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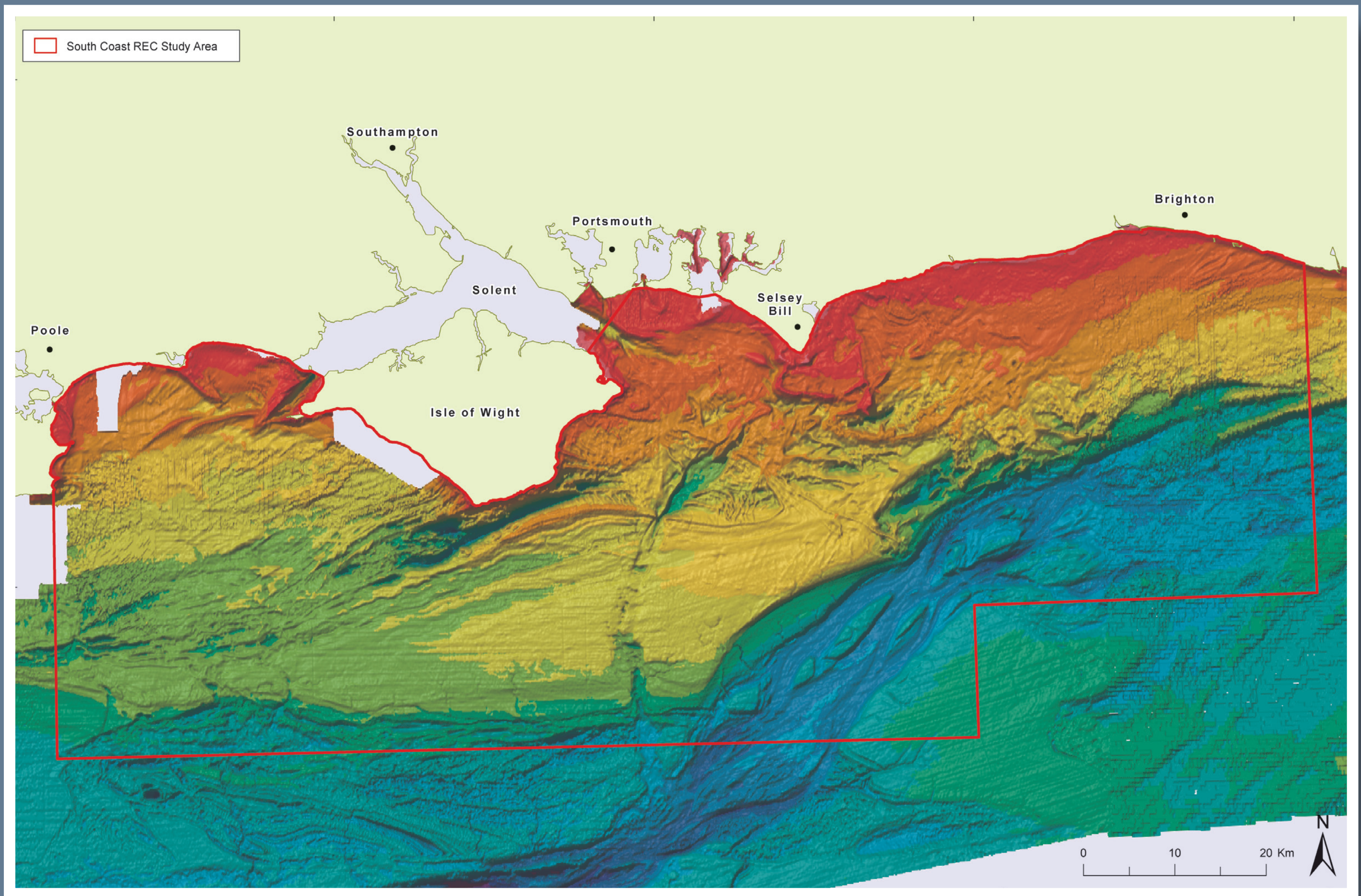
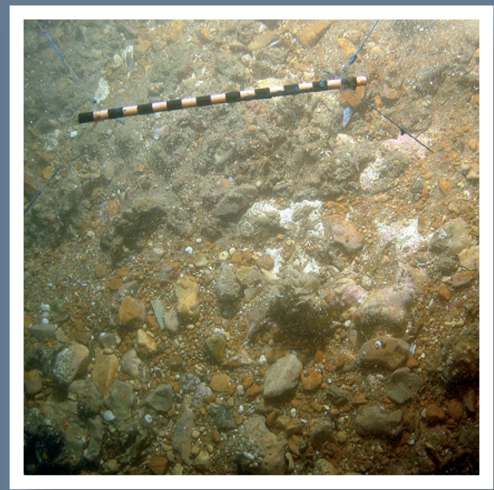
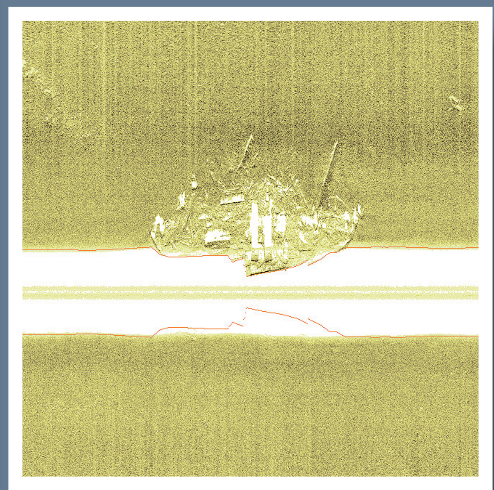
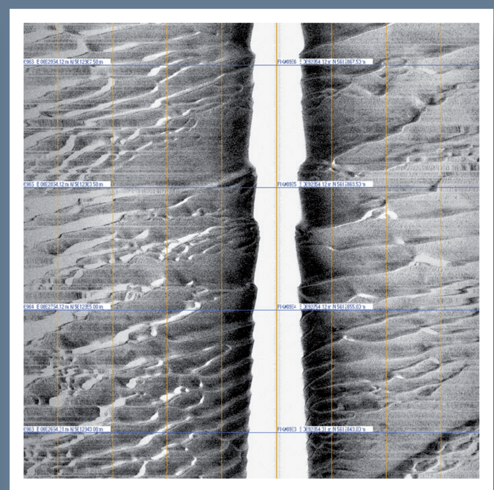
MALSF

The South Coast Regional Environmental Characterisation









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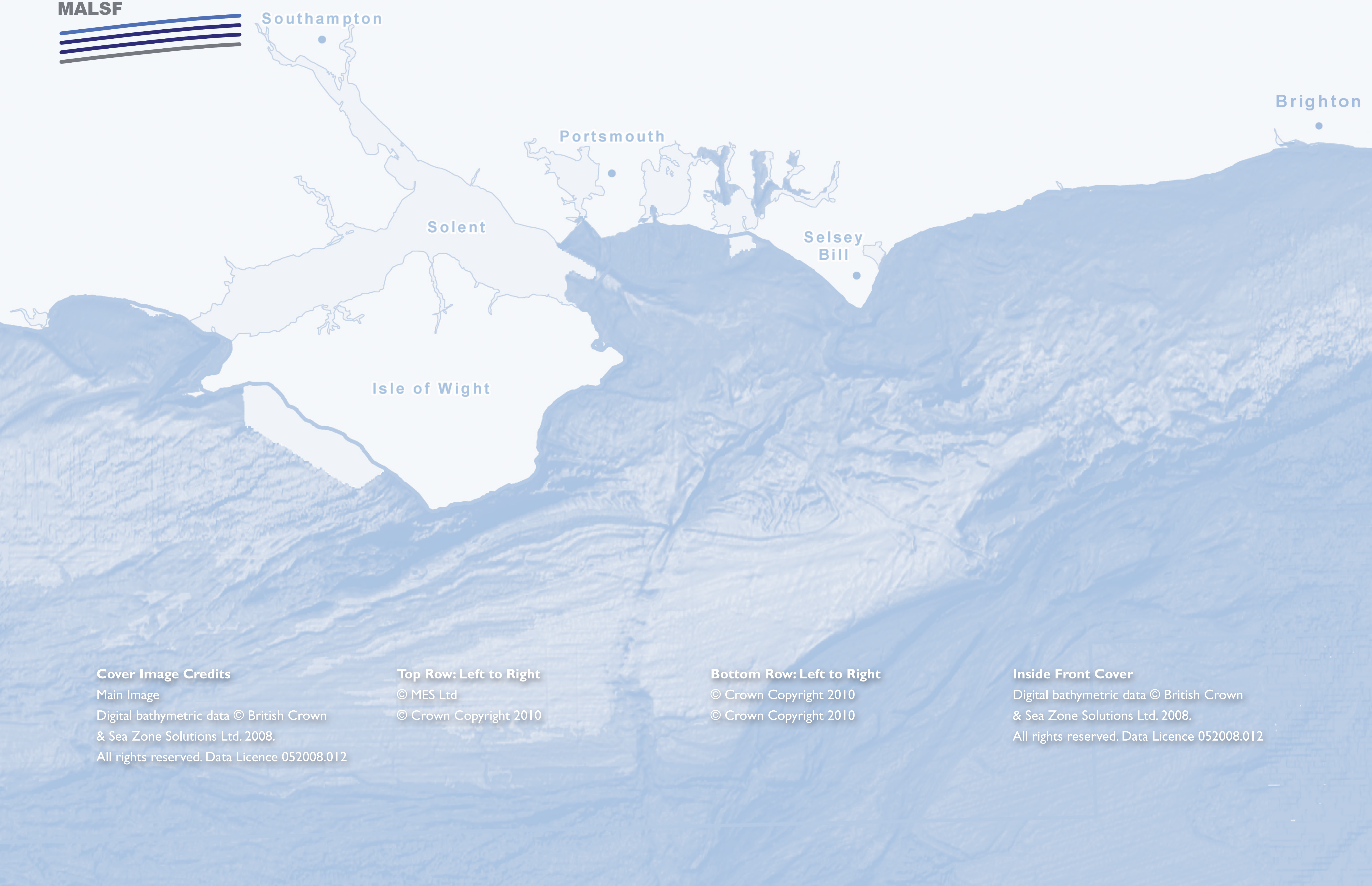

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The South Coast
Regional Environmental Characterisation

Marine Aggregate Levy Sustainability Fund (MALSF)

Administered by:

Report written by:

July 2010

British Geological Survey Open Report OR/09/51

MEPF 08/02

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Project funding

This work was funded by the **MALSF** and commissioned by the **MEPF**.

Background to the Fund

In 2002, the Government imposed a levy on all primary aggregates production (including marine aggregates) to reflect the environmental costs of winning these materials. A proportion of the revenue generated was used to provide a source of funding for research aimed at minimising the effects of aggregate production. This fund, delivered through Defra, is known as the Aggregate Levy Sustainability Fund (ALSF); marine is one element of the fund.

Governance

The Defra-chaired MALSF Steering Group develops the commissioning strategy and oversees the delivery arrangements of the Fund.

Delivery Partners

The **MALSF** is currently administered by two delivery partners - the **MEPF** (based at Cefas, Lowestoft) and **English Heritage.**

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Executive summary

1 The South Coast Regional Environmental Characterisation (REC) is a multidisciplinary marine study encompassing the geology, biology and archaeology of an extensive area – 5600 km^2 — of the English Channel which has been funded by the Marine Aggregate Levy Sustainability Fund (MALSF).

2 The South Coast Region is an important source of marine aggregates with a long-standing history of extraction. The industry is actively looking for new extraction areas and these have to be assessed in the light of increasing pressure on sea bed use. The South Coast REC provides a context for these assessments.

3 Eleven principal objectives for the interpretation were set by the MALSF and these included the characterisation of rock, sediments and biological communities across the region. The biological and geological character of the region was also integrated in order to map the occurrence of biotopes as well as areas of potential conservation interest. Archaeological objectives were also set to distinguish, characterise and map wrecks and objects on the sea bed, and also characterise the potential of the area to contain submerged sites of prehistoric occupation. Finally the study was to identify any gaps in data, analysis and interpretation prior to and remaining after completion of the study.

4 The study was hampered initially by a relative lack of survey geophysical data but the partners actively procured further survey data and this with sample coverage has mitigated the issue to a reasonable, if not complete, extent. These datasets have provided the basis for an adequate perspective of the regional character of the geology, biology and archaeology of the study area.

5 The South Coast REC area is characterised by large expanses of rock and thin sediment, with approximately 75% of the sea bed dominated by habitats resting on a rock based foundation. Thick (>1 m) sediment is confined to channel systems, banks and sand sheets with about 14% of the study area covered by sandy sediment and 11% covered by coarse sediment. Marine aggregate extraction and prospecting is confined to these areas of thicker sediment, particularly coarse sediment, rather than across the REC area as a whole.

6 Extensive areas of sand are limited to sand banks within the inner parts of Poole Bay and Christchurch Bay and the Northern Palaeovalley and sand sheets and wave fields on the coastal platform off West Sussex.

7 The sea bed south of the Isle of Wight is an area of relatively strong tidal currents with a winnowed sea bed comprising mostly immobile coarse sediment with cobbles and rock.

8 The complexity of the sediment filled channel systems which have been identified have not been adequately characterised during the study. A greater density of seismic lines would add greatly to our understanding of these channel systems which are the principal aggregate resource in the study area.

9 Analysis of the benthic macrofauna revealed 13 discrete assemblages. This is a relatively large number and a reflection of the geological and morphological diversity which exists in this area. The predominance of rock and coarse substrate, across much of the area, also plays an important role in shaping the benthic macrofauna.

10 A number of benthic assemblages were associated with sand deposits, and characterised by interstitial polychaetes and the pea urchin *Echinocyamus pusillus*.

11 Six discrete epibenthic assemblages were identified and are a reflection of the diverse environmental conditions within the study area. The influence of the rock and coarse sediments was also evident in the epibenthic trawl samples.

12 A few new biotopes were discovered in the South Coast REC area and a number of issues were encountered in regional biotope modelling using the EUNIS habitat classification system particularly in areas of rock and thin sediment. It may be appropriate to modify the EUNIS classification system to take account of this type of rock and thin sediment substrate which is very common in the English Channel and elsewhere in UK waters.

13 A number of rare species were identified from the grab and trawl samples collected from the study area, the most notable being the sea squirt, *Microcosmos claudicans* and the colonial bryozoan, *Hincksina fulstroides*.

14 The invasive American slipper limpet, *Crepidula fornicata*, was found to be very well established across the South Coast REC study area forming an important component of the benthic and epibenthic assemblages. Other alien species identified include the leathery sea squirt, *Styela clava* and the barnacle *Elminius modestus*.

15 Surveys conducted for the South Coast REC have highlighted two features of conservation interest within the area, namely rocky reefs and black bream *Spondyliosoma cantharus (L.)* nests. The reefs are listed under Annex I of the EU Habitats Directive. The black bream is a commercially important species whose nesting sites occur where bedrock is covered by a thin layer of gravel. As the nests are vulnerable, they are being considered within local management plans.

16 The tubiculous amphipod, *Ampelisca* spp. and the sand mason, *Lanice conchilega*, were both found to form bed features in this area, together and individually. Whilst these biogenic features would not be classified as biogenic reef under the current Annex I definition, they are certainly unusual and their influence on environment and associated fauna is not yet fully understood. A more detailed study on these small-scale biogenic features would be of value to both the scientific community and the conservation agencies.

17 The South Coast REC area is a region rich in archaeology, with finds ranging from the Lower Palaeolithic to the Second World War. Archaeological material found on or beneath the sea bed can be broadly divided into prehistoric, maritime and aviation and all categories are present in abundance.

18 The precise location of prehistoric archaeological material offshore is unknown at present but areas have been highlighted where there is a higher potential for the resource to survive. The characterisation indicates that, under the appropriate preservation conditions, there is potentially a very large resource of prehistoric archaeology present.

19 The maritime archaeological resource has been successfully characterised in respect of the late 19th century and more recently. However, no evidence from earlier periods was found and no conclusion can be drawn about the volume, distribution or character of the pre-19th century maritime activity.

20 The area has been a major focus for aviation throughout the 20th century. The vast majority of aircraft sites date from the Second World War and as most aircraft commonly break up on impact with the sea, wreckage is generally not intact on the sea bed. Therefore the distribution and location of aircraft crash sites are likely to be seriously underestimated.

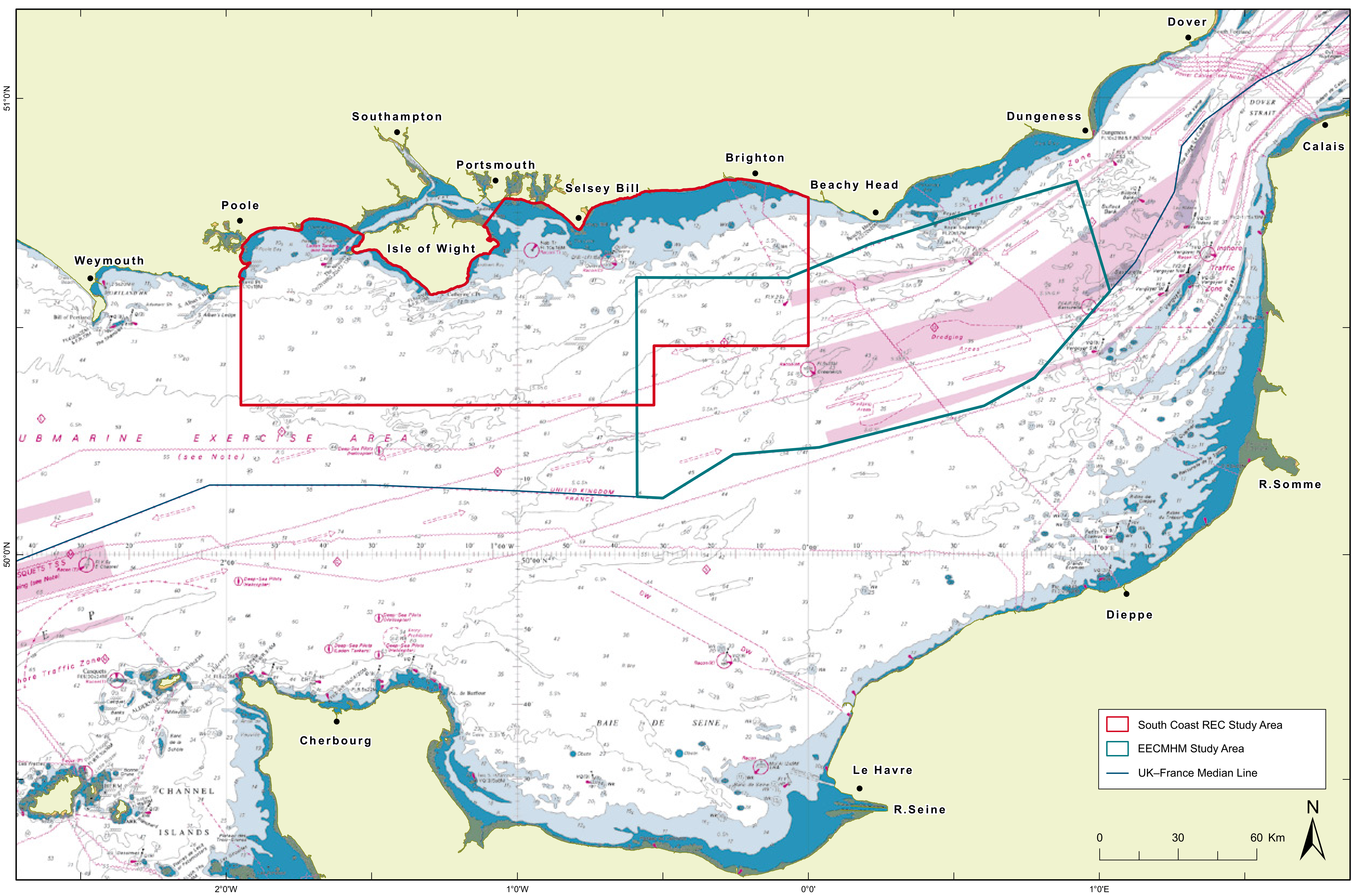


Figure 1.1: Location of South Coast Regional Environmental Characterisation (REC) study area in eastern English

This figure has been derived in part from material obtained from the UK Hydrographic Office with the permission of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk)
NOT TO BE USED FOR NAVIGATION

1 Introduction

The South Coast Regional Environmental Characterisation (REC) is a multidisciplinary marine study encompassing the geology, biology and archaeology of an extensive area of the English Channel, east, south and west of the Isle of Wight (Figure 1.1 and 1.2).

Figure 1.2: Location of South Coast REC.

The South Coast Region is an important source of marine aggregates with a long-standing history of extraction. Marine aggregates are a significant resource for the construction industry in south-east England providing around 30% of the regional supply of sand and gravel. Marine aggregates are also the only practical and cost-effective source of sediment for beach recharge, replenishing the beach as a natural defence element in modern coastal defence schemes (The Crown Estate — BMAPA, 2009a, b).

Within the South Coast Region a number of existing aggregate extraction licences are being considered for renewal in the near future, and the industry is also actively prospecting and applying for new licence areas. These have to be assessed in the light of increasing pressure on sea bed use not only from traditional industries such as fishing and telecoms cables, but also new entrants such as wind farms and power cables. Areas within the South Coast REC are being assessed by the Crown Estate for their potential as a wind energy resource (www.thecrownestate.co.uk/offshore_wind_energy).

Some species of fish in the region, which are commercially and ecologically important, are reliant on the sea bed as a habitat. The region is also sensitive with regard to the historic environment, in terms of shipwrecks, aircraft crash sites and the potential for pre-historic landscape features and artefacts.

The Marine and Coastal Access Act was enacted in November 2009. It provides for the establishment of Marine Conservation Zones (MCZs) which are designed to protect nationally important marine wildlife, habitats, geology and geomorphology. Four regional projects have been established in England to identify and recommend Marine Conservation Zones to Government. These new zones are to be designated by the end of 2012. The South Coast REC lies almost exclusively within the 'Balanced Seas' regional project at the western end of its project area, which extends from the Thames Estuary to Poole Bay (www.balancedseas.org).

The Act recognises the need for effective stewardship of the marine environment through a policy of integrated management, balancing the requirements for development with nature conservation. This is in line with European legislation including the Habitats Directive (European Commission, 1992).

To assess and manage these conflicting demands and minimise potential impacts requires a comprehensive dataset and significant knowledge of the principal natural and anthropogenic features which control or relate to the character of the sea bed. The South Coast REC aims to provide the context for these assessments over about 5600 km² of the English Channel, by providing regional scale geological, biological and archaeological data and interpretations.

The methodology adopted for this regional environmental characterisation follows the interdisciplinary approach successfully implemented for the Eastern English Channel Marine Habitat Map Study (EECMHM) (James *et al*., 2007) which covers an adjacent area of over 5000 km² to the east of the South Coast REC (Figure 1.1). Marine archaeology was not covered in the EECMHM study. Its inclusion in the South Coast REC provides a wider perspective and enhances the interdisciplinary ethos of the study.

This interdisciplinary approach is also being adopted by further regional environment characterisation studies currently being funded by the Marine Environment Protection Fund (MEPF) in three regions, the Thames (Emu Ltd, 2009), East Coast and Humber Regions. The latter two regions are due for publication in early 2011.

The South Coast REC study has been led by the British Geological Survey (BGS) with Marine Ecological Surveys (MES) Ltd, Cefas, Wessex Archaeology and Sussex Sea Fisheries District Committee as partners in the study.

The marine aggregate industry has commissioned a Regional Environmental Assessment (REA) in the South Coast Region from Emu Ltd. The results are due to be published in 2010. The REA aims to provide a description of the current regional environmental setting using existing information and new survey data. Its remit includes enhancing knowledge of the potential for cumulative effects arising from extraction as a result of existing and prospective aggregate licences. Any gaps in knowledge or data noted by the REA will be addressed during individual licence applications or renewals. It was recognised that more integrated data on a broader regional scale was required to support the current and future management of offshore resources. It was on this basis that the South Coast REC was enacted to provide a regional context based on an interdisciplinary approach.

1.1 Objectives

The Marine Environment Protection Fund (MEPF) stipulated eleven principal objectives for the interpretation section of the South Coast REC study and these fall under four principal headings.

Geological interpretation

- Interpret the acquired multibeam and sidescan sonar data to produce topographic maps and to delineate and characterise acoustically distinct regions in order to produce sea bed character maps of the region incorporating any data or information gained from the sub-bottom profiler and the ground-truth surveys and to provide a detailed description of sea bed morphology and bedforms.

- Interpret the acquired sub-bottom profiler data and develop an isopach model of the region with reference to published geological maps covering the survey area and where appropriate, findings from previous surveys in the region, for example UKHO, BGS, industry.
- Characterise the sea bed sediments within the region using the data acquired during the sea bed sampling, sea bed imagery and geophysical surveys.

Biological interpretation

- Analyse the acquired infaunal and epifaunal data, including sea-bed imagery, and to determine distinct species assemblages, identify the taxa that typify or discriminate between those assemblages, and determine environmental variables that best explain biotic distributions.
- Analyse the acquired sea bed imagery to describe the types of sea bed habitats and epifauna that exist within the region.
- Analyse synthesis of the geological and ecological interpretations.
- Based on an integrated assessment of the geological and biological interpretations generate thematic regional scale sea bed habitat maps of the distribution of infaunal and epifaunal biotope complexes.
- Determine the location and significance of rare or regionally unique habitats or those that might be considered for protection under the terms of national and international conservation legislation.
- Determine the significance of habitats and benthic species identified in maintaining the health of higher trophic levels of regional marine communities.

Archaeological interpretations

- Interpret the acquired sidescan sonar data and associated swath bathymetry data to delineate and characterise anthropogenic features of archaeological significance and to produce regional maps of the principal historical asset types.
- Interpret the acquired sub-bottom profiler data with reference to published geological maps covering the survey areas with a view to characterising areas of increased archaeological potential with regard to submerged palaeolandscapes.

Additional project objective

- Gap analysis — the final assessment of the data should identify any gaps (including those gaps prior to and remaining after analysis and interpretation) in the understanding of the characteristics of the sea bed and its associated communities (in consideration with the REA process).

The partners who have undertaken the interpretation outlined in this report were not responsible for planning or conducting the geophysical, sampling and video surveys undertaken in 2007 for the South Coast REC (Gardline, 2008). A description of the data and coverage of the 2007 survey is given in Chapter 3.

Due to very poor weather conditions there was a significant shortfall in geophysical survey coverage of the REC area by multibeam, sidescan sonar, magnetometer and sub-bottom profiler. Although geophysical, sample and video data from other sources have been used (Chapter 3), the analysis and interpretations conducted to meet the objectives outlined above have been compromised by the inability to fully integrate the interpretation and assessment of the sample and video data collected by the South Coast REC 2007 surveys with the limited geophysical coverage across the whole study area.

Organisation	Team
British Geological Survey (Natural Environment Research Council)	Ceri James Jennifer Plim Angela Morando Emma Bee Amanda Hill
MES	Bryony Pearce Jen Pinnion
Cefas	Roger Coggan Matthew Curtis Jacqueline Eggleton Christopher Barrio Froján
Wessex Archaeology	Stephanie Arnott Julie Gardiner Paul Baggaley Graham Scott Antony Firth Nicolas Bigourdan Kitty Brandon Patrick Dresch
Sussex Sea Fisheries District Committee	Robert Clark Tim Dapling Belinda Vause

Table 1.1: The South Coast Regional Environmental Characterisation study team.

1.2 Outputs

The results, interpretations and conclusions of the South Coast REC study are published within this report. Also attached to the back cover of the report is a DVD-ROM that includes appendices of data, analysed or interpreted results, plus a pdf copy of this report and the South Coast REC 2007 survey report (Gardline, 2008).

An ArcMap GIS and associated database, integrated with data from the adjacent Eastern English Channel Marine Habitat Map study (James *et al*., 2007) has been included in the DVD. ArcExplorer software (www.esri.com/software/arcexplorer/) which enables free display, query, and retrieval of South Coast REC GIS data has also been loaded on the DVD. Some aspects and results of the study are also available on the BGS website (www.bgs.ac.uk).

The ALSF Marine GIS database (http://www.marinealsf.org.uk/) provides access to marine aggregate research project metadata information and digital reports. The database holds a copy of this report and the survey data from the South Coast REC 2007 survey for download. Interpreted data is also available via the database. The database can be accessed using text and GIS map-based searches.

2 Regional Perspective

2.1 Physical setting

The English Channel is a shallow sea within the North-West European continental shelf. It is about 160 km wide at its western limit between Brittany on the north coast of France and Land's End in south-west England. To the east of this limit the English Channel gradually narrows between the coasts of England and France and reaches a width of 35 km in the Dover Strait. The east to west extent of the Channel is about 500 km. This regional perspective concentrates on the central to eastern half of the Channel from the Bill of Portland and Channel Islands in the west to the Dover Strait in the east, a distance of around 300 km (Figure 1.1). Its aim is to provide a wider context of the English Channel for the interpretation and results obtained within the South Coast REC study area.

The morphology of the sea bed in the eastern English Channel is dominated by a very low-angled marine planation surface (Curry, 1989; Stride, 1990). Over much of the central offshore part of the Channel between Cherbourg, Weymouth and the Isle of Wight (Figure 2.1) the sea bed lies at a depth of 60–70 m. It rises gradually to the east and reaches a depth of >40 m in the Dover Strait. However, there is a noticeable break of slope at the 50 to 60 m depth contour in the central part of the Channel south of Weymouth and the Isle of Wight and north of Cherbourg and around the Channel Islands. This marginal break of slope is much more extensive on the English side of the channel and extends east along the margin of the Northern Palaeovalley to Beachy Head. On the French side, the marginal break of slope fades within 20 km east of Cherbourg with the sea bed becoming a steady slope declining at a shallow angle offshore from here to the north of the River Somme estuary and Calais.

By Late Tertiary, Neogene times, about 5 millon years ago, the planation surface is likely to have been initiated. Subsequently a number of significant processes and linked events have impacted on the sea bed, in particular those associated with global climatic change during the Quaternary including glacial and interglacial cycles with respective sea level rise and fall. These have created a variety of fluvial, estuarine and marine environments with successive phases of sea bed erosion and deposition of sediments.

The Hurd Deep is the most prominent negative feature in the area (Figure 2.1). It is a narrow linear deep which trends north-east to south-west down the English Channel for about 15 km. It reaches a maximum depth of 172 m just north of the Channel Islands. The other significant linear deep in the area is St Catherine's Deep, again trending north-east to south-west. It lies just off the 300 m high cliffed south coast of the Isle of Wight and reaches a maximum depth of about 80 m (Figure 2.4).

The Northern Palaeovalley is a significant open channel system in the northern central part of the area with much of its floor around a depth of 60 to 70 m. The northern margin of the Palaeovalley is backed by a narrow, shallow coastal platform with depths of <30 m, which runs along much of the coastal fringe of the English coast. In contrast to the majority of the French coast where the sea bed just gradually declines in to the centre of the channel. The Northern Palaeovalley has a number of tributary channels, both open and filled with sediment, and the palaeovalley is also considered to be contiguous with the open Lobourg Channel further east in the Dover Strait (Hamblin *et al*, 1992).

As well as open channel systems the eastern English Channel has an extensive network of channels filled with sediment to the level of the surrounding sea bed rock based planation surface making both of them, in some cases, morphologically indistinguishable at the sea bed.

There are at least eleven sand banks which form positive features on the sea bed in the east of the area (Figure 2.2). These are significant linear features, up to >30 km in length, and can rise over 40 m above their surrounding sea bed. At low spring tides their crests may shoal or come within 5 m of the sea surface. There are also two large sand banks up to 40 km long on the margin of the Northern Palaeovalley and four smaller banks in Poole and Christchurch Bay, one of which, Shingle Bank is a gravel bank. Some of the sand banks have associated sand wave fields with some sand waves >10 m high.

The major morphological features such as the deeps and sand banks are relatively well defined but growing evidence from high resolution geophysical surveys has improved our knowledge of their relationship with associated bedforms such as sand waves and megaripples. This high resolution data also better resolves rock based morphological features and enables mapping of geological units and structure in much greater detail, especially where sediment is very thin and rock outcrops at the sea bed. Rock which has been disturbed by folding and faulting events can be particularly well defined. This type of rock based terrain is a common form of sea bed in the English Channel.

2.2 Geology

The offshore geology comprises three major elements. In their relative order with the youngest at the top, they are:-

- Sea bed sediments
- Quaternary sediments
- Solid geology — bedrock

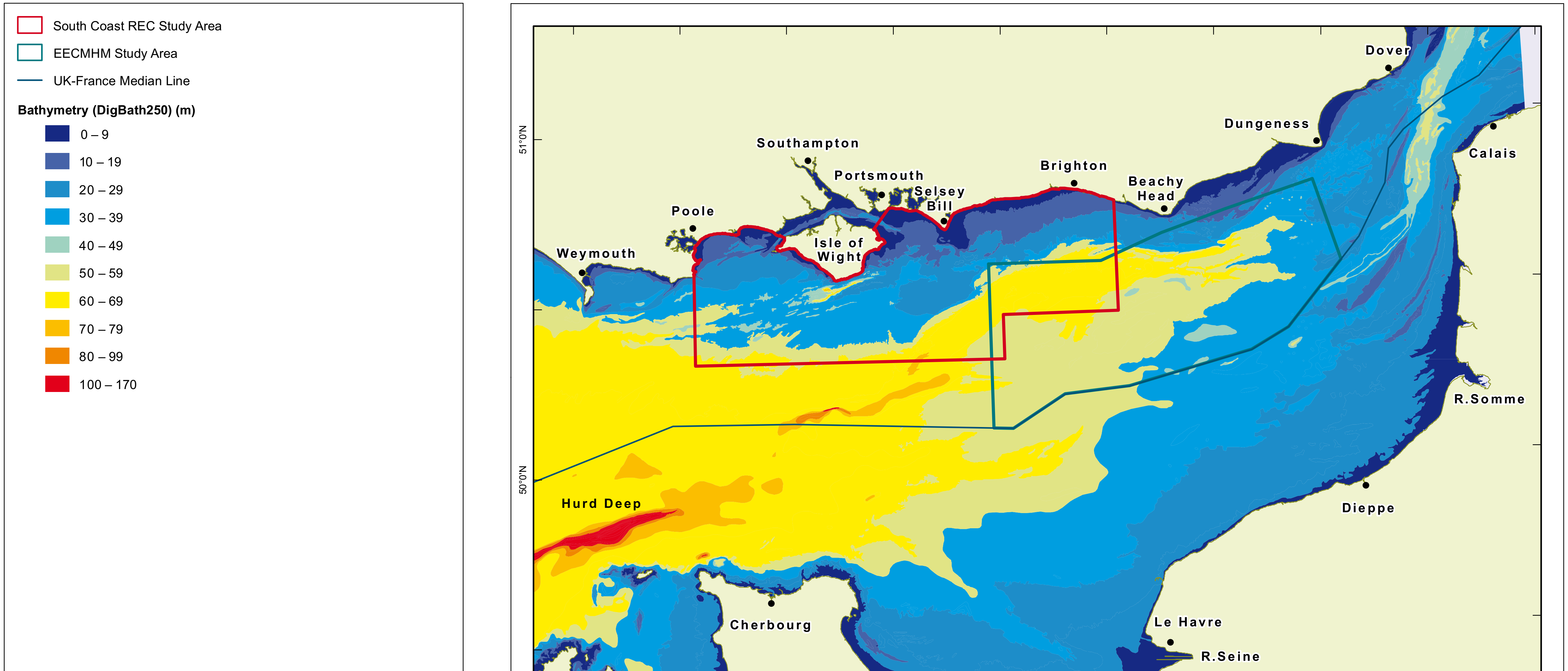
In the region the rocks which form the solid geology are all generally older than 35 million years. There was a long hiatus between the deposition of the youngest solid geology rocks and the onset of Quaternary sediment deposition which began about 2 million years ago, although sediments deposited within the early part of the Quaternary are thought unlikely to occur within the region. Where present they are likely to be <0.5 million years old.

There is also a distinction between the solid geology and Quaternary in their character and form. The relative longevity of the solid geology rocks has allowed them to be compressed and hardened into dense, cemented, solidified masses i.e. rock. Because of their relative youth the Quaternary sediments have not had time to go through this rock forming process. They are loose, uncemented grains of mud, sand and gravel.

Another distinction is the relative impact of tectonic activity. This is particularly marked in its effect on the solid geology in some areas, with large scale folding and faulting and disruption of bedding. Within the Quaternary the only major tectonic activity that has been proposed is simple horizontal uplift (Westaway et al, 2006) that has led to the formation and preservation of fluvial terraces and raised beaches onshore. Offshore the physical evidence for Quaternary uplift is not well defined from the limited available evidence.

Sea bed sediments can overlie and cover both Quaternary sediments and solid geology. They comprise immobile and mobile sediment lying at the sea bed surface. The sediments can consist of mud, sand and gravel, with the gravel ranging in size from pebble and cobble to boulders.

Sea bed sediments can occur in a number of forms and as the result of differing processes including:-

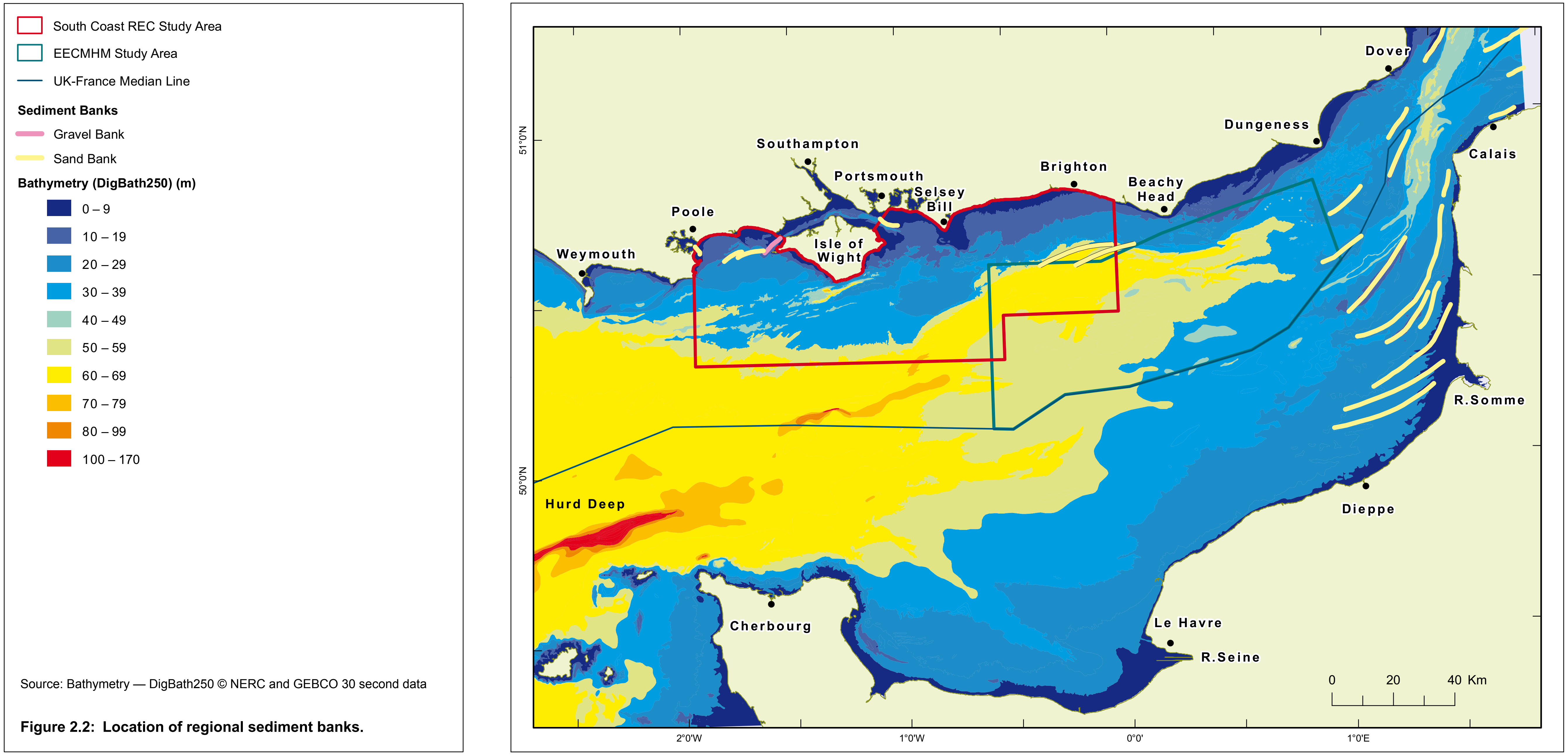


Source: DigBath250 © NERC and GEBCO 30 second data

Figure 2.1: Regional offshore bathymetry.

- Gravel as a lag deposit derived from underlying solid geology bedrock. This type of lag gravel can have undergone some reworking and rounding by currents and waves but can also simply be unmodified broken pieces of rock.
- Sand and gravel lying on the surface of Quaternary sediment. These sediments may also have been subject to wave and current action and undergone a degree of reworking and sorting, with the potential of creating a different type of sediment at the sea bed surface to the underlying source Quaternary sediment. For example, mud and sand could be winnowed from the source sediment leaving a veneer of coarser sediment at the sea bed.
- Tidal currents can create bedforms in sand including megaripples, sand waves and sand banks, and also sand sheets. These sandy bedforms can be numerous and extensive over large areas of the sea bed but they also commonly occur as isolated, single or small group features on gravel or rocky sea bed.

There are a number of issues in distinguishing and defining sea bed sediments in relation to the sediments or rock which underlie them. This is important because the nature of the geology which comprises the sea bed surface and its underlying ~0.5 m is significant in terms of habitat for marine life. Sea bed sediments are defined as a surface deposit which can include the underlying



Source: Bathymetry — DigBath250 © NERC and GEBCO 30 second data

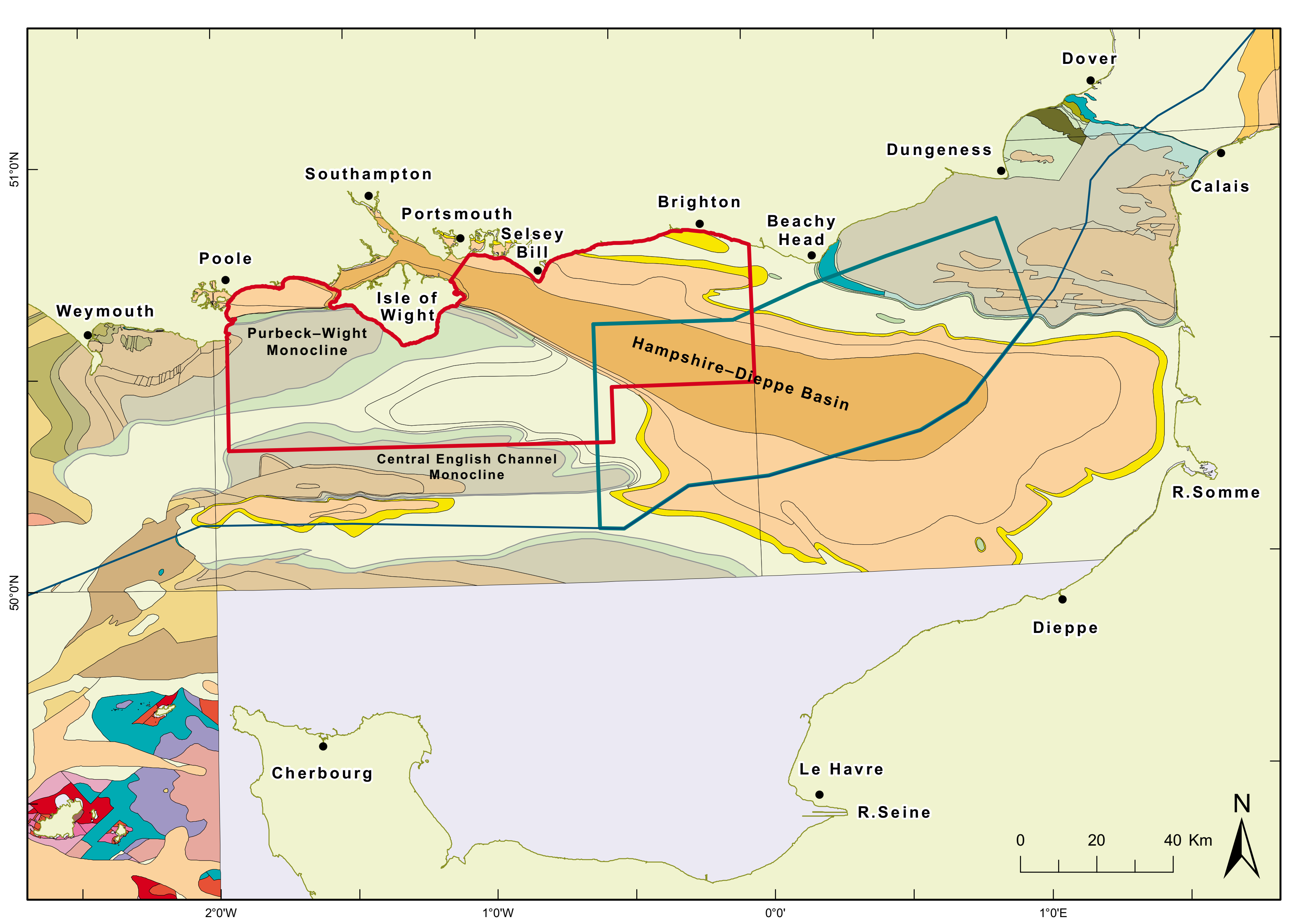
Figure 2.2: Location of regional sediment banks.

0.5 m and may reach depths of over 1 m. Resolving and defining the base of sea bed sediment deposits is difficult especially when they are thin (See Chapter 4).

The central and eastern English Channel includes a diverse and distinctive solid geology which outcrops or lies immediately beneath the sea bed over a relatively large proportion of the area. The oldest rocks in the region are Precambrian metamorphic rocks in the Channel Islands which are over 600 million years old whilst the youngest at about 39 million years old are from the Tertiary Barton Group (Figure 2.3).

The region has a long history of tectonic movement with evidence for a number of episodes of uplift and subsidence with associated faulting and folding since the Carboniferous, over 300 million years ago. Subsequent episodes have tended to align along a roughly east–west structural trend with reactivation of movement along pre-existing major fault lines. The last major tectonic episode is associated with the Alpine Orogeny during the Tertiary Miocene epoch, over 20 million years ago. The present day evidence of these tectonic events is regional scale structures such as the Hampshire–Dieppe Basin, the Purbeck–Wight Monocline and the Central English Channel Monocline (Figure 2.3).

The Upper Jurassic outcrops within the Weald–Artois Anticlinoreum (Hamblin *et al*. 1992), a major east–west anticlinal structure that crosses the Dover Strait. Widespread and well-exposed Wealden



South Coast REC Study Area
EECMHM Study Area
UK-France Median Line

Solid Geology

- Barton Group
- Bracklesham Group – London Clay
- Lambeth Group
- Chalk
- Greensand
- Gault – Greensand
- Aptian – Albian
- Wealden Group
- Upper Jurassic
- Bathonian – Jurassic (Middle)
- Lias
- Permo Triassic
- Devonian
- Ordovician – Silurian
- Metamorphic
- Igneous

Source: DigRock250 © NERC and published BGS 1:250,000 maps

Figure 2.3: Regional offshore solid geology

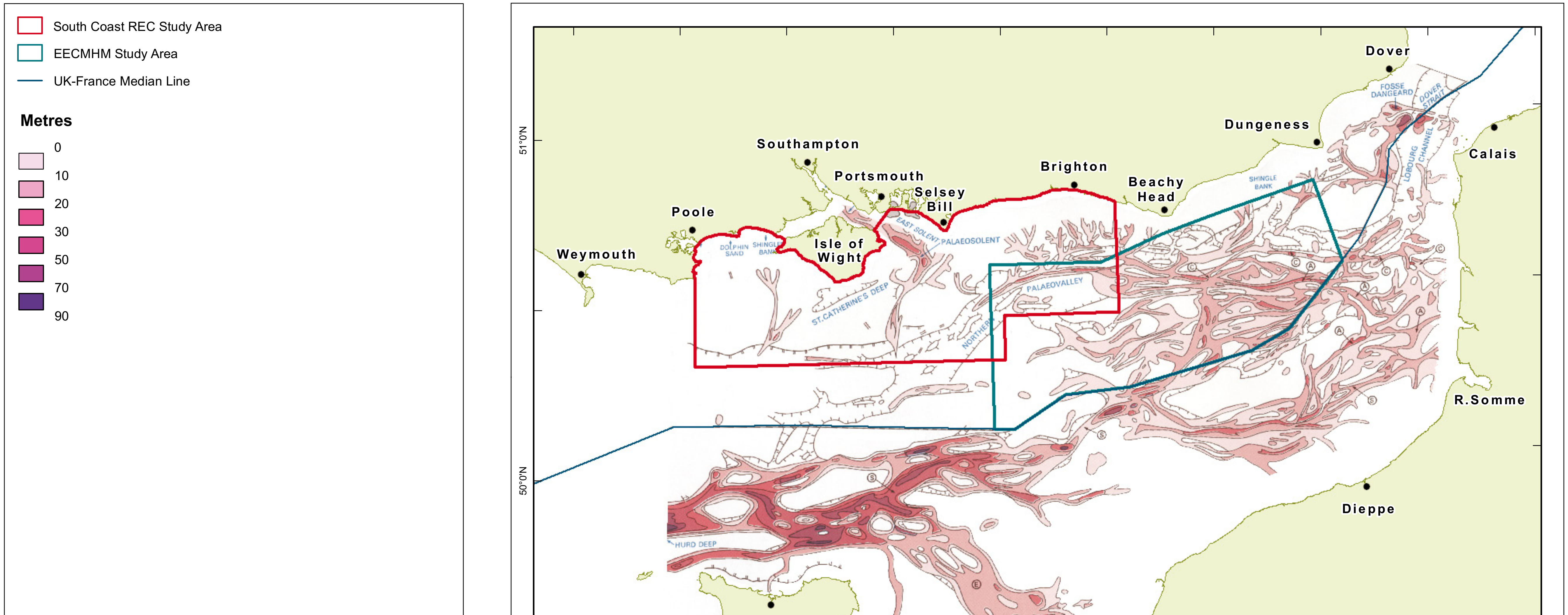
© NERC.

Group rocks and Chalk also occur within or at the margin of the Anticlinoreum.

West of the Hampshire–Dieppe Basin, Chalk is very extensive and sits within an east–west trending synclinal basin. Wealden Group rocks lie around margin of the basin. Steeply dipping monoclines lie to the north and south of the basin. The steeper limbs of the monocline produce narrow linear rock scarps on the sea bed. The northern monocline is the Purbeck–Wight monocline which extends east and west of the Isle of Wight and the southern one forms the Central English Channel Monocline.

South and south west of the Isle of Wight the sea bed is dominantly a rock platform with numerous small and large morphological features controlled by steeply dipping rock and bedding, and little (<0.5 m) or no sea bed sediment cover (British Geological Survey, 1989). Open channel systems cross the rock platform; some are small and almost ephemeral in scale whilst the largest and most significant is the Northern Palaeovalley. The Palaeosolent channel is the principal sediment infilled channel that crosses the platform (Figure 2.4). Further investigations may uncover examples of small infilled channels.

Other significant areas with rock at the sea bed include the English coastal margin east of Selsey Bill and in the Dover Strait particularly where the rocks have been disturbed by folding and form structural high features. The occurrence of numerous infilled



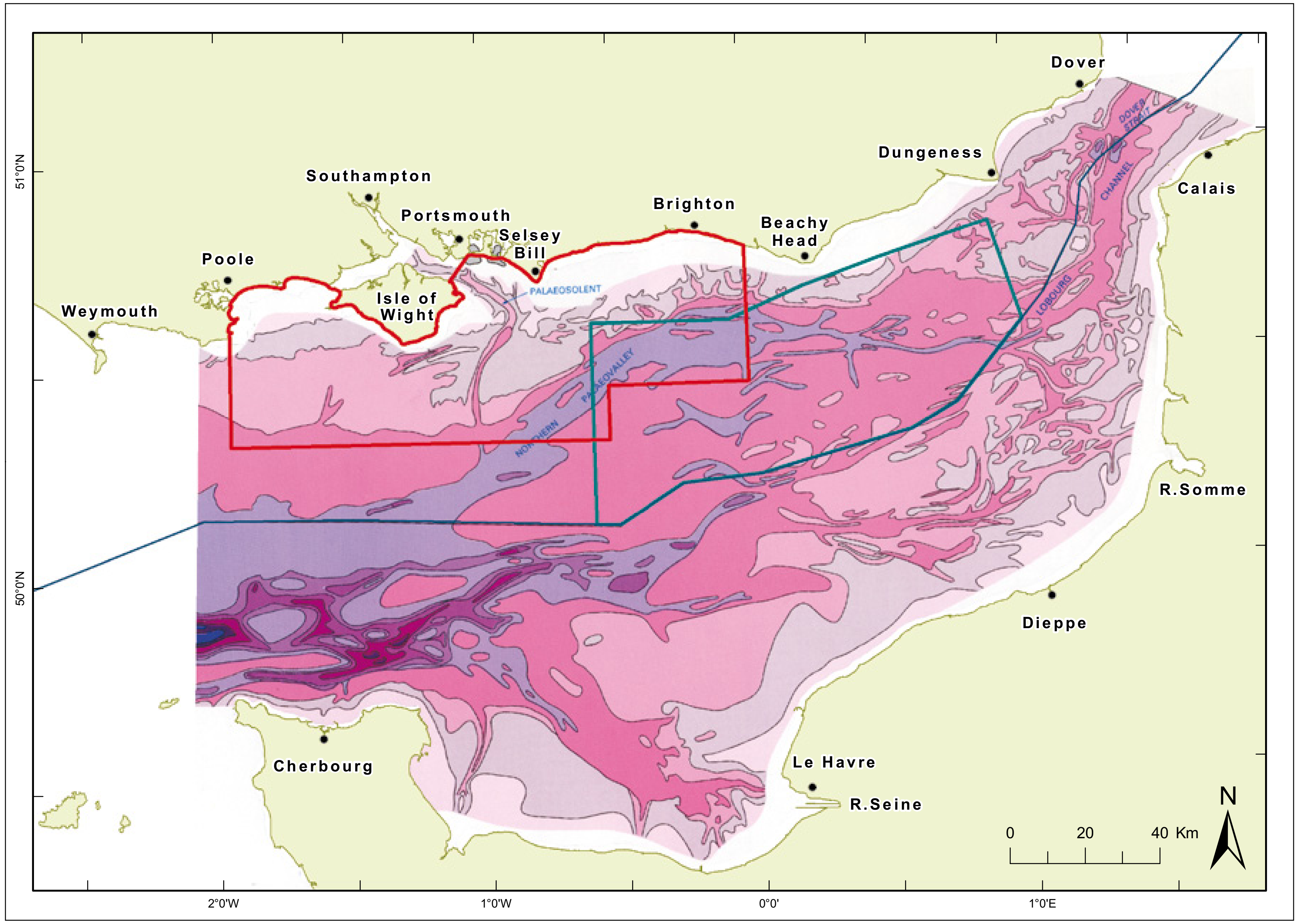
Source: The geology of the English Channel — United Kingdom offshore regional report (Hamblin *et al.*, 1992)

Figure 2.4: Regional palaeovalleys and thickness of sediment infill © NERC.

channels and sand banks, sand wave fields and sheets restricts the occurrence of rock at the sea bed elsewhere in the region (Figure 2.4).

There have been frequent glacial cycles during the Quaternary but there is no physical evidence for glacial ice encroaching into the English Channel. However, the English Channel has been affected by the major changes in sea level associated with cycles of glaciation and interglaciation during the Quaternary.

During sea level low stands in the Early to Middle Quaternary extensive east to west river systems flowing from English and French sources have developed in the English Channel (Figure 2.5) (Gibbard and Lautridou, 2003). The Thames and the Rhine also became a part of the channel system with the opening of the Dover Strait in the middle Quaternary (Gibbard, 1988, 1995). Both open and infilled channels and deeps have been formed within the system (Dingwall, 1975; Smith, 1985; Antoine *et al.*, 2003, Gupta *et al.*, 2007). The relatively soft Tertiary rocks of the Hampshire–Dieppe Basin appear to have been preferentially eroded by these river systems compared to the

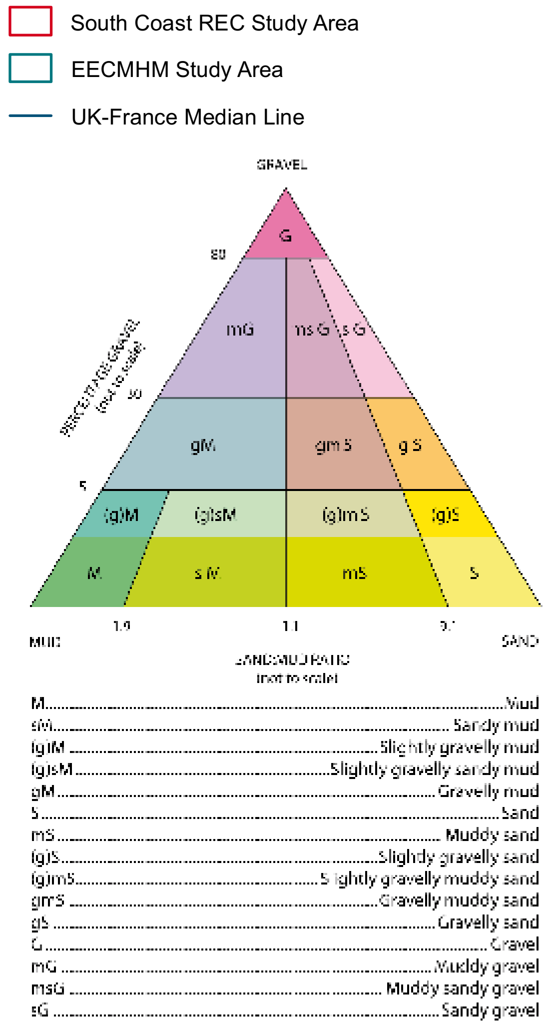


Source: The geology of the English Channel — United Kingdom offshore regional report (Hamblin *et al*, 1992)

Figure 2.5: Regional rockhead contours as depth to base of Quaternary sediments below sea level © NERC.

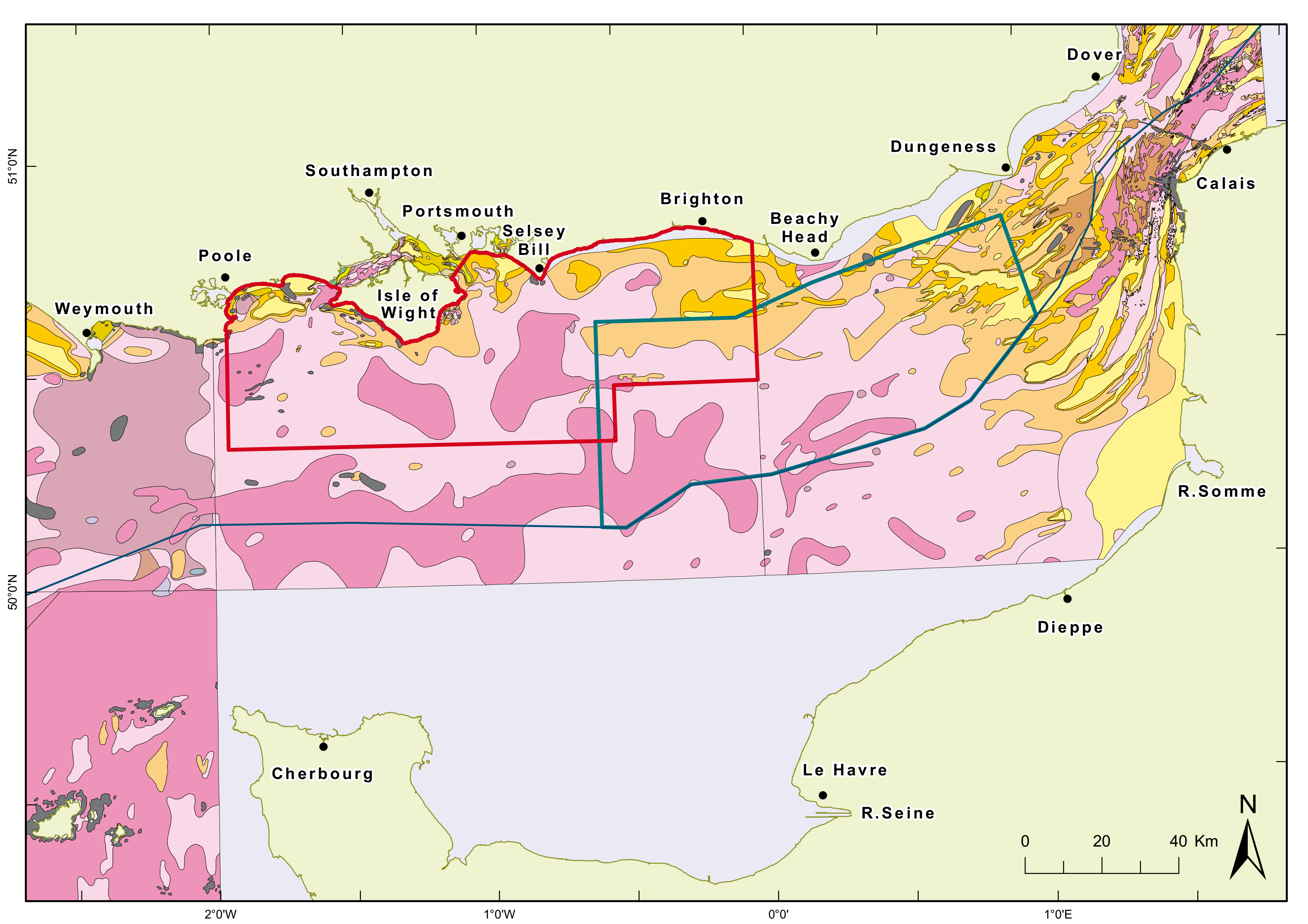
surrounding Cretaceous and Jurassic rocks, and they are infilled with relatively large volumes of Quaternary sediment (Hamblin *et al*., 1992; British Geological Survey, 1989). The Palaeosolent, Arun, Adur and Ouse rivers on the English coast (Bellamy, 1995) and the palaeo-Canche, Authie, Somme and Seine on the French coastal margin have acted as tributaries to the central channel system. Fluvial sediments will dominate the infill of these channel systems although some marine elements cannot be discounted as a consequence of sea level rise and marine transgressions eastwards across the English Channel.

Primarily the nature and form of the underlying substrate, and modern and long term hydrodynamic processes control the character of the sea bed sediments in the region. The published British Geological Survey (BGS) sea bed sediment map (1989) (Figure 2.6) is currently being revised in the light of new data collected in the last twenty years. It indicates gravel and sandy gravel dominates the western area of the region. Where rock is at or close to the sea bed much of the gravel is likely to be derived from the underlying bedrock. The relatively strong tidal currents in the area (Figure 2.7) have winnowed fine sandy sediment from the sea bed surface. These western gravelly sediments continue eastwards to overlie the Quaternary channel infill sediments. Fine sandy sediment has also been winnowed from the sand and gravel at the surface of these channel infills.



Source: DigSBS250 Version 1 © NERC and published BGS 1:250,000 maps

Figure 2.6: Regional sea bed sediments — Folk classification (Folk, 1954) © NERC.

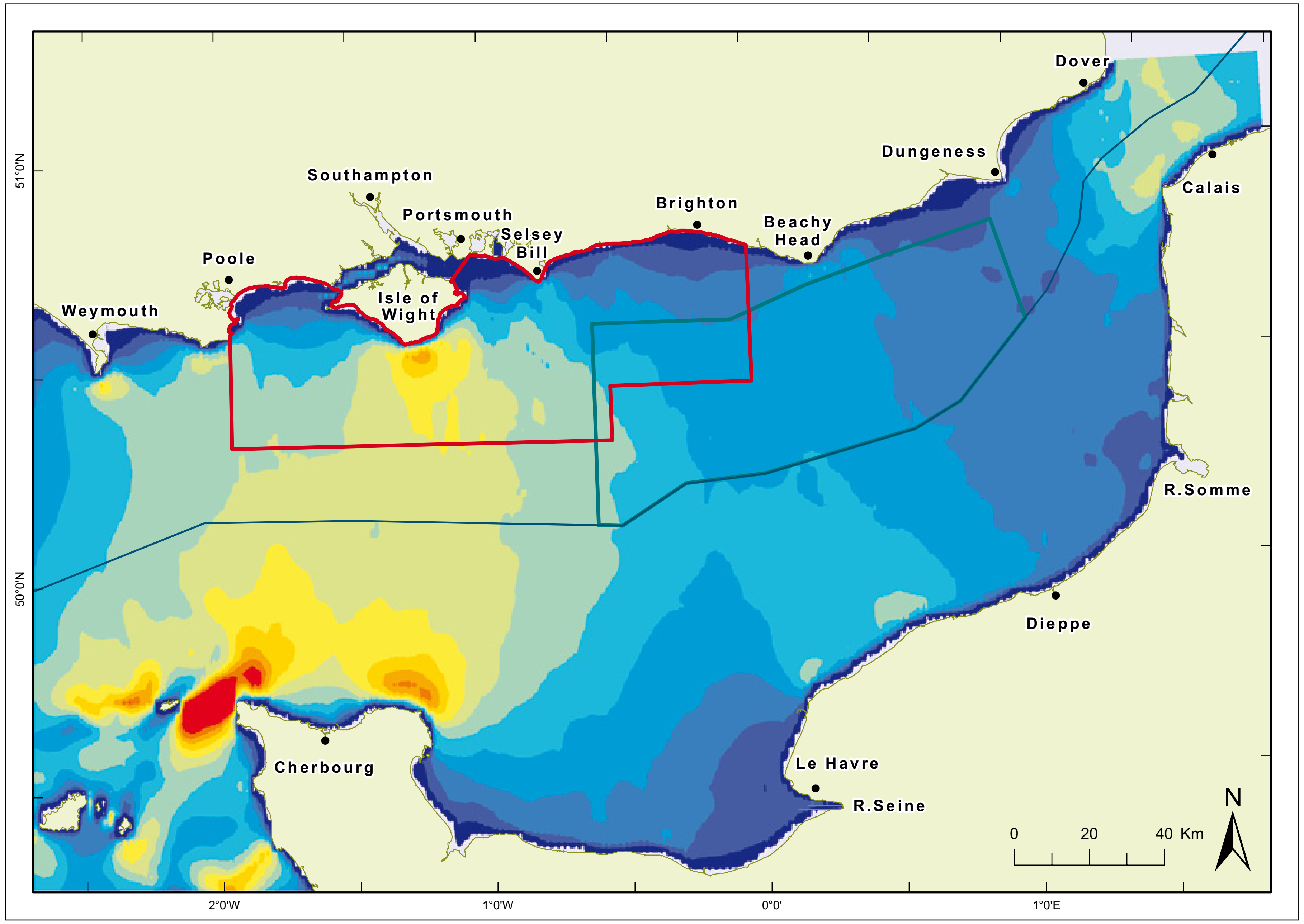


The movement and transport of fine sediment and sand to the east, and north along the coastal margins has been a long term process since at least the initiation of fully marine conditions in the region, around 5000 years ago. As a result, in the Eastern English Channel and on the coastal margin extensive areas of gravelly sand and sand have been formed. Tidal currents have fashioned these sediments into numerous large sand banks in the east and the approaches to the Dover Strait with extensive associated sand wave and megaripple fields. (Figure 2.2).

2.3 Hydrodynamics

The central and eastern English Channel is a semi-enclosed coastal sea. The semidiurnal lunar tide (M^2) is the most important tidal wave constituent (Pingree, 1980). The tidal wave takes about 6.5 hours to travel from Land's End to the Dover Strait. Tidal current velocities noted as depth averaged mean spring tidal currents (Figure 2.7) vary from <0.5 ms^{-1} to >3.0 ms^{-1}. Low tidal current velocities occur predominantly along the coastal margins but offshore from Dungeness there is an area of relatively low velocities that extends out in to the centre of the English Channel.

The highest tidal current velocities are in the narrows between the north-west tip of the Cotentin Peninsula, west of Cherbourg and the island of Alderney in the Channel Islands. Within the main body of the English Channel there is a zone of relatively high tidal current velocities >1.75 ms^{-1} which extends from the Cotentin Peninsula across to the Isle of Wight. A diminishing tidal current velocity



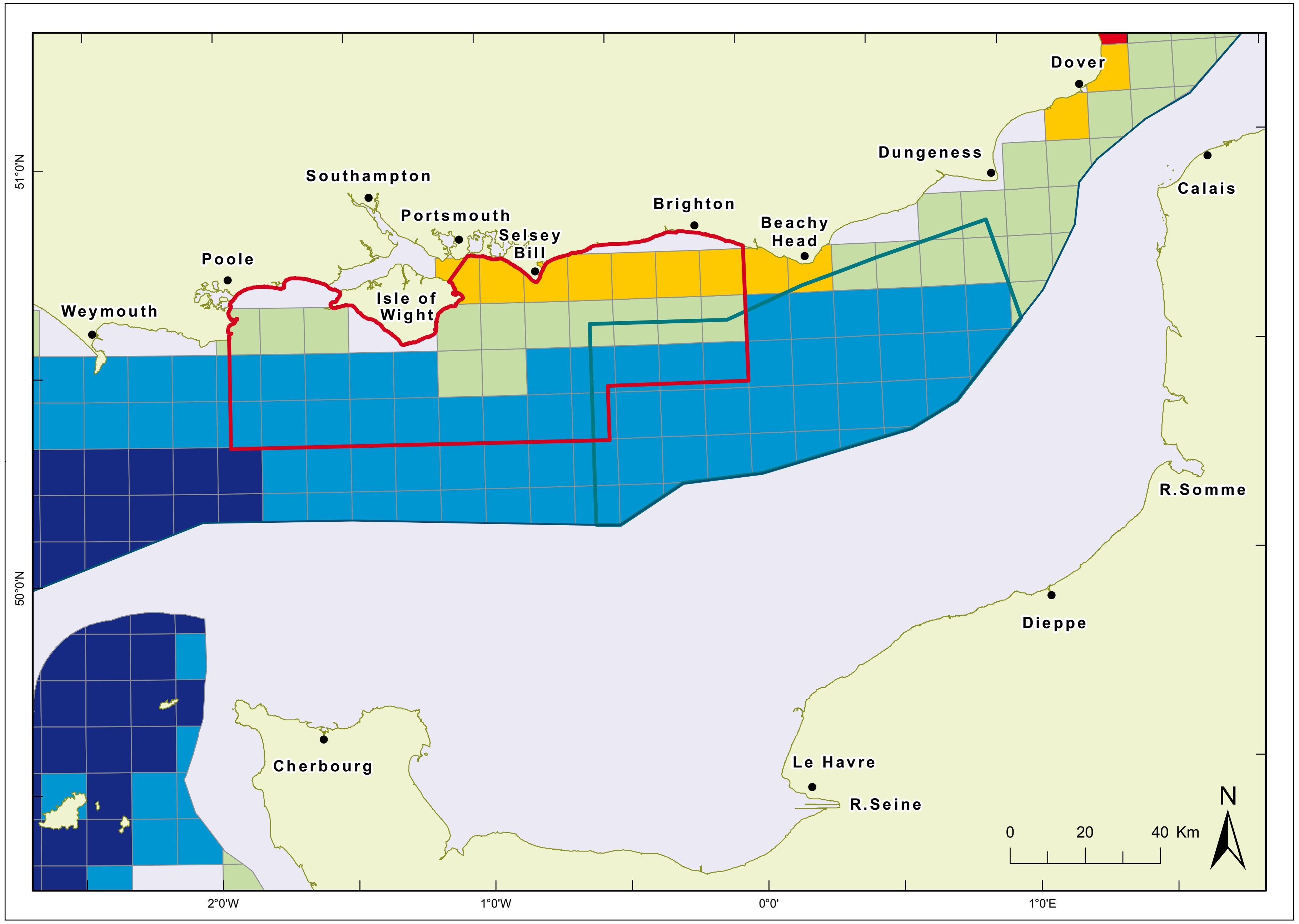
Source: Proudman Oceanographic Laboratory — M J Howarth

Figure 2.7: Maximum amplitude of the depth averaged mean spring tidal current © NERC.

gradient falls east and west away from this zone. Velocities only increase again further east in the constriction of the Dover Strait, with values in part >2.0 ms^{-1}.

The English Channel is open to the Atlantic Ocean in the south-west. With dominant south-westerly weather systems producing strong wind, wave and swell conditions in the Channel. 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). Significant annual mean wave heights between <0.75 and 1.75 m are typical for the Eastern English Channel (Figure 2.8), but extreme 50 year return significant wave heights over 8 m have been modelled (Cotton *et al*., 1999; Department of Trade and Industry, 2004). Tidal currents are the dominant factor in controlling sediment transport in water depths deeper than average wave base, and this is the case over most of the English Channel. It is only during large storm events when waves may have some impact on sediment transport at greater depths further out in the Channel.

Sea bed stress is a function of the interaction of tidal current velocity, water depth and bottom roughness. The maximum and minimum values seen in Figure 2.9 mirror the values for tidal current velocities seen in Figure 2.7. The distribution and grain size of sea bed sediment and its relationship with sea bed stress can be correlated. The relatively high sea bed stress zone across the English Channel between the Isle of Wight and Cotentin Peninsula is associated with a rock and gravel sea bed which has been swept of fine sediment. The lower bed stress levels in the east are associated with deposition of sand and fine sediment.



Source: Atlas of UK Marine Renewable Energy Resources

www.renewables-atlas.info

Figure 2.8: Regional annual mean significant wave height

2.4 Sedimentation processes

Sedimentation processes in the English Channel have both long-term effects, measured in decades and millennia, and short-term effects measured in lunar tidal cycles or episodic storm events. The evidence of the former are manifested on the sea bed in terms of large bedforms such as sand banks or simply maintaining a swept sea floor. The evidence for short term effects are small bedforms such as megaripples on the flanks of sand banks or the flattening of sand bank tops after a storm event.

The evidence for sediment transport in the region includes numerical modelling based on tidal current measurements at the sea bed, plus wave buoy and wind anemometer readings. These have been compared with the physical evidence of sediment movement from sand bedforms as seen on sidescan sonar , single beam and multibeam echo sounders, (Grochowski *et al.*, 1993a; Hamblin *et al.*, 1992; Johnson *et al.*, 1982). From this evidence the major sediment bedload parting and accumulation zones within the central and eastern English Channel have been identified as well as the pathways of sediment associated with these zones (Figure 2.10).

There is a correlation between sediment transport pathways (Figure 2.10) and tidal current velocity in the English Channel (Figure 2.7). The decreasing current velocity gradient from the central English Channel to the eastern English Channel is associated with a net sediment transport from west to east. The high current velocity zone in the central English Channel between the

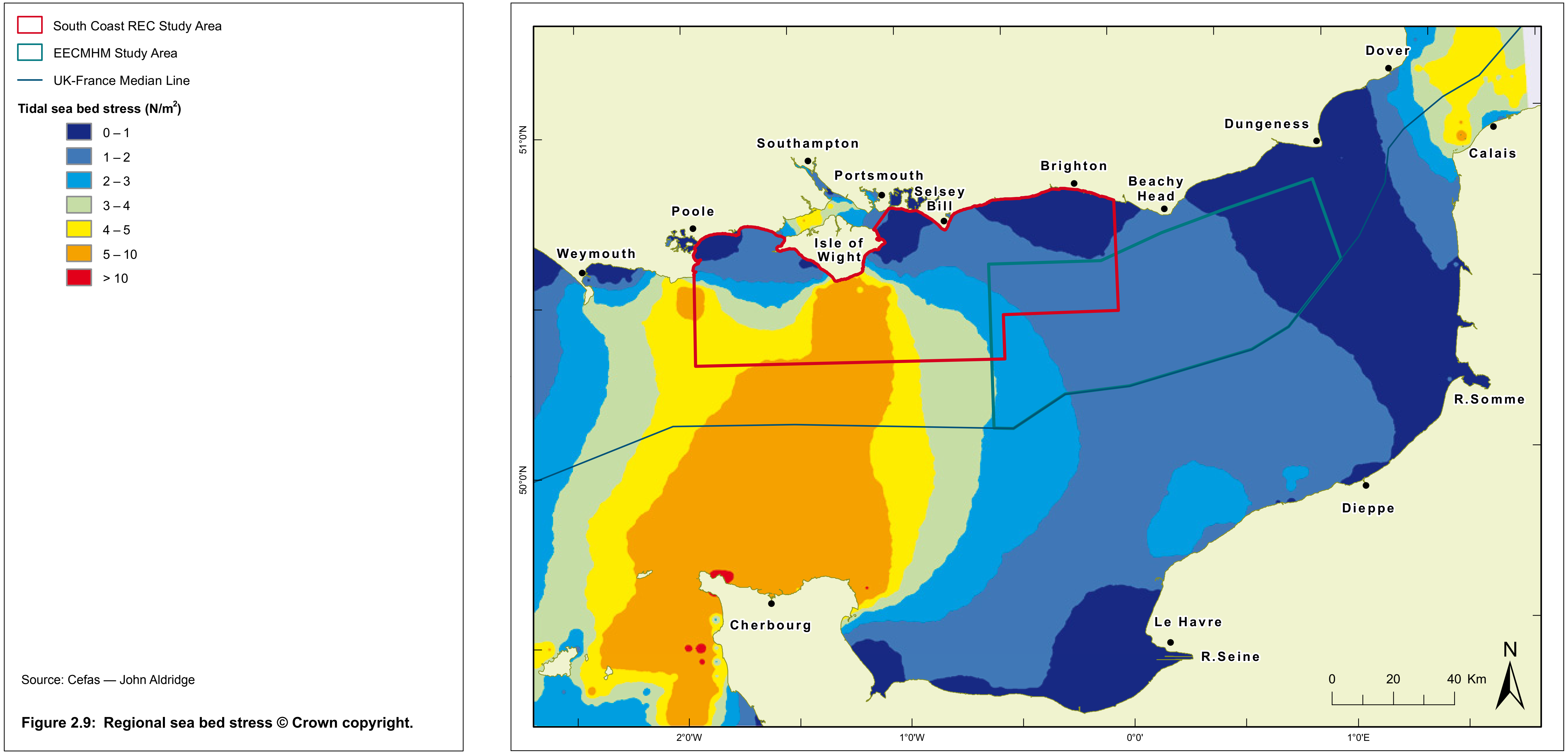
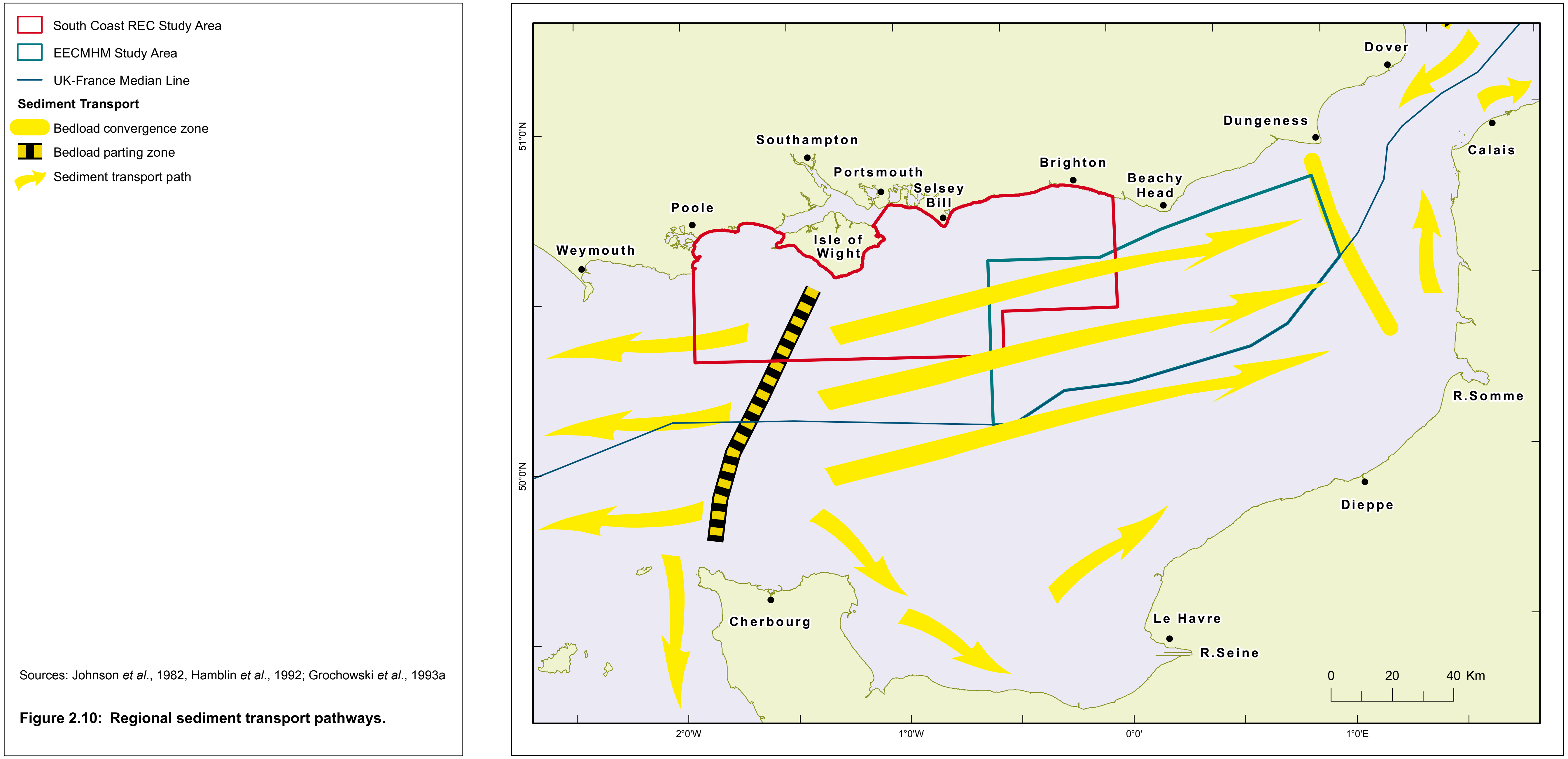


Figure 2.9: Regional sea bed stress © Crown copyright.

Isle of Wight and Cotentin Peninsula acts as a bedload parting with velocities high enough to entrain sand and fine sediment and create a swept sea floor dominated by rock and coarse gravel lag sediment. This entrained fine sediment is swept out of the bedload parting zone down the sediment transport pathway to the east and west.

The eastern sediment pathway leads to a sediment convergence zone south of Dungeness associated with an area of relatively low tidal current velocity and sea bed stress. The bedload convergence zone is also the result of the net effect of the interaction of 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). The convergence zone is bypassed along the French coast with the eastward movement of sand continuing towards the North Sea. There is also an indication that a similar bypassing eastward 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 bedload convergence zone is an area of sediment accumulation characterised by a number of sand banks (Figure 2.2). The sand banks are major and extensive morphological features, with individual banks over 20 km in length, and up to several kilometres wide. The crests of the sand banks may be in <5 m of water at low tide and some may shoal at spring tides. The sand banks generally comprise well to very well sorted, medium grained sands (Grochowski *et al*., 1993a).



Sources: Johnson *et al*., 1982, Hamblin *et al*., 1992; Grochowski *et al*., 1993a

Figure 2.10: Regional sediment transport pathways.

Dyer & Huntley (1999) produced a classification of sand bank types. They described the sand banks in the central part of the Dover Strait as open shelf ridges with some possibly formed as wide mouth estuary ridges. The sand banks close to the English and French coastline and associated with adjacent coastal headlands are classified as banner banks. Sand banks in the Bay of the Somme are classified as alternating ridges and may be the result of the break up and separation of what were originally formed as single banner banks.

All these sand banks are associated with local transport paths and gyres, which can be critical in maintaining the form of the sand banks and associated minor bedforms. These local processes may also have contributed in the original formation of the sand banks. However, it is also possible that other processes may have led to their development during the last postglacial sea-level rise (Reynaud *et al*., 2003).

The flanks of sand banks are commonly covered by sand waves and associated megaripples. These smaller bedforms can extend from the sand banks and create extensive sand wave fields such as the Greater Bassurelle Sands (James *et al*., 2007) These sand waves can be significantly large bedforms, with heights ranging from 7 m to 15 m in the Dover Strait.

Gravel furrows have been noted in the Central and Eastern English Channel, and are found in areas with a low supply of sediment and relatively high current velocities (Belderson *et al*., 1982). These furrows have been identified up to 9km long, with widths up to 30 m wide and 1 m deep in the bedload parting zone south of the Isle of Wight.

Flood tides dominate the west to east transport pathway in the eastern English Channel towards the south of the Dungeness convergence zone. East of this bedload convergence zone westward flowing ebb tidal currents are dominant (Reynaud *et al*., 2003). However, wind-generated currents, waves or storm surges, can create local or short-term sand transport in the opposite direction to long-term tidal sediment pathways (Johnson *et al*., 1982). Grochowski *et al*. (1993b) confirmed this observation and describes periods when south-westerly winds in the Dover Strait induce net sediment movement towards the North Sea against the long-term westerly sediment pathway. During periods of north-east winds they found the normal west-flowing sediment transport was amplified and created a slight movement of the convergence zone to the south and west.

Modern input of sediment to the central and eastern English Channel is minimal. The management of rivers and coastal protection has lessened the natural supply of sediment to the sea. What little fine-grained sediment that is supplied from rivers is predominantly from the Seine and Somme on the French coast. There is also unlikely to be a significant volume of sediment to be derived from erosion of the in-situ sea bed. The sediment budget of the English Channel is likely to be in virtual equilibrium and would require a major regional perturbation to disrupt this state.

2.5 Marine archaeology

The marine historic environment is made up of all forms of physical evidence of peoples' activities in the past, including indirect evidence presented by palaeo-environmental remains. Material in the central and eastern English Channel ranges from the Lower Palaeolithic to the Second World War.

Generally archaeological material found on or beneath the sea bed falls into three main categories: prehistoric, maritime and aviation. The character of the material from these categories ranges from isolated artefact find spots through to a variety of sites that may be discrete and coherent, or dispersed extensive spreads of material or landscape elements.

Prehistoric archaeology

The current sea bed presents an area which has previously been exposed at times of lower sea level and which has been modified by fluvial processes and repeated marine transgressions and regressions during the Pleistocene. These palaeoland surfaces would have been available for hominins to traverse and exploit leaving similar prehistoric material as found in present-day terrestrial settings. Although often associated with fluvial environments, these sites may have been many miles from the sea at the time they were being exploited by our ancestors (Oxley and O'Regan, 2001).

Evidence of palaeo-fluvial systems can be seen across the region where a complex network of palaeochannels provide (Figure 2.4) evidence of fluvial systems from the North Sea merging with those from the Solent, Arun, Somme, Seine and numerous others (Wessex Archaeology 2008a, Toucanne *et al*., 2009a, b). It is the land surfaces associated with these palaeovalleys that are considered to have the highest potential for containing prehistoric archaeological sites, either in primary contexts, where the spatial relationship of finds have remained the same since they were deposited, or secondary contexts, where artefacts have been derived or moved from their original positions by fluvial or marine processes (Wenban-Smith, 2002).

Any prehistoric sites which exist within the region are likely to only be found by chance during dredging for aggregates or other offshore developments. However, any such material has the potential to provide insights into patterns of past human land use and demography (Hotsfield *et al*, 2009).

To understand prehistoric material found on the continental shelf it is necessary to look beyond traditional UK sources and recognise that, at times, the region would have formed part of an embayment stretching from Brittany to Cornwall rather than a channel (Firth, 2004).

Maritime archaeology

The English Channel has been traversed by boats and ships for many thousands of years, ranging from prehistoric craft to modern warships and submarines. These vessels embody some of the most complex attributes of any society, not only in terms of their technology but also their organisation, communication and trade.

One of the earliest archaeological evidence for maritime activity appears to date from the Bronze Age with a harbour at Hengistbury Head, Dorset (Cunliffe, 1987). However, evidence for maritime activity from the Mesolithic onwards is known from other parts of the UK and from northern European coastal sites.

By the Iron Age a comprehensive trading network existed between Britain and continental Europe. Significant quantities of continental pottery and coins have been found at coastal settlements (Trott and Tomalin, 2003). These include an Iron Age gold coin from Syracuse (modern Sicily) found near Portsmouth (Wessex Archaeology 2009). Direct evidence for watercraft in the form of a 3rd century BC log boat has been found in Poole Harbour (Cullingford, 2003) and a late Iron Age anchor and chain has been found at Bulberry Camp near Wareham, Dorset (Williamson, 1998).

During the Roman period the focus of maritime activity within the South Coast REC area appears to have shifted to the Solent and parts of the Sussex coast, where a number of important coastal settlements, villas and military bases appear to have developed, including the provincial settlements of Chichester, Southampton and the late Roman shore fort at Portchester.

By the 6th century, Portsmouth Harbour was being used by cross-Channel vessels (Wessex Archaeology, 2009). By c.700 a harbour at Hamwic (the precursor to Southampton) was also in existence serving both coastal and cross-channel trade. Evidence suggests that goods from as far afield as Scandinavia and the mountains of the Eiffel region of France were being imported at this time (Williamson 1998).

During the medieval period (1066–1540) records of individual shipping losses attest to the international nature of the maritime activity at this time, with French, Italian and Spanish vessels recorded as being wrecked (Maritime Archaeology Ltd, 2007). During the later medieval period warships enter the archaeological record in the South Coast REC area reflecting the growing importance of the Solent and of Portsmouth in particular.

The expansion of overseas trade followed by the stimulus of the industrial revolution resulted in the size of the merchant fleet operating around and from England growing by a factor of five between 1580 and 1680. This growth continued in the 18th century.

Within sea areas Wight and Portland, 313 and 243 wrecks dating from this period have been identified during regional assessment (Maritime Archaeology Ltd, 2007). The majority of these vessels were engaged in coastal trading, although Dutch, Portuguese, Spanish and Swedish ships are represented. Other studies have identified 609 losses within 100 km of Dunnose Head on the Isle of Wight between 1508 and 1815 (Wessex Archaeology, 2004a). It has been speculatively suggested that the lack of systematic wreck recording means that these losses are likely to represent only a small proportion of the actual number of wrecks. It has been suggested that 3–5% of the merchant fleet was lost per year (Friel, 2003).

In addition to the growth in merchant shipping activity, there also appears to have seen an exponential growth in the amount of military traffic, mirroring the rapid growth in the significance of the naval port of Portsmouth and the vulnerability of the south coast to raids and invasion. Nine pre-18th century naval battlegrounds have been mapped within 100 km of Dunnose Head (Wessex Archaeology, 2004a).

The 19th century saw exponential growth in Britain's merchant, naval and fishing traffic, stimulated by population and urban growth, the development of the British Empire and the industrial revolution. It also saw the transition from wood to metal construction and from sail to steam.

The 20th century saw further growth in merchant trade (most notably liner traffic operating out of Southampton), although not necessarily in terms of vessel numbers, together with a gradual decline in accidental losses due to improvements in marine safety. However, the century also saw the two great world wars, which dominate the known maritime archaeological record of this period. Very large numbers of wrecks of the period 1914–18 and 1939–45 can be attributed to these events, due to the importance of Southampton and Portsmouth in terms of both trade and naval facilities and the proximity of the south coast and all its ports to occupied Europe.

Aviation archaeology

Aviation Archaeology comprises the remains of aircraft crash sites, where the aircraft have come to be on the sea bed as a result of a catastrophic loss, or after ditching in more controlled circumstances. The overwhelming majority of aviation sites found on the sea floor date from the Second World War when large numbers of aircraft were engaged in combat over UK waters (Wessex Archaeology, 2008b).

Given the close proximity of the south coast to the Continent, and the presence of strategic targets such as Southampton, Portsmouth and Dover the region has been a significant focus for both military and commercial aviation activity throughout the 20th century, particularly during the Second World War.

2.6 Benthic character

2.6.1 The English Channel

Large-scale benthic characterisation studies of the English Channel were initiated in the UK by Holme (1961; 1966) and in France by Cabioch (1968) and Cabioch *et al.*, (1976; 1977). Since then, smaller-scale, yet often more intensive studies have been carried out in areas along the Channel's length, occasionally spanning both sides of the Anglo-French Exclusive Economic Zone (EEZ) boundary. Notable examples of studies covering significant areas of the eastern and central Channel are reviewed by Cabioch (1984), Sanvicente-Añorve *et al*. (2002), James *et al*. (2007), Coggan *et al*. (2009) and Dauvin *et al* (2009). Cabioch (1968) is responsible for much of the detailed knowledge available on the benthos of the French western Channel. However, since his work, few studies appear to have been conducted specifically in the extreme western Channel on either side (Holme, 1983). A study by Bolam *et al*. (2008) encompasses this western area, at least in British waters. A great number of small-scale benthic characterisation studies have been carried out in inshore areas on both sides of the Channel. The findings from those on the British coast have been systematically reviewed by Irving (1999), Jones *et al*. (2004) and Pinnion *et al*. (2007), whereas Dauvin *et al*. (2009) provide some examples of similar inshore studies along the French coast. Carpentier *et al*, (2009) have reported on the CHARM-II project, (Channel Habitat Atlas for Marie Resource Management), which covers both UK and French waters in the central and eastern Channel.

One common finding running through all of the benthic characterisation studies along the Channel is the noted difference in benthic assemblage composition between the west and the east. This difference is a direct consequence of various interdependent physical factors known to influence benthic assemblage composition. Perhaps the most influential factor is the bedload parting zone (See Section 2.4 & Figure 2.10) between the Isle of Wight and the Cotentin Peninsula (also known as 'The Narrows'), caused by a divergence in net tidal flow, resulting in net sediment transport away from the central parting zone, towards both the east and the west (Grochowski *et al*., 1993, Johnson *et al*., 1982). Over several millennia, the winnowing of particulate sediments to east and west has resulted in a notable broadscale sorting of surficial material, leaving coarse-grained lag deposits or bare bedrock at the parting zone itself, with a gradation of progressively finer sediments on both sides, which in turn drives a longitudinal decline in the composition of benthic faunal communities (Coggan *et al*., 2009). In addition, the steadily decreasing depth profile of the Channel from west to east also has implications for the potential of waves to disturb the sea bed (greater in the shallower east; Grochowski and Collins, 1994) and for the establishment of a summer thermocline in the deeper west (Stanford and Pitcher, 2004). It is therefore not surprising that given the Channel's markedly different oceanographic characteristics along its length, the benthic assemblages reflect such changes as two broadly different ecosystems. Despite such apparent differences between the eastern and western Channel ecosystems, this does not mean that they are discrete and never intermix. Rather, substrate-specific communities in the west comprise a similar range of organisms as those in the east, but there are certain species substitutions depending on the particular environmental tolerances of each component species.

Long-term climatic changes are also known to affect the Channel's ecosystem. A fluctuating marine biogeographic boundary that separates cold water species in the north from warmer water species in the south currently lies towards the extreme south-west of the Channel (Southward *et al*., 1988). As this boundary drifts north or south past the Western Approaches, the western Channel ecosystem alternates between warmer and cooler states influencing the species composition of benthic and pelagic communities and the abundance of some fish populations. Time series records show a warm period from the 1930s to the 1960s followed by a return to the colder phase, which has persisted (see Stanford and

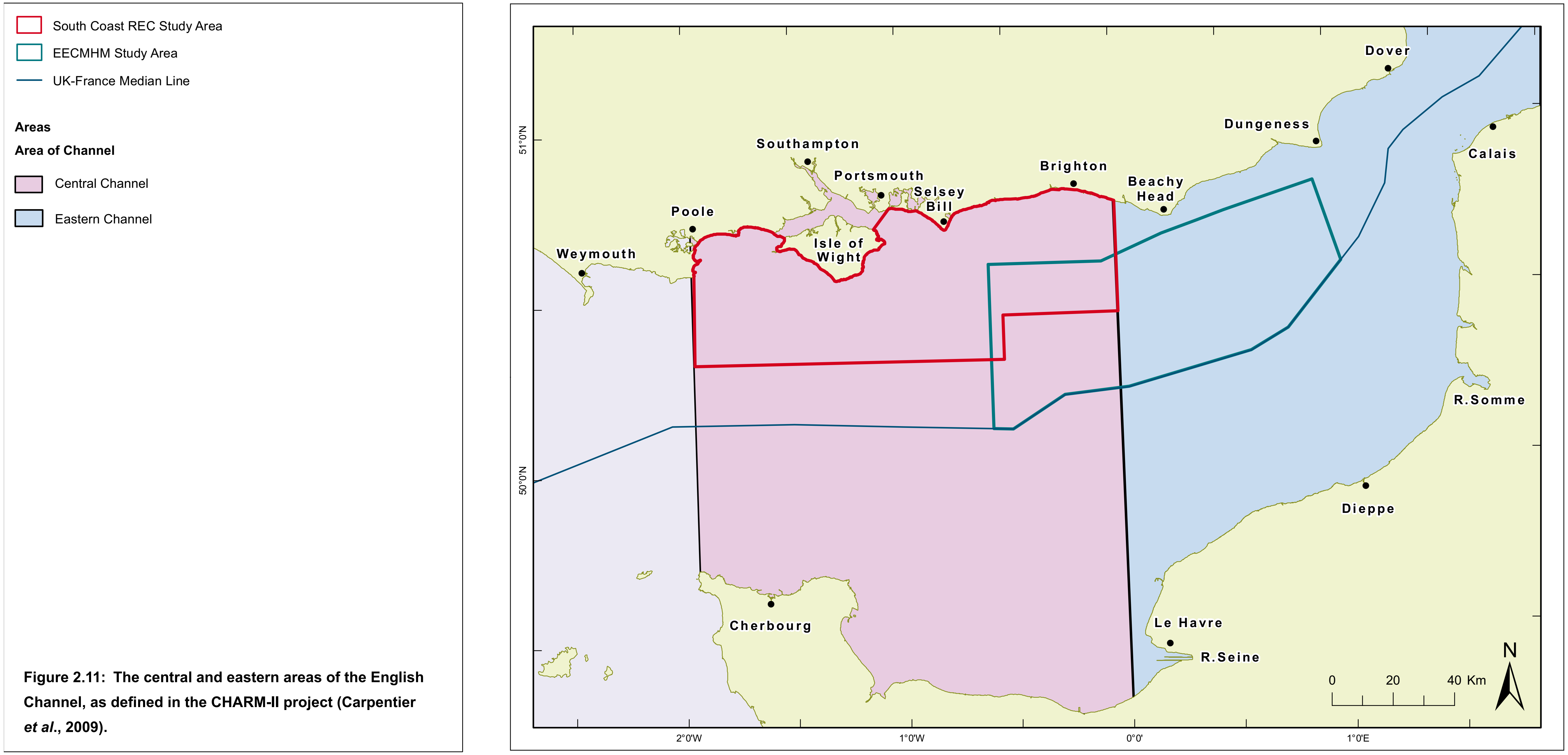


Figure 2.11: The central and eastern areas of the English Channel, as defined in the CHARM-II project (Carpentier *et al*., 2009).

Pitcher, 2004 for a review). Such changes will continue to affect the longitudinal distribution of temperature sensitive species in the Channel, as warmer (or cooler) water penetrates deeper eastwards up the Channel.

2.6.2 The central and eastern English Channel

The area covered by the South Coast REC lies within the British domain of the central Channel. The benthic ecology here is more similar to the eastern than the western Channel, and hence a more detailed description of this central and eastern ecosystem is presented here. The areas are defined as per the CHARM II project (Carpentier *et al*., 2009) with the central channel being that area between the tip of the Cotentin peninsula (1° 58' West) and the Greenwich Meridian (0° 0' West), and the eastern Channel being all points east of the Greenwich Meridian (Figure 2.11).

The benthic habitats represented here are defined primarily by the sea bed substrate. A wide variety of sea bed types are present, ranging from the fine mud present in low-energy areas, to bedrock exposures of sandstone, limestone, chalk and mudstone. In general, the nearshore sea bed is an assortment of mixed sediments (especially gravel and shells) with sand and, in sheltered locations, mud. There are also occasional and sometimes extensive areas of exposed bedrock and boulder reefs, often occurring off headlands. In deeper water further offshore, the sea bed has generally been perceived to be dominated by sediments, mainly of sand, sandy gravel and gravel with occasional rocky outcrops. Recent research, however, has unexpectedly revealed an extensive rocky reef system covering an area of 1,100 km^2 approximately 20 km south of the Isle of Wight (Diesing *et al*., 2009).

As a result of this mosaic of different sediment types, a wide variety of habitats is found on the sea bed of this region. A description of each habitat type — following a crude classification of rock, gravel, sand, mud and biogenic habitats — is presented below.

Rock habitats

The type of organisms that can colonise rock habitats, including stony reefs, can be strongly influenced by the type of rock present, be it chalk, sandstone or limestone. Therefore, benthic assemblages tend to differ between rocky substrate types.

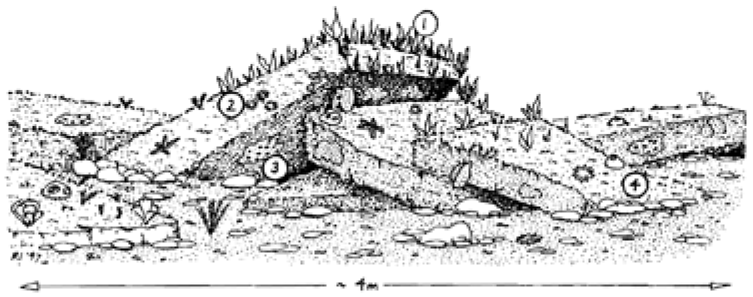


Figure 2.12: Representation of a jumbled mass of sandstone sarcens (as occurs at the Waldrons reef off Bognor). Key: (1) foliose red algae on shallowest parts of boulders, (2) *Actinothoe sphyrodeta* anemones, (3) underside of boulders with encrusting sponges, sea squirts and soft corals, (4) other surfaces with bryozoan and hydroid turf, anemones, sea squirts and sponges. Reproduced from Irving (1999).

