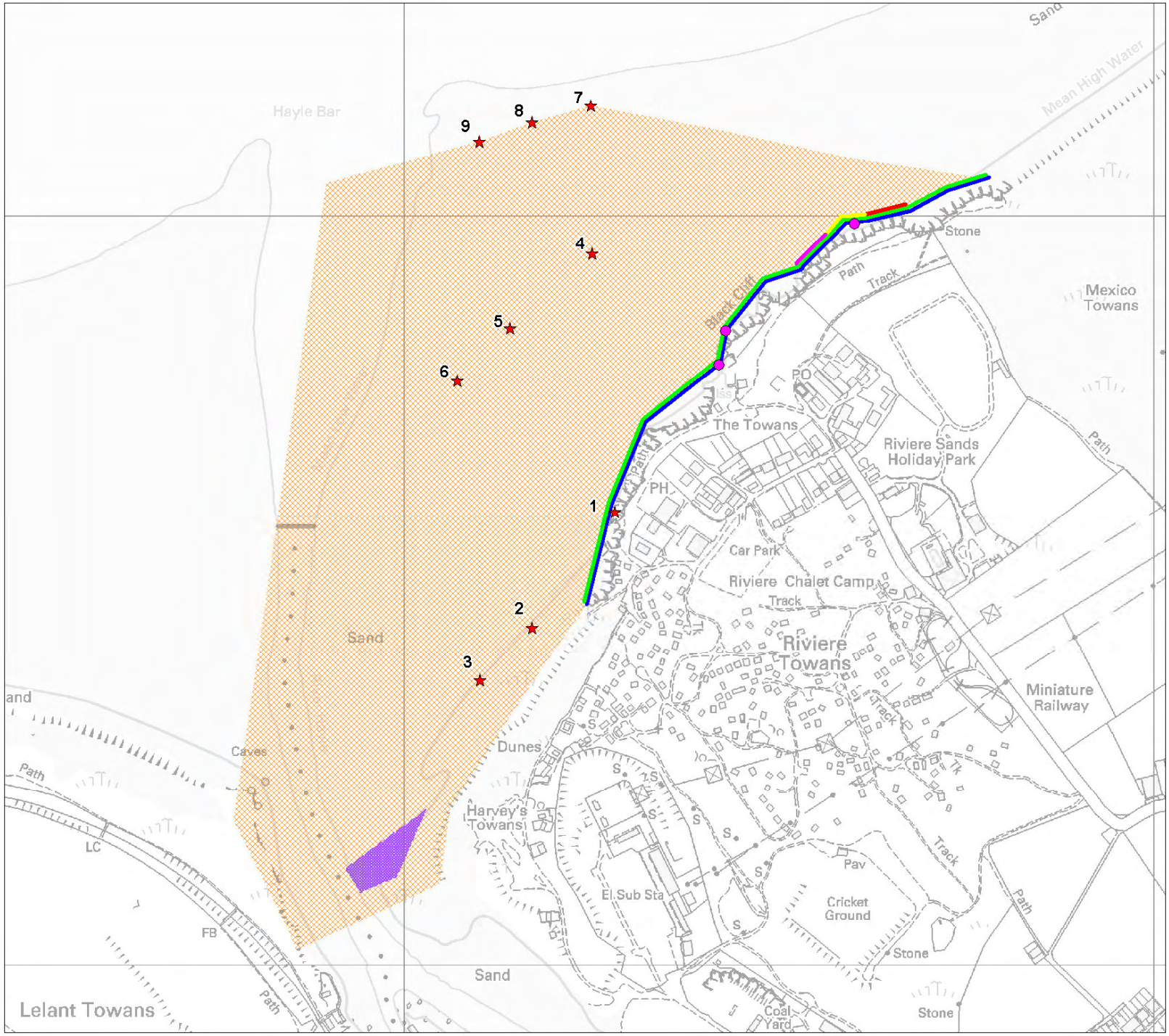


Figure 3.3

Biotope Map of the Study Area

Legend:

- Target Note
- Sampling Point
- Biotope LS.LSa.MoSa
- Biotope LR.LLR.FvesFS
- Biotope LLR.FLR.Lic.YG
- Biotope LLR.FLR.Lic.VerVer
- Biotope LR.HLR.MusB.Cht.Cht
- Biotope LR.HLR.MusB.MytB
  Biotope LR.HLR.MusB.ChtCht
- Biotope LR.MLR.BF.FspiB
  Biotope LR.FLR.Rkp.G

Scale:

0 100 200

metres

Datum: OSGB 36

Job No. J/1/03/0775

Wave Hub Intertidal

Emu Ltd
1, Mill Court
The Sawmills
Durley
Hampshire
SO32 2EJ

The intertidal area comprised an extensive sandy beach with no evident boundaries between upper-mid and lower shore (polygon 1). No obvious biota was present (e.g. burrows, casts) and on site dig overs revealed no anoxic layer, nor change in sediment type below the surface. Such habitat is typical of the biotope **LS.LSa.MoSa** characterised by clean mobile sand, with little very fine sand and no mud present. The sands were not cohesive with little water retention.

