Science Series
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This publication and information on the study is also available on the EECMHM website at www.bgs.ac.uk/eecmhm

Contents

* Map and DVD content available online at www.bgs.ac.uk/eecmhm

1. Executive summary

Background

The aim of the Eastern English Channel Marine Habitat Map (EECMHM) study is to produce integrated regional habitat maps. The principal driver is the planned exploitation of substantial marine aggregate resources in this area and the need to place these resources in a wider spatial context to inform management decisions relating to sustainable use and conservation. The EECMHM study provides this context through regional scale geological and biological interpretations and will contribute to the effective stewardship of the marine environment by providing a broader understanding of how the potential resource areas relate to the wider regional ecology and physical processes. The study covers an extensive sea bed area of approximately 5090 km^2 between Selsey Bill and Dungeness, out to the UK/France median line, centred on ten current aggregate licence application areas.

Survey strategy

The survey strategy adopted for the study reflected the requirement to cover a large area within budget, provide information on the regional distribution of dominant habitat types and on the presence or absence of 'rocky reef' habitat listed under Annex 1 of the EU Habitats Directive. The surveys were based on a 'corridor grid' design to maximise spatial coverage, with the corridors covered by geophysical survey followed by a campaign of directed ground-truth sampling. Thirty eight corridors up to 120 km long, ~500 m wide and spaced between 2 and 16 km apart were completed for geophysical data using multibeam, sidescan sonar and sub-bottom profiling. Approximately 6000 line km of geophysical data were collected.

Subsequent ground-truth surveys used a suite of complementary techniques targeting a proportion of the grid nodes and specific sea bed features interpreted from the geophysical surveys. Sampling effort was weighted ~60% towards grabs (0.1m^2 Hamon grab) as these provide quantitative data on both the sea bed substrate and their infaunal communities. The remaining effort was split between 2-metre beam trawls and drop-down camera techniques (video and stills), providing semi quantitative data on epifauna and substrate-type. A total of 225 grab, 73 beam trawl and 65 video stations were collected. No replicate samples were taken. Some data from aggregate company surveys were included in the interpretation.

Geological interpretation

Characteristic or common physical and geological features enabled five Physical Regions to be distinguished in the study area, namely:

- Region 1 - Northern Palaeovalley and Margin (1260 km^2)
- Region 2 - North-East Platform and Margin (350 km^2)
- Region 3 - Western Axial Platform (1050 km^2)
- Region 4 - Central Axial Platform (1640 km^2)
- Region 5 - Greater Bassurelle Sands (790 km^2)

A series of palaeochannels cut into bedrock during the Quaternary period (last 2 Million years) lie beneath Region 4 and 5. The Quaternary deposits over the palaeochannel systems in Region 4 generally constitute the resource material for marine aggregate. All bar one of the aggregate licence application areas fall within Region 4.

Although bedrock of solid geology underlies the whole EECMHM study area, it is only where it is exposed or covered by thin sediment that rock will influence sea bed habitat. Elsewhere thicker Quaternary and mobile sediment provides the sea bed surface for habitat.

In terms of sea bed character around 43% of the study area is covered by rock and thin sediment (<1.5 m thick), 27% by coarse sediment and 30% by sandy sediment. Rock and thin sediment extends over much of the two northern Regions (1 and 2), and is particularly extensive in the south-west in Region 3. Coarse sediment dominates Region 4 in the central south of the study area with sandy sediment increasing in significance to the east and encompassing all of Region 5 in the south-east. The areas of current aggregate licence applications are concentrated in Region 4. Both the areas of coarse sediment and much of rock and thin sediment are particularly scarce in sandy bedforms. Sand waves are most common in the north and east of Region 5, where there is an extensive sand wave field. Sand streaks, patches, sand ribbons and megaripple trains are more common in the two northern regions.

Grab sample analysis showed Region 1, 2 and 5 are dominated by sandy sediment, especially gravelly sand. Region 1 and 2 include some areas of sandy gravel but this is most extensive in Region 4 and extends westward into Region 3, which also has an extensive area of muddy sandy gravel at its core. Video footage showed Region 3 is also characterised by a cobble-rich sediment veneer on Tertiary and Chalk rock outcrop, the underlying rock providing the source for a significant proportion of the sea bed gravel, particularly the cobbles and boulders.

From west to east across the three southern regions (3, 4 and 5) there is a grain size trend of increasing sand content and decreasing gravel content. The west to east sediment fining trend can be related to a number of factors including: -

- The extensive area of immobile rock and coarse sediment with cobbles in the west in Region 3.
- Predominantly gravelly Quaternary sediment infilling the channel systems which underlie the central Region 4.
- The winnowing and transport of finer sediment from these coarse substrates towards the north and east.

In Region 5, seismic records provide evidence of long term eastward sand transport with the deposition of a thin transgressive sand sheet immediately beneath the sea bed. This provides an important context in which to view the potential remobilisation of similar fine sediment resulting from proposed aggregate extraction, feeding into a natural process of transport and deposition.

Biological interpretation

Data from grabs, trawls and camera techniques were treated separately, using a suite of multivariate analyses, including clustering techniques, to determine groups of samples that could reasonably be interpreted to represent broadscale biotope classes. A suite of environmental variables were analysed to determine which combination of variables best matched the observed patterns in the faunal communities. The physical and biological descriptors of the biotopes were subsequently matched against The Marine Habitat Classification for Britain and Ireland v 04.05 (Connor *et al.*, 2004).

Cluster analysis for grab samples showed 28 infaunal groups. Selection criteria were applied to exclude those groups that were poorly represented, leaving a total of nine Infaunal Biotopes (IB). One of these, IB4 was subdivided into 4a and 4b, to reflect the greater abundance of the bivalve *Glycymeris* in the latter. Most groups showed some spatial relationship; only IB6 occurred at spatially isolated stations.

Analysis for beam trawl samples identified 14 epifaunal groups, nine of which showed a spatial relationship giving some insight into the distribution of regional epifaunal biotopes. This was complemented by a consolidated interpretation of the video and stills analyses that grouped the observed stations into seven broad biotope classes. The concurring evidence from beam trawl and video/still photo analyses enabled the identification of 11 ‘Epifaunal Biotope Complexes’ (EBC).

Integrated assessment and map production

An integrated assessment of the geological and biological interpretations generated thematic regional scale habitat maps of the distribution of Infaunal Biotopes and Epifaunal Biotope Complexes. While the extent of each of the mapped polygons reflects a spatial association of sampling stations assigned to the same biotope group, the precise placement of borders between polygons relied heavily on geological mapping, particularly of the sea bed sediments and sea bed character. In some cases the placement of boundaries was speculative due to the relatively low density of sampling stations and evidence of sea bed heterogeneity or extensive transition zones between some sea bed types.

The principal characteristics of the morphology, geology, sediments, biology, habitats and biotopes of the study area have been integrated within the physical region framework produced for the study area and are outlined in a summary table for each of the five Physical Regions. Few of the mapped biotopes were exclusive to any one region; a notable exception being those associated with the cobble substrates in Region 3. The biotopes often straddled borders between Physical Regions and this was more marked for the Epifaunal Biotope Complexes as epifauna tend to show lower fidelity and exclusivity to particular substrate types than infauna.

A number of anthropogenic features and impacts on the sea bed were evident in some areas including a variety of wrecks and fishing gear trawl marks

Principal Conclusions

- Large scale geological processes and features are evident across the study area and influence the nature of the sea bed and the distribution of sediment and biotopes.
- The physical nature of the sea bed appears to be one of the most important factors in controlling the form, diversity and frequency of taxa particularly sediment grain size and sea bed substrate type with distinctions between areas of sand, and gravel/cobble dominance, the latter having a more diverse biotope.
- Difficulties were experienced in assigning biotopes to the infaunal and epifaunal assemblages identified by this study using The Marine Habitat Classification for Britain and Ireland v 04.05 (Connor *et al.*, 2004). Matches could be made at the rudimentary levels of the classification hierarchy, which deals mostly with the physical characteristics of the habitats, but were more

equivocal at higher levels of the classification dealing with faunal assemblages, indicating a need to further develop these higher levels with respect to ‘offshore’ biotopes.

- No extensive areas of potential Annex 1 ‘rocky reef’ habitat were noted. However, the western tip of the Bassurelle Bank extends into the south east corner of the study area and may have some characteristics of the Annex 1 habitat “Sandbanks which are slightly covered by sea water all the time”.
- The multidisciplinary approach of marrying geophysical and physical techniques and interpretations is recommended for future marine habitat mapping studies.

2. Introduction

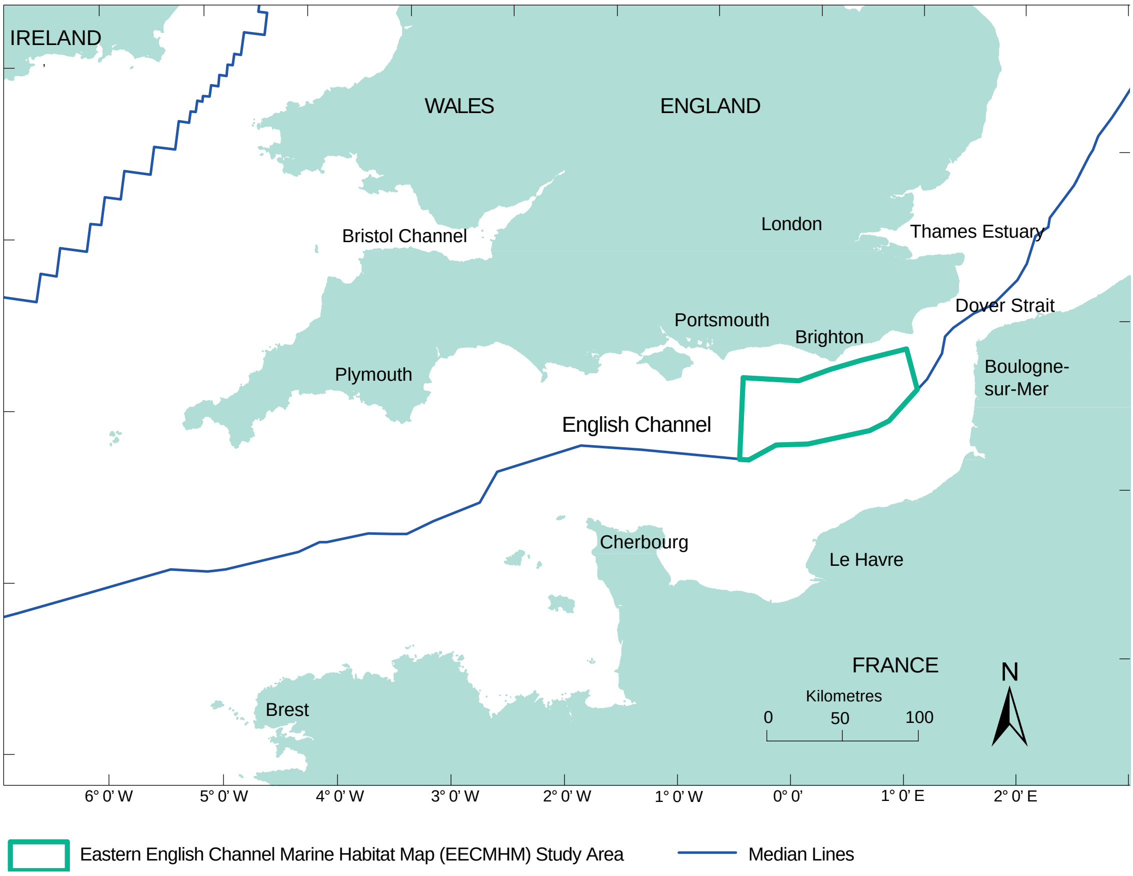


Figure 2.1. Location of Eastern English Channel Marine Habitat Map study area.

The eastern English Channel (Figure 2.1) is an area which has a long standing marine aggregate industry. The areas of traditional licensed extraction have been concentrated to the east and west of the Isle of Wight, and east of Selsey Bill (Figure 2.2). Marine aggregates are a significant source of supply for the construction industry in south-east England. In recent years the aggregate industry have been prospecting for new resources further offshore and in deeper water in the eastern English Channel. Six aggregate companies have made ten independent licence applications (Figure 2.2) to extract aggregate from this deeper offshore area which they have called the ‘East Channel Region’ (ECR). Each application has been accompanied by a comprehensive assessment of the environmental resources that might potentially be affected, as well as proposals for mitigation and monitoring. Some of these applications have been successful and licences to dredge aggregate have been granted whilst others are awaiting a decision (March 2007).

The necessity for an overview of the potential impacts of the entire proposal for the East Channel Region (ECR), which covers an area of 1132 km^2, was recognised at an early stage by the six aggregate companies. To deliver this, the companies cooperated under the banner of the ‘East Channel Association’ to compile additional information as a Regional Environment Assessment (REA) (Posford Haskoning, 2003) and in particular to evaluate potential ‘in-combination’ and ‘cumulative’ effects of the proposal on regional resources in the ECR. Further regional monitoring and management is continuing (EMU & MarineSpace, 2006). However, both the REA and subsequent monitoring data primarily relate to the ECR area within and adjacent to the licence applications and do not address the wider surrounding area in detail.

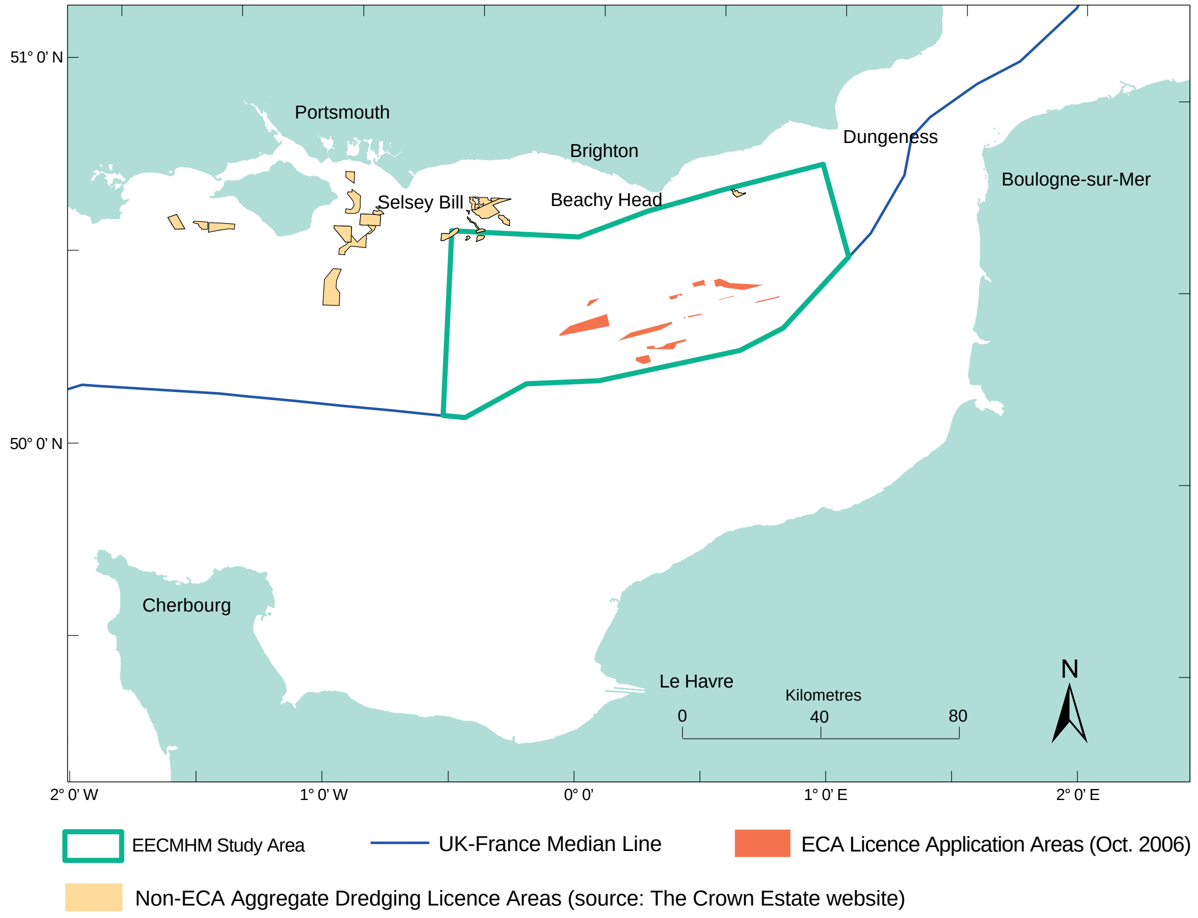


Figure 2.2. Licensed dredging and application areas.

The area of aggregate resource needs to be assessed within the broader context of the region and the Eastern English Channel Marine Habitat Map (EECMHM) study, which covers over 5000 km^2, aims to supply regional scale geological and biological data and interpretations to provide this context, and aid the requirement to manage the development of this resource and minimise potential impacts.

The need for effective stewardship of the marine environment through a policy of integrated management, balancing the requirements for development with nature conservation and legislation, has been widely recognised (OSPAR, Annex V; Safeguarding our Seas; EU Habitats Directive (Natura 2000); Marine Bill). Their implementation requires a significant knowledge of the nature of the sea bed. However, there is very little detailed information on the nature and distribution of sea bed habitats and associated biological resources of conservation significance in UK marine waters.

Technologies and methodologies have been developed and utilised for producing marine habitat and biotope maps. These maps have proved to be valuable tools in marine management in Canada, the USA and elsewhere. (Pickrill and Todd 2003; Kostylev *et al.*, 2001; Valentine *et al.*, 2005). The maps are based on an inter-disciplinary approach, which integrates geological, geophysical and biological data and interpretations as well as other physical and oceanographic parameters. An inter-disciplinary approach is becoming more widely adopted in the UK and recent examples include marine habitat studies in the Outer Bristol Channel in an area of potential marine aggregate resource (Mackie *et al.*, 2006), and in assessing the role of sea bed mapping techniques in environmental monitoring and management (Boyd *et al.*, 2006). A European perspective on the mapping of marine habitats is provided by MESH (**M**apping **E**uropean **S**ea bed **H**abitats) (www.searchmesh.net) which is an Interreg III B (North West Europe) funded project whose aims include developing and producing protocols, best practice guides and methodologies for marine habitat mapping. Some of the methods and work undertaken for the Eastern English Channel Marine Habitat Map has fed into MESH.

This inter-disciplinary approach as been fundamental to the methods adopted for the Eastern English Channel Marine Habitat Study, which has been jointly led by the British Geological Survey and Cefas, with the Joint Nature Conservation Committee (JNCC) and Marine Ecological Surveys Ltd as partners in the study. Funding for the study has been provided by the Marine Environment Protection Fund (MEPF) a marine component of the Aggregate Levy Sustainability Fund (ALSF)

2.1 Objectives

In planning the objectives and surveys for the study our knowledge of the sea bed geology in the eastern English Channel was based on regional surveys by BGS (Hamblin *et al*., 1992). The study area is significant for an extensive system of sediment infilled palaeochannels incised into bedrock. The aggregate licence application areas are concentrated in an area where the sea bed is underlain by these palaeochannels. Outside these palaeochannels bedrock may be exposed at the sea bed or covered by a thin lag gravel and to the east there is also an extensive sand wave field.

The study area includes a range of rock types which may be exposed at the sea bed in various localities. These exhibit important differences in terms of their physical properties. There is a therefore the potential for significant variability in sea bed geology both in terms of bedrock character and sea bed sediments. This geological variability is also likely to be significant for habitat and biotope characterisation.

The relationship between the bedrock types and the sediments which overlie them and their influence on biotopes and habitats is poorly understood. The relationship between habitats on sediment filled palaeochannels and elsewhere in the area also needs to be addressed. An important objective is to understand whether variability in the underlying geology influences the overlying sea bed habitats or are other physical and biological criteria and processes of equal or greater significance

By examining the relationships between the benthic biology and geology, we aim to be able to better understand the significance of any likely impacts arising from dredging operations in the ECR. In addition, because we are looking at the relationships between the underlying geology and the sediment and rock exposed at the sea bed and the associated epi- and in-fauna communities, it should improve our understanding of the significance of potential regional impacts of dredging.

The implementation of the EU Habitats Directive in UK offshore waters is lead by Defra with advice from the Joint Nature Conservation Committee (JNCC). Work by JNCC so far has used sea bed sediment maps produced by the British Geological Survey (BGS), combined with available biological and habitat information from a number of sources, to locate areas in UK offshore waters which may potentially fit the definition of Annex I habitats for reef and for shallow sandbanks. One of these is a large area of ‘gravel’ to the south and east of the Isle of Wight, which extends into the ECR. Some of this area may consist of fine gravels, but it may also contain significant areas of bedrock and large boulders and cobbles. Fine gravels do not fit within the Habitats Directive definition of ‘reef’, but bedrock, boulders and cobbles do. However, existing geological and biological information for the eastern English Channel area is not of sufficient resolution to be able to distinguish areas of boulders and cobbles from areas of finer gravels.

An objective therefore is to produce physical and biological data, which will distinguish rock, boulder/cobble and gravel habitats. In particular, through a photographic and video survey element which will provide valuable biological information on the epifaunal communities present on ‘reef’ habitats, which may be of conservation importance, and not resolvable by other means of sampling such as grabs or trawling.

To meet these objectives over the whole study area required the planning and conduct of new surveys using modern high-resolution geophysical systems, including multi-beam, digital sidescan and sub-bottom profiling. These were conducted along a widely spaced grid of survey corridors. Following an initial interpretation of the geophysical records ground truth sampling stations were located at various localities within the geophysical corridors to confirm or characterise the initial interpretation. Ground truth sampling was based principally on Hamon Grabs, 2 m beam trawls, sea bed video and still photography. A number of 4 m beam trawl and scallop dredge stations were also included.

The geophysical and biological data collected during the new surveys using modern digital techniques is a significant improvement on current data held in national datasets and make an important contribution to improving and enhancing our knowledge base.

The study includes data and information provided by the East Channel Association and this has added value to the data generated and gathered by the study and allowed sampling density to be improved outside the ECR without compromising the overall density of coverage.

2.2 Outputs

The results, interpretations and conclusions of the study are published within this report including copious figures, tables and illustrations to portray the wealth and diversity of the data collected and its interpretation. A sea bed character and bedforms map of the study area at 1:125,000 scale, including cartoons of associated parameters such as biotopes and sea bed sediments at a smaller scale, is included with the report. Also included with the report is a DVD-ROM which holds the primary survey data collected by the study and their analysed or interpreted results.

An ArcMap GIS and associated database has also been created to include the study's survey data and interpretations. This is available in Arc Explorer software for free viewing on the DVD-ROM. Some aspects and results of the study are also available on the BGS website at www.bgs.ac.uk/eecmhm.

3. Regional perspective

3.1 Physical setting

The English Channel is a relatively shallow shelf sea lying between England and France. From its entrance in the west between Land's End and the north coast of Brittany where it is ~160 km wide, it progressively narrows eastward to only 35 km at the Dover Strait. The eastern half of the English Channel extends from a north-south line between the Isle of White and Cherbourg east to the Dover Strait, a distance of about 200 km and it is mainly this eastern half which is included in this regional perspective (Figure 3.1).

The sea bed morphology of the eastern English Channel has a principal regional ambient element which is a very low angled marine planation surface (Curry, 1989; Stride, 1990). It has a maximum depth of 60 – 70 m in the centre of the channel between the Isle of Wight and Cherbourg. The surface rises gently to the east, in the centre of the Dover Strait it is at a depth >40 m, and also rises gently to the French and English coasts. The initiation of this surface is likely to have been in the Late Tertiary (Neogene ~ 5 millon years ago) and its form has been modified by a number of subsequent events, primarily associated with rise and fall in sea levels, and these have modified the planation surface with both negative and positive features.

The principal negative feature is St Catherine's Deep off the south coast of the Isle of Wight which is a narrow linear deep with a depth of 60 m below the surrounding ambient planation surface. There are numerous channels elsewhere in the eastern English Channel which have been eroded into this surface but many have been infilled with sediment up to the level of the ambient sea bed planation surface and are therefore morphologically indistinguishable from their surroundings. However, there are some open relatively shallow channel systems running across the sea bed, the most prominent of which is the Northern Palaeovalley. The northern margin of this Palaeovalley forms a relatively steep boundary to a narrow, shallow coastal platform with depths of <30 m, which runs along much of the coastal

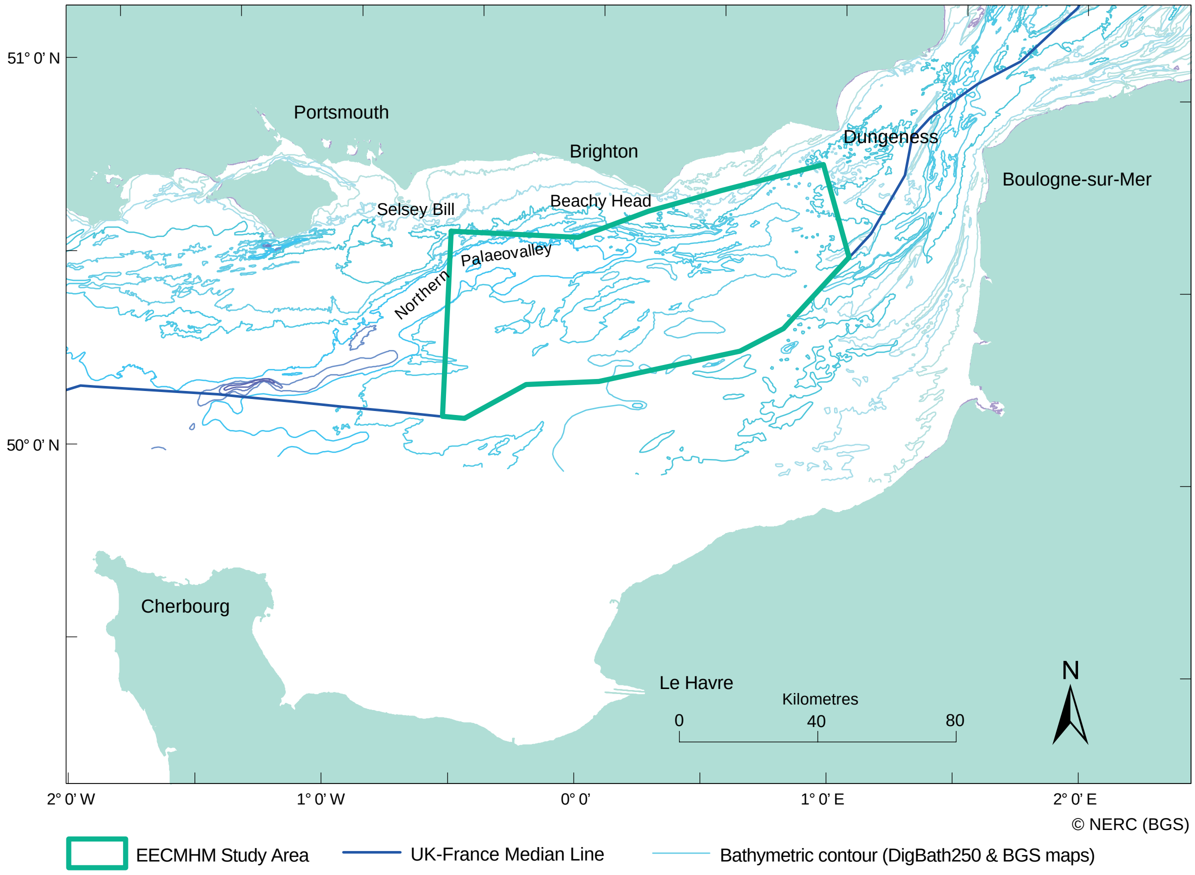


Figure 3.1. Regional offshore bathymetry.

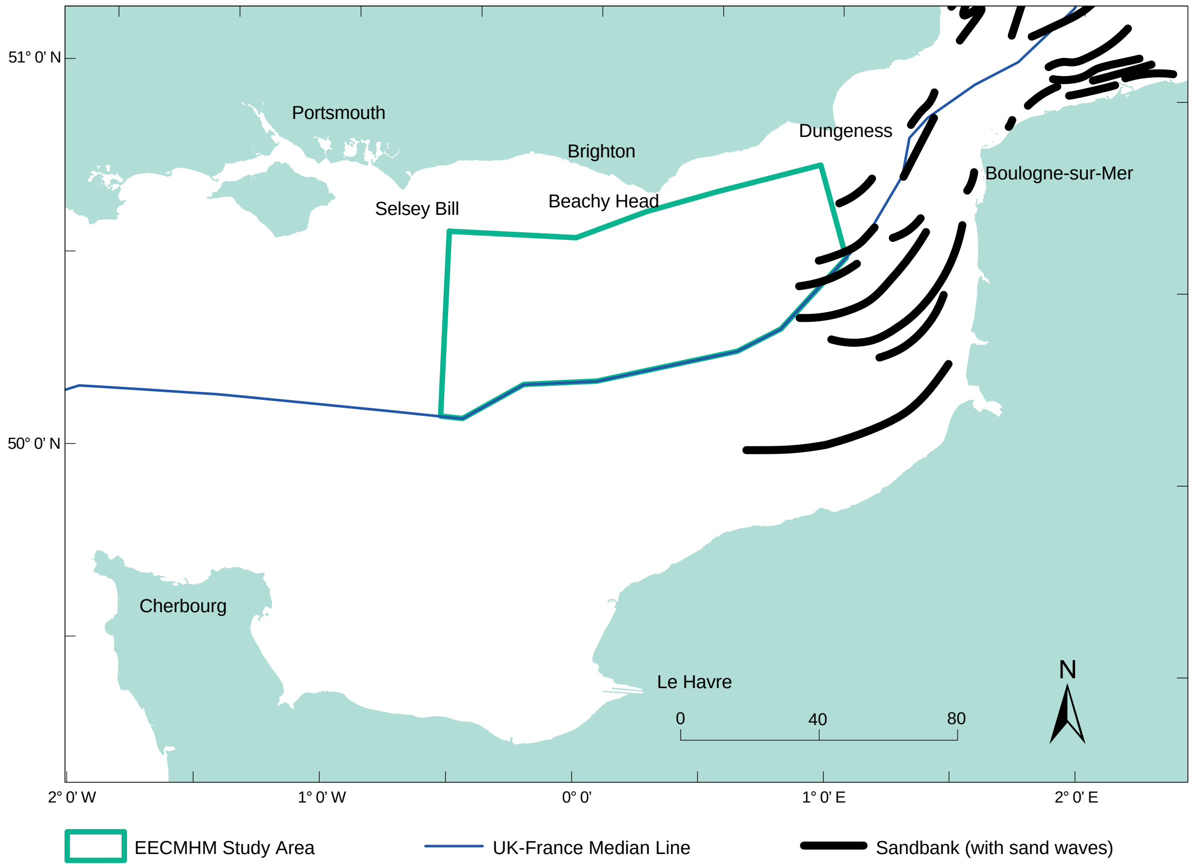


Figure 3.2. Situation of sandbanks in the eastern English Channel (adapted from Dyer and Huntley, 1999; Stride *et al.*, 1982).

fringe of southern England. There are a number of channel systems that flow into the Northern Palaeovalley and some of these are open and some are filled with sediment. The Northern Palaeovalley is also thought to be contiguous with the open Lobourg Channel in the Dover Strait.

The principal positive features on the planation surface are the numerous sand banks in the east of the area (Figure 3.2). There are at least eleven sand banks. These are extensive linear features, some are >30 km in length, and can rise over 40 m above the surrounding ambient sea bed. Their crests may shoal or come within 5 m of the sea surface at low spring tides. There are also a number of broad sand wave fields with some large sand waves, >10 m high, not only in the sand bank areas but also less extensively on the coastal margins and in isolated forms.

Although the planation surface, deeps, open channels and margins, and sand banks are the principal morphological elements in the eastern English Channel, it is obvious from the evidence of the high resolution geophysical surveys run in this study that there are numerous minor morphological features. These are common in the widespread areas of rock outcrop and thin sediment which dominate much of the central English Channel to the west and east of the Isle of Wight – Cherbourg line and to some extent on the coastal margins. Differential erosion of rock outcrop at the sea bed, particularly in areas where rocks are well bedded and disturbed by strong folding and faulting, can produce a micro morphology of small scarps and surfaces which can be significant in terms of habitat. Minor tributary channels of the major open channels are also features that have been noted. These scarps and lineations can act as conduits, guides and barriers to the movement and accumulation of sandy sediment, with the form and extent of these sediments being controlled by rock structure as much as, if not more than by hydrodynamic processes. This is particularly true where there is a minimal supply of sandy sediment.

3.2 Geology

Primarily only the geology which comprises the sea bed surface and its underlying ~0.5 m is significant in terms of habitat for marine life (see chapter 5). The geology of this thin sea bed and substrate "membrane" varies across the region of the eastern English Channel. It can comprise one or two of three principal geological elements. In age order with the youngest at the top, they are: -

- Sea bed sediments
- Quaternary sediments
- Solid Geology – Bedrock

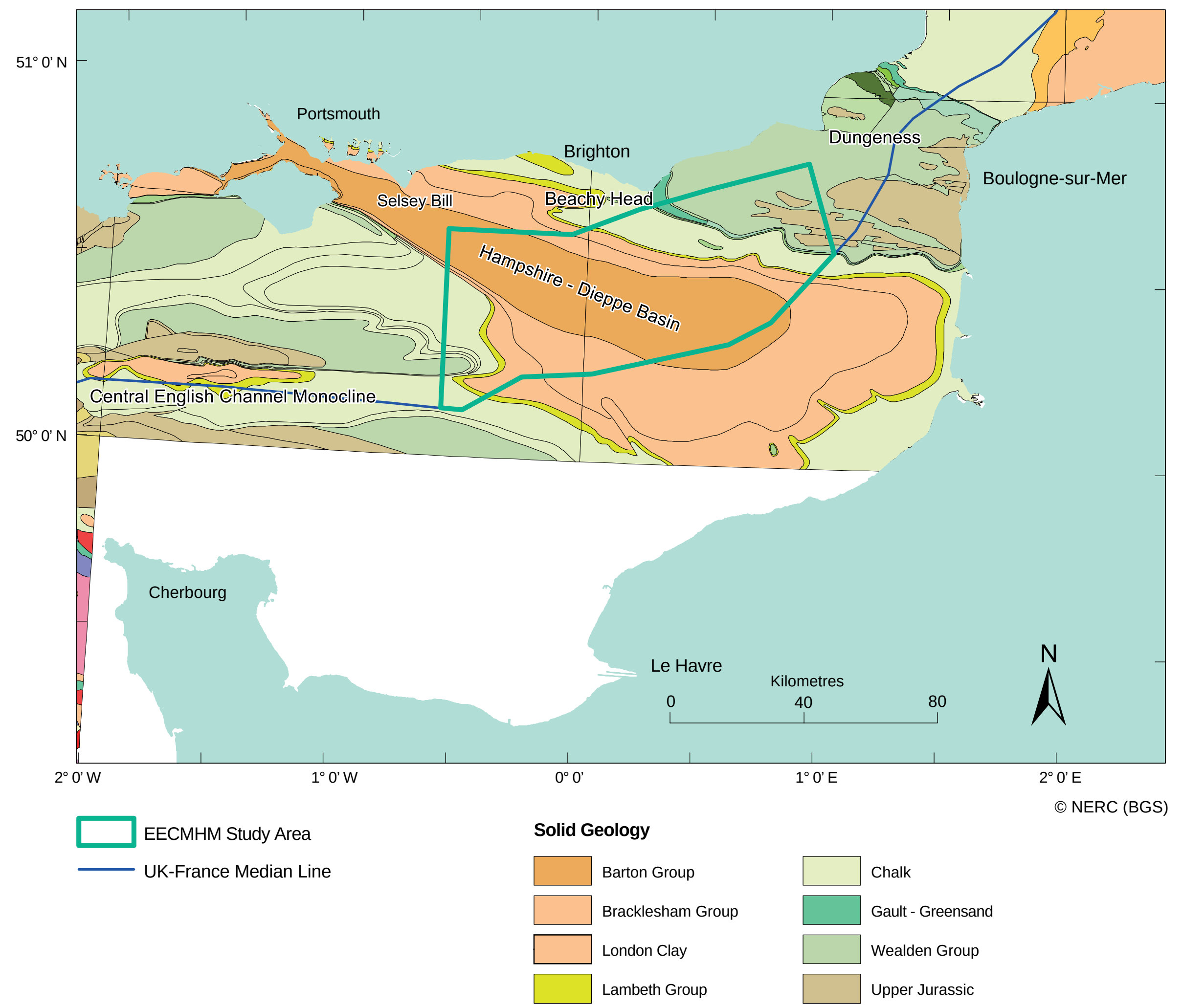


Figure 3.3. Regional offshore solid geology.

On a regional scale, simultaneous occurrence of the two older geological elements, Solid Geology and Quaternary sediments, within the top 0.5 m can be discounted. They can be regarded as being mutually exclusive at this scale and depth. The exclusivity is a product of: -

- Age. The rocks which form the Solid Geology in the region are all generally older than 35 million years. The Quaternary sediments are all less than 2 million years old, the majority probably <0.5 million. There was a long hiatus between the deposition of the youngest solid geology rocks and the onset of Quaternary sediment deposition.
- Nature of rock and sediment. Because of their age the solid geology rocks have had time to be compacted and hardened into dense, cemented, solidified masses i.e. rock. The Quaternary sediments have not had time to go through this process. They are loose, uncemented grains of mud, sand and gravel i.e. sediments.
- Tectonic history. Folding and faulting as a result of tectonic activity has modified the position and form of the Solid Geology rocks; they are not in their original depositional position. The Quaternary sediments have not been disturbed by major tectonic events; they remain in their original depositional position.
- Depositional history. The Quaternary sediments, where they occur, have been deposited on top of solid Geology rocks. Therefore any occurrences of Solid Geology in the sea bed "membrane" will be confined to those areas where Quaternary sediments are absent.

Both Solid Geology and Quaternary sediments can be covered by sea bed sediments. These are defined as mobile and immobile sediment forming the sea bed surface. They may include mud, sand and gravel up to boulder size. Their occurrence can take a number of forms including: -

- Gravel derived from underlying solid geology bedrock, creating a lag deposit
- Re-worked sand and gravel on the surface of Quaternary sediment
- Sand as sheets or fashioned into bedforms such as sand banks and sand waves, by tidal currents

Although sea bed sediments are defined as a surface deposit they can be thick enough to include the underlying 0.5 m and may reach depths of over 1 m. Defining the basal limit of sea bed sediments is difficult particularly where they are thin (see Chapter 5.2). BGS sea bed sediment

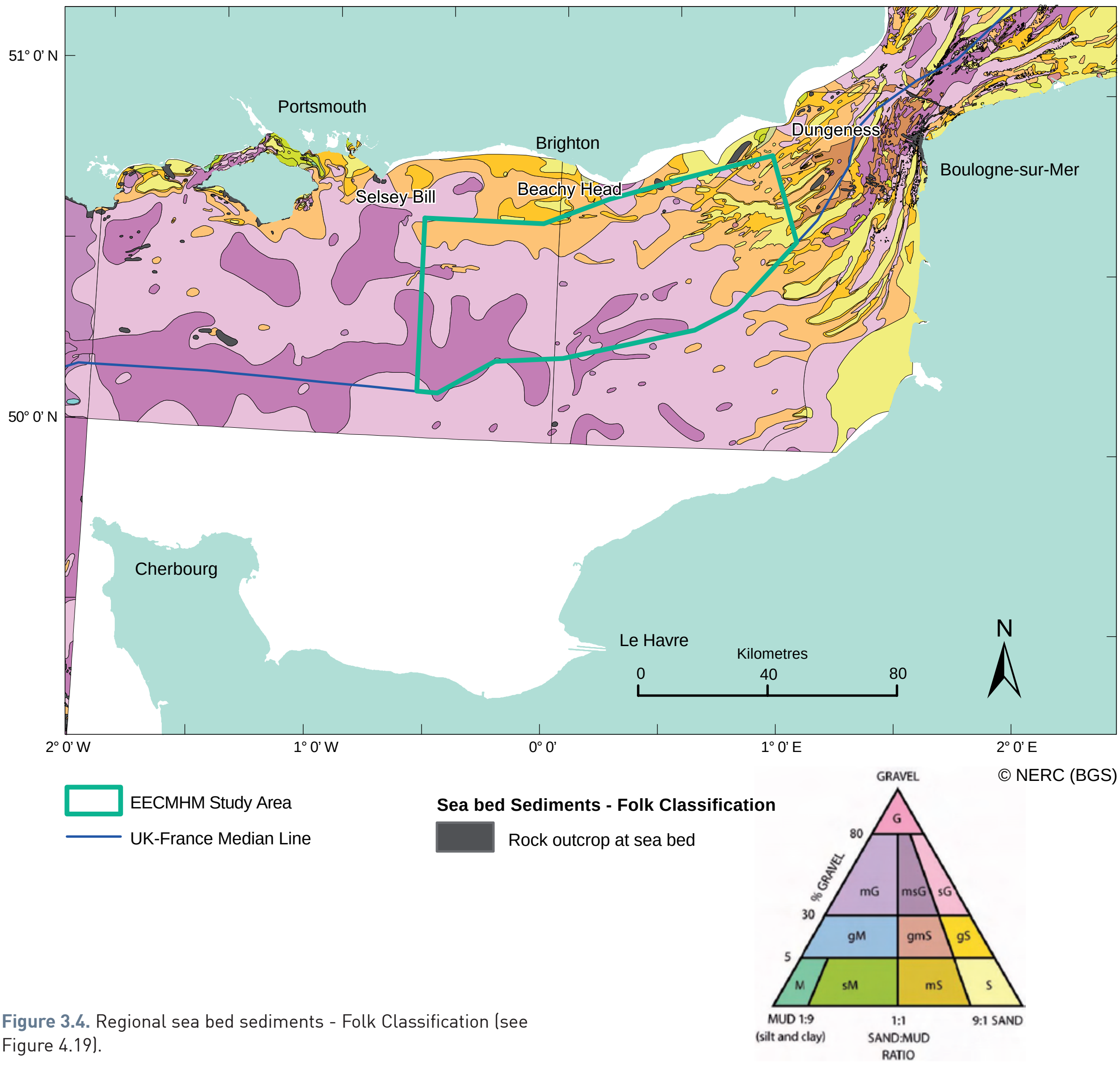


Figure 3.4. Regional sea bed sediments - Folk Classification (see Figure 4.19).

maps have nominally used 0.5 – 1 m as a defining basal limit for mapping sea bed sediments.

The solid geology in the eastern English Channel encompasses rocks from the Upper Jurassic, which are the oldest in the region at over 142 million years, to Tertiary Barton Group rocks which are about 39 million years old. These rocks have been folded and faulted by tectonic movement which have formed major regional scale structures such as the Hampshire-Dieppe Basin and the Central English Channel Monocline (Figure 3.3). Relatively young Tertiary rocks are associated with these two structures.

The Upper Jurassic is confined to an anticlinal structure in the east, which crosses from England to France between the Hampshire-Dieppe Basin and the Dover Strait. Cretaceous Chalk and extensive Wealden Group rocks also occur in this eastern area up to the Dover Strait.

Chalk is very extensive to the west of the Hampshire-Dieppe Basin and sits within an east-west trending synclinal basin with Wealden Group rocks on its margins. These margins are delineated by monoclines to the north and south. Monoclines are characterised by very steeply dipping rocks, which form narrow linear bedding at outcrop. The northern monocline runs east-west through the Isle of Wight and the southern one forms the Central English Channel Monocline (Figure 3.3). This area of sea bed west of the Hampshire-Dieppe Basin and south of the Isle of Wight, to at least 2° W, has little (<0.5 m) or no sea bed sediment cover (BGS, 1989a). It is essentially a rock platform where steeply dipping rock and bedding form prominent morphological features on the sea bed. There are a number of open channel systems crossing the rock platform including the Northern Palaeovalley. The only channel systems infilled with Quaternary sediment in this area are the Palaeo-Solent east of the Isle of Wight and those which occur south of the Central English Channel Monocline and are part of the Palaeo-Seine system on the French side of the English Channel (Hamblin *et al.*, 1992).

Elsewhere in the region the occurrences of solid geology rock at or near the sea bed are not as extensive because of numerous infilled channels and sand banks, sand wave fields and sheets. However there are significant areas of the sea bed of the English coastal margin and in the east and Dover Strait where rock is present, particularly where the rocks have been strongly folded, well bedded and relatively hard and dense.

The Quaternary is a period characterised by major changes in sea level associated with cycles of glaciation and inter-glaciation during the last two million years. There have been numerous glacial cycles during the Quaternary but there is no physical evidence for glacial ice encroaching into the English Channel. However, extensive east to west flowing river systems are believed to have developed in the English Channel during sea level low stands in the Early to Middle Quaternary fed by French and English rivers (Gibbard and Lautridou, 2003). The opening of the Dover Strait in the middle Quaternary meant the English Channel also became a conduit of water and sediment flowing from the Thames and Rhine (Gibbard, 1988, 1995). These river flows have created an extensive system of open and infilled channels and deeps (Dingwall, 1975; Smith, 1985; Antoine *et al.*, 2003). Channels infilled with Quaternary sediment are particularly extensive where they have incised into the relatively soft Tertiary rocks of the Hampshire-Dieppe Basin (Figure 5.3) (Hamblin *et al.*, 1992; BGS, 1989b; Wright, 2004). These infilled channels have tributary systems which flowed across the coastal margins such as the Palaeo Solent, Arun, Adur and Ouse rivers on the English coast (Bellamy, 1995) and the Palaeo-Canche, Authie, Somme and Seine on the French coastal margin. The Quaternary sediment which fills these channel systems are predominantly fluvial in origin although some marine elements are likely to occur within their upper sequences as a consequence of sea level rise and onset of marine conditions since the last glaciation.

The factors which control the character of the sea bed sediments in the region are primarily two-fold. Firstly the nature and form of the underlying substrate and secondly modern and long term hydrodynamic processes. The western area of the region is dominantly gravel and sandy gravel (Figure 3.4), rock is at or close to the sea bed and much of the gravel is likely to be derived from the underlying bedrock. Fine sandy sediment has been winnowed from the sea bed surface by the relatively strong tidal currents in the area (Figure 3.6). These gravelly sediments extend into the central part of the region and overlie Quaternary channel infill sediments. Fine sandy sediment has also been winnowed from the surface of these sediments.

The long term process in the region since at least the initiation of fully marine conditions, around 5000 years ago, has been the transport of fine sediment and sand to the east, and north along the coastal margin. This has created extensive areas of gravelly sand and sand in the east and on the coastal margin. These have been fashioned into numerous large sand banks in the east and approaches to the Dover Strait as well as extensive sand wave and megaripple fields.

3.3 Hydrodynamics

The eastern English Channel is considered to be a transition area between the Atlantic Ocean and the North Sea. Hydrodynamically, this semi-enclosed coastal sea is co-dominated by mixed tidal, wind and wave generated influences.

The dominant hydrodynamic force in the English Channel is tide. Moderate to large spring tidal ranges (3-12 m) are characteristic for the shallow environment (Department of Trade and Industry, 2004). Tidal amplitudes are largest in the eastern channel near the French coast (Figure 3.5), but are very low along the Dorset stretch of the English coast. Figure 3.6 shows the variation in tidal current velocity across the eastern English Channel and demonstrates that tidal strengths are at their strongest in the western central part of the Channel and through the Dover Strait. At spring tides the current velocity exceeds 2 ms^{-1} in the western central part of the English Channel, and Hamblin *et al.,* (1992) reported extreme current velocities of 4.6 ms^{-1} just west of the Cherbourg Peninsula. Moving eastwards, tidal current velocities decrease, throughout the central part of the region building again towards another maximum in the narrow Dover Strait.

In addition to the dominant tidal force, the hydrodynamic status of the English Channel can be influenced by wind and wave forces. The 50-year extreme wind speed in the eastern English Channel varies between 62 and 68 knots (Department of Trade and Industry, 2004; Hamblin *et al.*, 1992). In addition to locally generated wind induced waves, the eastern English Channel is also exposed to swell originating from the Atlantic Ocean (Velegrakis *et al.*, 1999). Cotton *et al.* (1999) reported significant wave heights between 0.5-1.5 m to be typical for the eastern English Channel, but extreme 50 year return significant wave heights over 8 m have been predicted by models (Cotton *et al.*, 1999; Department of Trade and Industry, 2004). Under average wave conditions the tidal currents will remain the controlling factor in water depths greater than a few metres. During storm events waves may have a more significant impact on the movement of sea bed sediments than tide, but from the lack of a clear correlation between water depth and sediment grain size it can be concluded that wave action is less important than

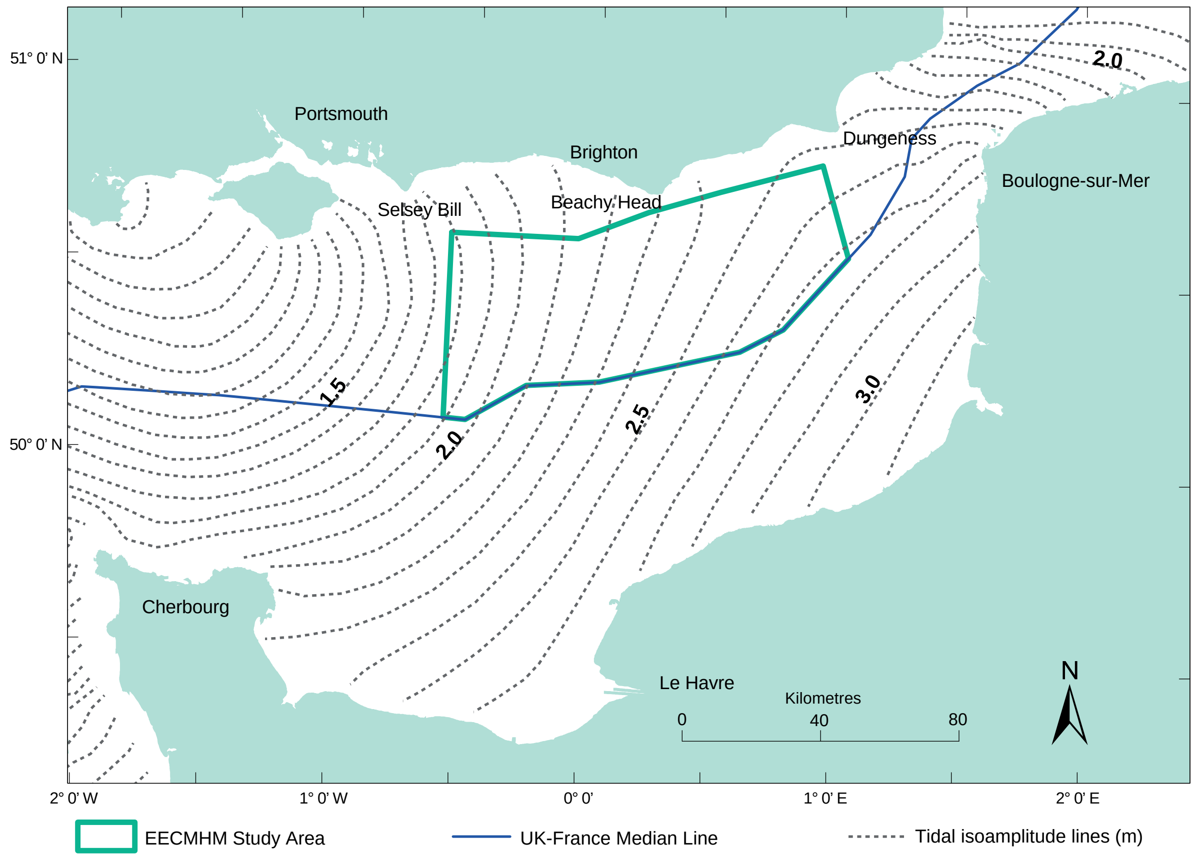


Figure 3.5. Amplitude of the M2 tidal harmonic in the eastern English Channel (after Chabert d'Hieres and Le Provost, 1978).

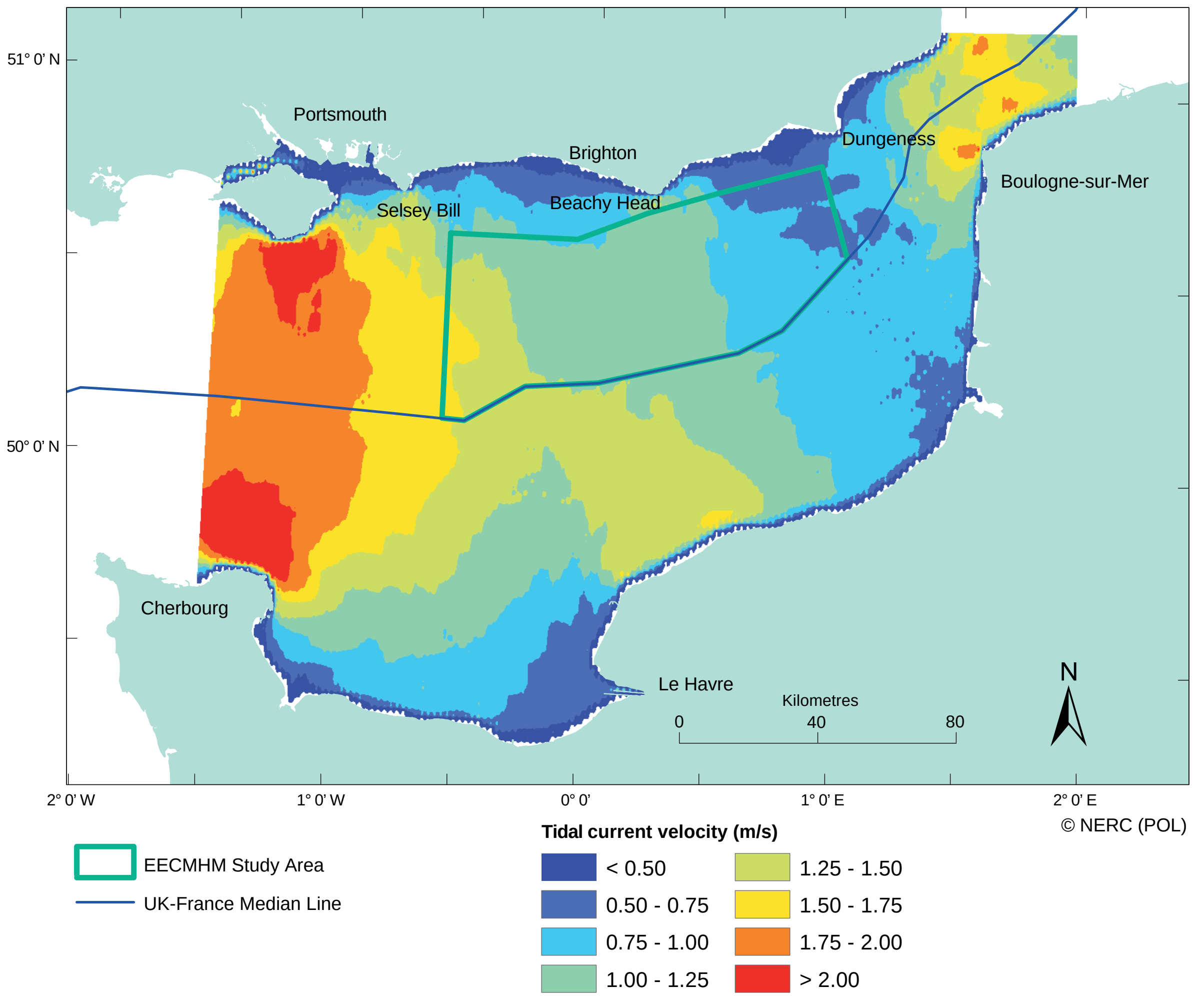


Figure 3.6. Maximum amplitude of the depth averaged mean spring tidal current (data supplied by Proudman Oceanographic Laboratory - M.J. Howarth)

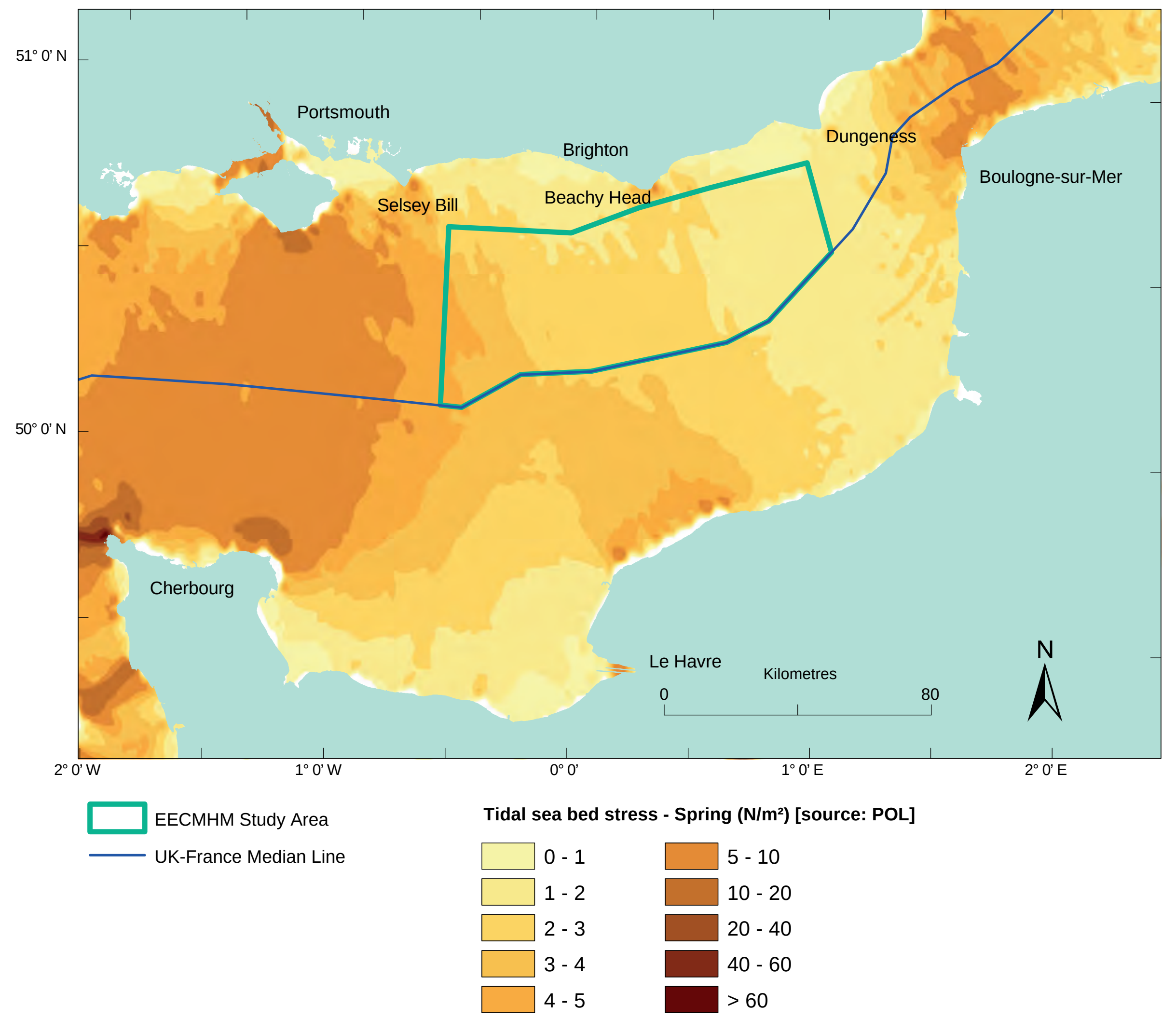


Figure 3.7. Sea bed stress at mean spring tide in the eastern English Channel.

tidal currents in the transport of sediments in the eastern English Channel (Hamblin *et al.*, 1992).

The stress generated at the sea bed is a function of the tidal current velocity, water depth and bottom roughness (Figure 3.7). Compared to the distribution of sea bed sediments in this part of the Channel, a correlation can be seen between the sea bed character and the exerted stress. The high sea bed stress area in the central English Channel correlates well with the coarser deposits, whereas the low bed stress levels along the axis Hastings – Somme Estuary correlate well with the sandy deposits (Anthony, 2004; Grochowski *et al.*, 1993a; Hamblin *et al.*, 1992).

3.4 Sedimentation processes

The sedimentation processes in the English Channel, and in particular the Dover Strait, have been extensively studied (Anthony, 2004; Boxall *et al.*, 1995; Dewez *et al.*, 1989; Grochowski *et al.*, 1993a; Grochowski *et al.*, 1993b; Reynaud *et al.*, 2003; Velegrakis *et al.*, 1999). Generally there has been agreement by the various researchers about the sediment transport pathways and processes at the regional scale of the English Channel. Opinions are more likely to vary at local scales in complex environments such as the Isle of Wight or the around the Cherbourg Peninsula and Channel Islands. Knowledge of sediment transport pathways in the area is based on in-situ data such as current measurements or sidescan sonar and seismic surveys, and from the results of numerical models (Grochowski *et al.*, 1993a; Hamblin *et al.*, 1992; Johnson *et al.*, 1982).

Present day inputs of sediments in the eastern English Channel are mainly rivers and coastal erosion. Rivers on both the English and French side of the Channel contribute towards the input of predominantly fine-grained sediments, with greatest inputs from the rivers Seine and Somme along the French coast. Some input of fine sediment are also derived from the erosion of the cliffs both on the English and French side of the Channel (Velegrakis *et al.*, 1999). Offshore sources of sediment are the erosion of

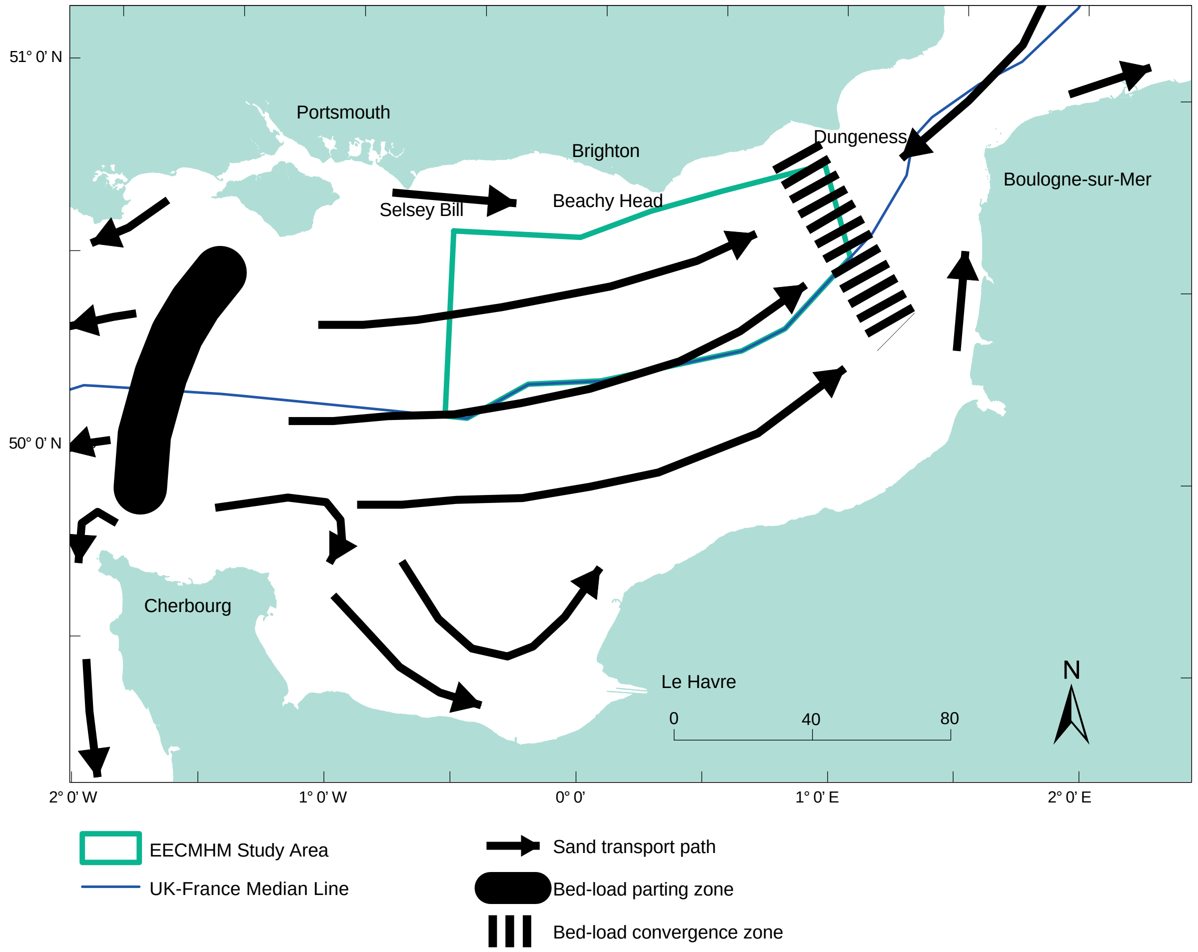


Figure 3.8. Sediment transport pathways in the eastern English Channel (adapted from Anthony, 2004; Grochowski *et al.*, 1993a; Grochowski *et al.*, 1993b; Hamblin *et al.*, 1992; Hamilton, 1979; Johnson *et al.*, 1982).

exposed sea bed and the winnowing of sea bed lag gravel deposits (Anthony, 2004). These are likely to be minimal in modern times.

A simplified map of the sediment transport pathways in the eastern English Channel is presented in Figure 3.8. Comparison of the sediment transport pathways with tidal current velocity in the eastern English Channel (Figure 3.6) shows a clear correlation. The decreasing trend in current velocity from the central English Channel to the eastern English Channel is associated with a net transport of sediment from west to east. The high current velocity region in the central English Channel corresponds to a bed-load parting zone. The net effect in this area results in the transport of fine sediment away from the high velocity area to the low velocity areas, contributing to the coarser nature of sea bed sediments in the central English Channel (Anthony, 2004; Grochowski *et al.*, 1993a). The bed-load parting zone in the central English Channel runs from the Isle of Wight to the Cherbourg Peninsula. Although bed-load parting zones are typically located in narrows between seas with high tidal currents, the Dover Strait forms an exception with the presence of a bed-load convergence zone. The bed-load convergence zone is a result of the net effect of the ebb and flood tidal currents in the Dover Strait, resulting in an accumulation of mainly sandy material in the area (Anthony, 2004; Grochowski *et al.*, 1993b). A coastal transport path by-passes the convergence zone along the French coast resulting in the movement of sand towards the North Sea (Figure 3.8). Some researchers suggest a similar coastal transport path may be present along the English coastline in the Dover Strait (Anthony, 2004; Dewez *et al.*, 1989; Grochowski *et al.*, 1993b).

The sediment accumulating bed-load convergence zone is characterised by the presence of sandbanks (Figure 3.2). The sandbanks form major morphological features in the eastern English Channel, with individual ridges exceeding 20km in length, and often several kilometres wide. The crests of the sandbanks are often only a few metres below the water level at low tide. The sandbanks are characterised by well to very well sorted, medium grained sands (Grochowski *et al.*, 1993a). The sandbanks in the central part of the Dover Strait are described by Dyer & Huntley (1999) as a combination of Open Shelf Ridges and possibly a number of Wide Mouth Estuary Ridges. The sandbanks found close to the English and French coastline are classified as Banner Banks and area associated with adjacent coastal headlands. Dyer and Huntley, (1999) suggest that sandbanks in the Bay of the Somme are classified as Alternating Ridges and may be the result of the separation of Banner Banks. Associated with these sandbanks are local transport paths and gyres, which are important for the maintenance of the sandbanks and may have been significant in the formation of sandbanks. However, it is also possible that other processes may have led to their development during the last post-glacial sea-level rise (Reynaud *et al.*, 2003).

Superimposed on the sandbanks are often sand waves, although sand waves can be found in many sandy substrates of the eastern English Channel. These sand waves can have significant heights, reported up to 7m south of Brighton and 15m in the Dover Strait. Associated with these large sand waves are often megaripples (Hamblin *et al.*, 1992). Other sedimentary features found in the eastern English Channel are gravel furrows, characteristic for environments with a low supply of sediments and high current velocities (Belderson *et al.*, 1982). These up to 9km long , 30m wide and 1m deep erosional features are mainly found around the bed-load parting zone in the western part of the eastern English Channel.

The sediment transport pathways presented in Figure 3.8 represents the long-term movement of sand over the area. The west to east transport paths in the eastern English Channel are a result of the dominant flood tides. East of the bed-load convergence zone off Dover, the dominant transport direction is east to west as a result of a strong ebb tidal flow (Reynaud *et al.*, 2003). However, local or short-term sand transport in the area can be induced by wind-generated currents, waves or storm surges, moving sediment against the tidally induced long-term sediment pathways (Johnson *et al.*, 1982). This is illustrated by Grochowski *et al.* (1993b) who found that during periods of southwesterly winds in the Dover Strait the net movement of sediments is towards the North Sea, overriding the bed-load convergence zone. During periods of northeasterly winds they found conditions similar to the pathways presented in Figure 3.8, with a slight movement of the convergence zone to the south.

3.5 Benthic biology

The determination of spatial patterns in benthic communities in relation to the physical properties of the seafloor dates back to the early work of Petersen (1913) and his collaborators. In the eastern English Channel similar efforts to describe and characterise the variability and distribution of benthic fauna over large geographical scales is illustrated in the work conducted by Holme (1961, 1966), Sanvicente-Anorve, *et al.*, (1996), Bremner *et al.*, (2006) and Cabioch (1968).

When studying the distribution of species and communities over large regional scales it is important to identify the environmental variables that might influence the fauna. In the English Channel, water depth, temperature, hydrodynamics and sediment type have been identified as the predominant environmental factors that are likely to influence the species composition (Bremner *et al.*, 2006, Sanvicente-Añorve, 2002; Kunitzer *et al.*, 1992).

Early research conducted by Holme (1961) in the English Channel addressed the benthic fauna off the south coast of England. He sampled 167 stations with an Anchor dredge between 1958 and 1959. The Anchor dredge was chosen because of its effectiveness for sampling coarse substrates and also because large samples of material were required to effectively sample the low diversity of species known to be present in the Channel. As part of this study, Holme defined four broad species distribution classifications (based predominantly on molluscs and echinoderms) for the English Channel: 1) Species generally distributed throughout the Channel; 2) Western Channel species (including species at the northern limit of their distribution); 3) Central Channel; 4) Northern species. Temperature and hydrographic conditions were the main factors identified that influenced the distribution of species in the Channel. Holme conducted additional survey work in the Channel between 1960 – 1962 using similar sampling methods to those used in his previous surveys (Holme, 1966) and widened his study area to cover the full extent of the English Channel (including Roscoff, Gulf of St. Malo and Bay of Seine) (Figure 3.9).

Once again, Holme classified each species according to its geographical distribution within the Channel. The main categories were: -

1) Species distributed throughout the length of the Channel
2) Western species
3) West Channel species
4) Cornurbian species
5) Sarnian species
6) Eastern species

In this regional perspective we have included a general description of these six categories. The species encountered during this project in the Eastern English Channel Marine Habitat Map Study Area fall within a number of the classification categories described below.

N.B. For species where the taxonomic name has recently changed, the most up to date name appears in parentheses after the species name used by the original author.

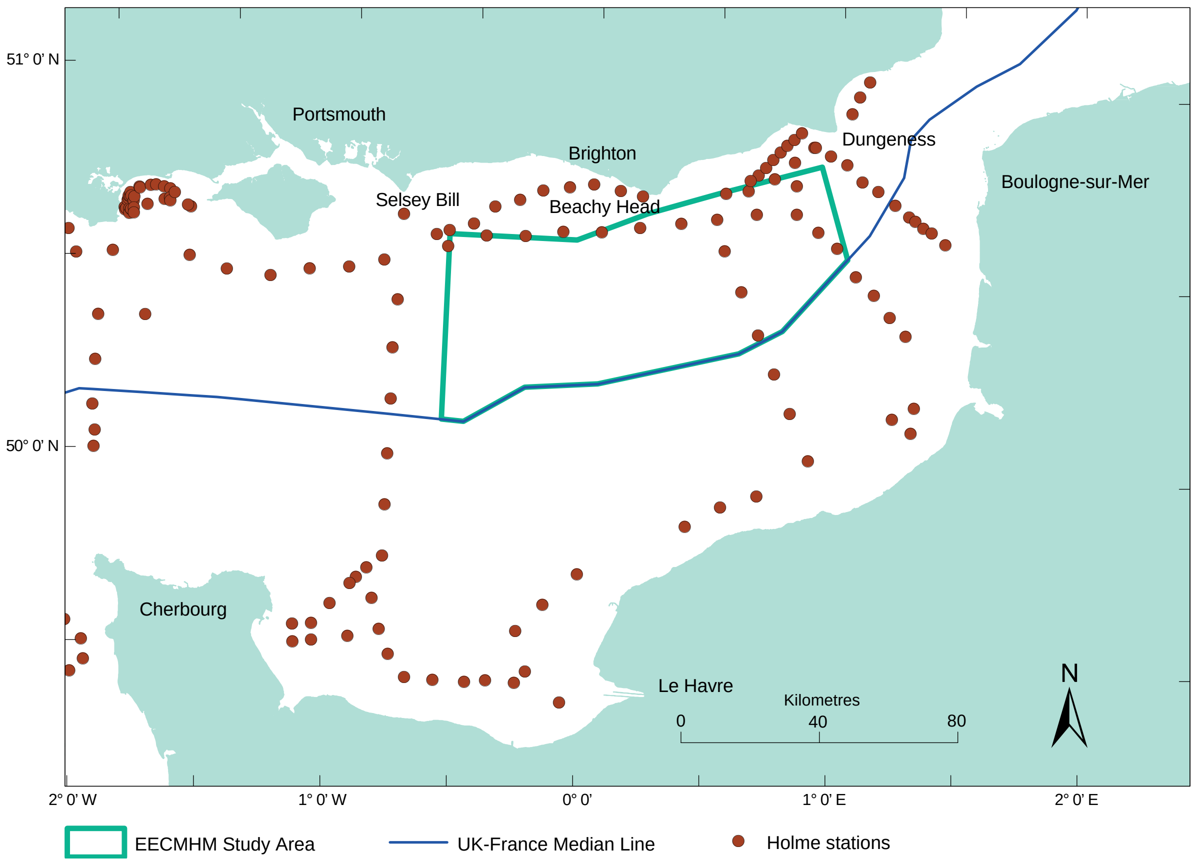


Figure 3.9. Anchor dredge stations in the eastern English Channel (Holme, 1961, 1966).

1 Species distributed throughout the length of the Channel.

a) Species generally distributed in the Channel. This category represents the larger group of species and includes three animals (*Diplodonta rotundata*, *Tellina donacina* (*Moerella donacina))* and *Amphiura branchiata (Acrocnida branchiata*) that are reaching their northern limits in British waters. Epifaunal species, with a preference for strong water movement such as *Ophiothrix fragilis*, *Chlamys opercularis* (*Aequipecten opercularis*) and *Glycymeris glycymeris* are found characteristically in hard or gravel bottoms in the central areas of the Channel but also elsewhere in the Channel. Other species which are more generally distributed included *Ensis arcuatus*, *Nassarius incrassatus* (*Hinia incrassata*), *Natica alderi* (*Polinices pulchellus*), *Spatangus purpureous* and *Echinocardium cordatum*. Some of these species are absent from the French side of the Western Channel. Additionally, *Venerupis rhomboides (Tapes rhomboides*) is a widely distributed mollusc which inhabits sandy to gravelly sediments.

b) Species present along the south coast of England, but rare or absent from the French side. The majority of these species inhabit fine sediments, which are mainly encountered off England. Some of the typical species include: *Nucula turgida* (*Nucula nitidosa*) – sand, *Nucula hanleyi* - gravels, *Diplodonta rotundata* - sand, *Thyasira flexuosa* - muddy sand, *Cardium echinatum* (*Acanthocardia echinata*) - sand, *Mysia undata* (*Fabulina fibula*) - sand, *Tellina fabula* - fine sand, *Abra alba* - mud or muddy sand, *Phaxas pellucidus* - sand, *Mactra corallina* (*Mactra stultorum)* - sand, *Lutraria lutraria* - fine sand, *Nassarius reticulates* (*Hinia reticulata*) - muddy sand and *Aphrodita aculeata* - sand.

c) Species present throughout the length of the Channel, but mainly on the French side in the eastern English Channel. The most characteristic species include: *Astarte triangularis* (*Goodallia triangularis* gravel), *Laevicardium crassum* (gravel), *Dosinia exoleta* (gravel), *Lutraria angustior* (gravel), *Golfingia vulgaris* (muddy sand and gravel), *Chaetopterus variopedatus* (sand) and *Upogebia deltaura* (sand). This category included a number of species whose localised distribution is mainly related to their preference for gravel deposits. Species like *Dosinia exoleta* and *Arcopagia sp* are fairly widespread, but uncommon.

2 Western Species.

This group comprises species that are present westwards of Start Point on the English side of the Channel and west of Guernsey on the French side. This group is formed by a mixed assemblage of species which are either stenothermal, cold-water loving or sensitive to the chemical condition of the water. Some of these species i.e. *Chlamys tigerina* (*Palliolum tigerinum*), *Lima hians* (*Limaria hians*), *Lima subauriculata* (*Limatula subauriculata*) and *Lucinoma boralis* live only in the cool water below the thermocline in the deeper parts of the western Channel. *Tellina pygmaea* (*Moerella pygmaea*) occurs in the western part of the Channel but interestingly also in the eastern part close to the French coast. On the French side, species such as *Ophiocomina nigra*, *Echinocardium flavescens* and *Echinocardium pennatifidum* are found.

3 West Channel species.
These species can be found on suitable types of substrates along the western part of the Channel. Off the English coast they reach as far as Weymouth Bay to Poole Bay. In the mid Channel area, the fauna is reduced and species will penetrate as far as the Cap de la Hague (NW of the Cotentin peninsula). Many of these species inhabit sandy substrates, which appear to be scarce in the western parts of the Channel and this may be the limiting factor governing their distribution. Some examples include: *Cyprina islandica* (*Arctica islandica*), *Dosinia lupinus*, *Venus casina* (*Circomphalus casina*), *Turritella communis, Callianassa subterranea, Upogebia stellata, Ophiura affinis* and *Venus striatula* (*Chamelea gallina*).

4 Cornubian species.
These are warm water species generally distributed in the shallow areas of the western Channel. Examples include *Callista chione*, *Tellina squalida* (*Angulus squalidus*) and *Marthasterias glacialis*. It is likely that the distribution of Cornubian species will vary with long-term changes in sea temperature.

5 Sarnian species.
The majority of these species show a warm-water preference and are found close to the Channel Islands and St. Malo region. Many of the species in this category are confined to this area but others can be found as far as the Portland-Isle of Wight area. Species such as *Venerupis rhomboides* (*Tapes rhomboides*) may also extend throughout the Channel. Some of the species found in this category are *Nucula nucleus*, *Chlamys varia*, *Venerupis verrucosa*, *Gari depressa*, *Pilumnus hirtellus* and *Anseropoda placenta*.

6 Eastern species.
These are cold water species found in the eastern part of the Channel. Species such as *Spisula elliptica* and *Buccinum undatum* typify this category and were either uncommon or absent in samples collected west of Start Point.

A general classification of faunal communities for the whole of the Channel is provided by Jones (1950):

1 *Boreal shallow-sand association.* This is mainly a shallow-water community that occurs intertidally.

2 *Boreal shallow-mud association.* This corresponds to Petersen's *Macoma* community, mainly found intertidally in estuaries and shallow water.

3 *Boreal offshore sand association.* This is Petersen's variant *Venus* community of the *Echinocardium cordatum-Venus striatula* (*Chamelea gallina)* community. In the Channel, deposits of fairly clean sand tend to be found very close inshore or further offshore where there is an influence of strong tidal streams. Some of the characteristic species include *Cardium echinatum* (*Acanthocardia echinata*), *Dosinia lupinus*, *Venus striatula* (*Chamelea gallina*), *Gari fervensis*, and *Echinocardium cordatum.*

4 *Boreal offshore muddy-sand association.* This is the equivalent of Petersen's *Echinocardium cordatum-Amphiura filiformis* community. This classification is a combination of the initial groups provided by Jones and Ford including a deeper and shallow-water silty-sand. Characteristics species includes *Nucula turgida* (*Nucula nitidosa*)*, Cyprina islandica* (*Arctica islandica*)*, Cardium echinatum* (*Acanthocardia echinata*)*, Lutraria lutraria, Corbula gibba* and *Amphuira filiformis* among others.

5 *Boreal offshore mud association.* This is the equivalent of Petersen's *Brissopsis lyrifera-Amphiura Chiajei* association, which is not present in the Channel. The presence of soft mud only occurred at a limited number of stations from Poole Bay and off Dungeness.

6 *Boreal offshore gravel association*. This is the equivalent of Petersen's *Spatangus purpureus-Venus fasciata (Clausinella fasciata*) community. Typical species include *Nucula hanleyi*, *Glycymeris glycymeris*, *Venus casina* (*Circomphalus casina*), *Echinocyamus pusillus* and *Echinocardium flavescens.*

7 *Boreal offshore muddy-gravel association.* This is a very distinct community that occurs off Plymouth. The commonest species are burrowing crustaceans such as *Upogebia deltaura* and *Upogebia stellata*. There are also molluscs present such as *Nucula nucleus*, *Turritella communis* and *Venus verrucosa*. Sipunculid worms

such as *Golfingia elongata* and *Golfingia vulgaris* are also found in the area.

While regional differences have been shown to be significant, the study by Holme and Wilson (1985) is a reminder of the potential for marked 'within region' contrasts. They examined the fauna associated with a clean, coarse aggregate which was subject to tidal scour by sand in an area of the central English Channel. In this study they described the conspicuous epifauna evident from underwater TV images in relation to the natural stability of sediments in the area.

The *'Type A'* described as a *'stable faunal assemblage with diverse sponge cover'* was found to occur in association with coarse substrates such as pebbles, cobbles, boulders and rock outcrops that were not subject to sand scour. This assemblage was characterised by a rich epifauna consisting of sponges, erect hydroids, bryozoans (most notably *Pentapora foliacea*) and ascidians.

Similarly, the *'Type B'* assemblage was found to occur on cobbles and pebbles but was subject to sand scour and/or submergence by sand. Three sub-types of the *'Type B'* assemblage were distinguished. Of these, *'Type B-1'* was most similar to *'Type A'* differing only in the frequency of sponges encountered and is described as a '*well developed faunal assemblage with Polycarpa violacea*'. This assemblage was thought to be subject to periodic scour by sand, although the fauna appeared quite rich and varied. In contrast, *'Type B-2'* was believed to be subject to considerable sand scour and periodic submergence by layers of sand. Sponges were absent from this sub-group and the only anthozoan was *Urticina felina*. The bryozoan *Pentapora foliacea* had also been replaced by the more flexible colonies of *Flustra foliacea*, presumably as a result of the intolerance of the former species to sand scour. The third sub-group, *'Type B-3'*, was defined as the '*Impoverished Balanus – Pomatoceros assemblage*'. This assemblage was limited to fast growing organisms such as *Balanus* sp and *Pomatoceros triqueter* which can rapidly settle and exploit the short periods of sediment stability available in the summer months.

The final assemblage, *'Type C'* is defined as '*Cobble floor covered by sand*' and this assemblage contained a number of species which were common to the *B-2* and *B-3* groupings, namely *Urticina felina*, *Flustra foliacea* and *Sabellaria spinulosa.*

More recent studies in the area concluded that the distribution of the benthic macrofauna is governed by environmental mechanisms, which are operating at different spatial scales (Sanvicente-Anorve, *et al.*, 1996). Additionally the benthic diversity observed was strongly influenced by recruitment effects, species interactions and environmental changes attributable to human activities.

The CHARM (*'Channel Habitat Atlas for Marine Resource Management'*) project is a Franco-British initiative which seeks to provide information on the resources, species and habitats of the eastern English Channel (Figure 3.10). The first phase of the CHARM project ended in 2005 and has produced an atlas of fish, shellfish and invertebrate species distributions in the eastern English Channel. Detailed outputs, including a 200 - page species atlas, are located on the CHARM website (http://charm.canterbury.ac.uk).

3.6 Sea bed areas of conservation interest

The UK Government has a responsibility to implement the 1992 Directive on the Conservation of natural habitats and of wild flora and fauna (92/43/EEC) (the 'Habitats Directive'). As part of this implementation the JNCC provide advice to UK Government on suitable areas in UK offshore waters that may qualify as Special Areas of Conservation (SACs). These sites must contain habitats listed on Annex I and/or species listed on Annex II to the Directive. Two of the four Annex I habitat types known to occur in UK offshore waters have been identified as potentially present in the eastern English Channel (European Commission (EC), 2007): -

- Reefs
- Sandbanks which are slightly covered by sea water all the time

Annex I 'reef' habitat in the context of the Habitats Directive may consist of bedrock, boulders and cobbles (cobbles generally >64 mm in diameter), including those composed of soft rock, such as chalk, and it should 'arise from the sea bed' or be topographically distinct from the surrounding sea bed (Johnston *et al.,* 2002). Figure 3.11 shows the areas of potential Annex I habitat in the eastern English Channel identified by JNCC, and also shows existing inshore SACs which have been identified for various coastal and marine habitats. Neither reef nor sandbank habitat are well represented within the existing inshore SAC series in the eastern English Channel, the only one where a substantial area of either habitat is present being the south side of the Isle of Wight for its sublittoral reef habitats.

Presently work by JNCC to locate areas in UK offshore waters which may potentially fit the definition of Annex I habitats for reef and for shallow sandbanks has used sea bed sediment maps produced by the British Geological Survey (BGS) and other available data. This methodology

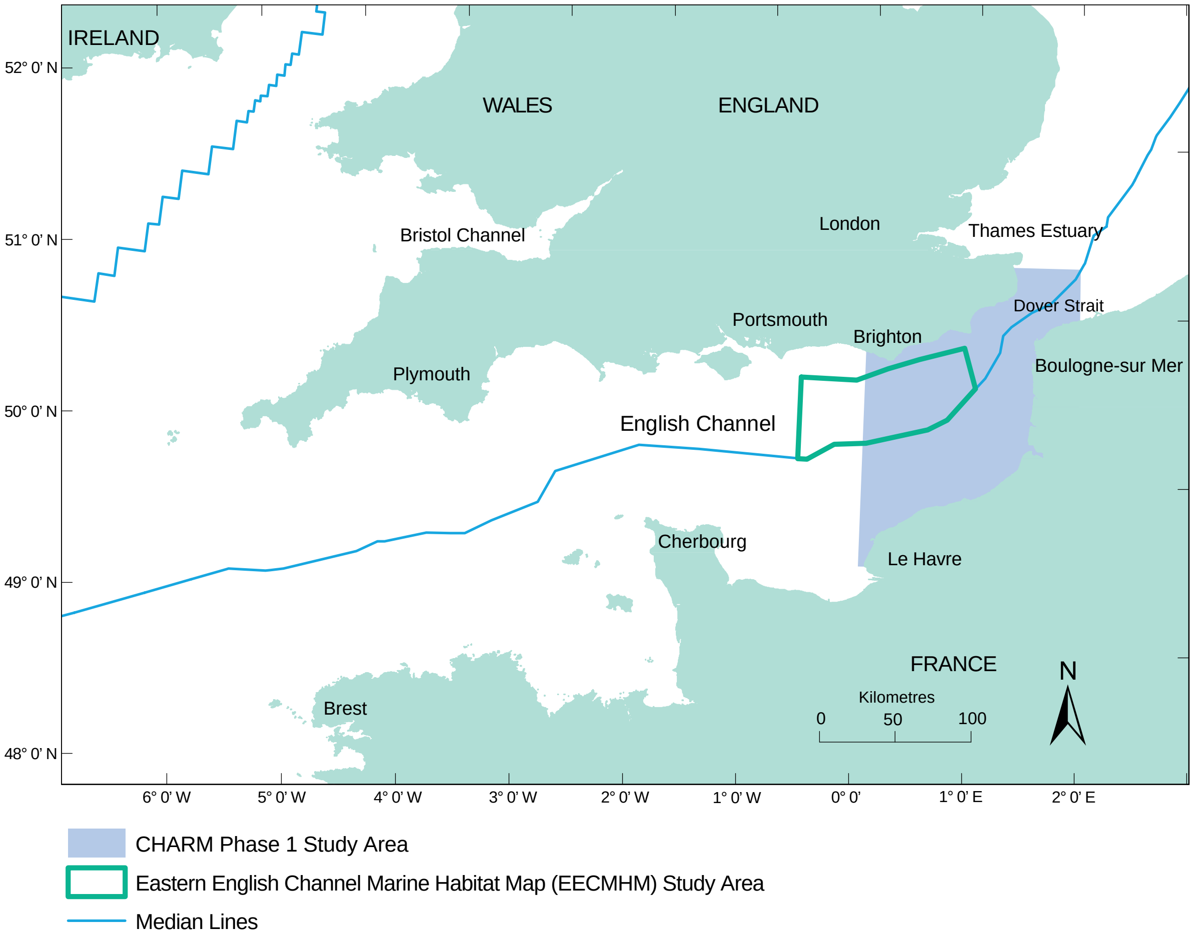


Figure 3.10. Channel Habitat Atlas for Marine Resource Management (CHARM) study area .

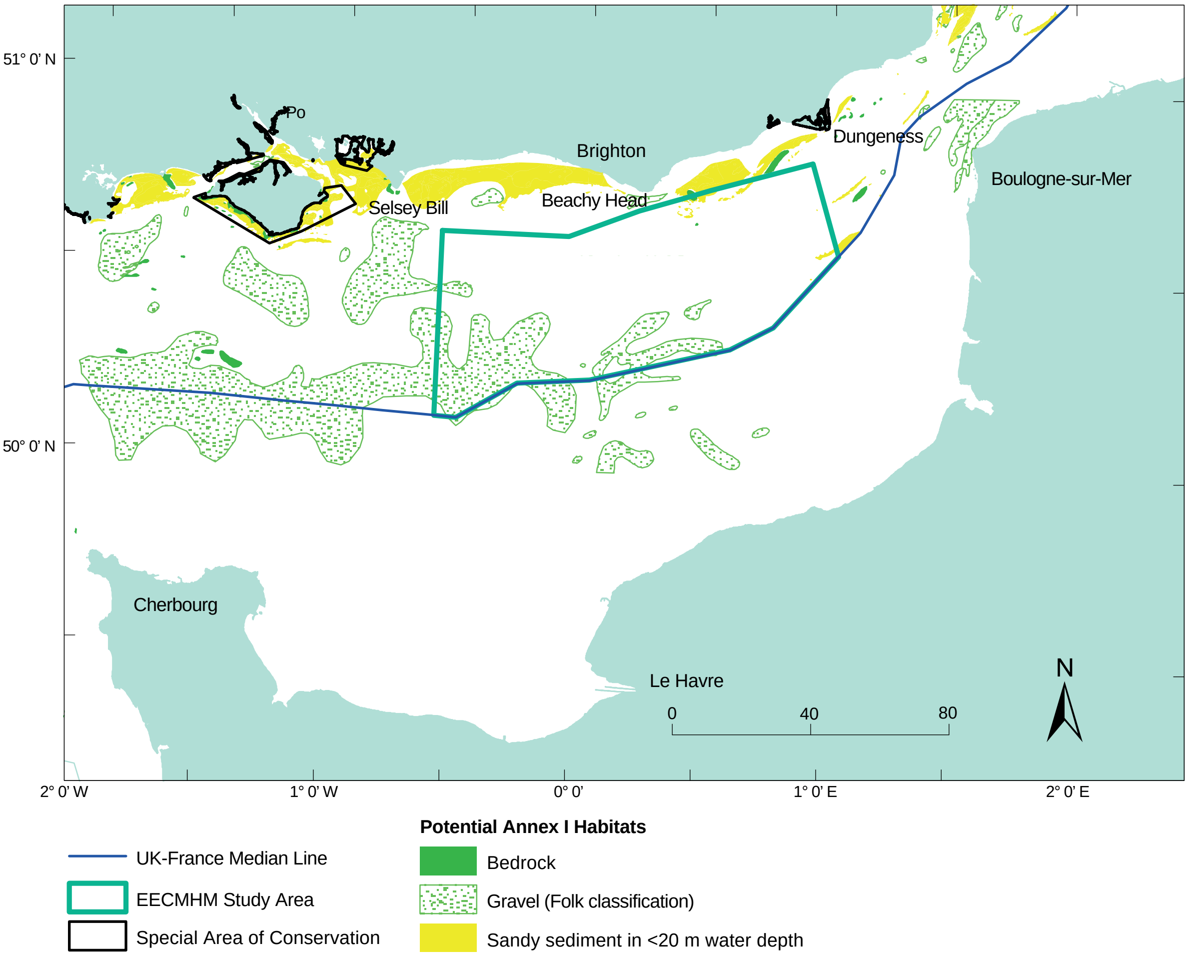


Figure 3.11. Candidate SACs, nature reserves and potential Annex 1 habitats in the eastern English Channel.

works well for bedrock and sandy habitats, but it is not possible using these maps to clearly distinguish between areas composed of boulders and cobbles and areas composed of finer gravel sediments. The modified Folk classification category 'gravel' used in the BGS sea bed sediment maps may include large boulders and cobbles (which would be considered 'reefs' for the purposes of the Habitats Directive) as well as much smaller particles down to 2mm diameter (which would not be considered 'reefs'). There is a large area of this category 'gravel' extending from south of the Isle of Wight into the East Channel Region. Some of this area may consist of fine gravels, but it may also contain significant areas of bedrock and of large boulders and cobbles.

One of the aims of the current study is to provide better resolution data over part of this 'gravel' area within the eastern English Channel, to map the extent of Annex I reef, and sandbank habitat, and to provide data on the biological communities present. This information will then be used by JNCC to assess if there are any areas in the region which should be recommended to Government as SACs.

As well as identifying and mapping Annex I habitats within the study area to enable the selection of SACs under the Habitats Directive, the results of the surveys reported here may be used in future to identify areas of biodiversity interest for consideration as marine protected areas at a national level or under OSPAR Annex V.

4. Survey methods, GIS and database

Surveys conducted for the Eastern English Channel Marine Habitat Map (EECMHM) study were designed to include a suite of geophysical and physical survey and sampling methods which would provide data for a comprehensive analysis and interpretation of the marine habitat of the study area. The EECMHM survey coverage was also planned to provide a context for the data and results acquired by the East Channel Association (ECA) in their prospecting areas (Figure 4.1) and licence application areas (Figure 4.2)

4.1 Geology and geophysics

4.1.1 Rationale

The aim of the geophysical survey of the Eastern English Channel Marine Habitat Map study area was to acquire detailed high-resolution multibeam bathymetry, sidescan sonar and shallow sub-bottom seismic data in order to assess the topography and morphology of the sea bed, establish its texture and character, and delineate the underlying geology and thickness of the superficial sediments. This was fundamental to provide the physical and regional framework on which to develop the biological sampling programme and the interpretation of sea bed habitats.

Two geophysical surveys were carried out for the study. The first survey was undertaken in May/June 2005 by Gardline Survey Ltd with the survey vessel *MV Tridens I*. The survey completed 4085 line km of Multibeam Echo Sounder (MBES), ~4085 line km of sidescan sonar producing 21 corridors of swath coverage and ~1232 line km of boomer sub-bottom data (Figure 4.3; 4.4; 4.5).