Generally, harder rock habitats are often colonised by keelworms *Pomatoceros triqueter* and by barnacles *Balanus* spp. In slightly deeper water, the hydroids *Halecium halecinum, Kirchenpaueria pinnata, Hydrallmania falcata, Nemertesia antennina* and the foliose bryozoan *Flustra fascialis* (formerly *F. foliacea*) can be found. Mobile species commonly found on rock are the whelk *Buccinum undatum*, the topshell *Gibbula cineraria* and the netted dogwhelk *Hinia reticulata*, together with hermit crabs *Pagurus* spp. and the swimming crabs *Liocarcinus* spp. Where there is foliose algal cover there is a greater range of mobile fauna, including the spider crabs *Macropodia rostrata* and *Pisa tetraodon*. In even deeper water, several species of sponge are likely to be conspicuous, including *Esperiopsis fucorum* and *Dysidea fragilis*. Ross coral *Pentapora fascialis*, a bryozoan is often conspicuous on bedrock outcrops.

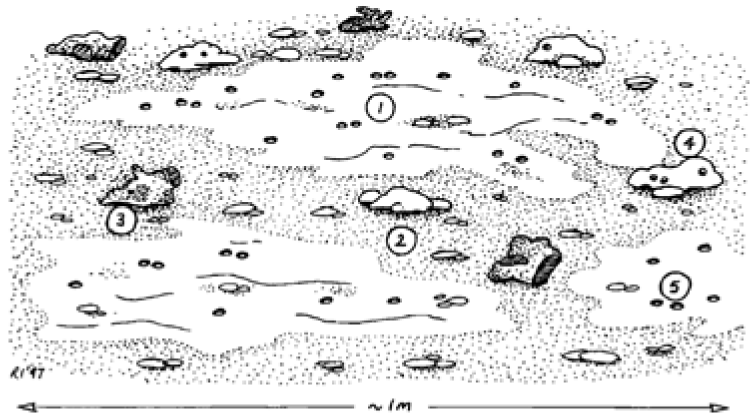


Figure 2.13: Representation of horizontal chalk bedrock exposures. Key: (1) areas of exposed chalk underlying mixed sediments, (2) thin covering of sand over the chalk, (3) occasional flint cobbles and pebbles, (4) occasional chalk cobbles and pebbles, (5) chalk bedrock with piddock holes, some of which are occupied by live *Pholas dactulus*. Reproduced from Irving (1999).

Overhangs may be dominated by a variety of sea squirts, bryozoans, hydroids, anemones and the soft coral *Alcyonium digitatum* (Figure 2.12). Crustacea include edible crabs, spider crabs, lobsters and squat lobsters. Common fish include goldsinny, corkwing and ballan wrasse, two-spotted gobies, butterfish and long-spined sea scorpions.

Softer chalk reef habitats in the eastern Channel (which represent 75% of all chalk reefs in Europe) support a wide range of characteristic species, some of which are predominantly found on or in this type of substrate. A number of species are capable of boring into the rock and these tend to dominate the associated subtidal communities. These species include bivalve piddocks (in particular *Pholas dactylus, Hiatella artica, Barnea* spp. and *Petricola pholadiformis*), polychaete worms (especially spionids) and sponges (Figure 2.13). The biotope dominated by piddocks is often the most widespread of the biotopes which occur on these reefs but is scarce in Britain as a whole.

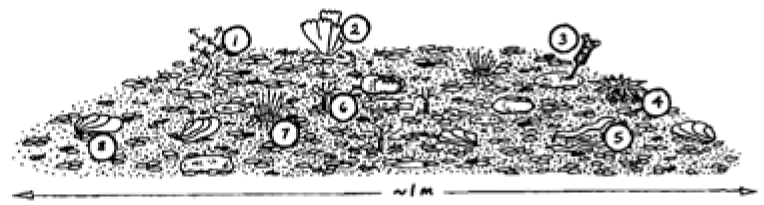


Figure 2.14: Representation of gravel-dominated mixed sediment. Key: (1) hydroid *Hydralmania falcata*, (2) erect bryozoan *Flustra fascialis*, (3) stalked sea squirt *Styela clava*, (3) anemone *Urticina felina*, (5) finger bryozoan *Alcyonidium diaphanum*, (6) sandmason worm *Lanice conchilega*, (7) burrowing anemone *Cerianthus lloydii*, (8) slipper limpets *Crepidula fornicata*. Reproduced from Irving (1999).

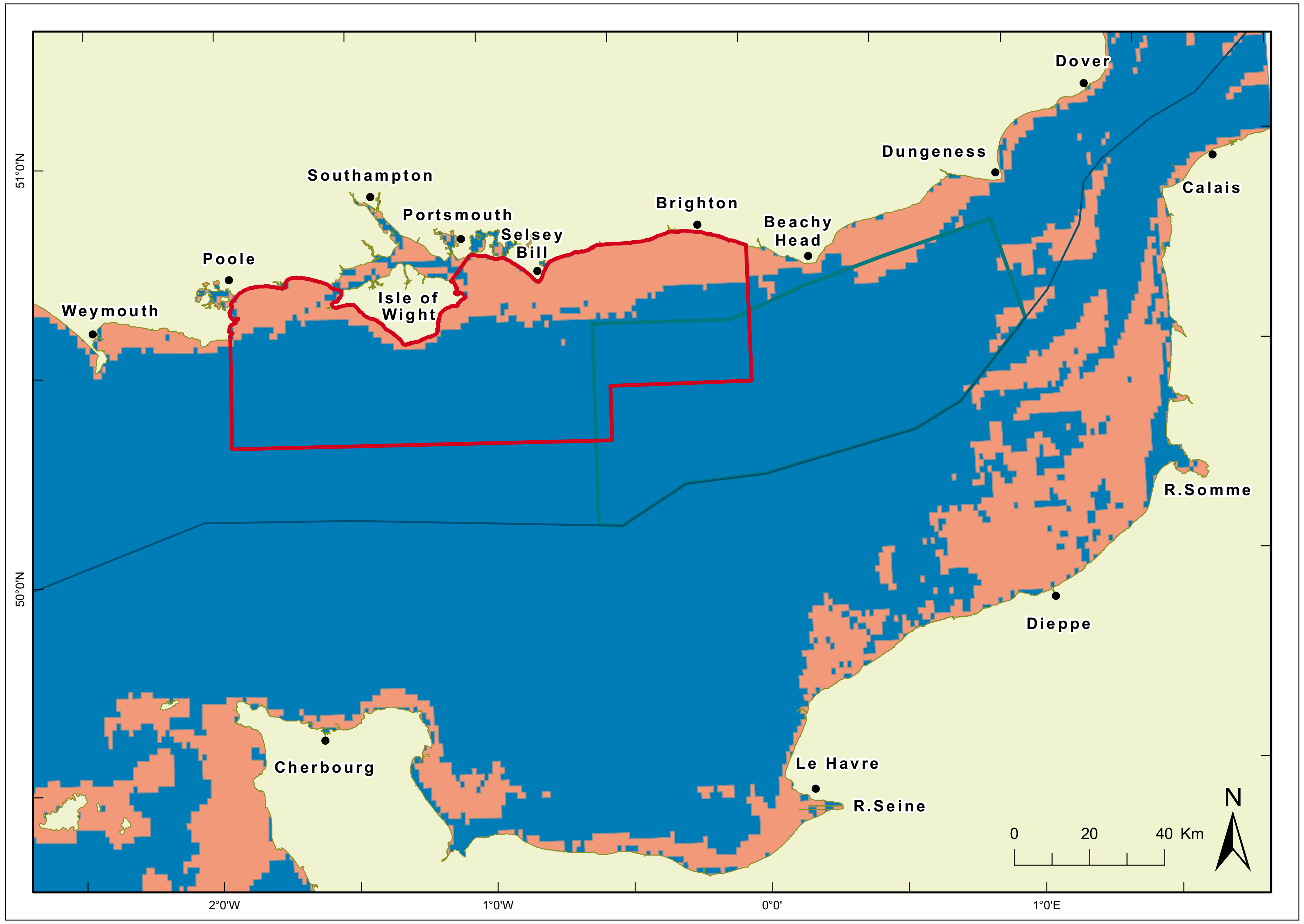
Gravel habitats

Gravel and mixed sediment habitats cover extensive subtidal and offshore areas of the eastern English Channel (Jones *et al*, 2004). Areas of nearshore mixed sediments tend to be formed of variable amounts of sand, gravel and cobble, often mixed with dead shells and shell gravel. In areas where these mixed sediments are stable, settlement and subsequent growth of a rich variety of plant and animal species occurs. The anemones *Anemonia viridis* and *Urticina felina* are typical of gravel areas, with *Cerianthus lloydii* also frequently encountered. The slipper limpet *Crepidula fornicata* is commonly associated with gravel and its shells can form the main hard substrate in areas of soft sediments. Gravel habitats found in deeper offshore areas (>30 metres), tend to be less affected by natural disturbance than those closer inshore. As a result, these areas tend to support diverse marine fauna which may include a wide range of anemones, polychaete worms,

South Coast REC Study Area
EECMHM Study Area
UK-France Median Line
Photic Zones
Photic
Aphotic

Sources: Map of the average light attenuation coefficient (Kd) for August 2007 provided by R Forster, Cefas, and model data from Coggan and Diesing (2009)

Figure 2.15: Modelled distribution of photic and aphotic zones.



bivalves and amphipods and both mobile and sessile epifauna (Figure 2.14).

Sand habitats

Sandy sediments are widespread throughout the eastern English Channel. Sand sediments are found in regions of moderate to strong tidal currents where they are able to settle but finer particles cannot. In such situations, the sand is often coarse and clean with little mud, but with occasional shell fragments present.

Mobile sands tend to be characterised by robust and sometimes impoverished faunas, typically venerid bivalves, amphipods, polychaete worms and heart urchins.

Clean sand is favoured by the burrowing heart urchin *Echinocardium cordatum*, the masked crab *Corystes cassivelaunus* and the sea mouse *Aphrodita aculeata*. A number of species, such as the anemones *Urticina felina* and *Cereus pedunculatus*, are sand-tolerant but require an underlying stone or hard substrate for attachment (Collins and Mallinson, 2000). Mobile species typically found in such areas include hermit crabs *Pagurus* spp. and gastropod molluscs such as *Hinia reticulata* and *Buccinum undatum*. Flatfish include brill *Scophthalmus rhombus*, plaice *Pleuronectes platessa*, dab *Limanda limanda* and Dover sole *Solea solea*.

Sand banks can also occur in the area, particularly to the eastern end of the Channel (Figure 2.2). They provide important nursery grounds for young commercial fish species, including plaice *Pleuronectes platessa*, cod *Gadus morhua* and sole *Solea solea* (Brown *et al*., 1997).

Mud habitats

Because of the exposed nature of the sea bed in much of the eastern Channel, few areas of mud-dominated sediment are present except in deeper, sheltered, inshore waters such as the Solent. Generally, the muddy and silty sediments of the Solent contain chains of slipper limpets *Crepidula fornicata*, which provide attachment for other organisms such as hydroids (e.g., *Kirchenpaueria pinnata* and *Hydrallmania falcata*) and sponges (e.g. *Halichondria* spp. and *Suberites* spp.). A number of small crab species, such as *Pisidia longicornis, Macropodia rostrata* and *Pagurus bernhardus*, are found in cover provided by the slipper limpet shell epifauna. Polychaete worms, bivalve molluscs such as cockles, and brittlestars can also be numerically dominant in mud habitats where hard biogenic substrates (i.e. *Crepidula* shells) are absent.

Biogenic habitats

Some organisms found in the eastern Channel can aggregate in sufficient numbers to influence significantly the number and variety of other organisms around them (e.g. kelp and seagrass in the photic zone (Figure 2.15), maerl, the common mussel *Mytilus edulis*, slipper limpets *Crepidula fornicata* and the Ross worm *Sabellaria* spp.). Particular biogenic habitats are often associated with specific broad habitats, for example, maerl is usually associated with gravel, seagrass beds with sand, mussels with mixed sediments, though reefs formed by animals such as the Ross worm *Sabellaria* spp. can be associated with a range of habitats such as gravel, pebbles and cobbles, and bedrock.

Species of interest

A number of species are of particular interest either because of their rarity or as a result of their ability to engineer their environment to attract other species (see 'Biogenic habitats' above). Rarity can be due to many factors, including resource limitation, disparate populations, a limited natural geographic range or strict habitat preferences. A number of examples are given below.

Pentapora fascialis — Ross coral (Figure 2.16). This erect species of bryozoan is typically thought of as having a southern and western distribution within the British Isles, extending eastwards only as far as Dorset. However, it has been recorded in the eastern Channel as far east as Worthing, attached, rather unusually, to chalk (Iriving, 1999).

Sabellaria spinulosa — Ross worm (Figure 2.17). This reef building species has been recorded throughout the eastern English Channel but most frequently as solitary individuals and small clusters or veneers encrusting pebbles, shells or bedrock. Thin crusts of *Sabellaria spinulosa* have also been recorded but tend to be ephemeral, breaking up in winter storms. However, *Sabellaria spinulosa* reefs have recently been recorded east of Swanage (Jones *et al*., 2004). *Sabellaria spinulosa* reefs have their own Habitat Action Plan and are also indirectly covered by the Habitats Action Plan for sublittoral sands and gravels.

Figure 2.16: *Pentapora fascialis* © Keith Hiscock.

Eunicella verrucosa — pink sea-fan (Figure 2.18). This slow-growing branching colonial species attaches to rocks and boulders in areas of strong tidal currents. Being erect and fragile it is easily damaged by towed fishing gear, and has therefore been the subject of conservation measures, particularly in the Lyme Bay area. Although not common, it is widely distributed in south-west Britain, with an eastward extent around the central English Channel.

Corynactis viridis — jewel anemone (Figure 2.19). Recorded as far east as Eastbourne, usually in uncommonly small aggregations on vertical surfaces of deep water wrecks. Becomes more frequent and occurring in denser aggregations further westwards on hard substrates in the English Channel.

Figure 2.17: *Sabellaria spinulosa* © Crown.

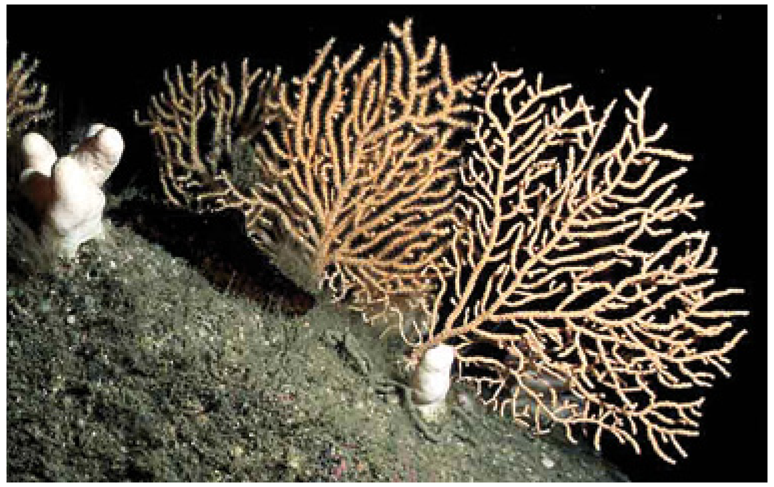


Figure 2.18: *Eunicella verrucosa* © Keith Hiscock.

Figure 2.19: *Corynactis viridis* © Crown.

Habitat mapping studies

A number of mapping projects have recently been undertaken in the central and eastern Channel to provide information to support the regional-scale management of the ecosystem and its resources. The Eastern English Channel Marine Habitat Map (EECMHM) (James *et al*., 2007) studied an extensive area centred on a cluster of offshore sites that were being considered for aggregate extraction. The study provided information on the wider region that allowed the potential impact of the aggregate dredging to be considered in a wider spatial context. An integrated analysis of geological and biological data resulted in the identification and mapping of infaunal and epifaunal biotope classes.

More recently, Coggan and Diesing (2009) have developed modelled habitat maps for the Channel, based on the hierarchical classification system used by the European Nature Information System (EUNIS), which draws heavily on the Marine Habitat Classification for Britain and Ireland (MHCBI) developed by the JNCC (Connor *et al*., 2004). At EUNIS Level 3 this showed the majority of the central and eastern Channel area to be sublittoral coarse sediments, but with significant areas of sand in the east and mixed sediment (gravel + sand + mud) in the west. Holme (1961; 1966) had previously described a number of distinct faunal assemblages associated with different sediment types in the Channel from an array of stations he had sampled in the1950s and 1960s. Coggan and Diesing (2009) found that these assemblages could be recognised within the modern biotope descriptions and so were able to reclassify Holme's stations according to the EUNIS scheme and test how well they matched to their own modelled map, finding an 82% agreement for sublittoral coarse sediments, 72% for sublittoral sand, 27% for sublittoral mud and 0% for mixed sediments. This reflects the relative proportion of each of these substrate types in both the modelled map and among Holme's sampling sites, with greater matching among the more common/extensive substrates. See Coggan and Diesing (2009) for detailed discussion. This work demonstrates that historical records can be of value in helping to interpret modern geophysical surveys for the purpose of developing habitat maps.

At the time of writing (November 2009) a further significant study is just being published, namely the Channel Habitat Atlas for Marine Resource Management (Carpentier *et al*., 2009). This takes a different approach, using the term 'habitat' in the Darwinian sense, meaning an area occupied by a particular type of animal (Darwin, 1859), as distinct from the modern term 'biotope' which refers to a recognisable assemblage of organisms repeatedly found under similar environmental conditions (such as a kelp forest or coral reef). Consequently, this work will present distribution maps of individual species and give brief descriptions of their biology and the conditions under which they are found (e.g. substrate type, temperature, depth, salinity etc.). This will clearly be an important reference text and source of information for those involved in marine resource management.

2.7 Marine mammals

Marine mammals are drawn from two groups; the cetaceans: whales, dolphins and porpoises, and the pinnipeds: walrus, sea lions and seals. The order Cetacea is divided in two sub-orders known as the Mysticeti and Odontoceti. Mysticete describes the filter feeding baleen whales often referred to as 'the great grazers of the ocean'. This group includes species such as the fin whale, the minke whale and the blue whale. The Odontoceti are the toothed cetaceans, a group of predatory whales, dolphins and porpoises. Species such as the sperm whale, bottlenose dolphin and the harbour porpoise are all members of this group. The pinnipeds evolved separately to the cetaceans and form a distinct superfamily known as the Pinnipedia. The pinnipeds are a group of fin-footed animals which are represented in the UK by true seals and eared or fur seals, the latter being restricted to the Shetland and Orkney islands.

Comparatively little is known about the ecology and natural distribution of marine mammals because they are difficult to observe. Indeed, knowledge of some species comes from only a handful of dead specimens (Santos *et al*., 2001; Barnett *et al*., 2009). That these creatures are difficult to observe, however, is not a reflection of their population size. Marine mammals are abundant in many of the world's oceans, including the Atlantic and other seas around Europe. For example, it has been estimated that there may be more than 100,000 minke whales present in north-west Europe at certain times of the year (Reid *et al*., 2003). Marine mammals can occur in such high densities that competion with commercial fisheries can lead to conflict (Matthiopoulos *et al*., 2005).

The English Channel is of comparatively limited importance to the overall UK distribution of cetaceans (Evans, 2000; Reid *et al*., 2003; Hammond, 2006; Hammond *et al*., 2008). This is reflected in the low numbers of species and the low abundance of individuals observed. Of the 28 species of cetacean which occur around the British coast, only 12 have been recorded in the English Channel since 1975 (Evans, 2000) and only five are considered regular visitors in the south coast region; the bottlenose dolphin *Tursiops truncatus*, the short-beaked common dolphin *Delphinus delphis*, the harbour porpoise *Phocoena phocoena*, the minke whale *Balaenoptera acutorostrata*, and the long-finned pilot whale *Globicephala melans* (Reid *et al*., 2003; Rowson, 2006).

Further species have also been recorded in the south coast region, however, these are recorded very infrequently and several have only ever been recorded as dead strandings (Reid *et al*., 2003; Rowson, 2006; Barnett *et al*., 2009). The possibility therefore remains that these species may have died and been subsequently carried to the shores of the south coast on prevailing currents. The cetacean species which have been infrequently recorded across the south coast region are the:

- white-beaked dolphin *(Lagenorhynchus albirostris)*
- atlantic white-sided dolphin *(Lagenorhynchus acutus)*
- striped dolphin *(Stenella coeruleoalba)*
- risso's dolphin *(Grampus griseus)*
- humpback whale *(Megaptera novaeangliae)*
- sei whale *(Balaenoptera borealis)*
- fin whale *(Balaenoptera physalus)*

Two representatives of the Pinnipedia are known to make use of the waters of the south coast region. These species are the common, or harbour seal, *Phoca vitulina* and the grey seal *Halichoerus grypus*.

2.7.1 The protected status of marine mammals

Effective conservation of marine mammals depends on knowledge of many aspects of their behaviour, ecology and population dynamics. This information is difficult to obtain and to assess because of the large distances travelled by these animals (Reid *et al*., 2003). Marine mammals occur across political and geographical borders making their conservation and management a global issue. Numerous national and international conventions and initiatives have been put in place to tackle this problem and those which are applicable to UK species are summarised in Table 2.1. The application of these initiatives is also given for the most commonly occuring marine mammals in the region.

Where reasonable temporal data exist it indicates a decline in many of the UK marine mammal populations over the course of the last 200 years (Reid *et al*., 2003). They have been affected by direct and indirect fishing pressure, collisions with shipping, pollution events and anthropogenic noise (Reid *et al*., 2003; Hammond, 2006; Hammond *et al*., 2008). In order to ensure that these trends of declining populations are halted the majority of marine mammal species now receive legal protection through both European and UK legislation. All seven of the marine mammals which are known to occur regularly in the south coast region (Table 2.1) are listed in the European Directive on the Conservation of Natural Habitats and of Wild fauna and Flora 92/43/EEC (the EC Habitats Directive) which was incorporated into UK law as the Conservation (Natural Habitats etc) Regulations in 1994. Cetaceans are listed under Annex IV of the Directive which means they are strictly protected. All forms of deliberate capture or killing are prohibited as is the disturbance or destruction of the animals themselves or the habitats which they use for breeding or resting. Similarly, it is illegal under the UK Wildlife and Countryside Act (1981) to intentionally kill, injure, or harass any cetacean species in UK waters.

Conservation efforts are likely to be greatly enhanced as more data become available and our understanding of the ecology of marine mammals improves. In recent years there has been a trend towards coordinated at-sea surveys which yield valuable information on the distribution and population dynamics of marine mammals. Examples of such surveys include the SCANS surveys of harbour porpoises, and subsequently of small cetaceans, in the North Sea and adjacent waters (Hammond *et al*., 2002; Dolman *et al*., 2003; Hammond, 2006). Observational data from a number of sources has been collated in the 'Atlas of cetacean distribution in north-west European waters' (Reid *et al*., 2003) and this has been

Legislation/Conservation Initiative	Details	Bottlenose Dolphin	Short-Beaked Common Dolphin	Harbour Porpoise	Minke Whale	Long-Finned Pilot Whale	Common Seal	Grey Seal
EC Habitats Directive	All cretacean species are protected from capture, killing, disturbance (particularly during periods of breeding) or the destruction of them or their habitat under Annex IV of the Habitats Directive. The UK is also required to designate areas of particular importance to the common dolphin, harbour porpoise, grey and common seals under Annex II. Incidental captures and killing of the common dolphin and harbour porpoise must also be recorded and monitored under Article 12. The habitats directive is transposed to UK law by the Conservation (Natural Habitats etc.) Regulations 1994.	*	*	*	*	*	*	*
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	CITES aims to protect certain plants and animals, including cetaceans, by regulating and monitoring their international trade to prevent it reaching unsustainable levels.	*	*	*	*	*		
The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention)	The principal aims of the Bern Convention are to ensure conservation and protection of all wild plant and animal species and their natural habitats (listed in Appendices I and II of the Convention), to increase cooperation between contracting parties, and to afford special protection to the most vulnerable or threatened species (including migratory species) (listed in Appendix 3). To this end the Convention imposes legal obligations on contracting parties, protecting over 500 wild plant species and more than 1000 wild animal species.	*	*	*	*	*		
Convention on the Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention)	Migratory species that would significantly benefit from international co-operation of conservation efforts are listed in Appendix II of the Bonn Convention. This encourages member states to conclude global or regional Agreements for the conservation and management of individual species or, more often, of a group of species listed on Appendix II. The Wildlife & Countryside Act and the ASCOBAN agreement are the main mechanisms adopted by the UK in order to implement the recommendations of the Bonn Convention (see below).	*	*	*		*	*	*
Wildlife and Countryside Act 1981	Act of Parliament which makes it an offence (subject to exceptions) to intentionally kill, injure, take, possess, or trade in any wild animal listed in Schedule 5, and prohibits interference with places used for shelter or protection, or intentionally disturbing animals occupying such places. The common dolphin, bottlenose dolphin and harbour porpoise are also listed under Schedule 6 which prevents them from being killed by certain methods.	*	*	*	*	*		
Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS)	Regional agreement covering all species of the toothed whales *(Odontoceti)*, with the exception of the sperm whale *(Physeter macrocephalus)*. A conservation and management plan forms part of the agreement and this obliges parties to engage in habitat conservation and management, surveys and research, pollution mitigation and public information.	*	*	*		*		
Section 74 Countryside Rights of Way (CRoW) Act 2000	The CRoW act amends the law relating to nature conservation and protection of wildlife. Section 74 of the act requires the preparation and maintenance of lists of priority species and habitats. The CRoW act also strengthens the legal protection for threatened species with regard to killing, injuring, disturbing or destroying places used for shelter and protection.			*				
Conservation of Seals Act 1970	Provides for a closed season during which it is an offence to take or kill any seal except under licence in particular circumstances. The closed season for grey seals is 1 September to 31 December inclusive and for common seals, 1 June to 31 August inclusive, coinciding with their respective pupping seasons. The act provides an exception which makes it lawful to kill a seal to prevent it from causing damage to fishing nets or tackle, or to any fish in the net, providing the seal is in the vicinity of the net or tackle at the time.						*	*
UK Biodiversity Action Plan (BAP)	The UK List of Priority Species and Habitats contains 1150 species and 65 habitats that have been listed as priorities for conservation action under the UK Biodiversity Action Plan (UK BAP).	*	*	*	*	*		
Species of Principal Importance in England (section 41) of the Natural Environment and Rural Communities Act 2006)	Species 'of principal importance for the purpose of conserving biodiversity' covered under section 41 (England) of the NERC Act (2006) need to be taken into consideration by public bodies when performing any of its functions with a view to conserving biodiversity.	*	*	*	*	*	*	

Table 2.1: Summary of conservation legislation and initiatives relating to marine mammals in the UK and their application to species which regularly occur in the region.

used here to examine the distribution of marine mammals across the south coast region (Figures 2.20–2.28).

2.7.2 Cetaceans

Common bottlenose dolphin

Tursiops truncatus, the common bottlenose dolphin, is a large dolphin with a distinct beak (Figure 2.20). It is a truly global species, being found in both the open ocean and inshore waters of temperate and tropical seas (Reid *et al*., 2003). In UK waters, this species is most commonly recorded in the coastal waters of west Wales, south-west England and northern/north-east Scotland (Figure 2.21). This species is not believed to be abundant in the south coast region, but it is one the most frequently recorded cetacean species in this area. The results of a photo-identification programme indicate that there is a semi-resident group of bottlenose dolphins which return to Durlston Head each spring (Rowson, 2006). This group of dolphins has also been observed in Cornwall and it is possible that the group moves between the two areas throughout the year (Reid *et al*., 2003).

Where the common bottlenose dolphin inhabits coastal waters it tends to be associated with estuaries, headlands and sandbanks; areas which are bathymetrically complex and subject to strong tidal currents (Lewis and Evans, 1993; Hammond, 2006; Hammond *et al*., 2008). The common bottlenose dolphin is a predatory cetacean which exploits a wide range of prey species including cephalopods and shellfish. Haddock, cod, saithe, whiting, sandeels, eels, and squid are also preyed upon by bottlenose dolphins. This list of prey species is, however, by no means exhaustive (Santos *et al*., 2001; Reid *et al*., 2003).

Figure 2.20: Common bottlenose dolphin, *Tursiops truncatus* © www.seasurvey.co.uk

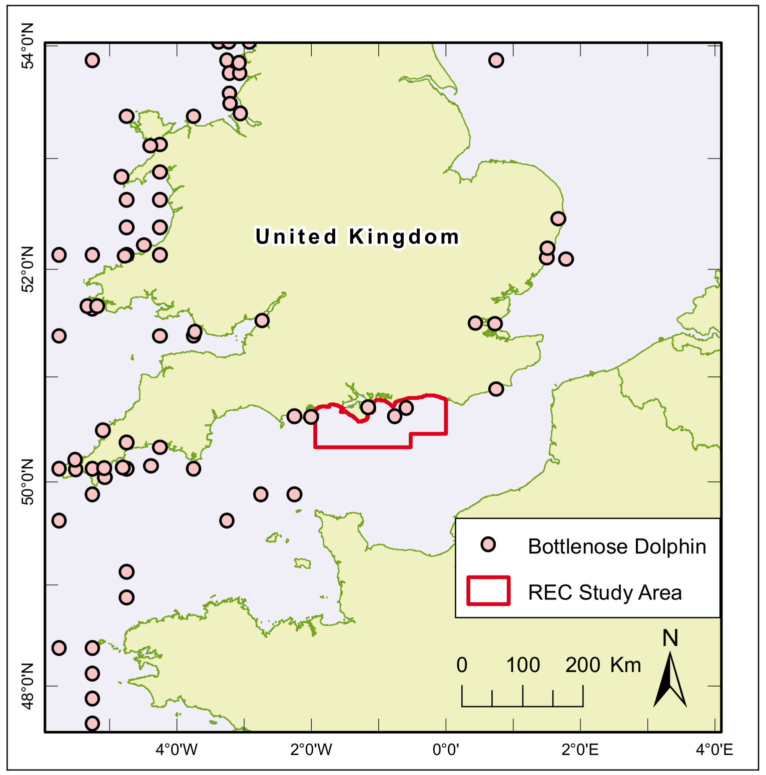


Figure 2.21: Recorded sightings of Common bottlenose dolphins, *Tursiops truncatus* (Reid et al., 2003; JNCC, 2010; NBN, 2009).

Short-beaked common dolphin

Delphinus delphis, the short-beaked common dolphin has, as its name suggests, a short beak (Figure 2.22) which it uses to feed on a wide variety of fish species as well as cephalopods (Reid *et al*., 2003). There are no published accounts of the diet of the common dolphin in the UK but it is generally accepted that they target schooling fish (Reid *et al*., 2003; Rowson, 2006a). The short-beaked common dolphin is most often observed in large groups although the precise social structure is poorly understood (Reid *et al*., 2003; Hammond *et al*., 2008). There have been a small number of sightings around Durlston Head and Poole Bay, and a young common dolphin took up residence in the vicinity of Calshot in the Solent between 1992 and 1994 (Rowson, 2006a). The short-beaked common dolphin is however, more normally found in deeper waters and so is unlikely to be more than an occasional visitor to the South Coast REC area.

Figure 2.22: Short-beaked common dolphin, *Delphinus delphis* © Gardline Environmental Limited.

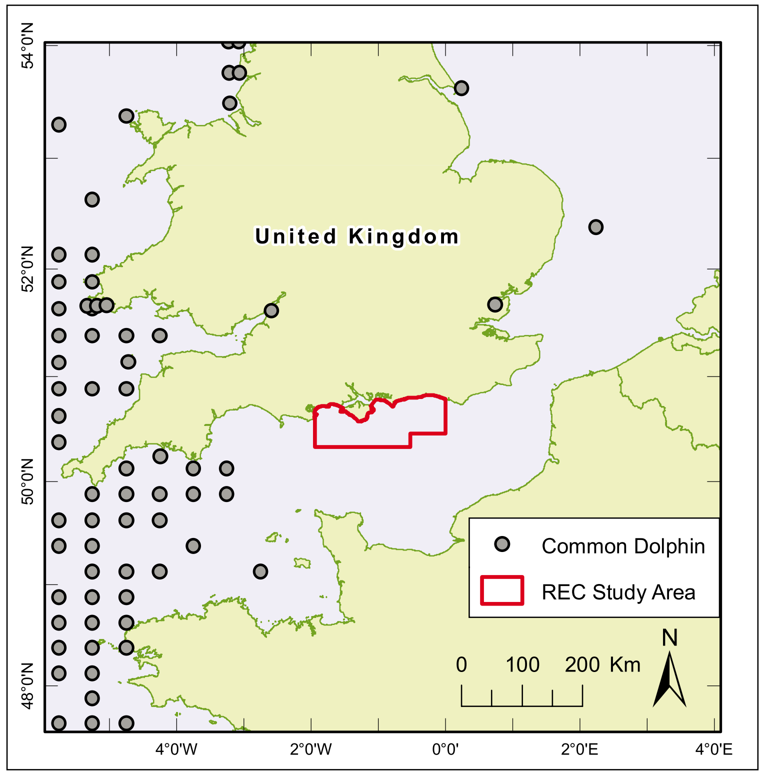


Figure 2.23: Recorded sightings of short-beaked common dolphin, *Delphinus delphis* (Reid et al., 2003; JNCC, 2010; NBN, 2009).

The original SCANS survey (Hammond, 2006) estimated that there are 75,500 common dolphins found across UK waters. Figure 2.23 illustrates that this population is distributed across the south-western waters of the UK. Whilst common dolphins do not appear to be frequently observed across the South Coast REC area, Evans (2000) and Rowson (2006a) assert that they are one of the two most commonly sighted species.

Harbour porpoise

Phocoena phocoena, the harbour porpoise can be difficult to observe because it is generally wary of boats, a brief glimpse of its low triangular fin is all that is normally seen (Figure 2.24). The harbour porpoise is the UK's smallest, most abundant and most widely distributed cetacean species. However, Figure 2.25 reveals that the waters of the South Coast REC area are of relatively limited importance to this species, which makes only infrequent visits.

Figure 2.24: Harbour porpoise, *Phocoena phocoena*
© Gardline Environmental Limited

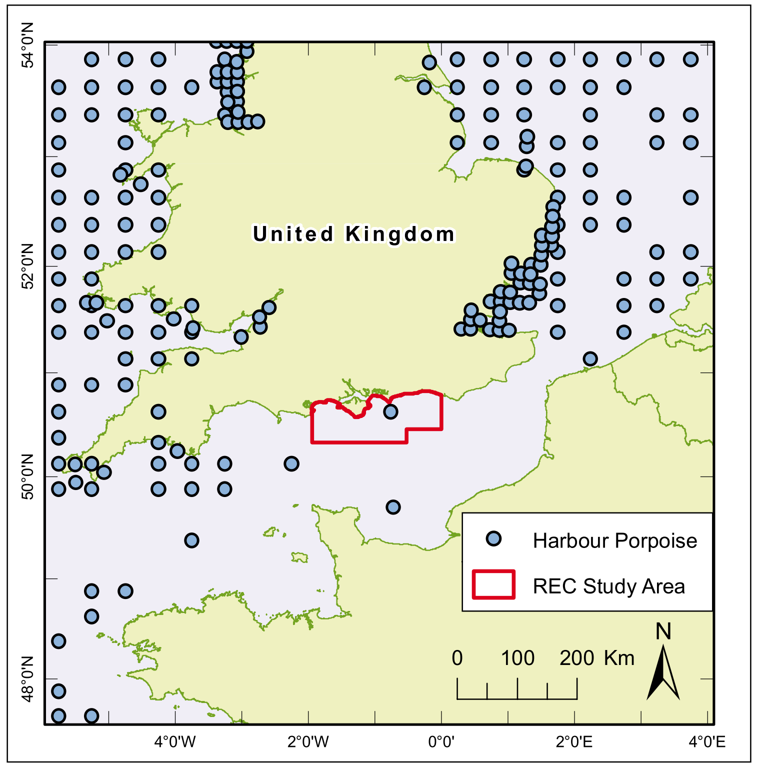


Figure 2.25: Recorded sightings of harbour porpoise, *Phocoena phocoena* (Reid *et al*., 2003; JNCC, 2010; NBN, 2009).

The harbour porpoise is particularly sensitive to fishing activities and is frequently found drowned in nets. For this reason the porpoise has disappeared from much of its former range (Carwardine, 2003).

Minke whale

Figure 2.26: Minke whale, *Balaenoptera acutorostrata*
© Gardline Environmental Limited

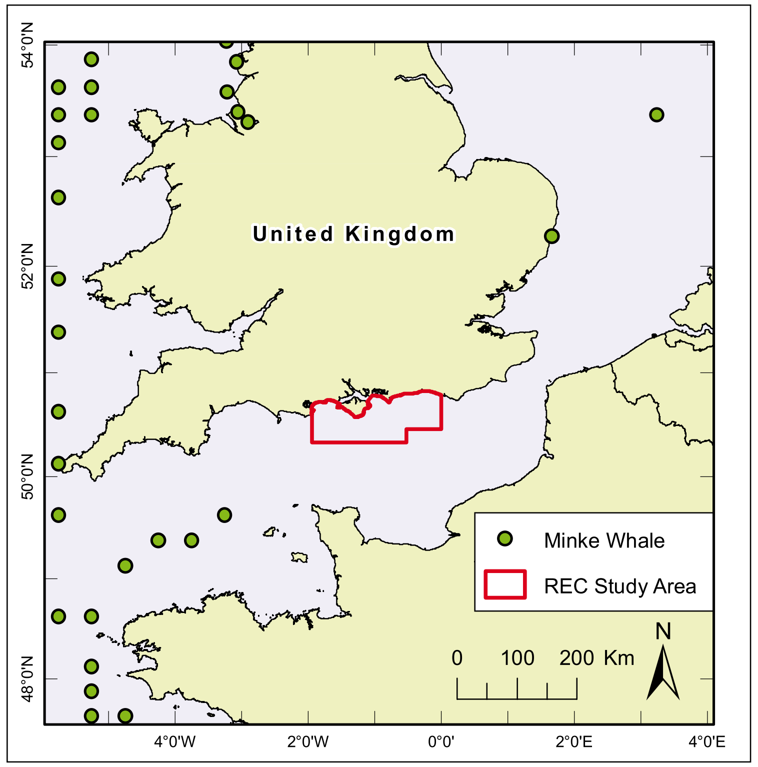


Figure 2.27: Recorded sightings of minke whale, *Balaenoptera acutorostrata* (Reid et al., 2003; JNCC, 2010; NBN, 2009).

Balaenoptera acutorostrata, the minke whale is the smallest member of the rorquals, a group of balaenopterid whales which includes species such as the sei, blue and fin whales (Carwardine, 2003).

Minke whales are slim with a sharply pointed head. They reveal very little of themselves when they surface but are easily recognised by their angled dorsal fin (Figure 2.26). Minke whales are primarily found across northern British waters, around the coasts of Scotland and north-eastern England. Figure 2.27 reveals that the minke whale is occasionally recorded in the English Channel and it has been sighted in the South Coast REC area (Evans, 2000; Reid *et al*., 2003).

Long-finned pilot whale

Globicephala melas, the long-finned pilot whale, is jet black or dark grey in colour and has a rounded bulbous forehead. Despite their name, pilot whales are in fact large dolphins which can reach 6.25 m in length (Reid *et al*., 2003). The long-finned pilot whale is a family animal, usually travelling in groups of 10–100 individuals. They are also well known for mass strandings and also for mass slaughter on the Faroe Islands (Carwardine, 2003). Figure 2.28 illustrates that this species is typically encountered in offshore waters. However, this figure, combined with the observations of Evans (2000) indicates that this species is infrequently observed

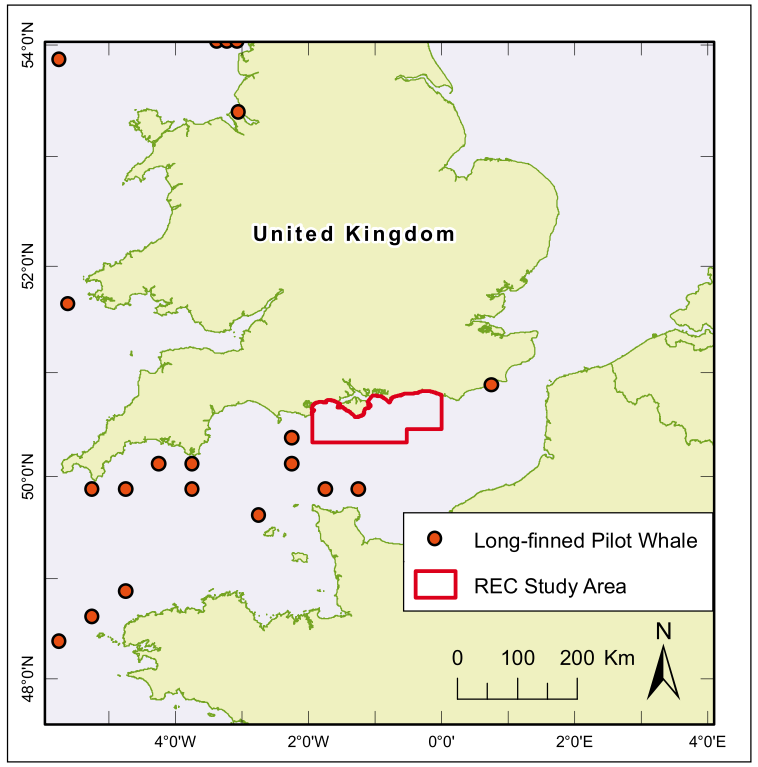


Figure 2.28: Recorded sightings of long-finned pilot whale, *Globicephala melas* (Reid et al., 2003; JNCC, 2010; NBN, 2009).

off the southern English coast, with a small number of sightings reported within the South Coast REC area.

2.7.3 Pinnipeds

The harbour seal and the grey seal are the only pinnipeds encountered around the coast of England (Rowson, 2006a). The grey seal, *Halichoerus grypus*, spends most of the year at sea, and may range widely in search of prey. Grey seals typically come ashore in autumn when they form breeding colonies on rocky shores, beaches, caves and sometimes on sand banks. At the start of the breeding season in 2000, Britain is reported to have as many as 124,000 grey seals (Rowson, 2006a). The largest pupping sites, or rookeries, occur in the Inner and Outer Hebrides, Orkney, the Isle of May, Farne Islands and Donna Nook. Only 15% of the grey seal pups are born outside of these sites and the nearest pupping ground is on the Isles of Scilly. The South Coast REC area is, therefore, unlikely to represent an important resource in terms of grey seal breeding and this species is thought to be only a casual visitor to this area (Evans, 2000; Rowson, 2006a).

The harbour seal, *Phoca vitulina*, is found through temperate and subarctic seas (Reid *et al*., 2003). Approximately 29,500 harbour seals are thought to inhabit UK waters (Evans, 2000), typically found in coastal waters and estuaries. Although the majority are found in Scottish waters there is a known haul-out site for this species within Poole Harbour (Rowson, 2006a). Since the mean distance travelled by the harbour seal to foraging areas is 46 km, the South Coast, and the REC area in particular, may form an important resource for harbour seals, particularly during their breeding season.

2.8 Ornithology

The extensive and varied coastline and expanse of open water found within the central and eastern English Channel region (Figure 2.1) contains a wide range of habitats which support both nationally and internationally important bird species. The region's importance to birds is reflected in the number of Special Protection Areas (SPAs) designated under the European Birds Directive (79/409/EEC), and Ramsar sites designated under the Ramsar convention, which exist in this locality (See Section 2.9 and Appendix D). It is important to note that whilst many of these protected sites abut the South Coast REC study area, none fall within its boundaries. Nevertheless, many important bird species utilise the REC study area for feeding, breeding and over-wintering.

2.8.1 Bird species of interest

A recent aerial survey of waterbirds in the UK observed high concentrations of birds across the south coast region and these are summarised in Table 2.2 (WWT Consulting, 2009). The results of this survey indicate that the region is of particular importance to gulls, auks, gannets and kittiwakes which were recorded in high abundances in both winter and summer. Significant numbers of rarer sea birds were also recorded including breeding tern species, cormorants, sea ducks, grebes and fulmar. The following sections give an overview of the important marine and coastal bird species which have been recorded in the region. It is anticipated that the South Coast Regional Environment Assessment (REA) (EMU Ltd in prep) will provide a more detailed assessment of the bird species found across the study area.

Category	Species observed	Winter	Summer
Terns	Little tern, sandwich tern, arctic tern, common tern and tern spp.	0	358
Cormorants	Cormorant and shag	25	36
Gulls	Black-headed gull, common gull, lesser black-backed gull, herring gull, great black-backed gull and gull spp.	13383	5591
Kittiwake		1452	703
Petrels & shearwaters	Fulmar, manx shearwater and British storm petrel	432	291
Auks	Guillemots, razorbill, puffin and auk spp.	10724	272
Divers	Great northern diver, black throated diver, red throated diver and diver spp.	171	2
Grebe	Great crested grebe and grebe spp	8	0
Skua	Arctic skua, great skua and skua spp.	13	24
Gannets		4380	1727
Ducks and geese	Brent goose, shelduck, common scoter, red-breasted merganser and duck spp.	552	119
Total		**31140**	**9123**

Table 2.2: Numbers of sea birds observed in the South Coast region during aerial surveys carried out in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009).

Terns

Sea terns are small sea birds which nest in large colonies along the coast, in coastal lagoons, islands, beaches and even rivers and reservoirs (RSPB, 2009; Parkin and Knox, 2010). Birds belonging to this family are typically silver/grey and white in colour except for the black 'cap' which lies across the upper portion of the head (Figure 2.29). The colours and detail of the legs and beaks are variable between species. The sandwich tern *(Sterna sandvicensis)*, common tern *(Sterna hirundo)*, little tern *(Sterna albifrons)* arctic tern *(Sterna pardisaea)* and roseate tern *(Sterna dougallii)* are all migratory species which inhabit the region during late spring, summer and early autumn (RSPB, 2009). Figure 2.29 shows the distribution of tern nesting sites and observations across the region (JNCC, 2009; WWT Consulting, 2009).

Terns feed primarily on fish including sand eels (Rock *et al*., 2007), pilchards, sand smelt and garfish (Paiva *et al*., 2006). They are active flyers and as such their use of any one feeding patch or prey concentration may be limited, indeed terns tend to carry only single prey items back to their waiting partner or chicks (Perrow *et al*., 2005). All of the tern species known to use the region have been classified as either high conservation concern (Red Status) or medium conservation concern (Amber Status) by the RSPB (2009). The conservation status of these birds is a reflection of a decline in their breeding populations both at a national and a European level (BirdLife International, 2004; RSPB, 2009; Parkin and Knox, 2010).

The common, little, arctic and sandwich terns have all been identified as being of medium conservation concern and hence have been given amber status. The decline in tern breeding populations and localisation of their breeding colonies (i.e. over 50% of the UK breeding population are found at ten sites or fewer) has raised concern about the future viability of tern populations and in the case of the little tern, the UK populations have been identified as internationally significant in their conservation (Eaton *et al*., 2009). The little tern is classified as declining in a European context (BirdLife International, 2004) and is in chronic long-term

South Coast REC Study Area
EECMHM Study Area
UK-France Median Line
Tern Nesting Sites
Tern Observations (Summer)
Aerial Observation Tracks

Common tern, *Sterna hirundo* © Gardline Environmental

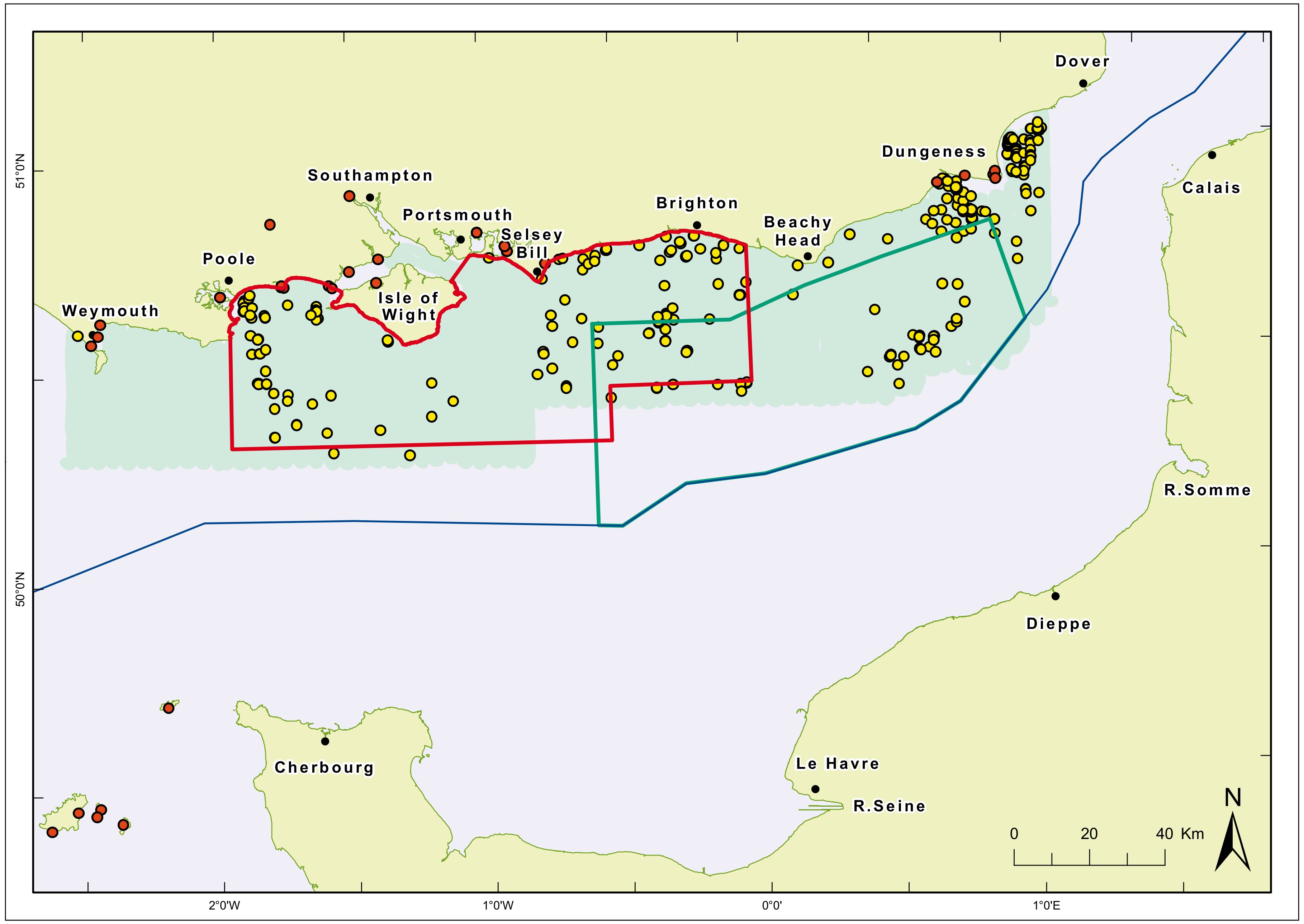


Figure 2.29: Distribution of tern Sternidae observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). Tern species encountered include the little tern, *Sterna albifrons*, the sandwich tern, *Sterna sandviscensis*, the arctic tern, *Sterna pardisaea*, and the common tern, *Sterna hirundo*. No terns were observed during winter surveys. The distribution of tern nesting sites are also shown (JNCC, 2009).

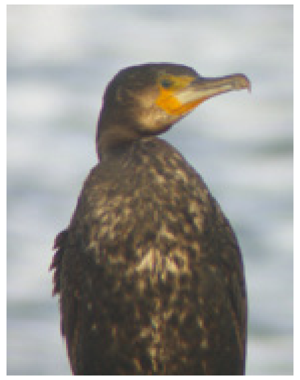
decline in the UK, having reduced by 27% between 1987 and 2000 (Ratcliffe, 2004). One of the UK's largest breeding colonies of little terns is found within the study area at Langstone Harbour, making this area of special significance for the long term conservation of this species (RSPB, 2009).

The sandwich and common tern are also known to breed in the region, although the national significance of these colonies is not known (RSPB, 2009). The roseate tern has been given red status by the RSPB indicating that urgent action is required to conserve this species (RSPB, 2009). The European breeding population of roseate terns suffered a large decline between 1970 and 1990. Although the breeding population has now stabilised, and even increased in some areas, its numbers in the UK are still declining (BirdLife International, 2004). With an estimated 56 breeding pairs in the UK the roseate tern population remains small and hence very vulnerable. There are two breeding pairs of roseate tern within the Solent and Southampton Water SPA forming a key feature of this area (JNCC, 1998).

Shags and cormorants

The European shag, *Phalacrocorax aristotelis* and the great cormorant, *Phalacrocorax carbo*, are large birds which are black in colour. The shag and the cormorant are sympatric species, that is, there exists significant overlap in their range. Both species are year round inhabitants of the British Isles and are widely distributed around the coast. Cormorants, however, often migrate landward during the winter months, whilst shags are largely absent from southern and eastern England. Of these species the European shag is the most

South Coast REC Study Area
EECMHM Study Area
UK-France Median Line
Cormorant Nesting Sites
Cormorant Observations (Summer)
Cormorant Observations (Winter)
Aerial Observation Tracks



Great cormorant, *Phalacrocorax carbo* © Barry Stewart

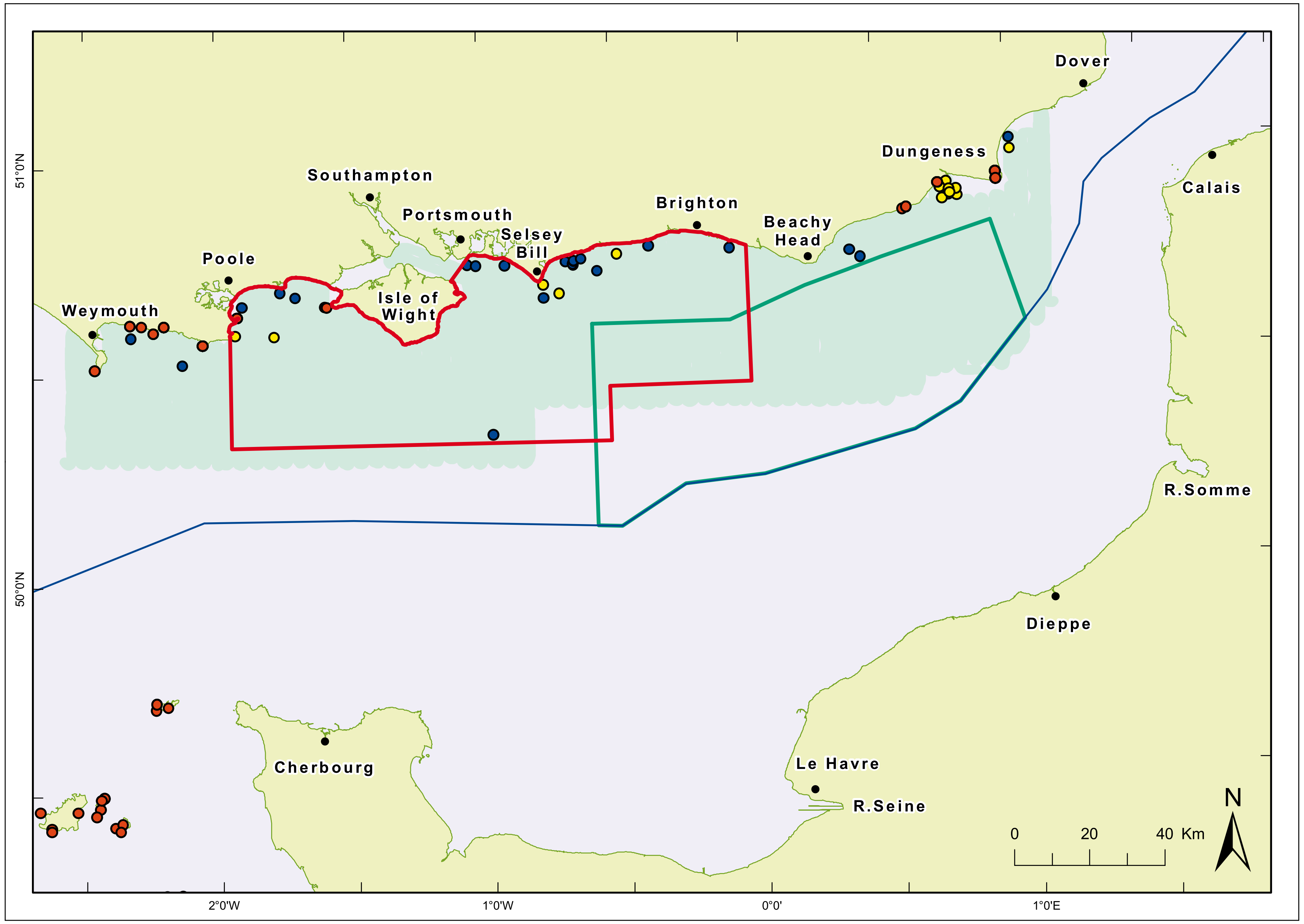
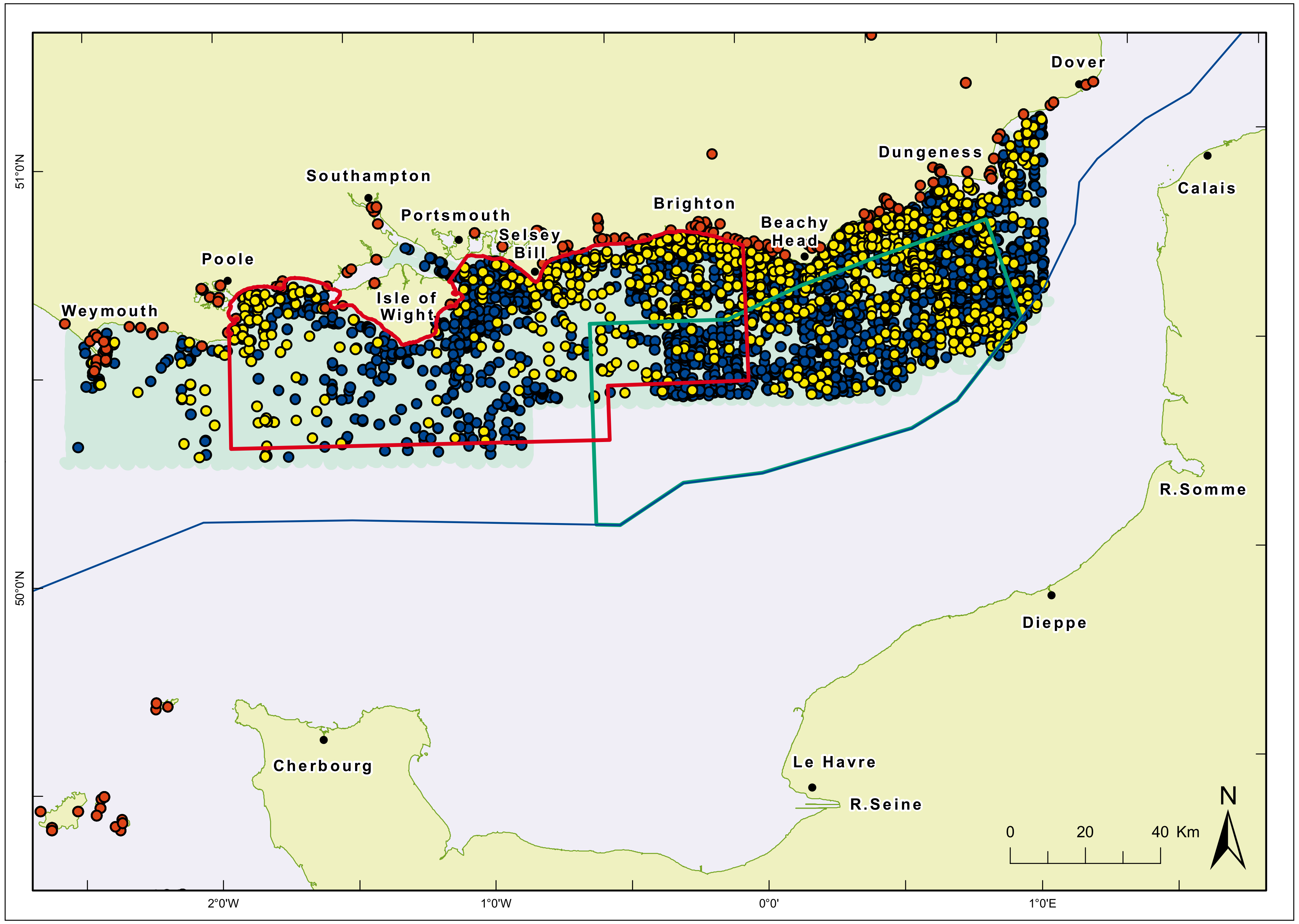


Figure 2.30: Distribution of cormorant observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). Cormorant species encountered include the great cormorant, *Phalacrocorax carbo*, and the European shag, *Phalacrocorax aristotelis*. The distribution of cormorant nesting sites are also shown (JNCC, 2009).

numerous with an estimated 29,000 breeding pairs being found across the UK. In contrast, there are an estimated 10,000 breeding pairs of great cormorants nationwide (RSPB, 2009). Figure 2.30 illustrates the distribution of shag and cormorant nesting sites and observations across the region (JNCC, 2009; WWT Consulting, 2009).

Both the European shag and great cormorant breed near the coast, building nests from marine vegetation and flotsam on cliff faces and in sea caves (BirdLife International, 2004). The great cormorant is also known to nest in trees and shrubs and on inland islands (BirdLife International, 2004). The UK is home to internationally important numbers of breeding cormorants and shags (RSPB, 2009; Parkin and Knox, 2010), with the European shag being particularly sensitive because of the localisation of their breeding sites (i.e. over 50% of the UK breeding population are found at ten or fewer sites). Numerous shag and cormorant breeding sites have been identified within the region although only two exist within the boundaries of the REC study area (Figure 2.30).

European shags are almost exclusively benthic feeders utilising two distinct foraging habitats, sandy areas, and rocky areas with brittle stars, soft coral and kelp (Watanuki *et al.*, 2008). They feed primarily on bottom living fish including sandeels and the butterfish, *Pholis gunnellus*, although smaller numbers of polychaetes, cephalopods and other benthic invertebrates have also been recorded in their diet (Lilliendahl and Solmundsson, 2006; Watanuki *et al.*, 2008). The great cormorant is also a benthic feeder, targeting bottom fish from bare or vegetated sea beds, occasionally also taking shoaling



Black-headed gull, *Larus ridibundus* © Gardline Environmental

Figure 2.31: Distribution of gull observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). Gull species encountered include the black-headed gull, *Larus ridibundus*, the common gull, *Larus canus*, the lesser black-backed gull, *Larus fuscus*, the herring gull, *Larus argentatus*, and the great black-backed gull, *Larus marinus*. The distribution of gull nesting sites are also shown (JNCC, 2009).

fish from deeper waters (BirdLife International, 2004; Lilliendahl and Solmundsson, 2006). Both the European Shag and great cormorant are known to target commercial fish species where they are found in high concentrations which has led to significant persecution by the aquaculture industry (Kirby *et al*., 1996, BirdLife International, 2004, Parkin & Knox, 2010, Smith *et al*., 2008). Oil spills also kill small numbers of great cormorants but despite the links between chemical contaminants and reproductive failure these impacts do not appear to impact on populations (Parkin and Knox, 2010, Budworth *et al*., 2000). European shag populations increased through the 20th century following the reduction of human exploitation for food (Potts, 1969) and the removal of a bounty directed at great cormorants in 1981 (Parkin and Knox, 2010). Localised declines in European shag populations have also been reported to be caused by paralytic shellfish poisoning (Armstrong *et al*., 1978) and adverse weather conditions (Harris and Wanless, 1996). The recovery of European shag following localised population declines is thought to be very good however, and so the progressive and widespread decline in this species remains a mystery (Parkin and Knox, 2010).

Gulls

Gulls are small to large sea birds which can live inland for part of the year, although some species are fully marine. Most gulls are grey, black and white when fully mature (Figure 2.31) but the juveniles are mottled brown. Gull species occurring in the region include the herring gull *Larus argentatus*, the great black-backed

South Coast REC Study Area
EECMHM Study Area
UK-France Median Line
Kittiwake Nesting Sites
Kittiwake Observations (Summer)
Kittiwake Observations (Winter)
Aerial Observation Tracks

Kittiwake, *Rissa tridactyla* © Barry Stewart

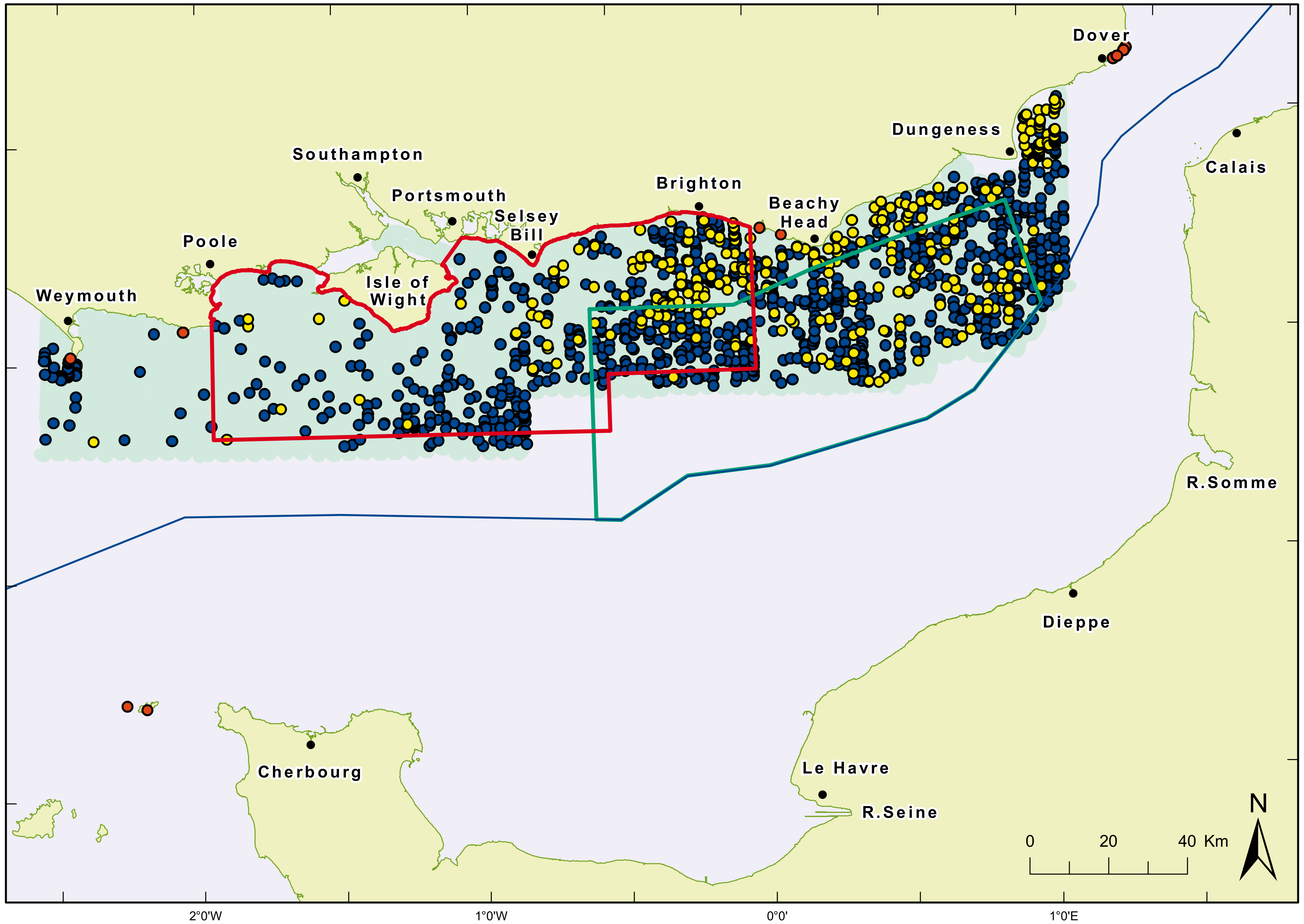


Figure 2.32: Distribution of kittiwake, *Rissa tridactyla*, observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). The distribution of kittiwake nesting sites are also shown (JNCC, 2009).

gull *Larus marinus*, the black-headed gull *Larus ridibundus*, the common gull *Larus canus*, the lesser black-backed gull *Larus fuscus* and the Mediterranean gull *Larus melanocephalus*. Collectively, these gulls are found in high numbers across the region (Figure 2.31) and most are widely distributed around the UK coast (RSPB, 2009). Declines have been reported in all six of these gull species in the UK, attributed to changes in anthropogenic activities and resource availability (Banks *et al.*, 2009). The RSPB has therefore categorised them as of moderate conservation concern (amber status). The greatest decline has been observed in the herring gull population and this coupled with its breeding localisation has earned it a place on the RSPB red list (RSPB, 2009).

Gulls are known to survive on a relatively diverse diet, opportunistically foraging on a range of worms, insects, fish and carrion including commercial fisheries waste (Furness *et al.*, 1989; BirdLife International, 2004; Kim and Monaghan, 2006; RSPB, 2009). Most gulls have no specific breeding habitat, but most show a preference for rocky shores, dunes and shallow wetlands (BirdLife International, 2004). As many of these habitats are found across the region the study area has the potential to provide crucial nesting areas as well as foraging resources. Indeed this is evident in the number of observations and nesting sites identified across the area (Figure 2.31).

Kittiwake

Kittiwakes are medium sized gulls belonging to the genus *Rissa*. There are two species of kittiwake which are very similar in appearance, with the exception of the colour of their legs. The red-

South Coast REC Study Area
EECMHM Study Area
UK-France Median Line
Fulmar Nesting Sites
Fulmar Observations (Summer)
Fulmar Observations (Winter)
Aerial Observation Tracks

Fulmar, *Fulmarus glacialis* © Gardline Environmental

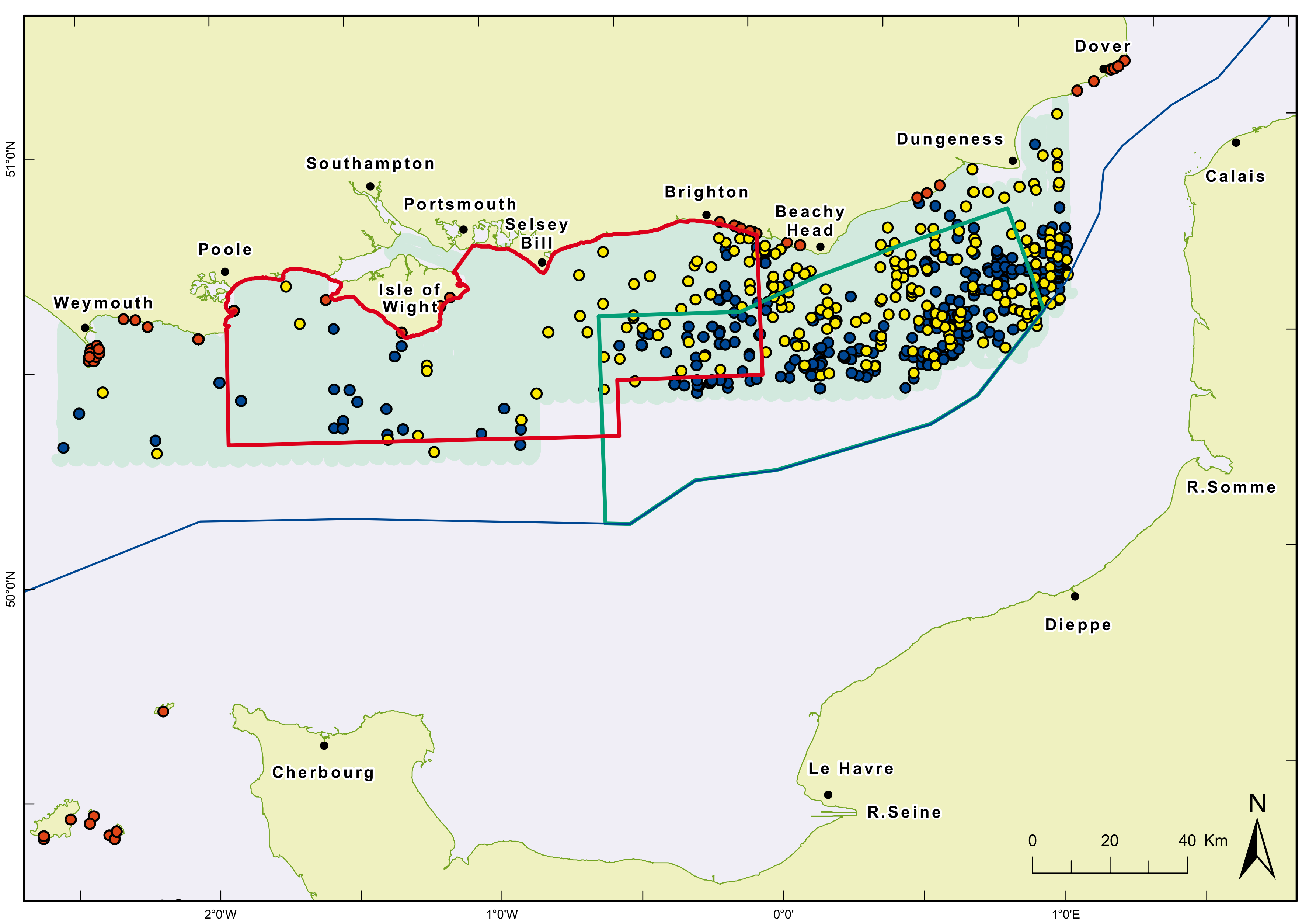


Figure 2.33: Distribution of fulmar, *Fulmarus glacialus*, observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). The distribution of fulmar nesting sites are also shown (JNCC, 2009).

legged kittiwake *Rissa brevirostris*, has a very limited distribution and does not occur in Europe. Conversely the black-legged kittiwake *Rissa tridactyla*, has a relatively cosmopolitan distribution and is one of the most numerous of the sea birds. Black-legged kittiwakes form large, dense colonies at coastal sites during the summer reproductive period but spend the winter months out at sea (RSPB, 2009). They have been observed across the region in high numbers, both in summer and winter (Figure 2.32). A limited number of nesting sites have also been identified.

The black-legged kittiwake is a gentle looking gull with a small yellow bill and dark eyes. It is distinct from other gulls as its black wing tips show no white during flight. The kittiwake breeding population is very large with 379,892 pairs reported in the UK alone (RSPB, 2009). However, this species showed a significant decline (greater than 50%) between 1990 and 2000 (BirdLife International, 2004; Frederiksen *et al.*, 2004) and as such has been assigned Amber Status by the RSPB (2009). The decline in the UK kittiwake population has been linked with a reduction in the abundance and nutritional quality of its preferred prey, the sandeel, and also on increased predation by the great skua, *Catharacta skua* (Oro and Furness, 2002; Frederiksen *et al.*, 2004; Wanless *et al.*, 2007; Votier *et al.*, 2008; JNCC, 2009).

Petrels and shearwaters

Possessing an almost gull-like appearance, the petrels and shearwaters are in fact close relatives of the albatross. These fully marine birds spend the majority of their existence at sea feeding mainly on fish (gadoids, sandeel and capelin) and crustaceans (pelagic zooplankton), but also supplementing their diet with fishery discards (Phillips *et al.*, 1999). Petrels and shearwaters come

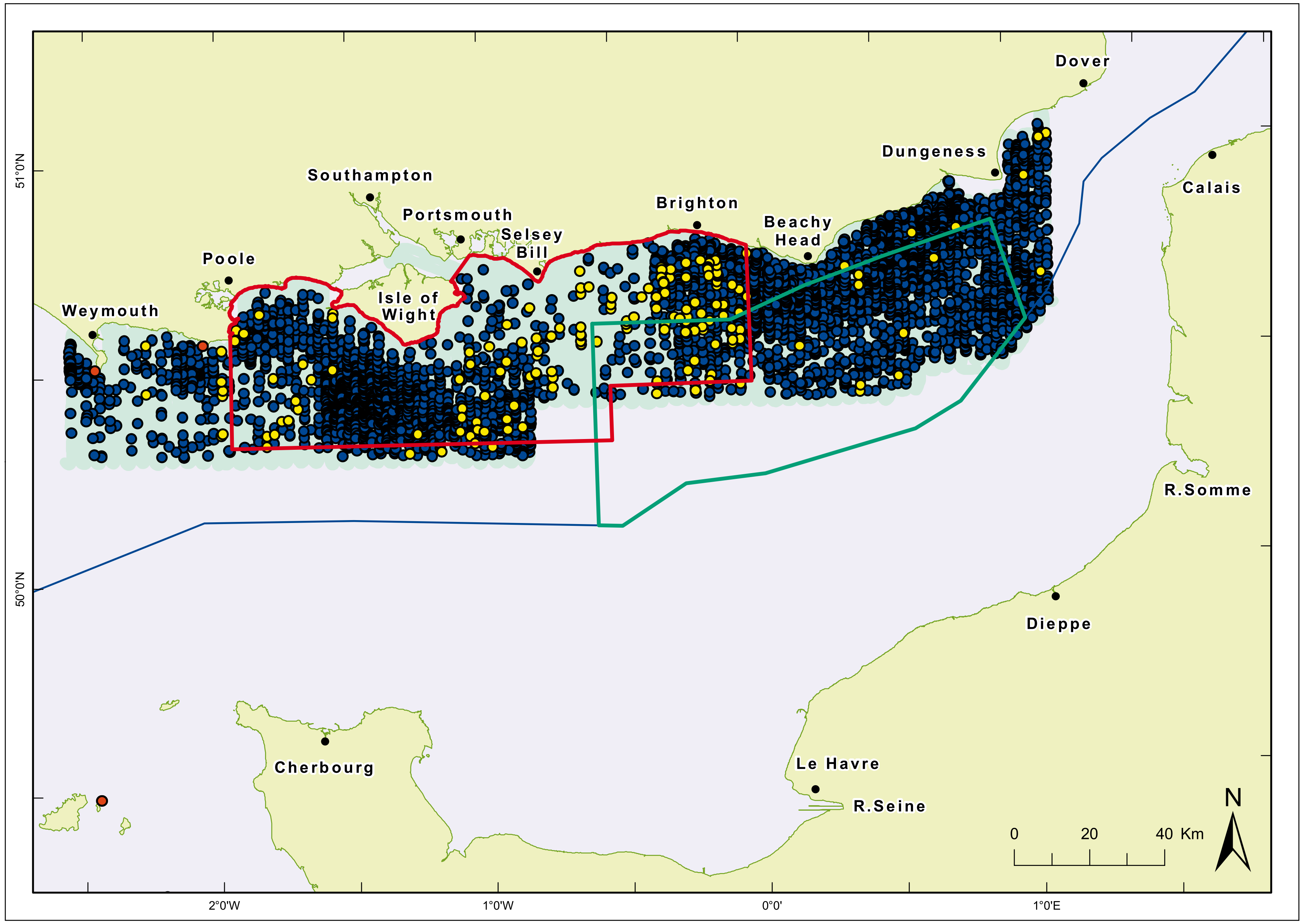


Figure 2.34: Distribution of auk observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). Auk species encountered include the common guillemot, *Uria aalge*, the puffin, *Fratercula arctica* and the razorbill, *Alca torda*. The distribution of auk nesting sites are also shown (JNCC, 2009).

ashore only to breed in burrows and then only under the cover of darkness. Three species have been recorded in the region. The fulmar, *Fulmarus glacialis* being by far the most common, with the manx shearwater, *Puffinus puffinus*, and the storm petrel, *Hydrobates pelagicus*, being observed only in very small numbers. Although not reported in the literature, it is likely that a further two species, the Balearic shearwater, *Puffinus mauretanicus*, and sooty shearwater, *Puffinus griseus*, will also pass through the region during their migrations (BirdLife International, 2004; RSPB, 2009). Fulmar have been observed across the region in both winter and summer, a much higher concentration being observed to the east of Portsmouth (Figure 2.33). Numerous fulmar nesting sites have also been recorded along the coastline, with a particularly high concentration between Brighton and Beachy Head (WWT Consulting, 2009).

The fulmar is present year-round at its breeding sites and can be found at other sites across the UK during the summer. It is estimated that there are 500,000 breeding pairs of this species across the British Isles with further 1–1.5 million birds over-wintering in the UK (RSPB, 2009). Despite these seemingly high numbers there has been a moderate decline in the breeding population. Since this species breeds in dense colonies at only a small number of sites it is all the more sensitive to anthropogenic disturbance and habitat loss. Fulmars have been reported as being particularly susceptible to entanglement in offshore fishing nets and are regularly caught on the baited hooks of long-line fisheries (JNCC, 2009).

Auks

Three species of auk have been recorded in the region, the common guillemot, *Uria aalge*, the puffin, *Fratercula arctica*, and the razorbill, *Alca torda* (RSPB, 2009; WWT Consulting, 2009). Auks are sea birds in the truest sense and spend the majority of their life at sea. Auks return to land only to breed although some species, including the common guillemot, spend a great part of the year defending their nesting sites (Thaxter *et al.*, 2009). The common guillemot and razorbill nest in large colonies on cliff edges. The puffin is also colonial but nests in burrows on grassy cliffs. Two auk nesting sites have been identified within the south coast region, one near Portland and another near Swanage (Figure 2.34). However, the region clearly represents a more significant resource during the winter months, evident in the very high number of auks observed at this time of year.

The auks are superficially similar to penguins due to their black-and-white coloration, their upright posture and also some of their habits. Auks have, to a large extent, sacrificed flight and also mobility on land in exchange for the ability to swim; their wings are a compromise between the best possible design for diving and the bare minimum needed for flying. The common guillemot and razorbill are the most efficient swimmers making them well adapted to target their preferred prey of schooling fish. Puffins are better adapted for flying and walking although they also dive for food including sandeel (RSPB, 2009). All three of these auk species have been assigned amber status despite having large breeding populations in the UK and across Europe. The breeding populations of these birds are concentrated at relatively few sites making them vulnerable to localised changes in environmental conditions, but particularly to changes in prey populations (BirdLife International, 2004; RSPB, 2009).

Grebe

Grebes are usually associated with areas of freshwater, although they can also be found at sheltered coastal sites during the winter months. Five species of grebe have been recorded across the region, the great-crested grebe, *Podiceps cristatus*, the black-necked grebe, *Podiceps nigricollis*, the little grebe, *Tachybaptus ruficollis*, the red-necked grebe, *Podiceps grisegena* and the slavonian or horned grebe, *Podiceps auritus*. Grebes are small to medium sized sea birds which possess elaborate plumage, most have an ornate crest indeed, the great-crested grebe was once nearly hunted to extinction for its valuable and attractive plumage (RSPB, 2009). The great crested grebe is also commonly drowned in monofilament gill nets, which is perhaps its biggest threat in the region. This species breeds in lakes and shallow inshore waters such as reservoirs with abundant emergent vegetation (BirdLife International, 2004; Konter, 2008). The slavonian grebe has a very restricted breeding distribution which , in the UK, is largely confined to Scotland (Parkin and Knox, 2010). There is an over-wintering population of slavonian grebes which utilise the Sussex coast and evidence suggests that these birds will have mostly come from Fennoscandia, with scottish breeders remaining further north (Parkin and Knox, 2010). The black-necked grebe also spends the winter in the region with a known wintering site in Poole Harbour (RSPB, 2009). A small number of red-necked grebe can be found in the UK over the summer and it is suspected that these individuals breed here, however the location of these birds is kept secret in order to protect them. The little grebe is present in the UK all year round and has a comparatively healthy breeding population of over 10,000 pairs (RSPB, 2009).

The larger grebe species feed primarily on fish, sometimes exhibiting flock-fishing behaviour similar to that observed in cormorants and mergansers (Kallander, 2008). Insects, crustaceans (crayfish and shrimp) and molluscs also form an important component in the diet, particularly in the smaller species (BirdLife International, 2004). It is not known how important the region is for grebes in a national context but all have been recorded in the area and it has been reported that the sheltered inshore areas which exist within the region are important for over-wintering (RSPB, 2009). All species except the great-crested grebe have been given amber status by the RSPB. The black-necked grebe, red-necked grebe and slavonian grebe are of moderate conservation concern because of their small breeding populations (<300 pairs). The rationale behind the inclusion of the little grebe in the amber list has not yet been published.

2.8.2 Divers

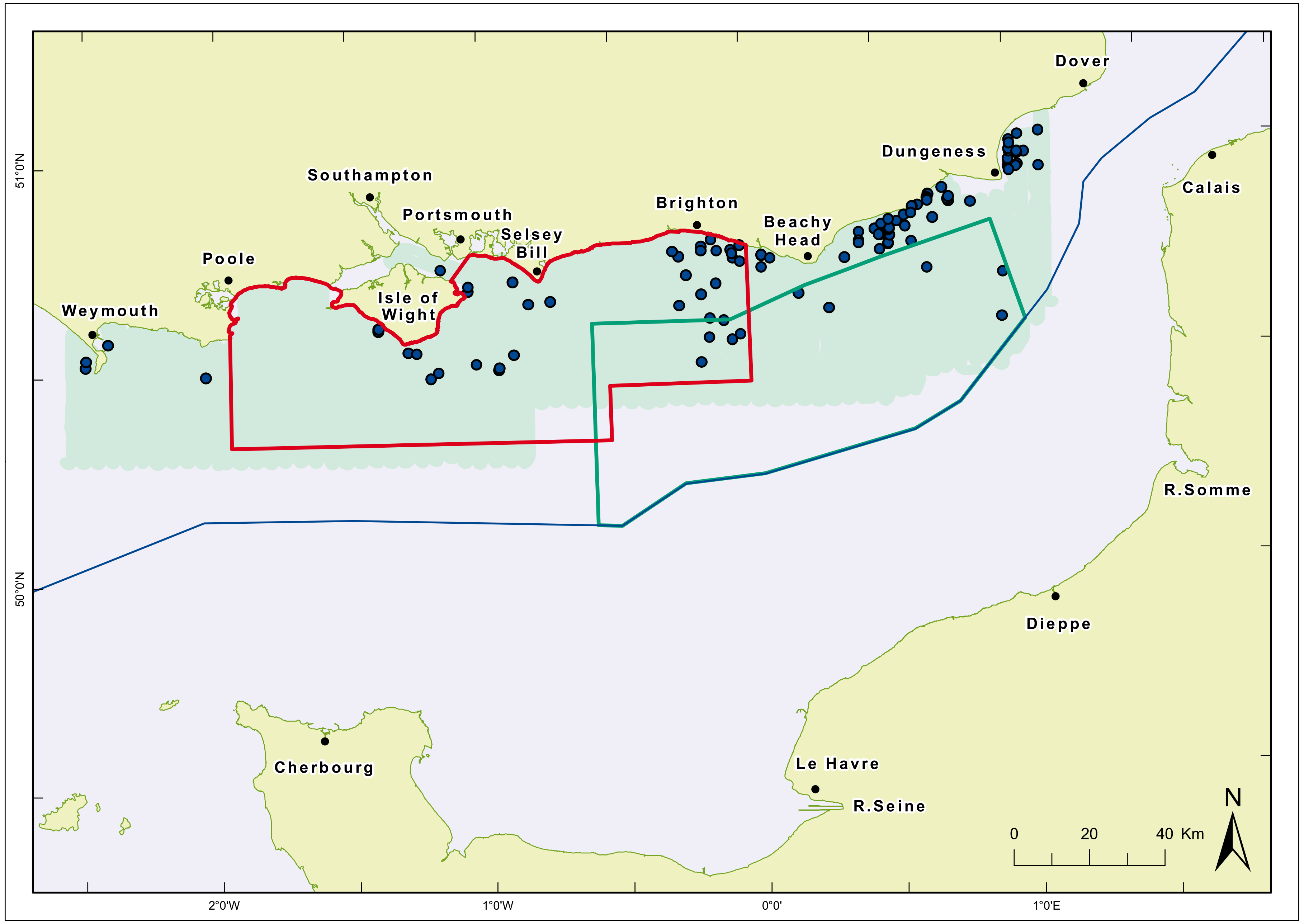
Three species of diver, or loon, have been observed in the region, the red-throated diver, *Gavia stellata*, the black-throated diver, *Gavia arctica* and the great northern diver, *Gavia immer* (JNCC, 2009; WWT Consulting, 2009). Divers are large water birds with long slender bodies and dagger shaped bills. The red-throated is the smallest of the divers and has grey-brown plumage with a distinct red patch on its throat during the summer. The other two divers have dark grey plumage, and all have white bellies (RSPB, 2009). All three divers over-winter in the UK but the red and black-throated divers also breed here, albeit in relatively small numbers (BirdLife International, 2004; RSPB, 2009). All three species have been assigned amber status, as their small population sizes makes them vulnerable to pollution and local disturbances (RSPB, 2009). The region is not thought to be of particular national or international importance to this group, although divers have been observed using the region (WWT Consulting, 2009). Figure 2.35 shows that relatively few divers have been recorded in the region and most of these were observed east of Brighton. No divers were reported in the region during the summer of 2008 (WWT Consulting, 2009).

Divers are excellent swimmers. They use their feet and wings to propel themselves above and below the water, but because their feet are far back on their body they are poorly adapted to moving on land (RSPB, 2009). All diver species are good fliers but have some difficulty taking off and thus must swim into the wind to pick up enough lift to become airborne. Only the red-throated diver can take off from land. Once airborne, the considerable stamina of the divers allows them to migrate long distances southwards in winter, where they reside in coastal waters (RSPB, 2009).

Skua

Skuas are medium to large sea birds typically with grey or brown plumage, often with white markings on the wings. Four species are known to pass through the region, the great skua, *Catharacta skua*, the arctic skua, *Stercorarius parasiticus*, the pomarine skua, *Stercorarius pomarinus* and the long-tailed skua, *Stercorarius longicaudus*, though none of these species use the region to breed or over-winter. Figure 2.36 shows that only a limited number of skuas are observed across the region in both winter and summer. Therefore, it is unlikely that this region represents a significant resource for this group of birds.

Skuas feed on fish, offal and carrion and many are partial kleptoparasites who chase gulls, terns and other sea birds to



Great northern diver, *Gavia immer* © Barry Stewart

Figure 2.35: Distribution of diver observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). Diver species encountered include the great northern diver, *Gavia immer*, the red-throated diver, *Gavia stellata* and the black-throated diver. No divers were observed during the summer.

steal their catches, earning them a reputation as the pirates of the sea. The larger species, such as great skua also regularly kill and eat adult birds such as puffins and gulls (Votier *et al*., 2008; RSPB, 2009). The great pomarine and long-tailed skua have all been assigned green status by the RSPB indicating that their populations are stable and not under-threat in the UK. The arctic skua, however, has been assigned red status because of a recent decline in their breeding population (RSPB, 2009).

Gannet

The northern gannet, *Morus bassanus*, is regularly recorded across the region particularly when migrating south in August and September (RSPB, 2009). This species is patchily distributed across the UK, but the majority of its breeding colonies are found throughout Scotland and in particular the Scottish Isles, with further concentrations in south-west Wales and north-east England. Figure 2.37 shows the gannet observations recorded across the region in summer and winter (WWT Consulting, 2009). This shows that whilst gannets are relatively evenly distributed across the region in summer, they are observed almost exclusively east of Chichester in the winter, possibly reflecting prey distributions. No breeding sites were identified.

The northern gannet is a large and distinctive bird, predominantly white in colour with black tips to its wings and a yellow/cream

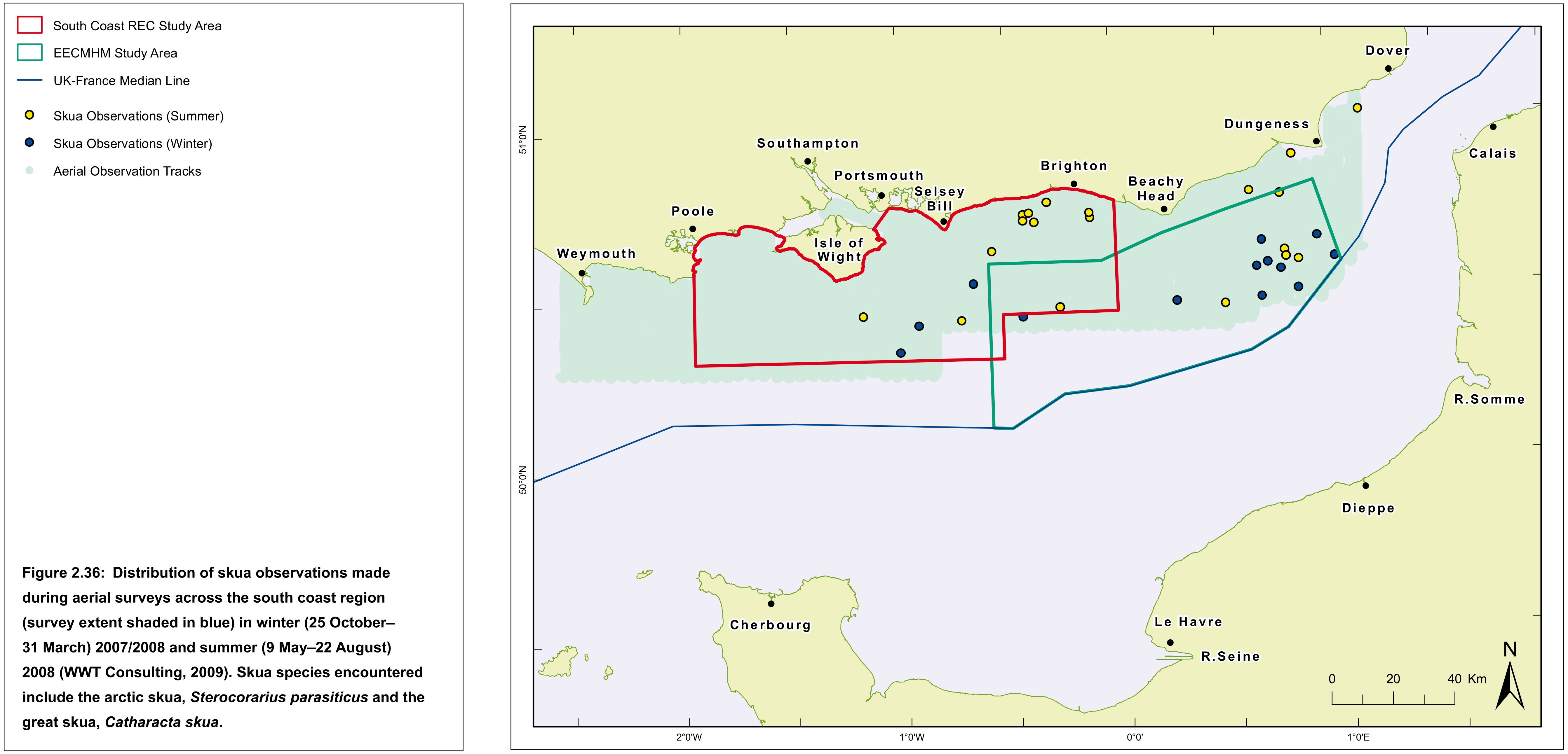
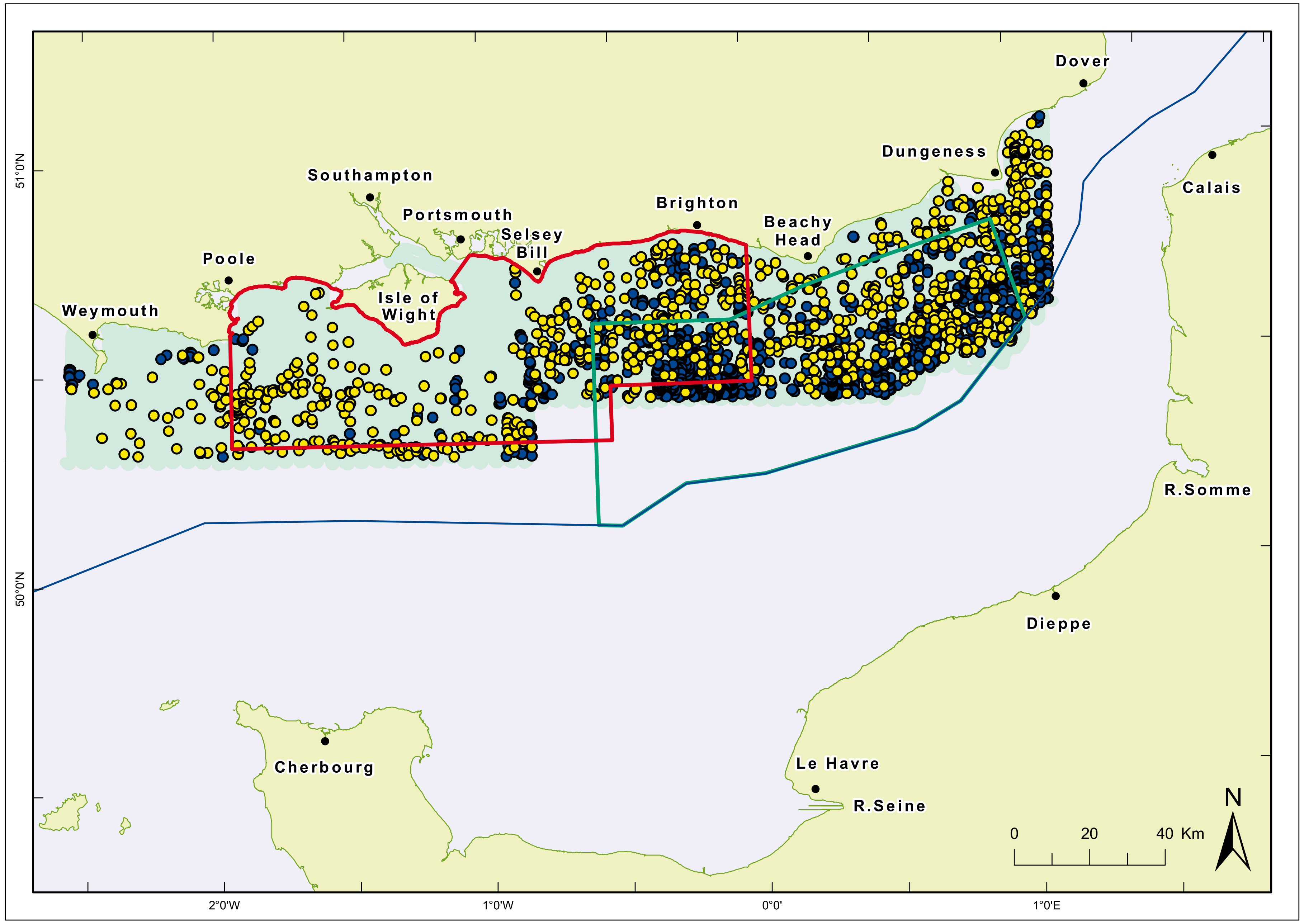


Figure 2.36: Distribution of skua observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). Skua species encountered include the arctic skua, *Sterocorarius parasiticus* and the great skua, *Catharacta skua*.

crown. There are approximately 250,000 breeding pairs of gannet in the UK (RSPB, 2009) but nevertheless their breeding localisation makes them sensitive to habitat loss and disturbance. The northern gannet is a generalist, opportunistic marine predator known to exploit large pelagic fish species including salmon (Montevecchi *et al*., 2009). It is likely therefore that this species will exploit the fish resources in the region although this area is of little importance for breeding.

2.8.3 Wading birds

Numerous wading birds are known to occur in the estuarine and shallow coastal areas of the region, including the avocet, *Recurvirostra avosetta*, dunlin, *Calidris alpine*, black-tailed godwit, *Limosa limosa*, and sanderling, *Calidris alba*. These birds typically have long legs and long beaks which allows them to feed on marine invertebrates and insects living in mudflats (RSPB, 2009). The avocet is perhaps the most well known of the waders as the emblem of the Royal Society for the Protection of Birds (RSPB). The avocet also signifies one of the UK's greatest conservation successes following its return in the 1940s and subsequent population increase (BirdLife International, 2004; RSPB, 2009). Both the dunlin and black-tailed godwit are listed as red status because of recent declines in their populations (BirdLife International, 2004; RSPB, 2009). The wading birds mentioned here and many others are listed as features in the conservation designations across the region (Appendix D1–D6). As their name suggests, these birds are typically found wading in shallow waters



Gannet, *Morus bassanus* © Gardline Environmental

Figure 2.37: Distribution of northern gannet, *Morus bassanus*, observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009).