The upper-shore was characterised by dry compact sand delimited by sand dunes or bedrock. Scattered stranded seaweeds were present on the upper-shore at the time of the survey but were not considered to constitute a real strandline (Table 3.7 Photo 7). No marine infauna was recorded from the upper-shore cores, a species Collembola being the only individual present.

Moving to the mid shore, the sand became more wet and rippled (Table 3.7 Photo 8). Analysis of the core samples revealed an infauna comprising mainly polychaetes.

The low shore was characterised by very wet sand and deep ripples (Table 3.7 Photo 9). The bivalve mollusc *Spisula solida* was recorded *in situ* on the eastern edge of the estuary, and analysis of the core samples revealed a macro-fauna comprising mainly crustaceans (*Pontocrates arenarius* and *Eurydice pulchra*). Copepods and polychaetes (*Nephtys cirrosa*) were also recorded but in low number.

A fucoid community was recorded on the eastern edge of the estuary at the western boundary of the survey area (polygon 7). The substrate was represented by patches of pebbles, cobbles and boulders overlying sand (Table 3.7 Photo 10). The sand was "sinking" in places, feeling like quick sand under foot. The biotope **LR.LLR.F.FvesFS** was recorded on boulders and cobbles which supported dense population of *Fucus vesiculosus* and *F. vesiculosus* var. *linerais* (Table 3.7 Photo 11). The green alga *Enteromorpha* sp. was also recorded in low abundances (P) and scattered plants of *F. serratus* (P) and *Chondrus crispus* (P) occurred at the edge of the estuary (Table 3.7 Photo 12). Under-storey fauna included limpets (*Patella vulgata*), barnacles (*Balanus crenatus*, *Elminius modestus*), peri-winkles (*Littorina obtusata*) and crustacean *(Carcinus maenas*). The whole area appeared as a raised platform at the mouth of the estuary, therefore fairly current swept. As a consequence, the surrounding sand appeared dimpled with dimples inter-connected via small channels with permanent tidal flow (Table 3.7 Photos 13). Flora recorded in such channels included red (*Polysiphonia denudata*, *Ceramium rubrum*, *C. shuttleworthianum*, *Gelidium pusillum*) and brown (*Hincksia granulosa*, *Schytosiphon lomentaria*, *Laminaria saccharina*) algae, typical of this habitat. Visible fauna on the sandy sediment included the polychaetes *Pomatoceros* sp. and *Lanice conchilega*. Due to the limited extent of the channels, they were not considered to constitute a separate biotope in this study.

The bedrock cliff extended vertically to meet the terrestrial vegetation (Table 3.7 Photo 14). The vertical extent of each biotope on the cliff was not measured, and the description and extent of each biotope identified on the bedrock cliff during the survey is presented in this report taking into account only the horizontal extent moving from east to west within the survey area.

Yellow and grey lichens (**LLR.FLR.Lic.YG**) were present on the supra-littoral zone across the entire length of the cliff (Table 3.7 Photo 15). Species composition within the biotope was not assessed as the biotope occurred too high up on the cliff. Beneath this band the biotope **LLR.FLR.Lic.VerVer** occurred, comprising the lichens *Verrucaria mucosa* and *V. maura*. The crustose red alga *Hildenbrandia* sp occurred within damp cracks of the rock surface. These biotopes were the only ones present at the easternmost end of the bedrock cliff and run across the whole length of the cliff.

Moving west from the eastern boundary of the survey area, the bedrock cliff gave way to a little cove within which boulders “sliding” from the top of the cliff met the ground (Table 3.7 Photo 16). No biota was recorded on the boulders, stranded seaweeds and remains of fishing nets were recorded in gaps between the boulders.

To the west of the "boulders slide" the biotope **LR.HLR.MusB.Cht.Cht** was recorded as the lowest biotope on the cliff face at the boundary with polygon 1 (Table 3.7 Photo 17). The biotope was characterised by barnacles (*Chthamalus montagui* which was the dominant species, *Elminius modestus* and *Balanus crenatus*). Littorinids (*Littorina neritoides* and *L. saxatilis*) and the red alga *Catenella caespitosa* occurred in moist crevices. The lichens *Verrucaria maura* and *V. mucosa* occurred beneath the barnacles.

Scattered fucoid communities were found within an area (ca 5x4m) of uneven stepped ledges in the bedrock. *Fucus spiralis* occurred on the horizontal upper ledges (ca 1m above the ground) and constituted the biotope **LR.MLR.BF.FspiB.** *F. vesiculosus* was recorded on the lower ledges, within the sand. Due to the sparseness of the algae and their limited extent, the *F. vesiculosus* community was not considered to constitute a separate biotope. Due to the strong sand scouring this community is likely to be a transient feature of the shore line. The vertical sides of the ledges hosted a mosaic of the biotopes **LR.HLR.MusB.Cht.Cht** and **LR.HLR.MusB.MytB**, the latter, characterised by the mussel *Mytilis edulis*, was found in moist gaps and corners (Table 3.7 Photo 18). Along the cliff, the biotope **LR.HLR.MusB.MytB** occurred in corners, gaps and fissures, usually at the shelter from direct sand scouring.

Upper-shore depressions within the ledges hosted shallow rock pools characterised by green (*Enteromorpha intestinalis* and *Cladophora hutchiensiae*) and red (*Porphyra purpurea* and *Gelidium pusillum*) algae, which are typical of the biotope **LR.FLR.Rkp.G** (Table 3.7 Photo 19).