The study area was surveyed using a “corridor approach” to maximize the coverage of the area within the allocated budget for the study. The survey strategy was devised to acquire three parallel lines with sidescan sonar and multibeam deployed simultaneously, aiming to provide a sea bed swath width of up to 500 m for each corridor, and to acquire shallow sub-sea bed seismic data with a surface towed boomer along the centre line of each corridor. The EECMHM study area covers over 5000 sq. km (Figure 2.1). This area was surveyed with a grid of corridors running in two principal directions. West-east following the line of

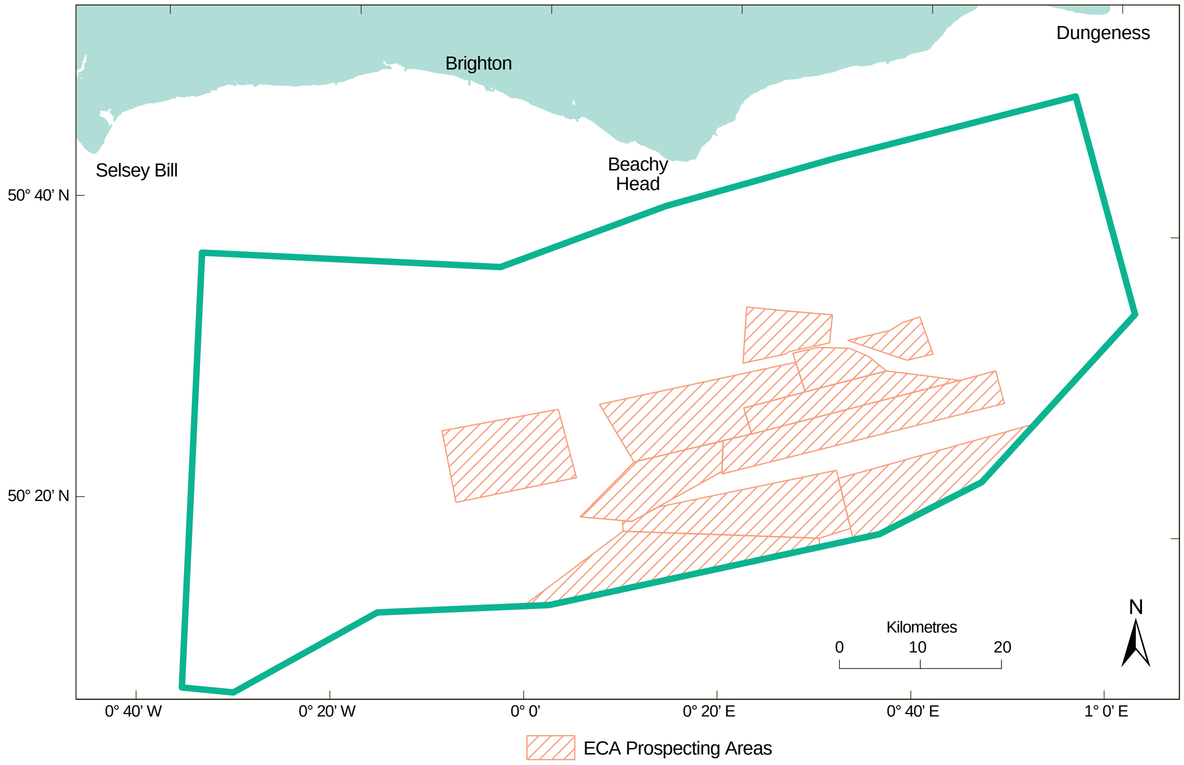


Figure 4.1. East Channel Association (ECA) prospecting areas.

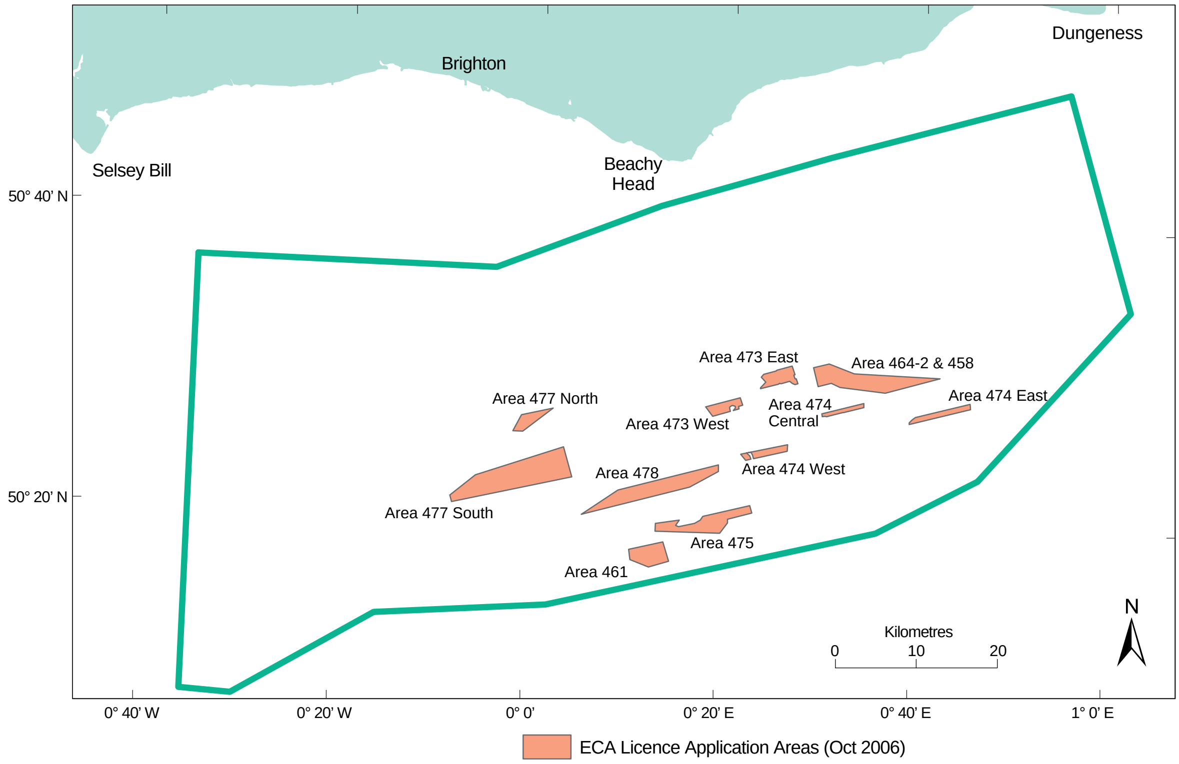


Figure 4.2. East Channel Association (ECA) licence application areas.

the Traffic Separation Zone and shorter crossing corridors running north-south. The W-E corridors were up to 120 km long and generally ran parallel to the peak tide direction. These lines and the N-S lines were designed to cross the major geological and geomorphological features present in the survey area. The N-S lines range in length from 27 km to 55 km.

The second geophysical survey took place in February/ March 2006 onboard the *RV Cefas Endeavour*, with the acquisition of multibeam and sidescan sonar data. Approximately 2,000 line kilometres were completed all running in an east-west direction, infilling between lines completed during the first survey (Figure 4.3 and 4.4). A surface towed boomer was not deployed during the second survey.

In general, the survey activities were undertaken in reasonable weather conditions with minimum loss of time due to weather, fishing activity or equipment failure. The MBES, sidescan sonar data and sub-bottom data were initially processed on board the survey vessels. This enabled interpretations to begin on board to build a physical framework for the selection of groundtruthing sites for the subsequent biological surveys.

4.1.2 Equipment, processing and interpretation

Multibeam echo sounder

Multibeam echo sounders (MBES) are used for the measurement of water depth. They consist of an array of transducers which are normally fixed to a survey vessel, and send a beam of acoustic signals to and across the sea bed which are reflected back and recorded by the multibeam as a swath of recorded sounding data (Figure 4.6). The sound travel times to the sea bed and back are converted to water depths based on a calculation of signal speed through the water column. Digital elevation models are produced from multibeam swath data enabling 3D visualisation of the sea bed bathymetry and interpretation of morphological features.

Gardline Survey Ltd was commissioned to provide the system for the acquisition and processing of the bathymetry data during the survey undertaken in May and June 2005. The MBES acquisition system onboard the *MV Tridens 1* was a hull mounted Kongsberg Simrad EM 3000 (operating frequency 300kHz). A Simrad EA502 single beam echo sounder (SBES) (operating frequencies 200/38) was used to record depths on all lines. These values were used to QC the multi-beam echo sounder data. Sound velocity profiles were measured throughout the survey. On average, two profiles per day were taken when the vessel was acquiring data.

The MBES survey was conducted to UKHO Order 1 standard with an across track overlap of 10%. The survey was specified to run at an average speed of 7 knots on the wing lines of the corridors when running only MBES and sidescan sonar. This speed was generally obtained although deviations were encountered during strong tidal conditions or poor weather. On the centre-lines, where the sub-bottom profiler was deployed in conjunction with the

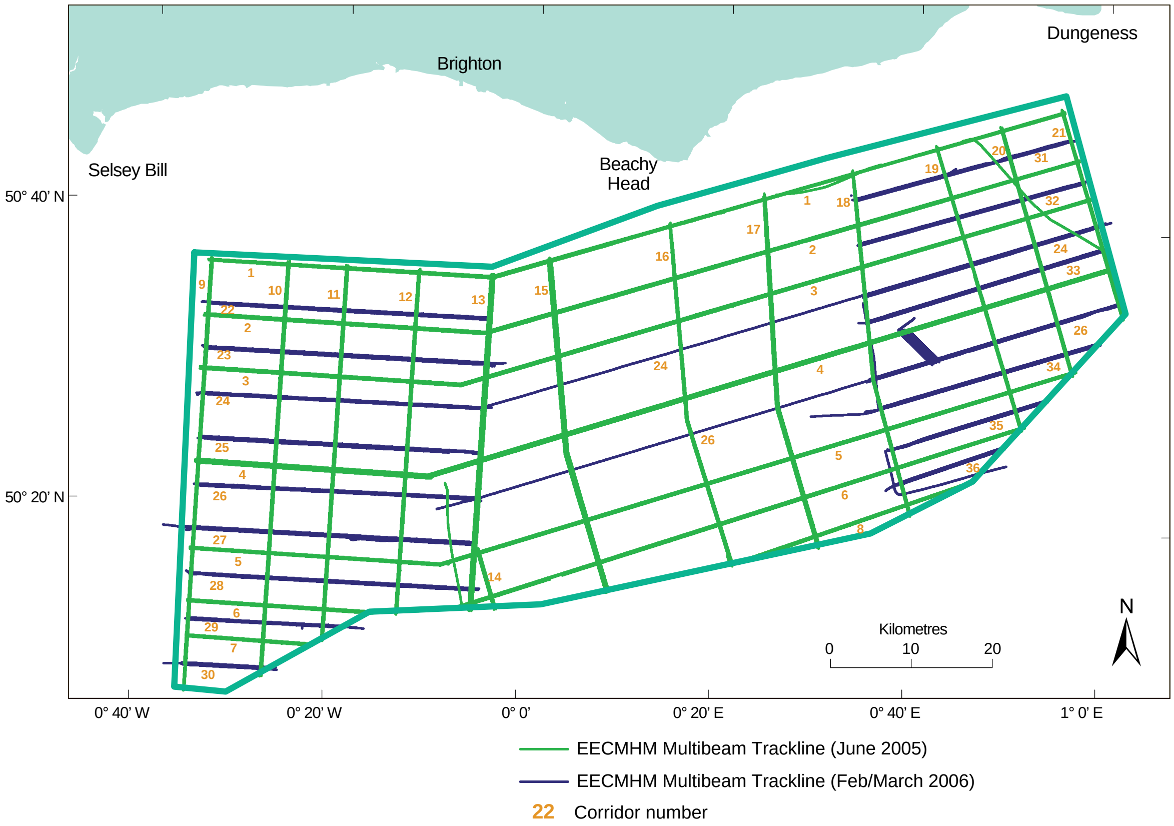


Figure 4.3. EECMHM multibeam survey coverage.

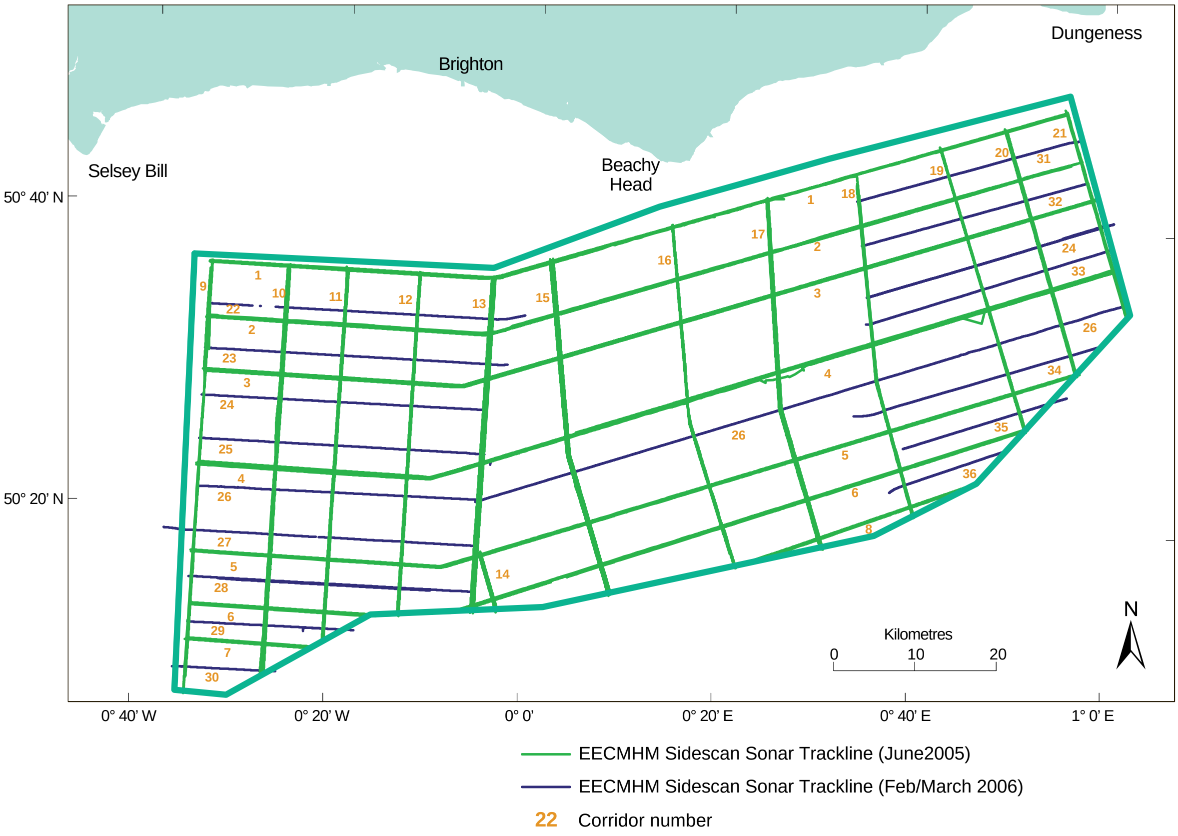


Figure 4.4. EECMHM sidescan survey coverage.

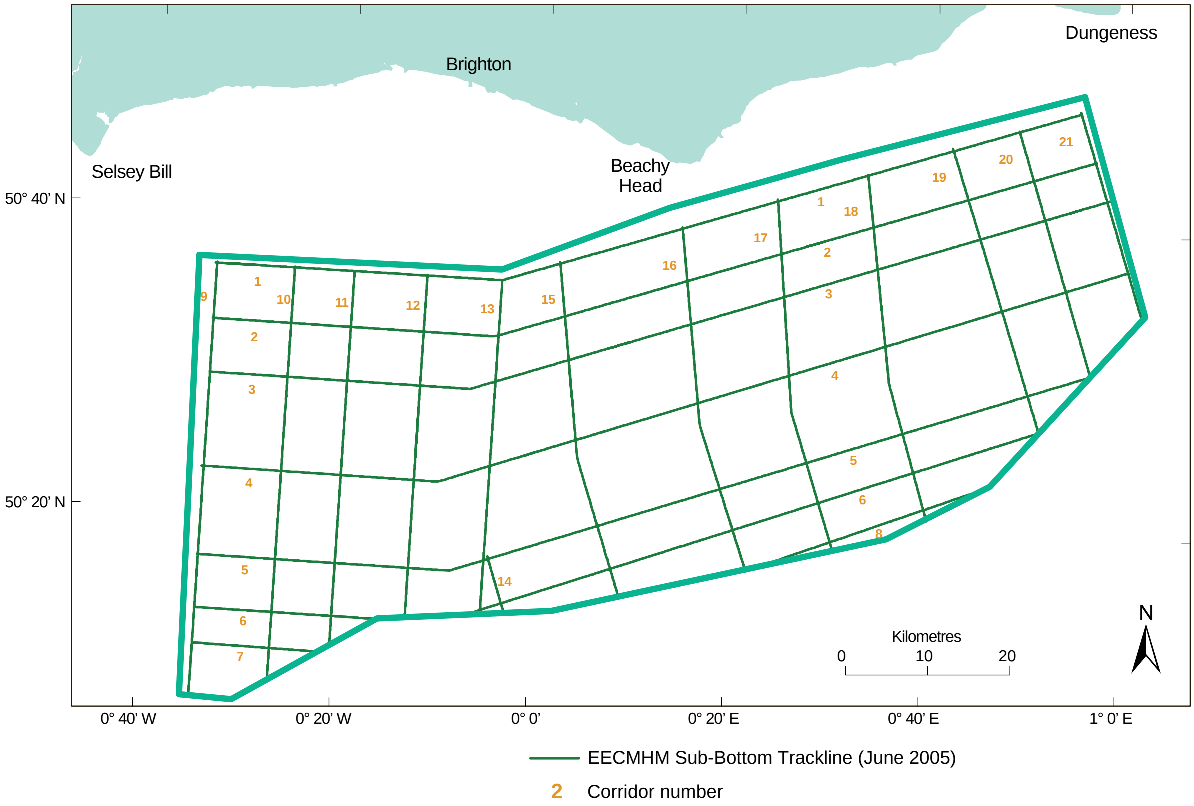


Figure 4.5. EECMHM sub-bottom survey coverage.

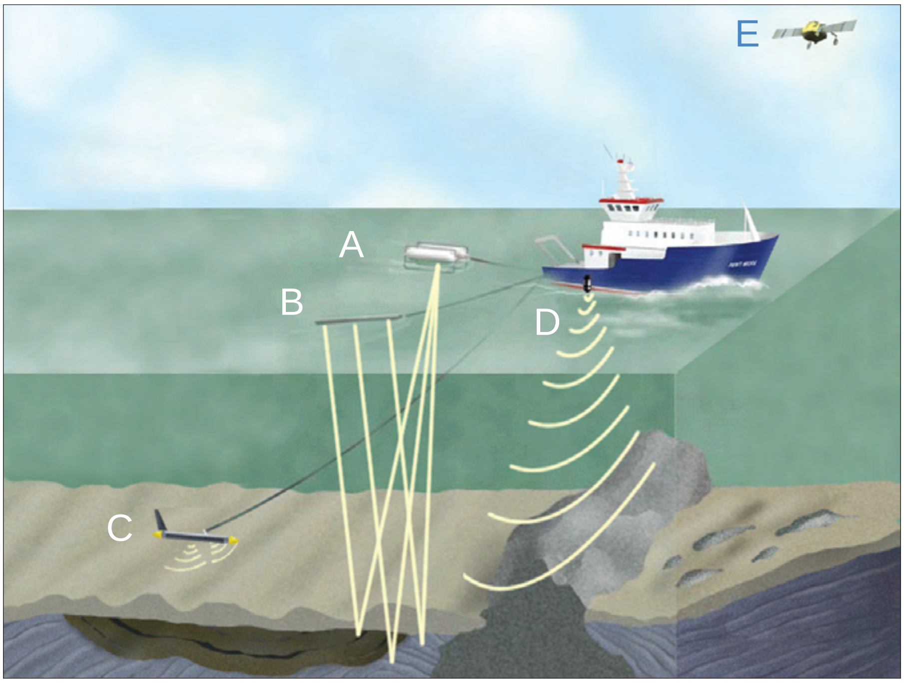


Figure 4.6. Geophysical equipment deployment:
(A) Boomer,
(B) Hydrophone,
(C) Sidescan Sonar,
(D) Multibeam (MBES),
(E) DGPS.
© NERC (BGS) and NMW.

MBES and sidescan, survey speed was reduced to around 4 knots to ensure good quality seismic records.

The second geophysical survey in February /March 2006 on the *Cefas Endeavour* ran a dual head Kongsberg EM3000D MBES coupled to an MRU5 motion reference unit, a hull mounted Reson SVP10 sound velocity gauge, and a Thales 3011 DGPS with Fugro Seastar corrections. A Simrad EA600 single-beam echo sounder was used to monitor the depth data produced by the multibeam echo sounder. Sound velocity profiles were conducted at least every 24hrs. The survey speed was generally around 6 knots which allowed collection of good quality sidescan sonar and multibeam data.

The MBES and SBES draughts were fixed at departure by reading the draught marks and using an offset to the depth of the respective transducers relative to the vessel hull. On completion of the survey this was repeated, and from this a daily rate of draught change was calculated and applied in post processing.

Multibeam data from both surveys was processed by Gardline Survey Ltd using the CARIS HIPS/SIPS hydrographic processing software suite. Tide gauges were deployed by both surveys in the area prior to commencement of survey to enable tidal reduction to be calculated with in-situ real time tidal data. Unfortunately, both tide-gauges were lost and local tide data was not recovered.

All soundings were reduced to Chart Datum (Lowest Astronomical Tide) using observed tidal elevations for Portsmouth, Newhaven and Dover. All tidal levels were corrected with Gardline's Voyager5 software using co-tidal information derived from Admiralty Co-Tidal/Co-Range Chart 5058 (Edition 5, 29 March 1996).

Multibeam data processed in CARIS HIPS/SIPS was gridded using a 2m bin size and provided as geo-referenced, sun illuminated bathymetry images and processed backscatter images. Corrected depth soundings were provided for each 2 m bin as an ASCII XYZ file which allowed the data to be imported in GIS and visualisation software. The Fledermaus software suite was used to produce 3D surfaces from the ASCII XYZ data and allowed integration with sidescan sonar and sub-bottom profiles for interpretation of the data.

Sidescan sonar

Sidescan sonars are towfish systems (Figure 4.7) which measure the intensity and the strength of the acoustic signal that is reflected back from the sea bed.

The sound received and recorded by a sidescan sonar system is a function of two primary mechanisms which affect the acoustic return from the sea bed. These are:

Reflection. Direct returns of sound bouncing back off features on the sea bed such as rock outcrops, sand waves and wrecks.

Backscatter. This is a diffuse and weaker process based on the interaction of sound energy with the ambient texture and character of the sea bed. The intensity of the backscattered sound is a function of bottom roughness and angle of incidence. The rougher the sea bed, the stronger the backscatter and the darker the resultant tone on a sidescan record. Gravels, rock pavements and some glacial sediment will produce good backscatter. The shallower the angle of incidence, the weaker the backscatter. This is a limiting factor in setting the range of a sidescan because angle of incidence decreases with increasing range.

During the first survey on board *MV Tridens 1* an Edgetech 4200 FS digital (operating frequency 120 kHz) multipulse sidescan sonar was towed on all lines, and positioning of the sidescan sonar was tracked using a Sonardyne Ultra Short Base Line (USBL) system. This sidescan was specified because it can survey at faster survey speeds than normal single beam sidescan without loss of along track resolution. Sidescan data was recorded and processed using CODA GeoSurvey software.

A Benthos SIS1624 dual frequency sidescan system (100/400kHz) linked to a Triton ISIS/Delphmap acquisition and processing suite was run during the second geophysical survey on board the *RV Cefas Endeavour*.

The sidescan sonar data from both surveys were subsequently processed using Coda GeoSurvey software, the sea bed was tracked for each line and parameters such as time variable gain (TVG) applied to the data to ensure visual consistency across the dataset. The navigation files were also processed creating smoothed navigation files and mosaic imagery was produced for each corridor.

The sidescan data were also interpreted using Coda Geokit software and preliminary sedimentary boundaries were defined on the basis of relative backscatter strength.

The interpretation permitted the identification of sedimentary boundaries and sea bed features such as sand waves, sand ribbons, trawl marks, wrecks and the distribution of gravel and sand within the different sea bed morphologies.

Geotiff images of sidescan mosaics have been correlated with multibeam data and other physical datasets within ArcGIS, and interpreted polygons validated using the groundtruthing results.

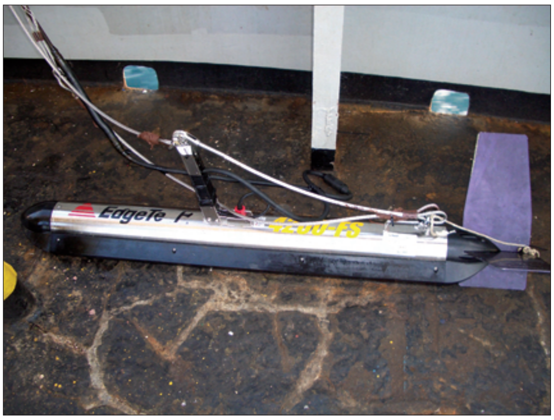


Figure 4.7. Sidescan sonar equipment.

Figure 4.8. Boomer equipment.

Boomer (seismic reflection profiling)

The Boomer is a towed sub-bottom profiler (Figure 4.8) used to acquire shallow seismic data to map geological structures and stratigraphic features immediately beneath the sea bed and down to a depth normally of 20 to 100 m depending on the nature of the sub-sea bed geology. It is a device that sends acoustic energy with a particular range of frequencies (generally between 2.0 and 4.0 kHz) to the sea bed.

The sound wave penetrates through the sea bed and is partially reflected, partially refracted each time a difference in acoustic impedance occurs. The acoustic impedance is defined as the product between the sound velocity and the density of the media; it defines the acoustic character of the signal, which varies with lithology. The signal travels back to the surface and is recorded by a hydrophone array or streamer. The acoustic energy received is then converted into an analogue electrical voltage, which in turn, is recorded digitally for further processing. The signal is also recorded on a paper plotter.

During the survey in May/June 2005 an EG&G surface towed boomer (300J, firing cycle 400 ms) was used to acquire shallow seismic data on the centre line of each corridor. The boomer was towed at the surface with a survey speed of around 4 knots.

The data were acquired with a Coda DA200 System. During acquisition, sweep time and bottom tracking were applied to the data. The recorded sweep was 80 milliseconds.

An initial interpretation of the seismic data was completed using the paper record profiles. This allowed correlation with the mapped solid geology of the English Channel and the identification of geological features.

CODA GeoSurvey software suite was used to playback seismic data and digitize the interpretation. The GeoSurvey software suite provides automated interpretation tools and interactive enhancement of the image, which are designed to improve data interpretation and to produce final report outputs. Interpreted features can be interactively marked and automatically logged in an events database for reporting and charting. The software was used to tag reflectors and generate an ASCII report output, with the geo-interpretation, for each line. These files were used to calculate the thickness of the superficial sediment units, and in correlation with the sidescan and multibeam data and the sample data these values were mapped using ArcGIS.

4.2 Sea bed sampling

4.2.1 Rationale

With a large spatial area to cover, the rationale for sea bed sampling had to be selective. As the central region within and immediately around the 'Aggregate Prospecting areas' had been well sampled as part of the EIA and REA studies (Figure 4.32 and 4.33), it was decided to direct the majority of sampling outside these areas, as the purpose of the work was to place the existing studies in a wider regional context. A small number of sampling stations were deliberately placed within the EIA and REA areas to provide some overlap and commonality between the studies.

It was reasoned that the sea bed sampling should only take place within the acoustic corridors, as the co-location of physical and biological information would maximise the power of the survey to describe, differentiate and delineate sea bed habitats. As the acoustic survey was based on a grid-design, it was logical to place one ground-truth sampling station at each of the grid nodes to ensure full spatial coverage. The placing of further sampling stations was decided following detailed scrutiny of the sidescan and multibeam images. Sites were selected to provide groundtruthing information for acoustically distinct areas which were related to changes in sediment type. Sites were also chosen to help interpret bedforms identified from the acoustic data and to establish the presence or absence of Annex 1 habitats (e.g. rock or cobble habitats).

A suite of complementary sampling techniques was selected for the groundtruth/biological surveys, comprising benthic grabs, small beam trawls and underwater video and photographic systems. Details of the specific equipment used are given in later sections. This combination of tools was selected to provide the range of information relating to the nature of the substrates and their infaunal and epifaunal communities that is typically used to describe and classify habitats and biotopes.

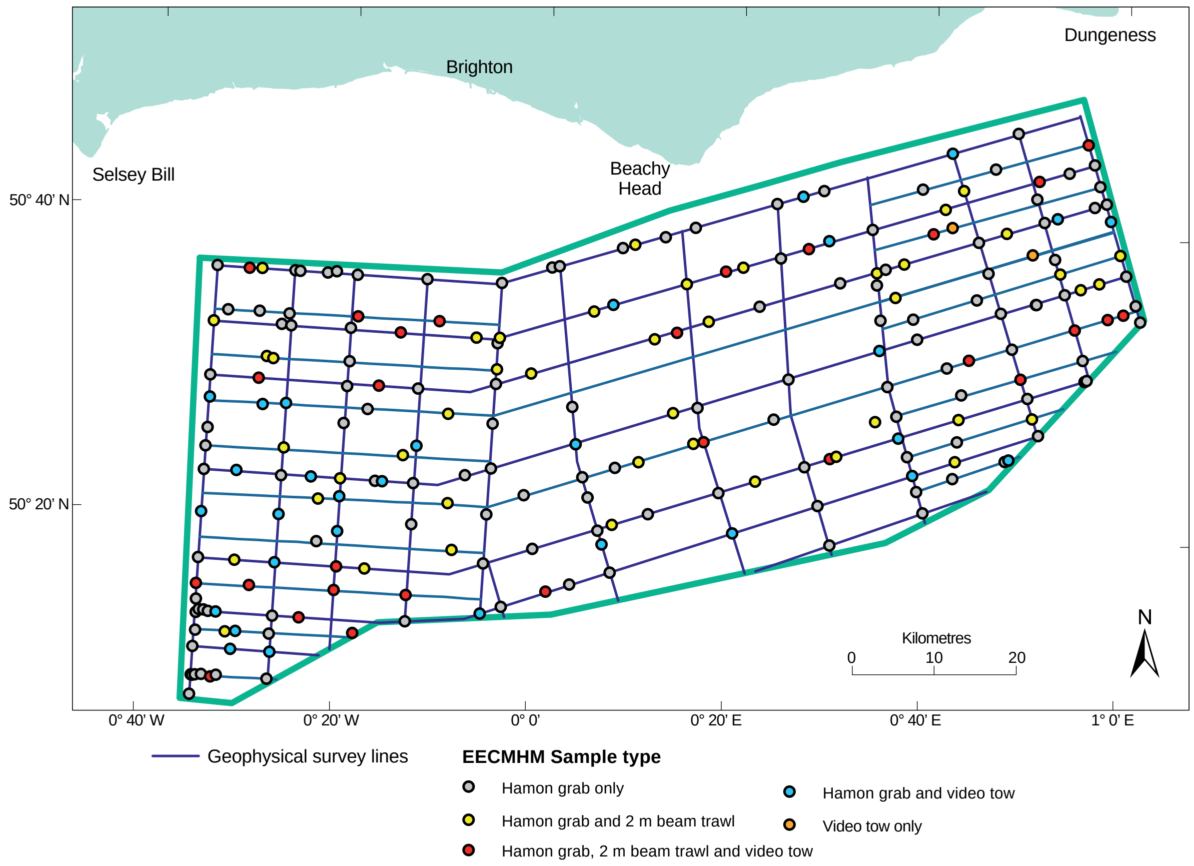


Figure 4.9. Combination of gears used for groundtruthing and biological/sediment sampling, in relation to geophysical survey lines.

Resources were not sufficient to allow all techniques to be used at every sampling station. Greatest priority was given to grab sampling as this provided both physical (sedimentological) and biological information. A lower priority was given to trawl and video sampling, with the aim of using these to provide complementary information at selected grab stations. Where there was a particular interest in potential Annex I 'reef' habitats, sampling was limited to video techniques only, as grab and trawl sampling would have been ineffective and potentially destructive.

Sampling stations were plotted over the acoustic data on a GIS and each designated with a code indicating the choice of gears that had been selected for use in sampling (Figure 4.9). These were:

- GTV – Grabs Trawls and Video
- GT – Grabs and Trawls
- GV – Grab and Video
- V – Video only

Information on the distribution of commercial fish and shellfish species was collected in less intensive surveys of the area using commercial fishing gear (scallop dredges and large beam trawls). These sites were selected in such a way that they complemented existing fisheries data and were also coincident with sampling sites and acoustic corridors surveyed during this programme of work.

Ship-board procedures and quality statement

The majority of ground truth sampling (Figure 4.30) was completed during two cruises (2005 and 2006) using the RV *CEFAS Endeavour*, a purpose built, ocean going research vessel equipped with dynamic positioning (DP) and a differential Global Positioning System (dGPS). All Hamon grab, 2-metre beam trawl and video/photographic samples were collected on these cruises, using sampling stations located at pre-planned waypoints. Vessel positioning for a Hamon grab sample was considered acceptable if the sampling gear landed on the sea bed inside a 50-metre radius bullring drawn around the waypoint. 2-metre beam trawls were typically made across a 200-metre radius bullring around the waypoint. Video sledge and drop camera deployments were normally made along a pre-defined transect line, as some tows were required to be made in a particular direction in order to target specific features.

The conduct of surveys, collection of samples and recording of metadata followed an internal quality control system. Standard Operating Procedures (SOPs) for the use of each gear type and the processing of samples are provided in the Appendix - DVD. The conduct of surveys and recording of metadata are supported by computer applications, the function and purpose of which are explained below by way of illustrating procedures and providing a 'quality statement'.

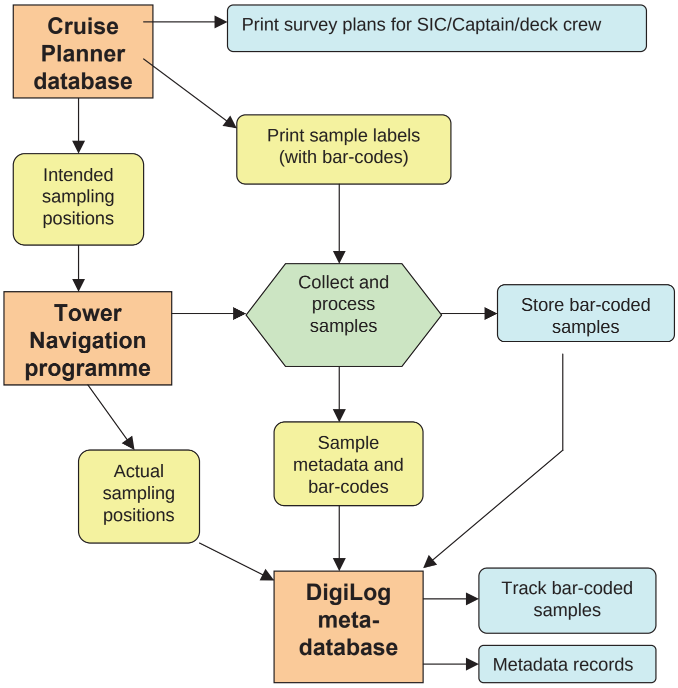


Figure 4.10. Schematic diagram illustrating relationship and function of the Cruise Planner database, Tower Navigation programme and DigiLog meta-database.

Three computer based systems were used to help in the planning and execution of surveys on the RV *CEFAS Endeavour* contributing to the administration, Quality Assurance and data capture requirements. Figure 4.10 gives an overview of their function and how they link to the sampling process.

Cruise Planner is an Access database developed by Cefas Burnham Laboratory that holds data pertaining to all the sampling events that are planned for a particular Cruise (e.g. which projects are involved in the Cruise, what samples they need to take and where those samples are to be taken). The Cruise Planner database prints detailed reports of the intended sampling events (e.g. station position, gear type, number of replicates etc) and also generates bar-coded labels for each of the samples to be collected.

Tower Navigation is a commercial hydrographic survey package used by the Cefas Burnham Laboratory on its sampling cruises. It is similar to an electronic chart. Prior to each survey, the target position(s) for each sampling event are loaded into Tower. The ship then uses this chart to navigate to the intended sampling positions. When the sampling gear is deployed, Tower records the actual sampling position by means of a manually logged event, which is later transferred into the DigiLog meta-database. As on most large research vessels, sampling gear can be deployed from several positions on the *CEFAS Endeavour*, such as the stern or side gantries, which are offset from the main GPS antenna. These offsets have been accurately surveyed, and can be applied within the Tower Navigation software to give an accurate position for each sample.

DigiLog is an Access database developed by the Cefas Burnham Laboratory that holds metadata records about when, where and how the samples were actually taken. In essence, it is an electronic log-book. The metadata is recorded on pro-forma logsheets, and later typed into the DigiLog database. Positional data relating to each sample is 'cut-and-pasted' into DigiLog from the Tower Navigation log files. DigiLog also acts as a sample tracking system. Each of the samples collected is given a bar-coded label, generated and printed by the Cruise Planner database. This bar code is scanned into DigiLog each time the sample is moved in order to track where it is stored and its status (e.g. unprocessed, processing underway, processing completed, discarded).

Following completion of all EECMHM survey sampling the 244 sample stations occupied by the study were given a unique EECMHM sample station number (Figure 4.30).

4.2.2 Multivariate analysis

Separate analyses were undertaken for grab, trawl and video/photographic samples (Chapter 5) followed by an integrated assessment of the available information (Chapter 6). The separate analyses made extensive use of analytical routines within version 6 of the PRIMER software package (**P**lymouth **R**outines **I**n **M**ultivariate **E**cological **R**esearch, Primer-E Ltd, Plymouth, UK; Clarke and Warwick, 2001; Clarke and Gorley, 2006). The PRIMER package is an 'industry standard', widely used throughout the UK, Europe and the rest of the world for multivariate analysis of biological communities, especially those in the marine environment. In the interest of brevity, a layman's summary of the principal analytical routines is provided in Table 4.1. These routines will be referred to by name throughout the rest of the report, without further elaboration. The reader is directed to the references given above for further details.

Unless otherwise stated, all biological analyses used resemblance matrices based on the Bray-Curtis similarity index, and all physical/environmental analyses used resemblance

Table 4.1. Layman's explanation of main PRIMER routines used in the multivariate statistical analyses (summarised from Clarke and Gorley, 2006).

Name of Routine	Explanation
CLUSTER	Carries out simple agglomerative, hierarchical clustering of samples, based on a sample similarity matrix. Outputs a dendrogram that displays how samples cluster together into successively larger groups at decreasing levels of similarity.
SIMPROF smilarity profile	When run in conjunction with the CLUSTER routine, this carries out permutation tests that identify clusters of samples **within which** there is no statistical difference. By inference, this determines that there is a statistical difference **between** clusters. The significance level for the test is set to 5% (p=0.05) by default, but can be varied (say to 1%) to make the test more stringent.
SIMPER contribution of variables to similarity	Examines the contribution of each variable to the average resemblances between sample groups. Results in two outputs, the first of which ranks the variables (species) that contribute most to the sample similarity within a cluster (i.e. species that characterise that cluster), and the second which ranks variables (species) that contribute most to the dissimilarity between pairs of clusters (i.e. species that discriminate between cluster groups).
MDS non-metric multi-dimensional scaling ordination	Provides a 2-d or 3-d scatter-plot representing the resemblance between samples, based on the same similarity matrix used to construct the dendrogram in CLUSTER. The relative distances between points reflect their similarity/dissimilarity: the most similar points are plotted closest together whilst the least similar points are plotted furthest apart. As the plots 'collapse' a multidimensional relationship into a 2-d or 3-d representation, a 'stress' value is provided to indicate how faithfully the true relationship is represented by the 2-d or 3-d ordination plot. A stress level of <0.1 corresponds to a good representation, <0.2 is reasonable, >0.3 is poor.
BEST includes BIOENV and BVSTEP	Finds the best match between the multivariate patterns in two related data sets by comparing their respective resemblance matrices. BIO-ENV matches faunal data (BIO) to environmental data (ENV), indicating which subset of environmental variables has a multivariate pattern that best matches the pattern observed in the biological data. Does not establish cause and effect, but indicates the environmental variables that appear to have most leverage in structuring the biological communities. BIO-ENV uses all the available environmental variables to find the combination that 'best explains' the patterns in the biological data. This can be computationally expensive (slow) where large numbers of variables are involved. BVSTEP provides a more rapid alternative, performing a stepwise search of the variables, starting with the variable which shows the maximum matching coefficient. Other variables are successively added, the combinations tested and the variable contributing least is eliminated. The procedure is instructed to stop when it reaches a 'satisfactory' match, which may differ slightly from the 'best' available match
ANOSIM analysis of similarities	Analogous to a traditional ANOVA (analysis of variance) test. ANOSIM tests for differences between groups of samples, where the groups have been determined according to some *a-priori* factor such as substrate type, depth zone, biotope class etc. Variants include 1-way and 2-way test. A 1-way ANOSIM test a single factor (e.g. depth zone); a 2-way ANOSIM test 2 factors (e.g. Depth zone and substrate type).

matrices based on Euclidean distance. Similarly, all CLUSTER routines used the 'group average' cluster mode.

By way of providing further understanding for the lay person, Figures 4.11 to 4.15 illustrate the type of graphical outputs presented by some of the PRIMER routines. These are for illustrative purposes only and are not derived from data obtained in the current study (data from PRIMER tutorials and R. Coggan). Note the way in which the symbology of the points has been altered to present different types of information.

Figure 4.11. Dendrogram: a graphical output of CLUSTER, showing sample clusters based on a 5% SIMPROF test (5pcSmPrf). Red lines connect samples between which there is no significant difference at p=0.05. Samples are given alphanumeric labels (S6, S11, S4 etc) but their symbols have been coded to reflect the various clusters.

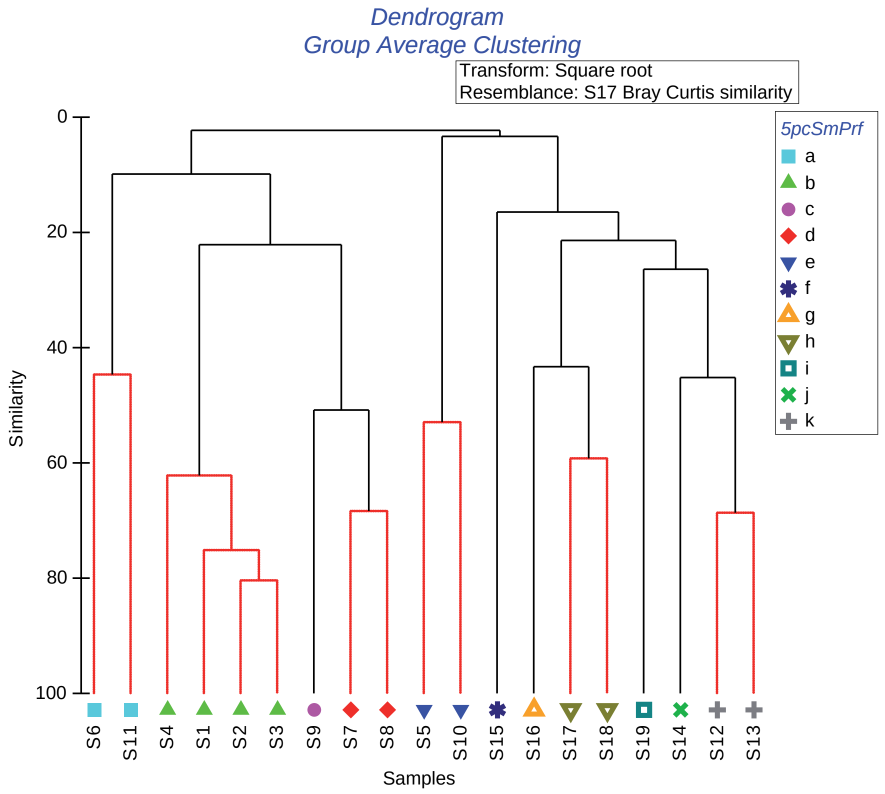


Figure 4.12. Two-dimensional MDS plot of the data shown in the dendrogram, with the same sample labels and symbols. The distance between any two sample points reflects their (rank) similarity. The closest points are the most similar samples, the furthest apart are least similar. Note the relative positions of cluster groups 'b' (green triangles) and 'e' (blue triangles), before looking at Figure 4.13.

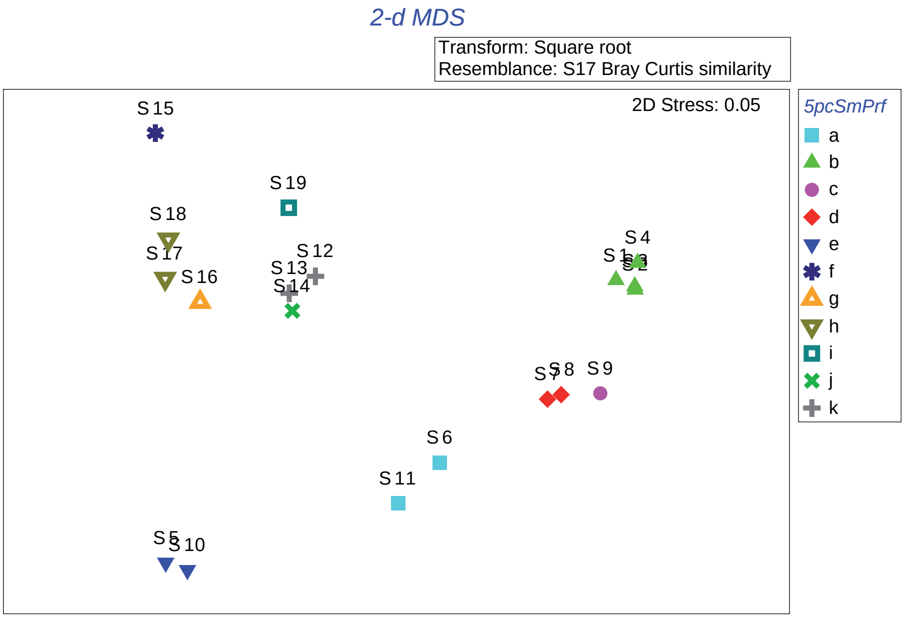


Figure 4.13. Three-dimensional MDS of the data shown in the cluster diagram and 2-d MDS above.

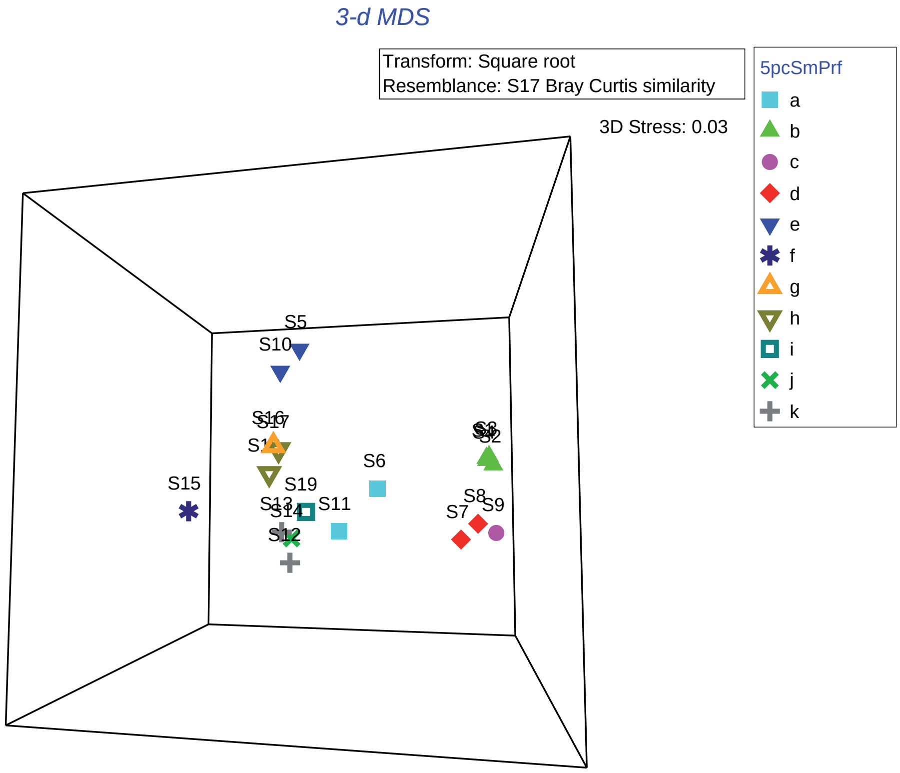
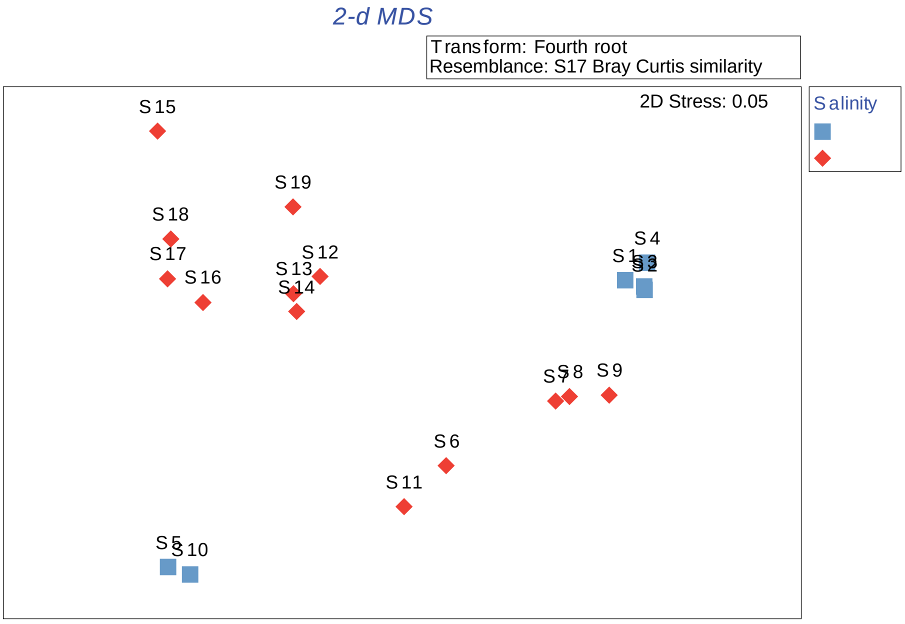


Figure 4.14. Two-dimensional MDS, exactly as in Figure 4.12, but with sample points re-symbolised to represent salinity classes (as in the key).



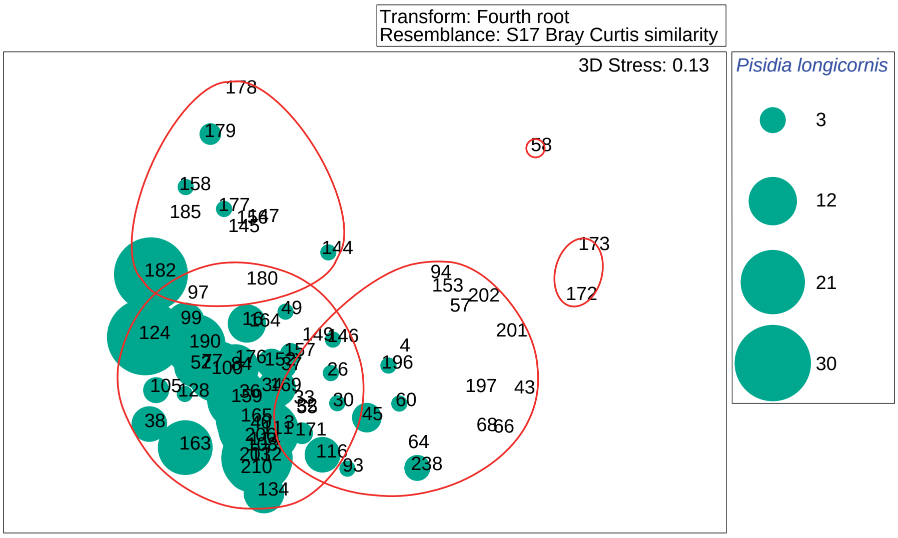


Figure 4.15. MDS bubble plot. Sample points are overlain with bubbles showng the relative abundance of the crab *Pisida longicornis* in each sample. Red elipses represent a 40% similarity contour, enclosing samples that have ›40% similarity. This illustrates that one of the clusters is characterised by a high abundance of *Pisidia longicornis* and hence this is likely to be one of the factors that discriminates this cluster from the others.

4.2.3 Collection of grab samples

Hamon grab (0.1 m^2) samples were collected to assess the distribution of macrofaunal assemblages and sediments in the area (Figure 4.16). A full description of this grab and its operation can be found in Boyd (2002). A sub-sample was taken from each of the samples for sediment particle size analysis (PSA) following the general methodology given in Boyd (2002). The remaining sample from each grab was washed over 64 mm, 5 mm and 1 mm square mesh sieves to remove the sediment and to separate the fauna into separate fractions. A detailed Standard Operating Procedure (SOP) for treatment of Hamon grab samples is provided in the Appendix - DVD. For samples where large cobble sized particles (>64 mm) were present, the cobbles were removed and their physical and geological characteristics determined (for further details of this process, see Cobble Analysis SOP in the Appendix - DVD). If epifauna was present on the cobble, it was preserved along with the bulk of the infaunal sample. The two resulting finer fractions (>1 mm – 5 mm and >5 mm – 64mm) were backwashed into separate containers and fixed in 4-6% buffered formaldehyde solution. Further details of field sampling methodology, follow-up laboratory analysis and related quality assurance activities can be found in Boyd (2002). The proportion of the total material retained on the 5 mm mesh that was composed of shell was assessed using a 0 – 4 scale (Table 4.2).

Figure 4.16. Deploying the 0.1 m^2 Hamon grab.

Table 4.2. Scale used to assess the quantity of shell component: -
i) retained on the 5 mm sieve and
ii) for sediment samples retained on each sieve as a result of the dry sieving process.

Shell percentage on sieve	Assigned value
0%	0
0% - 25%	1
25% - 50%	2
50% - 75%	3
75% - 100%	4

Data from a total of 224 grab samples collected in 2005 and 2006 were used for the infauna analysis. Additionally, a selection of 49 stations (Figure 4.32) from the earlier industry surveys (REA) (Figure 4.31) were chosen from the central region of the survey area to enhance the spatial coverage of the central area and to aid better characterisation of the macrofaunal composition.

Biological Variables

The three available data sets generated from both the current study (2005 and 2006) and from earlier industry surveys were used to create the species abundance/sample matrix. Sample similarities were calculated using the Bray-Curtis similarity measure based on square root transformed abundance data prior to group average clustering of the data and production of multi-dimensional scaling (MDS) plots. Cluster groups were determined by a 1% SIMPROF test within the CLUSTER routine. The taxa primarily accounting for their similarities/differences were determined using the similarity percentages routine (SIMPER, Clarke, 1993). Finally, in order to gain further insight into the distribution of macrofaunal communities, the BIOENV procedure was used (using the BEST routine) to identify the environmental variables which best 'explain' the observed patterns in the biotic data.

4.2.4 Laboratory analysis of infaunal samples

On arrival at Marine Ecological Surveys Ltd (MES), the samples were checked against the field notes in accordance with bespoke Standard Operating Procedures, and signed off against the list of samples collected. The excess formalin was eluted through a 1 mm mesh sieve. Each sample was then gently eluted with fresh water through a 1 mm sieve to extract the low density components (small crustacean and polychaetes) and combined with the material initially separated from the formalin in the sample. The eluted material was then sorted on white trays and the larger macrofauna and encrusting organisms removed. The extracted material was then preserved in a 40% methanol solution and transferred to the laboratory for analysis.

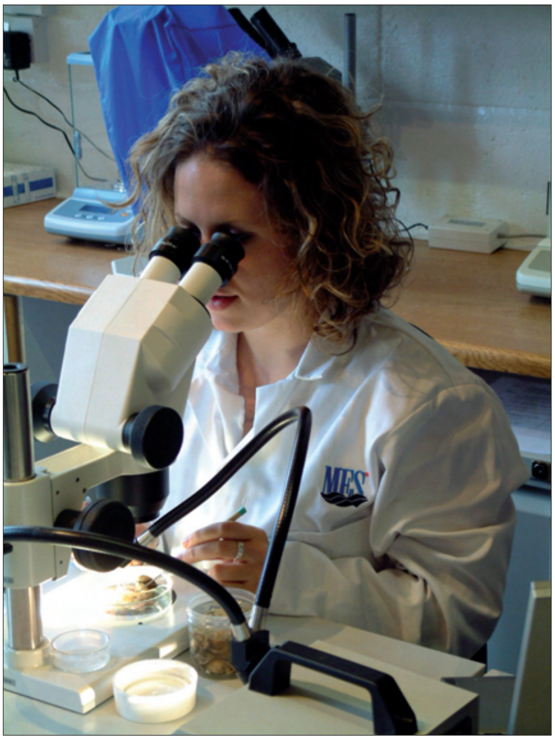


Figure 4.17. Infauna laboratory analysis.

In the laboratory, the extracted material was sorted under a stereomicroscope where the fauna were removed and sorted into major taxonomic groups before being analysed to species level (Figure 4.17). The blotted wet weight of each species identified in the sample was also determined. The identification of each sample was checked and a reference collection was created to ensure consistency. Once all checks were completed the data were entered into the MES UNICORN database (an Access based database specifically designed to store biological data).

4.2.5 Particle size analysis (PSA) of sediment samples

The collection of sediment samples for subsequent PSA is an essential accompaniment for macrofaunal surveys. Small-scale heterogeneity at the sea bed dictates that a PSA sample should be collected from the same sample as that collected for the benthic infauna. This allows the macrofaunal data to be accurately referenced against variations in particle size characteristics. Bespoke SOPs for the collection of PSA samples were developed for the purpose of this project and are provided in the Appendix to this report. In summary, the procedure for the collection of these samples was as follows. A 500 ml subsample of the sediment was collected from each of the Hamon grab samples that were collected for macrofaunal analysis. This subsample excluded any cobbles that were present in the sample as it was important that they were included in the macrofaunal analysis. However, in order that the cobble data could also be included in the PSA, each cobble was weighed and its dimensions and volume were measured and recorded.

Laboratory analysis

The particle size distribution of sediment samples was measured using a combination of sieve analysis and laser sizing techniques. Each sample was wet sieved through a 500 micron sieve to generate coarse and fine sub-fractions. The coarse (>500 micron) fraction was dried in an oven at 80°C, and the fine (<500 micron) fraction was freeze-dried to prevent concretion of the finer part of this fraction. The coarse fraction was dry sieved through a stack of sieves selected at half phi intervals, and the weight of sediment retained on each sieve was measured and recorded. The percentage of the total material retained on each sieve that was composed of shell material was also assessed on a 0 – 4 scale (see Table 4.2). This value was assessed by eye for the coarser fractions or, for the finer fractions, by binocular microscope.

When dry, the freeze-dried fine fraction was subsampled and analysed using a Malvern Mastersizer. This technique uses the varying diffraction of light by particles of different diameters in suspension to obtain a particle size distribution of the sample.

The results generated by the dry sieving and laser sizing techniques were combined to produce a full particle size distribution of the sample from the coarsest particle down to 0.1 micron. In addition, the contribution of the cobble particles that were measured at sea was added to the full particle size distribution data. Particle size distribution can be classified with a number of systems (Figure 4.18). Within this study Wentworth has been used to describe individual particle size and the Folk sea bed sediment classification system (Figure 4.19) as a method of mapping sediment distribution (Figure 5.7). The sediment distribution results were entered into a bespoke grain size statistical package (GRADISTAT V4; Blott and Pye, 2001) to calculate the mean, skewness, kurtosis and sorting statistics for each sample using the methods described in Folk and Ward, 1957. These parameters were used to describe the physical environment and were also used as physical variables within the multivariate analysis conducted as part of the analysis of the biological data.

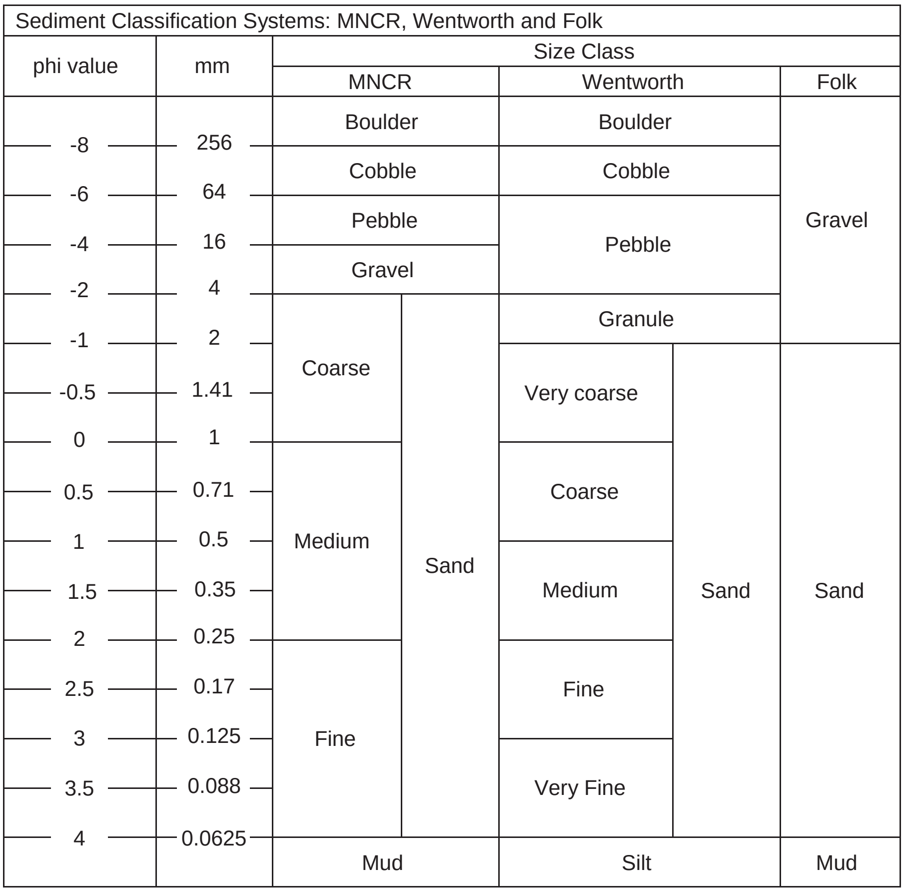
4.2.6 Data analysis

Associations between macrofaunal assemblages and a range of environmental variables were examined by undertaking univariate and multivariate analyses following the general methodology of Clarke and Warwick (1994) using the PRIMER software package (V.6, Clarke and Gorley, 2006).

Physical Variables

The physical variables available for analysis are shown in Table 4.3. DRAFTSMAN plots were used to identify correlated variables and those that required transformation to approximate normal distribution. Where correlated

Figure 4.18. Comparison of three classifications of sediment particle size.



Sediment Classification Systems: MNCR, Wentworth and Folk						
phi value	mm	Size Class				
		MNCR		Wentworth		Folk
		Boulder		Boulder		Gravel
-8	256	Cobble		Cobble		
-6	64	Pebble		Pebble		
-4	16	Gravel				
-2	4	Coarse	Sand	Granule		
-1	2			Very coarse	Sand	Sand
-0.5	1.41					
0	1	Medium		Coarse		
0.5	0.71					
1	0.5			Medium		
1.5	0.35					
2	0.25	Fine		Fine		
2.5	0.17					
3	0.125			Very Fine		
3.5	0.088					
4	0.0625	Mud		Silt		Mud

Figure 4.19. Sea bed sediments classification (based on Folk, R.L. 1954. Journal of Geology, Vol. 62, p 344-359).

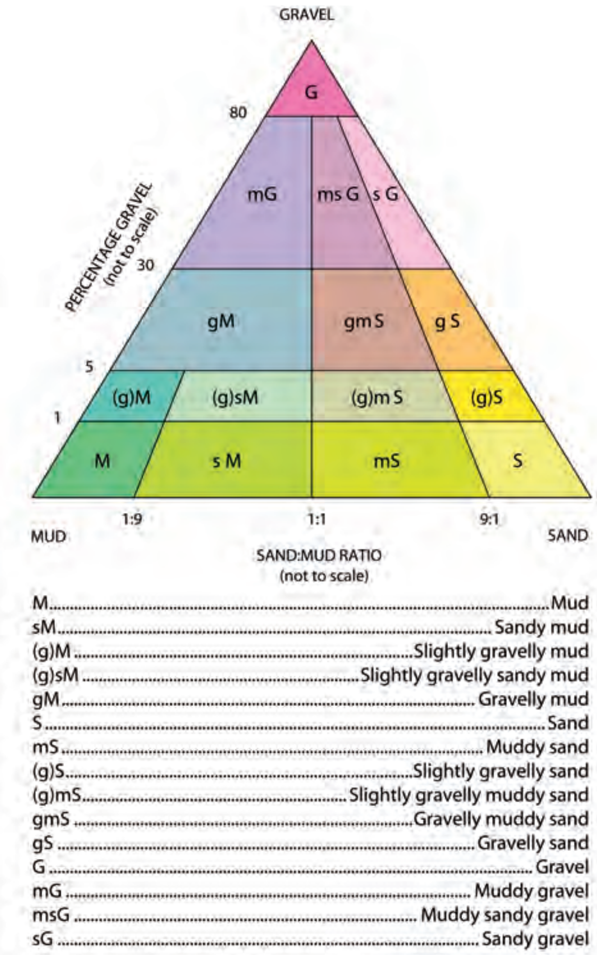


Table 4.3. Environmental variables tested using the Bio-Env procedure in Primer. Details of the variables are given in section 5.3.1 (physical environment) and Table 5.7.

No	Variables
1	Colonial Biomass
2	Mean (Phi)
3	Sorting (Phi)
4	Skewness (Phi)
5	Kurtosis (Phi)
6	Cobble
7	Pebl1
8	Pebl2
9	Grain
10	Sand1
11	Sand2
12	Silt
13	SHPebl1
14	SHPebl2
15	SHGrain
16	Tidal Current Spring
17	Average of depth
18	Sed_d
19	Sed_J'

variables were found, one was eliminated from the analysis. A correlation based principal components analysis (PCA) was then applied to ordinate the environmental data and identify which set of variables accounted for the majority of the variance in the physical data.

4.2.7 Epibenthic trawls

A small 2-metre wide beam trawl, following the design of Jennings *et al.* (1999), was used for the collection of semi-quantitative epifauna samples. The design made it particularly effective at sampling coarse substrates, being fitted with a chain mat, robust chafers and a 5 mm cod end liner (Figure 4.20). Tows were made from the stern of the vessel using a warp length of at least 3 times the water depth. As far as possible, each tow was made across a 200 m diameter 'bullring' centred on the waypoint marking the sampling site. Tows were standardized to 5 minutes duration at a speed of 1.5 knots to ensure consistency between sampling sites. A total of 73 sites were sampled (Figure 4.35) and the catches processed following a Standard Operating Procedure, which is summarised below. The full SOP is included in the Appendix to this report.

On retrieval, the catch volume was measured and the sample washed over a 5 mm square mesh to retain smaller and rarer free-living species. Samples were usually sorted in their entirety (Figure 4.21), taxa identified to

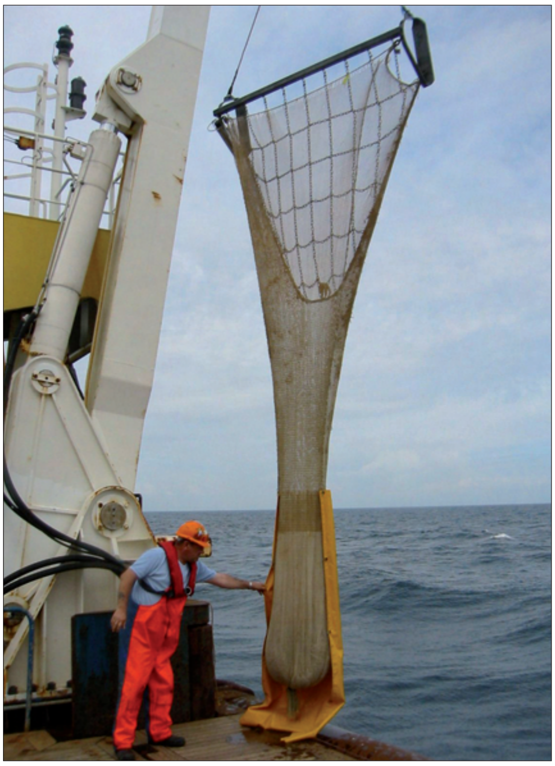


Figure 4.20. 2 m Beam trawl recovered on the deck of the *Cefas Endeavour*.

Figure 4.21. Processing a 2 m Beam trawl sample on-board the *Cefas Endeavour.*

species level and their abundance and biomass recorded. Representative specimens of each taxon were preserved in 4% buffered formaldehyde solution and identification confirmed in the laboratory. Where identification to species level could not be confidently achieved in the field (e.g. for *Macropodia* spp., *Galathea* spp.), all specimens were preserved and identified back in the laboratory.

Colonial and encrusting taxa were recorded on a presence/absence basis, with biomass being recorded whenever practical. Where encrusting taxa were discrete individuals such as barnacles or *Pomatocerus spp*, their abundance was estimated on a log scale, and recorded as Tens, Hundreds or Thousands (in words rather than numerals, to ensure that these gross estimates were distinct from actual counts).

For very large catches, or those where one or more species were highly numerous (e.g. many thousands of ophiuroids), a sub-sampling protocol was adopted. The guiding principal of this protocol was that the entire catch would be sorted in stages (aliquots, or 'sub-samples') to ensure that rarer taxa were properly accounted for, but the abundance of the highly numerous taxa would be estimated based on counts made from sub-samples of known volume. A measured sub-sample (usually of 4-10 litres) was washed and completely sorted and enumerated in the usual way. If the count for any taxon in this first sub-sample exceeded 100, the total abundance in the whole catch was estimated by simple calculation ('raising'), and that taxon was no longer counted in any subsequent sub-samples. A second measured sub-sample was then sorted and the principal applied again, but this time on the cumulative counts from the first two sub-samples. The process was repeated until the whole catch had been sorted. This protocol ensured that reliable estimates were made for abundant species and that rarer species were not missed, which frequently happens in sub-sampling protocols that process only a small part of a large catch and discard the rest.

Occasionally, trawl samples contained a significant proportion of large dead bivalve shells that provided a substrate for the attachment of sedentary organisms, such as anemones and sea-squirts. In such cases the shell fraction was sub-sampled as for the highly numerous taxa, picking out the large shells from consecutive aliquots until a representative sample had accumulated (approximately 100 shells) and then rigorously scrutinising this sub-sample to identify and enumerate the attached life forms. Their total abundance in the catch was then estimated by the 'raising' process.

Data analysis followed the same general procedures used for the infaunal data from grab samples and the epifaunal data from video tows, employing the routines available in PRIMER (v6) to explore the data, identify clusters of similar samples, find which taxa characterised or discriminated between those clusters and examine linkages between the spatial distribution of distinct communities and the physical environment within the study area. Habitat and biotope designations were assigned on the basis of expert judgement, drawing on the results of these statistical analyses and the outcome of the geophysical interpretation of the study area.

4.2.8 Sea bed imaging by video and photography

Acquiring the images

Video and photographic images were collected using a towed camera sledge or drop-frame camera system (Figure 4.22). Where the acoustic surveys indicated the ground was likely to be rough (bedrock outcrops, boulders or cobbles) the drop-camera was selected; otherwise the camera sledge was used. The positions of the stations

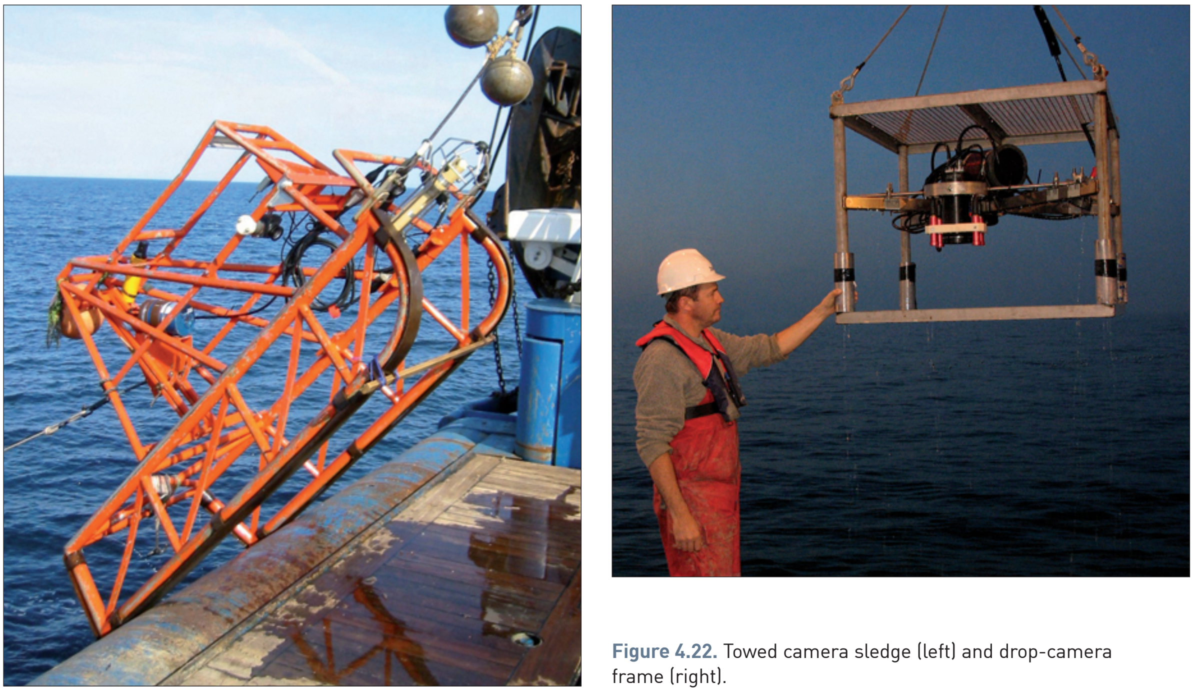


Figure 4.22. Towed camera sledge (left) and drop-camera frame (right).

occupied by camera sledge and drop camera are shown in Figure 4.34.

Similar camera, lighting and recording systems were used on both ground-truth surveys (2005 and 2006), comprising:

Subsea (on sledge or drop-frame)

- Kongsberg OE14-208 camera
- Kongsberg or Simrad underwater flash/strobe unit
- Luxion ruggedised white LED lights
- Simrad flood lamp

Topside

- Deck control units for camera and lighting
- Video overlay unit (providing event and real time positional data on the video image)
- Digital Video Tape, DVD and VHS recording units
- 20" colour TV monitor

The Kongsberg camera was capable of taking both video and digital stills images, the stills being fired at will from the deck control and downloaded to a PC on return to the deck. The trigger-delay when taking stills images was usually less than 1 second. Each still image was tagged with a time-stamp allowing it to be geo-located by cross-reference to the logged dGPS navigation data. The camera had a zoom facility, with a minimum focal length of about 10 cm, allowing the capture of close-up images, if required.

The configuration of the camera sledge differed slightly between the 2005 and 2006 surveys. In 2005, only one Kongsberg camera was available, so it was mounted to provide an oblique forward view between the runners of the sledge. A scale bar marked in 2 cm blocks was clamped near one of the sledge runners to provide a scale object. (Figure 4.23). The camera mounting had a pan-and-tilt mechanism allowing the view to be adjusted in real time as desired. This was most frequently used for short periods to look ahead of the sledge, giving a greater appreciation of the local topography. The camera could be returned to a 'home' position by tilting the mechanism until the image of the scale bar was properly located between two reference marks drawn on the TV monitor (Figure 4.23).

For the 2006 survey, two identical Kongsberg video/still camera units were used, with one dedicated for video imagery and the other for stills imagery (Figure 4.24). The video camera was again oriented to provide an oblique forward view between the sledge runners, but was now fitted with a 4-point laser-scaling device instead of the pan-and-tilt mechanism (limitations in the umbilical cable precluded the use of both laser-scaling and pan-and-tilt mechanism). The stills camera and flash unit were mounted vertically to provide a fixed view looking directly down between the sledge runners.

The configuration of the drop camera frame also differed slightly between surveys (Figure 4.25). In 2005, a 'lentil' frame was used fitted with a Simrad colour video camera and lighting; no stills photograph facility was available. In 2006, a square drop-frame was used fitted with a single Kongsberg video/stills camera, spot, flood and flashlights and the 4-point laser-scaling device.

A Standard Operating Procedure (SOP) was developed for the collection of video and stills images from the sea bed and is summarised below. The SOP has been incorporated into the Recommended Operating Guideline for underwater video and photographic imaging techniques for the MESH project (Mapping European Sea bed Habitats), a copy of which is included in the Appendix - DVD to this report.

Figure 4.23. Scale bar attached the camera sledge frame (left) and illustration of how this was located between two reference marks (red lines) on the TV monitor to ensure the camera angle was returned to a 'home' position after using the pan-and-tilt mechanism on the camera mounting (2005 survey only).

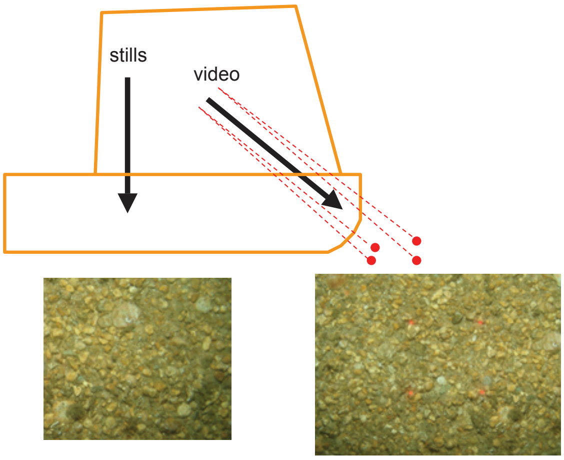


Figure 4.24. Schematic diagram showing the twin-camera configuration used on the camera sledge for the 2006 surveys, with sample images. Separate cameras were use for video and stills images, the latter having a 4-point laser-scaling device.

Figure 4.25. Lentil drop-frame camera used in 2005 (top) and square-frame camera used in 2006 (bottom; note the laser-scaling device mounted around the camera).

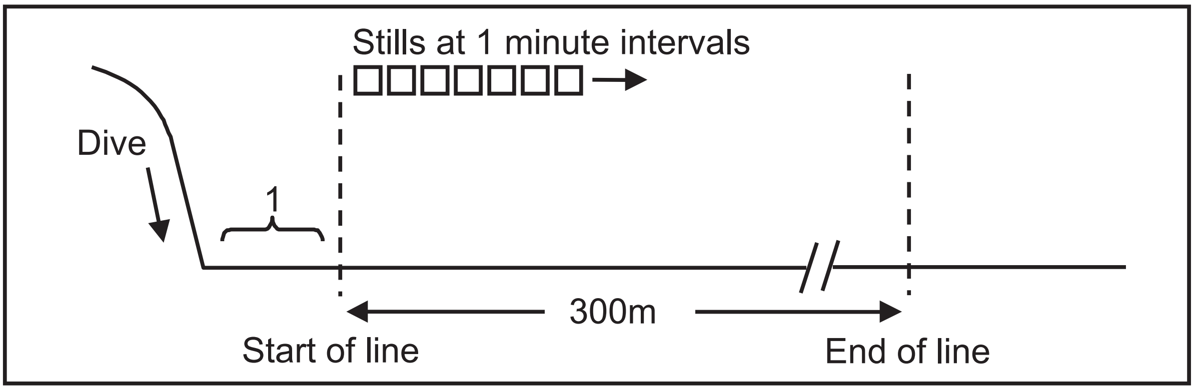


Figure 4.26. Schematic representation of the protocol for collecting video and still images along a transect line.

Figure 4.27. Examples illustrating 'header shots' taken on video (left) and stills (right) cameras to record station metadata prior to deploying the camera sledge.

The procedure for video-sledge operation is outlined schematically in Figure 4.26. Prior to deployment, the video and photographic record was marked with a header shot to record the station metadata (Figure 4.27). The vessel arrived on station and the gear was deployed to the sea bed, towing at approximately 0.5 knots (speed over ground) into the tidal flow. A period of a few minutes was allowed at the start of the tow ('1' in Figure 4.26) to adjust lighting systems and the length of cable deployed. Once the sledge was towing smoothly, the official start of the transect line was declared at which point the following occurred in rapid succession:

- A position fix was taken and the dGPS logging device started.
- The video recording was started
- A still image was taken.
- A clock was started to provide an alarm signal at one-minute intervals.
- The time, position, water depth and vessel speed were noted on the field log-sheet.

The sledge was then towed for approximately 20 minutes (~ 300 metres) taking still photographs at one-minute intervals. During this observation phase, notes were made on the nature of the sea bed, changes in sediment type and the fauna observed. If required, additional still images were taken on an ad-hoc basis to capture features of special interest. Position was logged automatically every 20 seconds, the recorded position being that of the towing vessel. Any changes to the length of cable deployed were noted.

The end of the transect line was declared after the required distance had been covered, whereupon the recordings were stopped and the gear retrieved back on deck. Still images were downloaded from the camera as required (usually on a daily basis).

Georeferencing

The actual position of the camera sledge was determined by layback calculation, using dGPS fixes from the logging device or from the ship's master navigation record (which logged position every 5 seconds). The point location of each still image was determined differently in the 2005 and 2006 surveys, due to the different configuration of the system. In 2005, the position was read from the live video overlay, each time the tell-tale flash of the strobe light was seen in the video image. In 2006, the internal clock of the stills camera was synchronised with GPS time, so the position of each image could be determined by cross-referencing the time the image was taken (recorded in the metadata embedded in the digital image) with the corresponding time on the adjusted lay-back position of the sledge.

Drop-camera deployments

The same protocol was followed for drop-camera deployments as had been used for the camera sledge, but with one minor modification. As the sea-swell caused the drop camera to move vertically relative to the sea bed, the lighting and focus of the image was constantly changing. Consequently the requirement to take still photographs at precise fixed intervals was relaxed, and instead they were take at *approximately* 60 second intervals, whenever the image conditions were acceptable.

Processing the images

Video footage and still images collected during surveys were analysed to describe the physical and biological characteristics of the habitats in the survey area, and to identify the range of biotopes present. Interpretation of video and still images as described in the following two sections were carried out by Marine Bio-Images Ltd (2005 data) and Envision Mapping Ltd (2006 data).

Video images

Each video was initially reviewed to determine whether it represented one or more biotope classes. Where notably different biotopes occurred, the video was segmented into sections representing each biotope. These sections were treated as discrete samples for the purpose of further analysis. If only a single biotope was seen, the entire video was treated as a single sample. Such segmentation occurred at two sites, producing a total of 69 samples from 65 video tows

Each sample was reviewed at a slow speed to assess the physical and biological characteristics of the sea bed, recording these on a proforma based on the Marine Nature Conservation Review (MNCR) Sublittoral Habitat Recording Form (see Appendix DVD-ROM). A visual assessment of the substrate was made and the abundance (percent cover) of different sediment types recorded using MNCR substratum categories (based on the Wentworth scale). Finer substrate classes could not be differentiated with confidence (a limitation of the video medium), so were grouped into a single class named ‘finer sediment’, incorporating all sediments with a particle size less than ~ 2 mm diameter (i.e. sand and finer materials). Other notable features of the substratum were also recorded (e.g. degree of scour, shape of cobbles etc). Visible benthic fauna (excluding fish) were identified to the lowest practical taxonomic level, and abundance recorded using the semi-quantitative MNCR SACFOR scale (http://www.jncc.gov.uk/page-2684). If fauna could not be identified to even a coarse taxonomic level they were assigned to a ‘lifeform’ category describing the growth-form of faunal complex e.g. short faunal turf (MNCR Sublittoral Habitat Recording Form).

Still Images

The analysis of still images followed a similar protocol to that for video samples, with a few notable differences. For the stills collected in 2005, only three images per video sample were analysed. These images were carefully selected to be representative of the biotope seen in the video sample and to be evenly spaced throughout that sample (i.e. to avoid selection of adjacent still images). For the stills collected in 2006, all images were analysed, providing a greater number of replicates per video sample. At six EECMHM stations (177, 178, 179, 180, 183, 185) the still images were found to be out of focus and it was not possible to identify any but the most conspicuous fauna. Consequently the stills from these stations were excluded from the analysis.

For all stills analysed, fully quantitative measures were used to record abundance of discrete, non-colonial taxa (i.e. ‘individuals’). The abundance of colonial taxa was recorded on a percentage-cover basis, and this measure subsequently converted to a numerical equivalent, scaled to represent a proxy for the number of individual colonies encountered.

Spatial Analysis

Sampling stations were plotted in a GIS environment and overlain on the various geophysical interpretations derived from the geological, sediment and physical datasets (see Chapter 5.1). The spatial join function in ArcGIS was used to link video stations with these additional attributes, and ten of these selected as variables (sediment thickness, maximum clast size, depth) or categorical factors (bedform, sea bed character, solid geology, Folk class, gravel fabric, gravel lithology and degree of sorting) for use in multivariate analysis and expert interpretation.

Multivariate analysis

Manipulation and preparation of data

Several data manipulations were required prior to analysis to ensure compatibility and consistency among data sets. Taxonomic data were reviewed to ensure that fauna were identified to a consistent taxonomic level. Identification to species level was retained as far as possible. If a taxon had been identified to species level in some samples but only to genus level in others, then all records were aggregated to genus level. This also applied if several species from the same genus had been inconsistently identified. Taxa identified to coarser taxonomic levels (e.g. Porifera or Cnidaria) were retained, but those recorded to life forms (e.g. faunal turf) were excluded.

Video data

Data from 2005 and 2006 were pooled prior to analysis. Data transformation frequently applied to down-weight the influence of highly abundant taxa was deemed unnecessary as the semi-quantitative SACFOR scale used to record abundance already represented a moderate 'transformation' (approximately equivalent to a square root or 4th root transformation of fully quantitative abundance data).

Stills data

Following the segmentation of video records into one or more samples (as described above) individual still images were re-labelled to maintain association with their parent video sample. Due to the small number of fauna visible within each still image, and to minimise bias caused by each video sample having a different number of associated still images, quantitative abundance data was averaged across all images from a single video sample and these mean values used in further analysis. The resulting data were 4th root transformed to down-weight the influence of numerically dominant taxa such as *Pomatoceros spp.*

Data analysis

Separate but similar analyses were carried out on video and stills data, using the routines described previously within the PRIMER v6 analytical package. The samples were divided into significantly distinct clusters ($p<0.05$) using the CLUSTER routine employing a 5% SIMPROF test. The SIMPER routine was used to identify species that characterised each cluster, and those that discriminated between clusters.

Samples were represented in an MDS ordination and symbolised in different ways to visually represent relationships to abundance of particular species, environmental factors, or biotope.

Environmental data for each video sample were imported into PRIMER, and data were normalised. Draftsman plots were generated for every combination of environmental variable, and any correlated variables were eliminated from further analyses. To determine if any patterns in the biological community correlated with any environmental variables, a BIOENV routine was run.

Those environmental variables that were categorical rather than continuous could not be tested in this way, and so 1-way ANOSIM tests were used to determine whether the biological communities differed between these factors.

Biotope Assignment

Each sample (video and still image) was assigned a biotope, using The Marine Habitat Classification for Britain and Ireland Version 04.05 (Connor *et al.*, 2004). This was done by using expert judgement, based on the results of all the analyses described above.

The results of the cluster analyses from both the video and stills were initially used to help identify which samples should be grouped together into similar biotopes. In addition, for each sample, species profiles and sediment characteristics from the video and stills analyses were assessed. These two sources of information were used in combination to determine groupings of samples into biotopes.

Still images and a selection of videos were visually assessed to ensure that samples placed within each group appeared to be of a similar type, both in terms of the biology and the sediment characteristics. Finally, MDS ordination plots that had been generated using taxa abundance from both video and stills analyses were symbolised, such that the symbol for each sample represented the biotope assignment. The MDS plot was then reviewed to ensure that samples assigned to the same biotope grouped together in a similar region of the plot, thus indicating that they contained similar biological communities.

The biotope represented by each group was determined by matching the species list and sediment characteristics for the video and still samples with the detailed biotope descriptions listed by Connor *et al*. (2004). Where matches could only be made at a broad 'biotope complex' level, due to a close match not existing at the biotope level, a new biotope was proposed and described.

Figure 4.28. 4 m Beam trawl (image courtesy of Rob Enever)

4.2.9 4 m beam trawl and scallop dredge surveys

A review of existing data at the beginning of this project identified that there was little information on commercial fish or shellfish species over the wider survey area. Consequently, it was considered important to collect new data which complemented existing surveys and provided information on the distribution of fish and shellfish over the region.

A series of 25 stations within the survey area was selected for sampling using standard commercial fishing gear suitable for the collection of demersal fish (4 m Beam trawl (Figure 4.28)) and scallops (Newhaven scallop dredge (Figure 4.29)) respectively. The sites were placed on a grid over the survey area and coincided with existing acoustic coverage and faunal sampling sites provided under this project. The 4 m Beam trawl survey was conducted in August 2005 on-board the *RV Corystes,* and the Scallop dredge survey was completed in November 2005 on-board the *Cefas Endeavour* (Figure 4.36). The procedures for collecting and processing the catch from both of these surveys followed the established Cefas Standard Operating Procedures provided in Appendix DVD-ROM.

4.3 EECMHM Geographical Information System (GIS) and database

All data collected and results produced for the EECMHM study have been placed in a Geographical Information System (GIS). A GIS facilitates the integration of disparate sources of geographical and non-geographical information into a single environment for visualisation, querying and analysis.

ESRI ArcGIS 9.1 software was used as the GIS system for the study. All data identified during the data review at the beginning of the study was collated as metadata in the GIS system. The integration of all this existing data in a GIS allowed visualisation of data density and was a crucial tool in the planning of the EECMHM geophysical and ground-truth surveys.

In parallel to the GIS, all navigational data, biological, physical and geological analysis and results from the study are stored using a Microsoft Access 2000 database. All positional data was given a unique identifier based on a station number, which can be linked to the results of the biological and geological data and results. This allows users to extract required data easily by developing custom database queries.

Figure 4.29. Scallop dredge.

The development of the database and GIS has also allowed direct linkage between the Access database and the GIS. By joining the geographical positions in the GIS to the relevant biological and geological data from the database, it is possible to instantly access the data stored in the database from the GIS. This facilitates the production of maps from data stored in the database or simple data querying. For example, the use of a unique identifier for each sample position and associated sample results makes it possible to link a sea bed camera sledge still position to its associated photographic image. This allows the user to study the images in relation to the geological and biological sea bed data within the GIS.

4.3.1 Contents of EECMHM DVD-ROM

When the DVD-ROM is opened, a number of folders and files will be displayed. Table 4.4 outlines what is enclosed in each folder. The EECMHM GIS can be used directly from the DVD-ROM or by copying the entire contents of the DVD-ROM to a single user PC, using the same folder structure as on the DVD-ROM.

Metadata

Metadata information has been completed in accordance with the ISO 19115 metadata standard for all GIS layers provided on the DVD-ROM that accompanies this report. The mandatory information to meet this standard are: -

- Creation data and language,
- Themes and categories,
- Abstract
- Metadata author.

Co-ordinate system

The coordinate system used for all data produced as part of this project is the Geographic coordinate system with WGS84 datum. Some of the historical data included in the GIS may be projected using a different datum. The maps presented in this report used a template using the projected coordinate system Universal Transverse Mercator Zone 31 North with the WGS84 datum.

Table 4.4. Contents of EECMHM DVD-ROM.

File or folder	Subfolder	Information
ArcReader	Data	This folder holds all the data as shapefiles required for the ArcReader GIS to be viewed. The contents of this folder should not be changed
	Pmf	This folder holds the GIS file that should be opened if ArcReader is being used. The file to open is: EECMHM_disseminationGIS.pmf
CEND1205_CS_images	Station folders	This folder contains several folders relating to each station of the 2005 EECMHM survey. Each station folder contains the camera stills taken during the survey. It is possible to hyperlink to these using the GIS or view them independently in this folder.
CEND1406_CS_images	Station folders	This folder contains several folders relating to each station of the 2006 EECMHM survey. Each station folder contains the camera stills taken during the survey. It is possible to hyperlink to these using the GIS or view them independently in this folder.
EECMHM_project_report		This folder contains a digital copy of the project report in pdf format.
Layer_Files		This folder contains ESRI .lyr files which store the symbology for each of the layers within the GIS. These can be used with the shapefiles to add the data into your own ESRI ArcGIS.
MapInfo_Files		This folder contains all the GIS data but as MapInfo files. This allows you to add any of the project GIS data into a MapInfo GIS.
MNCR_sublittoralHabitatRecording Form		A copy of the profoma used to capture sublittoral habitat information. Contact JNCC for further information.
Raster_Data	Raster data folders	This folder contains all of the raster data used within the GIS. This includes .jpgs but also ESRI Grids of the interpolations created salinity, temperature, mean grain size etc.
README		The readme document gives detailed information about the project GIS and its data and how to use it. There is also a file called Dataset_abstracts which is a copy of the information about every dataset within the GIS for non ESRI users.
Shapefiles		This folder has copies of the spatial data stored as ESRI shapefiles for use within any ESRI GIS or in ESRI ArcGIS in conjunction with the layer files.
EECMHM_Dissemination_GIS.mxd		If you already have ArcGIS installed on your machine you can open this file directly to view the project GIS.
Standard_Operating_Procedures		Draft Cefas standard operating procedures for grab, trawl and video in pdf format.

4.3.2 Using the EECMHM GIS

ESRI ArcGIS Users

The EECMHM GIS has been built using ESRI ArcGIS 9.1 software and stores all its spatial data and associated metadata within a personal geodatabase. This GIS is available on an accompanying DVD-ROM and can be viewed by anyone who has a licence to use ESRI ArcGIS software. To do this, all the data on the DVD-ROM should be copied to a local drive and then the user should open the **EECMHM_DISSEMINATION_GIS.mxd** map document file.

Free GIS viewer

For those users who do not have access to an ESRI ArcGIS licence the EECHMHM GIS has also been published for ArcReader which is a free downloadable GIS viewer. ArcReader can be installed using the executable within the folder on the accompanying DVD-ROM or by visiting the ESRI website (http://www.esri.com/software/arcgis/arcreader/download.html). Once ArcReader software has been installed on a machine, the user can open the **EECMHM_DISSEMINATION_GIS.pmf** file and view the data stored within the GIS.

MapInfo Users

The data has been converted to MapInfo.tab format. This data is stored within the MapInfo folder on the DVD. MapInfo users should select the files they wish to use within their own MapInfo GIS from the MapInfo folder. Legend fields for the MapInfo data exist.

Data availability and usage

The GIS does contain some data that was kindly provided by the East Channel Association (ECA) who have granted permission for use within the EECMHM dissemination GIS. The further use of this ECA data is possible only with the express written permission of the ECA. Any copyrighted data licensed to the EECMHM study is not freely available through the GIS. Its use is subject to the terms and conditions of the copyright holders.

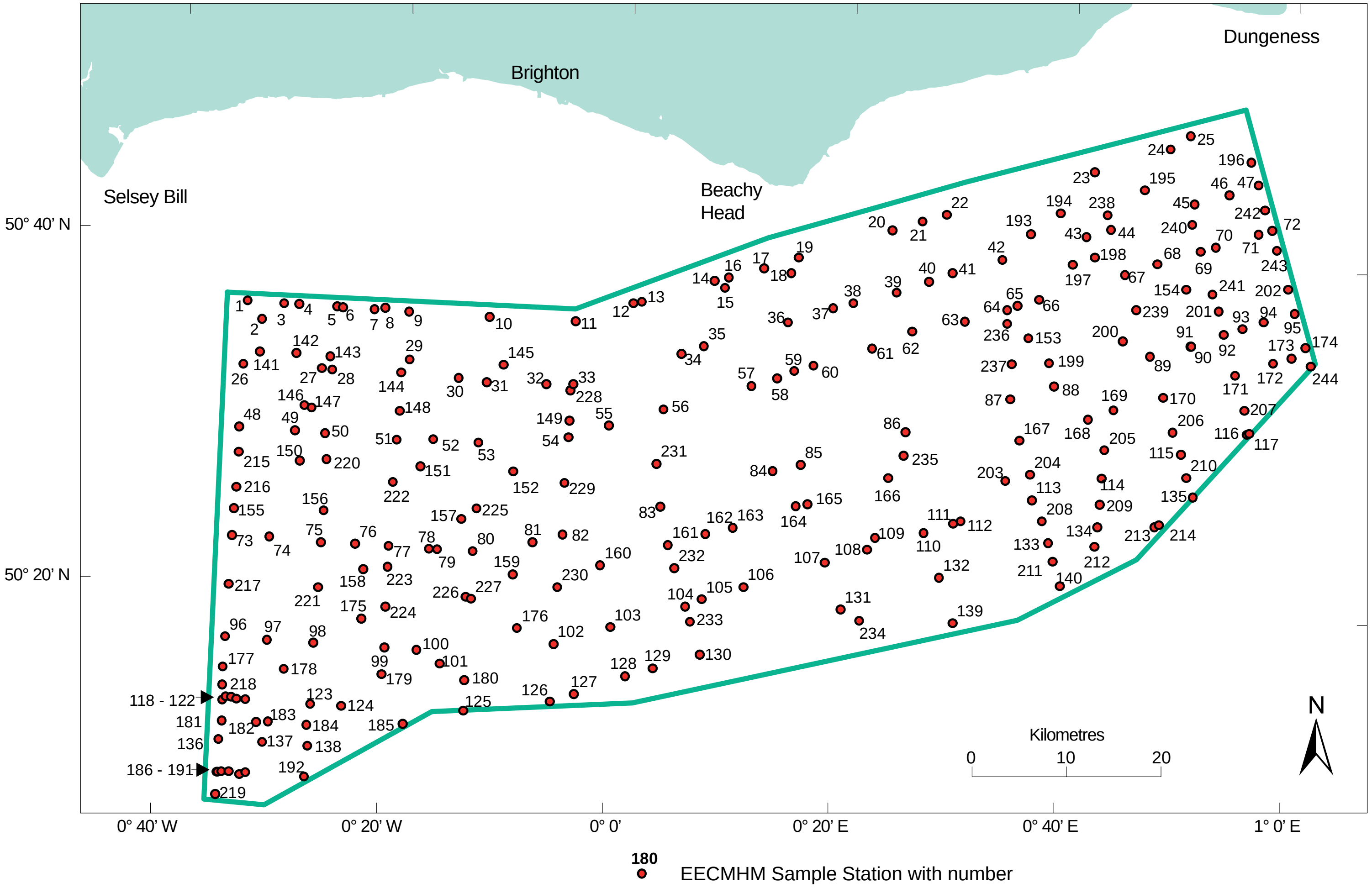


Figure 4.30. Eastern English Channel Marine Habitat Map (EECMHM) sample stations.