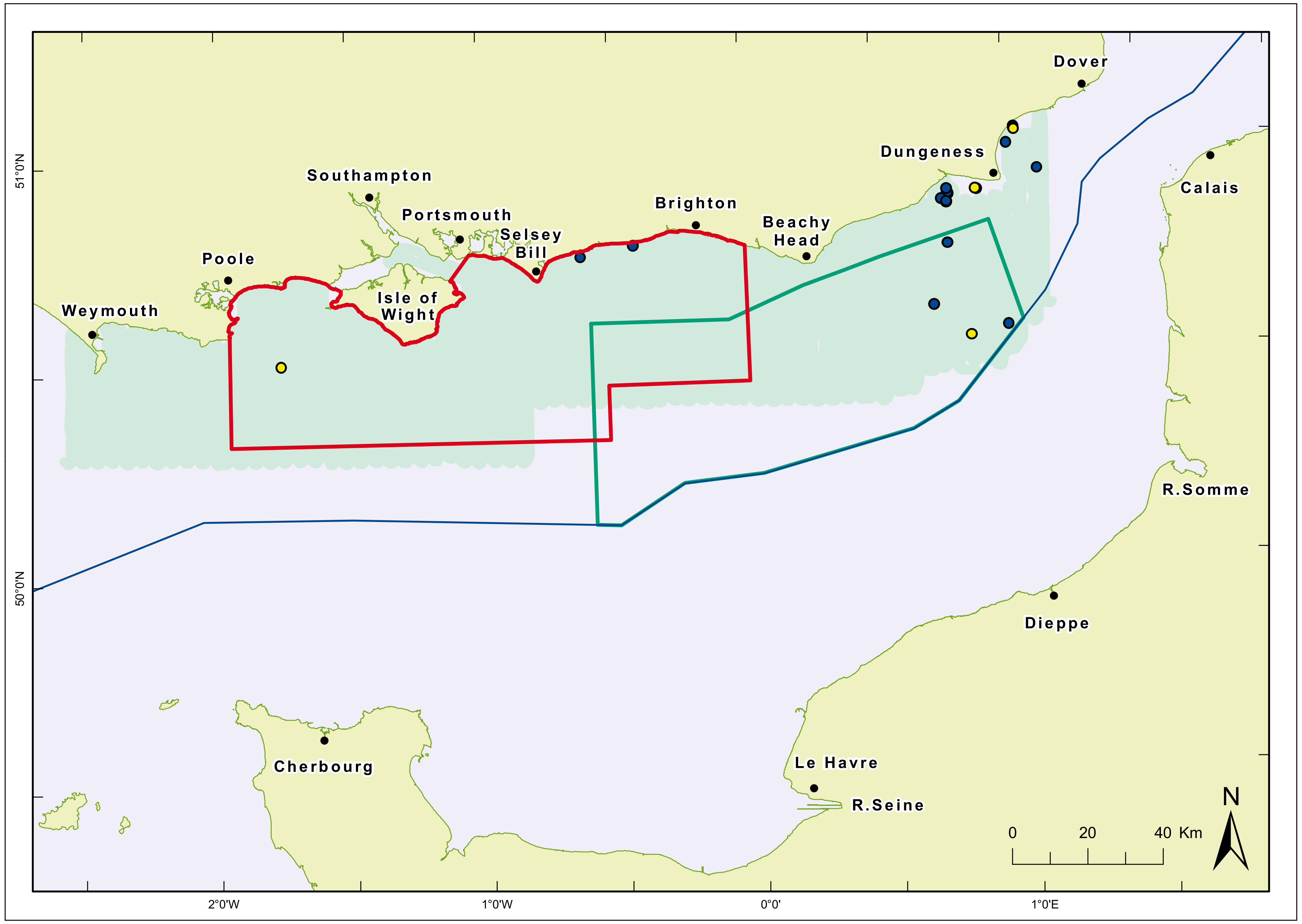
and whilst the region as a whole provides important habitat for these birds, the South Coast REC study area does not.

Swans, ducks and geese

Swans, ducks and geese are often grouped as ‘wildfowl’ and are not sea birds in the truest sense. Members of this family do however utilise coastal resources and many are listed as residents in conservation sites across the region (Appendix D1–D6).

Wildfowl species known to reside in the region include the mute swan, *Cygnus olor*, the dark-bellied brent goose, *Branta bernicla bernicla* (a subspecies of the brent goose, *Branta bernicla*), the red-breasted merganser, *Mergus serrator*, the eider duck, *Somateria mollissima*, the common shelduck, *Tadorna tadorna*, gadwall, *Anas strepera*, and the common scoter, *Melanitta nigra*. Figure 2.38 shows the observations of sea ducks recorded during aerial surveys in 2007 and 2008. Only a small number of duck observations were made during these surveys although this may be an underestimate of the significance of this group in the area since they spend a large proportion of their time on the sea surface rather than in flight.

The dark-bellied brent goose, red-breasted merganser, eider duck and common scoter are all winter residents of the region (RSPB, 2009). The dark-bellied brent goose breeds on the Arctic coasts of central and western Siberia and winters in western Europe with



Eider duck, *Somateria mollissima* © Dave Painter

Figure 2.38: Distribution of sea duck observations made during aerial surveys across the south coast region (survey extent shaded in blue) in winter (25 October–31 March) 2007/2008 and summer (9 May–22 August) 2008 (WWT Consulting, 2009). Sea duck species encountered include the common shelduck, *Tadorna tadorna*, the common scoter, *Melanitta nigra*, and the red-breasted merganser, *Mergus serrator*.

over half the population residing in southern England (BirdLife International, 2004; RSPB, 2009). This wintering population has declined in recent years and is now considered vulnerable (BirdLife International, 2004). There are some 2,370 breeding pairs of red-breasted merganser which reside in the UK all year round (RSPB, 2009). The winter population is supplemented by immigrants from Iceland, Greenland and elsewhere in Northern Europe (Parkin and Knox, 2010). There are however, some 2,370 breeding pairs which are known to reside in the UK year round (RSPB, 2009). Eider ducks and common scoter migrate over much shorter distances from breeding sites in Scotland and Northumberland, and also from Ireland and other parts of Europe (Kirby *et al*., 1993; RSPB, 2009).

The majority of these wildfowl species feed on marine organisms including, small shoaling fish in the case of the red-breasted merganser (Bur *et al*., 2008), eelgrass and seaweed in the case of the brent goose (RSPB, 2009) and shellfish in the case of the eider duck and common scoter (RSPB, 2009). The eider duck shows a particular preference for mussels which are known to be cultivated in the region (See Fisheries — Section 2.10) and this has led to significant persecution of the species by the aquaculture industry (BirdLife International, 2004). It also means that the eider duck is vulnerable to changes in the mussel resources caused by fishing. The mute swan and gadwall feed on riverine plants, insects and snails (RSPB, 2009).

2.8.4 Important prey resources for coastal and sea birds

Many of the sea bird species described above feed primarily on fish species and in particular on sandeels. Sandeel populations have been reported to be in decline in the north-east Atlantic and North Sea as a result of commercial fishing pressures combined with predation by birds, mammals and large fish (Holland *et al*., 2005; Harris *et al*., 2008). A parallel increase in the abundance and range of the snake pipefish *Entelurus aequoreus* has been noted since 2003 and this species has subsequently been recorded in the diet of both juvenile and adult sea birds (Kloppmann and Ulleweit, 2007; Harris *et al*., 2008). Whilst this new, increased abundance of fish might seemingly compensate for a reduction in sandeel populations the inferior nutritional value of the snake pipefish may actually be causing a reduction in breeding success in some sea bird colonies (Harris *et al*., 2008). Many of the species above have been observed having difficulty swallowing and even choking to death on snake pipefish (Harris *et al*., 2008). The sand eel and other prey populations including mussel beds will therefore be of central importance to the future preservation of sea bird populations in the region. These are discussed in further detail in Section 10 — Fisheries.

2.9 Areas of conservation interest

2.9.1 Nature conservation

The waters of the central and eastern English Channel region contain a number of protected sites which are of both national and international importance for nature conservation. In the UK there are several types of protected area, driven by different legislation and conservation priorities. Those which apply to the marine and coastal environment are summarised in Table 2.3.

The Joint Nature Conservation Committee (JNCC) has overall responsibility for the delivery of the UK and international conservation responsibilities of the four country nature conservation agencies — Council for Nature Conservation and the Countryside (Northern Ireland), the Countryside Council for Wales (CCW), Natural England (NE) and Scottish Natural Heritage (SNH). As such the JNCC have a duty to designate Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Sites of Special Scientific Interest (SSSIs) where specified threatened habitats and species occur. Furthermore, the UK government ratified the Ramsar Convention (1971) in 1976. As a signatory of this agreement the UK government is obliged to designate wetlands of international significance as Ramsar sites. Other nationally and locally important marine resources are protected through designations such as Marine Nature Reserves (MNR) National Nature Reserves (NNR) and marine Site of Nature Conservation Importance (mSNCI).

The UK has signed up to international agreements that aim to establish an 'ecologically coherent network of Marine Protected Areas (MPAs)' by 2012. This network will be made up of current MPAs as well as new type of MPA called a Marine Conservation Zone (MCZ) which will be designated under the Marine and Coastal Access Bill, which received royal assent on the 12th November 2009.

The network is being designed to deliver greater protection benefits than individual areas could on their own. Two projects are tasked with designing the network of MPAs and MCZs in the region. These are 'Balanced Seas' (www.balancedseas.org/) which covers the area east of the Dorset — Hampshire county boundary, which lies between Poole and Bournemouth, and 'Finding Sanctuary' (www.finding-sanctuary.org/) which covers the region west of this boundary.

Many threatened habitats and species are found across the South Coast REC study area and hence a number of protected sites have been established in the region. Designated sites often have a number of features which may be of importance in both a national and European context. An area of land may also hold a number of different designations. Maps of the designated sites in and around

Designation	Abbreviation	Legislation	Importance	Focus of protection
Special Areas of Conservation	SAC	European Habitats Directive (92/43/EEC)	European	Habitats and species (as listed under Annex I and Annex II of the Directive)
Special Protection Areas	SPA	European Wild Birds Directive (79/409/EEC)	European	Birds and habitats used by birds (bird species specified in Annex I of the Directive)
Ramsar Sites	Ramsar	Convention on Wetlands of International Importance (1971)	International	Wetlands utilised by birds
Protected Place or Controlled Site		Protection of Military Remains Act (1986)	International	Protection for the wreckage of military aircraft and vessels.
Historic Wreck		Protection of Wrecks Act (1973)	National	Sites identified as being likely to contain the remains of a vessel, or its contents, which are of historical, artistic or archaeological importance.
Sites of Special Scientific Interest	SSSI	Wildlife and Countryside Act (1981)	National	Species, habitats and geological features of national importance
National Nature Reserves	NNRs	Wildlife and Countryside Act (1981)	National	Best UK examples of SSSIs — species, habitats and geological features of national importance
Marine Nature Reserves	MNR	Wildlife and Countryside Act (1981)	National	Marine flora and fauna and geological/ physiographical features of special interest (e.g. Lundy Island) — to be replaced by MCZs
Marine Conservation Zones	MCZ	The Marine and Coastal Access Act (2009)	National	Nationally important marine wildlife, habitats, geology and geomorphology. The focus will extend to include the full range of UK marine wildlife not just those considered rare or threatened.
marine Sites of Nature Conservation Importance	mSNCI	N/A	Local	Non-statutory locally valued wildlife sites
Voluntary Marine Conservation Area	VMCA	N/A	Local	Areas of coastline which are of particular wildlife and scientific value that enjoy a level of voluntary protection. These are often extensions of statutory, terrestrial or coastal designations.

Table 2.3: Summary of marine and coastal conservation designations in the UK, their underlying legislation, level of importance and protection focus.

the South Coast REC area are presented in Figure 2.39 and 2.40. Figure 2.39 illustrates the distribution of conservation designations of International and European importance, SPAs, Ramsar Sites, SACs and dSACs (draft SACs) in the region. SSSIs often underpin the higher level designations presented in Figure 2.39, therefore, in order to produce clear figures, these sites have been presented in Figure 2.40, alongside other national and local conservation designations (NNRs and mSNCIs).

2.9.2 Protected sites of International and European importance

A relatively large number of protected sites designated under International and European legislation are found within the immediate vicinity of the South Coast REC study area (Natural England, 2009a, b, c). This is a result of the ecological diversity found within this area, which contains expanses of open sea, a varied coastline, estuaries, harbours, woodland, heath, many different types of wetland and other habitats. The significance of these habitats and species is reflected in the multiple designations applied to many of the sites.

Twenty eight internationally important sites have been designated within the region. A total of 9 SACs and 1 draft SAC exist in the region, with 8 SPAs and 10 Ramsar sites also present (Natural England, 2009c). However, the overwhelming majority of these are either coastal or fully terrestrial and are found beyond the borders of the South Coast REC study area itself. The names, sizes, and key features of each of the internationally important sites depicted in Figures 2.39 and 2.40 are listed in Appendix D1–D3.

Three internationally important sites exist within the South Coast REC study area. These sites consist of two SACs and one draft SAC (dSAC). A brief discussion of these sites and their primary reasons for designation is presented below.

South Wight Maritime SAC

In terms of size, the most significant internationally important protected site found within the South Coast REC study area is the South Wight Maritime SAC. This is relatively large, covering an area of almost 20,000 ha offshore from the Isle of Wight. This site has been designated in order to provide protection for three major features of interest namely, reefs, sea caves and cliffs.

A variety of different reef types are found at this site, however, of greatest significance are the chalk reefs and exposures which support diverse assemblages of species across the subtidal and intertidal zones. Other reef forms are also present with boulder reefs and hard rock reefs occurring in patches across the site.

The high energy of the waves, prevalent around the coast of the Isle of Wight, has had a profound impact in shaping the coastline of the island. Waves have eroded the cliffs of the area, resulting in the presence of submerged or partially submerged sea caves. The sea caves found at this site are highly significant as they are the only known examples of subtidal chalk caves in the UK. Sea caves are an important habitat as they often support a unique suite of species.

The sea cliffs found across the coastline of the South Wight Maritime SAC are of international significance as a result of the assemblages of vegetation which they support. A mosaic of exposed and sheltered, species rich calcareous grassland, chalk grassland, mesotrophic and acid grassland exists within the SAC. Patches of scrub and woodland are also present.

Solent Maritime SAC

The second most important protected site, in terms of size, to be found within the boundaries of the South Coast REC area is the Solent Maritime SAC. The site covers a total of 11,325 ha. It was primarily designated in order to conserve three major habitats, estuaries, cord-grass *(Spartina)* swards, and Atlantic salt meadows. However, a further nine qualifying features are also present.

The estuaries found across the Solent area are of international scientific interest because of their number and physical diversity. A total of four bar-built and four coastal plain estuaries are present. The Solent and its embayments, harbours and estuaries are unique in a European context, being subject to four tides each day. Extensive sand and mud flats are found across the estuaries of the Solent, seagrass *(Zostera)* beds are also present. Highly rare sponges are also to be found, as are patches of Ross worm, *Sabellaria spinulosa* reef.

The Solent Maritime SAC represents the only example of a site at which the smooth cord-grass, *Spartina alterniflora*, is found in the UK. It is also one of only two UK sites at which significant expanses of the small cord-grass *Spartina maritime*, are found. Patches of other *Spartina* species are also represented here.

The Solent Maritime SAC contains the second largest aggregations of Atlantic salt meadows in the south west. This feature is particularly notable as it represents an ungrazed form of this habitat, and unusual transitions to freshwater reed swamp and alluvial woodland and coastal grassland are also present.

Poole Bay to Lyme Bay dSAC

The designation of the Poole Bay to Lyme Bay SAC has recently been proposed by JNCC and Natural England. This site is therefore a ‘draft’ SAC. The draft SAC site covers just under 20,000 ha, however, only a very small proportion of the easternmost fringes encroach the boundary of the South Coast REC study area.

The Poole Bay to Lyme Bay dSAC has been put forward for designation on the basis of the sea caves and diverse array of different reef forms found within its boundaries. The site is host to bedrock, pebble, cobble and boulders. Biogenic reefs such as those formed by the Ross worm, *Sabellaria spinulosa*, and the mussel, *Mytilus edulis*, are also found across the site.

2.9.3 Nationally important protected sites

Sites of Special Scientific Interest (SSSIs) are sites which the country conservation agencies such as Natural England deem to be ‘of special interest by reason of any of its flora, fauna, or geological or physiographical features’. SSSIs are sites which are perceived to be important at a national level. National Nature Reserves (NNRs) are another type of nationally important site. NNRs are representatives of the very best examples of the UK’s wildlife habitats and geological features. The habitats found on NNRs are usually managed by a government agency or a proxy organisation. They are frequently open to the public as places for learning and recreation. There are also a limited number of Marine Nature Reserves (MNRs) which have been designated across the UK although none of these exist within the region.

Marine Sites of Nature Conservation Importance (mSNCIs) are nonstatutory sites which are designated in order to provide protection for wildlife and habitats or features of geological and geomorphological interest. These sites are essentially a marine

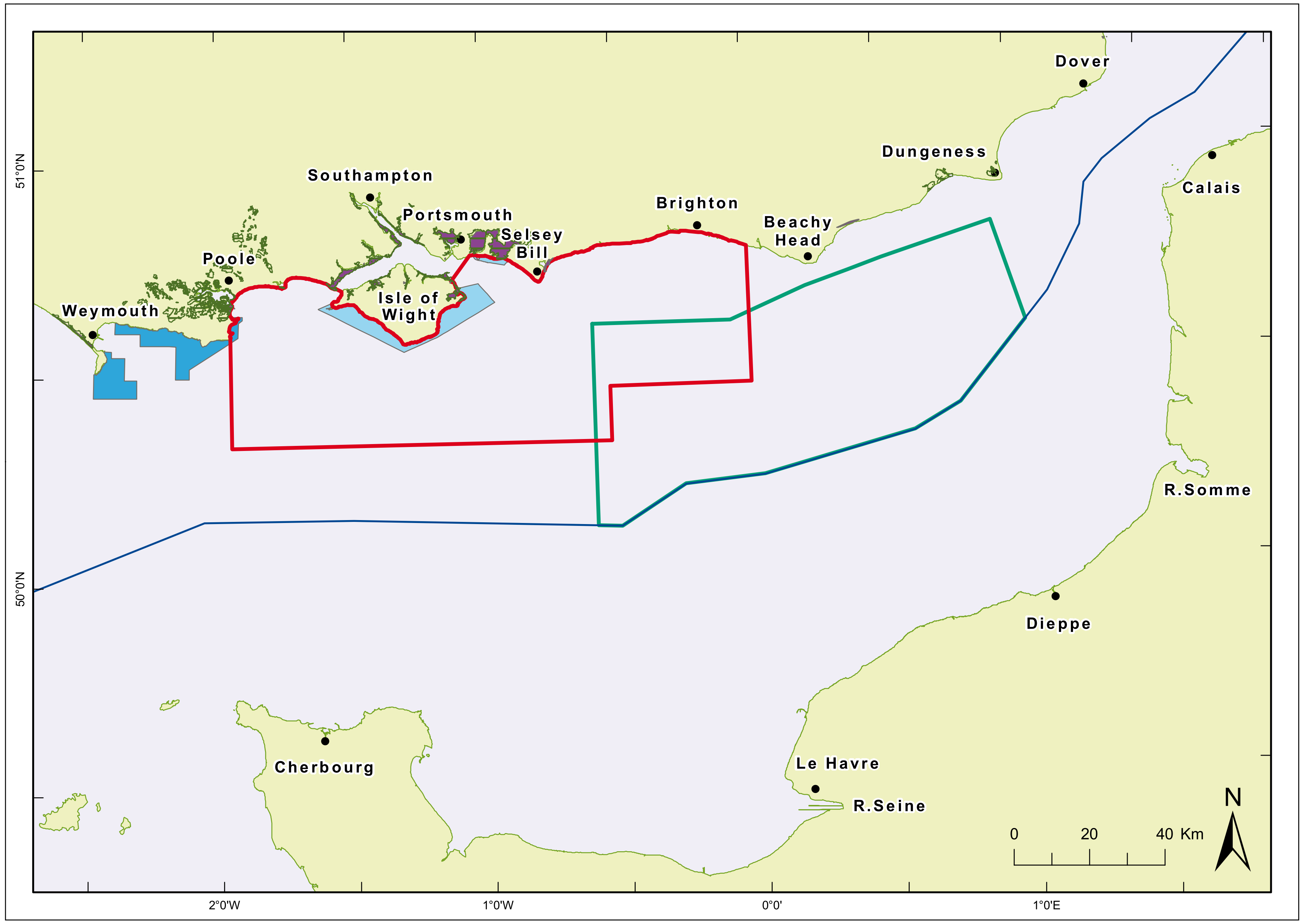


Figure 2.39: European and International marine and coastal (<1 km inland) conservation designations, Special Protection Areas (SPAs), Ramsar sites, Special Areas of Conservation (SACs) and draft Special Areas of Conservation (dSACs) in the south coast region (Natural England, 2009a, b).

equivalent of the terrestrial Sites of Importance for Nature Conservation (SINCs) and as such are designated at a local level by relevant county councils. There are a total of 12 mSNCIs in the region. There are also a suite of Voluntary Marine Conservation Areas (VMCAs) which have been set up around the UK. These are usually founded by local communities and organisations and are often extensions of existing terrestrial or coastal designated sites. The Seven Sisters Voluntary Marine Conservation Area is the only voluntary marine reserve in the region and was set up to protect sublittoral chalk and sandstone reefs offshore from the Seven Sisters SSSI (South Downs Joint Committee, 2009).

The distribution of SSSIs, NNRs, mSNCIs and VMCAs within the region are depicted in Figure 2.40. Whilst a vast number of these sites occur across the region, relatively few lie wholly within the boundaries of the South Coast REC. The names of these sites and their reasons for designation are given in Appendix D4 to D7.

Ten nationally protected sites exist within the South Coast REC study area and all of these are mSNCIs. A brief discussion of these sites and their primary reasons for designation is presented below.

The Bracklesham Balls

The Bracklesham Balls are an unusual, though not unique, geological feature. They are believed to be concretions of marl and shells and are thought to be the evidence of debris forced ahead of

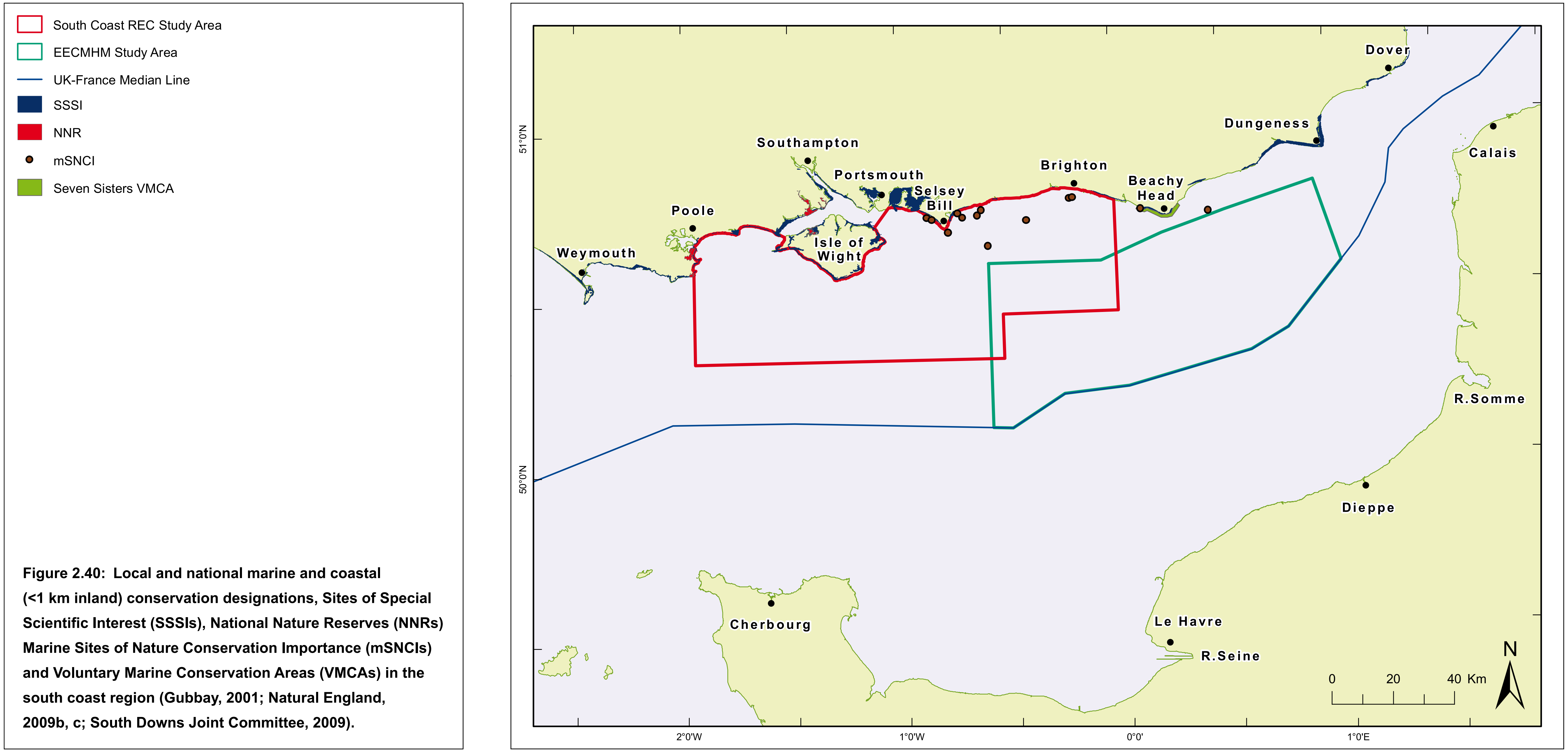


Figure 2.40: Local and national marine and coastal (<1 km inland) conservation designations, Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNRs) Marine Sites of Nature Conservation Importance (mSNCIs) and Voluntary Marine Conservation Areas (VMCAs) in the south coast region (Gubbay, 2001; Natural England, 2009b, c; South Downs Joint Committee, 2009).

the glaciers during the ice age. These large balls exist in numerous shapes and sizes, some of them reaching 8 ft in diameter, and perfectly round whilst others lay segmented or split in half. They are home to spider crabs, wrasse and dogfish and have become a popular recreational dive site. The tops of the shallowest boulders may be colonised by kelp and an assortment of red foliose algae. In deeper water hydroids and bryozoans are more dominant with occasional anemones, soft corals, sponges and ascidians. The surrounding sea bed is muddy sand, gravel and shell (Gubbay, 2001).

Mixon Hole

Mixon Hole is a famous dive site 1.5 km off Selsey Bill. Here the sea bed plummets suddenly from shallow sand down a precipitous wall of clay rock, dropping 30 m to a gravelly sea bed. Mixon Hole is thought by some to be the remains of a Roman fort or quarry used to supply the garrison town of Chichester (Natural England, 2009d). Others report its origin as an ancient river gorge swept clear by tidal currents (Gubbay, 2001). Whatever its origin, the Mixon Hole is a locally, and potentially nationally, unique geological feature.

The upper part of the Mixon Hole cliff is capped in limestone bedrock on the northern side, which breaks the water at low tide. At around 4 m the cliff forms a ledge with loose limestone slabs covered by foliose red algae. Below this the soft grey clay of the main cliff is exposed, with numerous ledges, crevices and fissures.

Unstable areas are uncolonised but other areas are extensively bored by piddocks. Crustaceans including lobsters and hermit crabs make use of the ledges and shoals of fish aggregate close to the cliff face. On the sea floor there are ball shaped rocks covered in sponges, hydroids and ascidians. The Mixon Hole is of interest to marine archaeologists because the remains of worked stone at the bottom are known to date back to Roman times (Gubbay, 2001).

HMS Northcoates

Known locally as the 'Armed Trawler' *HMS Northcoates* is a wreck of fishing vessel converted for minesweeping duties during World War II. The wreck lies upright in 26 m of water and remains largely intact. The surrounding sea bed sediment is composed of silty gravel deposits with coarse shell fragments (Gubbay, 2001). Like other wrecks in this area, the *HMS Northcoates* has become home to many marine animals. Vertical surfaces are dominated by bryozoan and hydroid turfs interspersed with patches of Devonshire cup coral and jewel anemones, both of which are at the eastern limit of their known distribution. Other anemones, soft corals and sponges also encrust the wreck whilst the surrounding sediments have been colonised by sandmason worms, *Lanice conchilega*, mussels and burrowing anemones (Gubbay, 2001). The wreck is also associated with a number of fish species, the most common being bib *Trisopterus luscus*, and poor cod, *Trisopterus minutus*.

Inner and outer Mulberry Harbour units

The Inner and Outer Mulberry Harbour Units are of interest for historic reasons and for their artificial reef communities. Both are wreckages of World War II Mulberry units off the coast of west Sussex, between Bognor Regis and Worthing. The steel reinforced concrete structures have eroded in places to expose steel rods and internal flotation compartments. The surfaces support substantial epilithic growth in the form of kelps, foliose algae, hydroid and bryozoan turfs as well as barnacles and mussels (Gubbay, 2001). Plumose and jewel anemones, soft corals and the native oyster colonise the internal surfaces. Fish species which have been observed to aggregate around the wreck include wrasse, pollack, bib and blennies.

The Waldrons Reef

Waldrons Reef is an extensive area of sandstone bedrock outcrops with large boulders, cobbles, pebbles and gravel offshore of west Sussex to the east of Bognor Regis. The rock has eroded away to form many fissures, crevices, overhangs and holes and hence is considered to be an excellent example of sandstone reef. The origin of these boulders is unknown, but it has been suggested that they were deposited by drift–ice melted during the glacial phase or that they are discarded ballast from early shipping.

The bedrock surfaces are encrusted in pink calcareous algae, foliose algae and sparse stunted kelp plants. Waldrons Reef is particularly rich in sponges with 24 species having been recorded including some rare species (Gubbay, 2001). Invertebrates are not common on this reef, perhaps because of the scarcity of finer sediments, but crustaceans and cuttlefish have been observed there. Fish, including the ballan wrasse, goldsinny and tompot blenny also seem to aggregate around this feature.

Shelley rocks

Shelley Rocks is an extensive area of shallow mixed sediments including boulders, cobbles, gravel and shell, sand on chalk bedrock and exposures of grey clay. This area has not been chosen for any one particularly unique feature but because of the wide range of substrates present in a relatively small area. All of these substrate types are common off the coast of west Sussex. The high habitat heterogeneity within this area supports a wide variety of marine life including epilithic species such as kelps, algae, hydroids and bryozoans, boring piddocks and mobile species such as whelks, cuttlefish and lumpsucker fish (Gubbay, 2001).

Worthing lumps

The Worthing Lumps are two northerly facing chalk cliff exposures ranging in height from 2–3 m, separated by an area of coarse mixed sediments approximately 200–300 m wide. Sublittoral exposures of chalk are rare on a national basis although they are relatively common off the coast of Sussex. This site has been designated as it is thought to represent the best examples of sublittoral cliffs in the region (Gubbay, 2001).

The cliff exposures provide a range of microhabitats which support a variety of marine life including foliose algae, bryozoan and hydroid turfs, tube worms, piddocks and the black tar sponge (Gubbay, 2001). Mobile life associated with the exposures includes crabs, gobies and blennies.

South-west rocks

The South-west Rocks are another example of chalk cliff exposures. They reach a maximum height of 2 m but extend for 270 m in length. The cliffs are protected because they are thought to be home to a small group of burrowing sea cucumbers found occupying abandoned piddock holes in a survey carried out in 1990 (Gubbay, 2001). This is believed to be the only record of this burrowing sea cucumber in the eastern English Channel although they have not been recorded since this time. The cowrie, *Trivia arctica* is also common in some areas.

Looe Gate

Looe Gate is a low lying chalk cliff surrounded by silty sand and shell debris. Like the other designated chalk cliff exposures Looe Gate supports a variety of marine life including faunal turfs, piddocks and a variety of fish (Gubbay, 2001).

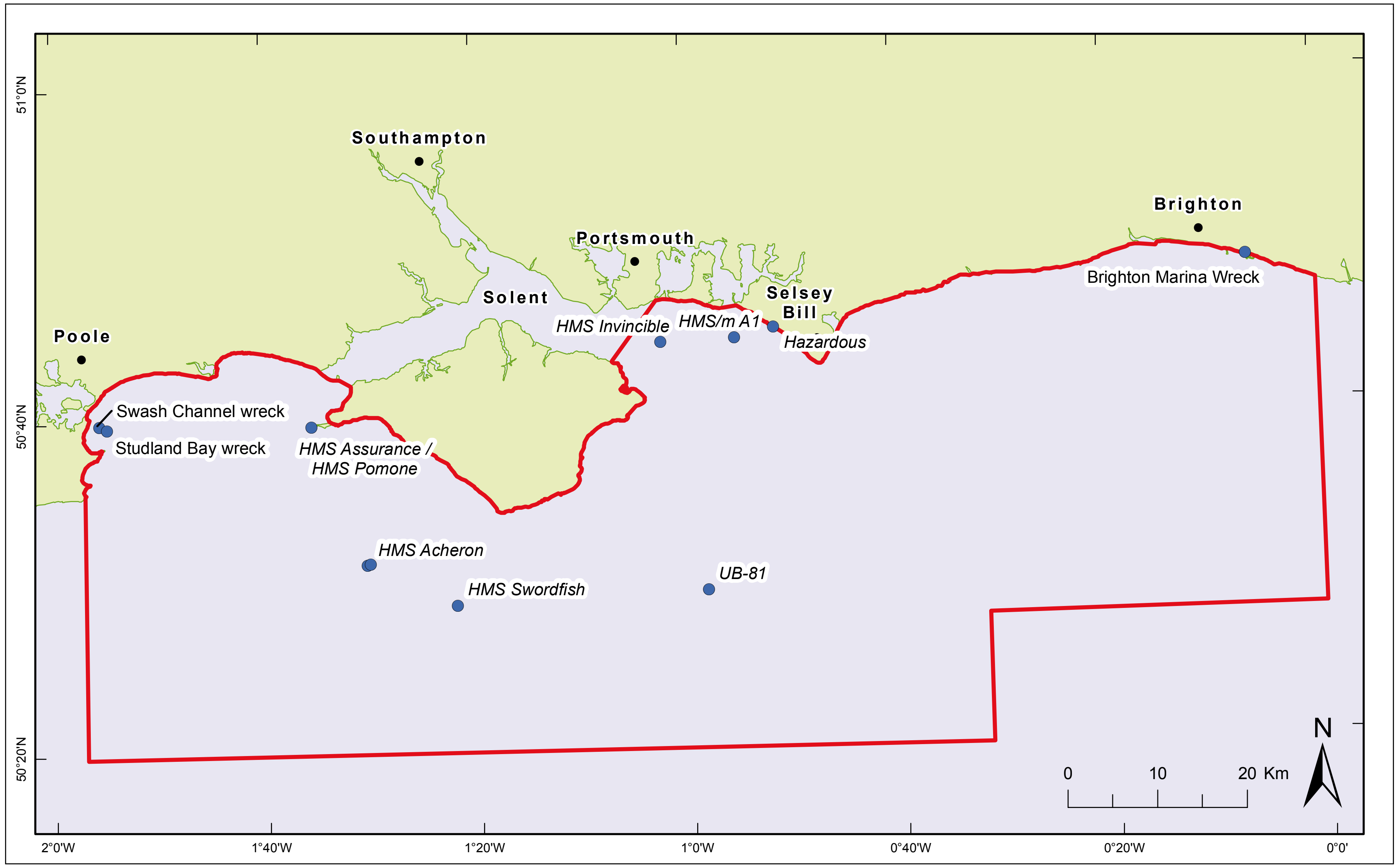


Figure 2.41: Location of protected wreck sites covered under the Protection of Wrecks Act (1973) or the Protection of Military Remains Act (1986).

2.9.4 Historic sites

A number of nationally important wreck sites are found within the South Coast REC study area (Figure 2.41). These sites are designated under the Protection of Wrecks Act (PWA) (1973) which identifies an area surrounding the historic wreck site within which it is a criminal offence to conduct diving or salvage operations, remove any part of the site or deposit anything such as anchors or fishing gear without an appropriate licence from the Secretary of State. In the South Coast REC study area the designations and licensing of the PWA sites are administered by English Heritage.

These PWA sites have been granted protection after having been identified as being likely to contain the remains of a vessel, or its contents, which are of historical, artistic or archaeological importance. Each wreck site is assessed on its individual merits with judgements made using a number of criteria including period, rarity, survival, vulnerability and diversity. Nationally the protected sites range from cargoes of Middle Bronze Age metal work through to large 20th century vessels. Government policy recognises that there are likely to be many undesignated sites of national importance in UK waters.

Seven protected wreck sites lie within the South Coast REC study area out of a total of 61 historic wreck sites currently protected by designation in the UK. This relatively large number of protected wreck sites within the study area reflects the fact that the south coast of England has numerous ports which have been in use for centuries by both civilian and military vessels.

A brief summary of the protected historic wreck sites which lie within the South Coast REC study area is presented below.

Swash channel

This site was discovered by geophysical survey in 2004 (Figure 2.42) and is the remains of an unidentified wooden vessel that lies on the eastern edge of the Swash Channel, in the approaches to Poole Harbour. At least two large sections of the side of the vessel's hull survive, including the rare survival of top timbers (Figure 2.43). The wreck site is over 40 m in length.

The surviving structure includes unusual features such as circular ports, and a rare survival in the form of at least one decorative carving. The vessel identification and the circumstances of the wrecking event are currently uncertain. However, limited pottery evidence suggests that the wrecking event is likely to have occurred in the mid 17th century (Wessex Archaeology, 2004a).

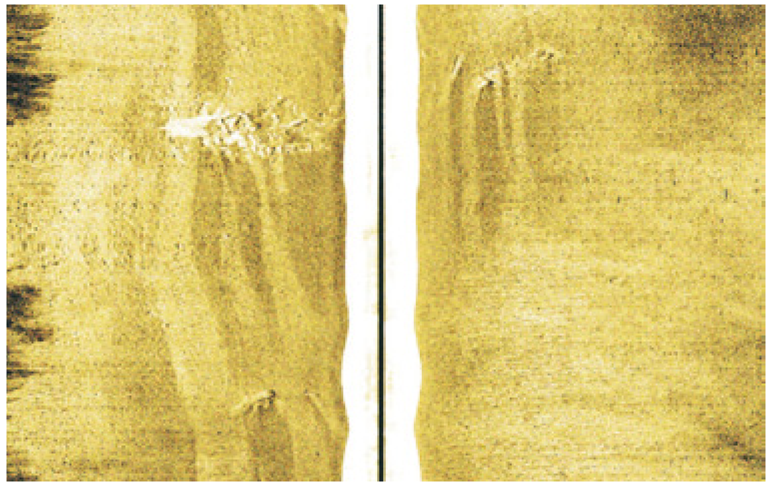


Figure 2.42: Sidescan sonar image of the Swash Channel Wreck. The data (acquired with a 50 m range setting) shows the wreck site which is approximately 40 m long with associated debris lying up to 40 m from the main site © Wessex Archaeology.

Figure 2.43: Photograph of the Swash Channel Wreck main site showing a section of the hull. The curvature of this structure suggests that it is part of the lower section of the vessels hull © Wessex Archaeology.

Studland Bay

Discovered in 1983 the site is thought to be the remains of a lightly armed merchant vessel which lies to the south-east of the entrance to Poole Harbour. The wreck is spread over a wide area and over 750 artefacts have been recovered during excavation. The vessel was of carvel style construction and is thought to date from the 16th century, while the cargo was pottery of the type known as Isabella Polychrome which was made in Seville for export to the West Indies and is rarely found in the UK. The site is designated for its rarity and archaeological significance (English Heritage 2009).

Needles

The site was discovered in 1970 and is thought to contain the remains of two vessels; *HMS Assurance*, a 44 gun, 5th rate warship lost in 1753, and *HMS Pomone*, a 38 gun, 5th rate warship lost in 1811. Material from these wrecks is spread over a wide area, mostly on an exposed wave cut platform. Over 3500 artefacts have been excavated from the site (Fenwick and Gale, 1998).

Hazardous

Originally a 3rd rate vessel in the French Navy the *Hazardous*, built in 1698, was captured by the British in 1703 and refitted and commissioned into the Royal Navy as a 4th rate vessel in 1704. In 1706 the *Hazardous* was one of four vessels acting as an escort for a convoy which had arrived from Virginia heading for the Thames Estuary. The *Hazardous* sought shelter from bad weather off the south coast of the Isle of Wight but was forced into Bracklesham Bay where the captain ran the ship aground to save the crew. The site was discovered by divers in 1977 in 7 m of water, just 800 m from the shore with some sections of the hull having been well preseved by sand cover. (English Heritage, 2009).

Invincible

The *Invincible*, built in 1744, was a 3rd rate, 74 gun warship in the French Navy before being captured by the British and being commissioned into the Royal Navy in 1747. The *Invincible* had been anchored in the Solent in February 1758 while awaiting orders to sail for Canada, as part of a fleet sent to combat the French. A series of problems which occurred while trying to raise her anchor ended with the rudder becoming jammed and the vessel running aground on Horse Tail Sands. Attempts were made to lighten the *Invincible* over the next few days by removing guns and stores but eventually the vessel rolled over and finally sank on the 22nd February 1758. The site was discovered in May 1979 by divers who investigated the site after a local fisherman's nets became caught on an obstruction (English Heritage, 2009).

HMS/m A1

This site was discovered by divers after fishing gear had been snagged on the wreck in 1989. Built by Vickers in 1902 the wreck of the *HMS/m A1* represents the remains of the first truly British designed and built submarine (Figure 2.44). The *HMS/m A1* sank twice in her career, first in 1904 when all 11 crew were lost following collision with another vessel during exercises. The *HMS/m A1* was lost in 1911 while being operated under automatic pilot as a submerged target for antisubmarine warfare training off Selsey Bill. The position of the loss was recorded but the wreck could not be found during subsequent surveys. It is thought that some residual buoyancy remained after the *HMS/m A1* sank, which coupled with the strong tides in the area is thought to account for the vessel finally coming to rest some five miles from its last known position (English Heritage, 2009).

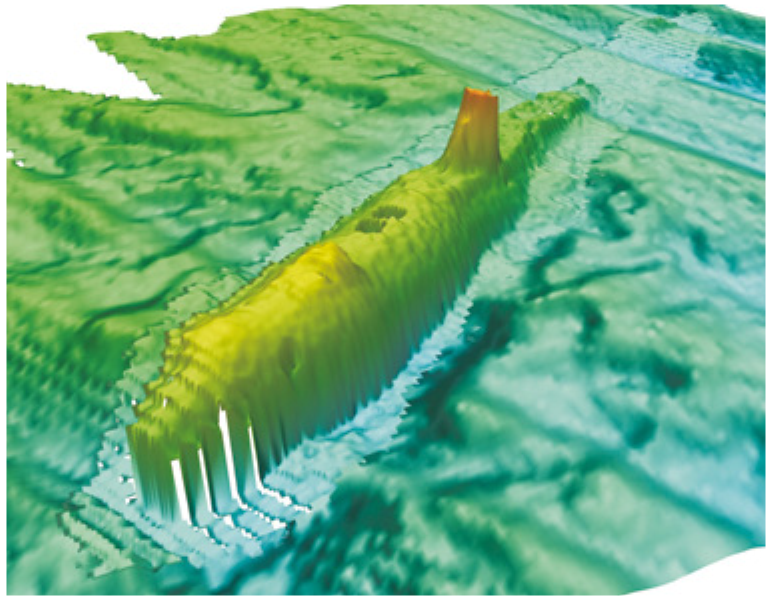


Figure 2.44: Multibeam image of the *HMS/m A1* submarine. The two uncovered hatches in front of the conning tower are clearly visible and evidence of the progressive degradation of the site due to diver theft and vandalism © Wessex Archaeology.

Brighton marina

This wreck site was discovered by divers in 1974, although at least one cannon had been recovered from the area in the 1960s. The site consisted of a number of bronze and iron guns, along with other associated artefacts, and is the remains of an unidentified armed vessel which may date to the late 15th century. The debris trail which form the site is orientated from west to east and has been interpreted as formed from a ship which ran aground in this direction. The designated site lies just outside the breakwater for Brighton Marina (Fenwick and Gale, 1998).

2.9.5 Military sites

The sites of military wrecks are designated as either 'protected places' or 'controlled sites' under the Protection of Military Remains Act (PMRA) (1986). This designation is primarily designed to protect war graves; however, the loss need not have occurred during a time of war.

Protected places are wreck sites which are designated by name, even if the exact location of the wreck is unknown. This type of designation allows all military aircraft to automatically be covered even if the location of the aircraft can not be identified. These sites may be visited by divers but it is a criminal offence to interfere, disturb or remove anything from these sites. Controlled sites are designated by location and can be applied to any military craft which was lost after 1786. It is a criminal offence to conduct any operations on these sites, including diving without a licence from the Ministry of Defence.

There are currently 46 protected places and 12 controlled sites, designated under the PMRA although these numbers do not include any aircraft sites. Of these wreck sites, three protected places and one controlled site lie within the South Coast REC study area.

A brief summary of the Protected Military Remains wreck sites which lie within the South Coast REC study area is presented below.

HMS Acheron

HMS Acheron was a 98 m long, 1350 ton destroyer which was launched in 1930 and which had served in the North Sea and North Western Approaches during the early stages of the Second World War. In July 1940 the *HMS Acheron* was operating in the English Channel when the vessel was damaged by German dive bombers. Repairs were carried out in Portsmouth dockyard and were fully completed by early December 1940, after which the vessel was undertaking trials offshore of the Isle of Wight when she struck a mine and sank with the loss of 196 crewmen and is designated as a protected place.

HMS Loyalty

HMS Loyalty was launched in December 1942 and originally named *HMS Rattler*. The vessel was renamed as *HMS Loyalty* in April 1943 and was a 69 m long minesweeper. *HMS Loyalty* was involved in the Normandy landings in 1944 and cleared a channel to Gold Beach. *HMS Loyalty* was lost in August 1944 while returning to Portsmouth when she was attacked and sunk by the German U-boat *U480* and is designated as a protected place.

HMS Swordfish

HMS Swordfish was an S class submarine launched in 1931. She departed from Portsmouth on the 7 November 1940 and is thought to have struck a mine off shore of the Isle of Wight sometime soon after with the loss of all 40 crewmen aboard and is designated as a protected place.

UB81

UB81 was a German U-boat which was launched in September 1917 and sank in December that year. The vessel first struck a mine and was then struck by a British patrol boat causing it to sink. Only seven of the 34 crewmen survived and the wreck is now designated as a controlled site.

Within the South Coast REC study area the *HMS Fisgard II* and *HMS Mourne* are currently under consideration for designation as protected places while the *SS Mendi* has already been approved for designation.

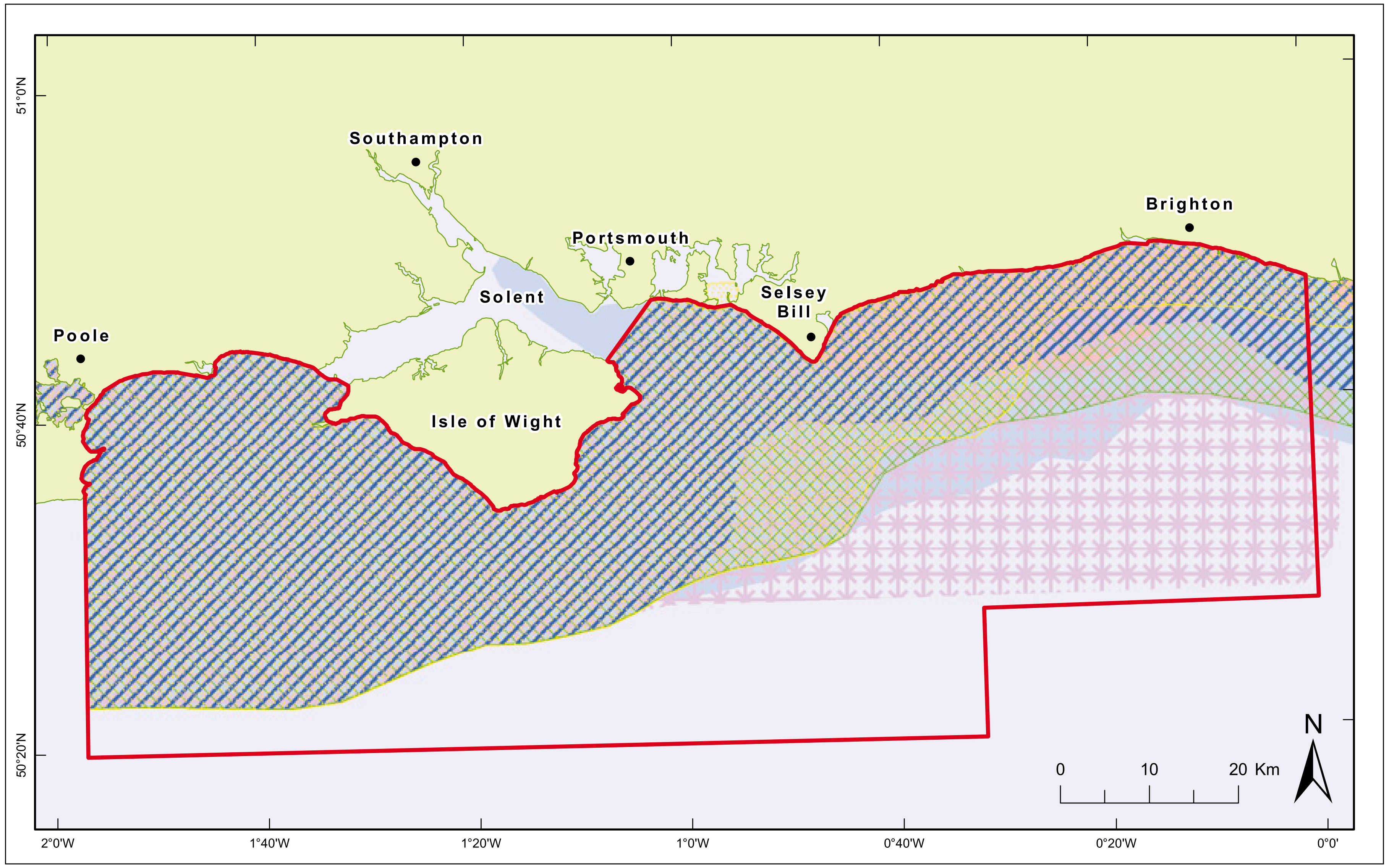
In addition to the sites designated under the Protection of Wrecks Act or the Protection of Military Remains Act, sites which are designated under other legislation may also be of archaeological importance, such as the Mulberry Harbour off the coast of west Sussex which is designated as a marine Site of Nature Conservation Importance (Section 2.9.1).

2.10 Fisheries

Fisheries in the European Union (EU) are managed under the Common Fisheries Policy (CFP), however by way of derogation, territorial seas up to the 12 nautical mile limit are managed exclusively by the nation state. In order to promote sustainability of fishing activities in EU waters and protect a specific stock or a group of stocks the EU CFP has introduced a number of conservation measures which include Total Allowable Catch (TAC) limits and technical measures such as mesh sizes, selective fishing gear, closed areas, minimum landing sizes, and by-catch limits.

Category	Subcategory	Species	Fishing gear
Finfish	Roundfish	Cod and whiting	Demersal otter trawl, pair trawl seine net, gill net, trammel net, longline and handline
	Flatfish	Dover sole, plaice, lemon sole, brill, turbot	Beam trawl, demersal otter trawl, seine net, tangle net, trammel net and longline
	Large pelagic	Sea bass, black bream, red mullet and baillon's wrasse	Gill net, pelagic trawl, beach seine, trolling and handline
	Small pelagic	Mackerel, herring and sprat	Gill net, pelagic trawl and handline
	Diadromous fish	Salmon, sea trout and eel	Gill net and beach seine (salmonids), trap hand held nets, otter trawl and fyke nets (eels)
	Elasmobranches	Thornback ray and skate	Beam trawl, demersal otter trawl, seine net, tangle net and trammel net
Shellfish	Crustacea	Lobster, edible/brown crab, spider crab, velvet swimming crab and prawns	Pots (parlour and inkwell), tangle net and beam trawl
	Molluscs	Oysters, scallops, whelks, clams, periwinkles, cockles, mussels and cuttlefish	Dredge (bivalves) traps and trawl (cuttlefish) pot (whelks) and hand-gather (bivalves and gastropods)

Table 2.4: A summary of the main types of fishing gear used in the South Coast region to catch specific species or groups of species.



Beam Trawler
© Sussex Sea Fisheries Committee

Offshore BeamTrawler
© Sussex Sea Fisheries Committee

Figure 2.45: Chart showing the approximate extents of fisheries targeting finfish in the South Coast region (Poseidon, 2003; Cooper, 2005; Drake, 2006; Clark, 2008).

In the UK the fishing rights in the 6–12 nautical mile area are shared by UK vessels and those of countries which have historic fishing rights. In the South Coast region (which falls within ICES subrectangle VIId) France has the right to exploit all species, and east of Selsey Bill they are joined by Belgian vessels that have the right to catch demersal fish only. Within the 0–6 nautical mile limit only UK vessels are allowed to operate and these are regulated by Sea Fisheries Committees, introduced in 1988 through the Sea Fisheries Regulation Act. The South Coast region falls under the jurisdiction of the Southern Sea Fisheries District Committee, who are responsible for the area between Lyme Regis and the Isle of Wight, and Sussex Sea Fisheries District Committee, who have a remit for the area between Chichester Harbour and Dungeness.

Under the Marine and Coastal Access Act (2009) the Sea Fisheries Committees will be replaced by Inshore Fisheries and Conservation Authorities (IFCAs).

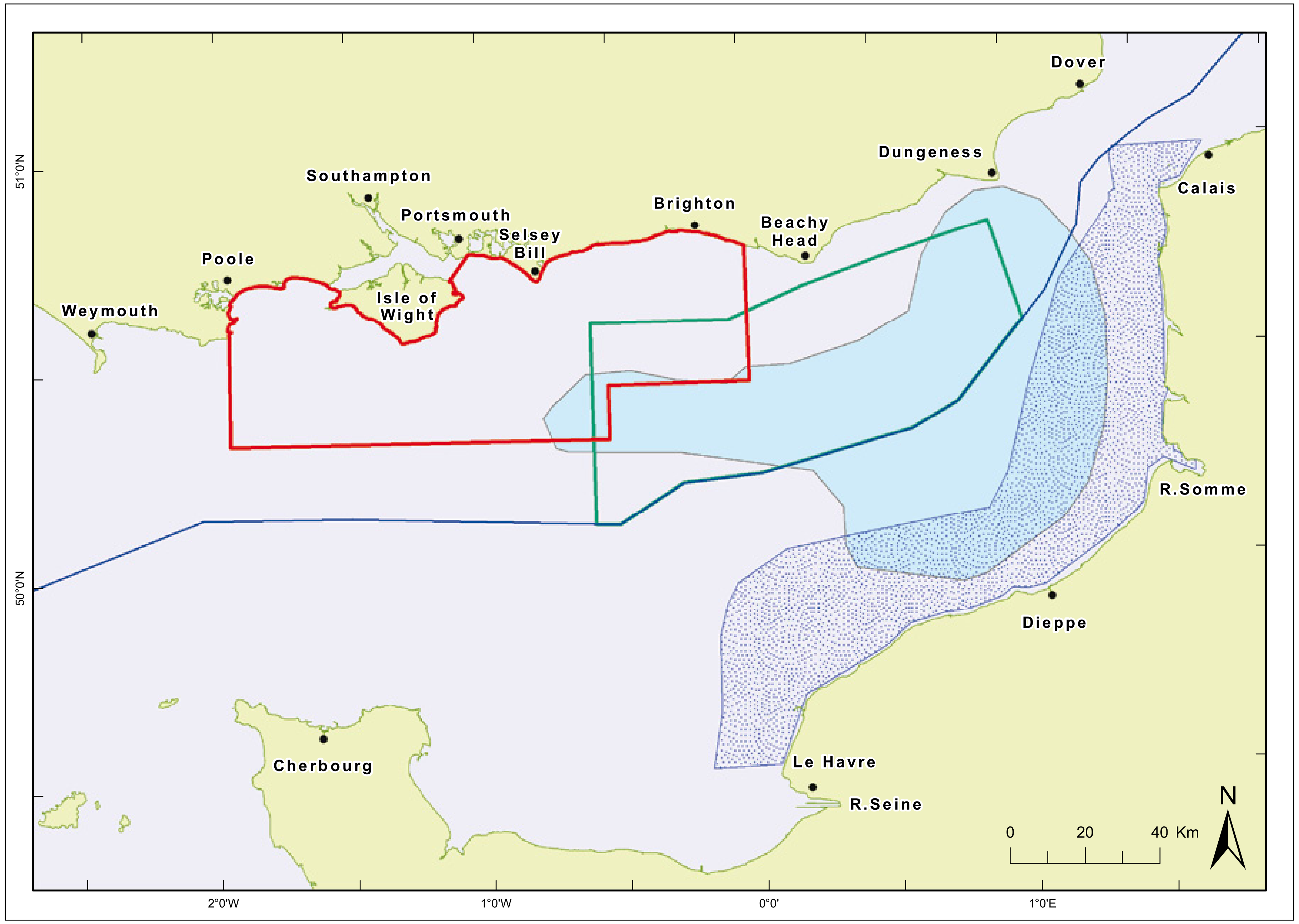
2.10.1 Finfish

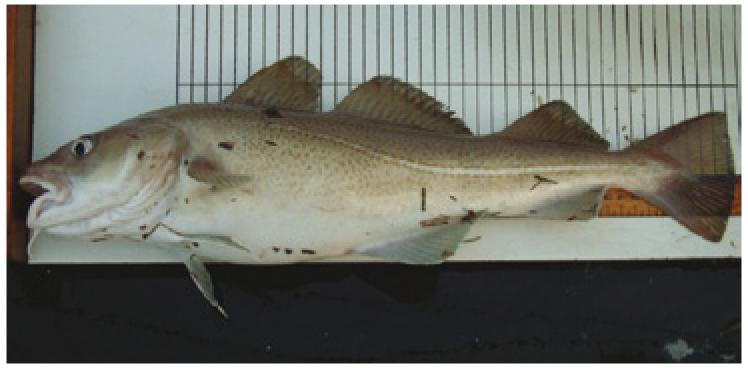
Figure 2.45 shows the approximate extents of fisheries targeting finfish in the South Coast area. The main fin fishery areas are concentrated to the east of the Isle of Wight and netting activities are further restricted to the inshore areas. It should be noted that these apparent concentrations of fishing effort may, in part, be a reflection of biases in the data reviewed. Sussex Sea Fisheries Committee take a very proactive approach to the management of fisheries in their jurisdiction and as part of this, collect and report data in a manner which is easily accessible and re-used by other stakeholders. Such a scientific approach to data collection, analysis and subsequent reporting is not commonplace and equivalent data on fishing activity further offshore and to the west of the Isle of Wight is not as comprehensive.

2.10.2 Roundfish

Cod — *Gadus morhua*

The cod, *Gadhus morhua*, is one of Britain's most important commercial species. Cod is a stout-bodied fish with a long chin barbel and distinct mottled markings along its back (Figure 2.46). Cod are widely distributed around the UK although fishing





Cod, *Gadus morhua* © www.seasurvey.co.uk

Figure 2.46: Cod, *Gadhus morhua*, spawning and nursery ground in the eastern English Channel (Poseidon, 2003).

pressures mean that it is less common in our waters than it has been historically. The feeding ecology of cod is comparatively well documented (Armstrong, 1982; Mattson, 1990; Dubuit, 1995) and this species is thought to be a generalist feeder, preying on a variety of fish and benthic invertebrates, particularly Crustacea.

Cod breed prolifically with females producing between 3 and 6 million eggs in a single spawning event. Unlike many of the fish targeted by commercial fisheries in the UK, they prefer cold waters for spawning and are known to migrate to well-defined spawning grounds offshore, from early spring. Cod tend to spawn at depths of about 200 m although in the North Sea they are known to spawn between 20 m and 100 m. In the Channel cod spawn between January and April with a peak in late February (Poseidon, 2003). Spawning areas in this region include Dieppe, the Baie de Seine, Bassurelle Bank and the central Channel between Beachy Head and Dieppe (Figure 2.46). It is generally accepted that once the spawning season is over the juvenile cod drift into coastal nursery areas. Indeed, young cod can be found in estuaries and shallow waters off Denmark, Germany, Holland and the UK.

Juvenile cod in the eastern Channel probably originate from eggs spawned by adults in the same area, but it is thought that the Channel may also be an important nursery ground for cod which subsequently migrate back to the North Sea (Poseidon, 2003). In this regard there is almost certainly some interaction between the two stocks.

ICES classify the VIId cod stocks as suffering reduced reproductive capacity and as being harvested sustainably, for this reason quota levels remain low. The small quota means that the cod fishery is currently limited in the South Coast region (Cappell and Nimmo, 2007; Clark, 2008).

Whiting — *Merlangius merlangus*

The whiting, *Merlangius merlangus* (Figure 2.47), is an important commercial fish species belonging to the same family as the cod and as such has been widely studied. It is common on all UK coasts, often found in large shoals. Juvenile whiting are known to feed predominantly on crustaceans with a shift towards fish as they mature (Hostens and Mees, 1999; Elliot *et al*., 2002; Pinnegar *et al*., 2003; Stafford *et al*., 2007). Whiting spawn in open waters between January and July, but mostly in early spring. Temperature seems to be the main trigger for spawning in this species with 5–10°C being optimal. Females produce up 300,000 eggs per year which, after hatching, remain in the plankton for as long as a year.

Figure 2.47: Whiting, *Merlangius merlangus* © seasurvey.co.uk

Juvenile whiting (~3 cm) have often been found sheltering in the tentacles of large jellyfish such as Cyanea lamarkii and Chrysaora isocoles, moving up into the bell to avoid large predators. It is not known how these fish escape from being stung, nor is it known if the jellyfish gains anything from the association (Dipper, 2001). As they increase in size the juvenile whiting migrate towards the sea bed and are most commonly recorded in coastal areas including estuaries. There is little evidence of any major seasonal migrations in this species although it has been noted that whiting move into the eastern Channel and southern North Sea during winter and move north between June and October (Carpentier *et al*., 2005).

Whiting represent an important commercial fishery in the UK and are caught and sold for food. The main gear used to catch whiting in the south coast region is the rock hopper otter trawl, although small numbers are also caught with gill nets and beam trawls (Clark, 2008). In the absence of defined reference points, the state of the stock cannot be evaluated. An analytical assessment estimates the spawning stock biomass (SSB) in 2008 as the lowest since the beginning of the time-series in 1990 (CEFAS, 2009c). Whiting are also eaten by large predatory fish and seabirds, making this species an important component of the food chain.

In addition to cod and whiting, ling and pollack are also caught in the South Coast region, particularly in gill nets set around wrecks (Pawson *et al*., 2002).

2.10.3 Flatfish

Dover sole — *Solea solea*

Dover sole, *Solea solea*, is a large and distinctive flatfish with a rounded head and curved mouth set to one side (Figure 2.48). *S. Solea* is widely distributed around the UK and Ireland, and found on predominantly sand and muddy substrata. Dover sole are most likely to be found in shallow water in the summer since they migrate to warmer, deeper waters in winter. Like many other demersal species, sole spends the daytime buried in sand and is most active at dawn and dusk (Dipper, 2001). *S. solea* has been reported as feeding on small bottom-living animals, mostly polychaetes, molluscs and crustaceans (Miller and Loates, 1997; Darnaude *et al*., 2001; Amezcua *et al*., 2003; Pritchard, 2004).

Sole spawn from late February to May in the eastern English Channel at depths of between 40 m and 60 m (CEFAS, 2009b). Female sole produce approximately 500,000 eggs which develop in the plankton over a period of roughly ten days. The larval fish then settle on the sea floor before drifting inshore to shallow coastal areas and estuaries. There are sole nurseries in estuaries, tidal inlets and shallow, sandy bays in the English Channel coast (CEFAS, 2009b), with Rye Bay to Newhaven being the main nursery area (Burt and Millner, 2008) (Figure 2.48).

Sole is the most economically important species landed in the south-east, representing 21% of the landed value to local ports (Cappell and Nimmo, 2007). The combined landings of Shoreham, Newhaven, Portsmouth, Eastbourne, Hastings and Rye account for nearly half of the south-east sole catch, exceeding £1.7 million in value in 2006 (Cappell and Nimmo, 2007). Sole are targeted by static and drift netters as well as by beam and otter trawlers (Cappell and Nimmo, 2007; Clark, 2008). Sole are targeted inshore and offshore by the international fleet between May and November (Cappell and Nimmo, 2007). The trawl and gill net sole fishery in Hastings has just recently been awarded MSC certification in recognition of their efforts to manage the fishery sustainably.

Lemon sole — *Microstomus kitt*

The lemon sole, *Microstomus kitt*, is one of the more attractive flat fishes found in the UK with a multicoloured mottled appearance (Figure 2.49). Lemon sole are found on all UK coasts but are generally uncommon and only abundant in certain areas, showing a preference for firm sand and gravel (Miller and Loates, 1997; Dipper, 2001; Pritchard, 2004). Lemon sole have much smaller mouths than many of their flatfish relatives and with a lack of powerful crushing teeth are limited in their diet. Lemon sole therefore tend to feed mainly on soft bodied polychaetes and bivalve siphons cutting the tops off with their sharp cutting teeth (Dipper, 2001; Amezcua *et al*., 2003).

Unlike plaice and sole, lemon sole do not have well-defined spawning grounds but are known to spawn in the deep waters of the western Channel in spring and summer (Rowson, 2006b). Spawning and nursery areas are identified in a report written by Poseidon (2003), although the source of this information is not given (Figure 2.49). The Poseidon report (2003), indicates that the area surrounding the Isle of Wight could be an important nursery ground for this species and that this fish spawns offshore, in general agreement with Rowson (2006b). Inshore, lemon sole are not as commercially important as Dover sole but are caught further offshore by beam trawlers (Clark, 2008).

Plaice — *Pleuronectes platessa*

The plaice, *Pleuronectes platessa*, is probably the most easily recognisable flatfish with its distinct orange to red spots (Figure 2.50). It is found on all UK coasts, typically on sandy substrata. Plaice also live on gravel and mud and are frequently observed on sand patches in rocky areas. Continued pressure from fishing means that larger specimens have become a rarity,

South Coast REC Study Area
EECMHM Study Area
UK-France Median Line
Sole Nursery Areas
Sole Spawning Grounds

Sole, *Solea solea* © www.seasurvey.co.uk

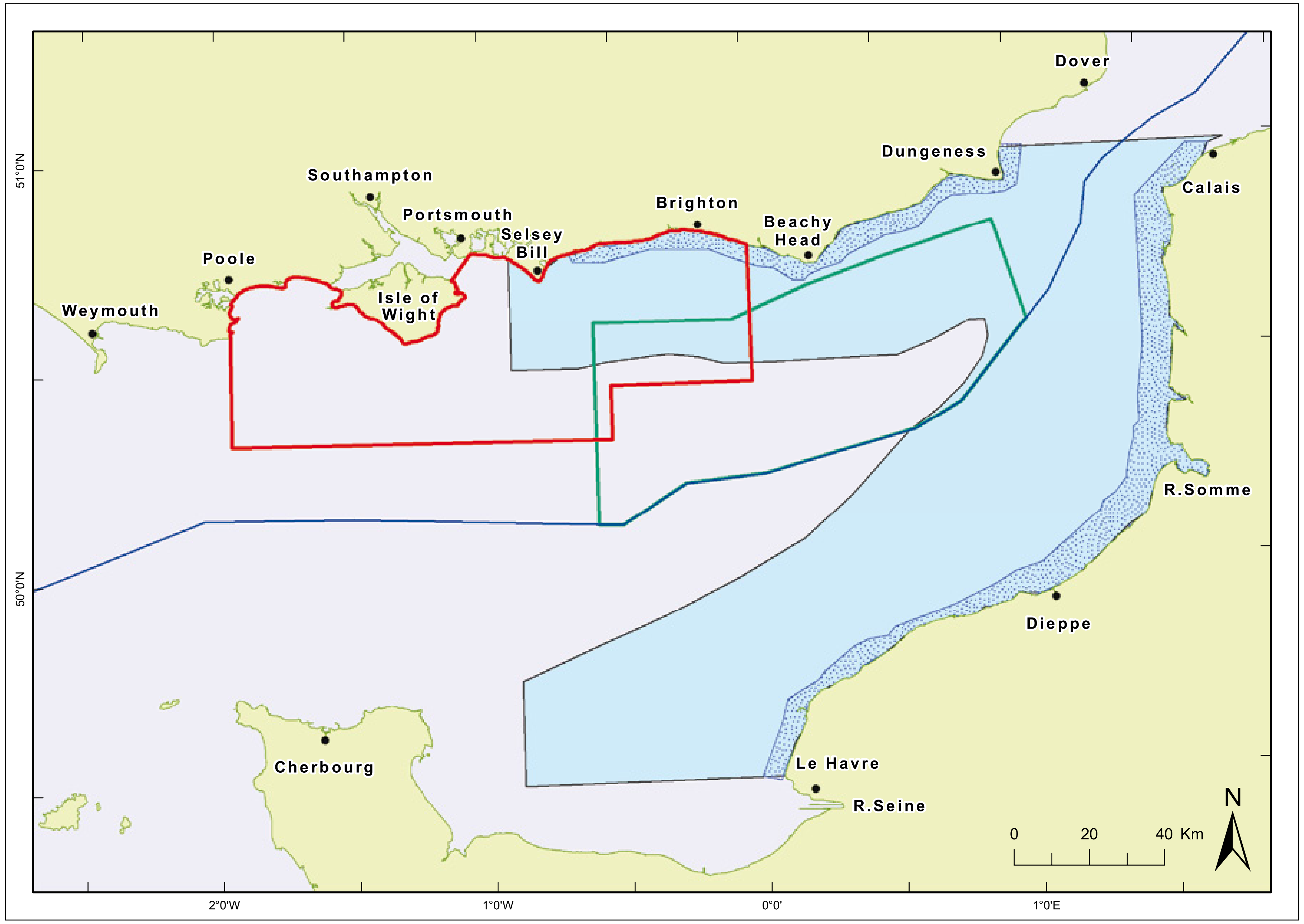
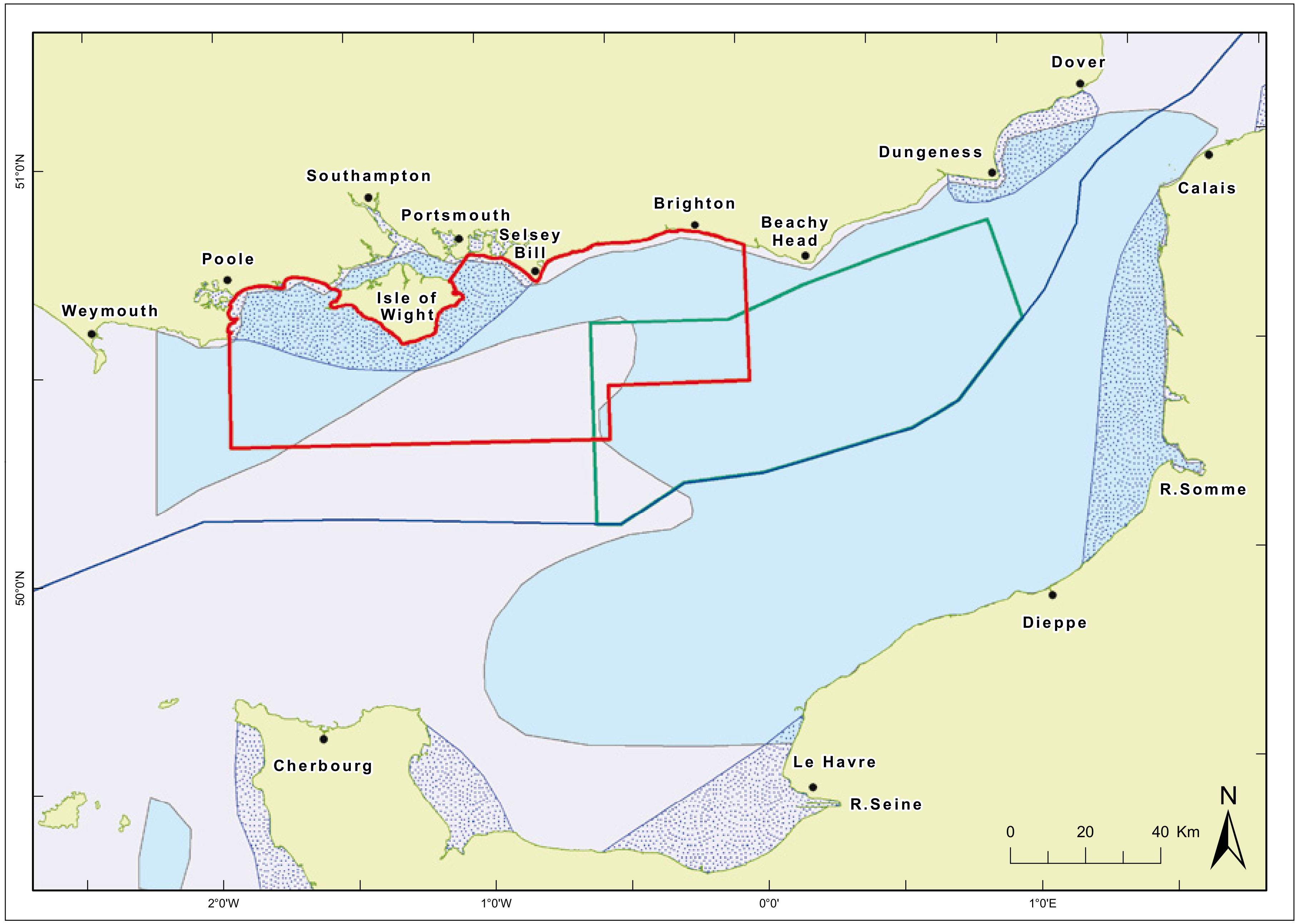


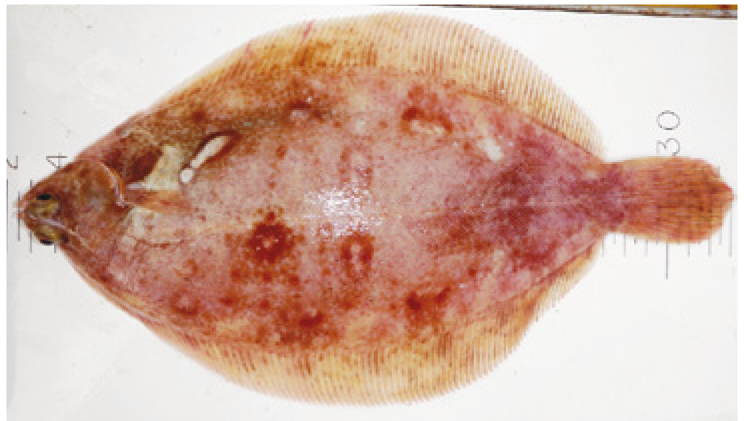
Figure 2.48: Dover sole, *Solea solea*, spawning and nursery ground in the eastern English Channel (Poseidon, 2003).

but individuals up to 50 cm are still recorded fairly frequently (Miller and Loates, 1997; Dipper, 2001; Pritchard, 2004). Like other flatfish, plaice feed on bottom dwelling animals, although a preference for shellfish such as cockles and razor clams has been reported (Dipper, 2001; Amezcua *et al*., 2003). Shellfish are of greater importance in the diet of adult plaice as they are able to crush the shells with their strong pharyngeal teeth (Dipper, 2001).

Plaice spawn between January and March with each female producing up to half a million eggs. Plaice spawning in the UK occurs in well-defined areas at depths between 20 and 40 m. Most plaice from the southern North Sea congregate on the Flemish Bight to spawn, between the Thames Estuary and the Dutch and Belgian coasts (Dipper, 2001). There is also a large spawning area in the central Channel stretching from Dungeness to the Isle of Wight and beyond (Poseidon, 2003; CEFAS, 2009a) (Figure 2.50). Spawning females found in this area consist both of residents and fish which have migrated temporarily from the North Sea. After spawning the eggs float on the surface for 2–3 weeks before hatching. The larval fish then spend a further 4–6 weeks in the plankton before finally settling on sandy areas which act as nursery grounds.

Plaice are an important commercial species in this region, caught using trawls and seine nets. They are a quota species and fishery regulations are in place to help to conserve stocks (Cappell and Nimmo, 2007; Clark, 2008). However, plaice are slow growing and can live for up to 30 years, so many stocks are over fished. The peak seasons for plaice are in spring and winter.





Lemon Sole, *Microstomus kitt* © www.seasurvey.co.uk

Figure 2.49: Lemon sole, *Microstomus kitt*, spawning and nursery ground in the eastern English Channel (Poseidon, 2003).

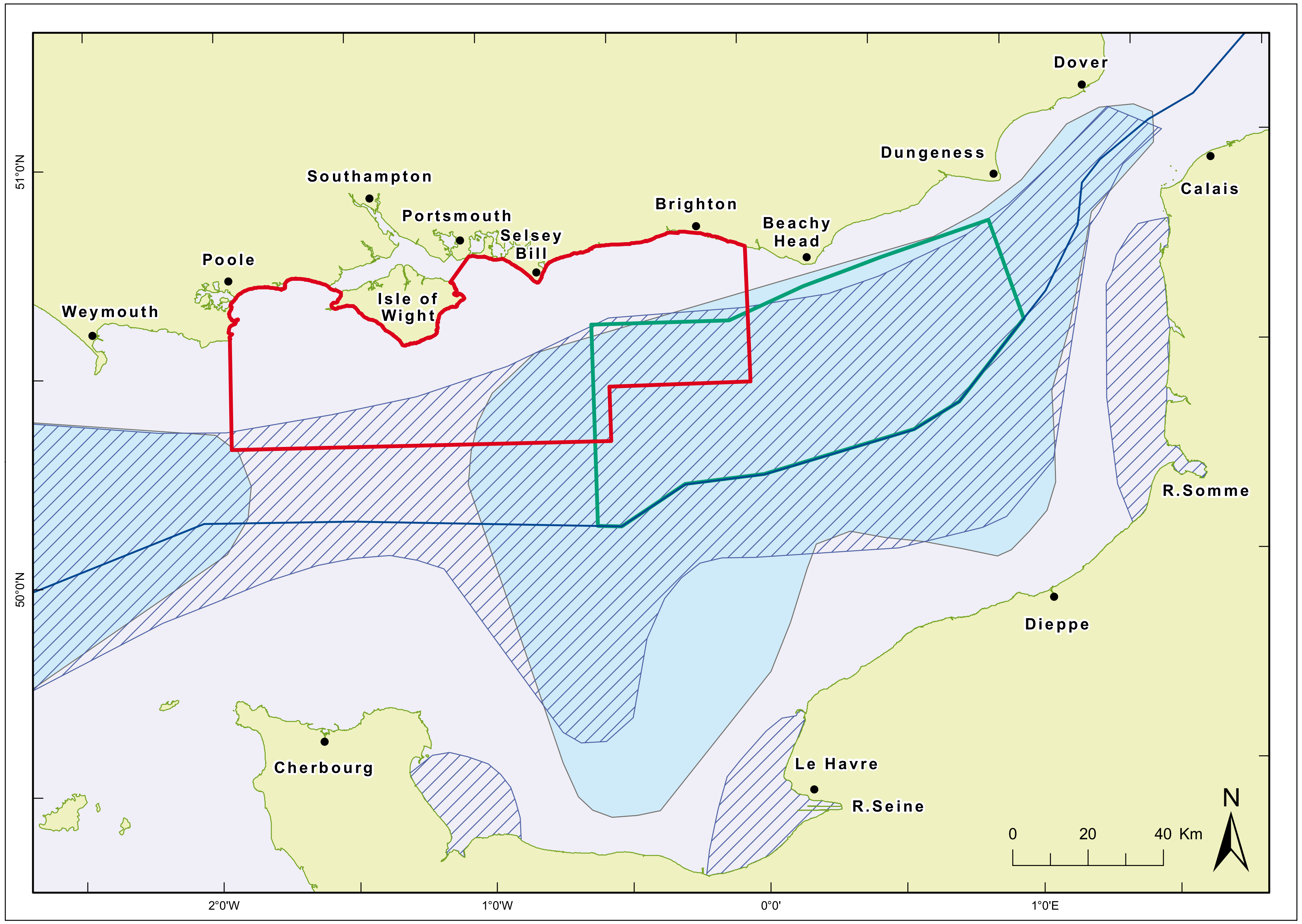
Brill — *Scophthalmus rhombus*

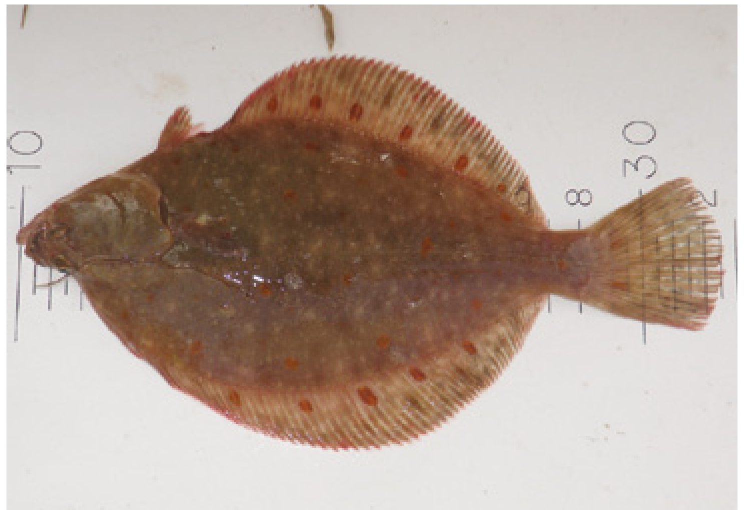
Brill is a broad bodied fish with a large curved mouth (Figure 2.51) (Dipper, 2001). Brill are found on all UK coasts but are most common in the south, on sandy bottoms, but also on gravel and mud. Brill spawn in spring and summer in water <20 m deep where the young tend to stay for a year or two. Brill feed mostly on other fish, favouring juvenile whiting and gobies (Dipper, 2001). They are also known to eat crustaceans and can take a large number of squid. Brill are fished commercially by beam trawlers and are caught in fixed nets (Clark, 2008).

Turbot — *Psetta maxima*

The turbot is one of the largest flatfish and its body is almost completely round (Figure 2.52). Like brill, turbot are most common in the south of the UK although they are found in lower abundances all around the coast. The preferred habitat of the turbot is sand or gravel but they are also known to inhabit muddy areas and mixed rocky substrata. Turbot spawn from May to September on gravel bottoms at depths of <40 m and after an extended period in the plankton (4–6 months) the young drift into shallow waters to settle and develop. Juvenile turbot are commonly found in the surf zone of sandy west-facing bays from September onwards (Poseidon, 2003).

Turbot feed mostly on other fish which they can catch easily with their large extendable mouth. Preferred prey are sprat, herring, whiting and other gadoids (Dipper, 2001). The turbot is a very





Plaice, *Pleuronectes platessa* © www.seasurvey.co.uk

Figure 2.50: Plaice, *Pleuronectes platessa*, spawning and nursery ground in the eastern English Channel (Poseidon, 2003).

valuable commercial fish, with most of the catch coming from beam trawling, netting and long lines (Dipper, 2001; Clark, 2008). This species has also been successfully cultivated in captivity and farmed turbot are now available from the UK.

2.10.4 Large pelagic fish

Sea bass — *Dicentrachus labrax*

The sea bass is perhaps the UK's leading saltwater sport fish as well as being a popular restaurant dish. It is a thick bodied but streamlined fish, brilliant silver in colour, with darker fins (Figure 2.53). Sea bass is found on all UK coasts but is essentially a warm water species favouring the south. Large numbers of bass can be found in the Thames Estuary and up the west coast as far as Cumbria in the summer, but in autumn they migrate south down to western Cornwall and the English Channel. Sea bass spawn in the Channel from February to June, with eggs being most abundant in the mid-western Channel in April. Spawning spreads eastwards as the sea temperature rises (typically above 9°C) and spawning is observed between the Isle of Wight and Beachy Head in May (Pawson, 1995). Spawning in the area to the east of the Isle of Wight is thought to be associated with the gravel banks and rock outcrops, with the main spawning areas thought to occur in deeper waters (Poseidon, 2003). Many bass will have completed spawning by the time they reach the eastern Channel, hence it seems their migrations into this area may be as much for feeding as for spawning (Pawson, 1995).

Bass larvae move inshore as they grow and actively congregate in sheltered estuaries and creeks where they spend several years before moving out to coastal waters. Many of the harbours within the Solent (Portsmouth, Chichester and Langstone) and Southampton Water have been designated as sea bass nursery areas by Defra and fishing in these areas is prohibited between 1 May and 31 October (Figure 2.54).

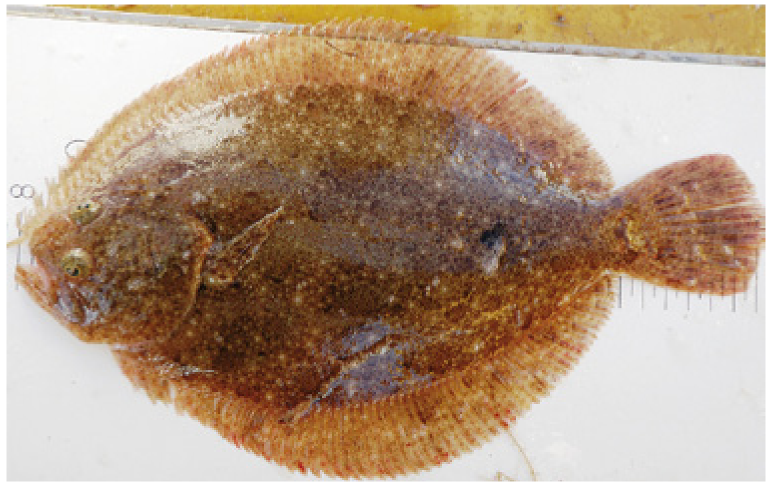


Figure 2.51: Brill, *Scophthalmus rhombus* © seasurvey.co.uk

Figure 2.52: Turbot, *Psetta maxima* ©seasurvey.co.uk

Bass account for only 2% of commercial landings in the south east but their high market value means that that their contribution to value is approaching 10% (Cappell and Nimmo, 2007). Key ports for bass include Shoreham, Newhaven, Portsmouth and Eastbourne which collectively account for 50% of the volume landed in the south east region (Cappell and Nimmo, 2007). Bass are targeted using drift and gill nets as well as by both pair and otter trawlers and are mostly fished at night and after strong winds when the fish tend to shoal (Clark, 2008).

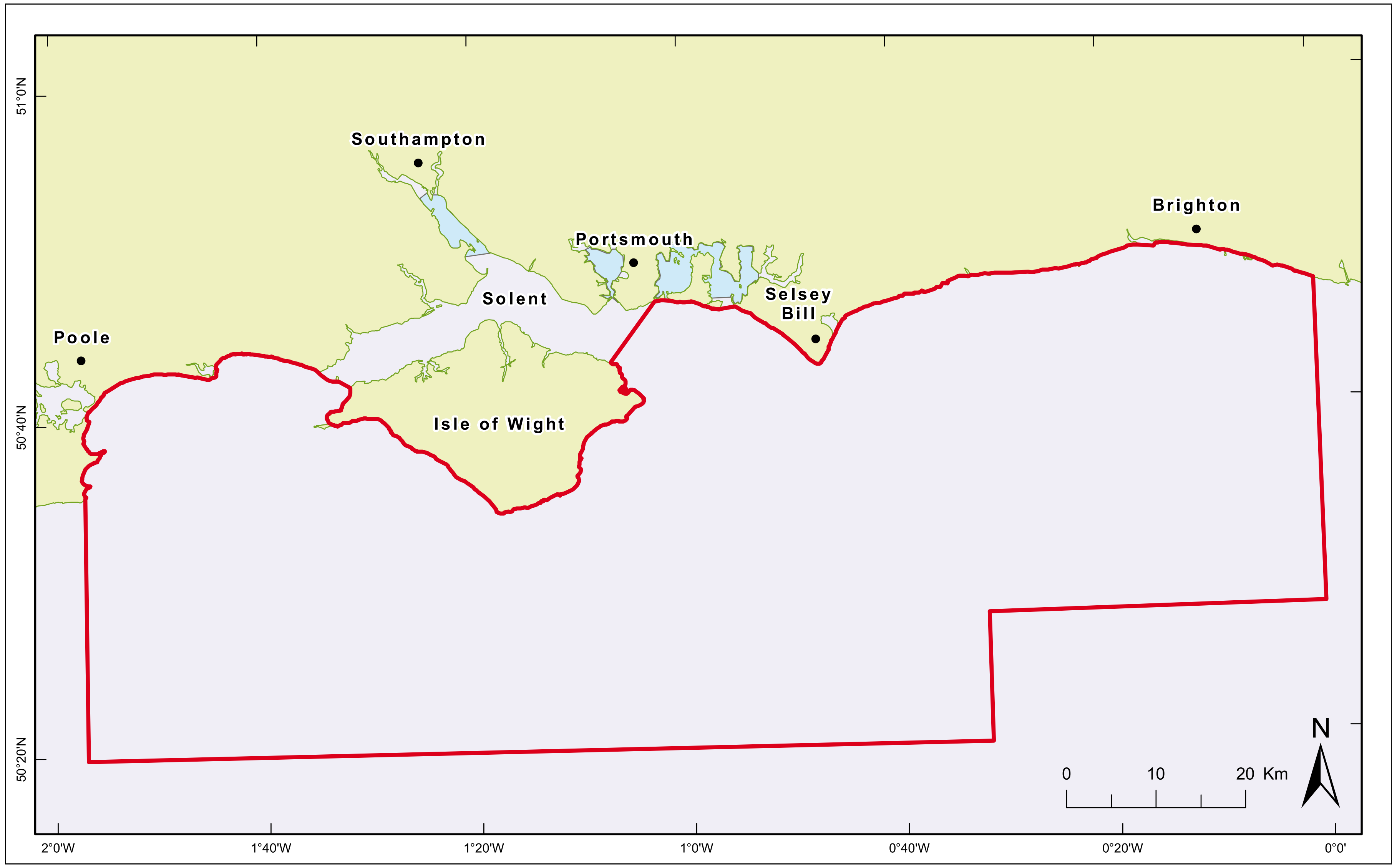
Black bream — *Spondyliosoma cantharus*

Black bream is a dark grey fish with a laterally flattened body and large, tough scales (Figure 2.53). Black bream are hermaphroditic, thought to exhibit protogynous development, maturing as females and later changing to males (Pajuelo and Lorenzo, 1999). Black bream exhibit schooling behaviour and mostly inhabit the inshore shelf region. The black bream stock which occupy the English Channel overwinter in water depths of 50–100 m, migrating inshore in spring to breed (Clark, 2009). Black bream are thought to be very selective in the types of sea bed used for spawning and this is largely due to their unique breeding behaviour. Male bream use their tails to remove surface gravels to expose the bedrock or compacted gravels below, creating nests between 1 and 2 m across and approximately 10 cm deep (Gubbay, 2005). The females then lay their sticky eggs in a thin layer within the nest, which adheres to the rock surface. The male will then fertilise the eggs and guard the nest. To facilitate this nest building behaviour, black bream tend to select areas of hard substrate with loose overlying gravel (ICES, 2000) although they have also been reported on sandy bottoms and seagrass beds (Pajuelo and Lorenzo, 1999). One such site identified in the UK lies just offshore of Littlehampton, where nests have been identified at the base of the chalk cliffs (Pawson, 1995; ICES, 2000). Juvenile black bream remain in the vicinity of their nest until they reach 7–8 cm in length when they disperse slightly. The juveniles then remain in inshore areas for 2–3 years until they reach sexual maturity whereupon they assimilate into the adult stock. See also Chapter 8.

Black bream are fished both on a commercial and recreational basis within the South Coast region (Morton, 2009) where they are present between April and November; being most abundant between April and July. Black bream move into the shallow inshore hard ground areas to feed before breeding in April. During this time they are targeted by small inshore vessels using fixed nets. The fish then move on to breeding grounds where they build their nests and begin to spawn. During this time the bream are targeted by pair and stern trawlers as well as commercial and recreational anglers. The pair trawlers are reported to get the best catches during daylight hours, presumably because the fish are closer to the sea bed, either actively spawning or guarding their nests.

There are no specific management regimes applied to the black bream fishery, although they are subject to the EU technical measure relating to towed gear used to catch any sea bream species. This measure states that towed gear must have a mesh size greater than 80 mm where sea bream constitutes over 70% of the catch. The black bream fishery is also subject to the Sussex Sea Fisheries Committee (SSFC) byelaw which states that from 1 April to 30 June inclusive, any pair trawl used west of Shoreham harbour must have a cod end mesh greater than 95 mm (Clark, 2009). Fixed nets are subject to similar regulations with a mesh size greater than 220 mm required under EU law where the catch constitutes over 70% sea bream which is more stringent than the 90 mm mesh specified by SSFC and therefore takes precedence. Despite the management measures and fines enforced by the SSFC illegal fishing on known black bream nesting sites continues. SSFC have no less than eight pending prosecutions against pair trawlers for illegal fishing on the Littlehampton site in 2009 and have made 13 prior prosecutions for the same act in that area. Even in the absence of illegal fishing activities the management measures in place selectively target larger individuals, which given the reproductive development of this species, has the potential to effect the sex ratio of the population and hence future reproduction and the long term viability of the population (Pawson, 1995).

Figure 2.53: Black bream, *Spodyliosoma cantharus* © Sussex Sea Fisheries Committee.



Sea Bass, *Dicentrarchus labrax* © www.seasurvey.co.uk

Figure 2.54: Sea bass, *Dicentrachus labrax*, nursery areas in the South Coast region (Drummond, 1997).

Red mullet — *Mullus surmuletus*

The red mullet is the only species of goatfish (Mullidae) found in UK waters. This species is easily recognisable by its two long chin barbels and yellow to red colouration (Figure 2.55). Red mullet are not common, although they are at times quite numerous in the Channel and the southern North Sea. It is thought the red mullet numbers are swollen in these areas by fish migrating north from the Mediterranean and other southern areas (Dipper, 2001) Little is known about the spawning behaviour of red mullet in UK waters although they are known to spawn in summer in the Mediterranean, laying eggs on the sea bed in shallow water less than 50 m deep. Like other goatfish, red mullet use their sensitive chin barbels to search out small animals in the sediment, and so it is probable that they prefer finer substrates. Red mullet are too scarce in the UK to be targeted in their own right on a commercial basis but they are commonly caught as by-catch since they shoal with other species such as sea bream and wrasse. Red mullet are a much sought after food source and so have a high market value.

Figure 2.55: Red mullet, *Mullus sermuletus* © Sussex Sea Fisheries Committee.

Baillon's wrasse — *Symphodus bailloni*

Baillon's wrasse is thought to be at the northern limit of its range in the English Channel but, nevertheless, is noted as a valuable by-catch of the black bream fishery in the region (Clark, 2008). The first record of this species in the peer reviewed literature was made by Dunn and Brown (2003). The authors observed its presence in a survey of the Solent and adjacent harbours during annual sea bass monitoring undertaken by the Centre for Environment, Fisheries and Aquaculture Science (Cefas). A total of 89 individuals were captured in trawl samples, with the biggest catches being recorded near the entrances of Southampton Water and Chichester Harbour. Such dense aggregations of Ballion's wrasse are believed to occur infrequently in the UK, it therefore seems likely that this fishery could be relatively unique.

Red gurnard — *Aspitrigla cuculus*

The red gurnard, *Aspitrigla cuculus*, is a large and distinctive demersal fish with bright colouration and a heavily armoured head (Figure 2.56). It searches out food using three pectoral feelers, which are covered in sensitive taste buds (Dipper, 2001). Little is known about the diet and feeding behaviours of the red gurnard but it has been reported to have a diet primarily consisting of crustaceans and occasionally fish (Miller and Loates, 1997; Dipper, 2001; Pritchard, 2004).The red gurnard spawns in spring and early summer and the young tend to shelter in shallow inshore waters such as estuaries. The main spawning area for the red gurnard in the Channel is between the Cherbourg Peninsula and the Isle of Wight. During spawning the fish move westwards until early August when they return to the central Channel. The nursery areas of this species are, as yet, unknown (Poseidon, 2003).

Figure 2.56: Red gurnard, *Aspitrigla cuculus* © seasurvey.co.uk

Red gurnards occur on all coasts although dense aggregations are uncommon, and this species appears to be absent from the east coast. The red gurnard shows a preference for sandy and muddy bottoms but can also be found in areas of mixed sand and rock. The red gurnard is not abundant enough to be the sole target of commercial fishing efforts but is a valuable by-catch species.

2.10.5 Small pelagic fish

Herring — *Clupea harengus*

The herring is a pelagic fish, silvery in colour with deep blue shading along its back. Herring are abundant and widely distributed around the UK, with geographically distinct breeding stocks or races, the majority of which are migratory. The times and places of spawning vary according to the stock but all have distinct grounds, a number of which occur in the English Channel (Figure 2.59). Stocks that spawn in spring tend to use inshore spawning grounds, whilst autumn and winter spawners tend to move offshore using the edges of ocean banks. In all cases large numbers of eggs (up to 50,000) are laid by the females near to the sea floor which sink and stick to gravel, shell and stones to form a dense mat. Juvenile fish aggregate in shoals and migrate into estuaries and other shallow waters where they remain for six months to a year (Dipper, 2001).

Most herring stocks migrate in huge shoals between spawning, overwintering and feeding grounds, covering great distances in their lifetime. Herring have historically been a very important commercial fishery and continue to be targeted to this day. The North Atlantic herring stocks collapsed in the 1960s due to prolonged overfishing. Despite a complete ban imposed in 1977, herring stocks remain under pressure with some authorities postulating that they may never fully recover. Herring are caught using drift nets in the South Coast region and this includes the MSC certified fishery at Hastings, one of only 14 worldwide to receive such recognition for sustainable practices. As well as being an important commercial fish resource, herring form an important component of the diet of seabirds, dolphins, porpoises and large predatory fish.

Mackerel — Scomber scombrus

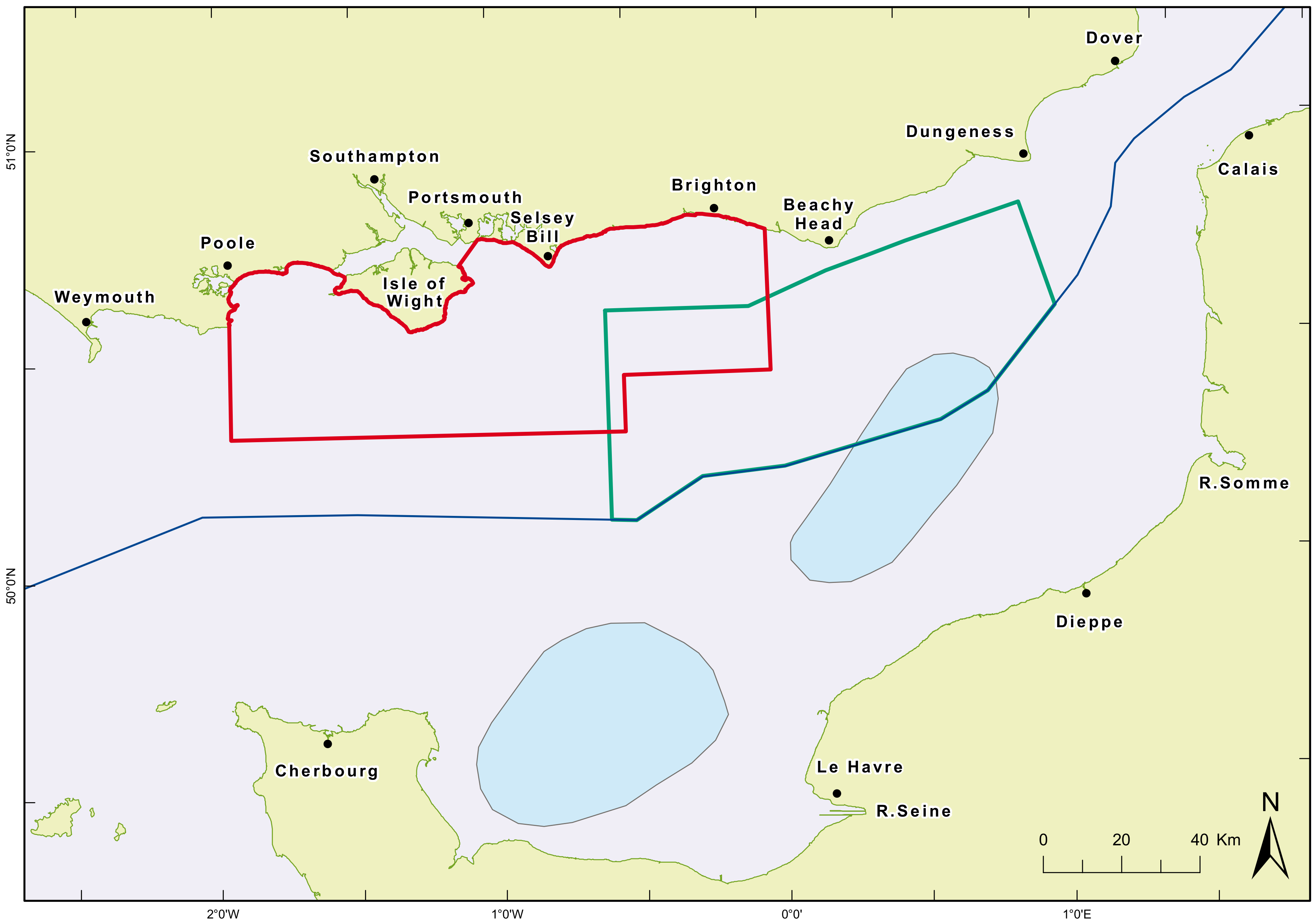
The mackerel is a silver coloured pelagic fish with brilliant iridescent blue green along its back with irregular zebra-like dark lines (Figure 2.57). Mackerel are found all around the UK in large open water schools. They move inshore in the summer to spawn and then retreat back to deeper waters over the winter. Mackerel are an important food source for tuna, sharks and dolphins and are also exploited by commercial fisheries. Mackerel are caught using seine nets, pelagic trawls and also on long lines. They have been heavily exploited in the past leading to the collapse of many, once abundant stocks, particularly those in the North Sea. They are a slow growing species and as such are particularly vulnerable to commercial fishing pressures. Mackerel are caught in the South Coast area using gill nets although this is not a popular fishery due to low market demand, the fish are primarily sold for bait (Pawson *et al*., 2002).

Figure 2.57: Mackerel, *Scomber scombrus* © seasurvey.co.uk

Sprat — *Sprattus sprattus*

The sprat, *Sprattus sprattus*, is a smaller relative of the herring and is an important component in the diet of larger fish (Figure 2.58).