A small intertidal cave was recorded along the cliff. The cave entrance was ca 3m wide and extended for approximately 10m into the bedrock. Biotopes recorded included: **LR.FLR.CvOv.AudPil**, characterised by the red alga *Audouinella purpurea* which formed extensive carpet-like growths. The brown alga *Pilinia maritima*, usually found within this biotope was not recorded in the present study. A mosaic of the lichens *Verrucaria mucosa* and *V. maura*, together with the crustose red alga *Hildenbrandia* sp. was also recorded on the cave walls and constitute the biotope **LR.FLR.CvOv.VmucHil**.

At the entrance of the cave a small pool ca 20cm deep overlaid a sandy floor. Where the pool met the cave wall, algal communities were present at the waterline level (Table 3.7 Photo 20). They included red (*Polysiphonia nigra*, *P. fucoides*) and green (*Cladophora hutchiensiae*, *Ulva lactuca*, *Enteromorpha intestinalis*) algae. Above the water line the biotope **LR.HLR.MusB.Cht.Cht** occurred, with dense communities of barnacles (*Chthamalus* sp) and the littorinids *Littorina littorea* and *L. neritoides*.

Table 3.6 Polygon Log and associated biotope codes recorded at Hayle Estuary and beach

Polygon no	Habitat description	Species recorded in situ and overall abundance (SACFOR scale)	Cores/ samples taken within polygon	Biotope code	Comments
1	Fine sand extending from upper-shore boundary with bedrock/sand dunes to low water mark (Table 3.7 Photos 21, 5, 6)	No obvious biota; no burrows; no casts; no anoxic layer; no real strandline on upper shore part of this polygon. 2 individuals of *Spisula solida* (bivalve molluscs) found at low water by eastern edge of estuary	Core sites 1-3 (upper-shore) Core sites 4-6 (mid shore) Core sites 7-9 (low shore) Photos 22-24; 25-27; 28-30.	**LS.LSa.MoSa**	
2	Yellow and Grey Lichens on supra-littoral steep/near vertical bedrock cliff at the boundary with polygon 1. Terrestrial vegetation on top of the cliff (Table 3.7 Photos 14)	Not possible to assess the species composition as polygon too high up on the cliff.	None	**LLR.FLR.Lic.YG**	Vertical extent of the polygon not measured. Polygon extends from wp 219 to wp 228
3	*Verrucaria* sp on supra-littoral bedrock cliff, below Yellow and Grey Lichens. (Table 3.7 Photo 14)	*Verrucaria maura*, *V. mucosa* (both dominant), *Hildenbrandia* sp (P) in damp cracks of the rock surface. Abundance of *Verrucaria* sp. varies throughout the entire length of the polygon.	None	**LLR.FLR.Lic.VerVer**	Vertical extent of the polygon not measured. Polygon extends from wp 219 to wp 228, below polygon 2. Between wp 219 and 221 this biotope was the lowest on the cliff face
4	Littorinids and barnacles on steep/near vertical cliff and outcrops. *Verrucaria maura* and *V. mucosa* present under barnacles (Table 3.7 Photo 17)	*Verrucaria maura* (P), *V. mucosa* (P), *Chthamalus montagui* (C) *Balanus crenatus* (P) *Elminius modestus* (P), Cirripedia sp. (P) *Littorina saxatilis* (P), *L. neritoides* (P). Algae included *Porphyra purpurea* (P), *Catenella caespitosa* (P) on barnacles, *Enteromorpha intestinalis* (P)	None	**LR.HLR.Mus.B.Cht.Cht.**	Vertical extent of the polygon not measured . Polygon run horizontally from wp 221 to wp 231.

Table 3.6 cont.

Polygon no	Habitat description	Species recorded in situ and overall abundance (SACFOR scale)	Cores/ samples taken within polygon	Biotope code	Comments
5	Barnacles and *Mytilus edule* on bedrock cliff. *Verrucaria* sp present beneath the barnacles and Littorinids and limpets in crevices. Ephemeral red algae also present	*Verrucaria maura* (P), *V. mucosa* (P), *Chthamalus montagui* (C) (dominant species overall), *Balanus crenatus* (P), *Elminius modestus* (P), *Mytilus edulis* and *Patella vulgata* both (P) in crevices. *Porphyra umbilicalis* (P), *Catenella caespitosa* (P) *Ceramium shuttleworthianum* (P) and colonial diatoms on barnacles.	None	**LR.HLR.MusB.MytB** And **LR.HLR.MusB.Cht.Cht**	Vertical extent of the polygon not measured. Polygon extends horizontally from wp 231 to wp 233 and was the lowest on the cliff face between these two way points
6	Stepped bedrock with numerous horizontal ledges along the cliff. (Table 3.7 Photos 18 & 19)	Same species as those recorded in polygon 5. In addition *F. spiralis* (P); *Enteromorpha intestinalis* (P), *Porphyra umbilicalis* (P), *Gelidium pusillum* (P), F. vesiculosus (P) forming a narrow band near the boundary with sand (polygon 1). Upper shore rock pool present on horizontal ledge and dominated by *Enteromorpha* sp. and *Cladophora* sp.	None	**LR.MLR.BF.FspiB** **LR.FLR.Rkp.G**	Vertical extent of polygon not measured. Polygon extends horizontally from wp 233 to wp 234, and was the lowest on the cliff between these two way points

Table 3.6 cont.