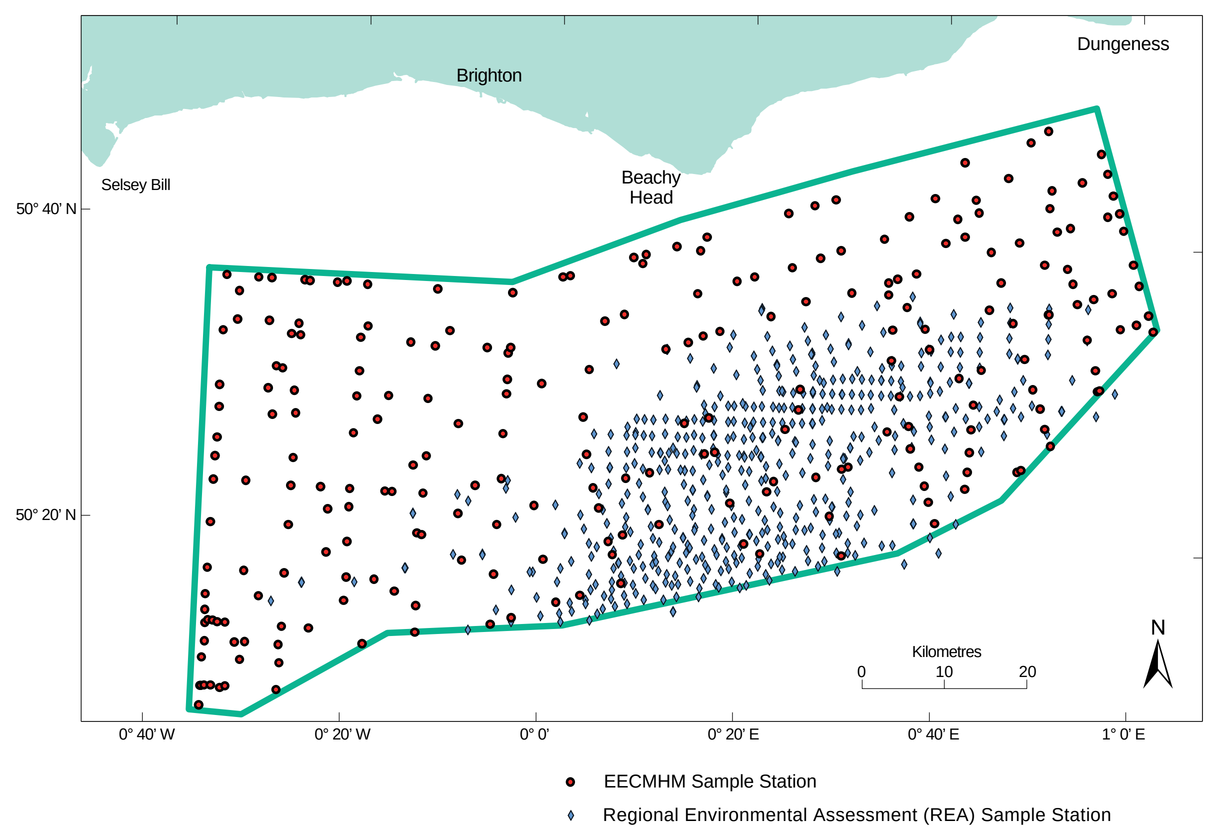


Figure 4.31. EECMHM and Regional Environment Assessment (REA) sample stations.

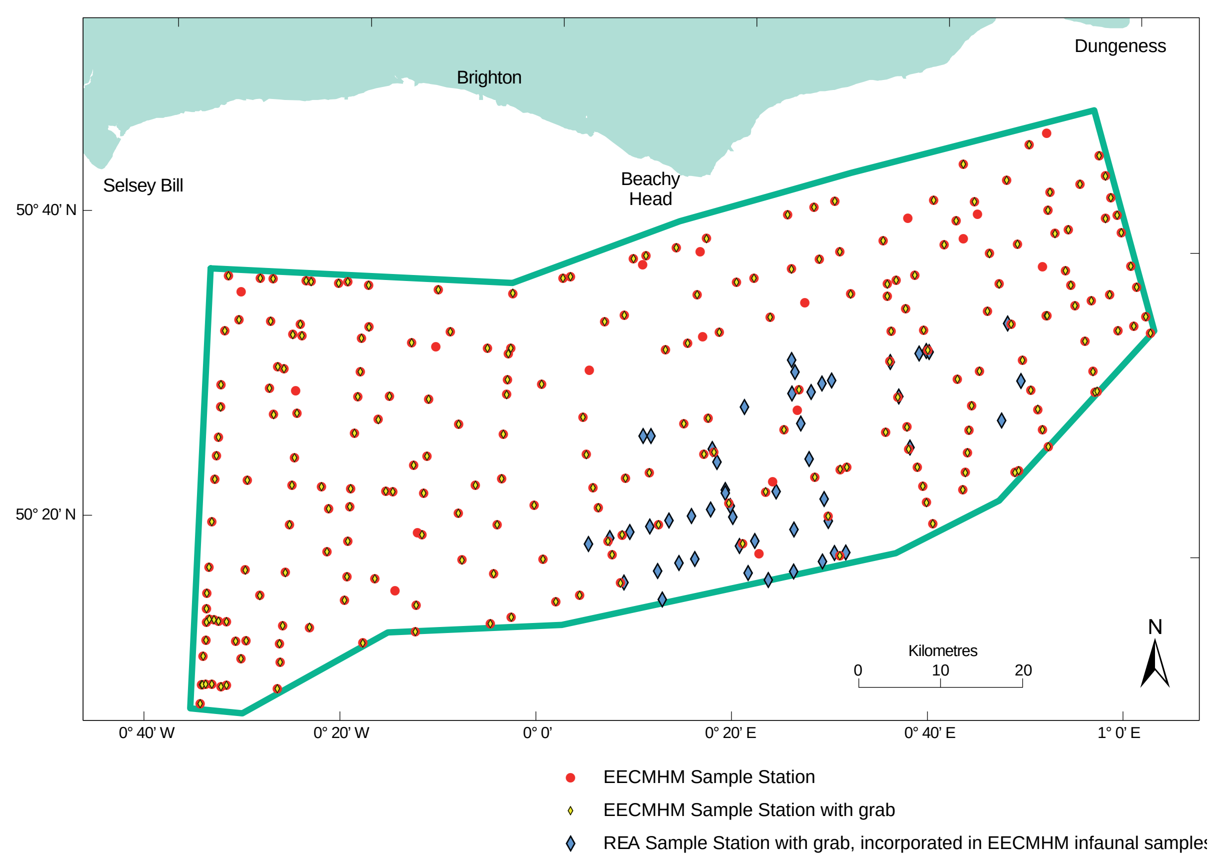


Figure 4.32. EECMHM with REA sample stations incorporated in analysis.

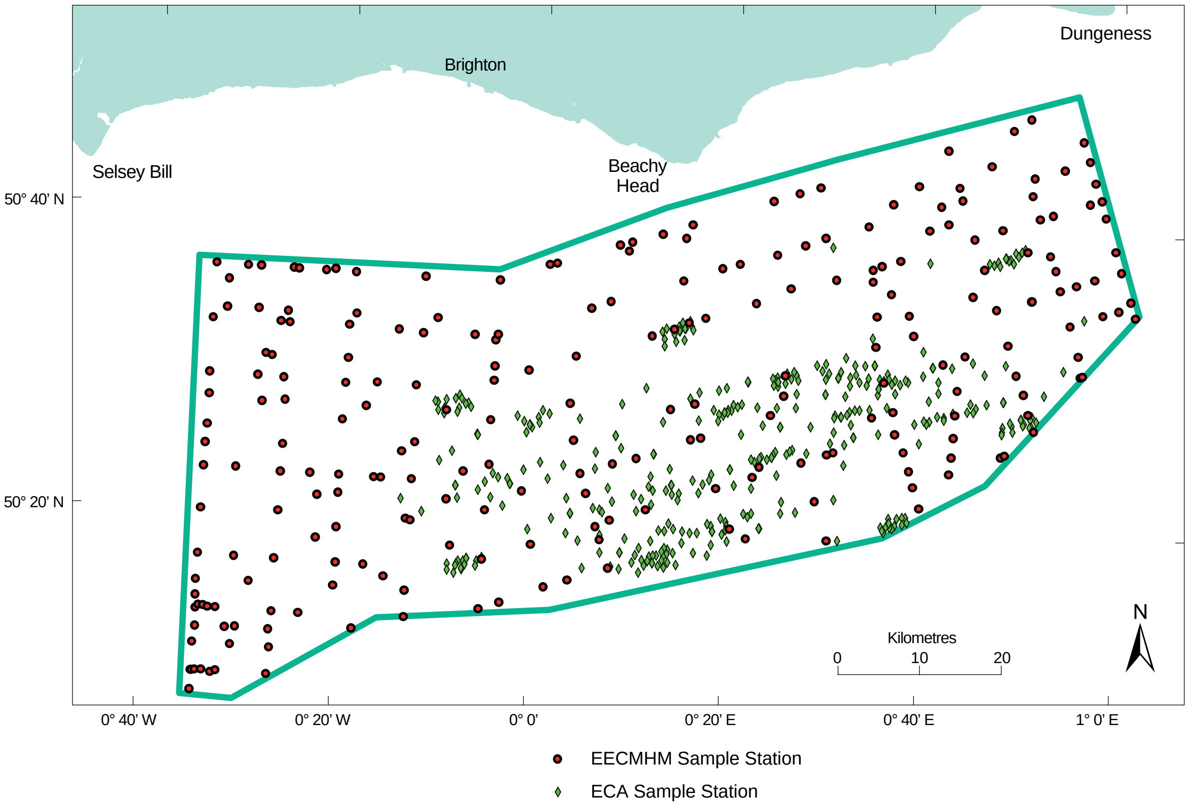


Figure 4.33. EECMHM and East Channel Association (ECA) sample stations.

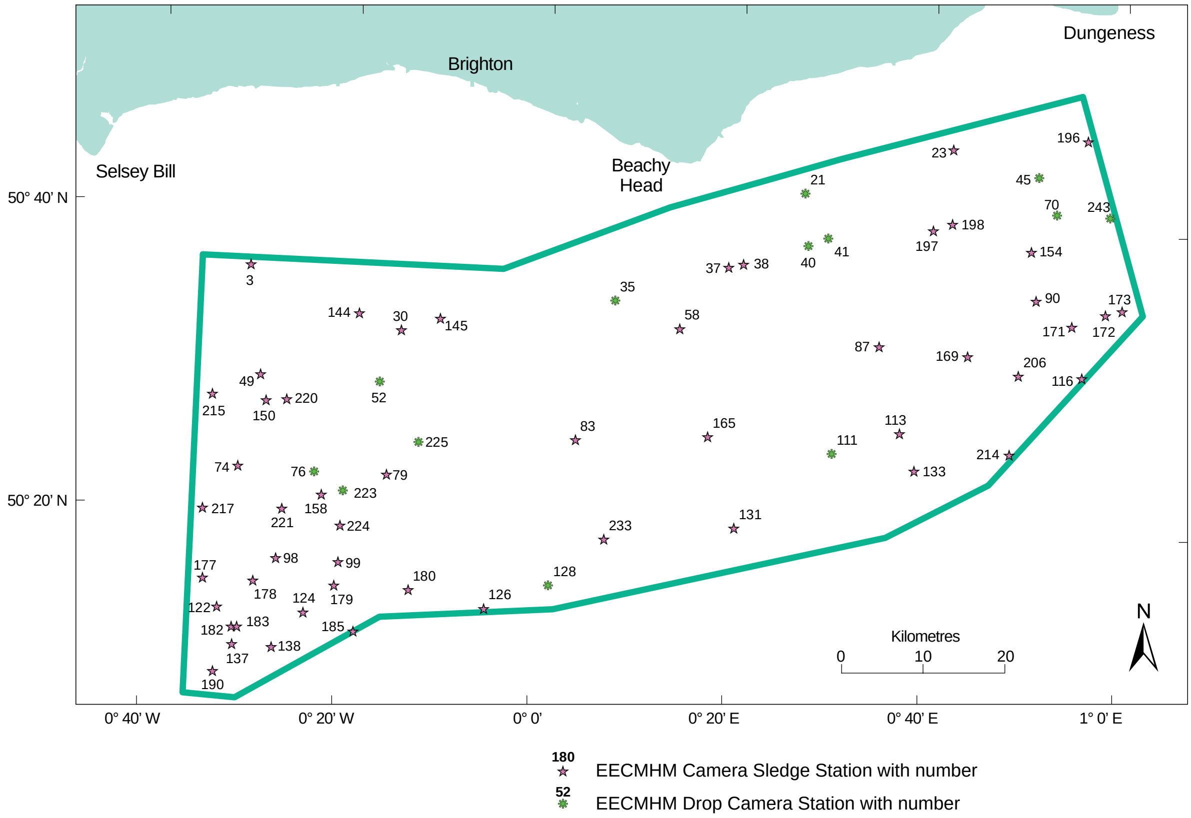


Figure 4.34. EECMHM camera sledge and drop camera stations.

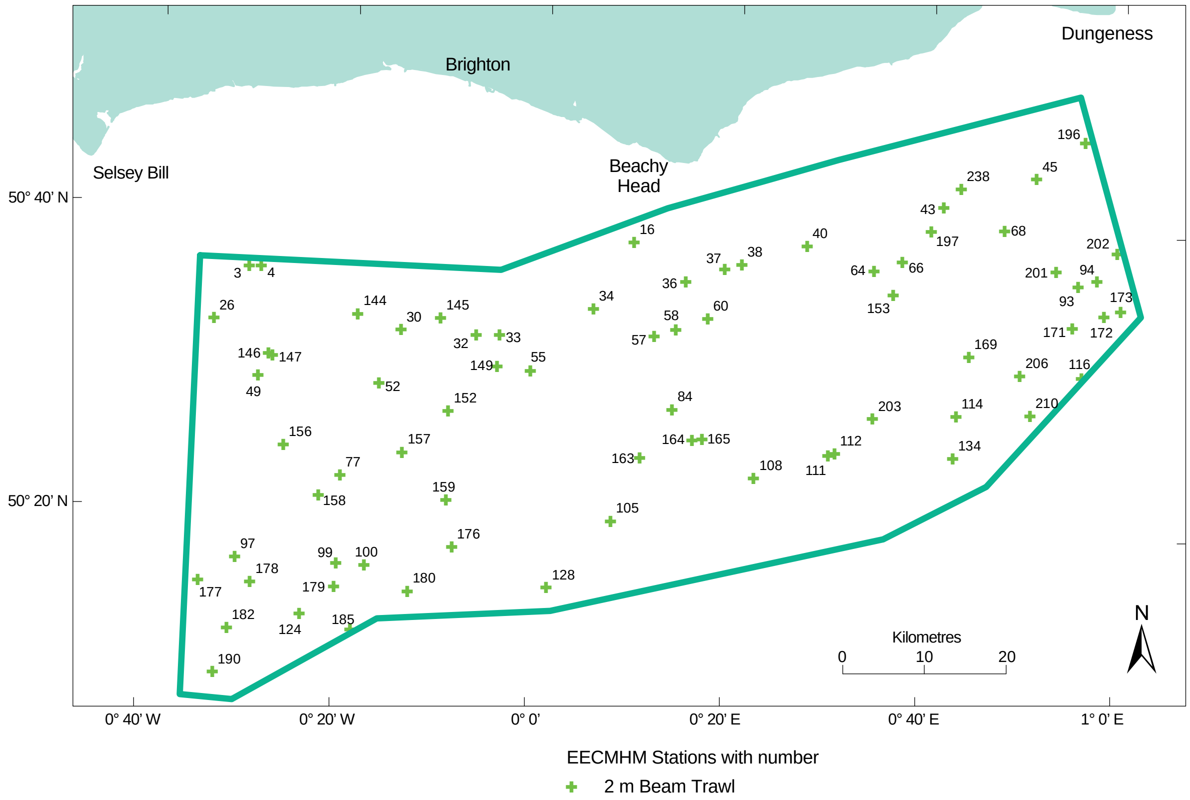


Figure 4.35. EECMHM 2 m beam trawl stations.

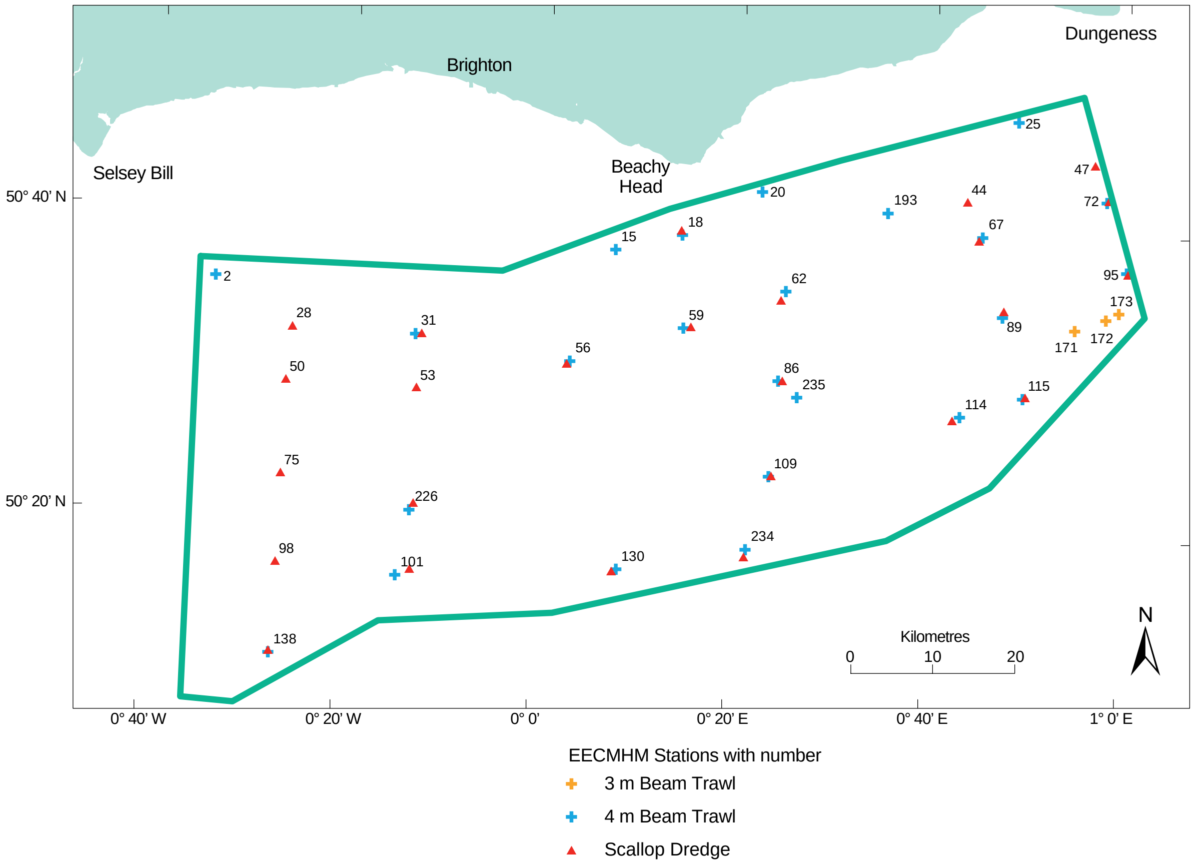


Figure 4.36. EECMHM 3 m and 4 m beam trawl and scallop dredge stations.

5. Interpretation

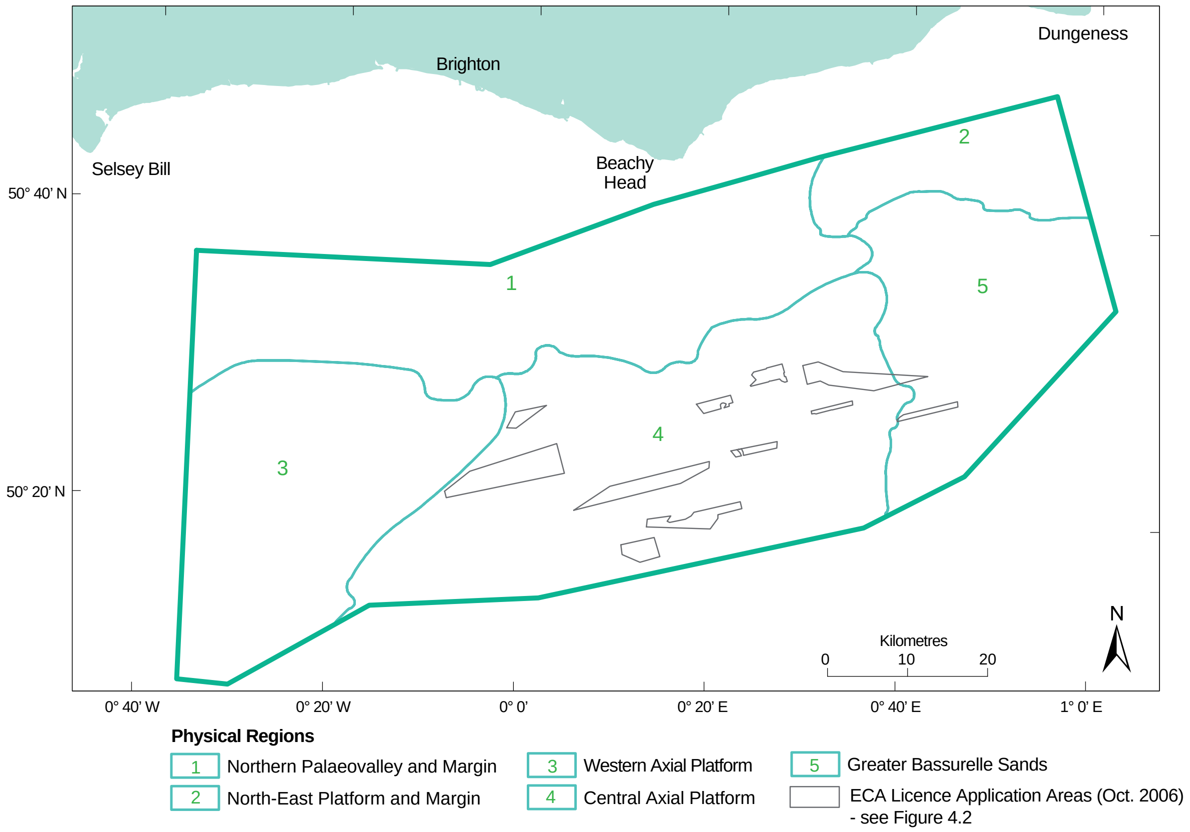


Figure 5.1. EECMHM physical regions with licence application areas.

The study area boundary of the Eastern English Channel Marine Habitat Map (EECMHM) (Figure 5.1) was drawn to provide a wider perspective of the nature of the sea bed in and around the area originally prospected by the East Channel Association (ECA) (Figure 4.1) and subsequently subject to aggregate licence applications (Figure 4.2 and 5.1). The study area covers approximately 5090 km^2 of the sea bed in the eastern English Channel. Significantly larger than the ECA prospecting areas which extended over about 1500 km^2.

The study area has a west-east extent of about 115 km from 0° 37′W (a longitude 10 km east of Selsey Bill) to 1° 5′E (a longitude just east of Dungeness). Its northern limit is an arbitrary line drawn at over 20 km offshore for much of its western half but comes to within 5 km of the coast off Beachy Head and continues eastward at about 10 km offshore to Dungeness. Its southern limit is the political boundary of the UK – France median line. The width of the study area is about 45 km along the majority of its length but it reaches 55 km at its western boundary and narrows to about 29 km at its eastern limit.

The limits of the study area, apart from the political boundary, were also drawn with the perspective of its bathymetry, geology, sediment, biology and hydrodynamics, and the aim of providing the context of these parameters in the ECA prospecting and licensing areas with a wider regional setting.

5.1 Physical regions

The interpretation of the geophysical and geological data gathered by or made available to the study indicated that certain areas had characteristic or common physical and geological features which distinguished them. These areas have been classified as physical regions and five in all have been delineated. Their boundaries are drawn on a number of criteria and include: -

- Water depth and sea bed morphology
- Sea bed sediment classification
- Bedforms
- Sea bed character and sediment thickness

These criteria are not common to all boundaries between regions. Some may be the primary criteria at a number of boundaries and at others they will not be significant. For some criteria the boundaries can be transitional or gradational e.g. a fining or coarsening of sediment, elsewhere they can be relatively fixed e.g. a break of slope or channel margin.

There are few named sea bed physical features on bathymetric charts and geological maps in the study area; therefore the five physical regions have been arbitrarily named for the EECMHM (Figure 5.1). They are: -

1. Northern Palaeovalley and Margin
2. North-East Platform and Margin
3. Western Axial Platform
4. Central Axial Platform
5. Greater Bassurelle Sands

The study area could be broken into a greater number of regions but these five are suitably distinctive to provide a framework for the interpretation and characterisation of sea bed marine habitat and a geographic structure to aid in considering the physical, geological and biological datasets and interpretations that have been created during the study. The physical region boundaries are included in virtually all the EECMHM wide figures in Chapter 5 to assist the process of assessment and interpretation.

Physical Region 1
Northern Palaeovalley and Margin

The offshore coastal fringe between Selsey Bill and Beachy Head is a relatively shallow sea bed which declines gently across 15 to 20 km from the shore to a depth of around 30 m (Figure 5.2). At this point there is a break of slope which descends to a depth of around 60 m. This slope is not everywhere a single slope but can include a number of discrete slopes, some formed by scarps and dip slopes in tilted bedrock. In total the slope can vary from <2 km in width up to 5 km and forms the northern margin of the Northern Palaeovalley (Figure 5.3).

The line of the northern margin forms an arc that roughly parallels the line of the coast. Within the EECMHM boundary the northern margin is only present in the north-west corner of Region 1 and over a much wider extent in the north-east quarter off Beachy Head. This northern margin has been breached in a number of places by channels of tributary rivers and streams running into the Northern Palaeovalley system. Some of these are open channels with little or no sediment, others, have substantial channel infill.

The floor of the Northern Palaeovalley covers the western half of the region and is up to 15 km wide. It narrows eastward to around 5 km and its valley form is not so distinctive. In the west the Palaeovalley floor can reach depths in excess of 70 m, the deepest sea bed in the EECMHM. It very gradually shallows eastward across its 90 km length to around 50 m depth.

The southern limit of the Northern Palaeovalley has a distinctive break of slope in the west, over 10 m high, but this becomes less distinct as a morphological feature to the east. The floor of the Palaeovalley also appears to bifurcate in the east into two narrow shallow depressions, although the evidence is limited by the very wide spacing of EECMHM survey lines

Physical Region 1 is about 90 km in length from west to east and 13 to 20 km wide and covers an area of about 1260 km^2.

Physical Region 2
North-East Platform and Margin

The North-East Platform and Margin lies in water depths generally less than 40 m. In its north-west quarter where it rises on to the coastal margin it can shallow to <20 m. The southern boundary of the region is primarily based on the extent of rock and thin sediment at the sea bed which forms the underlying foundation of the region (Figure 5.5). Rock structural lineation and bedding is a prominent feature of the sea bed, although these appear to be less prominent in the north of the region.

A channel infilled with Quaternary sediment underlies the region in the west and the western boundary of the region follows the boundary of this channel (Figure 5.4). Other minor sediment infills occur elsewhere on the platform.

Physical Region 2 is the smallest of the regions and extends for 34 km from west to east and varies in width from 7 to 16 km. It covers an area of about 350 km^2.

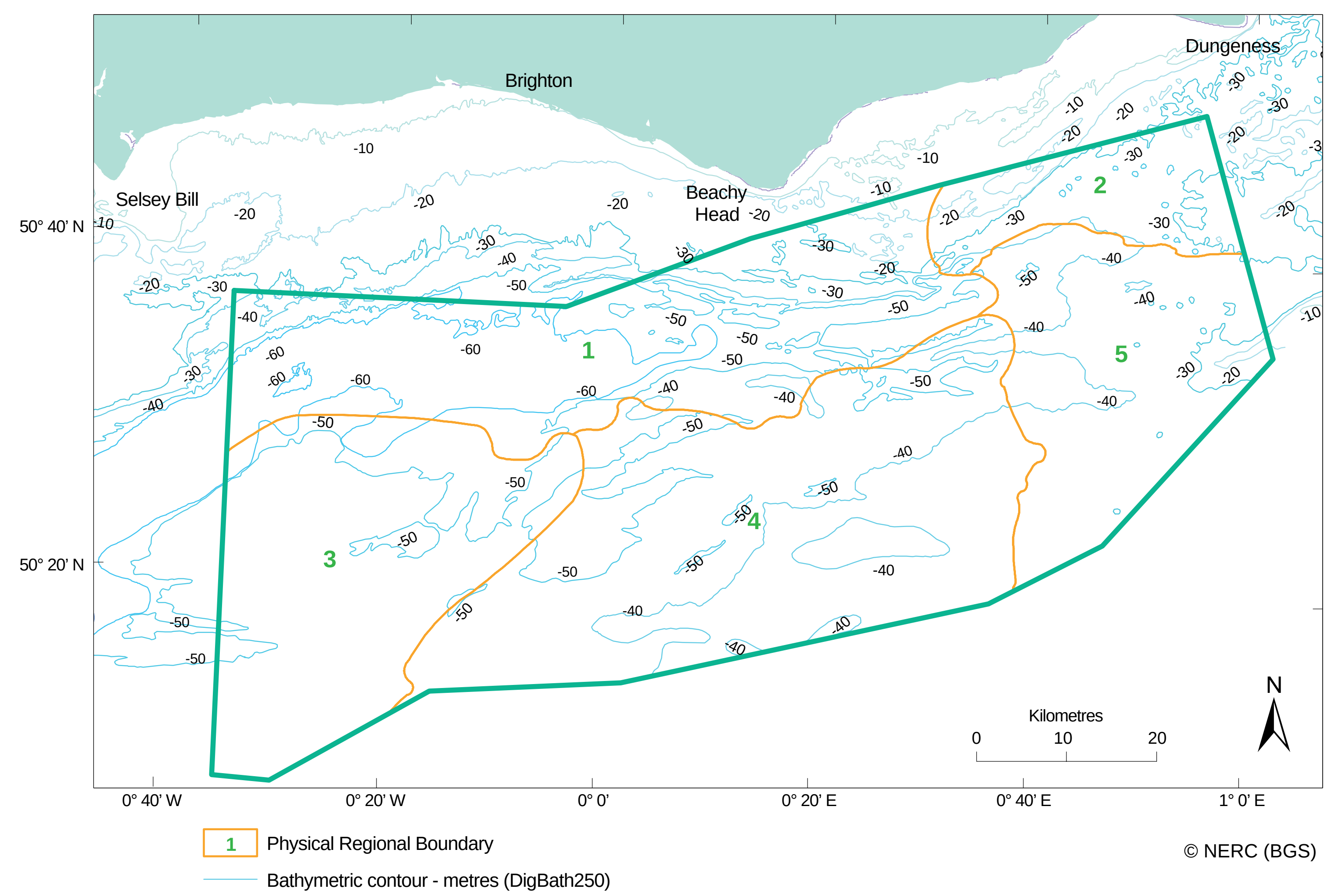


Figure 5.2. EECMHM bathymetry.

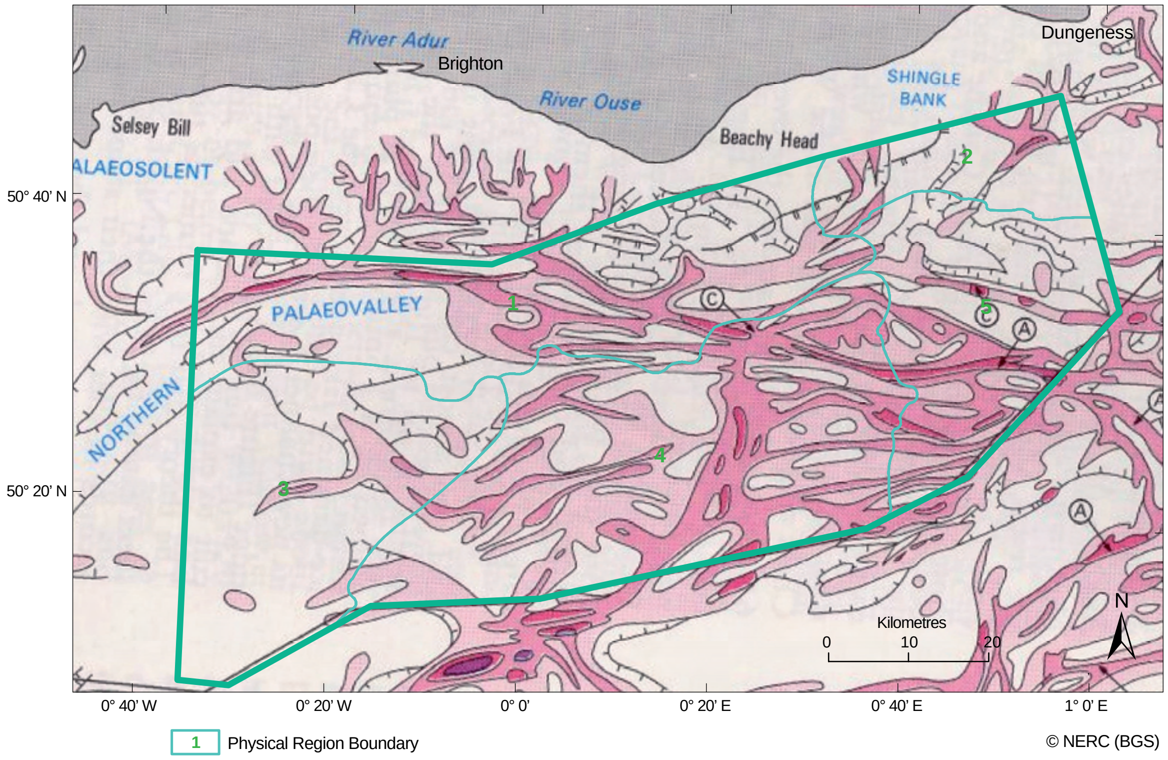


Figure 5.3. Palaeovalleys and channel infill sediments (Hamblin *et al*., 1992).

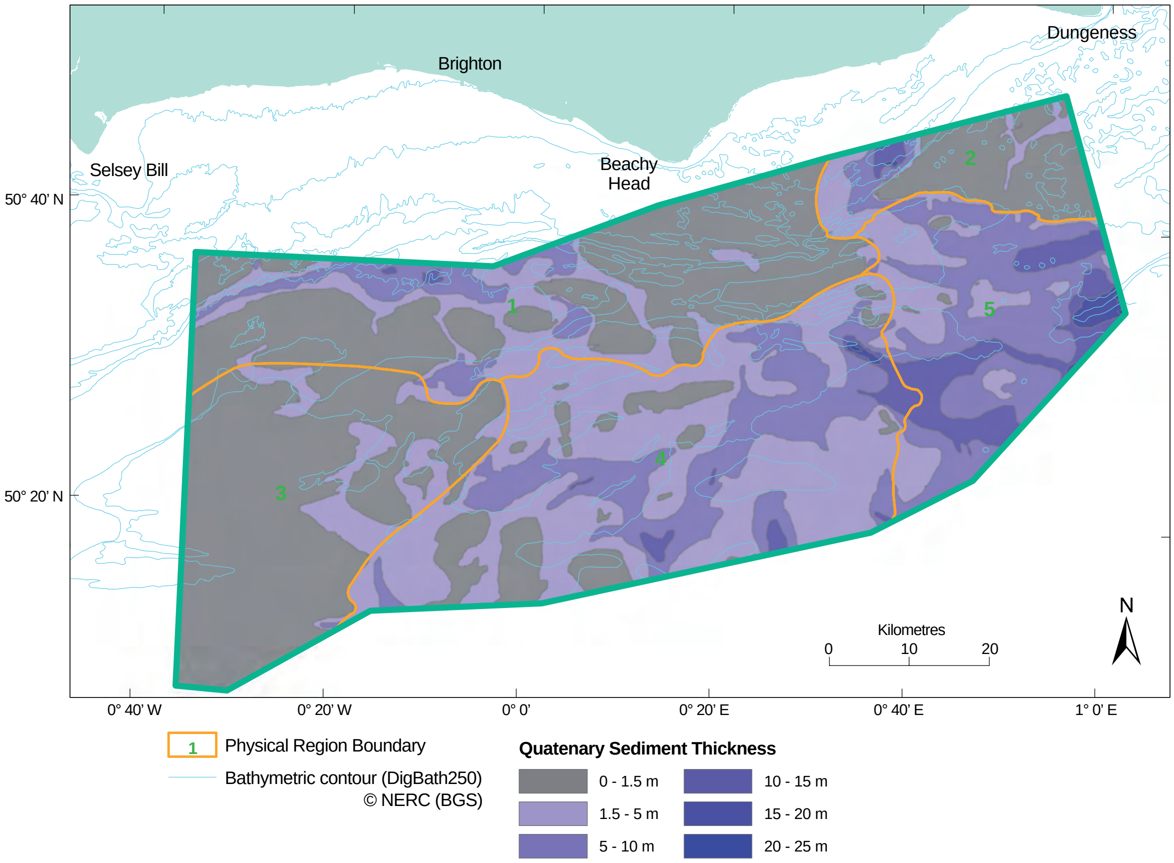


Figure 5.4. EECMHM Quaternary sediment thickness.

Physical Region 3
Western Axial Platform

The Western Axial Platform lies in the south-west quadrant of the study area. It is predominantly characterised by extensive rock and thin sediment at the sea bed (Figure 5.5). In the north and east of the region there are some channels infilled with Quaternary sediment (Figure 5.4). Its eastern boundary is drawn along a line which marks the limit of the extensive rock platform. To the north is the Northern Palaeovalley.

The platform is relatively flat on a regional scale and lies in about 45 to 50 m of water. It is slightly deeper, >50 m, in the north of the region. There is some rock structural lineation and bedding and these produce some minor positive and negative features on the sea bed.

Physical Region 3 varies in west-east length from 20 to 40 km. It is about 40 km wide at its western boundary and although it narrows slightly to the north-east it covers an area of 1050 km^2.

Physical Region 4
Central Axial Platform

There is an almost imperceptible regional rise in the sea bed across a distance of 50 to 70 km, from 45 to 50 m depth in the west to 35 to 40 m in the east (Figure 5.2). The region is covered by predominantly coarse sediment which becomes sandier to the east (Figure 5.5). It is underlain by a network of sediment filled palaeochannels (Figure 5.3; 5.4) with little apparent surface expression at the sea bed, which is relatively featureless apart from minor channelling evident on the very widely spaced EECMHM geophysical lines across Region 4. A greater density of survey lines would provide confirmation. There are some interfluves between the palaeochannels where rock reaches the sea bed and these are commonly covered by thin sediment, although some do feature lineation and bedding (Figure 5.6).

The palaeochannels continue east beyond the eastern boundary of the region which has been drawn at the eastern limit of any extensive sandy gravel at the sea bed (Figure 5.7) and beyond which gravel is <30% of the sea bed sediment (Figure 5.35).

The Central Axial Platform is the largest of the five regions and covers an area of about 1640 km^2.

The majority of the ECA licence application areas lie within Region 4 with a couple of application areas just straddling the eastern boundary with Region 5 (Figure 4.2; 5.1).

Physical Region 5
Greater Bassurelle Sands

The Greater Bassurelle Sands are named after the Bassurelle Sand Bank whose western tip just encroaches into the south-east corner of the region. The bank itself extends for a further 17 km to the north-east of the EECMHM study area.

The sea bed of the region is predominantly at a depth of 30 to 40 m. It is slightly deeper in the north-west where the Northern Palaeovalley extends to the east. The imperceptible eastward incline of the sea bed continues across the region and at the Bassurelle Bank its crest lies in <20 m of water (Figure 5.2).

The sea bed is dominantly sandy. It is generally featureless in the southern half of the region but isolated sand waves gradually appear to the north and east and these become more frequent and form an extensive sand wave field over the northern half of the region up to the edge of the North-East Platform.

The region has west-east extent of about 30 km. It is about 38 km wide at its western boundary and narrows eastward to about 12 km. It covers an area of about 790 km^2.

5.2 Geology

Introduction

Physical features which include geology, sediment and morphology of the sea bed greatly influence the distribution and range of species and biological communities and together comprise the marine habitat at the sea bed. However, in terms of habitat, only the physical characteristics of the sea bed surface and its underlying geology and sediment down to a depth of ~0.5 m is thought to be significant. Although the level of this habitat-depth-interface is likely to depend on the nature of the sea bed substrate e.g. it could be lower in muddy sediment, where infauna may burrow deeper, than in gravel or rock. It should also be borne in mind that physical sampling techniques, such as the Hamon grab and beam trawls used in the EECMHM, are unlikely to penetrate depths >0.15 m. Video and still photography also only characterise the sea bed surface. Therefore the ground truthing biological evidence and results are restricted to these relatively shallow depths; a similar depth restriction applies to sediment grain size analysis based on grab sampling.

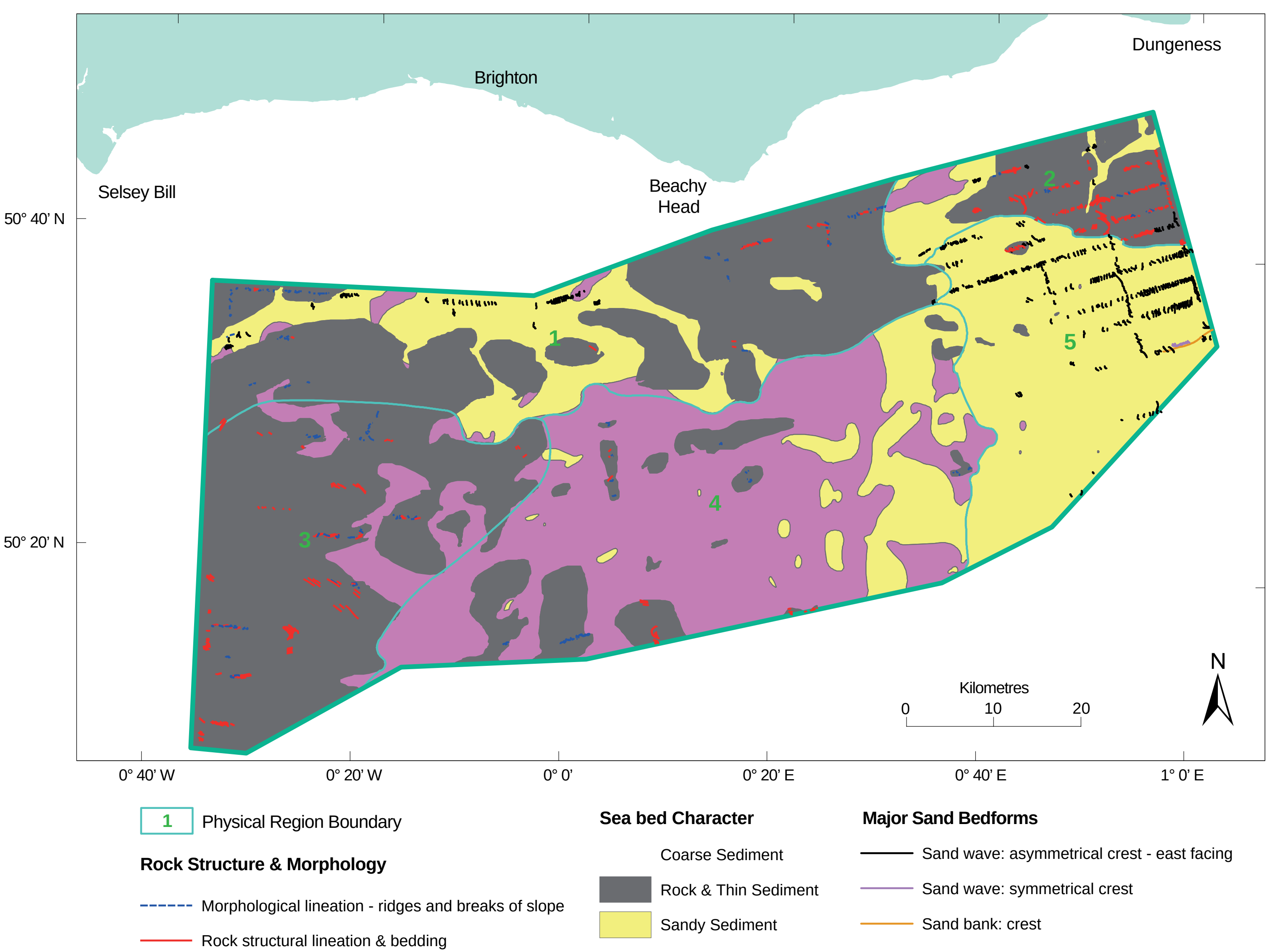


Figure 5.5. EECMHM sea bed character (rock structure, morphology and crest lines only interpreted on survey corridors).

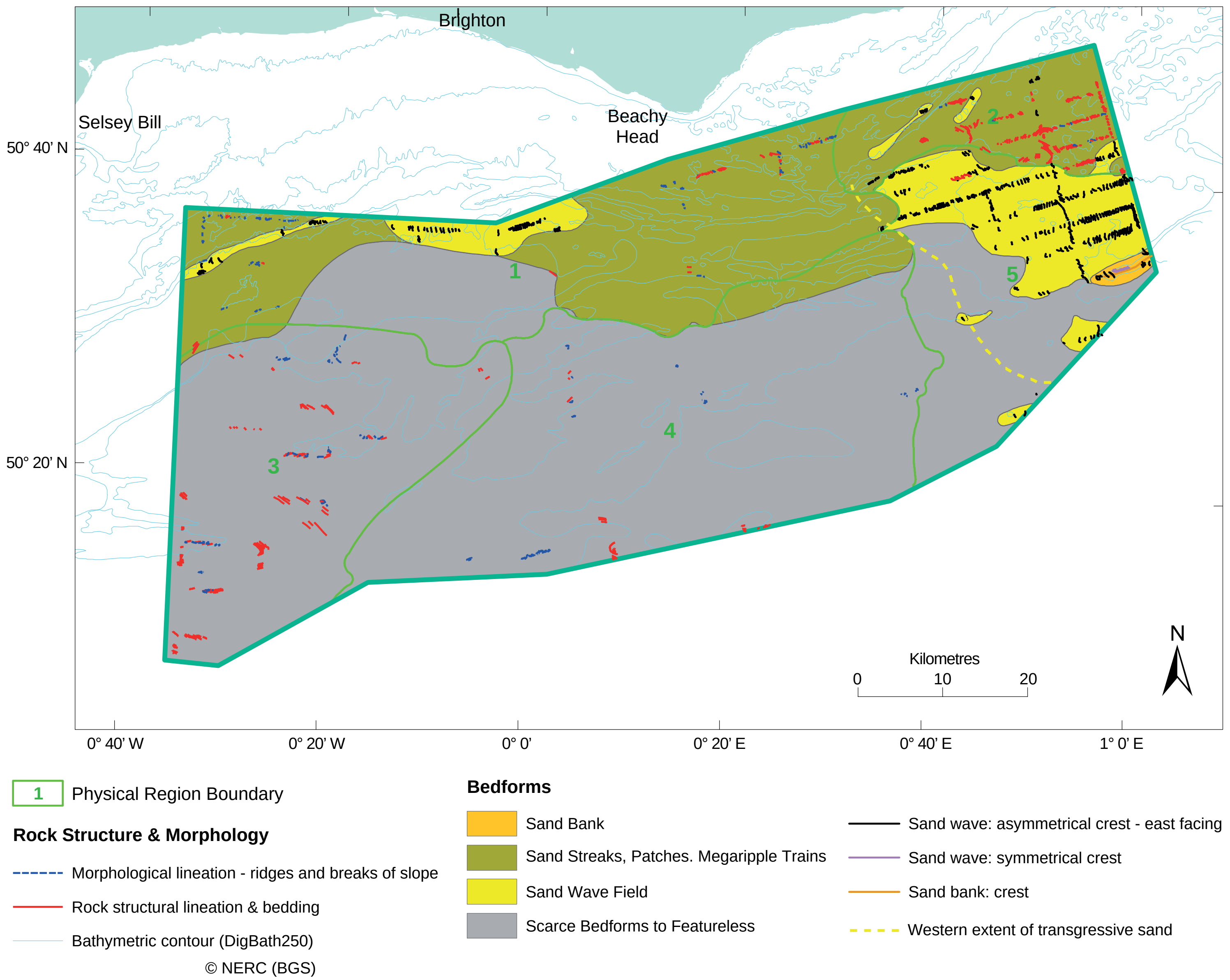


Figure 5.6. EECMHM bedforms and morphology (rock structure, morphology and crest lines only interpreted on survey corridors).

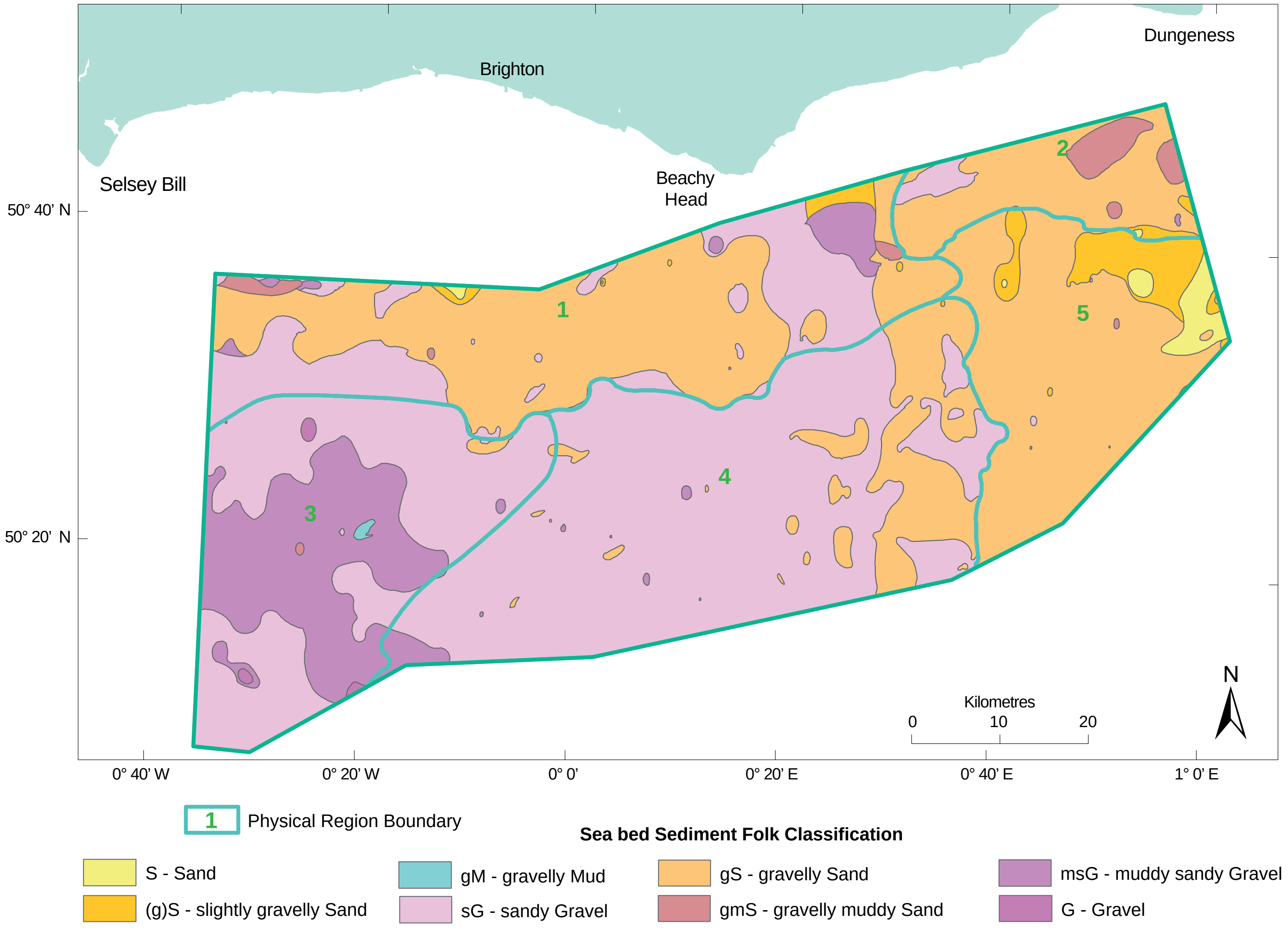


Figure 5.7. EECMHM sea bed sediments - Folk Classification (after Folk, R.L. 1954. Journal of Geology, Vol. 62, p.344-359).

Given the significance of the relatively thin sea bed substrate for marine habitat, the principal aim of the geological investigations for the EECMHM has been to characterise the physical nature of the sea bed and the processes which have contributed to form and maintain its present day character.

Interpretation methodology

Three geophysical techniques, multibeam echo sounder (MBES) (Figure 4.3), sidescan sonar (Figure 4.4) and Boomer sub-bottom profiler (Figure 4.5) were deployed along a widely spaced corridor grid to provide geophysical data for the geological interpretation of sea bed and sub-sea bed geology and sediments. The ground truthing EECMHM sample stations (Figure 4.30) were sited after an initial interpretation of the geophysical data. The results from these EECMHM sample stations and those provided by the East Channel Association (Figure 4.33) have been incorporated in the final geological interpretation.

The diversity of processes and events that have contributed to producing the sea bed geology and sediments within the EECMHM area required a systematic approach to the analysis in order to provide a framework on which to build an integrated interpretation and produce a series of themed geological and sediment maps. The systematic approach involved a sequence of interpretive steps: -

- The first step in the geological interpretation process to understand and interpret the sub-sea bed geology was to distinguish and map those areas where rock outcropped at the sea bed, and identify the type and age of the rock, also the occurrence of palaeochannels filled with Quaternary sediment, as well as other areas where relatively thick and extensive Quaternary sediment were found.

  This sub-sea bed geological framework was provided by the interpretation of boomer seismic reflection profiling records (Figure 4.5) and digitising on these records within CODA GeoSurvey software the base of superficial Quaternary sediment lying on top of bedrock (solid geology). This rock head limit between bedrock (solid geology) and Quaternary sediment, when present, was generally well defined. The seismic lines have been interpreted and the position and depth from the sea bed of the rock head horizon has been tracked for the EECMHM area. The digitised rock head/base Quaternary sediment horizon has been used to extrapolate thickness values for Quaternary sediment at regular fix points along the EECMHM seismic lines and these have been interpolated to produce a simplified isopach map of Quaternary sediment thickness for the EECMHM area (Figure 5.4).

- The second step was to integrate the boomer interpretation with multibeam and sidescan sonar data especially in those areas where Quaternary sediments were thin and bedrock was exposed or virtually at the sea bed. In terms of habitat mapping it is important to delineate the area of bedrock exposed at the sea bed, and it was possible to distinguish rock structures and bedding planes on the EECMHM multibeam and sidescan data and where noted these bedrock occurrences were confirmed by the corresponding boomer record. However, the boomer data commonly indicated a more extensive outcrop of bedrock at or virtually at the sea bed than apparent from the multibeam or sidescan. The comparison indicated a problem of resolution.

  In cases of thin sediment over bedrock the multibeam signal may not penetrate thin sediment but will, to all intent and purpose, reflect underlying bedrock surface structure. Conversely, the Boomer signal is designed to reflect and penetrate beneath the sea bed. The width of the pulse reflected by the sea bed will vary with differences in the coefficient of reflectivity of the substrata. The harder and denser the material forming the sea bed the larger the pulse response recorded. The Boomer pulse width can vary with a magnitude of a few milliseconds and when the thin veneer of sediment was less than 1 to 1.5 m thick the boomer was unable to distinguish the rock/sediment interface. Therefore, areas where the boomer records generally cannot resolve the sediment/rock interface are mapped as areas of 0 –1.5 m Quaternary sediment thickness (Figure 5.4). These areas have been copied on to the sea bed character map (Figure 5.5) and distinguished as rock and thin sediment

- The third step was to interpret multibeam and sidescan data for morphology, and bedforms. These were included in the sea bed character map (Figure 5.5) and bedforms map (Figure 5.6) and shown as sand wave and sand bank crest lines, morphological lineation, rock structure and bedding. Highly diffractive signature on the boomer records was correlated with high reflective backscatter on the sidescan records. Rippled sand and megaripple ribbons and trains were recognised and delineated in sidescan records and were also characterised on the boomer records by a loss of the first return at the sea bed i.e. the bottom tracking of the sea bed was unlocked and lost at each megaripple crest. Video and still pictures were analysed to ground truth bedforms and sea bed character and verify the composition of thin veneer sediment and confirm the presence of bedrock at the sea bed. The video and stills were also analysed to provide sedimentological data on gravels and cobbles (Figures 5.48-52).

- The fourth step was to interpret particle size analysis (PSA) data provided by sediment sampling from EECMHM grabs (Figure 4.32) and those conducted by the ECA (Figure 4.33). The interpretation produced a series of maps of the EECMHM area purely based on sediment PSA including sea bed sediment distribution based on the Folk classification (Figure 5.7) and sedimentological parameters, d_{50} (Figure 5.36), mean grain size (Figure 5.37), skewness (Figure 5.38), sorting (Figure 5.39), sand % (Figure 5.34), gravel % (Figure 5.35) and mud % (Figure 5.40). Some of the lines from the Folk map have been used to delineate coarse sediment and sandy sediment on the sea bed character map (Figure 5.5) typically at the boundary between gravelly sand and sandy gravel. Note that the Folk map sediment coverage extends over the area shown as rock and thin sediment on the sea bed character map because no account has been taken of geophysical data in compiling the Folk map, it is purely based on the interpolation of grab sampled PSA data across the whole EECMHM area.

The range of techniques utilised in gathering geological data for the EECMHM has provided a wealth of information, interpretations and maps, the variety of which underscores the diversity of physical attributes which impact on sea bed marine habitat.

5.2.1 Solid geology - bedrock

Although the bedrock of solid geology underlies the whole EECMHM study area (Figure 5.8) it is only in those areas of sea bed underlain by rock and thin sediment (Figure

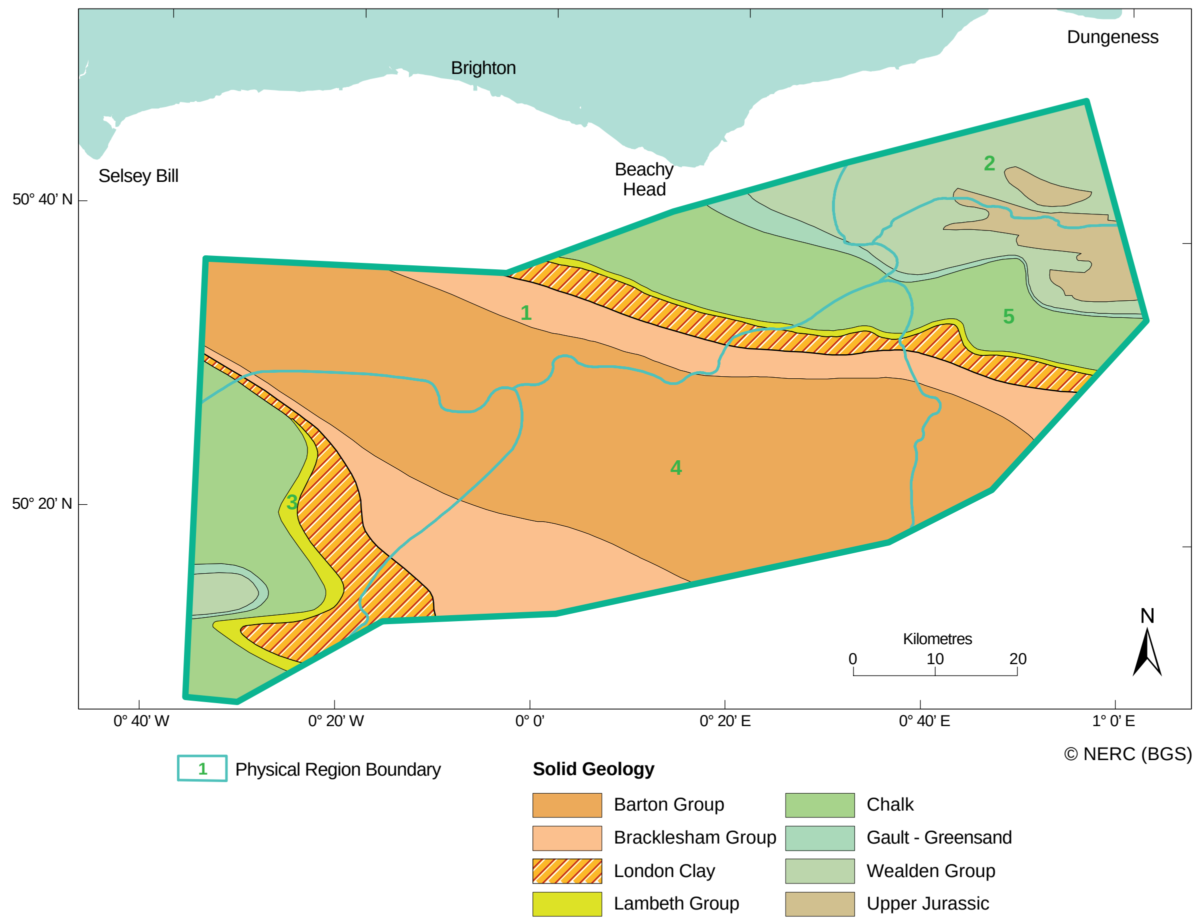


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Figure 5.8. EECMHM solid geology.

5.5) where the nature, lithology and form of the bedrock is likely to have any impact on marine habitat. Elsewhere the thicker Quaternary and mobile sediment cover provides the sea bed surface for habitat. The stratigraphy of the solid geology within the study area is outlined in Table 5.1 with the oldest at the base and ascending in age.

Table 5.1. Solid geology stratigraphy in EECMHM study area.

Solid Geology	Age
Barton Group	Upper Eocene - Tertiary
Bracklesham Group	Middle Eocene - Tertiary
London Clay	Lower Eocene - Tertiary
Lambeth Group	Palaeocene - Tertiary
Chalk	Upper Cretaceous
Gault-Greensand	Lower Cretaceous
Wealden Group	Lower Cretaceous
Upper Jurassic (Portlandian)	Upper Jurassic

Tertiary rocks within the NW - SE trending Hampshire – Dieppe Basin (Hamblin *et al.*, 1992. BGS 1988 and 1995) dominate the study area, specifically in the western half of Region 1 and over much of the southern half of the EECMHM study area which includes Regions 3, 4 and 5. The Tertiary are bordered to the west and east by older Cretaceous rocks, namely Chalk, Gault – Greensand and Wealden Group with underlying Upper Jurassic rocks only occurring in the north east. The EECMHM study area boundaries were deliberately drawn to include these older Cretaceous and Jurassic strata to investigate whether there were any habitat relationships and associations specific to sea bed on Tertiary, Cretaceous or Jurassic bedrock. The ECA licence application areas are purposely sited on sand and gravel deposits (Figure 5.1) not bedrock and these sand and gravel deposits are all underlain at depth by Tertiary bedrock.

Upper Jurassic

Upper Jurassic rocks occur in Region 2 - North-East Platform and Margin and within the northern boundary of Region 5 – Greater Bassurelle Sands (Figure 5.8).

They include organic-rich shales and mudstones, calcareous mudstones with sandstones and limestones in places. These Upper Jurassic rocks lie within the Weald-Artois Anticlinorium (Hamblin *et al.*,1992), a major tectonic structure that crosses from England to France and underlies the far east of the English Channel and Dover Strait. These rocks have undergone more folding and faulting than the overlying Cretaceous and Tertiary rocks. For example, the south-east limb of the anticline is shown in Figure 5.9 and it is possible to distinguish between the well layered structure in the Cretaceous Wealden Group compared to the disturbed chaotic bedding of the Upper Jurassic.

The disturbed pattern of bedding at depth is also manifest at the sea bed with folds and flexures cut and exposed (Figure 5.10), and scarps and ridges visible as rock structures on the sea floor as they emerge for a few metres. In between these rock outcrops the sea bed may be covered by rippled sand (Figure 5.11)

On boomer seismic records the acoustic signature of these rocks are generally well defined with thin laminae and bedding with steep dips visible (Figure 5.10).

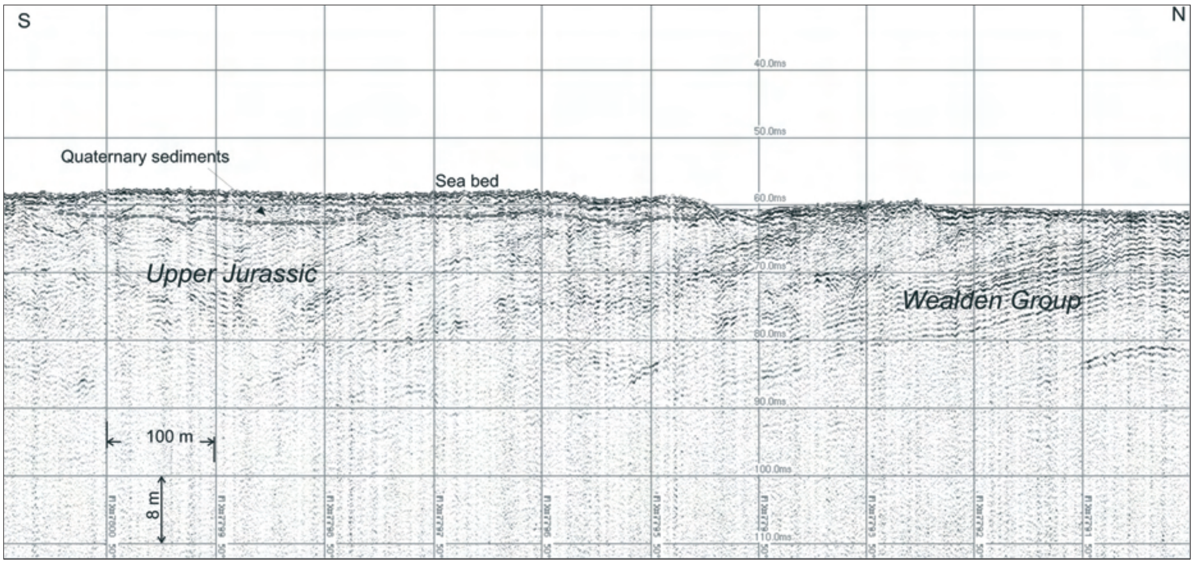


Figure 5.9. Seismic section showing the area of contact between the Upper Jurassic and the Wealden group on Corridor 19, Region 5.

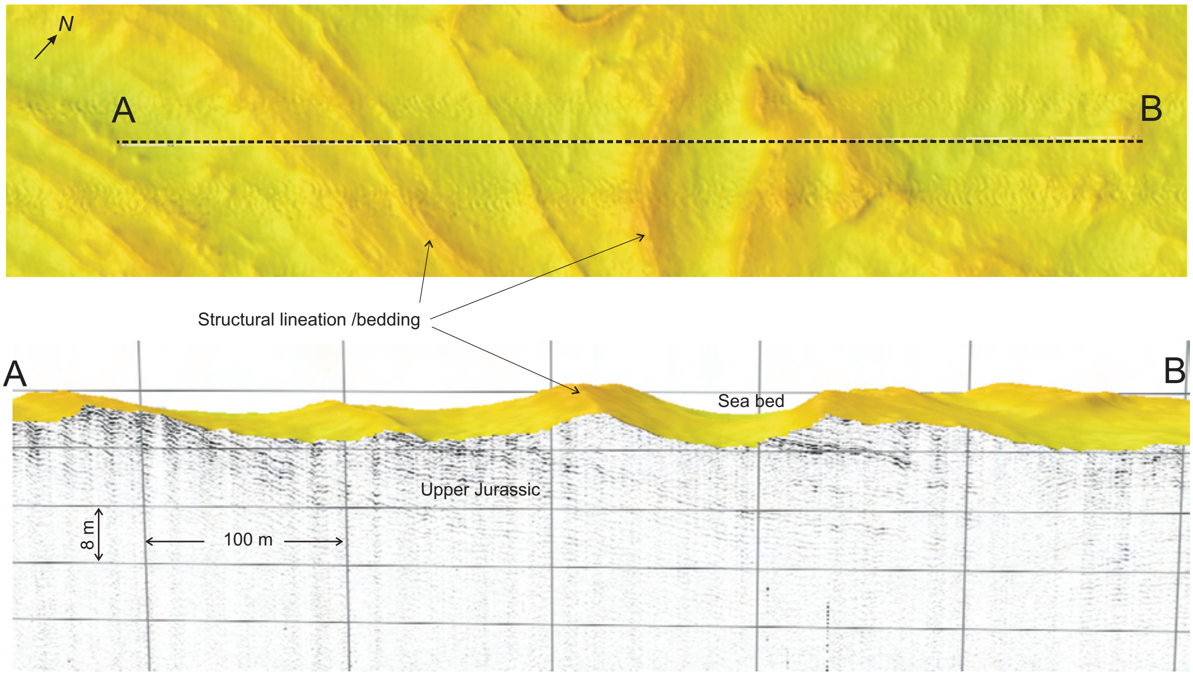


Figure 5.10. Multibeam and Sub bottom sections: rock structures at seabed from the outcropping of the Upper Jurassic unit on Corridor 2, Region 2.

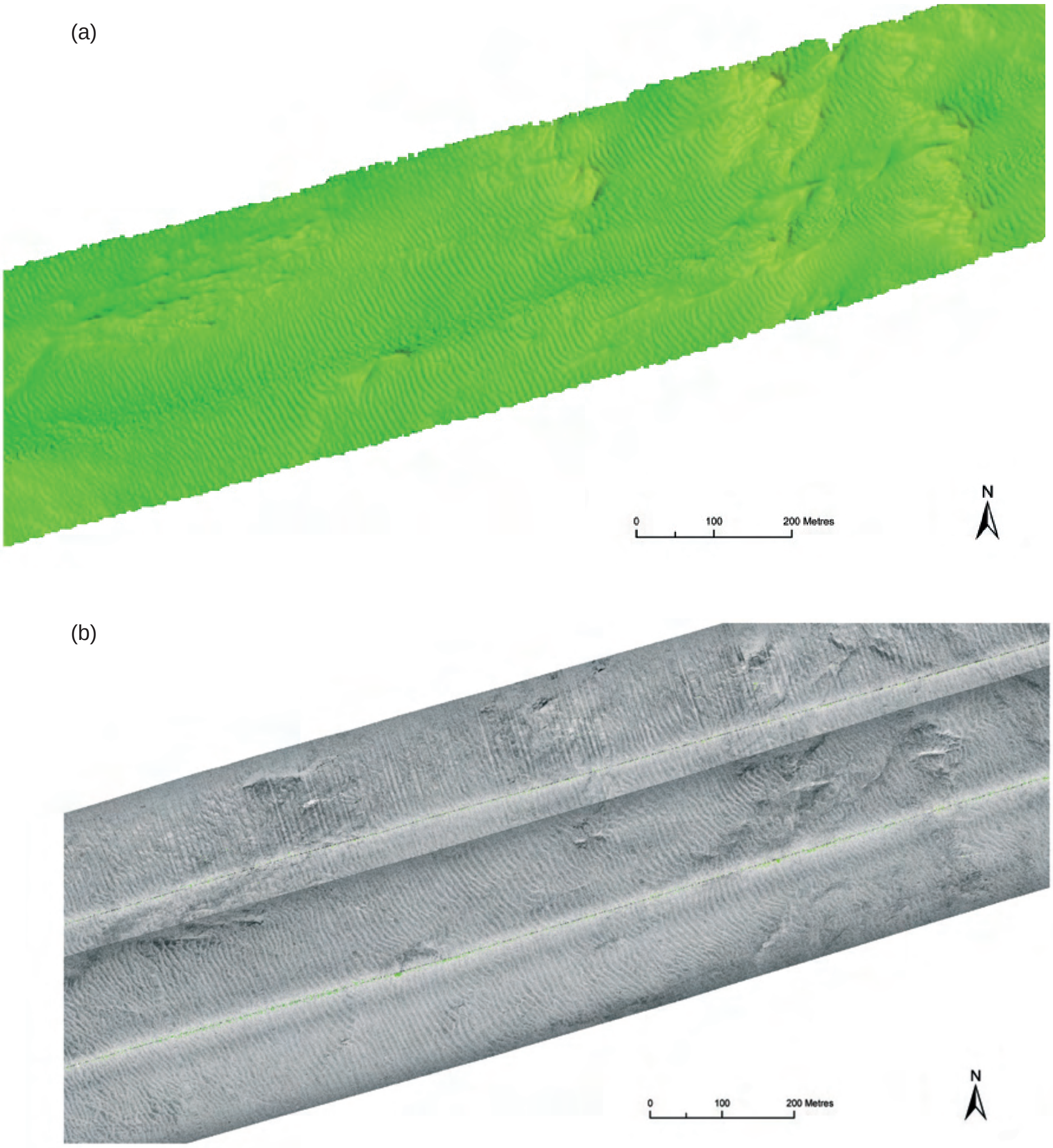


Figure 5.11. Multibeam (a) and sidescan sonar (b) images showing megaripple trains in between rock ridges of the Jurassic outcrop on Corridor 2, Region 2.

Wealden Group

Wealden Group rock underlies most of the north-east corner of the EECMHM study area including Region 2 - North-East Platform and Margin and some parts of Region 1 and 5. It also occurs as a small outcrop in the core of an anticline in the south-west corner of Region 3 – Western Axial Platform. This anticline is at the eastern limit of the Central English Channel Monocline (Figure 5.8).

The Wealden Group is of Lower Cretaceous age and comprises a lower unit with mainly sandy sediments and an upper muddier formation with interbedded sandstones and siltstones. A commercial oil well, 99/18-1, drilled in Region 3 penetrated 157 m of Wealden Group and found "variegated mudstone with abundant carbonaceous material and numerous bed of lignite, sandstone and siltstone" (Hamblin *et al.*,1992).

The acoustic signature of the Wealden group is very distinctive with well developed reflectors associated with fine bedding and flexures (Figure 5.12 and 5.13). In Region 2 where Wealden Group rock is exposed at the sea bed there are extensive areas showing structural lineation intersecting the sea bed. The rock lineations visible on the sea bed are more chaotic and less extensive linearly than those associated with the adjacent Upper Jurassic. This may be because the Wealden rocks are not as durable as the Jurassic rocks and are therefore eroded into smaller outcrops. However they can be readily mapped where they outcrop at the sea bed.

In many areas dipping Wealden Group bedding is truncated by a regional sub-horizontal planar erosion surface (Figure 5.12 and 5.13). This surface commonly forms a rock head horizon overlain by sediment including sand waves but can be exposed as rock outcrop at the sea bed. The surface is primarily the product of marine erosion by rising transgressive seas.

Gault and Greensand

The Lower Greensand, Gault and Upper Greensand have been amalgamated in this report and described as Gault-Greensand. They are the youngest units in the Lower Cretaceous and are relatively thin, probably <175 m thick, as a consequence they are restricted to two narrow linear occurrences. The longest lies along the eastern limb of the syncline of the Hampshire-Dieppe Basin as it crosses the study area. The other is around the Wealden cored anticline in the south west of Region 3 (Figure 5.8).

The Gault includes soft and silty mudstones with the Greensand comprising glauconitic sandstones and clays. They may also include calcareous beds with layers of phosphatic nodules. A BGS core in Region 1 located on an outcrop pf Upper Greensand recovered 1.86 m of fine to very fine grained, well sorted glauconitic and bioturbated sandstone (Hamblin *et al.*, 1992).

In the east of the study area the contact between the relatively soft Gault – Greensand and the overlying Chalk forms a positive feature where the durable and resistant Chalk creates a scarp (Figure 5.14 and 5.15) up to 25 m high because of differential erosion of the Gault-Greensand and Chalk. The foot of the scarp has also been a focus for fluvial erosion and deposition evidenced by an infilled palaeochannel at its base (Figure 5.14).

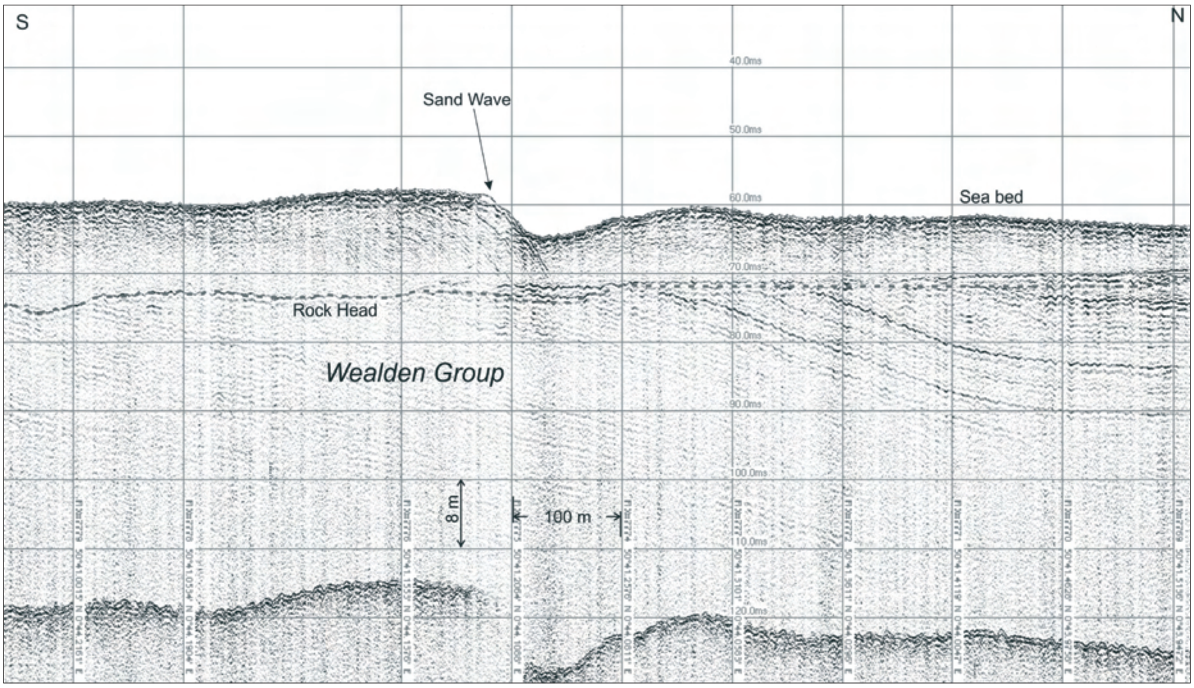


Figure 5.12. Seismic section showing sand wave over Wealden group on Corridor 19, Region 5.

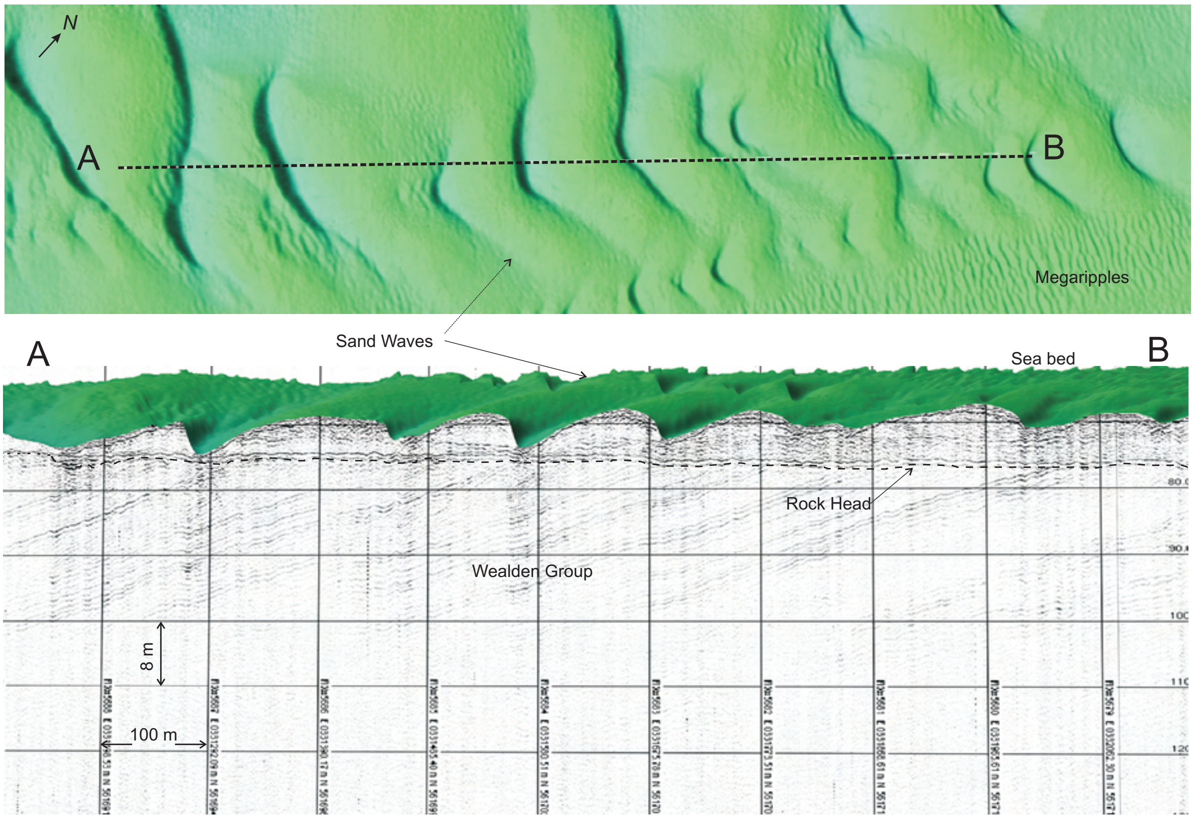


Figure 5.13. Multibeam and Sub bottom sections: sand waves and mega ripples on the seabed, overlying Wealden Group on Corridor 2, Region 2.

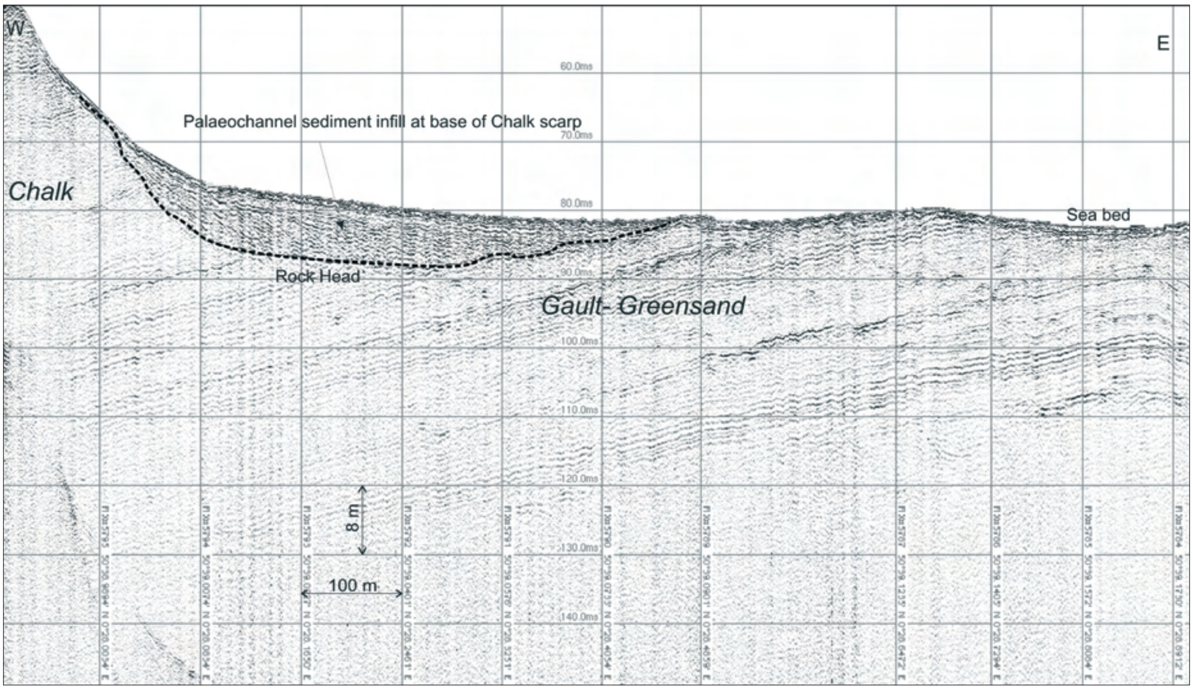


Figure 5.14. Seismic section showing Gault-Greensand and a palaeochannel sediment infill at base of Chalk scarp on Corridor 2, Region 1.

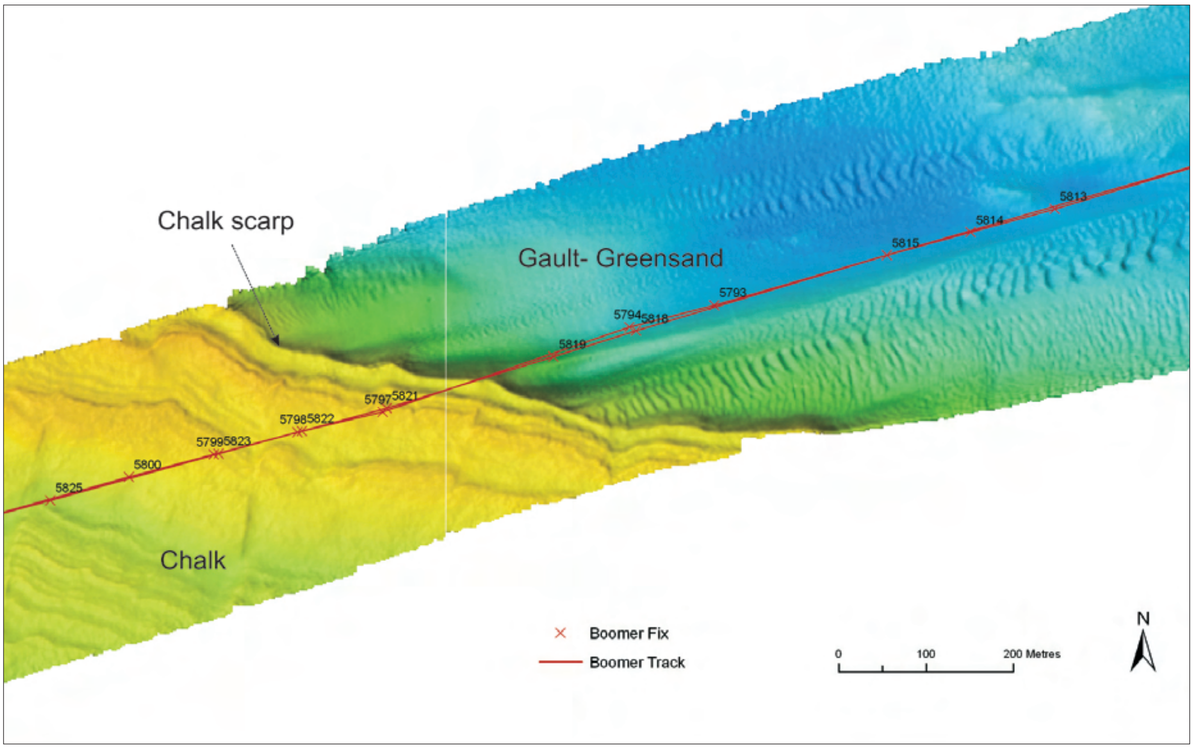


Figure 5.15. Multibeam image showing the contact between the Chalk and Gault-Greensand on Corridor 2, Region 1.

Chalk

The Chalk is present on both limbs of the Hampshire-Dieppe Basin syncline (Figure 5.8). It is a linear occurrence between Region 1 and 5, but is more extensive in Region 3. Chalk underlies areas of rock and thin sediment in Region 1 and also its outcrop in Region 3 is in areas with a peneplanation surface of rock and thin sediment (Figure 5.5).

Upper Cretaceous Chalk comprises micritic limestone and nodular calcareous limestone with nodules of siliceous flint, thin marl seams and hard grounds. The flint is significant in that it is extremely durable. It can form a lag gravel pavement over outcrops of Chalk but its primary significance is that its durability has enabled it to survive repeated glacial cycles with reworking, transport and deposition during the Quaternary to emerge as the principal gravel component within Quaternary sediments in the English Channel. There is also evidence that it can be a significant component of lag gravel on bedrock outcrops in the English Channel where the solid geology is not Chalk (Hamblin *et al.,* 1992). Chalk derived flint is therefore important in terms of physical substrate for sea bed habitat in the English Channel.

The thickness of Quaternary sediments over the Chalk in Region 3 is very thin and locally ephemeral (Figure 5.4). The sediments mainly comprise flint nodules and lithic cobbles and few boulders, the distribution, shape and the size of these material suggest an in situ origin with a less important transport component (Figure 5.16 and 5.17)

The boomer seismic records in the Chalk primarily show a very compact seismic signature with shallow penetration and strong sea bed return. This is interpreted as bedrock exposed at the sea bed or with a very thin layer of sediment overlying. Any thin sediment layer is impossible to resolve on the boomer scale but is well documented by camera sledge video and photographs. The planar flat character of the Chalk in Region 3 is very well seen in multibeam images and the highly reflective backscatter of the sidescan sonar corridor mosaic (Figure 5.17).

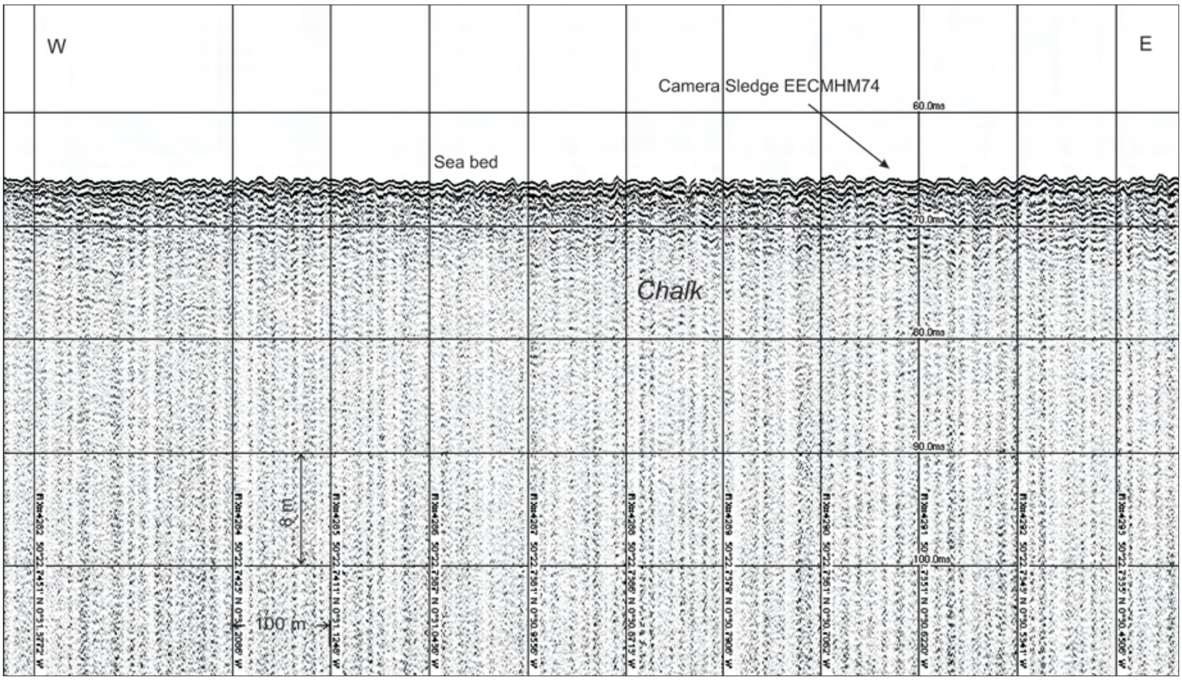


Figure 5.16. Seismic section showing the Chalk outcropping at the sea bed and location for camera sledge EECMHM74 on Corridor 4, Region 3.

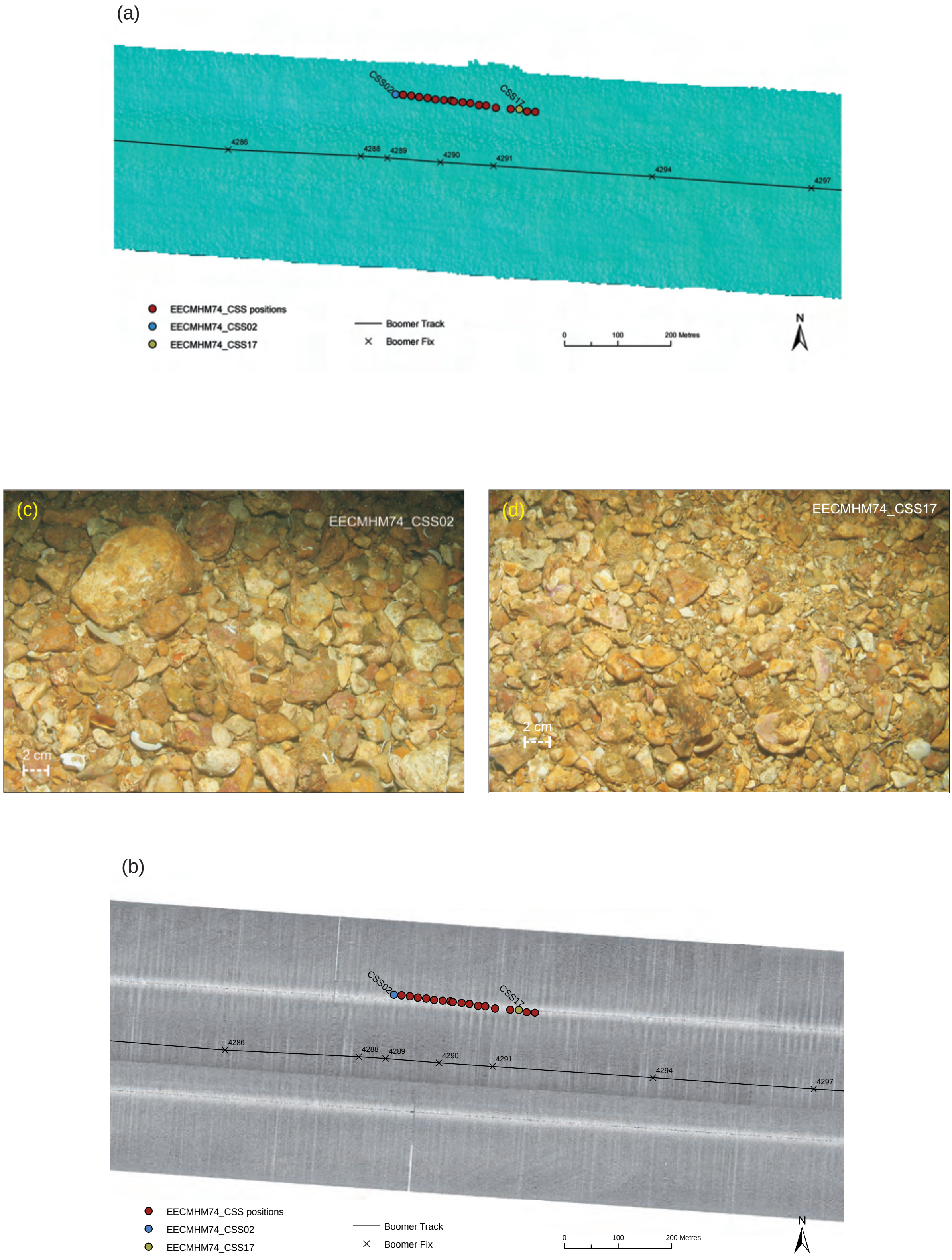


Figure 5.17. Photo stills from EECMHM74 (c) and (d); multibeam (a) and sidescan sonar (b) images of Chalk outcropping at the seabed, at the same location, on Corridor 4, Region 3.