Figure 2.58: Sprat, *Sprattus sprattus* © seasurvey.co.uk



Herring, *Clupea harengus* © www.seasurvey.co.uk

Figure 2.59: Herring, *Clupea harengus*, spawning and nursery ground in the eastern English Channel (Poseidon, 2003).

Sprat eggs, larvae, juveniles and adults are distributed almost continuously throughout the English Channel (Pawson, 1995). The sprat fishery is an example of an industrial fishery; the fish are not caught for food but are rather used in fish meal and as bait.

Sandeels

Sandeels are small eel like fish with long thin bodies and a pointed jaw (Figure 2.60). There are three main species found in the UK, *Ammodytes tobianus, Ammodytes marinus* and *Hyperoplus lanceolatus* which are relatively difficult to tell apart and hence not normally separated in fisheries data. Sandeels lay their eggs mostly in spring and summer in the sand over which they live. Each female can lay between about 4,000 and 20,000 eggs. The eggs hatch a few weeks later and the tiny fish move out of the sand and into the water column. Sandeels feed on small planktonic animals living in the water column as well as on worms, small crustaceans and fish. Sandeels are a shoaling fish and spend much of their time in the water column, but when danger

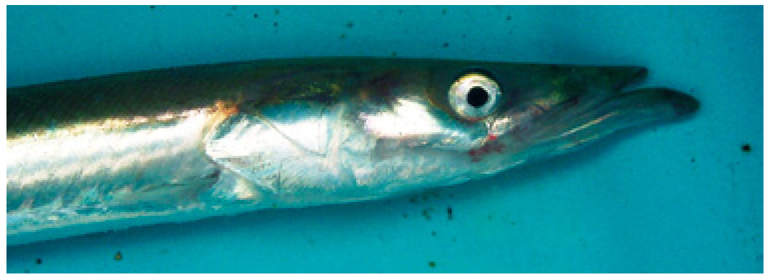
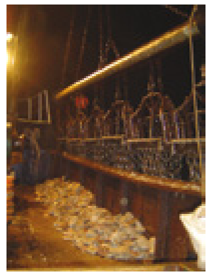


Figure 2.60: Greater sandeel, *Hyperoplus laceolatus* © seasurvey.co.uk

South Coast REC Study Area
Oyster Dreging
Scallop Dredging
Whelk Potting
Crab & Lobster Potting
Clam & Cockle Fisheries
Cuttlefish Fisheries
Mussel Beds
Unidentified Fishing Effort

Solent-type Oyster Dredger
© Sussex Sea Fisheries Committee

Whelk potting
© Sussex Sea Fisheries Committee



Scallop Dredges
© Sussex Sea Fisheries Committee

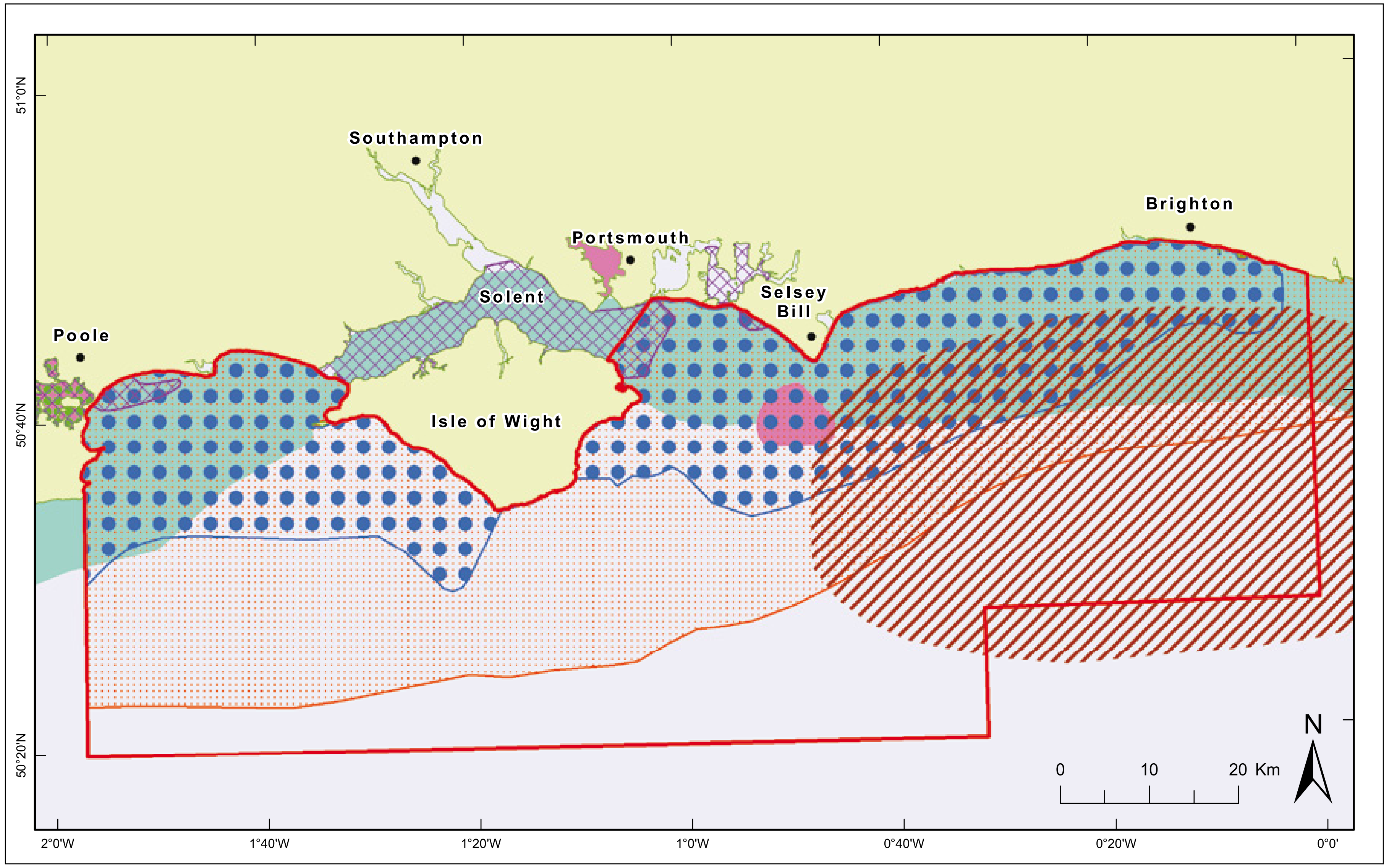


Figure 2.61: Chart showing the approximate extents of fisheries targeting shellfish in the south coast region (Dunn, 1999; Poseidon, 2003; Jensen *et al.*, 2004; Cooper, 2005; Drake, 2006; Clark, 2008).

threatens they swim head down into the sand and immediately disappear.

The sandeel fishery is one of the largest industrial fisheries in the UK; the fish are caught for purposes other than for human consumption, mainly fish meal. Sandeels also constitute important prey for many marine predators including grey seal, harbour seal, porpoise, whiting, cod, mackerel and bass as well as many seabirds. With so many predators dependent on sandeels, the level of exploitation has raised concerns regarding its impact on marine food webs (Holland *et al*., 2005). Sandeels are known to prefer medium to coarse sand and have been shown to avoid areas with high levels of coarse gravel, fine gravel, and silts (Holland *et al*., 2005). Sandeels are exploited in many of the harbours and bays in the South Coast region using light trawls or beach seines, caught primarily to provide bait for the bass fishery.

2.10.6 Diadromous fish

The Solent is used by migratory fish including sea trout, Salmo trutta trutta and occasionally Atlantic salmon, Salmo salar, which pass through the Solent on their way to breeding/spawning grounds in the rivers Test, Itchen, Meon, Hamble, and the New Forest streams (Lockwood, 1986; Drummond, 1997). The main trout runs are on the Dark Water and Beaulieu River and the fish are reported to be present around these areas for much of the year (Cappell and Nimmo, 2007). There are licensed salmon and sea trout seine net fisheries in the common estuary of the Avon and Stour (part of Christchurch Harbour), and in the joint estuary of the Frome and Piddle (Poole Harbour) (Pawson *et al*., 2002; Drake, 2006). A national byelaw was introduced by the Environment Agency in 1999 which restricts the salmon season. This states that salmon caught before June 1st must be returned alive (the season starts on 15 April).

Eels also migrate from rivers in the Solent area to spawn at sea and licensed fyke nets are set to catch the adults in many of the harbours between spring and autumn, and elvers (juvenile eel) in traps as they migrate up the rivers in winter and spring (Pawson *et al*., 2002).

2.10.7 Shellfish

Figure 2.61 shows the approximate extents of fisheries targeting shellfish in the South Coast region. The main potting and dredging areas are concentrated in inshore waters, with only scallop dredging extending into the central channel. Clams and oysters are the focus of fishing effort in the harbours and estuaries of the South Coast region. Gaps in the quality and availability of data related to shell fisheries in the South Coast region were identified during the course of this review. The reliance on data published by the Sussex Sea Fisheries Committee may serve to overemphasise the fishing activities to the east of the Isle of Wight, and therefore the following should be treated as an overview rather than a definitive guide to fisheries activities in the South Coast region.

2.10.8 Crustacea

Lobster — *Homarus gammarus*

The common lobster, *Homarus gammarus*, (Figure 2.62) is found from the intertidal zone down to 200 m on all UK coasts, but are particularly abundant around the Isle of Wight (Poseidon, 2003). Mating occurs in the summer and the fertilised eggs are held between the body and abdominal flap giving the crabs a 'berried' appearance. Berried females appear between September and December on both inshore and offshore grounds (Poseidon, 2003). Berried lobsters do not make extensive movements and hatching takes place in spring to early summer on the same grounds used for mating. Offshore lobsters are less abundant than inshore animals but their larger size and fecundity indicates that they are of particular importance to overall recruitment. Hatched lobster larvae remain in the plankton for approximately 3 weeks before settling. The main nursery areas in the eastern Channel are in rocky coastal waters off Sussex and Hampshire. There is no apparent adult migration beyond random foraging and habitat changes during moulting (Poseidon, 2003).

The South Coast region is a very important area for lobster with Selsey alone landing 72% of the total south east volume (Cappell and Nimmo, 2007). Lobster is mainly targeted by potters, with the Parlour pot being the favoured gear. The lobster fishery is increasingly less seasonal with efforts often extending into the winter season. However, the highest landings are still seen over the summer (Clark, 2008). In Sussex, fishing for lobster requires a permit issued by the Sea Fisheries Committee which restricts the number of lobster pots set by each vessel within 3 nautical miles of the coast to 100 per crew member (Pawson *et al*., 2002).

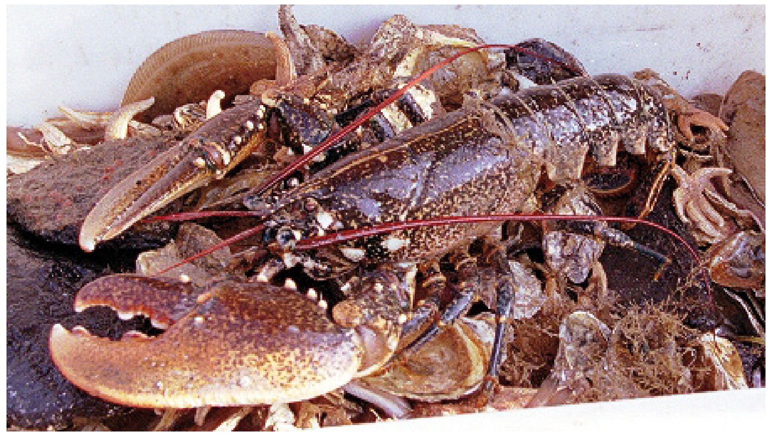


Figure 2.62: Common lobster, *Homarus gammarus*
© seasurvey.co.uk

Edible Crab — *Cancer pagurus*

Edible or brown crabs are widely distributed throughout the western and eastern English Channel and there is an important spawning and migration area within the South Coast region (Figure 2.64). Female crabs lay eggs in November and December shortly after copulating, although they are able to store sperm for several months. To keep the eggs healthy, the female crab continually 'waves' water over the eggs with the pleopods (tiny leg like appendages on the abdomen). Berried females which over-winter in the mid-Channel are rarely caught by fishermen and so it is assumed that, like other species of crab, they hide in rocks and crevices, or bury themselves in the sea bed in order to protect their brooding young. Once hatched the larvae remain in the water column for between 60 and 90 days and have been widely recorded throughout the Channel in spring and early summer (Poseidon, 2003). After settlement, juveniles move into shallow waters and are mostly found on rocky shores. Once they reach maturity they move back into deeper waters.

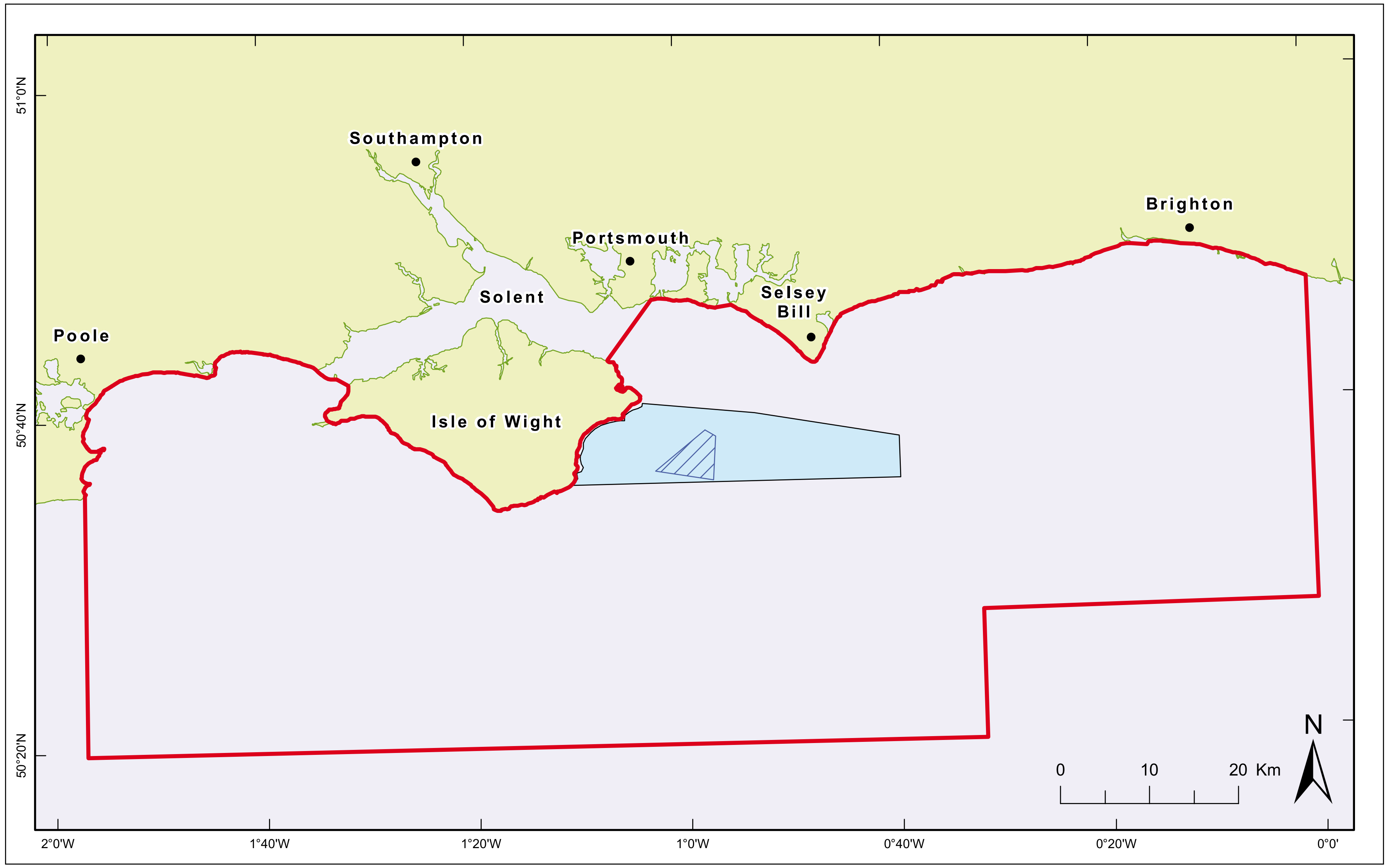
Tagging experiments in the English Channel have shown that female edible crab movements occur in a west or south westerly direction, with little evidence of a return movement. It has been postulated that since these movements are against the current they may serve to ensure that larvae drift back eastwards towards suitable nursery grounds. However, larval studies carried out by Thompson *et al* (1995) found contradictory results in their larval studies on the same species. Here they identified a westerly movement of the larvae although it is possible that variations in spawning times and mixing between adult populations confounded these results. Further work is clearly required in order to fully elucidate the migratory patterns of this species. There are however, known migratory routes through the area of study as illustrated in Figure 2.64. It would seem that the gravel deposits to the east of the Isle of Wight may also be important over-wintering grounds for this species (Poseidon, 2003).

Edible crab make an important contribution to commercial fisheries in this region. The edible crab is a non-quota species targeted by potters, primarily using ink-well pots. Key ports fishing for crab include Eastbourne, Selsey and the Isle of Wight (Cappell and Nimmo, 2007; Clark, 2008). Crab is targeted all year with peak catches from July to November (Cappell and Nimmo, 2007). Recent declines in the edible crab fishery south of the Isle of Wight have been reported by fishermen (Cooper, 2005).

Spider Crab — *Maja brachydactyla*

Berried spider crabs (Figure 2.63) are found in high abundance in the shallow waters off the Brittany coast and also in English coastal waters including the eastern Channel in April. The eggs hatch

Figure 2.63: Spider crab, *Maja brachydactyla* © seasurvey.co.uk



Edible Crab, *Cancer pagurus* © www.seasurvey.co.uk

Figure 2.64: Edible crab, *Cancer pagurus*, spawning and migration grounds in the eastern English Channel (Cooper, 2005).

between July and November and a short pelagic stage follows (2–3 weeks), giving rise to relatively limited larval dispersion. Juvenile crab settle and accumulate in inshore nursery grounds, typically in areas of rock or gravel with alternating sand or mud (Poseidon, 2003). Nursery areas have been clearly identified along the French west Channel coast but no attempts have been made to identify such areas on the English coast. It is possible, if not likely, that such areas exist within the area of study. Unlike the edible crab, spider crab do not make seasonal east to west migrations but do move inshore to shallow waters to spawn, following an overwintering period in deep water (greater than 50 m) (Poseidon, 2003). Some lateral migrations have been observed in spider crab, but these do not appear to be seasonal and are likely to represent expansion of their range (Pawson, 1995).

Spider crab form an important secondary resource for the potting fisheries on the south coast, albeit a seasonal one (Cappell and Nimmo, 2007). The establishment of live exports to France and Spain has meant that spider crab often fetch a greater market value than the edible crab and most are destined for the continental market (Pawson *et al*., 2002). The velvet swimming crab is also targeted by some vessels in the region (Cappell and Nimmo, 2007) and exported to the continent (Pawson *et al*., 2002).

Prawns

A small number of boats set pots for prawns (Figure 2.65) (Pawson *et al*., 2002) in some of the harbours and bays, especially Poole

Figure 2.65: Prawns, *Pandalus monatgui* © seasurvey.co.uk

Bay, although there is a closed season between 1 January and 31 July. Prawns are caught in relatively small numbers and supply only the local market.

2.10.9 Molluscs

Native Oysters — *Ostrea edulis*

The Solent and its surrounding harbours is one of largest and most productive self-sustaining oyster grounds in Europe and is of international conservation importance. In the late sixties, the Solent stocks helped to stabilise the otherwise diminishing national oyster stocks through re-seeding (Davidson, 1976). It was also one of the few native oyster fisheries to survive the outbreak of the parasite Bonamia in the 1980's (Pawson *et al*., 2002). Today the oyster fishery is tightly regulated and both public and private (Regulated and Severed) fisheries exist within Solent. In the Solent regulated fishery vessels must obtain one of 90 available Solent oyster licences issued by the Southern Sea Fisheries District Committee. Solent oyster fisheries open on the 1 November and annual surveys determine the duration of the season (Cappell and Nimmo, 2007). Oysters are mostly targeted by small vessels (less than10 m) using oyster dredges and when the season closes these vessels switch to work trawl gear, pots and line (Cappell and Nimmo, 2007; Clark, 2008). There is limited commercial by-catch associated with this fishery, though clams are becoming increasingly sought after.

A minimum landing size has been created by regulations which prescribe that oysters must not pass through a 70 mm ring. The Solent oysters are sold directly as food (after a period of purification) and also for relaying material, in the UK and abroad, most notably France. During the first week of the season approximately 50% of the native oysters are marketable and the other 50% are sold as seed. The proportion sold as seed increases through the season and enters both the European and national markets (Cappell and Nimmo, 2007). Most of the oysters caught before Christmas are exported to the continent although, with the recovery of continental oyster stocks, this market is declining. There does however remain a demand for seed to restock national oyster fisheries, particularly on the east coast (Pawson *et al*., 2002). The sustainability of this fishery has been questioned by some (Cappell and Nimmo, 2007) and it is believed that one year of poor recruitment could be enough to cause its collapse.

Scallops

Scallops are most commonly encountered on coarse substrates dominated by gravel or shell (Pawson, 1995) at depths of 15–75 m (Poseidon, 2003). Two species of scallop are found in the channel, the king scallop (Figure 2.66) *Pecten maximus* and the smaller queen scallop *Aequipecten opercularis*. Numbers of both species have been recorded in trawl surveys across the English Channel (EMU, 2000a; MESL, 2006; James *et al*., 2007) and these indicate the queen scallop is usually the most dominant in terms of abundance, however, the king scallop is by far the most important in commercial terms.

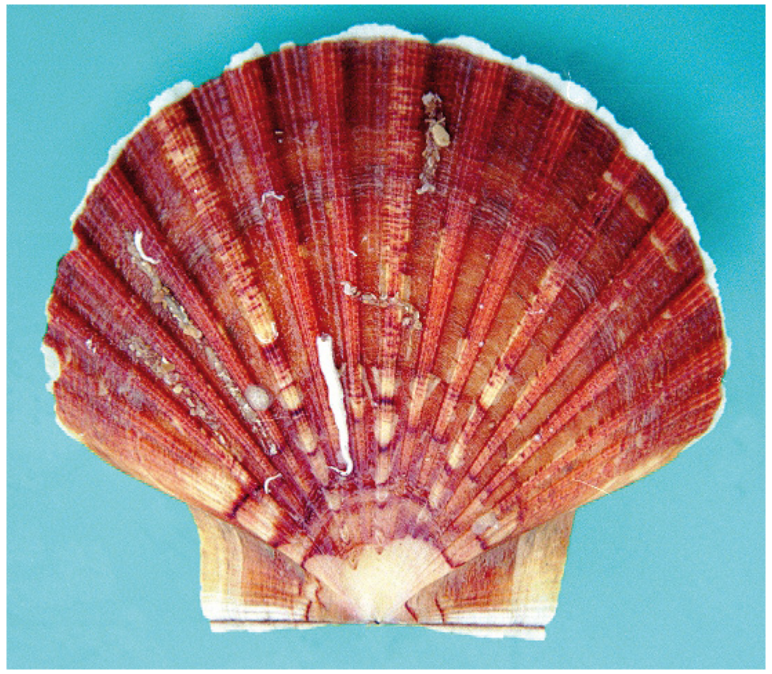


Figure 2.66: King scallop, *Pecten maximus* © seasurvey.co.uk

Despite the mobility of scallops, they are sedentary for most of their life and spawning areas correspond closely with the adult distribution. Scallops spawn between spring and autumn although there is considerable regional variation. Pawson (1995) suggests that a minimum density of spawning adults may be required for good spat recruitment and that productive spawning areas may therefore be more restricted than the overall distribution would suggest. Following successful fertilisation the developing eggs remain in the plankton for 4–6 weeks before descending to the seafloor. It is thought that settlement is triggered by temperature cues as well as the presence of suitable attachment sites (Poseidon, 2003). A lack of organic matter is described by Poseidon (2003) as an important feature of attachment sites and Minchin (1992) goes as far to suggest that the presence of fine material can cause mass mortality of pre and post larval stages. Following initial settlement and growth, detachment usually occurs and after 3 to 4 years king scallop are of a marketable size (greater than 89 mm).

Scallops are the one of the most important fishery species in the south east in terms of both value and volume (Cappell and Nimmo, 2007). Shoreham and Newhaven land the largest volume, collectively accounting for over 85% of the total volume caught in the region (Cappell and Nimmo, 2007). Scallops are a non-quota species but do have a minimum landing size of 110mm in the eastern Channel (ICES rectangle VIId). Scallops are fished using a scallop dredge which has high tensile spring loaded teeth. These teeth make contact with the seabed and rake the scallops into the dredge (Clark, 2008). There is a limited commercial by-catch associated with this fishing method but there can be significant non-commercial discards. There is a byelaw in place which prevents the use of scallop dredgers inside 3 nautical miles of the Sussex coast (Clark, 2008).

Cockles — *Cerastoderma edule*

The cockle is a bivalve mollusc which feeds on organic material (microscopic plants animals and debris) suspended in the water column (Figure 2.67). Unlike other molluscs, cockles are either male or female, though there is little obvious morphological difference between them. Cockles spawn mostly in early spring, but may continue to some extent throughout the summer and even into autumn (Franklin, 1972). Eggs and sperm are released into the water column where the developing larvae remain for about three weeks. The larvae settle en-masse when they reach about 1 mm in size. Young cockles, known as 'spat' are easily moved and redistributed from the sea bed by tides until they reach about 4 mm in size. At this stage they are able to anchor themselves using their muscular foot. Once settled, cockles are unlikely to move voluntarily for the rest of their lives.

It is not known whether cockles are able to select their place of settlement but the presence of vast accumulations of cockles in situations unsuitable for growth and survival suggests that this is a passive process occurring when the cockles are large enough to sink to the sea floor (Franklin, 1972). Cockles reach maturity after about one year and may live for more than ten years, although a lifespan of four to five years is more common in commercially exploited beds (Franklin, 1972).

Figure 2.67: Cockles, *Cerastoderma edule* © seasurvey.co.uk

Cockles occur all round our coasts in a wide variety of substrates, from soft muds to gravel, but are most common on the intertidal flats of large river estuaries. The commercial fisheries for cockles are concentrated in estuaries, although there is also a long standing fishery in Poole Harbour (Franklin, 1972).

Mussels — *Mytillus edulis*

Mussels are filter feeding bivalves which feed on microscopic animals and organic material suspended in the water column. They are gregarious in nature and form extensive beds which may be up to 6 layers deep (Figure 2.68). The individuals are held in place by their byssal threads and young mussels colonise any spaces which acts to further stabilise the beds and also increases complexity. Overcrowding results in mortality as underlying mussels are starved or suffocated by the accumulation of silt, faeces and pseudofaeces, especially in rapidly growing populations (Richardson and Seed, 1990). Death of underlying individuals may detach the mussel bed from the substratum, leaving it vulnerable to tidal scour and wave action (Seed and Suchanek, 1992).

Figure 2.68: Mussels, *Mytilus edulis* © seasurvey.co.uk

Mussels spawn over a protracted period, peaking in spring and summer. Mussel larvae remain in the water column for between one and six months before settling onto a hard surface. Mussels are capable of limited movement by detaching and reattaching their byssal threads which anchor them to the seafloor but they are essentially sedentary in nature.

Mussel (seed) is landed in Portsmouth which is reported to be sold on to Holland, where it is re-laid and harvested after 3 years (Cappell and Nimmo, 2007). There is also an important mussel fishery in Poole harbour which is seeded regularly with mussels from Portland. This covers an area of over 500 acres and was established in the 1980s when the local oyster fishery was wiped out by *Bonamia* (Pawson *et al*., 2002). Mussel beds have also been identified to the east of the Isle of Wight by Plumb (1996), although the Sussex Sea Fisheries Committee byelaws prevent this from becoming a commercial fishery.

Manila Clam — *Tapes philippinarum*

The natural distribution of the manila clam is confined to the western Pacific Ocean although accidental and intentional introductions have expanded its range considerably (Jensen *et al*., 2004). The manila clam was first introduced into the UK in 1992 by Othiniel Shell Fisheries who seeded Poole Harbour with juvenile clams (Utting and Spencer, 1992). By 1994 it was evident that successful reproduction had occurred in the harbour and fishermen were exploiting the new intertidal resource at high tide (Jensen *et al*., 2004). In an effort to ensure the sustainability of this fishery the Southern Sea Fisheries Committee licensed the fishery and introduced an 8-10 week season (October to January) as well as regulations for allowable fishing techniques. A European 40 mm minimum landing size was also enforced.

The manila clams are currently harvested using a 'pump scoop', a pole mounted with a mesh basket through which seawater is pumped as the scoop is pulled through the sediment. There are concerns that this method of fishing could alter the sediment composition and have negative impacts on both benthic invertebrates and roosting birds. A recent study by Jensen *et al* (2004) concluded that this introduction may also have positive ecological impacts by providing an additional food source for wading birds and fish. The manila clam does not appear to be competing with our native clam species which have only been recorded sporadically in this area and manila clam appear to be providing a fishery resource which is sustainable at current exploitation rates. Investigations are now underway into other potential negative impacts associated with this fishery and it is hoped that the results will feed into the management of this fishery in due course (Jensen *et al*., 2004).

American hard-shell clam — *Merceraria merceraria*

There is a fishery for the non-native American hard-shelled clams, Merceraria merceraria, in Southampton Water, the northern part of the Solent. This fishery is concentrated around Lee and Hillhead, and in Portsmouth and Langstone Harbours, although this is reported to be much reduced from previous levels (Lockwood, 1986; Drummond, 1997). The origin of this species is uncertain although it has been attributed to seeding by fishermen in the 1930s and disposal overboard from vessels in the docks (Lockwood, 1986). Successful reproduction and naturalisation was thought to have occurred in the mid 1950s which was more or less coincident with the opening of a power station at Marchwood. The power-station closed in 1986 and this has been attributed to the decline observed in this fishery (Lockwood, 1986). Since this clam naturally occurs in much warmer waters it is possible that it was the warming influence of the outfall from the power plant that made naturalisation possible.

Whelks — *Buccinum undatum*

Whelks are common in the UK and are found mostly subtidally down to 1200 m. They are found on muddy sand, gravel and also rocks and are sometimes present in brackish water (Figure 2.69). Whelks lay small masses of lentil shaped eggs which they attach to rocks, stones and shells. The sponge like egg cases are relatively persistent and are often found washed up on the shoreline. Whelks are targeted on the extensive gravel deposits in the eastern Channel which provide the ideal substratum for this species (Clark, 2008).

Figure 2.69: Whelk, *Buccinum undatum* © seasurvey.co.uk

Whelks were the most important commercial species in terms of volume landed in the south east in 2006 (Cappell and Nimmo, 2007) although their relatively low market value means that they only ranked third in terms of value. Key ports for whelk landings include Eastbourne, Poole, Portsmouth, Selsey and Shoreham. The volume of whelks landed has increased significantly since 2000 and it is thought that this is a reflection of shifts in fishing efforts towards non-quota species. Whelks are fished using purpose designed pots or large reclaimed plastic drums which are weighted with concrete. The pots are baited, typically with crab or dogfish, and are shot in strings in a similar fashion to lobster pots (Clark, 2008).

Periwinkles — *Littorina littorea*

The periwinkle, *Littorina littorea*, is widely distributed on rocky coasts, in all except the most exposed areas, from the upper shore to the sublittoral. In sheltered conditions they can also be found in sandy or muddy habitats such as estuaries and mudflats. The species is fairly tolerant of brackish water. Periwinkle can breed throughout the year but the duration and timing of the breeding period is extremely dependent on climatic conditions. Sexes are separate, fertilisation is internal and L. littorea sheds egg capsules directly into the sea. Egg capsules are about 1 mm across and each capsule can contain up to nine eggs but normally there are only two or three. Egg release is synchronised with spring tides. In estuaries the population matures earlier in the year with maximum spawning occurring in January. Female periwinkles lay up to 100,000 eggs per year, released on several separate occasions.

Periwinkles are collected by hand between 15th May and the 15th September along the Sussex coastline (Sussex SFC byelaw), and also from Medina river on the Isle of Wight.

Cuttlefish — *Sepia officinalis*

Cuttlefish (Figure 2.70) are the most important cephalopod group for commercial fisheries in the north-east Atlantic, in terms of yield, and the English Channel (ICES rectangles VIId and VIIe) is the main fishing ground for this resource (Arkley *et al*., 1996; Denis and Robin, 2001; Royer *et al*., 2006). *Sepia officinalis* has a life span of around 2 years (Challier *et al*., 2002; Royer *et al*., 2006). They migrate inshore to spawn between spring and mid-summer, an event which is followed by mass adult mortality (Wang *et al*., 2003). Eggs are laid on suitable biogenic substrates such as polychaete tubes, seagrass or algae. Cuttlefish are also known to lay their eggs on man-made surfaces, including the traps used to catch them (Clark, 2007). The juvenile cuttlefish remain inshore until late autumn when they migrate to their offshore over-wintering grounds (Challier *et al*., 2002; Wang *et al*., 2003). Because of the short life cycle and migratory movements of this species, *S. officinalis* tend to occur in geographically and temporally distinct patches, and these concentrations are naturally targeted by fishermen. In the English Channel it is the inshore nursery areas that are the main focus of local fishing efforts (Dunn, 1999; Clark, 2007), although the offshore wintering areas are also targeted by the French (Clarke and Pascoe, 1985).

Figure 2.70: Cuttlefish, *Sepia officinalis* © seasurvey.co.uk

There has been a rapid increase in cuttlefish landings since the early 1980s and this is thought to be due both to the increase in its market value (Dunn, 1999) and the lack of restrictions compared with other commercial species (Royer *et al*., 2006; Clark, 2007). Dunn (1999) notes that no management measures have been applied to this fishery despite significant increases in exploitation levels. The use of cuttlefish traps has been encouraged and is now widespread in the UK (Dunn, 1999; Clark, 2007, 2008). Traps are encouraged because they only catch spawning cuttlefish with little or no by-catch. However, Arkley *et al* (1996) note that there may be high mortalities amongst eggs that remain attached to traps. Cuttlefish are also caught using otter and beam trawls as well as fixed nets (Clark, 2008). Minimum mesh sizes are set for these fisheries, but these are not specific to cuttlefish and so do not prevent the exploitation of juveniles (Dunn, 1999).

In a study by Clark (2007) cuttlefish were observed to lay their eggs in much higher densities on the traps than on natural substrata. It is likely that this phenomenon arises because the adults are trapped during spawning, but is perhaps also a reflection of the limited availability of their preferred natural substrata. Given the densities of eggs which are laid upon the traps, mortalities associated with their removal are likely to be significant. Preliminary trials have been undertaken by Sussex Sea Fisheries Committee into the possibility of offsetting this impact using artificial egg receptors (Clark, 2007). The findings of this study were very promising and so it seems likely that fisheries in this area will be encouraged to adopt practices which protect cuttlefish eggs in the future.

As well as representing an important fishery resource, cuttlefish fulfill potentially important ecological roles as both predators of crustaceans and small fish (Castro and Guerra, 1990) and as prey for marine mammals such as Risso's dolphin (Clarke and Pascoe, 1985).

2.10.10 Sharks & rays

There are over 50 species of sharks and rays, collectively termed elasmobranches, which can be found in British waters, many of which appear on the IUCN Red List (Camhi *et al*., 2007). Elasmobranches are typically slow growing and have a low reproductive output making them more sensitive to fishing pressures than other target groups. Smaller species, including skates, rays and dogfish form an important component of the commercial fishery in the South Coast region, although they are mostly caught as by-catch. Larger sharks have historically been the target of commercial fisheries in the UK but are now caught primarily by recreational anglers, if at all. For completeness the following section provides a brief overview of both commercial and non-commercial shark and ray species which are known to occur in the South Coast region.

2.10.11 Pelagic sharks

Basking shark

The basking shark, *Cetorhinus maximus*, is the second largest fish in the world and the largest fish found in British waters, attaining lengths of up to 9.8 m (Figure 2.71). The basking shark is usually dark grey to black but paler patches are often found on the snout and on the ventral surface. This species has a large triangular dorsal fin and a moon shaped caudal fin. Basking sharks are easily distinguished by their huge mouths and gill slits. A very large liver provides the basking shark with sufficient buoyancy to passively feed on surface aggregations of plankton (Greenberg, 2008). This species is most commonly sighted during summer in western Ireland, western Scotland, the Clyde area, the central Irish Sea, approaches to the Bristol Channel and the western English Channel (Sims *et al*., 1997; Sims *et al*., 2000a; Sims *et al*., 2000b; Southall *et al*., 2006). This species has been recorded across the majority of the UK's coastline, although they are sighted relatively infrequently across the waters of the South Coast region.

Figure 2.71: Basking Shark, *Cetorhinus maximus* © Sally Sharrock

Basking shark have been targeted for centuries to supply liver oil, leather, meat and fishmeal (Camhi *et al*., 2007). Most fisheries for this species have undergone classic boom-or-bust cycles, with very high yields followed by population collapse. One of the Irish basking shark fisheries for example, took up to 1,800 sharks per year at its peak in the early 1950s but landings had decreased by over 90% by the 1970s. There are still few basking shark sightings in this area, suggesting that this population has yet to recover from overfishing which occurred more than half a century ago (Camhi *et al*., 2007). The demand for basking shark for oil subsided with the shift to synthetic oils but they remain sought after for their large and valuable fins. Trade in all basking shark parts is now regulated and monitored as the species is listed as 'Endangered' on the IUCN red list and is one of few sharks listed in the Convention on International Trade in Endangered Species (CITES). Fishing by all EU vessels is now prohibited and in the UK basking shark are also protected under Schedule 5 of the Wildlife and Countryside Act (1981), making it an offence to kill, injure or recklessly disturb this species. Basking shark are however still caught occasionally as by-catch (Clarke *et al*., 2008).

Thresher shark

There are three species of thresher shark, pelagic thresher, Alopias pelagicus, bigeye thresher, *A. superciliosus*, and the common thresher, *A. vulpinus*. Thresher sharks are found in all oceans and are seasonally migratory. Occurrences of the common thresher off the south coast of England are regular, making it the most common of the large sharks in this area, although the bigeye thresher has been recorded intermittently (Pascoe, 1986; Thorpe, 1997).

Thresher sharks have relatively short heads and are easily recognised by the extremely long upper lobe of the caudal fin which they use to stun prey. The common thresher shark is blue, grey or silver above and white below. Stomach content analysis of a common thresher shark found entangled in a gill net at Bigbury Bay in Devon revealed a diet consisting solely of teleost fish. More detailed stomach analysis of sharks is difficult since the soft tissue of prey taken by these large predators is often macerated and digested rapidly. The common thresher is thought to utilise coastal waters as nursery areas but their location and extent is as yet unknown.

Thresher sharks are highly vulnerable to overfishing worldwide as their meat and fins are of great value. Studies in the Mediterranean show a decline in abundance and biomass of over 99% in the last 100 years (Greenberg, 2008). In a study of the composition of shark fins entering the Hong Kong market, Clarke *et al* (2006) established that threshers accounted for over 2%. This translates to between 0.4 and 3.9 million tonnes of thresher shark entering the fin market per year. Although targeted fisheries for thresher shark are uncommon, these sharks are often retained when caught as by-catch and they are also a prized game fish (Pascoe, 1986). Despite being listed in Annex I of the United Nations Convention on the Law of the Sea (UNCLOS) few management measures have been adopted for thresher sharks in international and national waters (Camhi *et al*., 2007).

Porbeagle shark

The porbeagle, *Lamna nasus*, inhabits waters between 5°C and 20°C in the temperate seas of the north and south Atlantic, as well as the Mediterranean and the Baltic seas (Ellis and Shackley, 1995; Pade *et al*., 2009). Tagging experiments have recently revealed that porbeagle sharks show a degree of fidelity to coastal and shelf habitats during the summer (Pade *et al*., 2009). Towards late summer and early autumn porbeagle sharks undertake long-distance migrations to the shelf edge and off shelf areas (Greenberg, 2008; Pade *et al*., 2009).

Porbeagle sharks feed on small fish, other sharks and squid (Greenberg, 2008). The inshore migrations of the porbeagle are thought to be part of their breeding cycle. Female porbeagle produce an average of four pups per litter (Greenberg, 2008). Pregnant female porbeagle sharks have been caught off the Isle of Wight and so it is possible that they are using this area as a nursery, although no conclusive records of defined nursery or breeding grounds currently exist.

The porbeagle has been intensely targeted by commercial fisheries since the 1920s for their high quality meat and also as a preferred species for skin to produce leather. Porbeagle have also been used historically for liver oil and fishmeal (Camhi *et al*., 2007). Since the 1920s the porbeagle fishery has suffered several collapses due to overfishing (Camhi *et al*., 2007; Dulvy *et al*., 2008). The porbeagle shark is now listed in the IUCN red list as Critically Endangered in the Northeast Atlantic but despite this, and listings under other conservation instruments, the EU fishing quotas for this species are currently set well above scientific recommendations (Camhi *et al*., 2007; Greenberg, 2008). Targeted porbeagle fisheries remain active in the UK with recorded landings of 26 tonnes in 2008 (Camhi *et al*., 2007; Clarke *et al*., 2008). This shark is also caught as by-catch in the pelagic and long line fisheries and is targeted by recreational anglers (Dulvy *et al*., 2008; Greenberg, 2008).

Blue shark

The blue shark, *Prionace glauca* (Figure 2.72), is a slender and agile shark with a conical snout and clear delineation between its blue dorsal surface and white underside (Greenberg, 2008). The blue shark is a pelagic species having a virtually circumglobal distribution in tropical and temperate seas (Stevens, 1973; Henderson *et al*., 2001; Camhi *et al*., 2007; Dulvy *et al*., 2008; Greenberg, 2008). Blue sharks extend their range northwards in the summer months in both the Pacific and Atlantic. Blue sharks occur regularly and in high numbers around the south coast of England during this time (Stevens, 1973). The migratory movements of this species are thought to be linked to prey movements and reproductive cycles (Greenberg, 2008). Male blue sharks are rarely recorded in inshore areas indicating that females move here to give birth (Henderson *et al*., 2001). Blue shark feed primarily on cephalopods although they are also known to take fish, other sharks and even small cetaceans (Stevens, 1973; Greenberg, 2008).

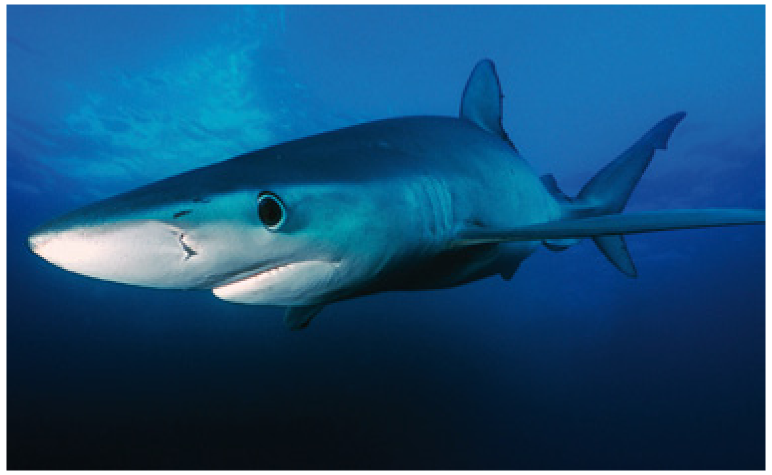


Figure 2.72: Blue Shark, *Prionace glauca* © Sally Pitkin

As well as being one of the most wide-ranging and historically abundant sharks, the blue shark is also the most heavily fished shark species in the world (Greenberg, 2008). The blue shark is primarily fished with pelagic longlines but also represents a major commercialised by-catch in tuna and swordfish fisheries (Greenberg, 2008). Historically of low commercial value, blue sharks were frequently discarded and their catches unrecorded (Camhi *et al*., 2007). In response to the growing demand and high prices paid for shark fins, the demand for blue shark has increased. Today, blue shark account for over 55% of all pelagic shark landings recorded to species, and contribute at least 17% of the fins identified in the Hong Kong markets (Clarke *et al*., 2006; Camhi *et al*., 2007). The blue shark is listed as near threatened on the IUCN red list but there remains much uncertainty associated with its global status (Camhi *et al*., 2007). Whilst the blue shark is not fished commercially in the south coast region, it is a target for sport fishing and this practice has been found to have a negative impact on the population since sub-adult females are often caught and killed in high numbers (Vas, 1990).

Shortfin Mako shark

The shortfin mako, *Isurus oxyrinchus*, is a large, robust shark reaching up to 4 m in length (Figure 2.73). This species is recognisable by its lunate caudal fin and strong caudal keel but the snow white colouration around the mouth and snout means the shortfin mako is frequently mistaken for the great white, Carcharodon carcharias.

The shortfin mako has a circumglobal distribution occurring in the coastal and oceanic waters of all of the world's oceans. Shortfin makos are frequently taken as by-catch in long line and gill net fisheries and are discarded much less often than other pelagic sharks because of their high market value (Camhi *et al*., 2007). Shortfin makos are targeted for their high quality meat and also account for a significant proportion (~3%) of the shark fins in Hong Kong markets (Clarke *et al*., 2006). The shortfin mako is not known to be fished commercially in the south coast region but it is likley to be a target for recreational fishermen. The shortfin mako shark has been classified as vulnerable on the IUCN red list because of their low reproductive capacity and vulnerability to pelagic fisheries (Camhi *et al*., 2007; Dulvy *et al*., 2008). There is little available information regarding the distribution of this shark species but it has been recorded off the south coast of England and is likely to at least pass through the region of study.

Figure 2.73: Shortfin Mako, *Isurus oxyrinchus* © Jeremy Stafford-Deitsch.

2.10.12 Dogfish & triakid sharks

Dogfish (Figure 2.74) and triakid sharks (tope and smooth hounds) are widely distributed in the eastern Channel, and the eastern Solent has been identified as one of the few areas in the UK where tope *(Galeorhinus galeus)* and smooth hound *(Mustelus mustelus)* congregate in large numbers at certain times of the year (Poseidon, 2003). Smooth hounds give birth to between 4 and 10 well developed live young and feed mainly on crab, fish and molluscs. Tope have a very similar life history and it is thought that they are attracted to the Solent area between May and August both as part of their breeding cycle and because of the abundance of mussels, bass and soft-shelled hen crabs at this time (Poseidon, 2003). Tope and smooth hounds enter the east Solent from the south-west and collect in an area east of the Isle of Wight, they are known to lay their eggs in this area making it one of the main breeding areas of these two species in the UK (Poseidon, 2003).

Figure 2.74: Lesser spotted dogfish, *Scyliorhinus canicula* © seasurvey.co.uk

Large numbers of dogfish egg cases have also been observed in association with the Flustra foliacea beds of the eastern English Channel (Ellis *et al*., 2004).

Dogfish and triakid sharks do not represent a commercial fishery in their own right in this region but are caught incidentally through longlines and trawling (Pawson *et al*., 2002; Clark, 2008).

2.10.13 Skates & rays

The thornback ray, *Raja clavata*, or roker (Figure 2.75), is one of the most common ray species found in the South Coast region and it is known to occur on mud, sand, gravel and shingle substrate. Other rays found in the region include the spotted ray, Raja montagui, the undulate ray, *Raja undulata*, the cuckoo ray, Raja naevus, the starry ray, *Raja radiata*, the blonde ray, *Raja brachyuran*, and the marbled electric ray, *Torpedo marmorata* (Ellis *et al*., 2004). Rays lay encased eggs in shallow water over a long season following internal fertilisation from February to September and hatching occurs after 16–20 weeks. The precise spawning habits of the different ray species is not recorded in the literature although fishermen in the Inner Owers area suggest that eggs may be attached to stony, gravely areas in about 10m water depth (EMU, 2000b). Ellis *et al* (2004) observed high numbers of juvenile thornback and blonde rays in the South Coast region and so it is likely that this area could represent an important nursery area for rays.

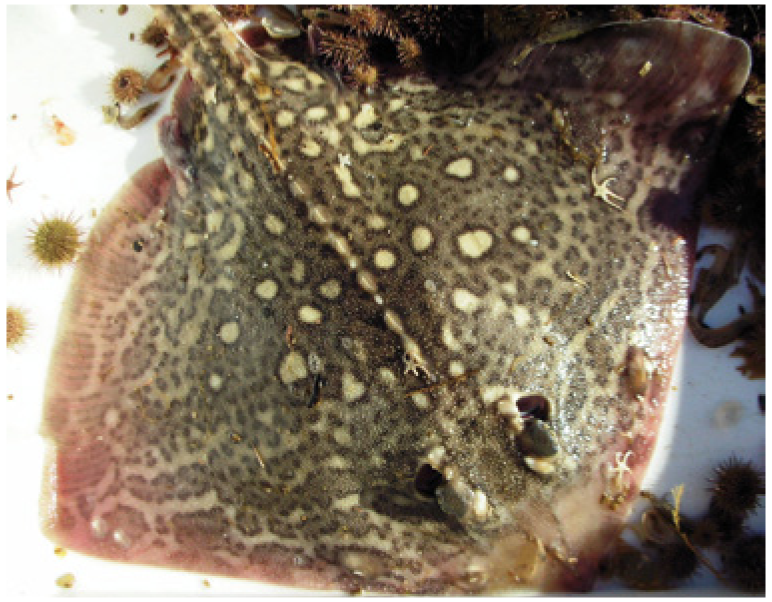


Figure 2.75: Thornback ray, *Raja clavata* © seasurvey.co.uk

Juvenile rays appear in the inshore areas of the Channel between November and December (Poseidon, 2003). Thornback rays have been observed to move progressively offshore as they grow with adults forming single sex shoals in water depths around 30 m. Tagging experiments have revealed that thornback rays rarely travel further than 15 miles in the eastern Channel although it is thought that they all belong to a single stock originating from the Celtic Sea (Poseidon, 2003).

Skates and rays are not targeted specifically by commercial fisheries in this area but do nevertheless represent an important by-catch of the trawl fisheries in this area (Cappell and Nimmo, 2007; Clark, 2008). Rays are also caught in the larger meshed tangle nets set to catch turbot and brill in the warmer months (Pawson *et al*., 2002). The thornback ray (Figure 2.75) is most commonly caught although; other rays such as the cuckoo, starry and blonde are also landed.

2.10.14 Angling

The South Coast region is a nationally significant area for recreational sea angling, driven by a number of factors:

- the proximity to a large human population,
- the diversity of features and habitats known as ‘marks’,
- the diverse assemblage of fish species,
- good access by boats provided by sheltered moorings.

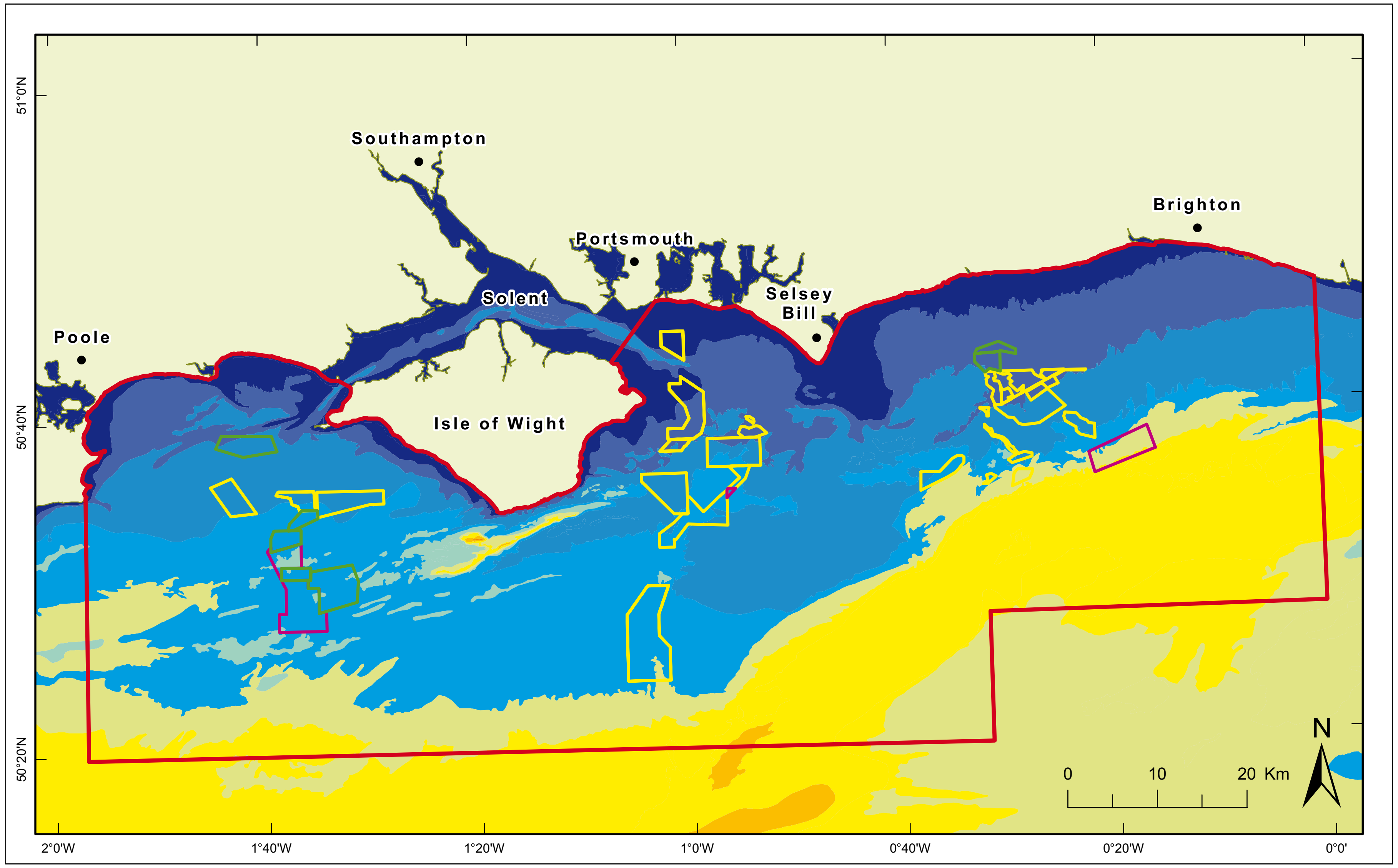
Onshore recreational angling occurs all along the coastline of the South Coast region; piers, marinas and harbour walls are all busy with anglers throughout the year. The open beaches and the many closed bays and estuaries are all important areas for recreational sea anglers. The diversity of these nearshore habitats produce a diverse range of fish species that are prized by sea anglers.

Offshore the South Coast region contains ‘marks’ that are nationally recognised as offering a unique angling experience. These include, but are not limited to, an area known as ‘Utopia’; famed for tope fishing; bass angling at ‘The Overfalls’, (both sites in the eastern Solent) and a bream nesting area near ‘Kingmere’ offshore from Littlehampton.

The offshore angling experience is facilitated by a flotilla of small privately owned craft, numerous angling club boats and a high proportion of the English charter angling fleet. Crabtree *et al*., (2004) estimated that there were some 120 registered charter angling vessels in 2004 which were based in ports within the south coast region.

Fish commonly targeted by sea anglers in the REC study area include bass, brill, turbot, cod, blonde ray, tope, smoothound, whiting, black bream, skate, pout and bull huss, as well as the larger shark species found in the region.

The disparate and diverse nature of recreational sea angling means that it is difficult to quantify the economic value of this activity, it is however likely to be locally significant. Tingley *et al*., (2006), in their multi-use, planning assessment of ‘The Overfalls’ area use the economic enjoyment criteria, also known as the consumer surplus factor, developed by Crabtree *et al*., (2004) to assess value of the site;



Source: www.thecrownestate.co.uk

Figure 2.76: Location of licensed aggregate areas.

> 'Whilst no money changes hands for this 'value or enjoyment' factor, it can be measured as the difference between what anglers would be willing to pay to get the same experience and what they do actually pay now.'

Tingley *et al*., (2006) value the Overfalls site, which is approximately 5 km² in extent, at between £12,700 and £83,900 per year (depending on the method used to calculate the figure). They further estimated that anglers spent between £100,000 and £200,000 annually to fish the Overfalls site.

It is clear that recreational sea angling is an important feature of the south coast region and an integral feature of the human use of the area.

2.11 Aggregates

The South Coast is one of seven regions in England and Wales where marine aggregates are dredged within designated licensed dredging areas. Marine aggregates are an important source of sand and gravel accounting for about 20% of total sand and gravel supply in England and Wales (Highley *et al*, 2007). In 2006 total marine aggregate production in England and Wales was 24.3 million tonnes (Mt), of which, 7.6 Mt (31.3%) was produced in the South Coast Region. (The South Coast Region in this aggregates section refers to the Region as defined by The Crown Estate in their aggregate statistics www.thecrownestate.co.uk/dredge_areas_statistics).

Marine aggregates account for about 32% of the total aggregate supplied to London and the South East and about 70% of total UK production of marine sand and gravel is landed in these two areas. The South Coast Region is a significant contributor to meeting the demand for aggregates in the South East. Over the ten-year period from 1998 to 2007, 48.581 Mt of marine sand and gravel was extracted from licensed dredging areas in the South Coast Region (The Crown Estate & BMAPA, 2009a). The cumulative footprint of dredging during this ten-year period covered 78.21 km² of the sea bed which is 1.37% of the 5673 km² area encompassed by the South Coast REC study area.

In 2008, 3.93 Mt of aggregate for construction purposes was dredged in the South Coast Region. Of this tonnage, 2.35 Mt was landed at eight wharves along the south coast from Poole in the west to Shoreham in the east. The wharves at Southampton and

Shoreham are the most significant and take 70% of the tonnage landed in the Region (www.thecrownestate.co.uk/dredge_areas_statistics). Elsewhere in England, 1.14 Mt was landed, and wharves in continental Europe received 0.44 Mt from the South Coast Region. In addition a further 0.22 Mt was dredged for beach nourishment schemes in 2008 (The Crown Estate & BMAPA, 2009b).

There are currently, in 2009, twenty four licensed dredging areas in the South Coast Region assigned with seven operating companies. These are clustered in three groups (Figure 2.76), two of which are west and east of the Isle of Wight, and the third group is east of Selsey Bill in an area that is designated as the Owers Bank by The Crown Estate. There are also seven licence application areas (Figure 2.76) that are currently in the process of evaluation; none of these application areas are in the group east of the Isle of Wight.

Marine sand and gravel in economic quantities is a relatively finite resource. The requirement to seek new resources as extraction proceeds in licensed areas is an important consideration not only for operating companies wishing to maintain aggregate supplies for their business, but also for regional and national planning in maintaining aggregate resources for economic development. To this end, The Crown Estate issues prospecting area licences to companies to undertake geological and geophysical surveys for the assessment of sediments and geology in an area, and its potential as an aggregate resource. There are currently (2009) four prospecting areas in the South Coast Region (Figure 2.76). Two of these are in the group of areas west of the Isle of Wight, One very small area lies in the group east of the Isle of Wight and the fourth prospecting area is in the south east corner of the Owers Bank group.

The location of these licensed dredging and application areas is primarily controlled by the location of sand and gravel of suitable quality and in sufficient quantity to sustain the economic extraction of marine aggregate. There are obviously other factors that have to be accounted for including legislation, environmental issues, fisheries, conservation and shipping, but the availability of aggregate is a primary control on location.

Chapter 4 describes the interpretation of the geology and sediments of the South Coast REC study area. A notable feature of the study area is the extent of rock and thin sediment (<1.0 m) (Figure 4.17a, b). It underlies 75% of the sea bed. Sediments of any thickness >1.0 m are interpreted as underlying only around 25% of the sea bed. Rock and thin sediment are not likely to be economically viable marine aggregate resources. This conclusion is confirmed by comparing the location and extent of the licensed dredging, application and prospecting areas shown in Figure 2.76 with the sea bed character geology seen in Figure 4.17a, b. All the licensed areas are associated with areas of thicker sand and coarse sediment.

The majority of the licensed areas are aligned within and along ancient river channel systems with their associated infill and marginal terraces. A few areas in the group west of the Isle of Wight appear to be associated with sediment sheets which are relatively thin and widespread, as well as river channel systems. A couple of licensed areas are linked with sand banks west of the Isle of Wight and in the south east of the Owers Bank. Although not currently licensed, gravel from Shingle Bank at the western entrance of the Solent has been dredged in the past for beach nourishment in Christchurch Bay.

Marine aggregate extraction is not the only industry to have exploited the sea bed for construction material. In the 17th and 18th centuries, limestone was being quarried from below the high water mark on the Bembridge Ledges off the northeast tip of the Isle of White from Tyne Ledge at the entrance to Bembridge Harbour around past the Foreland to Whitecliff Bay (Fenn, R W D, 2009?). The Tertiary Bembridge Limestone which is exposed on the ledges was easily split along its bedding planes in to blocks which could be used in masonry. The locality was accessible by boat and therefore the limestone was readily transported by sea, not only for use on the island but across the Solent on the mainland. It was only the coming of brick making on an industrial scale in the 19th century that brought an end to offshore quarrying.

2.12 Disposal sites

Disposal of material at sea is a regulated activity and requires a license under the Food and Environment Protection Act. Certain areas of sea bed are designated as licensed disposal sites. Ten such sites exist within the REC area (Figure 2.77) and are designated for Dredge Material Disposal (DMD) sites. These sites have well defined boundaries and the type and amount of material deposited each year is monitored. There is a further disposal site in the vicinity of St Catherine's Deep, just south of the Isle of Wight, which is known to have been used as a munitions dump during the Second World War. The bounds of this site are approximate and records of the materials deposited there could not be obtained.

2.12.1 Dredge Material Disposal (DMD)

Types of material

Records exist for eight types of material that have been deposited in the area. Although colloquially referred to as 'dredge material', they include substances that are not related to dredging. The types of materials are as follows:

Capital Dredgings (CD). This is material that has either been dredged for the first time, such as during the construction of a new port or marina, or is from areas that have not been dredged in the last 10 years.

Maintenance Dredgings (MD). This is material considered to originate from natural siltation processes (i.e. mud or sand) removed from areas such as ports, marinas and navigation channels in order to maintain access and function. It only applies to material from areas that have been dredged within the last 10 years.

Re-deposited Dredgings (RD). This is material that originates from dredging trials, or sometimes from aggregate dredging where the material brought on board the dredger does not meet the target requirements, so is deposited back on the sea bed. The term 'spoilt cargo' is used in the aggregate industry, but this does not imply the material is contaminated in any way.

Sediment (SE). This is the unwanted, finer material washed from aggregate cargos which is not of commercial value and so is returned to sea.

Aqueous Organics (AO) and Aqueous Solids (AS). This is liquid industrial waste, which used to be disposed of at sea. This practice is reported to have stopped at the end of 1992 (info. from MFA website).

Drilling Muds (DM). These are the various types of lubricating mud used in drilling rigs. In the REC area this material originates from a few directional drilling operations related to the installation of coastal pipelines.

Sewage Sludge (SS). This is material derived from sewage plants. The disposal of this material at sea is reported to have been phased out during 1998 (info. from MFA website).

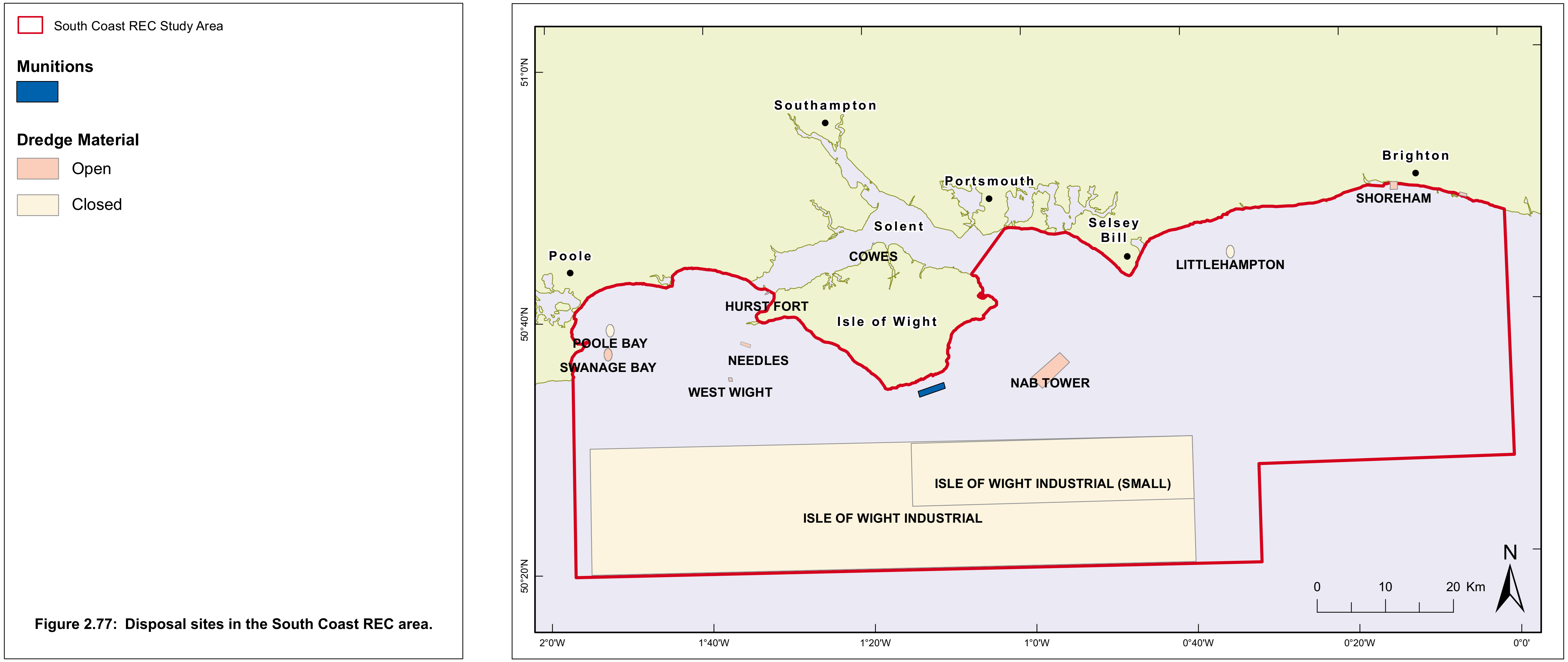


Figure 2.77: Disposal sites in the South Coast REC area.

Licensed disposal sites

Of the ten licensed disposal sites in the REC area, four are closed (Figure 2.77 and Table 2.5). The remaining six are open and DMD records for the years 2000 to 2008 show these have received material each year, except the Needles site which has a zero return for 2007 and 2008. The total amount of DMD recorded for the nine year period is 264.5 million tonnes (Mt).

The amount and type of material deposited at each of the open sites is illustrated graphically in Figure 2.78, 2.79 and 2.80. The Nab Tower site is by far the most used, taking 80% of all DMD material deposited in the South Coast REC, with a total of 211.5 Mt over the 9 years, peaking at 50.5 Mt in 2004. By far the greatest proportion of this is Maintenance Dredgings (95%) followed by Capital Dredgings (3.9%). The site lies in the centre of a cluster of licensed aggregate dredging areas and received 2.28 Mt of Sediment material.

The two next most heavily used sites are Swanage Bay (24 Mt; 9%) and Shoreham (22 Mt; 8%). 60% of the material deposited in the Swanage Bay site is Capital Dredgings, and 40% Maintenance Dredgings, while at Shoreham it is 99.95% Maintenance Dredging.

The other sites received fewer than 3% of the total, with Hurst Fort at 1.79 Mt, Needles at 0.54 Mt and West Wight at 0.33 Mt. Hurst Fort only received Maintenance Dredging. The Needles site received approximately equal amounts of Capital and Maintenance Dredging. The West Wight site lies at the edge of a licensed Aggregate site, and receives only Re-deposited material.

The two large disposal sites in the south of the REC area and the much smaller Littlehampton site were all closed in 1998, while the Poole Bay site was closed in favour of the Swanage Bay site in 2002.

2.12.2 Source of information

The information on disposal sites has been provided by Cefas' Regulatory Assessment Team and was sourced from the Marine Consents Management System (MCMS), which is currently run by the Marine and Fisheries Agency (MFA) who deal with applications for disposal under FEPA regulations.

Site name	Year Closed	Type of material							
		AO	AS	CD	DM	MD	RD	SE	SS
Swanage Bay				x	x	x		x	
West Wight							x		
Needles				x		x			
Hurst Fort				x		x		x	
Nab Tower		x		x	x	x		x	x
Shoreham				x		x		x	
Poole Bay	2002					x			
IoW Industrial	1998		x						
IoW Industrial (small)	1998		x						
Littlehampton	1998					x			

Table 2.5: Type of dredge materials received by the 10 licensed disposal sites recorded in the South Coast REC area, with year of closure (where appropriate). AO = Aqueous Organics, AS = Aqueous Solids, CD = Capital Dredgings, DM = Drilling Muds, MD = Maintenance Dredgings, RD = Re-deposited Dredgings, SE = Sediment, SS = Sewage Sludge.

For further information see following web resources.

Cefas information leaflet on disposal at sea:

http://www.cefas.co.uk/publications/marketing/disposal_to_sea.pdf

Marine and Fisheries Agency (MFA) and Marine Consents & Environment Unit (MCEU information on disposal at sea:

http://www.mceu.gov.uk/MCEU_LOCAL/FEPA/FEPA-waste-disposal.htm

http://www.mfa.gov.uk/environment/works/consents-disposal.htm

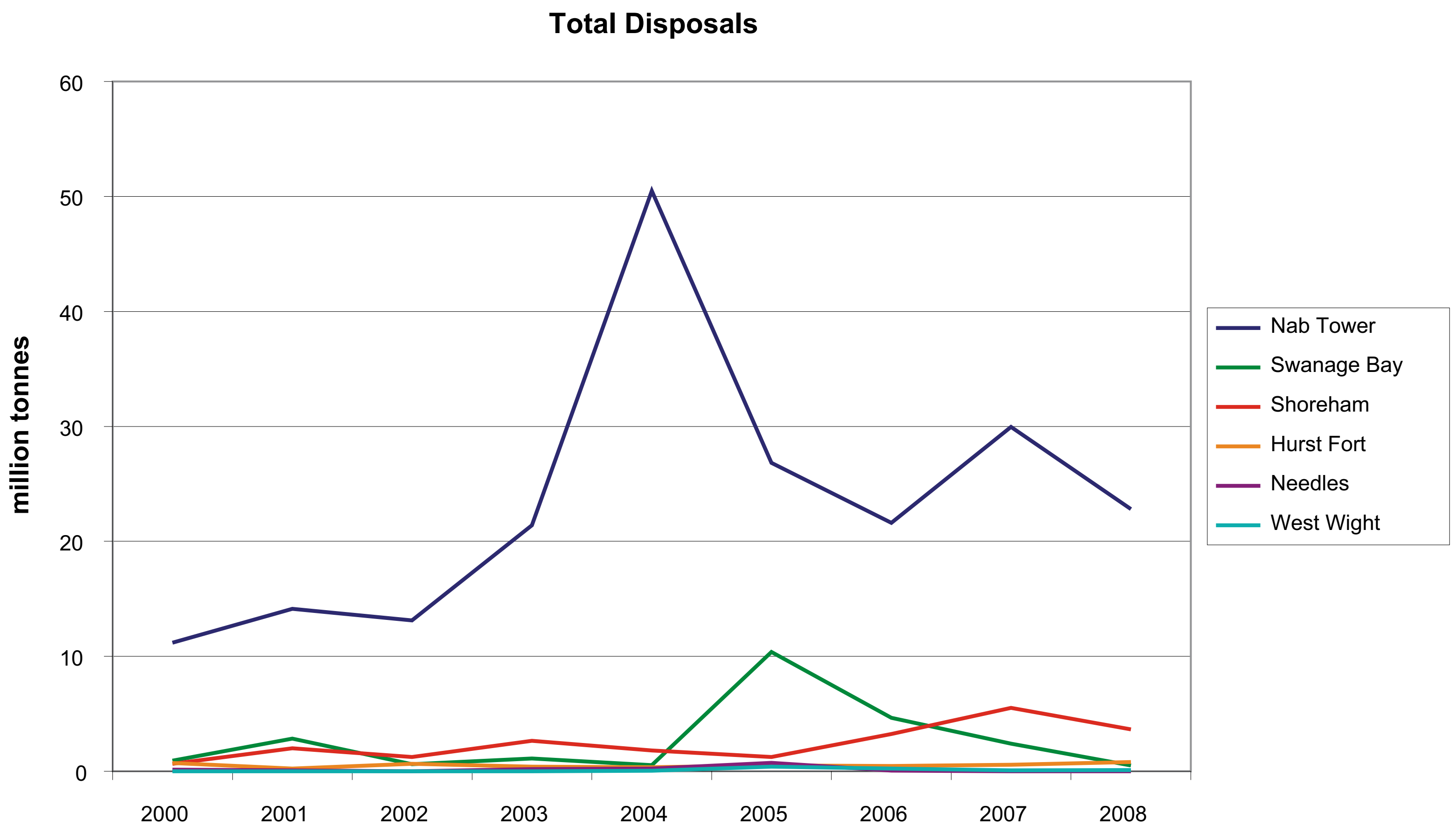


Figure 2.78: Total amount of 'dredge material' deposited each year at six licensed disposal sites in the South Coast REC area for the period 2000 to 2008 (millions of tonnes).

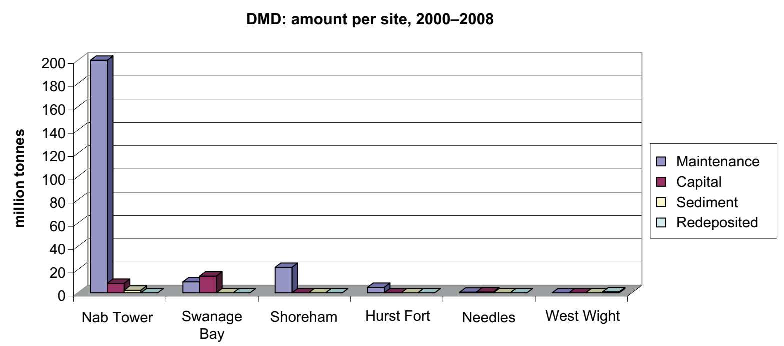


Figure 2.79: Dredge material disposals (DMD) 2000–2008 showing dominance of Nab Tower site.

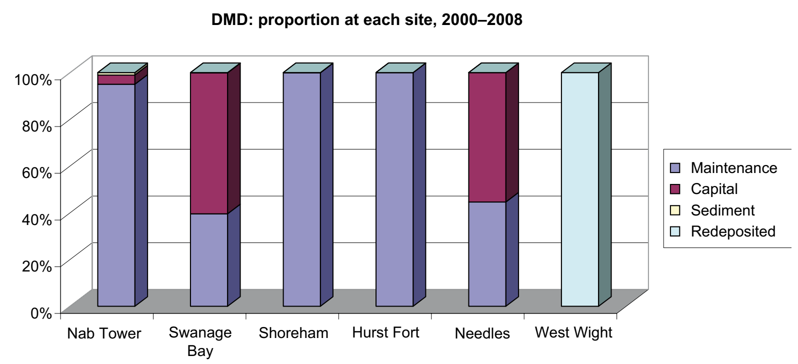


Figure 2.80: The proportion of each type of dredge material disposal (DMD) at the six licensed disposal sites for the period 2000–2008.

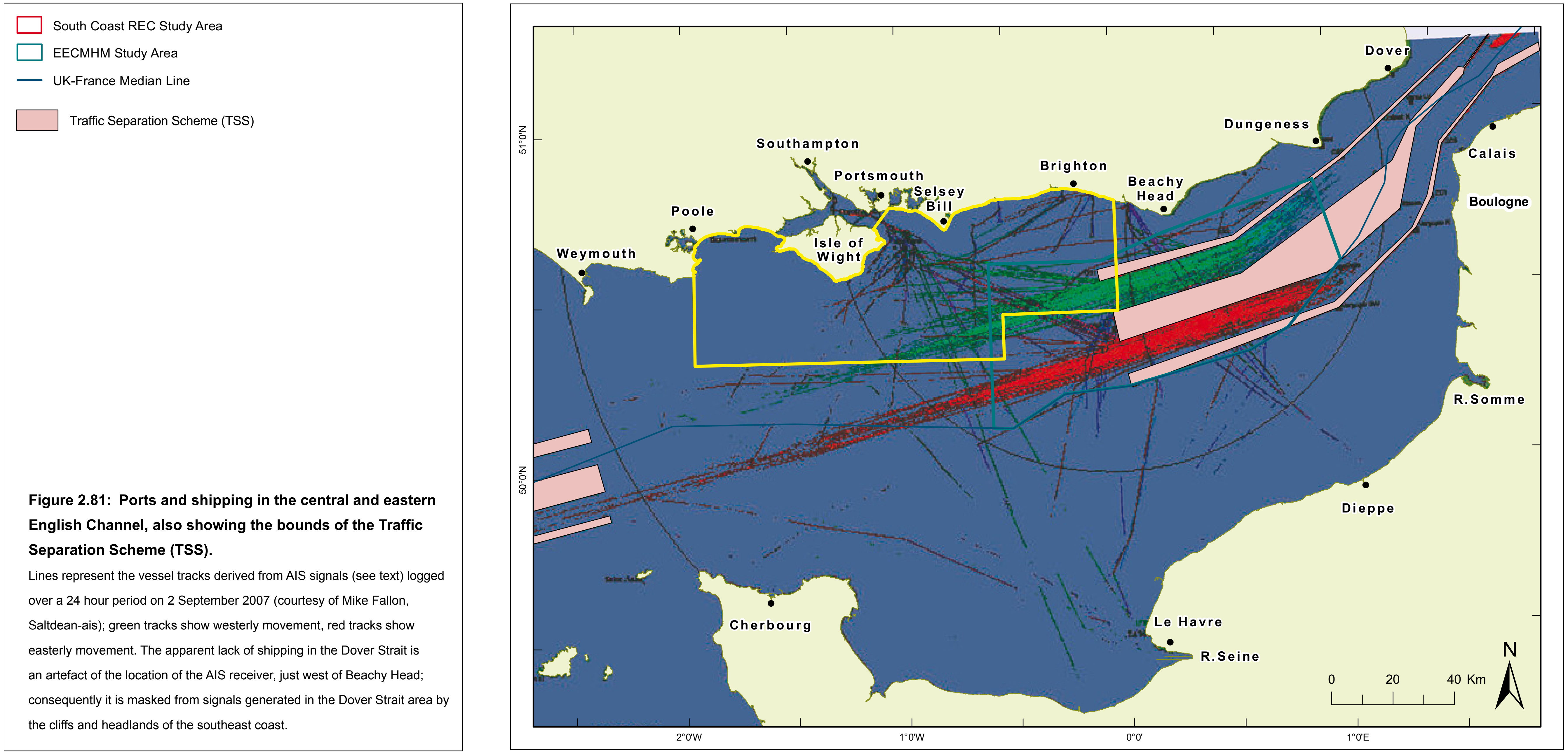


Figure 2.81: Ports and shipping in the central and eastern English Channel, also showing the bounds of the Traffic Separation Scheme (TSS).

Lines represent the vessel tracks derived from AIS signals (see text) logged over a 24 hour period on 2 September 2007 (courtesy of Mike Fallon, Saltdean-ais); green tracks show westerly movement, red tracks show easterly movement. The apparent lack of shipping in the Dover Strait is an artefact of the location of the AIS receiver, just west of Beachy Head; consequently it is masked from signals generated in the Dover Strait area by the cliffs and headlands of the southeast coast.

2.13 Ports and shipping

The English Channel is one of the world's busiest shipping routes, linking the North Sea to the northwest Atlantic. Ship traffic is likely to increase in future, given the general expansion in world trade and the desire to ease land transport problems. It is estimated that the European Union (EU) transports about 90% of its external trade by means of ships. (Anon, 2005).

In addition to vessels transporting goods through the Channel, there is also a significant amount of traffic engaged in transporting goods and people across the Channel, between many of the well known ferry ports. A large proportion of the shipping in the Channel therefore follows well defined routes, but vessels engaged in other activities, such as fishing or leisure, tend to navigate more freely within the area, though some popular boating routes are shown in the UK Coastal Atlas of Recreational Boating, developed by Trinity House and the RYA primarily 'as a tool for offshore energy developers to assist them in their planning' (www.rya.org.uk/infoadvice/planningenvironment/Pages/boatingatlas.aspx). This brief review deals with the area outlined in Figure 2.81.

2.13.1 Ports

Trade between England and Europe has historically relied on there being good sea ports on the English south coast and the French north coast. Even with the advent of the Channel Tunnel, these ports are still important. From west to east, the major British ports are Portland (by Weymouth), Southampton, Portsmouth, Newhaven (just west of Beachy Head), Folkestone and Dover, but there are also a number of secondary ports used mainly by smaller fishing and leisure vessels, including Poole Harbour, Cowes, Chichester, Littlehampton and Rye.

Four of the five ancient 'Cinque Ports' are located in the eastern channel, namely Hastings, New Romney, Hythe and Dover. The fifth, Sandwich, is located on the east Kent coast, north of Dover. In medieval times these were assigned an advantageous legal and financial status by the English monarchy in exchange for providing ships and sailors to defend the realm against invaders. Since then, the sea has receded to an extent that some of the ports are now riverine rather than coastal.

On the French coast the major ports are Cherbourg, Le Havre, Dieppe, Boulogne and Calais. They are familiar to many who travel to Europe by ferry and their importance is highlighted by the disruption caused to commerce during modern-day blockades that are occasionally used to focus political attention on industrial or trade disputes.

Southampton and Portsmouth are the major British ports in the central Channel, accounting for much of the traffic that crosses the Soutn Coast REC area. Southampton is a deep water port specialising in freight and cruise liners, while Portsmouth hosts a busy ferry port, a historic dockyard and a modern Naval base.

2.13.2 Shipping movements; observation and monitoring

There are a number of websites that display live shipping movements in the Channel, through tracking and plotting positional information encoded in the Automatic Identification System (AIS) signals from passing vessels. This is a VHF transmission and is mandatory for the majority of ships greater than 300 gross tonnes. Some other vessels e.g., fishing and leisure craft, carry it voluntarily. The Saltdean AIS website specialises in shipping movements in the English Channel and has provided the image of ship movements used in constructing Figure 2.81. Such sites provide a useful, easily accessible overview of shipping movements.

A more detailed radar-based vessel tracking system (VTS) is run by the Maritime and Coastguard Agency (MCA) through its Channel Navigation Information Service (CNIS). This provides a 24 hour radio and radar safety service for all shipping in the Dover Strait and is jointly operated by the UK and French Administrations from the Dover Maritime Rescue Co-ordination Centre (MRCC) and CROSS Gris Nez in France. The functions of CNIS are to keep the Dover Strait Traffic Separation Scheme (TSS) under observation, to monitor the flow of traffic and to detect and report vessels which contravene the International Regulations for Preventing Collisions at Sea (COLREGS).

A ShipRoutes database is commercially available from Anatec UK Ltd (www.anatec.com/) and can provide details on shipping routes passing any site in the Channel.

Ships on passage through the central and eastern Channel minimise the risk of collision by adhering to the Traffic Separation Scheme (TSS) (Figure 2.81), which was established by the UK, France, Belgium and The Netherlands. The practice of following predetermined routes has been in existence for nearly a hundred years and was applied in the Dover Straits in the 1960s, leading to the present-day scheme where opposing traffic is separated into 'lanes'. This starts in the west with the Casquets TSS and continues through the Dover Strait TSS which extends into the southern North Sea. Vessels heading west keep to the northern lane (English side) while those heading east keep to the southern lane (French side). There are special routes for deep draught vessels, and an Inshore Traffic Zone (ITZ) between the Dover TSS and the Kent coast, the use of which is being progressively restricted to smaller vessels.

Whilst in the Channel, shipping is monitored and controlled by the Coastguard, who have stations in the Portland, Solent and Dover areas. The French Coastguard controls the area around the Cas-quets TSS.

The volume of traffic in the Channel is considerable. Within a 15 mile radius of the Channel Light Vessel, which lies just west of the Casquets TSS at 49° 55′ N, 2° 54′ W, there are around 47,000 commercial vessel movements a year. This reduces to around 19,000 per year within a 15 mile radius of the St Catherine's Lighthouse, located on the south coast of the Isle of Wight. In addition, there is a high level of small craft activity, including fishing and pleasure craft that are not included in these figures (Anon, 2005).

Some vessels travel very quickly, with high-speed ferries operating at speeds up to 50 knots and some inshore fishing vessels capable of speeds in the region of 30 knots. Other vessels, like sailing boats and pleasure craft move more slowly and some, such as aggregate dredgers working at licensed extraction sites or dive-support vessels, can be almost stationary.

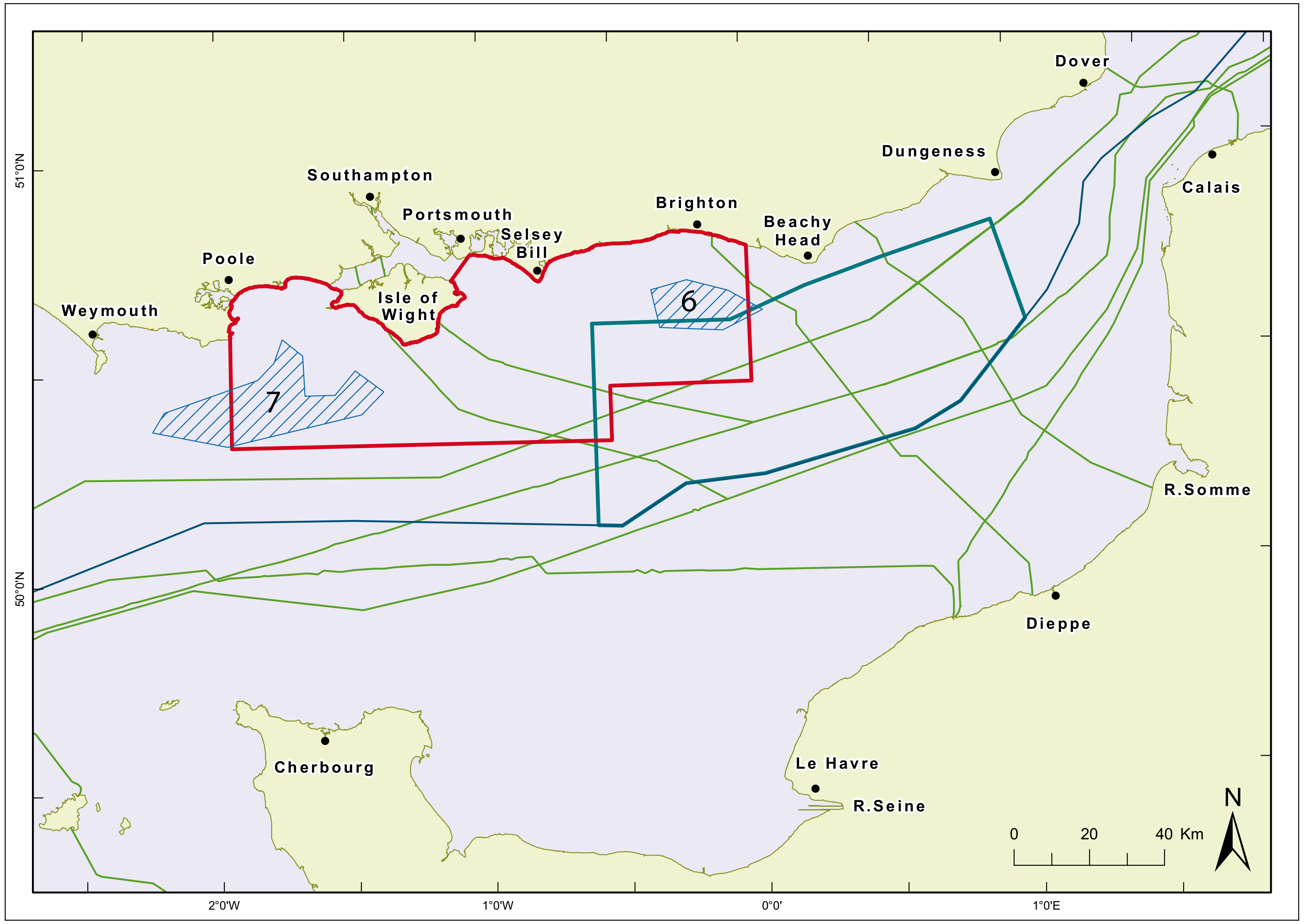


Figure 2.82: Location of Crown Estate Round 3 windfarm development zones and identified submarine cables (may not be comprehensive).

2.14 Offshore windfarms

In June 2008 The Crown Estate launched its 'Round 3' leasing programme for the delivery of up to 25 gigawatts (GW) of new offshore windfarm sites by 2020. There are to be nine development zones around the country, two of which overlap the South Coast REC study area, namely Zone 6 'Hastings' and Zone 7 'West of Isle of Wight' (Figure 2.82).

The selection of zones has followed a Strategic Environmental Assessment (SEA) programme conducted by the Department for Business, Enterprise & Regulatory Reform (BERR) to assess suitability of UK offshore waters for windfarm development. The Crown Estate will take a more prominent role in the Round 3 development than in Rounds 1 or 2, co-investing with developers and being more involved in programme delivery and zonal contract management. The Crown Estate will work with development partners to identify suitable windfarm sites within each zone, but will not be involved in the construction or operation of the windfarm sites.

Progress on the Round 3 development issues can be followed on the websites of The Crown Estate and RenewableUK (formerly the British Wind Energy Association) at:

http://www.thecrownestate.co.uk/our_portfolio/marine/offshore_wind_energy/round3

http://www.bwea.com/offshore/index.html

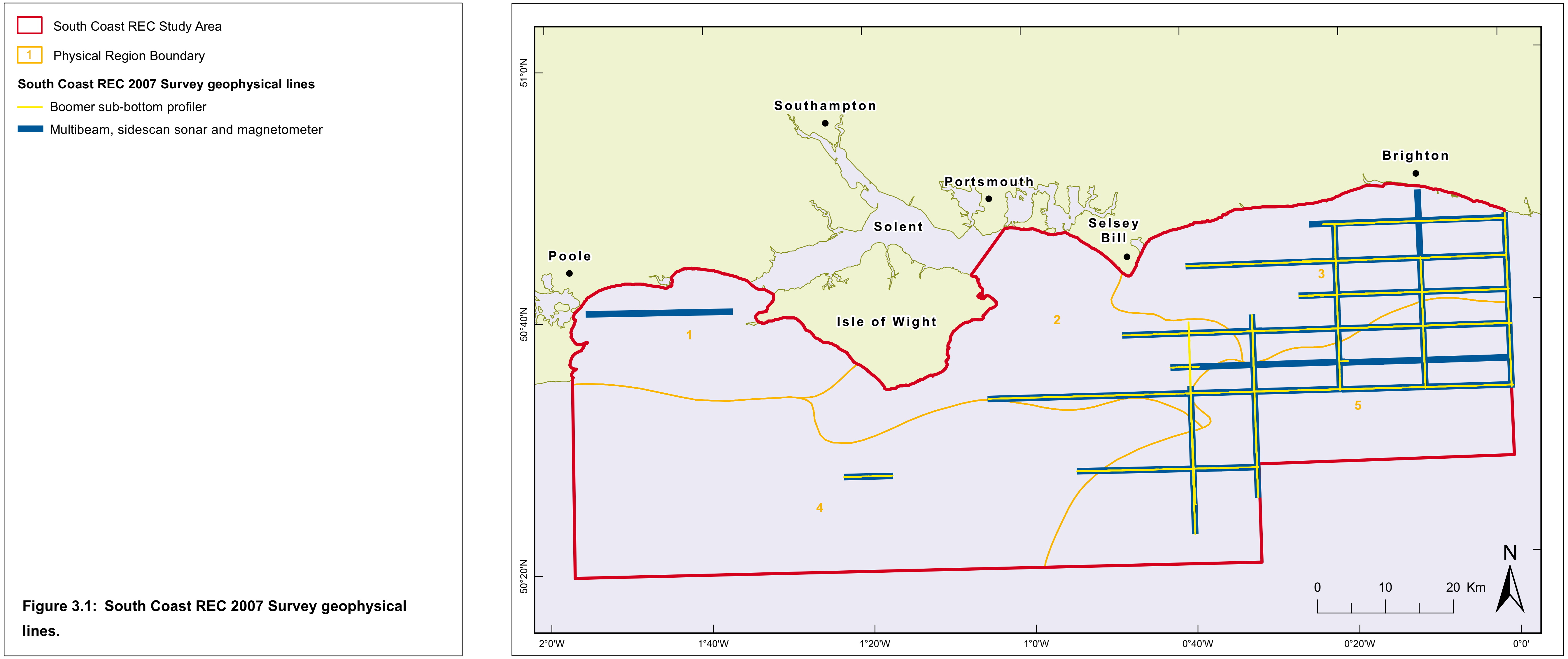


Figure 3.1: South Coast REC 2007 Survey geophysical lines.

3 Survey Data and GIS

The South Coast Regional Environmental Characterisation (REC) study was completed as two separate programmes of work by two different contract consortia. The first was a survey programme in 2007 that collected geophysical, underwater video and sample data, allied with initial analysis of the collected grab and trawl data for particle size and species identification. The second programme, started in 2008, comprised the interpretation of the survey data and the production and publication of this report and associated data sets.

3.1 Survey planning

The planned surveys were designed to provide coverage of the whole study area at a regional scale. The geophysical survey was to comprise 28 survey corridors, each containing one centre line and two parallel wing lines, totalling approximately 4100 line km. The corridors were to be spaced at intervals from 5 to about 12 km apart in a north-south and east-west grid.

The geophysical survey strategy was similar to that undertaken for the Eastern English Channel Marine Habitat Map (EECMHM) (James *et al*., 2007) with sidescan sonar and multibeam echo sounder (MBES) deployed simultaneously along each of the three adjacent lines with the aim of providing a sea bed swath width of up to 500 m (depending on water depth) for each corridor. Shallow sub-sea bed seismic data were to be acquired with a boomer sub-bottom profiler running along the centre line of each corridor simultaneously with the sidescan and MBES. The boomer was not run on the wing lines. A magnetometer was not included in the EECMHM survey but was included in the South Coast REC survey and was run on both the centre and wing lines.

The geophysical survey was to be followed by a sampling survey with grab, trawl and sea bed camera at each sample station. The sample stations were to be located at the crossing point of each corridor on the grid, with a few other additional stations elsewhere on the corridors. Their location on corridors was to enable the direct

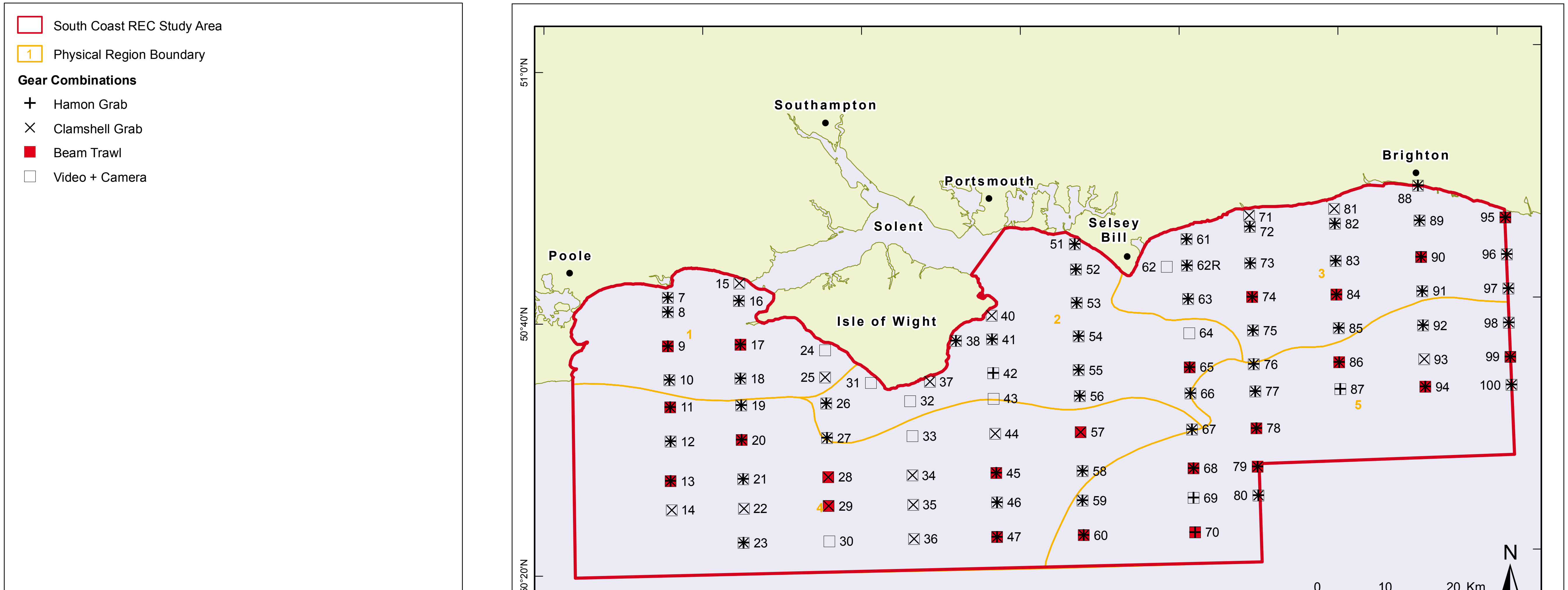


Figure 3.2: South Coast REC 2007 Survey sample stations with sample gear.

correlation of sample station results with the geophysical data to provide an integrated physical/geophysical interpretation at each station, which could be extended, using the geophysical corridor results and other data, into a wider interpretation of the South Coast REC study area. In total 90 sample stations were proposed.

3.2 South Coast REC 2007 Survey data

The survey programme contract for the South Coast REC was awarded to Gardline Ltd in association with MES Ltd and Cefas.

3.2.1 Geophysical survey and methods

The geophysical survey was undertaken in June/July 2007 with the survey vessel MV *Confidante*. Unfortunately the survey period was characterised by a phase of prolonged bad weather, this and issues with fishing activity, shallow water, strong currents and heavy vessel activity meant that the corridor line plan was revised in early July 2007 (Gardline, 2008). The revised survey plan reduced the line kilometres by about 50% from 4122 km to 1945 km. This was achieved in part by removing the wing lines from the east-west corridors, leaving just the centre lines, and some corridors were shortened or removed completely.

However, bad weather went on through July and the survey was halted on a number of occasions, and at other times data acquisition continued when of marginal quality to ensure at least some data was available for interpretation. Throughout the survey, data quality was generally marginal to good (Gardline, 2008). At the close of the geophysical survey 650 line km of data had been acquired, this was 33.4% of the revised line plan and only 15.8% of the original line plan of 4,100 km.

Figure 3.1 illustrates the completed geophysical coverage of the South Coast REC 2007 survey. The relative lack of coverage is evident with much of the sea bed west of Selsey Bill devoid of geophysical line data. It is only east of Selsey Bill where a grid of lines has been completed. Also not all lines have a complete suite of sidescan, MBES, boomer and magnetometer data. The boomer sub-bottom profiler is particularly susceptible to poor sea conditions, more so than the other equipment which can continue to produce acceptable data in conditions when the boomer is redundant. Hence there are a number of lines shown in Figure 3.1 where boomer data is missing and only MBES, sidescan and magnetometer data were collected. In the study area west of the Isle of Wight no boomer data were collected and only a single short boomer line, <10 km long, lies south of the Isle of Wight.

Multibeam echo sounder (MBES)

A Simrad EM3002D multibeam echo sounder was hull mounted on the MV Confidante and was used to provide swath bathymetry data. This is a 300 kHz frequency system with an angular coverage of 130° giving swath coverage of about 4 x water depth.

All soundings were reduced to the level of Chart Datum (Lowest Astronomical Tide) using GPS data that were recorded on the vessel throughout the survey period. A geodetic class, dual-frequency Trimble MS750 GPS receiver was used to acquire raw GPS data, and these data were logged at the rate of 1Hz, and were post-processed using the Precise Point Positioning (PPP) method. *TerraPos* software, produced by TerraTec of Norway, was used for this purpose. Vessel positioning met or bettered the survey specification of ± 5 m.

The multibeam data was provisionally processed using CARIS HIPS software with the positional data also processed and tidal corrections applied. For final production of bathymetry and contours, the multi-beam data were gridded into a 2 m x 2 m Digital Terrain Model (DTM). Profiles from the centre beams were compared against single beam echo sounder profiles, before various levels of smoothing were applied to the DTM, this giving a realistic impression of the sea bed without losing real topographical features (Gardline, 2008).

Data were exported as an ASCII xyz file and contours produced as a Microstation DGN file. The ASCII xyz file was imported into Ermapper and colour Tiff's of the bathymetry produced.

Sidescan sonar

An Edgetech 4200 sidescan sonar system was deployed. This is a dual frequency 100/410 kHz system. Data were stored as .XTF files and displayed on paper records. A sonar mosaic was also produced as a GeoTiff after being processed in CODA.

A Simrad HPR 400 USBL acoustic tracking system was installed on the Confidante and was used to track positions of the sidescan sonar. The USBL system was operated with the transponder located 1 m from the Edgetech sidescan sonar fish. The positional accuracy of the system is around ± 10 m.

Magnetometer

A Geometrics 880 marine proton precession magnetometer was deployed to survey for metallic objects. Records were of reasonable quality with a background noise level of 2–5 gammas, depending on tow direction and/or proximity to sea bed. Anomalies could be identified to about 10 gammas, given identifiable shape and a spread of about 8 readings (Gardline, 2008). Data were converted to ASCII .XYZ format.