Polygon no	Habitat description	Species recorded in situ and overall abundance (SACFOR scale)	Cores/ samples taken within polygon	Biotope code	Comments
7	Area of fucoids on eastern edge of estuary near the western boundary of the survey area. Patches of pebbles, cobbles and boulders overlying sand. Sand quite "sinking" in places like quick sand. Boulders and pebble dominated by *Fucus vesiculosus*. *Enteromorha* sp. is also present. In the middle of the polygon there is a sand bank feature which covered in 100% *Fucus vesiculosus* sticking through the sand. (Table 3.7 Photos 31, 32, 12, 11)	*Fucus vesiculosus* (A) (dominant) including *F. vesiculosus* var. *linearis*, *Enteromorpha* sp., *F. serratus*, *Chondrus crispus* (near the edge of the estuary). Fauna on rock/boulders included *Patella vulgata* (P), *Littorina obtusata* (P), *Balanus crenatus* (P), *Elminius modestus* (P). In permanent current swept channel additional biota included: *Lanice conchilega* (P), *Pomatoceros* sp (P), *Hincksia granulosa* (P), *Laminaria saccharina* (P) (juvenile plant).	None	**LR.LLR.F.FvesFS**	The current swept channel was not considered to constitute a separate biotope in the present study due to its limited occurrence and extent.

Table 3.7 List of Photos, Hayle Beach and Estuary, Cornwall

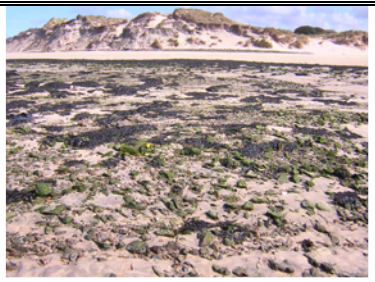


Table 3.7 Photo 1

Table 3.7 Photo 2

Table 3.7 Photo 3

Table 3.7 Photo 4

Table 3.7 Photo 5

Table 3.7 Photo 6

Table 3.7 Photo 7

Table 3.7 Photo 8

Table 3.7 Photo 9

Table 3.7 Photo 10

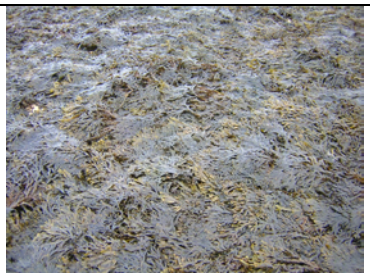


Table 3.7 Photo 11

Table 3.7 Photo 12

Table 3.7 cont.

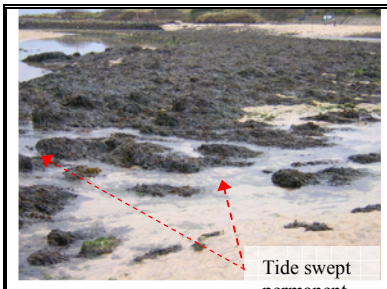


Table 3.7 Photo 13

Table 3.7 Photo 14

Table 3.7 Photo 15

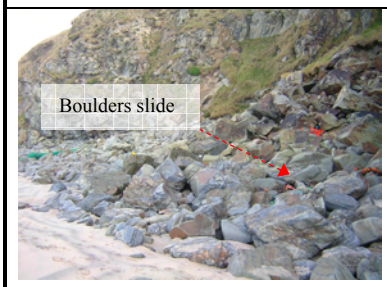


Table 3.7 Photo 16

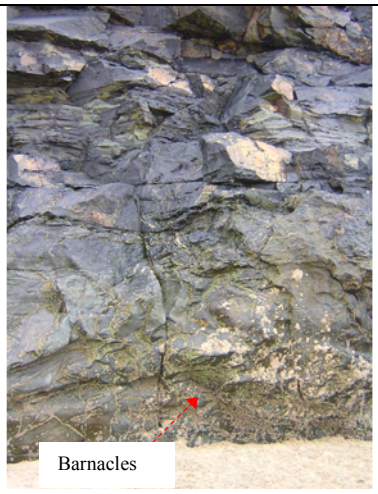


Table 3.7 Photo 17

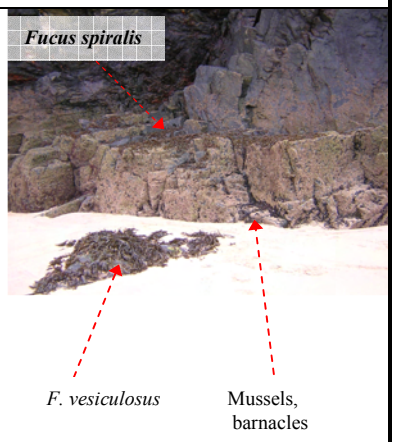


Table 3.7 Photo 18

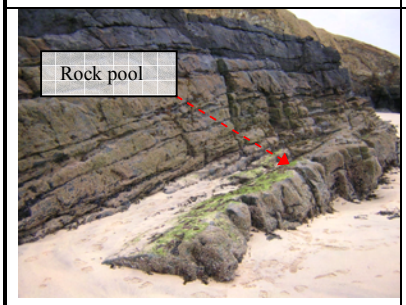


Table 3.7 Photo 19

Table 3.7 Photo 20

Table 3.7 Photo 21

Table 3.7 cont.