Lambeth Group

Lambeth Group rocks lie at the base of the Tertiary in the English Channel. They are thin and restricted to two narrow linear occurrences. The longest lies along the north-eastern limb of the Hampshire-Dieppe Basin syncline. The other is around the margin of the Chalk outcrop in Region 3 (Figure 5.8).

Lambeth Group in the English Channel is composed of two different sequences: one marine (Woolwich Beds) and one non-marine (Reading Beds). The rocks on the southern margin of the Hampshire - Dieppe Basin consists of clay, lignite and marl with oysters and ostracods.

On boomer records the seismic signature has high amplitude sub-parallel inclined reflectors (Figure 5.18).

London Clay

The Tertiary London Clay has its most extensive occurrence in the south-west of the study area in Region 3 and the extreme south-west corner of Region 4. It is also a linear occurrence along the north-east limb of the Hampshire-Dieppe Basin syncline (Figure 5.8).

London Clay is dominated by clays and silts with some muddy sands. A BGS borehole 75/27 to the west of the ECMHM study area encountered a layer of well rounded flint pebbles within the unit. On boomer seismic records the London Clay is predominantly homogenous to transparent in terms of its seismic character. There are a series of parallel high amplitude reflectors at its boundary with the overlying Bracklesham Group and these may be associated with pebble beds at the base of the Bracklesham Group (Figure 5.19).

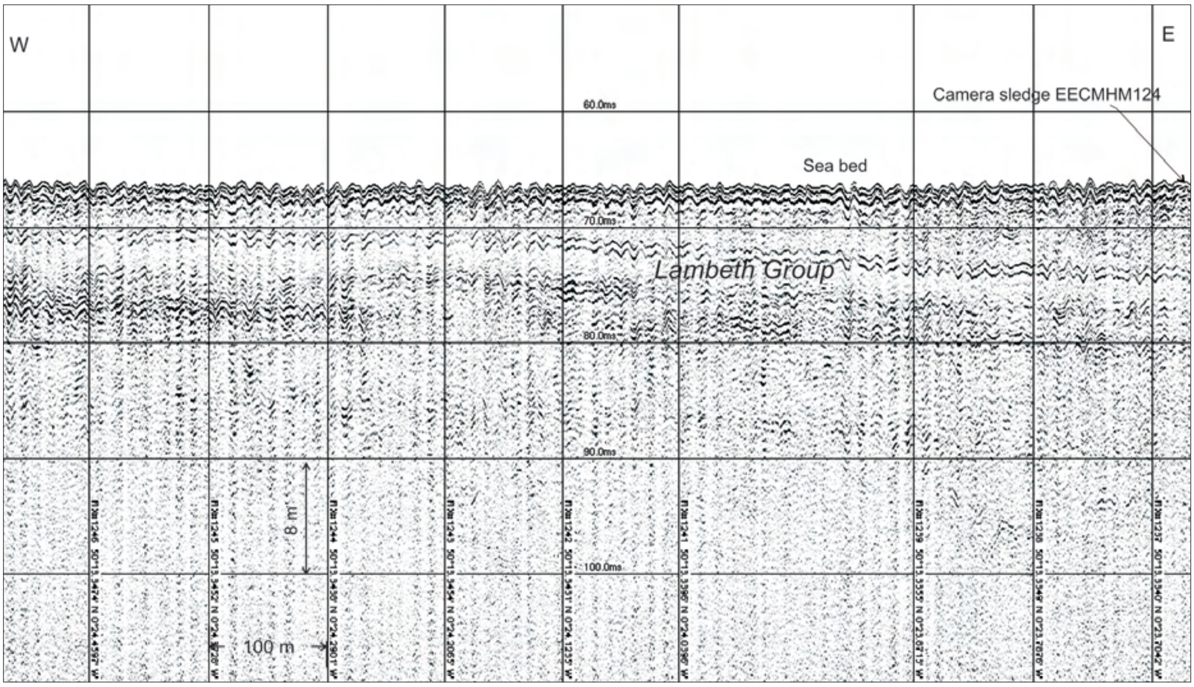


Figure 5.18. Seismic section showing the Lambeth Group outcropping at the sea bed and location for camera sledge EECMHM124 on Corridor 6, Region 3.

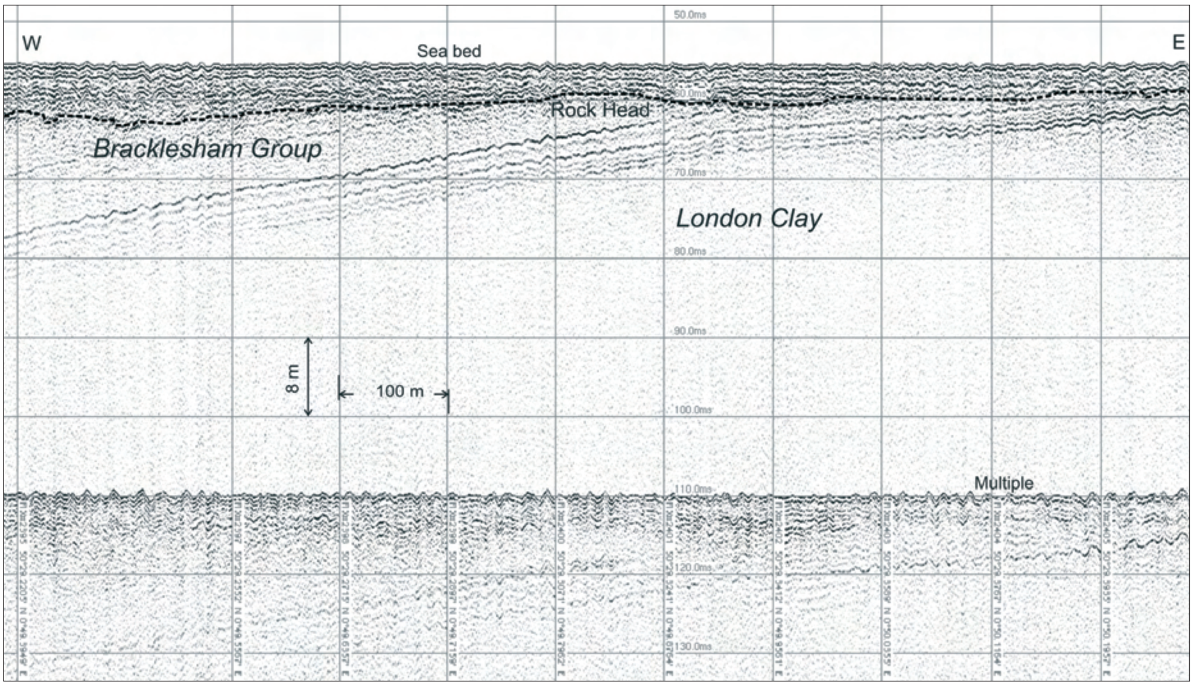


Figure 5.19. Seismic section showing the contact between London Clay and Bracklesham Group in Corridor 5, Region 5.

Bracklesham Group

Bracklesham Group rocks overly the London Clay and mirrors the latter's linear occurrence on the north-east side of the Hampshire-Dieppe Basin with a wider occurrence in the south west in Region 3 and more extensively in the south-west corner of Region 4.

Lithologically Bracklesham Group rocks include silty sand and clayey silt formations, lignitic and fine-grained sand with pebbles beds, and glauconitic sandy marls.

The variety of lithologies within the Bracklesham Group has contributed to a distinctive seismic character on Boomer seismic records with a series of inclined sub-parallel high amplitude reflectors possibly associated with coarser or denser rock types. Some of these reflectors are associated with positive features at the sea bed (Figure 5.20) and these are apparent as linear ridges on multibeam images and sidescan sonar mosaics (Figure 5.21).

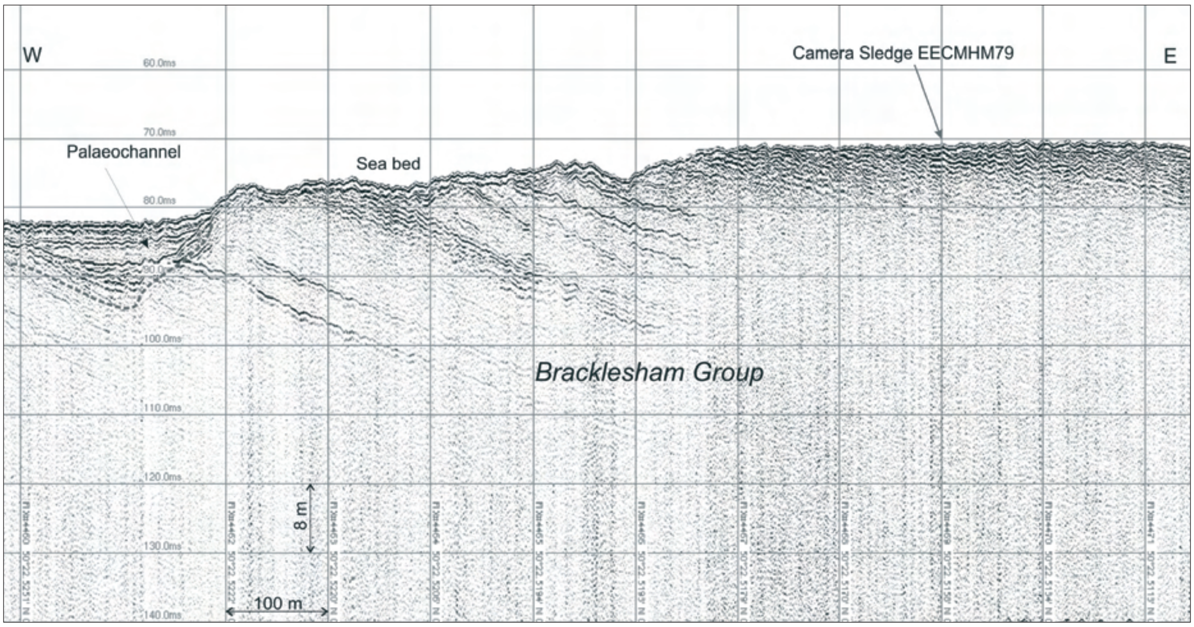


Figure 5.20. Seismic section showing the outcrop of Bracklesham Group and location for camera sledge EECMHM79 on Corridor 4, Region 3.

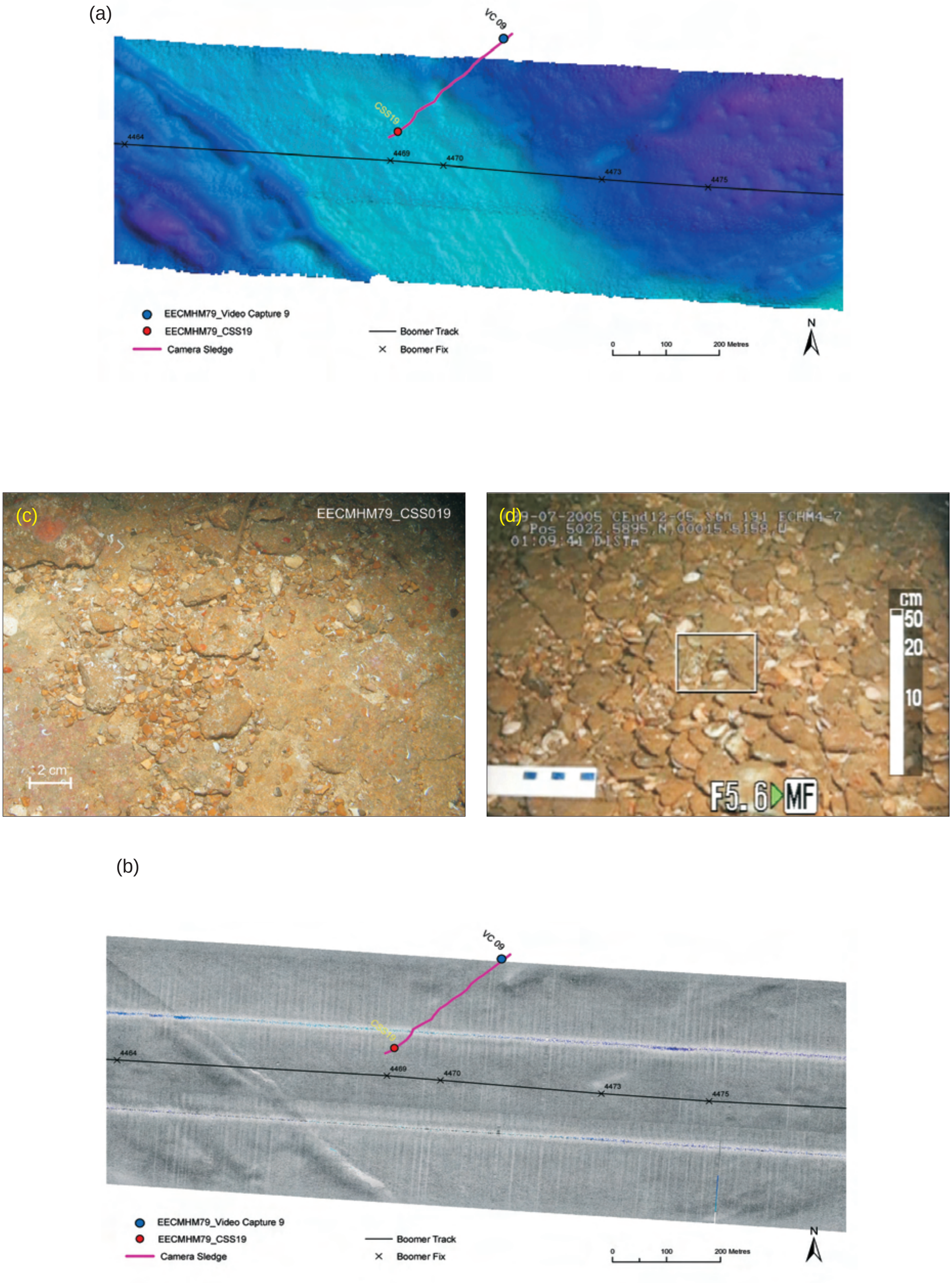


Figure 5.21. Photo still (c) and video-capture (d) from EECMHM79; multibeam (a) and sidescan sonar (b) image of Bracklesham Group outcropping at the sea bed at the same location on Corridor 4, Region 3.

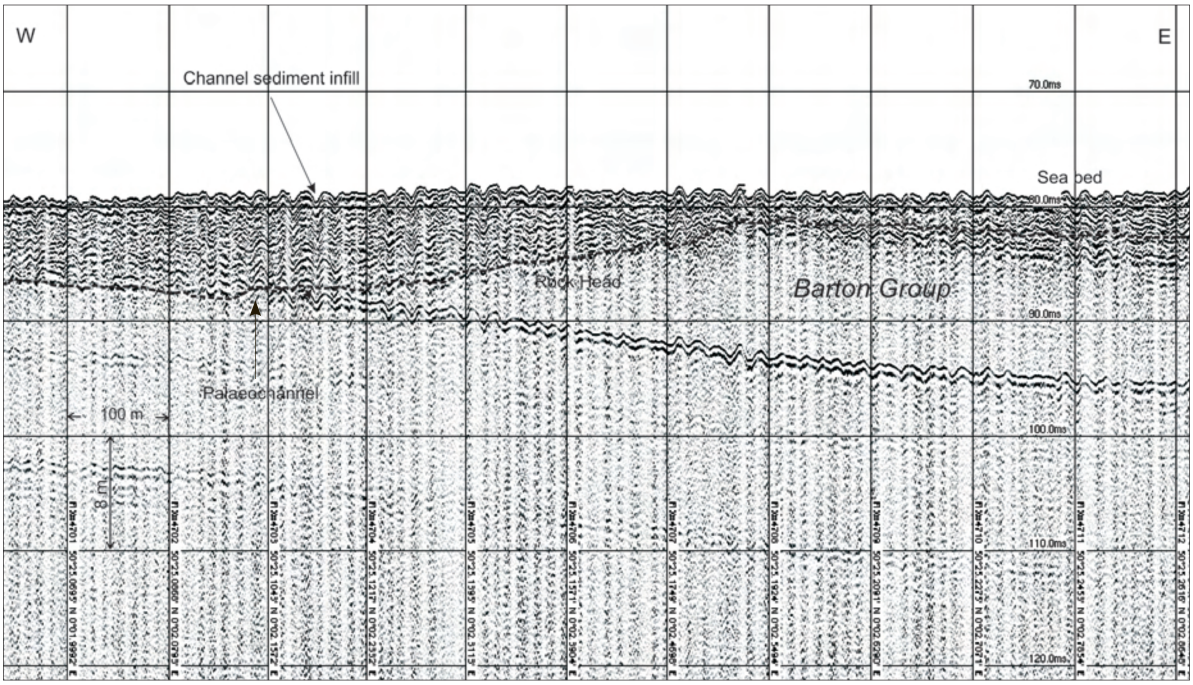


Figure 5.22. Seismic section showing the signature of Barton Group with palaeochannel sediment infill on Corridor 4, Region 4.

Barton Group

Barton Group rocks form the core of the Hampshire-Dieppe Basin. It is the most widespread solid geology unit in the study area and extends from the north-west in Region 1 across a large part of Region 4 and into the south of Region 5 (Figure 5.8). They are the youngest of the Tertiary units.

BGS borehole 75/38 located in Region 3 recovered 62 m of interbedded clay and sandy glauconitic limestone and clay within Barton Group sediments. The unit can include large boulder size nodules of ferroan calcite.

The seismic character of the unit is dominantly transparent with few long high amplitude reflectors some of which are shallowly inclined or locally concordant with the sea bed (Figure 5.22 and 5.23).

The Barton Group is the unit most affected by fluvial erosion and down cutting and is overlain by a number of palaeochannels (Figure 5.22) and a thick cover of Quaternary sediment, particularly in Region 4 (Figure 5.4). Although in some parts of Region 3 there are localities where it outcrops at the sea bed (Figure 5.24).

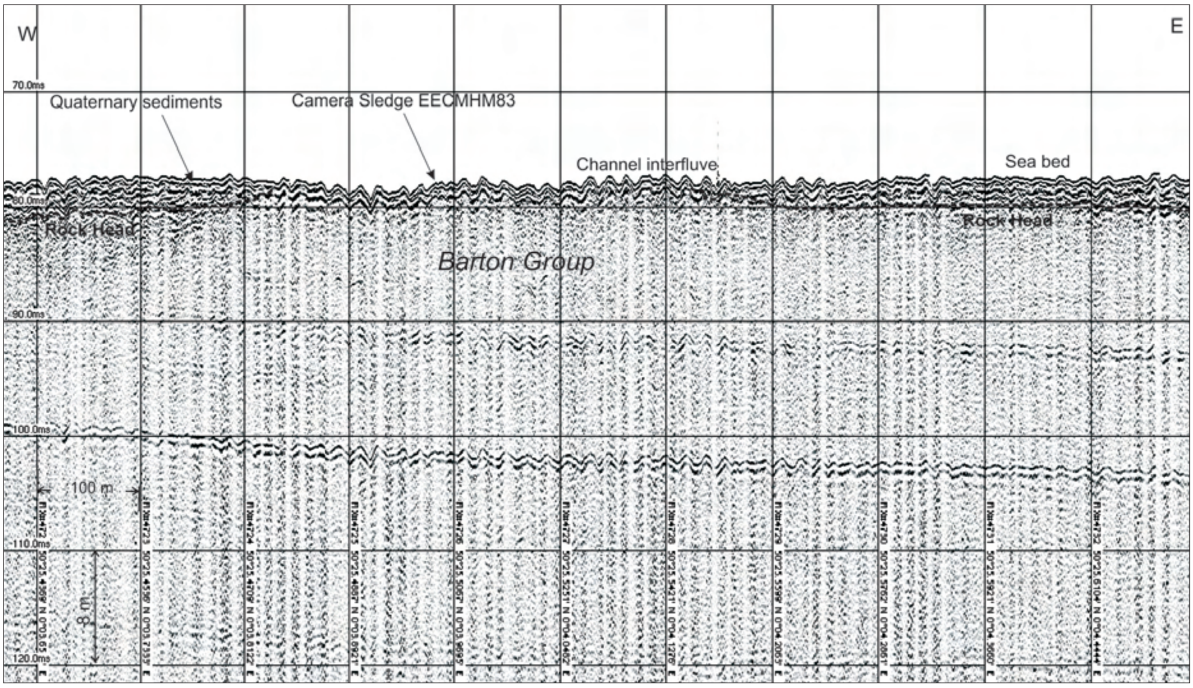


Figure 5.23. Seismic section showing the outcrop of Barton Group and location for Camera Sledge EECMHM83 on Corridor 4, Region 4.

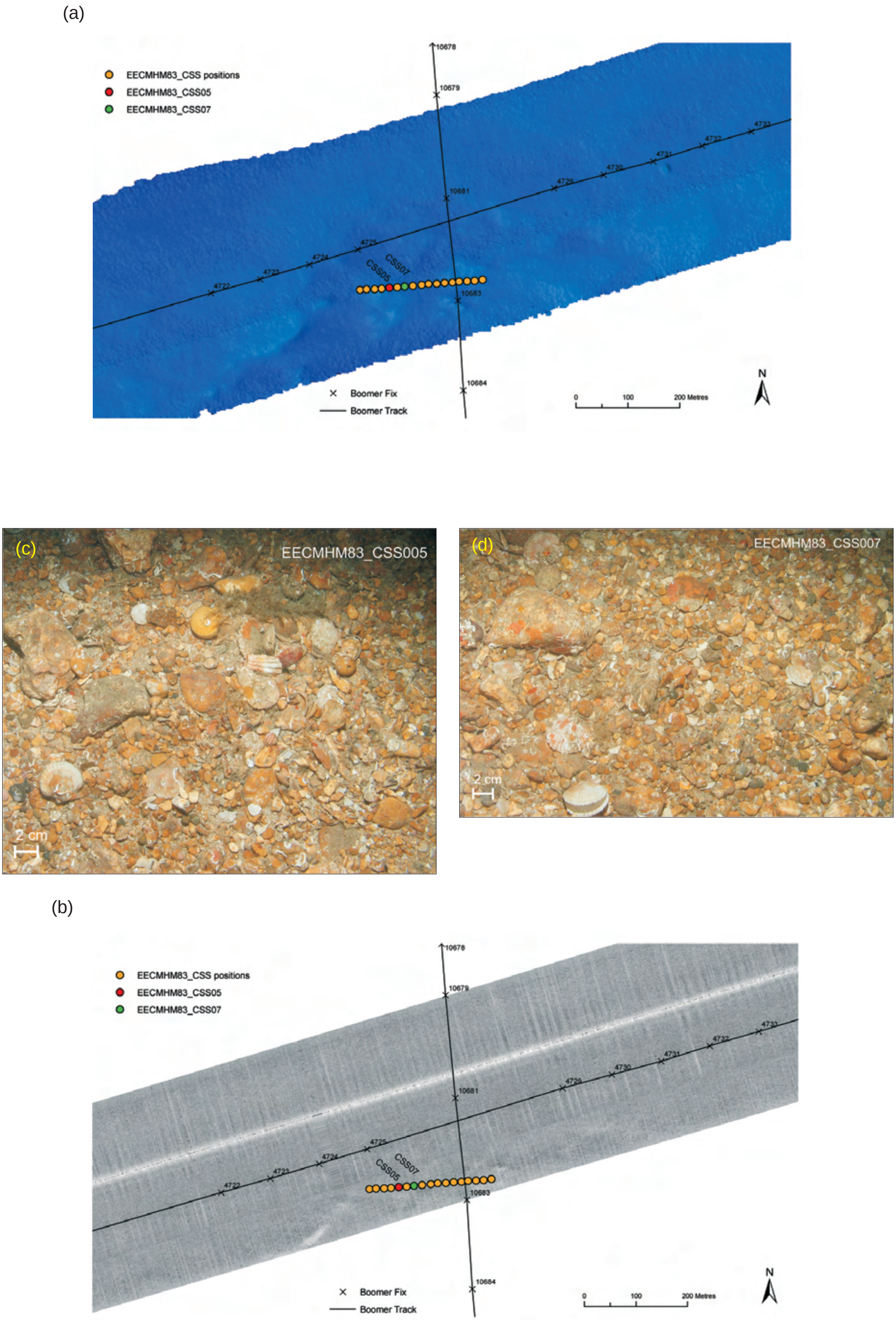


Figure 5.24. Photo stills from EECMHM83 (c) and (d); multibeam (a) and sidescan sonar (b) image of Barton Group outcropping at the sea bed, at the same location, on Corridor 4, Region 3.

5.2.2 Quaternary sediments

As noted in the introduction to Section 5 only the physical characteristics of the sea bed surface and its underlying geology and sediment down to a depth of ~0.5 m is thought to be significant in terms of habitat. Therefore, the stratigraphy and nature of Quaternary sediments thicker than one or two metres below the sea bed may not appear so important in terms of defining habitat. However a knowledge of thicker Quaternary sediments can indicate what type of sediment lies at the sea bed and how it was deposited, both of which could be significant in terms of habitat.

Although the EECMHM study has a very widely spaced grid (>10 km spacing) of boomer seismic lines it has been possible to discriminate between older Pleistocene sediments infilling palaeochannels (Figure 5.7) and reworked younger sediments of Holocene age deposited in flat beds and sheets.

The base of the Quaternary sediments has been identified on boomer seismic section as an erosional surface cut on the bedrock that is marked by a strong reflector. This reflector has been digitized and the depth values from the sea bed extrapolated to produce a map of Quaternary Sediment thickness (Figure 5.4).

The Quaternary sediments are predominantly thicker in Region 4 - Central Axial Platform and Region 5 - Greater Bassurelle Sands. They generally thin to the north and west in the study area.

The seismic sections in Figure 5.25 and 5.26 indicate how the palaeochannels were influenced by successive phases of incision and deposition of sediment, each phase would possibly correspond to a different base level for the river flowing at the time. The internal depositional structure in the channels also show lateral accretion, typical of fluvial environments.

The upper deposits of the palaeochannels constitute the resource material for marine aggregate in a number of licence applications. They include sediments of fluvial origin composed of sand and gravel with a high percentage of flint.

At the end of the Pleistocene estuarine and then marine sediment continued to infill the palaeochannels and these appear to be indicated on the seismic sections by sub horizontal reflectors concordant with the sea bed and overlying fluvial sequences (Figure 5.27).

Holocene sea level rise and its associated marine transgression has winnowed fine sediment from gravel and rock surfaces and transported sediment to the east in the English Channel. In Region 5 – Greater Bassurelle Sands seismic records provide evidence of a thin transgressive unit with eastward prograding foresets, probably comprised of sand (Figure 5.28). The transgressive sand sheet unit is extensive and its western limit has been drawn on Figure 5.6. Further to the east in the Greater Bassurelle Sands the transgressive sand sheet unit becomes thicker, >5 m, and merges into the sand wave field with the basal seismic reflector of the sand sheet commonly forming the basal reflector of the sand waves.

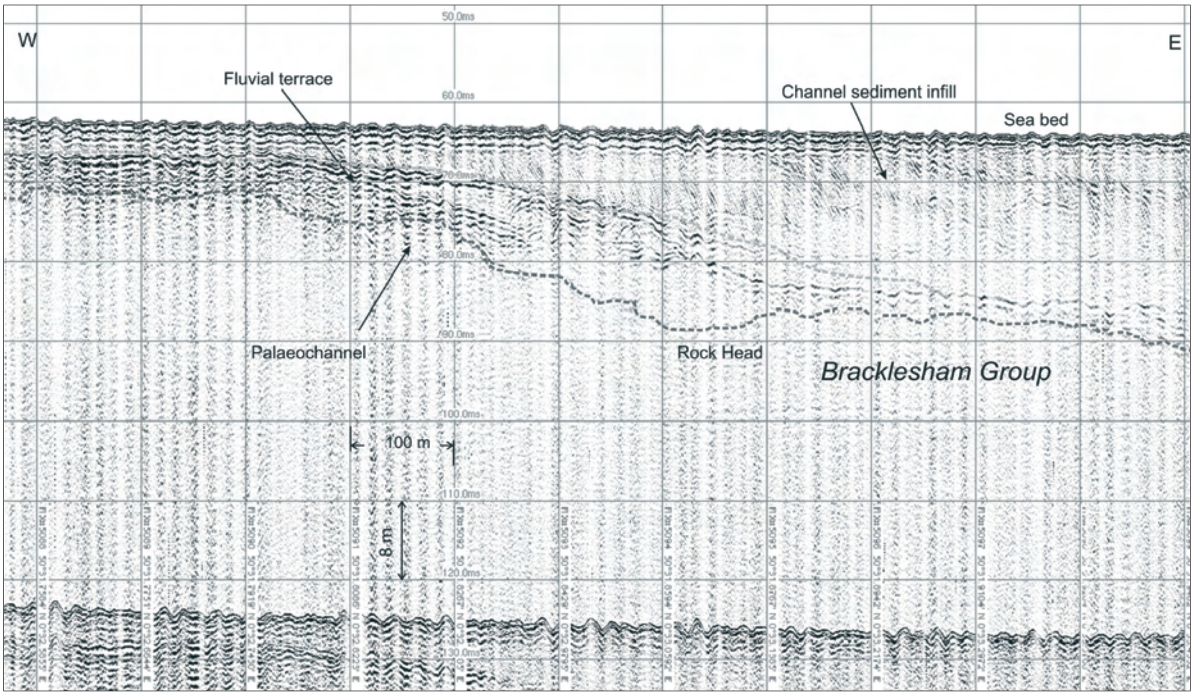


Figure 5.25. Seismic section showing Bracklesham Group and Palaeochannel internal structure on Corridor 4, Region 4.

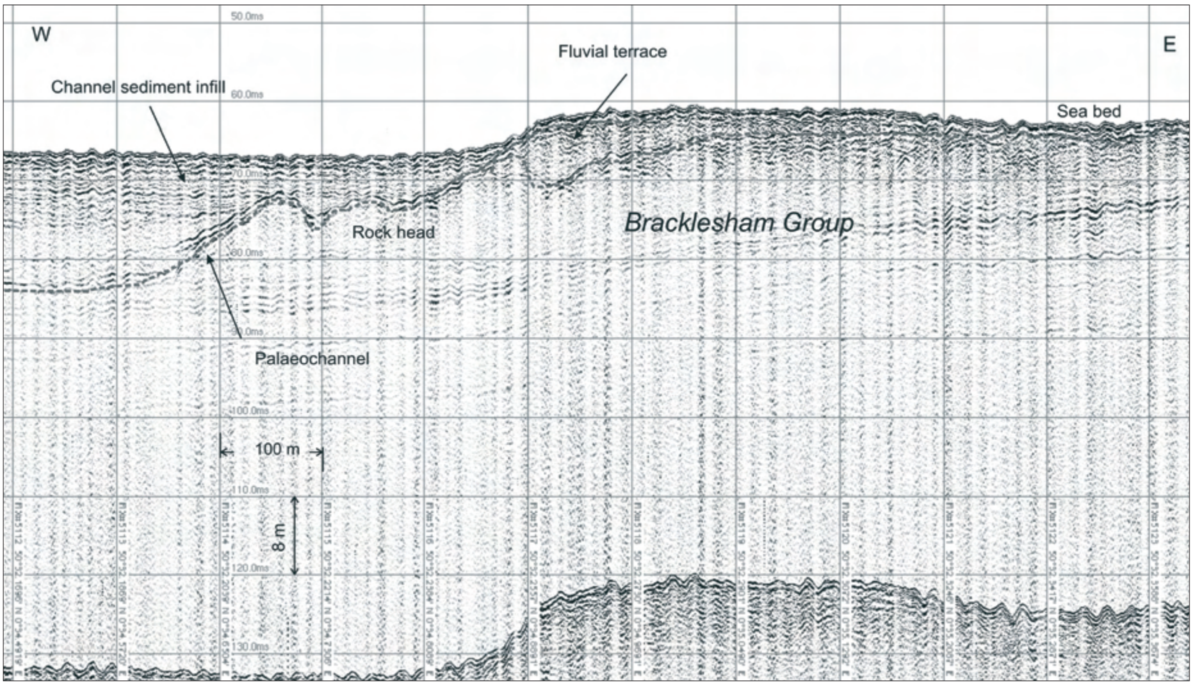


Figure 5.26. Seismic section showing Bracklesham Group and fluvial terrace in the palaeochannel on Corridor 4, Region 4.

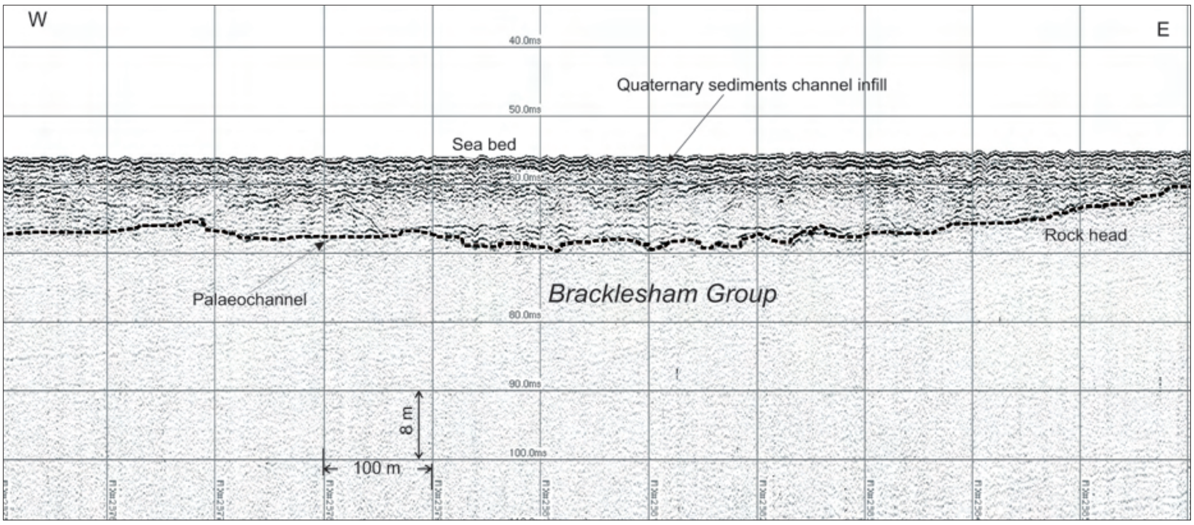


Figure 5.27. Seismic section showing Quaternary sediments channel infill on Corridor 5, Region 5.

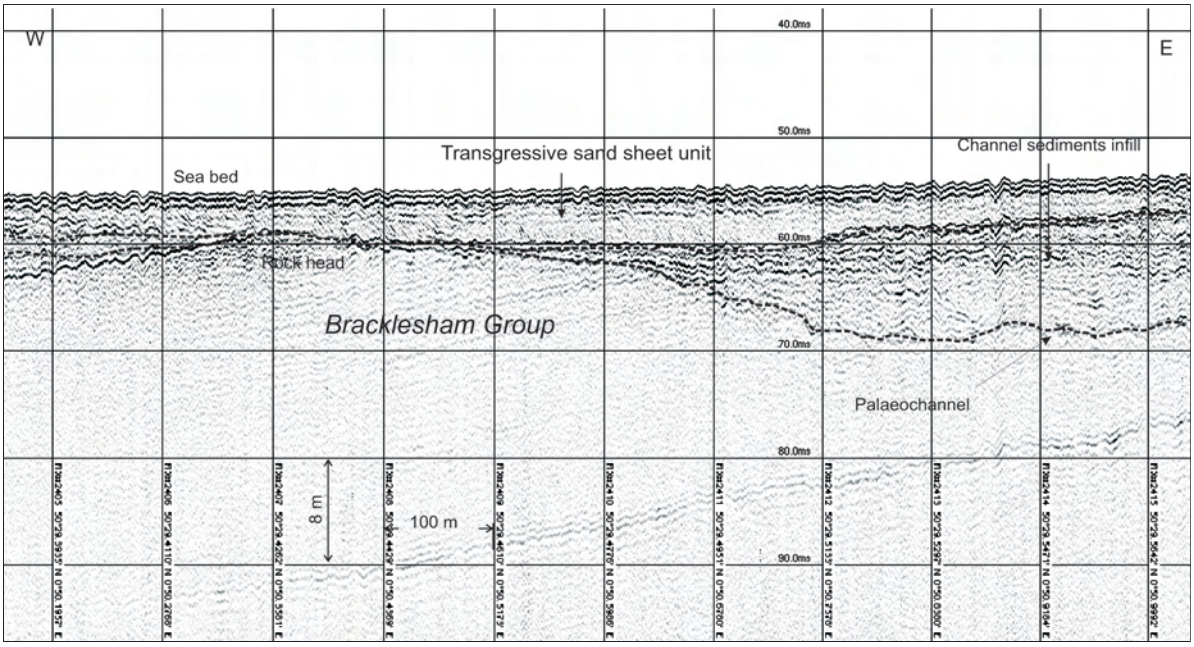


Figure 5.28. Seismic section showing the transgressive sand sheet unit in Corridor 5, Region 5.

5.2.3 Sea bed character and bedforms (SBCB)

Introduction

Sea bed character and bedforms (Figure 5.5 and Map 1 (in pocket)) marries the dynamic process driven morphological elements which occur on the sea bed as sandy bedforms, including sand waves, ribbons and banks (Figure 5.6), with those morphological elements which are stable and immobile such as rock scarps, bedding, lineation and channel margins. These morphological elements have been mapped in-situ along the geophysical corridors and they are superimposed on a substrate that has been divided into a threefold classification of sea bed character: -

- Sandy sediment
- Coarse sediment
- Rock and thin sediment

The interpretation of sea bed character is based on an integrated analysis of data provided by multibeam, sidescan sonar, boomer seismic reflection, grab sediment sampling, video and still photo imagery. The sidescan sonar has been correlated with the boomer and the multibeam to verify occurrences of rock outcrop, delineate bedforms and the reflectivity and backscatter variations of the sea bed. Highly diffractive signatures on the boomer records were correlated with strong backscatter on the sidescan records. Rippled sand and megaripple trains were recognised on sidescan records and were also noted on boomer records by loss of the first return at the sea bed (i.e. the bottom tracking of the sea bed was unlocked and lost at each ripple crest). The sidescan sonar records have been analysed in detail and correlated with the multibeam data and with the position and extension of positive features and outcrops on boomer records (Figure 5.10 and 5.11) The morphological and rock structural elements on the sea bed have been digitised and overlaid as ornament along the line of geophysical corridors on Figure 5.5 and Map 1. Video camera images were analysed to verify the nature of sediment and to confirm the presence of rock outcrops at the sea bed. The archive of BGS historical data including maps, cores, logs and geophysical records have been utilised in the interpretation.

The sea bed character interpretation (Figure 5.5 and Map 1) has also been completed in conjunction with the sea bed sediment Folk classification map (Figure 5.7). Both interpretations are complimentary and should be read in tandem to gain a fuller understanding of the character of the sea bed. For example, the coarse sediment classification in the SBCB interpretation includes Folk sediment categories with >30% gravel and the sandy sediment classification includes Folk sediment categories with >70% sand. For those areas where rock and thin sediment is mapped in the SBCB interpretation, the Folk sediment category of any thin sediment is shown on Figure 5.7.

The present character of the sea bed is the result of both ancient and modern processes. Ancient processes include those that controlled and produced the nature and form of its underlying substrate, the most significant being: -

- Glacial/interglacial cycles during the Quaternary that eroded channel systems which are now either open or infilled with thick sediment
- Folding and faulting of older Tertiary to Upper Jurassic rocks producing strong morphological lineations, bedding and dip slope surfaces etched by differential erosion of strong and weak rocks

Modern processes include: -

- The marine transgression which swept eastwards across the English Channel as sea level rose from depths >100 m after the last glacial maximum, eroding, reworking and transporting sediment along its path.
- Marine tides and currents over the last 5000 years since sea level attained its modern day level. The impact of tides and currents during this period has been significant in terms of erosion, transport and deposition of sediment and the fashioning of sand bedforms, lag gravel and swept rock outcrop; their influence continues in the present day.

The nature and occurrence of sand bedforms in the EECMHM study area have been divided into four categories (Figure 5.6 and Map 1): -

- Sand bank
- Sand wave field
- Sand streaks, patches, ribbons and megaripple trains
- Scarce bedforms to featureless

Their form and extent is controlled by sediment supply, tidal current velocity, duration and orientation, and in some areas, sea bed morphology such as rock outcrop and channels. Bedforms include those which are: -

- Transverse, with crestlines orientated across the paths of the principal current flows. These are primarily waveforms - sand waves, megaripples and ripples (Figure 5.13).

- Linear, current flow parallel. These are generally narrow and associated with low sand sediment supply and include sand ribbons, streaks and megaripple trains. Linear bedforms commonly include transverse bedforms on their surface e.g. megaripples on sand ribbons and trains.

Sand banks are very large-scale linear bedforms, e.g. the Bassurelle Bank is >24 km in length, and they may be covered by extensive transverse bedforms, sand waves and megaripples.

In areas of rock and thin sediment two types of lineation have been interpreted from the geophysical data: -

- Morphological lineation - ridges and breaks of slope associated with channel margins, interfluve erosion, possibly Quaternary river sediment bars and beach ridges. Their common denominator is that none are related directly to rock structure and appear to be the result, primarily, of erosion and deposition processes within environments that preceded present day fully marine conditions.
- Rock structural lineation – scarps, ridges and breaks of slope formed by differential erosion of bedrock. Bedding, folds and faults are etched in plan view on the sea bed where relatively resistant harder rocks are exposed (Figure 5.10 and 5.29).

The mapping of sea bed character and bedforms is an attempt to indicate the variety of physical elements, features and processes, not simply sediment, which can impact the nature and occurrence of habitat and biotope assemblages.

Although not included in the interpretation, the sidescan sonar and multibeam recorded a number of anthropogenic features and impacts on the sea bed including a variety of wrecks and fishing gear trawl marks.

EECMHM study area

The EECMHM study area covers approximately 5090 km^2. In terms of sea bed character around 43% of the area is covered by rock and thin sediment. 27% by coarse sediment and 30% by sandy sediment. Rock and thin sediment extends over much of the sea bed in the north of the study area in Regions 1 and 2, and is particularly extensive in the west in Region 3. Coarse sediment dominates Region 4 in the central south of the study area with sandy sediment increasing in significance to the east and encompassing all of Region 5 in the south-east. Sandy sediment are also a feature of some parts of the Northern Palaeovalley. Both the areas of coarse sediment and much of rock and thin sediment are particularly scarce in sandy bedforms. Sand waves are confined to the far east of the study area where they are numerous, some parts of the Northern Palaeovalley and isolated examples in the north-east. Sand streaks, patches, sand ribbons and megaripple trains are also more common in both northern regions. There has been a long term process in the eastern English Channel of fine and sandy sediment being swept by tidal currents, and to some extent wave action, to the north and east, with the shallower coastal margins and eastern sand wave fields and banks acting as sinks and conduits for these sediments. Hence the winnowed and swept lag sea bed surface in the south and west with sand more prevalent in the north and particularly extensive in the south-east.

Physical Region 1 - Northern Palaeovalley and Margin

The Northern Palaeovalley and Margin region has a rather complex sea bed character, particularly in the area of rock and thin sediment in its north-west corner. Here the geophysical corridor data has provided glimpses of numerous composite features, which are obviously extensive and allied, in part, to erosional and depositional Quaternary channel systems (Figure 5.3), which flowed southwards across the coastal platform as tributaries of the Northern Palaeovalley. A number of small channels are seen in Figure 5.29. These channels can be infilled with sediment or be open and rock floored, they can also act as pathways for mobile sandy sediment as in this case where three sand waves with N-S crest lines are sitting in a channel.

The smooth flat sea bed surfaces on the channel margin in Figure 5.29 are a tilted bedding plane of underlying Barton Group rock dipping at a shallow angle to the south-west. These relatively smooth tilted bedding plane surfaces are extensively developed as low angled slopes along the northern margin of the Northern Palaeovalley and the coastal platform where Barton Group and older Tertiary rocks outcrop at the sea bed (Gupta *et al.*, 2004).

The large area of rock and thin sediment in the east of the region extends from the relatively shallow coastal platform south of Beachy Head over the margin of the Northern Palaeovalley and across its floor. Chalk underlies much of this area and is relatively scarce in terms of structural and morphological lineation although these are common on the shallow coastal platform. However, further east the Chalk forms a large NW-SE trending scarp up to 25 m high along the boundary with Gault –Greensand rocks (Figure 5.15).

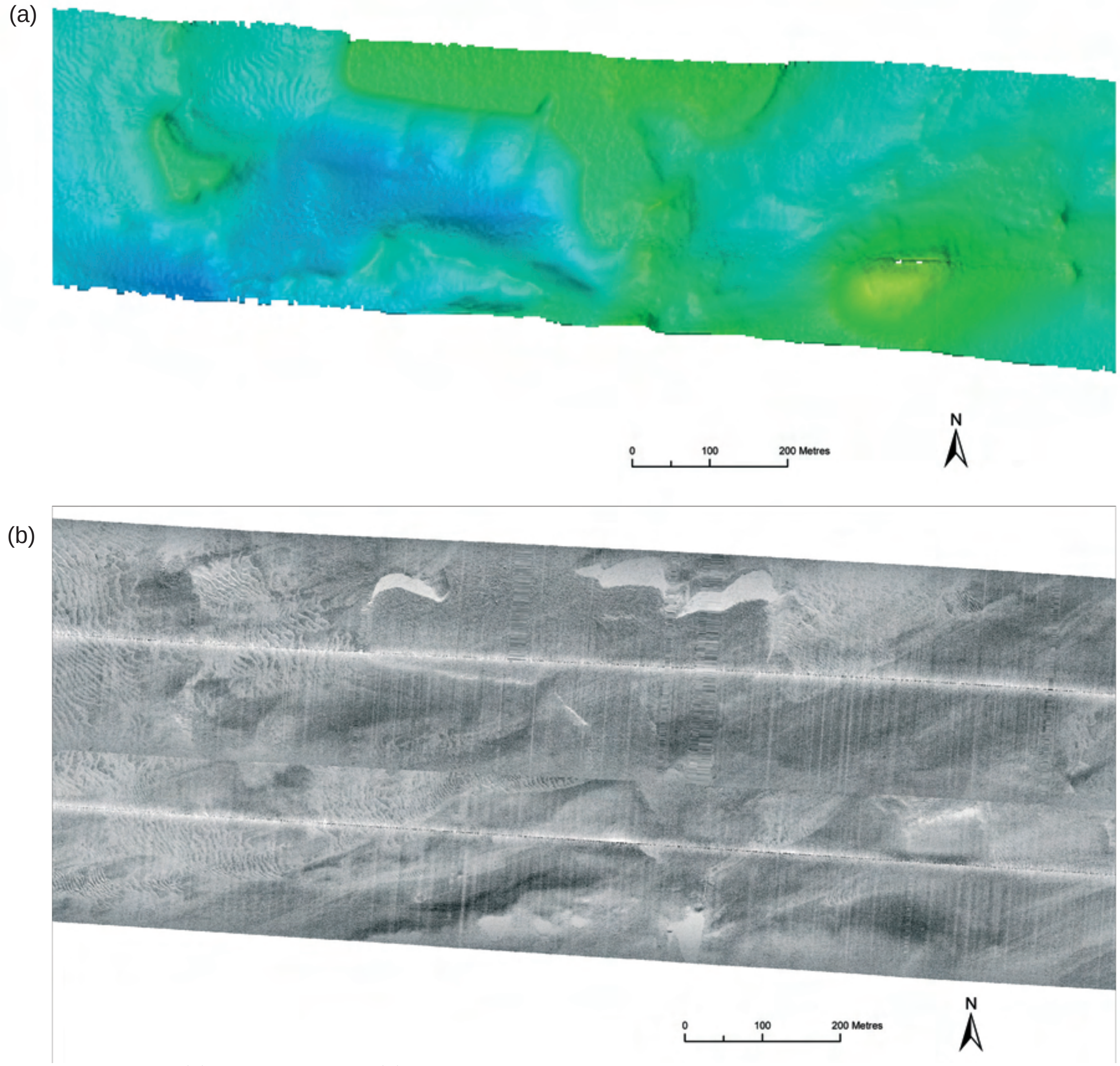


Figure 5.29. Multibeam (a) and sidescan sonar (b) images showing open floored channel and sand streaks on Corridor 1, Region 1.

Extensive sheets of sandy sediment in the floor of the Northern Palaeovalley are generally restricted to those areas underlain by sediment filled palaeochannels. In the central part of the region the sands are bisected by interfluves of rock and thin sediment. Sand waves occur in the north-central area of the Palaeovalley as groups and isolated occurrences. They are asymmetrical and east facing and range in height from 2 to 10 m. The sand narrows to the north-west where it is banked against the Palaeovalley margin and forms a narrow, ~2 km wide, linear, > 20 km long, field of isolated east facing sand waves. Evidence from elsewhere (James and Brown, 2002) indicates that banking of sandy sediment along the northern margin of the Palaeovalley is extensive and suggests that northern and eastward transport and deposition of sandy sediment in this environment has been a long term and continuing process.

Most of the southern half of the Northern Palaeovalley is underlain by rock and thin sediment with a relatively smooth surface; morphological and structural lineation are not common. This is probably because the underlying Barton Group rocks in this locality are in the centre of the Hampshire-Dieppe Basin where bedding is horizontal or with very shallow dips and therefore will produce extensive bedding surfaces unbroken by scarps or ridges.

Sand ribbons, patches, streaks and megaripple trains occur as linear bedforms over much of the rock and thin sediment in the region. Their linearity and direction is controlled by peak tidal current orientation, SW-NE, and the alignment of major and minor morphological features such as channels and scarps. The only area where sandy bedforms are scarce on rock is in the central southern area of the Palaeovalley.

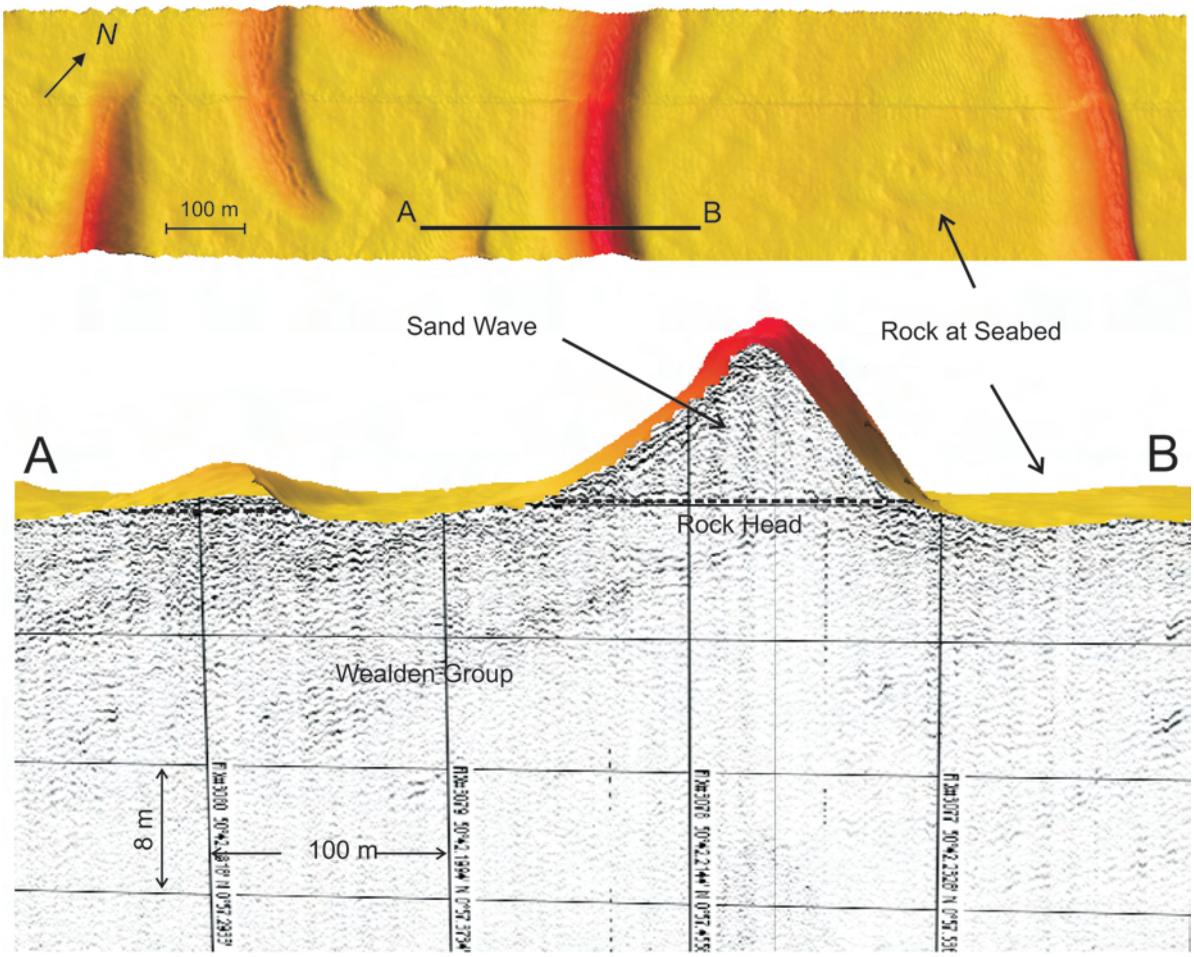


Figure 5.30. Multibeam and Sub bottom sections: isolated sand waves over rock on Corridor 3, Region 2.

Physical Region 2 -
North East Platform and Margin

The North-East Platform and Margin region is the smallest of the five regions and is characterized by a large platform of rock and thin sediment with abundant rock structural lineations of bedding and scarps, particularly in the southern half of the region underlain by folded Upper Jurassic rocks (Figure 5.10). Similar structural lineations occur in surrounding Wealden Group rocks but they are not as abundant and their frequency diminishes to the north.

The abundant structural lineations are locally an important control on the occurrence of sand that are deposited preferentially in the troughs between scarps. Where the sea bed is more open with fewer rock outcrops (Figure 5.11), megaripple trains, sand ribbons and patches are current orientated and plentiful, especially in the north. There are also some sheets of sand overlying small channels. Isolated east facing sand waves occur within the rock platform and are particularly numerous in the south-east of the region (Figure 5.30) just outside the boundary with the Greater Bassurelle Sands.

An extensive sheet of sandy sediment with a large patch of coarse sediment covers the western margin of the region. These lie on a large N-S orientated palaeochannel, 7 –10 km wide. The coarse sediment includes licenced dredging areas (Areas 366-370). A narrow linear sand wave field orientated SW-NE runs close to the eastern margin of the sand sheet.

Physical Region 3 -
Western Axial Platform

The region is predominantly a platform of rock and thin sediment. There are a few small areas of coarse sediment overlying palaeochannels in the north and east.

Structural and morphological lineations become more common and abundant to the south and south-west of the region. This is a reflection of the greater degree of folding within the underlying bedrock to the south and south-west (Figure 5.8). The east and north-east of the region is underlain by relatively low angled Barton Group rocks. Bedding steepens to the south-west (Figure 5.20) and there are a greater variety of rock types from Bracklesham Group to Wealden Group and therefore a greater propensity for differential erosion and low ridges and structural lineations.

Sandy bedforms are scarce within the region. Video and geophysical evidence indicates the region's sea bed character is dominantly a thin coarse lag gravel with rock outcropping at or close to the surface (Figure 5.21 and 5.24). The angularity, abundance of cobbles and boulders, local and in-situ provenance, and lower percentage of flint indicates that much of the gravel in the region has not been re-worked or transported and is primarily derived from the immediately underlying bedrock.

The sea bed has been effectively swept by strong currents. There is little fine and sandy sediment remaining. Much has been winnowed and transported to the east. The coarse sea bed is probably in part, the result of in situ weathering processes, which took place when the area was subject to continental subareal conditions during the last glaciation. Subsequently the east migrating marine transgression scoured the area and re-worked sea bed sediment. A marine transgression induces high bed shear stresses through wave energy and storms, high enough to move or re-work gravel. However, as water depth increases with the progress of the transgression, wave and storm processes will normally cease to impact the sea bed in water depths >20 m. Evidence for unidirectional re-working of gravel associated with marine transgressions is rare, however Figure 5.21d shows imbricated platy gravel at EECMHM sample station 79 on Bracklesham Group rocks. A strong unidirectional current has moved these platy gravels to a position where they are stacked on each other like a pack of cards with their flat surface sloping back to the west. This type of unidirectional stacking in gravel is called imbrication and the gravel slopes face into the primary current. Therefore in this example the primary current flowed to the east.

Imbrication in gravels is common in fluvial systems where waters flow in one direction but unusual in marine environments where currents are commonly bidirectional with ebb and flood tidal currents predominating. The fact that the EECMHM area includes a network of open and infilled palaeochannels which are associated with a fluvial environment might indicate that these imbricated gravels could be linked with these fluvial conditions. However, the orientation of these channels indicate current flows would generally be to the west and south west rather than east, hence the conclusion of these imbricated gravels being associated with the east migrating marine transgression.

Physical Region 4 - Central Axial Platform

The density of seismic lines across the region is lower than Regions 3 and 5 to its west and east, with only four east-west and four north-south lines across the region (Figures 4.3, 4.4 and 4.5). Therefore the level of detail in terms of bedforms, sea bed character and morphology is relatively limited although this is offset to some degree for sediment by the greater number of sample stations in the region (Figure 4.33).

The region has the most extensive cover of coarse sediment within the EECHM study area with sand only becoming common at its eastern margin (Figure 5.5). These sediments overlie a network of palaeochannels which are infilled with Quaternary sediment (Figure 5.3 and 5.4). Although the stratigraphy of the Quaternary sediment has not been interpreted for this study the gravels at the sea bed are thought to be associated with, and derived from the underlying Quaternary sediment, with reworked fluvial sediment infilling the palaeochannels redistributed by the successive marine transgression.

Rock and thin sediment occurs in small patches on palaeochannel interfluves, these are all in relatively soft Tertiary rocks and exhibit few occurrences of morphological or structural lineation and bedding. Coarse sediment on these interfluves can be extremely thin and pebbles dragged across the surface by fishing gear can expose rock at the sea bed as in Figure 5.31.

Sandy bedforms are scarce with much of the region being relatively featureless. Sand streaks, ribbons and patches along with megaripple trains are common in the extreme north-east of the region in slightly deeper water at the margin of the Northern Palaeovalley.

Although the sea bed surface is a relatively smooth gravelly plain, the limited seismic and bathymetric evidence suggests that there are some open channels within the sea bed with channel margins of a few metres in height.

Physical Region 5 - Greater Bassurelle Sands

The Greater Bassurelle Sands are an extensive area of sandy sediment which covers the whole of Region 5. In the west of the region it comprises a smooth sand sheet with no large bedforms discernable on multibeam or sidescan records. However, the sand sheet surface is likely to be rippled given the tidal current velocities in the region. Gradually eastwards across the region isolated sand waves become evident and these increase in number to form a large field of sand waves in the eastern half of the region (Figure 5.5). The sand wave field within the region covers an area of 329 km^2 and it extends further east outside the EECMHM study area.

The sand waves are dominantly asymmetrical in cross profile (Figure 5.32) with east and north-east facing steeper lee slopes, Asymmetrical sand waves can be an indicator of net sand transport in the facing direction of the lee slope. The sand waves in the Greater Bassurelle Sands

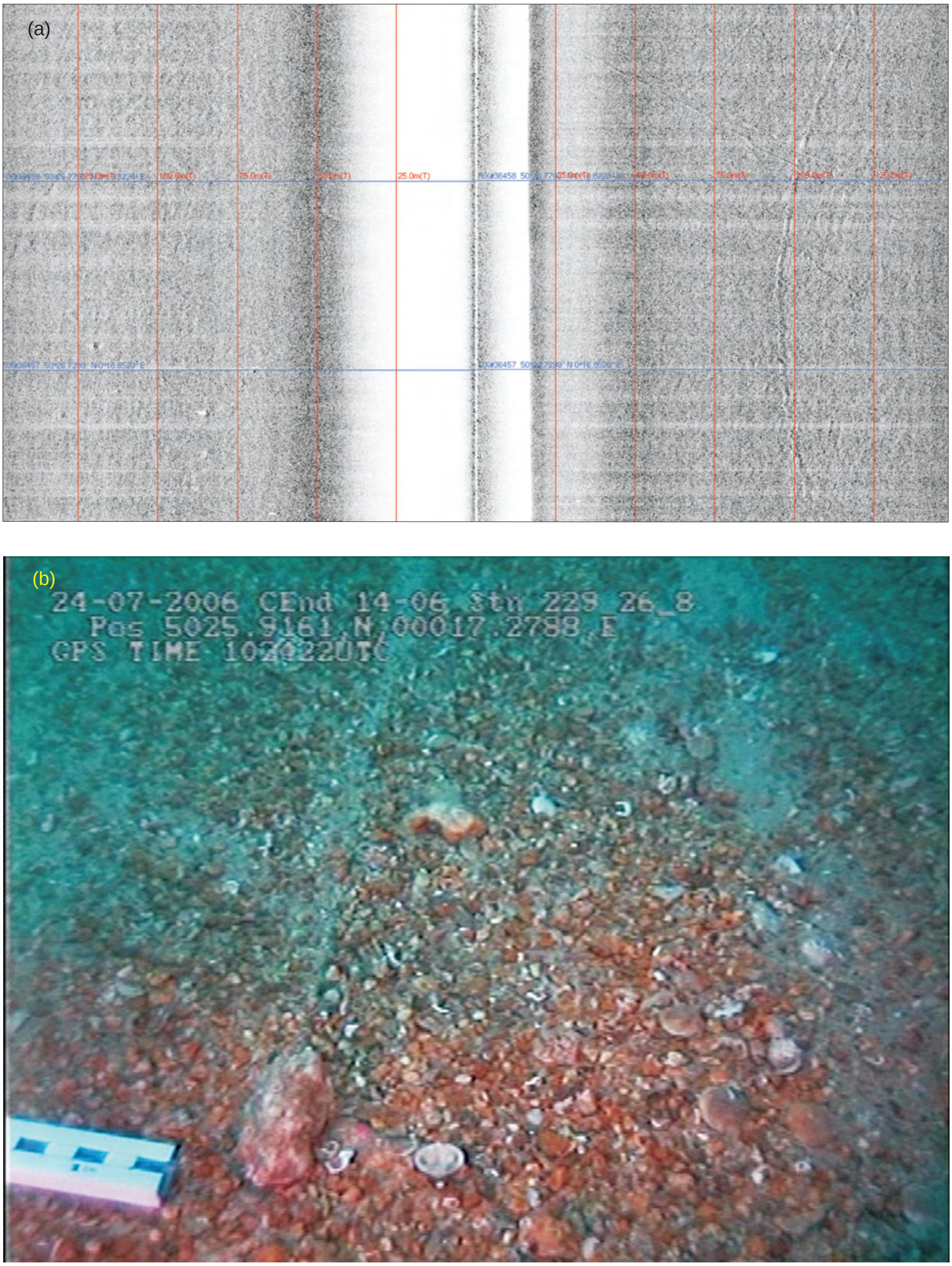


Figure 5.31. Sidescan Sonar image (a) and video capture (b) of fish trawl mark on Corridor 16, Region 3 (Scale bar - 2 cm divisions).

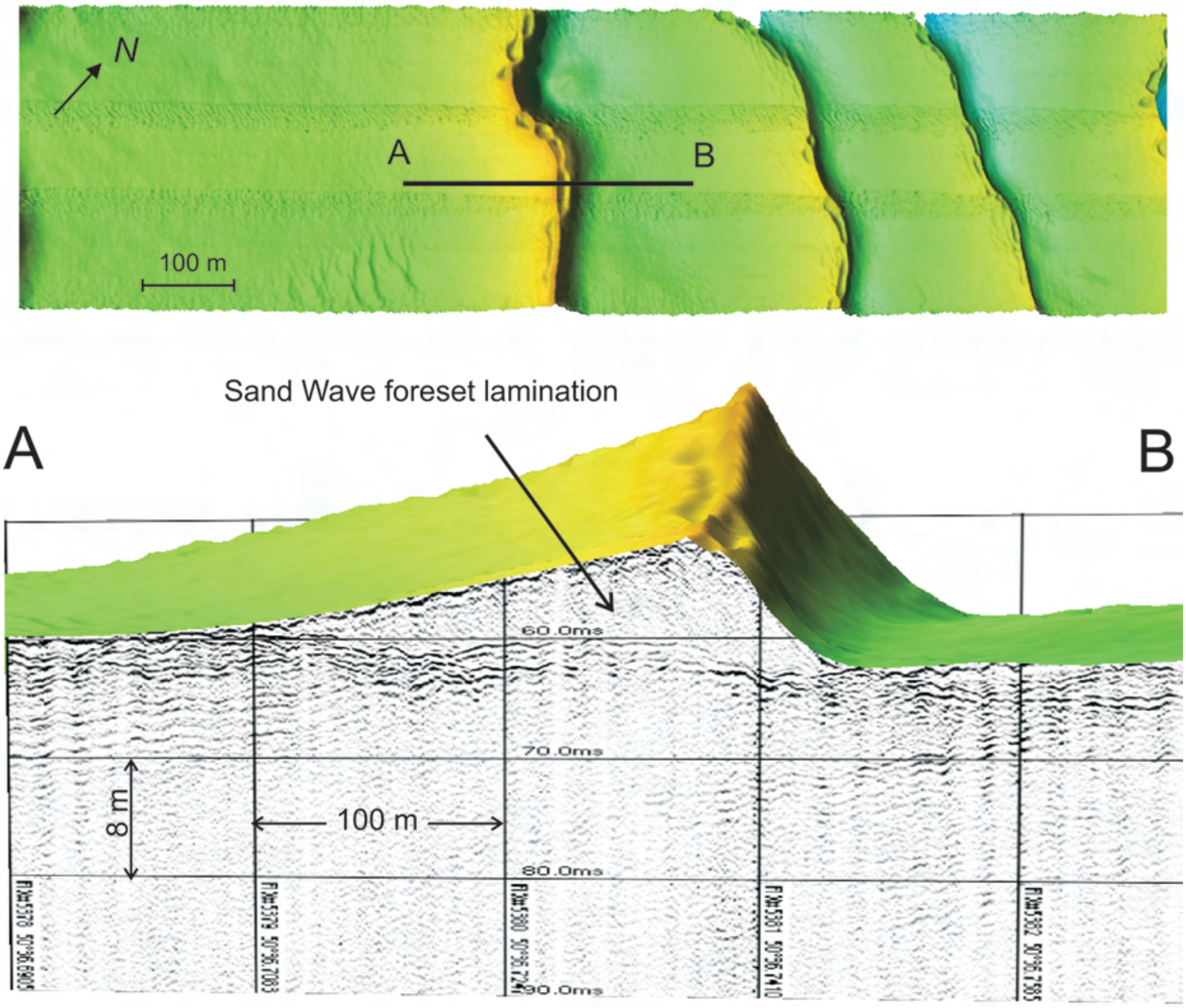


Figure 5.32. Multibeam and Sub bottom sections: Sand wave section showing the foreset lamination and basal reflector on Corridor 4, Region 5.

therefore imply that net sediment transport is to the east. The internal structure of the sand waves with east facing foresets is evidence of the growth of the sand waves in height and volume to the east as a long term process (Figure 5.32). This confirms other evidence for eastward sediment transport across the region including east facing foresets in the underlying transgressive sand sheet (Figure 5.5) and the fining of mean grain size and better sorting of sediment to the east.

The sand waves vary in height from 1.5 to 12 m and their wavelengths range from 200 to 1300 m. Their crest orientation can be straight or sinuous and some may bifurcate. Their orientation varies from NW-SE to N-S. Double crests are common and in plan view they form a series of ovoid crests along the tops of sand waves (Figure 5.32 and 5.33).

The western end of the Bassurelle Sand Bank impinges into the southeast corner of the region. Only 7 km of the sand bank crest lies within the region but it extends for a further 17 km to the north-east. Within the region it has a maximum width of 2.5 km and covers an area of around 17 km^2 with a maximum height of around 15 m The evidence from the single geophysical corridor that crosses the bank indicates east facing and symmetrical sand waves up to 2.5 m in height occur on its northern flank and crest. The NE-SW trend of the sand bank crest is virtually parallel to the strongly rectilinear tidal currents in the area. A surface tidal current station near the south-west tip of the sand bank (Admiralty Chart 2451) indicates peak spring surface current velocities of 0.7 m s^{-1} to the north-east and south-west.

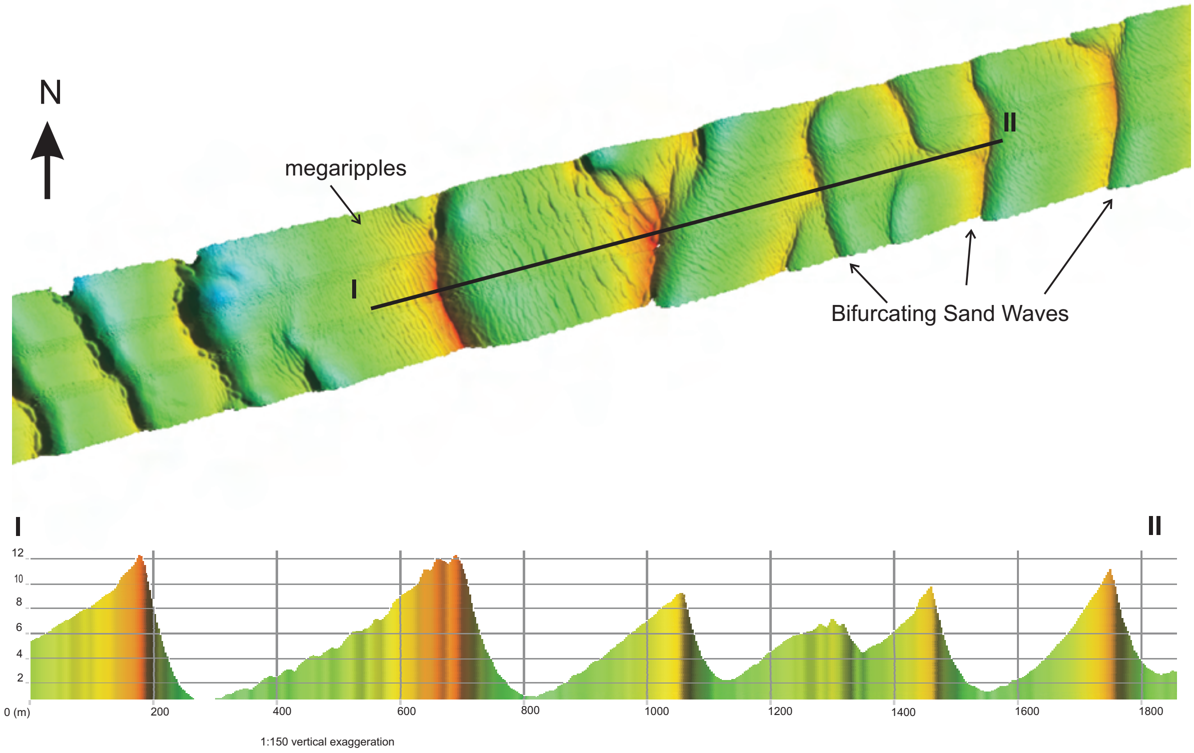


Figure 5.33. Multibeam record and profile of bifurcating sand waves on Corridor 4, Region 5.

5.2.4 Sea bed sediments

Sediment collected by Hamon grab (Figure 4.16) at 225 EECMHM and 468 ECA sample stations (Figure 4.30, 4.33 and Map 1) have been used in the analysis of sediment particle size for each sample station. The weight and percentage of sediment at half phi and whole phi intervals has been calculated and this data has been used to determine the size class distribution based on Wentworth and Folk (Figure 4.18) and a number of sediment statistical parameters including mean grain size, d_{50} - median grain size, sorting and skewness (Figure 5.34 – 5.40). The calculated values for all sediment particle size analysis at each grab station have been included in the Appendix DVD-ROM.

The Hamon grab has a sampling footprint at the sea bed of 0.1 m^2 and its maximum depth of penetration into sediment is ~15 cm. This footprint and penetration depth is obviously a constraint on the maximum clast size that can be sampled by the Hamon grab and also on the volume of sediment retained (Boyd *et al.*, 2006). It cannot sample boulders, and although cobbles can be collected they will be limited in the number sampled and restricted in size generally to those <20 cm. Therefore in those areas where cobbles, boulders and rock dominates the sea bed the Hamon grab may not to produce a representative sea bed sediment sample for particle size analysis.

This sampling clast size constraint has been mitigated to some extent by the deployment of a camera sledge at 58 stations (Figure 4.34). This has enabled a visual examination and analysis of the sea bed both for biology and sediments by JNCC and its contractors (Chapter 5.3.3). BGS also analysed the video and photos, in particular for evidence of rock outcrop, cobbles and boulders and produced results for a number of cobble and gravel sediment parameters (Tucker, 2003). These include: -

- Average number of cobbles per photo still (Figure 5.48).
- Maximum clast size of sediment (Figure 5.49). A slightly random parameter because it may refer only to a single clast seen in a 20 minute video tow and be unrepresentative of the surrounding ambient sea bed sediment. However, it can be an indicator of sediment source and environment.
- Principal gravel fabric from photo stills (Figure 5.50). The amount of sandy matrix and the matrix to clast (gravel/cobble) relationship affect the packing and fabric of sediment and are important indicators of depositional environment and sediment source.
- Principal cobble roundness (Figure 5.51). Only subangular and subrounded recognised. Both are indicators of sediment source, degree of erosion and abrasion, sediment transport and environment.
- Principal cobble shape (Figure 5.52). Two shapes have been recognised, sphere and blade. Spheres are shapes whose axes are more or less equal. Blades have unequal axes and are tabular and flatter. Both are indicators of sediment source, degree of erosion and abrasion, sediment transport and environment.

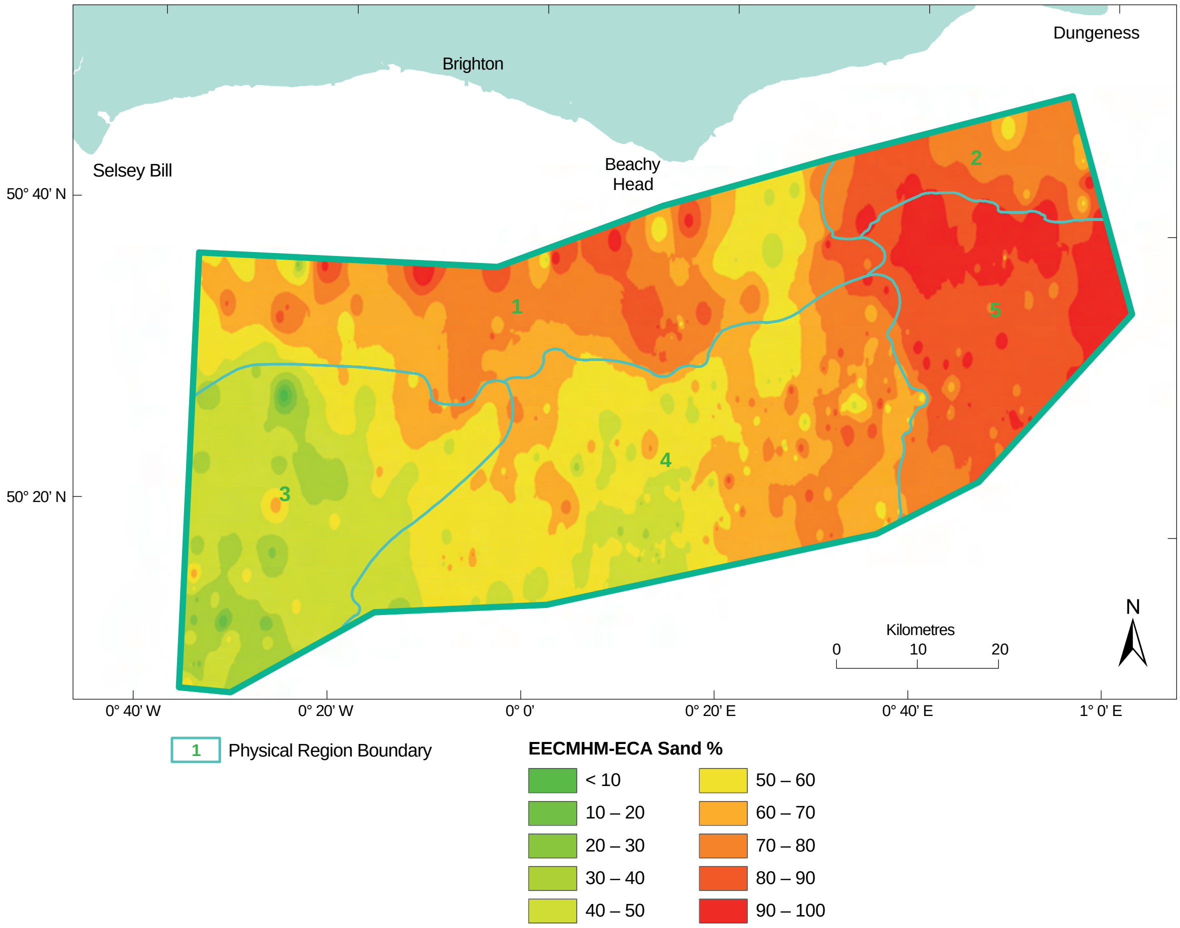


Figure 5.34. Sand distribution (%) from analysis of EECMHM and ECA samples.

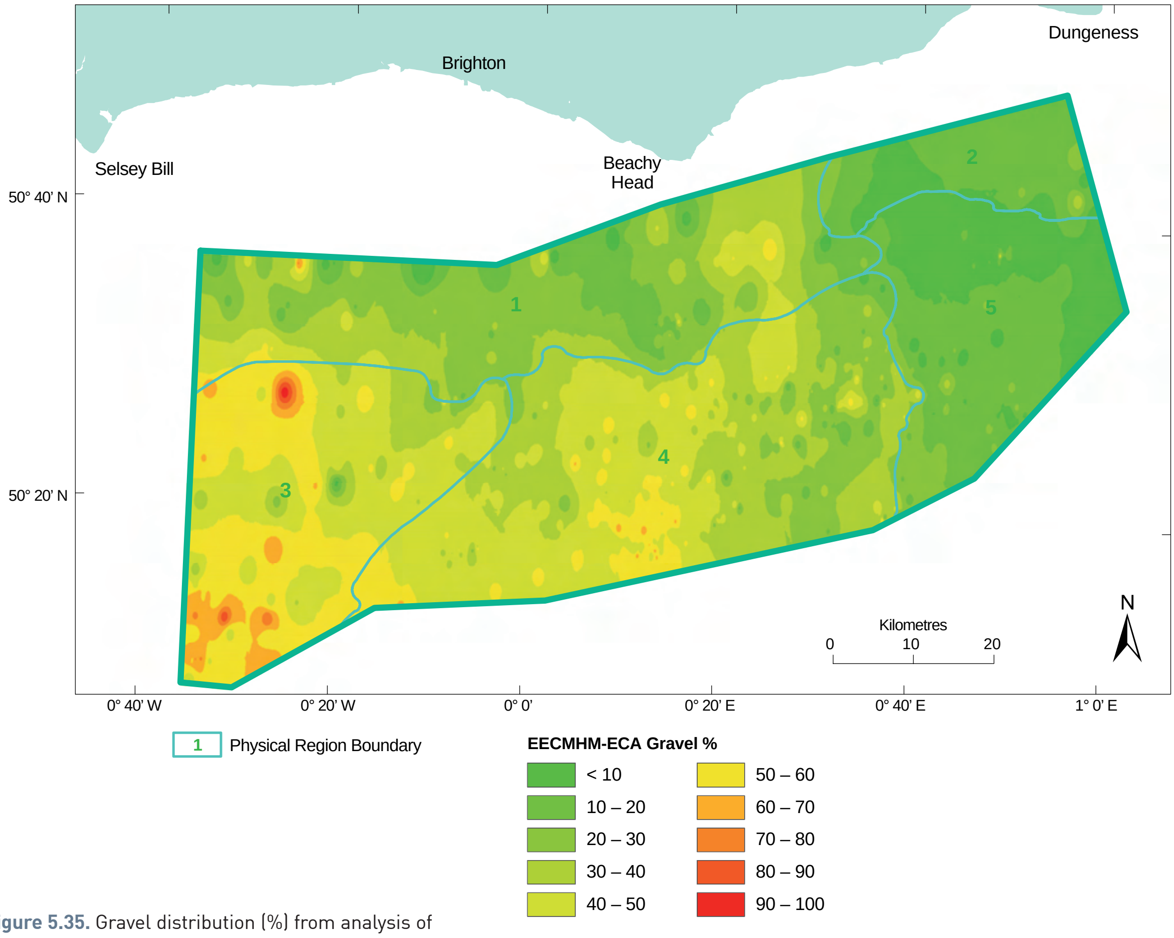


Figure 5.35. Gravel distribution (%) from analysis of EECMHM and ECA samples.

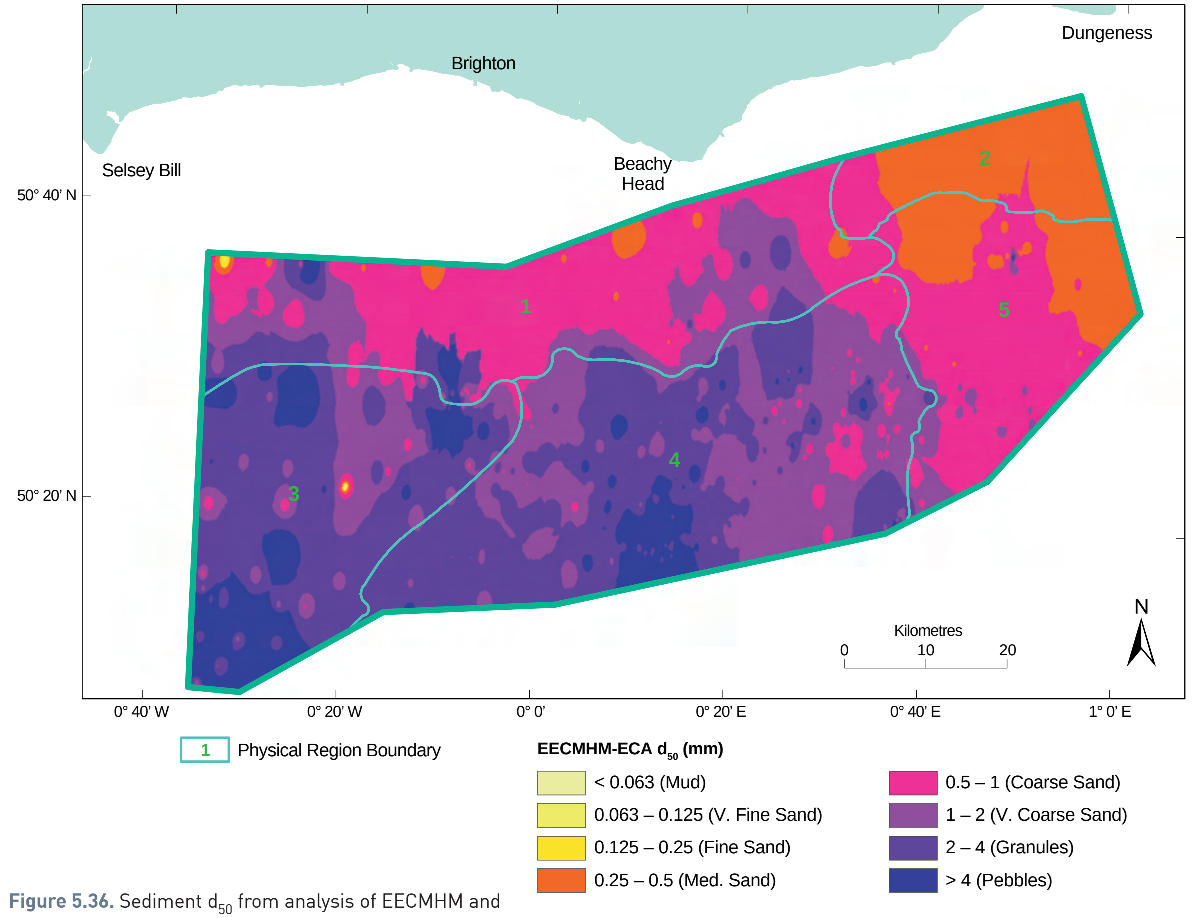


Figure 5.36. Sediment d_{50} from analysis of EECMHM and ECA samples.

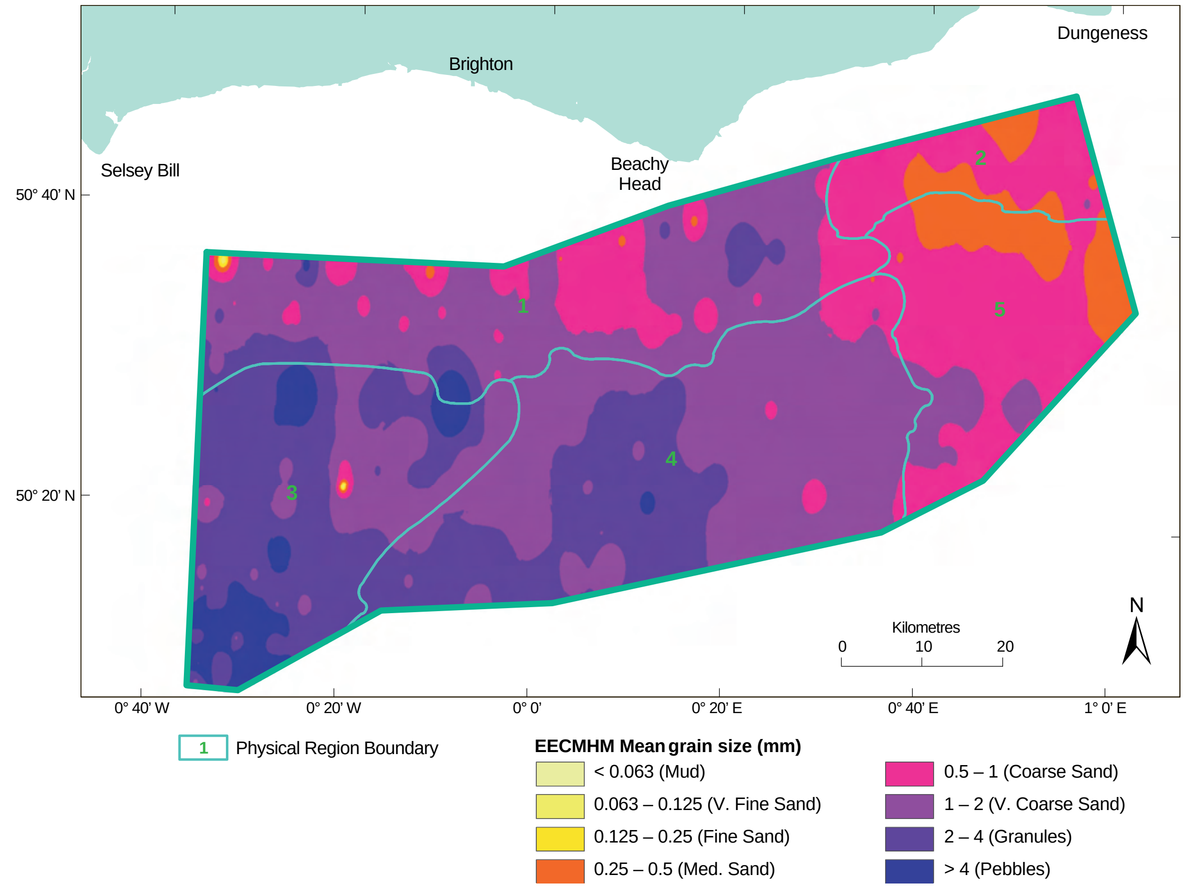


Figure 5.37. Sediment mean grain size from analysis of EECMHM samples.

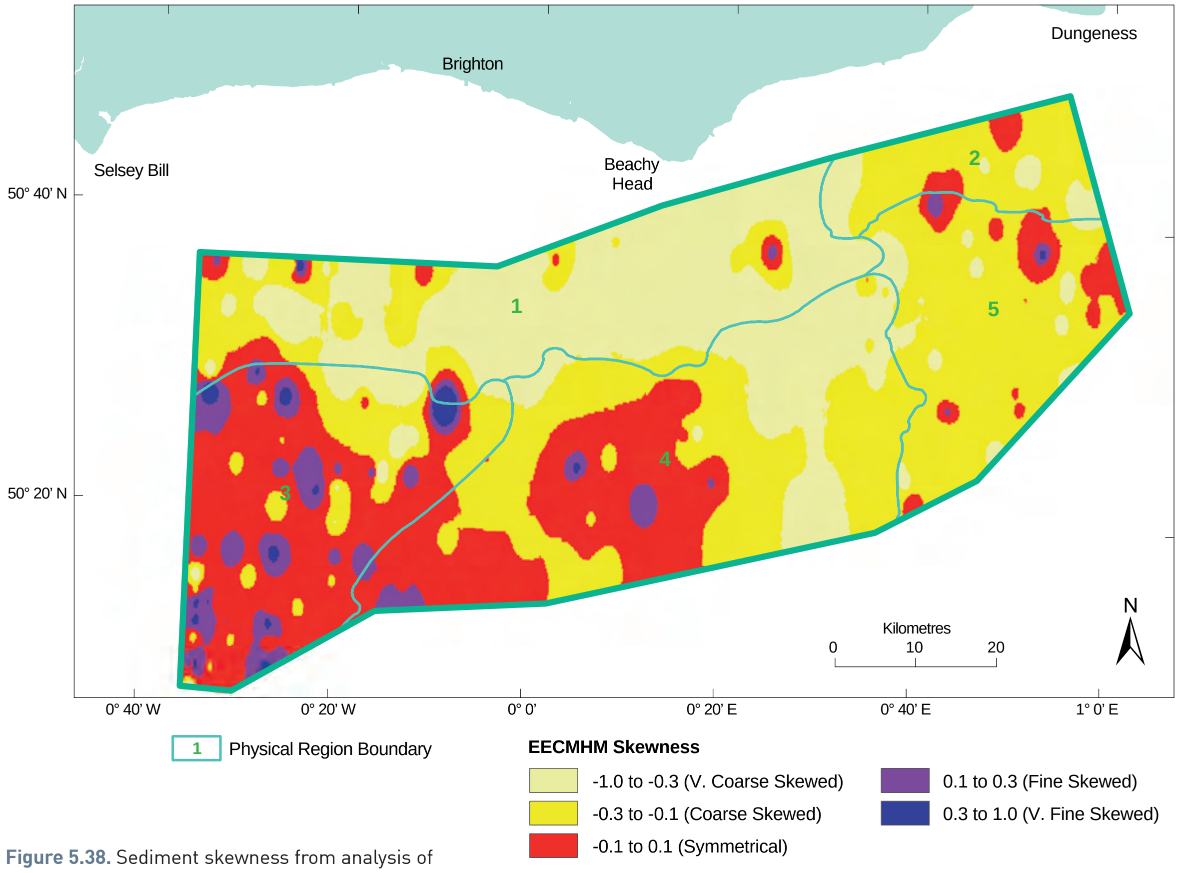


Figure 5.38. Sediment skewness from analysis of EECMHM samples.

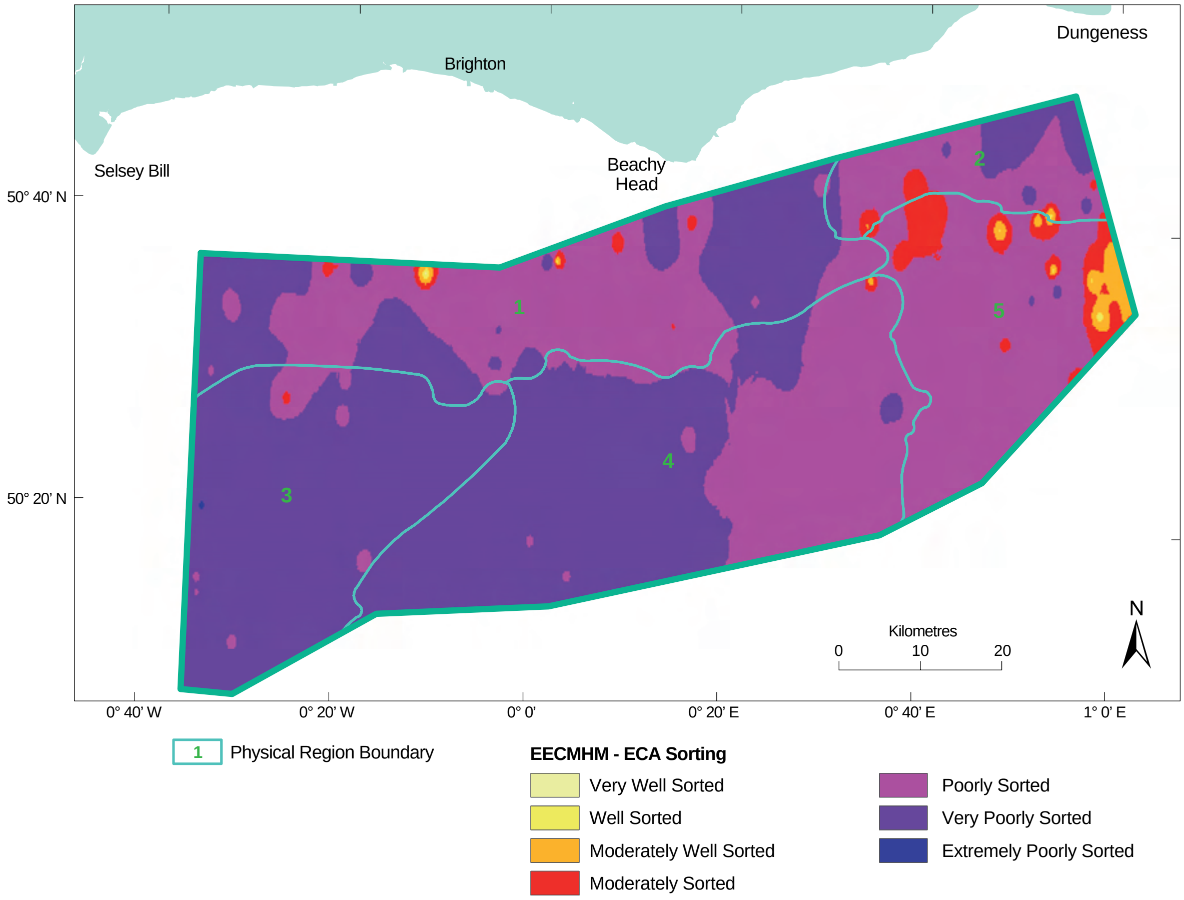


Figure 5.39. Sediment sorting from analysis of EECMHM and ECA samples.