Sub-bottom profiler

A surface tow boomer was deployed as the sub-bottom profiler to provide data on the geology at depth beneath the sea bed down to an average depth of ~10 m. In some areas the boomer reached to depths of ~20 m. Data were stored as .cod files and converted to SEGY format.

3.2.2 Sampling survey and methods

The sampling survey was undertaken on the MV *Ocean Seeker* during three weeks in late August and early September 2007 and during this period the weather was better and not a great issue with regard to impacting the planned survey.

Pre-planning for the sampling survey produced 100 sample station sites, numbered 1 to 100. This was reduced to 90 proposed sample station sites shortly before commencement of the sampling survey. The original pre-planning station numbers were retained which accounts for some numbers missing in the station sequence. All the 90 proposed sample stations for grab, video and stills were occupied, although some were originally positioned in too shallow water and were moved further offshore along the survey corridors to enable safe deployment of the survey vessel. All positional data was recorded on differential GPS, with the vessel position being accurate to ± 5 m and any sampling equipment deployed tracked using a Nautronix ATSII USBL acoustic tracking system providing positional accuracy to ± 10 m.

Table 3.1 outlines the occupancy success statistics with regard to deployment of sampling equipment during the survey. Figure 3.2 shows the position of the sample stations that were occupied during the survey, each station is annotated with the relevant ornament for a particular sample method. The annotation is only shown at those stations with either a 'good' or 'qualitative' sample and used in the analysis for the interpretations in this report.

Clamshell grabs

A 1 m^2 hydraulic Clamshell grab was used to obtain large-volume samples of sea bed sediments for particle size analysis. The bigger footprint of the Clamshell grab meant it was more successful than the Hamon grab in sampling with a total of 78 'good' and 'qualitative' stations and these were analysed for particle size (PSA). Sample positions were recorded as GPS fixes taken when the grab reached the sea floor. Samples were inspected for suitability and rejected if the grab did not operate properly or if it returned material that was deemed to be unrepresentative of the site, as determined from the preceding video observation.

Retained samples were photographed and homogenised on deck by mixing with a shovel. A 10-litre sub sample was taken for granulometric analysis by Ambios Environmental Consultants (AEC Ltd) who employed a sub-sampling strategy to handle the large volume samples (see section 3.4.4 in Appendix 3 of Gardline (2008) for full details). Particle size analysis was achieved using wet and/or dry sieving for the coarse fraction (>63 µm) and, with pipette analysis for the silt fraction (< 63 µm) following methodologies to the British Standard (BS1377).

The Clamshell grab sediment was not used for benthic analysis. Photographs taken on deck of sampled sediment in Clamshell jaws were used as comparisons with the sea bed still imagery analysis and they were particularly useful in confirming the presence of rock at the sea bed. The Clamshell jaws are powerful enough to rip in to rock in some areas and enable the sampled rock to be identified and confirm the solid geology.

Because the Hamon grab samples were used for benthic infaunal analysis we have only integrated the Hamon grab PSA data and not the Clamshell grab PSA data into the overall PSA dataset used in the interpretation for this report.

Hamon grabs

Benthic samples were collected for faunal and granulometric analysis using a 0.1 m^2 Hamon grab. Samples were collected within 200 m of the planned target sampling position, with actual sample positions being recorded by GPS fix when the grab reached the sea floor. No replication was used (single samples only). Although the Hamon grab is shown in Table 3.1 with a total of 69 'good' and 'qualitative' sample stations only 67 of these were used for the benthic analysis, and only 63 provided sediment for particle size analysis (PSA). The 'no sample' Hamon grab stations shown in Figure 3.2 are predominantly in areas where rock or thin coarse sediment lies at the sea bed, a substrate in which the relatively small footprint of the Hamon grab may not normally collect a representative sample. Samples were processed in line with standard protocols detailed in Boyd (2002).

Sample method	Total proposed sample stations	'Good' sample stations	'Qualitative' sample stations	'No sample' stations
Video & stills	92	92 (100%)	0	0
Hamon grab	90	51 (56.7%)	18 (20%)	21
Clamshell grab	90	64 (71.1%)	14(15.6%)	12
2 m beam trawl	26	23 (88.5%)	0	0

Table 3.1: South Coast REC 2007 Survey — sample station occupancy (modified after Gardline, 2008).

On recovery, samples were inspected for suitability and rejected if the grab had not operated properly. A minimum acceptable volume of 5-litres was set for fully quantitative sampling. Where this was not achieved, smaller samples were retained to provide 'qualitative' information.

Samples were photographed prior to processing and a representative sub-sample (250 to 500 ml) retained for granulometric analysis. The remaining material was sieved through a 1 mm mesh prior to preserving in formalin for faunal analysis.

Granulometric analysis was undertaken by Ambios Environmental Consultants (AEC Ltd) using wet and dry sieving in 1-phi size units (Wentworth scale) for the coarse fraction (>63µm) and pipette analysis for the silt fraction (< 63 µm), following methodologies to the British Standard (BS1377). Data were expressed as the cumulative percent (by weight) of the sample passing through each sieve, and were converted by Marine Ecological Surveys Ltd to absolute percentage retained on each sieve size.

Faunal analysis was undertaken by Marine Ecological Surveys Ltd., a participant in the National Marine Biological Analytical Quality Control (NMBAQC) scheme. All taxa present were identified to species level (wherever practical) and their abundance recorded. Taxa were then sorted into major faunal groups and blotted wet weight measured for Annelida, Crustacea, Mollusca, Echinodermata and Miscellania (including Porifera and Bryozoa). This was converted to ash-free dry weight (AFDW) using conversion factors given by Eleftheriou & Basford (1989). Data records were compiled in a UNICORN database and coded using species codes in Howson & Picton (1997).

Scientific beam trawls

A 2-metre scientific beam trawl with 5 mm mesh liner was used to sample epibenthic fauna. Some of the 26 proposed trawl sites were relocated but they were moved to other stations within the original plan. However, three trawl stations were dropped from the plan following video acquisition, which deemed the sites were unsuitable for trawling. The 2 m beam trawl was successfully deployed at all the remaining 23 planned sites. The trawl was towed for a nominal distance of 500 m through the sampling site. The catches were sorted and photographed on deck.

Commercially important fish and shellfish were identified, counted, weighed and measured before being returned to sea. The percentage (by volume) of the catch comprising of shell, macroalgae and boulders/cobbles was estimated. The boulder/cobble fraction was washed over a 5 mm sieve to remove mobile fauna, and tufts of hydroid and bryozoan were picked off. The percentage of the boulder/cobble fraction covered by the main encrusting faunal groups was also estimated. The remaining part of the catch was sorted and the fauna were identified to species level, counted and weighed (grams wet weight). Small or cryptic analysis requiring more detailed identification were preserved in formalin and taken back to the laboratory at Marine Ecological Surveys Ltd for microscopic examination.

The analysis of the grab and trawl data followed similar protocols to those used for the Eastern English Channel Marine Habitat Map (EECMHM) (James *et al*, 2007). A pdf copy of the EECMHM report is included in Appendix A with a full description of the protocols

Seabed imagery

A drop camera frame equipped with a Kongsberg OE14-208 underwater camera was used to collect sea bed images at the sampling sites. Video footage (video) and photographic still images (stills) were successfully collected at 90 of the proposed sample stations. Two additional ad-hoc stations were also sampled (62R and 76M), providing a total of 39 hours of video and 2150 stills.

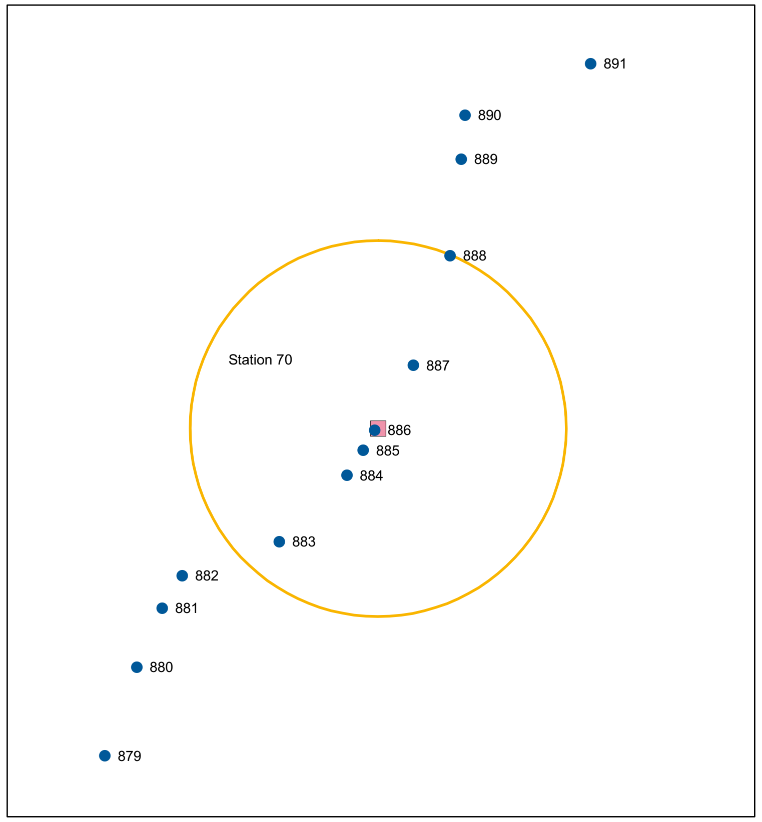
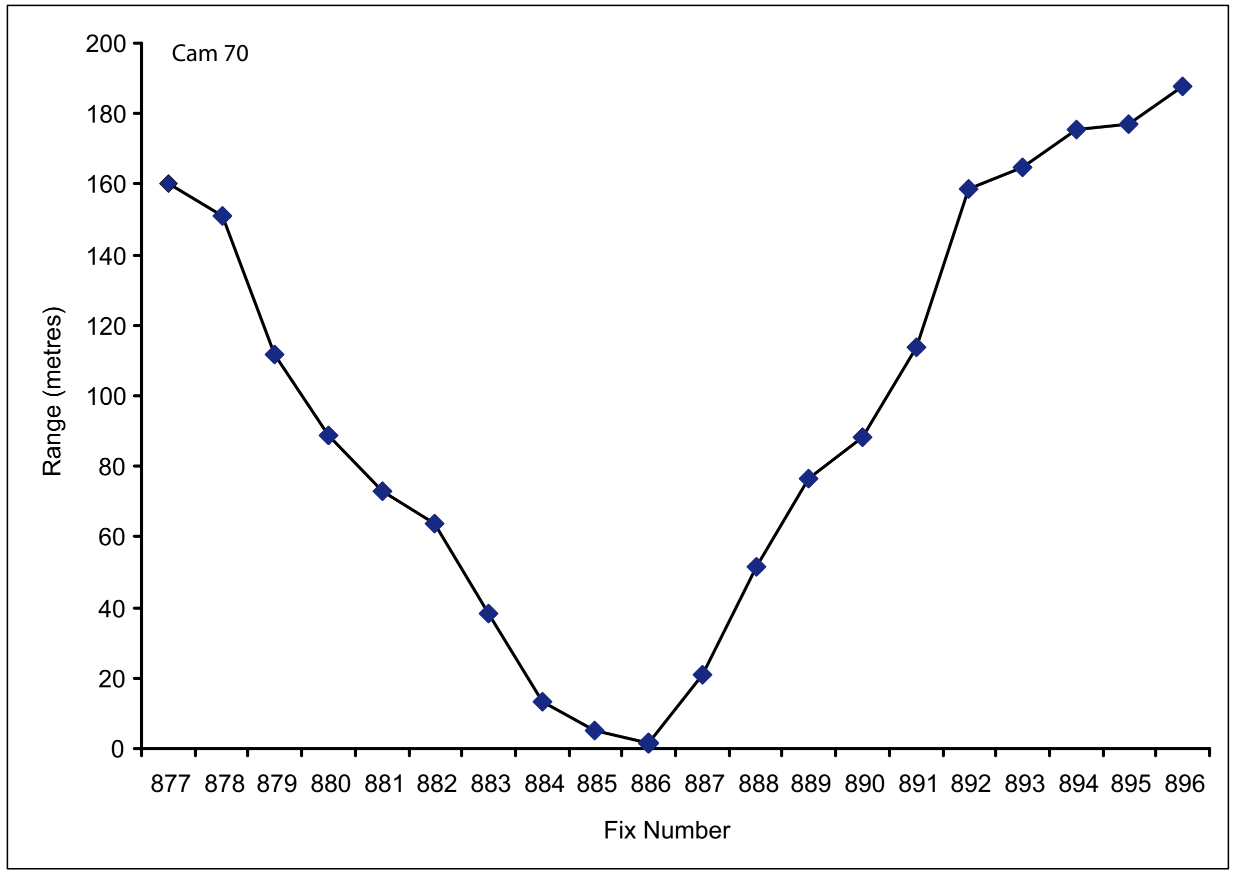


Figure 3.3: Schematic illustration of video sampling at a station. The target sampling point is shown by a pink square, surrounded by a 50m buffer zone. Blue points show the sequence of GPS-fixes taken as the drop-camera passed through the station. Fixes were taken at ~1 minute intervals, whenever a still photograph was taken.

Figure 3.4: Schematic diagram illustrating the method of selecting the 10 minutes of video footage closest to the target sampling point.

The table on the left gives an extract of the survey log. The graph on the right plots the range from the target point for each of the GPS fixes. The fix closest to the target is identified (here Fix No 886) and the GPS time record used to highlight the section of the record that includes five minutes before and five minutes after this fix.

Station Code	Fix Number	GP S Ti me	Range from Target	Still image filenam e
Cam 70	877	23:00:29	160	7261 stn 70-fix(877).jpg
Cam 70	878	23:02:14	151	7261 stn 70-fix(878).jpg
Cam 70	879	23:04:25	112	7261 stn 70-fix(879).jpg
Cam 70	880	23:05:32	89	7261 stn 70-fix(880).jpg
Cam 70	881	23:06:39	73	7261 stn 70-fix(881).jpg
Cam 70	882	23:07:44	64	7261 stn 70-fix(882).jpg
Cam 70	883	23:10:01	38	7261 stn 70-fix(883).jpg
Cam 70	884	23:11:38	13	7261 stn 70-fix(884).jpg
Cam 70	885	23:12:36	5	7261 stn 70-fix(885).jpg
Cam 70	886	23:13:28	1	7261 stn 70-fix(886).jpg
Cam 70	887	23:15:33	21	7261 stn 70-fix(887).jpg
Cam 70	888	23:17:13	52	7261 stn 70-fix(888).jpg
Cam 70	889	23:18:36	77	7261 stn 70-fix(889).jpg
Cam 70	890	23:19:21	88	7261 stn 70-fix(890).jpg
Cam 70	891	23:22:57	114	7261 stn 70-fix(891).jpg
Cam 70	892	23:25:50	159	7261 stn 70-fix(892).jpg
Cam 70	893	23:26:19	165	7261 stn 70-fix(893).jpg
Cam 70	894	23:27:36	176	7261 stn 70-fix(894).jpg
Cam 70	895	23:28:02	177	7261 stn 70-fix(895).jpg
Cam 70	896	23:30:48	188	7261 stn 70-fix(896).jpg



The video acquisition protocol and analysis methodology undertaken for the South Coast REC study varied from that adopted in the EECMHM. The protocol for acquiring underwater images was to transit the target area with a drop camera system held approximately 1 m from the seafloor, passing as close to the target sampling point as practical given the prevailing sea and weather conditions (Figure 3.3). The camera was capable of taking both video and still images, the latter being manually triggered on the deck-side unit at approximately 1-minute intervals, accompanied by a simultaneous, manual GPS fix. A video overlay showed time, depth and positional data (of the GPS antenna) on the video, but not the stills. A scale object was visible in both video and still images, in the form of an 18 cm long 'ruler' divided into 1 cm segments.

The duration of video samples ranged from 11 to 55 minutes, with some sections of video being up to 330 m away from the target point. The majority were in the region of 15 to 20 minutes duration, reflecting the need to have the camera properly functioning at the correct altitude above the sea bed with an acceptable speed-over-ground (~0.75 knots) before transiting the target station.

To provide an equitable analysis of underwater imagery for this grid-based survey, a selection procedure was devised to identify the 10 minute section of video that was closest to each target point (Figure 3.4), and to undertake a detailed analysis of the video and stills material for that 10 minute section. This also helped to ensure an acceptable spatial association between the data sets derived from grab, trawl and video sampling.

A file with a full account of the video analysis methodology and a spreadsheet of compiled video results can be found in Appendix C. The South Coast REC 2007 survey operations report (Gardline, 2008) is available in Appendix A as a pdf document.

The geophysical and sample station data collected during the South Coast REC 2007 survey is available through the Marine ALSF GIS (http://www.marinealsf.org.uk/). The database provides access to marine aggregate research project metadata information and digital reports. The database can be accessed using text and GIS map-based searches.

3.3 Additional data

The completed South Coast REC 2007 geophysical survey coverage only provided a grid of data adequate for interpretation at a regional scale for the area east of Selsey Bill and even here there were gaps. This lack of extensive geophysical survey coverage was obviously an issue for the implementation of the interpretation programme for the South Coast REC study area. However the lack of coverage has been reasonably mitigated, for the interpretation in this report, by the incorporation of geophysical data from other sources, either as survey line data in electronic and paper record form or previously completed interpretations of survey lines. This additional geophysical line data is shown in Figures 3.5 and 5.1 and includes: -

- BGS Survey 1988/02 sidescan and boomer sub-bottom interpreted data. Approximately 900 km line length.

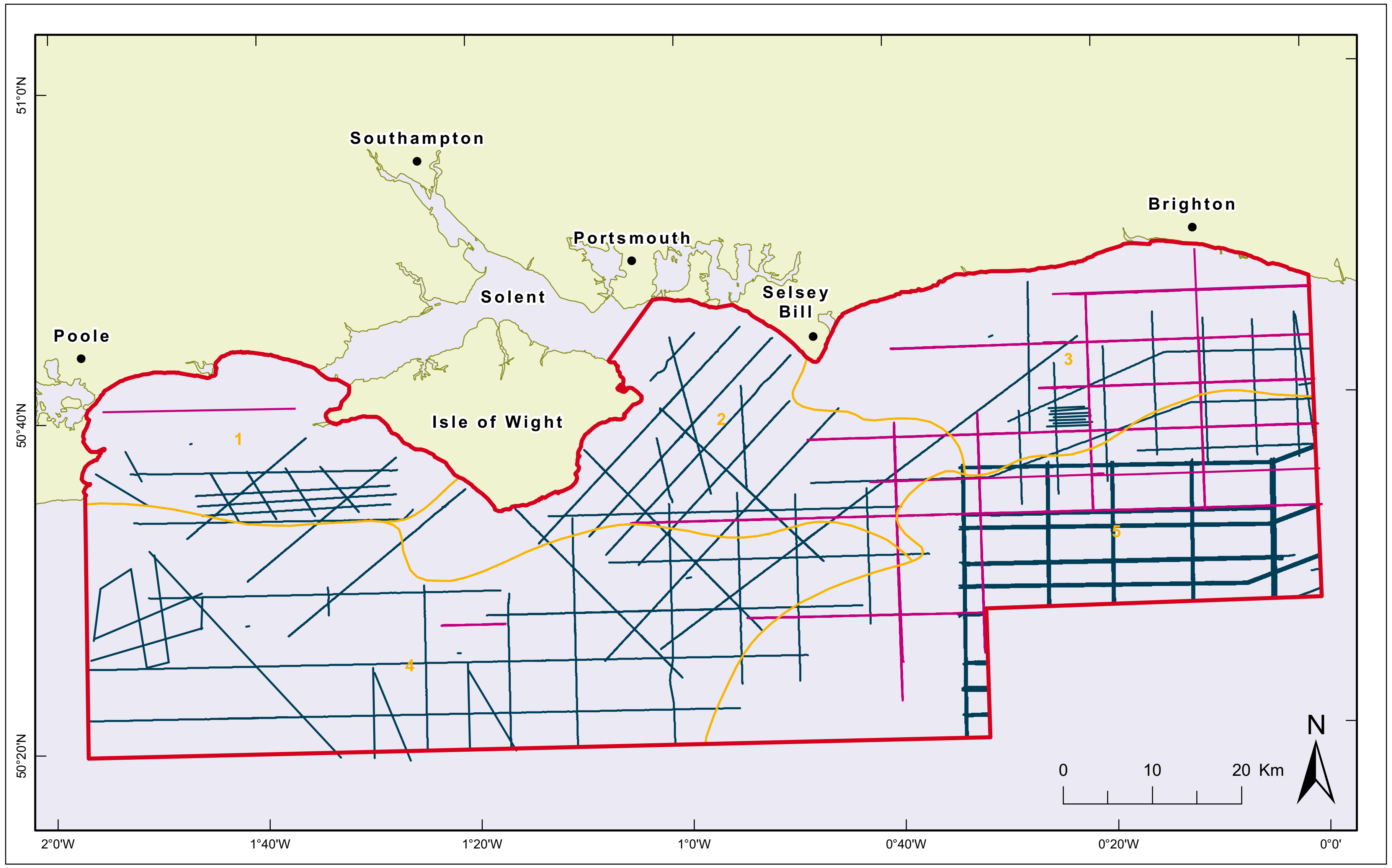


Figure 3.5: South Coast REC 2007 Survey and other geophysical lines.

- South Coast Regional Environment Assessment (REA) boomer sub-bottom and sidescan records, approximately 500 km line length. Kindly provided by the South Coast Dredging Association (SCDA) and supplied by EMU Ltd.
- Cefas multibeam and sidescan records, approximately 180 km line length.
- Eastern English Channel Marine Habitat Map (EECMHM) MBES, sidescan and boomer sub-bottom interpreted data, approximately 250 km line length.
- Arun boomer sub-bottom survey run by Wessex Archaeology. 41 km line length (Figure 5.1).

These lines provide about 1870 km of additional data which when included with the South Coast REC 2007 survey means that total enhanced line coverage used in the study area interpretation is around 2520 km. Although the additional data is aligned at various angles and grid spacing (Figure 3.5 and 5.1) they do provide a reasonable coverage across the area west of Selsey Bill that was previously relatively bare (Figure 3.1). While there are still gaps in the data coverage in some areas the enhanced line coverage means that a relatively practical geophysical interpretation could be produced at a regional scale across the study area.

The geophysical and geological interpretation for the South Coast REC study was also improved by the provision of aggregate industry data and interpretations at some licensed aggregate sites east and west of the Isle of Wight and in the Owers area, and discussions with Andrew Bellamy — Tarmac Marine, Graham Singleton and Joe Holcroft — Cemex, and Robert Langman — Hanson Marine.

The study area biological interpretation is solely based on South Coast REC 2007 survey data and no additional biological data from other sources has been incorporated in the analysis, although the data from 132 video stations undertaken by the Sussex Sea Fisheries District Committee has informed the analysis.

A considerable quantity of sea bed particle size data exists within the study area. It varies from a simple tripartite total percentage

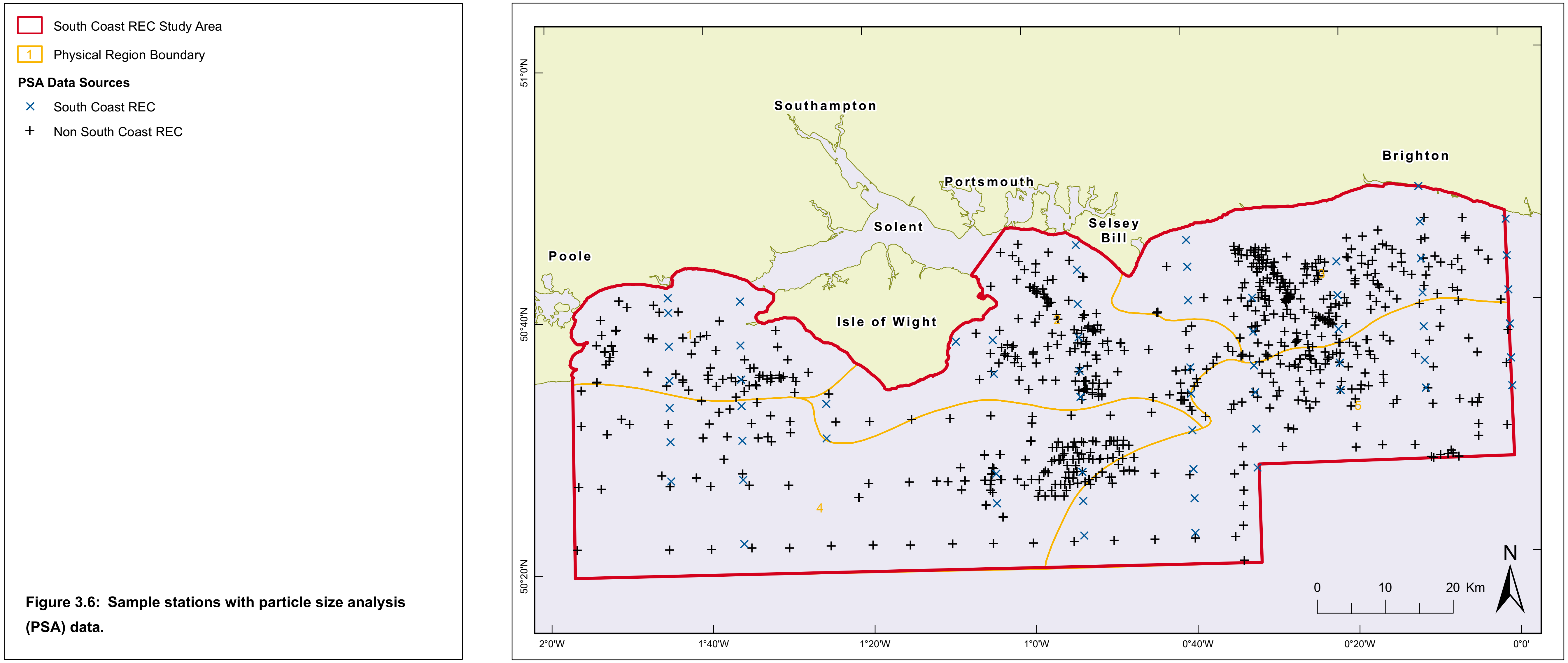


Figure 3.6: Sample stations with particle size analysis (PSA) data.

of gravel, sand and mud to full sediment grain size distribution. The source of this sediment data includes the British Geological Survey, Cefas, Sussex Sea Fisheries Committee, The South Coast Dredging Association and a report produced for BMAPA and the Crown Estate (Morgan *et al*., 2008).

In total 912 sample stations have provided simple % gravel/sand/mud statistics (Figure 4.27, 4.29 and 4.33), which have enabled a Folk sediment classification to be produced (Figure 4.25), and also fed in to the EUNIS biotope modelling (Chapter 7). The distribution of these PSA sample stations can be seen in Figure 3.6. There is a reasonable distribution across the study area with a greater frequency east of the Isle of Wight. Up to 400 sample stations have provided statistical sediment data for sorting, mean grain size and median grain size (Chapter 4).

Digital single beam bathymetric data licensed from SeaZone Solutions Ltd has enabled us to model the sea bed morphology at various resolutions from 100 m to ~500 m grids (Figure 4.1 & 4.2).

Shuttle Radar Topography Mission (SRTM) data, with a Digital Elevation Model of 90 m grid resolution was obtained for the coastal region adjoining the study area (Figure 5.3) (http://srtm.csi.cgiar.org/). Any additional datasets specifically used in the marine archaeological interpretations are described in Chapter 5.

3.4 South Coast REC Geographical Information System (GIS) and database

All data collected and results produced for the South Coast REC 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 9.3 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.

In parallel to the GIS, all biological, physical, archaeological and geological data, analysis and results from the study are stored using a Microsoft Access 2003 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.

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.

3.4.1 Contents of South Coast REC DVD-ROM

When the DVD-ROM is opened, a number of folders and files will be displayed. Table 3.2 outlines what is enclosed in each folder. The South Coast REC 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 co-ordinate system used for all data produced as part of this project is the projected coordinate system Universal Transverse Mercator Zone 30 North 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 30 North with the WGS84 datum.

File or Folder	Subfolder	Information
ARCREADER	Pmf	This folder holds the GIS file that should be opened if ArcReader is being used. The file to open is: SC_REC_Dissemination_GIS.pmf
D11_SC_Sub_Bottom_Images		This folder contains sub bottom images for each of the 2007 South Coast REC sample stations. It is possible to hyperlink to these using the GIS or view them independently in this folder.
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
RASTER_DATA	Raster data folders	This folder contains all of the raster data used within the GIS. This includes .jpgs and .tifs as well as ESRI Grids of the interpolations created mean grain size, sorting 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 he layer files.
SC_REC_Dissemination_GIS.mdb		Personal geodatabase containing the GIS data. It is possible to view the spatial extent of this data within the GIS or to independently view the associated tables within Microsoft Access.
SC_REC_Dissemination_GIS.mxd		If you already have ArcGIS installed on your machine you can open this file directly to view the project GIS
SC_REC_Master_Data_GIS.mdb		Personal geodatabase containing master datasets such as PSA data used within the GIS. It is possible to view the spatial extent of this data within the GIS or to independently view the associated tables within Microsoft Access.

Table 3.2: GIS content of South Coast REC DVD-ROM.

3.4.2 Using the South Coast REC GIS

ESRI ArcGIS Users

The South Coast REC GIS has been built using ESRI ArcGIS 9.3 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 **SC_REC_Dissemination_GIS_93.mxd** map document file.

Free GIS viewer

For those users who do not have access to an ESRI ArcGIS licence the South Coast REC 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 **SC_REC_Dissemination_GIS_93.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-ROM. 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.

3.4.3 Data availability and usage

Original data collected by the South Coast REC study is freely available. Any copyrighted data licensed to the South Coast REC study is not freely available through the GIS. Its use is subject to the terms and conditions of the copyright holders.

If approved, a web based GIS of the results of the South Coast REC study may be constructed later in 2010 following completion of the study and publication of the report. It would be made available through the Marine ALSF GIS (http://www.marinealsf.org.uk/).

4 Geology

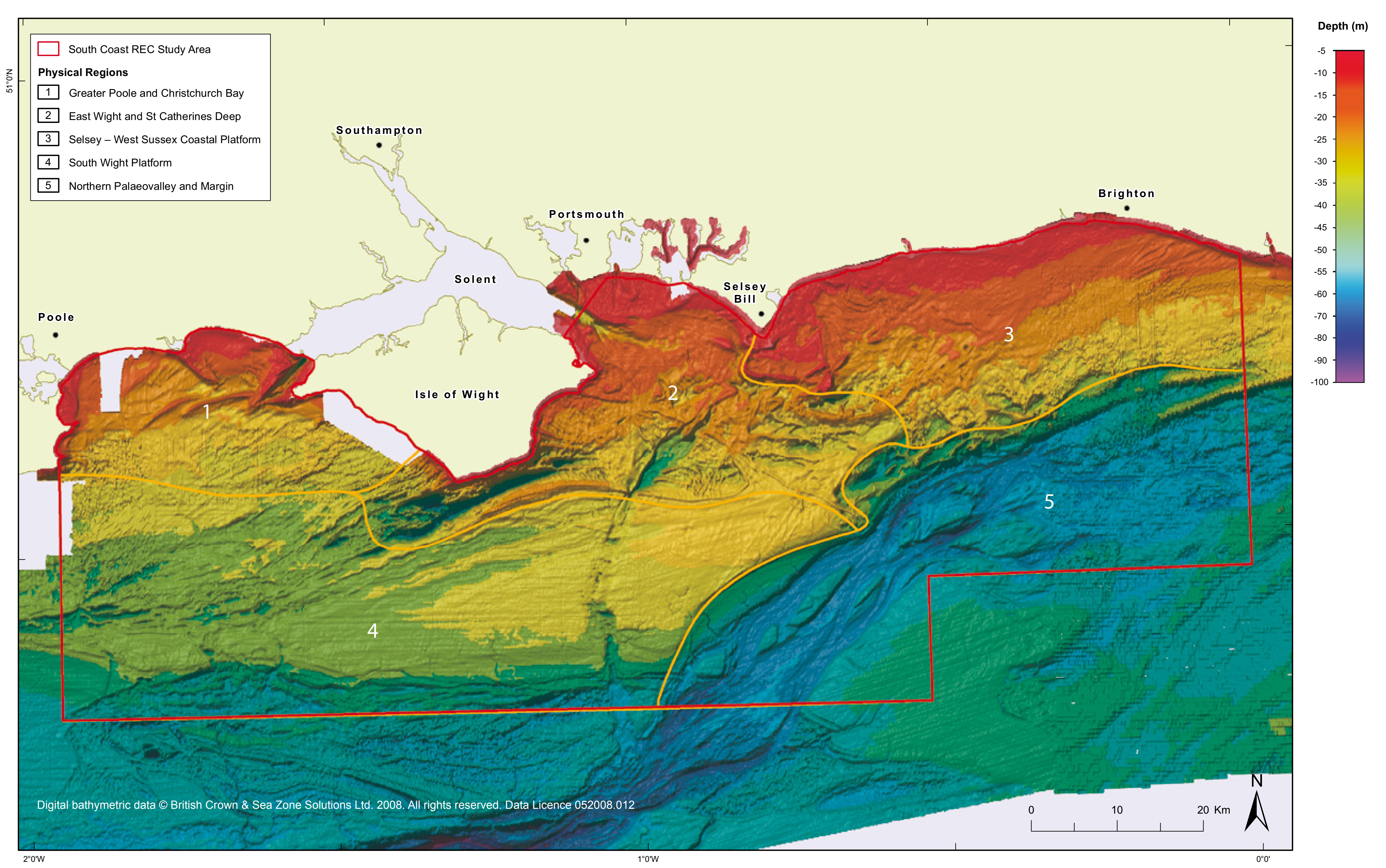


Figure 4.1: Sea bed morphology of South Coast REC study area with location of physical regions.

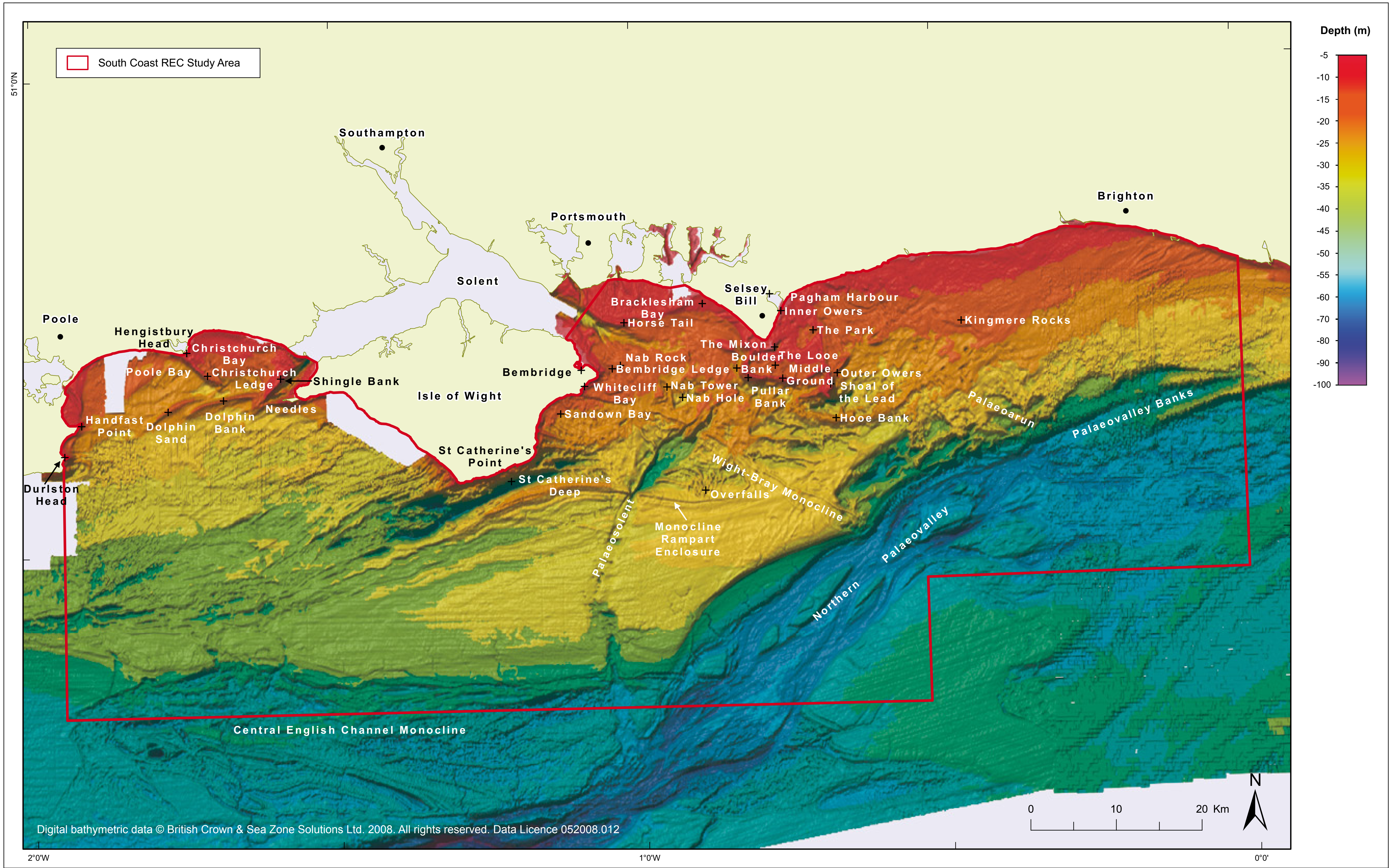


Figure 4.2: Sea bed morphology of South Coast REC study area with named localities.

The area included in the South Coast Regional Environment Characterisation (REC) study shown in Figure 4.1 was defined on a number of criteria including:-

- Incorporation of the area covered by the seismic lines and sample stations completed for the South Coast REC geophysical and sampling surveys in 2007 (Gardline, 2008).
- Overlap with the area covered by the adjacent Eastern English Channel Marine Habitat Map Study.
- Ensuring that regional scale physical features were incorporated within their natural boundaries e.g. Poole and Christchurch Bay and the Northern Palaeovalley.
- Incorporation of all marine aggregate licence, application and prospecting areas east and west of the Isle of Wight, and east of Selsey Bill (Figure 2.76).

The western limit of the study area is a north-south line at around 1° 57'W that bisects the coast at Durlston Head near Swanage. The coast forms the northern boundary of the study area from Durlston Head to where the Greenwich meridian - 0° 0', which forms the eastern limit, crosses the coast just east of Brighton. The southern coast of the Isle of Wight lies on the northern boundary, as the Solent is not included in the study area.

The southern boundary is stepped in its south-east corner by the intrusion of the Eastern English Channel Marine Habitat Map (EECMHM) study area (James *et al*, 2007). There is some overlap with the EECMHM to enable inclusion of the Northern Palaeovalley in the South Coast REC study area. The continuation of the southern boundary to the west is around 50° 20'N and follows a natural break between relatively smooth sea bed to the north and broken ground to the south.

The distance from east to west across the study area is approximately 138 km and its north-south extent varies from 27 km to 50 km. In total, the area of the REC study covers approximately 5670 km^2.

4.1 Physical regions

The study area has a diversity of physical and geological features. Some of these have common or distinctive attributes in particular areas that distinguish them from each other.

These particular areas have been grouped in to five physical regions. These afford a framework for the interpretation and characterisation of the physical, geological, biological and archaeological datasets and a geographic structure to aid in describing the results of the study.

The basis of the grouping includes

- Sea bed morphology and water depth
- Solid geology and bedrock type
- Bedforms
- Sea bed character
- Quaternary sediments and channels

Not all criteria are relevant in defining each region; their significance varies for each region. Some boundaries are drawn along distinctive physical features such as a ridge or channel margin, others are more tentative and drawn on a sum of criteria that distinguishes a region.

The five physical regions (Figure 4.1) are named as:-

1 Greater Poole and Christchurch Bay

2 East Wight and St Catherine's Deep

3 Selsey and West Sussex Coastal Platform

4 South Wight Platform

5 Northern Palaeovalley and Margin

Physical habitat is the principal determinant of biological communities and the physical regions are distinctive enough to be used as a framework for reporting the integrated analysis and interpretation of the available geological and biological data and information.

From Chapter 4 onwards the physical region boundaries are drawn on almost all the standard study area figures in the report to clarify the spatial setting of the datasets and interpretation and assist in comparing geographically the results of the principal disciplines that are included in this report.

Physical Region 1 — Greater Poole and Christchurch Bay

Greater Poole and Christchurch Bay lies in the north-west corner of the study area between the Isle of Wight in the east and the Dorset coast of Durlston Head to Poole in the west (Figure 4.2). Poole Bay itself lies inshore in the north-west of the region and similarly Christchurch Bay lies inshore in the north-east corner of the region. Traditionally both of these bays do not extend geographically south of a line drawn from the Needles on the Isle of Wight to Handfast Point on the Dorset coast. However, the Greater prefix has been given to the region because the joint bays have been extended further south to a line from Durlston Head in the west to Atherfield Point, Brighstone Bay on the Isle of Wight.

The sea bed within Poole Bay and Christchurch Bay is generally <20 m deep and is dominated by four large banks and at least two prominent rock ridges. The banks include Hook Sand in the west of Poole Bay, which is <4 km long. Dolphin Sand and Dolphin Bank are adjacent, closely associated east-west trending banks in the central part of the region about 7 km south of Hengistbury Head; both banks are 7–8 km long. The fourth bank is Shingles Bank, which lies north of the Needles at the entrance to the Solent. It is also about 7 km long.

The most prominent rock feature is Christchurch Ledge, also known as Hengistbury Ridge, which extends for about 6 km south- east from Hengistbury Head and is up to 2 km wide. It has a steep south-west facing scarp up to 15 m high and forms the natural inshore boundary between Poole Bay and Christchurch Bay. The resistant chalk at the Needles continues offshore to the west and forms a submerged ridge up to 20 m high which fades out into the sea bed after about 5 km, adjacent to the southern tip of Shingles Bank.

All of these large features are north of the Handfast Point to Needles line which divides the inner part of the region from the outer. The outer region does not have any large scale morphological features. The sea bed gently slopes to the south, reaching depths of around 30 m at its southern boundary. The outer region does have relatively extensive deposits of sediments (Figure 4.17a, b) associated with shallow channels and sheets and these have been exploited for marine aggregates (Figure 2.76). The line of the southern boundary was drawn to encompass the bulk of these deposits in Region 1.

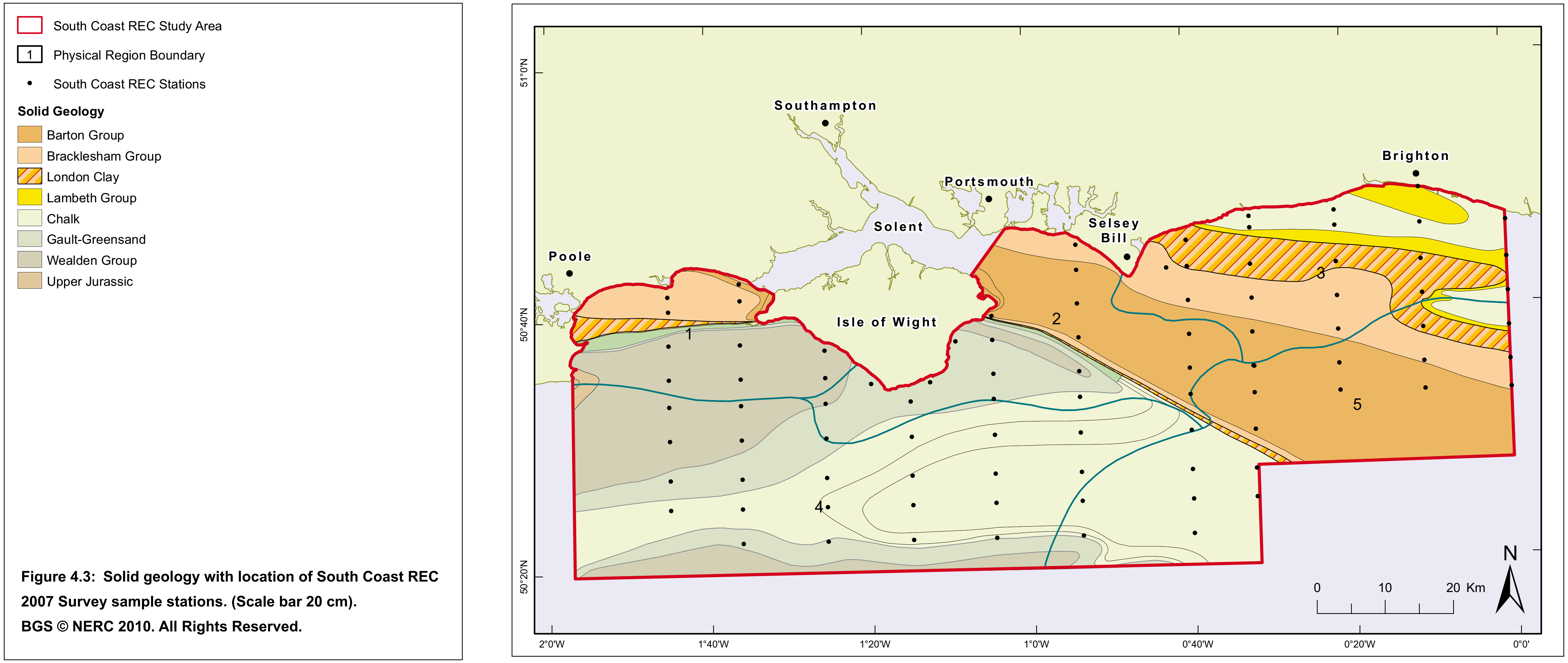


Figure 4.3: Solid geology with location of South Coast REC 2007 Survey sample stations. (Scale bar 20 cm).

Physical Region 1 varies from around 23 to 41 km in length from west to east and 11 to 19 km from north to south and covers an area of about 570 km².

Physical Region 2 — East Wight and St Catherine's Deep

The East Wight and St Catherine's Deep region includes a diverse range of physical features at the sea bed. In the East Wight part of the region a distinction can be drawn between the sea bed which is north of a line which runs ESE from Whitecliff Bay on the Isle of Wight along a distinctive rock ridge to the south-east corner of the region, and the area to the south of this line. This line also marks the solid geology boundary between Cretaceous rocks to the south and Tertiary rocks to the north (Figure 4.3). This northern area has at its western end the narrow 2 km wide, 29 m deep bathymetric channel in the entrance to the East Solent with the Horsetail sand bank to its north and the rock floored Bembridge Ledge to its south. 9 km eastward of the East Solent entrance and the sea bed rises to a depth of ~15 m and becomes a 13 km wide open channel as it reaches Bracklesham Bay. The sea bed in Bracklesham Bay is a gentle decline to about 7 km offshore with water depths of <12 m. In this central part of Region 2 the sea bed becomes more chaotic with ridges and deeps with amplitudes up to 10 m high, aligned relatively randomly. The Nab Tower sits on one of these rock cored ridges, adjacent to which is the Nab Hole, an enclosed depression of about 3 x 3 km in water depths of 20 to 25 m which includes a number of sand waves up to 3 m high.

A further 3 km east of the Nab Hole a distinctive 15 to 20 m deep narrow, 1 km wide channel is aligned NE–SW and cuts across the ridge that divides the northern area from the southern area. This narrow channel is also at a point where the northern area tapers to a width of about 7 km where the shoals and ridges of The Mixon, Pullar Bank and Middle Ground lie offshore of Selsey Bill and push the Region 2 boundary offshore. Pullar Bank and Middle Ground have steep south facing slopes up to 25 m high with a narrow channel which runs east-west at their base in water depths of 25 to 35 m. South of this channel the sea bed rises to a relatively flat 6 km wide surface at ~15 m depth.

Continuing east the furthest eastern segment of Region 2 is distinguished by four east-west trending ridges from 8 to 13 km long and ~2 km apart. They are generally about 1500 m wide and range in height from ~5 m to >15 mm. Their tops are at ~20 to 25 m depth. The northernmost, and longest and highest of these ridges is Hooe Bank, it appears more rounded than the other ridges and is wider at ~2500 m with a top at a shallower depth of ~15 m.

The distinctive SE trending ridge which forms the boundary of the region in its south-east corner is generally <3 m high and is a northern split from the ridge that extends from Whitecliff Bay. The split in this ridge occurs about 21 km east of Whitecliff Bay with its southern arm turning back westward to form the southern boundary of Region 2. This ridge forms a rampart around the distinctive southern area of the region and can vary from 2 m to >20 m high although it is generally <10 m. The rampart is formed of relatively steeply dipping Chalk bedrock. This rampart-enclosed area is a sea bed expression of the underlying Wight–Bray monocline (Figure 4.2).

The Monocline Rampart Enclosure area extends for about 25 km from the coast of the Isle of Wight to its eastern nose and is generally 7 to 10 km wide from north to south (Figure 4.2). Much of the sea bed within the Enclosure area is undulating at depths of 20 to 30 m with some linear E–W ridges but the area is split by a significant NE–SW trending channel over 10 km long which extends further north east for 3 km beyond the rampart ridge. The channel, interpreted as part of the Palaeosolent river system (Dyer, 1975, Hamblin *et al*, 1992) varies in width from <1 to >3.5 km; it narrows at its northern and southern ends where it cuts through the rampart ridges. Its floor is distinctively flat around a depth of 40 to 42 m and its sides, which may be relatively steep, range in height from <8 m to ~18 m. The other significant feature within the Enclosure is the Overfalls (Tingley *et al*, 2006) an area of sinuous north-south trending rock ridges from ~2 to 8 m high which appear to mask some of the shallow east-west trending ridges in the area. The Overfalls cover an area of ~15 km^2 in the south-east corner of the Enclosure.

The southern rampart of the Monocline Enclosure becomes more prominent and larger as it continues to the west and becomes the southern wall of St Catherine's Deep. Here it reaches heights of over 45 m as the Deep descends to depths of over 65 m. The Deep is about 21 km long and commonly characterised by an asymmetrical cross profile with a steep southern wall up to its rim at ~20 m depth and a gentler slope to the north towards the coast of the Isle of Wight. It is generally 1 to >2 km wide but much narrower at its base. The floor of the Deep in the east includes a number of significant transverse ridges 2 to 4 m high and over a kilometre long. The western 8 km or so of St Catherine's Deep is complemented to its north by an adjacent parallel deep. This parallel deep is about 3 km long and 2 km wide and is separated from St Catherine's Deep by a ridge at a depth of 40 to 50 m. The parallel deep floor is deeper than the adjacent St Catherine's Deep and reaches a maximum depth of >80 m.

As a whole, Physical Region 2 is about 63 km from east to west and its maximum north-south extent is about 26 km and it covers an area of 876 km^2.

Physical Region 3 — Selsey–West Sussex Coastal Platform

The Selsey — West Sussex Coastal Platform is a relatively simple planar sea bed surface across most of its area with a gentle decline from the shore to about 30 m water depth at the margin of the Northern Palaeovalley, which forms the Platform's southern boundary.

The Platform is a little more complicated south and east of Selsey Bill with a number of ridges and depressions associated with The Mixon, Middle Ground, Inner Owers and Outer Owers. Most of these are in shallow waters of <10 m, some may shoal in spring tides. However, the steep southern margin of the Outer Owers reaches a height of >55 m with its base at a depth of 62 m within an over deepened depression. The platform's boundary in the south-west includes a number of parallel ridges and troughs up to 12 m high with the troughs at about 40 m water depth. Some of these open out into the Northern Palaeovalley.

Close to shore in the north-east of the Platform the sea bed includes a series of sub-parallel ENE–WSW ridges up to a metre high and up to 8 km long.

Physical Region 3 is about 58 km wide from east to west and varies in its N–S extent from ~13 to 22 km and includes an area of 969 km^2.

Physical Region 4 — South Wight Platform

The South Wight Platform is a relatively flat rock platform in water depths of 30 to 40 m with a very low decline from north to south. There are some low rock ridges and open channels up to 8 m deep in the west of the region and few channels which are filled with sediment. The eastern half of the region is relatively smooth, the only significant feature being the 1 to 3 km wide Palaeosolent channel that stretches 25 km across the whole region from north to south on its way to the Northern Palaeovalley. The Palaeosolent is filled with sediment and in some parts of its length the infill is level with the surrounding rock platform, making the channel surface imperceptible from the rock surface at the sea bed.

The southern margin of the region is aligned just south of the margin of the rock platform where the sea bed becomes a series of narrow east-west ridges, shelves and depressions, and quickly drops to depths of 50 to 60 m within a few kilometres of the platform edge. The eastern limit of the region is a very well defined physical boundary at the margin of the Northern Palaeovalley formed by a relatively steep slope, 10 to 15 m high. In the eastern half of the region the northern boundary follows an east-west Chalk ridge up to 20 m high.

The South Wight Platform is the largest of the South Coast REC regions and covers an area of about 1919 km^2. It varies in east to west length from 70 to 90 km and north to south from 18 to 28 km.

Physical Region 5 — Northern Palaeovalley and Margin.

The Northern Palaeovalley is a large regional scale feature within the central and eastern English Channel (Figure 2.4). About 66 km of its length lies within the south-east corner of the South Coast REC study area. The resolution of the sea bed morphology model in the eastern third of the Region is poor compared to the western area which has a much greater level of detail with major and minor physical elements well resolved.

The northern margin of the Palaeovalley occurs at a break of slope around 30 m water depth with the base of the slope generally at a depth of 60 to 65 m. The nature of the margin varies across its length from east to west. In the east it is characterised by two slope parallel ridges up to 20 m high which extend for 15 to 25 km along the margin. The central third of the margin is about 20 km long and up to 7 km wide with a series of sub-parallel ridges and troughs from 10 to 25 m high, with one over deepened to a depth of 60 m.

In the central and eastern part of the Region the Palaeovalley floor is about 13 to 15 km wide with water depths of 55 to 60 m and is a relatively open floor with some funnelling and poorly resolved bars. The northern margin steepens up to a single slope where the Palaeovalley crosses the solid geology boundary from the Tertiary on to the Cretaceous. This boundary forms a pinch point in the Palaeovalley where it constricts to a width of 8.5 km and the floor is excavated to over 80 m in one of the channel narrows.

East of the pinch point the southern margin of the Palaeovalley is a low slope generally <5 m high associated with minor ridges at depths of around 50 m. West of the pinch point the southern margin is a well defined slope up to 14 m high backed by relatively smooth flat platform at a depth of 48 to 50 m. In contrast the northern margin west of the pinch point includes two slopes divided by a terrace up to 3.5 km wide at a depth of 45 to 50 m. A feature of this terrace and the platform on both sides of the Palaeovalley in this area are the number of shallow, <2 m deep dendritic channels which are very minor tributaries to the Palaeovalley.

The main channel of the Palaeovalley becomes wider to the south-west reaching 15 km at the southern boundary of the region with depths of 65 to 70 m. Within the main channel there are a number of elongate along-channel bars up to 10 km long and 2 km wide, they are ~10 m high with their surfaces at a depth of about 55 m.

Physical Region 5 is the second largest region with an area of 1340 km^2.

4.2 Interpretation methodology

Introduction

The methodology adopted for the geological interpretation outlined below follows the principles and procedures implemented for the Eastern English Channel Marine Habitat Map (EECMHM) study (James *et al*, 2007). The EECMHM study did not include marine archaeology, it was purely a marine habitat study, therefore, its geological interpretation concentrated on the geology, sediment and morphology of the sea bed down to a depth of ~0.5 m because in terms of habitat, only the physical characteristics of the sea bed surface is thought to be significant. With regard to maritime and aviation archaeology (Section 5.3 and 5.4) the nature of the sea bed is also important because this is the surface on which wrecks, aircraft and artefacts are laid or buried. However, characterising the archaeological potential of the South Coast REC area and its prehistoric archaeology (Section 5.2) requires a knowledge of the erosional and depositional processes which have formed the deposits of sub-sea bed geology, particularly those associated with climatic glacial and interglacial cycles during the Quaternary Period, and the sediments produced in the resulting phases of marine and terrestrial environments as sea level rose and fell across the length of the English Channel. These are confined to Quaternary sediments within channel systems which lie on the older solid geology — bedrock. There is no archaeological potential within the solid geology rocks, which are older than the Quaternary sediments.

Interpretation methodology

The geophysical data available for interpretation includes four techniques, multibeam echo sounder (MBES), sidescan sonar, Boomer sub-bottom profiler and magnetometer. The latter was deployed to locate metal objects on the sea bed for the archaeological interpretation (Chapter 5) and was not used in the geological interpretation. In addition single beam echo sounder data (James *et al.*, 2008) has been modelled to provide a complete sea bed morphology across the South Coast REC study area (Figure 4.1 & 4.2).

The results from sea bed ground truthing sample stations comprising grab sampling and photography have been incorporated in the final geological interpretation (Figure 3.4 & 3.6). No sediment core sampling was undertaken for the South Coast REC 2007 survey; therefore the ground truthing is only relevant for the sea bed and not the sediments that lie at greater depths.

A systematic approach, incorporating a series of interpretive steps, has been adopted in order to provide a framework on which to build an integrated interpretation and produce a series of geological and sediment maps.

The first step to interpret the sub-sea bed geology was to 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 sub-bottom profiler records to distinguish the base of superficial Quaternary sediment lying on top of bedrock (solid geology). This rock head limit between bedrock (solid geology) and Quaternary sediment was generally well defined when Quaternary sediment was thicker than a metre or two. However the incomplete coverage of the South Coast REC 2007 survey seismics and the relatively limited extent of thick Quaternary sediment precluded the creation of a robust isopach map of Quaternary superficial deposits for the study area.

The second step was to integrate the boomer interpretation with multibeam, sidescan sonar and sea bed morphology data especially in those areas where Quaternary sediments were thin and bedrock was exposed or virtually at the sea bed. It is important to delineate the area of bedrock exposed at the sea bed, and the sea bed morphology, multibeam and sidescan data indicated rock structures and bedding planes extensively within the study area and these bedrock occurrences at the sea bed were confirmed where boomer records were available. However, there were issues of resolution with the integration of these data sets because the boomer data commonly indicated a more extensive outcrop of bedrock at or virtually at the sea bed than apparent from the other three datasets.

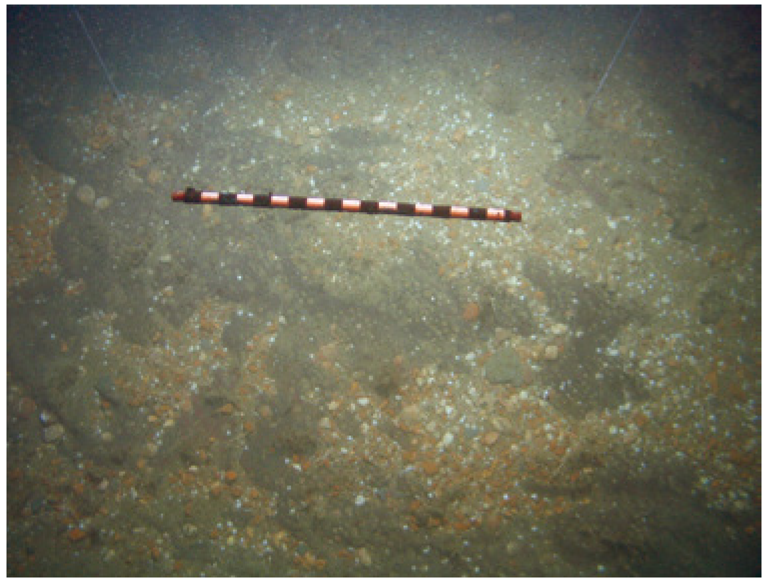


Figure 4.4: Wealden Group bedrock with thin patchy veneer of sediment at sample station 25 (Scale bar 20 cm).

It appears that when the thin veneer of sediment is less than 1 to 1.5 m thick the boomer is unable to distinguish the rock/sediment interface (James *et al*., 2007). Therefore, areas where the boomer records generally cannot resolve the sediment/rock interface are mapped as rock and thin sediment on the sea bed character map (Figure 4.17a, b).

The third step was to interpret multibeam, sidescan and sea bed morphology data for morphology and bedforms. These were included in the sea bed character map (Figure 4.17a, b) and bedforms map (Figure 4.20). 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.

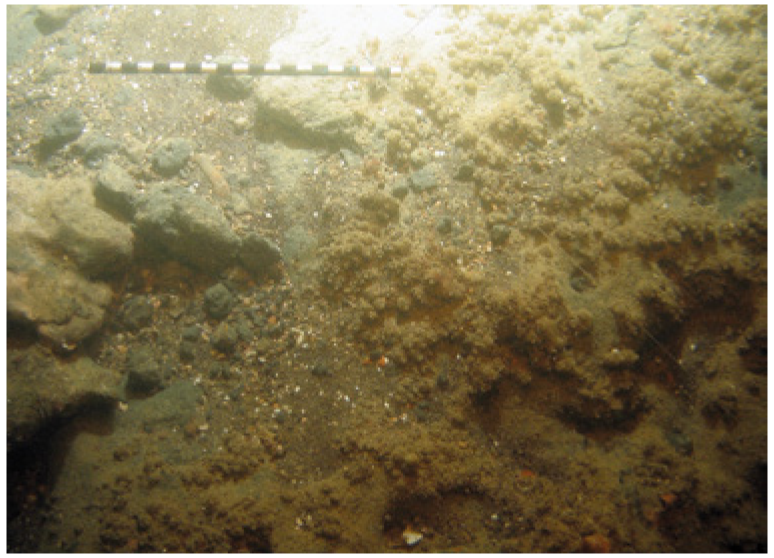


Figure 4.5: Angular cobbles and pebbles of Lower Greensand with small windows of bedrock through sediment at sample station 31 (Scale bar 20 cm).

The fourth step was to interpret particle size analysis (PSA) data provided by sediment sampling from grabs from a number of sources (Figure 3.6). The interpretation produced a series of maps of the study area purely based on sediment PSA including sea bed sediment distribution based on the Folk classification (Figure 4.25) and sedimentological parameters, d_{50} (Figure 4.30), mean grain size (Figure 4.31), sorting (Figure 4.32), sand % (Figure 4.27), gravel % (Figure 4.29) and mud % (Figure 4.33). Some of the lines from the Folk map have been used to delineate

Era	Period		Epoch	Stage/Age	Solid Geology - Group/Formation	
Cenozoic (65 Ma–Present)		Quaternary (2.6 Ma - Present)	Holocene (11.5 ka–Present)	Holocene MIS 1		
			Pleistocene (2.6 Ma–11.5 ka)	Devensian MIS 5d–2		
				Ipswichian MIS 5e		
				Wolstonian/Saalian MIS 6–10		
				Hoxnian MIS 11		
				Anglian MIS 12		
				Cromerian–Beestonian MIS 13–63		
				Pre–Beestonian MIS 64–163		
	Tertiary (65–2.6 Ma)	Neogene 23–2.6 Ma	Pliocene (5–2.6 Ma)			
			Miocene (23–5 Ma)			
		Palaeogene (65–23 Ma)	Oligocene (34–23 Ma)		Solent Group	Bouldnor Formation
			Eocene (56–34 Ma)			Bembridge Limestone
						Headon Hill Formation
					Barton Group	
					Bracklesham Group	
					London Clay Formation	
			Palaeocene (65–56 Ma)		Lambeth Group	
Mesozoic (251–65 Ma)		Cretaceous (145–65 Ma)	Upper Cretaceous (100–65 Ma)		Chalk Group	
			Lower Cretaceous (145–100 Ma)		Upper Greensand Formation	
					Gault Formation	
					Lower Greensand Group	
					Wealden Group	
		Jurassic (200–145 Ma)	Upper Jurassic (161–145 Ma)		Portland & Purbeck Groups	

Table 4.1: Geological timescale, and stratigraphy of Solid Geology within South Coast REC area.

coarse sediment and sandy sediment on the sea bed character map (Figure 4.17a, b) 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 modelled interpolation of grab sampled PSA data across the whole South Coast REC area.

4.3 Solid geology — bedrock

The bedrock of solid geology underlies the whole South Coast REC study area (Figure 4.3), however, it is only in those areas of sea bed underlain by rock and thin sediment (Figure 4.17a, b) where the nature, lithology and form of the bedrock will impact on the character of the sea bed. Elsewhere, relatively thick Quaternary and mobile sediment provide the base for the sea bed surface. Table 4.1 outlines the stratigraphy of the geology within the study area in ascending in age with the oldest rocks at the base.

The solid geology rocks are confined to two principal sequences (Hamblin *et al*, 1992; BGS 1988 & 1995; Insole *et al*., 1998; Hopson, 2009). The oldest are Cretaceous rocks which form an almost continuous sequence from the Wealden Group to the Upper Chalk. These Cretaceous rocks dominate the south and west of the study area and also occur in the north-east. They underlie the southern half of Region 1 and Region 2, the northern coastal margin of Region 3, the whole of Region 4 and the south-west extension of Region 5. Since their deposition these Cretaceous rocks have undergone structural uplift and folding which have created east-west trending anticlines and synclines and some of these major structures have formed distinctive morphological features on the sea bed.

The second principal sequence is formed of Tertiary rocks. These lie unconformably on the Cretaceous Upper Chalk. The unconformity represents a hiatus of about 15 million years during which time there was some uplift and erosion of the Cretaceous rocks prior to the deposition of Lambeth Group rocks as the first episode of Tertiary sedimentation. These were subsequently followed over a period of around 20 million years by the deposition of successive Tertiary rocks within the NW–SE trending Hampshire–Dieppe Basin. This Tertiary basin runs across the north-west quadrant of the study area east of the Isle of Wight with Tertiary rocks underlying the northern half of Region 2, the southern half of Region 3 and the eastern half of Region 5. To the west of the Isle of Wight, Tertiary rocks only underlie the northern half of Region 1.

The tectonic movements which affected the structure of the Cretaceous rocks began in the latest Cretaceous or earliest Tertiary and continued intermittently in the Eocene. These movements also affected Tertiary sedimentation, and the form of the Hampshire–Dieppe Basin was defined during this period. These tectonic movements were associated with the compressional forces which were building the Alpine mountain chain on continental Europe, these came to a culmination in the Oligocene to early Miocene, possibly 10 million years after the deposition of the youngest Tertiary rocks in the study area. This tectonic culmination was significant in that it produced the Wight–Bray monocline with its steep north facing flexures and basinal shape which forms the distinctive enclosure feature on the sea bed in Region 2.

Although the Cretaceous and Tertiary rocks are dominant there is one very small occurrence of Upper Jurassic to Lower Cretaceous Portland and Purbeck Group rocks on the sea bed off Durlston Head in the far west of the study area at the boundary of Region 1 and 4. The Purbeck Group rocks typically comprise thin beds of limestone and mudstones with sporadic lenses of sandstone. Evaporites in the form of gypsum and anhydrite can also occur. The underlying Portland Group rocks are dominated by bedded limestones.

Wealden Group

Wealden Group rock underlies the South Coast REC study area in three localities. The largest is an extensive area, which stretches from the west coast of the Isle of Wight in a swath 15 to 20 km wide across to the western boundary of the study area. Its northern limit is a line from the Needles to Handfast Point and it covers the southern half of Region 1 and the north-west quadrant of Region 4. Figure 4.4 shows a small area of rock exposed at the sea bed in an area mapped as Wealden (BGS, 1995) off the west coast off the Isle of Wight.

The occurrence of Wealden Group east of the Isle of Wight is smaller, within a narrow, <2 km wide area stretching about 20 km offshore from Sandown Bay. It runs within and parallel to the northern rampart of the Monocline Rampart Enclosure. The third locality is along the southern boundary of the study area where it exists as a narrow, 1–4 km crop in Region 4. Here it lies at the margin of the Central English Channel Monocline and the relatively steeper dips of the bedding and relative softness of the Wealden rocks means that it has been eroded deeper, by 15–25 m, than the Chalk platform to its north (Figure 4.2), with an etched and irregular sea bed with numerous positive morphological features (<2–5 m high).

The Wealden Group is of Lower Cretaceous age and comprises a lower unit, the Wessex Formation, which comprises predominantly red mudstones with subordinate sandstones. It also includes, in part, lenses of grey silty or sandy clay with plant debris and also fossil material such as crocodile, turtle and dinosaur bones (Insole *et al*., 1998). Above is an upper unit, the Vectis Formation, formed mainly of dark grey mudstones and siltstones with some sandstones in part.

Lower Greensand — Gault — Upper Greensand

The Lower Greensand, Gault and Upper Greensand are amalgamated offshore into a single mapped unit and they are the youngest rocks of the Lower Cretaceous. Their extent is controlled by the major anticlinal/monoclinal and synclinal tectonic structures, which run roughly west to east across the western half of the study area including the Wight–Bray monocline and the Central English Channel Monocline. These rocks have a very narrow footprint, <1 km wide, on the steep northern limb of the Wight–Bray monocline both west and east of the Isle of Wight. They infill the Monocline Rampart Enclosure and extend off the south coast of the Isle of Wight west through St Catherine's Deep and on across the west of Region 4 gradually narrowing from 8 km at the Isle of Wight to 2 km at the western boundary of the study area.

St Catherine's Deep has been wholly eroded within the outcrop of this unit. The Deep's southern margin is constrained by the more durable and resistant Chalk that forms this rampart, forcing tidal currents to move along its axis. The tectonic structure and differential character of the Greensand and Chalk have obviously controlled the alignment and over deepening, however the history and mechanism of its origin is not certain. It has probably had both fluvial and marine processes influencing its development with the former possibly critical in its early development in the Pleistocene and the latter later in the Pleistocene with more than

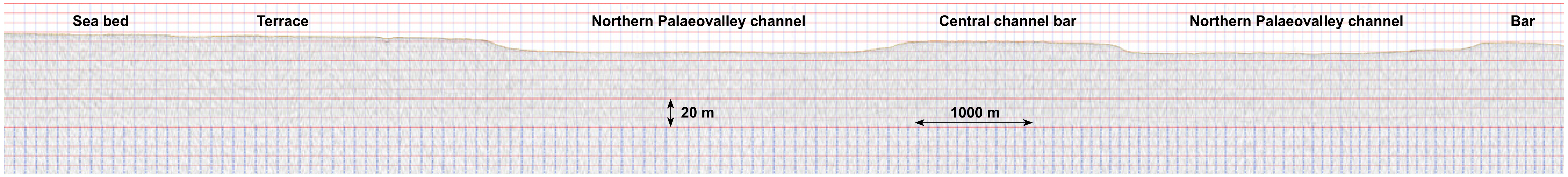


Figure 4.6: Seismic section across Northern Palaeovalley in Chalk bedrock.

one marine interglacial cycle contributing to funnelling tidal currents in these narrows off the high 300 m cliffs of the Isle of Wight which essentially can be thought of as the northern margin of the Deep.

The Lower Greensand comprises grey-green and green glauconitic muddy sands, some are very fossiliferous. It also includes brown grey, silty muds, silts and fine sands and there may be thin conglomerates near the top of the succession.

The Gault is dominated by dark grey soft silty mudstones; it can be sandy in part. The overlying Upper Greensand includes silts, sandy muds and fine muddy sands, some of which can be glauconitic.

Figure 4.5 is a photograph of the sea bed 1500 m west of St Catherine's Point in this Greensand/Gault unit with distinctive grey-green rock visible at the surface, some of which have broken off to form grey-green pebbles and cobbles.

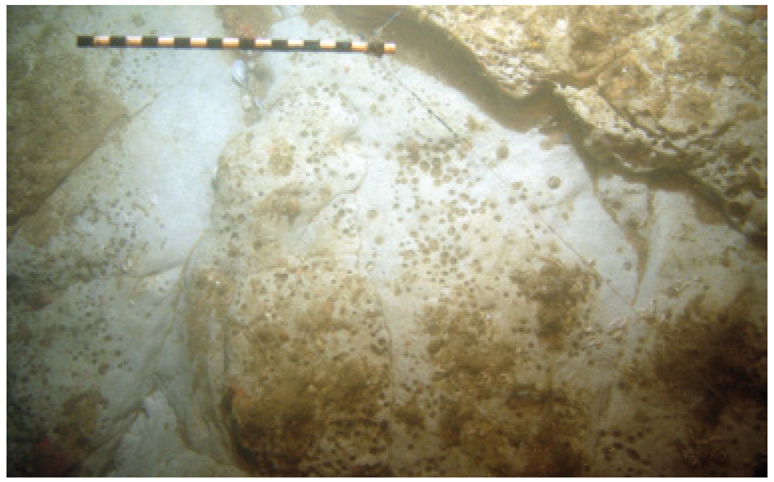


Figure 4.7: Chalk exposed at sample station 33 (Scale bar 20 cm).

Chalk

The occurrence of Chalk is also controlled by the tectonic structures. It is most extensive in Region 4 where it forms a sub-horizontal platform between the Monocline Rampart Enclosure of the Wight–Bray Monocline and the Central English Channel Monocline to the south. The Chalk platform runs across the whole east–west width of Region 4 and is about 20 km in north-south width but narrows to ~8 km in the western quarter of Region 4. Figure 4.7 is an example of Chalk exposed at the sea bed in this platform area of strong tidal currents (Figure 2.7).

Chalk underlies the western end of the Northern Palaeovalley where it forms distinctive terraces and central channel bars at depths of 50 to 55 m (Figure 4.6). Chalk forms the distinctive rampart of the Monocline Rampart Enclosure. Its outcrop is narrow along the northern rampart, <1 km, where the beds are near vertical in the Wight-Bray monocline. These near vertical Chalk beds come ashore at Whitecliff Bay (Figure 4.8) and forms a headland at the south end of the Bay with near vertical Tertiary rocks on the southern limb of the Hampshire Dieppe Basin within the Bay to the north.

Figure 4.8: View to north across south end of Whitecliff Bay, Isle of Wight where Wight–Bray monocline comes on land. Near vertical Chalk in foreground followed by red-grey Lambeth Group muds and in the distance London Clay Formation BGS © NERC 2010. All Rights Reserved.

The Chalk also occurs on the northern side of the Tertiary Hampshire-Dieppe Basin in Region 3 offshore from Bognor Regis along the coast to the eastern boundary of the study area. It extends offshore up to 8 km and lies within a slight syncline but offshore of Brighton it is overlain by a narrow band, ~4 km wide, of Tertiary Lambeth Group rocks in the core of the syncline.

Upper Cretaceous Chalk comprises micritic limestone and nodular calcareous limestone with nodules of siliceous flint, thin marl seams and hard grounds.

Lambeth Group

The Tertiary rocks in the South Coast REC area have, at their base, Lambeth Group rocks lying uncomformably on the Chalk. They occur within the Hampshire–Dieppe Basin and although they are not thick enough to be mapped offshore, on the near vertical limb of the Bray-Wight monocline they do come ashore at Whitecliff Bay where Lambeth Group Reading Formation rocks rest on the Chalk (Figure 4.8). Here it comprises a thin basal conglomerate overlain by grey and red muds.

Lambeth Group rocks are more extensive on the northern side of the Hampshire-Dieppe Basin in Region 3 on the coastal platform. Here shallow synclinal and anticlinal flexures give a sinuous plan form to its narrow, <2 km, occurrence. It is more extensive a little

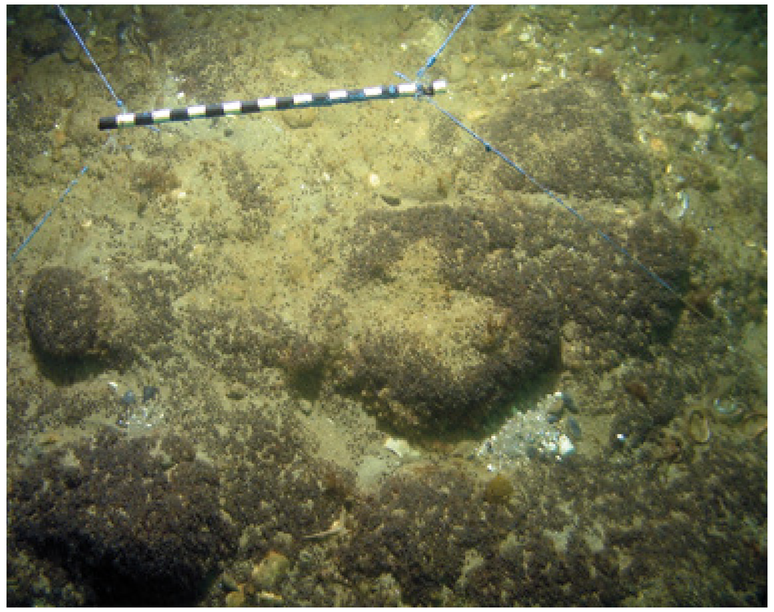


Figure 4.9: Lambeth Group bedrock exposed at sample station 88 (Scale bar 20 cm).

further north lying on Chalk at the core of the syncline offshore of Brighton. Sea bed exposure of Lambeth Group bedrock in this area is seen in Figure 4.9.

London Clay

On the southern limb of the Hampshire Dieppe Basin the London Clay forms a narrow occurrence <300 m, on the near vertical limb of the Wight–Bray Monocline and may form the south-east trending low ridge <4 m high and ~500 m wide which marks the line of the monocline towards the Northern Palaeovalley and beyond (Figure 4.2 and 4.10). Evidence from Whitecliff Bay indicates a resistant ferruginous sandstone in the Portsmouth Member of the London Clay extends offshore and may form the core of this low ridge (Figure 4.10 and 4.11). The London Clay also forms a narrow occurrence west of the Isle of Wight, across Christchurch Bay and Poole Bay from the Needles to Studland Bay near Poole.

London Clay on the north side of the Hampshire-Dieppe Basin extends eastwards offshore from Selsey and Bognor across Region 3 and ranges in width from 3–10 km. It has a sinuous pattern in the east of the Region as its form is disturbed by an anticline bringing Chalk to the sea bed.

Figure 4.11: Resistant bed of London Clay Formation ferruginous sandstone in beach at Whitecliff Bay ~1 m wide — view offshore. BGS © NERC 2010. All Rights Reserved.

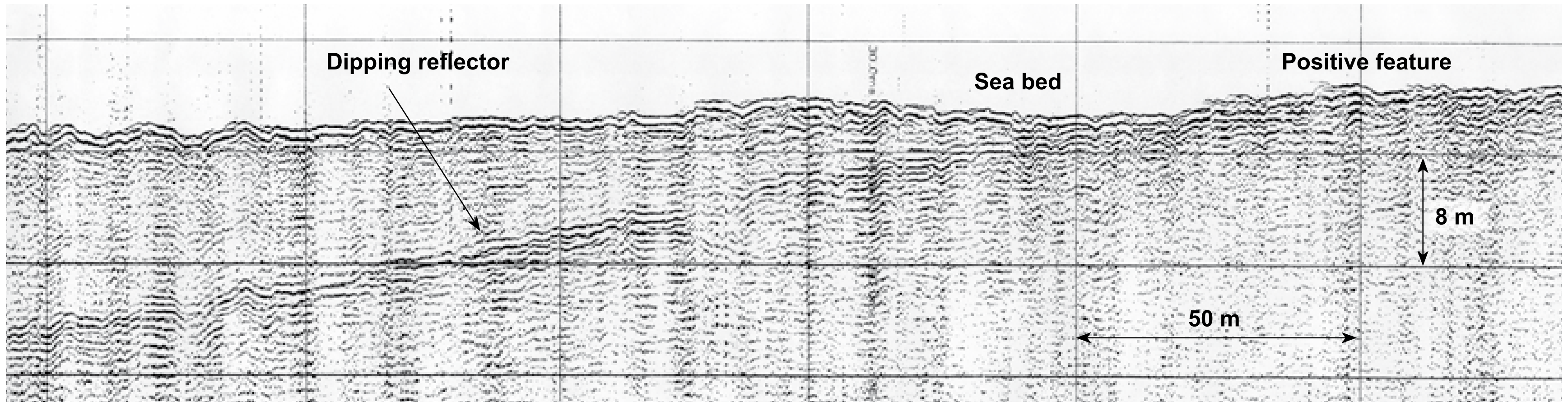


Figure 4.10: E–W seismic section through line of Wight–Bray monocline with strong dipping reflector associated with positive feature on sea bed. This reflector may be associated with resistant bed in London Clay Formation as seen in Figure 4.11 and 4.12.

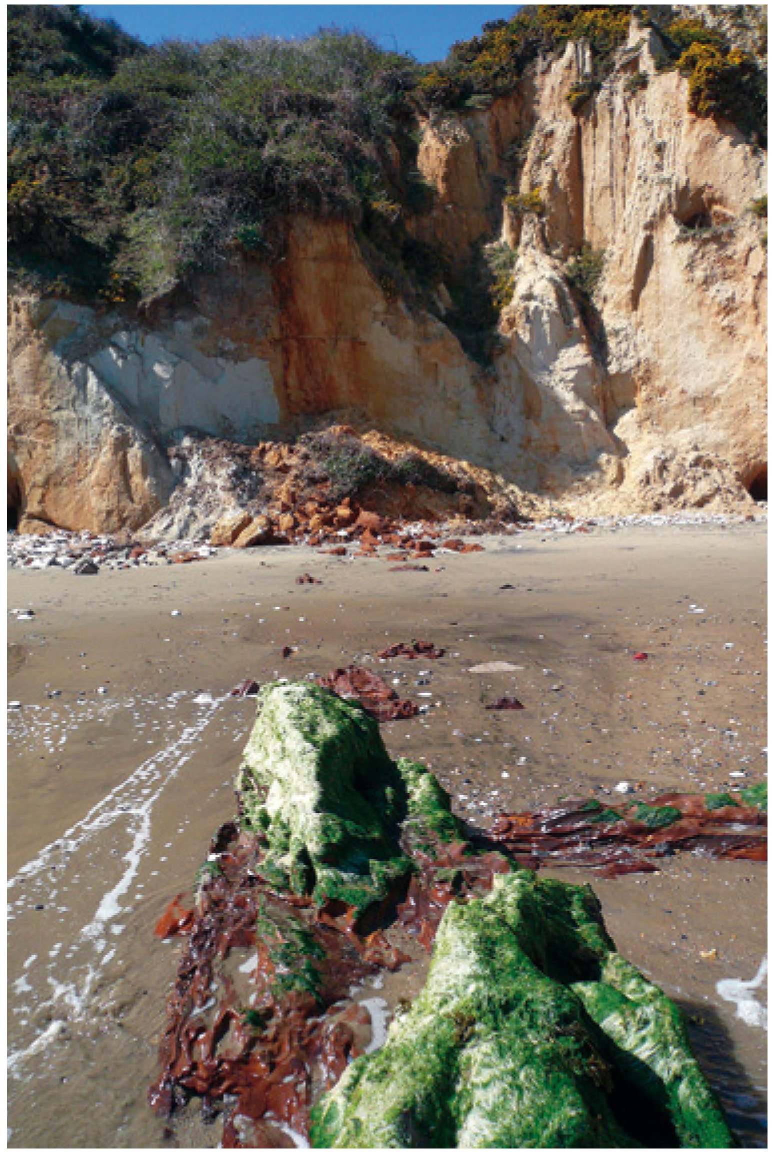


Figure 4.12: Resistant bed of London Clay Formation ferruginous sandstone in beach at Whitecliff Bay — view onshore to exposure in cliff. BGS © NERC 2010. All Rights Reserved.

The London Clay is a diverse mix of lithologies including sands and silty muds with some coarser units near its base.

Bracklesham Group

Bracklesham Group rocks lie beneath the inner parts of Poole Bay and Christchurch Bay including the Christchurch Ledge, which extends offshore from Hengistbury Head. West of the Isle of Wight it has a narrow extent, <1 km wide, on the south side of the Hampshire–Dieppe Basin. Where it comes ashore at Whitecliff Bay it's outcrop is only ~130 m wide. To the north it underlies the inner Bracklesham Bay and heads east into Region 3 including the area around the Mixon south of Selsey Bill and then continues across to the Northern Palaeovalley with a width of 4–10 km. Figure 4.13 illustrates the type of sea bed underlain by these rocks in Region 3 with a very thin veneer of gravel overlying sediment which may be reworked or bioturbated Bracklesham Group rocks. The evidence from the clamshell grab (Figure 4.14) sample indicates that some of the relatively soft rock may be at the sea bed.

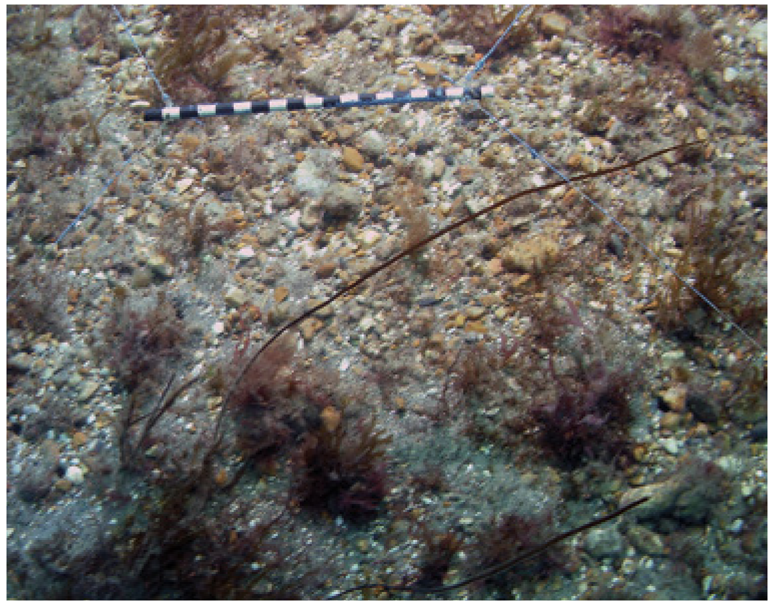


Figure 4.13: Bracklesham Group bedrock exposed at sample station 62 (Scale bar 20 cm).

The Bracklesham Group rocks are a diverse mix with a great deal of variety both laterally across the study area and vertically through the succession. It can include glauconitic sands and sandy muds, shell bands and interbedded muds, slits and sands. It also has occurrences of lignite, some of which can be relatively thick (Figure 4.14).

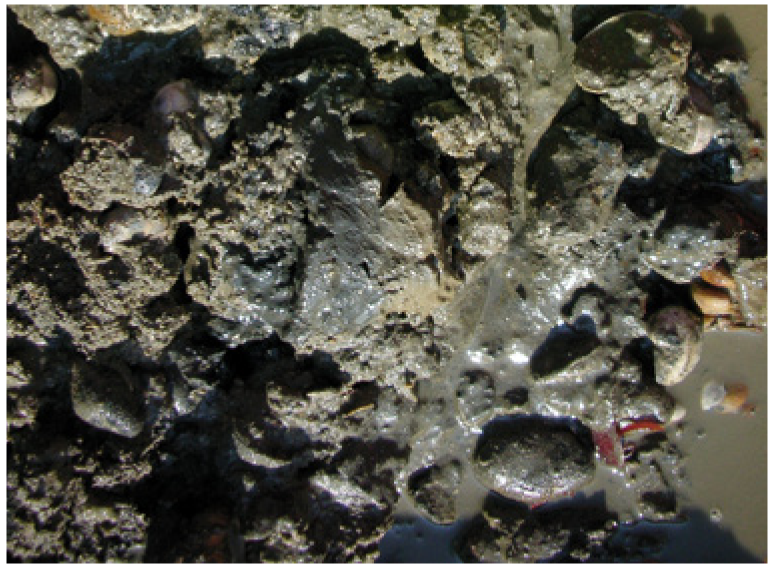


Figure 4.14: Bracklesham Group soft bedrock mixed with *Crepidula fornicata* retrieved in clamshell grab at sample station 62.

Figure 4.15: Metre wide bed of Bracklesham Group lignite exposed in cliff at Whitecliff Bay. BGS © NERC 2010. All Rights Reserved.

Barton Group

Barton Group comprise the youngest Tertiary rocks in the area and form the core of the Hampshire–Dieppe Basin. They are most widespread to the east of the Isle of Wight from the entrance to the Solent south-east to the Northern Palaeovalley. Its extent here has a width of 9 to 18 km and a maximum length of 84 km. They also have a narrow extent nearshore in Christchurch Bay which comes onshore at the cliffs at Barton, after which the group is named.

It comprises silty muds with some beds of sand. The example of sea bed illustrated in Figure 4.16 shows a resistant and relatively durable exposure of rock mapped as Barton Group (BGS, 1995) in the area of Hooe Bank south-east of Selsey Bill.

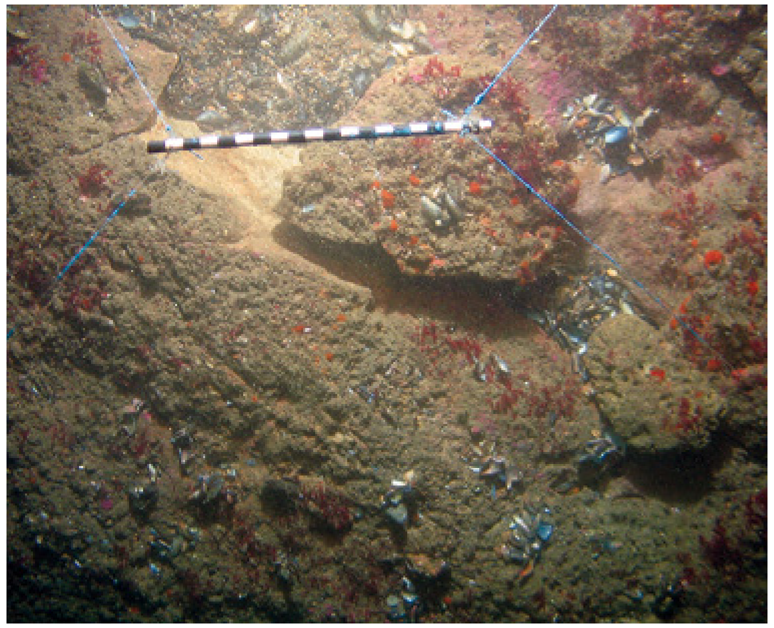


Figure 4.16: Barton Group bedrock exposed at sample station 64 (Scale bar 20 cm).

Solent Group

The Solent Group include the Headon Hill Formation at its base, overlain by the Bembridge Limestone which in turn is topped by the Bouldner Formation. The two former units are found at the northern end of Whitecliff Bay and extend offshore for up to 2 km. They follow the coast round into the Solent and continue as a narrow band offshore to the western entrance to the Solent. The limestone forms the shoal of the Bembridge Ledge, which has been disturbed by quarrying in some parts (Section 2.11). There appears to be no mapped occurrence of the Bouldner Formation offshore.

The Headon Hill Formation comprises muds, muddy sands and occasional ironstone. The Bembridge Limestone is predominantly fossiliferous limestones and marls.

4.4 Quaternary sediments

There was a long hiatus of over 25 million years between the deposition of the youngest Palaeogene Solent Group rocks in the study area and the earliest physical evidence of deposition during the Quaternary which are the highest river terraces onshore. These fed in to an ancient Solent River which at certain periods during the Quaternary flowed west to east between the Isle of Wight and the mainland (Green, 1946; Edwards and Freshney, 1987; Bridgland, 2001; Briant *et al*., 2009). There is no evidence of Neogene deposits in the study area or elsewhere in this part of Southern England (Table 4.1). During this long hiatus period, tectonic activity in the Miocene associated with Alpine mountain building is estimated to have uplifted the landmass by about 1500 m (Simpson, *et al*., 1989). The erosion and denudation of the landscape formed on the structures created by these Miocene tectonic events has greatly influenced the form of Quaternary sedimentation both onshore and offshore. Uplift has been on-going through the Quaternary, although not associated with Alpine tectonism.

Westaway *et al* (2006) has calculated from research on the altitude of onshore terraces in the Solent catchment that the area has been uplifted by ~70 m since the late Early Pleistocene and ~150 m since the Middle Pliocene. These rates would be applicable to the South Coast REC area. This uplift has enabled the preservation of suites of progressively higher terraces onshore particularly in the rivers Frome, Stour, Avon and Test, which fed into a Solent River (Figure 5.3). Westaway *et al* (2006) appears to tentatively model the date of the Chilworth Gravel, the highest terrace in the Test River system, as Marine Isotope Stage (MIS) 36, which would place it in the late Early Pleistocene, around 1.2 Ma BP. This would be the oldest occurrence of Quaternary sediment in the Solent area.

The other principal Quaternary deposits that are preserved onshore are marine raised beach deposits, of which there are at least four within the West Sussex Coastal Plain (Figure 5.5) (Bates *et al*., 1997; 2000; Briant *et al*., 2009). The oldest of these is the Goodwood — Slindon Raised Beach which has been correlated with MIS 13, around 0.5 Ma BP (Roberts & Parfitt, 1999).

These onshore fluvial and marine deposits have provided a considerable wealth of archaeological material and evidence of human occupation. The potential for the preservation of archaeological material offshore in the South Coast REC area and the possible scenarios for hominin land use offshore at various stages in the Quaternary since MIS 13 are explained in detail in Chapter 5 — Marine Archaeology. In this geological chapter we provide a brief account of the evidence for Quaternary sedimentation in the South Coast REC study area from the relatively limited survey data available. We did not have a sufficient grid of sub-bottom seismic data to map in detail the internal character of these sediments nor produce an isopach map of sediment thickness.

Figure 4.17a, b illustrates the sea bed character of the South Coast REC area. It shows that 75% of the sea bed comprises rock and thin sediment, therefore only 25% of the sea bed has the potential to be underlain by significant deposits of Quaternary sediment. The relative lack of Quaternary sediment is due to a number of factors.

None of the ice sheets associated with the major glaciations that have occurred in the British Isles back to the Anglian (MIS 12) have reached the English Channel. Their limits have all been at various points in England north of the Thames. Glaciations are significant erosional and depositional events and leave a strong direct footprint in terms of landforms and sediment. This direct glacial footprint is missing in the South Coast REC study area.

The catchments of the rivers which have flowed in to the study area are relatively short and also have limited tributaries. The east-west structural grain of the landscape onshore mitigates against long north-south flowing rivers on the scale of the Thames, Trent or Severn flowing in to the English Channel which would have had the capacity to provide sediment in to the system.

The English Channel has only been open to the North Sea since the Anglian Glaciation (MIS 12) (Hamblin *et al*, 1992; Gibbard, 1988, 1995; Toucanne *et al*., 2009a, b). Prior to MIS 12 it would have been a large embayment during high interglacial sea levels with a very different oceanographic and marine environment to the post MIS 12 interglacials which are likely to be more erosive and less depositional in the study area, with conditions similar to the present day. This limits the possibility of pre MIS 12 sediments surviving in the study area during the glacial and interglacial cycles that have occurred since MIS 12. They are only likely to survive at depth in channel systems.

A number of sediment filled channel systems have been noted and described in the study area, the Solent and Palaeosolent (Dyer, 1975; Hamblin *et al*., 1992), Poole and Christchurch Bay (Velagrakis *et al*., 1999) the Arun/Palaeoarun (Bellamy, 1995; Gupta *et al*, 2004) and also the open channel system of the Northern Palaeovalley. The three principal sediment filled channel systems noted above lie under the three largest occurrences of coarse sediment in Figure 4.17a, b, with the Poole and Christchurch Bay system to the west of the Isle of Wight in Region 1, the Solent/Palaeosolent system to the east of the Isle of Wight in Region 2 and the Palaeoarun system in Region 3.

Velegrakis *et al* (1999) indicate that in Poole and Christchurch Bay three south flowing rivers breached the Needles-Handfast Point Chalk ridge. However only in Poole Bay are two of the channel systems filled with sediment, up to 7 m maximum thickness, elsewhere in Christchurch Bay there is no evidence of thick channel fill. Velegrakis indicates there are no submerged terraces associated with these channels, unlike in the Palaeosolent and Palaeoarun channels east of the Isle of Wight, he suggests this is due to marine erosion and the exposed position of these Bays to strong currents and wave energy. His research only went a few kilometres south of the Chalk in Region 1 and the limited evidence available suggest that these channel systems become less significant in thickness towards the south of Region 1 and peter out on the rock platform in Region 2. Only one narrow channel extends for any length across Region 2, it does not reach the southern boundary of the study area. There are some small relatively thin channels <3 m thick, associated with a sheet of sediment on the Region 1 and 4 boundary, their provenance is not clear but in part, the sheet appears to be banked against an east–west trending rock ridge a few metres high.

The Solent and Palaeosolent channel system is the largest and most extensive of the three principal systems. Within Region 2 its channel fill is about 4 to 6 km wide for over 24 km down the Solent in a NW–SE direction and reaches depths of 40 m (Dyer, 1975). Sediment can be up to 25 m thick with a number of erosion surfaces, prograding bars, foresets and horizontal fill evident in seismic profiles. The limited seismic evidence suggests that rock may be more extensive than shown on the sea bed character map. Certainly the channel fill becomes disrupted by rock outcrop south of Pullar Bank where it becomes narrower and thinner between elongated rock scarps. However, although the Solent system appears to peter out to the south east it does make a radical 90º turn to the south west and breaches the Chalk of the Monocline Rampart through a 2 km wide gap south of Nab Hole. This breach appears to be semi-filled by a bar or bank feature which internally has a strong single foreset development.

However, this is not the only breach of the rampart, another occurs 5 km to the north west and again this is about 2 km wide. This latter system curves round within the Rampart Enclosure to join the other Palaeosolent channel after about 11 km. Apart from the breach in the Rampart this channel has no great surface expression on the sea bed unlike the other channel which has incised a 10 to 15 m deep steep sided channel within the Lower Greensand of the Rampart Enclosure. The floor of the channel is relatively flat at a depth of 40 m and it widens out to 4 km across but then narrows again to around 500 m as it cuts through the Chalk of the southern Rampart. Sediment within this part of the channel is relatively uniform in thickness around 7 to 9 m and the channel base beneath the sediment is relatively planar.

The form of the Palaeosolent as it cuts across the Monocline Rampart Enclosure is intriguing, as is the question of how it developed. Water flow with relatively significant erosive power has obviously been directed to flow almost unnaturally across a narrow resistant rock unit and also down cut a steep almost gorge like profile in less resistant rock. The fact that the Enclosure is associated with a large rock structure, the Wight–Bray monocline, created by compression and uplift might suggest that tectonics had some effect by creating lines of weaker or broken rock within the Chalk rampart and along the Greensand. An alternative is that the channel is following the alignment of an older Tertiary channel which has superimposed itself on the Chalk and Greensand as the overlying Tertiary rock was eroded.

Once out of the confines of the Rampart Enclosure the Palaeosolent Channel remains relatively narrow with a width of <1 to 2 km as it crosses the Chalk platform of Region 4 for a length of over 24 km down to the Northern Palaeovalley.

The Palaeoarun in Region 3 also flows in to the Northern Palaeovalley. It is a relatively simple system, which extends for about 25 km across the Selsey — West Sussex Platform. It comprises a number of sediment bodies formed during cut and fill events (Bellamy, 1995; Gupta *et al*., 2004, Wessex Archaeology, 2008a) with gravels, sands and peats associated with estuarine, marine and sub-littoral environments. The alignment of the Palaeoarun is strongly controlled by the structure of the underlying rock in its southern half with the channel aligned parallel to the local dip slopes and scarps before finally breaking out through a narrow gorge in to the Northern Palaeovalley.

A common feature of almost all these channel systems is the apparent thinning or absence of channel sediments within the shallow nearshore zone. This may be due to increased planation and marine erosion in the nearshore zone during and after the culmination of the Holocene marine transgression. This makes onshore and offshore correlations of Quaternary deposits particularly difficult in this area (Bates *et al*., 2007a, b).

4.5 Sea bed character

The sea bed character (Figure 4.17a, b) and bedforms (Figure 4.20) interpretation follows in part the procedure adopted for the EECMHM study (James *et al*., 2007). The substrate has been divided into a four fold classification of sea bed character:-

- Muddy sediment
- 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.. Rippled sand and megaripple trains were recognised on sidescan records. 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 4.17a, b) has also been completed in conjunction with the sea bed sediment Folk classification map (Figure 4.25). 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 sea bed character 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 sea bed character interpretation, the modelled Folk sediment category of any thin sediment is shown on Figure 4.25.

A number of processes have influenced the character of the present sea bed. These include:-

- 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.
- Marine erosion during inundation as sea level rose across the English Channel since the Last Glacial Maximum.
- 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.