Table 3.7 Photo 22

Table 3.7 Photo 23

Table 3.7 Photo 24

Table 3.7 Photo 25

Table 3.7 Photo 26

Table 3.7 Photo 27

Table 3.7 Photo 28

Table 3.7 Photo 29

Table 3.7 Photo 30

Table 3.7 Photo 31

Table 3.7 Photo 32

4.0 Discussion

The survey area comprised an extensive sandy beach delimited upper-shore by a bedrock cliff and sand dunes. Due to its strong exposure to wave, current and wind action, the shore is a high energy area characterised by a low infauna diversity which lacks of sedentary forms, whilst agile swimmers such as amphipods and isopods can be numerically dominant. These species are characterised by a short life span and are able to withstand sediment disturbance. In general, on wave-exposed sandy beaches, it is rare to find stable benthic communities, as waves continually disturbs the surface of the beach reworking the sediment.

4.1 Conservation value

The proposed onshore site for the wave hub development is located in an industrial area beside the Hayle Estuary, just to the north of Hayle town. The site hosts a current sub-station and disused power station surrounded by a high crest of sand dunes behind which lies the estuary and a wide sandy beach. The estuary is of significant importance for nature conservation, particularly migrating birds, and is designated as a Site of Special Scientific interest and an RSPB Reserve. The beach in front of the dunes is covered by two county-level designation: Area of Great Scientific Value, and Cornwall Nature Conservation Site. The site itself is of little ecological importance and low visual amenity being a disused power station in an industrial area.

4.2 Particle Size Analysis

The beach comprised all grades of sand, and negligible levels of mud at all sites. Small fractions of gravel were recorded from the upper-shore sites. The percentage of fine sand (grain size between 0.063 and 0.125mm) increased from upper to low shore, from an average of 8.18% across the mid-shore sites to an average of 15.1% across the low shore sites.

4.3 Macro-fauna

The upper-shore sites were abiotic, except for the presence of a spring tail insect (Collembola) whose presence was likely to be associated with the presence of organic matter in the drift line. The sandy sediment of the upper shore dries out completely at low water tide leaving a very harsh environment in which very few invertebrates are able to survive. These are usually represented by amphipods and/or larvae of flies and beetles which feed on the drift line.

The distribution of infauna was found to be rather patchy at the mid shore sites, as fauna was recorded only in 1 replicate from core site 4. Species distribution and abundance varies across the shore (vertical gradient, e.g. from high to low water tide) but can also vary along the shore (horizontal gradient), creating patchiness in the infaunal distribution. Horizontal gradients are associated with the local topography of the area, including sand depth and grain size sediment, which influences oxygen concentrations and nutrients availability.

The low shore sites accounted for the highest number of species and individuals (as total number across the sites), represented mainly by crustaceans (*Pontocrates arenarius*, *Eurydice pulchra*) and the scavenger polychaete *Nephytis.*

At low tide levels the sand seldom dries out, offering more benign conditions to the infauna. However, sand is still mobile due to currents and wave actions, particularly on exposed sandy beaches which, are, consequently naturally high stressed environments. In addition, infaunal animals are able to migrate in response to both environmental (seasonal changes, fluctuation in salinity-temperatures) and physical (storms heavy rain, wave disturbance, changes in moisture and oxygen over the tidal cycle) events. For example, seasonal storm events can

change sediment distribution and composition significantly, by removing as much as the top 20cm of sand (Dolphin *et al*., 1995 citation form *marLIN,* June 2005).

4.4 Biotopes

The biotopes identified in the present study hold importance under the UK Biodiversity Action Plan and the UK Habitat Directive for providing habitat to shore birds. However, none of the species identified are considered to be of structural or functional importance within the biotopes.

The most extensive biotope **LS.LSa.MoSa** was recorded within the sandy beach area extending from the dune/cliff to the low water mark. The biotope is typical of areas characterised by high hydrodynamic regime which allows accumulation of sandy substrate that is subject to redistribution by tide and currents. Because of the continual mobility of the sediment and consequent abrasion, sandy beaches often lack an established faunal community and the species present tend to be mobile and robust (crustaceans and some polychaete worms). These can provide species prey for waders, wildfowl and marine predators such as fish. Intertidal sandy sediment are also important areas for ringed plover which pass through in the autumn and over-winter on the site.

Of particular interest was the biotope (**LR.LLR.FvesFS**), recorded within an outcrop of fucoid population to the west of the survey area, at the mouth of the estuary. Fucoid population are important because they provide substratum and shelter for a variety of species, including worms, isopods, amphipods and surface grazing snails. They also provide considerable substratum for epiphytic species and act as nursery ground for various species. In addition, fish and crustaceans migrate into the intertidal zone to feed as the tide rises. Fish and large crustaceans, as well as shore birds also feed on fucoid communities because the invertebrates attracted to seaweed are a particularly important food source.