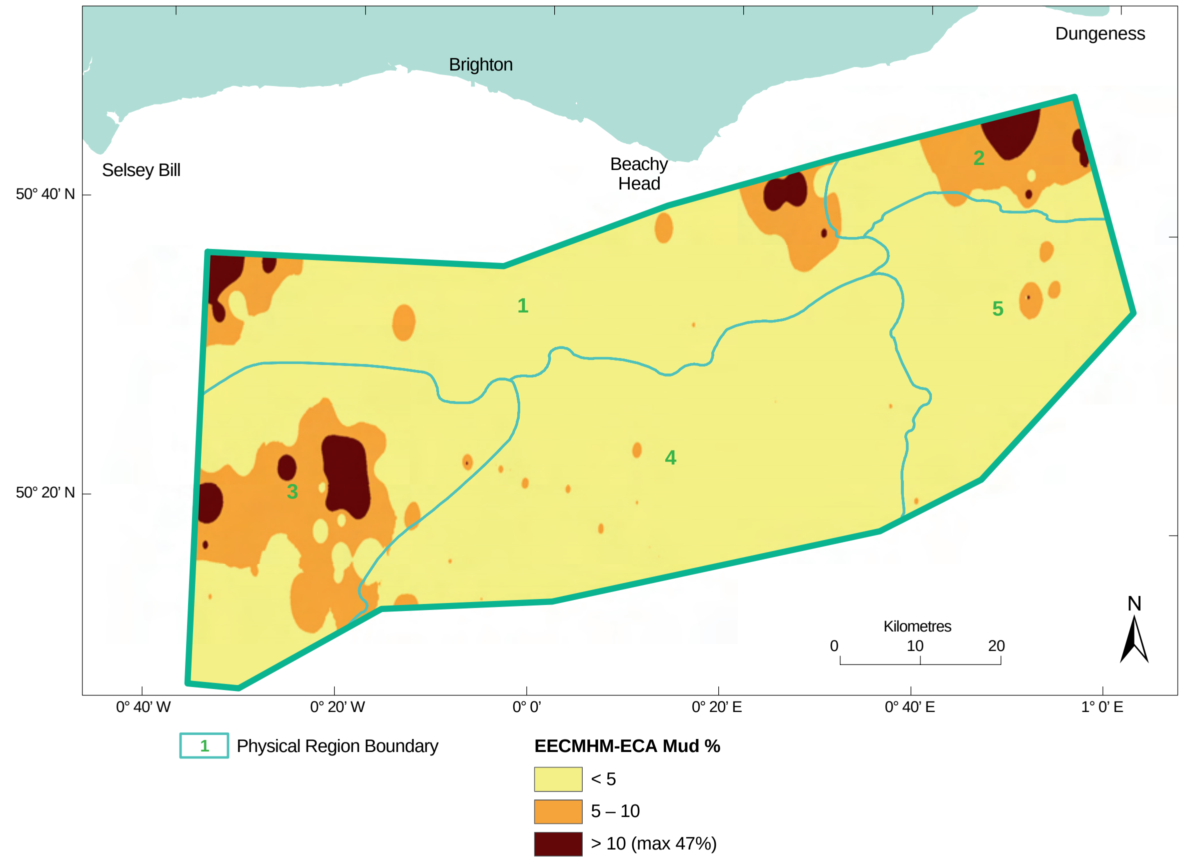


Figure 5.40. Mud distribution (%) from analysis of EECMHM and ECA samples.

The distribution of sea bed sediments across the EECMHM study area shown in Figure 5.7 is based on the analysis of sediment obtained by Hamon grab sampling. Each sample has been classified by grain size with the Folk classification system (Folk, 1954) using the relative proportions of gravel, sand and mud (Figure 4.19). The Folk sediment distribution covers the whole EECMHM study area. Little or no account is taken in the Folk sediment interpretation of evidence from multibeam, sidescan, sub-bottom or camera sledge data. For example, outcrops of rock are not shown on Figure 5.7. It is therefore important that the sea bed sediment distribution map is read in conjunction with the sea bed character interpretation (Figure 5.5 and Map 1), bedforms (Figure 5.6), sediment parameters (Figure 5.34 – 5.40) and gravel/cobble parameters (Figure 5.48 – 5.52). All are complimentary and provide a comprehensive understanding of the character of the sea bed.

Sediment characteristics from sampling

Three of the study area's five physical regions are dominated by sandy sediment, predominantly gravelly sand. These are the two northern regions, Northern Palaeovalley and Margin (Region 1) and North-East Platform and Margin (Region 2) plus the eastern region, Greater Bassurelle Sands (Region 5). Region 1 and 2 include some areas of sandy gravel but sandy gravel is most extensive in Region 4 – Central Axial Platform. Sandy gravel extends westward into the Western Axial Platform (Region 3) but Region 3 has an extensive area of muddy sandy gravel at its core.

In the two northern regions there are large areas where sand comprises over 70% of the analysed sediment (Figure 5.34), although the distribution of sand is patchy reflecting the relatively complex nature of the sea bed with rock and thin sediment, and intermittent sandy bedforms common. The patchiness of sand is mirrored in the distribution of gravel with only a few areas where gravel exceeds 30% of the analysed sediment (Figure 5.35) and these are in the east and south-west of Region 1. There is also a coarser mixture and wider range of sediment grain size in Region 1 although sorting in both regions varies from very poorly sorted to well sorted, reflecting the heterogeneity of the sampled sediments (Figure 5.46).

The overall dominance of sand in the sampled sediment in these two northern regions is also reflected in the average proportions of sediment by grain size category (Figure 5.41 and 5.42), they are both mainly unimodal in character with medium sand (36%) as the mode sediment category in Region 1 with fine sand (33%) being equally significant as the joint mode sediment in Region 2. Although in Region 1 there is a noteworthy proportion of pebbles (20%) the quantity of medium and fine sand may indicate that mobile sediment and associated sandy bedforms are significant in these regions particularly as fine sand becomes more important to the east.

Figure 5.41. Region 1 EECMHM sediment samples – grain size histogram.

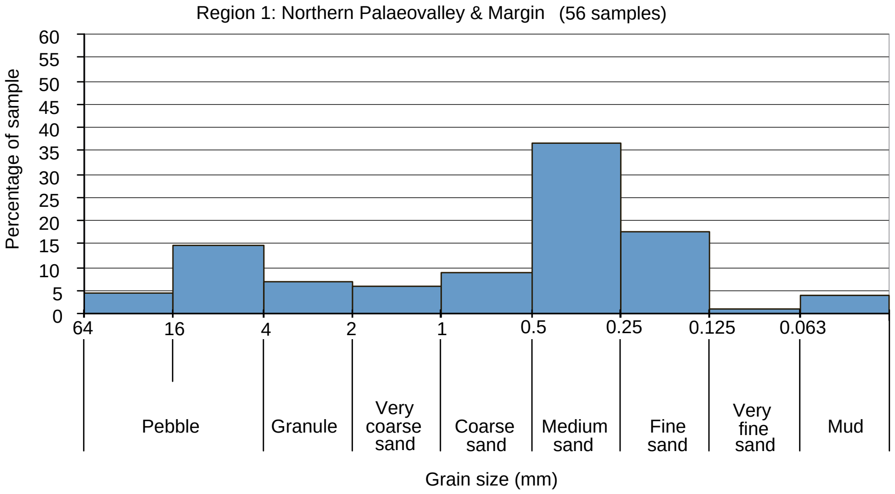
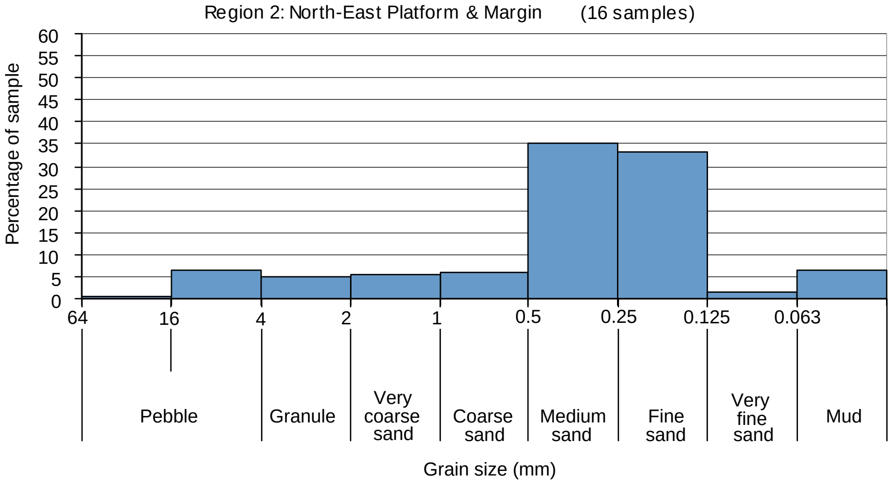


Figure 5.42. Region 2 EECMHM sediment samples – grain size histogram.



From west to east across the three southern regions there is a grain size trend of increasing sand content and decreasing gravel content. In the Western Axial Platform (Region 3) there are a number of areas with <40% sand - >60% gravel and most of the region has <50% sand - >50% gravel. Although there are patches of sandier or gravellier sediment in the Central Axial Platform (Region 4) the sand content at its western margin is commonly around 50%-60% and this increases to 70%-80% at its eastern boundary with the Greater Bassurelle Sands, and here there is <20% gravel. Across the Greater Bassurelle Sands the sand content increases to over 90% in the north and east of Region 5 associated with an extensive sand wave field and the Bassurelle Sand Bank.

The southern regions west to east sediment fining trend is also reflected in the values for median grain size - d_{50} (Figure 5.36), mean grain size (Figure 5.37), skewness (Figure 5.38) and sorting (Figure 5.39). Mean and median grain size of pebble grade (>4 mm) occur in the south west corner of Region 3 and as patches elsewhere in the region and also in the middle of the southern boundary of the Central Axial Platform (Region 4). Elsewhere over Region 3 and the western half of Region 4 granules (2-4mm) are extensive with large areas of very coarse sand (1-2 mm), the latter become dominant in the eastern half of Region 4. Very coarse sand becomes patchy across the boundary into the Greater Bassurelle Sands and coarse sand (0.5 – 1 mm) quickly becomes the principal mean and median grain size in Region 5, gradually becoming finer to the east and north with medium sand (0.25 – 0.5 mm) prevailing over much of the sand wave field and the Bassurelle Bank and also extending further north into the North-East Platform and Margin (Region 2).

The average proportions of sediment by grain size category within the three southern regions become finer to the east, although in Region 3 and 4 the distribution is bimodal with pebbles (4-16 mm) and medium sand being the mode sediments with over 20% of each in both regions (Figure 5.43 and 5.44). In the Greater Bassurelle Sands the sediments are strongly unimodal with over 40% medium sand as the mode sediment category increasing in number at the expense of pebbles and granules (Figure 5.45).

Sorting which relates to the spread of sediment particles about the average, i.e. a measure of the standard deviation, is a useful parameter, particularly as an indictor of the effectiveness of sedimentary environments and processes in separating, transporting and depositing grains of different size classes. The fact that sorting improves from west to east across the three southern regions (Figure 5.39 and 5.47) from very poorly sorted through poorly sorted to moderately well sorted in the area of the Bassurelle Bank can be related to a number of factors including: -

- The extensive area of immobile rock and coarse sediment substrate in the west in Region 3
- Quaternary sediment infilling the channel systems in the Central Axial Platform providing a predominantly gravelly substrate beneath the sea bed.
- The winnowing of sediment by strong tidal currents from these coarse substrates, particularly sediment <1mm in grain size, and their transport to the north and east and deposition as sand sheets and bedforms including sand waves and sand banks.

Although over much of the EECMHM study area the percentage of mud found in grab samples is <5% (Figure 5.40), there are significant patches where mud is >10%, with a maximum recorded value of 47%. The muddy patches are confined predominantly to areas of rock with thin sediment with the largest area in the central core of the Western Axial Platform (Region 3), elsewhere they occur in the eastern half of the North-East Platform and Margin (Region 2) and in the north-east and north-west corners of the Northern Palaeovalley and Margin (Region 1). The occurrences of mud in Regions 4 and 5 are relatively insignificant.

The occurrences and proportions of mud are unlikely to be related to settlement of mud out of the water column. The velocity of currents in the study area are high enough to keep mud in suspension and entrain any mud that settled on the sea bed in slack tide periods. The fact that the occurrences are on rock outcrop and thin sediment, and many of these rocks have a muddy component such as the London Clay, Bracklesham Group, Barton Group and Wealden Group clays and silts suggests that grab sediment may include some soft mud liberated from a clay or silt rock substrate. The video evidence in some of these areas indicates that relatively soft rock can occur at the sea bed (Figure 5.21) with the potential to be scraped and sampled by a Hamon grab. The presence of a significant proportion of mud (>10%) within sampled sediment in the EECMHM study area is therefore interpreted as a likely indicator of relatively soft rock outcrop at the sea bed.

Sediment characteristics from video and photos

The results from the camera sledge video and still photographs provides excellent supporting evidence for the statistical results obtained from the analysis of sediment grab samples and generally confirms the overall pattern and distribution of sea bed sediment produced in the Folk sea bed sediment map (Figure 5.7). In those areas of sea bed where rock and thin sediment are extensive it was apparent from video and photographs that sediment sampling was only providing some part of the evidence for the nature of the sea bed, especially with regard to defining the abundance of large cobbles and boulders. The analysis of video and photographs by BGS concentrated on these and produced results for a number of cobble and gravel sediment parameters.

During a camera sledge tow a still photo is taken every minute and for most tows there are at least twenty photos. Each photo image is about 80 cm by 60 cm. The number of cobbles per photo were counted and the average number of cobbles per photo for each tow are shown in Figure 5.48. The Western Axial Platform (Region 3) is the only region with a significant number of tows with >7 cobbles per photo, many photos have over 60% cobble cover. One tow in the region had over 13 cobbles per photo. None of the four other regions had tows with cobbles per photo >3-4, most were just 1 or 2, or almost zero in sandy areas such as the Greater Bassurelle Sands.

Region 3 has an extensive substrate of rock and thin sediment and was preferentially targeted with a number of video tows because of its potential as a reef habitat. The other areas of extensive rock and thin sediment such as, the Chalk of Region 1 south of Beachy Head, and the Upper Jurassic outcrops in Region 2 have few tows and therefore the presence of more numerous cobbles than currently apparent should not be discounted in these areas. Certainly the maximum clast size noted in all photo stills (Figure 5.49) indicates that cobbles, if only randomly, occur in all regions with the apparent exception of the Bassurelle Bank and its adjacent sand wave field. On this maximum clast size parameter, boulders are more common in the Western Axial Platform, including one boulder on Barton Group substrate which has been interpreted as a nodule of ferroan calcite. These are common as individual nodules within the Barton Clay and this example has been eroded out of the clay and left as a boulder on the sea bed. This is an indicator that some coarse gravel in the Western Axial Platform is derived from its immediate substrate with little or no transport or reworking. The only other boulder occurrence noted in the study area is a large flint on the Chalk platform south of Beachy Head.

Figure 5.43. Region 3 EECMHM sediment samples – grain size histogram.

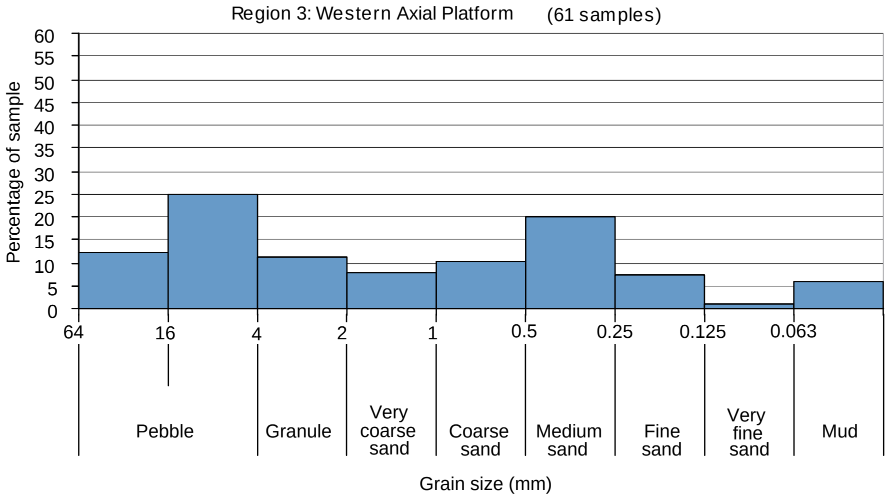


Figure 5.44. Region 4 EECMHM sediment samples – grain size histogram.

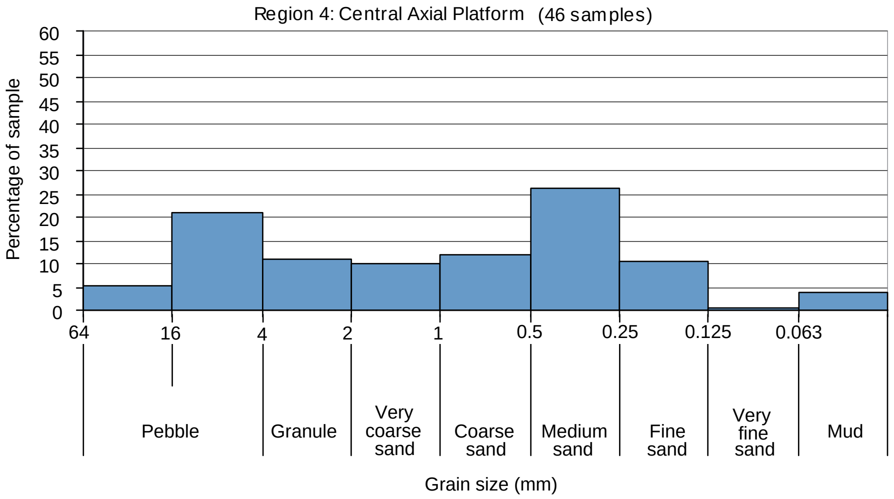
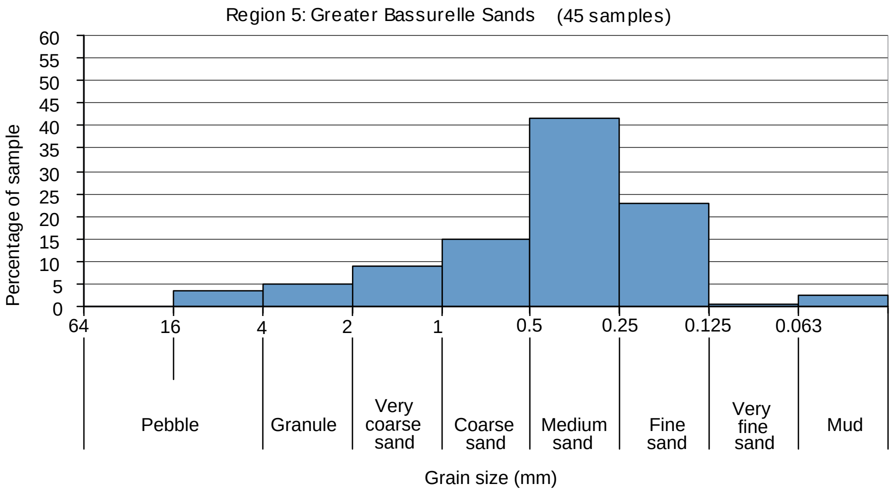


Figure 5.45. Region 5 EECMHM sediment samples – grain size histogram.



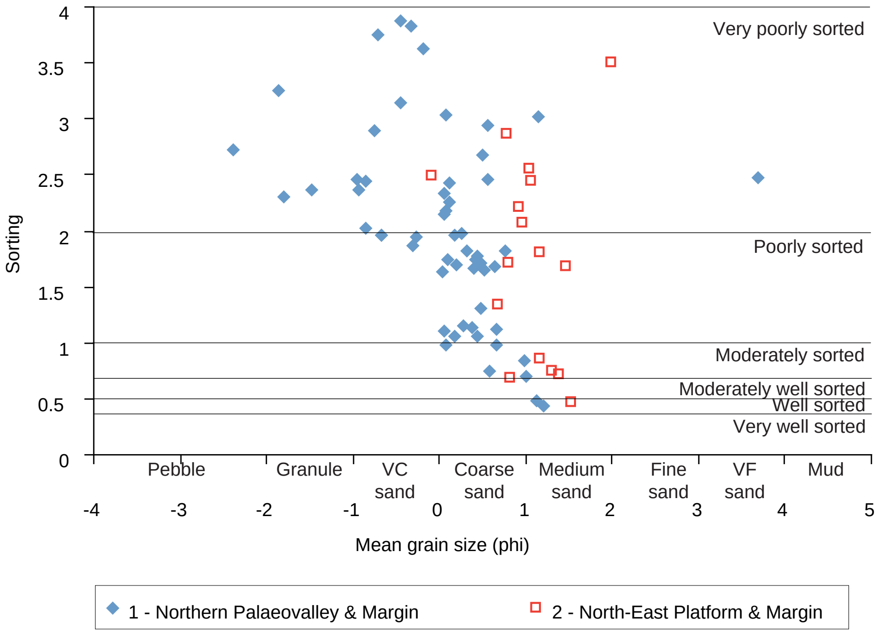


Figure 5.46. Region 1 & 2 EECMHM sediment samples – sorting versus mean grain size.

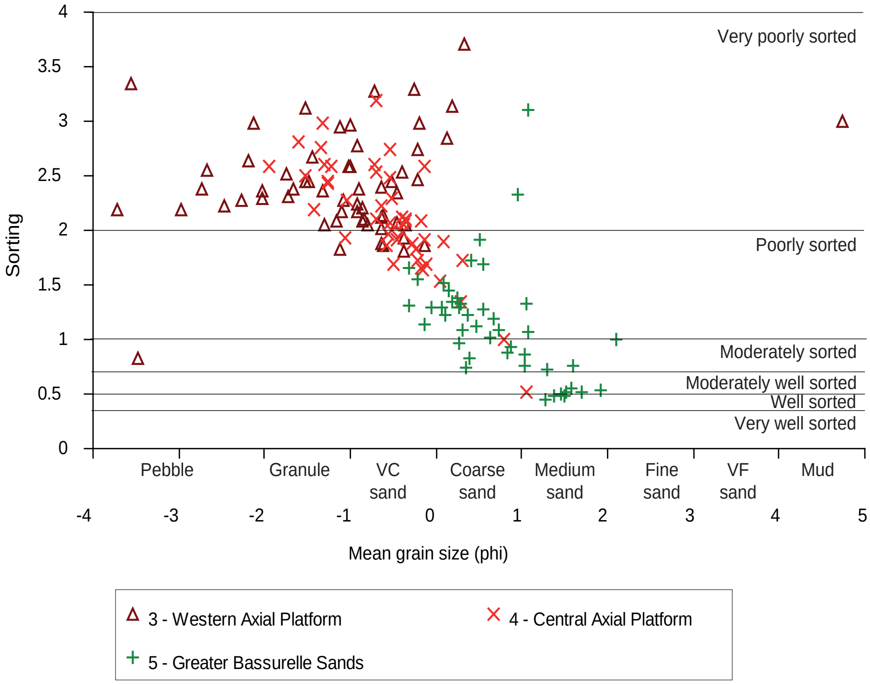


Figure 5.47. Region 3, 4 & 5 EECMHM sediment samples – sorting versus mean grain size.

The fact that the Western Axial Platform has a significant cover of cobbles and extensive areas with>50% gravel (Figure 5.35) suggests there is the potential for clast supported gravel in the area i.e. where individual gravel clasts touch and support each other as in Figure 5.21d. Matrix supported gravel is defined as gravel which is supported and separated by finer sediment as in Figure 5.82 and 5.83. Clast supported gravels are therefore indicative of coarse substrates with very high abundance of gravel and devoid or depleted in fine sediment. They are common as lag gravel surfaces. The photo still analysis identifies that within the Western Axial Platform clast supported gravel is the principal gravel fabric (Figure 5.50) and extends eastward along the southern margin of the Central Axial Platform – Region 4.

Elsewhere across the EECMHM study area, in the north and east of Region 4 and the whole of Region 1, 2 and 5 matrix supported gravels are ubiquitous in line with the increasing and higher proportions of sand to the north and east.

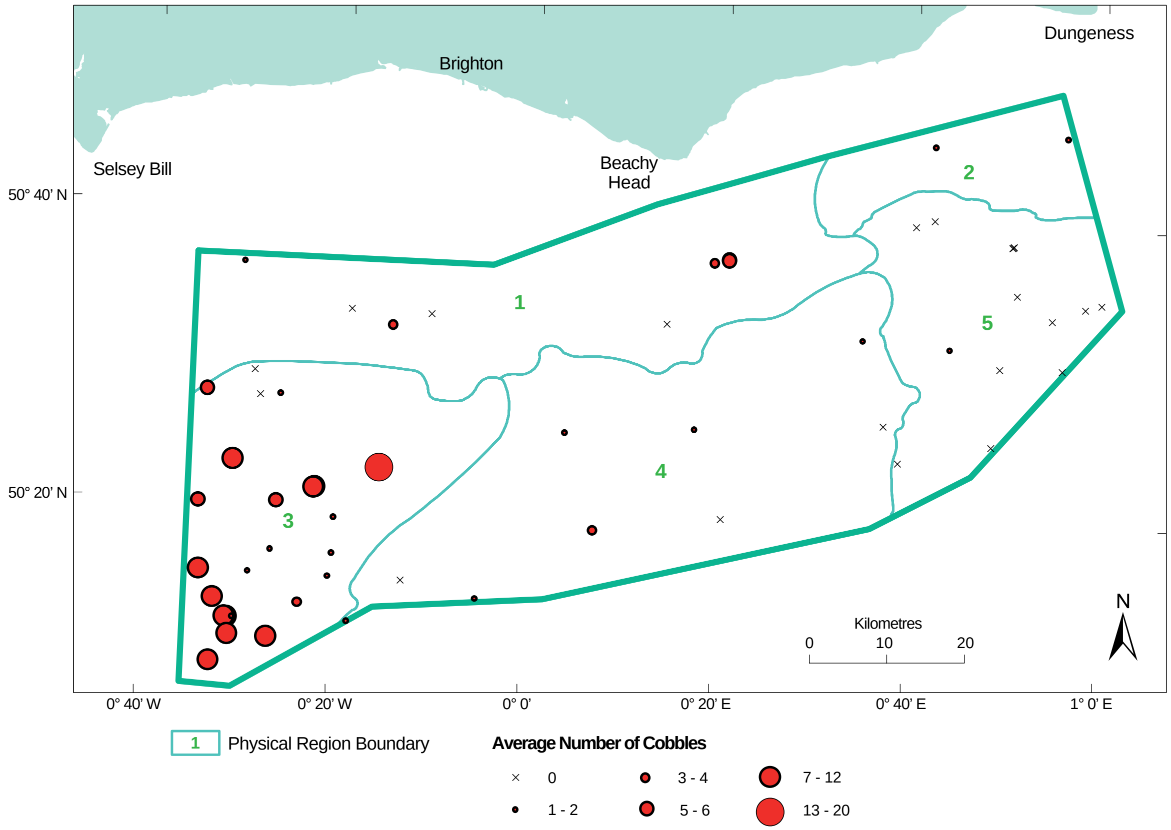


Figure 5.48. Average number of cobbles per photo still from camera sledge tow.

No systematic interpretation and counting of the type of gravel lithologies seen on video and photos has been undertaken, and also not for sediment sampled by Hamon grab. Therefore we have no statistics as to the relative abundance of flint, quartz, mudstone, sandstone, shell, ferroan calcite nodules or other lithologies within the sea bed sediment. However, some broad conjectures can be drawn with regard to the provenance of the gravels in the study area from the camera sledge tows.

It is an assumption that within the English Channel, gravel at the sea bed is dominated by flint and commonly comprises up to 80% of the total (Hamblin *et al.*, 1992). Flint is very durable and although originally formed predominantly in the Cretaceous Chalk it has undergone numerous phases of recycling and sorting through the Tertiary and Quaternary to be left as the principal gravel component in river systems and channels in south-east England and the English Channel.

Certainly the gravels at the sea bed within the Central Axial Plaform appear to be dominated by subrounded flint (Figure 5.51). This is consistent with the fact that Region 4 is underlain by palaeochannel systems infilled with fluvial gravels whose principal component is likely to be flint. The limited number of tows in the two northern regions make it difficult to produce any assumptions on gravel lithology although flints are common in the tows on the Chalk platform in the east of Region 1. The tows in the North-East Platform and Margin are inconclusive with regard to gravel lithology because of the low volume of gravel, although some bedding in the Wealden was exposed at the sea bed (Figure 5.81) and bladed cobbles were noted at station EECMHM23 (Figure 5.52). Bladed cobbles are believed to be derived from immediately underlying bedrock, having not been abraded by transport and reworking.

The evidence from the camera sledge tows in the Western Axial Platform (Region 3) suggests that flints are not as common as in the other regions. Gravels derived from the underlying bedrock can be seen in a number of tows as well as outcrops of rock (Figure 5.21c and d, 5.24c, 5.83, 5.86 and 5.87). These include tows on Barton Group, Bracklesham Group and Chalk outcrops. Subangular cobbles occur in five tows in Region 3 (Figure 5.51) and bladed shapes in another three tows including Figure 5.21. The video, sampling and geophysical data indicates that the Western Axial Platform is commonly characterised by a cobble rich sediment veneer on rock outcrop which is exposed in some parts and provides the source for a significant proportion of the overlying gravel, particularly the cobbles and boulders.

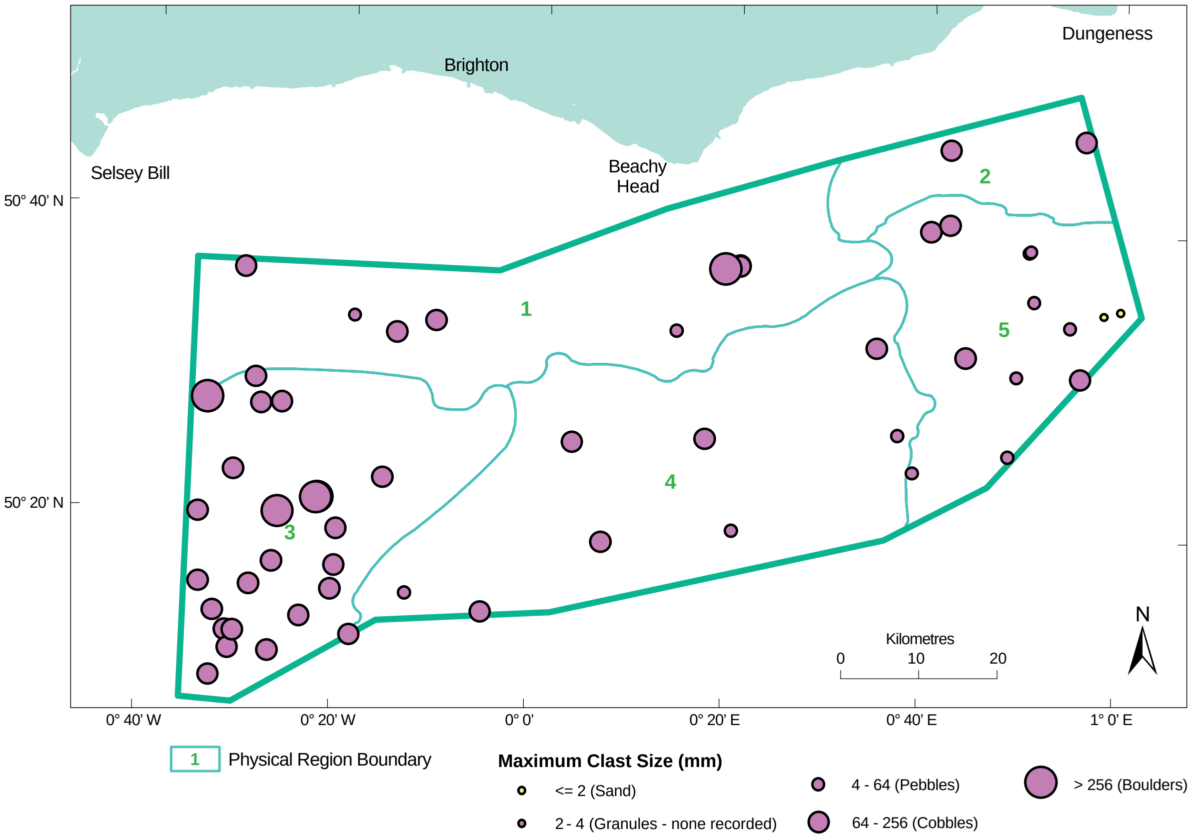


Figure 5.49. Maximum clast size of sediment interpreted from camera sledge photo stills.

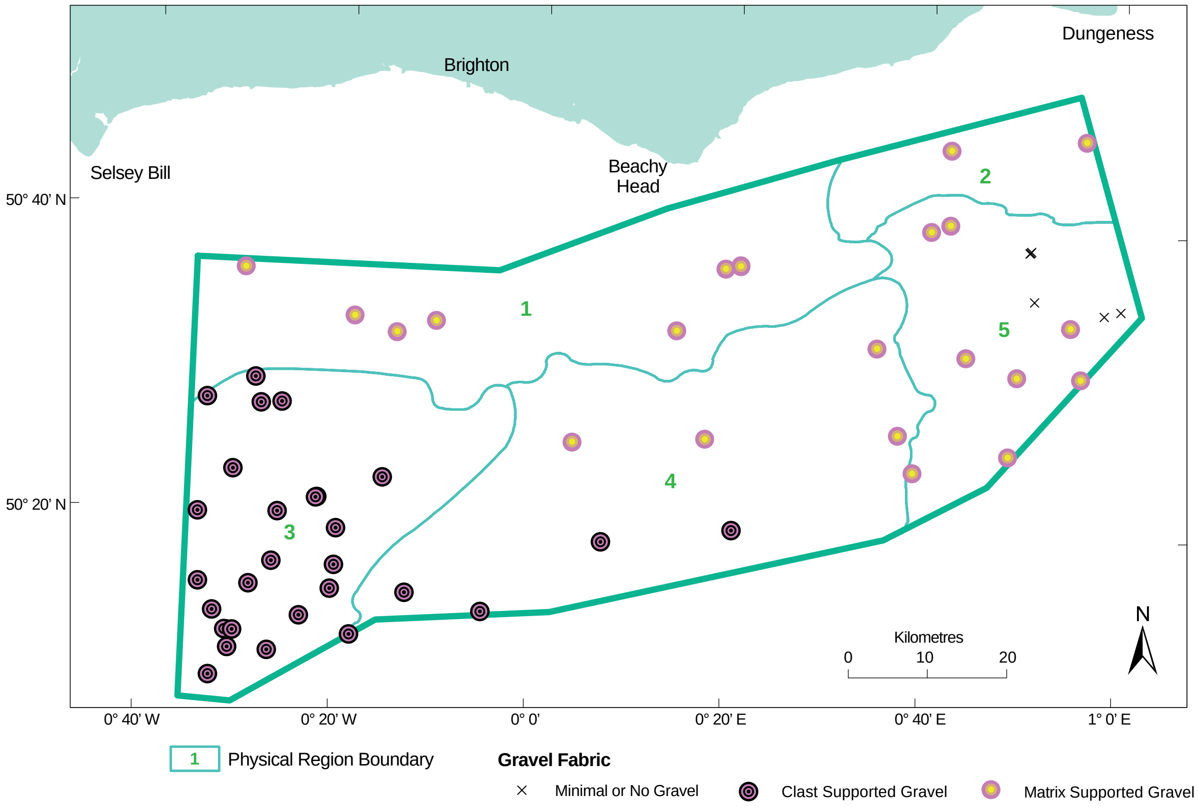


Figure 5.50. Principal gravel fabric interpreted from camera sledge photo stills.

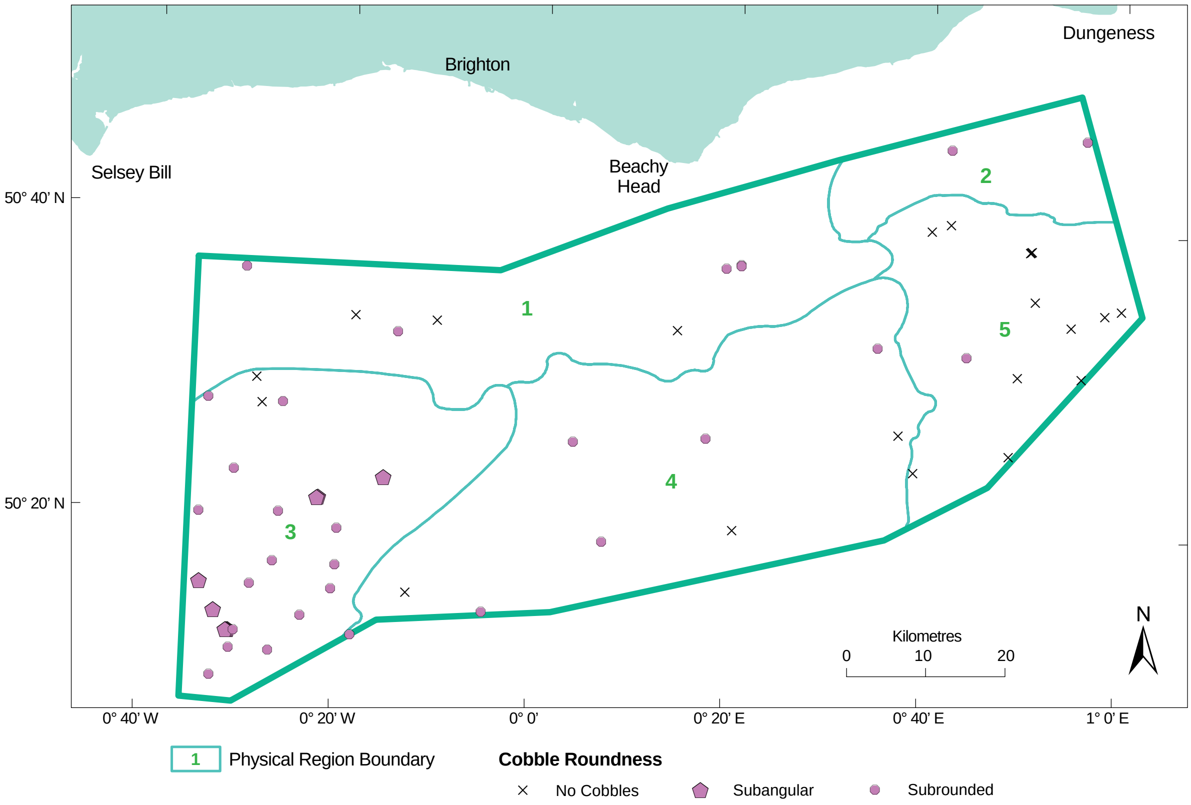


Figure 5.51. Principal cobble roundness interpreted from camera sledge photo stills.

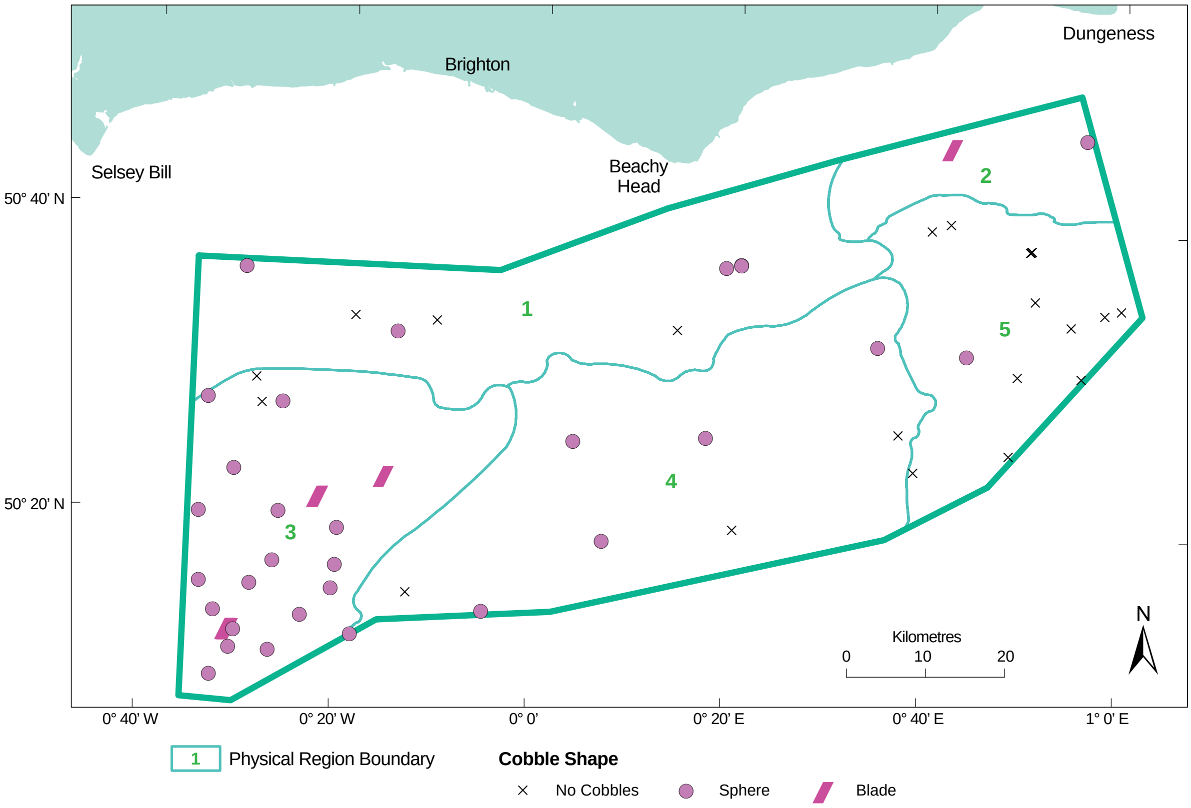


Figure 5.52. Principal cobble shape interpreted from camera sledge photo stills.

5.3 Biology

Separate biological analyses are presented below of the three main biological sampling techniques, Hamon grab, 2-metre beam trawls and video/still photography. The general approach to the analyses has been outlined in Chapter 4, but specific approaches for each analysis differed, due to the different nature of the information collected by each sampling technique. Consequently, some methodological details are included below.

5.3.1 Analysis of benthic infauna from Hamon grab samples

A total of 225 successful 0.1 m^2 Hamon grabs were collected within an area of approximately 5090 km^2. This section presents the results of the benthic infauna analysis conducted for the EECMHM study. The total abundance of individuals ranged from 50 to 6820 per 0.1 m^2 across the study area. Overall, higher values were found in the regions where a coarser and a mixture of sediment types were observed. Total number of species ranged from 2 to 20 species per 0.1 m^2 over the area (not including the colonial organisms) (Figure 5.53a-b). When colonial organisms were included in the overall species count the number of species ranged from 5 to 82 per 0.1 m^2 over the area. It may be noted that higher values for number of species were encountered in Region 2 and 4, where a combination of gravelly muddy sand, sandy gravel and gravelly sand was observed. Shannon diversity ranged between 0.13 to 2.5. The values for Pielou evenness were found to vary from 0.13 to 0.9 (Figure 5.53c-d). Overall, there was no evidence from univariate indices of a marked gradient of change across the study area.

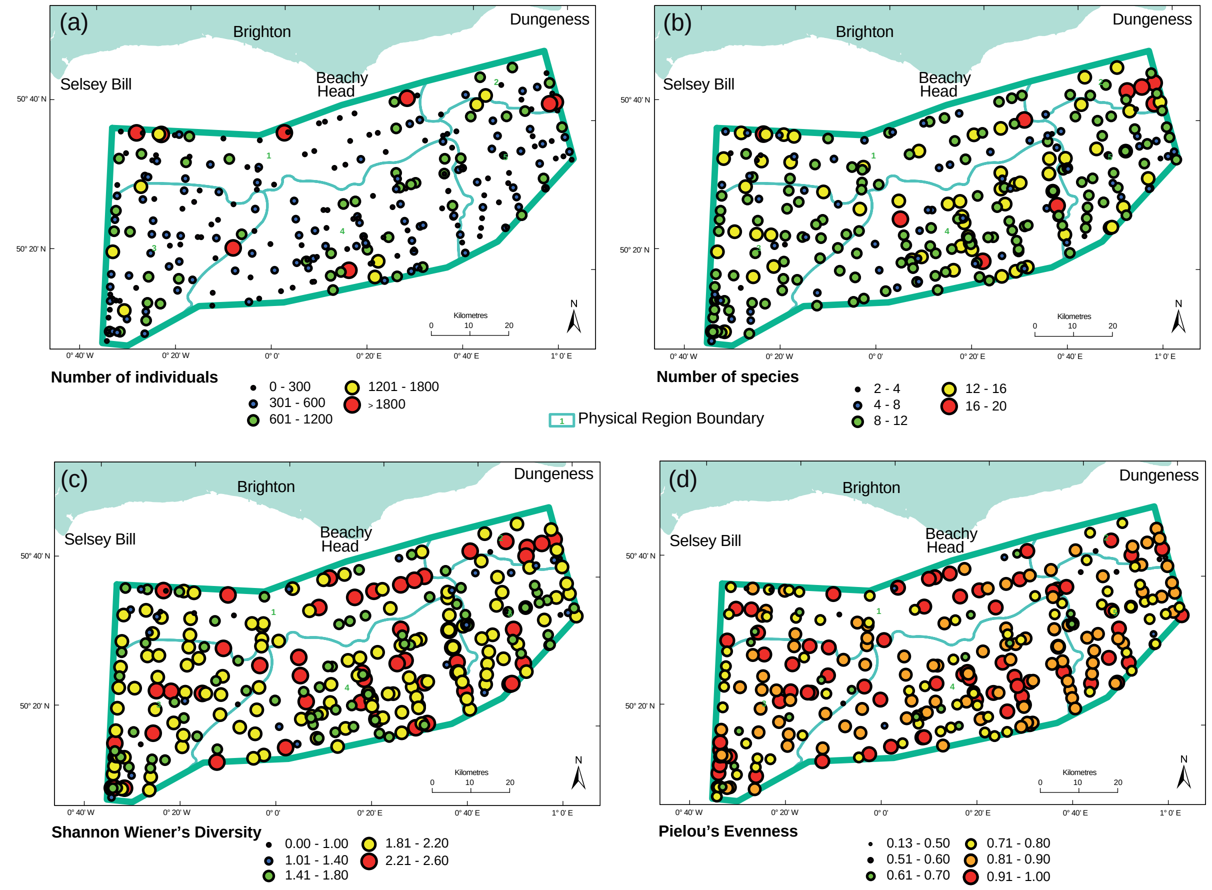


Figure 5.53. Univariate measures for infaunal data: (a) total number of individuals, (b) total number of species, c) Shannon diversity index and (d) Pielou evenness.

Physical environment

A suite of nineteen physical variables (Table 4.3) was available for testing with the biological data. Variables such as temperature and salinity were not included in the analysis since subtle gradients were not expected to be influential, given the relatively broad geographical scale and uniformity in hydrographic condition under investigation.

The sediment composition was observed to be an admixture of sand, gravelly sand and sandy gravel (Region 2 and 5) and sandy gravels and some muddy sandy gravels (Region 3 and 4) over the study area (Section 5.2.4). Depth also ranged from 71 metres (Region 3 and 4) to 23 metres (Region 2 and 5). The biomass data were obtained from the 0.1 m^2 Hamon grab samples (Chapter 4, section 4.2.4 presents details of the laboratory procedures). The biomass values of colonial organisms (in grams) were considered in the analysis as physical variables, since they represent structural entities providing attachment, protection and habitats for other organisms present in the area.

Principal Components Analysis (PCA) (Figure 5.54) was conducted using the following physical variables: colonial biomass, mean particle size (phi), sorting, skewness, kurtosis, tidal current spring (tidal data in m s^{-1} courtesy of M.J. Howarth, Proudman Oceanographic Laboratory), average of depth, sediment diversity (Sed_d, this data was calculated in the DIVERSE routine in PRIMER and was derived from sediment percentages) and sediment evenness (Sed_J' data was calculated in the DIVERSE routine in PRIMER and was derived from sediment percentages). Results from the PCA ordination showed a distinct set of clusters of stations. The Folk classification groups were overlain on to the PCA results to assess the patterns present in the study area. A clear W-E gradation of sediment types occurs in the area, from coarse sediments (gravels) to sands, respectively. The distribution of the samples along the PC1 axis accounted for 42% of the variability, and could be explained mainly by the mean particle size (phi) and the inverse variation of sorting, tidal current spring and sediment diversity index. PC2 represented a further 14% of the variability, which was associated principally with sediment evenness (Sed_J') (Table 5.2). Overall, the area is influenced by a combination of factors. Particle size and tidal currents were the most influential variables in accounting for patterns in the PCA output.

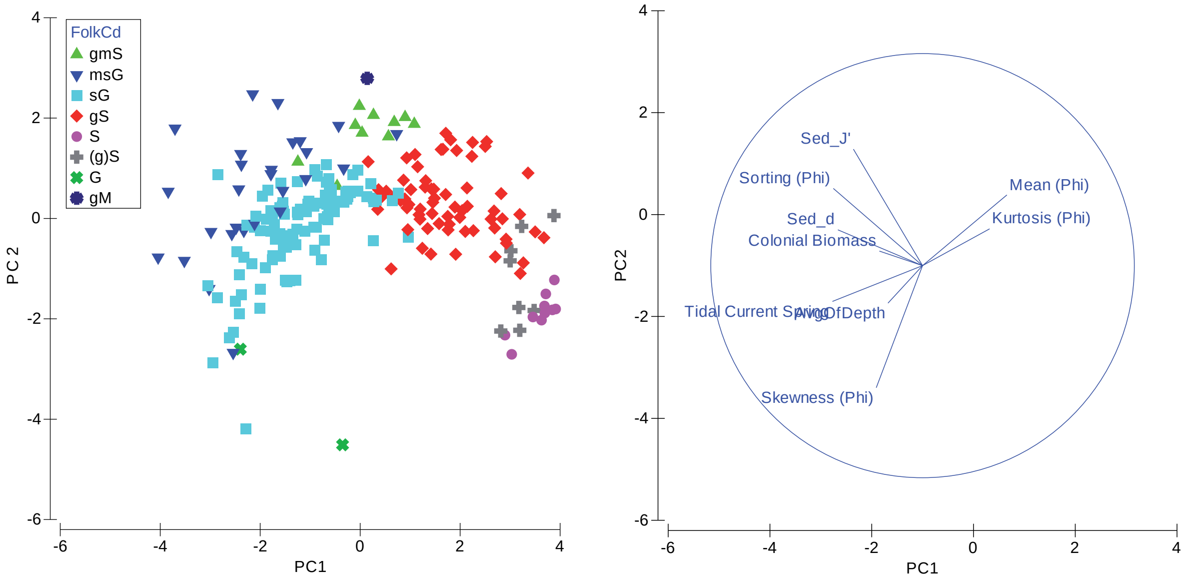


Figure 5.54. Principal Components Analysis (PCA) of physical variables (colonial biomass, mean (phi), sorting, skewness, Kurtosis, Tidal current spring, average of depth, sediment diversity (Sed_d) and sediment evenness (Sed_J') at infaunal station in Eastern English Channel over 2005-2006 overlaid with Folk Classification codes.

Figure 5.55. Non-metric multidimensional scaling ordination (MDS) using Euclidean distance similarities measure for normalised sediment data for 2005-2006 overlaid with Folk Classification codes.

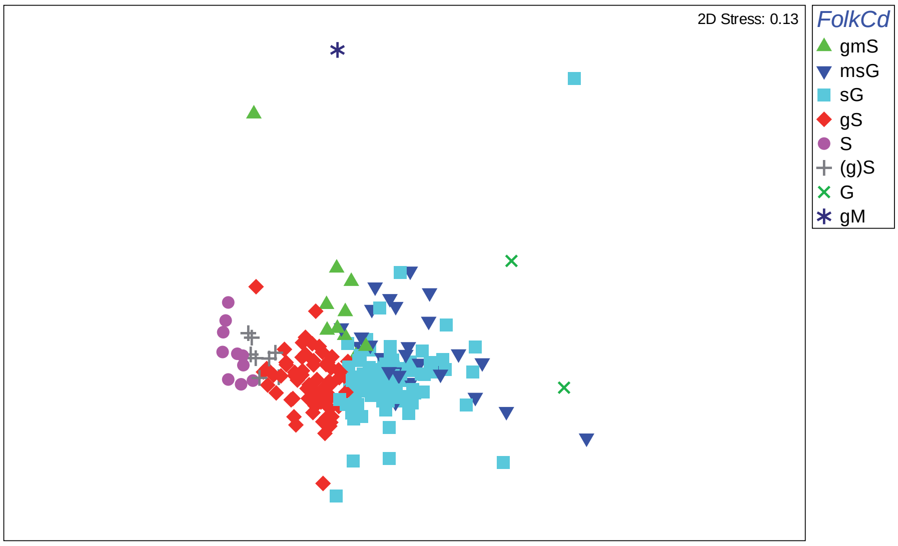


Table 5.2. Eigenvector values for the main axis PC1 and PC2 for the Principal Component Analysis of the physical variables and colonial biomass for the 225 stations during 2005-2006.

Variable	PC1	PC2
Colonial Biomass	-0.204	0.069
Mean (Phi)	0.398	0.334
Sorting (Phi)	-0.421	0.364
Skewness (Phi)	-0.219	-0.576
Kurtosis (Phi)	0.317	0.174
Tidal Current Spring	-0.426	-0.169
AvgOfDepth	-0.163	-0.177
Sed_d	-0.4	0.169
Sed_J'	-0.327	0.549

Figure 5.55 shows multivariate results for the sediment data. Six main clusters were identified over the study area. The codes from the Folk Classification scheme were overlain on the multidimensional ordination to illustrate the distinctions between the main clusters. It can be seen that a variety of sediment types were encountered in the area. The main cluster observed corresponded to a combination of gravelly sand (gS), sandy gravel (sG) and sand (S). Stations characterised by the presence of mixed sediment (msG) were relatively sparsely distributed and are located towards the right of the main cluster in the ordination (Figure 5.55).

Biological composition

All data from Hamon grab samples (i.e. including colonial organisms) were employed in the analysis. Colonial organisms were represented as units of occurrence (a value of 1 to record their presence) to enable analysis with the rest of the infaunal data. The data collected with the Hamon grab reflected the high presence of colonial organisms. It was important to determine whether there was an association between the distribution of colonial organisms and the infaunal abundance in the area. To facilitate testing, a sub-set of the data were examined. Correlation analysis demonstrated that there was a significant positive relationship between the biomass of colonial organisms and the densities of infauna (R^2=66.3%, P<0.001) (Figure 5.56).

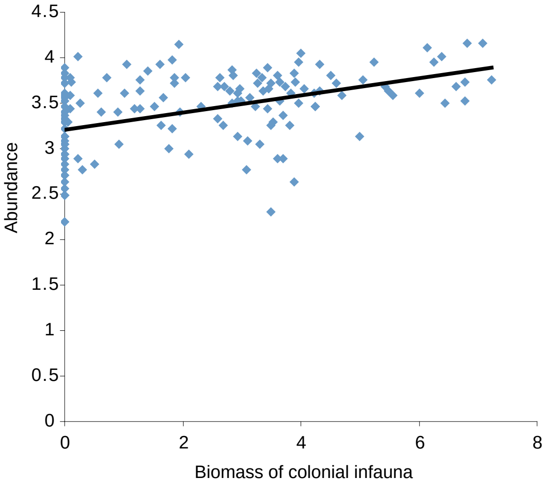
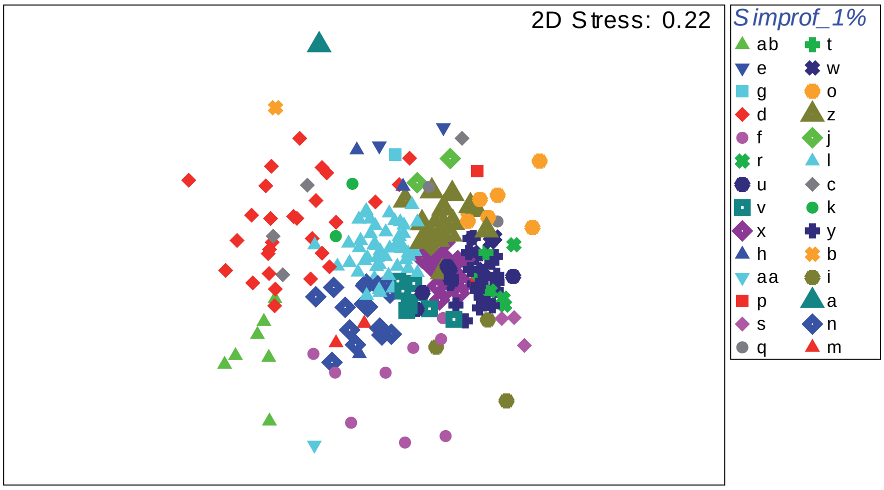


Figure 5.56. Correlation of the biomass of colonial organisms and the numbers of infaunal organisms obtained from 0.1 m^2 Hamon grab samples.

Multivariate techniques (SIMPROF analysis with p=1%) identified the presence of twenty-eight infaunal groups (Figure 5.57 and 5.58). To reduce them to a more manageable number a selection criterion was applied, which only considered clusters that were composed of a minimum of seven stations. This approach resulted in a total of nine major groups close together in discrete locations. The majority of stations were grouped under clusters l, d, y, z, n and x (Figure 5.58). Additionally, there were also small groups, which were scattered throughout the study area, or

Figure 5.57. Non-metric multidimensional scaling ordination (MDS) representing clustering of the infaunal groups overlain by symbols representing 1% SIMPROF.



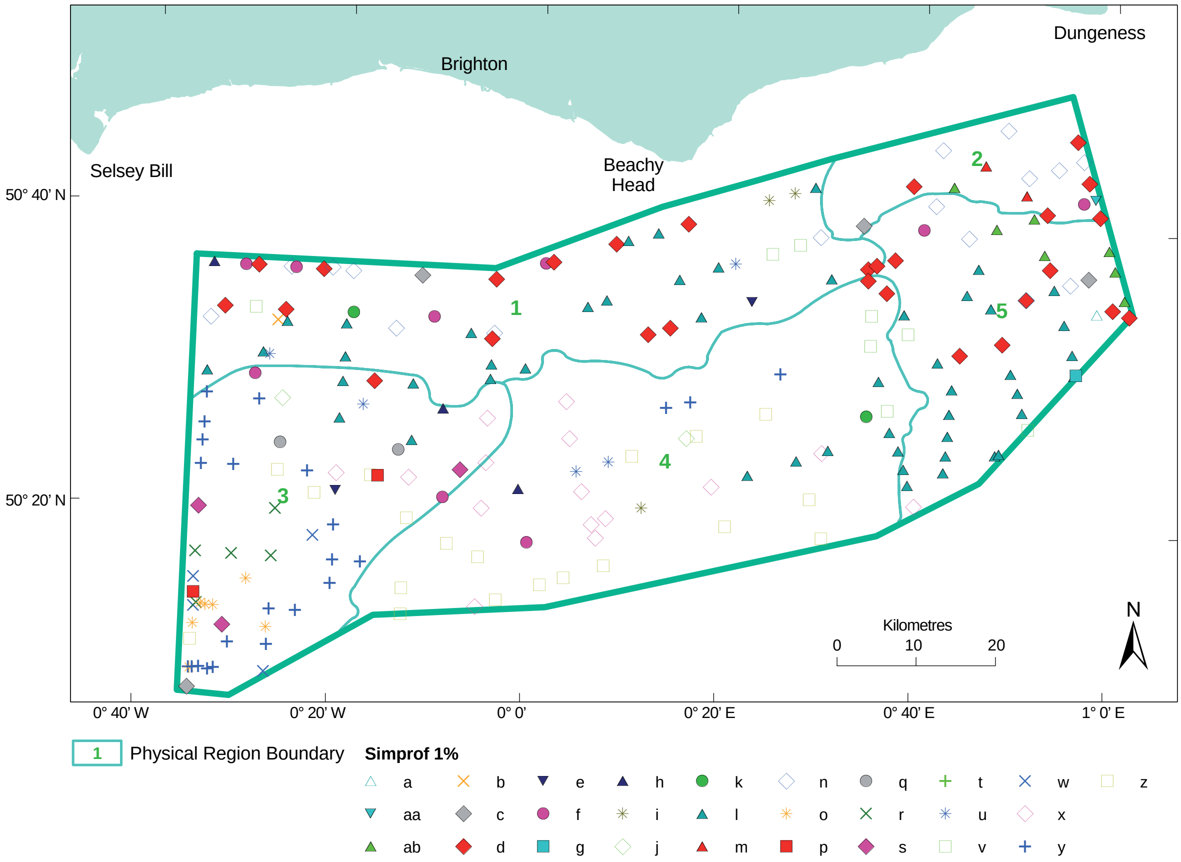


Figure 5.58. Spatial representation for infaunal biotopes.

were close together in small discrete locations. They were considered as small clusters, unless distinct aggregations were observed in the area. A clear example of a distinct small cluster can be seen in the western area formed by cluster r with 5 stations (Figure 5.58). However, there was one small cluster (cluster r), which showed a clear pattern, which we have chosen to include in our result section.

SIMPER analysis was employed to identify the key species contributing to the nine main groups plus the additional small group (Table 5.3). SIMPROF analysis at the 1% significance level separated the nine main clusters. These cluster groups were fitted into the Marine Habitat Classification for Britain and Ireland (Connor *et al.*, 2004).

Table 5.3. Summary of infaunal clusters obtained from the multivariate analysis (SIMPROF, p=1%)

Infaunal cluster	Number of samples	Characterising species and sediment description
L	49	Sandy gravel sediment present. High abundance of *Echinocyamus, Aonides, Glycera* and *pomatoceros* encountered.
D	28	Sandy gravel and mixed sediment present. High abundance of *Echinocyamus* and polychaetes from the genus *Spio*, *Nepthys* and *Glycera*
AB	7	Sandy substrata. High abundance of the tubicolous worm *Lagis, Spiophanes, Poecilochaetus* and *Magelona*.
X	15	Sandy with pebbles and shells. Low abundance of Paguridae, *Aequipecten opercularis* and the common brittlestar *Ophiothrix fragilis;* no other visible epifauna.
Y	23	Similar to X but with a mixture of muddy sandy gravel. High abundances of the porcelanid crab *Pisidia*, the squat lobster *Galathea* and the bivalve *Glycymeris*.
N	16	Sandy gravel substrata with high abundance of *Echinocyamus, Scalibregma, Poecilochaetus, Notomastus* and *Lumbrineris*.
F	9	Muddy sandy gravel substrata with high abundance of *Balanus, Pomatoceros* and other polychaetes.
Z	19	Sandy gravel substrata typically supporting of *Laonice*, *Ampharete*, *Pomatoceros* and *Glycymeris*.
O	7	Mixed sediment and strongly characterised by *Glycymeris* and attached epifauna including the ascidians *Dendrodoa* and *Pyura* and the tubiculous polychaete *Pomotoceros*.
R	5	Mixed sediment and strongly characterised by *Harmothoe, Ophiothrix, Nucula, Lumbrineris, Glycymeris* and *Galathea*.

These can be classified into three main categories: -

- circalittoral fine sands (l, d and ab)
- circalittoral coarse sands (x, y, n and f)
- offshore circalittoral mixed sediments (z, r and o)

Clusters z and o were polychaete-rich offshore mixed sediments with encrusting epifauna. This information was clearly limited in the infaunal data sets, and so complementary information from trawl and video was also checked to confirm the presence of these epifaunal species. Additionally, the distribution of *Ophiothrix* beds was confined to the west corner of the area, where the coarsest sediment occurred (Figure 5.85).

Clusters d, l and n showed higher numbers of the small sea urchin *Echinocyamus* with a distinct associated community of polychaetes and bivalves. Figure 5.59b shows the distribution of *Echinocyamus* over all stations. It is clear that this sea urchin is widely distributed over different habitats encountered in the study area.

The group of stations in cluster ab was very different, and characterised by high abundances of the tube-forming polychaete *Lagis* and the razor shell *Ensis*.

Groups x and y ('circalittoral coarse sediment') contained a very similar set of species and were characterised by the presence of *Galathea, Pomatoceros* and *Pisidia*. One of the most notable differences between these two clusters was the presence of *Glycymeris*, which was highly abundant in cluster x (Figure 5.59c). Nine stations were contained within cluster f; these appeared to be spatially scattered across the area. It was also noted that cobbles and pebbles with *Pomotoceros triqueter,* barnacles and encrusting bryozoa were part of this group. However, it is relevant to mention that *Pomatoceros* was found scattered across many stations throughout the study area and mainly characterised cluster F (Figure 5.59d).

The spatial distribution of the clusters is illustrated in Figure 5.58. Cluster l consisted of sandy gravel sediments running across the top of Region 1 in the west and also scattered in the Greater Bassurelle Sands (Region 5). This was mainly dominated by the presence of *Echinocyamus pusillus, Pomotoceros,* and *Galathea* in fine sands. Cluster d was the second most abundant group of stations, and characterised by *Echinocyamus, Nephtys* and *Glycera.* These stations occurred in similar areas to those of cluster l. Stations in clusters x and y were encountered predominantly in the Central Axial Platform and the Western Axial Platform (Region 4 and 3 respectively), where coarse sediment was present, characterised by the predominance of *Galathea, Pomatoceros*, *Pisidia* and (group y only) the presence of *Glycymeris.*

Cluster z was composed of 19 stations and observed mainly along the central area (Region 4) with a few stations located in Region 3 characterised by mixed sediments (i.e. gravelly sand and muddy sandy gravel) offshore and a polychaete-rich community. Cluster n was a very distinct community located in the two corners of the study area (Region 2 and Region 1), associated with gravelly sand and sandy gravel sediments with *Notomastus* and *Lumbrineris.*

In the study area distinct but smaller clusters (with 7 to 9 stations) were also identified (i.e. ab, o and v) which supported distinct communities. These were also included in the general description for biotopes in Table 5.5. Cluster v was mainly composed by the same species noted under

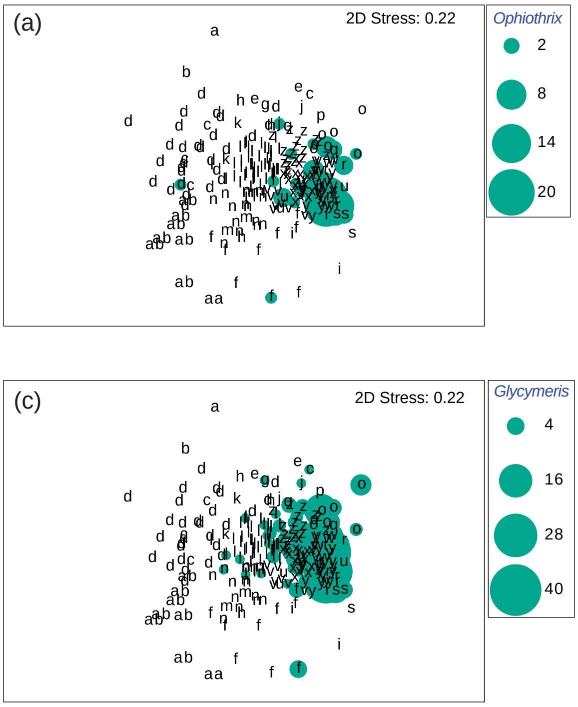


Figure 5.59. Non-metric multidimensional scaling ordination (MDS) computed for untransformed data for species abundances for 2005-2006. Superimposed upon the MDS output are the densities of: (a) *Ophiothrix*, (b) *Echinocyamus*, (c) *Glycymeris*, and (d) *Pomatoceros*. Letters as for clusters in Figure 5.58.

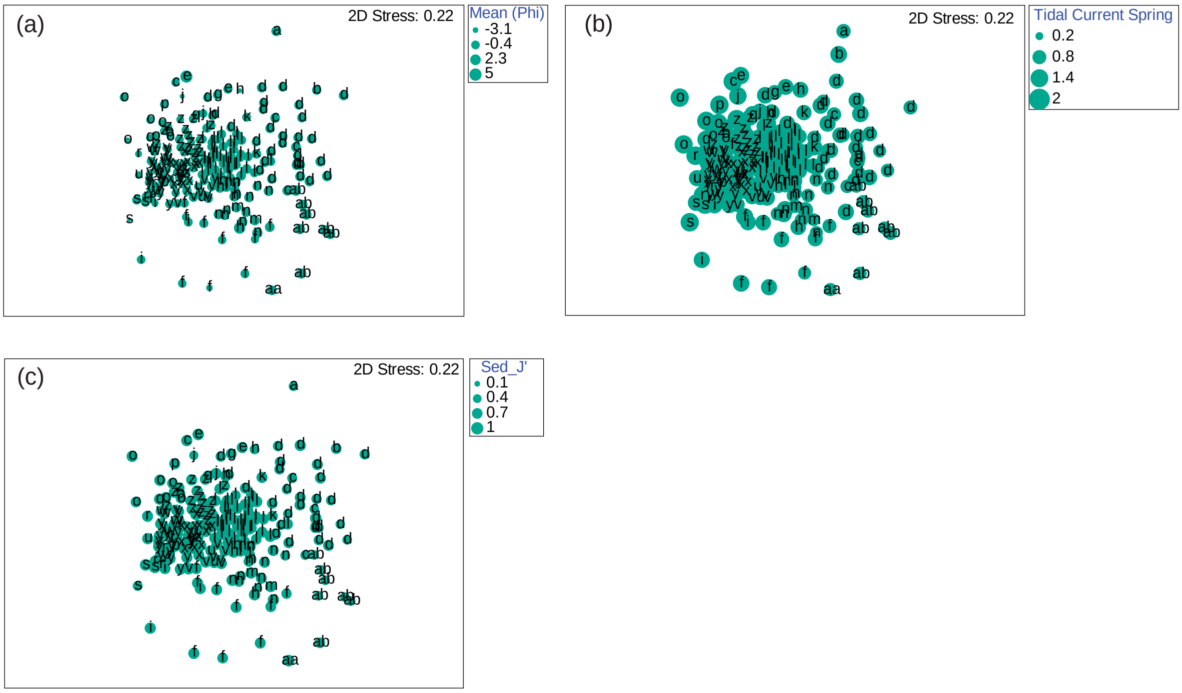


Figure 5.60. Non-metric multidimensional scaling ordination (MDS) computed for untransformed data for species abundances for 2005-2006. Superimposed upon the MDS output are: a) mean (phi), b) tidal current spring and c) sediment evenness.

Table 5.4. Summary of BEST results.

No. Vars	Correlations	Selections
4	0.565	2,16,18,19
5	0.563	2,3,16,18,19
5	0.56	2,5,16,18,19
5	0.553	2,16-19
5	0.55	1,2,16,18,19
5	0.548	3,5,16,18,19
5	0.548	2,3,5,16,18
4	0.546	2,3,16,18
4	0.541	5,16,18,19
3	0.541	16,18,19

cluster I. Therefore this was considered to be a variant of cluster I rather than a new biotope group.

Bio-Env analysis was employed to provide the ‘best’ match between the multivariate sample patterns and the suite of environmental variables associated with those samples. Results showed that community composition was best represented by a combination of mean particle size, tidal current spring, sediment diversity (Sed_d) and sediment evenness (Sed_J’) (Table 5.4). The main variables resulting from Bio-Env analyses were superimposed upon the infaunal multidimensional scaling ordination. Examples of the patterns are plotted in Figure 5.60.

Infaunal biotope distribution

Samples were grouped into nine main biotopes and one small cluster and classified under the Marine Habitat Classification for Britain and Ireland v 04.05 (Connor *et al.*, 2004). It is widely acknowledged that this classification system is limited in terms of its capability to describe offshore biotopes due to a lack of available information on these at the time of its original construction. An attempt was made in this study to match the infaunal biotopes with the existing classification. It was clear that there were few direct matches, although several of the existing biotopes were near matches. Finally this study erected new biotope descriptions and codes following the existing format in Connor *et al.*, 2004. Table 5.5 summarises the translation of infaunal clusters into biotopes and the closest matches to the Marine Habitat Classification.

In this section the use of biotope numbers from 1 to 9 was adopted to represent the cluster groups obtained from the multivariate analysis (Figure 5.61). A total of nine biotopes were identified from this study (see Table 5.5 for details and Figure 5.62 for spatial representation). Biotope 4 was also further divided into 4a and 4b, due to relatively subtle differences in species composition. Group x (colour-coded as orange triangles) was adopted to represent all other groups that were not considered to be major infaunal biotopes (Figure 5.62).

Figure 5.61. Non-metric multidimensional scaling ordination (MDS) displaying the main biotope groups according to the Marine Habitat Classification for Britain and Ireland (v 04.05), together with unclassified stations and results from single point station.

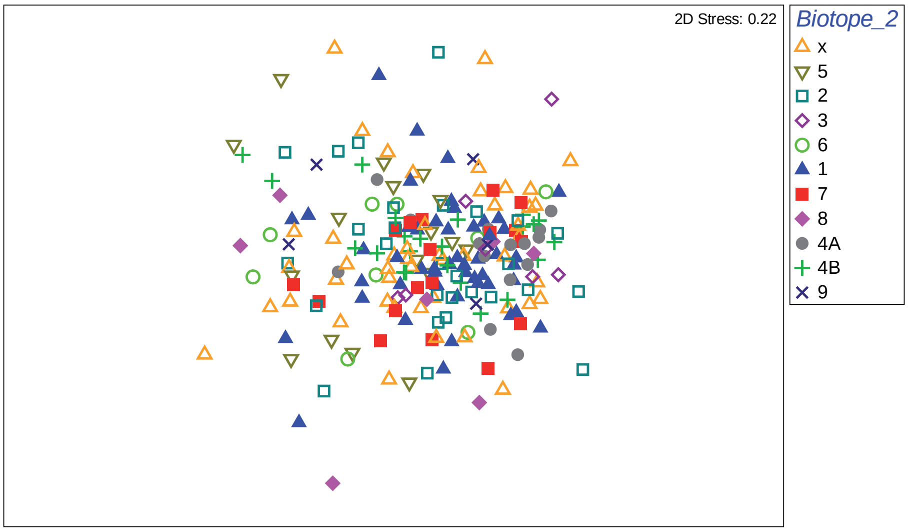


Table 5.5. Summary of sediment and species characteristics of regional biotopes in the study area, based on (and adapted from) The Marine Habitat Classification for Britain and Ireland (version 04.05). See Figure 6.1, 6.3 and Map 1 for regional distribution.

Infaunal Biotope	Description	Primer cluster	Marine Habitat Classification Biotope equivalent
SS.SSA.CFiSa.EpusPomGal (Infaunal Biotope 1 – IB1)	'*Echinocyamus pusillus, Pomatoceros*, and *Galathea* in circalittoral fine sand'. This group contains a variety of crustaceans and polychaetes. A slightly coarser element to the substrata gives rise to the presence of species more typical of gravel biotopes such as *Galathea* and *Pomotoceros*. This group is most closely related to the *Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand classification.	L	SS.SSA.CFiSa.EpusOborApri
SS.SSA.CFiSa.EpusNephGlyc. (Infaunal Biotope 2 – IB2)	'*Echinocyamus pusillus, Nephtys* and *Glycera* in circalittoral fine sand'. This group is most closely related to the existing biotope formed by *Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand according to the description provided in Connor *et al.,* 2004. Differences in the fauna compared with the original classification may be attributable to the more limited information available at the time. The species presences can still fit into a more 'relaxed' version of this biotope.	D	SS.SSA.CFiSa.EpusOborApri
SS.SSA.CFiSa.Lkor.Ens. (Infaunal Biotope 3 – IB3)	'*Lagis koreni* and *Ensis* found in circalittoral fine sand'. This group is VERY closely related to the existing description with *Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud.	AB	SS.SMU.CSaMu.Lkor.Ppel
SS.SCS.CCS.Gal.Pom.Pis(Eun) (Infaunal Biotope 4a – IB4a))	'*Galathea* and *Pomotoceros* with *Pisidia* and *Eunice* in circalittoral coarse sediment'. There is no real match with the existing MNCR biotope classification: the nearest category is the *Pomotoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles. It is likely to be a similar predominantly coarse sediment biotope but a small amount of finer sediment indicated by the lack of attached epifauna.	X	SS.SCS.CCS.PomB
SS.SCS.CCS.Gal.Pom.Pis(Gly) (Infaunal Biotope 4b – IB4b)	'*Galathea* and *Pomotoceros* with *Pisidia* and *Glycymeris* in circalittoral coarse sediment'.Very similar community composition to Group 4a with the addition of *Glycymeris* although great significance should not be placed on this difference as these *Glycymeris* are very widely separated spatially and not sampled effectively using the grab. No real match with existing MNCR biotope classification.	Y	SS.SCS.CCS.PomB
SS.SCS.CCS.Not.Lum (Infaunal Biotope 5 – IB5)	'*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel'. This biotope contains low numbers of venerid bivalves and *Notomastus*. The polychaete *Mediomastus* is performing the same function in the community. There is an overall very good agreement between the fauna. A more 'relaxed' version of this biotope will better match these data (i.e. *Capitellids* with *Lumbrineris* and occasional venerid bivalves).	N	SS.SCS.CCS.MedLumVen
SS.SCS.CCS.PomB (Infaunal Biotope 6 – IB6)	This biotope is represented by 9 stations that are spread throughout the study area. It is characterised by *Pomatoceros triqueter* with barnacles and encrusting bryozoans on unstable circalittoral cobbles and pebbles as described in Connor *et al.*, 2004.	F	SS.SCS.CCS.PomB

Table 5.5. continued: Summary of sediment and species characteristics of regional biotopes in the study area, based on (and adapted from)The Marine Habitat Classification for Britain and Ireland (version 04.05). See Figure 6.1, 6.3 and Map 1 for regional distribution.

Infaunal Biotope	**Description**	**Primer cluster**	**Marine Habitat Classification Biotope equivalent**
SS.SMX.OMx.Po (Infaunal Biotope 7 – IB7)	'Polychaete-rich offshore mixed sediments. This group is very closely related to a Polychaete-rich deep *Venus* community in offshore mixed sediments'. Only a minimal occurrence of venerid bivalves in these samples, which may be a function of sampling; a more 'relaxed' version of this biotope will better match these data.	Z	SS.SMX.OMx.PoVen
SS.SMX.OMx.PoGlyEpi (Infaunal Biotope 8 – IB8)	'Polychaete-rich offshore mixed sediments with *Glycymeris* and attached epifauna'. Most closely related to a Polychaete-rich deep *Venus* community in offshore mixed sediments. Only limited occurrence of venerid bivalves, strongly characterised by *Glycymeris* and attached epifauna including the ascidians *Dendrodoa* and *Pyura* and the tubiculous polychaete *Pomatoceros*.	O	SS.SMX.OMx.PoVen
SS.SMX.CMx.OphMX (Infaunal Biotope 9 – IB9)	This is a small but very distinct biotope, located in circalittoral coarse sediment with *Harmothoe, Ophiothrix, Nucula, Lumbrineris, Glycymeris* and *Galathea*. The existing MNCR biotope classification only describes the presence of *Ophiothrix* and epifauna; the allocation of biotope code was solely based on sediment and abundant presence of *Ophiothrix*.	R	SS.SMX.CMx.OphMX

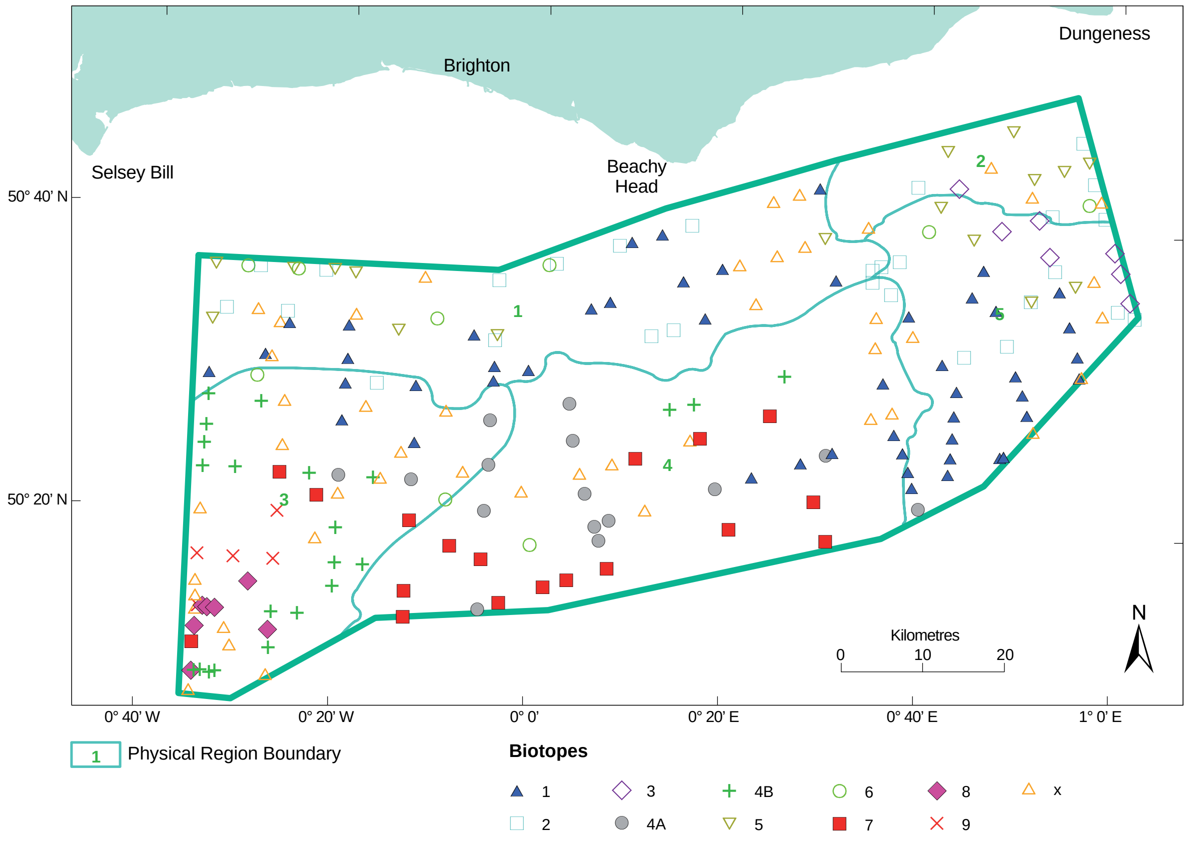


Figure 5.62. Spatial representation of the nine main biotopes erected from this study.

EECMHM and REA infaunal data

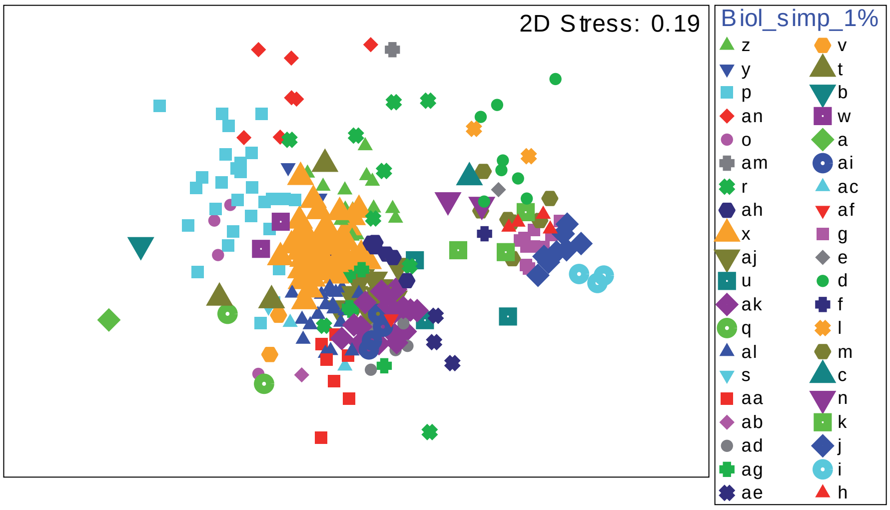
The first stage of this work was to analyse the data to determine the presence of biotopes in the area. It was clear that during the survey planning stage there was a limited set of samples placed in Region 4 where the majority of aggregate resources are known to exist. To augment the data in the central area generated under the present contract a selection of stations positioned within the geophysical survey zone was also extracted from existing industry reports to cover Region 4.

A total of 50 stations from the Regional Environment Assessment conducted by the aggregate industry during the 1990s (MES, 2002) were included in the analysis for the EECMHM study. These stations were located in the centre of the area (mainly Region 4) (Figure 4.32) where a consortium of aggregate companies (ECA) identified sand and gravel deposits, with potential for commercial exploitation. The data from the EECMHM were pooled with the selected industry stations. The analysis to determine the presence of biotopes in the area was conducted only at the Genus level to avoid taxonomic errors. This was mainly to assess the biological distribution in Region 4. There was also some limitation in terms of the availability of physical data, which was collected in parallel with the biological component. The sediment data from industry contained fewer size categories, which made it difficult to match with the data collected by this study.

A multivariate analysis was performed to compare the clustering patterns of both sets of data. The data were also compared in terms of number of species, number of individuals and species composition lists. This comparison showed similar number of species and number of individuals, indicating that the combined data were 'fit for purpose' to augment the central area of our study. Multivariate analysis was conducted using 275 (EECMHM and REA) grab samples identified to the genus level. The inclusion of the earlier data provided improved spatial resolution for the central area (Region 4). From SIMPROF analysis (p=1%) of the combined data, a total of 40 main clusters were identified. The same criteria used previously with the EECMHM data were employed to reduce the number of clusters, considering only the clusters with a minimum of seven stations resulting in 14 main clusters (aa, ah, aj, ak, al, an, d, g, j, m, p, r, x and z). Additionally, a series of 7 small clusters (ad, ag, ai, h and o) were also identified over the entire area (Figure 5.63 and 5.64). The footprint of the biotopes initially identified with only the MEPF data sets remained consistent in the area. Specific variations were noted in Region 4 with the addition of samples. One specific example can be seen in cluster g, which is located in Region 4. This cluster appeared to be different, although results from SIMPER analysis revealed a more detailed level of resolution in terms of the species comprising this biotope. The species composition was similar to the biotope IB4a identified as part of the EECMHM infaunal analysis. The only difference observed was in the number of *Ophiothrix* observed in the SIMPER analysis.

Overall, the inclusion of REA data in the present study has benefited the level of detail in terms of community associations in the central area. Spatially this has provided an enhanced level of resolution in the central southern areas where there were data gaps. One of the main limitations in combining the two sets of data was the lack of environmental variables to conduct a full assessment of the biological and physical information at the site. Nevertheless, this information has the potential to contribute with the management of species and habitats to allow a consistent management of the site.

Figure 5.63. Non-metric multidimensional ordination (MDS) representing clustering of MEPF and REA infaunal groups overlain by symbols representing 1% SIMPRO.



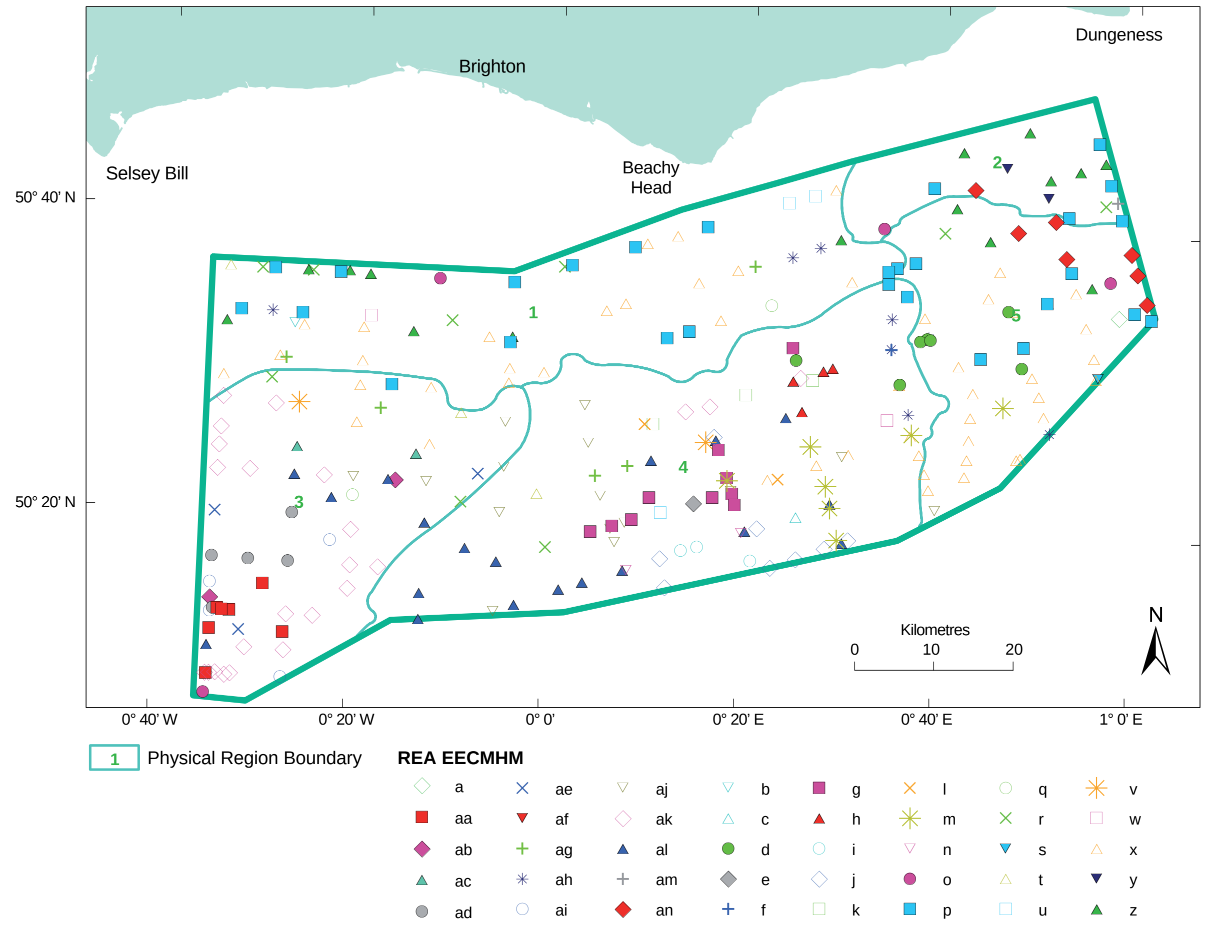


Figure 5.64. Spatial representation of the 14 main clusters and single point station resulting from the multivariate analysis for the EECMHM and REA grab data.

5.3.2 Analysis of benthic epifauna from 2-metre beam trawl samples

A total of 262 taxa were identified at the 73 stations sampled by 2-metre beam trawl (Table 5.6 and Figure 4.35). Of these taxa, Molluscs were the most commonly encountered group (25.5%) followed by Crustacea (19.1%), Chordata (17.9%), Annelida (8.4%) and Echinodermata (6.5%) (Figure 5.65). Catch volume was usually from 10 to 50 litres, but occasionally much greater (max 202 l) when a large amount of substrate was collected.

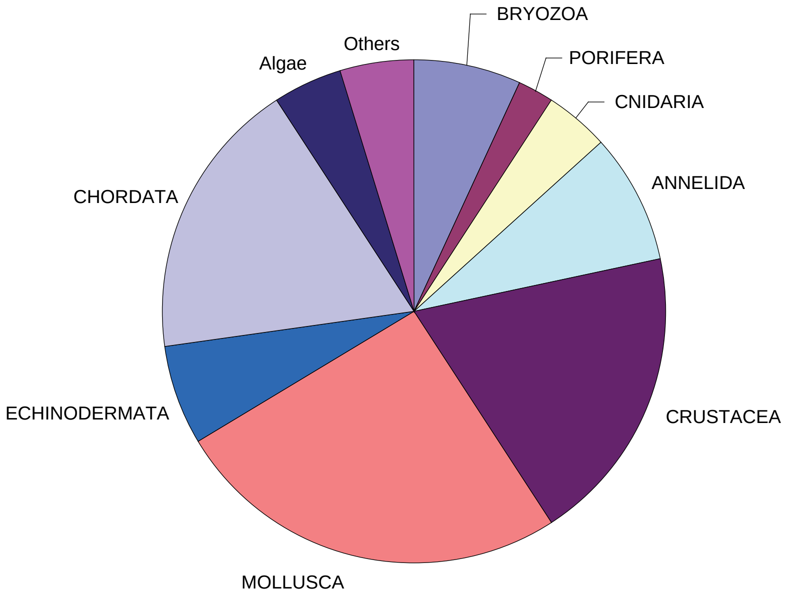


Figure 5.65. Relative proportions of major groups among the 262 taxa identified from 2-metre beam trawl samples.

Table 5.6. Summary of taxonomic groups represented among the 262 taxa sampled by 2-metre beam trawls.

Major groups	%	Minor groups	Number
Bryozoa	6.8	Gymnolaemata	13
		Stenolaemata	4
		Bryozoa	1
Porifera	2.3	Demospongiae	4
		Calcarea	1
		Porifera	1
Cnidaria	4.2	Hexacorallia	7
		Hydrozoa	3
		Octocorallia	1
Annelida	8.4	Polychaeta	21
		Hirudinea	1
Crustacea	19.1	Decapoda	41
		Isopoda	5
		Amphipoda	1
		Thoracica	2
		Stomatopoda	1
Mollusca	25.5	Gastropoda	35
		Pelecypoda	23
		Polyplacophora	3
		Cephalopoda	5
		Solenogastres	1
Echinodermata	6.5	Ophiuroidea	5
		Asteroidea	4
		Echinoidea	4
		Holothurioidea	3
		Crinoidea	1
Chordata	17.9	Osteichthyes	33
		Ascidiacea	13
		Chondrichthyes	1
Rhodophyta	0.8	Rhodophyceae	2
Chromophyta	3.1	Phaeophyceae	8
Chlorophyta	0.8	Chlorophyceae	1
		Ulvophyceae	1
Others	4.6	Hydroids	7
		Pycnogonids	2
		Branchiostoma	1
		Sipunculidea	1
		Ciliophora	1
Total	100		262

As outlined in the methods section (Chapter 4), data were analysed following a multivariate approach to community analysis (Clarke and Warwick, 2001), using the routines available in PRIMER v6 (Clarke and Gorley, 2006). These were applied in a 3-part process, firstly to identify distinct epifaunal communities using trawl sample data, secondly to examine patterns in the measured environmental variables, and thirdly to identify any relationship between the multivariate patterns in the biotic and abiotic data. The results were examined in conjunction with the geophysical interpretation of the study area and the UK Marine Habitat Classification system, to assign and map putative biotopes.

Data preparation

Both biological and environmental data underwent some manipulation prior to the PRIMER analysis. The biological analysis was based on a species abundance matrix which provided actual counts for the vast majority of taxa. Where an order of magnitude estimate had been made for abundance, recording 'Tens', 'Hundreds' or 'Thousands', the numerical equivalent of 10, 100 or 1000 was substituted. This method of estimation had been used primarily for encrusting, non-colonial species that proved impractical to enumerate in beam trawl samples, such as barnacles or *Pomatoceros sp.*

No count had been made for colonial organisms (e.g. Hydroids, *Alcyonium*) or algae, but their presence had been noted with a 'P'. In these cases, the 'P' was replaced by the recorded biomass, rounded to the nearest gram. It was reasoned that this was a consistent and equitable method of representing the relative presence of colonial organisms, as they usually had a density approximating to that of seawater, so the biomass value would be a consistent measure across different colonial taxa and was considered preferable to recording their presence as unity (1). The validity of this augmentation of the abundance data was considered at length, and it is recognised as a short-term practical expedient that requires further investigation. However, the over-riding purpose of the analysis was to identify assemblages of biota such that they could be matched with the existing MNCR biotope classification, and on some substrata colonial organisms were demonstrably of great structural and functional importance. The maximum score assigned to a colonial organism in this way was 403, for *Alcyonium digitatum.*

The manipulation of environmental data was more straightforward, and applied only to the data from particle size analysis (PSA). Here, the raw data were aggregated into 1-phi and 2-phi size classes, and assigned labels that would be used within the analysis (Table 5.7).

Table 5.7. Explanation of labels used to identify PSA data aggregated to 1-phi and 2-phi bin sizes (V = very, C = coarse, M = medium, F = fine, P and Pebl = pebble, S = sand

Sieve size (metric)	Sieve size (phi)	1-phi bin label	2-phi bin label
>63 mm	-6	Cobbles	Cobble
45 mm	-5.5	VCP	
31.5 mm	-5		Pebl1
22.4 mm	-4.5	CP	
16 mm	-4		
11.2 mm	-3.5	MP	
8 mm	-3		Pebl2
5.6 mm	-2.5	FP	
4 mm	-2		
2.8 mm	-1.5	Granule	
2 mm	-1		Grain
1.4 mm	-0.5	VCS	
1 mm	0		
710 µm	0.5	CS	
500 µm	1		Sand1
355 µm	1.5	MS	
250 µm	2		
180 µm	2.5	FS	
125 µm	3		Sand2
90 µm	3.5	VFS	
63 µm	4		
44.2 µm	4.5		
31.3 µm	5		
22.1 µm	5.5		
15.6 µm	6	Silts	Silt
11 µm	6.5		
7.8 µm	7		
5.5 µm	7.5		
3.9 µm	8		
2.75 µm	8.5		
1.95 µm	9		
1.38 µm	9.5		
0.98 µm	10		
0.69 µm	10.5		
0.49 µm	11		
<0.49 µm	11.5		

Epifaunal analysis, 2-metre beam trawls

Prior to analysis, the dataset was reduced by two operations; firstly removing taxa that were present in trivial amounts (<1% of the total abundance), and secondly excluding five species that were considered to be wholly infaunal in habit and so incidental to the catch (the polychaetes *Eupolymnia sp* and *Thelepus cincinnatus* and the bivalves *Spisula elliptica*, *Abra prismatica* and *Timoclea ovata*). This reduced the number of taxa from 262 to 123.