Sediment bedforms in the study area have been divided into three categories (Figure 4.20):-

- Sand bank
- Gravel bank
- Sand wave field

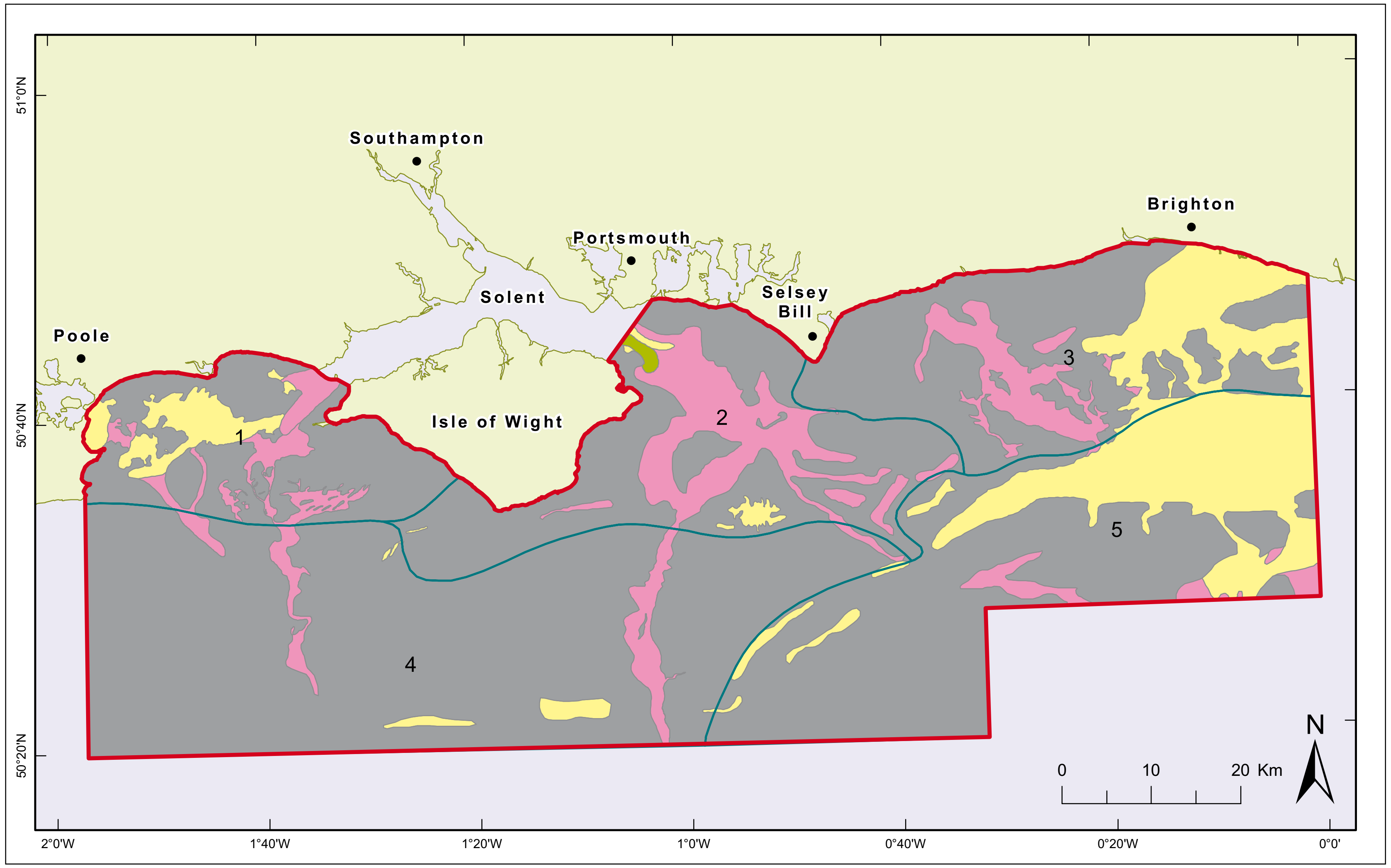


Figure 4.17a: Sea bed character in South Coast REC area.

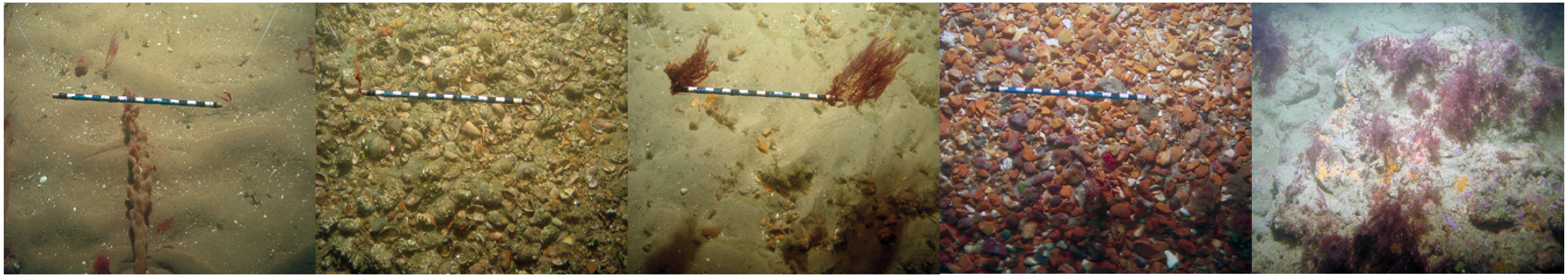


Figure 4.18: Still image examples of sea bed character across Region 1 — Greater Poole Bay and Christchurch Bay (Scale bar 20 cm).

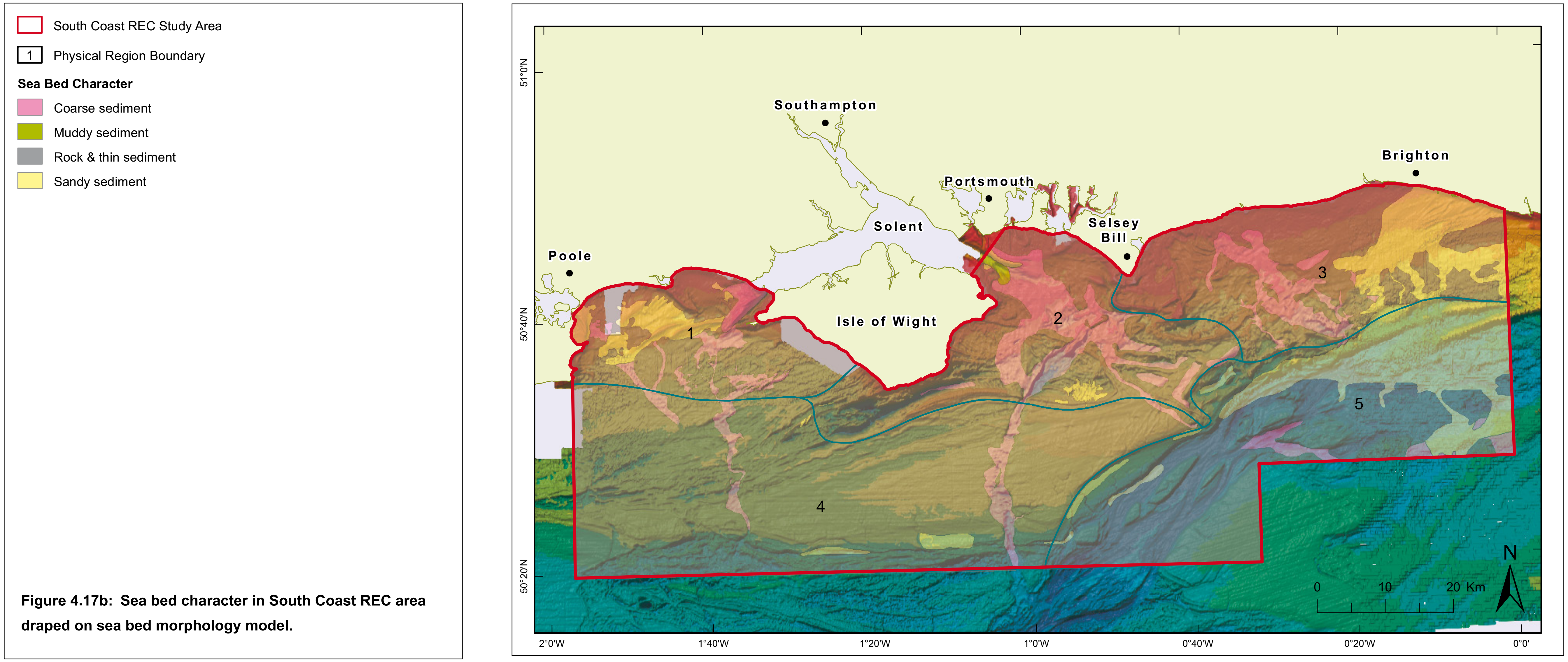


Figure 4.17b: Sea bed character in South Coast REC area draped on sea bed morphology model.

Figure 4.19: Still image examples of sea bed character across Region 2 — East Wight and St Catherine's Deep (Scale bar 20 cm).

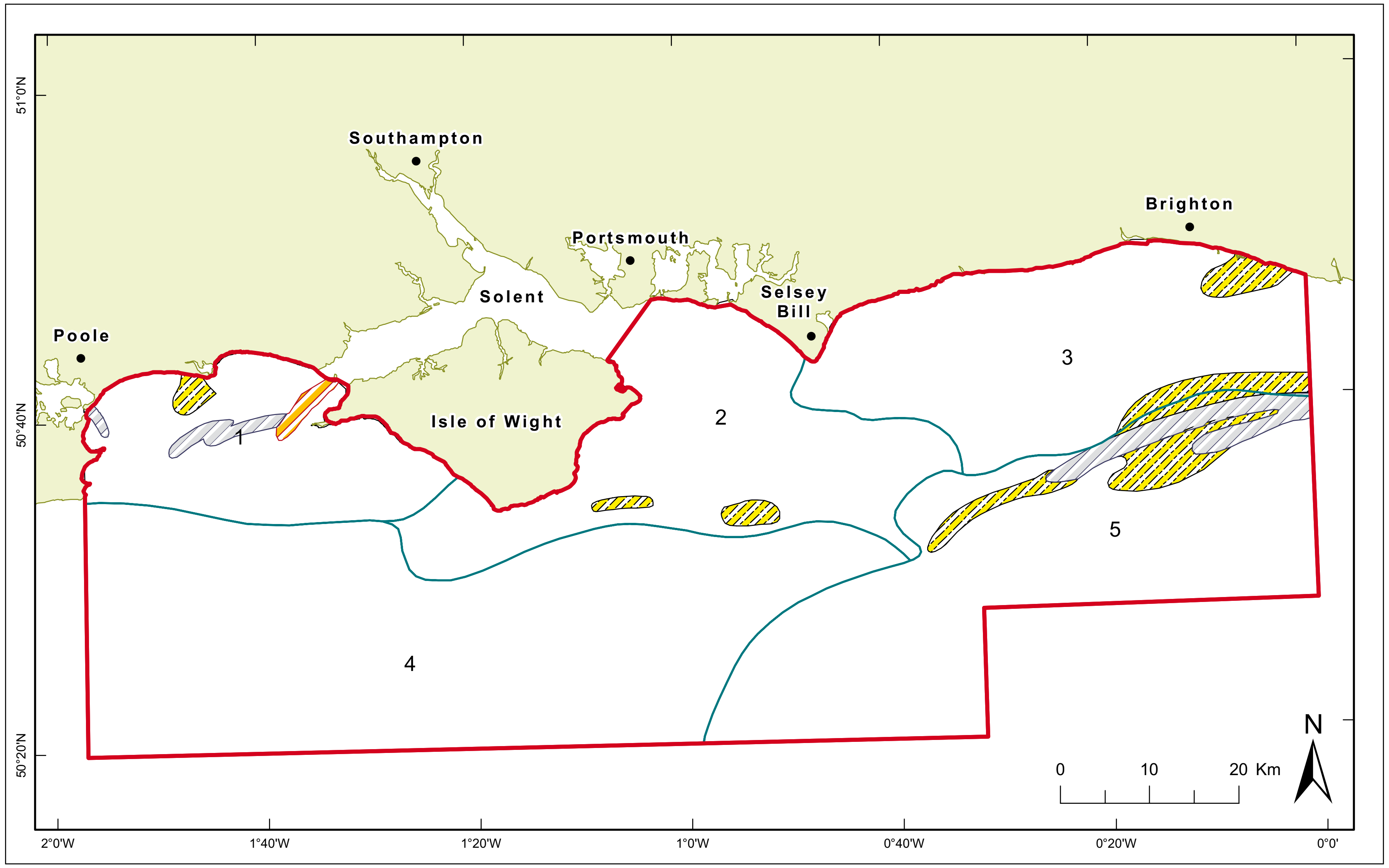


Figure 4.20: Major bedform types in South Coast REC area.

Figure 4.21: Still image examples of sea bed character across Region 3 — Selsey — West Sussex Coastal Platform (Scale bar 20 cm).

Their extent and form is controlled by a number of factors including tidal current velocity, duration and orientation, sediment supply and in some areas, morphological features such as channels and rock outcrop. Bedforms can be classified as:-

- Transverse, with crestlines orientated across the paths of the principal current flows. These include waveforms such as sand waves, megaripples and ripples.
- Linear, which are parallel to current flow. These are generally narrow and associated with low 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 generally large linear bedforms. Both Dolphin Sand and Dolphin Bank in Poole and Christchurch Bay are about 8 km long and commonly are covered by well-developed transverse bedforms, sand waves and megaripples.

In areas of rock and thin sediment the sea bed morphology model (Figure 4.1) readily picks out features such as:-

- Morphological lineation — ridges and breaks of slope associated with channel margins and interfluve erosion. Their common denominator is that none are related directly to rock structure and appear to be the result, primarily but not exclusively, 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.

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 sea bed.

South Coast REC study area

The South Coast REC study area covers approximately 5670 km^2. Rock and thin sediment is the dominant form of sea bed character lying over 75% of the study area, both sandy and coarse sediment are subordinate with 14% sea bed cover for the former and 11% for the latter (Figure 17a, b).

Rock and thin sediment is virtually ubiquitous across the southern half of the study area in Region 4 and 5 and extends northward to around the Isle of Wight in Region 1 and 2, and in both these areas its extent is broken by areas of sand and coarse sediment although rock and thin sediment areas remain significant. It continues to be significant in the western half of Region 3. Coarse sediment is primarily associated with the major channel systems within Poole and Christchurch Bay, the Solent and Palaeosolent, and the Arun/Palaeoarun system, although there is a bank of coarse sediment in the east of Region 1. Sandy sediment is relatively extensive within the shallower inner area of Region 1 but the most extensive accumulation of sands are in the east of Region 3 and the north east of Region 5. Muddy sediment has only been noted in <0.1% of the study area in the Solent in the north west of Region 2.

The dominance of rock and thin sediment plus the areas of coarse sediment means that the study area has a limited extent of major sandy bedforms (Figure 4.20) although sand streaks, sand patches, sand ribbons and megaripple trains do occur on these rocky substrates. The area south of the Isle of Wight including Region 4 is an area of relatively strong tidal currents (Figure 2.7) and high values of tidal sea bed stress (Figure 2.9) this has contributed to the creation of a sea bed with a winnowed lag surface of rock and thin coarse sediment with fine sediment being driven to the east away from this bedload parting zone (Figure 2.10).

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 (James *et al.*, 2007). The sand banks in Region 5 and the sand wave field and sand sheets in the east of Region 3 are within this sediment conduit and sink system. The sand banks in Poole and Christchurch Bay are associated with nearshore current processes with fine sediment trapped within these bays.

Physical Region 1 — Greater Poole and Christchurch Bay

Region 1 has a relatively complex sea bed character which includes three sand banks, a gravel bank, a sand wave field and prominent rock scarp and ledge. These are within the northern half of the Region bounded to the south by a line from the Needles to Handfast Point. The smallest of these sand banks is Hook Sand in the east of Poole Bay. It is <4 km long and aligned at almost a right angle to the entrance of Poole Harbour. It has an asymmetric cross profile with a steeper west facing lee slope up to 5 m high.

The distance from Handfast Point to the Needles is 25 km and the sand banks of Dolphin Sand and Dolphin Bank underlie 14 km of this stretch of sea bed (Figure 4.1 and 4.2). They are aligned in a slightly offset en-echelon form, virtually east-west. Their crests are at a depth of 8 to 13 m, they also have an asymmetrical cross profile with steep south facing lee slopes up to 14 m high. Limited evidence suggests there may be a sand wave field inshore between Dolphin Sand and Christchurch Ledge.

Christchurch Ledge has a south-west facing rock scarp 10–12 m high which extends offshore for about 6 km from the high cliffs of Hengistbury Head. There are hard bands of siderite nodules in these Barton Group cliffs but unfortunately we have no evidence of the resistant rock type that forms the Christchurch Ledge scarp, and whether these siderite bands are associated with the scarp. The back of the ledge is relatively flat at a depth of 4 to 6 m.

Shingles Bank at the western entrance to the Solent is a north-east to south-west trending gravel bank about 7 km long. It is attached onshore to the gravel based Hurst Spit and derives gravel from Hurst Spit as part of the eastward longshore transport of sediment around Christchurch Bay. Shingles Bank is the ultimate sink for this longshore derived gravel.

The southern half of the region is a slightly undulating surface of coarse sediment and rock and thin sediment with little apparent surface expression to distinguish these two types. There are some linear north-east to south-west trending ridges up to 8 m high which are distinguishable on the sea bed morphology (Figure 4.1) and these parallel the strike of the underlying Wealden Group rocks. However, there is also evidence of coarse sediment associated with thin sediment sheets and small channels.

Although the region is relatively complex, rock and thin sediment remains dominant covering about 68% of the region's 570 km^2, with coarse and sandy sediment covering equal amounts of sea bed at 16% each. Sea bed photographs of examples of the variety of sea bed within Region 1 are shown in Figure 4.18.

Physical Region 2 — East Wight and St Catherine's Deep

As noted in Section 4.1 Region 2 can be divided into two distinctive northern and southern sea bed areas. The northern area is an extension of the eastern Solent and trends north-west to south-east down to the Northern Palaeovalley. It has a central channel system with coarse sediment dominating its centre flanked to the north in Bracklesham Bay by rock and thin sediment. The Horsetail sand bank, at the entrance to the Solent, also flanks the central channel and has a crest at about 5 m depth. It has a steep >20 m high southern slope but continues horizontally back on shore. Although we have no seismic evidence we have interpreted the sea bed behind the bank as rock and thin sediment as seen elsewhere in Bracklesham Bay. The rock-based floor to Bracklesham Bay has a gentle southern decline that appears to mirror the low southern dip of the underlying Tertiary Bracklesham and Barton Group rocks. Some low, <1 m high, parallel linear ridges on the sea bed here are likely to be hard rock bands. Within Nab Hole in the central channel a small sand wave field has formed with small ~3 m high east facing sand waves. This appears to be an isolated occurrence of sandy bedforms within a generally coarse sediment environment.

South of Pullar Bank a number of linear east-west rock ridges 8 to 14 m high appear in the central channel forcing the break up of the central coarse sediment deposit into discrete linear occurrences in the depressions between these ridges.

The only notable evidence of muddy sediment in Region 2 is a small area at the entrance to the East Solent between Bembridge Ledge and Horsetail Bank; its interpretation is based on sample station data, although this appears to be slightly contradictory as tidal currents may be high enough to maintain mud in suspension in this channel.

The southern flank of the central channel is formed by the rock of the Bembridge Ledge in the north–west and rock and thin sediment continues along the northern margin of the Monocline Rampart Enclosure and beyond to the Northern Palaeovalley.

The southern area is the distinctive Monocline Rampart Enclosure (Figure 4.1 & 4.2). Coarse sediment here is associated with the two channel systems that cross the floor of the Enclosure before merging and exiting through a narrow gap in the southern wall of the Rampart. The Enclosure includes linear east-west ridges of rock up to 4 m high that are common within a sea floor of rock and thin sediment. These ridges become higher >20 m in the south-west of the Enclosure where the sea bed descends in to St Catherine's Deep. The sea floor between some of these ridges have large transverse bedforms up to 7 m high which are interpreted as sand waves. The depressions between linear ridges are likely to form conduits for mobile sediment driven by tidal currents and harbour rippled sand and winnowed gravel.

Sand waves also occur within a small sand wave field in the south-east corner of the Enclosure in what appears to be a unique occurrence. This sand wave field is known as the Overfalls (Tingley *et al*., 2006). It covers an area of 5 km by 3 km with its southern margin along the Rampart. The sand waves, of which there appear to be at least nine, are sinuous in plan and up to 3 km long with crests at depths of 23 to 27 m. They are symmetrical or asymmetrical with a steep east facing lee slope. Tingley *et al* (op cit) (quoting an unpublished report by Evans, 2005) indicate that the major sand waves are covered by smaller waves and megaripples indicating that the surface of the major waves are mobile. However this may not indicate that the form and position of the major waves will change over time, their primary form could be static and in equilibrium within their current environment with only the secondary wave forms being mobile.

St Catherine's Deep is characterised by rock and thin sediment. It has an undulating rough sea bed (see description of biotope A4.1 in Chapter 7). The Deep, on its north side, is backed by the 300 m high cliffs of the Isle of Wight, some of these cliffs are noted for land slips and it should not be discounted that ancient landslip material may exist within the northern margin of St Catherine's Deep. There are certainly large boulders apparent within the Deep.

Rock and thin sediment covers about 69% of the region's 876 km^2, with coarse sediment accounting for 28% and sandy sediment only 3%, although the latter is likely to be an underestimate. Mud is <0.1%. Sea bed photographs of examples of sea bed within Region 2 are shown in Figure 4.20.

Physical Region 3 — Selsey — West Sussex Coastal Platform

The Selsey – West Sussex Coastal Platform comprises a large platform of rock and thin sediment with abundant rock structural lineations of bedding and scarps, particularly in the west off Selsey Bill where the Mixon, Boulder Bank, Pullar Bank and the Shoal of Lead form substantial rock ridges of Bracklesham and Barton Group with their tops at depths of around 5m. These extend to a maximum of 10 km offshore. Rock structural lineations associated with bedding (Figure 4.22), dip slopes and scraps are common in The Park and Outer Owers and along the southern boundary of the Region with the Northern Palaeovalley. The Park and Inner Owers are within a shallow 10 km wide embayment that cuts back into the Platform towards Pagham Harbour, possibly an indicator of an ancient fluvial system flowing from the back of Selsey Bill. However, the limited seismic lines hereabouts have not shown a significant sediment filled channel within the embayment, it appears to be rock and thin sediment, with the embayment floor being sandy in part.

Coarse sediment is associated with the Palaeoarun channel system which cuts across the Platform to the Northern Palaeovalley. These include river terrace deposits and channel fill (Bellamy, 1995; Gupta *et al*, 2004) To the east of the Palaeoarun the rock platform has a gentle decline but minor rock lineations caused by bedding in the relatively steeply dipping underlying rock are common (Figure 4.23).

Further east an extensive sheet of sandy sediment with windows of rock and thin sediment covers the platform. The sand sheet has well developed megaripples and minor sand waves with cross profile asymmetry to the east (Figure 4.24).

Rock and thin sediment covers about 64% of the region's 968 km^2, with sandy sediment covering 23% and coarse sediment 13%. Sea bed photographs of examples of sea bed within Region 3 are shown in Figure 4.21.

Physical Region 4 — South Wight Platform

The region is dominantly a platform of rock and thin sediment. There are two narrow north-south areas of coarse sediment overlying palaeochannels in the west and east.

The central and eastern half of the region is a remarkably flat and relatively smooth sea bed surface underlain by horizontally bedded Chalk. In the north-west of the region where the sea bed is underlain by Lower Greensand and Wealden rocks the slightly steeper dips, thinner bedding and variable lithological properties create a sea bed of linear rock ridges up to 4 m high. These rock types also occur along the southern margin of the region where

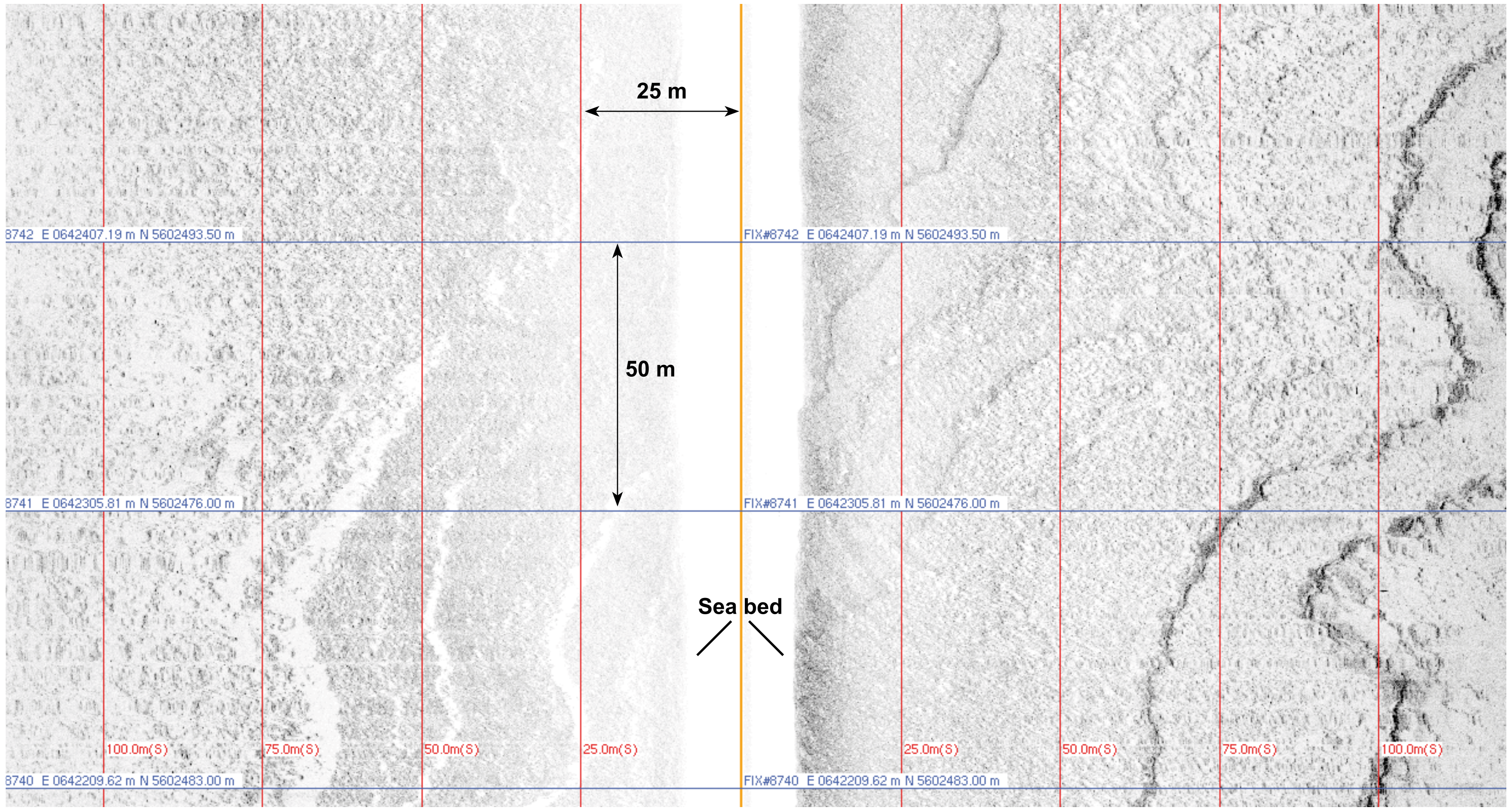


Figure 4.22: Sidescan sonar record of small rock scarps in Tertiary bedrock on coastal platform.

intensive folding associated with the Central English Channel Monocline has produced significant scarps at the Chalk-Lower Greensand boundary and prominent linear ridges. These scarps have also been cut through by small rivers which have left open channels in the sea bed surface.

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. The angularity, abundance of cobbles and boulders, local and in-situ provenance 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 only significant sand deposits that are apparent on the limited seismic data are sand patches with megaripples aligned at the foot of the southern Chalk scarp where sand is trapped as it migrates eastward.

Rock and thin sediment covers about 93% of the region's 1918 km^2, with coarse sediment accounting for only 5% and sandy sediment 2%. Sea bed photographs of examples of sea bed within Region 4 are shown in Figure 4.26.

Physical Region 5 — Northern Palaeovalley and margin

The Northern Palaeovalley is a significant regional feature in this part of the English Channel. In the west of the region it includes a number of classic fluvial morphology features such as a channel margin terrace and a number of flow elongated flat topped bars within the main channel. Both the terraces and one of the bars have small dendritic stream channels etched in their surfaces. However, the limited seismic data available suggests that the channel floor, terrace and central bars are all underlain by rock and thin sediment (Figure 4.6), there is no evidence for significant channel fill or terrace sediments on the seismic line. Linear sheets of megarippled sand are aligned along the break of slope at the northern margin of the main channel and the scarp at the back of the channel terrace. These linear sand sheets become much more extensive east of the Wight–Bray monocline pinch point where the main channel narrows to 8 km. The wider and thicker sands, which remain banked against the northern margin of the Palaeovalley, support east facing sand waves up to 4 m high.

Immediately east of the pinch point the main channel floor is overdeepened between a central channel bar but further east the channel floor becomes wider and loses its bars. The accumulation of sand becomes much more extensive and extends across the channel floor. However, the build up of sand, associated with eastern transport of sediment, against the Palaeovalley margin has created two large linear sand banks, the Northern Palaeovalley Banks. The outer bank is well developed with a single virtually straight crest line over 16 km long which is attached at its eastern end to the coastal platform. The inner bank in total length is about 28 km. It is not as well developed through its entire length. As with the outer bank its eastern end is attached to the coastal platform. The Northern Palaeovalley Banks are described in more detail in Chapter 8 — Features of Interest.

East of the pinch point there are some over deepened hollows within the rock and thin sediment of the Palaeovalley margin and also relatively smooth tilted bedding plane surfaces are extensively developed as low angled slopes in the margin where Barton Group and older Tertiary rocks outcrop at the sea bed.

Rock and thin sediment covers about 63% of the region's 1339 km^2, with sandy sediment at 33% and coarse sediment accounting for only 4%. Sea bed photographs of examples of sea bed within Region 5 are shown in Figure 4.28.

4.6 Sea bed sediments

Sediment collected by Hamon grab at 63 South Coast REC 2007 Survey sample stations and 912 other sample stations (Figure 3.6) have been used in the analysis of sediment particle size for each sample station. This data has been used to determine the size class distribution based on Wentworth and Folk for a number of sediment statistical parameters including %sand, %gravel, %mud, mean grain

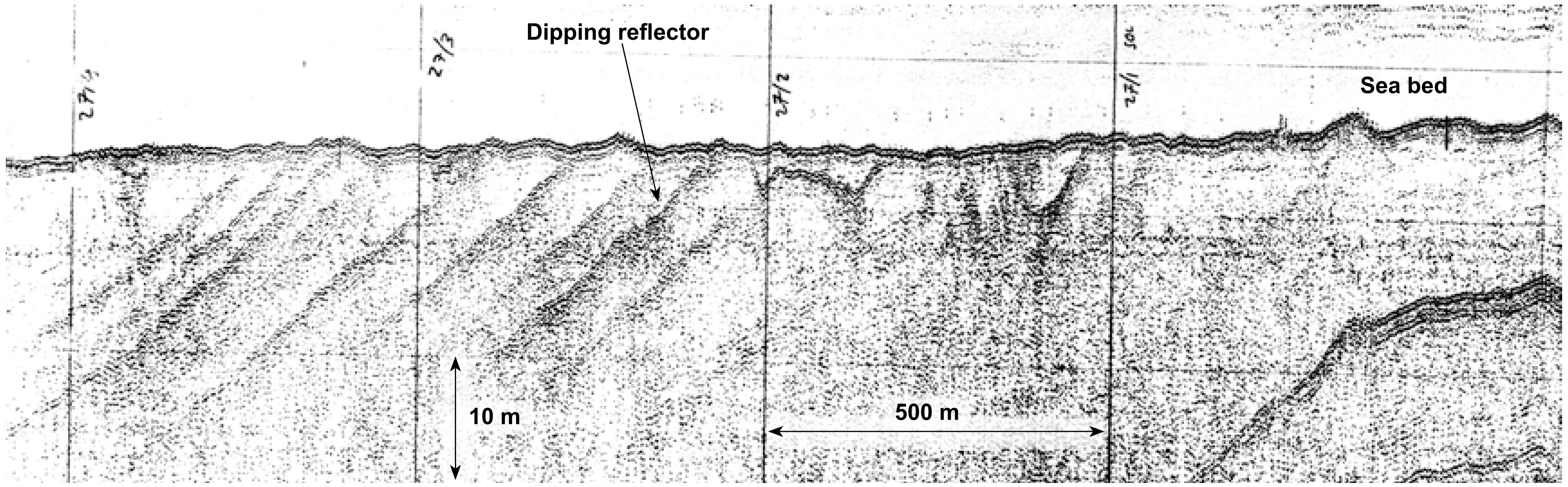


Figure 4.23: Seismic section in rock and thin sediment on coastal platform with steeply dipping reflectors associated with low rock ridges at sea bed. BGS © NERC 2010. All Rights Reserved.

size, d_{50} — median grain size and sorting (Figure 4.27, 4.29–4.33). The calculated values for all sediment particle size analysis at each South Coast REC 2007 Survey sample stations at half phi and whole phi intervals 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*, 2002). 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 <15 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 90 South Coast REC sample stations (Figure 3.2). This has enabled a visual examination and analysis of the sea bed both for biology and sediments, and for evidence of rock outcrop, cobbles and boulders.

The modelled distribution of sea bed sediments across the South Coast REC study area shown in Figure 4.25 is based on the PSA analysis (Figure 3.6) where each sample has been classified by grain size with the Folk classification system (Folk, 1954) using the relative proportions of gravel, sand and mud. The modelled Folk sediment distribution covers the whole South Coast REC 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 4.25. It is therefore important that the sea bed sediment distribution map is read in conjunction with the sea bed character interpretation (Figure 4.17a, b), bedforms (Figure 4.20), sediment parameters (Figure 4.27, 4.29–4.33) and the biotope summaries in Chapter 7.All are complimentary and provide a comprehensive understanding of the character of the sea bed.

Sediment characteristics from sampling

The extensive areas of rock and thin sediment seen in the sea bed character interpretation (Figure 4.17a, b) are generally associated

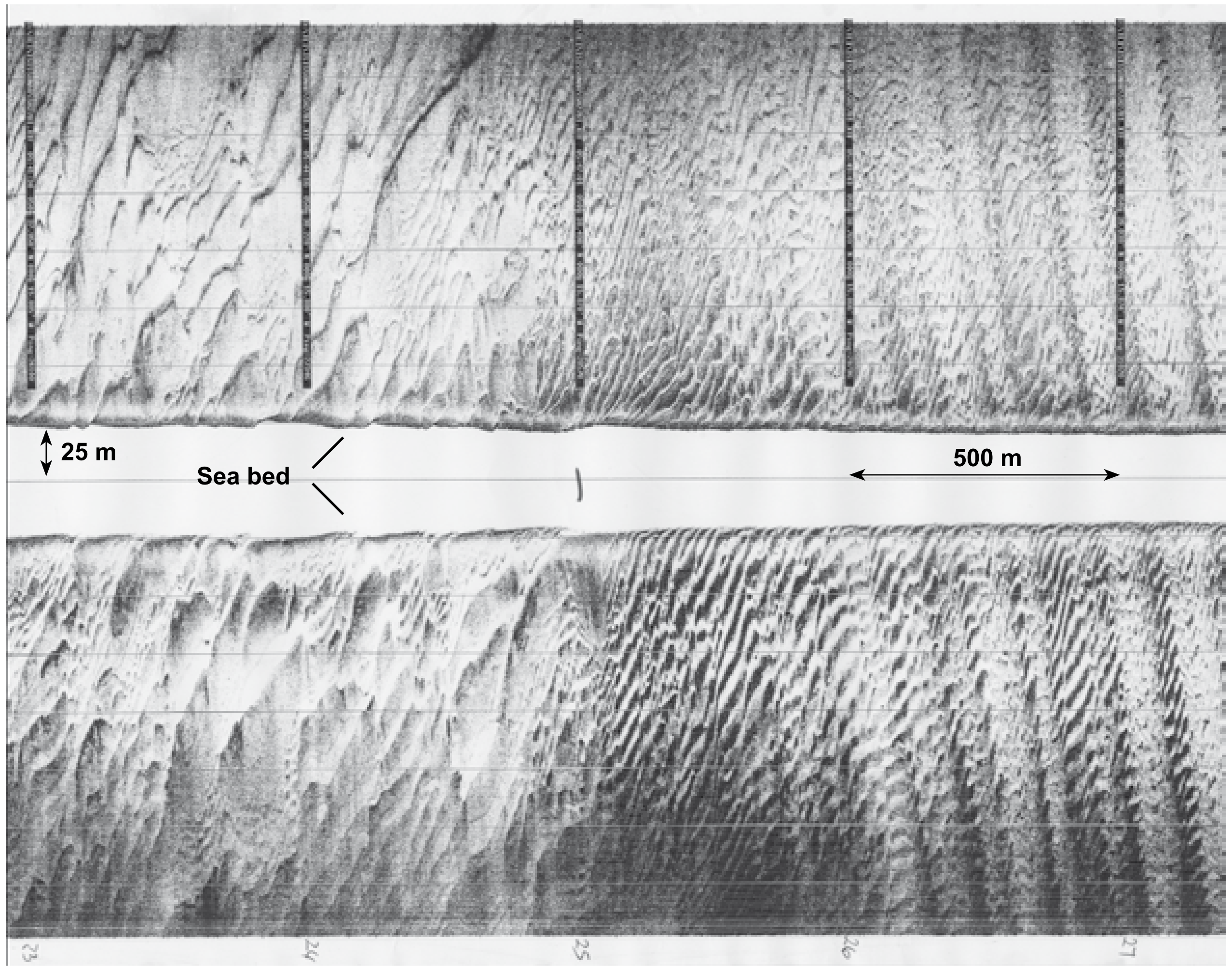


Figure 4.24: Sidescan sonar record of megaripples and small sand waves on eastern sand sheet of coastal platform.

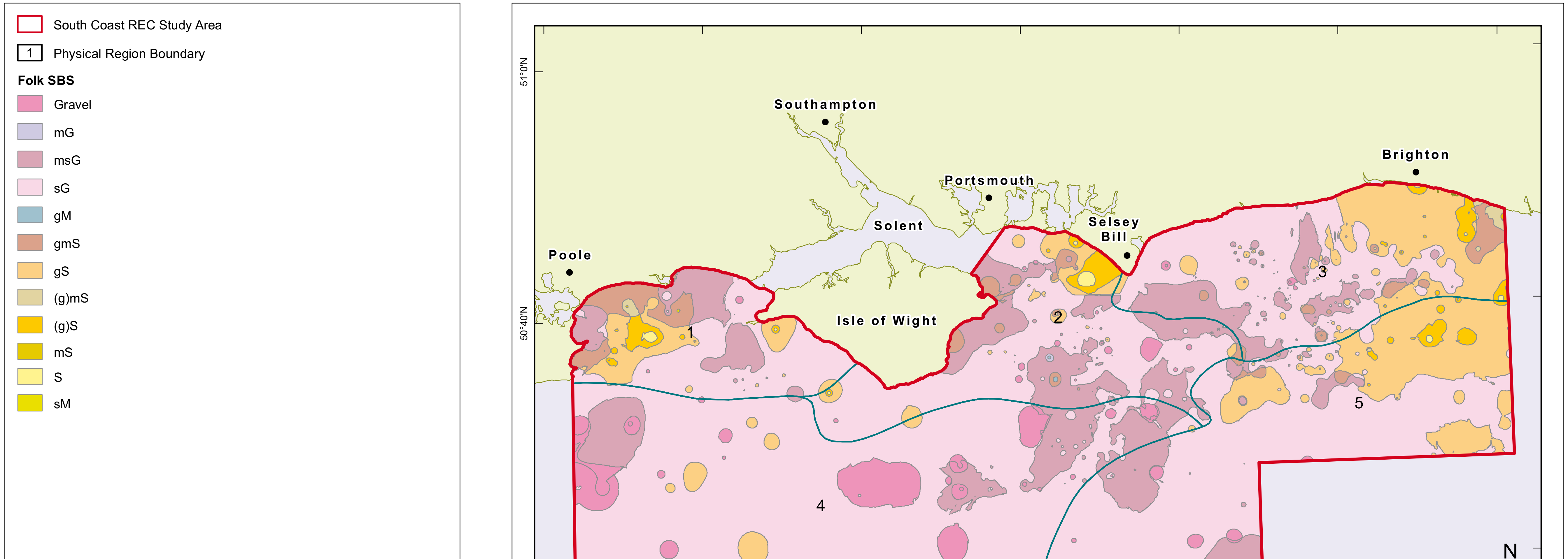


Figure 4.25: Modelled sea bed sediment distribution in South Coast REC area (after Folk, R.L. 1954. Journal of Geology. Vol. 62).

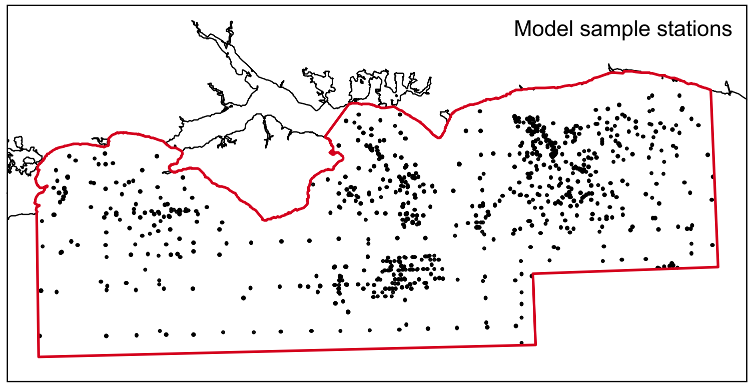
Figure 4.26: Still image examples of sea bed character across Region 4 — South Wight Platform (Scale bar 20 cm).

South Coast REC Study Area

1 Physical Region Boundary

Sand %

< 10	50 - 60
10 - 20	60 - 70
20 - 30	70 - 80
30 - 40	80 - 90
40 - 50	90 - 100



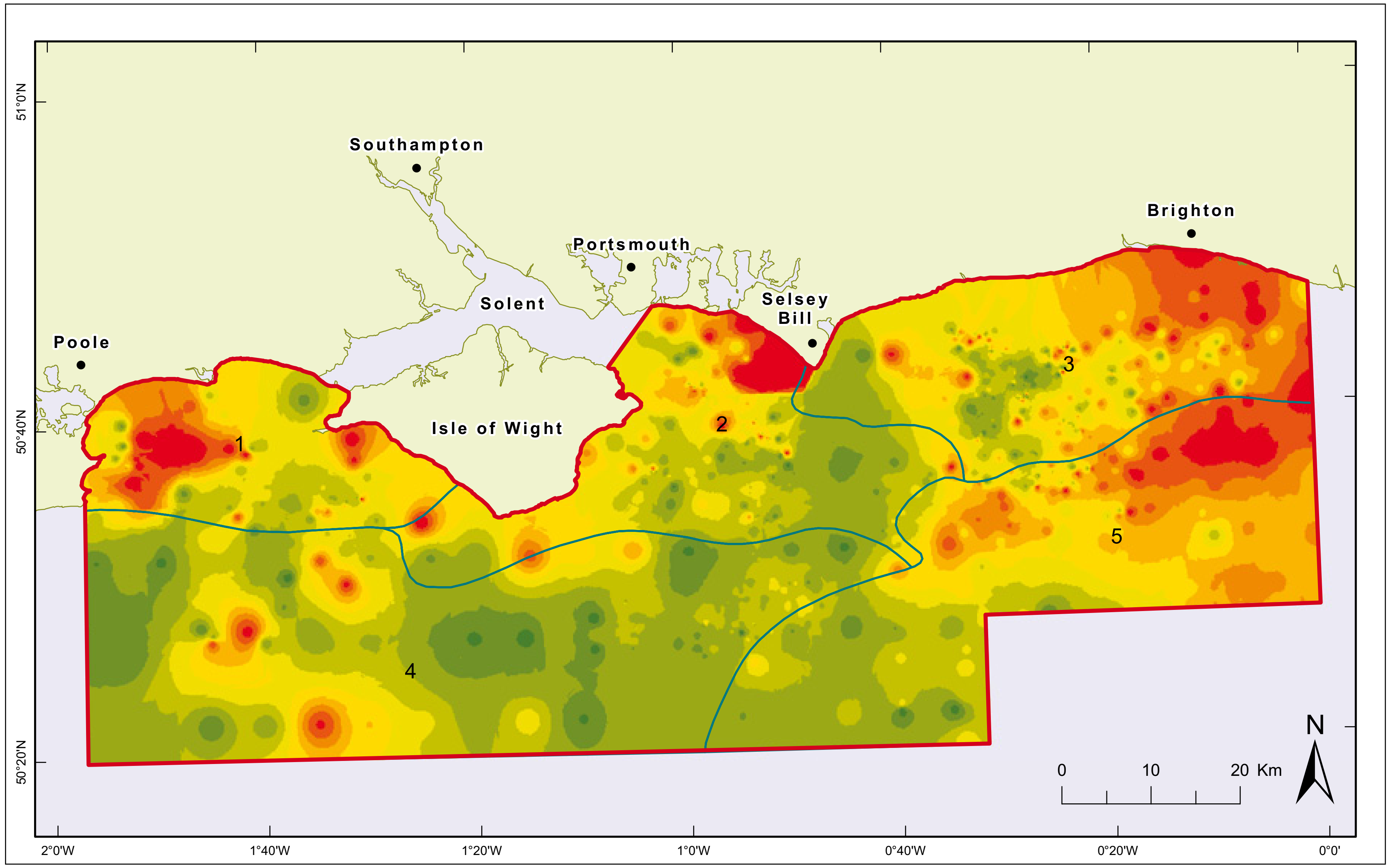


Figure 4.27: Modelled sand distribution (%) in South Coast REC area.

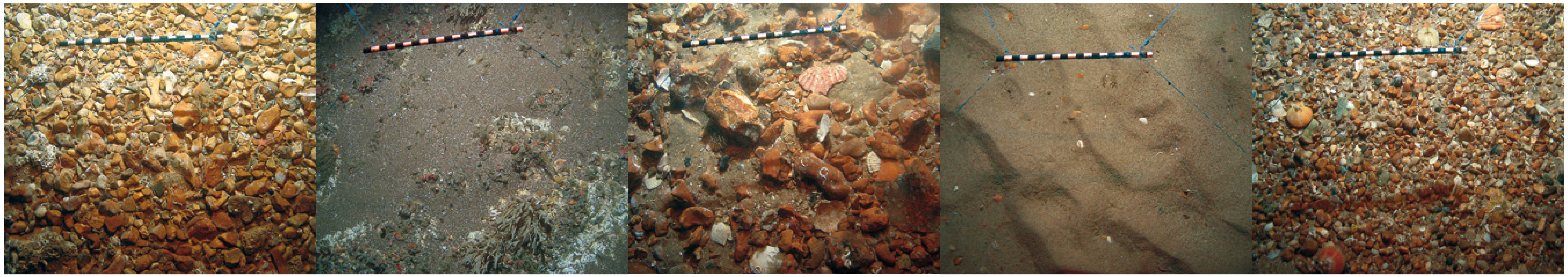
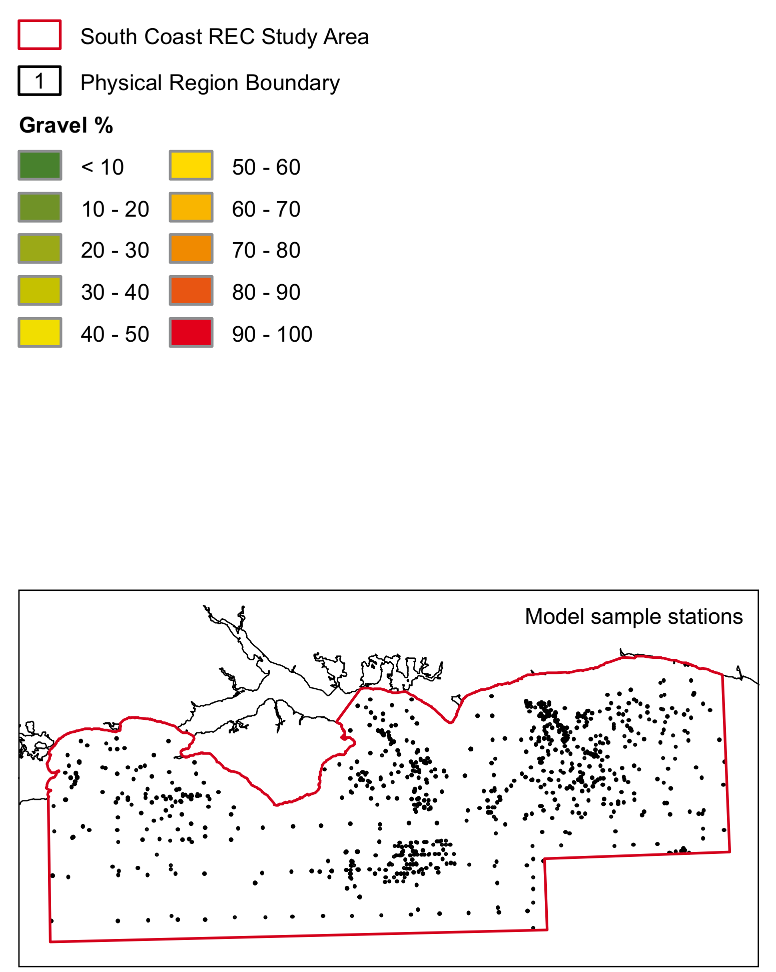


Figure 4.28: Still image examples of sea bed character across Region 5 — Northern Palaeovalley and Margin (Scale bar 20 cm).



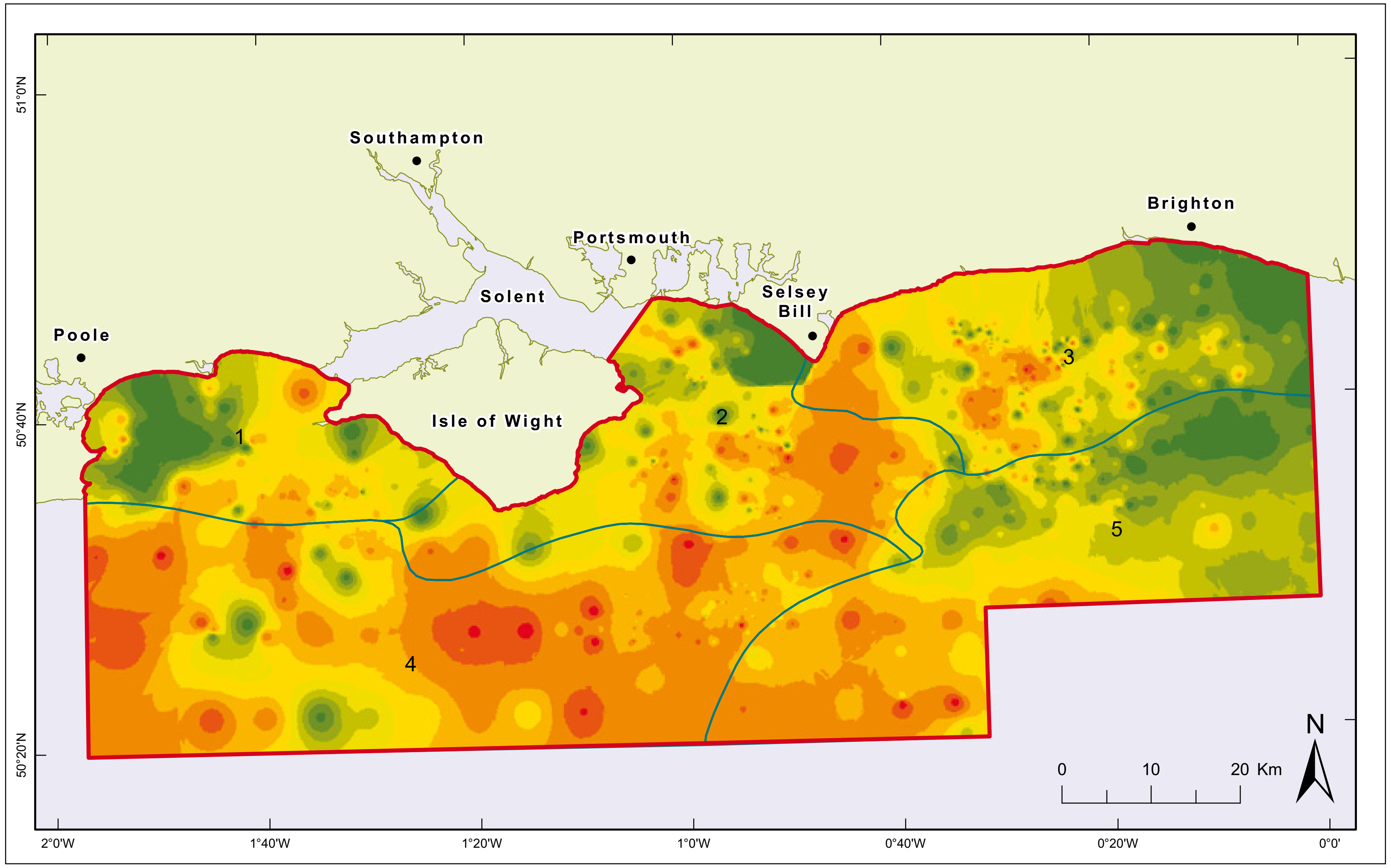


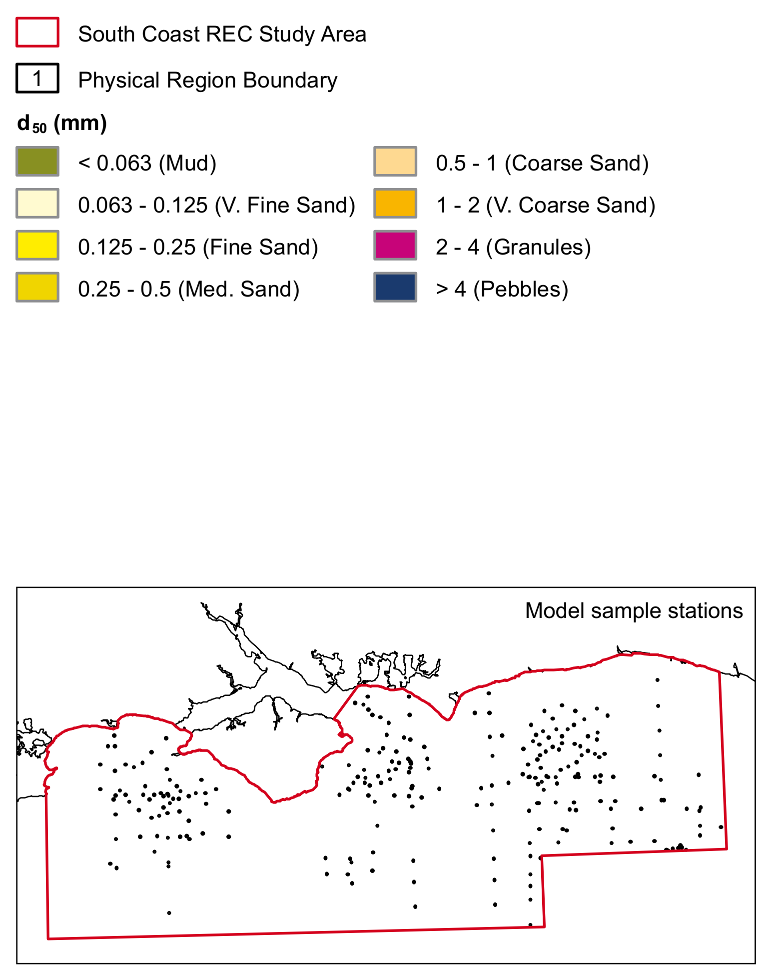
Figure 4.29: Modelled gravel distribution (%) in South Coast REC area.

with the coarser end members of sandy gravel, muddy sandy gravel and gravel (Figure 4.25). These are virtually ubiquitous across the rock platform of Region 4 and extend across in to the western half of the Northern Palaeovalley and on to the western half of the Selsey — West Sussex Coastal Platform.

Within the East Solent channel and the Monocline Rampart Enclosure of Region 2 sandy gravel and muddy gravel are dominant although the inner part of Bracklesham Bay has an extensive area of sand and gravelly sand, perhaps reflecting nearshore currents and wave action trapping sand in the Bay. The model has also picked out the area of sand waves in Nab Hole but the lack of sample points has meant that the Overfalls sand wave field in the Rampart Enclosure has not been identified as sand, it is shown as a muddy sandy gravel. Contradictions in the model due to lack of sampling can also be seen in Poole and Christchurch Bay where Hook Sand, outside Poole Harbour, and the eastern half of Dolphin Bank are modelled as sandy gravel when they are obviously sand.

Gravelly sand with >70% sand is the most common form of sand represented in the model (Figure 4.25). It is relatively extensive within inner Poole Bay, Christchurch Bay and Bracklesham Bay but its largest occurrence is in the east of the Northern Palaeovalley which continues on to the adjacent Selsey and West Sussex Coastal Platform to encompass much of this eastern segment of the South Coast REC study area. There is an eastward trend of decreasing grain size in Regions 3 and 5 reflected in the decreasing gravel percentage (Figure 4.29). This eastward fining trend is also reflected in the median d_{50} (Figure 4.30) and mean grain size (Figure 4.31) distribution.

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 study area is dominated by very poorly sorted sediment (Figure 4.32) particularly in areas of rock and thin sediment and coarse sediment. There is a large area of poorly sorted sediment on the rock platform of



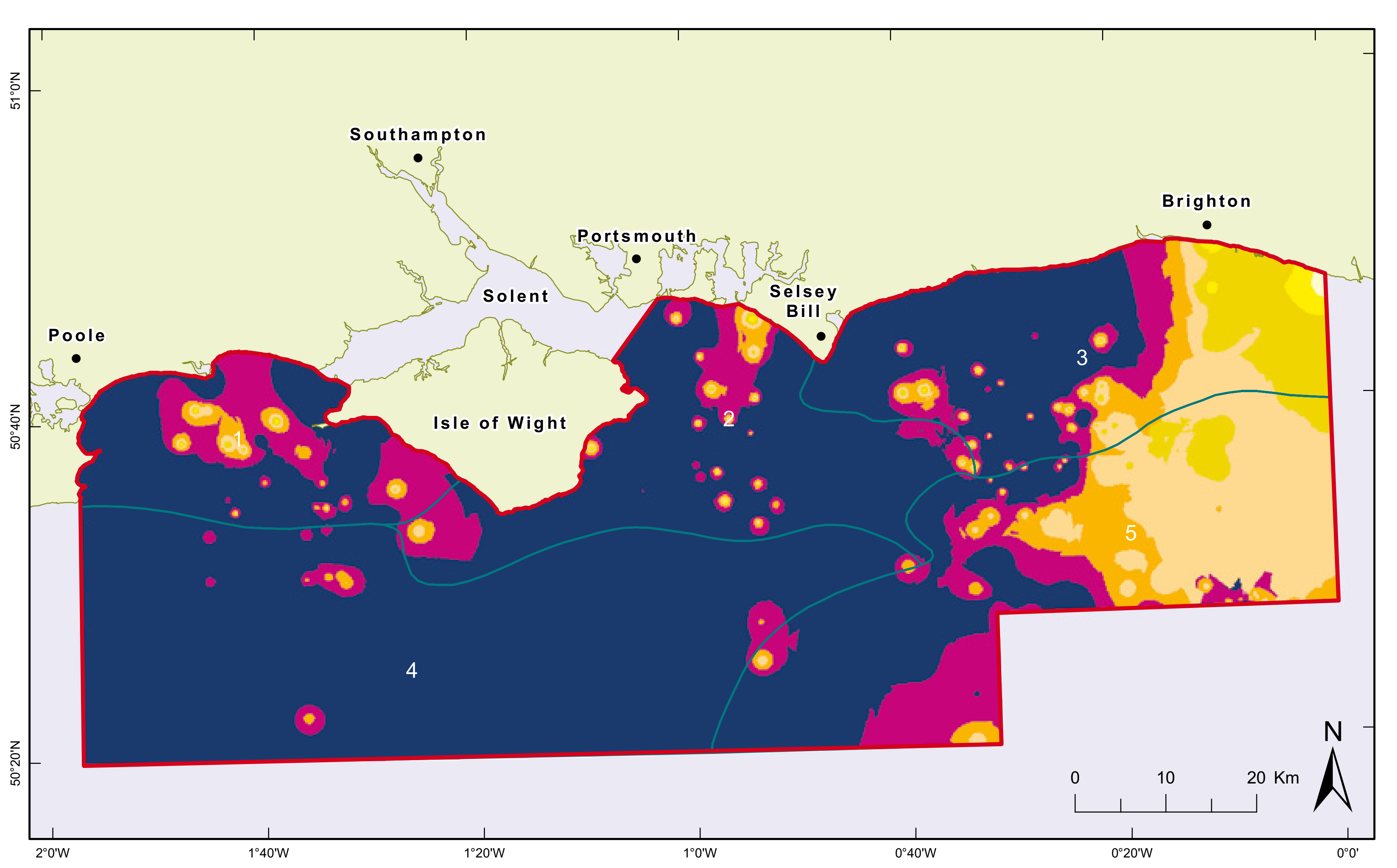


Figure 4.30: Modelled sediment d_{50} distribution in South Coast REC area.

Region 4 but the model has few sample points here and therefore is likely to be an overestimate, as adjacent similar areas of rock and thin sediment with a denser sample array are very poorly sorted in the model. Elsewhere the more extensive areas of moderately sorted to well sorted sediment are associated with the sand banks and sand sheets of inner Poole Bay, Christchurch Bay, Bracklesham Bay, the east of the Northern Palaeovalley and the adjacent Selsey and West Sussex Coastal Platform.

The eastward fining and sorting trend reflect the strong currents moving sediment away from the area of relatively high sea bed stress south of the Isle of Wight (Figure 2.9 and 2.7) and the poorer sorting of sediment in this area south of the Isle of Wight with a winnowed sea bed surface of pebbles, cobbles, boulders and rock.

The percentage of mud found in grab samples over much of the South Coast REC study area is <5% (Figure 4.33), however there are patches where mud is >10%, with a maximum recorded value of 55%. The muddy patches are most extensive in inner Poole Bay, inner Christchurch Bay, nearshore off the east and north-east of the Isle of Wight and the extreme north-east corner of the Selsey-West Sussex Coastal Platform. This platform also has numerous small sample point occurrences of mud >10%.

Some of these occurrences are likely to be due to sheltered areas in bays and behind headlands where mud can settle on the sea bed. However, some occurrences are on rock outcrop and thin sediment underlain by London Clay, Bracklesham Group, Barton Group and Wealden Group clays and silts, many of these rocks have a muddy component which could be sampled by a grab. Figure 4.14 illustrates a clamshell grab sample that may include muddy Bracklesham Group rock.

Mud is insignificant on the swept rock platform of Region 4 and also over much of the Northern Palaeovalley.

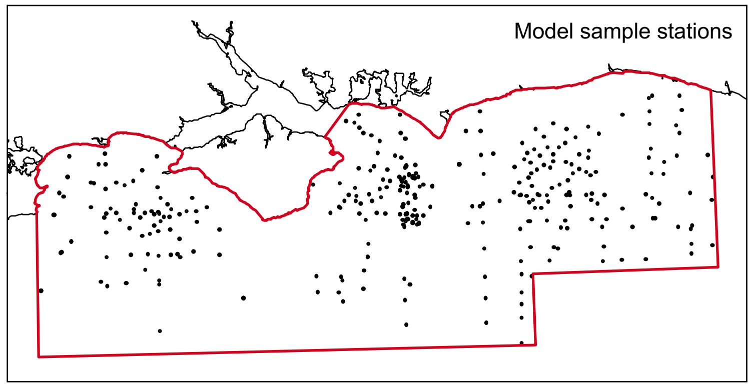
A number of patches of >25% mud also occur in the Palaeosolent channel as it crosses the Monocline Rampart Enclosure. This appears anomalous given its position and the local hydrodynamic conditions. It may be the product of dredged material dumped in the adjacent dumping ground (Figure 2.77).

South Coast REC Study Area

1 Physical Region Boundary

Mean grain size (mm)

- < 0.063 (Mud)
- 0.063 - 0.125 (V. Fine Sand)
- 0.125 - 0.25 (Fine Sand)
- 0.25 - 0.5 (Med. Sand)
- 0.5 - 1 (Coarse Sand)
- 1 - 2 (V. Coarse Sand)
- 2 - 4 (Granules)
- > 4 (Pebbles)



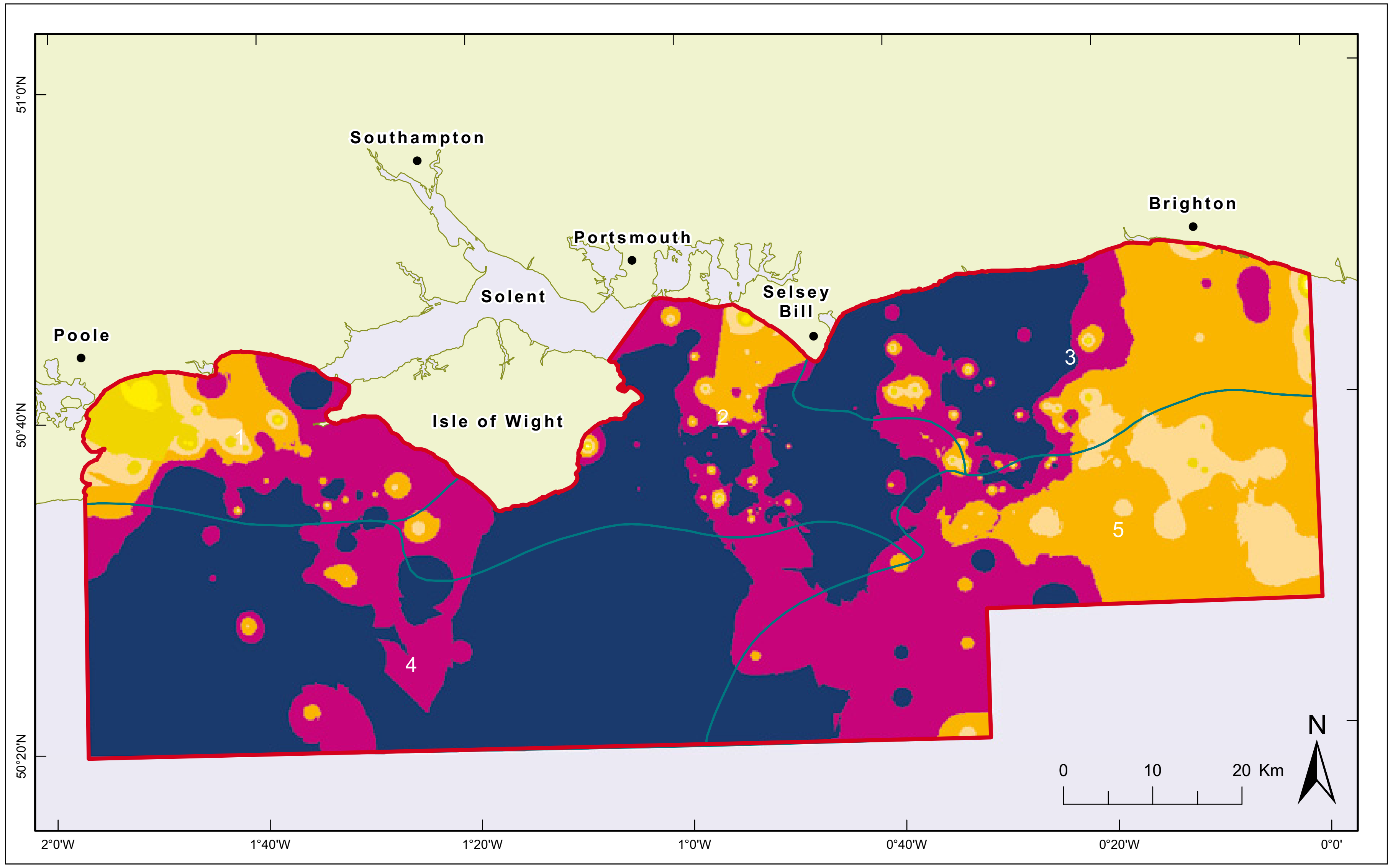
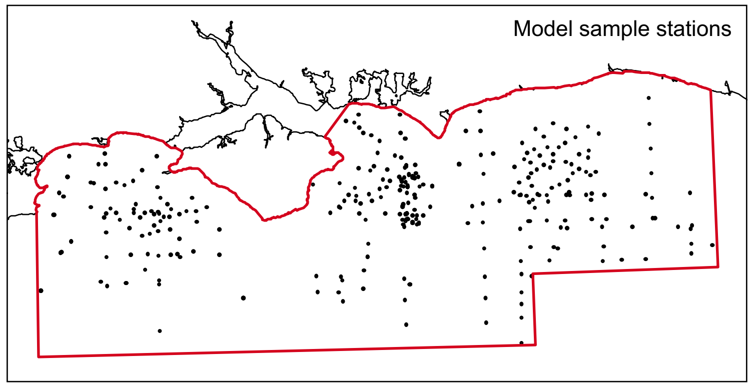


Figure 4.31: Modelled sediment mean grain size distribution in South Coast REC area.

South Coast REC Study Area
1 Physical Region Boundary

Sorting

- < 0.35 (Very Well Sorted)
- 0.35 - 0.5 (Well Sorted)
- 0.5 - 0.7 (Moderately Well Sorted)
- 0.7 - 1 (Moderately Sorted)
- 1 - 2 (Poorly Sorted)
- 2 - 4 (Very Poorly Sorted)
- > 4 (Extremely Poorly Sorted)



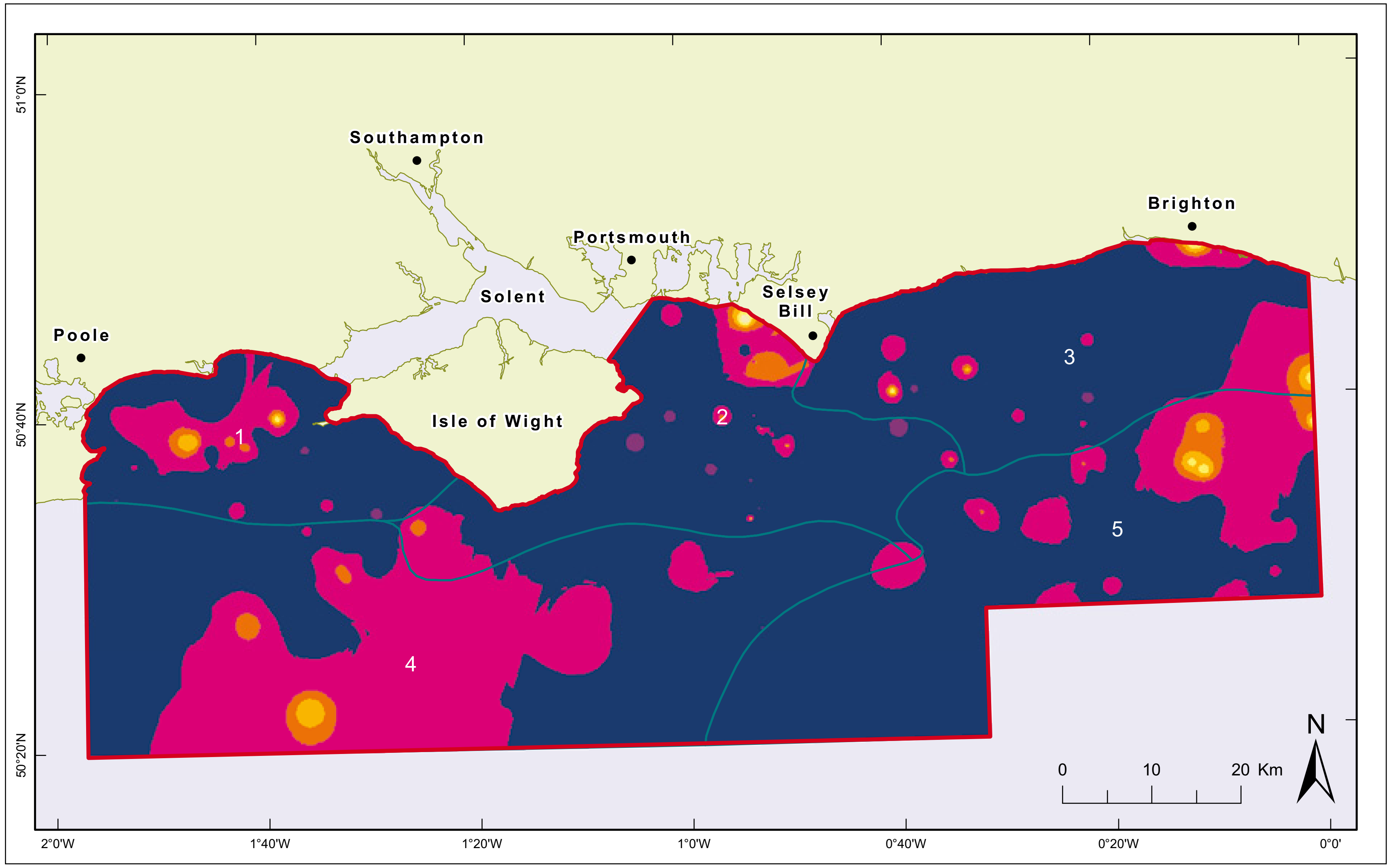


Figure 4.32: Modelled sediment sorting distribution in South Coast REC area.

South Coast REC Study Area

1 Physical Region Boundary

Mud %

- < 5
- 5 - 10
- 10 - 25
- > 25 (max 55%)

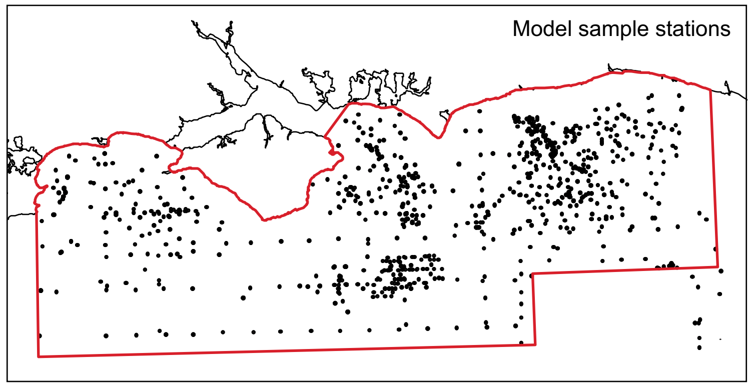
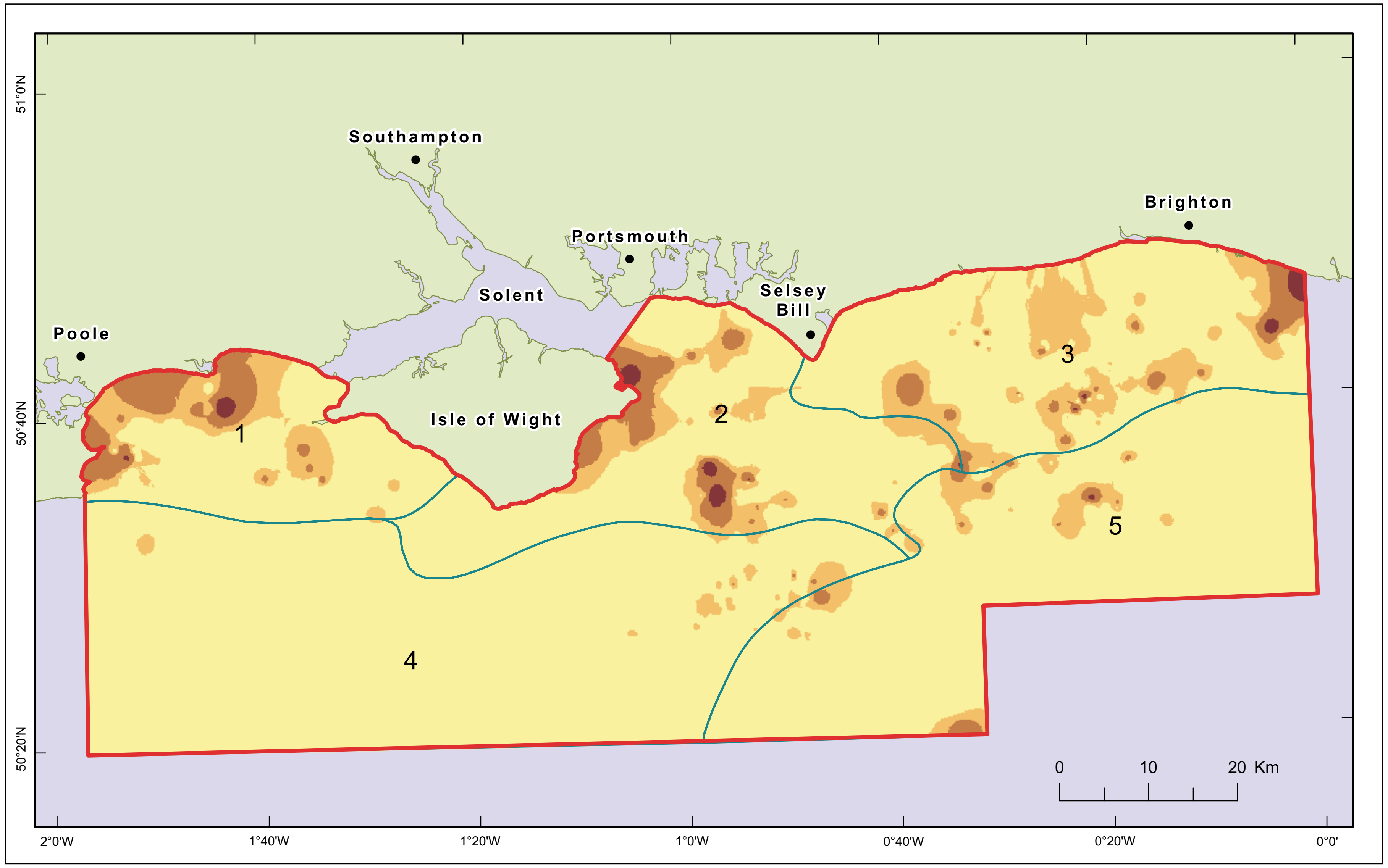


Figure 4.33: Modelled mud distribution (%) in South Coast REC area.



5 Marine Archaeology

5.1 Introduction

The marine archaeological resource of the South Coast REC area is known to comprise elements of prehistoric, maritime and aviation archaeology. Understanding the distribution of archaeological material within this region, based on the geophysical data acquired during the REC survey, has the potential to greatly enhance our understanding of how the use of this area has changed over the last 500,000 years as well as indicating where further material may be found, and in what context.

The characterisation of this resource has primarily been based upon data generated by the South Coast REC 2007 survey, complemented by records held by national inventories and secondary sources (Figure 5.1).

The datasets from the South Coast REC 2007 geophysical survey that were utilised for the evaluation of the archaeology in the study area are:-

- Sidescan sonar — high frequency only;
- Magnetometer;
- Sub-bottom profiler;
- Multibeam bathymetry.

In addition, to increase the coverage of the REC study area the following datasets were used in the archaeological characterisation:-

- South Coast Regional Environmental Assessment (REA) sub-bottom profiler (2008);
- Arun sub-bottom profiler data from Wessex Archaeology (2003);
- British Geological Survey 1988/02 survey — sidescan sonar;
- Shuttle Radar Topography Mission (SRTM) topographic data;
- SeaZone bathymetry data.

The Arun sub-bottom profiler data were acquired by Wessex Archaeology (WA) during 2003 for the Aggregate Levy Sustainability Fund (ALSF) Seabed Prehistory project, administered by the Mineral Industry Research Organisation. These data were interpreted for the South Coast REC project specifically to try to trace the course of the palaeo-Arun river. The section of data assessed consists of 6 prospection lines run in the Owers Bank area and totalling 41 km (Figure 5.1).

Shuttle Radar Topography Mission (SRTM) data, with a Digital Elevation Model (DEM) of 90 m x 90 m resolution, was obtained for the coastal region adjoining the REC area (http://srtm.csi.cgiar.org). These data were used together with the bathymetry data to reconstruct the land surface in the South Coast REC area at different stages in the past. The other datasets listed above are described in Chapter 3.

The principal desk-based sources used during the archaeological characterisation are as follows:-

- Records held in the maritime section of the National Monument Record (NMR).
- Records held in the Sites and Monuments Record/Historic Environment Record (SMR/HER) for the counties bordered by the study area: Sussex; Dorset; Hampshire and the Isle of Wight.
- Records of wrecks and obstructions held by the United Kingdom Hydrographic Office (UKHO) and collated by SeaZone.
- Various secondary sources relating to the palaeo-environment and to the Palaeolithic and Mesolithic archaeology of Northern Europe with specific reference to the ALSF Seascapes (Wessex Archaeology, 2006a), Seabed Prehistory (Wessex Archaeology, 2004b; 2008c; 2008d) and Palaeoarun Landscape (Gupta *et al*., 2004) projects, as well as sources relating to known and potential wreck sites and casualties.
- Various secondary sources, with specific reference to the ALSF England's Shipping and Navigational Hazards projects with regard to historic shipping patterns.
- The ALSF Aircraft Crash Sites at Sea project and various secondary sources relating to historic aviation patterns (Wessex Archaeology, 2008e).
- A range of previous archaeological assessments undertaken by WA that focused on the maritime archaeology of areas within the REC area, ranging from large-scale strategic projects to small-scale assessments of individual wreck sites.
- The annual reports of the British Marine Aggregate Producers Association Protocol Implementation Service (Wessex Archaeology, 2006b; 2007a; 2008f).

5.1.1 Methodology and approach

Maritime and Aviation Archaeology — South Coast REC 2007 Survey data

The sidescan sonar data were processed by WA using Coda Geosurvey software. This allowed the data to be replayed with various gain settings in order to optimise the quality of the images. The data were initially scanned to give an understanding of the geological nature of the area and were then interpreted for any objects of possible anthropogenic origin: the position and dimensions of any such objects were recorded into a gazetteer and an image of each anomaly acquired.

The magnetic data were processed to give XYT files comprising grid co-ordinates (X, Y) and total magnetic field strength (T) recorded in nanoTeslas (nT). Each line of data was smoothed and processed to remove the regional magnetic field and also any long period diurnal variations by effectively applying a low pass filter to each magnetic profile in the data set to create smoothed profiles which are then subtracted from the original profiles. The data were then gridded to produce a contour map of the survey area and plotted with the magnetic field strength values represented by graded colour bands to show changes in the magnetic field strength. The positions and amplitudes of anomalies greater than 5 nT in amplitude were recorded.

The positions of the sidescan and magnetometer anomalies were uploaded to the project GIS and grouped together as sites. This grouping process addresses situations where the same feature was seen in more than one dataset or line of data or where several anomalies occur in close physical proximity and are thought to be related.

The multibeam bathymetry was only examined for wrecks. The data were received gridded at 2 m so were not suitable for looking for small features. All wrecks and possible wrecks seen in the sidescan sonar and magnetometer data were searched for in the bathymetry data. In addition, slope analysis was used to bring out areas of the sea bed where the slope changed rapidly, possibly indicative of a wreck.

The sea bed character map (Figure 4.17a, b) was used to characterise the sea bed environment surrounding the wrecks.

South Coast REC Study Area
Physical Regions
1988 BGS survey - sidescan sonar data
2003 WA Arun survey - sub-bottom profiler data
2007 REC survey - sidescan sonar, sub-bottom profiler, multibeam bathymetry and magnetometer data
2008 REA survey - sub-bottom profiler data

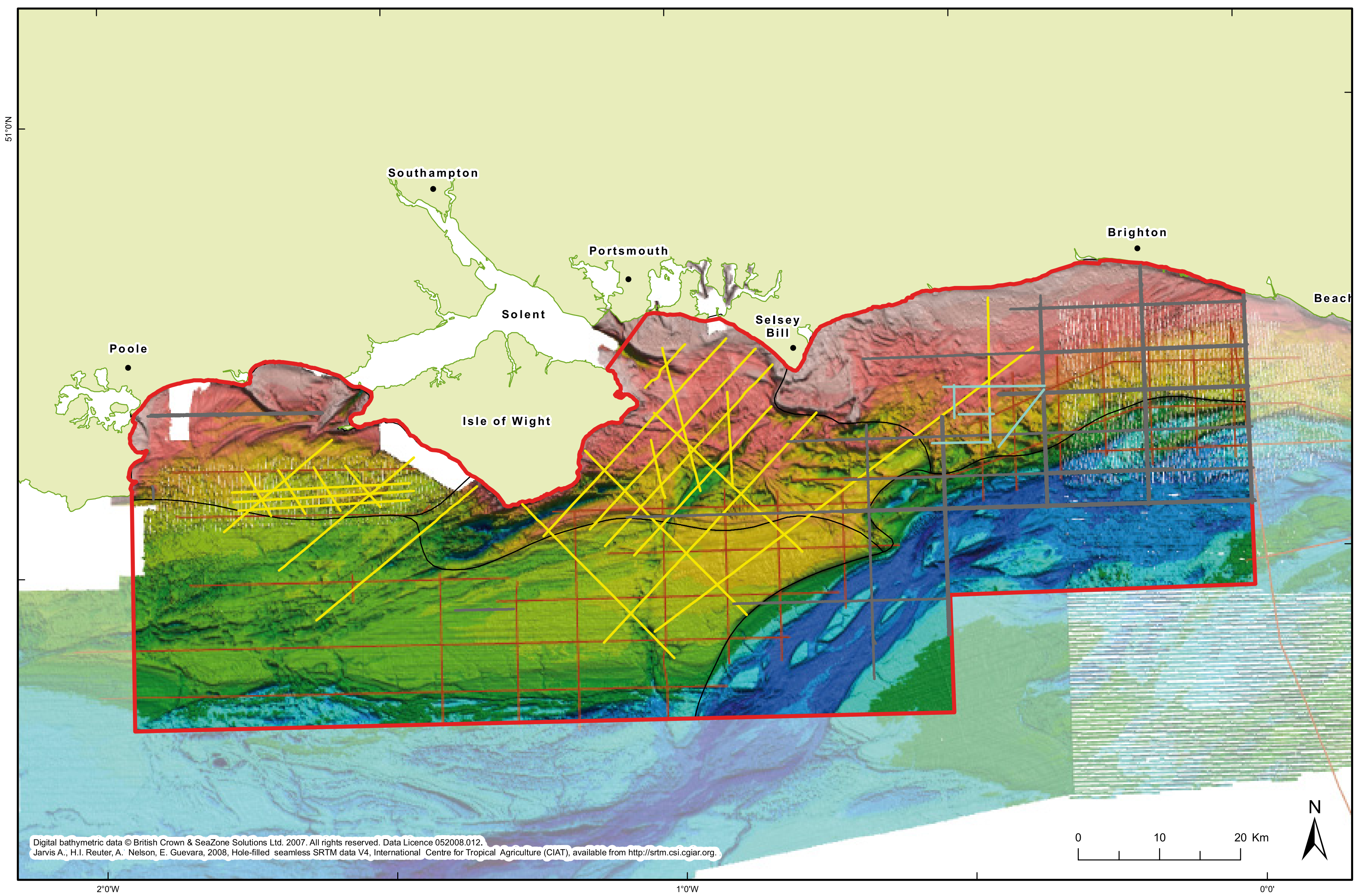


Figure 5.1: Geophysical data reviewed for marine archaeology.

The South Coast REC 2007 Survey sub-bottom profiler data were not used for the detection of maritime or aviation sites.

Maritime and Aviation Archaeology — BGS 1988/02 Survey data

The original specifications for this dataset were much lower than those used in modern surveys. This dataset was recorded as paper rolls, not digitally. Not all the paper rolls were available but all were scanned either in grey scale or black and white. The relatively poor quality of the original data meant only possible wrecks were targeted.

BGS had originally drawn their interpretations of the data in 1988 by hand on to plastic transparencies, with the track plots being drawn on by fix only. These map interpretations were scanned, georeferenced and added to the project GIS. Again owing to the scans being done in black and white the quality was relatively poor with not all fix positions seen amongst the surrounding interpretation. The fix numbers, written every 5 fixes, were also not always legible.

Wrecks and possible wrecks were marked by BGS on the interpretation by asterisks. The line and fix number were read off the original paper charts and a list compiled. The charts were examined in the GIS to try and link UKHO and NMR sites to these wrecks. UKHO and NMR sites that lie along the survey lines were also compiled into lists. The scanned images were looked at in conjunction with these lists to try to determine whether the features originally seen were indeed wrecks. In addition, the data were examined for further wrecks.

Features of interest were measured by hand on printouts, using the range of 150 m and the distance between fixes as measured in the GIS. The relative positions of the features between the adjacent fixes was measured and along with the distance from the centreline this was used to position the features in the GIS.

Prehistory

The South Coast REC 2007 sub-bottom profiler data were interpreted by WA using Coda Geosurvey software using a seismic velocity of 1600 ms^{-1}. This is a standard estimate for shallow, unconsolidated sediments (Sheriff and Geldart, 1983).

The data were examined for evidence of palaeochannels, erosion surfaces, cuts and fills and peat horizons as indications of past land surfaces. All such features were marked on the data in the processing software, an image was taken and the points exported to the project GIS. Features occurring together were grouped as a site. The features were compared to those tagged by BGS in their geological interpretation.

The features identified in the South Coast REA dataset (Wessex Archaeology, 2009) were integrated with the results from the REC dataset to provide a more extensive interpretation of the project area.

In order to investigate the topography and bathymetry of the study area and adjoining coast as a whole, Shuttle Radar Topography Mission (SRTM) data, with a Digital Elevation Model (DEM) of 90 m resolution, was obtained from the Consultative Group for International Agriculture Research Consortium for Spatial Information (srtm.csi.cgiar.org). The data were edited using the IVS Fledermaus software suite so the required section of the south coast of Britain could be selected. The SRTM and SeaZone bathymetric datasets were converted into a single digital terrain map. A colour map was then developed using a similar scheme to UKHO charts (yellow: >10 m; green: 0–10 m; blue: -5–0 m; light blue: -10– -5 m; white: <-10 m).

By using the chart colour map but reducing the values it became possible to emphasize features at increasing depth e.g yellow:>-10m; green-20--10m; blue: -25--20m; light blue: -30--25m; white:<-30m. Existing sea level curves were input into the model to illustrate coastal morphology for different periods with sea levels ranging from 5 m below mean sea level to 80 m below mean sea level (Funnell, 1995; Jelgersma, 1979, Sidall *et al*., 2003; Wessex Archaeology 2008h). Local sea level curves were used for renditions of the more recent land surface, while less accurate global sea-level curves were used for further back in time. This information was used to assess land surfaces at different stages in the past in terms of their potential for human habitation.

5.2 Characterisation of the archaeological potential

The sea bed is a submerged land surface which is an extension of the terrestrial landscape. It has been much modified, both by fluvial action and by sub-aerial erosion during repeated cycles of Pleistocene marine transgression and regression, and for very considerable periods it constituted part of the dry land inhabited by successions of floral and faunal communities and, intermittently, by hominins. During periods of sea level stands lower than today's, varying proportions of what is now the English Channel presented a series of topographic, hydrological and vegetational mosaics capable of supporting communities of terrestrial creatures adapted to life under diverse climatic conditions. At suitable times, the most adaptive of these creatures, hominins, walked among them, exploiting whatever riches the contemporaneous landscape had to offer and leaving behind a palimpsest of traces of his activities. In the permanently terrestrial regions of southern England (Figure 5.2), wholesale post-depositional movement of prehistoric sediments/soils and their contained artefacts can mostly be shown to be relatively limited in extent and their progenitors are reasonably well understood. In the marine environment, however, taphonomic factors affecting the preservation and recovery of material are very much more difficult to establish, map and evaluate. Moreover, the archaeological data are sparse, generally serendipitous and, like the sediments that contain them, difficult to date with any accuracy. Thus any discussion of prehistoric sea bed archaeology tends to be either very general (Wymer, 1999) or very local (Wenban-Smith *et al*., 2009).

It is self-evident that any archaeological material surviving in the marine environment can only do so if it is trapped in sediment and not exposed to dynamic forces. Ultimately the aim of this characterisation of the prehistory of the South Coast REC area is to identify areas of the sea bed which have the potential for the recovery of archaeological material, and key to this is an understanding of the erosional and depositional regimes that accompanied cycles of marine transgression and regression; but that is not the full story. A map of potential with simple dots and lines (even a 3-D terrain model) that could be generated from a geophysical approach coupled with a 'desktop' study of known archaeological finds would belie the potential richness of the archaeological resource in terms of our understanding of the human use of this extensive 'lost' landscape. In order to make sense of any surviving distributions and sedimentary associations, it is necessary to reach an appreciation of where material was deposited in the first place, how and why it got there, what it represented at the time of deposition and its subsequent taphonomic history. In short, we need to think more broadly in four dimensions. In order to do this, some attempt needs to be made to paint pictures of the South Coast REC area's landscape at various times during the later Pleistocene (and early Holocene). Such pictures can only be made with a broad brush — 'reconstruction' is too strong a word for the available information — and rely much on terrestrial analogues coloured with a fair amount of supposition and extrapolation. The basic intention here is to work forwards from periods of initial anthropogenic discard to the nature and position of ultimate allocthonous deposition rather than working backwards through those sedimentary sequences.

5.2.1 Sea bed topography and landforms

The landscape beneath the South Coast REC area may have been subject to rather different sequences and rates of modification to the permanent terrestrial region, but most of the processes involved are entirely analogous and will have produced landforms and drainage patterns that are familiar from southern England, though somewhat asynchronously. As such, there is no reason why they should not have presented very similar geographies and ecologies to their dry land counterparts at various times during the Pleistocene and provided suitable habitat ranges for a familiar suite of land animals, including hominins.

Our knowledge of this landscape — or rather, this succession of landscapes — is severely hampered, first and most obviously by our inability to walk on it and observe it for ourselves, and secondly because the cycles of inundation and emergence have left rather different scars and patterns of deposition to those of the terrestrial zone and we are, as yet, unable to map it in either sufficient detail or sufficient extent to be able to assess its true character today, let alone at any period in the past. However, the geological,

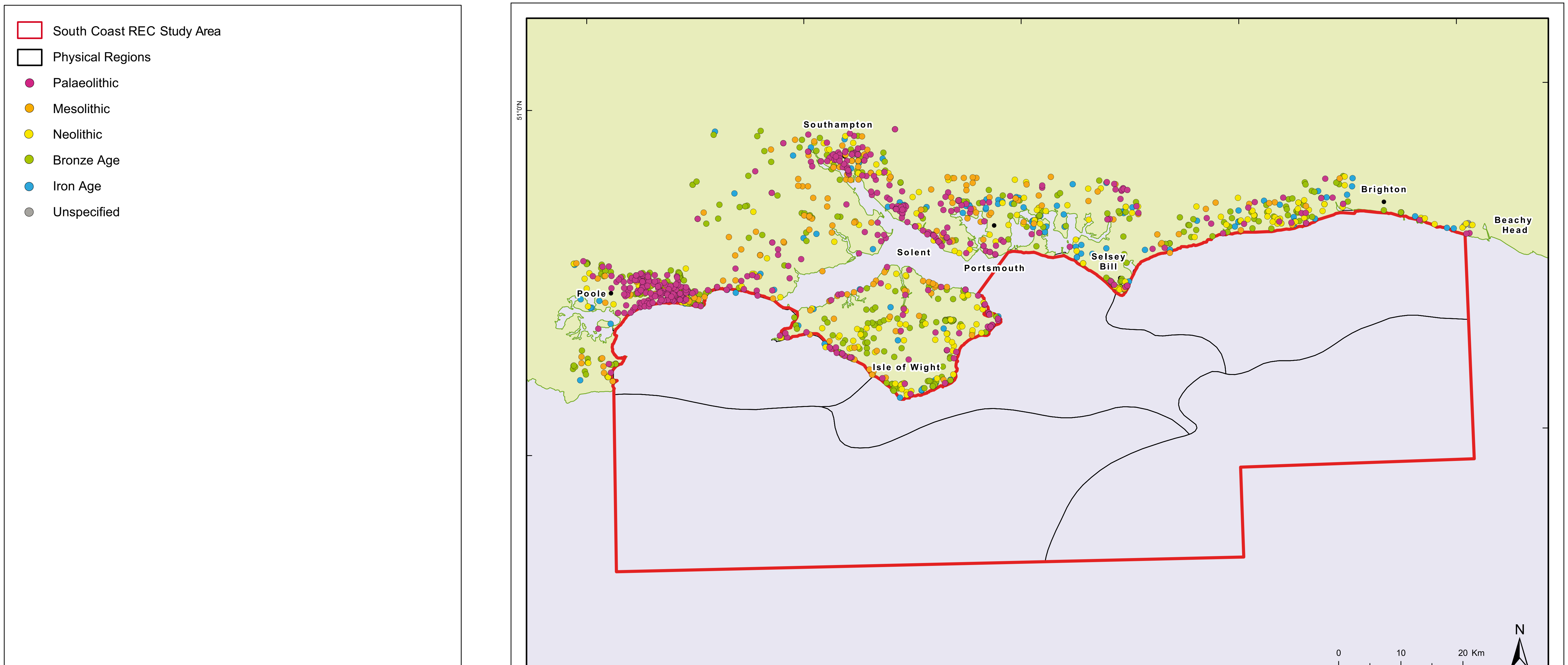


Figure 5.2: Known prehistoric sites.

borehole, bathymetric and seismic data generated by or accessible to the South Coast REC, is sufficient to be able to identify some key topographical features, drainage systems and sedimentary sequences which enable us to put some of the main building blocks in place. By combining such information with terrestrial analogues for particular types of feature (such as river terraces, cliff lines and former shores) and for hominin habitat preferences, we can begin to develop models of landscape, land-use and discard that can assist in characterising the REC area for its archaeological potential.

Geological and sedimentary influences on surviving sea bed topography

Any such attempt must, however, be tempered by an appreciation of the main physical influences on sea bed topography as it can be recorded today and on the creation and destruction of landscape features that can be seen to have more-or-less direct terrestrial correlates, as discussed elsewhere in this report. A summary of these influences is given below.

Bedrock formations and uplift

Structurally the region as a whole falls within the Wessex Basin which has a complex early history of sedimentation, uplift and deformation (Hamblin *et al*., 1992; Briant *et al*., 2009). All across the south of England, at varying distance from the present shoreline, is the belt of Late Cretaceous Chalk stretching, west to east, from Cranborne Chase to its meeting with the coast just west of Eastbourne. The principal and several secondary scarps face north, diverging in eastern Hampshire so that the primary scarp runs north to bracket the western end of the Weald and the secondary scarps continue west, where the wider extent of the Chalk across Hampshire and Wiltshire forms the dissected, undulating plateaux of the Hampshire and Salisbury Plains. The south-facing dipslope comprises typically rounded hills dissected by a series of southward flowing rivers and their tributaries, dry valleys and coombes, many of which are choked with periglacial and colluvial deposits. In the west of the region, rivers arise within the Chalk while the Sussex rivers have their headwaters in the Weald and cut deeply through the Chalk. A narrow spine of Chalk also outcrops in a sharp west-east ridge on the Isle of Wight, having been separated from the mainland during the late Devensian.

The Chalk is fringed on its northern side by Early Cretaceous Upper Greensand, Gault and Lower Greensand formations which form a fairly narrow band south and west of the Wealden clays and sands. Facing onto the coast west of Littlehampton is the northern part of the Hampshire Basin which is here filled with Tertiary deposits, a complex sequence of sand, clay and mud deposits of which the predominantly clay Reading Beds, flint pebbly Woolwich Beds and poorly consolidated sandy Bracklesham Beds are, on land, the most important in terms of the distribution of surviving archaeological material. Tertiary beds have been mapped by seismic profiling beneath the English Channel where they form an elongated lobe extending south and east, resting on Chalk.

There are many fault lines and unconformities within the region and many formations have been subject to uplift and/or tilting of varying degrees. In addition, eustatic rise resulting from the periodic melting of ice sheets has played its part and continues to do so. Such factors complicate the pattern of landforms at different periods on both the regional and local scales.

Fluviatile histories

Although, today, the English Channel constitutes a substantial body of seawater, it is important to remember that one of the main influences on sea bed development during the Pleistocene were riverine, in terms of both sediment deposition and erosion. This is a point emphasised by Wenban-Smith (2002) in relation to the potential target areas for marine aggregate extraction.

Marine sediments comprise principally sand banks and the series of raised beach deposits that survive today on land below the Chalk dipslope between Portsmouth and Brighton. At least four such beaches have been defined, each representing deposition of sands and gravels parallel to the coast on high sea level stand platforms that were repeatedly cut to lower levels. At least one more is extant on the Isle of Wight. Uplift of a marine platform would lead to creation of a new platform at a lower level and removal of deposits associated with older events (Roberts and Pope, 2009). It is likely that other remnant shoreline features of marine origin, such as beaches, wave-cut platforms, cliff lines and gravel spits lie submerged (Hamblin *et al*., 1992; Gupta *et al*., 2004).

Paramount in determining the surviving topography and sediment regimes in the northern Channel area are the effects of rivers. Principal among these is the Solent river which, prior to breaching of the Chalk ridge between the Isle of Wight and Purbeck, flowed eastwards to the north of the Isle of Wight and turned sharply south to its east, debouching onto the Northern Palaeovalley — itself a west flowing watercourse deflected south-west off the Isle of Wight, that persisted throughout much of the Pleistocene during periods of low sea level stand. The actual course of the Solent river fluctuated and shifted during various glacial and interglacial periods but it formed a major estuary over many millennia. To the south of the Isle of Wight lies the deep, narrow channel known as St Catherine's Deep, which cuts more than 60m into the bedrock. It was most likely formed by tidal scour during successive marine advances but nevertheless may represent overdeepening of a pre-existing river valley, as its south-western end is aligned with a branch of an infilled palaeovalley. The deep follows an outcrop of soft Lower Cretaceous strata immediately north of the Chalk and it is reasonable to expect that a river would have developed along this line (Hamblin *et al*., 1992).

The Solent and the south flowing watercourses of the Hampshire Basin are flanked by varying numbers of gravel terraces, laid down successively during periods of high sea level stand and left in a typical 'staircase' flight by the subsequent downcutting of the rivers when sea levels fell and failed subsequently to attain previous heights (Bridgland, 1994; 2001; Allen and Gibbard, 1993; Westaway *et al*., 2006). Typically, the highest terraces are the oldest, though their individual histories are complex, many are discontinuous and — in the case of the Solent in particular — their detailed sequencing and dates are still the subject of much debate. They are, however, renowned for their association with Palaeolithic archaeology.

What happens to river terraces in the marine zone is unclear. Direct physical links between onshore and offshore terraces have rarely been demonstrated, though there are some indications that the Solent terraces extend offshore on similar gradients (Bates *et al*., 2007). This implies that they once extended across the shelf area but to what extent they have been eroded and reworked during interglacials is largely unknown. It should be remembered that, at periods of low sea level, those parts of the river systems where flights of terraces survive would have constituted the upper catchments of rivers that may have had very different regimes producing landscape features that may no longer be observable on land *(ibid.)*. Also, while the lower reaches of these extended palaeorivers would have been subject to sequences of erosion and downcutting, the time intervals available (during sea level low stands) would have been much shorter than further upstream. The absence of terraces on the coastal plain is, therefore, more likely to be the result of marine erosion during transgressive episodes, with truncation of lower river gravels, than of the action of the rivers themselves.