Biotopes recorded on the bedrock cliff are typical of exposed rocky shores. An upper-shore band of yellow and grey lichens (**LR.FLR.Lic.YG**) was recorded along the whole length of the cliff. Below this a band of *Verrucaria* (**LLR.FLR.Lic.VerVer**) occurred. Barnacles (**LR.HLR.MusB.ChtCht**) and mussels (**LR.HLR.MusB.MytB**) were also found scattered along the cliff. Their presence was found to be associated with the presence of rugged substrate, as well as cracks and fissures in the rock which provided a continuously moist environment and shelter from the scouring action of the sand.

Horizontal ledges where present along the cliff and some supported small outcrops of fucoid population. (**LR.MLR.BF.FspiB**). Depressions within the horizontal ledges supported *Enteromorpha* sp dominated upper-shore rock pools (**LR.FLR.Rkp.G**).

The cliff also hosted small intertidal caves. Biotopes recorded on the cave walls and ceiling (**LR.FLR.CvOv.AudPil** and **LR.FLR.CvOv.VmucHil**) did not show any clear boundaries between them and seemed arranged according to the degree of light and dampness.

5.0 Conclusions

Results of the present study showed that Hayle beach, proposed as the potential onshore site for the development and implementation of a Wave Hub off the north Cornwall coast, is a very exposed area, with high energy hydrodynamic regimes. Consequently, the substrate, characterised by a clean sandy sediment is subject to a great degree of disturbance by winds, tide and currents.

Results from the macrobenthic analysis of the core samples showed a rather impoverished macrofaunal community, with ten species of invertebrates recorded across the sampling stations. These included crustaceans (*Eurydice pulchra, Pontocrates arenarius*), polychaetes (*Ampharete lindstroemi*, Glyceridae sp, *Lumbrineris gracilis*, *Nephtys cirrosa, Nephtys* sp), molluscs (Copepoda sp), echinoderms (*Amphiura* sp) and spring-tail insects (*Collembola* sp). Some of these species can provide species prey for waders, wildfowl and marine predators such as fish. The habitats recorded are typical of the biotope **LS.LSa.MoSa.**

A dense fucoid population, comprising mainly *Fucus vesiculosus* and *F. vesiculosus* var. *linearis* (**LR.LLR.FvesFS**) occurred to the west of the survey area at the mouth of the estuary. Fucoid population are considered to be important for providing substratum and shelter for many invertebrate species (worms, isopods, amphipods, surface grazing snails) which represent species prey for a variety of shore birds. Fucoids also provide considerable substratum for epiphytic species as well as acting as nursery ground for various species.

The bedrock cliff delimiting the upper-shore limit of the beach supported biotopes typical of exposed rocky shores. Lichens (**LLR.FLR.Lic.YG** and **LLR.FLR.Lic.VerVer**) were recorded on the upper limit of the cliff at the boundary with the terrestrial vegetation. The presence of barnacle (**LR.HLR.MusB.ChtCht**), mussel (**LR.HLR.MusB.ChtCht**) and fucoid communities (**LR.Mlr.BF.FspiB**) was discontinuous along the cliff and seemed dictated by the presence of continuously moist cracks/fissures in the rock as well as horizontal ledges which provided a degree of shelter from sand scouring thus allowing the establishment of such communities.

6.0 References

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Davis J, Baxter J, Bradley M, Connor D, Khan J, Murray E, Sanderson W, Turnbull C & Vincent M. 2001. Marine Monitoring Handbook. Joint nature Conservation Committee.

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Appendices

Appendix I Photo Log

Photo no	Type	Dir	WP	Position			Date	Comments
				BNG	E	N		
1	View /habitat	W	214	SW	54942	38097	11/03/2005	Looking upper-shore over polygon 7 @ south-western boundary of survey area
2	view	SW	215	SW	55047	38108	11/03/2005	From upper-shore on south-western boundary of survey area looking onto the estuary and at the cave on opposite bank of estuary.
3	view	NE	219	SW	55777	39049	11/03/2005	easternmost point of survey area, looking east at boundary between sand dunes upper-shore and polygon 1
4	view	NW	219	SW	55777	39049	11/03/2005	looking lower shore over polygon 1 @ south-eastern boundary of survey area
5	view	N	228	SW	55241	38479	11/03/2005	boundary between vertical cliff and polygon 1
6	view	S	228	SW	55241	38479	11/03/2005	looking at boundary between sand dunes upper-shore and polygon 1
7	view	S	core 2	SW	55170	38450	11/03/2005	looking at sand dunes and polygon 1 upper-shore with poorly developed strand line
8	view	W	core 3	SW	55100	38380	11/03/2005	over polygon 1
9		W	239	SW	54895	39044	12/03/2005	over polygon 1
10	view/ habitat	N	nr 236	SW	55029	38206	12/03/2005	over polygon 7 N end with sparse outcrops of fucoids
11	habitat		238	SW	54990	38117	12/03/2005	within polygon 7 dense populations of fucoids
12	view	N	214	SW	54942	38097	11/03/2005	South-western boundary of survey area on eastern bank of estuary edge looking down the estuary over polygon 7
13	view/ habitat	S	nr 236	SW	55029	38206	12/03/2005	over polygon 7 North end with dense populations of fucoids
14	habitat		219	SW	55777	39049	11/03/2005	looking upper-shore at boundary between cliff and polygon 1
15	view	N	228	SW	55241	38479	11/03/2005	boundary between vertical cliff and polygon 1
16	habitat		221	SW	55672	39005	11/03/2005	western boundary of boulder slide (ca 20m wide) along the vertical cliff
17	habitat		221	SW	55672	39005	12/03/2005	looking upper-shore at vertical cliff with lichens and barnacles
18	habitat		232	SW	55600	38990	12/03/2005	looking at horizontal ledge in bedrock supporting fucoids (*F. spiralis* upper ledge, *F. vesiculosus* lower ledge by sand)
19	habitat		233	SW	55566	38966	12/03/2005	looking onto stepped bedrock with numerous horizontal ledges and rock pool
20	habitat		225	SW			12/03/2005	looking into intertidal cave
21	view	N	core 3	SW	55100	38380	11/03/2005	looking lower shore over polygon 1
22	close up		core 1	SW	55280	38605	11/03/2005	
23	close up		core 2	SW	55170	38450	11/03/2005	
24	close up		core 3	SW	55100	38380	11/03/2005	
25	habitat		core 6	SW	55070	38780	11/03/2005	
26	habitat		core 5	SW	55140	38850	11/03/2005	