This reduced dataset was initially explored using univariate indices: the number of taxa (S), number of individuals (N), evenness (J') and diversity ($H'(\log_e)$). These are presented as georeferenced bubble plots in Figure 5.66. No systematic latitudinal trends were evident across the study area, but some local similarities were, such as a general reduction in S and N in the sand wave field in the north of Region 5. Three stations in the south west (Region 3; stations 97, 124 and 185) had a notably low diversity and evenness, attributed to the presence of large numbers of ophiuroids in the catch. Two stations in the south east (Region 5; stations 172 and 173) located on the western extension of the Bassurelle Bank had very low numbers of species, as did another station in the mid north (Region 1; station 58) also located on fine sand. These observations were later used to inform the multivariate analysis.

Prior to the multivariate analysis, a square root transformation was applied to down-weight the influence of the few highly abundant taxa (maximum abundance = 6349 *Ophiothrix fragilis* at station 124; square root = 79.7).

A series of four CLUSTER analyses were performed, each using a progressively stricter SIMPROF test (p= 5%, 1%, 0.5% and 0.1%), and these were compared to select which was most appropriate for defining clusters in the context of the current analysis. The effect of making the test progressively stricter is to merge the most similar clusters, resulting in larger but fewer (and more certain) cluster groups. In terms of community analysis, this represents a progressive relaxing of the criteria used to differentiate communities, and can be seen to be analogous to moving up the levels of a hierarchical habitat classification system (i.e. from tightly defined 'biotopes' to more loosely defined 'habitats' or 'marine landscapes'). The logical extension of this iterative process is that the SIMPROF test will be so strict that all samples are contained within a single cluster, and hence would fall under a single description, such as 'fully marine' rather than 'estuarine' or 'terrestrial' habitats. This was the outcome of the 0.1% SIMPROF test in the current analysis, so it was eliminated.

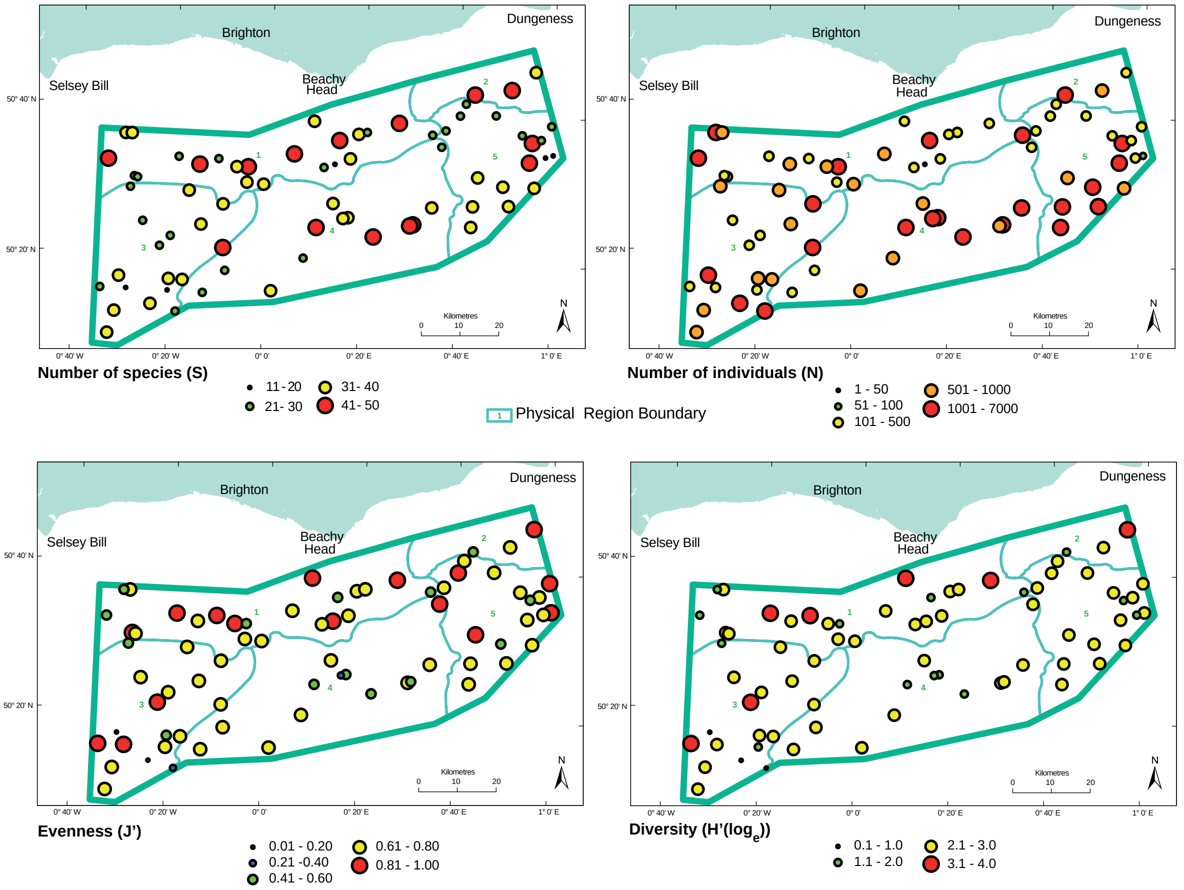


Figure 5.66. Univariate indices describing samples taken by 2 metre beam trawls at 73 stations in the EECMHM area. Number of Species (S), Number of individuals (N), Evenness (J'), Diversity (H'($\log_e$)).

Dendrograms from the three cluster analyses using 5%, 1% and 0.5% SIMPROF tests were compared, after the symbology had been harmonised across the three plots (Figure 5.67). The different groupings resulting from these tests will be referred to as the S5, S1 and S05 groups. All three groupings identified stations 58,172 and 173 as a single cluster, consistent with the univariate analyses that had recognised similarities between these stations. However, there was a difference between the S1 and S05 groupings for the set of three stations from Region 3 (97, 124 and 185) that had already been noted in the univariate analysis for their low diversity. The S1 groupings placed these stations in a separate cluster to those in the immediate surroundings within Region 3 (see Figures 5.67 and 5.68, symbols as red filled squares and red open squares), while the S05 groupings merged these two clusters into one (S05 cluster b, represented by a red filled square). Consequently, the S05 clustering was assessed as being insufficiently sensitive for the current analysis, and was eliminated. A similar consideration was given to the choice between the S1 and S5 cluster groups. As the aim of the project was to characterise broad scale habitats, there was a marginal preference to proceed with the S1 groupings as this had fewer groups in total, and fewer outliers (i.e. groups represented by a single station). The S1 groups (and group labels) were therefore adopted for the remainder of the epifaunal analysis relating to samples for the 2-metre beam trawls. The geographical distribution of these groups is mapped in Figure 5.69. Five of the groups contained only one or two stations (groups d, e, g, h and k) and were therefore considered to be insufficiently represented for regional mapping. Consequently, these were not examined further, leaving a total of nine groups, each representing three or more sampling stations.

Similarity contour lines on the MDS plot for the S1 group (top right image, Figure 5.68) suggest there were four major epifaunal assemblages, each containing a number of subgroups (31% and 40% similarity contour lines). These contours help to visualise the relationship between the various S1 group, but were not used to define any groups

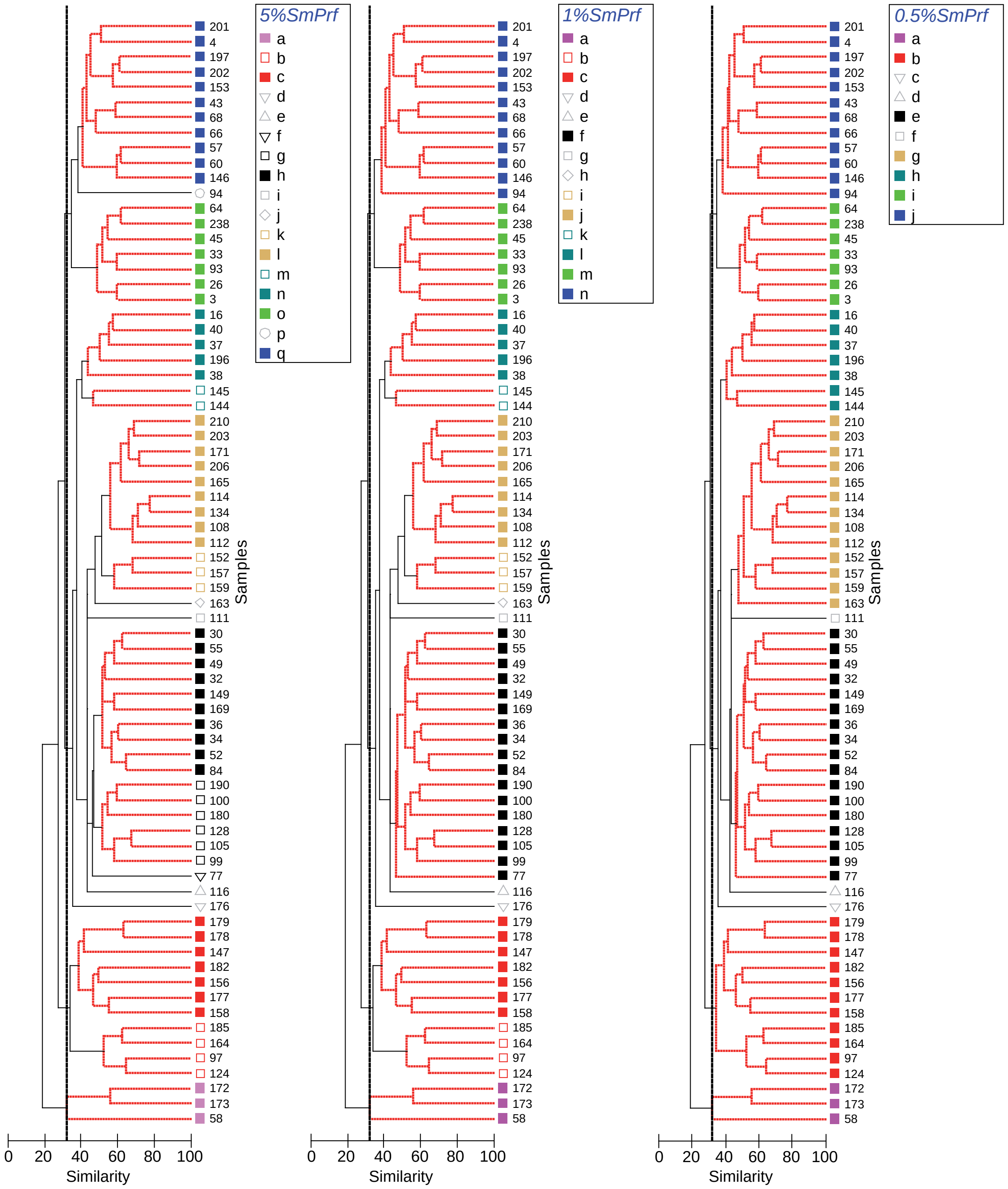


Figure 5.67. Dendrograms showing clustering of beam trawl samples based on three SIMPROF tests (p=5%, 1% and 0.5%). The word SIMPROF has been abbreviated in the Keys to 'SmPrf'. Red lines connect samples between which there is no statistical difference. Samples are assigned symbols based on their cluster group. Symbols (but not group labels) have been harmonised across the three plots. Similar colours but different symbols represent cluster groups that become merged under a stricter SIMPROF test (e.g. clusters f, g and h under the 5%SmPrf test merge into cluster f under the 1% test). A vertical line represents a similarity slice (contour) at 31%.

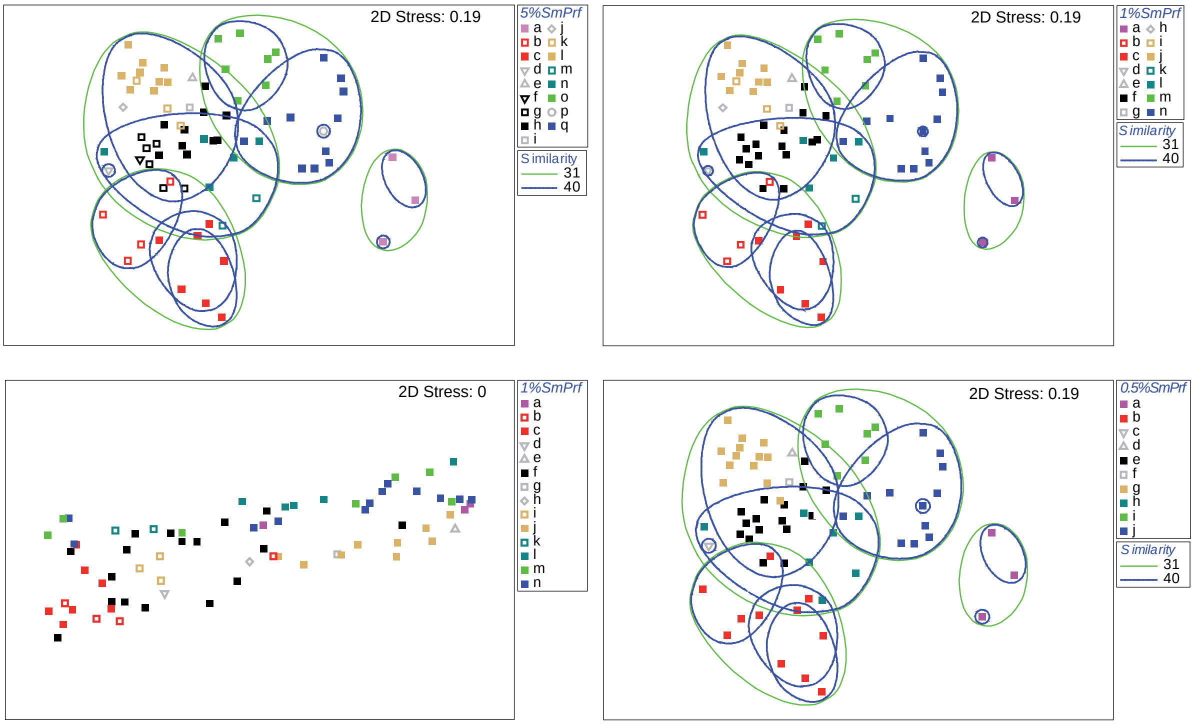


Figure 5.68. As for figure 5.67 but represented as MDS plots, with similarity contours drawn at 31 and 40%. Also, an MDS of the Latitude and Longitude of the sampling sites (bottom left) overlain by symbols representing the 1% SIMPROF, approximating to a map of the geographical distribution of groups.

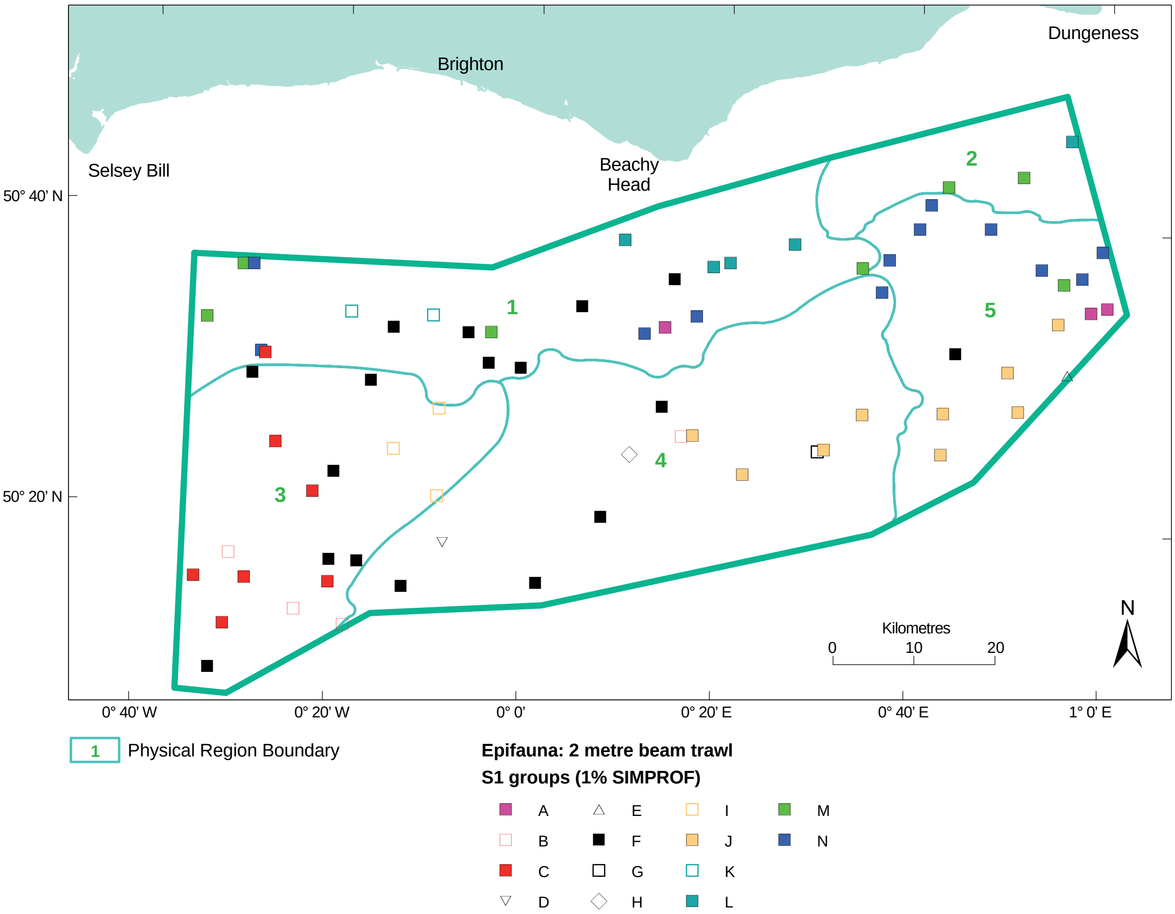


Figure 5.69. Map of the stations sampled by 2-metre beam trawls, classified according to the cluster groups identified by the 1% SIMPROF test (see text).

or clusters. (Prior to the introduction of the SIMPROF test within the CLUSTER routine, clusters would have been defined by these similarity contours).

The SIMPER routine was run to identify taxa that characterised the S1 groups (Table 5.8) and those that discriminated between groups. In the interest of brevity, the discriminant analysis is only presented for the main groups in the three major assemblages (i.e. groups b *vs* c, i *vs* j and m *vs* n; Table 5.9).

Table 5.8. PRIMER output from SIMPER analysis for 2-metre beam trawls, listing the top ranked taxa for the nine main epifaunal groups and their contributions to average similarity. Listings terminated when the cumulative % exceeds 75. Text in square brackets cross-references these epifaunal groups with the Epifaunal Biotope Complexes (EBCs) derived in Chapter 6.

Group M (7 stations)
[EBC 10 & 7] **Average similarity: 51.57**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Balanus crenatus	28.53	15.87	2.44	30.78	30.78
Hydrallmania falcata	14.22	4.47	1.32	8.68	39.46
Alcyonidium diaphanum	7.11	2.77	2.06	5.37	44.83
Pagurus bernhardus	4.75	2.63	8.17	5.09	49.92
Liocarcinus holsatus	5.91	2.12	1.7	4.11	54.03
Anapagurus laevis	3.78	1.53	1.42	2.96	56.98
Macropodia tenuirostris	3.94	1.52	1.25	2.94	59.92
Pagurus prideaux	3.22	1.51	2.55	2.92	62.85
Ophiura albida	3.66	1.41	2.33	2.73	65.57
Psammechinus miliaris	2.78	1.21	2.12	2.36	67.93
Aequipecten opercularis	5.08	1.15	0.75	2.23	70.16
Callionymus lyra	2.21	1.05	2.5	2.04	72.2
Inachus dorsettensis	2.52	1	2.82	1.93	74.14
Galathea intermedia	2.08	0.93	2.62	1.8	75.94

Group N (12 stations)
[EBC 10 & 8] **Average similarity: 43.48**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Pagurus bernhardus	4.32	4.79	3.3	11.02	11.02
Liocarcinus holsatus	5.15	4.16	1.56	9.56	20.58
Hydrallmania falcata	2.8	3.48	2.04	8.01	28.58
Anapagurus laevis	3.31	3.2	1.46	7.36	35.95
Ophiura albida	3.42	3.05	1.52	7.01	42.96
Alcyonidium diaphanum	3.44	3.04	1.53	6.99	49.95
Pagurus prideaux	2.28	2.06	2.67	4.73	54.68
Callionymus lyra	2.16	1.97	1.68	4.54	59.22
Adamsia carciniopados	1.88	1.76	2.73	4.05	63.27
Asterias rubens	1.68	1.66	1.62	3.81	67.08
Balanus crenatus	2.98	1.46	0.62	3.36	70.44
Macropodia tenuirostris	1.67	1.42	1.25	3.27	73.71
Psammechinus miliaris	2.44	1.17	0.57	2.7	76.41

Table 5.8. continued: PRIMER output from SIMPER analysis for 2-metre beam trawls, listing the top ranked taxa for the nine main epifaunal groups and their contributions to average similarity. Listings terminated when the cumulative % exceeds 75. Text in square brackets cross-references these epifaunal groups with the Epifaunal Biotope Complexes (EBCs) derived in Chapter 6.

Group F (17 stations)
[EBC 3] **Average similarity: 49.61**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Psammechinus miliaris	9.87	7.21	4.46	14.53	14.53
Aequipecten opercularis	8.71	5.53	1.68	11.16	25.69
Hydrallmania falcata	6.78	4.27	1.73	8.61	34.3
Pomatoceros triqueter	7.37	3.2	0.96	6.45	40.75
Pagurus bernhardus	3.92	2.8	3.83	5.64	46.39
Ophiothrix fragilis	4.41	2.22	1.33	4.47	50.86
Alcyonium digitatum	3.71	1.98	1.47	3.99	54.84
Galathea intermedia	3.08	1.95	2.26	3.93	58.77
Asterias rubens	2.48	1.65	2.27	3.34	62.11
Macropodia tenuirostris	2.46	1.47	2.57	2.97	65.08
Balanus crenatus	3.44	1.41	0.84	2.84	67.92
Anomia ephippium	2.83	1.31	1.13	2.64	70.56
Pagurus prideaux	2.18	0.91	1.02	1.83	72.39
BRYOZOA	3.1	0.83	0.42	1.68	74.07
Pisidia longicornis	1.81	0.83	0.9	1.67	75.74

Group J (9 stations)
[EBC 6] **Average similarity: 60.75**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Psammechinus miliaris	23.65	8.13	3.56	13.39	13.39
Pomatoceros triqueter	23.66	7.68	1.41	12.64	26.02
Aequipecten opercularis	19.25	6.47	2.31	10.65	36.68
Ophiura albida	12.94	4.43	4.42	7.28	43.96
Asterias rubens	7.71	2.78	3.29	4.58	48.54
Balanus crenatus	11.82	2.27	0.84	3.73	52.27
Anomia ephippium	6.95	2.23	1.64	3.68	55.95
Galathea intermedia	5.71	2.09	2.66	3.44	59.39
Alcyonium digitatum	7.6	2.04	1.33	3.36	62.75
Ophiothrix fragilis	4.57	1.61	3.14	2.65	65.39
Pagurus bernhardus	4.91	1.59	1.46	2.62	68.01
Pagurus prideaux	4.57	1.49	2.62	2.46	70.47
Hydrallmania falcata	4.13	1.43	9.53	2.36	72.83
Liocarcinus pusillus	4.64	1.4	2.49	2.31	75.14

Group A (3 stations)
[EBC 9 & 8] **Average similarity: 39.89**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Hydrallmania falcata	5.44	10.91	4.65	27.35	27.35
Ammodytes tobianus	1.69	4.88	4.65	12.23	39.58
Pagurus bernhardus	1.82	4.75	2.24	11.91	51.49
Liocarcinus holsatus	1.28	3.89	4.52	9.74	61.23
Balanus crenatus	2.11	3.33	0.58	8.35	69.58
Alcyonidium diaphanum	2.11	3.06	0.58	7.66	77.24

Group B (4 stations)
[EBC 1] **Average similarity: 55.85**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Ophiothrix fragilis	48.45	29.52	4.97	52.86	52.86
Aequipecten opercularis	5.67	4.5	3.99	8.06	60.92
Psammechinus miliaris	5.71	2.95	1.4	5.28	66.19
Hydrallmania falcata	3.37	2.79	7.11	5	71.19
Pomatoceros triqueter	3.16	2.79	7.11	5	76.19

Table 5.8. continued: PRIMER output from SIMPER analysis for 2-metre beam trawls, listing the top ranked taxa for the nine main epifaunal groups and their contributions to average similarity. Listings terminated when the cumulative % exceeds 75. Text in square brackets cross-references these epifaunal groups with the Epifaunal Biotope Complexes (EBCs) derived in Chapter 6.

Group L (5 stations)
[EBC 11] **Average similarity: 49.35**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Alcyonium digitatum	5.27	3.6	3.43	7.29	7.29
Pomatoceros triqueter	4.53	3.31	9.92	6.7	13.99
Balanus crenatus	4.53	3.31	9.92	6.7	20.7
Asterias rubens	3.48	3.25	8.83	6.59	27.29
Psammechinus miliaris	3.33	2.98	4.06	6.03	33.32
Aequipecten opercularis	2.94	2.4	4.55	4.87	38.18
Hydrallmania falcata	2.53	1.97	1.15	3.99	42.18
Sertularia	2.53	1.97	1.15	3.99	46.17
Macropodia rostrata	2.55	1.96	2.4	3.96	50.14
Macropodia tenuirostris	2.62	1.79	2.39	3.63	53.77
Pisidia longicornis	2.56	1.62	2.64	3.28	57.05
Ophiothrix fragilis	3.1	1.56	0.96	3.17	60.22
Pandalina brevirostris	2.86	1.5	1.05	3.04	63.26
Sagartia	2.6	1.38	0.99	2.79	66.05
Pagurus bernhardus	1.64	1.33	4.9	2.7	68.75
Abietinaria abietina	2.1	1.27	0.91	2.57	71.32
Pomatoschistus	1.84	1.21	1.12	2.45	73.78
Crepidula fornicata	1.74	1.16	3.52	2.35	76.13

Group I (3 stations)
[EBC 5] **Average similarity: 61.10**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Aequipecten opercularis	19.49	9.8	6.07	16.04	16.04
Psammechinus miliaris	12.73	6.2	1.4	10.14	26.19
Pagurus bernhardus	8.41	4.38	3.55	7.17	33.36
Galathea intermedia	6.22	3.69	4.99	6.04	39.41
Ophiura albida	5.89	2.69	2.72	4.4	43.81
Ascidia conchilega	4.78	2.19	6.29	3.58	47.39
Abietinaria abietina	3.16	1.89	4.99	3.1	50.49
Hydrallmania falcata	3.16	1.89	4.99	3.1	53.59
Pomatoceros triqueter	3.16	1.89	4.99	3.1	56.69
Flustra foliacea	3.16	1.89	4.99	3.1	59.79
Sargassum muticum	3.16	1.89	4.99	3.1	62.89
Disporella hispida	6.67	1.73	0.58	2.84	65.73
Escharella	6.67	1.73	0.58	2.84	68.56
Dendrodoa	4.62	1.67	6.39	2.74	71.3
Pagurus prideaux	2.76	1.4	2.37	2.29	73.6
Buccinum undatum	3.16	1.2	4.41	1.97	75.57

Group C (7 stations)
EBC 2] **Average similarity: 42.74**

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Ophiothrix fragilis	6.26	6.37	1.13	14.9	14.9
Aequipecten opercularis	4.21	4.98	3.82	11.66	26.56
Hydrallmania falcata	3.16	4.9	4.75	11.46	38.02
Flustra foliacea	4.14	4.9	4.75	11.46	49.49
PORIFERA	3.69	3.56	1.43	8.33	57.82
Cellepora pumicosa	2.26	2.17	0.9	5.08	62.89
Pagurus bernhardus	1.66	1.9	3.66	4.45	67.35
Nemertesia ramosa	1.81	1.45	0.61	3.4	70.75
Pomatoceros triqueter	1.81	1.34	0.59	3.13	73.88
Abietinaria abietina	1.81	1.2	0.61	2.8	76.68

Table 5.9. PRIMER output from SIMPER analysis for 2-metre beam trawls, listing the top ranked taxa that discriminate between groups (other details as for Table 5.8). Data are presented only for three pairs of groups that constitute the major epifaunal assemblages indicated in Figure 5.67. Listings terminated when the cumulative % exceeds 50.

Groups B & C
[EBC 2 & 1]

Average dissimilarity = 66.20

	Group B	Group C				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Ophiothrix fragilis	48.45	6.26	22.36	2.62	33.77	33.77
Psammechinus miliaris	5.71	1.43	2.53	1.51	3.82	37.59
Flustra foliacea	1.6	4.14	1.74	1.89	2.62	40.22
PORIFERA	1.29	3.69	1.39	1.16	2.11	42.32
Ophiura albida	1.85	1	1.32	0.71	2	44.32
Dysidea fragilis	2.13	0.45	1.14	1.15	1.72	46.04
Aequipecten opercularis	5.67	4.21	1.11	1.21	1.67	47.71
Cellepora pumicosa	1.04	2.26	1.05	1.23	1.58	49.29
Nemertesia ramosa	0.43	1.81	1	1.2	1.51	50.81

Groups F & J
[EBC 3 & 6]

Average dissimilarity = 57.36

	Group F	Group J				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pomatoceros triqueter	7.37	23.66	5.29	1.56	9.23	9.23
Psammechinus miliaris	9.87	23.65	4.02	1.74	7.01	16.23
Aequipecten opercularis	8.71	19.25	3.38	1.53	5.9	22.13
Ophiura albida	1.89	12.94	3.25	1.98	5.66	27.8
Balanus crenatus	3.44	11.82	2.93	1	5.1	32.9
Ascidia conchilega	0.51	8.01	2.26	0.93	3.95	36.85
BRYOZOA	3.1	6.96	2.14	0.83	3.73	40.58
Ascidiella aspersa	1.52	5.73	1.62	1.06	2.82	43.39
Alcyonium digitatum	3.71	7.6	1.53	1.27	2.67	46.06
Asterias rubens	2.48	7.71	1.53	2.31	2.66	48.72
Anomia ephippium	2.83	6.95	1.46	1.72	2.54	51.26

Groups M & N
[EBC 7, 8 & 10]

Average dissimilarity = 65.27

	Group M	Group N				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Balanus crenatus	28.53	2.98	11.14	2.74	17.07	17.07
Hydrallmania falcata	14.22	2.8	4.56	1.08	6.98	24.06
Alcyonidium diaphanum	7.11	3.44	1.99	1.08	3.05	27.11
Aequipecten opercularis	5.08	1.35	1.97	0.98	3.02	30.12
Liocarcinus holsatus	5.91	5.15	1.9	1.07	2.9	33.03
Crangon allmanni	2.03	2.52	1.44	0.88	2.21	35.24
Pomatoceros lamarcki	3.31	0.26	1.42	0.78	2.17	37.42
Alcyonium digitatum	3.32	0.45	1.29	0.54	1.98	39.4
Flustra foliacea	2.58	1.24	1.27	0.84	1.94	41.34
Macropodia tenuirostris	3.94	1.67	1.25	1.47	1.91	43.25
Molgula	2.93	0.24	1.22	1.04	1.86	45.11
Nemertesia antennina	3.05	0.71	1.21	0.65	1.85	46.96
Psammechinus miliaris	2.78	2.44	1.17	1.48	1.79	48.75
Cellepora pumicosa	2.49	1.52	1.13	1	1.74	50.49

Environmental analysis, 2-metre beam trawls

The interpretation of environmental data was necessarily cautious, as the available data were typically recorded for point samples (e.g. PSA from grab stations), or derived from models (e.g. tidal stress). Temperature and salinity were excluded from the analysis as all sampling sites were exposed to similar annual temperature variations, and the variability of the salinity data was trivial (min 35.00‰, max 35.39‰).

Two separate Principal Components Analyses (PCA) were undertaken, the first on univariate measures (e.g. depth, maximum current speed) and indices describing the particle size distribution, where the variables could be regarded as independent, and the second on PSA data where the variables (% by weight in various sieve sizes) were not independent. The former required a correlation-based PCA and the latter a covariance-based PCA.

Eight variables were used in the first analysis, namely mean grain size, median grain size (d50), sorting, skewness, kurtosis, % shell content of the sediment, average current speed and depth. Right and left skewness in the data were corrected using log and inverse transformations (respectively), and the data normalised to remove dependence on measurement scale. The vectorised PCA plot is shown in Figure 5.70. Sixty percent of the variance was captured in the first three principal component (PC) axes, with current, sorting, depth and kurtosis scoring most highly on PC1 (31%), skewness and median grain size on PC2 (16%) and mean grain size and shell content on PC3 (12%). This was interpreted as showing that current speed and depth were the major influencing factors, as sorting was likely to be partly dependant on current speed (faster current, better sorting). High skewness reflects non-uniformity in particle size, so the prominence of skewness in PC2 indicated that sediment types varied between those with reasonably uniform grain size to those that were highly mixed.

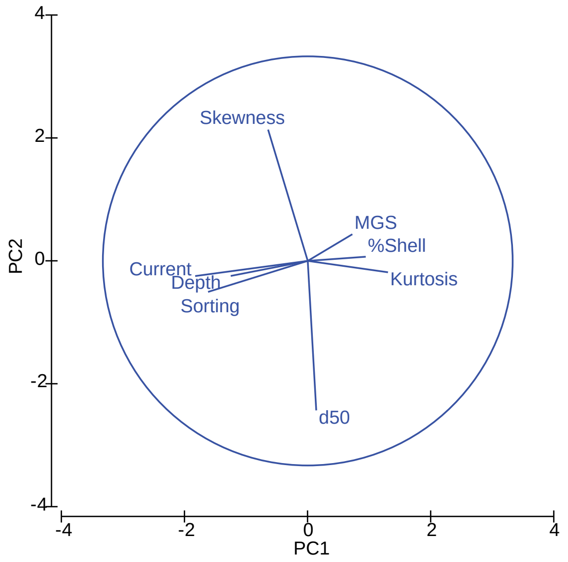


Figure 5.70. Vectorised PCA for environmental data represented by univariate measures and derived indices. MGS = mean grain size, d50 = median grain size.

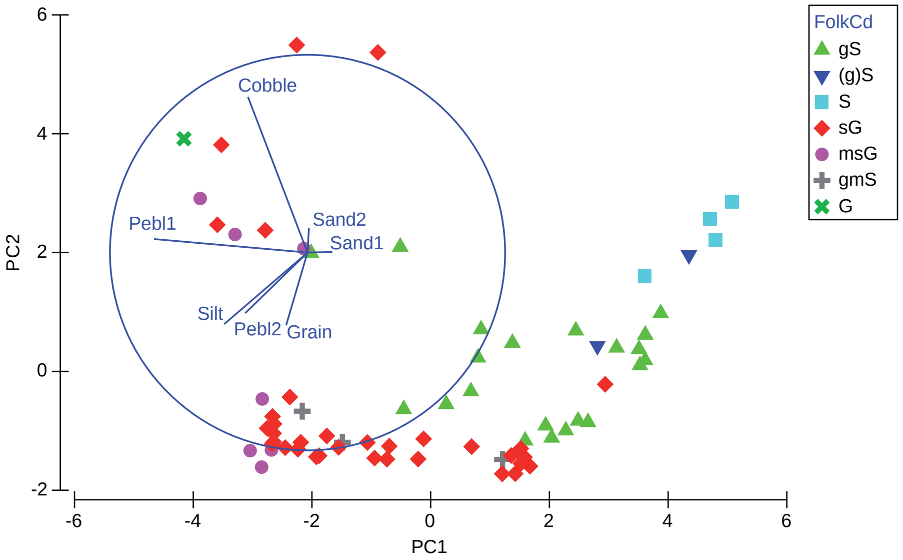
For the second analysis, the PCA data were aggregated into 2-phi size groups, as indicated in Table 5.7. Right and left skewness in the data were again corrected using log and inverse transformations, but the data were not normalised as they were all on a common scale (% by weight). The vectorised PCA plot is shown in Figure 5.71. Seventy one percent of the variance was captured in the first two PC axes, with the larger pebble class featuring strongly on PC1 (48%) and the cobble class on PC2 (23%). The analysis clearly shows a seriation in Folk class along PC1, and PC2 appears to split stations on the basis of the presence/absence (or proportion) of cobbles.

The two analyses indicated that there were some discernable patterns in the available environmental data, and hence it was valid to conduct a BEST analysis to see which variables best explained the pattern of variability in the epifaunal data.

Linking multivariate patterns in environmental and epifaunal data.

A suite of 27 'environmental variables' was available for the analysis, comprising the PSA and univariate data sets mentioned above. The data were transformed and normalised prior to checking for highly correlated variables. Where these were found, one of the variables was removed, leaving 18 variables to be used in the analysis. Within the BEST routine, a full BIO-ENV analysis was selected and showed that four variables, namely current speed and the 2-phi sediment classes 'Grain', 'Sand1' and 'Sand2' provided the best match to the patterns in the epifaunal data (rho = 0.536). None of the variables removed prior to the analyses had been closely correlated to these. This analysis indicated that faunal composition of the biotopes identified by the cluster analysis using a 1% SIMPROF test was moderately influenced by the maximum tidal current and the grade of sand (coarse to fine) occurring at the site.

Figure 5.71. Vectorised PCA for granulometric data (PSA) aggregated to 2-phi size groups (labels as in Table 5.7), with sample points symbolised according to the Folk sediment classification.



Identification and distribution of epifaunal biotopes from 2-metre beam trawl data

An attempt was made to match the nine S1 epifaunal cluster groups to habitat/biotope classes described in the UK Marine Habitat Classification (Connor *et al.*, 2004), based on the characterising taxa for each cluster (as identified by SIMPER analysis) and a sediment characterisation drawn from a cross-tabulation of the Folk classes assigned to each sampling site by the geological analysis (Table 5.10). Assignment of biotopes was found to be extremely difficult as the limited data available at this stage was usually insufficient to allow discrimination at the more detailed levels of the MNCR classification. The assignment was therefore limited to a series of possible matches between levels 2 and 4 of the classification hierarchy (Table 5.11). The data were later scrutinised in conjunction with the results of the video analyses and the extensive geophysical interpretation to draw up the final regional map of eleven Epifaunal Biotope Complexes (EBCs) (Figure 6.3 and Map 1).

Table 5.10. Cross tabulation of Folk classification vs S1 epifaunal groups for the 73 stations sampled by 2-metre beam trawl. Standard abbreviations are used for the Folk classes. Symbols for the epifaunal groups replicate the keys for the 1% SmPrf groups given in Figure 5.67 and 5.69.

S1 group		**Folk classification**							
		G	**msG**	**sG**	**gmS**	**gS**	**(g)S**	**S**	**Total**
F	■		1	11	1	4			17
N	🟦			1	1	5	2	3	12
J	🟧			4		5			9
C	🟥	1		6					7
M	🟩		2	1		4			7
L	■		1	2	1	1			5
B	□		3	1					4
A	🟪					2		1	3
I	□			3					3
K	□					2			2
D	▽			1					1
E	△					1			1
G	□			1					1
H	◇		1						1
Total		1	8	31	3	24	2	4	73

Table 5.11. Major biotope characteristics of the nine S1 epifaunal groups, with an assessment of how these map to biotope classes defined in the UK Marine Habitat Classification. Symbols for the epifaunal groups replicate the keys for the 1% SmPrf groups given in Figure 5.67 and 5.69. Text in square brackets cross-references the groups with the Epifaunal Biotope Complexes (EBCs) derived in Chapter 6.

S1 group	Characteristics	Possible biotope matches
F ■ [EBC 3]	Sandy gravel to gravelly sand (sublittoral coarse or mixed sediment) *Psammechinus, Aequipecten, Hydrallmania, Pomatoceros, Pagurus, Ophiothrix.*	SS.SCS.OCSSS.SCS.CCS
N 🟦 [EBC 10 & 8]	Gravelly sands to sand (sublittoral sands) *Pagurus bernhardus, Liocarcinus, Hydrallmania, Anapagurus, Ophiura, Alcyonidium, Pagurus prideaux, Callionymus.*	SS.SMX.Omx. similar to: SS.SMX.IMx.SpavSpAn
J 🟧 [EBC 6]	Sandy gravel to gravelly sand (sublittoral coarse or mixed sediment) *Psammechinus, Pomatoceros, Aequipecten, Ophiura, Asterias.*	SS.SCS.CCS similar to: SS.SCS.CCS.PomB SS.SMX.CMx.FluHyd
C 🟥 [EBC 2]	Sandy gravel, one station is gravel (sublittoral coarse or mixed sediment) *Ophiothrix, Aequipecten, Hydrallmania, Flustra, PORIFERA, Cellepora.*	SS.SMX.CMx.OphMx similar to: CR.LCR.BrAs.AmenCio.Bri
M 🟩 [EBC 10 & 7]	Muddy sandy gravel to gravelly sand (sublittoral mixed sediment) *Balanus, Hydrallmania, Alcyonidium, Pagurus, Liocarcinus.*	SS.SMX.CMx.FluHyd similar to: SS.SSA.IFiSa.ScupHyd
L ■ [EBC 11]	Muddy sandy gravel to gravelly sand (sublittoral coarse or mixed sediment) *Aequipecten, Psammechinus, Pagurus, Galathea, Ophiura.* Classic gravely sand community, but not adequately described in MNCR biotopes.	SS.SCS possibly SS.SCS.CCS.Nmix ?
B □ EBC 1]	Muddy sandy gravel predominates (sublittoral mixed sediment) *Ophiothrix fragilis* (beds), *Aequipecten, Psammechinus, Hydrallmania, Pomatoceros* Similar to group C, but notably without sponges. Ophiothrix beds.	SS.SMX.CMx.OphMx similar to: CR.LCR.BrAs.AmenCio.Bri
A 🟪 [EBC 9 & 8]	Gravelly sand to sand (sublittoral sands). Includes Bassurelle sand bank *Hydrallmania, Ammodytes, Pagurus, Liocarcinus.* Presence of weever fish (Echiichthys) is characteristic.	Most similar to SS.SSa.IFiSa.IMoSa or SS.SSa.NcirBat/New biotope? Offshore sandbank.
I □ [EBC 5]	Sandy gravel (sublittoral coarse or mixed sediment). *Aequipecten, Psammechinus, Pagurus, Galathea, Ophiura, Ascidia, Abietinaria.* Discriminated from J by far fewer *Pomatoceros* and *Psammechinus*	SS.SCS.CCS similar to: SS.SCS.CCS.PomB SS.SMX.CMx.FluHyd

The geographical distribution of the S1 cluster groups is shown in Figure 5.69. Groups M and N were associated with sandy sediments, predominantly in the north east of the study area where sand occurs across Region 2 and 5, but also in the extreme north west of Region 1. Group M included *Balanus* and *Hydrallmania*, indicating the inclusion of some coarser elements to the substrate than Group N.

Group L was confined to the eastern half of Region 1, where there were coarse mixed sediments. Queen scallops (*Aequipecten*), the urchin *Psammechinus* and the squat-lobster *Galathea* were prominent and are commonly found on coarse or gravel substrates.

Groups B and C were restricted to the south west of the study area, almost exclusively within the western part of Region 3. *Ophiothrix, Aequipecten* and *Hydrallmania* indicated hard stony/gravely grounds with little sand component. The occurrence of sponges in group C indicated the presence of stable, consolidated substrates such as cobble or boulder fields. Group B was dominated by *Ophiothrix* (>50% of total abundance), suggesting the presence of dense aggregations of ophiuroids moving over the coarser substrates in this area.

Group F was the most numerous group, being widespread in the mid west, spanning the area where Regions 1, 3 and 4 met, with a mixture of fauna typical of extensive 'gravel plains' (*Psammechinus, Aequipecten, Hydrallmania, Pomatoceros, Pagurus, Ophiothrix*). Group I occurred in the centre of this distribution (northeast of Region 3), the inclusion of *Ophiura albida* and a reduction in the prominence of *Pomatoceros* and *Psammechinus* suggesting an area of substrate with a greater sand component than group F.

Group J covered an extensive area in the mid south east, spanning the border between Regions 4 and 5. The epifauna were typical of sandy gravels and gravelly sands, with *Psammechinus, Pomatoceros, Aequipecten, Ophiura* and *Asterias*.

Finally, group A was represented by only 3 stations, but was notable for the inclusion of fish species that are commonly associated with fine sandy substrates

Table 5.12. Summary of successful video tows and still images.

	Camera Sledge	Drop Camera	Stills taken	Stills analysed
2005 survey	29	13	577	87
2006 survey	23	0	478	351

(the sandeel, *Ammodytes tobianus*, and the weever fish, *Echiichthys vipera*). The two stations in the extreme southeast of Region 5 were sited to target the Bassurelle Bank, but the third station, in the centre of Region 1, due south of Beachy Head, was not anticipated as a sandy area.

The information provided by trawl samples alone was not sufficient to confidently attribute biotope classes. To do so required further information, provided by video observations, on the nature of the sea bed (sea bed character) and any notable associations between epifauna and the substrate (i.e. sponge communities encrusting consolidated cobble beds). Video methods themselves tend to be poor at sampling dispersed epifauna, but the combined use of trawl and video sampling techniques would appear to provide the required mix of biological and physical information to allow a reasonably confident biotope classification.

In Chapter 6, trawl and video analyses are considered together with the extensive geophysical interpretation for the EECMHM to develop a map of Epifaunal Biotope Complexes (EBCs; Figure 6.2). The inclusion of this additional information means there is not always a 1:1 match between the epifaunal groups identified above and the EBC groups of Chapter 6. Six of the nine epifaunal groups do show a 1:1 relationship, but the other three, groups A, M and N, occur in more than one of the EBC groups (Table 5.11).

5.3.3 Analysis of benthic epifauna using video and still imagery

A total of 65 successful camera tows were completed during two surveys using both the drop-frame camera and the towed camera sledge (Figure 4.34). On the camera sledge tows, 1055 still images were obtained, of which a subset were analysed (Table 5.12).

The video and stills data were analysed in two ways. Firstly, a series of multivariate analyses were conducted using PRIMER 6 software to reveal patterns in the biological community and to determine biological assemblages. Secondly, biological and environmental data were assessed visually and according to their species and sediment composition to assign biotopes based on The Marine Habitat Classification for Britain and Ireland v 04.05 (Connor *et al.*, 2004). The distribution of these biotopes was then mapped across the study area.

Multivariate analysis of video samples

The video footage collected in 2005 was of considerably poorer quality than that collected in 2006, which naturally resulted in some between-year differences in the number and type of taxa that could be identified and quantified. Overall however, the video footage provided valuable data on the nature of the sea bed and the biological community present.

In total, 43 taxa were identified from the video footage. Despite the difference in quality of footage, similar numbers of taxa were identified in 2005 compared to 2006 (31 in 2005; 32 in 2006). The most frequently occurring taxa (i.e. present in most video stations) were the common starfish *Asterias rubens*, hermit crabs Paguridae and the queen scallop *Aequipecten opercularis* all of which were present in more than 50% of video samples (i.e. section of video tow). Also occurring frequently were the anemones *Urticina* spp., which was recorded in 41% of video samples. However *Urticina* spp. were only recorded in 12% of samples from the still images, indicating the importance of using video footage for sampling the less frequent species. Number of taxa recorded within video samples ranged from one to 15.

The data were first investigated to determine whether the type of camera system used (drop-frame camera versus towed camera sledge) had any effect on the data collected. In general a drop-frame camera can be towed at variable height above the sea bed, thus resulting in a varying field of view and consequently affecting the ability to identify taxa on the sea bed. The drop-frame camera was selected for use at stations that had been identified from the multibeam data as having potentially rough ground, or rapid changes in depth, therefore making them unsuitable for towed video equipment. When these stations were subsequently surveyed, it was found that in most cases the ground was not as rough as indicated from the acoustic data, and thus it was possible to hold the camera at an approximately constant height above the sea bed. A 1-way ANOSIM test on the video taxon abundance data was performed, using the type of camera system as a factor, and it was found that there was no significant assemblage difference between towed video stations versus drop-frame camera stations. Similarly, an MDS ordination plot of the video abundance data symbolised according to camera system indicated stations sampled using the drop-frame camera system were evenly distributed throughout. Thus, the camera system used did not appear to have any affect on the results described below.

Hierarchical cluster analysis of the abundance data in PRIMER (SIMPROF test, $p=0.05$) resulted in video samples being divided into ten significantly different video clusters; three large clusters, five small clusters, and two clusters composed of isolated samples (Figure 5.72).

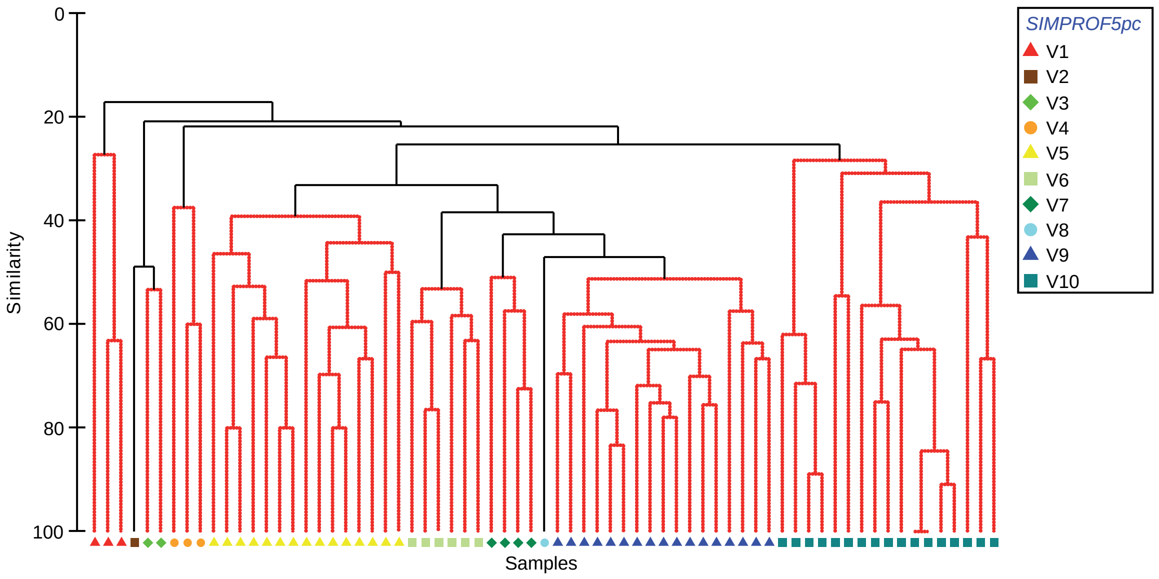


Figure 5.72. Dendrogram showing clustering of video samples based on SIMPROF test (p=0.05). Black lines connecting clusters of video samples indicate a significant difference between the connected clusters. Each sample has been assigned a symbol, which represents the cluster within which it is grouped.

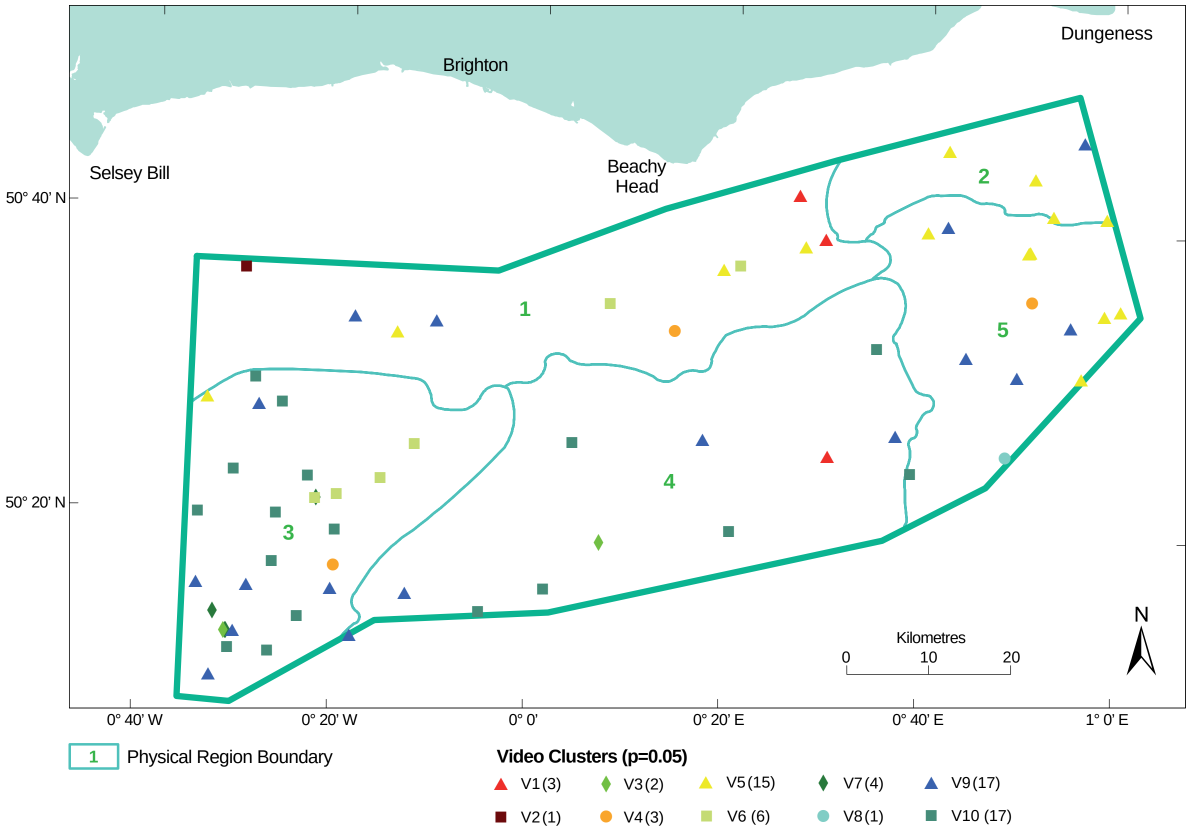


Figure 5.73. The distribution of video clusters within the study area. Video sample points are symbolised according to the cluster assigned through the SIMPROF test (p=0.05). Symbols and labels match those in Figure 5.72 and numbers in brackets indicate the number of samples within each biotope category.

Table 5.13. Sediment characteristics and species profile of SIMPROF video clusters.

Video Cluster	Number of video samples	Characterising species and sediment description
V1	3	Sandy sediment with outcropping bedrock, and cobbles and pebbles. Low abundance of *Urticina* spp., the fleshy bryozoan *Alcyonidium diaphanum, A. rubens* and the soft coral *Alcyonium digitatum*, with rare occurrences of other epifauna.
V2	1	Predominantly sandy substrata with cobbles, pebbles and shells. Moderate abundance of *A. opercularis* and the king scallop *Pecten maximus*, rare occurrence of the bryozoan *Flustra foliacea* and no other fauna.
V3	2	Coarse pebbles, cobbles and shelly substrata. Moderate abundance of the keel worm *Pomatoceros* spp. Low to moderate abundance of *A. opercularis* and *P. maximus*, rare occurrences of other epifauna.
V4	3	Sandy with pebbles and shells. Low abundance of Paguridae, *A. opercularis* and the common brittlestar *Ophiothrix fragilis*, no other visible epifauna.
V5	15	Similar to V4 with higher proportion of sand and small amount of cobbles and pebbles. Low/moderate abundance of Paguridae, *A. rubens* and the brittlestar *Ophiura* spp., rare occurrences of other epifauna.
V6	6	Coarse pebble and cobbles with moderate abundance of the hydroid *Nemertesia antennina*. Low abundance of *A. rubens, Urticina* spp. and Paguridae.
V7	4	Similar to V6, with higher diversity of fauna. Moderate abundance of Porifera (sponges), *F. foliacea*. Low abundance of *A. rubens*, Paguridae, *A. opercularis*, Hydroida, *Urticina* spp., *A. diaphanum*, the erect bryozoan *Pentapora foliacea* and other epifauna.
V8	1	Pebble and gravel substrata with some shell and sand. Moderate abundance *Pomatoceros* spp., *A. opercularis, A. digitatum, A. rubens, Ophiura* spp., Paguridae. Low abundance of the bryozoan *Cellepora pumicosa*, the hydroid *Sertularia* spp., the green sea urchin *Psammechinus miliaris*, and rare occurrence of other epifauna.
V9	17	Predominantly pebble substrata with gravel, shells, sand and cobbles. Low to moderate abundance of Paguridae, *A. opercularis*, low abundance of *A. rubens*, Hydroida, *P. maximus*, the dog cockle *Glycymeris glycymeris, N. antennina*, and rare occurrences of other epifauna.
V10	17	Similar to V9 with higher proportion of cobbles and pebbles. Low abundance of *A. rubens, A. opercularis, O. fragilis*, and rare occurrences of other epifauna.

Table 5.14. Detail of analyses carried out using environmental variables.

Environmental variable	Unit	Data source	Analysis Type
Depth	Metres	Ships reading	BIOENV
Sediment thickness	Metres	Interpretation of acoustic data	BIOENV
Maximum clast size	mm	Estimated from video footage	BIOENV
Bedrock	% cover	Visual assessment of video footage	BIOENV
Boulders	% cover	Visual assessment of video footage	BIOENV
Cobbles	% cover	Visual assessment of video footage	BIOENV
Pebbles	% cover	Visual assessment of video footage	BIOENV
Gravel (stone)	% cover	Visual assessment of video footage	BIOENV
Gravel (shell)	% cover	Visual assessment of video footage	BIOENV
Fine sediment	% cover	Visual assessment of video footage	BIOENV
Empty shells	% cover	Visual assessment of video footage	BIOENV
Bedform	Categorical	Geology and geophysics interpretation	ANOSIM
Seabed character	Categorical	Geology and geophysics interpretation	ANOSIM
Solid geology	Categorical	Geology and geophysics interpretation	ANOSIM
Sediment classification (Folk)	Categorical	Geology interpretation	ANOSIM
Gravel fabric	Categorical	Geology interpretation	ANOSIM
Gravel lithology	Categorical	Geology interpretation	ANOSIM
Sorting	Categorical	Geology interpretation	ANOSIM

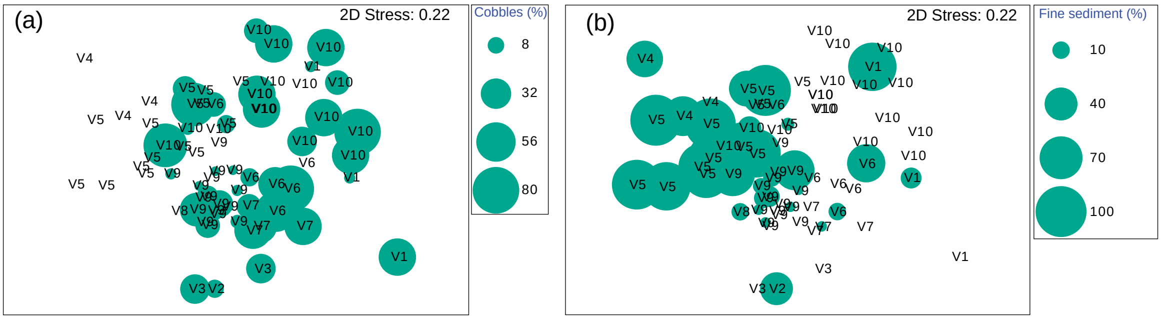


Figure 5.74. Two-dimensional MDS ordination of video samples. Samples are labelled according to the SIMPROF cluster. Size of bubbles represents (a) the amount of cobble by % cover of substrata and (b) the amount of fine sediment by % cover of substrata.

The data were inspected to see how the nature of the substrata differed between the video clusters, and SIMPER analysis was used to determine the biological composition of the video clusters (Table 5.13).

The spatial distribution of video clusters showed a loose pattern with the clusters composed of sandy sediment video samples (V1, V2, V4, V5) generally occurring in Region 2, extending southward into Region 5, and west into Region 1. In contrast the clusters with more gravelly sediment video samples (V3, V6, V7, V8, V9, V10) occurred mainly in Regions 3, 4 and 5 but with some video samples in Region 1 (Figure 5.73). These six different video clusters representing gravel communities do not show distinct spatial distributions, but are intermingled within the broad gravel area.

The ability to decipher clear biological assemblages using video data may have been affected by the sparse nature of the data, and the limited taxonomic resolution that can be achieved. The descriptions of the video clusters in Table 5.13 indicate that many of the clusters are discriminated on the basis of slight differences in relative abundance of epifauna, rather than due to distinct species assemblages. The video clusters determined by the analysis could therefore have reflected the patchy distribution of sparse, and often mobile, epifaunal species rather than permanently distinct assemblages.

Each video sample was assigned environmental attributes based on sediment characteristics, depth and geological and geophysical interpretation of the sea bed at that location (Table 5.14).

For eleven continuous environmental variables, A BIOENV analysis was run to determine whether the patterns observed within the biological community were correlated with any of these environmental factors. Other environmental parameters such as salinity and temperature were not tested as they showed little variation across the survey area.

The best correlation to the biological community was produced by a combination of three variables as follows: amount of bedrock (% cover), amount of cobbles (% cover) and amount of fine sediment (% cover) ($\rho = 0.249$; $p=0.01$). Plotting the percentage cover of cobbles (Figure 5.74a) and fine sediment (Figure 5.74b) as bubbles on an MDS plot showed a clear gradient of the two variables across the plot. Cobbles were largely absent from clusters V4 and V5 in the top-left corner of the plot, but these clusters had a high percentage cover of fine sediment. A gradient of decreasing abundance of fine sediment and increasing abundance of cobbles is apparent moving towards the right and bottom of the ordination.

A further seven attributes were categorical and therefore could not be included in the BIOENV test described above. For each of these, a 1-way ANOSIM test was performed, to determine whether there was a significant assemblage difference according to any of these attributes. None of the seven attributes tested showed any statistical relationship to the biological community.

Multivariate analysis of still images

In general the still images were of excellent quality. The fine resolution of the digital images allowed a greater number of taxa to be identified than from video, and also increased the taxonomic resolution of the identification. In total, 84 taxa were identified from the still images. 65 taxa were identified in 2006 compared to 47 in 2005. This was probably due to the additional still images that were analysed in 2006 compared to 2005, although differences in habitat type encountered, environmental conditions, equipment set-up and contractor experience cannot be ruled out.

The number of taxa within individual still images ranged from 0 to 16, but for many images only 3 or 4 taxa were represented. Therefore all analyses were carried out on abundance data that had been averaged by video sample (i.e. section of tow). With respect to the stills analyses, ‘sample’ refers to the abundance of each taxon averaged from all still images within a particular video sample. The most frequently occurring taxa (i.e. present

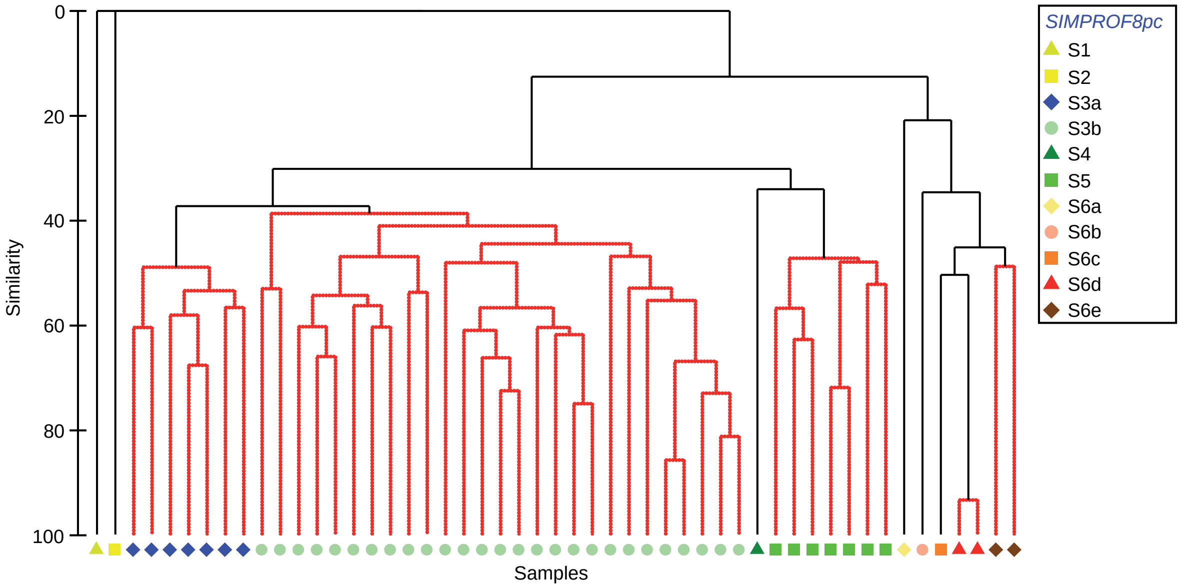


Figure 5.75. Dendrogram showing clustering of still samples based on SIMPROF test (p=0.08). Black lines connecting still clusters of samples indicate a significant difference between the connected clusters. Each sample has been assigned a symbol, which represents the still cluster within which it is grouped. SIMPROF (p=0.08) clusters are labelled to retain the broader clusters in which they were found for the SIMPROF (p=0.05) (e.g. Still clusters 3a and 3b in the SIMPROF (p=0.08) test were both in cluster S3 for the SIMPROF (p=0.05) test).

in most still samples) were *Pomatoceros* spp. and *A. opercularis*, which were present in 83% and 62% of still samples respectively. Also frequently occurring were *Ophiura* spp., which occurred in 46% of still samples, but were only recorded in 29% of video samples, highlighting the advantages of using still photography for identification of more cryptic species. The number of taxa within still samples ranged from 0 to 34.

Six significantly different still clusters were identified using hierarchical cluster analysis of the still samples (SIMPROF test, p=0.05; Figure 5.75). The majority of still samples were within still cluster S3, with the remainder split between two smaller groups, S5 and S6, and three clusters of just one sample each (S1, S2 and S4). Re-running the cluster analysis with the significance level relaxed to p=0.08 resulted in the largest still cluster (S3) being further sub-divided into two smaller clusters (S3a, S3b) and S6 being sub-divided into five smaller clusters (S6a, S6b, S6c, S6d, S6e) (Figure 5.75). SIMPER analysis was used to determine the key species characterising each of these still clusters (Table 5.15).

S3a was characterised by the presence of the brittlestar *O. albida* which is usually found on muddy sand or gravel, and S3b by the presence of the brittlestar *O. fragilis*, which tends to be found on coarser sediment. The epifaunal community of these two still clusters was otherwise similar. The same cluster analysis also sub-divided still cluster S6 into 5 small clusters (S6a to S6e). Within these, S6a, S6c and S6d were very impoverished and were separated on the basis of the presence of one or two taxa absent from the other clusters. S6b and S6e were slightly more taxon-rich and separated due to having *O. albida* and an additional range of epifaunal taxa. They were distinct from the other cluster characterised by *O. albida* (S3) in that they did not have a significant abundance of *Pomatoceros* spp.

The distribution of still clusters across the study area is illustrated in Figure 5.76. Still clusters S1, S2 and S6, which describe sandier habitats, were found mainly in the northern part of the Greater Bassurelle Sands (Region 5) and in the North-East Platform and Margin (Region 2), with one still sample (still cluster S1) found in Region 1. Moving into the southern part of Region 5, and west into Regions 1 and 4, still cluster S3b was more dominant, describing a gravelly community with *O. albida* that characterised most of the still samples in the central area. The south-western corner of the study area in Region 3 was dominated by a gravel community characterised by *O. fragilis*, represented by still cluster S3a. Samples from still cluster S5 were interspersed, indicating patches of coarser gravel with cobbles characterised by the presence of hydroids and bryozoans. Finally, still cluster S4, which described a rich sponge and bryozoan community, was also found in this location.

Relationships between the biological and environmental variables were tested in the same way as described above for video analysis. A BIOENV test using the continuous environmental variables described in Table 4.3 indicated that the patterns identified in the biological community were best explained by just one variable: amount of fine sediment (% cover) (ρ=0.571; p=0.01). Overlaying the

Table 5.15. Sediment characteristics and species profile of SIMPROF still clusters

Still Cluster	Number of still samples	Characterising species and sediment description
S1	1	Shelly sand. No visible fauna identified.
S2	1	Sand. No visible fauna identified.
S3a&b	34	Pebbles, with cobbles and gravel. *Pomatoceros* spp., *A. opercularis*, the brittlestar *Ophiura albida* and other visible epifauna at lower average abundance. Sub-divided into S3a, characterised by presence of *O. albida* and S3b, characterised by presence of *O. fragilis*.
S4	1	Cobbles, with pebbles and gravels. Rich community of sponges, *P. foliacea*, anemones and other epifauna.
S5	7	Coarse gravel and pebbles. *Pomatoceros* spp., Bryozoa, the annelid worm *Filograna* spp., the hydroid *Hydrallmania* spp. and *Sertularia* spp.. Similar to S4 but with less sponges or *P. foliacea*.
S6	7	Very sandy, distinct cluster characterised by presence of *O. albida*, Hydroida and *Pagurus* spp. Sub-divided into five clusters; S6a, S6c and S6d, all very impoverished; and, S6b and S6e, slightly more taxon-rich with *O. albida* and an additional range of epifaunal taxa.

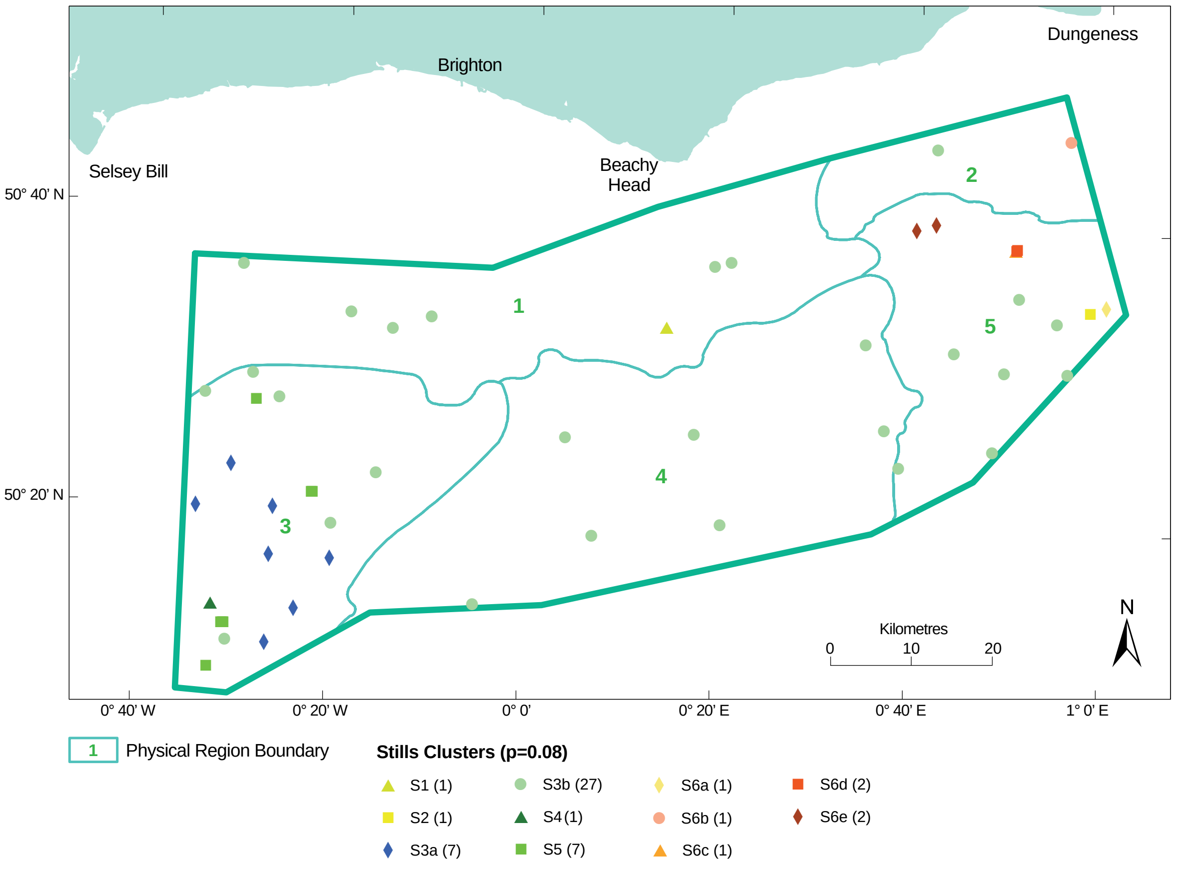


Figure 5.76. Distribution of clusters within study area. Still sample points are symbolised according to the still cluster assigned through the SIMPROF test (p=0.08). Symbols and labels match those in Figure 5.75. Numbers in brackets indicate the number of still samples assigned to each still cluster.

amount of fine sediment on to an MDS ordination of the still samples revealed a gradient of decreasing cover of fine sediment from still clusters S6a to S6e on the left of the plot, to still clusters S3 and S5 which have very little fine sediment (Figure 5.77).

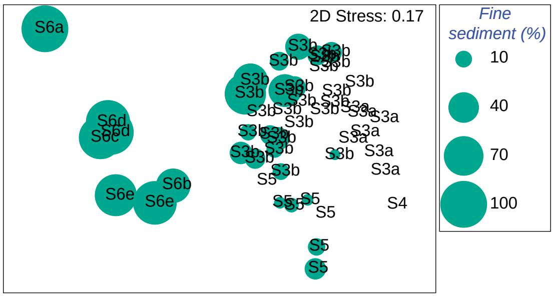


Figure 5.77. Two-dimensional MDS ordination plot of still samples. Samples are labelled according to the SIMPROF still cluster. Size of bubbles represents the amount of fine sediment by % cover of substrata.

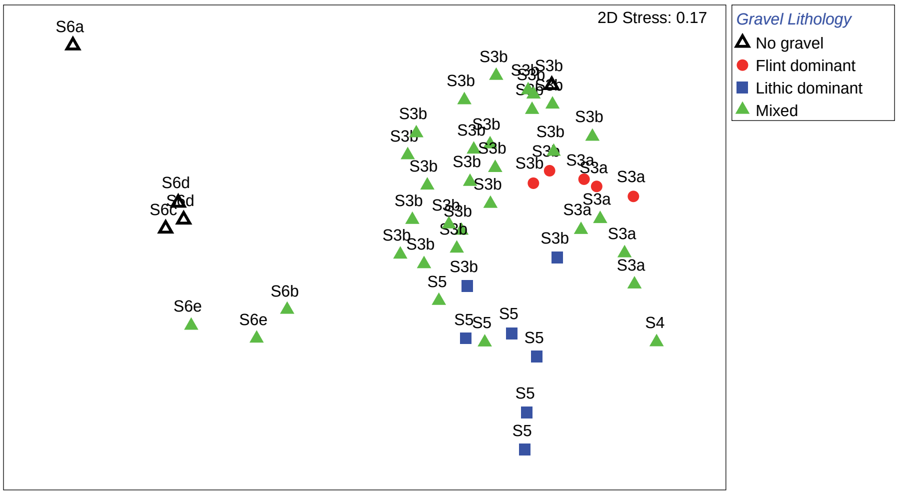
Relationships between the faunal assemblages and the remaining environmental variables were tested using a 1-way ANOSIM. Significant relationships were found between the faunal assemblages and gravel lithology (R = 0.38, p=0.001), gravel fabric (R = 0.322, p=0.001) and degree of sorting of sediment (R = 0.366, p=0.001). To further investigate these relationships, pair-wise tests were conducted.

The relationship between the faunal assemblage and gravel lithology was explained mainly by a large and highly significant difference between assemblages on lithic dominant versus flint dominant gravel (R=0.806; p=0.001) and by a smaller but still significant difference between assemblages on lithic dominant versus mixed gravel (R=0.272; p=0.018). There was also a large and significant difference between assemblages on shell dominant versus mixed gravel (R=0.974; p=0.03), although the low number of still samples meant that there was limited power to determine the extent of this result. Plotting the gravel lithology as a symbol on an MDS ordination of the still samples (Figure 5.78) showed the clear separation of the lithic versus flint dominant gravel (blue squares v red circles) and the general separation of the lithic-dominant versus mixed gravel (blue squares v green triangles).

The relationship between the faunal assemblage and the degree of sorting was explained mainly by the large and significant differences between assemblages on very well-sorted sediment and well-sorted sediment (R=0.789; p=0.001), moderately-sorted sediment (R=0.657; p=0.001) and poorly-sorted sediment (R=0.693; p=0.001). The samples with well-sorted sediment were those with a high proportion of sand.

The relationship observed between faunal assemblage and gravel fabric was due to the large and significant differences between assemblages where no gravel was present versus clast-supported substrata (R=0.798; p=0.001) and versus matrix-supported substrata (R= 0.461; p=0.001).

Figure 5.78. Two-dimensional MDS ordination of still samples, symbolised according to the lithology category to which the visible gravel in the images was assigned. Annotated with still cluster number. Stations assigned to "shell dominated gravel" were outliers and thus are not visible here.



Identification and distribution of biotopes

Video and still samples were grouped into seven biotopes, which were then considered in more detail to find the most appropriate match in The Marine Habitat Classification for Britain and Ireland v 04.05 (Connor *et al.*, 2004). It is known that The Marine Habitat Classification is limited in its description of offshore biotopes, as historically few data have been available for offshore areas outside inshore coastal waters to contribute to development of appropriate biotopes. Therefore it was unsurprising that for most biotopes identified no direct match was found except at a very coarse level. However, it was recognised that this coarse level of separation did not adequately distinguish between what appeared to be distinct biotopes. Therefore, new biotopes were proposed and described in terms of their sediment characteristics and species profile. These are summarised in Table 5.16 with their relationship to existing biotopes in the Marine Habitat Classification identified. They are described in more detail below. Although the new biotopes could only be directly matched at a coarse level in the Marine Habitat Classification, closest matches to the species profile of existing biotopes were found.

The MDS ordination of taxa abundance (from stills data), symbolised according to biotope, showed that samples within most of the biotopes grouped closely together (Figure 5.79). However, one biotope (CFiSa) was much more widely scattered, indicating a low degree of similarity between the different samples. Some biotopes showed a degree of overlap, reflecting the transitional nature of the faunal assemblages from one biotope to another. The MDS ordination also indicated that there was a reasonable correlation between the clusters generated from the hierarchical cluster analysis of the stills data, and the biotopes, which are discussed in more detail below.

Three of the biotopes identified were dominated by sandy sediments. CFiSa was predominantly characterised by sand waves and rippled sand, with coarser shelly debris in the troughs of the ripples (Figure 5.81a) and waves. Samples within this biotope were fairly impoverished, which resulted in a low degree of similarity between the samples, as represented in the MDS ordination (Figure 5.79). This biotope was found exclusively in the north-eastern part of the study area in Region 2 and the northern part of Region 5 (Figure 5.80). Whilst the more southern CFiSa stations appeared to show a more uniform sandy substrate, still images taken at a small number of stations further north showed what appeared to be bedrock at the surface (EECMHM stations 23, 196 and 198) confirming geophysical evidence that the overlying sand layer was thin (Figure 5.81b) and rock outcrop was relatively common in some parts of the North-East Platform and Margin (Region 2). Where rock was present, the diversity was higher as the hard substrate allowed the colonisation by sessile epifauna such as hydroids, anemones and soft corals.

CCS.1 was a coarser, more impoverished sand and gravel community, which was present in only two of the samples (Figure 5.82). Due to the lack of fauna, these samples had a very low degree of similarity and hence did not group together in the cluster analysis. One sample was located on the western periphery of the sand wave field in the Greater Bassurelle Sands, and the other in the northern central part of the study area, which could indicate that this was a transitional biotope between the sandier CFiSa and the more gravelly CCS.2.

The final sand-dominated biotope, CMx.1 had a predominantly sand substrate, with occasional boulders. Again, the presence of boulders allowed colonisation of sessile epifauna. Four samples were assigned to this biotope and all were found to the north of the study area in Region 1. The analyses carried out in PRIMER did not show any distinction between the biological community present at these stations and those present in the gravel biotopes (CCS.2 and CCS.3). However, visually and in terms of the sediment profile, the biotope appeared to be very distinct (Figure 5.83).

The remaining four biotopes were of a more gravelly nature, CCS.2 being a finer gravel, and CCS.3, CCS.4 and CMx.2 being coarser and less well-sorted.

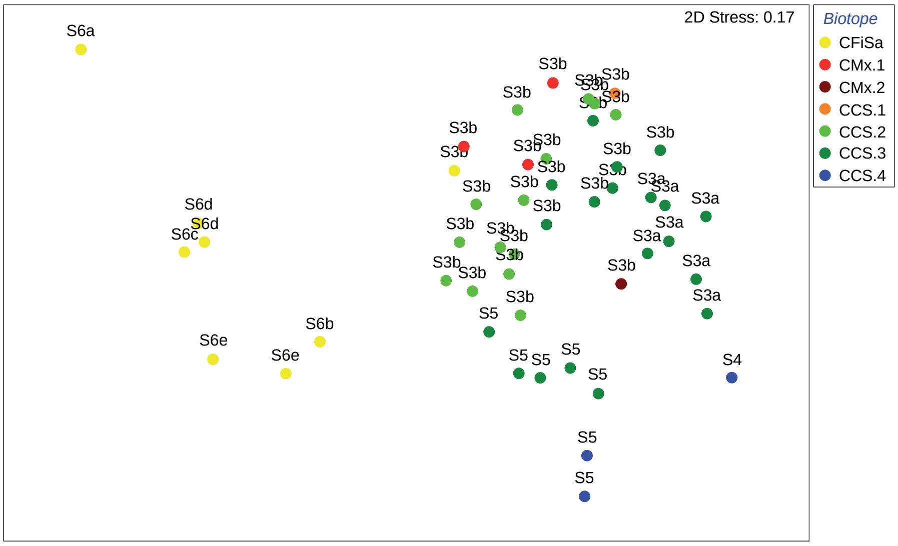
CCS.2 had a well-sorted fine gravel substrate, with frequent patches of dense *Glycymeris glycymeris* shells. *A. opercularis* was common throughout, and *O. albida* also occurred where more sand was present (Figure 5.84a and b). *Pomatoceros* spp. occurred at high densities on larger particles.

CCS.2 was widespread across the central southern part of the study area in Regions 4 and 5, forming a transition between the sandy CFiSa to the east, the coarser gravel CCS.3 and CCS.4 to the west in Region 2 and the more mixed CMx.1 and CMx.2 to the north in Region 1. This is reflected in the distribution of the CCS.2 samples in the MDS plot (Figure 5.79).

Table 5.16. Description of sediment characteristics and species profile of regional biotopes found in the study area. Closest match to clusters derived from stills and video analyses is shown ('-' indicates that biotope did not correlate strongly with clusters) as is the correlation to Epifaunal Biotope Complex, described in Chapter 6. Closest match to existing biotope or biotope complex in The Marine Habitat Classification for Britain and Ireland Version 04.05 (Connor *et al.*, 2004) is also given.

New Biotope	Description	Video cluster	Stills cluster	Marine Habitat Classification Biotope equivalent	Epifaunal Biotope Complex
CMx.1	Mixed sediment of occasional boulders on sand with frequent patches of cobbles and pebbles. Characterised by moderate to high abundance of *Pomatoceros* and Balanidae with rare occurrences of *Ophiura albida* and attached epifauna.	-	-	SS.SMx.CMx	EBC3 EBC10 EBC11
CFiSa	Circalittoral sand with patches of shelly debris and bedrock occasionally visible at surface. Impoverished epifauna, characterised by occasional attached epifaunal such as hydroids where shell fragments or larger particles are present. *Ophiura albida* occurs. Low abundance of fauna results in a low similarity of samples within this biotope.	V5	S6	SS.SSa.CFiSa. Insufficient information with epifauna alone to allow further definition of this biotope.	EBC9 EBC10 EBC11
CCS.1	Circalittoral mosaic of coarse sand with patches of shell and gravel. Coarser sediment than SS.SSa.CFiSa with greater proportion of shell and gravel. Largely barren with only *Pomatoceros* spp. present on larger particles.	V4	-	SS.SCS.CCS. Barren nature of these samples preclude further definition of this biotope.	EBC8 EBC10
CCS.2	Well sorted fine gravel and pebbles with patches of shell and sand. High abundance of *Pomatoceros* spp., and occasional occurrence of Bryozoa, *Ophiura albida*, Cirripedia, *Asterias rubens*, Paguridae and *Aequipecten opercularis*.	-	S3b	SS.SCS.CCS. Most closely resembles SS.SCS.CCS.PomB but with significant densities of *A. opercularis* and *O. albida*.	EBC2 EBC3 EBC5 EBC6
CCS.3	Coarse gravel with cobbles. High abundance of *Pomatoceros* spp. with dense patches of *Ophiothrix fragilis*. *Aequipecten opercularis* occurs occasionally. Similar to CCS.2 but with coarser sediment and *Ophiothrix fragilis* patches.	-	S3a	SS.SCS.CCS. Fauna resembles SS.SCS.CCS.PomB or SS.SMx.CMx.FluHyd equally but with significant densities of *A. opercularis*. Also resembles SS.SMx.CMx.OphMx due to presence of dense beds of *O. fragilis*.	EBC1 EBC2 EBC3
CCS.4	Predominantly cobble and pebbles with occasional boulders and some gravel. Very diverse epifaunal community, characterised by high abundance of sponges, erect bryozoans and hydroids (Indeterminate Porifera, Indeterminate Bryozoa, *Cellapora* spp, *Pentapora foliacea, Flustra foliacea, Abietinaria* spp, *Nemertesia* spp.). Is associated with CCS.3	V7	S4, S5	No clear equivalent but is a more cobbly variant of SS.SCS.CCS. Sediment also bears similarities to SS.SMx.CMx but fauna is similar to CR.HCR.XFa.ByErSp but lacks erect sponges.	EBC2
CMx.2	Pebbles, gravel and cobbles with occasional outcroppings of bedrock and small boulders at surface. Cobbles characteristically flat and angular. High abundance of *Pomatoceros* spp. And moderate abundance of hydroids (*Abietinaria* spp., *Nemertesia* spp., *Hydrallmania* spp. and *Sertularia* spp.) and *Flustra foliacea*. Less diverse than CCS.2 or CCS.3.	-	-	Due to the mixture of sediment types present, the faunal composition is similar to several biotopes, for example CR.HCR.XFa, SS.SCS.CCS.PomB and SS.SMx.CMx.FluHyd.	EBC3 EBC11

Figure 5.79. Two-dimensional MDS ordination of still samples, symbolised according to biotope. Annotated with still cluster number



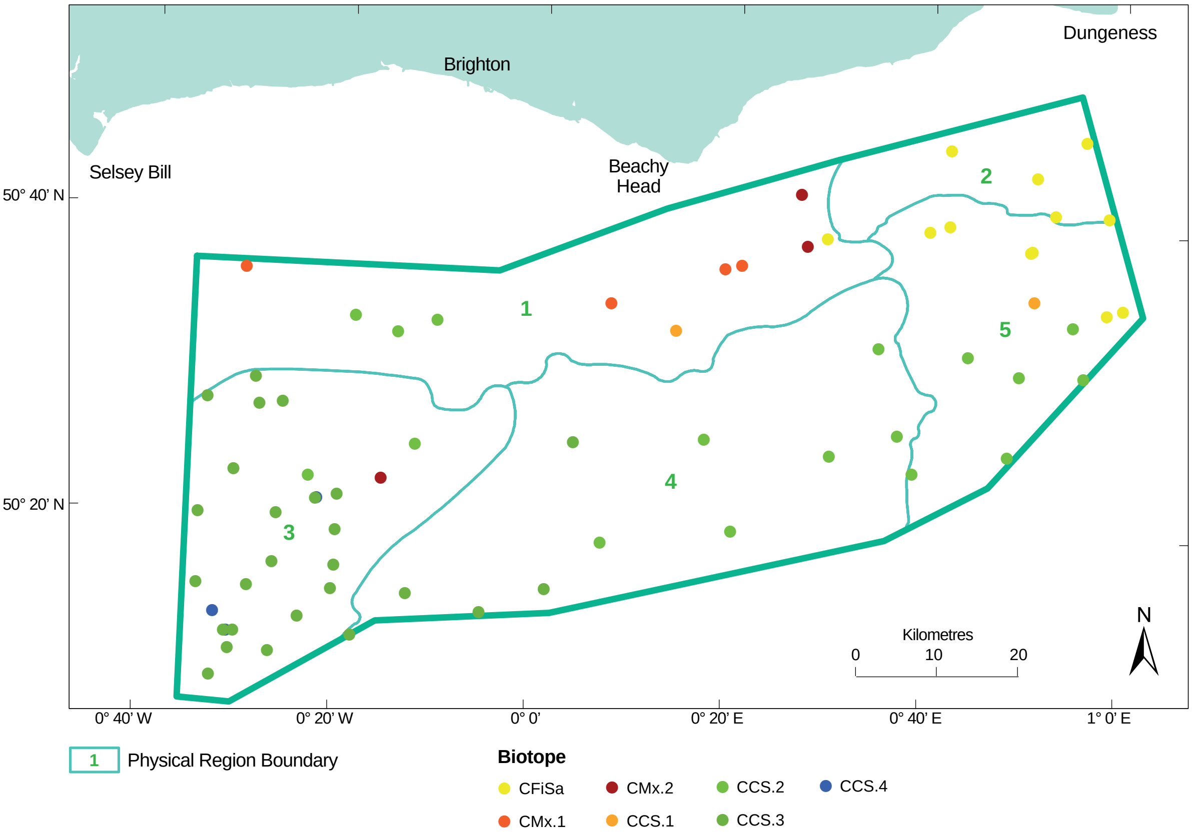


Figure 5.80. Distribution of biotopes across study area from video and still analysis.

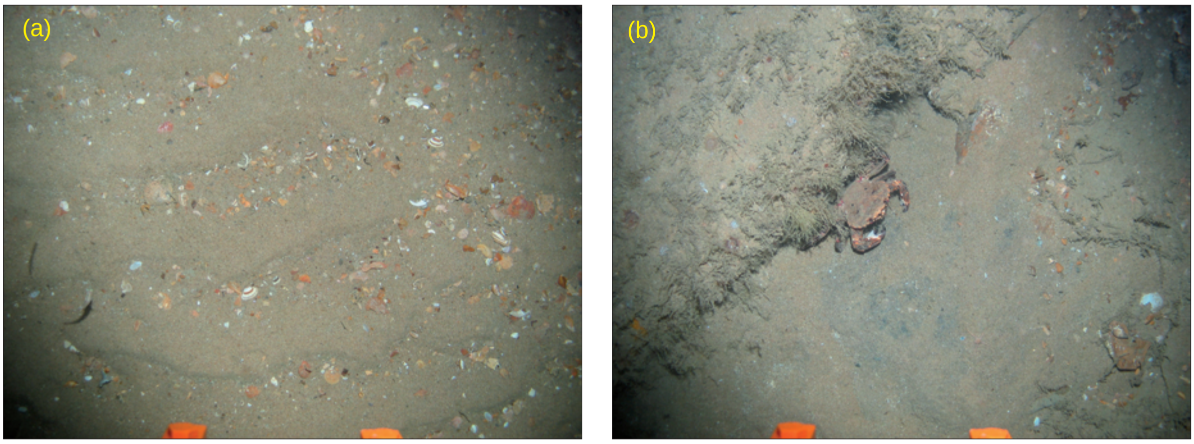


Figure 5.81. Photographs of sea bed from sample assigned to CFiSa, showing (a) shelly debris between sand ripples (EECMHM Station 198); (b) bedrock (Wealden Group) visible at surface, colonised by hydroids (Station 198).

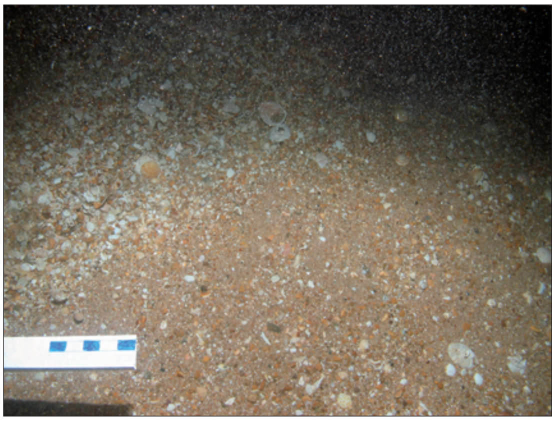


Figure 5.82. Photograph of sea bed from sample assigned to CCS.1 (EECMHM Station 58). Blue and white marks on scale bar in this and subsequent photographs each represent 2 cm.

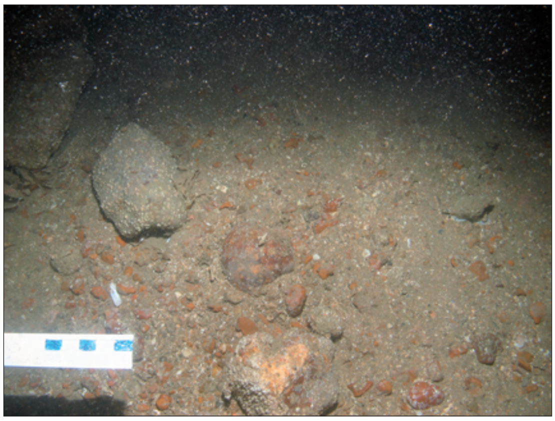


Figure 5.83. Photograph of sea bed from sample assigned to CMx.1, showing mixed nature of sediment, and boulders heavily encrusted with barnacles (EECMHM Station 3).

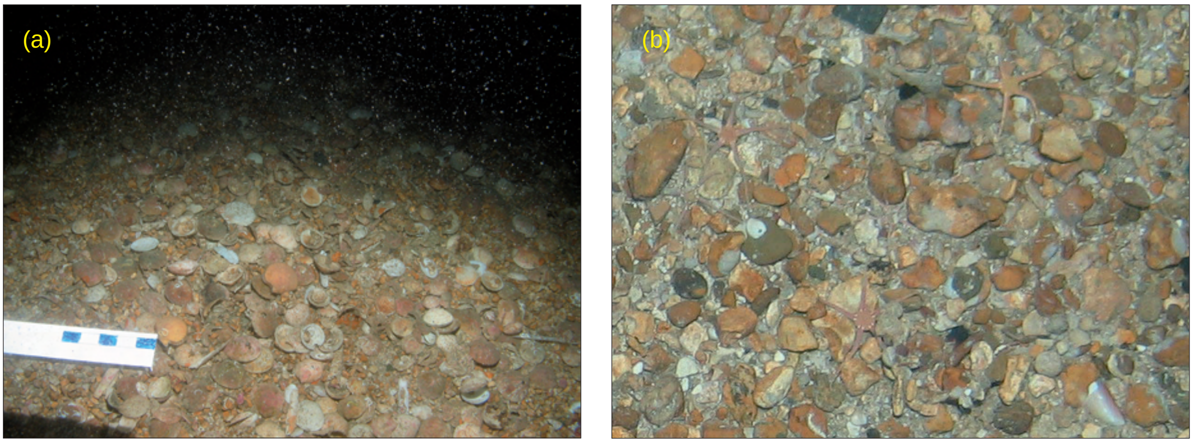


Figure 5.84. Photographs of sea bed from sample assigned to CCS.2, showing (a) patches of empty *G. glycymeris* shells (EECMHM Station 113), and (b) close-up photo of sea bed showing three *O. albida* (Station 145).

CCS.3 was a similar biotope to CCS.2, but was generally coarser and with cobbles occurring more frequently (Figure 5.85a). CCS.3 was also distinct in that there were frequently dense patches of *O. fragilis*, which were absent from CCS.2 (Figure 5.85b). CCS.3 had a good correlation with still cluster S3a identified from the stills analysis. Some samples were also in still cluster S3b, and were plotted on the MDS ordination (Figure 5.79) close to the finer gravel CCS.2. This reflects the transition between these two gravelly biotopes. A second group of CCS.3 samples correlated with still cluster S5. These still samples were distinct due to having lithic-dominant rather than mixed gravel lithology. CCS.3 was common within the study area, mainly confined to the western part of the study area in Region 5, although occasionally found further east.

CCS.4 was the most diverse of all the biotopes encountered in the study area. It was predominantly composed of cobbles and pebbles and occasional small boulders. It appeared that the sediment was more stable than the other biotopes, as the substrate was colonised by a high density and diverse range of sponges and bryozoans (Figure 5.86a). Due to the limitations of identification of species by sight alone, the majority of the sponges visible could not be identified, but for the purposes of analysis were grouped together to Phylum Porifera. However some of the more distinctive species such as *Haliclona* spp. and *Hemimycale columella* could be identified (Figure 5.86b). It is anticipated that if samples were to be collected and identified, the biological community would be found to be exceptionally diverse in comparison to the surrounding area.