Many small, relict dendritic river systems have been identified to the east of the Isle of Wight (Bates and Briant, 2009; Gupta *et al*., 2004; Wessex Archaeology, 2008a; 2008c; 2008d). The larger of these seem to be extensions of the main drainages of the Sussex rivers (Arun, Adur, Ouse and Cuckmere). Although the date of initial downcutting of these channels has not been ascertained, where investigated it is clear that they are of considerable antiquity, possibly the result of rapid downcutting during the Anglian glaciation (480 000–430 000 years ago, Marine Isotope Stage (MIS) 12), and that they preserve their own terraces of limited and often fragmentary extent. Coring of the Palaeoarun valley *(ibid.)* recorded up to 3 m of coarse grained gravel sediments at the base which were interpreted as having been deposited concurrent with or shortly after the erosion of the valley in a high energy environment. The majority of sediments infilling the valley, however, are clearly late Devensian and/or Holocene and appear to have been deposited in the lower section of the valley in an estuarine or marshy environment prior to post-glacial inundation. This infilling by recent sediments is a feature of other palaeochannels in the region.

Breaching of the Isle of Wight-Purbeck Chalk ridge began in late MIS 6 about 135 000 years ago (Westaway *et al*., 2005) and widening of the breach continued in subsequent stages to MIS 2 in the Devensian, effectively capturing the headwaters of the Solent, diverting a major part of its drainage and energy to the west of the island (Velegrakis *et al*., 1999).

Shoreline configuration

Shoreline positions have obviously fluctuated markedly with rises and falls in sea level. However, the configuration of the coastline at different periods will have had considerable influence on the nature and rate of sedimentation and erosion and also on the wider coastal landscape, its ecology, soils and habitat mosaic. During Early Pleistocene high sea level stands (Cromerian complex: MIS 13), before the main Channel ridge was breached and during which the Slindon Raised Beach deposits were laid down, the Solent river ran southwards to the east of the Isle of Wight and the eastern part of the Channel presented an embayed estuarine coastline with probably coastal cliffs extending south in the Portsdown area and east of Arundel (Bates and Briant, 2009). This basic configuration seems to have persisted through the Hoxnian interglacial (MIS 11), with the Channel open for at least part of this time, and probably into MIS 9 or 7 (Aldingbourne Raised Beach deposits). The eastern Channel continued to be dominated on its northern side by the Solent estuary though the coastline became more open (presumably partly as a result of increased flow in the Northern Palaeovalley following breaching of the Dover Straits), as indicated by the much greater lateral extent of the Brighton–Norton cliff line. During cold periods, when sea levels fell, the Solent itself migrated further east and the developed coastal plain was traversed by a series of southward flowing rivers. The changing configuration of estuary and open coast would have influenced patterns of coastal erosion during transgressions and following stabilisation of high sea level stands, leading to truncation of deposits, over-riding, and mixing (Bates and Briant, 2009).

The breaching of the Isle of Wight-Purbeck ridge, which truncated the Solent river system, led to formation of the current coastline with episodes of marine gravel deposition including the Selsey Ridge, and development of shallow harbours ‘behind’ gravel ridges.

Latest Pleistocene and Holocene sedimentation

During the Last Glacial Maximum (LGM) sea levels fell to exceptionally low values leaving what is now southern England subject to intense cold and dry conditions and uninhabited by any human populations. What happened to the lower reaches of rivers flowing into the South Cost REC area is very difficult to determine but the principal mechanisms of erosion were not fluvial in origin but periglacial. The northern icesheet did not extend into the region but periglacial conditions and the gradual thawing of permafrost promoted sheet movements by solifluction and created localised landforms on varying scales from landslip and slump features (especially on Greensands) to ice wedge hollows and fissures, polygonal and striped ground and naileds (mounds of redeposited chalky gravel resulting from glacial outwash). In regional terms these latter are minor features but can be demonstrated to have had important local influences on the preservation of archaeological material (Green, 2000).

Solifluction deposits fill many dry and river valleys, especially on the Chalk. Head deposits mask lower slopes. These are composed of locally derived materials and are, therefore, very variable in composition though often with a Chalk matrix and fill some ice-wedge features and solution pipes, for instance on Portsdown (Hughes and Apsimon, 1977). Any of these deposits may contain archaeological material. In the marine zone, such deposits are best preserved where there is a well-developed shore platform and a fossil cliff to provide a foundation for accumulation (Bates and Briant, 2009). However, they are very vulnerable to erosion and may only rarely survive away from palaeochannels.

Rapid changes in sea level and climate following the Last Glacial Maximum had profound effects on the lower reaches of rivers in the region and complex depositional sequences have been recorded from a number of palaeochannels and gravel deposits all along the present coast. Downcutting due to increased run-off in the face of ice-melt was gradually replaced by the net accumulation of sediments outwashed from solifluction deposits. This in turn altered the gradient of valleys, leading to ponding and overbank flooding and the development of marshland. As sea level continued to rise, estuarine influences increased with eventual inundation and transgressive sedimentation (eg Briant *et al*, 2009).

5.2.2 Chronology and climatic variation

Archaeology: chronology and typology

Even in the terrestrial environment, the majority of archaeological assemblages are palimpsests of the remains of multiple activities that may reflect very short chronologies (i.e. near contemporaneous events) to extremely lengthy ones covering as much as several millennia, separated temporally, if not necessarily spatially, by periods of hiatus. Stratified sites allow for the extrapolation of such chronologies but unstratified surface scatters are much more difficult to disentangle. Prehistoric lithic assemblages are particularly pertinent to this discussion as the majority occur as undifferentiated scatters in the ploughzone or incorporated into colluvial and alluvial deposits, including in the intertidal zone (Gardiner, 1988; Schofield, 1991; Allen and Gardiner, 2000). There are also many thousands of finds of individual flint objects, such as Neolithic axes and Palaeolithic bifaces. Whilst such material is without direct chronological or stratigraphic context it can, nevertheless, yield much information concerning the large-scale use of landscape, enabling broad definition of, for instance, settlement and procurement activities, raw material acquisition and use, and many technical aspects of tool production. Crucially, the types, range and technological attributes of worked lithics, particularly flint, follow a clear chronological sequence which, with relatively minor, local, variations, holds good for much of NW Europe from the earliest of Palaeolithic finds (c.750,000 years before present (BP), with ‘present’ being 1950) to at least the later Bronze Age (c.1000 BP). While it is not proposed to discuss the typology and chronology of stone tools here, suffice it to say that even individual tools and many types of unretouched pieces and core materials can be dated at least to period without any other cultural association.

Most archaeological finds from the English Channel will be of Palaeolithic or earlier Mesolithic date. Recovery of material of later periods (from c.8000 BP) will be generally confined to intertidal and near-shore locations as they post-date the principal episode(s) of Holocene marine transgression. In practical terms, post-depositional factors will dictate that very little material will be in primary context and it will retain the similarly limited spatial and temporal integrity as terrestrial ploughzone assemblages, thus restricting the level of interpretation that can be attempted. Moving back in time, material that is diagnostically late Upper Palaeolithic and earlier Mesolithic post-dates the Last Glacial Maximum and reflects the recolonisation of southern Britain by anatomically modern humans from c.12,500 BP (Housley *et al*., 1997; Jacobi, 2004) after a period of perhaps 10,000 years of glaciation during which it was uninhabited.

Homo sapiens sapiens was present here during the Upton Warren stage of the late Devensian (MIS 3; Upper Palaeolithic) with radiocarbon dates back to at least 38,000 BP, and a potential period (and range) of overlap with *Homo Neanderthalensis* during the previous 10,000 years or so. Throughout these periods changes in lithic technology are distinct, providing strong chronological indicators. Associated bone and antler working technologies, along with faunal assemblages, are also diagnostic and provide clear indications of the resource base.

Neanderthal skeletal remains have only been found at one site in Britain but the presence, again, of distinctive types of flint artefact of so-called Mousterian affinity that are well-associated with Neanderthal remains on the Continent indicate that they must have been present in some numbers, even if sporadically. The Devensian (c.120,000–10,000 BP) witnessed a series of climatic fluctuations that are very difficult to correlate with hominin activity but there does seem to be a genuine lacuna in the evidence from perhaps close to the onset of the previous glacial period (MIS 6) down to around 40,000 BP (Middle Palaeolithic) even, perhaps surprisingly, during the Ipswichian interglacial (c.130,000–115,000 BP) when climatic conditions were closely similar to those of the present day.

Prior to this, the Lower Palaeolithic saw the use of a very restricted range of lithic tools among which the biface or handaxe was dominant. Technological changes can be documented but the dating and sequence of biface development is very difficult to define and continues to be open to much debate (White, 1998; Ashton and White, 2003). Suffice it to say that, over a period of perhaps 350,000 years during which earlier forms of hominin are known to have come and gone from what is now the British Isles, there are very few fixed chronological points.

It is important to highlight this basic sequence in order to emphasise the fact that the potential archaeological resource does not represent a single period during which a uniform toolkit was employed by one species of the class Hominidae in a limited range of unchanging tasks that was merely interrupted by periods of extreme cold. The further back in time we go the more difficult it is to correlate archaeological data with specific climatic events but there are key nodal points — terrestrial archaeological sites and assemblages in specific locations — that may help us to model the use of the South Coast REC area at different periods. These are used in the chronological scenarios presented below.

Fauna and flora

In the terrestrial zone we can recognise periods in which substantially different climatic conditions prevailed by the presence/absence and even the succession of species whose remains are recovered. Faunal assemblages containing woolly mammoth, reindeer, bison and/or cave lion will belong to glacial stages, for instance, while those containing spotted hyaena, straight-tusked elephant, aurochs or wild boar will indicate interglacial conditions. Some species, such as horse and red deer, will tolerate both extreme cold tundra and more temperate steppe or woodland conditions and are, therefore, less indicative. When viewed in combination, it can be shown that some species were or were not present in specific glacial/interglacial stages and, in some cases, that specific evolutionary anatomical features are peculiar to particular stages of the Middle Pleistocene (Wymer, 1999). Small mammals are also useful as they exhibit fairly rapid rates of change and analysis of various types of vole has proved particularly efficacious in distinguishing specific interglacial deposits.

However, in the South Coast REC area, where finds of bones of larger animals are made sporadically but rarely with any helpful provenance (Wessex Archaeology, 2004c), such biostratigraphic distinctions are rarely likely to be achievable. Even where conditions suitable for their preservation pertain, bones will almost certainly have been redeposited and material of different periods quite possibly mixed so, because most of the larger animals were present in most glacial or interglacial periods, it will not be possible to assign such finds to any particular Pleistocene stage.

Potentially of much more use in elucidating environmental conditions, however, are the micro-faunal elements such as molluscs and beetles, and micro-organisms such as ostracods, diatoms and foraminifera which can not only reflect local environmental conditions at the time of sediment deposition quite accurately (e.g. terrestrial; lacustrine, intertidal or freshwater; fast or slow-moving water; temperature range) but also, when studied in sequence, reveal changes in climate and habitat. Pollen data can provide a picture of the wider landscape and indicate larger scale changes, for instance from coniferous to deciduous woodland to open grassland. In combination such organisms, which are widely preserved in a variety of sediments, have the potential to ‘flesh out’ our understanding of past landscapes. Organic layers, predominantly peat, have the additional potential to provide material for absolute dating (by either radiocarbon or Optically Stimulated Luminescence (OSL)).

Correlation with geochronology

Table 5.1 provides a correlation between the main Pleistocene stages, archaeological periods, sea bed characterisation and archaeological potential.

5.2.3 Terrestrial analogues for hominin habitat preferences

Key to any prehistoric regime of land-use and resource exploitation is the availability and reliability of food, fresh water and shelter. Modern humans of the Upper Palaeolithic and Mesolithic were highly efficient hunters and foragers and, though there is no surviving evidence for foraging in the earlier periods it seems most unlikely that advantage was not taken of fruits and nuts and even edible roots to supplement what has long been assumed to have been a largely meat diet. Edible plant remains are extremely rare on early archaeological sites though fossil fruits, nutlets and seeds were recorded at Hoxne, Suffolk dating to the Hoxnian interglacial (MIS 11).

Raw material procurement and activities

The most durable of materials employed by early populations using the English Channel area are lithic. Throughout much of the Lower Palaeolithic a limited range of tools was made and utilised. Flint was the most commonly utilised stone though a variety of non-flint materials were also used. The key issue here is size: in lithic technological terms Lower Palaeolithic objects are large and their production resulted in a considerable amount of waste. This required the acquisition of nodules that were not

Geochronology			British Archaeological Record		South Coast Regional Environmental Characterisation
Period	**Epoch**	**MIS stage**	**Period**	**Date**	
Quaternary (2.5 mya to present)	Holocene	MIS 1	Modern	AD 1800–present	Characterisation is one of a zone of use. Maritime activity within the study area of fundamental importance, regionally, nationally and internationally. Continuing development of ports and rapid intensification of maritime activity of all types during 19th and 20th centuries. Portsmouth consolidated as the UK's principal naval base. Southampton becomes UK's principal liner port. Region of great importance to the defence of the realm and the liberation of Europe in the Second World War. Very large number of shipwreck and aviation crash sites. High concentration of nationally important shipwreck sites. Very high maritime archaeological potential, both inshore and offshore.
		MIS 1	Post-medieval	AD 1500–1800	Characterisation is one of a zone of use. Increasingly intense trade, fishing and naval activity, increasingly international. Maritime activity increasingly important regionally, nationally and internationally. Further development of trading, fishing and naval ports, most notably at Portsmouth. Large number of shipwreck sites from this period known, mainly naval. High concentration of nationally important shipwreck sites. Very high maritime archaeological potential, both inshore and offshore.
		MIS 1	Medieval	AD 1066–1500	Characterisation is one of a zone of use. Extent of maritime activity uncertain in early medieval period but evidence suggests significant maritime activity. Subsequent growth of trade, fishing and naval activity, with the development of important trading and fishing ports and the beginnings of a naval base at Portsmouth. A small number of shipwreck sites of the 15-16th centuries known, all nationally important due to their rarity. High maritime archaeological potential, both inshore and offshore.
		MIS 1	Anglo-Saxon (early medieval outside England)	AD 410–1066	
		MIS 1	Romano-British	AD 43–410	Characterisation is one of a zone of use. Coastal regions supporting settlement including some large urban centres, villas, farmsteads, temples and road network. Use of harbours and estuarine coasts for salterns. No shipwreck sites known from this period. Uncertain archaeological potential, although all maritime sites of this period likely to be very important.
		MIS 1	Iron Age	700 BC–AD 43	Characterisation is one of a zone of use. Coastal harbours and estuaries in modern configuration. Potential for coastal activity including settlement and burial sites, temples, salterns and deposition of metal objects in shallow water. Potential for wooden coastal structures such as jetties, causeways and fish traps extending across current intertidal zone. Offshore potential limited to material washed out of harbours and saltmarshes.
		MIS 1	Bronze Age	2,200–700 BC	Sea level approaching modern position. Characterisation is one of limited and discontinuous use. Potential for coastal activity including burial sites and deposition of metal objects in shallow water. Potential for wooden coastal structures such as jetties, causeways and fish traps extending across current intertidal zone. Offshore potential limited to material washed out of harbours and saltmarshes
		MIS 1	Neolithic	4,000–2,200 BC	As above. Development of coastal harbours behind sand and shingle banks. Characterisation is one of limited and discontinuous use. Potential for submerged land surfaces within harbours, estuaries and in lower intertidal zones. Much eroding material from coastal saltmarshes. Offshore potential limited to material washed out of harbours and saltmarshes.
		MIS 1	Mesolithic	9,500–4,000 BC	Period of rapidly rising post-glacial sea level and climatic amelioration. Development of organic land surfaces, especially in coastal plain river valleys. Geologically the Holocene is characterised by transgressive deposition of inorganic fine silts and muds sealing organic surfaces and filling palaeovalleys, with gradual coastal retreat. Archaeologically the region is characterised by the occurrence of extensive scatters of worked flint, sometimes accompanied by hearths, faunal assemblages and environmental sequences. High potential for archaeological remains in near shore locations and extending beyond modern intertidal zone onto shelf with some potential for recovery in palaeovalleys where net sedimentation rates greater than net erosion rates.
	Pleistocene	MIS 3-1	Upper Palaeolithic	40,000–9,500 BC	Prior to Last Glacial Maximum rapidly falling temperatures and sea levels leading to abandonment of Britain and N. France. After LGM rapid rise in sea level from low of c. 110m bOD and in climatic amelioration leading to recolonisation by modern humans. Characterisation of open lowland plain with cliffs, bluffs, downcutting river valleys and extensive sand blows backed by high hills. Occupation and utilisation of caves, rock shelters and later, open air hunting sites. High potential for recovery of material.
		MIS7-MIS 3	Middle Palaeolithic	300,000–40,000 BC	Period of complex and poorly understood fluctuations in climate and sea level but mostly fairly cold. For large parts of period Britain probably uninhabited. Later part archaeologically characterised by distinctive lithic technology but population likely to have been low and occupation sporadic. Net erosion of river valleys leading to removal of much archaeological material and overall potential probably quite low.
		?MIS 17–7	Lower Palaeolithic	650,000–300,000 BC	Complex pattern of glacial and interglacials, fluctuating sea levels and coastal morphology. English Channel closed for long periods and main influence fluviatile rather than marine. Series of raised beaches, wave-cut platforms and river terraces associated with archaeological material, latter mostly derived and reworked at later periods. Raised beaches of particular importance for archaeology and associated faunal and micro-faunal assemblages; high potential where any such submerged features occur.

Table 5.1: Summary characterisation table.

only large enough but also those which were of good quality with good flaking characteristics — i.e. which would not disintegrate while being worked into tools because of the presence of flaws, 'foreign' inclusions and frost fractures. The best quality flints are those in primary position in seams within the Chalk and, indeed, such seams were actively mined during the Neolithic period, but would only have been available to earlier populations where they outcropped, most obviously in river and coastal cliffs or in periglacial footslope deposits. Secondary context material that derived and redeposited in, for instance, river and marine gravels is generally of very variable size and quality but certain deposits, particularly some of those associated with raised beaches and specific river terraces, may comprise nodules of exceptional size and quality.

Many years of analysis of Palaeolithic biface assemblages makes it clear that their makers were both very skilled and well aware of the distribution of sources of good quality stone. Procurement of this essential raw material was not haphazard; known sources were the subject of knowledge which was handed down through generations and were deliberately and repeatedly exploited over many thousands of years. Flint was always the preferred material but its availability was geographically limited and, in some areas, it was simply not available, so alternative rocks were used instead. This pattern of exploitation in turn implies specific patterns of behaviour both in terms of the actual procurement of lithic material: i.e. in the visiting of resource areas, and in the manner in which nodules were worked and transported. Flint is heavy and sharp so questions arise as to whether finished tools were manufactured at the point of procurement and carried away, or whether nodules were simply taken away unworked, broken down by preliminary working or even 'roughed out' into tools to enable transportation and then worked into finished objects elsewhere, or any combination of these scenarios.

It follows, therefore, that sources of suitable, good quality flint (or other stone) are likely to have been repeatedly visited and, therefore, have the potential to produce large quantities of Palaeolithic implements. One such location that can be cited is at Dunbridge in the Test valley, Hampshire, where over 1000 handaxes have been recovered along with axe making debitage (Roe, 1968; Wymer, 1999).

Hunting and scavenging

The image of 'man the hunter' is a familiar one but though there were many early accounts of Palaeolithic stone tools being found in association with animal bones, it has only been in recent decades that it has been possible, through a variety of analytical techniques, to demonstrate that early hominins were both scavengers and real hunters capable of bringing down some of the largest mammals. Scavenging would almost certainly have put them in competition with predators. Hunting with weapons had to be at 'close-quarters', requiring taught knowledge of animal behaviour and stone tool production as well as guile and understanding of risk. It is this relatively high degree of cognitive behaviour and ability to learn and adapt that soon set them apart from other predatory species. Locations where herd animals could be viewed undisturbed at close range, could be easily ambushed or indeed driven over cliff edges; riverside locations where animals congregated to drink or were crossing points for migrating herds; and ecotonal positions e.g. a transition zone between forest and grassland, where a range of species would be likely to be present would all be favoured places in which to find evidence of past activity.

Corridors of movement

The major land bridges that linked southern England to the Continent at various stages of the Middle and Late Pleistocene provided routes for the movement of hominins and other fauna. There is a tendency to assume that waterways presented barriers to movement and while this was undoubtedly so in the case of major, deep, fast-flowing channels, it is clear from the distribution of large quantities of Palaeolithic material that river valleys were major routeways for hominins, as they would have been for other animals. Bogs, marshes and swamps are likely to have been difficult to cross but tidal estuaries and even larger channels could be waded at suitable times and we should not assume that early populations were averse to crossing water.

5.2.4 Sea bed landscape as habitat: land-use scenarios

The importance of recovered archaeological material from the sea bed is that it is not just a collection of disparate, if intrinsically interesting, objects but that it indicates the presence of past populations inhabiting a lost landscape, albeit one heavily transformed by subsequent taphonomic processes. We cannot easily separate material of different periods for much of the Palaeolithic period, except where techno-chronological characteristics can be identified, but we can suggest areas that are likely to have been more or less favoured for occupation and discard. In this section, a series of chronological scenarios is presented. No account is taken of the subsequent history of the sea bed as the intention is to indicate the potential of the resource and highlight any locations that may be of particular interest should suitable deposits survive. The predicted extent of sub-aerial exposure, potentially important topographical features and major river courses at appropriate sea level height are provided for each scenario.

Two associations cross-cut this discussion. First, in the terrestrial zone a majority of Palaeolithic artefacts are associated with river terrace gravels. As discussed above, much of this material has been reworked from its original point of deposition, probably several times, and it is extremely difficult to date. Virtually any gravel terrace surviving beneath later deposits on the sea bed therefore has the potential for producing such material. Secondly, artefacts of all early prehistoric periods up to the Neolithic are preferentially associated in the terrestrial zone with remnant Tertiary deposits known as Clay-with-flints, which commonly overlie Chalk. Where such deposits survive in the marine zone (Chapter 4) then they are also likely to contain Palaeolithic material (and/or artefacts of later date should they be encountered close to the present shoreline).

It should be borne in mind that the periods when direct access between the continent and southern Britain was most easily achievable in terms of area of dry land were also those of most intense dry cold and therefore most inhospitable. Periods of changing climate, particularly warming, offered the greatest variety of habitats and resources.

Scenario 1. c.500,000 BP (MIS 13/Sea level at -40 m) Figure 5.3

Falling sea levels in the later part of MIS 13 exposed former beach deposits that cut into the base of the Chalk cliff forming the southern edge of the Upper Chalk escarpment of what is now West Sussex. These sand and silt deposits, the Slindon Beach Formation, lie at an average height of 40 m above Ordnance Datum (aOD). As it is unlikely that sea levels were ever significantly higher than those of the present day during the Middle Pleistocene, it is considered most probable that this beach was subject to subsequent tectonic uplift (Roberts and Parfitt, 1999). The mapped extent of the Slindon Raised Beach cliff line is shown in Figure 5.4. The deposits 'exhibit the features of a classic nearshore, subtidal, and intertidal sand deposits' *(ibid.)*.The Chalk cliff now lies some 12 km inland and would have been more than 10 m in height (see Figure 5.5).

At the base of this cliff lies a series of Palaeolithic sites, the most famous of them being Boxgrove. Establishing a tight chronology, even a relative one, for assemblages of this age is almost impossible but it seems clear that the same hominin groups were operating over a wide area and presumably over a considerable

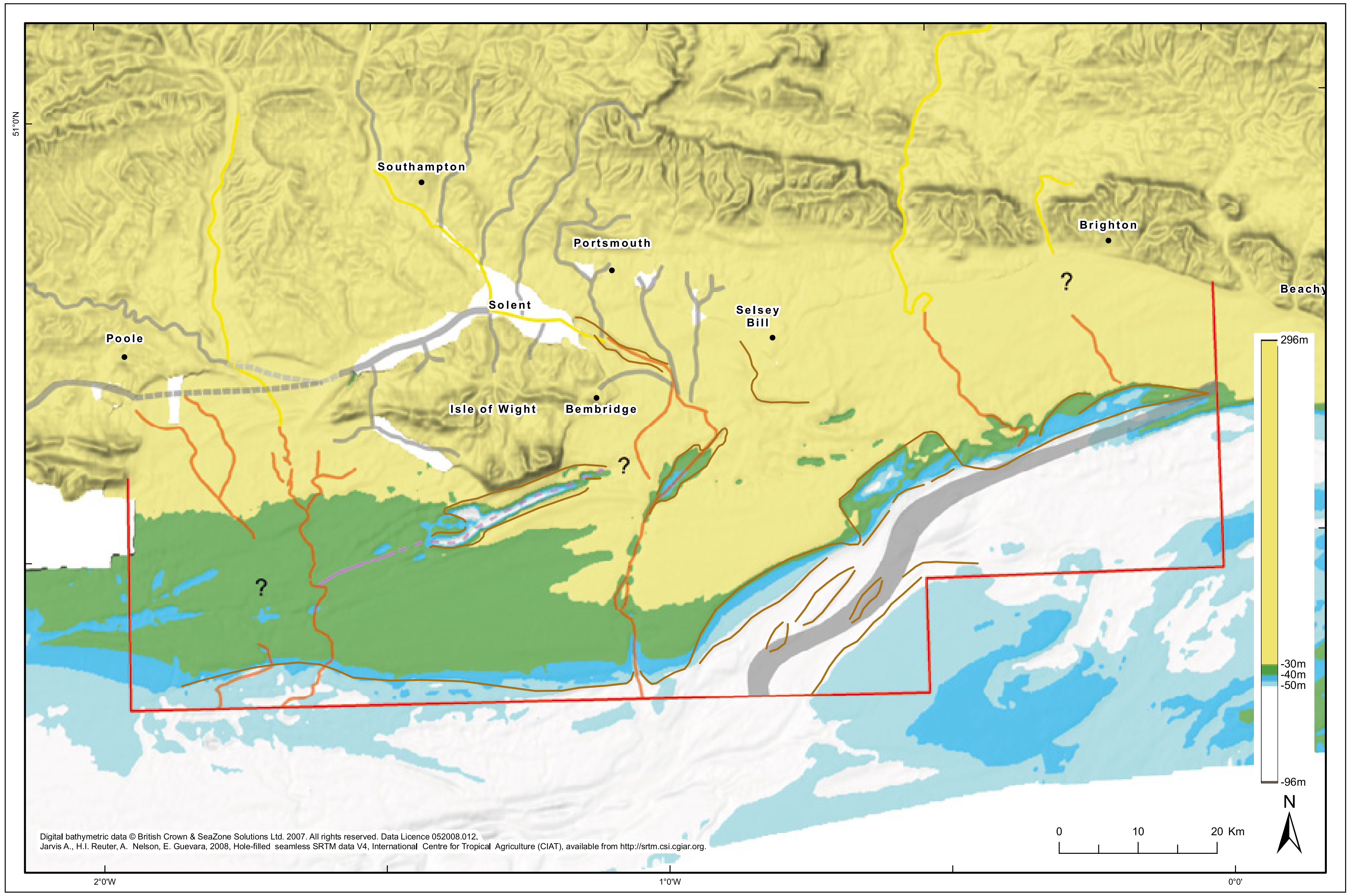


Figure 5.3: South Coast REC study area modelled with sea level at -40 m, illustrating Scenario 1 at c.500,000 BP.

period of time. Material of very similar technological characteristics occurs in association with specific deposits and with a similar range of micro- and macro-faunal remains. At Boxgrove, the most important of the stratified sedimentary units preserved *in situ* knapping debris, butchered fauna and hominin remains of *Homo Heidelbergensis* (Roberts *et al.*, 1997; Roberts and Parfitt, 1999). Although other hominin remains are lacking, sites such the Valdoe Quarry, Slindon Bottom, Penfolds Pit and West Stoke occur in identical landscape positions at the foot of the cliff (Pope *et al.*, in press).

As sea level fell a large, tidally-fed, salt lagoon developed which, in time, gave way to drier conditions and the development of a palaeo-land surface. An extensive vertebrate assemblage was preserved on this land surface at Boxgrove which supported an open grassland with forest cover on the downland block to the north. The lithic assemblage mostly consisted of ovate handaxes (Figure 5.6), which were used to butcher large carcasses of giant deer, red deer, bison and rhinoceros. Bones of smaller animals, such as roe deer, do not show evidence of butchery and may not have been exploited — large beasts seem to have been the target and there is ample evidence for both scavenging of whole carcasses and hunting. At other sites along the Slindon Raised Beach, differences in the composition of assemblages and in the palaeo-ecological evidence indicate rather different environmental conditions and behavioural variability. At the Valdoe, just 3 km from Boxgrove, a more distinctly estuarine signature could be detected with indications of seasonal flooding and a lack of woodland (Pope *et al.*, in press). The lithic asssemblage here indicated the production of handaxes from good quality flint that was locally available.

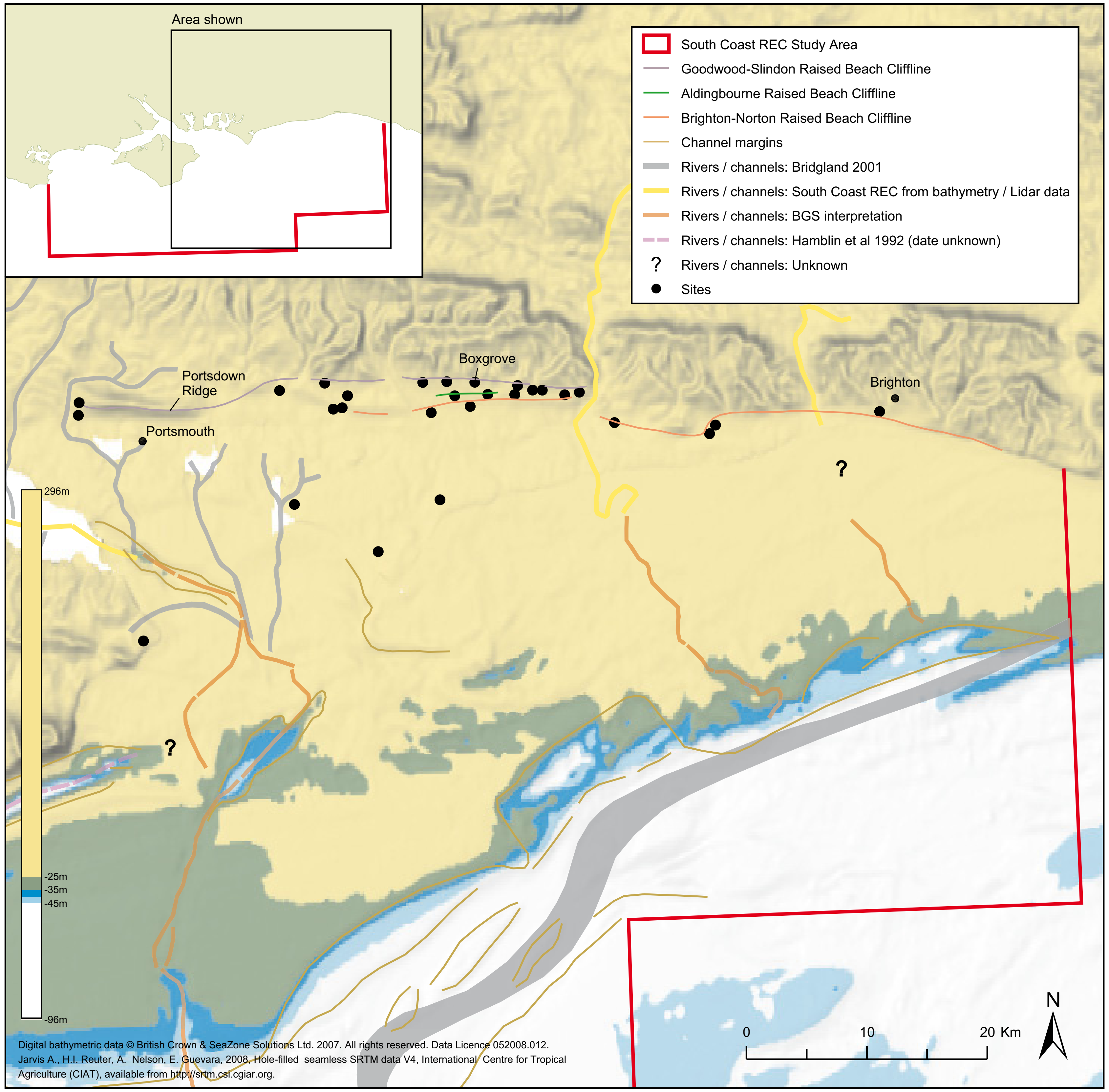


Figure 5.4: Map of Sussex raised beaches with Palaeolithic sites marked.

Raised beach deposits with associated handaxes at Bembridge on the Isle of Wight are probably also of this date (Preece *et al.*, 1990). Elsewhere in Britain at this time, other hominin groups were exploiting rhinoceros, bison, deer, horses and straight-tusked elephants in East Anglia and the Midlands. These sites are all located within the drainage basin of the long extinct Bytham river, though the material here is not *in situ* having been transported during subsequent glacial periods. Deposits containing handaxes and sealed below glacial till belong to the Anglian glacial stage — MIS 12 (Wymer, 1999).

While unequivocal evidence of hominin activity in the current terrestrial zone is undoubtedly limited, these finds may have important implications for the potential for finding material of this date in the marine zone. With a sea level at -40 m, large parts of the current marine zone would have been dry land (Figure 5.3). The Slindon Raised Beach formed part of an embayment that fronted the land bridge between southern England and France. Viewed from the northern shoreline of the estuary, the greater part of the contemporary terrestrial landscape seems likely to have been one of a low-lying coastal plain with occasional lakes and pools, framed to the north by the imposing Chalk uplands of the South Downs, rising to as much as 400 m, and to the west by the high ridges of the Isle of Wight. In part the Downs were fronted by the lower cliff and platform of the Slindon Raised Beach, and the Solent debouched into the Northern Palaeovalley east of the Isle of Wight. Bathymetric data collected off St Catherine's Point (Area 451) recorded the presence of a wide shallow north-east to south-west aligned valley descending from c.34 m below (bOD) to c.48 m bOD, probably a former course of the Solent (Figure 5.3). This valley does not widen at its southern end but is constrained to a deep gorge through an east-west aligned ridge at 26 m bOD, beyond which the sea bed levels out at c.35 m bOD. Several lesser palaeovalleys converge here, including two that trend west-east to the north of the ridge (Wessex Archaeology, 1998) which appears to be part of the Lower Greensand formation. Bathymetric evidence may indicate the presence of a low cliff line along much of the northern shore of the estuary with only a narrow intertidal zone. Further west, a wide coastal plain fronted by an extensive intertidal or seasonally flooded marshland with occasional lagoons lay south of an unbroken Chalk ridge.

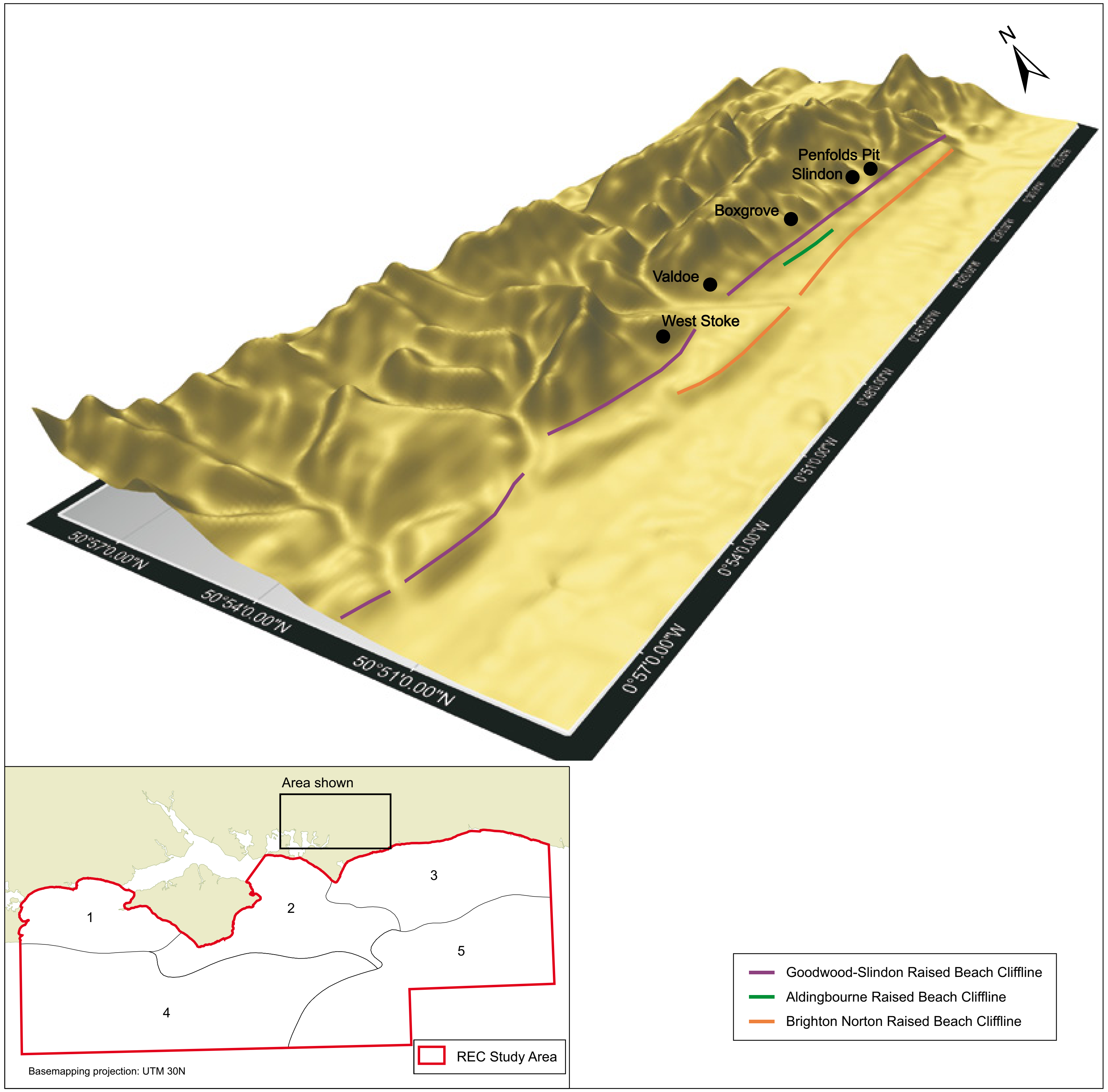


Figure 5.5: Isometric view showing position of Sussex raised beaches with the sea level at -40 m.

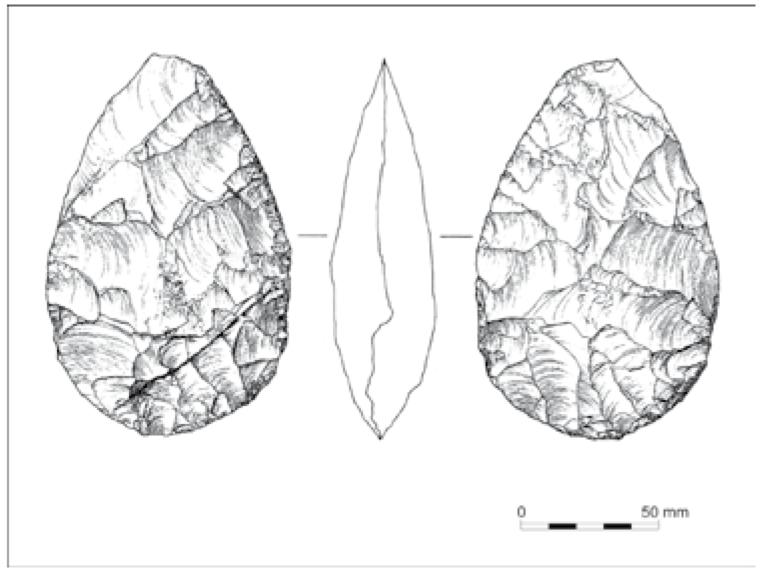


Figure 5.6: Typical Palaeolithic handaxe from Boxgrove (Wymer, 1999).

The bathymetric data further suggest that it is quite possible that the estuary was periodically fordable in places (an image rather like Morecambe Bay comes to mind) and that hominins crossed to the area of southern Britain by routes other than the main land bridge in the east. Finds from East Anglia suggest movement along major river valleys. The faunal assemblage from the Boxgrove site indicates a rich fauna and we may envisage herds of large vertebrates as well as rabbits, mountain hares, and many small creatures inhabiting an extensive grassy prairie with occasional brackish lagoons and/or freshwater lakes. A range of ducks and other waterfowl were present. In other words, this was largely a very attractive landscape for hominins to exploit and ecotonal locations, such as the base of cliffs with grassland backed by wooded upland, saltmarshes and littoral positions are likely to have been favoured. If the choice of animals for hunting was not enough, seafish such as conger eel, cod, wrasse and blue fin tuna were available; all have been recorded at Boxgrove (Roberts and Parfitt, 1999). Predators capable of taking hominins were also in evidence, including wolf, bear, spotted hyaena and lion. Hominin groups are likely to have sought shelter and protection in rock shelters and fissures.

Consequently, there are areas of the sea bed which have the potential for having been favoured locations around 500,000 BP. If buried deposits should be encountered or identified, their potential

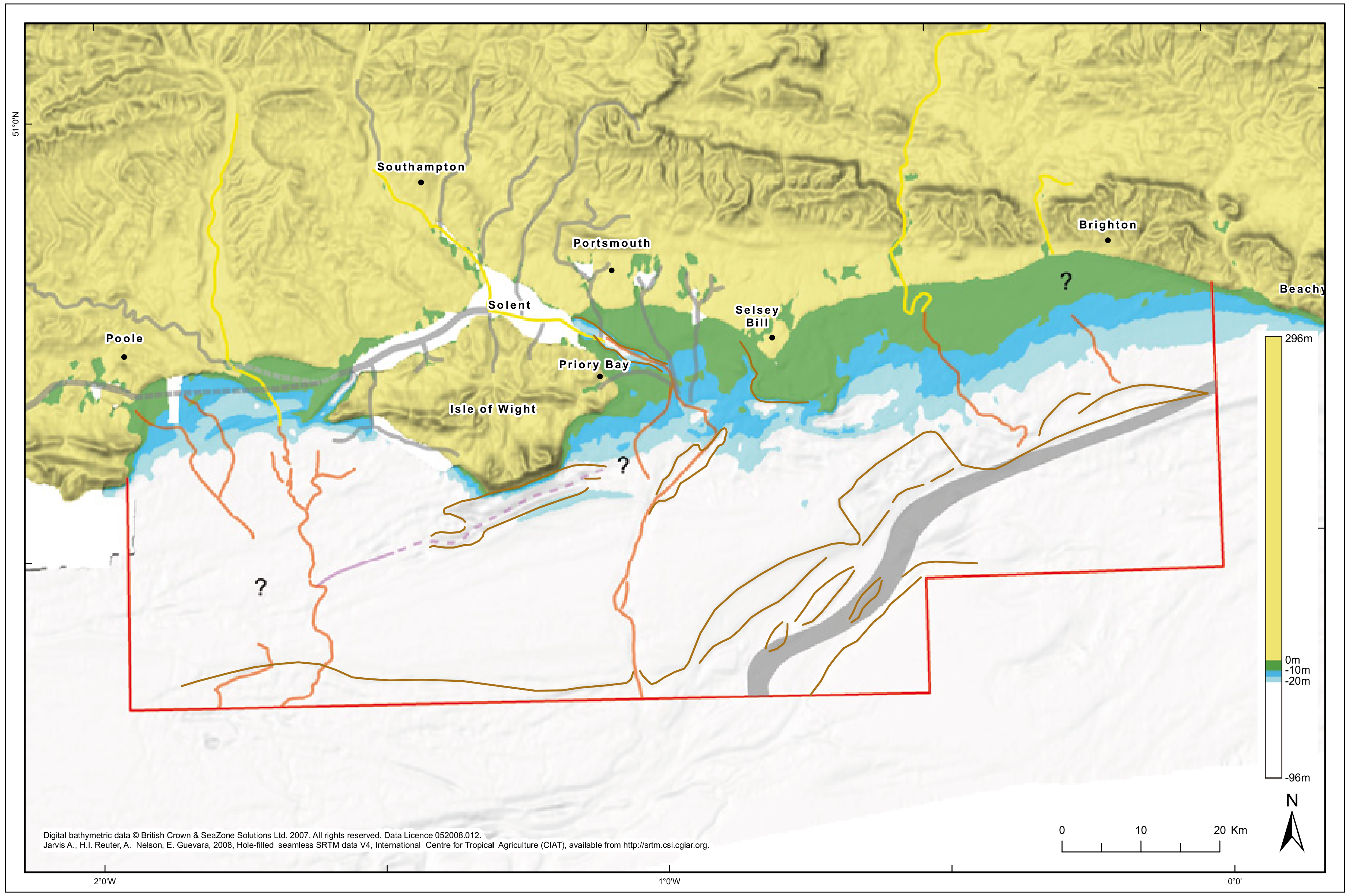


Figure 5.7: South Coast REC study area modelled with sea level at -10m, illustrating Scenario 2 at c.400,000 BP.

for yielding very ancient remains would be very high. Such locations would be any remnant raised beaches, which have been shown to exist (Hamblin *et al*., 1992), the coastal plain west and south of the Isle of Wight, especially where the contour map suggests the presence of lakes or lagoons, and any shoreline cliffs or ridges.

The period c.500,000–400,000 BP covers the Anglian glaciation and subsequent return to interglacial conditions. The Anglian ice sheet is the most extensive known to have covered Britain, extending as far south as the Thames Valley in the London area, diverting the course of the Thames in the process, and even as far as the north Cornish coast in the west of England. Throughout much of this period Britain would have been uninhabited.

Scenario 2. c.400,000 BP Hoxnian interglacial (MIS 11/sea level at c.-10 m) Figure 5.7

In an area of what is now Hoxne in East Anglia, a lake was formed in a kettle hole produced in the glacial till deposited as the Anglian ice sheet retreated. The shore of this lake attracted human activity during the following Hoxnian interglacial. At Hoxne, a complex sequence of laminated lacustrine deposits reflecting fluctuating climatic conditions contained a Lower and an Upper flint industry with a clear, if probably short, hiatus between the two episodes of deposition. Large numbers of handaxes in near mint condition (Figure 5.8) indicated more or less *in situ* deposits, associated with mammalian teeth and bones with indications of deliberate cut-marks.

A major cluster of sites of the Hoxnian interglacial occurs in the lower Thames valley around Swanscombe, Kent. There is a complex series of gravel deposits in this area, capping the Orsett Heath Terrace, and material of several periods is clearly mixed in a number of locations. Various gravel pits have produced large

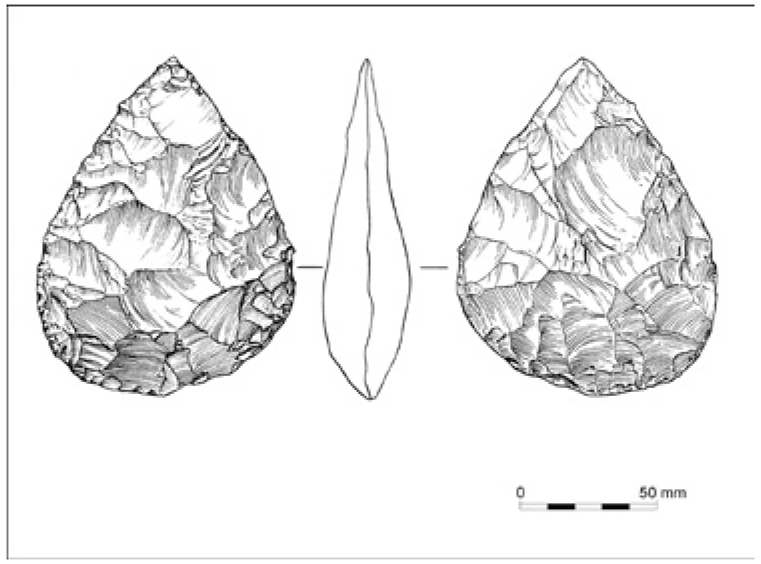


Figure 5.8: Cordate handaxe from the Lower Industry at Hoxne (Wymer, 1999).

assemblages of elegant handaxes associated with faunal remains, shells, teeth and tusks and, at Swanscombe Barnfield Pit, part of a human skull (Wymer, 1999). Some of this material could be seen to be in primary, i.e. more-or-less *in situ*, context. More recent excavations have recorded similar material in other nearby gravel pits (Wenban-Smith and Bridgland, 2001). Elephant, rhino and fallow deer were among the animals butchered.

Environmental evidence for the Hoxnian, including that from another lakeside location, at Mark's Tey near Colchester, records rapid climatic fluctuations and a rich faunal and floral record indicating a mixed oak forest with lime, hazel, and alder. Later hornbeam, spruce and particularly silver fir developed, suggesting acidification of soils. Among the other exploitable animal species recorded are red and roe deer, giant beaver, aurochs (wild cattle), hippopotamus, wild boar and wild ass, as well as fish and birds.

Sea level fell quite rapidly in the latter part of the Hoxnian interglacial and dating of the archaeological sites has been open to question, but with sea levels at between -10 m and -15 m at around the period that the Swanscombe and East Anglian sites were occupied, the coastal plain of the South Coast REC area would have been considerably more extensive than today. However, it probably did not extend much beyond a west-east line level with the southern edge of the Isle of Wight, with the Solent estuary and much of the Sussex coast fronted by a wide intertidal zone giving way quite rapidly to comparatively deep water (Figure 5.7). The Channel seems to have been open for much of this period. The environmental evidence suggests that the Chalk hills lying beyond the coastal plain would have been well wooded supporting a wide range of animals. Our understanding of hominin movements and settlement in the Hoxnian interglacial is fragmentary but we might suggest that the coastal plain was used for occasional forays into the intertidal marshes and the lower portions of river valleys for fishing and fowling with some sea fishing. Many handaxes are known from the gravel terraces of the Solent river, including possibly a collection of more than 1000 handaxes from Priory Bay on the Isle of Wight (Wenban-Smith *et al*., 2009) that seem to correlate with (or are no earlier than) this period. In many cases such finds are from areas close to the base of the Chalk slopes where material may have become concentrated partly as a result of outwash from the Chalk. In any event these areas would have been located higher up the river valleys than they are now. We may further suggest, therefore, that settlement activity was concentrated in these higher regions and on the hills where there are equally large numbers of artefacts associated with Clay-with-flint deposits. Consequently, it would seem that the potential for recovery of Hoxnian assemblages in the South Coast REC area is comparatively low except possibly in near shore areas where remnant river terraces or valleys may be buried. The recovery of animal bone including a bison horn core, elephant tusk and possible aurochs femurs from gravel banks at Newtown near the mouth of the Yar on the Isle of Wight is of possible interest in this context (Wessex Archaeology, 2004c).

The Wolstonian complex, lasting from c.380,000 BP to c.130,000 BP (MIS 10-6) saw alternating periods of warm and cold with fluctuating sea levels and climatic conditions. In warm phases hominins were certainly active in southern Britain and many Palaeolithic sites and finds occur. Dating evidence is, however, sparse and it is very difficult to differentiate material belonging to different phases. A major glacial phase centred on 150,000 BP was followed by very rapid climatic amelioration and sea level rising to nearly 10 m above present mean sea level. Surprisingly, however, this warm phase (the Ipswichian; MIS 5e) has not produced any certain evidence of occupation in Britain despite similar conditions in other periods of similar climate having abundant evidence for occupation..

Scenario 3. c.120,000 BP, Middle Palaeolithic (MIS 5a/sea level at c.-15 m) Figure 5.9

In north-west Europe the Middle Palaeolithic is synonymous with the appearance and use of a specific flint technology known as the Mousterian which includes distinctive flat-butted handaxes *(bout coupé)* and flakes and cores employing a technique known as Levallois (Figure 5.10). This technological complex is generally also synonymous with Neanderthals and persisted in use from around 300,000 to perhaps 40,000 BP. The only probable Neanderthal bones from Britain are some teeth and jaw fragments from Pontnewydd cave in Denbighshire, dated to MIS 7. What does seem to be clear, puzzling as it is, is that humans were absent from Britain during the last interglacial, the Ipswichian, so some Mousterian material may be earlier, belonging to MIS 7, but most is more likely to be later (Devensian). Assemblages based on Levallois technology have a wide distribution across southern Britain though few have been investigated using modern archaeological techniques.

At around 120,000 BP sea level was falling from its highest level over the last 700,000 years (c.15 m aOD). The sea level curve for the Devensian reflects considerable climatic variability with long periods of realtive cold and, overall, a general trend towards ever colder conditions, culminating in the last ice age. Comparatively few archaeological sites have been found that can confidently be dated to the earlier part of the Devensian and though Wymer's (1999) map of Middle Palaeolithic sites in the Thames Valley records 83 findspots, including some very large assemblages, there is, of course, no time-depth to this distribution. Wymer suggests that overall, the population was very thin throughout this period of the Middle Palaeolithic (the Windermere interstadial). A particularly important feature of Levallois assemblages (which are based on the production of large flakes of particular form from distinctive, specially prepared 'discoidal' cores) is that the technique is both extremely wasteful and requires large nodules of good quality flint or flakeable stone. The Thames Valley assemblages are notably based on the use of Chalk flint rather

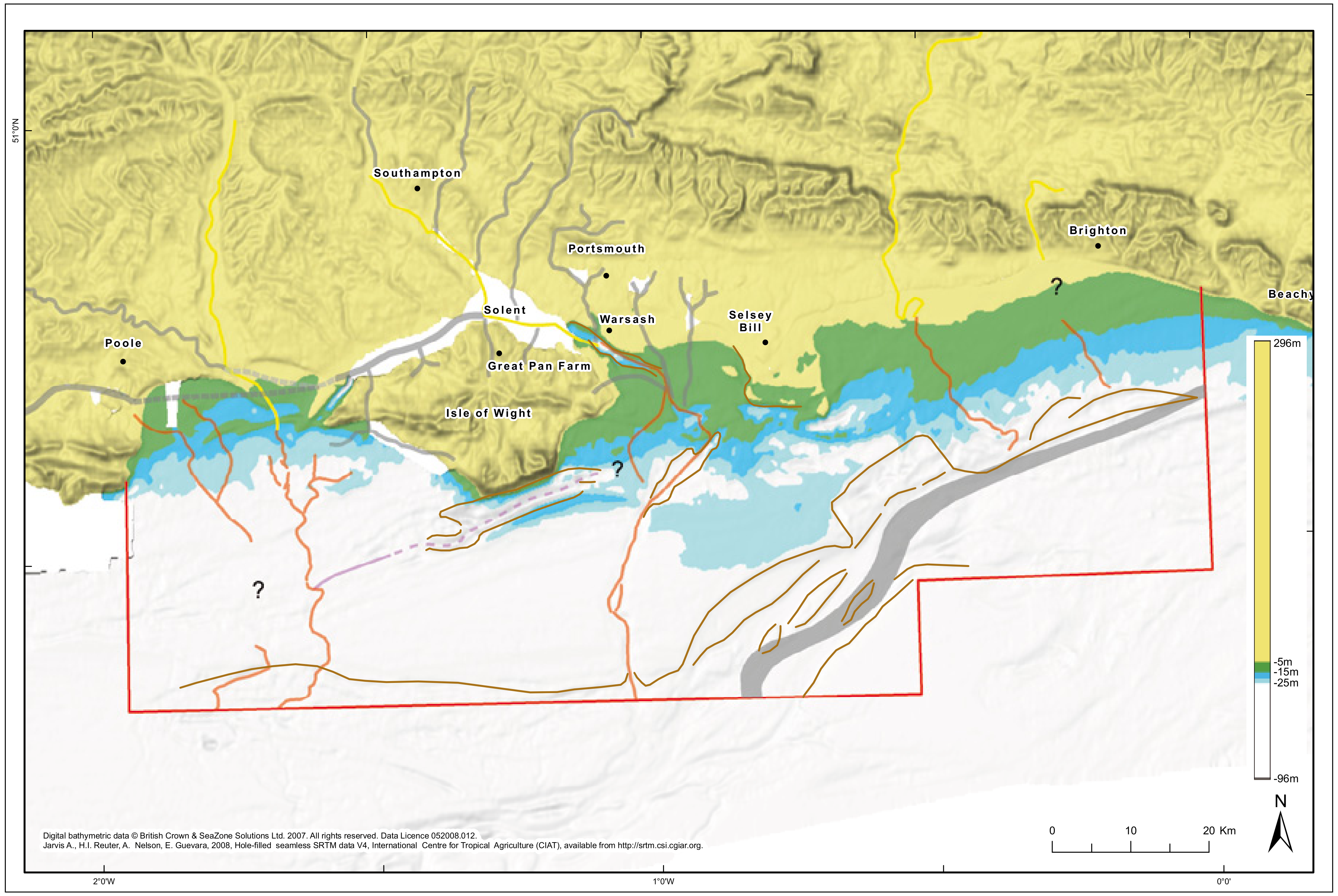


Figure 5.9: South Coast REC study area modelled with sea level at -15m, illustrating Scenario 3 at c.120,000 BP.

than on derived pebble gravels of the valley floor. The valley itself would have been an ecotonal location for much of its length with largely open tundra grassland supporting horses, mammoth, woolly rhinoceros and reindeer, and boreal forest on the Chalk hills interspersed with glades and clearings. In warmer periods the woodland cover would have been more extensive with cold climate species becoming locally extinct and replaced by forest animals.

Rivers of the Solent and Avon drainage of the Hampshire Basin have produced very few Middle Palaeolithic artefacts. Calkin and Green (1949) regarded the area south of the present Stour-Avon estuary as having been a 'bay delta' and such material as there is seems to come from higher bluffs (Wymer, 1999) and from a raised beach deposit at Warsash. On the Isle of Wight, Great Pan Farm at Newport has produced Levallois material associated with a marine sand deposit from a gravel pit about 8m above the River Medina, which would have been a tributary of the Solent (Roberts *et al.*, 2006).

An open shoreline with grassland was probably fronted by a wide intertidal zone across much of the eastern part of the region. This configuration, coupled with rapidly falling sea level, would be likely to have seen significant erosion of lower river terraces, downcutting of lower river valleys and the loss of archaeological material in high-energy environments. Subsequent fluctuations resulted in a complicated pattern of transgressive and regressive sedimentation and erosion including, on the one hand, the creation of shoreline gravel bars and, on the other, scouring of valleys and surfaces. This would imply that the potential for recovery of Middle Palaeolithic material from the marine zone would be fairly low. However, the climatic history of the period is particularly complex and it is quite possible that remnant terraces, infilled valley profiles, wave-cut platforms and beach deposits may survive and preserve archaeological remains (Regions 1–3).

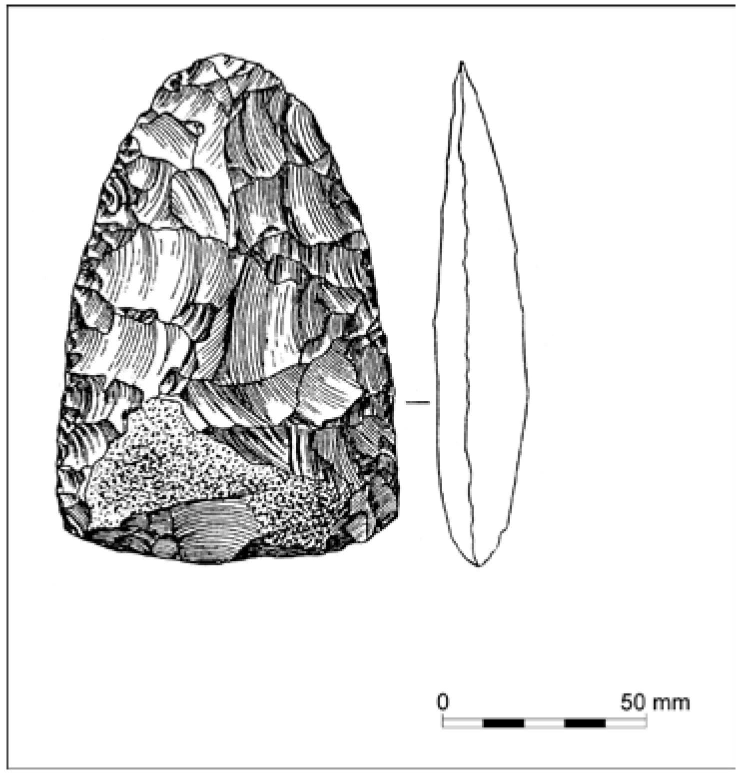


Figure 5.10: Mousterian handaxe, probably of Devensian age from the Bournemouth gravels (Wymer, 1999).

Although interspersed with relatively short warmer phases, the general trend in temperature, climatic conditions and sea level during the later Middle and earlier Upper Palaeolithic (MIS 4–2) was downwards. Intermittent occupation is likely and certainly anatomically modern humans were active in southern Britain around 38 000 BP (e.g. Kent's Cavern, Devon) before intense cold all across northern Europe forced human populations to retreat to a few key areas before the Last Glacial Maximum (Housley et al.*, 1997).*

Scenario 4. c.12,000 BP. Upper Palaeolithic: Late Devensian (sea level at c.-110 to -80 m) Figure 5.11

Southern Britain was recolonised rapidly by anatomically modern humans after the Last Glacial Maximum (c.18,000 BP). By 13,000 BP cave and rock shelter sites such as Gough's Cave, Badger's Hole and Sun Hole on Mendip, Kent's Cavern, Devon and Robin Hood's Cave in Derbyshire were being occupied on at least a seasonal basis. It appears, therefore, that some human groups were arriving even before the onset of interstadial warming. This is reflected in the animal bone assemblages from these sites which indicate the hunting of predominantly reindeer along with elk, Saiga antelope and giant deer. As the climate warmed, the specifically cold climate mammals retreated north, along with the open steppe country that they habitually grazed, with horse, aurochs, red deer and possibly roe deer becoming more common. Low scrub of juniper and willow, followed by pine and birch forest, began to develop.

An increasing number of open air Upper Palaeolithic sites have been recorded and seem to also represent hunting camps. These are frequently situated on hilltops and bluffs overlooking open country, as at Hengistbury Head, Dorset, in Region 1 (Barton, 1992), where they were visited repeatedly, being ideally suited for exploiting herds of large herbivores. Low bluffs beside rivers (especially at fording points) with easy access to water, flint and a variety of animals and riverine resources, as at La Sagesse, Romsey (Conneller and Ellis, 2007), and Nea Farm, Ringwood (Barton *et al*., in preparation), both in Hampshire, were also favoured as locations for short-term camps, probably exploiting seasonally available produce. Flint assemblages of this period consist of large quantities of finely worked and highly portable tools in a much greater variety of forms than in earlier periods. Assemblages show not only regional variation in composition and technology but also local variation and intra-site differences indicating specific activity areas and the performance of a number of different tasks. Bone tools are also found.

The impression is one of a highly mobile and very adaptable population, skilled in hunting, fishing and gathering, spreading rapidly throughout much of England and Wales. Entry points into southern Britain could have been many since, although the climate was changing rapidly and marine influence in the Channel area advanced quickly, at the time of the earliest recolonisation, sea level would have been around -80 to -110 m and, for a comparatively brief period, the Channel almost entirely dry land. We might envisage a vast undulating plain with trains of gravel deposited by retreating waters with bars and dunes of blown sand, many intermittent cliff lines, relict river channels and the great northern barrier of the high chalklands, rising to nearly 600 m above the plain. The Chalk itself probably presented a cold and bleak landscape for many generations, dissected by rivers whose courses would have downcut rapidly as meltwaters poured out of the receding icesheet. The middle parts of these valleys, in turn, became filled with solifluction deposits as large surface areas of the periglacial landscape turned from permafrost essentially to sludge and slumped, creating unstable slope deposits. The finer elements of these head and coombe rock deposits were flushed downstream leaving gravel bars and terrace-like formations.

The larger and wider valleys, such as the Test, Stour and Hampshire Avon, in contrast, seem to have contained much quieter watercourses in their middle reaches with braided streams flowing between low terraces and gravel spreads with intermittent development of bedded gravels, alluvial and meltwater deposits and stabilisation horizons including peats. Lower valleys were cut into what is now the near-coastal shelf and may have tumbled over the edge of low cliffs into a much-reduced, probably braided, watercourse within the Northern Palaeovalley.

The South Coast REC area is thus likely to have presented a generally very favourable habitat, albeit still a cold one prone to dust and sand blows, for Upper Palaeolithic herd animals and humans alike. A combination of open grassland, fresh water, vantage points for hunting and the possibility of rock shelter sites was available. As the climate warmed so vegetation would have changed, producing a mosaic of habitat zones with increasing maritime influence. Almost anywhere within the marine zone where buried sediments survive has the potential to produce Upper Palaeolithic material. In particular, land forms indicative of bluff positions overlooking former river channels, cliff lines that may preserve infilled fissures or be fronted by slump deposits or sand accumulations, and palaeochannels containing peat deposits indicative of stabilisation horizons or lag deposits of large clast-size gravels, have high potential for the preservation of such material.

A further potential area of interest would be any remnant cliff lines associated with Greensand formations. On the southern edge of the Weald are a series of fissures or 'gulls' lying back from the scarp slope of the Greensand ridge. Gulls are superficial structures usually trending parallel to the strike of cambered strata which are best developed where gently dipping strata, such as sandstone or limestone, overlie thick clays (e.g. Hythe Beds overlying Atherfield Clay) and arch over the crests of escarpments. Gulls develop associated with this arching. They may have provided shelter when open but, equally importantly, in the Weald, these fissures have become filled with material from

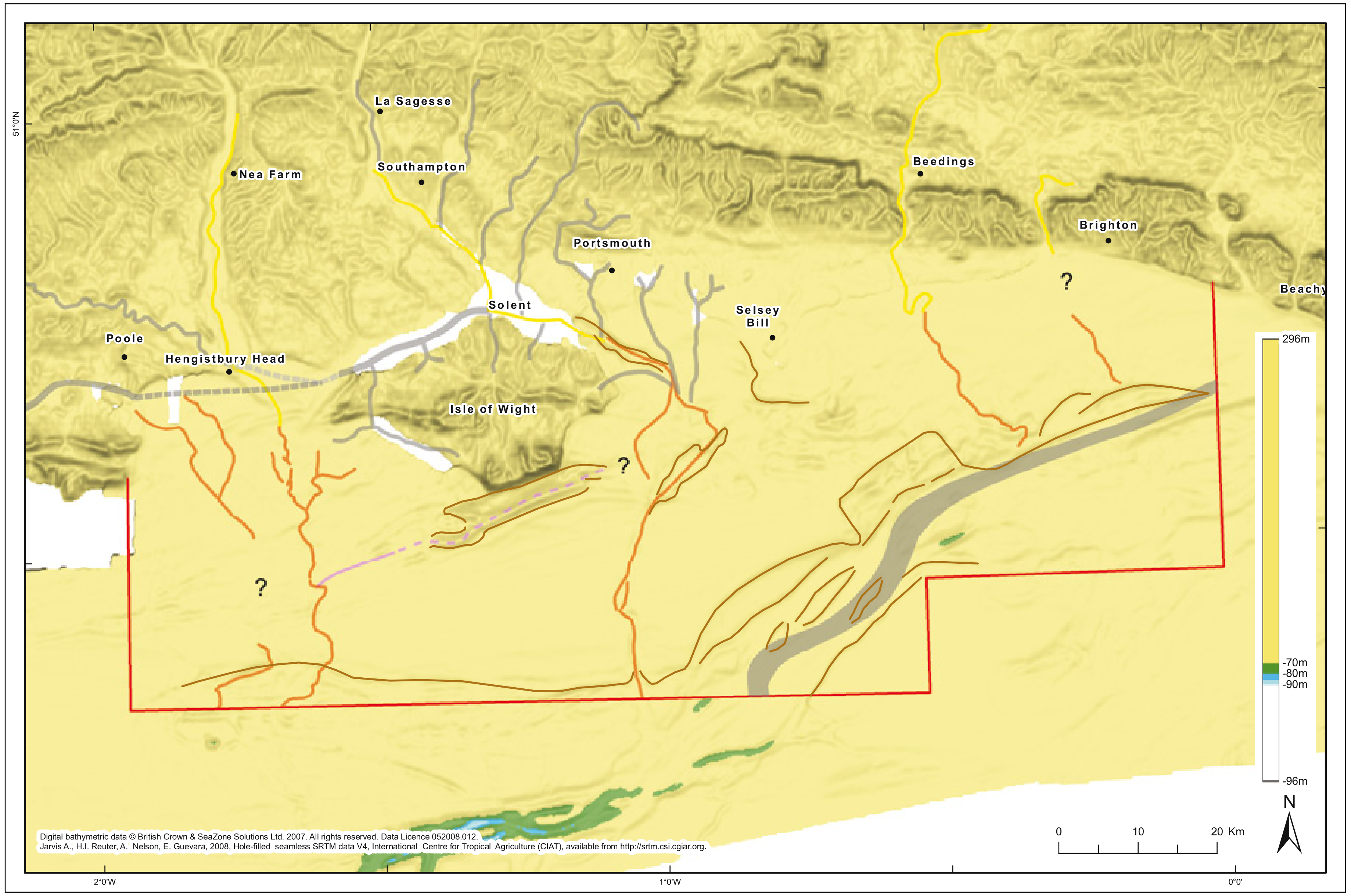


Figure 5.11: South Coast REC study area modelled with sea level at -80m, illustrating Scenario 4 at c.12,000 BP.

above and may contain faunal remains and/or Upper Palaeolithic artefacts (Jacobi, 2007). At Beedings, Pulborough, large quantities of early Upper Palaeolithic flints were found associated with such a gull *(ibid.)*. The survival of similar cliff lines is indicated to the east of the Isle of Wight (Figure 5.12). An archaeological assessment of dredging area 451 25 km east of St Catherine's point, identified the presence of valley side cliff tops and spurs overlooking the developing estuary of the Solent River, and of similar spurs flanking the narrow gorge through which the lower reaches of the river passed (Wessex Archaeology, 1998). In the event of the survival of suitable deposits these would seem to be areas of particularly high potential (Region 2 into 4).

Scenario 5. 9500–5000 cal BC (calibrated radio carbon date). Mesolithic Holocene-Flandrian developments (sea level at c.-30 m and rising) Figure 5.13

Around 11,000 BP there was a rapid return to sub-Arctic conditions such that it seems possible that Britain was once again deserted by humans and much of southern England was a dry, cold desert. Within a thousand years, however, sharp rises in temperature were accompanied by an equally rapid rise in sea level. Sometime during the 9th millennium BC Britain became an island. Much of it was occupied by seasonally mobile human groups exploiting an ever more diverse range of resources and leaving behind many thousands of assemblages of artefacts testifying to an organised and diverse lifestyle ranging all across the landscape. River valley sides and lakesides, especially bluff locations overlooking rivers with locally available flint sources, and locations close to spring lines, were particularly favoured as were the lower benches associated with the Greensand formations of the Wealden edge, where early Mesolithic flintwork is especially abundant. On the high Chalk there is a clear association between Mesolithic assemblages and superficial deposits of gravels (Gardiner, 1988). This association is not random but probably reflects obvious differences in vegetation type and available resources. Other Tertiary deposits

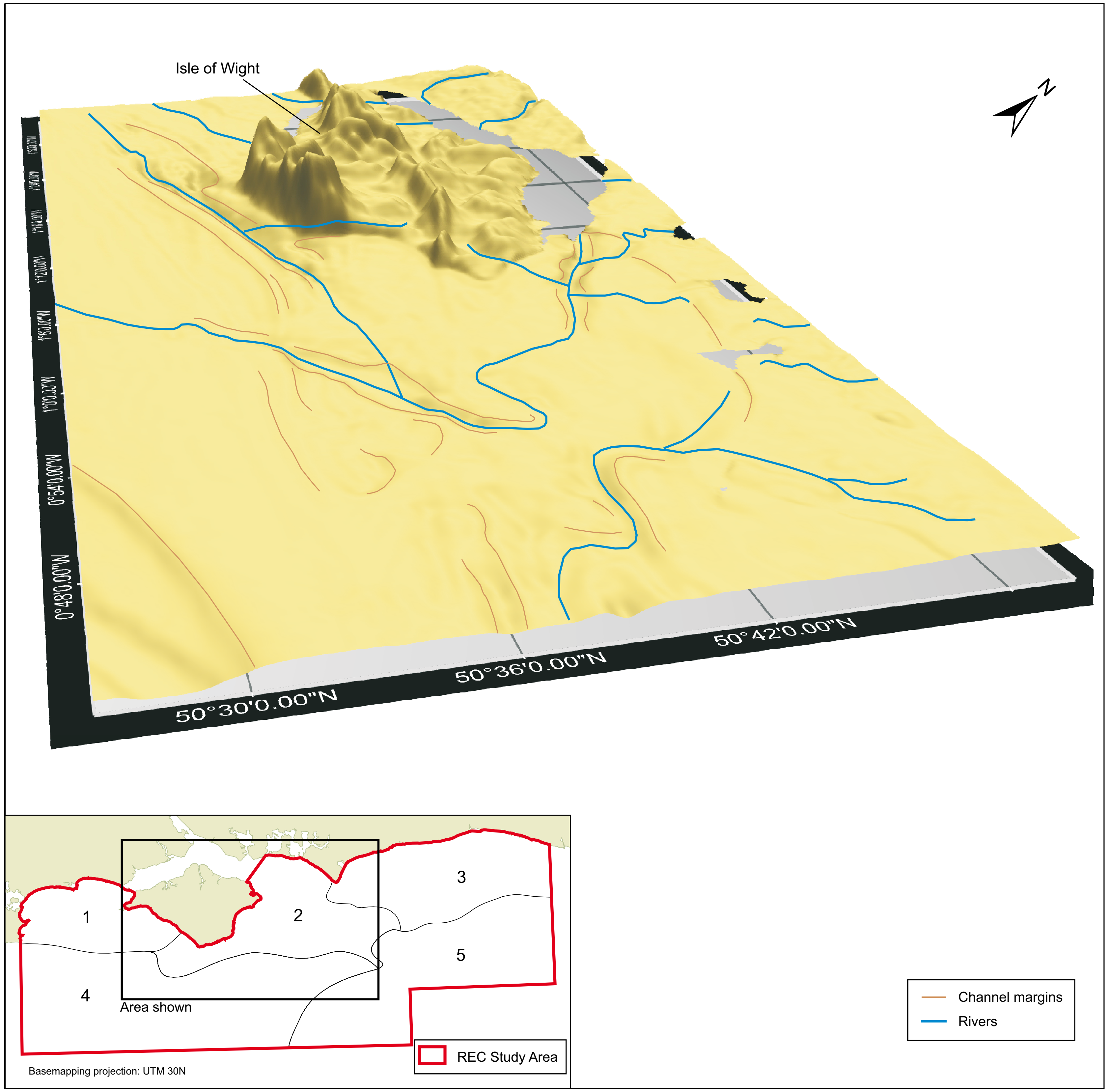


Figure 5.12: Possible landform features off the Isle of Wight.

such as Clay-with-flints, Woolwich Beds and Reading Beds, were specifically exploited for flint (*ibid.*; Care, 1982).

Current terrestrial areas adjacent to the Solent abound in Mesolithic flintwork ranging in date from the earliest recolonisation period to the 5th millennium BC and these distributions are known to extend into the intertidal zone and beyond. Rising sea levels resulted in the drowning of some valleys and gradual infill of others with fine sediment. The current harbours of the Solent coast are fringed with Mesolithic finds washing out from the intertidal saltmarshes. Research in Langstone and Chichester Harbours (Allen and Gardiner, 2000; Cartwright, 1982) has indicated the presence of substantial assemblages of flintwork associated with hearths and well-preserved animal bone assemblages. The raw material employed was the immediately available, generally small, nodular gravel flint which was perfectly adequate for the much smaller tools in use at this time.

Langstone Harbour is a shallow basin, developed as part of a low-lying, dry, largely grassy coastal plain supporting some stands of hazel, birch, pine, elm and oak (Bellamy, 1995), that extended from Southampton Water to Brighton. This was fronted by saltmarshes and gravel bars, and probably contained a few freshwater pools or small lakes formed in former ice-wedge features and by ponding. Areas of marshland akin to the Amberley Wild Brook near Lewes in East Sussex may be envisaged. Langstone itself was crossed by at least two deeply incised, steep-sided valleys with flat floors at about 13 m bOD. Constrained floodplains supported rich damp vegetation, promoting the growth of floodplain and possibly channel peat (Allen and Gardiner, 2000) (Figure 5.14). This scenario is likely to have been typical of much of the extended coastal plain (Bates and Briant, 2009).

To begin with, net erosion of lower river valleys can be demonstrated but as climate ameliorated and sea levels rose, this gave way to net accretion and the deposition of inorganic silts, muds and sands which filled valleys and cloaked large areas of the current intertidal zone (Mottershead, 1976; Scaife and Burrin, 1983; Burrin and Scaife, 1984; Allen and Gardiner, 2000). However, the driving force within the harbours may not have been sea level rise alone — accretion of over-bank and channel alluvium would have raised valley floors resulting in shallower gradients, decrease in river velocity and ponding. Seasonal waterlogging with freshwater did, however, gradually give way to estuarine and

- South Coast REC Study Area
- Peat deposits
- Channel margins
- Rivers/channels: Bridgland 2001
- Rivers/channels: Bridgland 2001 (Early Pleistocene)
- Rivers/channels: Bridgland 2001 (date unknown)
- Rivers/channels: South Coast REC from bathymetry/Lidar data
- Rivers/channels: BGS interpretation
- Rivers/channels: Hamblin et al 1992
- Rivers/channels: Hamblin et al 1992 (date unknown)
- ? Rivers/channels: Unknown

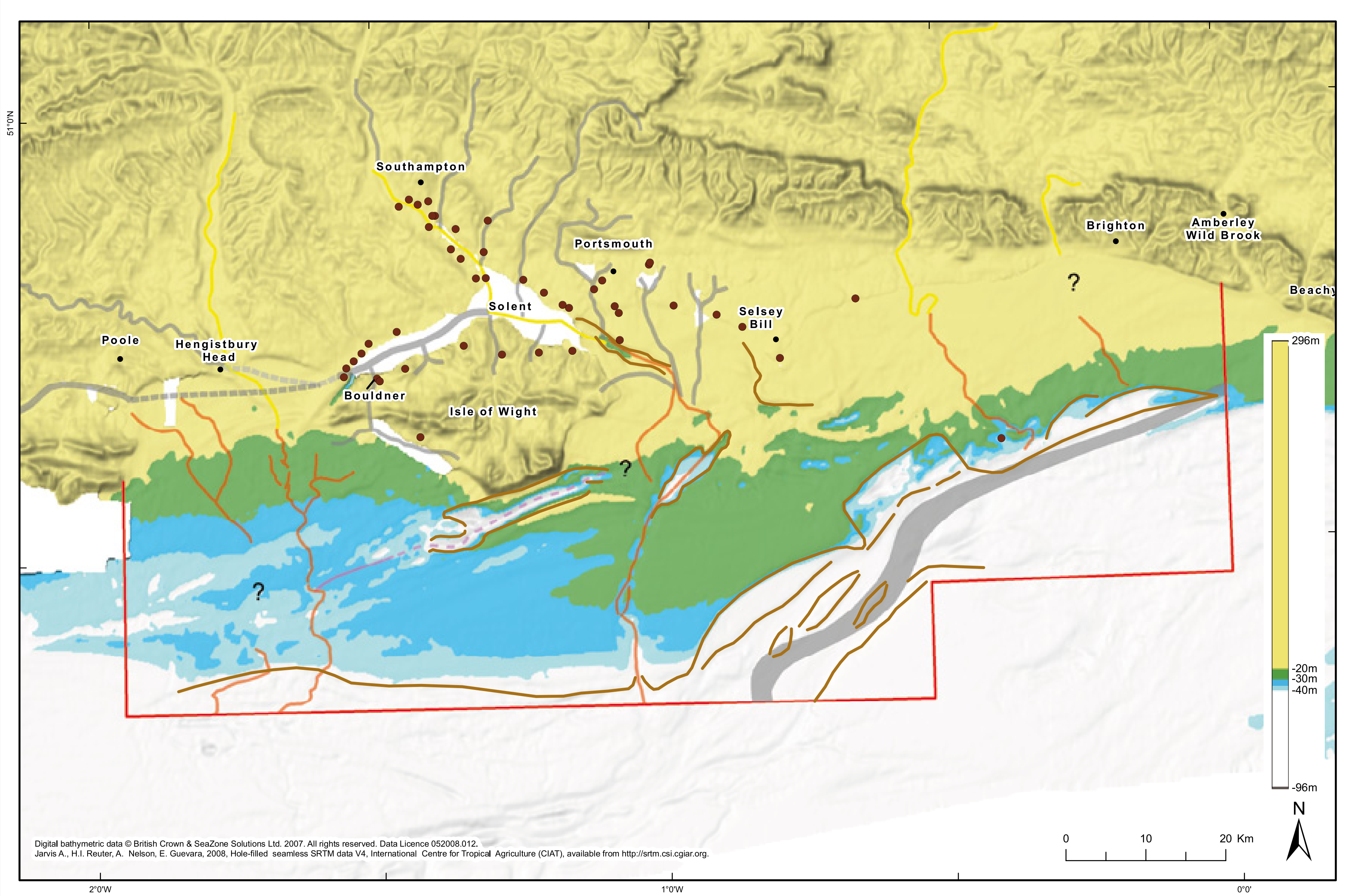


Figure 5.13: South Coast REC study area modelled with sea level at -30 m, illustrating Scenario 5 at c.9500–5000 cal BC.

marine influences, including probably the creation of occasional inland brackish lagoons, and eventual marine inundation.

Portsmouth and Southampton harbours present rather different morphologies with much larger, deeper channels containing peat deposits (Figure 5.14). Deep peat-filled channels have been identified at c.20 m bOD (Bellamy, 1995). The outer reaches of Southampton Water were probably inundated around 7000 cal BC with estuary drowning of extensive alder-dominated woodland by about 5000 cal BC.

Mesolithic sites also occur in the valleys of the Yar and Medina on the Isle of Wight as well as offshore. At Bouldnor Cliff a Mesolithic site lies at the base of the cliff c.12 m below sea level. Flint artefacts are associated with charred hazelnut shells and oak charcoal. Environmental and sediment analyses have indicated the presence of a semi-stable river bar associated with a river channel that saw seasonal Mesolithic encampment during the summer. Local pine woodland gradually gave way to oak and hazel, with alder probably fringing the rivers and streams. In time the vegetation changed, indicating the onset of wetter environmental conditions. The diatom assemblage showed brackish water, saltmarsh or mudflat habitat developing before complete marine inundation. Peat layers have been cored further offshore here and the remains of oak and pine forest recorded and dated to the 9th millennium BC (Hosfield *et al*., 2009).

Archaeological material currently present in the Solent harbours (and in the mudflats of Wootton-Quarr at the north-east end of the Isle of Wight's northern shore) is subject to tidal erosion, especially where dieback of spartina grass is exposing the saltmarshes to repeated wave action. Artefacts tend to lie around

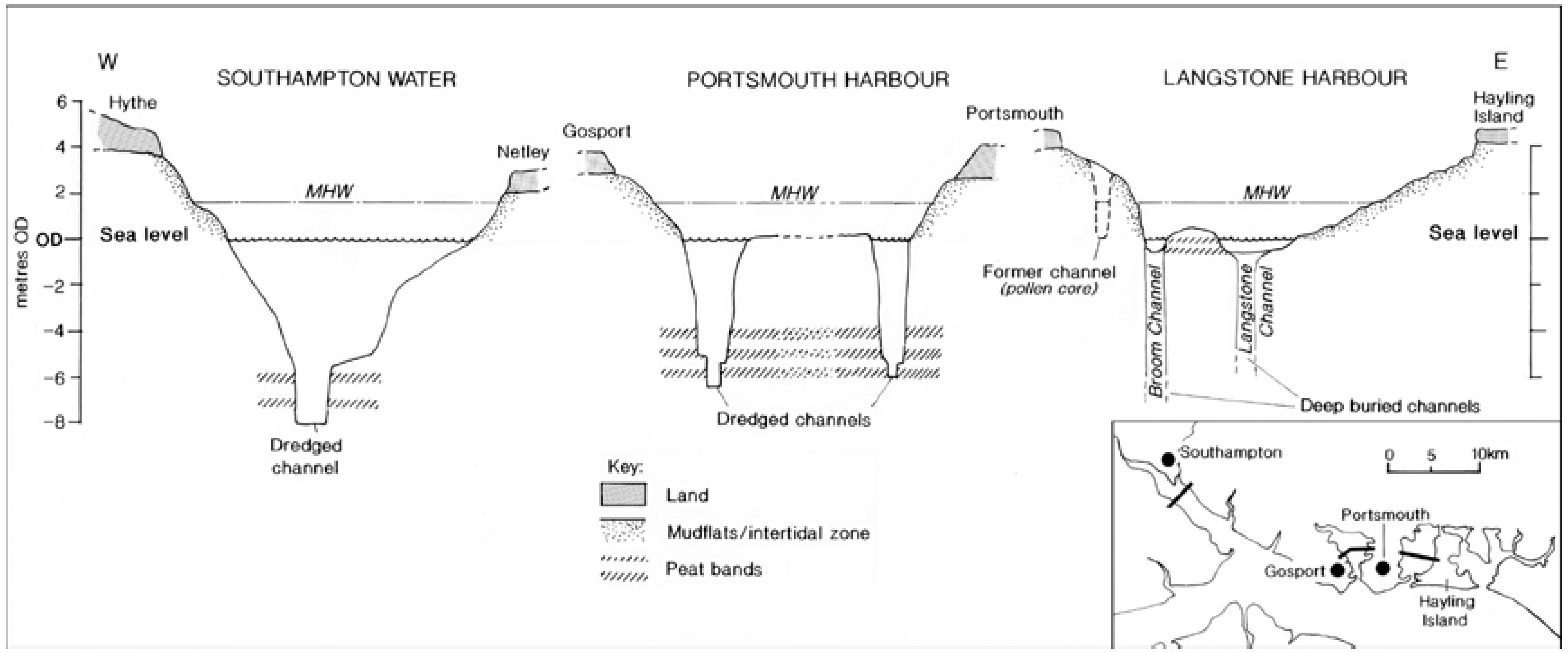


Figure 5.14: Cross-section comparing Southampton, Portsmouth and Langstone Harbours showing the deeply incised channels and buried levels in Portsmouth and Southampton and the shallow eroded nature of Langstone (Allen and Gardiner, 2000).

in the mudflats until washed out on spring tides and storm surges and may be redeposited in delta-like formations beyond the harbour mouth (such a formation is clearly visible on Google Earth, for instance, to the east side of the mouth of Langstone Harbour at 50° 46' 46.82" N 1° 00' 58.85" W or National Grid Reference SZ 6995 9650).

The coastal plain extended across the offshore marine shelf where it was dissected by the lowest reaches of the various southward flowing rivers and tributaries that emptied into the Northern Palaeovalley about 30 km off the present shore. Rivers flowing through the shallow basins that are the Solent harbours probably had their confluence with the main Solent river some kilometres south of Chichester, the combined watercourse turning south-south-west. As discussed above, where such palaeochannels have been identified it is clear that individual histories of channel formation and infill can be both complex and varied.

Vibrocore data from the Palaeoarun (Region 3) revealed peat deposits indicative of periods of sub-aerial exposure dating to the 11th-10th millennia BC in a temperate, mature woodland environment (Gupta *et al.*, 2004). Organic rich clays interleaved with sand lenses dating to around 10,500 cal BC were deposited in estuarine or peat marsh conditions prior to inundation. Further vibrocore data in the area of the Palaeoarun valley, 18 km offshore from Littlehampton, which included peat deposits dated to the 11th–10th millennia BC (NZA-19276-9), recorded several detailed pollen sequences. Valley floor sequences in the area of the main channel indicated rapid deposition of some 5 m of sediment, initially with aquatic fen adjacent to slow moving water with local saltmarsh or periodic ingress of salt water. Boreal woodland developed in the early Mesolithic bordering grass-sedge reed swamp or fen with increasing salinity (Wessex Archaeology, 2008a; 2008c; 2008d). The pollen sequence from the wider valley edge indicated an early Mesolithic birch and pine woodland fringing a wetland freshwater and reed swamp habitat. This was followed by a marked change in vegetation indicative of a hiatus in deposition and formation of a stabilised land surface with mixed deciduous woodland followed by increasing wetness, overbank flooding and saline/brackish influence. Grab sampling recovered *Phragmites* peat which incorporated oak charcoal radiocarbon dated to 8230–7740 cal BC (8893 ± 30 BP and 8815 ± 40 BP; NZA–26303, SUERC–12007; Wessex Archaeology, 2008a; 2008c; 2008d). Environmental remains included both freshwater and terrestrial molluscs as well as amphibian bones and beetles, twigs and reeds. Nearly 700 pieces of struck or probably struck flint were recovered, some of which bore attributes of early Mesolithic technology. Limited information on the distribution of this material showed that it was most closely associated with the wider valley edges and coincided with the occurrence of the charcoal.

Environmental evidence from the Dorset coast within the South Coast REC area is limited. Christchurch Harbour is fringed by findspots of Mesolithic flintwork, including on Hengistbury Head, but most of this comes from surface collection with no associated environmental sampling. The stretch of coast between Hengistbury and Poole is also prolific in Mesolithic findspots. Velegrakis *et al.* (1999) consider that, following breaching of the Purbeck-Needles Chalk ridge, an embayed coastline developed with subsequent rapid drowning of the lower reaches of rivers that had formerly drained into the Solent River occurring as sea level rose. Poole Harbour has preserved transgressive sequences within the palaeovalleys it contains and peat deposits dating to the 8th millennium BC have been recorded. Inundation of peat bogs around Wareham in the Neolithic is also indicated. Christchurch Harbour, however, seems to have been inundated later and very quickly, without the deposition of transgressive sediments and today is a fairly high energy environment so may not preserve evidence of Holocene land surfaces. Off-shore only shallow sediments are preserved *(ibid.)*.

This evidence indicates the clear potential for recovery of Mesolithic artefactual material and Holocene land surfaces in the rapidly infilled palaeovalleys of the shelf area. The distribution of known (but mostly undated) peat deposits is shown in Figure 5.13. Sub-bottom profiler data indicate the presence of a large number of palaeochannels off the Sussex coast (Regions 3 and 5) which have the potential for containing archaeological material. Preserved sediments resting against former terrace edges or river cliffs could also preserve artefacts of this period. Any dredging or aggregate removal in the shelf area in Region 3 therefore has the potential to encounter such material and grab sampling exercises (Wessex

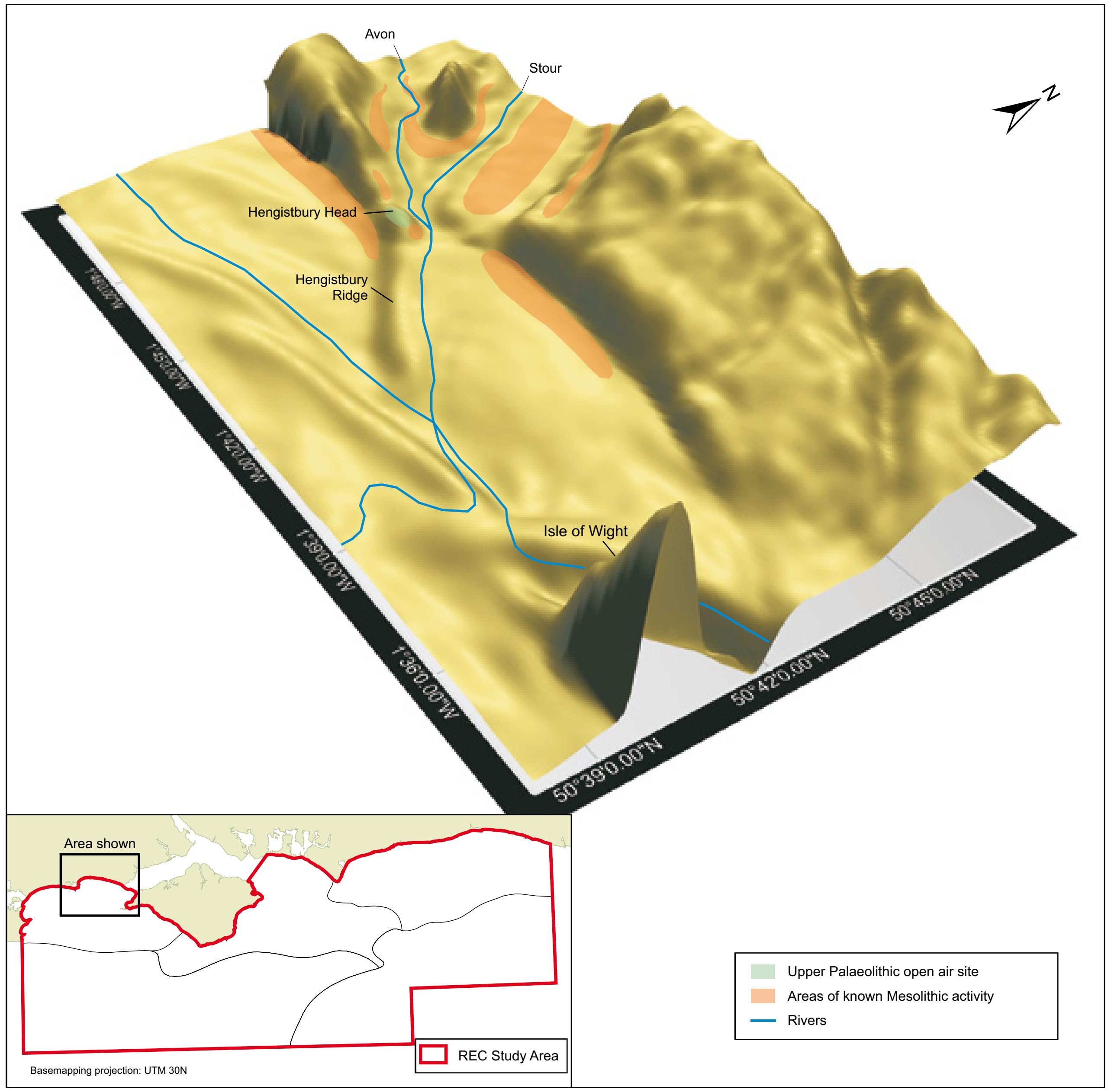


Figure 5.15: Isometric view of the northern part of Christchurch Bay in the early Mesolithic with sea level at -40 m (c. 8500 cal BC). Areas of known archaeological activity highlighted.

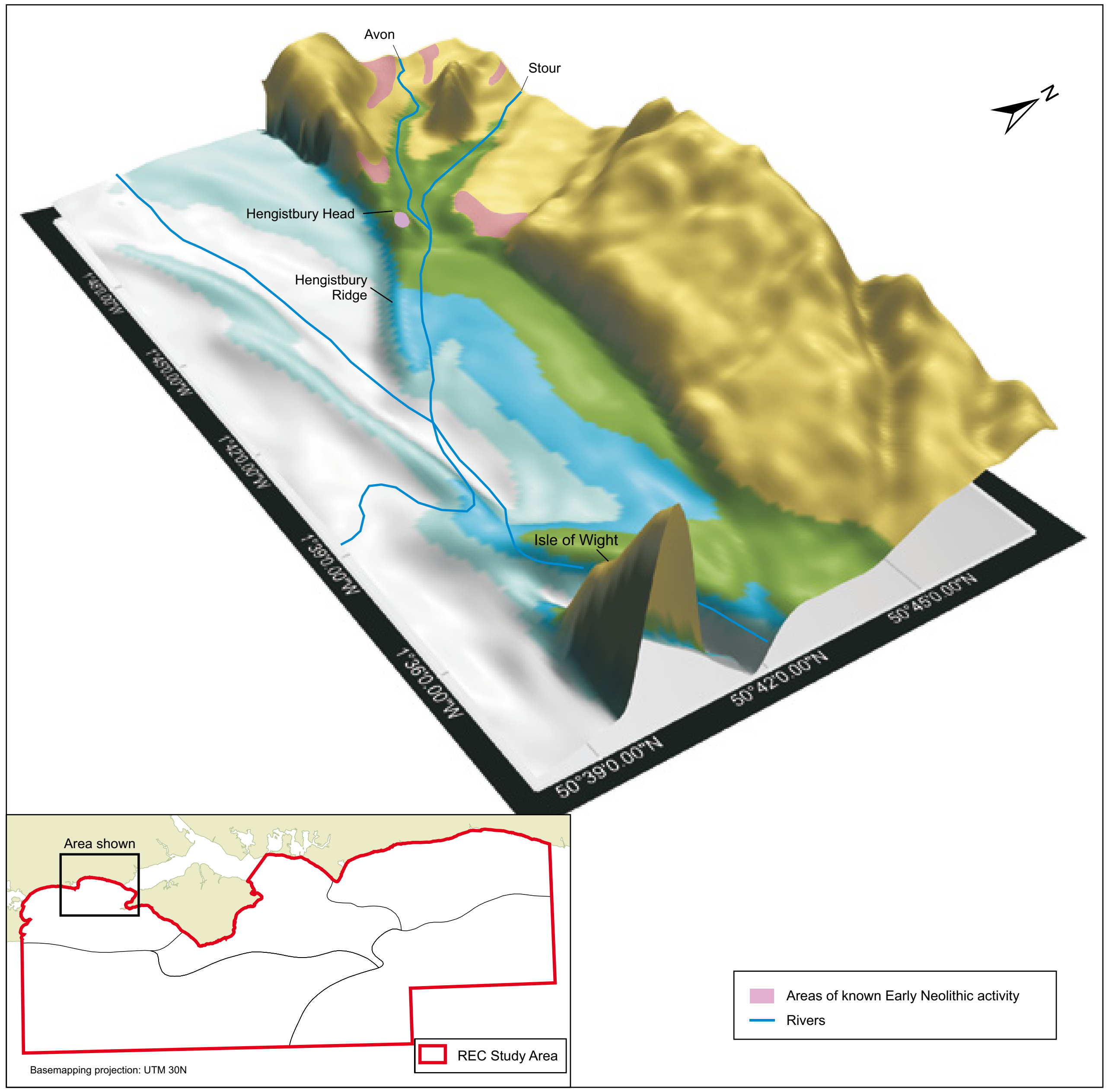


Figure 5.16: Isometric view of the northern part of Christchurch Bay in the Early Neolithic with sea level at -5m (c. 4000 cal BC). Areas of known archaeological activity highlighted.

Archaeology, 2008c; 2008d) indicate that peat bodies may lie close to the surface of the sea bed.

A series of south-east to south flowing, Late Devensian, palaeovalleys have been recorded off the Dorset coast, developed after breaching of the Chalk ridge (Devoy, 1982; Velegrakis *et al*., 1999). The western Poole Bay area, off Poole Harbour, contains preserved sedimentary sequences within infilled palaeovalleys but there is no clear evidence for a continuation of a major river valley in Christchurch Bay that would have constituted the lower reaches of the Stour and Avon. Velegrakis *et al*. (1999) suggest that the radical change in hydrodynamic conditions resulting from the breaching would have led to massive erosion in this area. Sea bed dynamics would have been further affected by the 'Hengistbury Ridge/Christchurch Ledge' which survives on the axis of the former ridge. Consequently, while the Poole Bay palaeovalleys may contain archaeological material it seems unlikely that much will be preserved in the marine zone at any distance off the coast between Christchurch and the Needles (Region 1). Most of the material recorded in this area is from the current inter-tidal zone or eroding from sea cliffs and Mesolithic tranchet adzes have been recovered in near-shore oyster dredging off Lymington (Wessex Archaeology, 2004c). Figures 5.15 and 5.16 present a comparison of the topography and possible drainage of the northern part of Christchurch Bay in the early Mesolithic with sea level at -40 m (c.8500 cal BC) and Early Neolithic with sea level at -5 m (c.4000 cal BC).

5.2.5 Later prehistoric

Sea level continued to rise, though more gently, through the Neolithic and Bronze Age. Very low tides occasionally expose fallen trees and tree stumps representing former forests growing on the Mesolithic and Neolithic coastal plain. In Langstone oak and yew trees with an understorey of alder and willow were growing on a peaty land surface beside a palaeochannel at c.1 m bOD in the Neolithic (4431 ± 70 BP and 3735 ± 60 BP: R-24993/1–2). Examination of cross-sections indicated that the mature trees suffered stress as the result of increasing salinity. Reid (1913) described the submerged forests of the Solent coast and bemoaned their ongoing erosion. Their extent has been much reduced since that publication but occasional recent reports of Neolithic forest remains have been made. Examples include fallen trunks in intertidal, former channel edge, locations at Littlehampton (Allen *et al*., 2004), apparently associated with red and fallow deer bones and antlers, at depths of up to 3 m bOD. At Wootton-Quarr, on the Isle of Wight, tree stumps have been found *in situ* as well as wooden structures dating to the Neolithic and Bronze Age (Tomalin *et al*., in preparation).

Wooden structures, including fish traps, jetties and possible causeways are features of all the harbours and many parts of the coastline. While a majority belong to the historic period, some may be much older. A close alignment of oak timber stakes, recorded at Northney on the north coast of Hayling Island, for instance, seems to represent part of a causeway dating to around 1000 BC.