Photo no	Type	Dir	WP	Position			Date	Comments
				BNG	E	N		
27	habitat		core 4	SW	55250	38950	11/03/2005	
28	habitat		core 7	SW	55248	39146	11/03/2005	
29	habitat		core 8	SW	55170	39124	11/03/2005	
30	habitat		core 9	SW	55099	39098	11/03/2005	

Appendix II Target Notes

T.N. no	Wp	BNG	E	N	Description	Photo
1	232	SW	55600	38990	Approximately 30m along cliff from wp 231. Horizontal ledges in bedrock supporting fucoids (*Fucus spiralis* on upper ledge, *Fucus vesiculosus* on lower ledge near sand). Area ca 5x4m (uneven stepped ledge)	 cfr Table 3.7 Photo 18
2	225		55428	38846	Small, intertidal cave. ~3m wide at mouth extending back ~10m into bedrock. Sandy floor. Walls with lots of low level horizontal platforms. Small pool at mouth of cave with sandy floor and fringed with green and brown filamentous algae. Species recorded include: *Hildenbrandia* sp., *Audouinella purpurea*, *A. floridula*, *Enteromorpha intestinalis*, *Polysiphonia nigra*, *P. fucoides*, *Chondrus crispus*, colonial diatoms, *Cladophora hutchiensiae*, *Gracilaria gracilis*, *Ulva lactuca*. Walls covered in *Verrucaria. mucosa*, *V. maura*, *Hildenbrandia* sp.. Lower parts of walls also with *Chthamalus* and *Littorina saxatilis* and *L. neritoides*	
3	235		55419	38801	Waypoint marking 'front' centre of low lying bedrock feature where it borders polygon 1. Bedrock with large patches of interstitial sand from polygon 1 (presumably when tide pushes into this area). Waypoint ~20m from back of feature where it meets steep bedrock cliff. Feature ~ 40m wide at front. Species on low lying rocky outcrops (interspersed with sand) include *Chthamalus* Sp, Littorinids, *Enteromorpha* sp, and *Porphyra* Sp. Above the low lying outcrops at the back of the feature where it meets steep bedrock, the steep bedrock cliff vertical zonation comprising Yellow and Grey lichens on the upper limit and *Verrucaria* sp on the lower limit.	

Appendix III Waypoint Log

WP no.	BNG	E	N	Comments
214	SW	54942	38097	South-western boundary of survey area on eastern edge of creek
215	SW	55047	38108	South-western boundary of survey area at the boundary of high water mark and sand dunes
216	SW	55248	39146	core site 7 by water edge at 13:36 on 11/03/05
217	SW	55170	39124	core site 8 by water edge at 13:43 on 11/03/05
218	SW	55099	39098	core site 9 by water edge at 13:55 on 11/03/05
219	SW	55777	39049	Eastern boundary of survey area with sand dunes. Boundary of upper-shore sand with bedrock cliff
220	SW	55723	39032	eastern edge of boulder slide. Boundary of upper-shore sand with bedrock cliff
221	SW	55672	39005	Western edge of boulder slide. Boundary of upper-shore sand with bedrock cliff
222	SW	55586	38989	Boundary of upper-shore sand with bedrock cliff
223	SW	55529	38930	Boundary of upper-shore sand with bedrock cliff
224	SW	55479	38910	Boundary of upper-shore sand with bedrock cliff
225	SW	55428	38846	In front of small intertidal cave feature
226	SW	55319	38722	Boundary of upper-shore sand with bedrock cliff
227	SW	55274	38613	Boundary of upper-shore sand with bedrock cliff
228	SW	55241	38479	Boundary of upper-shore sand with bedrock cliff. Bedrock meets sand dunes to the west
229	SW	55180	38392	Boundary of upper-shore with sand dunes
230	SW	55061	38210	Boundary of upper-shore with sand dunes
231	SW	55618	38992	Boundary of upper-shore with sand dunes. Start of barnacles and mussels
232	SW	55600	38990	Boundary of upper shore sand and bedrock cliff
233	SW	55566	38966	Boundary of upper shore sand with bedrock cliff. End of barnacles and mussels. Start of ledges
234	SW	55527	38926	Boundary between upper shore sand and bedrock cliff. End of ledges
235	SW	55419	38801	Polygon 1 boundary with upper-shore rock. WP taken in the centre of rock feature which is comprised of low lying rock outcrops
236	SW	55029	38206	NE corner of polygon 7
237	SW	54921	38128	NW corner of polygon 7
238	SW	54990	38117	in the middle of polygon 7
239	SW	54895	39044	NW edge of polygon 1 eastern edge of creek at water edge @ 12:52
240	SW	54855	38019	Western bank of estuary on promontory Photo WP
241	SW	54772	38192	Western bank of estuary on promontory Photo WP