CCS.4 was identified at only three of the stations surveyed. Video footage suggested that this biotope might also be present in patches at stations 128 and 21. These stations were sampled in 2005 and the video footage was of insufficient quality to be sure whether biotope CCS.4 was present. Furthermore they were sampled using the drop camera and hence no still photographs were available for confirmation. Therefore all confirmed areas of CCS.4 were confined to the south-west corner of the study area in Region 3. At stations 158 and 182 CCS.4 was confined to only part of the video tow, and only at station 122 did the biotope appear to cover the entire video tow. These results suggest that this biotope is patchily distributed within the wider area of coarse gravel (CCS.3) and is therefore likely that there are many more patches of this biotope distributed within the survey area that were not identified due to the low spatial resolution of the survey stations.

The final biotope to be identified, CMx.2, was similar in species composition to CCS.3 in that there was a high abundance of *Pomatoceros* spp., however it lacked the *O. fragilis* beds present in CCS.3. In comparison there was also a greater abundance of the hydroids *Abietinaria abietina, Nemertesia* spp., *Hydrallmania* spp., and *Sertularia* spp. and a greater abundance of Bryozoans although overall this biotope was less diverse than CCS.3. Pebbles and cobbles dominated the substratum, although bedrock was occasionally visible at the surface (Figure 5.87a). The cobbles present at these stations were distinctly flat and angular, in comparison to the more rounded cobbles found in CCS.4 (Figure 5.87b). The cluster analysis of the video data suggested that the fauna was not distinct from that found in the other gravelly biotopes, however the presence of significant amounts of bedrock indicated a distinct sediment profile, and resulted in the biotope fitting into a different sedimentary section of the Marine Habitat Classification. Three samples corresponded to this biotope; two at stations in the Northern Palaeovalley and Margin (Region 1), and one within the Western Axial Platform (Region 3) in an area mainly represented by CCS.3.

Overview of habitats encountered

Using the results of the video and stills analysis alone, a map was created to represent the spatial distribution of biotopes across the Eastern English Channel study area (Figure 5.80). The broad picture portrayed was of a region characterised by sand-dominated communities to the east and north, with gravel-dominated communities to the south and west. The gravel area appeared to show a general gradient from finer gravel in the east, to coarser gravel in the west, with increasing quantities of larger cobbles (Figure 5.88). Within the coarse gravel area, patches of more consolidated sediment habitat with reef-like fauna were also present. A distinct community on bedrock and lithic-dominated gravel also occurred at a small number of stations (CMx.2), although the sampling density was not sufficient to describe any patterns in the distribution.

The majority of previous studies in the area have been carried out on behalf of the marine aggregate industry, and hence have focused on the area of potential aggregate resource (Figure 4.1) in the south-central part of the EECMHM study area, mainly Region 4. Within the current study, video sampling densities within the licence areas were low, making detailed comparisons difficult. However in general, our study supports previous findings. Within the area of proposed aggregate licences, the video and stills analyses indicated that a biological community associated with fine gravel particles was present (CCS.2). This represented a new biotope within the biotope complex SS.SCS.CCS (Circalittoral coarse sediment) as defined in The Marine Habitat Classification for Britain and Ireland

Figure 5.85. Photographs of sea bed from sample assigned to CCS.3 showing (a) Substrata dominated by coarse gravel and cobbles (EECMHM Station 126); (b) close-up photograph of sea bed showing dense bed of *O. fragilis* (Station 124).

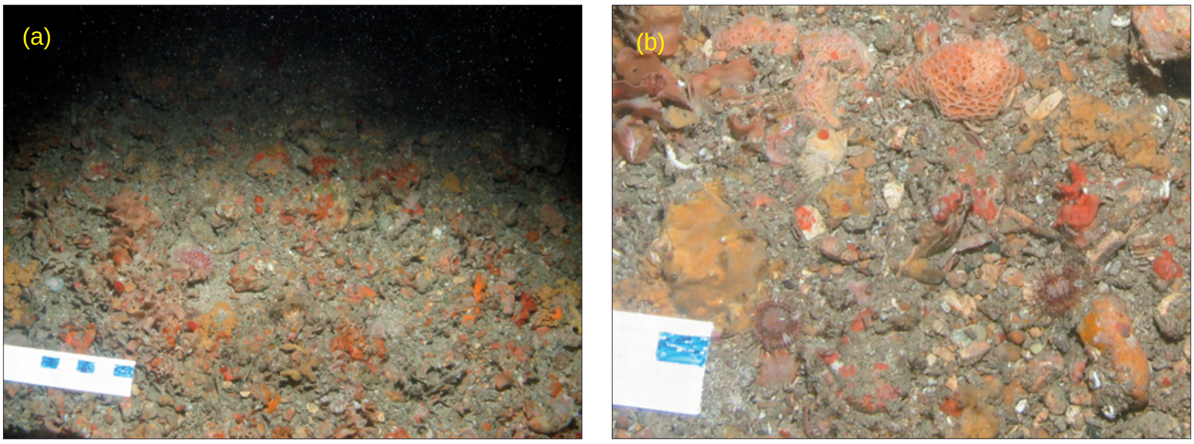


Figure 5.86. Photographs of sea bed from sample assigned to CCS.4 showing (a) substrata covered with sponges and bryozoans (EECMHM Station 122) and (b) *Hemimycale columella*, distinctive peach-coloured honeycomb sponge (top centre) (Station 122).

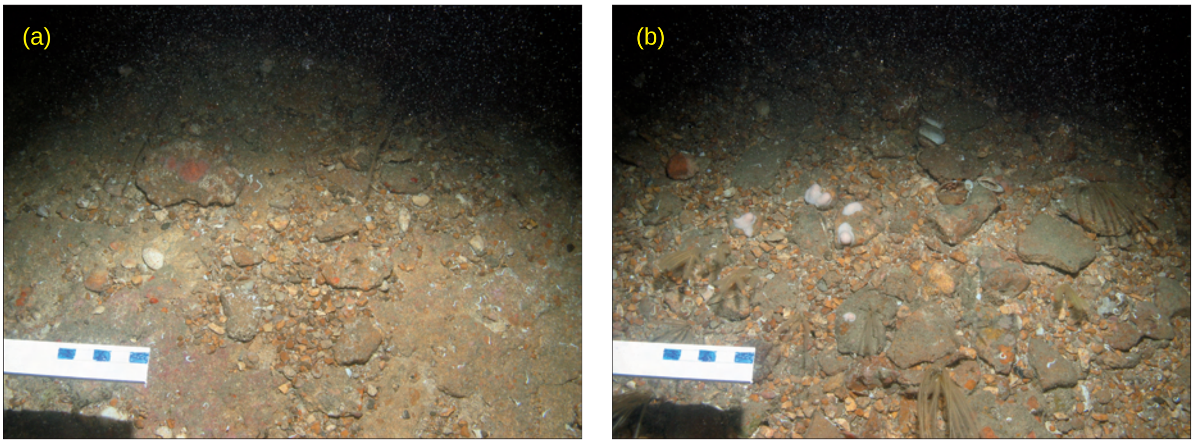


Figure 5.87. Photographs from sample assigned to CMx.2 showing (a) exposed bedrock (Bracklesham Group) at surface (EECMHM Station 79) and (b) distinctly angular cobbles, colonised by the hydroid *Nemertesia* spp. and the soft coral, *Alcyonium digitatum* (Station 79). Cobbles derived from underlying Bracklesham Group bedrock are clearly different from those found in areas assigned to CCS.3 as shown in Figure 5.85(a).

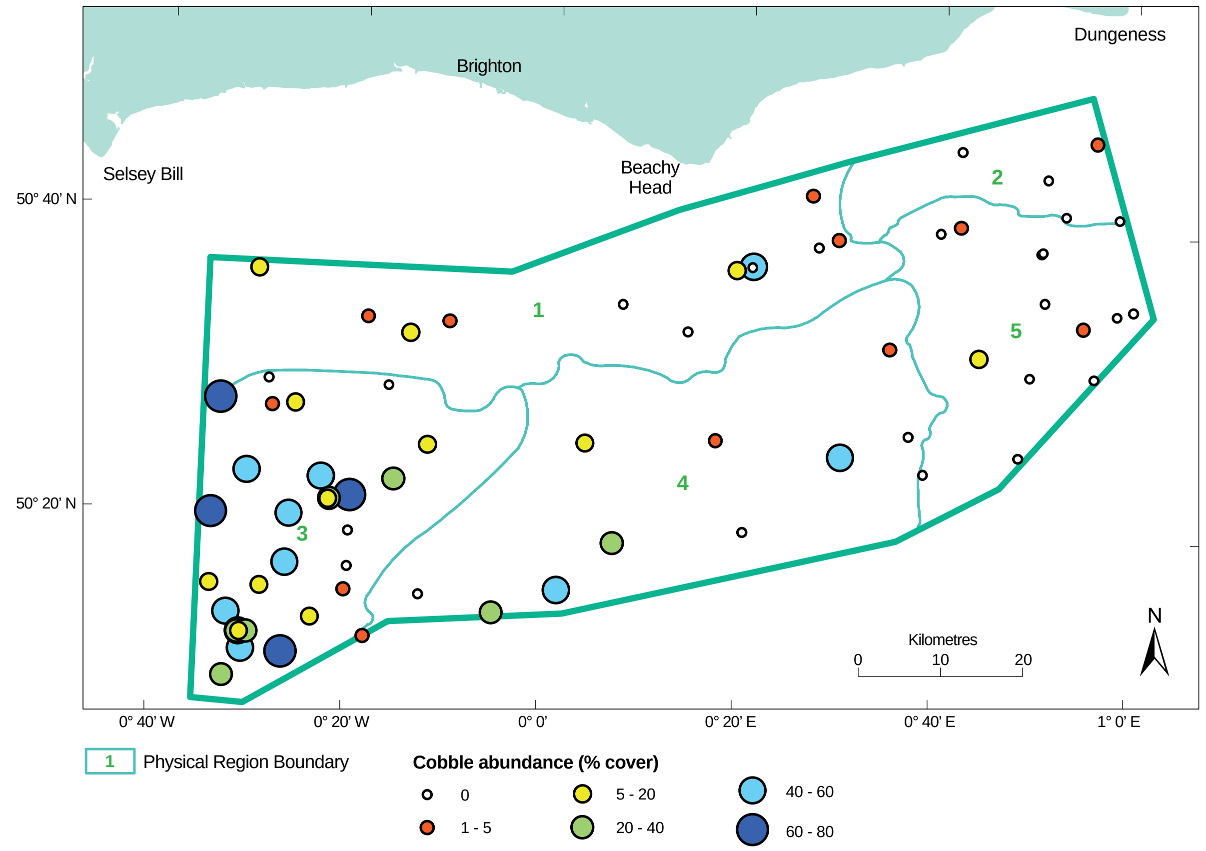


Figure 5.88. Abundance of cobbles across study area (by % cover of substratum), determined from analysis of video footage.

v 04.05 (Connor *et al.*, 2004). Studies carried out for the aggregates industry have identified this same species assemblage associated with fine-gravel, and divided it into two biotopes, PomB and PomAequi, within the biotope complex SS.SCS.CCS (Emu and MarineSpace, 2006). PomB (*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles) is an existing biotope within the Marine Habitat Classification, whereas PomAequi is not, but has been described by Emu Ltd (Emu and MarineSpace, 2006) as a variant of the existing biotope PomB, containing a higher abundance of *Aequipecten opercularis*. In the present study, most of the samples within CCS.2 had *A. opercularis* recorded as present (occasional, common or frequent on the SACFOR scale) although it was not recorded in all samples (Figure 5.89). These results suggest that the same habitat is being identified by each of these studies, but due to the lack of an exact biotope match in the existing Marine Habitat Classification, different approaches have been taken to propose new biotopes.

A comparison between the present study and studies within the East Channel Association (ECA) prospecting areas (Emu and MarineSpace, 2006; Emu Environmental, 2002) highlights the effect of sampling density on production of habitat maps. Sampling strategies are built and designed around the specific needs of the projects involved. The sampling strategy adopted for the EECMHM study was designed to meet the needs of producing a regional habitat map, obtaining the maximum amount of information over a broad area. Sampling stations were widely spaced within the large study area, and several different sampling gears were used (although not all gear types were used at all stations). The benefit of this strategy was that a very large area was covered and information was collected on several different aspects of the biological communities in the area (e.g. infaunal and epifaunal information). This allowed the broad habitat types in the area to be identified, mapped and, due to the collection of different data types, habitats could be well-described from a number of different perspectives.

In other studies carried out in smaller areas within the eastern English Channel, sampling stations were more densely distributed and this allowed the heterogeneity of habitats and the existence of local variation to be assessed (Emu Ltd, 2006; Emu Environmental, 2002). Within the ECA prospecting area, local variations in biotope were encountered that were not picked up by the present study. Not only were the two distinct biotopes described above recognised (PomB and PomAequi), but within the area predominantly composed of fine gravel, several patches of coarser gravel with cobbles and *Ophiothrix fragilis* (Emu Ltd, 2006) and a small area of large boulders (Emu Environmental, 2002) were also encountered. This serves to emphasise that the map produced in Figure 5.80 should not be interpreted as a complete picture of the biotopes present within the study area, but rather provides a broad overview of some of the most common biotopes present. Thus, interpolation between

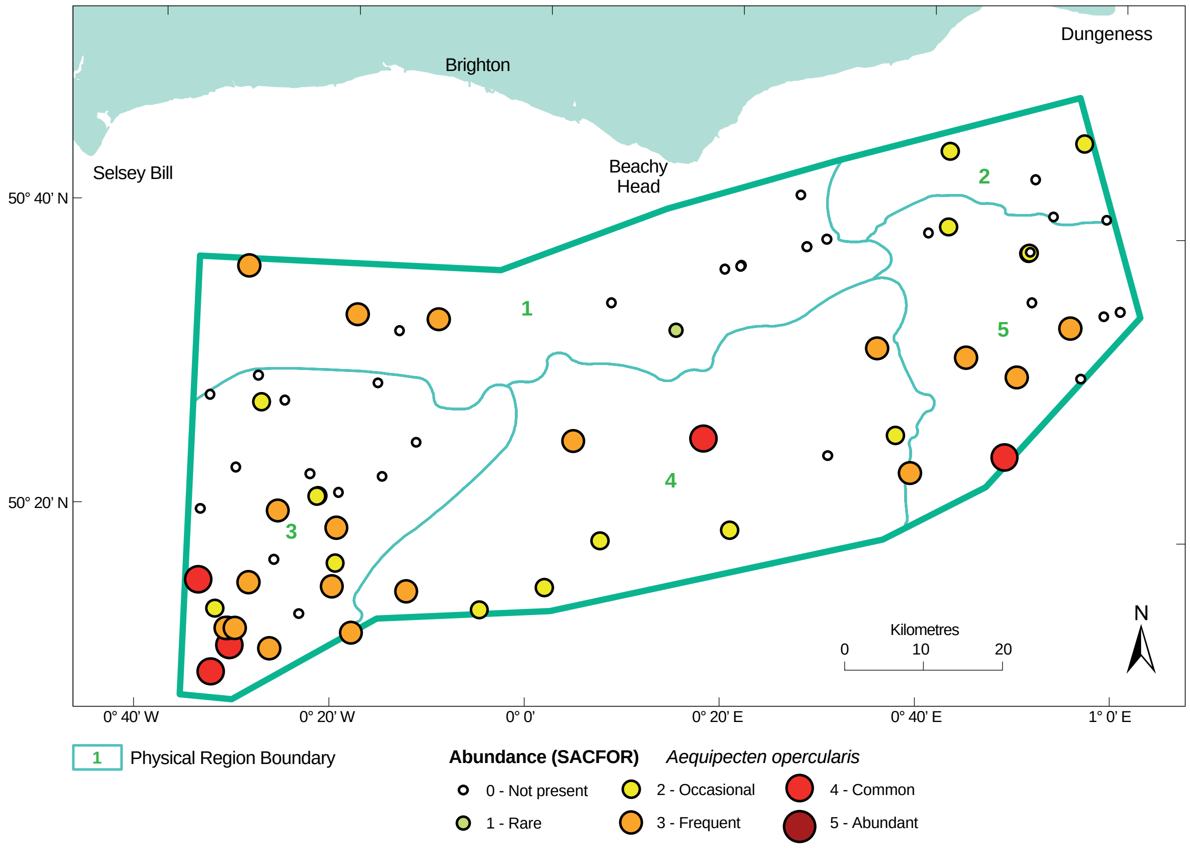


Figure 5.89. Distribution of the queen scallop, *Aequipecten opercularis* across the study area. Coloured symbols represent abundance of *A. opercularis* in each video sample, using the semi-quantitative SACFOR scale.

the sampling stations should not be encouraged, as local variation is likely to be missed. Furthermore, the map shown in Figure 5.80, if considered in isolation, suggests a clearer division between coarse and fine gravel (moving from west to east) than may actually exist.

Features of interest found within the present study include the presence of very dense beds of the brittle star *Ophiothrix fragilis*. These beds were found only in the south-west corner of the study area (Figure 5.90) although, as referred to above, previous studies have noted that such beds are also found in other parts of the eastern English Channel (Emu Ltd, 2006; Holme 1966). A study by Ellis and Rogers (2000) where benthic macrofaunal by-catch from beam trawls was used to investigate the distribution of echinoderms in the English Channel, noted abundances of up to 2.4 million individuals per hectare.

A second feature of interest was the presence of moderate densities of the rosy feather star, *Antedon bifida*, at seven sample stations in the south-west of the study area, at densities up to 40 per still image. This species of feather star is found in a variety of habitats, generally on boulders or bedrock, in a wide range of depths. *A. bifida* has a known distribution around western and north-eastern coasts of the UK, but has only been previously recorded at three locations in the English Channel (off the coasts of Bognor Regis and Brighton, and at one location in the central Channel).

A final feature of interest was the presence of a coarse gravel and cobble habitat that supported a community of sponges, erect bryozoans and hydroids (CCS.4). This biotope occurred in small patches in the south-west of the study area, within a wider area of coarse gravel and cobbles. It was patchily distributed, occurring in only one full tow, and in short sections of two other tows, where the habitat transitioned between CCS.3 and CCS.4 (Figure 5.86). Although the presence of cobbles and, in some cases, boulders was noted in previous studies, this distinctive epifaunal community was not identified within this area (Emu Environmental, 2002). However, a study conducted in an area further west in the English Channel identified a similar epifaunal community, which was described as 'Type A: Stable faunal assemblage with diverse sponge cover' (Holme and Wilson, 1985). The epifaunal community present in biotope CCS.4 consisted of a rich and diverse reef fauna in relation to the surrounding coarse gravel habitat. The presence of a range of sponges and other attached epifauna suggests there may be some environmental characteristics, absent in the surrounding coarse gravel, which allows this community to develop. For example, this biotope may have a more consolidated and less mobile substrate, a slightly different sediment composition, or may have developed in the absence of significant human impacts, or it may alternatively be due to reduced sand scour as suggested by Holme and Wilson (1985).

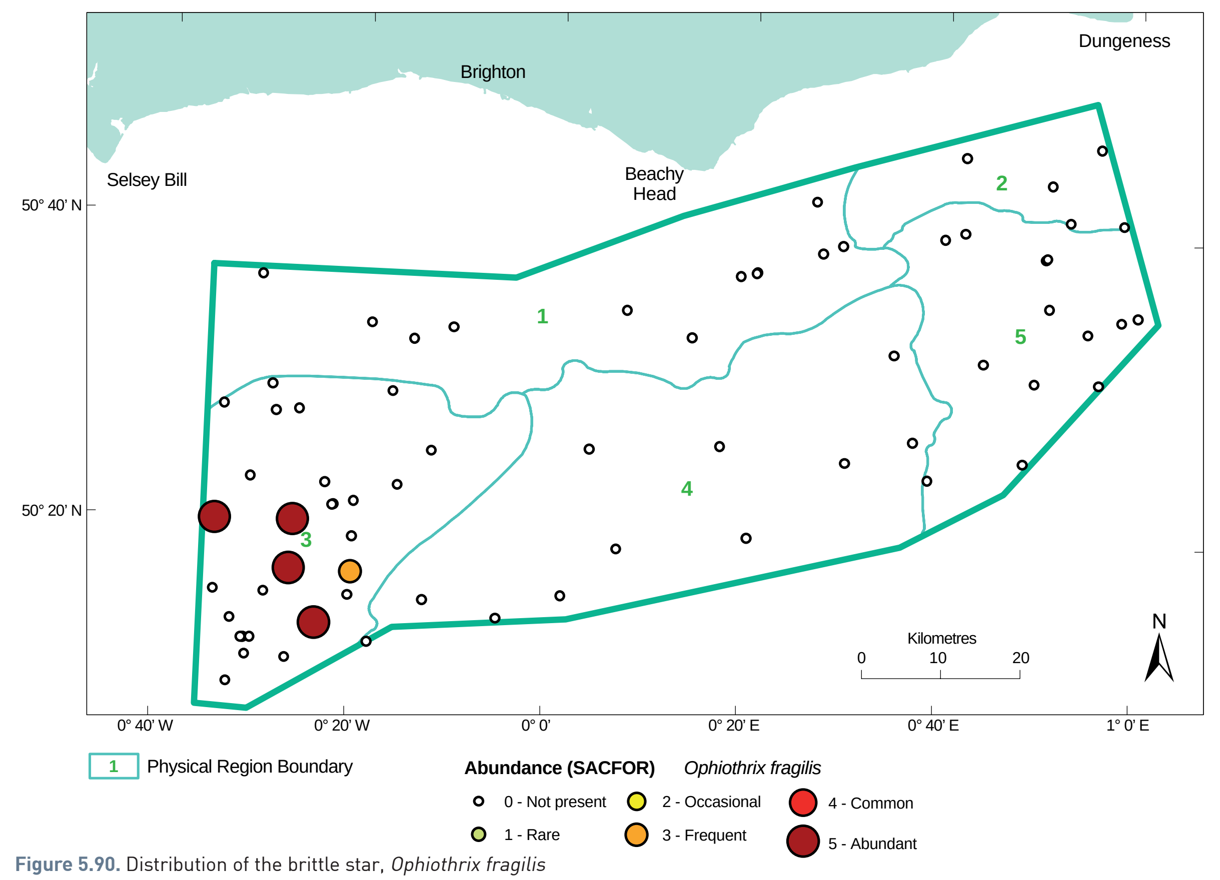


Figure 5.90. Distribution of the brittle star, *Ophiothrix fragilis* across the study area. Coloured symbols represent abundance of *O. fragilis* in each video sample, using the semi-quantitative SACFOR scale.

Review of methodology

For this project, both stills photography and mobile video tows were used to collect visual information at sampling stations in the eastern English Channel. Analyses of the data showed that used together, these two data collection techniques are in many ways complimentary, but that individually they can also collect useful data. Therefore, depending on the aims and data needs of a project, the use of one or both techniques might be appropriate.

For the purposes of regional habitat mapping or biotope identification, data collected with video tow is particularly useful. It can be used to cover large areas and provides a good general 'overview' both in terms of the biological communities present and sediment characteristics. Therefore the range and diversity of habitats as well as an estimation of boundaries between habitats could be mapped with reasonable accuracy using video. However, for the purposes of species identification, taxonomic resolution is usually reduced with video data compared to still photographs. Although organisms can frequently be identified to broad taxonomic group or genus using video, detailed species-level identification is not possible in many cases. This is due mainly to the dynamic nature of video data and the reduced resolution of the image.

This project has shown that still photography is particularly important where a detailed description of biological communities is required. Because the resolution of the data is better compared to that of towed video, there is a greater chance of identifying small, cryptic or inconspicuous organisms. Moreover, organisms can usually be identified to a finer taxonomic level than is possible with towed video data, thus where description of a new habitat or biotope is required, this increased taxonomic resolution is valuable. However, the area sampled using still photography is smaller. On the other hand, it should also be borne in mind that footage collected using video can often allow the identification of large, rare or mobile fauna that might not necessarily be captured in a 'one off' still photograph. In this sense, the two techniques compliment each other very well.

A final benefit of collecting both video footage and still images is that the use of two simultaneous but related techniques provides a 'backup' in the event of one technique failing. For example, in the 2006 data, stills at six stations were found to be out of focus, but video data taken simultaneously meant that at least some information was gathered for these stations. Likewise, the video footage collected during 2005 was of a poor quality, but the collection of simultaneous still images compensated for this loss of data.

Use of the Marine Habitat Classification for Britain and Ireland v 04.05

A significant issue identified through this study was the difficulty of assigning biotopes to the epifaunal assemblages identified with the video and stills data, using The Marine Habitat Classification for Britain and Ireland v 04.05 (Connor *et al.*, 2004). The use of a standardised classification scheme is essential as it allows biological assemblages to be categorised and mapped, and allows comparison with other studies. The Marine Habitat Classification for Britain and Ireland is currently the most comprehensive marine benthic classification system available, and is fully compatible with the European EUNIS classification system, thus ensuring consistency and allowing comparison of results on a Europe-wide scale.

A problem encountered within this study was the lack of suitable biotopes within the existing classification to describe the habitats encountered, for which there are two main reasons. The first reason is that The Marine Habitat Classification was developed using pre-existing data and, historically, the majority of marine survey around the UK has been focussed on shallow inshore areas. Consequently areas further offshore, including the area covered by this study, have not been extensively surveyed, and thus limited data has been available to feed into the development of The Marine Habitat Classification for Britain and Ireland.

The second reason for the lack of suitable biotopes is that previous marine surveys have often used sampling gear that targets a particular part of the faunal community, for example, grabs to sample soft-sediment infauna and visual methods (video or diver observations) to sample harder sediments and epifauna, but have not used different sampling-gears simultaneously. This has led to biotopes having been described that reflect the sampling method used to acquire the data, and hence has resulted in some separation between infauna and epifauna within the Classification. It is therefore possible that some of the habitats encountered in this study have been sampled previously but using a gear-type that samples infauna rather than epifauna. Biotopes may therefore exist within The Marine Habitat Classification that describe the habitats encountered within the present study, but due to being described on the basis of infaunal data alone, can not be related to the data derived from the analysis of video and stills. As new data becomes available, further work is required to integrate the biotopes relating to infauna to those relating to epifauna, and to identify whether there are separate biotopes within the existing Classification that relate to different aspects (the infaunal and the epifaunal component) of what is essentially the same biotope. The data collected within this study, where stations were specifically selected to be sampled using two or three different sampling gears, will make a valuable contribution to such work.

The lack of relevant historic data to feed into the Classification, and the bias of sampling gears influencing the description of biotopes, therefore results in a lack of biotopes within the Classification that describe the habitats present. Although at the Biotope Complex level (Level 4 of the Classification) there is the biotope complex, Circalittoral Coarse Sediment, there are insufficient biotopes described within this complex to adequately classify the variation that exists. This has led to different studies proposing new biotopes, each of which may differ slightly from other proposed new biotopes. These issues can only be resolved as new data for the offshore area becomes available, which can then be strategically assessed to further develop this part of the classification system. The data collected within this study will thus make a significant contribution to further development of The Marine Habitat Classification for Britain and Ireland.

5.3.4 Areas of conservation interest within the EECMHM study area

Within the EC Habitats Directive (EEC 1992) (as amended by Directive 97/62/EC) there are two habitats listed in Annex I that potentially occur within the EECMHM study area. These are ‘reefs’ and ‘sandbanks which are slightly covered by seawater at all time’. The results of this study were examined to consider whether any of the habitats sampled fitted the definitions for these two Annex I habitats, and to identify any communities or species of interest in these habitats.

Reefs

Two biotopes were identified by the video survey that had the potential to be considered as Annex I reef habitat, biotopes CMx.2 and CCS.4.

Rocky reefs are a sub-type of the Annex I habitat ‘reef’. The draft Interpretation Manual of European Habitats (EC, 2007) defines reefs as: -

- Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions.”

The term 'arise from the sea floor' is further clarified as meaning "the reef is topographically distinct from the surrounding seafloor" (EC, 2007).

CMx.2 was characterised by a mixed substrate with bedrock present at the surface in some areas. At several places on the sea bed within CMx.2, rock was visible in the photographs and videos. The rock was characteristically flat, and covered with a thin layer of gravel, and did not appear to be topographically distinct from the surrounding seafloor. The epifaunal community in this biotope did not represent a particularly diverse reef fauna. The exposed rock appeared to have little attached epifauna, suggesting that the gravel layer was mobile and thus scoured the underlying rock, preventing successful colonisation by epifauna. These characteristics indicate that none of the areas where biotope CMx.2 was recorded during the surveys fitted the description of Annex I reef habitat.

The second biotope to consider, CCS.4 was characterised by a cobble and coarse gravel substrate, and therefore could potentially be considered as stony-reef.

The term 'hard compact substrata' within the draft Interpretation Manual of European Habitats (EC, 2007) is further clarified as meaning "rocks (including soft rock, e.g. chalk), boulders and cobbles (generally >64 mm in diameter)." CCS.4 was certainly characterized by the presence of cobbles, >64mm in diameter (on average 35% cover), but the distribution of cobbles was very patchy where the biotope was recorded.

The epifaunal community supported by the cobbles and coarse gravel within this biotope was rich and diverse in relation to the surrounding coarse gravel biotope (CCS.3). The fauna present was characteristic of that found on hard substrata, and fitted in well with the examples of reef animals within the draft Interpretation Manual of European Habitats (EC, 2007): -

> "In general sessile invertebrates specialized on hard marine substrates such as sponges, anthozoa or cnidaria, bryozoans, polychaetes, hydroids, ascidians, molluscs and cirripedia (barnacles) as well as diverse mobile species of crustaceans and fish."

From the above information, biotope CCS.4 appears to fit the general description of stony reef according to the Habitats Directive interpretation manual. However, it was only distributed over a small spatial extent within the westernmost part of the study area, had a very patchy distribution and also does not appear to form structures 'topographically distinct from the surrounding seafloor.' On only one occasion did it occur throughout a video tow, occurring only in short sections of two other tows, in an area otherwise represented by CCS.3. Although the number of survey stations in this area was relatively low and sparsely distributed, the survey suggests that this biotope is unlikely to have a wide continuous distribution within the study area.

Further surveys are planned to identify potential reef, if present, to the west of the present study area. It is possible that if extensive presence of biotope CCS.4 is identified further west, that those stations where it was recorded during the current survey could be patchy occurrences on the edge of a more extensive area of the biotope present further west.

The presence of biotope CCS.4 is of conservation interest, but due to its patchiness and small extent within the present study area, it appears unlikely that it would be determined to form a 'reef' suitable for identification as SAC under the Habitats Directive. However, it is not possible to put the recorded occurrence of this biotope fully into context until further work has been completed in the area immediately west of the current study area.

Sandbanks which are slightly covered by seawater at all time

The only area within the present study that could be considered to be Annex I habitat defined as: -

- Sandbanks which are slightly covered by seawater all the time

lies in the south-east corner of Region 5. This area is the western part of the Bassurelle Bank in UK waters; the bank extends eastwards into French waters (Figure 3.2). Although a significant proportion of the study area is covered with gravelly sand or sand (Figure 5.7), Bassurelle Bank is the only distinct sandbank in less than 20m of water. In order to fit the European interpretation of 'sandbanks slightly covered by seawater all the time', the sea bed must be composed of sandy sediments, have deeper water around the bank, and lie mainly in water less than 20m deep (EC, 2007).

Interpretation of the geophysical data and sediment samples indicated that the sandbank is comprised of a substantial layer (up to 25m thick) of 'featureless' sand and gravelly sand, distinct from thinner sediments elsewhere, and distinct from sand wave fields further north.

This small part of the study area was sampled using the beam trawl, towed camera sledge and Hamon grab, each of which sampling method provides slightly different information on the epifauna or infauna of the bank.

Beam trawl data provides information on more mobile and wider distributed epifauna, as well as sessile epifauna, of the bank. Analysis of the beam trawl data, revealed an epifaunal community that was biologically distinct from other sandy habitats within the study area. The two stations upon the bank were assigned to Cluster A (see Section 5.3.2) which was a gravelly sand and sand habitat, characterised by the hydroid *Hydrallmania falcata*, the sand eel *Ammodytes tobianus*, the common hermit crab Pagurus bernhardus and the crab *Liocarcinus holsatus*. Weever fish (Echiichthys) were also characteristically present.

Towed camera sledge provides video and stills images illustrating sessile and mobile epifauna present, and providing information on their specific distribution and abundance along the video tow. Analysis of the video footage collected on the bank identified the biotope CFiSa. This was the same biotope that was attributed to samples in the other sandy areas in Region 2 and 5, as there was little epifauna visible that could be identified to be able to distinguish any variation in sand-dominated habitats. At the two stations sampled on Bassurelle Bank a small number of hydroids, hermit crabs and brittle stars (*Ophiura* spp.) were the only fauna visible.

Grab sampling provides information on the animals living within the sediments of the bank. Analyses of the infaunal data identified three distinct biotopes that occurred within the sand bank area, although these biotopes were not restricted to the sandbank, but were also found across the north and east of the study area (see Section 5.3.1).

- Infaunal group D was described as '*Echinocyamus pusillus, Nephtys* and *Glycera* in circalittoral fine sand' (SS.SSa.CFiSa.EpusNephGlyc) which was a new biotope that most closely resembled the existing biotope '*Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' (SS.SSa.CFiSa.EpusOborApri).

- Infaunal group AB was described as '*Lagis koreni* and *Ensis* in circalittoral fine sand' (SS.SSA.CFiSa.Lkor.Ens), which was a new biotope, almost identical to the fauna of the existing biotope '*Lagis koreni* and *Phaxus pellucides* in circalittoral sandy mud' (SS.SMu.CSaMu.LkorPpel) but with a sandy rather than muddy sand sediment.

- Finally, infaunal group A only represented one sample, and therefore was not assigned a biotope. The sediment was again sandy with *Echinocyamus* spp., *Moerella* spp. and Copepods.

The western part of Bassurelle Bank clearly fits the interpretation of this habitat type according to the EC interpretation manual (EC, 2007), and supports a range of small fish, epifaunal and infaunal species typical of sublittoral sandy sediments, including mobile epifauna found on the bank itself but not on other sandy habitats within the study area.

6. Integrated assessment of habitats and biotopes

6.1 Infaunal biotopes – interpretation and mapping

The collection of infaunal samples was the most comprehensive biological survey conducted in the study area (see section 4.2 for details). The spatial distribution of samples covered a wide range of habitats and multivariate analysis identified distinct clusters of stations that accorded well with the existing BGS sea bed sediment classification and mapping of the area. The infaunal analysis showed the species and assemblages to inhabit specific sediment types known to be present in the area. Nine biotopes were considered to be sufficient to classify the infaunal data.

In the majority of cases, geographically distinct groups of stations were found to conform to well-defined biotopes. However, in some cases individual samples within clusters were scattered over the entire area, so this presented challenges when there was the need to delineate biotope boundaries. In such cases, additional epifaunal or geological data were used to assist the process, and the mapped biological polygons were delineated by informed interpolation. Results from this combined approach are presented in the form of an interpreted distribution map for infaunal biotopes (IB) (Figure 6.1).

In the north-west of the study area, where the Northern Palaeovalley and Margin (Region 1) is located there was a mixture of gravelly sand and sandy gravel sediment. Patches of granules, pebbles, cobbles and dead *Glycymeris glycymeris* shells were also observed. A variety of crustaceans and polychaetes were encountered across this area, which contained a total of three infaunal biotopes. IB1 extends over the southern part of the palaeovalley floor, in the south-west and central parts of Region 1 and the north-eastern limit of Region 3, and was mainly dominated by *Echinocyamus pusillus*, *Pomatoceros* spp., *Glycera* spp., *Aonides* spp. and *Galathea* spp.. IB2 extended mostly along the sandy sediment on the northern half of the Palaeovalley floor and was characterised by *Echinocyamus pusillus, Nephtys* spp., *Glycera* spp., *Notomastus* spp., *Aonides* spp. and *Lumbrineris* spp.. IB5 was also found in small distinct patches of sandy gravel sediments intermixed with IB2, and mainly comprised *Mediomastus fragilis*, *Lumbrineris* spp., *Echinocyamus pusillus, Scalibregma* spp., and *Poecilochaetus* spp..

On the North-East Platform and Margin (Region 2), small patches of IB2 were found on the boundaries of IB5 and IB3. IB5 was itself dominated by polychaetes and covered the majority of the area where rock, thin sediments and sand sheets had been identified. The border between Region 2 and Region 5 marks the northern limit of the Greater Bassurelle Sands and a distinct infaunal community, IB3, was associated with the sandwave field in the north of Region 5 and extended onto the Bassurelle Bank. The characteristic infuana of IB3 were dominated by the razor shell, *Ensis* spp., and tubiculous polychaetes such as *Lagis* spp., *Spiophanes* spp. and *Magelona* spp..

On the Western Axial Platform (Region 3) a distinct community IB8 was closely associated with an area of mixed sediment overlying the Wealden Group rocks and was characterised by the presence of *Glycymeris* spp. and attached epifauna including the ascidians *Dendrodoa* and *Pyura* and the tubiculous polychaete *Pomatoceros.* IB9 was restricted to an area immediately north of IB8 and was characterised by mixed sediment supporting *Ophiothrix fragilis* beds and associated infauna species such as *Nucula* spp.*, Lumbrineris* spp.*, Glycymeris* spp. and *Galathea* spp. Surrounding these two biotopes, IB4b covered most of the western half of Region 3 where a mixture of muddy sandy gravel sediment was dominated by *Galathea* spp., *Pomatoceros* spp., *Pisidia* spp. and *Glycymeris* spp.. A very similar faunal association, IB4b, was found to span from the eastern extremity of Region 3 across the north central part of the Central Axial Platform (Region 4). This biotope was associated with a mixture of muddy sandy gravel and had high abundances of *Pisidia* spp., *Galathea* spp. and *Glycymeris* spp. IB4b recurred immediately east of IB4a, in an area where there are a number of palaeochannel interfluves with thin sediment on rock (Figure 5.5 and Map 1).

The southerly parts of Region 4 were dominated by two biotopes, IB7 and IB1. IB7 covered the south-western area, being a polychaete-rich offshore mixed sediment, and this graded, eastwards, into IB1 as the sediments graded from sandy gravels to gravelly sands. IB1 extended eastwards to occupy the central and southern area of Region 5, until reaching the sand wave field of the Greater Bassurelle Sands. Limited patches of IB2 recurred at the edge of the sand wave field, associated with restricted areas of sandy gravels.

Finally, IB6 comprised a small group of 9 stations scattered throughout the study area. This was mainly associated with patches of muddy sandy gravel with a distinct fauna characterised by *Balanus* spp., *Pomatoceros* spp. and polychaetes.

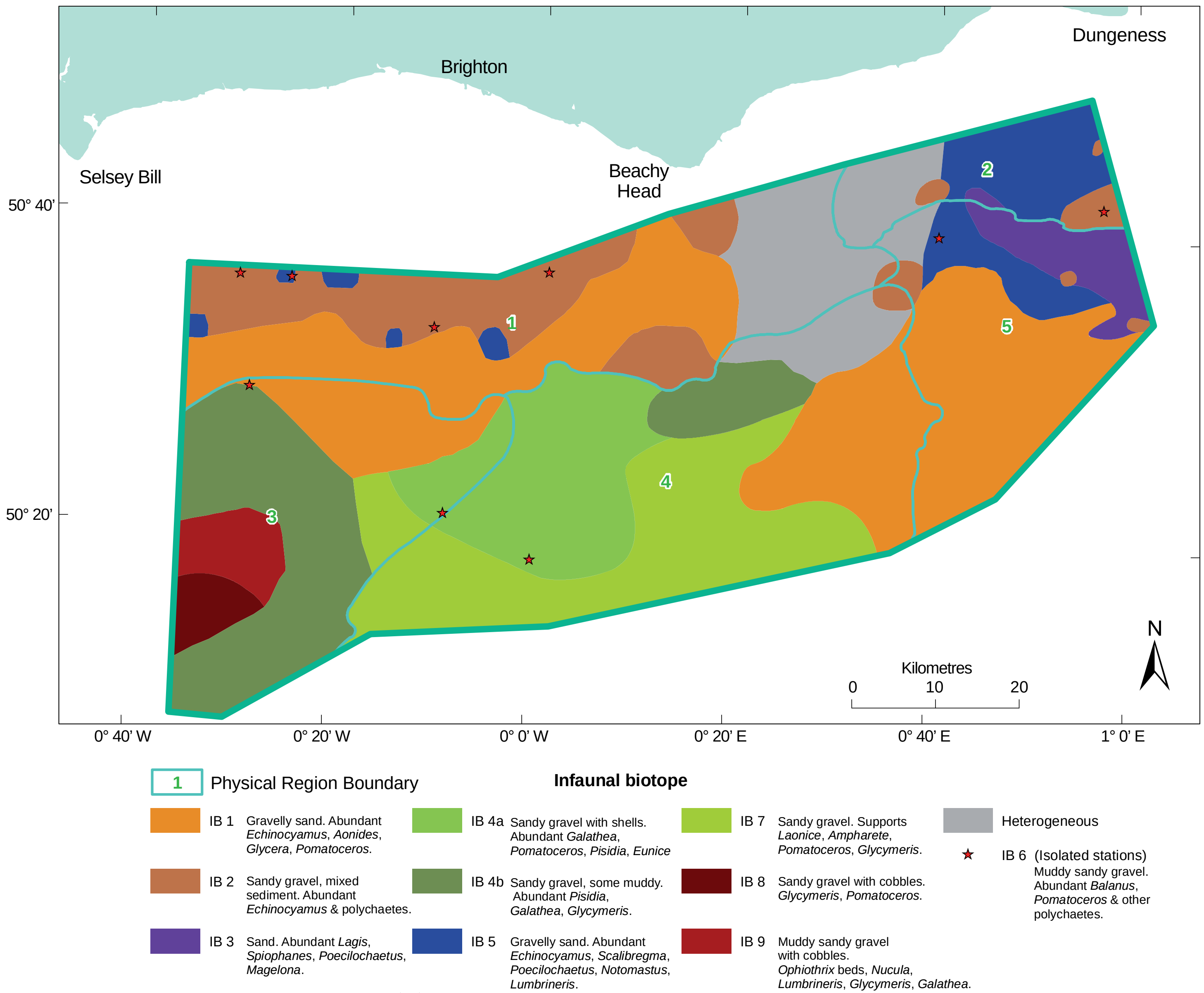


Figure 6.1. Interpreted distribution of infaunal biotopes (IB) in EECMHM study area.

6.2 Epifaunal biotopes – interpretation of video, stills and trawl analyses

Beam trawl and video data provided different but complementary information. The beam trawl allowed fauna to be fully identified, and gave a more reliable quantification of abundance than could be achieved with the video. However, trawl samples had limitations in that there was no certainty (only an assumption) that the trawl had discretely sampled a single biotope. If the tow crossed more than one biotope, material from these would be integrated into a single sample, so limiting the power of any analysis to identify and discriminate discrete biotopes. In contrast, video images allowed the spatial relationship between different biotopes to be seen (e.g. rapid transitions versus intermingling), and there was a greater certainty that discrete biotopes could be observed and identified.

Despite these different sampling biases, both techniques essentially target the same part of the biological community, i.e. the epifauna, so a joint interpretation of the trawl and video analyses was undertaken to provide a unified mapped distribution of the epifaunal biotope complexes (EBCs) across the study area.

The outputs of the video, stills and beam trawl analyses were examined to determine any similarities or differences between the clusters and biotopes which each had detected. A spatial analysis was then made by overlaying the mapped outputs from the video, stills and trawl analyses in a GIS environment, using expert judgement to draw polygons around stations that were considered to represent similar 'epifaunal biotopes'.

In most cases, the video and beam trawl information reflected similar patterns. Where there were conflicts, these were resolved by scrutinising the original information and giving precedence to that which best fitted with other biological and geological information in the immediate area.

Spatial changes in sediment and community types were typically gradual rather than abrupt, so there were cases where the placement of the biotope borders could not be decided on biological information alone, for example, when there was a large area in which no biological information existed. In these cases, additional weighting was given to the information from the geological GIS layers, to determine whether delineations in any of these geological interpretations could sensibly be used to delineate epifaunal polygons. In this way, the resulting lines were based on an informed interpolation rather than an uninformed guess.

The result of this joint interpretation and spatial analysis was an interpreted distribution of epifaunal biotope complexes (EBCs) (Figure 6.2) across the whole study area rather than discrete localised biotopes, in keeping with the purpose of the study.

Details of the Epifaunal Biotope Complexes are provided below, giving a general description of the sea bed substrate and listing prominent genera. Examples of Marine Habitat Classification (Connor *et al.*, 2004) biotopes and other characterising species noted in the trawl and/or video analyses are included for illustration.

EBC 1
Dense *Ophiothrix* beds on pebbles and cobbles.
SS.SMX.CMx.OphMx.
Pagurus prideaux, Hyas coarctatus, Aequipecten opercularis, Flustra foliacea.

EBC 2
Pebbles and cobbles, some bedrock; sponge beds, *Pentapora* and *Ophiothrix.*
SS.SMx.CMx.OphMx; SS.SCS.CCS.PomB; SS.SMX.CMx.FluHyd.
Pomatoceros spp., *Pagurus bernhardus, Hyas coarctatus, Macropodia spp., Psammechinus miliaris, Calliostoma zizyphinum, Phrynorhombus regius, Flustra foliacea, Abietinaria* spp, *Nemertesia* spp. *Ebalia* spp, *Pisidia longicornis.*

EBC 3
Coarse, featureless sandy gravel with reduced epifauna; *Psammechinus, Aequipecten, Hydrallmania, Pomatoceros.*
SS.SCS.CCS; SS.SCS.CCS.PomB; SS.SMx.CMx.FluHyd.
Pagurus spp, *Ophiothrix fragilis, Aequipecten opercularis, Nemertesia antenina, Galathea intermedia, Alcyonium digitatum, Liocarcinus pusillus, Anomia ephippium, Pomatoschistus* spp., *Pisidia longicornis*

EBC 4
Gravelly sand, some sandwaves; sparse epifauna, including *Psammechinus* and *Aequipecten.*
S.SCS.CCS; SS.SCS.CCS.PomB.
Ophiura albida, Asterias rubens, Paguridae.

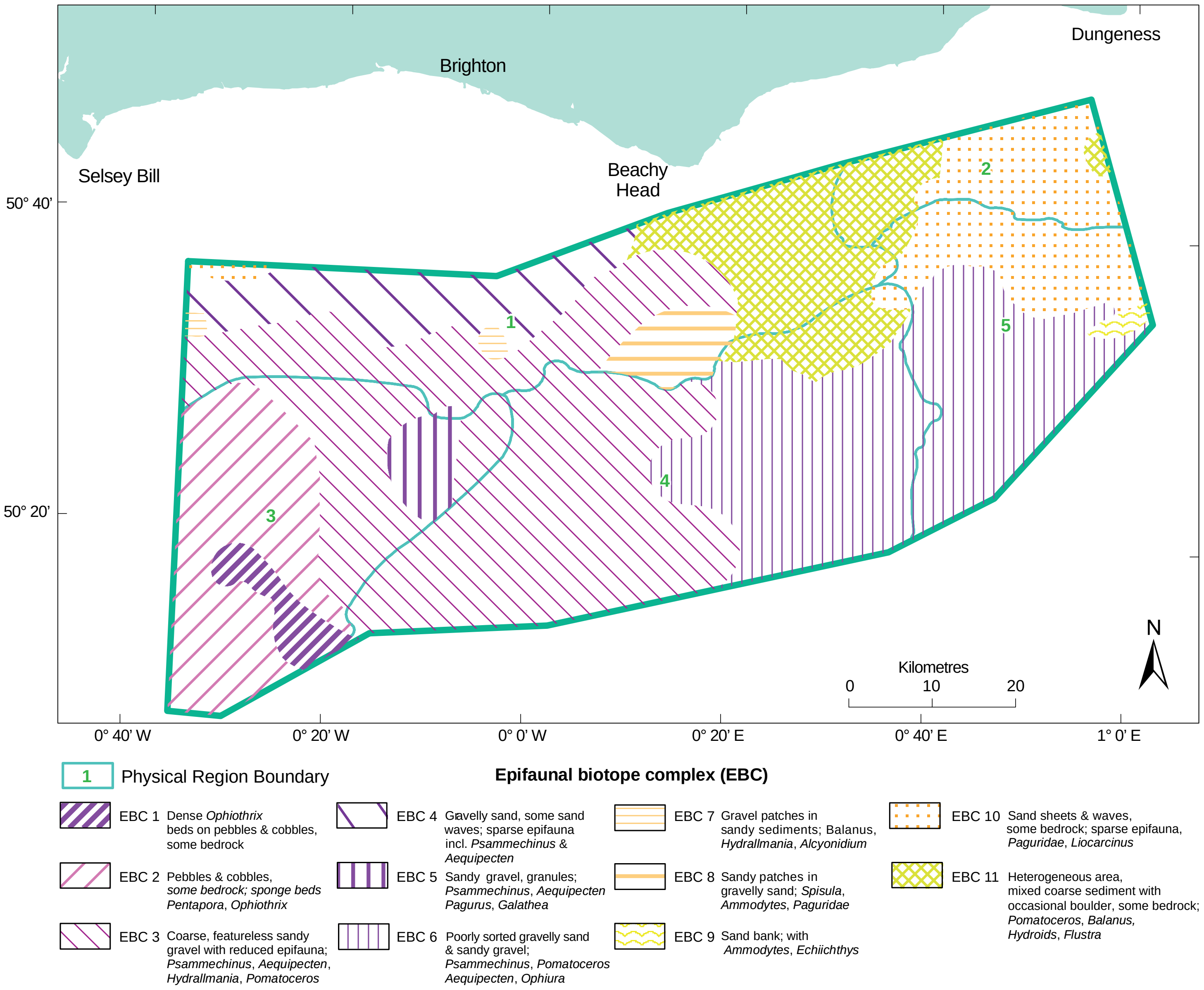


Figure 6.2. Interpreted distribution of epifaunal biotope complexes (EBCs) in EECMHM study area.

EBC 5

Sandy gravel, granules; *Psammechinus, Aequipecten, Pagurus* and *Galathea.*

SS.SCS.CCS; SS.SCS.CCS.PomB; SS.SMX.CMx.FluHyd.

Ophiura albida, Ascidia conchilega, Abietinaria abietina, Hydrallmania falcata, Pomatoceros triqueter, Flustra foliacea.

Discriminated from EB6 by far fewer *Pomatoceros* and *Psammechinus,* and more uniform gravel size.

EBC 6

Poorly sorted, thick deposits of featureless gravelly sand/ sandy gravel; *Psammechinus, Pomatoceros, Aequipecten, Ophiura.*

SS.SCS.CCS; SS.SCS.CCS.PomB; SS.SMX.CMx.FluHyd.

Ophiura albida, Asterias rubens, Balanus crenatus, Anomia ephippium, Galathea intermedia, Alcyonium digitatum, Ophiothrix fragilis, Pagurus bernhardus, Pagurus prideaux, Hydrallmania falcate, Liocarcinus pusillus.

EBC 7

Gravel patches in sandy sediments; *Balanus, Hydrallmania, Alcyonidium.*

SS.SMX.CMx.FluHyd; SS.SSA.IFiSa.ScupHyd

Pagurus bernhardus, Liocarcinus holsatus, Anapagurus laevis, Macropodia tenuirostris, Pagurus prideaux, Ophiura albida, Psammechinus miliaris, Aequipecten opercularis.

EBC 8

Sand patches in gravelly sand; *Spisula, Ammodytes* and *Paguridae.*

SS.SSa.IFiSa.ImoSa; SS.SSa.IFiSa.NcirBat.

Hydrallmania falcata, Ammodytes tobianus, Pagurus bernhardus, Liocarcinus holsatus, Anapagurus laevis, Echiichthys vipera.

EBC 9

Sand bank; with *Ammodytes* and *Echiichthys.*

SS.SSa.IFiSa.ImoSa; SS.Ssa.IFiSa.NcirBat; SS.Ssa.CFiSa.

Pagurus bernhardus, Liocarcinus holsatus.

EBC 10

Sand sheets and waves, some bedrock; sparse epifauna; *Paguridae* and *Liocarcinus.*

SS.SCS.CCS; SS.SSa.CFiSa; SS.SMX.CMx.FluHyd; SS.SSA.IFiSa.ScupHyd.

Pagurus bernhardus, Liocarcinus holsatus, Hydrallmania falcata, Ophiura albida, Pagurus prideaux, Anapagurus laevis, Callionymus lyra, Crangon allmanni, Trisopterus minutus, Inachus dorsettensis, Macropodia rostrata, Macropodia tenuirostris, Pomatoschistus spp. and *Echiichthys vipera.*

EBC 11

Heterogeneous area. Mixed coarse sediment with occasional boulders, some bedrock; *Pomatoceros, Balanus,* Hydroids and *Flustra.*

SS.SMX; SS.SCS.

Alcyonium digitatum, Asterias rubens, Psammechinus miliaris, Aequipecten opercularis, Hydrallmania falcata, Sertularia sp. Macropodia rostrata, Macropodia tenuirostris.

In the north-west of the study area in Region 1, there was a distinct difference between the epifaunal communities on the floor of the palaeovalley, which approximately mirrors the sea bed character (Figure 5.5). The relatively sparse EBC4 communities, characterised by motile species such as *Psammechinus miliaris*, *Aequipecten opercularis* and *Ophiura* spp. were associated with the thicker sandier sediment (mostly gravelly sands with sand waves) that backs up against the northern margin of the palaeovalley, while the thinner and coarser sediments in the southern part of the valley floor formed an extension of EBC3 biotopes that typified the deep, coarse sediments (mainly sandy gravels) typical of the Central Axial Platform (Region 4).

In the centre and extreme west of Region 1, the beam trawl analysis identified two smaller patches where the epifaunal community was more varied (EBC7) and similar to those on the thinner sands in region 2. In the extreme north west of Region 1, in the shallower waters on top of the palaeovalley margin, a patch of sand and mixed sediment supported the same mix of epifauna (EBC 10) as was found in the more extensive sand sheets and sand wave fields in the north-east of the study area (Regions 2 and 5), although Region 2 has significant areas of rock outcrop and thin sediment (Figure 5.5 and 5.6).

In the eastern part of Region 1, the palaeovalley becomes less prominent, the geology more diverse (Figure 5.8) and the bathymetry more variable (Figure 5.2). The sea bed character is predominantly rock overlain with thin sediment (Figure 5.5). The video and stills analysis showed great variability in this area (Figure 5.8) with mixed sediment, boulders and bedrock typically colonised by sessile epifauna such as *Pomatoceros* spp., *Balanus* spp., hydroids and *Flustra foliacea* (EBC11). This mixed, coarse sediment community extended into the western area of Region 2 and was also recognised from a beam trawl sample in the extreme east of Region 2.

The beam trawl, video and stills data all determined a distinct epifaunal community - EBC8 (see station 58 in Biotope Summaries) associated with a shelly-sandy patch overlying gravelly sand on the southern central margin of Region 1, directly south of Beachy Head. The epifauna here were very sparse, the beam trawl sample including the sand-eel *Ammodytes tobianus*, hermit crabs (Paguridae) and the infaunal bivalve *Spisula* sp., which is typical of sandy sediments. The video sample within this patch had no visible epifauna that could be used to determine similarity or dissimilarity to other sandy areas.

In the north-east part of the study area (Region 2 and the northern part of Region 5) there was a clear spatial association between the extent of the sand sheet described by the geological interpretation for the area (see previous sections) and the distribution of epifaunal cluster groups characterised by species commonly associated with sand habitats. The epifaunal assemblage was sparse, and characterised by motile species such as Paguridae, *Liocarcinus* spp. and *Ophiura* spp. with attached epifauna such as hydroids and barnacles where larger particles or shells provided a substrate for colonisation. Beam trawls clearly differentiated an epifaunal biotope associated with the sand streaks, patches, megaripple trains and rock outcrops confined to Region 2 from a similar fauna associated with the sand wave field confined to the north of Region 5 (Figure 5.69, Epifaunal cluster groups M and N, respectively; see also station 23 and 68 in Biotope Summaries). This spatial differentiation was not as clear in the video and stills analysis (Figure 5.73, 5.76 and 5.80) although different clusters were recognised. Hence, the whole of this commonly sandy area has been recognised as EBC10, except for the extreme south-east corner of the study area (in Region 5), where the thicker sands of the Bassurelle Bank were associated with a distinct epifaunal community identified from the beam trawl. The motile epifauna here were similar to those in the sandy areas to the north, but included the sand eel (*Ammodytes tobianus*) and the poisonous weever fish, *Echiichthys vipera*. This area is denoted as a specific biotope complex (EBC9) due to the prominence of the sandbank feature.

Both the beam trawl and video data identified a distinct epifaunal community (EBC6) associated with an expansive area of poorly sorted, featureless thick deposits of gravelly sand and sandy gravel in the south-east of the study area, spanning the east of Region 4 and the west of Region 5. The characteristic epifauna were motile species such as *Psammechinus miliaris*, *Aequipecten opercularis* and *Ophiura* spp., although attached species such as *Pomatoceros* spp. were also present on larger particles. Epifauna in EBC6 were similar to those in EBC4, but notably more abundant, and the sediments were not developed into sand waves as was noted for some parts of EBC4.

West of EBC6, the sediment graded into a coarser, featureless sandy gravel (EBC3, see station 131 in Biotope Summaries) supporting a range of biotopes with species similar to those in EBC6, but in different proportions and with the brittle star *Ophiothrix fragilis* tending to replace *Ophiura* spp. EBC3 was the most widespread of the epifaunal biotope complexes, occupying the entire western part of Region 4, the east of Region 5 and the south of Region 1. The EBC3/EBC6 boundary to the east, and EBC3/EBC2 boundary to the west are considered to be indistinct and have been delineated largely on the basis of the beam trawl analysis, which identified three distinct epifaunal communities. In this Central Axial Platform (Region 4), the video data identified only two biotopes (Figure 5.80). The apparent mis-match between the two data sets reflected the gradual transition of finer sediments in the east to coarser sediments in the west, and highlighted the difficulties of drawing boundaries within a continuum.

Lying within EBC3 and in the north-west of Region 3 was an area where the beam trawl samples showed a distinct epifaunal community, EBC5, and where the sediment appeared on video to be sandy granules. The community was characterised by the motile species *Psammechinus miliaris*, *Aequipecten opercularis*, *Pagurus* sp., and *Galathea* sp. and was similar to the EBC6 community found on sandy gravel/gravelly sand in the south east of the EECMHM area, but with far fewer *Pomatoceros*.

Two epifaunal communities, EBC1 and EBC2 were restricted to the extreme south west of the study area, the western part of Region 3, and reflect the physical distinctness of this area in terms of sea bed character and sediment type, having thin coarse sediments with a high proportion of pebbles and cobbles, with gravels derived from the underlying rock rather than fluvial deposits filling river channels and palaeovalleys. EBC2 covered most of this area of rock with thin sediment, with both beam trawl and video analysis indicating abundant sessile taxa, such as hydroids and *Flustra foliacea*, and a dominance of *Ophiothrix fragilis*. Dense beds of this ophiuroid were found within EBC2 (see station 74 in Biotope Summaries), their very high abundance in adjacent beam trawl samples from stations 97, 124 and 185 leading to the delineation of EBC1 (see station 98 in Biotope Summaries). As such *Ophiothrix* 'beds' are known to be ephemeral and to move *en-masse* over the substrate, the decision had been taken during the

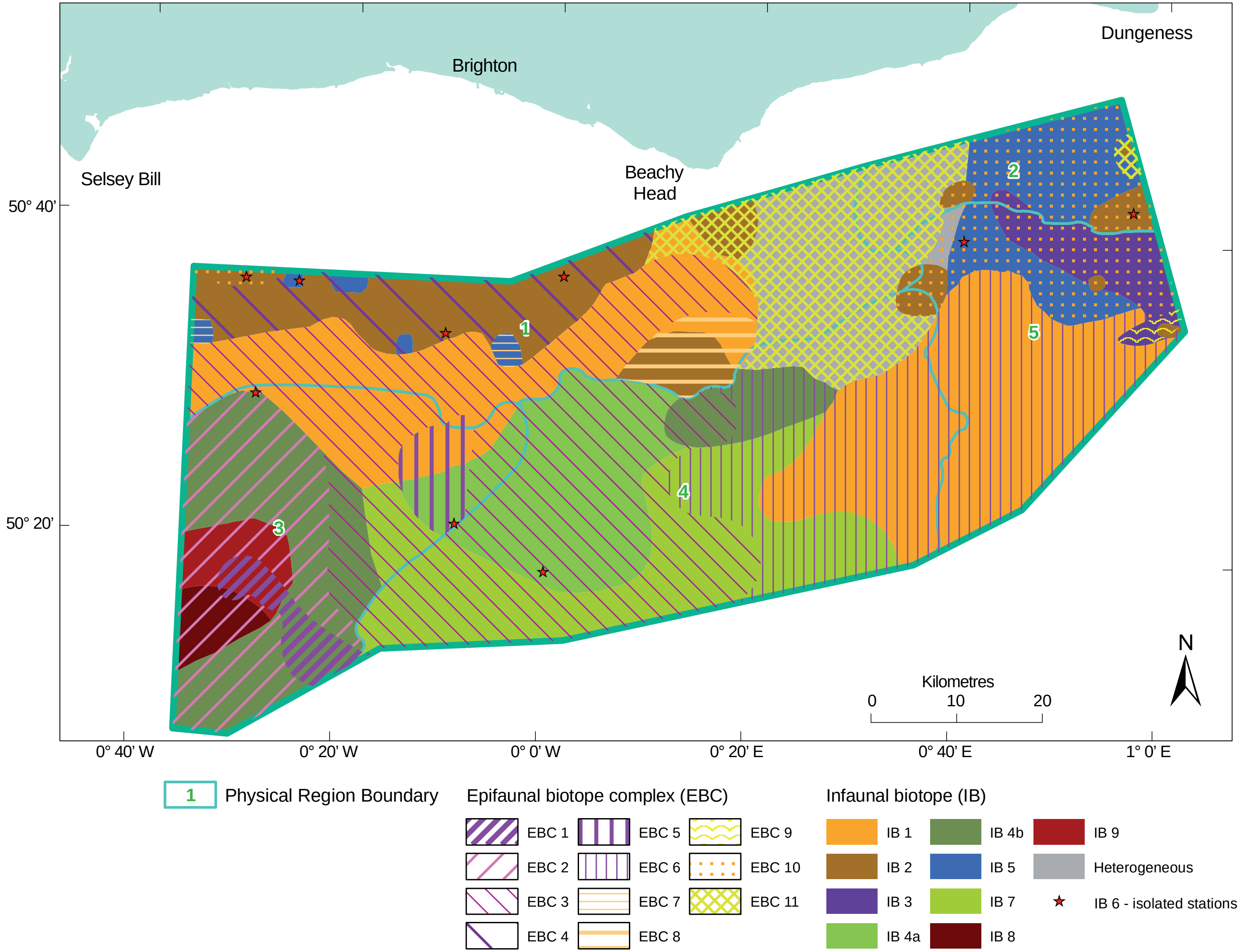


Figure 6.3. Interpreted distribution of epifaunal biotope complexes (EBCs) overlain on infaunal biotopes (IB) in EECMHM study area.

video analysis not to use the superabundance of *Ophiothrix* as a criterion for discriminating a separate biotope; rather they were recognised as a local feature of a more general biotope covering the larger coarse gravel area. Therefore, EBC1 should be viewed as having a variable shape and location within EBC2.

Within the western area of Region 3, covered by EBC1 and 2, the video and stills images revealed some patches of a highly distinct sponge and bryozoan community associated with areas of more consolidated sediment (Figure 5.86). These clearly form a distinct biotope, but their limited size and patchy distribution precludes them being mapped within the broader epifaunal biotope complex. Such communities were recorded in still images from stations 122, 158 and 182, all of which lie in the western area of Region 3.

Combined maps

Overlaying the IB and EBC maps provides an overview of the broad scale habitats in the study area (Figure 6.3 and Map 1). Some of the IBC and EBC polygons have common borders, particularly where there is a marked change in sediment type or bedform, such as the southern boundary of the sand wave field that spans Region 2 and 5. Here too it is notable that distinct infaunal biotopes may exist under a single epifaunal biotope complex e.g. IB2, IB3 and IB5 exist under EBC10. This reflects the fact that motile epifaunal species are generally less specific in their habitat requirements and more tolerant to variability than infauna.

Where the IB and EBC interpreted boundaries do not correspond, such as in Region 4, the area has usually been noted as one over which there is a gradual rather than an abrupt change in both sediments and biotopes. Hence, the representation of boundaries as lines is less appropriate. Their position should be considered as uncertain and indicative of the centre of a broader band or zone of change.

It is interesting to note that the epifaunal studies picked out the Bassurelle Bank as a distinct biotope, whereas the infaunal studies did not. The sand bank is clearly a geological and physical feature differentiated from the nearby sand wave field. The factors that cause its formation and maintenance seem to be of significance in shaping the epifaunal community but of far less consequence to the infauna.

On the contrary, in the west of Region 3, the infaunal analyses proved more discriminating, recognising IB8 and IB9 to be contained within the larger area covered by EBC2 (and IB4a). Comparing Figure 6.3 with that of the solid geology (Figure 5.8) and outcrop (Figure 5.4 and 5.5) provides compelling evidence that rock at outcrop on or close to the sea bed is directly or indirectly influencing the infaunal and epifaunal biotope.

6.3 Biotope summaries

In presenting biotope summaries, the intention is to provide an overview of the results of the study from a biotope perspective and these summaries should be read in conjunction with the regional integrated summaries in section 6.4. We have considered the variety and amount of information available from geological, infaunal and epifaunal interpretations. As there had been 225 Hamon grab samples compared to 73 two-metre beam trawls and 65 camera tows, it was reasoned that the infaunal biotope map was likely to be the more robust than the map of epifaunal biotope complexes, on account of the greater sampling density. Therefore the biotope summaries are presented with a bias towards the 10 infaunal biotopes identified in the study. A summary is provided for each of these infaunal biotopes, using a single sampling station as an examplar (Figure 6.4). The illustrations are complemented with available multibeam, sidescan sonar, boomer sub-bottom and photographic images from the selected station, or a close neighbour of the same type. The summaries include descriptions of the individual example images and an overall perspective of the biotopes within the EECMHM study area.

Within the biotope summaries, a colour coding has been applied to the assigned biotope codes that follow the format 'SS.SCS.CCS.MedLumVen', as used in 'The Marine Habitat Classification for Britain and Ireland' (version 04.05, Connor *et al.*, 2004). Where these are printed in blue, the codes have been erected by this study; where printed in red, the codes exist within the published classification (v04.05).

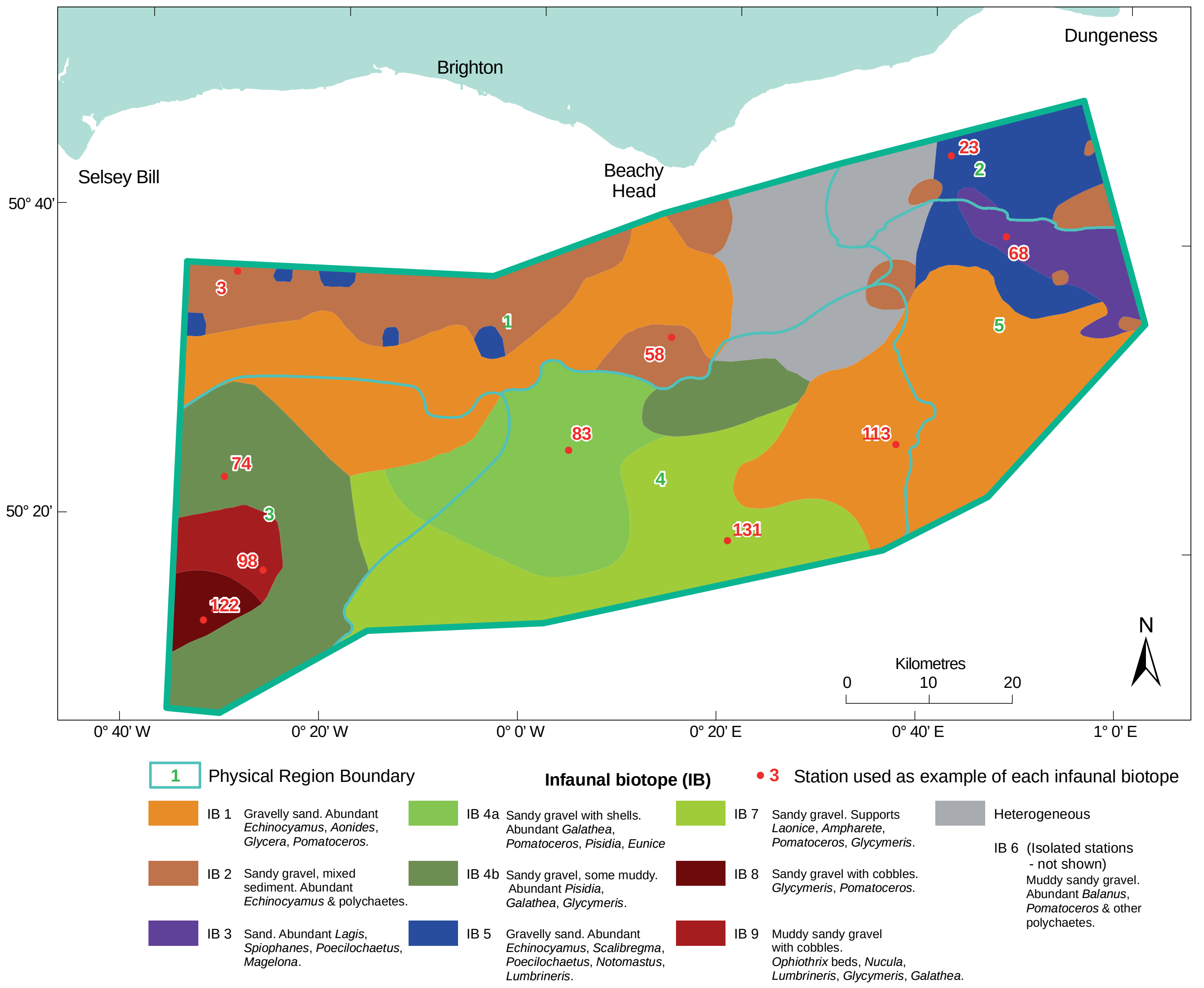
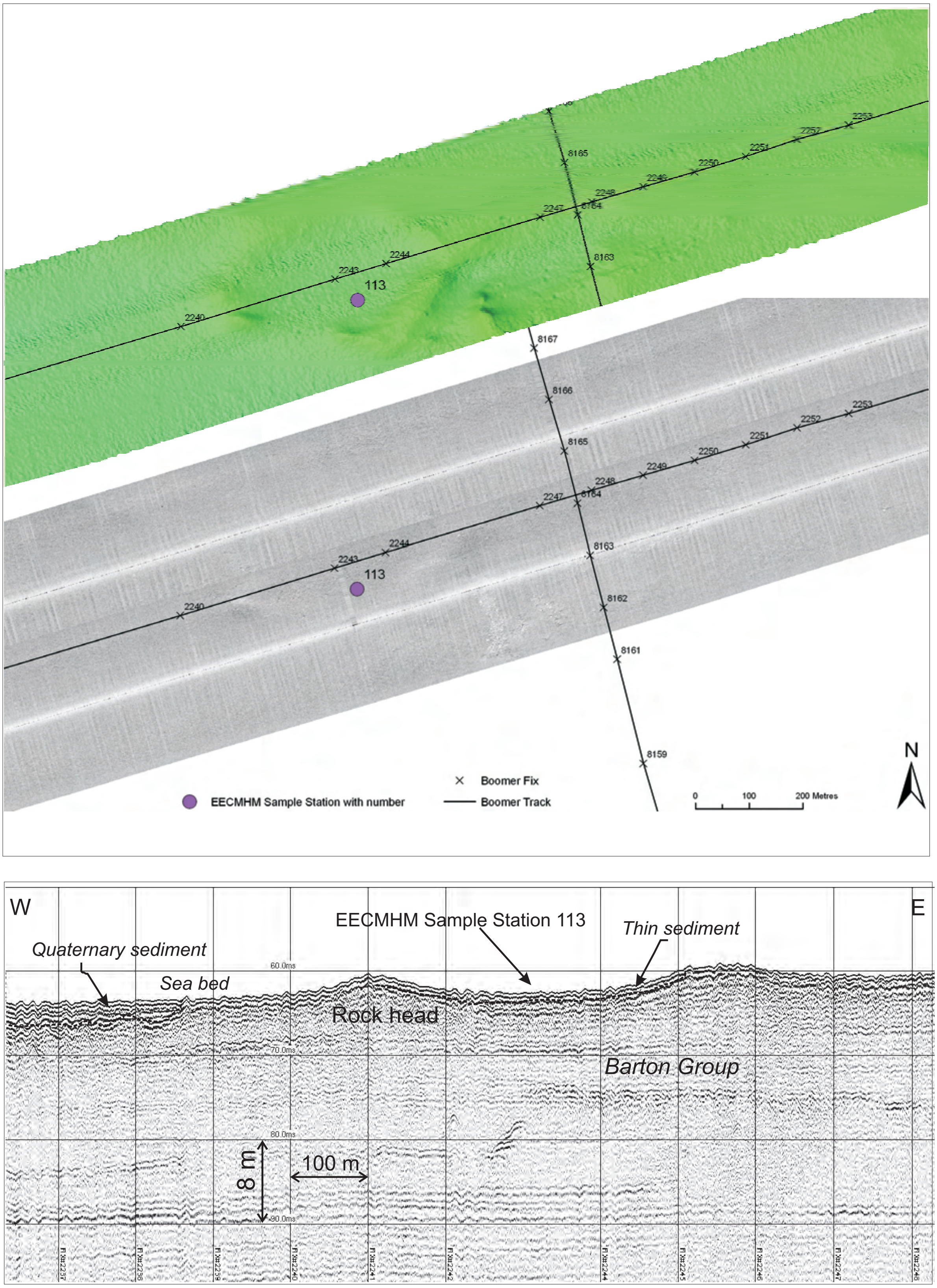


Figure 6.4 Location of EECMHM stations used as examples in the Biotope Summaries (Section 6.3.3)

Infaunal Biotope No. 1

Example: Station No. 113 – 50°27’N 0°37’E - Water Depth 42 m (below chart datum)



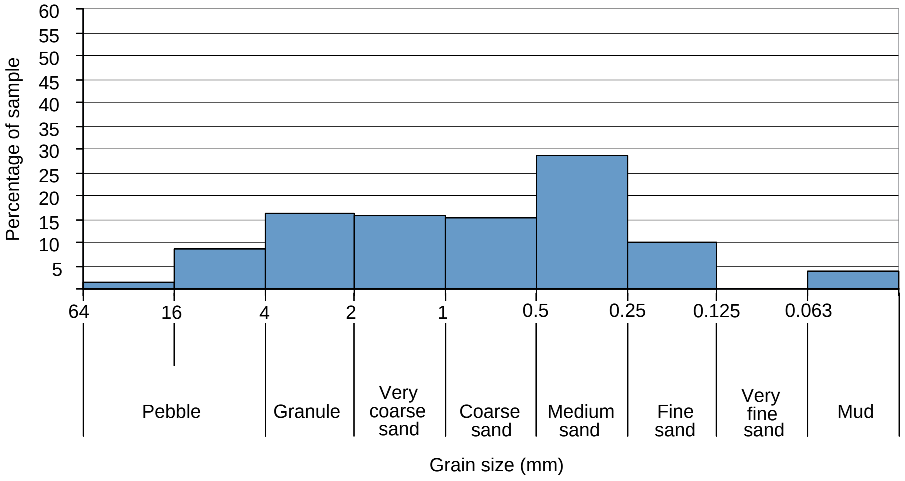
Multibeam, Sidescan Sonar and Boomer images of Sample Station EECMHM 113.

Infaunal Biotope No. 1

Example: Station No. 113 – 50°27'N 0°37'E - Water Depth 42 m (below chart datum)

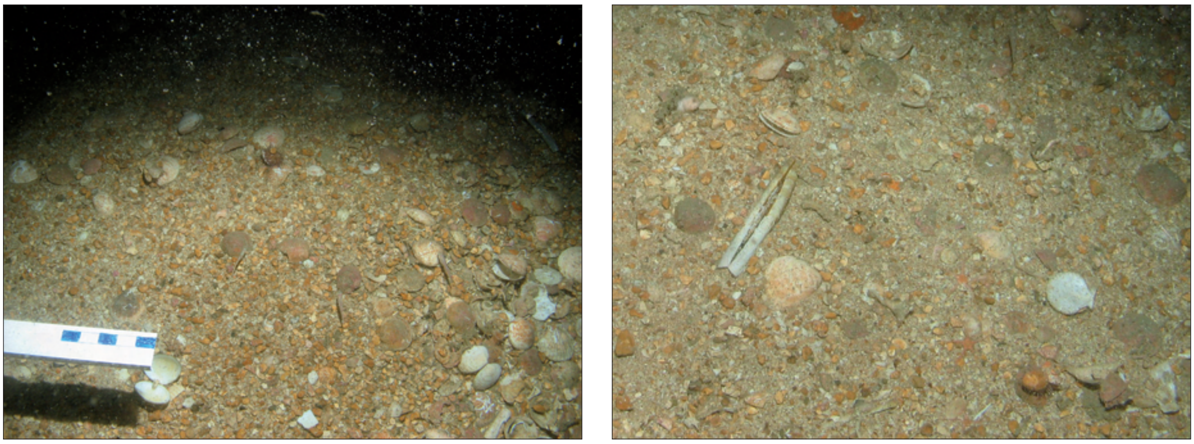
Physical regions and occurrence	Infauna Biotope 1 is the most extensive biotope in the EECMHM study area covering over 1500 km^2, which is about 29% of the area. It has two occurrences. • In Region 1 as an east west trending zone 65 km long and 5 to 15 km wide in the southern half of the Northern Palaeovalley, which also climbs on to the coastal platform at Beachy Head and south of the Palaeovalley on to the Western Axial Platform - Region 3. The sediments are sandy gravel in the western half and gravelly sand in the east. • On the eastern margin of Region 4 and extending over the western half of the Greater Bassurelle Sands - Region 5, a distance of about 48 km. It is a sheet of gravelly sand with patches of sandy gravel in the west. Grain size fines to the east with d50 falling from 1-2 mm (Very coarse sand), with some patches of granules (2-4mm), to 0.25-0.5 mm (medium sand).
Multibeam	The multibeam example is from the eastern margin of Region 4 – Central Axial Platform. It is a dominantly smooth sea bed with no sand bedforms visible, typical of the biotope occurrence in this area. The small ridges and mounds of rock outcrop, 2-3 m high, seen on the image are an exception in Region 4 and 5 although they are more common in Regions 1 and 3 where there is extensive cover of rock and thin sediment.
Sidescan Sonar	Even texture and monotone backscatter. No evidence of sand bedforms. Some variation in reflectivity and backscatter around rock ridges.
Boomer	Sub-horizontal to horizontal reflectors of Barton Group rocks. EECMHM sample station 113 is located in thin sediment between two rock ridges at a water depth of 42 m. The western end of the record shows a layer of Quaternary sediment over 5 m thick at the margin of a palaeochannel. The boundary between the Quaternary sediment and rock is smooth with no break of slope indicating possibly planation of the whole sea bed surface or transgressive infill of the channel up to the rock surface.

EECMHM Sample Station 113
– grain size histogram



Infaunal Biotope No. 1

Example: Station No. 113 – 50°27'N 0°37'E - Water Depth 42 m (below chart datum)

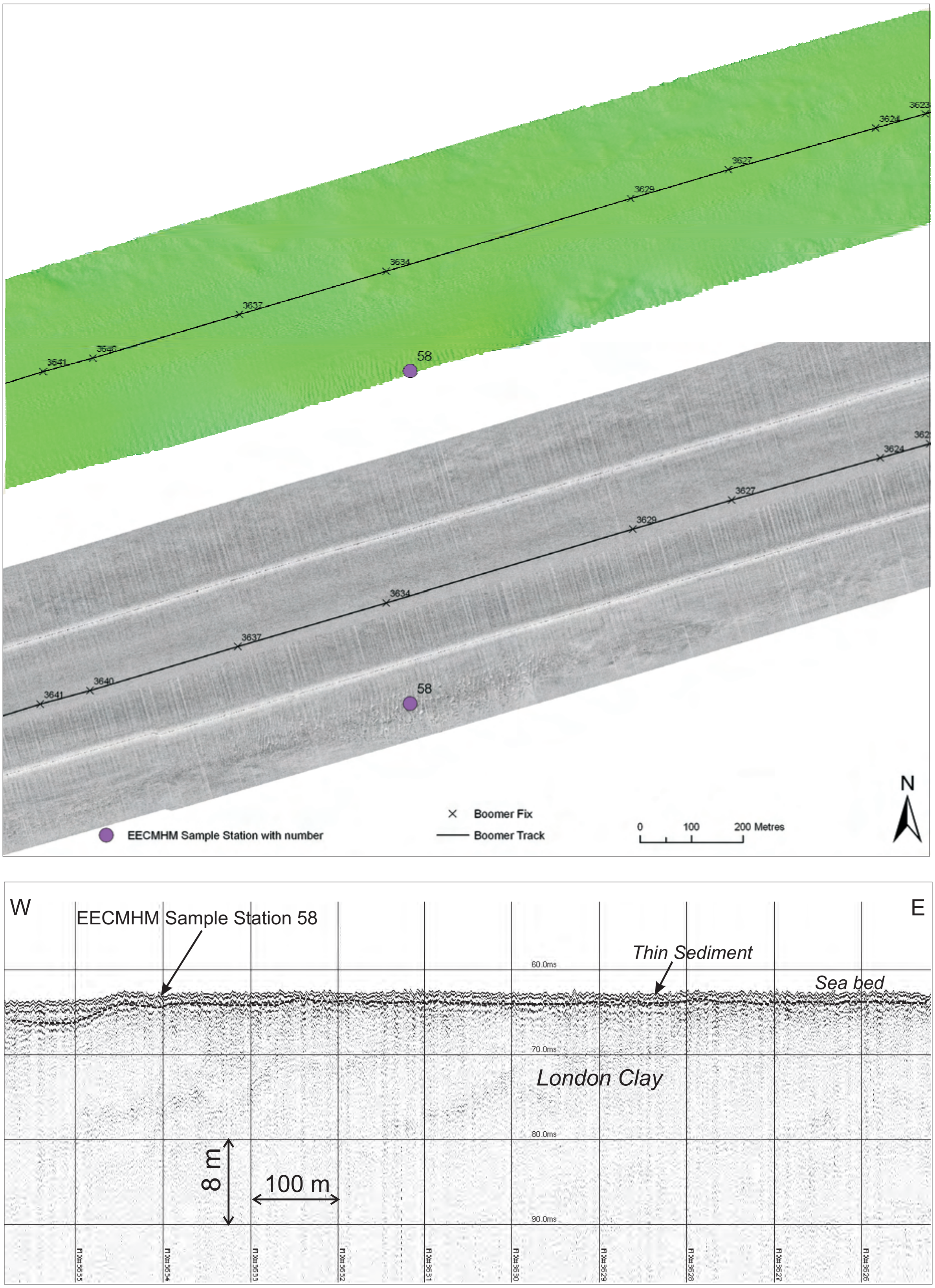


Sea bed photographs from Station 113. Left: Sandy gravel plain with Glycymeris shells and little attached epifauna. Right: *Ensis* shells and *Aequipecten*.

General description	Gravelly sand / sandy gravel. Frequent patches of pebbles, few cobbles and accumulated *Glycymeris* shells (dead). Occasional exposed bedrock. *Pomatoceros* and hydroids attach to larger cobbles. Occasional *Ensis* shells, Bryozoans, *Ophiura albida*, *Cirripedia*, *Asterias*, *Paguridae* and *Aequipecten*. Frequent small fish.
Infaunal Biotope	SS.SSA.CFiSa.EpusPomGal Similar to SS.SSA.CFiSa.EpusOborApri *Echinocyamus pusillus*, *Pomatoceros*, and *Galathea* in circalittoral fine sand. This group contains a variety of crustaceans and polychaetes. A slightly coarser element to the substrata (sandy gravel) gives rise to the presence of species more typical of gravel biotopes such as *Galathea* and *Pomatoceros*. Closely related to the existing biotope having *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand. Other characterising genera: *Aonides*, *Glycera*, *Notomastus*, *Ampelisca*, *Typosyllis* and *Eulalia*. Infaunal biotope cluster L
Epifaunal Biotope Complex	SS.SCS.CCS (similar to SS.SCS.CCS.PomB and SS.SMX.CMx.FluHyd) Circalittoral Coarse Sediment Sandy gravel to gravely sand (sublittoral coarse or mixed sediment). *Psammechinus, Pomatoceros, Aequipecten, Ophiura albida, Asterias* Other characterising species: *Balanus crenatus, Anomia ephippium, Galathea intermedia, Alcyonium digitatum, Ophiothrix fragilis, Pagurus bernhardus, Pagurus prideaux, Hydrallmania falcate, Liocarcinus pusillus* Epifaunal Biotope Complex 6.

Infaunal Biotope No. 2

Example: Station No. 58 – 50°33'N 0°14'E - Water Depth 42 m (below chart datum)



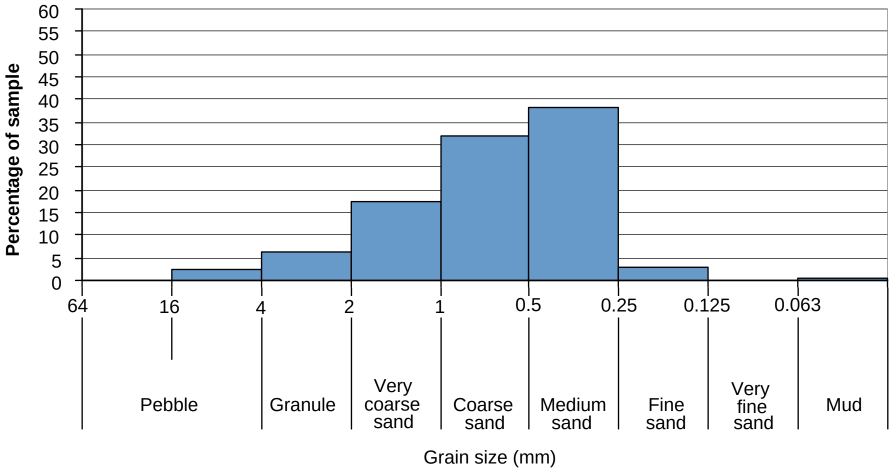
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 58.

Infaunal Biotope No. 2

Example: Station No. 58 – 50°33'N 0°14'E - Water Depth 42 m (below chart datum)

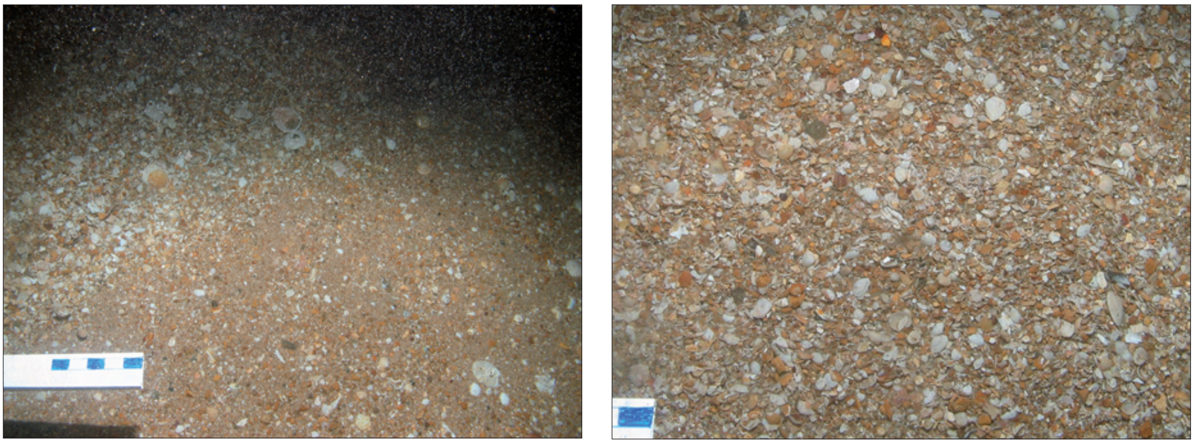
Physical Region and occurrence	Infaunal Biotope 2 occurs in the northern half of Region 1 and in smaller patches in Region 2 and 5. It occupies 568 km^2 which is about 11% of the EECMHM study area. • In Region 1 it extends from west to east along the northern half of the Northern Palaeovalley for over 60 km and on to the coastal margin to Beachy Head. The sediments are dominantly gravelly sand with some sandy gravel and occasional gravelly muddy sand. The median grain size d_{50} is 0.5-1 mm (Coarse sand) for the majority of the area. • In Region 2 and 5 the biotope occurs in patches at the margins of the sand wave field in the Greater Bassurelle Sands. Again the sediments are dominantly gravelly sand although finer in these eastern regions with medium sand more common
Multibeam	The multibeam example is taken from the centre of the study area in Region 1- Northern Palaeovalley and Margins at water depth of around 42 m. It is a diverse sea bed with rock structure outcropping at the sea bed covered by a thin veneer of sediments.The southern part of the multibeam corridor where Station 58 is located shows megaripple trains and occasional sand waves.
Side scan Sonar	Even texture and monotone backscatter. Small and medium scale bedforms in the southern part of the corridor with megaripples trains. Some variation in reflectivity and backscatter around rock ridges.
Boomer	The bedrock of London Clay occurs at or very close to the sea bed and is covered by a thin veneer of sediment. On the western end of the boomer record the sediments thicken up to 5 m in a small channel.

EECMHM Sample Station 58 – grain size histogram



Infaunal Biotope No. 2

Example: Station No. 58 – 50°33'N 0°14'E - Water Depth 42 m (below chart datum)

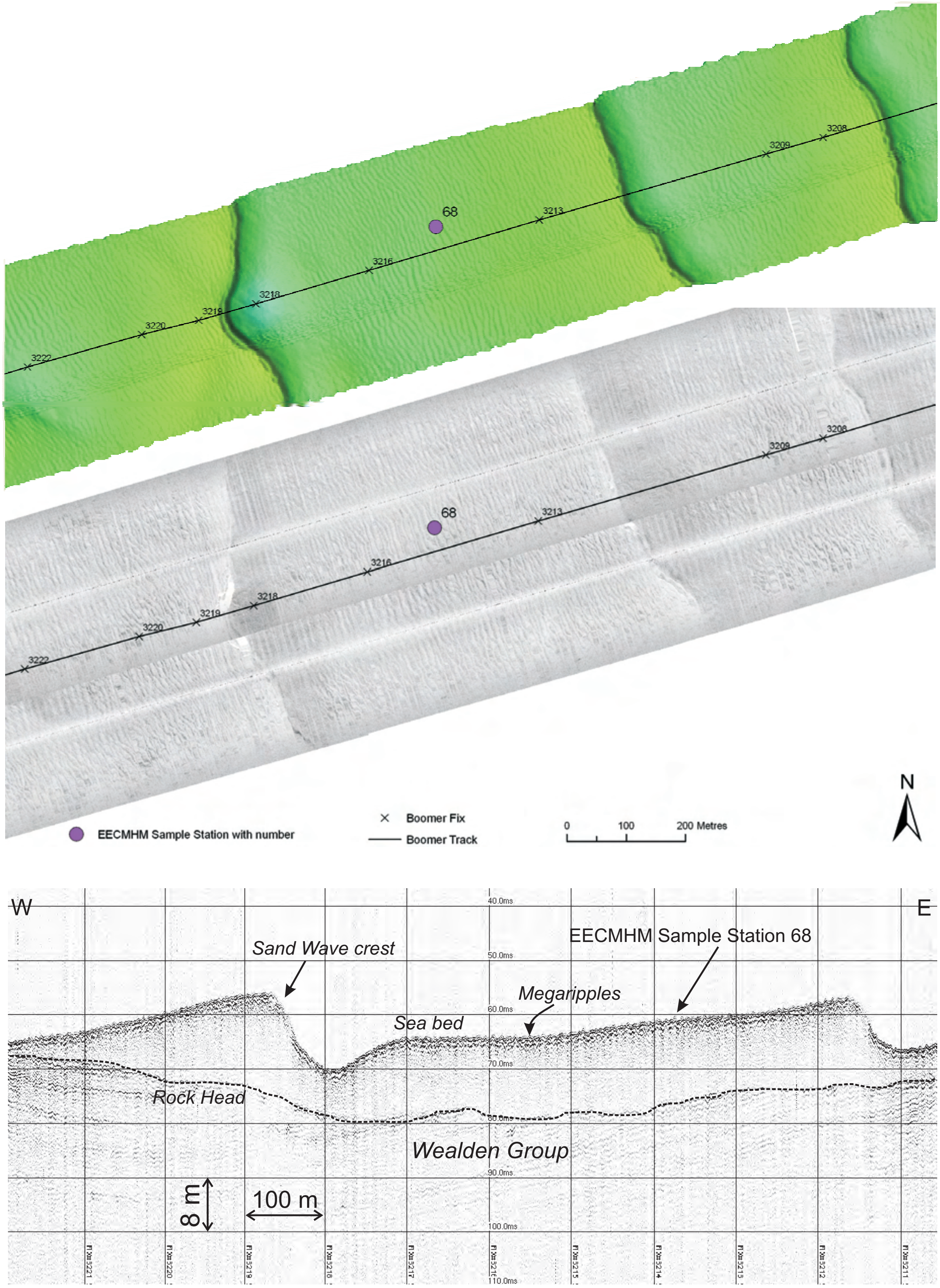


Sea bed photographs from Station 58. Left: gravelly shelly sand.
Right: aggregation of shell fragments.

General description	Shelly, gravelly sand. Light, fragile shell material tends to accumulate in the base of the ripples. Largely barren with only *Pomatoceros* spp. present on occasional larger particles.
Infaunal Biotope	SS.SSA.CFiSa.EpusNephGlyc. Similar to SS.SSA.CFiSa.EpusOborApri *Echinocyamus pusillus, Nephtys* and *Glycera* in circalittoral fine sand. This group is most closely related to the existing biotope formed by *Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand. **Other characterising genera**: *Spio, Notomastus, Aonides, Lumbrineris, Poecilochaetu*s and Nemertea Infaunal biotope cluster D
Epifaunal Biotope Complex	Most similar to SS.SSa.IFiSa.IMoSa (or SS.SSa.NcirBat) Infralittoral mobile clean sand with sparse fauna, or *Nephtys cirrosa* and *Bathyporeia spp.* in infralittoral sand Circalittoral mosaic of coarse sand with patches of shell and gravel. Coarser sediment than SS.SSa.CFiSa with greater proportion of shell and gravel. *Hydrallmania falcata, Ammodytes tobianus, Pagurus bernhardus, Liocarcinus holsatus.* **Other characterising species**: *Anapagurus laevis, Echiichthys vipera* may be present. Epifaunal Biotope Complex 8.
Further notes	Trawl samples similar to those taken on the Bassurelle sand bank. Sandbank biotope not described per se in UK Marine Habitat Classification

Infaunal Biotope No. 3

Example: Station No. 68 – 50°40’N 0°48’E - Water Depth 44 m (below chart datum)



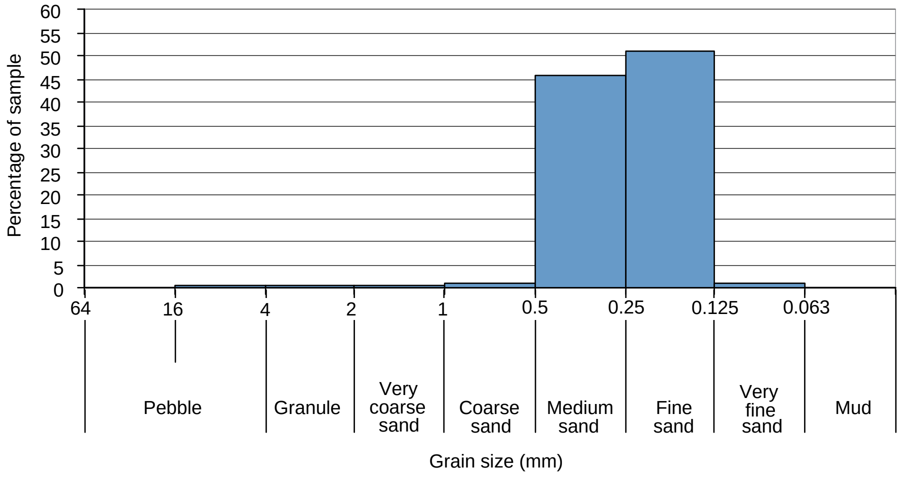
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 68.

Infaunal Biotope No. 3

Example: Station No. 68 – 50°40’N 0°48’E - Water Depth 44 m (below chart datum)

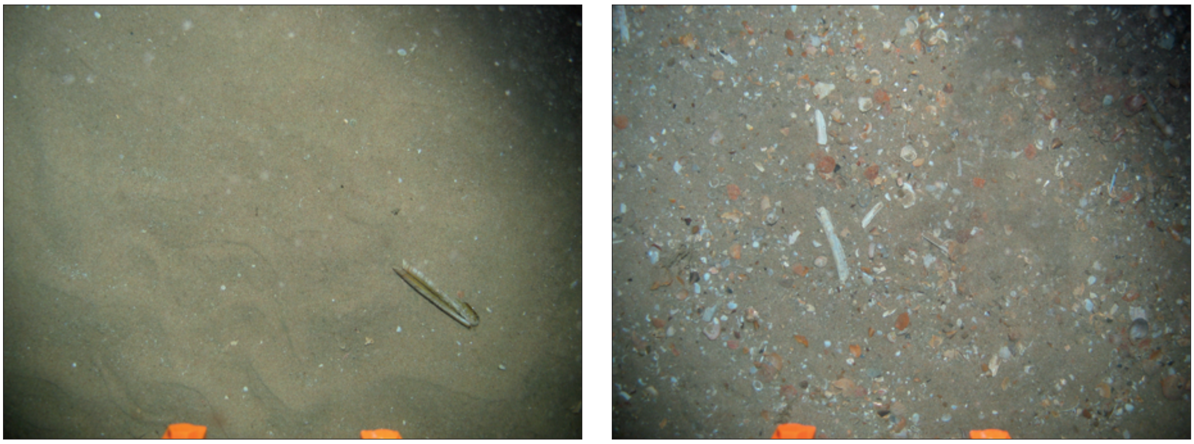
Physical Region and occurrence	Infaunal Biotope 3 occurs in the east of the Greater Bassurelle Sands –Region 5 and crosses slightly into Region 2. It covers 146 km^2, almost 3% of the EECMHM study area. It includes the extensive sand wave field and also extends over the much of the Bassurelle Sand Bank. The sediments encompass slightly gravelly sand and sand with some gravelly sand. The grain size distribution is generally unimodal with a high percentage of fine and medium sand; they are moderately to well sorted.
Multibeam	Sample station 68, which is at a water depth of 44 m, is within an area of sand waves and megaripples. The highest sand wave in the east measures 9.5 m in height and has a double crest and concave profile with a depression in the centre. The following two sand waves are 7 and 7.5 m high and have an asymmetrical profile with lee slopes facing east, and 500 metres distance between crests. On the long stoss slope of the sand waves megaripples have an average height of 0.5 m and wavelength of 8 m.
Side Scan Sonar	Area of sand waves and megaripples with mixed texture and high reflectivity sediment on the megaripples.
Boomer	The seismic section shows bedded Wealden Group rocks dipping to the west. The erosion surface at rock head is undulating with harder resistant bands of rock forming small scarps and ridges. The rock head surface is overlaid by a thick sequence of sand with large sand waves across their surface. On the long stoss slopes the characteristic diffractive seismic signature indicative of a rippled surface is very abundant

Sample Station EECMHM 68 – grain size histogram.



Infaunal Biotope No. 3

Example: Station No. 68 – 50°40'N 0°48'E - Water Depth 44 m (below chart datum)

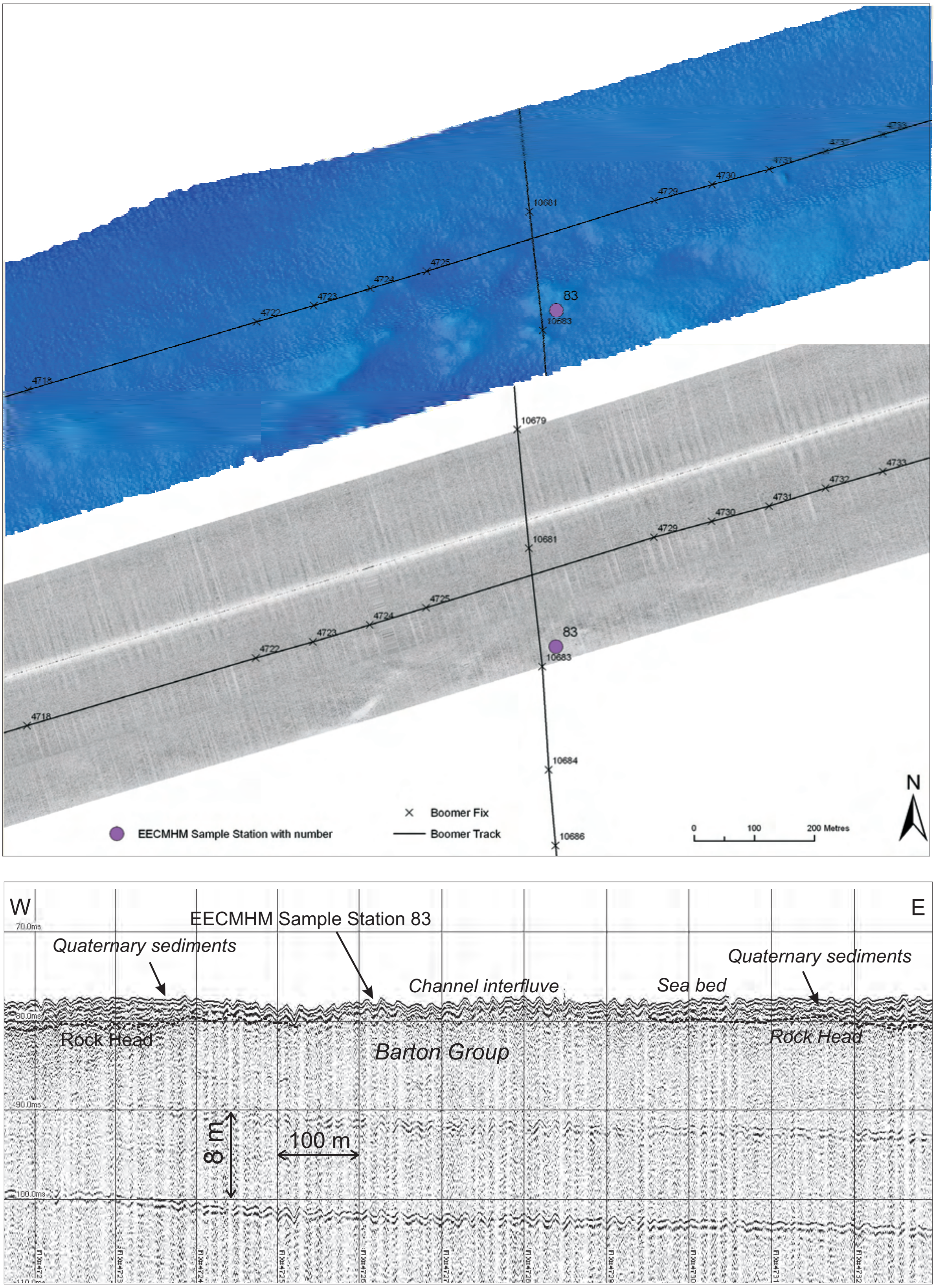


Sea bed photographs from Station 154 (close to Stn 68). Left: fine rippled sand on the top and slope of a large sand wave. Right: aggregation of coarser material and dead shells at the base of the sand wave.

General description	Sand wave field. Fine sand with regular bands of coarser material and shell debris accumulating in wave troughs. *Ensis* shells prominent. Impoverished epifauna with *Ophiura albida*; hydroids attached to larger shell fragments or occasional cobbles.
Infaunal Biotope	SS.SSA.CFiSa.Lkor.Ens. Similar to SS.SMU.CSaMu.Lkor.Ppel *Lagis koreni* and *Ensis* found in circalittoral fine sand. Sandy substrata. High abundance of the tubicolous worms *Lagis, Spiophanes, Poecilochaetus* and *Magelona.* This group is very closely related to the existing description with *Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud. **Other characterising genera**: *Scoloplos, Spio*, Nemertea and Nephtys Infaunal biotope cluster AB
Epifaunal Biotope Complex	SS.SSa.CFiSa. Circalittoral Fine Sand Sands and slightly gravelly sands with *Pagurus bernhardus, Liocarcinus holsatus, Hydrallmania, Ophiura albida, Pagurus prideaux, Anapagurus laevis, Callionymus lyra.* **Other characterising species**: *Crangon allmanni, Trisopterus minutus, Pomatoschistus spp.* and *Echiichthys vipera* Epifaunal Biotope Complex 10.
Further notes	Usually does not contain sand eels (*Ammodytes*)

Infaunal Biotope No. 4a

Example: Station No. 83 – 50°25’N 0°04’E - Water Depth 53 m (below chart datum)



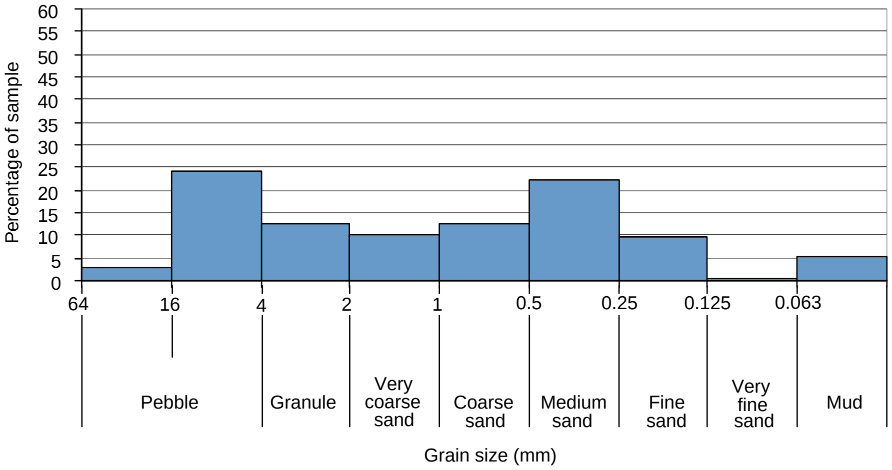
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 83.

Infaunal Biotope No. 4a

Example: Station No. 83 – 50°25’N 0°04’E - Water Depth 53 m (below chart datum)

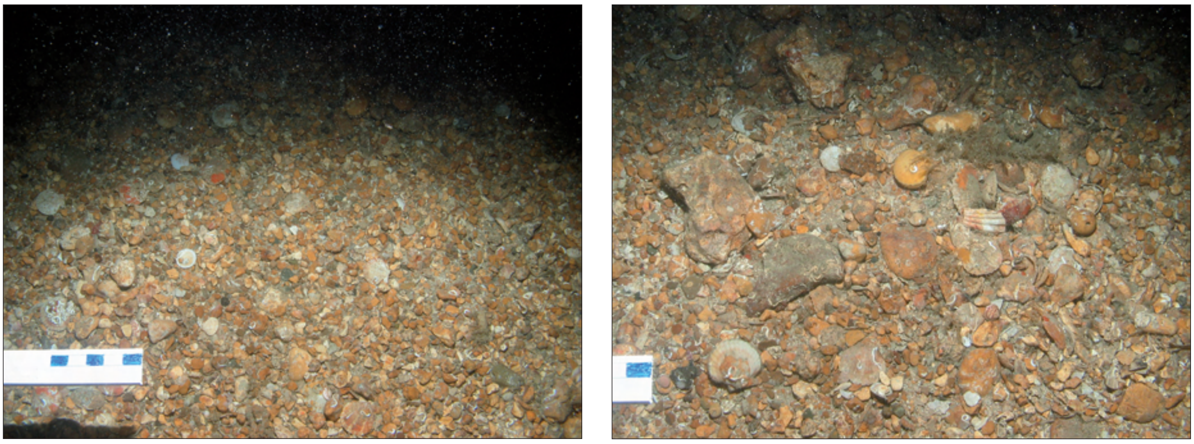
Physical Region and occurrence	Infaunal Biotope 4a occurs in the north-west quadrant of the Central Axial Platform –Region 4. and extends slightly to the west into Region 3. It covers 509 km^2 around 10% of the total area. The area is characterized by a generally featureless sea bed with sandy gravel. The sediments are slightly bimodal at medium sand and 4-16 mm pebbles. Median grain size (d_{50}) varies from very coarse sand to granules with areas of pebbles. The sediments are very poorly sorted and include cobbles. The area is underlain by palaeochannels infilled with Quaternary sediment. There are a few occasional rock outcrops that represent the expression at the sea bed of interfluves between Quaternary sediment filled palaeochannels.
Multibeam	The Multibeam image shows a slightly undulating sea bed at water depth around 53 m on a channel interfluve with rock ridges less than 2 m high, and the rock is covered by a thin veneer of sediment. The smoother featureless surface along the top of the image is sediment lying on a palaeochannel.
Side Scan Sonar	Even texture and monotone backscatter. No evidence of sand bedforms. Some variation in reflectivity and backscatter, including shadows, around rock ridges.
Boomer	The seismic section shows sub horizontal reflectors in the Barton Group, outcropping at the centre around the Station 83-position. Palaeochannel to the west and to the east covered by 1.5-5 m of Quaternary sediments.

Sample Station EECMHM 83 – grain size histogram.



Infaunal Biotope No. 4a

Example: Station No. 83 – 50°25’N 0°04’E - Water Depth 53 m (below chart datum)

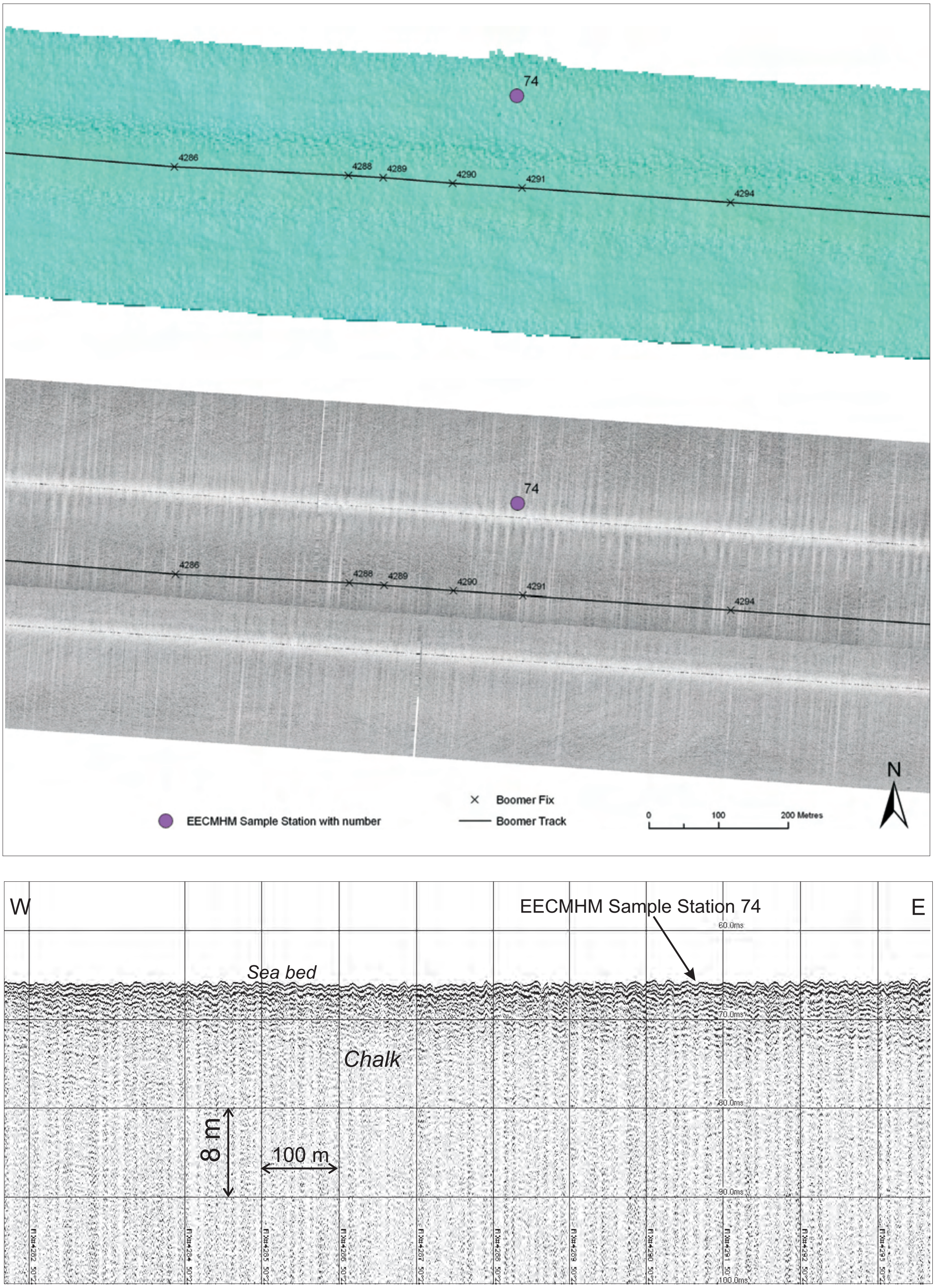


Sea bed photographs from Station 83. Left: Typically moderately sorted sandy gravel. Right: Occasional patches of pebbles and cobbles.

General description	Relatively flat, poorly sorted gravel plain with frequent sub-angular cobbles, often covered in *Pomatoceros*. Hydroids and *Aequipecten* present. Substrate appears similar to that on the Western Axial platform (Region 3), but the epifauna lacks the *Ophiothrix* beds and *Antendon* found there.
Infaunal Biotope	SS.SCS.CCS.Gal.Pom.Pis(Eun) Similar to S.SCS.CCS.PomB *Galathea* and *Pomatoceros* with *Pisidia* and *Eunice* in circalittoral coarse sediment. Sandy with pebbles and shells. Low abundance of *Paguridae, Aequipecten* and *Ophiothrix fragilis*. No direct match with the existing MNCR biotope classification: the nearest category is the *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles. Other characterising genera: *Ampharete, Laonice, Harmothoe, Aonides, Lumbrineris* and *Asclerocheilus.* Infaunal biotope cluster X
Epifaunal Biotope Complex	SS.SCS.CCS (similar to SS.SCS.CCS.PomB and SS.SMx.CMx.FluHyd) Circalittoral Coarse Sediment. Coarse, moderately sorted gravel with cobbles with reduced epifauna. *Psammechinus, Hydrallmania, Pomatoceros, Pagurus, Ophiothrix. Aequipecten opercularis* in significant densities. **Other characterising species**: *Nemertesia, Galathea intermedia, Alcyonium digitatum, Liocarcinus pusillus, Anomia ephippium, Pomatoschistus spp., Pisidia longicornis.* Epifaunal Biotope Complex 3.

Infaunal Biotope No. 4b

Example: Station No. 74 – 50°23'N 0°31'W - Water Depth 47 m (below chart datum)



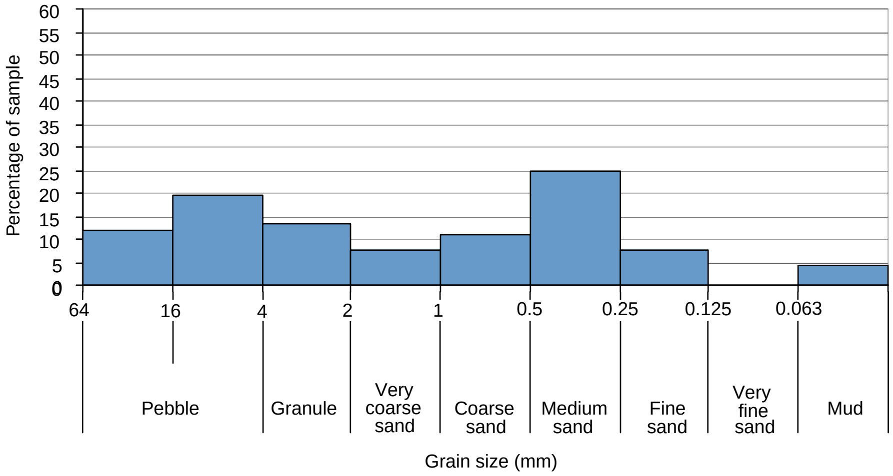
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 74.

Infaunal Biotope No. 4b

Example: Station No. 74 – 50°23’N 0°31’W - Water Depth 47 m (below chart datum)

Physical Region and occurrence	Infaunal Biotope 4b covers 655 km^2 and 13% of the area. It occurs in the Western Axial Platform- Region 3 and in a smaller occurrence in the northern central part of Region 4- Central Axial Platform. In both areas the sea bed is characterised by rock outcrops with thin veneer of sediments with featureless sea bed or scarce bedforms. The sediments are constituted mainly by very poorly or poorly sorted sandy gravel and muddy sandy gravel. The median grain d50 varies between 2-4 (Granules) and > 4 (Pebbles) and reflects the coarse nature of the sea bed with cobbles common in Region 3. Much of the sea bed gravel may be derived directly from the underlying bedrock.
Multibeam	Flat featureless sea bed at a water depth of 47 m with some slight undulations
Sidescan Sonar	The Side scan Sonar image shows a featureless sea bed with faint NE-SW lineations and high reflective backscatter. These may be ephemeral sandy streaks parallel to the peak tidal current direction.
Boomer	The boomer section shows a generally massive transparent signature for the Chalk with some poor dipping reflectors and wider pulse return at the sea bed indicative of rock or a very thin veneer of sediment covering the flat surface.

Sample Station EECMHM 74 – grain size histogram.



Infaunal Biotope No. 4b

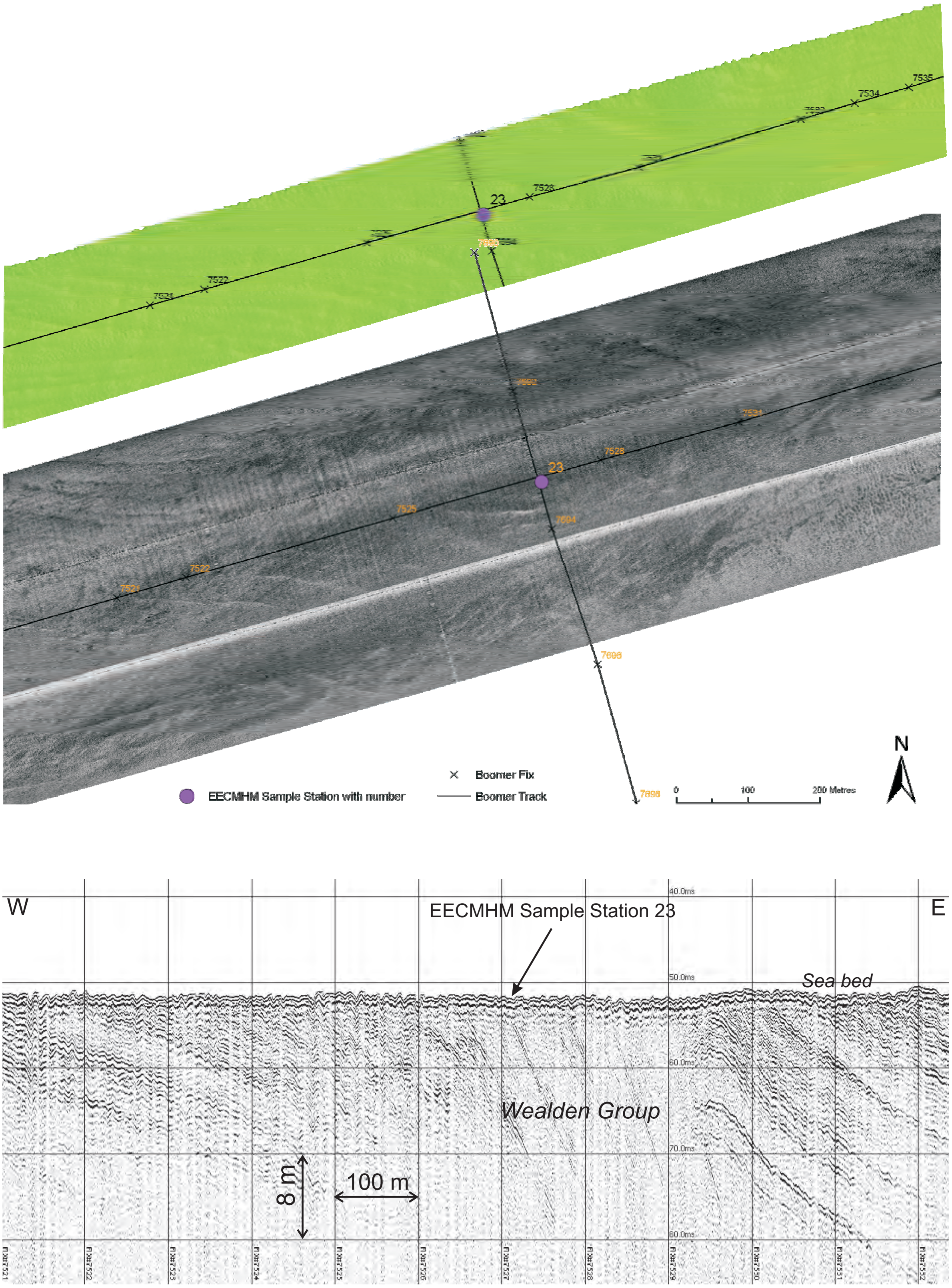
Example: Station No. 74 – 50°23'N 0°31'W - Water Depth 47 m (below chart datum)

Sea bed photographs from Station 74. Left: Pebble gravel and cobbles. Right: dense ophiuroid beds (*Ophiothrix fragilis*).

General description	Plains of coarse pebble gravel and some cobbles with frequent *Glycymeris* shells. *Pomatoceros* on cobbles and shells. Notable aggregations of *Ophiothrix*. Does not have significant cover of encrusting sponge communities.
Infaunal Biotope	SS.SCS.CCS.Gal.Pom.Pis(Gly) Similar to SS.SCS.CCS.PomB *Galathea* and *Pomatoceros* with *Pisidia* and *Glycymeris* in circalittoral coarse sediment. Very similar to Biotope 4a, but with a mixture of muddy sandy gravel. High abundances of *Pisidia, Galathea* and *Glycymeris*. No direct match with existing MNCR biotope. **Other characterising genera**: *Harmothoe, Laonice, Aonides, Nemertea, Lumbrineris and Caulleriella* Infaunal biotope cluster Y
Epifaunal Biotope Complex	SS.SMx.CMx.OphMx (similar to SS.SCS.CCS.PomB and SS.SMX.CMx.FluHyd) Ophiothrix fragilis brittlestar beds on sublittoral mixed sediment. Pebble gravel and cobbles with epifaunal dominated by *Ophiothrix fragilis* and *Pomatoceros spp*. Some *Aequipecten*, encrusting sponges and *Pentapora*, but not in large amounts. **Other characterising species**: *Pagurus bernhardus, Hyas coarctatus, Macropodia spp., Psammechinus miliaris, Calliostoma zizyphinum, Phrynorhombus regius.* Epifaunal Biotope Complex 2.

Infaunal Biotope No. 5

Example: Station No. 23 – 50°45'N 0°42'E - Water Depth 33 m (below chart datum)



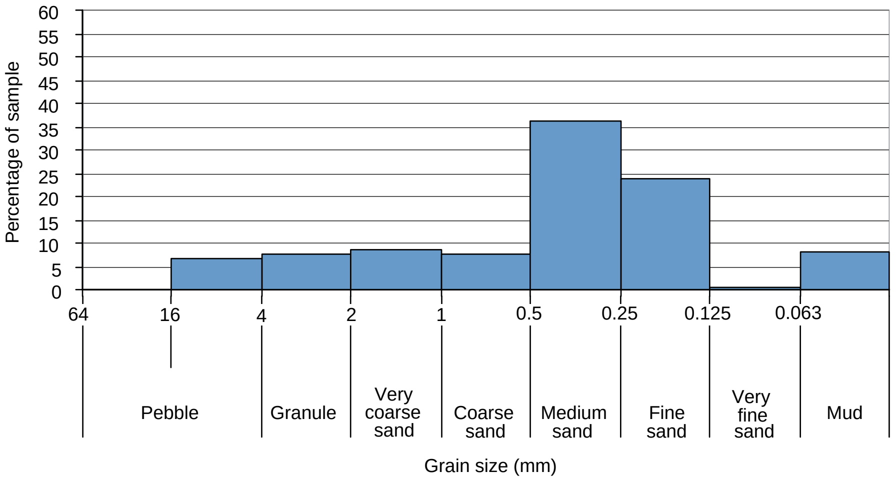
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 23.

Infaunal Biotope No. 5

Example: Station No. 23 – 50°45’N 0°42’E - Water Depth 33 m (below chart datum)

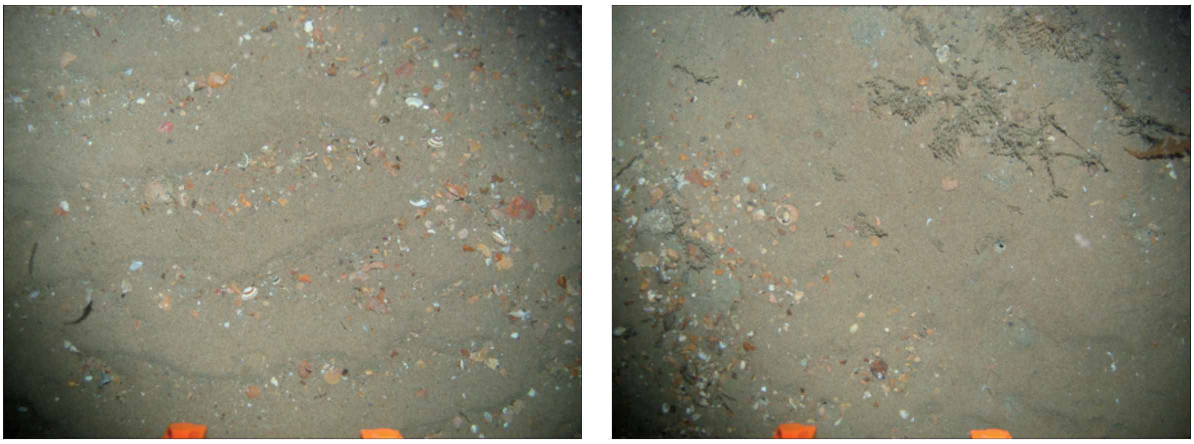
Physical Region and occurrence	Infaunal Biotope 5 covers most of the eastern half of Region 2 – North –East Platform and Margin where there is extensive rock and thin sediment. It extends southwards into the large sand wave field of the Greater Bassurelle Sands where it surrounds and abuts against the western margin of Infaunal Biotope 3. Rock structures and lineations are numerous on the sea bed in Region 2 with sand between ridges, especially in areas underlain by Upper Jurassic rocks. Infaunal Biotope 5 covers 337 km^2 (~7%) of the study area and also occurs in small patches on Region 1- Northern Palaeovalley and Margin. Sediment cover is predominantly gravelly sand with patches of gravelly muddy sand in Region 2 and sandy gravel in Region 1. It is in general very poorly sorted or poorly sorted with a median grain size (d_{50}) of 0.25 1 mm medium to coarse sand, although it may be finer in part.
Multibeam	Abundant linear and slightly sinuous structural bedding of the Wealden Group outcropping at the sea bed surface in water depth around 33 m. Some features at right angles to each other indicating faulting and lateral displacement of the rock by ancient tectonic events. Has produced a patterned micro-morphology.
Side scan Sonar	The Side scan sonar images show structural lineation in lighter backscatter with NW-SE trend. These lineations are overlaid by a different type of linear features with variable direction and darker backscatter; some of these include parallel fishing trawl marks. Numerous sand streaks and coarse sediment in patches reflect the occurrence of sediment over the rock. An area of rippled sand lies in the SW corner.
Boomer	Steeply dipping bedding planes in an anticline in the Wealden Group cut by sub-horizontal erosion surface. Slight sea bed high in east of record due to faulting and uplift of relatively resistant rocks with stronger bedding reflectors.

Sample Station EECMHM 23 – grain size histogram.



Infaunal Biotope No. 5

Example: Station No. 23 – 50°45'N 0°42'E - Water Depth 33 m (below chart datum)

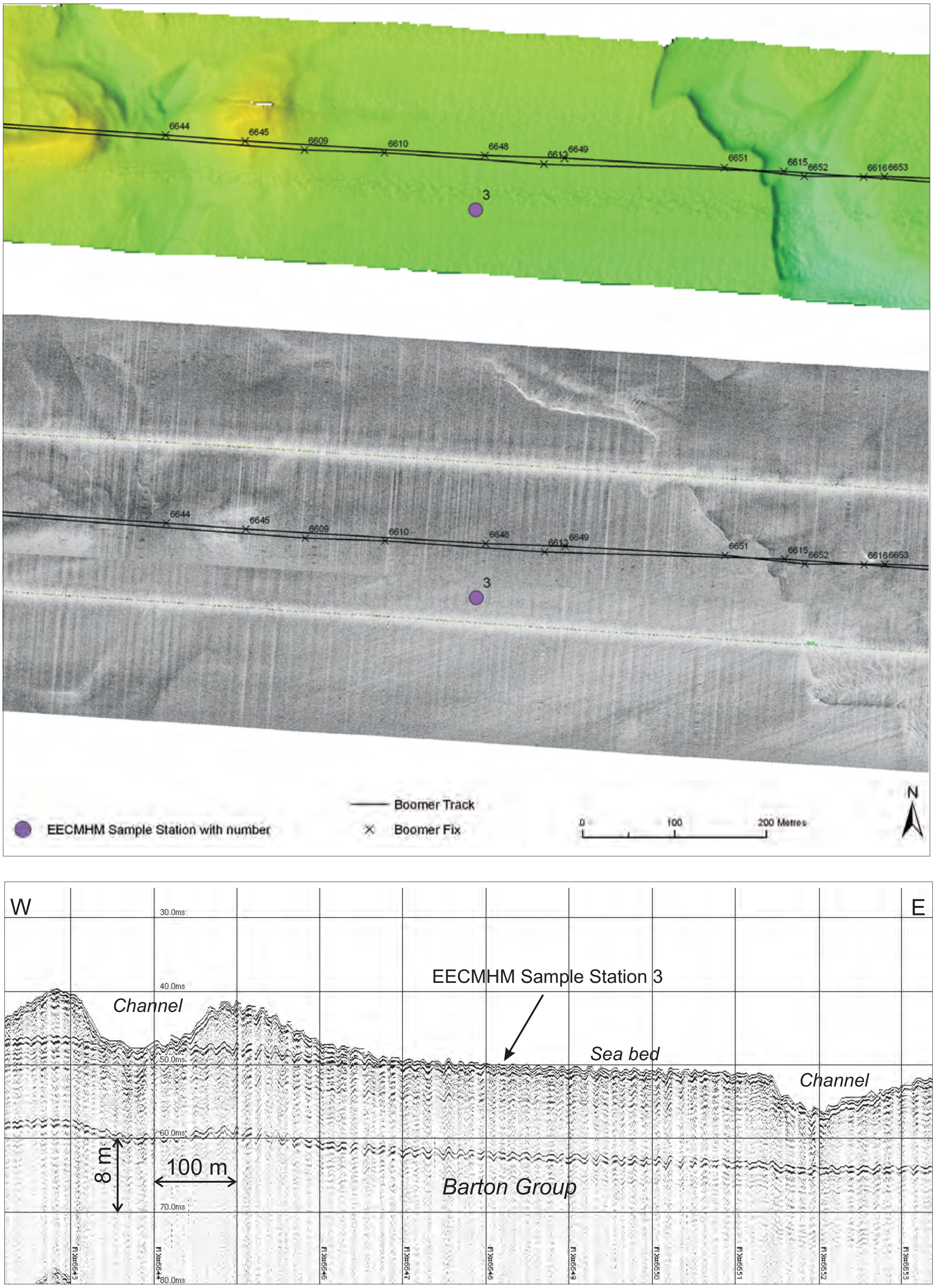


Sea bed photographs from Station 198 (close to Stn 23). Left: Sand sheets, rippled sand with some gravel. Right: Hydroid patches and worm burrows.

General description	Rippled gravelly sand with irregular but low relief bedforms. Some gravelly or muddier patches and dispersed shell debris. Occasional cobbles or rock outcrop. Burrow openings visible in the muddier areas. Some sparse mats of hydroids. Rippled sands, presence of hydroids and lack of accumulated shell debris give the impression of moderately strong tidal currents.
Infaunal Biotope	SS.SCS.CCS.Not.Lum Similar to SS.SCS.CCS.MedLumVen *Mediomastus fragilis, Lumbrineris spp.* and venerid bivalves in circalittoral coarse sand or gravel. Sandy gravel substrata with *Echinocyamus, Scalibregma, Poecilochaetus, Notomastus and Lumbrineris*. Possibly a variant of the MedLumVen community. **Other characterising genera**: *Lagis, Aonides, Upogebi*a, Nemertea, *Ampelisca* and *Polycirrus*. Infaunal biotope cluster N
Epifaunal Biotope Complex	SS.SCS.CCS, similar to SS.SMX.CMx.FluHyd and SS.SSA.IFiSa.ScupHyd Circalittoral Coarse Sediment. Sand sheets. Muddy sandy gravel to gravelly sand with sparse epifauna characterised by attached hydroids. *Balanus, Hydrallmania, Alcyonidium, Paguridae* and *Liocarcinus*. **Other characterising species**: *Nemertesia ramose, Anapagurus laevis, Pagurus bernhardus, Pagurus prideaux, Inachus dorsettensis, Macropodia rostrata, Macropodia tenuirostris, Pomatoschistus.* Epifaunal Biotope Complex 10.

Infaunal Biotope No. 6

Example: Station No. 3 – 50°36’N 0°30’W - Water Depth 34 m (below chart datum)



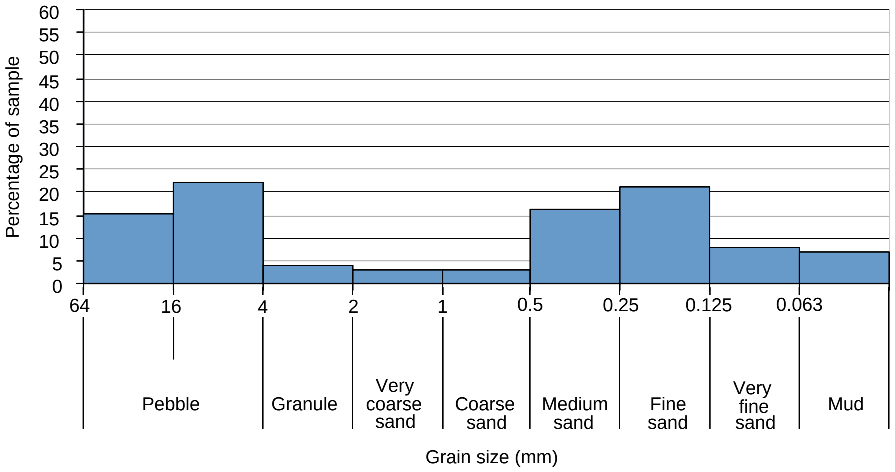
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 3.

Infaunal Biotope No. 6

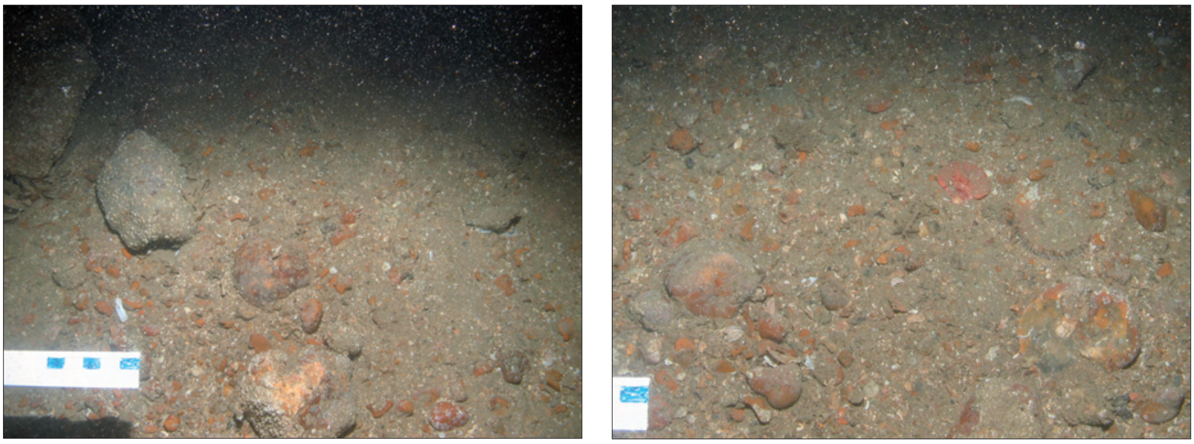
Example: Station No. 3 – 50°36’N 0°30’W - Water Depth 34 m (below chart datum)

Physical Region and occurrence	Infaunal Biotope 6 comprises isolated stations with different types of sea bed. There are nine in total, the majority (7) are in the western half of the study area particularly the north-west including Region 1. The example shown here at EECMHM 3 lies on a dipping bedding plane of Barton Group rock within the northern margin of the Northern Palaeovalley. Although only forming a few small occurrences in the EECMHM study area these bedding plane surfaces are extensive features to the north and cover many tens of square kilometres.
Multibeam	Smooth dipping bedding plane surface on Barton Group rock at a water depth around 34 m, with two rock ridges in the west as erosional remnants, around 5 m high, on the flanks of a small channel. The sharp shadow in the east marks the margin of another shallow channel ~ 4 m deep which runs from NW to SE and bifurcates in the north.
Side scan Sonar	Area of high reflectivity backscatter with rock outcrop at the sea bed. Flat platform covered by thin sediment forming sand patches and sand streaks.Rippled sand covers the flank of eastern channel.
Boomer	Excellent example of rock structure controlling sea bed morphology. Smooth dipping surface formed on bedding plane of relatively hard dense rock within the Barton Group. This harder bed has produced a higher amplitude, darker reflector within the seismic record and this can be traced west beneath the two ridges. Note that the harder bed forms the base of the western channel.

Sample Station EECMHM 3 – grain size histogram.



Infaunal Biotope No. 6
Example: Station No. 3 – 50°36'N 0°30'W - Water Depth 34 m (below chart datum)

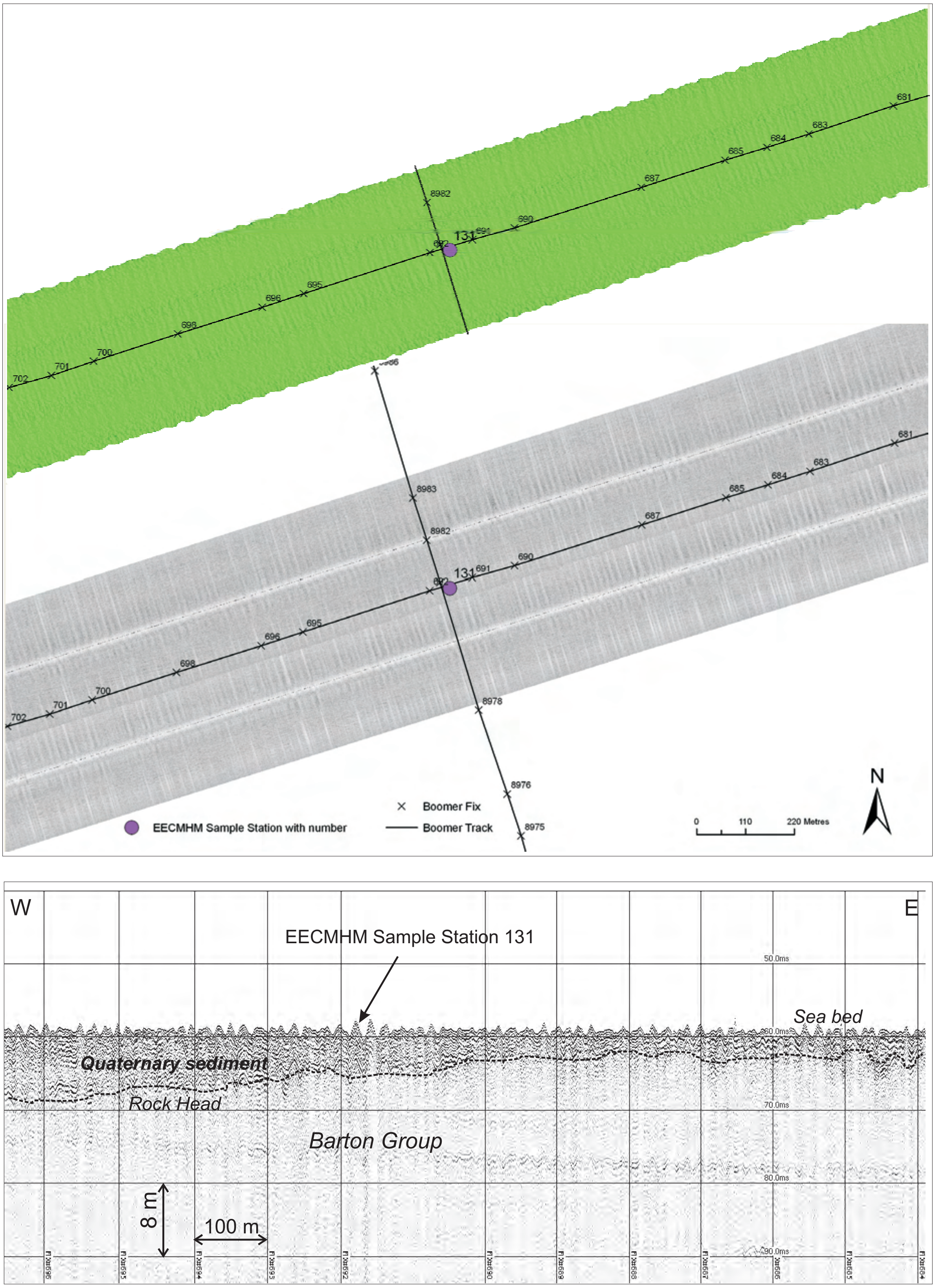


Sea bed photographs from Station 3. Left and right: Coarse mixed substrate with cobbles and pebbles.

General description	Acoustic images show the camera tow was on a featureless, rather hard, flat area. Video and stills images reveal a very mixed, coarse substrate with barnacle and *Pomatoceros* encrusted cobbles. Occasionally cobbles also had sponge and bryozoans attached. No large patches of attached hydroids. **The biotope occurred at localised points, rather than as a continuous feature over a large area.**
Infaunal Biotope	SS.SCS.CCS.PomB *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles. Muddy sandy gravel with high abundance of *Balanus, Pomatoceros* and other polychaetes. The nine representative stations were not geographically clustered. **Other characterising genera**: *Aonides,* Nemertea, *Polycirrus, Scalibregma* and *Glycera.* Infaunal biotope cluster F
Epifaunal Biotope Complex	SS.SMx.CMx (similar to SS.SMX.CMx.FluHyd) Circalittoral Coarse Sediment. Mixed sediment of occasional boulders on sand with frequent patches of cobbles and pebbles. Characterised by moderate to high abundance of *Pomatoceros* and *Balanidae* with rare occurrences of *Ophiura albida* and attached epifauna (Hydrallmania, Alcyonidium). **Other characterising species**: *Pandalus montagui, Anapagurus laevis, Pagurus bernhardus, Galathea squamifera, Crepidula fornicata, Ocenebra erinacea, Buccinum undatum, Aequipecten opercularis, Anomia ephippium, Alcyonidium diaphanum, Flustra foliacea, Psammechinus miliaris.* Epifaunal Biotope Complex 10.
Further notes	

Infaunal Biotope No. 7

Example: Station No. 131 – 50°20'N 0°20'E - Water Depth 38 m (below chart datum)



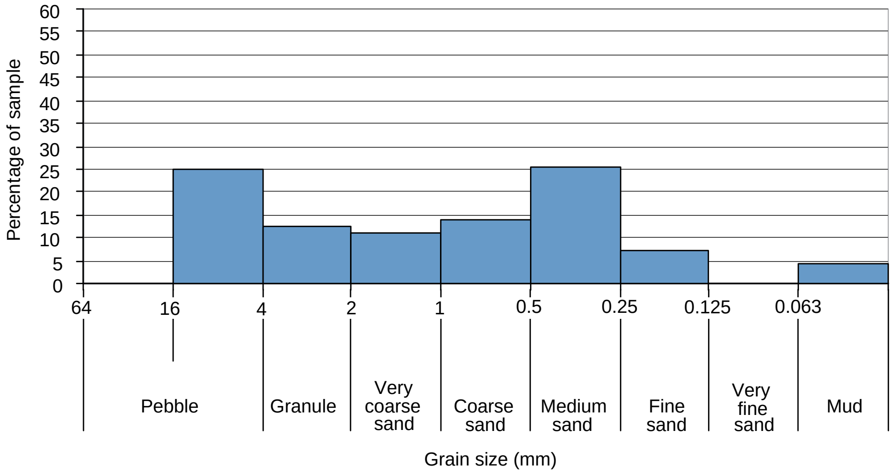
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 131.

Infaunal Biotope No. 7

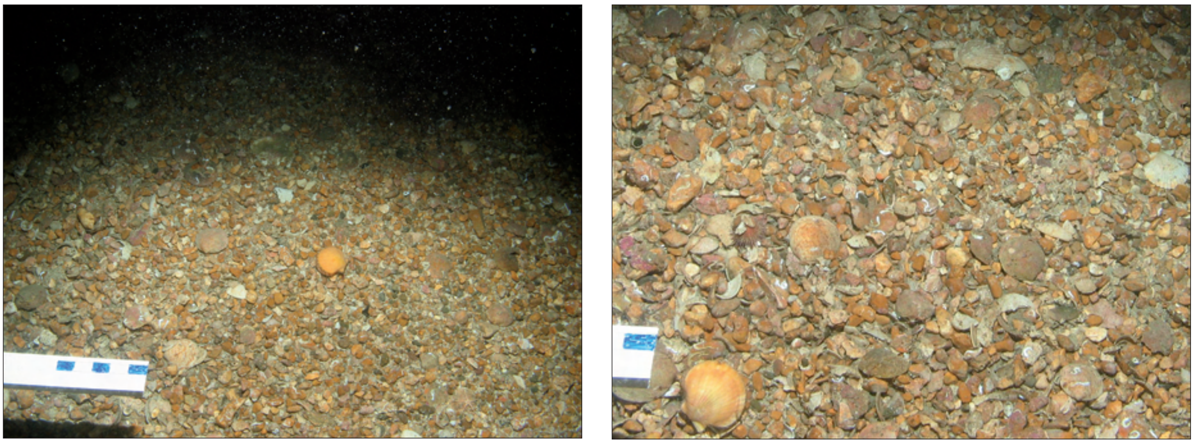
Example: Station No. 131 – 50°20’N 0°20’E - Water Depth 38 m (below chart datum)

Physical Region and occurrence	Infaunal Biotope 7 occurs in the southern and middle part of the Central Axial Platform – Region 4 and extends a little way into the Western Axial Platform- Region 3. It covers an area of 711 km^2, which is about 14% of the study area. The sea bed surface is mainly covered by sandy gravel sediment, which tends to become sandier towards the east. The sediment has a median grain size (d50) varying from 0.5-1mm (Coarse Sand) to >4 mm (Pebbles) with a bimodal distribution of 25% medium sand and 25% pebbles (4-16 mm). The area also has west-east trend in improved sorting with very poorly sorted sediment in the west and poorly sorted sediment on the east.
Multibeam	Flat featureless sea bed at a water depth of 38 m with no bedforms apparent.
Sidescan Sonar	The sidescan sonar mosaic has an even featureless monotone with high reflectivity backscatter.
Boomer	The sea bed is a flat sub horizontal surface lying on a sequence of Quaternary sediment, 2 to 8 m thick, infilling a palaeochannel. The floor of the palaeochannel is an undulating rock head surface on Barton Group rocks. The Quaternary sediments have strong dark high amplitude reflectors indicative of relatively coarse sediment in contrast to the more transparent and weaker reflectors in the underlying Barton Group.

Sample Station EECMHM 131 – grain size histogram.



Infaunal Biotope No. 7
Example: Station No. 131 – 50°20’N 0°20’E - Water Depth 38 m (below chart datum)

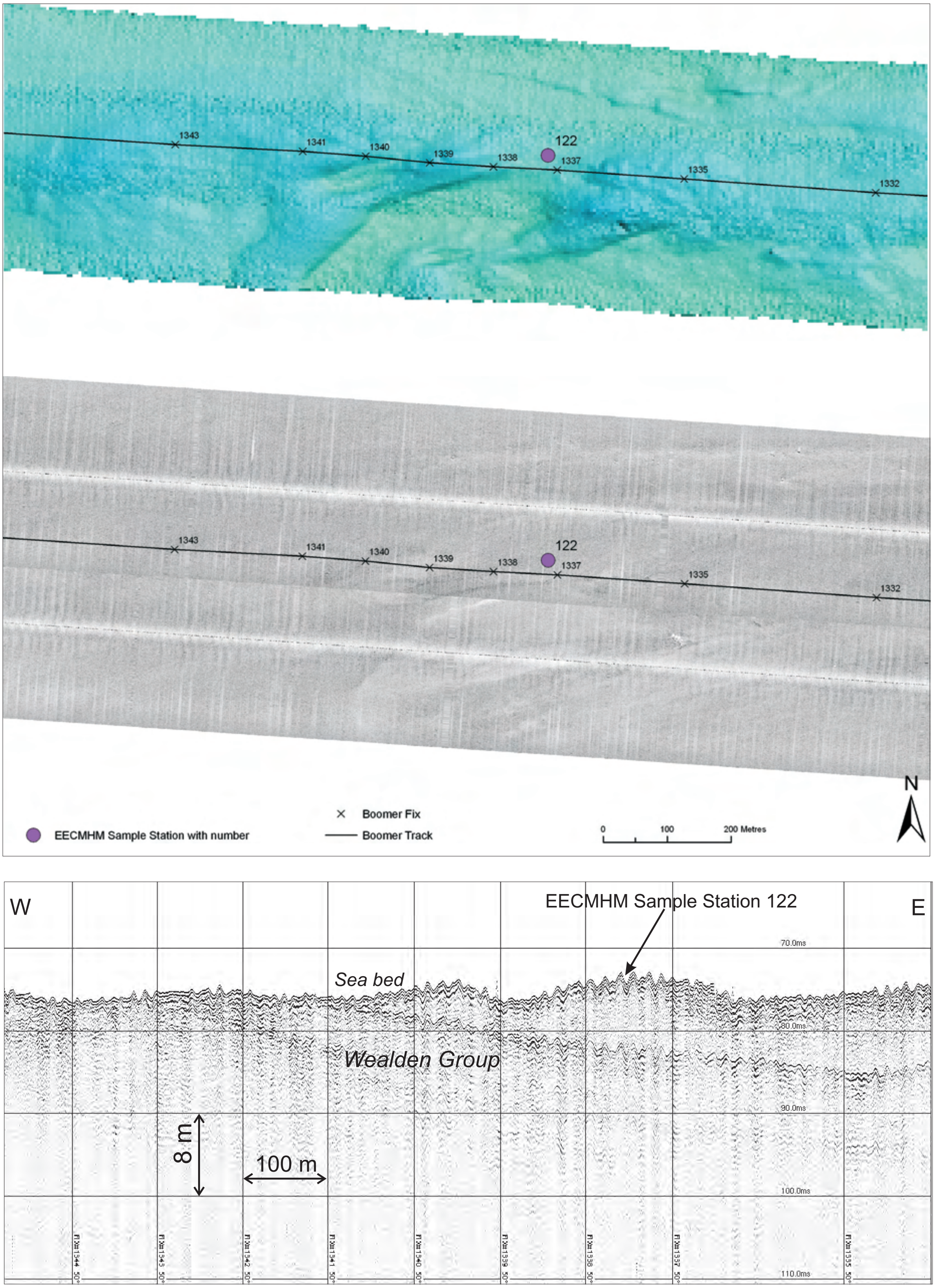


Sea bed photographs from Station 131. Left: features plains of well sorted clean gravel with sparse epifauna. Right: Close up of same.

General description	Featureless plains of bimodal sandy gravel with *Glycymeris* shells. Frequent *Aequipecten*, but no obvious ophiuroids, hydroids or attached epifauna. Gravel size mode ~ 10 mm (-3 phi).
Infaunal Biotope	SS.SMX.OMx.Po Similar to SS.SMX.OMx.PoVen Polychaete-rich offshore mixed sediments. Sandy gravel substrata typically supporting of *Laonice*, *Ampharete, Pomatoceros* and *Glycymeris*. Very similar to the existing Polychaete-rich deep Venus community in offshore mixed sediments, but with minimal occurrence of venerid bivalves. Other characterising genera: *Glycera, Harmothoe, Galathea, Aonides, Notomastus* and *Ampelisca*. Infaunal biotope cluster Z
Epifaunal Biotope Complex	SS.SCS.CCS (similar to SS.SCS.CCS.PomB and SS.SMX.CMx.FluHyd) Circalittoral Coarse Sediment. Area of transition between Epifaunal Biotope Complexes 3 and 6, moving from moderately sorted gravel beds with reduced epifauna to more abundant epifauna on sandier gravels. *Psammechinus, Aequipecten, Hydrallmania, Pomatoceros, Pagurus bernhardus, Ophiothrix fragilis* and *Ophiura albida.* **Other characterising species**: *Alcyonium digitatum, Anomia ephippium, Asterias rubens, Balanus crenatus, Galathea intermedia, Liocarcinus pusillus, Pagurus prideaux.* Epifaunal Biotope Complex 3, 6.
Further notes	

Infaunal Biotope No. 8

Example: Station No. 122 – 50°13'N 0°32'W - Water Depth 52 m (below chart datum)

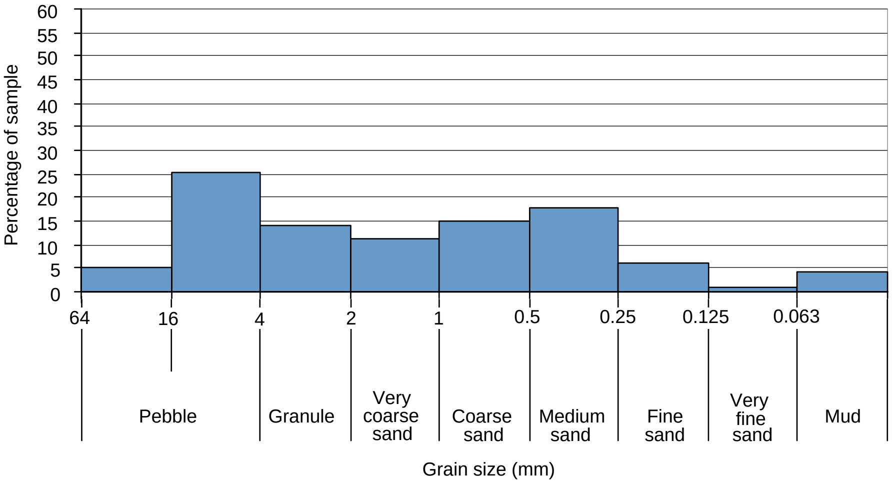


Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 122.

Infaunal Biotope No. 8
Example: Station No. 122 – 50°13’N 0°32’W - Water Depth 52 m (below chart datum)

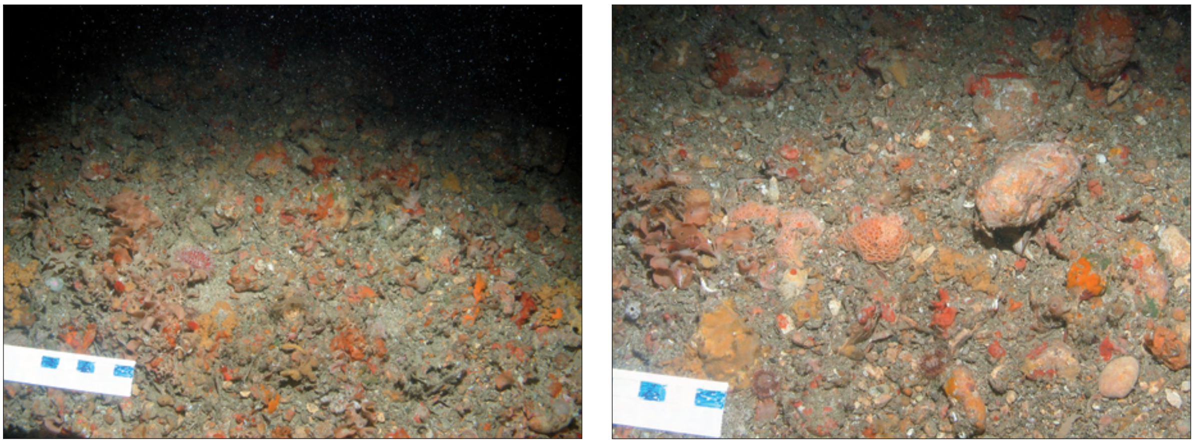
Physical Region and occurrence	Infaunal Biotope 8 is associated with an outcrop of Wealden Group rock in the core of an anticline in the south-west of Region 3 - Western Axial Platform. It covers a small area of 67 km^2, which is just over 1% of the total study area. The sediment is mainly a bimodal sandy gravel with some muddy sandy gravel, cobbles are common and include the occasional boulder. They are very poorly sorted with a clast-supported gravel, some of which appears to be of local origin from the underlying bedrock.
Multibeam	Ridges, depressions and breaks of slope around 2 m high associated with differential erosion of bedding in the underlying Wealden. Water depth around 52 m.
Side Scan Sonar	Slight monotone to sea bed reflectivity, some linear NE-SW streaks and a greater variation in reflectivity and backscatter around the ridges and slopes.
Boomer	Dipping reflectors to the east. Harder bands within Wealden produced high amplitude reflector and account for undulating sea bed of a few metres amplitude.

Sample Station EECMHM 122 – grain size histogram.



Infaunal Biotope No. 8

Example: Station No. 122 – 50°13'N 0°32'W - Water Depth 52 m (below chart datum)

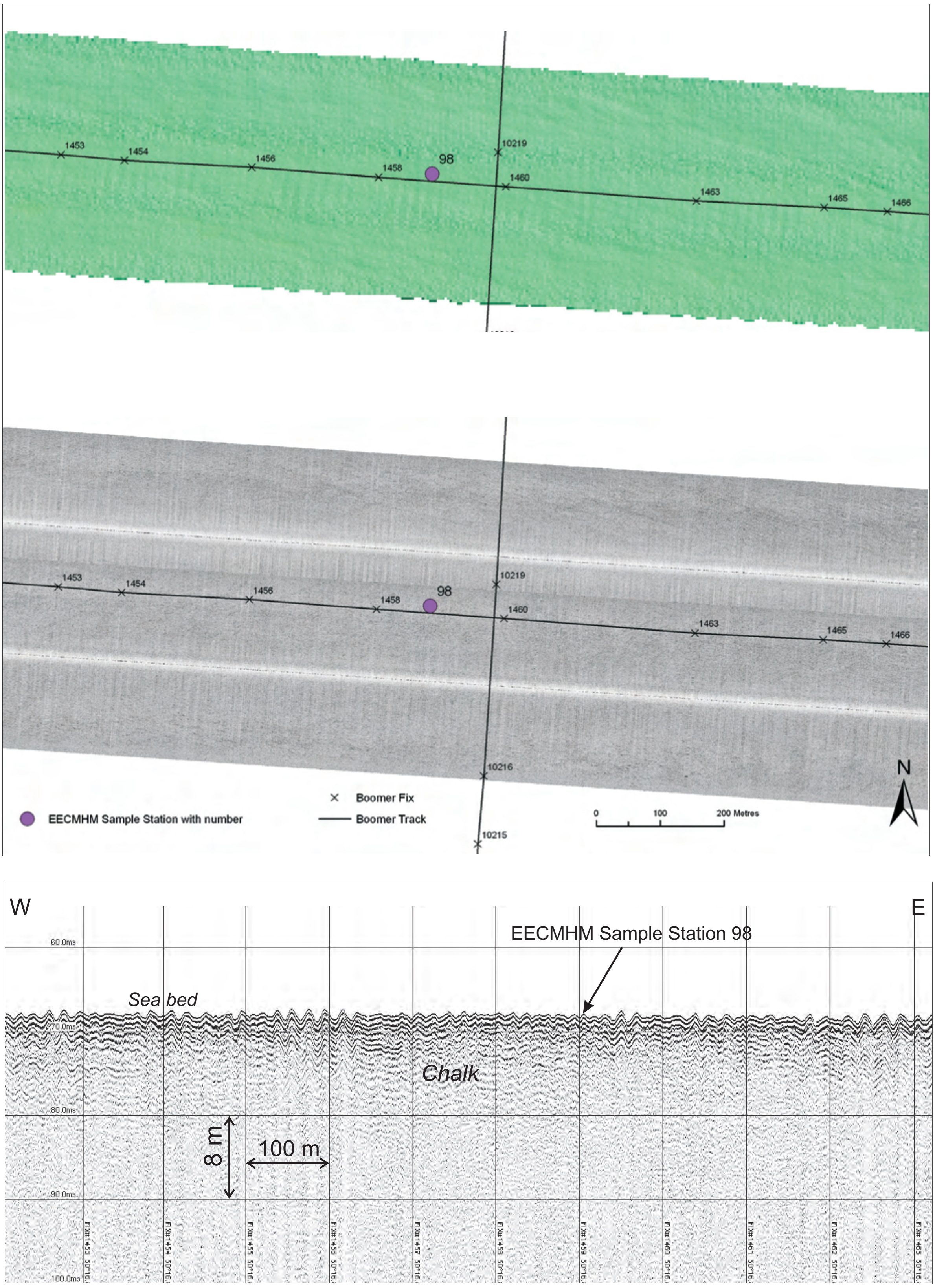


Sea bed photographs from Station 122. Left: Sponge communities on consolidated pebbles and cobbles. Right: Mixed sponges and Pentapora ('Ross coral', bryozoan).

General description	Areas of consolidated cobbles covered with a rich community of encrusting and erects sponges. Also foliose bryozoans, *Flustra* and *Pentapora*. Many small crabs (*Ebalia* and *Paguridae*) present, and some anemones.
Infaunal Biotope	SS.SMX.OMx.PoGlyEpi Similar to SS.SMX.OMx.PoVen Polychaete-rich offshore mixed sediments with *Glycymeris* and attached epifauna. Mixed sediment strongly characterised by *Glycymeris* and attached epifauna including the ascidians *Dendrodoa* and *Pyura* and the tubiculous polychaete *Pomatoceros*. Closely related to a Polychaete-rich deep Venus community in offshore mixed sediments, but has limited occurrence of venerid bivalves. **Other characterising genera**: *Aonides, Aphelochaeta, Amphipholis, Galathea, Eulalia* and *Harmothoe*. Infaunal biotope cluster O
Epifaunal Biotope Complex	SS.SCS.CCS (similar to SS.SMx.CMx and CR.HCR.XFa.ByErSp) Circalittoral Coarse Sediment. Predominantly cobble and pebbles with occasional boulders and some gravel. Very diverse epifaunal community, characterised by high abundance of sponges, erect bryozoans and hydroids. Porifera, Bryozoa, *Cellapora spp, Pentapora foliacea, Flustra foliacea, Abietinaria spp, Nemertesia spp.* **Other characterising species**: *Aequipecten opercularis, Ophiothrix fragilis, Ebalia spp, Pisidia longicornis, Pagurus bernhardus, Macropodia tenuirostris.* Epifaunal Biotope Complex 2

Infaunal Biotope No. 9

Example: Station No. 98 – 50°17'N 0°26'W - Water Depth 45 m (below chart datum)



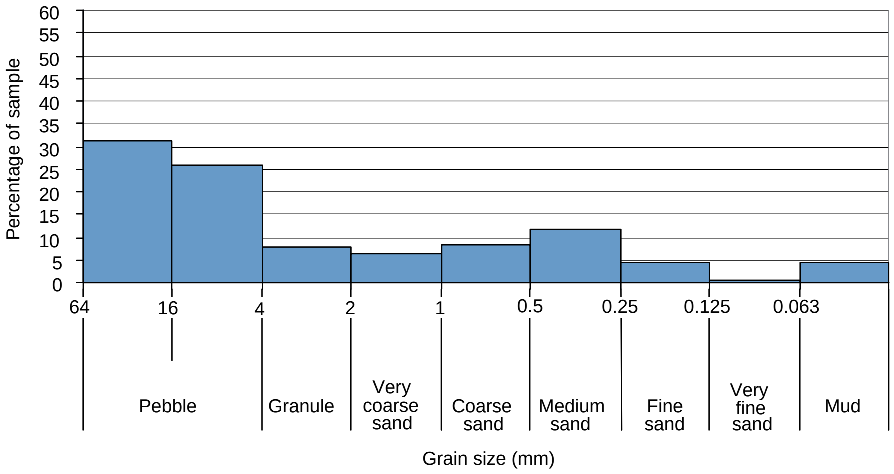
Multibeam, Sidescan Sonar and Boomer images of EECMHM Sample Station 98.

Infaunal Biotope No. 9

Example: Station No. 98 – 50°17'N 0°26'W - Water Depth 45 m (below chart datum)

Physical Region and occurrence	Infaunal Biotope 9 occurs in a small area adjacent and to the north of Infaunal Biotope 8 in Region 3- Western Axial Platform. It lies on Chalk and covers 104 km^2, around 2% of the study area. The Chalk bedrock is covered by a thin veneer of sediment composed predominantly of muddy sandy gravel with some sandy gravel. The mud component although small is significant and may be associated with relatively soft bedock rather than mud settled from the water column. The median (d_{50}) is commonly 2-4 mm (Granules). The abundance of pebbles is a feature of the area along with some cobbles and these give a poorly sorted, dense clast supported fabric to the gravel.
Multibeam	Flat relatively featureless sea bed at a water depth of 45 m with some NW-SE structural lineations from the underlying bedrock visible at the sea bed.
Side Scan Sonar	Relatively featureless sea bed with faint NW-SE bedding structures and high reflective backscatter
Boomer	Flat sea bed with Chalk at or very close to the surface. Massive fairly transparent internal signature with some poor dipping reflectors. Wide pulse return at the sea bed with a very thin veneer of sediment covering the flat surface.

Sample Station EECMHM 98 – grain size histogram.



Infaunal Biotope No. 9
Example: Station No. 98 – 50°17'N 0°26'W - Water Depth 45 m (below chart datum)

Sea bed photographs from Station 98. Left: Coarse gravel with hydroids and *Ophiothrix*. Right: Patches of imbricated *Glycymeris* shells.

General description	Plains of pebbles and coarse gravel with occasional cobbles and notable aggregations of *Glycymeris* shells often imbricated (overlapping, racked together) to form a stable substrate. Superabundant *Ophiothrix fragilis*, abundant filamentous hydroids and *Flustra*. Small crabs (e.g. *Ebalia* and *Eurynome spp*) are common.
Infaunal Biotope	SS.SMX.CMx.OphMX *Ophiothrix fragilis* brittlestar beds on sublittoral mixed sediment. Mixed sediment strongly characterised by *Harmothoe, Ophiothrix, Nucula, Lumbrineris, Glycymeris* and *Galathea*. A localised but distinct biotope, consistent with the existing OphMX class, though the latter does not describe any infaunal component. **Other characterising genera**: *Notomastus, Asclerocheilus, Janira, Typosyllis, Nemertea* and *Eualus*. Infaunal biotope cluster R
Epifaunal Biotope Complex	SS.SMX.CMx.OphMx *Ophiothrix fragilis* brittlestar beds on sublittoral mixed sediment. Dense *Ophiothrix* beds over pebble gravel and cobbles, with *Aequipecten, Psammechinus, Hydrallmania* and *Pomatoceros*, but without dense cover of encrusting sponges. **Other characterising species**: *Pagurus prideaux, Hyas coarctatus, Aequipecten opercularis, Flustra foliacea.* Epifaunal Biotope Complex 1

6.4 Physical regions – integrated summaries

The physical regions were distinguished and delineated because they were identified in the study as having characteristic or common physical and geological features and these are described in detail in Section 5.1. Throughout Chapter 5 and elsewhere in the report the Regions have provided a geographical context for the geological and biological interpretations. The Region boundaries have been shown on the majority of the study area figures.

The following integrated summaries indicate the principal characteristics of each Region based on three themes:-

- Geology and sediments
- Broad habitat
- Detailed biotopes

The range of water depth across each region is included, as well as its total area. The survey data included refers only to data collected during surveys conducted for the EECMHM study.

Region 1 — Northern Palaeovalley and Margin Integrated Summary

Water depth (m)	Area (km^2)	Grab stations	Trawl stations	Video stations	Multibeam Corridor (km)	Sidescan Corridor (km)	Boomer Line (km)
20 - >70	1,260	54	22	11	417	401	327

Geology and Sediments

Sea bed sediment (Figure 5.7)	• Gravelly sand covers majority of region with sandy gravel in southwest quarter of Northern Palaeovalley and in the east. • Dominantly poorly sorted, very poorly sorted in east and west. Few cobbles, rare boulder. • Patches of gravelly muddy sand and muddy sandy gravel – mud possibly associated with rock outcrop.
Sea bed character and bedforms (Figures 5.4, 5.5 and 5.6)	• Northern Palaeovalley floor (15 km wide) in western half of region. Max depth >70 m. Floor bifurcates to east. • Palaeovalley margin shallows to < 30 m depth in north-west and north-east. • Northern half of Palaeovalley floored by sandy sediment. Linear sand wave field, 1.5 – 8 m high, banked along margin. • Sandy bedforms dominantly sand streaks, sand patches and megaripple trains, primarily over rock and thin sediment. • East facing asymmetry and linear orientation of sand bedforms indicative of current driven net sediment transport to east. • Extensive areas of rock and thin sediment in east and north-west, and southern half of Northern Palaeovalley. • Sea bed character and morphology controlled by rock structure and channel erosion in north-west.
Rock outcrops (Figures 5.5 and 5.8)	• Smooth south-west dip slopes of Barton Group rocks common in north-west along margin of Northern Palaeovalley. • Some structural lineation, bedding and breaks of slope within Chalk and Wealden in east. • Chalk scarp up to 24 m high at boundary with Gault-Greensand south of Beachy Head.
Quaternary sediment (Figure 5.4)	• Quaternary sediment up to 15 m thick infill parts of the Northern Palaeovalley. • In areas of rock and thin sediment accumulations of thicker Quaternary sediments can occur.

Broad Habitat (Figures 6.1 - 6.3)	Detailed Biotopes (Figures 6.1 – 6.3)

The Region divides into three broad habitats:
• Southern part of the Palaeovalley floor with thin cover of mixed sediment over rock. Most infaunal samples indistinguishable to those from the south-west of region 4; epifauna are also similar but less abundant. SS.SCS.CCS and SS.SSA.CFiSa.
• Thicker finer sand and gravel in northern part of the Palaeovalley and its margin. A variety of infaunal types, most commonly sand with *Echinocyamus*, *Nephtys* and *Glycera*, but alternating where patchy sediment varies in the extreme north-west.
• Eastern third of the area, where Chalk and Greensand are overlain by thin gravel and sand. Infauna typical of patchy sand and gravel. Few encrusting or attached colonial epifauna, possibly as a result of scouring and smothering by mobile sediments. Typical of the CR.HCR.XFa complex.
	• Described mainly by infauna:
	  • SS.SSA.CFiSa.EpusPomGal and SS.SSA.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Pomatoceros*, and *Galathea*).
	  • SS.SSA.CFiSa.EpusNephGlyc and or SS.SSA.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Nephtys* and *Glycera*).
	  • SS.SCS.CCS.NotLum and SS.SCS.CCS.MedLumVen (*Notomastus* and *Lumbrineris*).
	• Described mainly by epifauna:
	  • SS.SCS.CSS.
	  • SS.SMX.Omx.
	  • SS.SMX.CMx.FluHyd.
	• For hard substrates:
	  • CR.HCR.XFa.FluCoAs and similar.
	
	Blue text highlights biotopes erected in this study; red text denotes those existing in Connor *et al*, 2004.

Region 2 – North-East Platform and Margin Integrated Summary

Water Depth (m)	Area (km^2)	Grab stations	Trawl stations	Video stations	Multibeam Corridor (km)	Sidescan Corridor (km)	Boomer Line (km)
20 - 50	350	16	3	5	154	135	96

Geology and Sediments

Sea bed sediment (Figure 5.7)	• Gravelly sand dominant across region, generally poorly sorted. Occasional cobble. • Gravelly muddy sand in east, very poorly sorted – mud possibly associated with rock outcrop. • Sandy gravel patch in west overlying Quaternary sediment filled channel.
Sea bed Character and Bedforms (Figures 5.4, 5.5 and 5.6)	• Rock and thin sediment occurs extensively. • West of region covered by thicker sandy and coarse sediment. • Sea bed morphology conditioned by structure of bedrock. • Structural lineations and bedding widespread at the sea bed. • Sandy bedforms such as sand streaks, sand patches and megaripple trains are common. • Bedforms aligned parallel to peak tidal current direction or in direction of rock structure scarps and troughs. • Some groups of isolated asymmetrical east facing sand waves - max height 12 m.
Rock Outcrops (Figures 5.8 and 5.5)	• Steeply dipping Upper Jurassic and Wealden rocks extensively exposed as scarps and ridges. • Large platform with erosion surface cutting the bedding and exposing core of anticline at sea bed.
Quaternary Sediment (Figure 5.4)	• In west sediment up to 15 m thick infill large north–south palaeochannel. • Small palaeochannels in north-east infilled with up to 5 m of sediment.

Broad Habitat (Figures 6.1 - 6.3)	**Detailed Biotopes (Figures 6.1 - 6.3)**

• Majority of the region comprises gravelly sand, with occasional cobbles, giving the general habitat type SS.SCS.CCS.
• Sediment transport with sandy bedforms and bedrock gives rise to local patchiness; including gravel, finer sand, accumulations of shell fragments and much exposed rock. *Ophiura albida* is particularly typical on the sediment surface.
• Finer sands in the south-east are characterised by *Echinocyamus*, *Nephtys* and *Glycera*.
	• Described mainly by infauna:
	  • SS.SCS.CCS.NotLum and SS.SCS.CCS.MedLumVen (*Notomastus* and *Lumbrineris*).
	  •SS.SSA.CFiSa.EpusNephGlyc and SS.SSA.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Nephtys* and *Glycera*).
	  • SS.SSA.CFiSa.LkorEns and SS.SMU.CSaMu.LkorPpel (*Lagis koreni* and *Ensis*).
	• Described mainly by epifauna:
	  • SS.SMX.CMx.FluHyd.
	• For hard substrates:
	  • SS.SCS.CCS.PomB.
	
	Blue text highlights biotopes erected in this study; red text denotes those existing in Connor *et al*, 2004.

Region 3 – Western Axial Platform Integrated Summary

Water Depth (m)	Area (km^2)	Grab stations	Trawl stations	Video stations	Multibeam Corridor (km)	Sidescan Corridor (km)	Boomer Line (km)
50 - 60	1,050	63	17	26	435	429	253

Geology and Sediments

Sea bed sediment (Figure 5.7)	• Sandy gravel with extensive central area of muddy sandy gravel. • Dominantly very poorly sorted. Cobbles are widespread. Some boulders. • Gravelly mud in small patches – possibly associated with rock outcrop. • Mean grain size and gravel % decreases to east and north-east.
Sea bed character and bedforms (Figures 5.5, 5.6 and 5.7)	• Extensive relatively flat platform dominated by rock and thin coarse sediment. • Much gravel, particularly cobbles and boulders, derived directly from underlying bedrock. • Morphological and structural lineations become numerous to south and west. • Generally featureless with very few sandy bedforms. • Fine sediment winnowed from sea bed surface.
Rock outcrops (Figures 5.8 and 5.5)	• Pattern of major and minor synclines and anticlines across region. • Wide range of rock type exposed from Wealden through Chalk to Barton Group. • Areas of steeper dips and narrower bedding producing ridges and lineation at outcrop. • Wealden Group rocks in core of monocline in south-west well exposed as series of ridges.
Quaternary sediment (Figure 5.4)	• Some channels infilled up to 5 m thick. Aligned to north and south. • Sediment may also occur between some rock ridges.

Broad Habitat (Figures 6.1 - 6.3)	**Detailed Biotopes (Figures 6.1 - 6.3)**

• Central and western parts characterised by circalittoral coarse sediments, mostly very poorly sorted, coarse gravels with *Galathea*, *Pomatoceros*, *Pisidia* and *Glycymeris* and featuring localised but dense beds of *Ophiothrix fragilis*. SS.SMX.CMx.
• A clast supported gravel and cobble substrate, mainly overlying Wealden and Gault-Greensand rock in the south-west, supports a rich encrusting epifauna of sponges and bryozoans not seen elsewhere in the EECMHM study area.
• The north of the region descends to the floor of the Northern Palaeovalley in Region 1, while the east grades into finer, thicker gravel where polychaetes become more prominent in the infauna and *Psammechinus* and *Aequipecten* in the epifauna. SS.SCS.CCS.
	• Described mainly by infauna:
	  • SS.SCS.CCS.GalPomPis(Gly) and SS.SCS.CCS.PomB (*Galathea*, *Pomatoceros*, *Pisidia* and *Glycymeris*).
	  • SS.SMX.OMx.PoGlyEpi and SS.SMX.OMx.PoVen (Polychaete-rich with *Glycymeris* and attached epifauna).
	  • SS.SMX.CMx.OphMX.
	Described mainly by epifauna:
	  • SS.SMX.CMx.OphMX.
	  • SS.SMX.OMx.
	For hard substrates:
	Similar to CR.HCR.Xfa.ByErSp (but no erect sponges).
	
	Blue text highlights biotopes erected in this study; red text denotes those existing in Connor *et al,* 2004.

Region 4 - Central Axial Platform Integrated Summary

Water Depth (m)	Area (km^2)	Grab stations	Trawl stations	Video stations	Multibeam Corridor (km)	Sidescan Corridor (km)	Boomer Line (km)
40 - 55	1,640	46	14	11	512	446	345

Geology and Sediments

Sea bed sediment (Figure 5.7, 5.36, 5.39)	• Sandy gravel dominant, passing to gravelly sand at east of region. Occasional cobble. • West to east sediment fining trend; d_{50} 2-4 mm in west; 0.5-1 mm in east. • Some patches where d_{50} >4 mm i.e. pebble size. • Sorting improves west to east from very poorly sorted to poorly sorted. • Evidence for long term winnowing and transport of fine sediment to east. • Flint is major component of gravel fraction. • Surface of youngest underlying palaeochannel deposit principal source of sea bed sediment.
Sea bed character and bedforms (Figures 5.4, 5.5 and 5.6)	• Extensive relatively flat platform dominated by coarse sediment. • Some open channels with low slopes at margins. • Generally featureless with scarce sandy bedforms. • Small area of sand streaks, patches and megaripple trains in north-east. • Rare structural lineations associated with rock outcrops and thin sediment on palaeochannel interfluves.
Rock Outcrops (Figures 5.8 and 5.5)	• Confined to minor structural and morphological lineations on few palaeochannel interfluves. • Bracklesham and Barton Group rocks.
Quaternary Sediment (Figure 5.4)	• Region underlain by extensive network of palaeochannels. • Substantial sediment accumulation, up to 25 m thick, infilling palaeochannels.

Broad Habitat (Figures 6.1 - 6.3)	Detailed Biotopes (Figures 6.1 - 6.3)

• Region divides into three main habitats. Two split the central sandy gravels north and south, and the third covers the transition to gravelly sand eastwards into Region 5.
• The central sandy gravels have a common epifauna, characterised by *Psammechinus*, and *Aequipecten*, but the infauna differ between the sandier gravels in the north-west area and the less sandy gravels in the south-west and south-central areas which are richer in polychaetes. SS.SCS.CCS.
• In the eastern transition zone, the epifauna taxa remain largely the same but become notably more abundant, while the infaunal samples lose species characteristic of gravels (*Galathea*, *Pomatoceros*) and gain those more typical of sands (*Echinocyamus*). SS.SSA.CFiSa.
• 'Circalittoral rock' habitats (i.e. rock outcrops, or notable aggregations of boulders or cobbles) were not recorded in this region.
	• Described mainly by infauna:
	  • SS.SSA.CFiSa.LkorEns and SS.SMU.CSaMu.LkorPpel (*Lagis koreni* and *Ensis*).
	  • SS.SCS.CCS.GalPomPis(Eun) and SS.SCS.CCS.PomB (*Galathea*, *Pomatoceros*, *Pisidia* and *Eunice*).
	  • SS.SCS.CCS.GalPomPis(Gly) and SS.SCS.CCS.PomB (*Galathea*, *Pomatoceros*, *Pisidia* and *Glycymeris*).
	  • SS.SSA.CFiSa.EpusPomGal and SS.SSA.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Pomatoceros* and *Galathea*).
	• Described mainly by epifauna:
	  • SS.SCS.CCS.PomB.
	  • SS.SMxCMx.
	• For hard substrates:
	None.
	
	Blue text highlights biotopes erected in this study; red text denotes those existing in Connor *et al*, 2004.

Region 5 – Greater Bassurelle Sands Integrated Summary

Water Depth (m)	Area (km^2)	Grab stations	Trawl stations	Video stations	Multibeam Corridor (km)	Sidescan Corridor (km)	Boomer Line (km)
15 - 50	790	45	17	12	364	335	180

Geology and Sediments

Sea bed sediment (Figure 5.7)	• Majority of region covered by gravelly sand with slightly gravelly sand in east. • Sand on and around Bassurelle Bank in south-east. • West to east fining trend, d_{50} 0.5-1 mm in west half, 0.25-0.5 mm in north and east. • Although sorting dominantly poor improves to moderately well sorted in south-east around Bassurelle Bank.
Sea bed character and bedforms (Figures 5.4, 5.5 and 5.6)	• Extensive sand sheet in south and west; featureless with few bedforms. • Isolated sand waves multiply to north and east into extensive sand wave field, • Asymmetric sand waves, lee slopes facing east / north-east. • Height 1.5 - 10 m, wave lengths 200 - 1300 m. Some bifurcating crest lines. • West end of Bassurelle Sand Bank encroaches for 8 km into south-east of region. • Symmetric sand waves, 2.5 m high, on top of bank. Asymmetrical waves on flank. • Very few small patches of rock and thin sediment associated with palaeochannel interfluves.
Rock Outcrops (Figures 5.5 and 5.8)	• Linear outcrops of Chalk on small interfluve in north.
Quaternary Sediment (Figure 5.4)	• Quaternary sediments infilling Palaeochannels with a sequence 10-20 m thick. • Transgressive sand sheet unit developed beneath sea bed in central-eastern area. • Sheet thickens eastward to > 5m, merges into sand wave field, increases to >10 m thick. • Sediment reaches maximum thickness in area of sand bank, > 25 m thick. • Evidence of long term, >5000 years, eastward sand transport and accumulation.

Broad Habitat (Figures 6.1 - 6.3)	**Detailed Biotopes (Figure 6.1 - 6.3)**

• The region divides into five broad habitat types:
• The extensive sand wave field in the north is divided in two, the north-east sector comprising fine sand and slightly gravelly sand (SS.SSA.CFiSa) with notable presence of the tube building polychaete *Lagis* and the razor-shell bivalve *Ensis*. The south-west sector holds coarser gravelly sand and is a southerly extension of the sand communities in Region 2 (SS.SCS.CCS). Epifauna in both sand wave areas are similar, but the coarser material supports a far greater abundance of *Balanus* and *Hydrallmania*.
• The Bassurelle Sand Bank in the south-east, the thickest part of which has the same infauna as the sand wave field. However, the epifauna are different, notably including sand-eels, *Ammodytes*, and weever fish, *Echiichthys* (SS.SSa.IFiSa).
• A sand-field fringe community occurs in transitions to the west of the sand wave field and the south of the Bassurelle Bank (also SS.SSA.CFiSa).
• The remainder of the region in the south-west is an extensive, flat, gravelly sand sheet with the same type of infauna found in the sandier areas of Region 1. Epifaunal communities are similar too, but with notably greater abundance in Region 5 (SS.SCS.CCS & SS.SSA.CFiSa).
	• Described mainly by infauna:
	  • SS.SSA.CFiSa.EpusPomGal and SS.SSA.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Pomatoceros* and *Galathea*).
	  • SS.SSA.CFiSa.EpusNephGlyc and SS.SSA.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Nephtys* and *Glycera*).
	  • SS.SCS.CCS.NotLum and SS.SCS.CCS.MedLumVen (*Notomastus* and *Lumbrineris*).
	  • SS.SSA.CFiSa.LkorEns and SS.SMU.CSaMu.LkorPpel (*Lagis koreni* and *Ensis*).
	• Described mainly by epifauna:
	SS.SMx.
	OMxSS.SCS.CCS.
	Similar to SS.SSA.IFiSa.IMoSa (sandbanks).
	• For hard substrates:
	None.
	
	Blue text highlights biotopes erected in this study; red text denotes those existing in Connor *et al*, 2004.

7. Conclusions and recommendations

Conclusions

- The study covered a large area, over 5000 km^2, of the eastern English Channel. The survey strategy within the funding provided was adequate to give an overall perspective of the regional character of the geology and biology of the sea bed in the area, but the large > 5 km survey line and sample station spacing in some areas meant only gross interpolations could be made in terms of mapping geological and biological parameters and producing biotope maps. The maps are therefore indicative of the regional distribution of the most common habitat types. While they are suitable for placing the aggregate companies' licence application areas in a wider spatial context, they do not constitute definitive maps of all the habitats that may exist in the area and do not reflect the fine scale, local variability in habitats that might be shown by more intensive studies.

- Characteristic or common physical and geological features enabled five Physical Regions to be distinguished. The northern part of the study area was divided in two, Region 1 to the west and Region 2 to the east, while the southern part was divided into three, Region 3 in the west, Region 4 in the centre and Region 5 in the east. The areas of current aggregate licence applications are concentrated almost entirely in Region 4.

- In terms of sea bed character around 43% of the study area is covered by rock and thin sediment (<1.5 m thick), 27% by coarse sediment and 30% by sandy sediment. Rock and thin sediment extends over much of the two northern Regions, and is particularly extensive in the south-west in Region 3. Coarse sediment dominates Region 4 in the central south of the study area with sandy sediment increasing in significance to the east and encompassing all of Region 5 in the south-east.

- Both the areas of coarse sediment and much of rock and thin sediment are particularly scarce in sandy bedforms. Sand streaks, patches, sand ribbons and megaripple trains are more common in both northern regions. Sand waves are most common in Region 5 which contains an extensive sand wave field. The western tip of the Bassurelle Bank sand bank extends into the south-east corner of Region 5.

- Grab sample analysis showed Region 1, 2 and 5 to be dominated by sandy sediment, especially gravelly sand. Region 1 and 2 include some areas of sandy gravel but this is most extensive in Region 4 and extends westward into Region 3, which also has an extensive area of muddy sandy gravel at its core. Video and still photography showed areas of Region 3 to be characterised by cobble substrates.

- From west to east across the southern half of the study area there is a grain size trend of increasing sand content and decreasing gravel content. In the west there are extensive areas of immobile coarse sediment with cobbles, and rock outcrop. Quaternary sediment associated with palaeochannel systems in the central Region 4 provides a predominantly gravelly substrate beneath the sea bed.

- There has been a long term process in the eastern English Channel of fine and sandy sediment being swept by tidal currents, and to some extent wave action, to the north and east, with the shallower coastal margins and eastern sand wave fields and banks acting as sinks and conduits for these sediments. In Region 5, seismic records provide evidence of this process with the deposition of a thin transgressive sand sheet immediately beneath the sea bed. This provides an important context in which to view the potential remobilisation of similar fine sediment resulting from proposed aggregate extraction, feeding into a natural process of transport and deposition.

- Sediment and sea bed substrate type was the principal physical/environmental factor controlling the nature and composition of benthic communities. The presence of encrusting and colonial fauna increased notably on cobble substrates, and there was a concomitant increase in diversity and abundance of motile infauna and epifauna. Distinctive communities were also found on sand in the east.

- Analysis of epifauna from still images showed different ophiuroid (brittle star) species characterised different types of gravel with *Ophiura albida* on the finer gravels in Region 4 and *Ophiothrix fragilis* on the patches of coarser gravel with cobbles in Region 3. A rich sponge and bryozoan community was also found on consolidated cobble substrate in Region 3.

- Analysis of infauna from grab samples identified nine principal groups that could reasonably be interpreted as representing regional Infaunal Biotopes (IB). One group, IB4, was sub-divided on account of significant differences in the abundance of the bivalve species, *Glycymeris glycymeris*.

- Analysis of beam trawl samples identified nine epifaunal groups showing a spatial relationship that gave some insight into the distribution of regional epifaunal biotopes. This was complemented by a consolidated interpretation of the video and stills analyses that grouped the observed stations into seven broad biotope classes. The different sampling characteristics of trawl and video techniques precluded the pooling of data for joint analysis. Instead, the evidence from the trawl and video/stills analyses was considered in conjunction with the available geological interpretations, and used to describe and map a series of eleven 'Epifaunal Biotope Complexes' (EBC).

- Few of the mapped biotopes were exclusive to any one Region; a notable exception being those associated with the cobble substrates in Region 3. The biotopes often straddled borders between Physical Regions and this was more marked for the Epifaunal Biotope Complexes as epifauna tend to show lower fidelity and exclusivity to particular substrate types than infauna.

- Although small areas supporting reef fauna were found within the study area, no extensive areas of Annex 1 "rocky reef" habitat suitable for identification as SACs were noted..

- The western tip of the Bassurelle Bank extends into the study area in the south-east corner (Region 5) and some of its characteristics fit the description of the Annex 1 habitat "Sandbanks which are slightly covered by sea water all the time"

Recommendations

- In planning marine habitat surveys the nature of the sea bed and the objectives of the study will be primary determining factors in producing a survey strategy. We would recommend geophysical corridor/line spacing at a scale which matches the sea bed footprint of the physical, geological or biological features under investigation. In practical terms for regional scale surveys the spacing may be from 1 to 5 km. We would not recommend spacing wider than 5 km. For each corridor we would recommend a minimum of three overlapping parallel multibeam and sidescan lines with a single sub-bottom line in the centre. The number of lines per corridor should be governed by the size and nature of the feature footprint under investigation. A corridor/line approach may not always be applicable, indeed some areas may warrant complete 100% multibeam and sidescan cover with a suitable complimentary sub-bottom seismic line spacing.

- The study area included extensive areas of rock and thin sediment. Resolving the thickness and distribution of sediment when it less than a metre or so thick is an important issue for mapping habitat as only the physical characteristics of the sea bed and its underlying geology and sediment down to a depth of ~0.5 m is thought to be significant. However, the boomer sub-bottom seismic system cannot resolve sediment at the sea bed < 1 to 1.5 m thick and both the multibeam and sidescan can indicate rock outcrop at the sea bed where both sampling and video provide evidence of sediment. It would seem that thin veneers, including cobble gravel derived from the immediately underlying bedrock and ephemeral sands, might be relatively common in those areas where the geophysical evidence indicates rock. Consequently, a ground truthing system based on coring or a large clamshell grab is recommended to provide physical evidence for sediment thickness.

- Techniques for rigorous, quantitative sampling of coarse cobble and rock substrates for fauna or sediments are not well developed. Further work to assess existing tools and to develop new tools would be beneficial.

- The ground truthing strategy of using a suite of complementary sampling techniques, deploying 0.1 m^2 Hamon grab, 2 m beam trawl and camera sledge, worked well in areas of sand and gravel. When the sea bed sediment became coarse with numerous cobbles and also rock outcrop the relatively small footprint of the Hamon grab could not gather a representative sample. This was mitigated to some extent by analysis of video and stills from the camera sledge. Consequently, in areas of cobble gravel and rock outcrop where epifauna are likely to be well developed we would recommend promoting the use of camera systems to the principal ground truthing tool. The camera sledge produced excellent results and provided new and revealing insights including imbricated gravels, ferroan calcite boulder nodules, fishing gear impact and *Ophiothrix* beds.

- A significant issue was the difficulty of assigning biotopes to the infaunal and epifaunal assemblages identified by the EECMHM study using The Marine Habitat Classification for Britain and Ireland v 04.05 (Connor *et al.*, 2004). There was a lack of suitable biotopes within the existing classification to describe the habitats encountered in this study. The classification requires further development at the more detailed levels of the hierarchy specific to sediments typical of 'offshore' habitats. Data collected within this study, will be used to improve existing biotopes and produce new ones for incorporation in the classification.

- The multidisciplinary approach of marrying geophysical and physical techniques used in this study greatly enhanced the interpretation of the resulting data and this multidisciplinary approach is recommended for future habitat mapping studies.

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