Appendix IV

Samples Log

Date 12th March 2005
Time in GMT
Datum OSGB 36 Low water @ 13:53

Location	Core no.	Position			Comments
		BNG	E	N	
Upper-shore	Core 3	SW	55100	38380	
	Core 2	SW	55170	38450	
	Core 1	SW	55249	38605	
Mid shore	Core 6	SW	55070	38780	
	Core 5	SW	55140	38850	
	Core 4	SW	55250	38950	
Lower shore	Core 9	SW	55099	39098	Core taken @ waters edge @13:55. Tide turned whilst sampling with crashing waves
	Core 8	SW	55170	39124	Core taken @ waters edge @ 13:43
	Core 7	SW	55248	39146	Core taken @ waters edge @ 13:36

Appendix V

Species list

Location			Upper shore									Mid shore									Low shore								
Site			1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	5a	5b	5c	6a	6b	6c	7a	7b	7c	8a	8b	8c	9a	9b	9c
Wet lab reg no.		WL01	5547	5548	5549	5550	5551	5552	5553	5554	5555	5556	5557	5558	5559	5560	5561	5562	5563	5564	5565	5566	5567	5568	5569	5570	5571	5572	5573
Species Name	MCS	Ref Coll																											
Ampharete lindstroemi	P1139	006											2																
Amphiura sp. indet.	ZB0149	na											1																
Collembola	T0002	002	1															1											
Copepoda	R0142	na																											1
Eurydice pulchra	S0854	004																										3	
Glyceridae sp. indet. (juv.)	P0254	na											1																
Lumbrineris gracilis	P0579	007											1																
Nephtys cirrosa	P0498	003																					1					1	
Nephtys sp. indet. (juv.)	P0494	005											4																
Pontocrates arenarius	S0135	001																			1	1	1	1	1				1

Appendix VI

Biomass as wet weight (g) (raw data)

Location	Mid shore			Low shore								
Site	4a	4b	4c	7a	7b	7c	8a	8b	8c	9a	9b	9c
Species Name												
Biomass												
	Wet weight (g)											
Polychaeta		0.0186				0.0716		0.0008			0.0134	
Crustacea				0.0006	0.0005	0.0003	0.0004	0.0009			0.007	nr
Echinodermata		0.0036										
Insecta												

Appendix VII

Particle Size Analysis

	Upper shore			Mid shore			Low shore		
SITE NAME	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
LAB REGISTRATION NO.	**WL015574**	**WL015575**	**WL015576**	**WL015577**	**WL015578**	**WL015579**	**WL015580**	**WL015581**	**WL015582**
Sieve Aperture (mm)	**% Of Total Start Dry Weight**								
63000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8000	0.000	0.663	1.174	0.000	0.000	0.291	0.000	0.000	0.000
4000	0.047	0.000	2.154	0.024	0.163	0.051	0.000	0.025	0.047
2000	0.000	0.043	0.328	0.126	0.274	0.193	0.147	0.107	0.302
1000	0.095	1.217	3.872	0.825	3.608	1.317	1.834	1.808	2.496
500	13.855	23.345	38.513	15.612	39.082	24.791	24.212	21.406	24.127
250	77.436	64.393	48.283	66.836	51.561	61.342	60.410	59.624	58.201
125	8.542	10.289	5.645	16.509	5.297	11.975	13.347	16.972	14.744
>63	0.017	0.031	0.019	0.044	0.008	0.031	0.045	0.047	0.056
<63	0.007	0.019	0.011	0.024	0.007	0.008	0.006	0.011	0.026

AUDIT TRAIL

Title : Wave Hub Intertidal Studies			
Report No : 05/J/1/03/0775/0503- FINAL Job No : J/1/03/0775 Client Name : Halcrow Client Contact : Mr Robert Harvey/Steve Challinor			
Project Manager	Dr Stefania DeGregorio		
Field work undertaken by	Dr Stefania DeGregorio Miss Claire Dalgleish		
Laboratory work undertaken by	Miss Tamsin Gamble Miss Karen Hamilton		
Data Analysis undertaken by	Dr Stefania DeGregorio		
Report written by	Dr Stefania DeGregorio		
Report checked by	Dr Nigel Thomas		
Report Authorised by	Dr Nigel Thomas		