Throughout the Neolithic and Bronze Age the harbours slowly developed as first brackish and then tidal inlets. Their grass and saltmarsh margins seem to have been largely used on a seasonal basis for grazing livestock and for burial. A later Bronze Age urnfield extends from Portsmouth across Langstone Harbour and the present coastal margin and into Hayling Island. Extensive assemblages of worked and burnt flint also occur and a number of bronze objects have been recovered reflecting the later Bronze Age and Iron Age phenomenon of depositing metal goods in 'wet places' (Bradley, 1990). Neolithic and Bronze Age material is also present in large quantities on the foreshore and coastal margins of the Isle of Wight, especially off Wootton-Quarr. The area around Bournemouth and Christchurch Harbour is particularly abundant in both flint scatters and Bronze Age urnfields, indicating quite intensive settlement (Gardiner, 1987). By the Late Iron Age sea level approached its current level and the harbour margins and possibly other coastal areas such as that around Lymington seem to have been utilised largely for salt production and fishing with most settlement evidence confined to higher and drier land.

For the Neolithic onwards, therefore, the potential for recovery of archaeological material will be essentially confined to coastal margins.

5.2.6 Geophysical characterisation

The interpretation of the SCREC sub-bottom profiler data identified three types of features of potential archaeological interest. These are:-

- Cuts and fills (Figure 5.17);
- Erosion surfaces (Figure 5.18);
- Gas blanking (Figure 5.19).

A total of 47 features were identified in the South Coast REC data, all to the east of the Isle of Wight but this is a direct result of very limited sub-bottom profiler coverage (one line measuring 7.2 km) to the west of the island. A further 33 features were identified in the South Coast REA data and these are distributed to both sides of the Isle of Wight (Figure 5.20). These geophysical features and the palaeochannels interpreted from the bathymetry data demonstrate that the licensed aggregate areas target sand and gravel deposits associated with the infill, banks and terraces of the large palaeochannels which drained through the South Coast REC area (Figure 5.21).

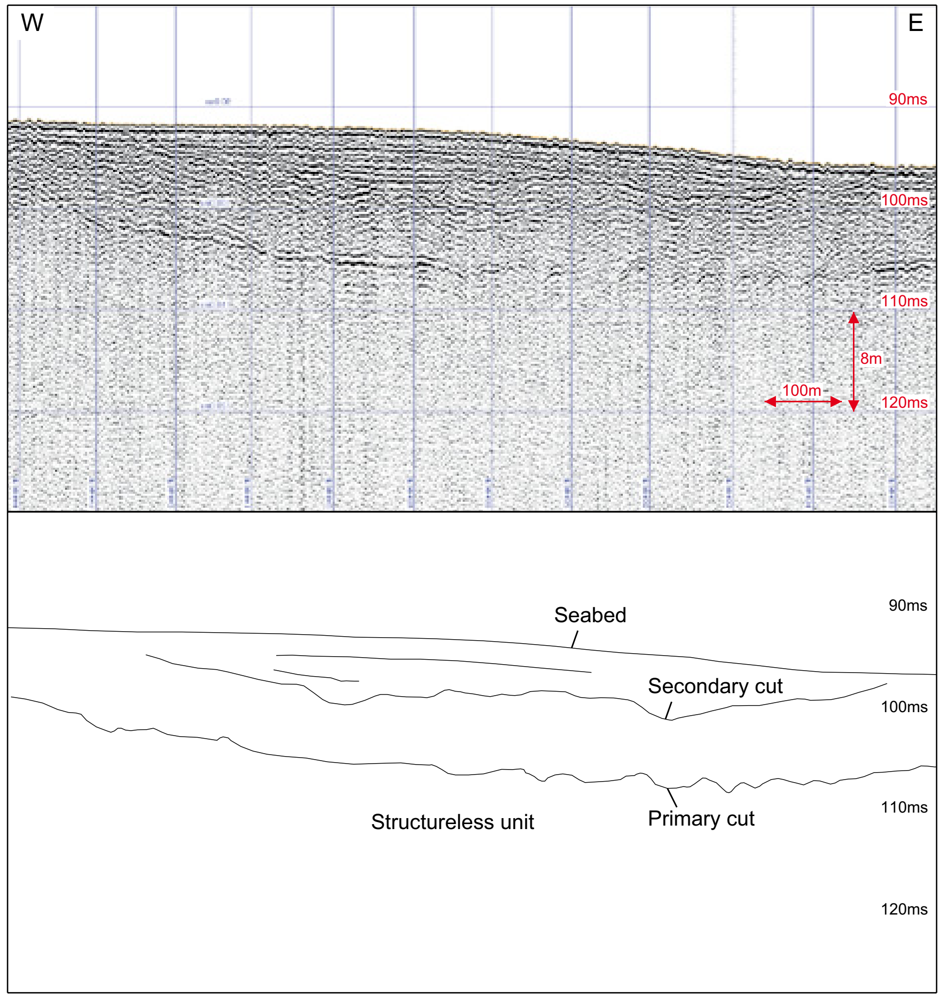
Cuts and fills were the most commonly identified feature type, with all but two in the REC dataset occurring in the east-west survey corridors (Figure 5.17). This is consistent with these features having been formed through erosion by rivers flowing off the land to the north. All but one of the features occur to the east of Selsey Bill, becoming more common in the area to the south of Brighton. Archaeological material may be associated with these features in a number of ways. An environment containing streams and rivers would have been an attractive one for hominins to live or hunt in and traces of their presence may remain. As described in Section 5.2.1, material may preferentially be preserved in palaeochannels as the deposits likely to contain artefacts are very vulnerable to erosion. Archaeological material deriving from coastal terrestrial contexts may also be found in these features as a consequence of material washed out of harbours and saltmarshes.

Erosion surfaces and gas blanking were less commonly seen, with nine occurrences of each. Erosion surfaces are similar to cut and fill features but differ in that they are shallower and typically undulating. They are present in locations that were once exposed land surfaces and subsequently infilled by sediments (Figure 5.18). As past land surfaces, these features have the potential to contain archaeological sites in primary contexts and also in secondary contexts within the sediment infill.

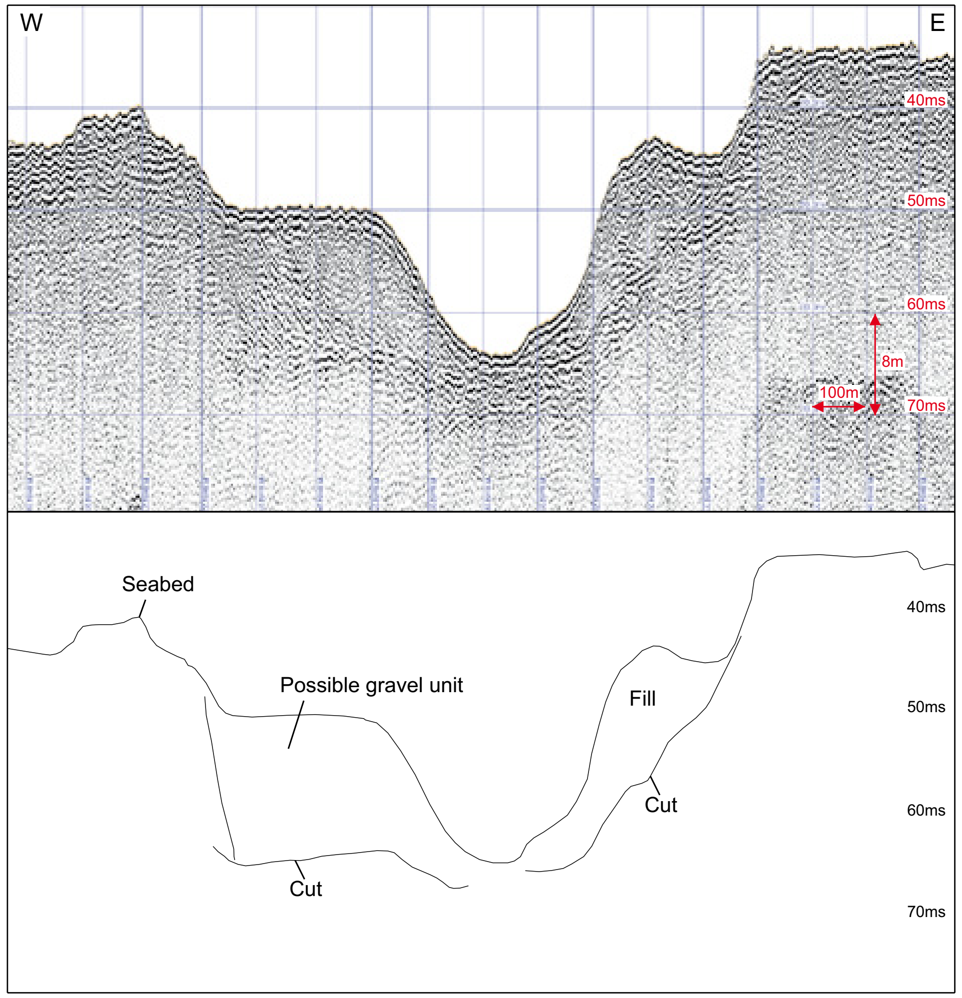
All nine occurrences of gas blanking occur in the eastern side of Region 5. Gas blanking occurs where gas is present as a product of microbial activity in organic matter within shallow sediments or alternatively it may have travelled along migration pathways from depth. It can be associated with channels, cuts and fills or erosion surfaces or may appear in isolation (Figure 5.19). Gas blanking can be associated with organic layers that may be of archaeological importance. Peat layers are indicative of periods of sub-aerial exposure and have high potential for the preservation of palaeolithic material. In addition, organic layers, predominantly peat, have the potential to provide material for absolute dating and for determining the type of landscape in existence in an area.

The widely spaced geophysical lines mean that it is not possible to study any one single channel in the detail to which the palaeoarun was studied in previous ALSF funded projects (Gupta *et al*,. 2004; Wessex Archaeology, 2007d–f). However, the REC data has helped to map out the extents of the palaeochannels in the east of the study area which could also be interpreted from the bathymetry data. This was done through drainage analysis which

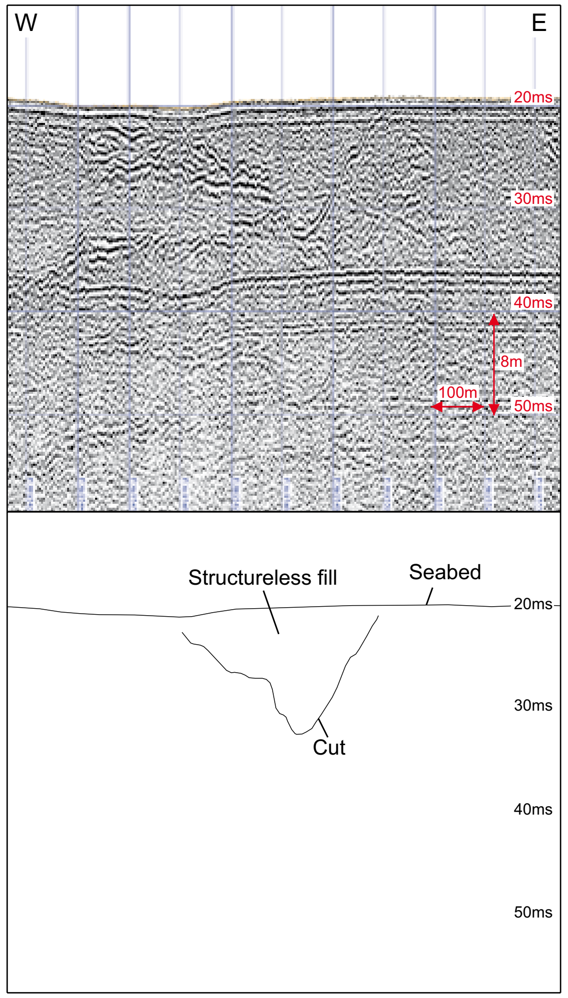
Figure 5.17: Sub-Bottom Profiler Anomaly Types - Cut and Fill



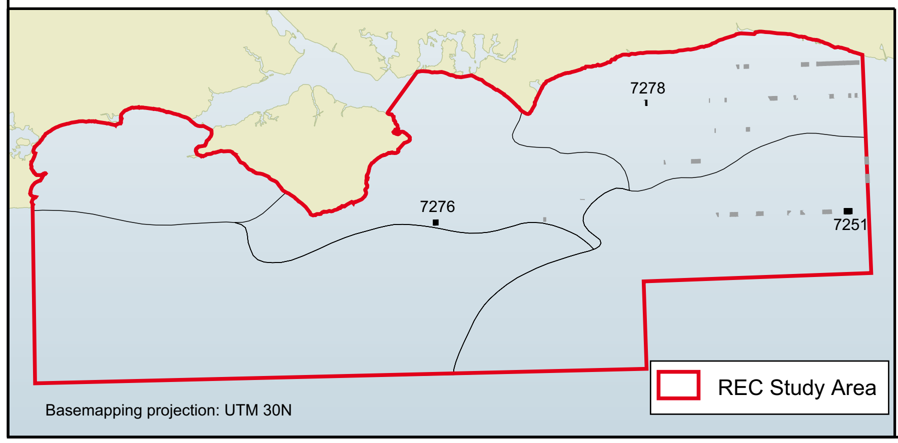
7251 - Region 5 - Primary cut into bedrock has an irregular surface. The bedrock appears structureless. The fill is discontinuous and chaotic. A secondary cut has been made into this unit. The fill above is clearly stratified and contains sub-parallel reflectors. It has an average thickness of 3.4 m with the secondary cut having a maximum depth of 5.6 m.



7276 - Region 2 - Cut at eastern side of a channel has a maximum depth of 8.7 m and a minimum depth of 0.7 m. Present channel appears to have been cut into the fill. Another cut on the western side of the channel has a maximum depth of 11.6 m and a minimum depth of 2.5 m. Possible gravel unit above containing chaotic slanting reflectors.



7278 - Region 3 - Cut containing structureless fill and with a maximum depth of 9.9 m and a minimum depth of 1.1 m. Unit below contains chaotic reflectors.

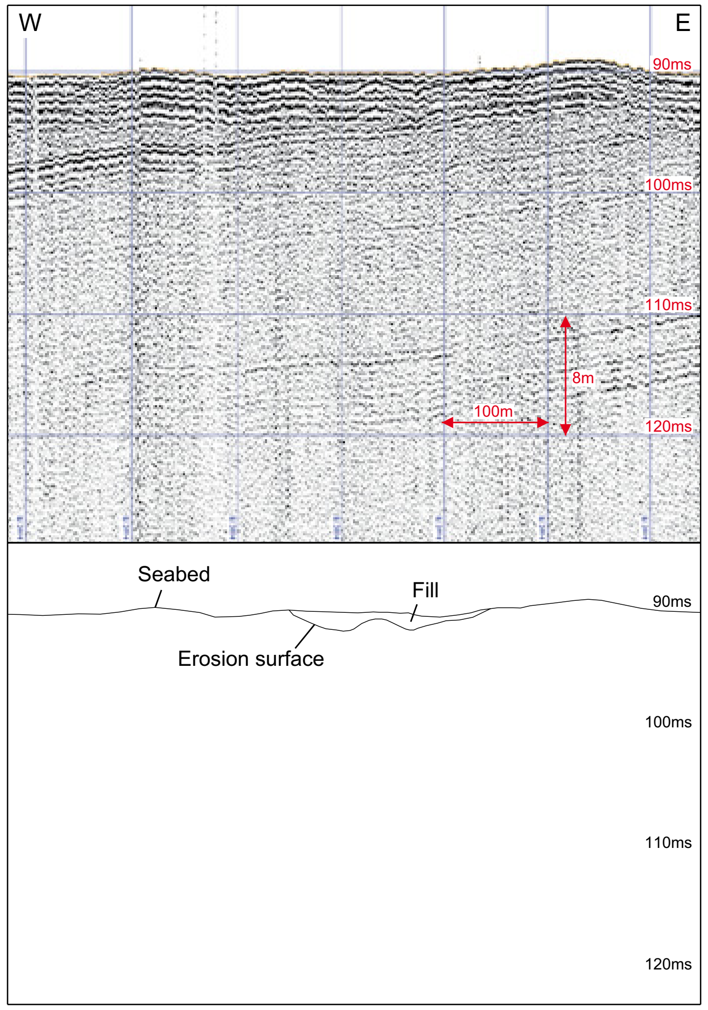


Cut and fill features consist of a cut into the underlying geology that has later been infilled by sediments. These features may contain several sequences of cuts and fills giving evidence of multiple phases of erosion and deposition.

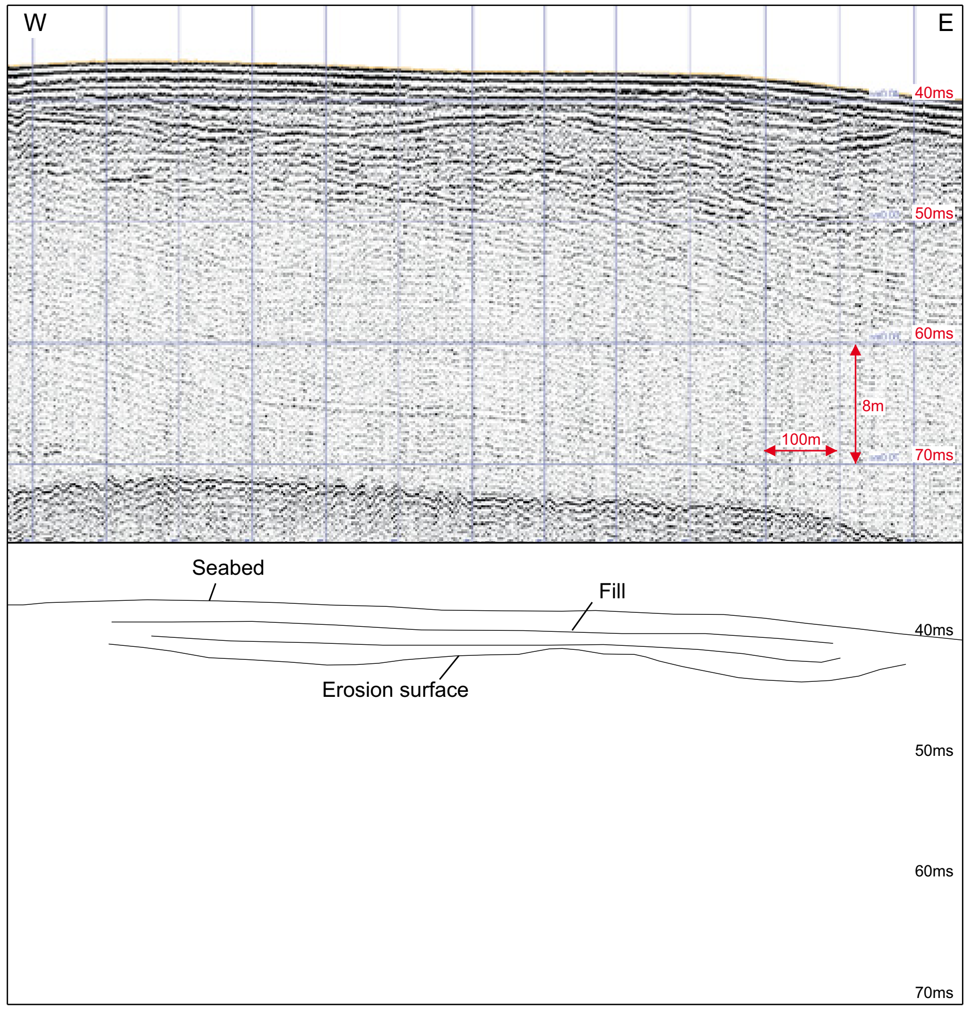
Distribution of cut and fill features across the physical regions

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Cut and Fill	13	16	20	3	9	**61**

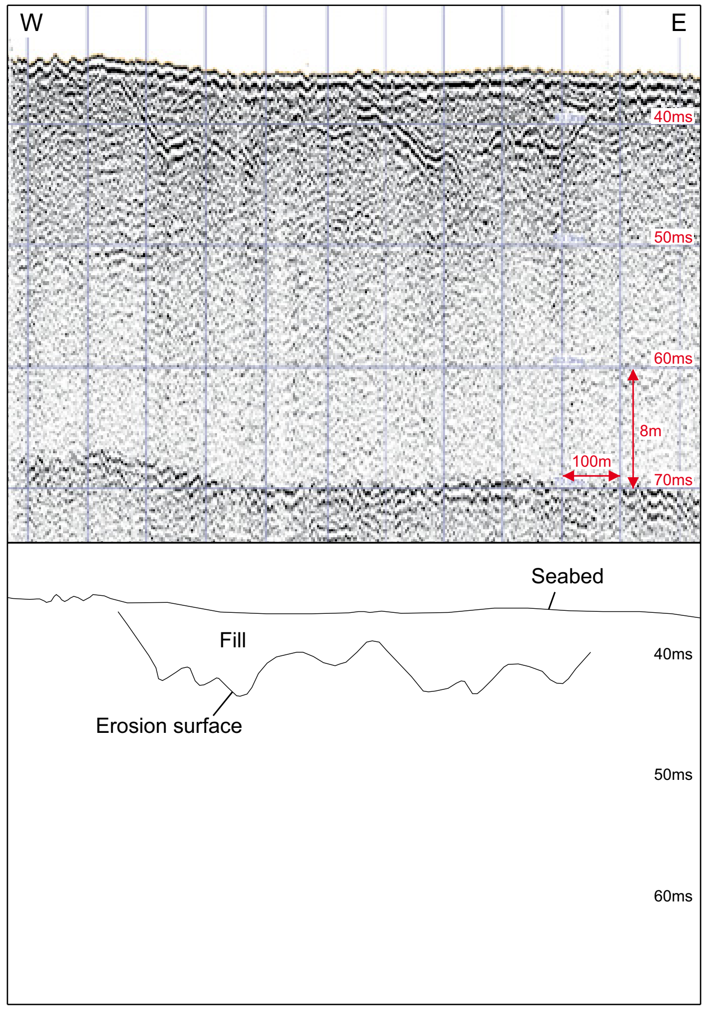
Figure 5.18: Sub-Bottom Profiler Anomaly Types - Erosion Surface



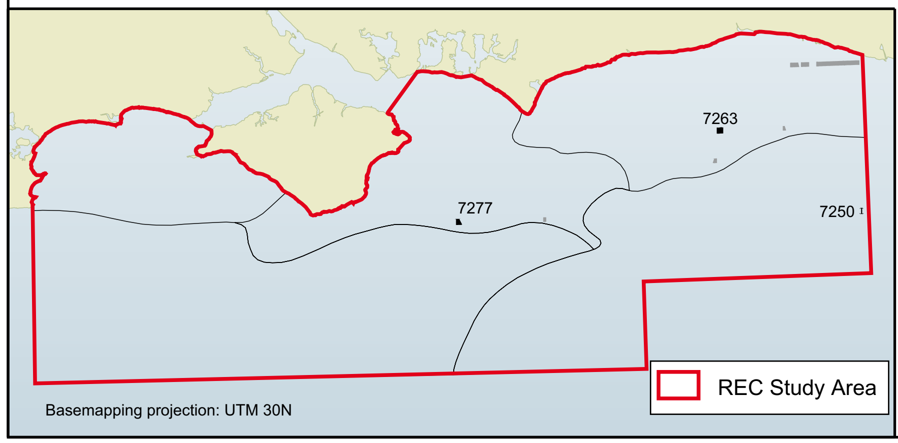
7250 - Region 5 - Very shallow erosion surface with fill to within 1 m of seabed. The fill character is not distinguishable. The erosion surface has a maximum depth of 1.3 m below the seabed.



7263 - Region 3 - Shallow, undulating erosion surface with a maximum depth of 4.1 m and a minimum depth of 2.1 m. The fill approaches to within 1 m of the seabed and is strongly stratified with parallel reflectors. Below erosion surface reflectors are less well-structured.



7277 - Region 2 - Erosion surface with a maximum depth of 5.3 m and a minimum depth of 1.1 m. The fill is structureless and approaches to within 1 m of the seabed.

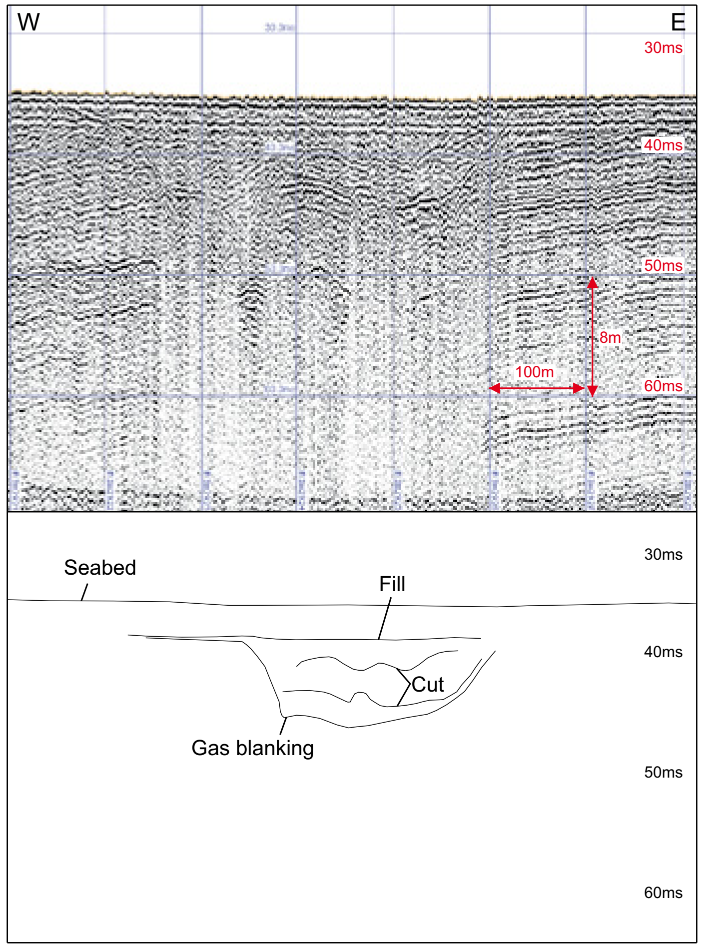


Erosion surfaces are features that were once exposed land surfaces and have been eroded and subsequently infilled by sediments. They differ from cuts in that they are shallower and typically undulating.

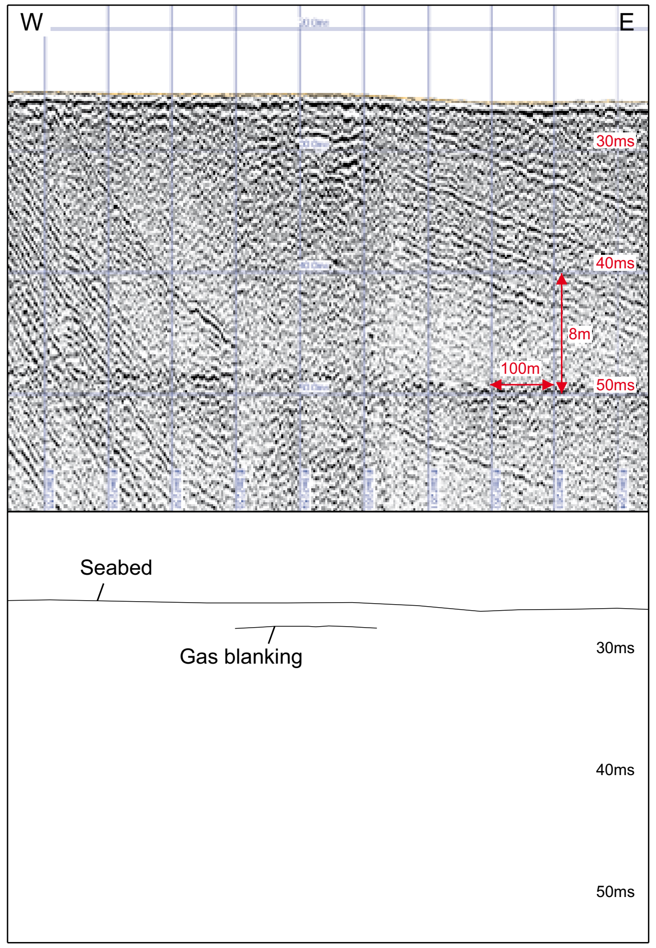
Distribution of erosion surfaces across the physical regions

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Erosion Surface	0	2	6	0	1	**9**

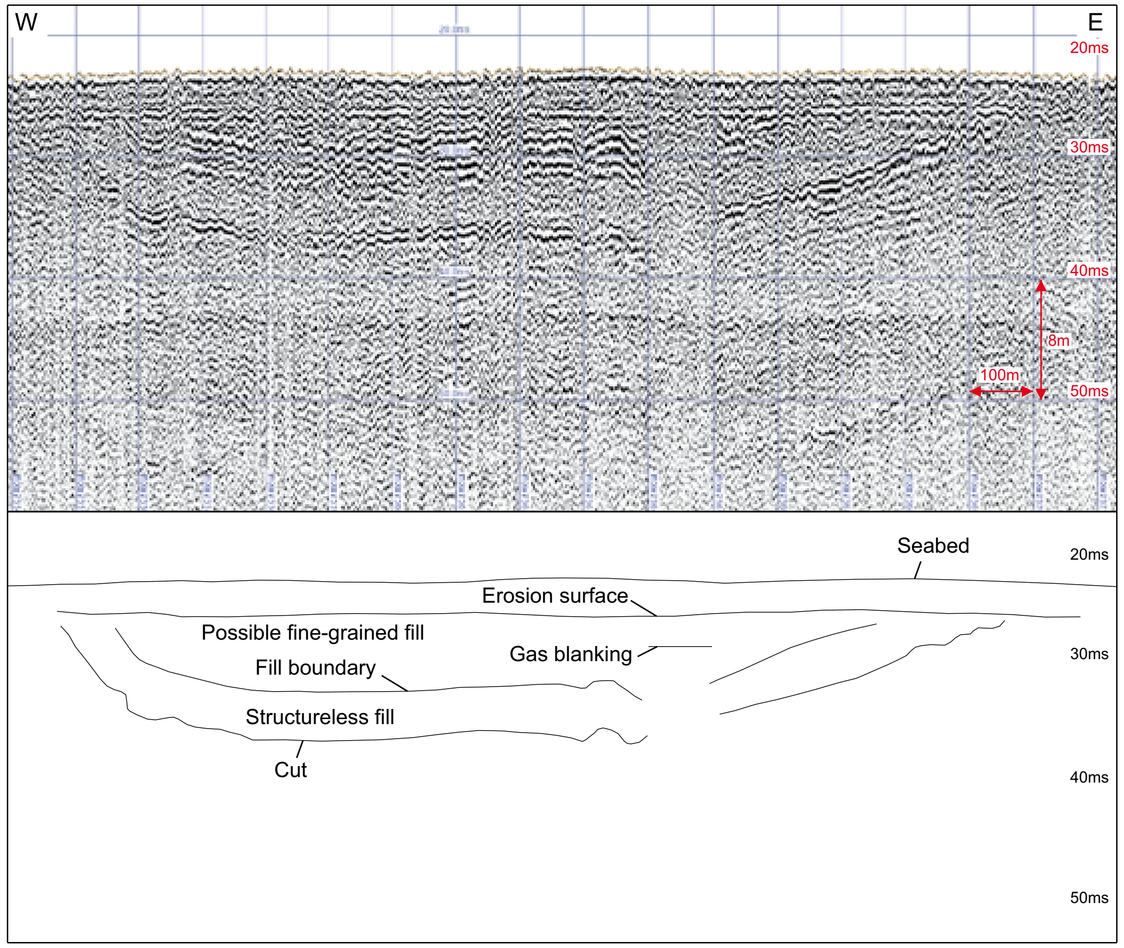
Figure 5.19: Sub-Bottom Profiler Anomaly Types - Gas Blanking



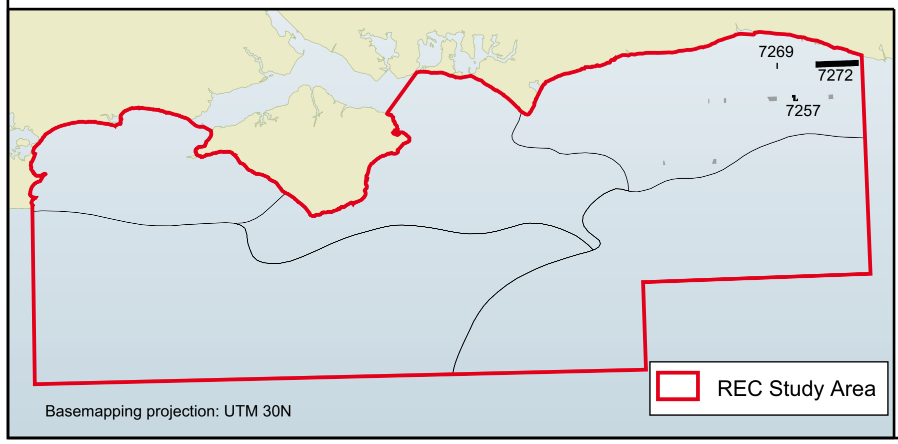
7257 - Region 3 - Possible channel features but indistinct. Gas blanking occurs beneath and to the west. The deeper cut has a maximum depth of 6.8 m and a minimum depth of 5.7 m. The fill contains a further incised cut with a maximum depth of 4.3 m and a minimum depth of 2.0 m. The fill contains irregular, undulating reflectors and is overlain by seabed sediments.



7269 - Region 3 - Area of gas blanking. The gas may be sourced from deeper geology or from organic sediments, it is not possible to tell from the data.



7272 - Region 3 - Cut with fill and gas blanking overlain by a long erosion surface. The cut has a maximum depth of 11.3 m and a minimum depth of 2.8 m. The fill in the base of the cut is structureless while the overlying fill unit contains strong sub-parallel, undulating reflectors. This upper unit is possibly fine-grained and is overlain by an erosion surface which extends approximately 3 km to the west and 2.5 km to the east. Gas blanking obscures part of the cut and fill.



Gas blanking is masking of seismic reflectors caused by the presence of gas in higher layers. The gas may be a product of microbial activity in organic matter within shallow sediments or alternatively it may have travelled along migration pathways from depth. Gas blanking may be isolated or associated with features such as channels, cuts, fills and erosion surfaces.

Distribution of gas blanking across the physical regions

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Gas Blanking	0	0	9	0	0	**9**

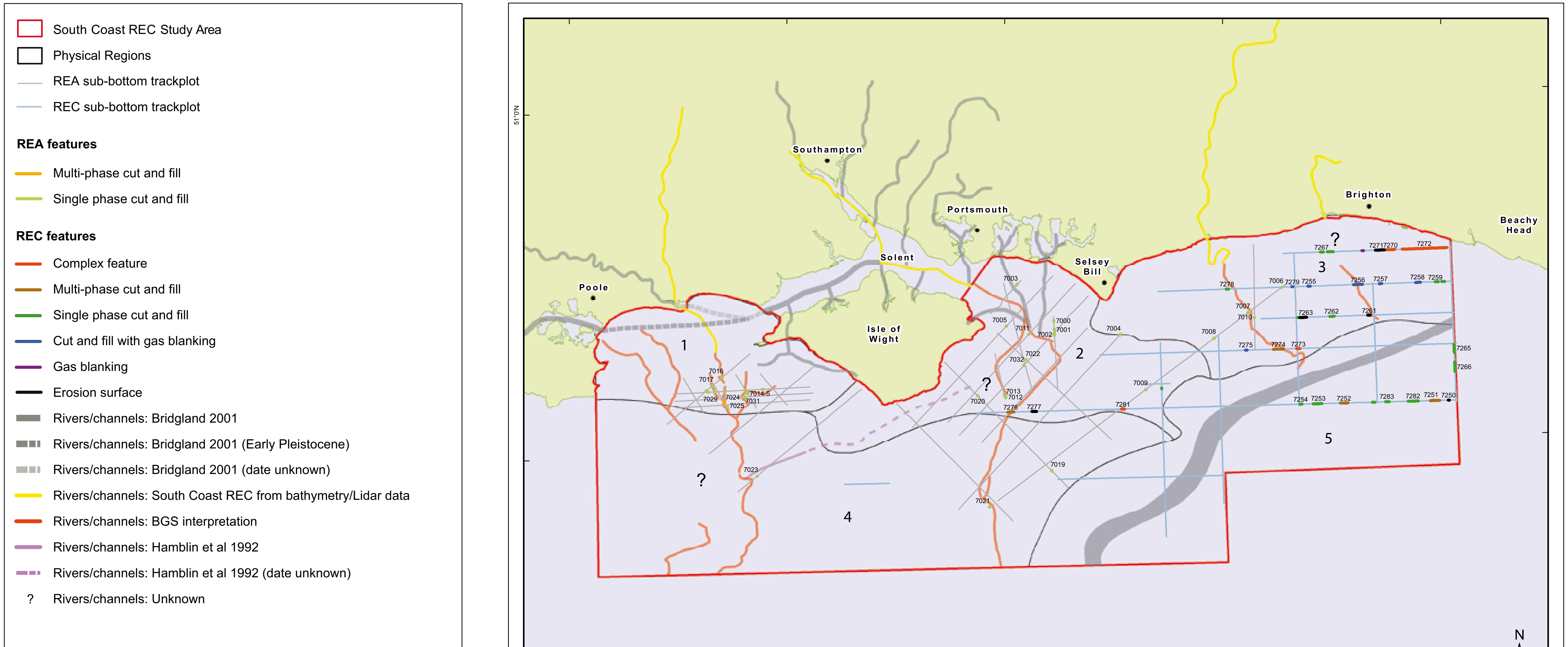


Figure 5.20: Sub-bottom profiler anomalies with palaeo-river systems shown.

was interpreted together with the evidence for channels from the sub-bottom data from the REC, REA and BGS 1988 surveys as well as prior knowledge of the course of the palaeoarun and information in the literature (Hamblin *et al*., 1992; Bridgland, 2001; Bellamy, 1995).

5.3 Characterisation of maritime archaeology

5.3.1 Introduction

Maritime archaeological sites on the sea bed broadly fall into two categories. Firstly there are the remains of vessels that have been lost in tidal waters as a result of stranding, foundering, collision, enemy action and other causes. Secondly there are those sites that consist of material related to the use of vessels but not of the vessel itself, for example material lost overboard or deliberately jettisoned, including lost fishing gear and abandoned anchors.

The aim of this characterisation is to assess the evidence for these maritime archaeological sites within the South Coast REC area. This characterisation also aims to derive information about the potential for survival of archaeological features from existing information about sea bed features and sediments within the survey corridors.

The review is restricted to the South Coast REC 2007 Survey corridors covered by the swath of the sidescan sonar. It is based upon the geophysical survey results acquired during the South Coast REC survey. However, additional datasets including records of wrecks and obstructions collated by UKHO and NMR, and information concerning sea bed features and sediments have been utilised to inform and enhance the results of the geophysical survey and also to provide comparative material.

The total data coverage (i.e. the area of the sea bed corridors covered by the swath of the sidescan sonar during the geophysical

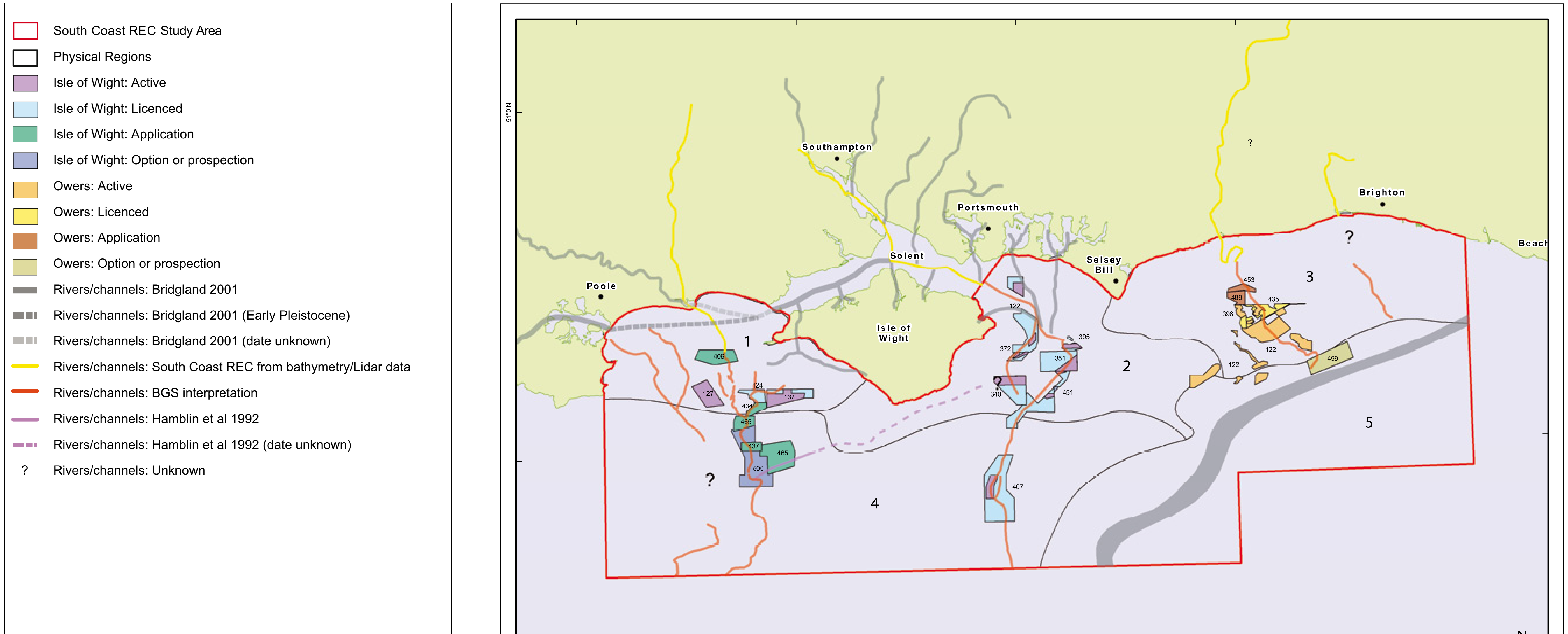


Figure 5.21: Licensed dredging areas, application areas and prospecting areas with palaeo-river systems shown.

survey) is 153.8 km². However, as several survey lines were slightly extended beyond the limits of the REC area, the actual area covered within the study area is 148.7 km². Table 5.2 shows a breakdown of this total by Physical Region.

In order to take into account any discrepancies in the accuracy of wreck or obstruction positioning between the NMR, UKHO and South Coast REC datasets, a 500 m buffer zone has been used on both sides of the sidescan sonar survey coverage (Figure 5.22). This allows the inclusion of records whose position may not match exactly those recorded during the South Coast REC survey in

Physical Region	Area covered by sidescan sonar (km²)
1	7.7
2	15.3
3	56.8
4	3.1
5	65.8
Total	148.7

Table 5.2: South Coast REC survey data coverage by region.

2007, for example because their georeferenced position has been allocated to a different part of the wreckage, because the wreck/obstruction has been affected to some degree by sea bed movements or because of simple human error.

Table 5.3 shows how the records from the two main datasets can be broken down according to their location and type.

No attempt has been made to correlate the NMR records with the UKHO records for the South Coast REC area, as the ALSF funded AMAP project (Merritt, 2007) has demonstrated that there are

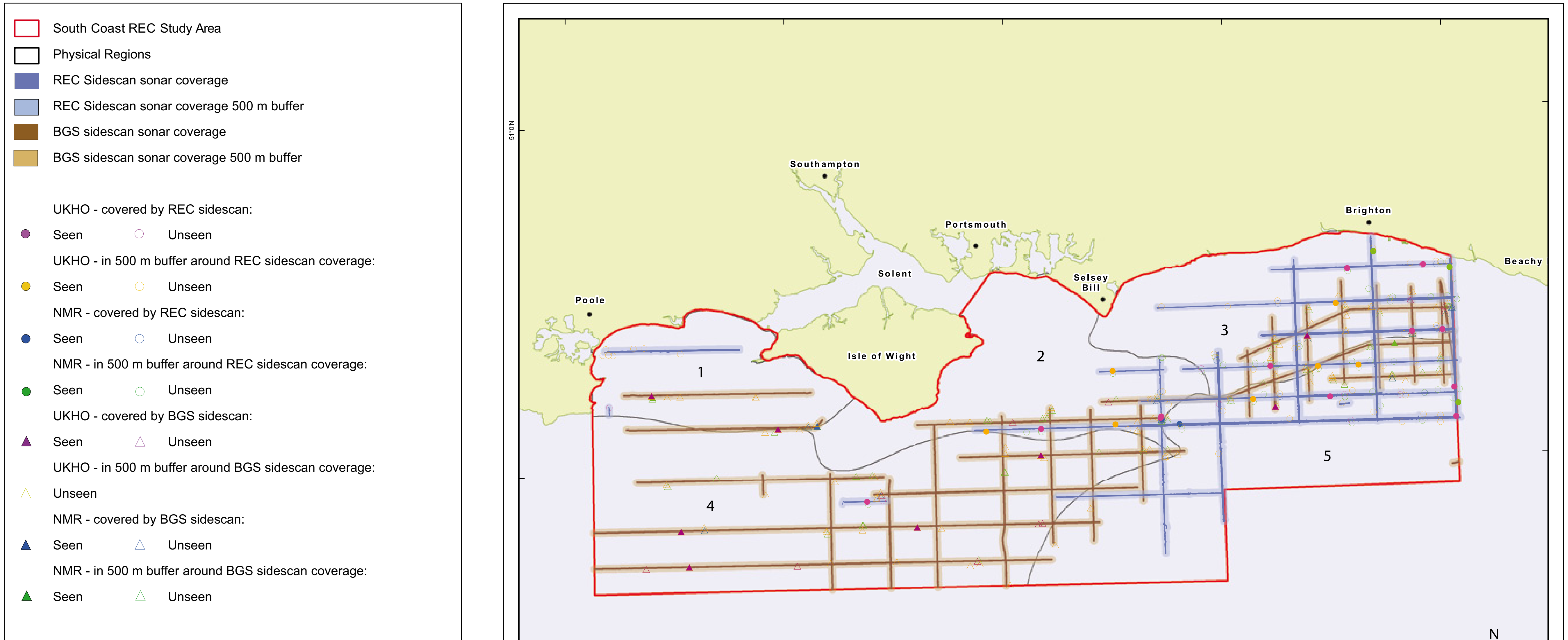


Figure 5.22: Wrecks and obstructions covered by the data.

numerous conflicting and mismatched records between the two databases which cannot be easily resolved by conducting a simple proximity analysis; some known wrecks in the UKHO and NMR databases were found to be located at positions up to 700 m apart. The discrepancies in position between the two databases have no obvious pattern and do not appear to be caused by a datum or projection issue.

For all wreck sites in the AMAP project only 1/6th of sites could be identified as the same wreck from both databases. The difference between the two databases is partly due to their different remits: the NMR database aims to record historic (pre-1950) sites, while the UKHO database seeks to record wrecks and obstructions which are a potential navigational hazard, regardless of their age (Figure 5.23).

An attempt has been made to assess the archaeological importance of each wreck identified from the geophysical data. In order to indicate the relation between the sites and their wider national context, a notional value for importance (low, medium, high) has been ascribed, based on expert judgement taking into account: the build/construction of the vessel; what it was used for and the wider events in which it was involved; the circumstances of its loss; the degree to which it has survived; and the extent to which it has already been investigated. Full details are given for each wreck in Appendix B. Whilst rarity is important, particularly in respect of pre-1850 wrecks which are traditionally viewed as being very scarce, wrecks can also be important because they are ‘typical’, i.e. because they are a well preserved example of a common type.

5.3.2 Physical Region 1 — Greater Poole and Christchurch Bay

This Region covers 570 km², bounded to the north by the coast of

Poole Bay, to the west by Poole Harbour and Purbeck and to the east by the western entrance to the Solent and the Isle of Wight.

UKHO	Within corridors	Within buffers	Within REC area
Wrecks	15	47	606
Obstructions	5	15	211
Total	20	62	817

NMR	Within corridors	Within buffers	Within REC area
Wrecks	6	26	313
Obstructions and Features	9	30	627
Total	15	56	940

Table 5.3: UKHO and NMR datasets.

Region 1 contains two full survey corridors, covering an area of 7.7 km² or about 1.4% of the total area.

The first, oriented west to east, is located towards the north part of the Region, whereas the second much shorter survey corridor is located very close to Region 4 in a north to south orientation. The corridors displays uniform type of sea bed sediment, being a rocky surface covered with a range (coarse to sandy) of thin sediments.

Data searches have identified one NMR record of an obstruction in the east-west survey corridor, one UKHO wreck record in the north-south corridor and a total of seven UKHO records (four wrecks and three obstructions) within the buffer areas (Table 5.4). None of these sites were observed in the geophysical data reviewed for this characterisation.

Anomaly **7183** has sonar dimensions of 29.6 m by 10 m and a height of 0.4 m. It has the characteristics of a wreck. It does not correlate with any NMR or UKHO record and appears to be an unidentified and uncharted wreck (Figure 5.24). In the absence of identification or sea bed inspection its importance is uncertain.

5.3.3 Physical Region 2 — East Wight and St Catherine's Deep

Feature type	Within corridors	Within buffers	Total
UKHO shipwrecks	1	4	5
NMR shipwrecks	0	0	0
UKHO obstructions	0	3	3
NMR obstructions and features	1	0	1
Total	2	7	9

Table 5.4: Recorded shipwrecks and obstructions in Region 1.

Physical Region 2 includes the area to the immediate south and east of the Isle of Wight as well as the whole of Portsmouth Approach. The Region has an area of 876 km².

The Region includes one full survey corridor and portions of four others. The corridors totalled 15.3 km², or about 1.7% of the area of the Region.

Four corridors are orientated west to east and one is orientated north to south. All of the corridors are located in the eastern and southern areas of the Region. These corridors offer examples of wrecks and obstructions with anomalies lying within each of the three types of sea bed character: coarse sediment; rock and thin sediment; sandy sediment.

Data searches identified five NMR records (two obstructions and three wrecks) and three UKHO records (all wrecks) in the survey corridors (Table 5.5). Additionally, within the buffer areas 16 records were identified, eight from UKHO (seven wrecks and one obstruction) and eight from NMR (four wrecks and four obstructions).

Eight possible correlations between recorded sites and geophysical anomalies were identified. Four of the correlations were between anomalies and records located in the buffer zones.

Feature type	Within corridors	Within buffers	Total
UKHO shipwrecks	3	7	10
NMR shipwrecks	3	4	7
UKHO obstructions	0	1	1
NMR obstructions and features	2	4	6
Total	8	16	24

Table 5.5: Recorded shipwrecks and obstructions in Region 2.

Anomaly **7000** covers an area 73 m by 46 m and has a maximum vertical height of 6.9 m. It has the characteristics of a broken up wreck (Figure 5.25). The BGS sediment characteristics for the location are rock and thin sediment.

The location of **7000** corresponds with UKHO charted wreck 19930. It is described by UKHO as being an intact and upright wreck and was similarly described by divers (McDonald, 1999), although it appears to have broken up to some extent since these reports were made.

UKHO 19930, and therefore **7000**, is identified as being SS *Lola*, a 458 Gross Registered Tonnage (GRT) merchant screw steamship built in 1897 in Scotland. The *Lola*, which was probably operated as a coastal tramp ship in the home trade, was on passage from Cornwall to London on 20 October 1929 when it foundered, probably as a result of the macadam cargo shifting in rough seas.

Like the earlier *Quail* **(7125)** in Region 3 (see below), the *Lola* is not remarkable in itself, but it is representative of late 19th century merchant steamship design and probably representative of a very important class of ship, the tramp ship. These vessels, extremely numerous between the late 19th century and the mid 20th, were the backbone of the world's merchant shipping fleets. They did not operate to a fixed schedule and carried a great variety of bulk and general cargoes on an as available basis. Coastal and foreign going vessels of this type would have been a very common sight in the South Coast REC area during this period and in ports such as Southampton, Portsmouth and Poole.

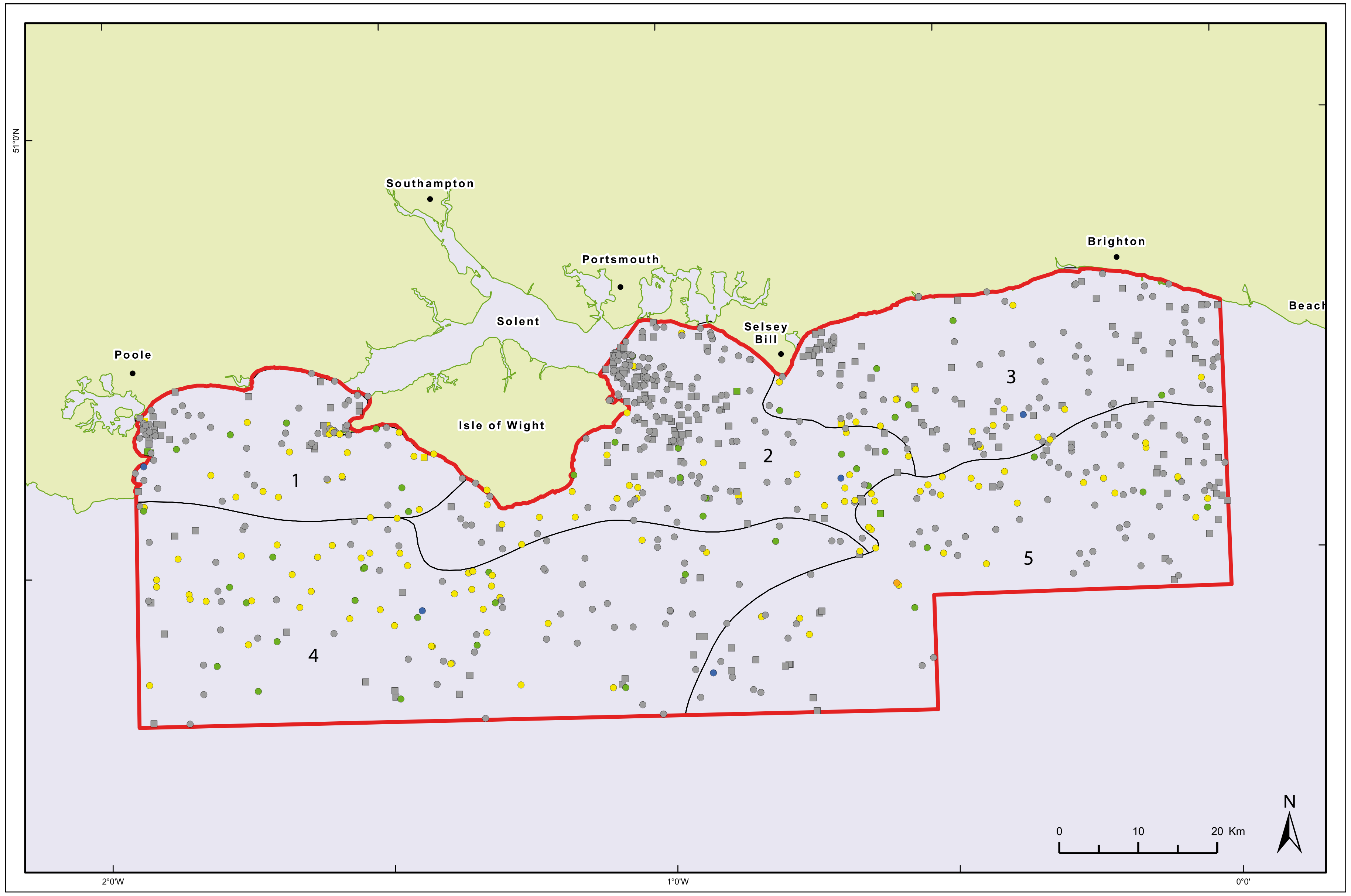


Figure 5.23: Charted wrecks and obstructions in the South Coast REC area.

Anomaly **7080** has sonar dimensions of 68 m by 9 m and a vertical height of 3.8 m. It has the characteristics of a coherent wreck (Figure 5.26). The sediment characteristics of the location are described by BGS as being rock and thin sediment.

The location of the anomaly corresponds with UKHO charted wreck 19919 (NMR 804910). This is identified as being *U-1195*, a German Type VIIC U-boat lost during the Second World War as a result of a depth charge attack on 6 April 1945, just a month before VE day. This wreck is visited by recreational divers and although one regional dive guide gives a location for the wreck that is several hundred metres away (Pritchard and McDonald, 2001), **7080** is very probably *U-1195*. Diver descriptions suggest that the geophysical data is consistent with the wreck and confirm that the submarine is largely intact, although the deck gun is missing.

By the time *U-1195* was sunk, the Battle of the Atlantic had been lost by the Germans. No longer able to cut the convoy routes in the open Atlantic, the German strategy had shifted to inshore waters around the UK. U-boats fitted with the revolutionary Schnorkel, a device that for the first time enabled submarines to operate for prolonged periods without surfacing, largely negated the Allied advantage of air superiority. Adopting the simple tactic of sitting silently on the sea bed at locations frequented by merchant ships and waiting for targets to come to them, U-boats operating in coastal waters caused the Allies serious difficulties in the closing months of the war. *U-1195* appears to have used this tactic to intercept Convoy VWP-16 and sink the liner *Cuba* before itself being sunk by the convoy escorts with the loss of 18 lives.

U-1195 is important for a number of reasons. As a U-boat, it is representative of a class of warship that played a very significant and notorious part in the Second World War. U-boats sank a significant proportion of the Allied vessels lost in that war and are therefore responsible for the presence of a significant proportion of the wrecks in the South Coast REC area. It is in all probability a 'war grave'. In design terms, although not one of the advanced U-boat designs produced in small numbers towards the end of the war, it is typical of the U-boat types mass-produced during the mid-war years. It is also unusual and therefore significant in that it was one of the limited numbers of German submarines fitted with the Schnorkel device. It is also largely intact. In terms of its use, it was lost whilst employing classic late war tactics. In terms of location, it is where it might be expected to be, at or near the point where Southampton or Portsmouth-bound convoys would be approaching the eastern entrance to the Solent. Furthermore, the wreck is the subject of continued interest and a memorial service was held over the site in 1988 involving local divers and former crew members. For all of these reasons **7080** is assessed as having high archaeological importance.

Anomaly **7121** has sonar dimensions of 21.7 m and 9.2 m (height not determinable) (Figure 5.27). However, the anomaly, which has the characteristics of a wreck, extends off range. The sea bed in the vicinity is characterised by BGS as rock with thin sediment or sandy sediment. Sand waves appear to be present alongside the wreck.

The anomaly position corresponds with UKHO charted wreck 20004 and is described as a barge or LCT (landing craft tank). Recent recreational diver investigations have confirmed that it is an LCT and it is described as being intact, inverted and largely buried. It has been identified as probably being *LCT(A)-2428*. This landing craft was assigned to support the amphibious operations on Juno Beach on D-Day on 6 June 1944 by carrying armoured vehicles and artillery. It sailed on the evening of 5 June but got into difficulties as a result of engine trouble and capsized whilst being towed back to England. It continued to float and was eventually sunk by naval gunfire. An isolated group of tanks, bulldozers and guns have been located on the sea bed in Bracklesham Bay and it is believed that this is where the vessel capsized.

As a relatively well preserved LCT wreck, **7121** is rare but not unique. Its real significance comes from the fact that it is representative of and a rare survival of an iconic event of much contemporary resonance and of the mighty Allied armada that was involved. It has therefore been assessed as having high archaeological importance.

Anomaly **7002** has sonar dimensions of 66 m by 30 m and a height of 3.3 m, although it extends off range (Figure 5.28). It has the characteristics of a broken up wreck on a sea bed described by BGS as sandy sediment.

The anomaly position corresponds approximately with that of a UKHO charted wreck (UKHO 19923). It has been visited by recreational divers. The presence of a boiler has been noted and the wreck is reported as a probable requisitioned trawler of the First World War. The position of the wreck also roughly corresponds with two NMR records of requisitioned trawler wrecks (NMR 767302 and 911166). The name of the trawler does not appear to have been established.

As with HMT *Inverclyde* **(7130)** in Region 3, **7002** is not rare. It is however representative of an unglamorous but significant class of warship that would have been a common sight in the area during the World Wars of the 20th century. Therefore even though it is well broken up it merits assessment as being of medium importance.

Magnetometer anomaly **7224** is a small unidentified metal object or wooden shipwreck in a location identified by BGS as a rock and thin sediment sea bed (Figure 5.29). There was no anomaly apparent in the sidescan data and the source of the magnetic anomaly may be buried. It is approximately 290 m from the charted position of the wreck of a coaster and may be associated with it (UKHO 18999).

7193 is another magnetometer anomaly in a location described as having sandy sediment by BGS (Figure 5.30). It is a very large anomaly with the characteristics of a buried metal wreck. It is not charted or identified. In the absence of further information its importance is assessed as uncertain.

5.3.4 Physical Region 3 — Selsey-West Sussex Coastal Platform

Region 3 comprises coastal waters up to 21 km offshore between Selsey Bill in the west and Peacehaven in the east and covers an area of 969 km².

The Region contains 3 full survey corridors and 5 portions of corridors. The corridors have a total sea bed area of 56.8 km² or about 5.9% of the area of the Region.

Four of the corridors are orientated west to east and four corridors are orientated north to south and are distributed evenly, covering approximately two-thirds of the area of Region 3. These corridors offer examples of wrecks, obstructions and anomalies lying within each of the three types of sea bed character: coarse sediment; rock and thin sediment; sandy sediment.

Data searches identified six NMR records (three wrecks and three obstructions) and seven UKHO records (four wrecks and three obstructions) within the corridors (Table 5.6). Within the buffer areas 23 NMR records (8 wrecks and 15 obstructions) and 25 UKHO records (17 wrecks and 8 obstructions) were identified.

A total of seven correlations between NMR or UKHO records and anomalies were identified, five with records located in the corridors and two with records in the buffer zones.

Feature type	Within corridors	Within buffers	Total
UKHO shipwrecks	4	17	21
NMR shipwrecks	3	8	11
UKHO obstructions	3	8	11
NMR obstructions and features	3	15	18
Total	13	48	61

Table 5.6: Recorded shipwrecks and obstructions in Region 3.

Anomaly **7125** has sonar dimensions of 40.8 m and 19.3 m (height not determinable) (Figure 5.31). It has the characteristics of a possible wreck. The anomaly is surrounded by sand ripples and the sediment in the area is described by BGS as being sandy. The anomaly extends off range towards the UKHO charted position of a wreck (20000) about 100 m away. Available evidence suggests that the anomaly is part of the charted wreck.

The charted wreck is reported by divers to be upright with its bow broken off and lying with its port side to the west and its large counter-stern lying to the east. There is reported to be no sign of its superstructure and masts, although one or both of the engines can be seen (McDonald, 1999). The wreck is reported to be rich in mid-late 19th century artefacts.

UKHO 20000 is reported to have been identified as the *Quail*, an iron merchant screw steamship which sank with the loss of one life on 27 August 1886 following a collision. It was built in 1870 by Palmers Shipbuilding and Iron Company of Jarrow, the company that built the world's first bulk carrier. It was 68.3 m in length, with a beam of 8.5 m, a draught of 5.2 m and 924 gross tons. It had auxiliary sail power, not untypical for its build date and it was probably a typical type of merchant steam ship known as a tramp ship. It is recorded as having been carrying a general cargo from Antwerp to Glasgow at the time of loss.

Although the *Quail* is not remarkable in itself, it is representative of early merchant steamship design and probably representative, like the *Lola* **(7000)**, of a very important class of ship, the tramp ship. The overall importance of **7125** is therefore assessed as being medium.

Anomaly **7130** has sonar dimensions of 40.8 m and 19.3 m (height not determinable) (Figure 5.32). It contains three items of apparent debris, one of which has a height of 2.8 m. BGS describe the location as being one of sandy sediment.

The location of the anomaly corresponds with UKHO charted wreck 20137. It is described as a scatter of wreckage which lies in a scour. The site is visited by recreational divers and is described as the broken up remains of a metal hulled wreck with a boiler standing 3 m high on a 'sandy-mud' sea bed (McDonald, 1999). The wreck is recorded by UKHO as having been dispersed in 1946. All of these descriptions are consistent with **7130**.

20137 has been identified by the UKHO as the 1914 built HMT *Inverclyde*, a steam trawler requisitioned for use as a minesweeper in 1939 which subsequently sank whilst under tow. The *Inverclyde* is unusual, although not unique, in that it also served as a requisitioned minesweeper in the First World War under its original name of *Perihelion*.

As the well broken up remains of a requisitioned trawler, **7130** does not have any special importance. It is however representative of an important class of *ad hoc* warship that made a significant contribution to the defence of the UK in both World Wars of the 20th century. Steam trawlers would have been common sights in the REC area and in local ports such as Shoreham and Poole. Likewise, requisitioned trawlers would have patrolled the area and therefore been common sights during the World Wars. Overall importance is therefore assessed as medium.

Anomaly **7113** has sonar dimensions of 32 m length, 7 m width and 0.4 m height (Figure 5.33). It has the characteristics of a wreck and is possibly partly buried. No superstructure is obvious. The wreck cannot be seen in the bathymetric data.

The wreck is visited by recreational divers who describe it a being a small fishing vessel. As of 1999 the hull was intact and upright but the deck had collapsed. This is consistent with the geophysical data, which also suggests collapse of the superstructure and partial burial by sand. It was also reported to be partially buried in 1980.

The wreck has been identified as the motor fishing vessel *Girlvine*, which foundered on 15 May 1957. Details of the *Girlvine* are not available, but it is presumed to have been a single deck trawler design, powered by a diesel engine driving a single screw.

There is no information to suggest that the *Girlvine* has any special archaeological or other importance. Assuming that **7113** is the wreck of a motor fishing vessel, then it is not rare. However it does acquire some representative value, being typical of a large class of mid-late 20th century watercraft used in an industry of great significance to the UK. Motor fishing vessels had largely replaced steam trawlers and drifters such as the *Inverclyde* by the 1950s and remain in use today. Such vessels would have been a common sight in the area in the mid-late 20th century, either fishing or transiting to fishing grounds elsewhere and in local fishing ports. Overall importance is therefore assessed as medium.

5.3.5 Physical Region 4 — South–West Wight Platform

Region 4 is located offshore of the south of the Isle of Wight and stretches from Purbeck to a point east of Selsey Bill. The Region has an area of 1919 km².

The Region includes one full survey corridor with a total sea bed area of 3.1 km², or approximately 0.2% of the total area of the Region. The corridor is orientated west to east. It is located in the middle of Region 4. It offers examples of wrecks, obstructions and anomalies lying within each type of sea bed character: coarse sediment; rock and thin sediment; sandy sediment.

Within the corridor, data searches have identified two UKHO wreck records (Table 5.7). Within the buffer area surrounding the corridor, two UKHO wreck records, one UKHO obstruction record and one NMR obstruction record were identified.

A single correlation between records and geophysical anomalies from the South Coast REC regional survey was identified within the corridor. This correlation is linked to records within the corridors.

Feature type	Within corridors	Within buffers	Total
UKHO shipwrecks	2	2	4
NMR shipwrecks	0	0	0
UKHO obstructions	0	1	1
NMR obstructions and features	0	1	1
Total	2	4	6

Table 5.7: Recorded shipwrecks and obstructions in Region 4.

Anomaly **7089** has sonar dimensions of 124 m by 41 m and a height of 6 m (Figure 5.34). It has the characteristics of a wreck. The wreck is located in an area characterised by BGS as having rock and thin sea bed sediment.

The anomaly location corresponds with the position of UKHO charted wreck 18958. That wreck has been identified as the SS *Mendi*, a 4230 GRT screw steamer. Built in 1905 at Govan on the Clyde, the *Mendi* was operated as a cargo liner on regular services between Liverpool and West Africa before being requisitioned during the First World War for use as a troopship. In February 1917 the *Mendi* was lost as a result of a collision off the Isle of Wight. There was great loss of life amongst the men of the South African Native Labour Corps that the ship was carrying from South Africa to the Western Front.

The *Mendi* is unusual because of its international profile. Largely forgotten in the UK, the public profile of the tragic loss of the *Mendi* has remained strong in South Africa. The loss became a long standing focus for the struggle against white rule and then the Apartheid regime. As a result the loss and the wreck itself became and have remained part of the South African national consciousness. Today there is still a 'Mendi Day' and a warship of the South African navy is named after the ship.

Identified by recreational divers in the 1970s and subject to extensive small scale and largely unreported salvage in the 1980s and 1990s, the wreck has been investigated archaeologically in recent years, with a major desk-based assessment and geophysical survey undertaken in 2006–8 (Wessex Archaeology, 2007b; 2008g). There is ongoing media interest as a result of renewed interest in the wreck and its loss in the UK and a small display of artefacts at a private museum on the Isle of Wight.

The international interest in the *Mendi* means that **7089** is undoubtedly of high archaeological importance; it is in the process of being designated as a Protected Place under the Protection of Military Remains Act (1986).

5.3.6 Physical Region 5 — Northern Palaeovalley and Margin

Region 5 is located offshore to the east of the Isle of Wight and directly south of Region 3. It covers an area of 1340 km².

The Region includes nine partial survey corridors with a total sea bed area of 65.8 km², representing approximately 4.9% of the area of the Region. Four of the corridors are orientated west to east and four corridors are orientated north to south. Most of the corridors are distributed evenly in a methodical rectangular manner, covering approximately between half and two-thirds of the area of Region 5. These corridors offer examples of wrecks, obstructions and anomalies lying within each type of sea bed character: coarse sediment; rock and thin sediment; sandy sediment.

Data searches have identified three NMR records (all obstructions) and seven UKHO records (five wrecks and two obstructions) within the corridors (Table 5.8). Within the buffer area 43 records have been identified, comprising 24 NMR records (14 wrecks and 10 obstructions) and 19 UKHO records (17 wrecks and 2 obstructions).

A total of eight correlations between NMR or UKHO records and geophysical anomalies were identified, five and three within the corridors and buffer areas respectively.

Feature type	Within corridors	Within buffers	Total
UKHO shipwrecks	5	17	22
NMR shipwrecks	0	14	14
UKHO obstructions	2	2	4
NMR obstructions and features	3	10	13
Total	10	43	53

Table 5.8: Recorded shipwrecks and obstructions in Region 5.

Anomaly **7126** has sonar dimensions of 82 m by 28 m and a height of 13 m (Figure 5.35). The anomaly extends off range. The anomaly has the characteristics of a wreck in an area of sea bed described as being sandy sediment.

The position of the wreck corresponds with that of UKHO charted wreck 20001. This wreck has been investigated by recreational divers and is described as being partially intact and partly on its side.

The wreck has been identified as the SS *Pagenturm*, a 5000 GRT merchant steamship built in 1909 in Germany. Seized by the British in an Indian port at the outbreak of the First World War, the vessel was requisitioned by the Admiralty for war service. On 16 May 1917 the *Pagenturm* was torpedoed and sunk by *UB-40* 16 miles west of Beachy Head whilst on passage from Chatham to Mesopotamia and India via Falmouth and Barry. At the time of loss it was being escorted by armed trawlers, probably similar to **7002** and **7130**.

The *Pagenturm* was probably a tramp type ship, and therefore similar in function to **7000** and **7125**. On the basis that it is representative of this type, is partially intact and has an unusual history (including being sunk by one of the most successful U-boats of the First World War), the importance of **7126** is assessed as medium.

Anomaly **7181** has sonar dimensions of 96 m by 17.1 m and 8 m height (Figure 5.36). It has the characteristics of a fairly coherent metal wreck. It is in an area of sea bed described by BGS as being of sandy sediment.

The position of **7181** corresponds with the charted position of UKHO wreck 20170. This wreck is not identified by UKHO. Although their records indicate that the wreck has been visited by recreational divers a search of diving literature has failed to identify it. However as a coherent wreck its importance is assessed as medium.

5.3.7 Additional Sites identified from BGS 1988/02 survey data

In addition to the South Coast REC geophysical dataset some sidescan sonar data acquired by the BGS in 1988 was made available for archaeological assessment. These data were only available as paper records and while the data were of lower quality than the South Coast REC dataset, it was still possible to identify a number of wreck sites in the dataset which adds to our knowledge of the wreck sites in Regions 1, 3, 4 and 5.

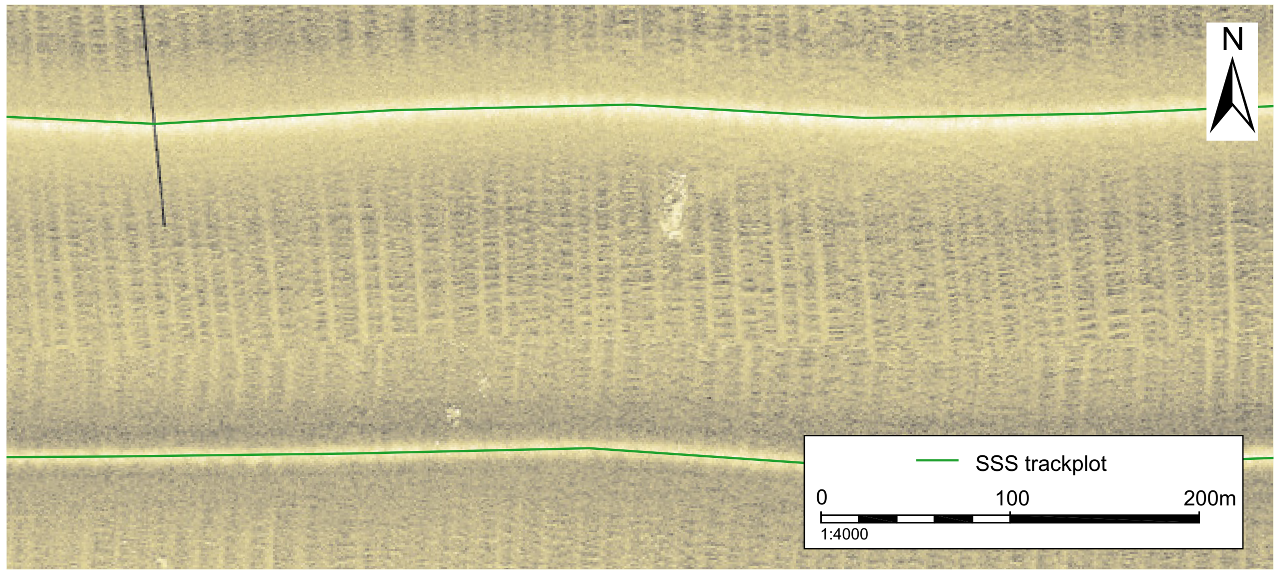
5.3.8 Physical Region 1

7505 is a sidescan anomaly measuring 48 m by 15 m with a height of 3.5 m in a general depth of 23 m. It is UKHO charted wreck 19428 and is recorded by the NMR as 895838.

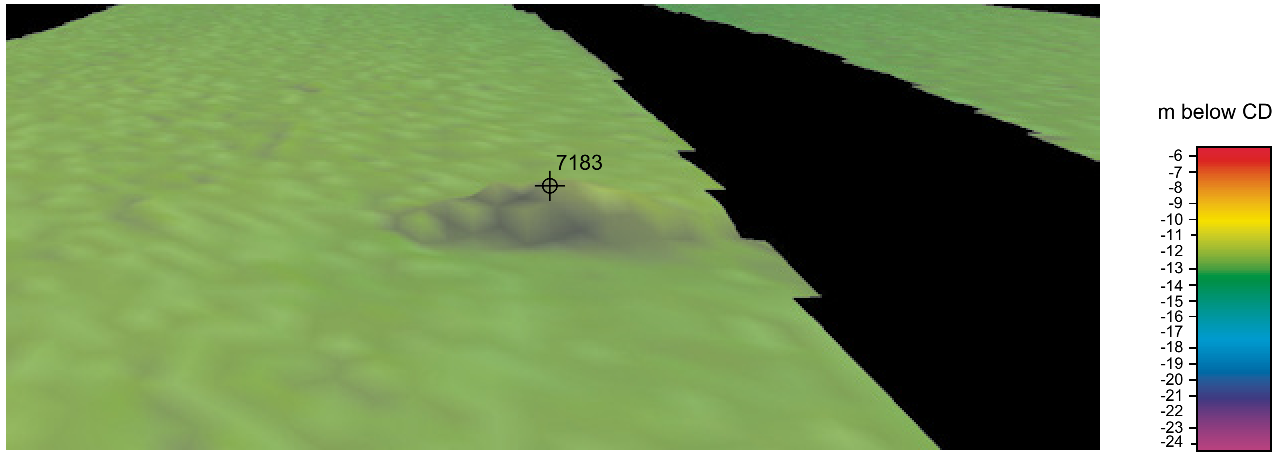
This anomaly is the wreck of the SS *Betsy Anne*, an 1892 Newcastle built 880 ton 63 m long tramp steamship. This single screw steel ship was powered by a triple expansion three cylinder steam engine fed by a single boiler. Dutch registered at the time of loss, the ship had been built by W Dobson and Company as the collier *Ashington* for the Ashington Coal Company. The NMR record for the wreck states that the ship had originally been built as a schooner rigged iron hulled ship. The *Betsy Anne* foundered in heavy weather on 12 October 1926, without loss of life. At the time of loss the ship was owned by the Cowes Salvage Company. They had salvaged the ship after it had run aground in fog at Prawle Point in Devon whilst on passage from Fleetwood to Amsterdam in ballast. Having been temporarily repaired, it was on passage for Cowes for more permanent repairs when lost.

Figure 5.24: WA ID 7183 — Possible uncharted wreck

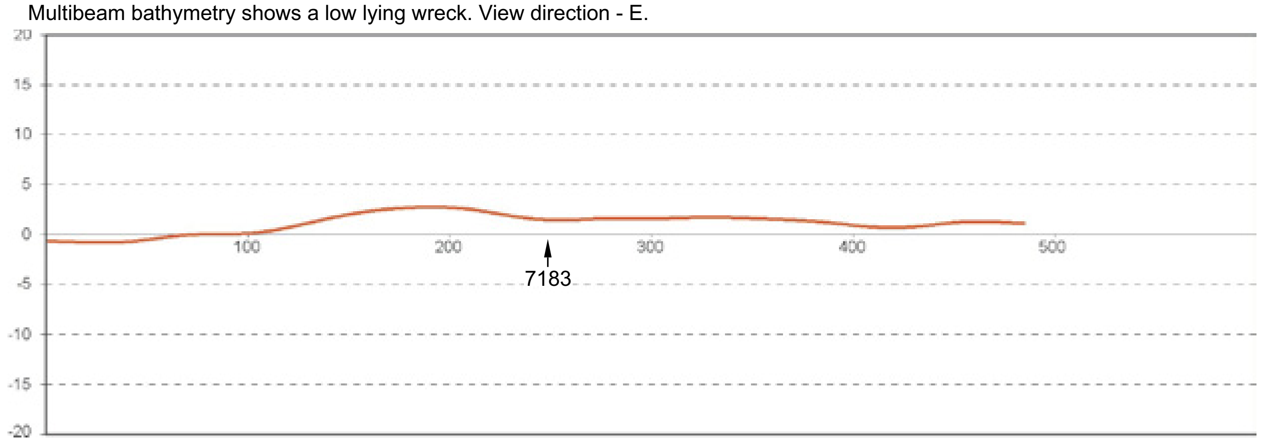
Location		578844 E 5614885 N (UTM 30N) 50 40.83 N 01 53.04 W (WGS84)	**Region**	1
Archaeological Importance		Uncertain		
Geophysical survey dimensions and notes		29.6 m long x 10 m wide x 0.4 m high. Wreck with an orientation of 20/200°. Scour on west side, 0.2 m deep. The general seabed depth is 12.8 m.		
Build	**Type**	Unknown		
	Construction	Unknown		
	Dimensions	Unknown		
	Shipyard	Unknown		
Loss	**Cause**	Unknown		
Extent of Survival		The geophysics data suggest that the wreck is broken up. No bedforms are apparent surrounding the wreck but there is a slight scour on the western side, measuring approximately 0.2 m deep.		
BGS Sediment Characterisation		Rock and thin sediment		



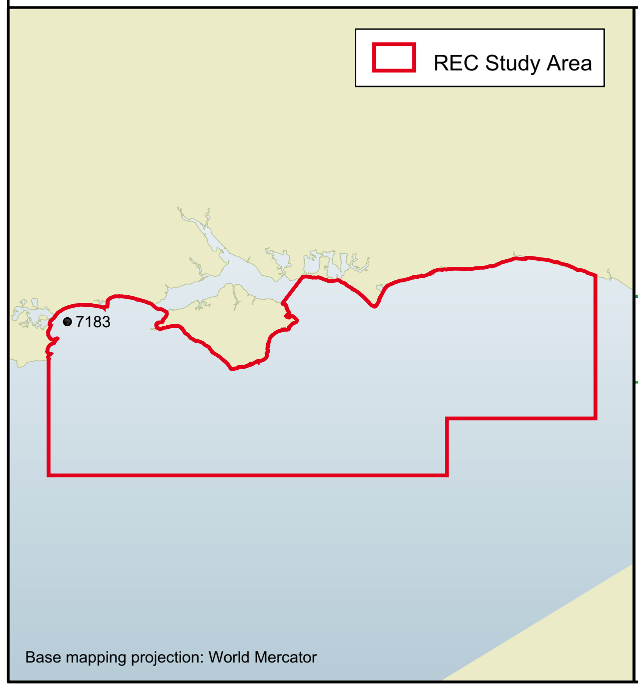
Mosaiced sidescan sonar image shows a broken up wreck.



Multibeam bathymetry shows a low lying wreck. View direction - E.



Magnetic profile shows no anomaly adjacent to the wreck location.



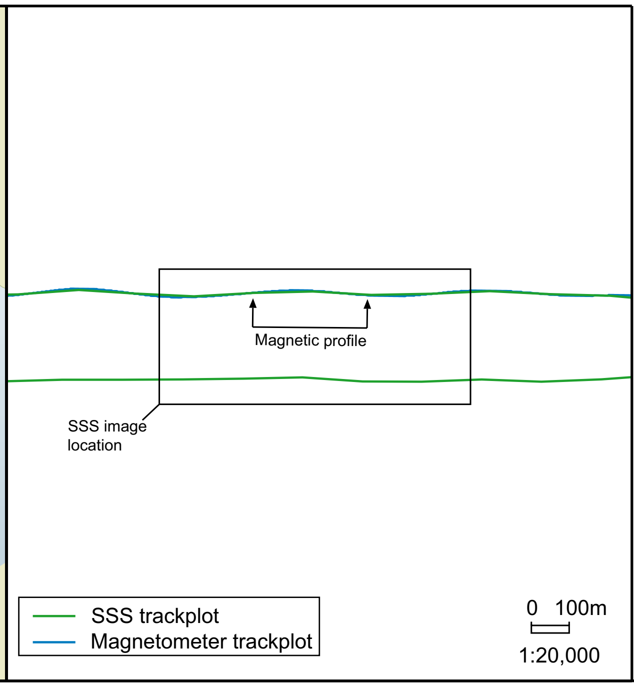
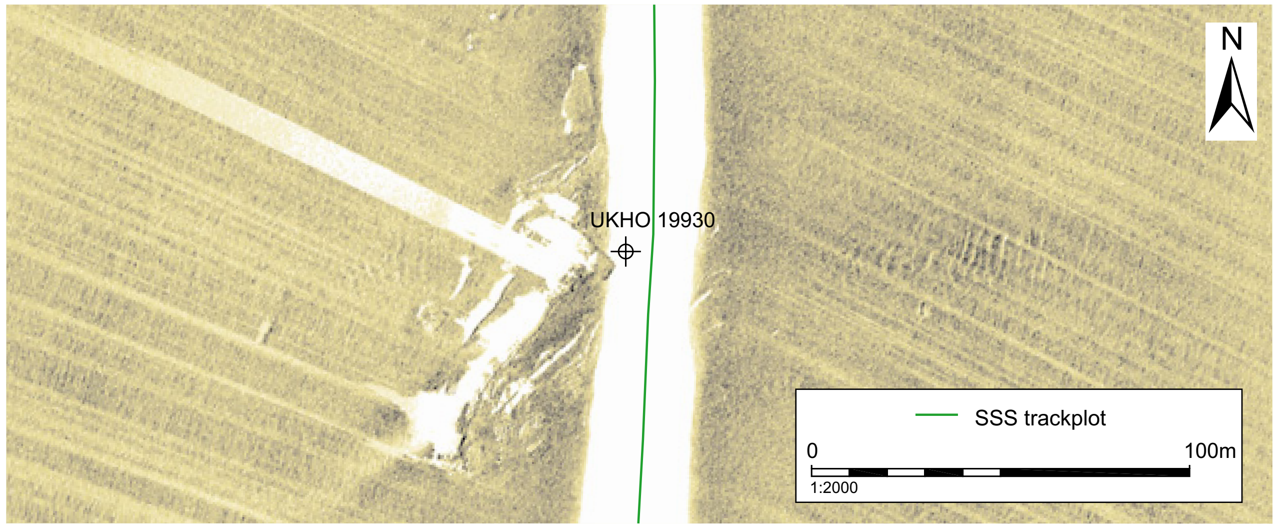
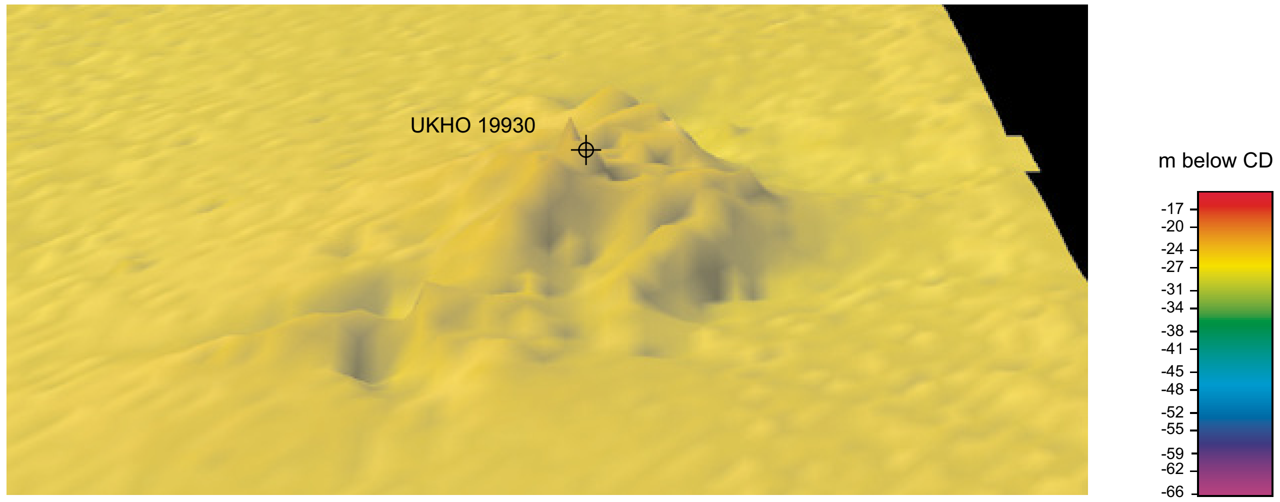


Figure 5.25: WA ID 7000 — SS *Lola* UKHO 19930

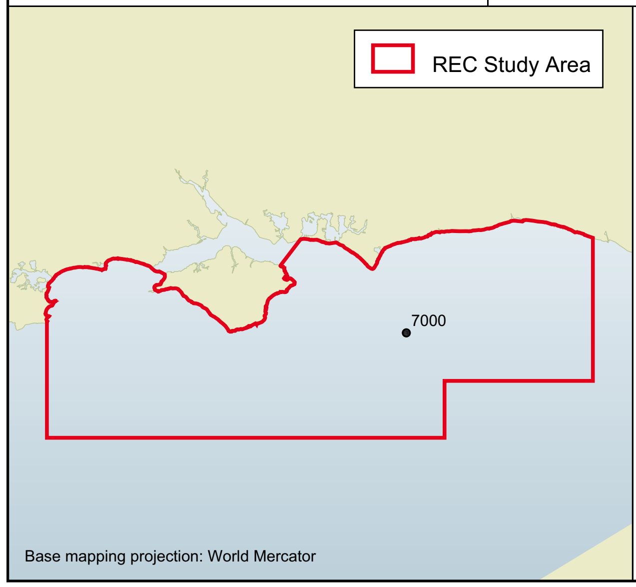
Location		665245 E 5604522 N (UTM 30N) 50 34.15 N 00 39.99 W (WGS84)	**Region**	2
Archaeological Importance		Medium		
Geophysical survey dimensions and notes		73 m long x 46 m wide x 6.9 m height. Broken up wreck containing a section measuring 15.2 x 0.5 x 1.1 m. An item of debris measuring 3.7x1.4 x 0.0 m lies 16 m NW of the northern end of the wreck. A similar object measuring 2.5x1.2x0.0 m lies 19 m NW of the northern end of the wreck. A third item of debris lies 25 m west of the wreck. The wreck has an orientation of 015-195°. The general seabed depth is 25.5 m. At position of 19930.		
Build	**Type**	Merchant steamship; probably a coastal tramp		
	Construction	Possibly steel		
	Dimensions	48.7 m length x 7.35 m breadth x ? m draught; 458 Gross Registered Tonnage.		
	Shipyard	Built in 1897 as *Latchford* by S McKnight Ayr Shipyard, Ayr, Scotland.		
Loss	**Cause**	Foundered		
Extent of Survival		Described by UKHO as being intact and upright, with the lower part of the hull buried and the bows lying to the ENE. A depth of 22.8 m is recorded in a general depth of 26m, with a scour of 0.4 m depth. Seabed is recorded as being "regular and sedimentary" and "sand". Diver reports refer to the wreck "lying north-east to south-west…8 m proud of the sea bed at 25 m" (McDonald 1999: 43). The project geophysics data suggests that the wreck has broken up to a large extent since these diver reports were collated in the 1990s. The extent of the wreck is approximately one third longer than the vessel and several times wider. This suggests a substantial debris field. No scouring or bedforms around the wreck are evident in the geophysical data.		
BGS Sediment Characterisation		Rock and thin sediment		

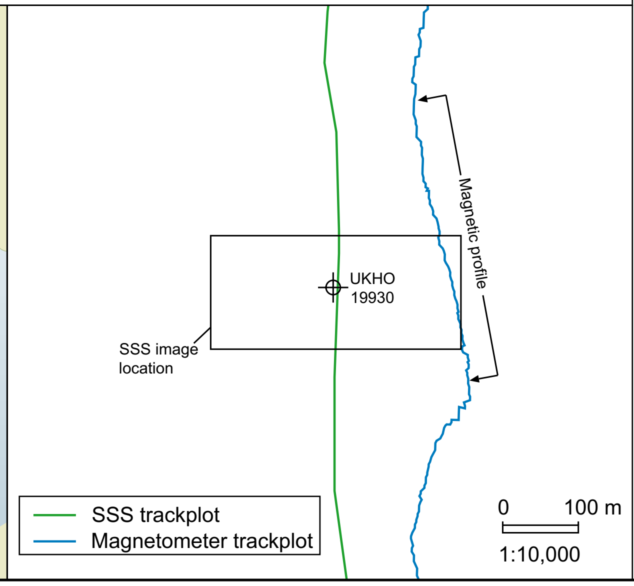


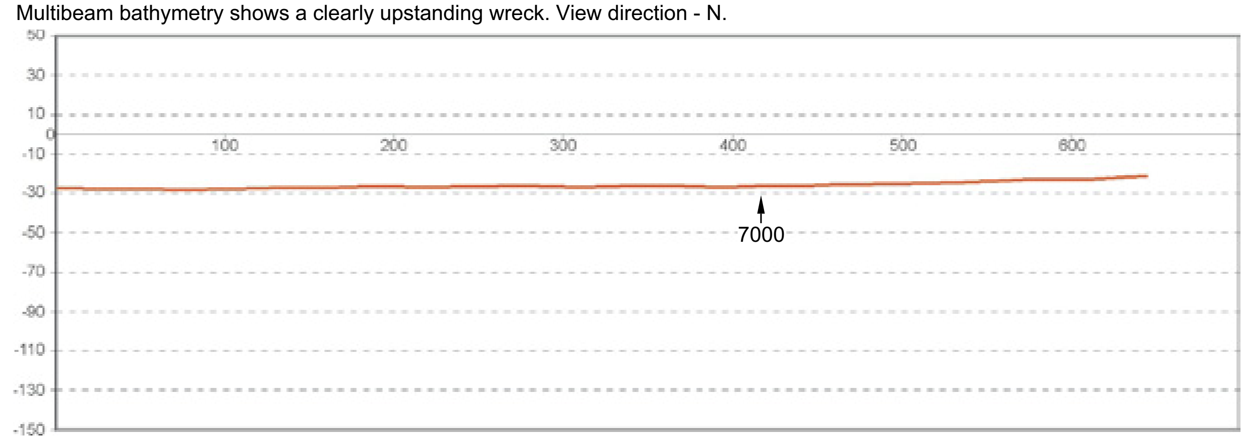
Mosaiced sidescan sonar image shows a broken up wreck (water column intentionally not removed).



Multibeam bathymetry shows a clearly upstanding wreck. View direction - N.







Magnetic profile shows no anomaly adjacent to the wreck location.

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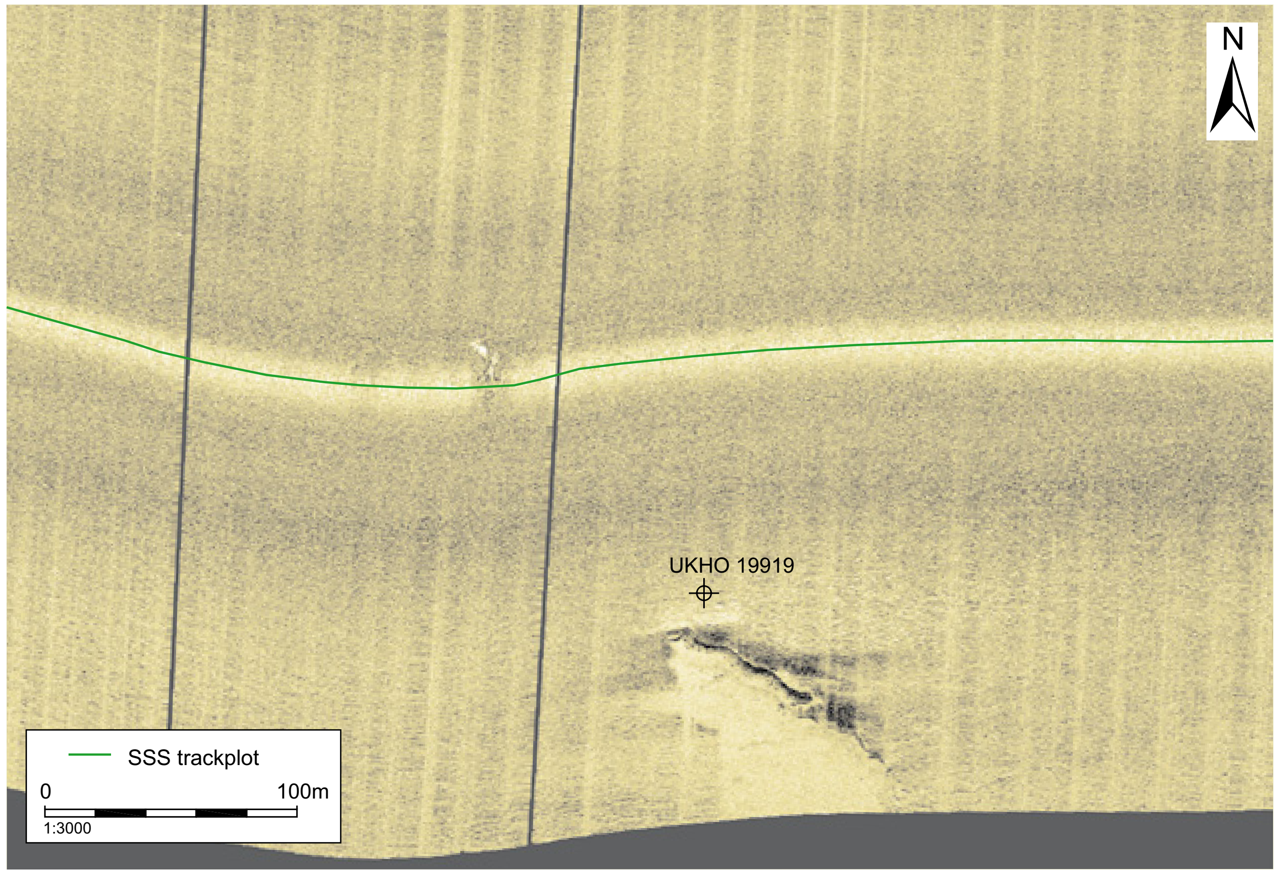
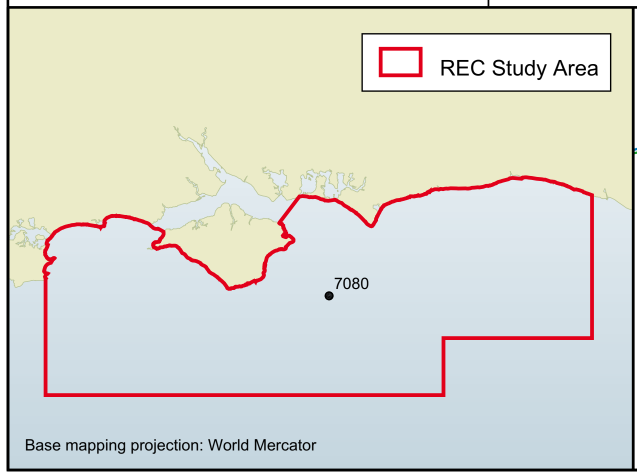
Figure 5.26: WA ID 7080 — *U-1195* UKHO 19919/NMR 804910

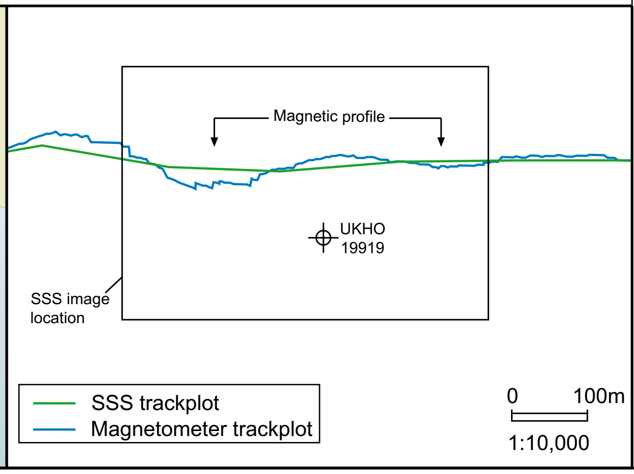
Location		646053 E 5602498 N (UTM 30N) 50 33.37 N 00 56.29 W (WGS84)	**Region**	2
Archaeological Importance		High		
Geophysical survey dimensions and notes		68m x 9m x 3.8m. Coherent wreck with no apparent debris field. Orientation 120/300°. Height underestimated as shadow extends beyond range. Width underestimated and side only of wreck visible as obscured by shadow. Scour on NE side. NW end lies 9m south of 19919. 4036 is 64m N of wreck. Not covered by bathymetry.		
Build	**Type**	Submarine. Type VIIC U-boat.		
	Construction	Steel construction		
	Dimensions	67.1m LOA x 6.2m beam x 4.74m draught x 9.6m height; 769/871/1070 tons (surface/submerged/total).		
	Shipyard	*U-1195* was built by the shipyard F Schichau GmbH in Danzig, Germany in 1943.		
Loss	**Cause**	Enemy action; depth-charged.		
Extent of Survival		The submarine is reported by divers to lie on a shallow sand and shingle slope with a starboard list of approximately 45°, its bow down slope to the north-east and the stern above the seabed. The wreck has a maximum height above the seabed of about 4m. There is considerable damage forward of the conning tower where the depth charge impacted and divers describe the submarine as being almost cut in two. Geophysical results suggest the wreck is lying approximately NW-SE, contrary to diver reports. Wreck length is consistent with length of U-1195, discrepancy in width against known beam can be explained by the list. However, published diver position (Pritchard & MacDonald 2001: 134) is approximately 430m to the SE. A bright reflector measuring 6.5m x 2.5m x 0m lies approximately 85m NW of 7080. It may be debris associated with 7080 and may be the cause of the rumours of another submarine wreck in the "very near vicinity" (McCartney 2003: 102). No scours or bedforms adjacent to the wreck are apparent in the geophysical data.		
BGS Sediment Characterisation		Rock and thin sediment		

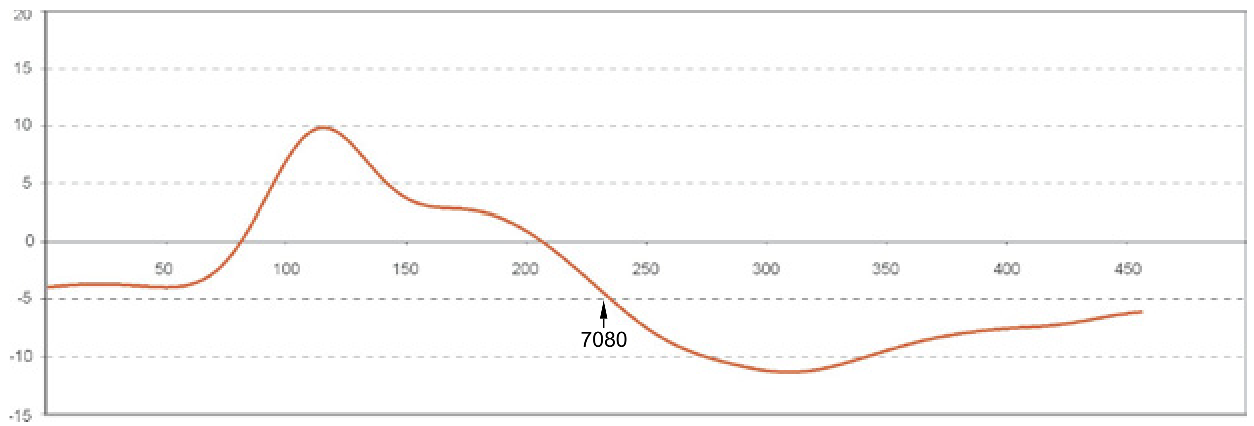


Mosaiced sidescan sonar image shows a clearly upstanding, intact wreck.

This site was not covered by multibeam bathymetry



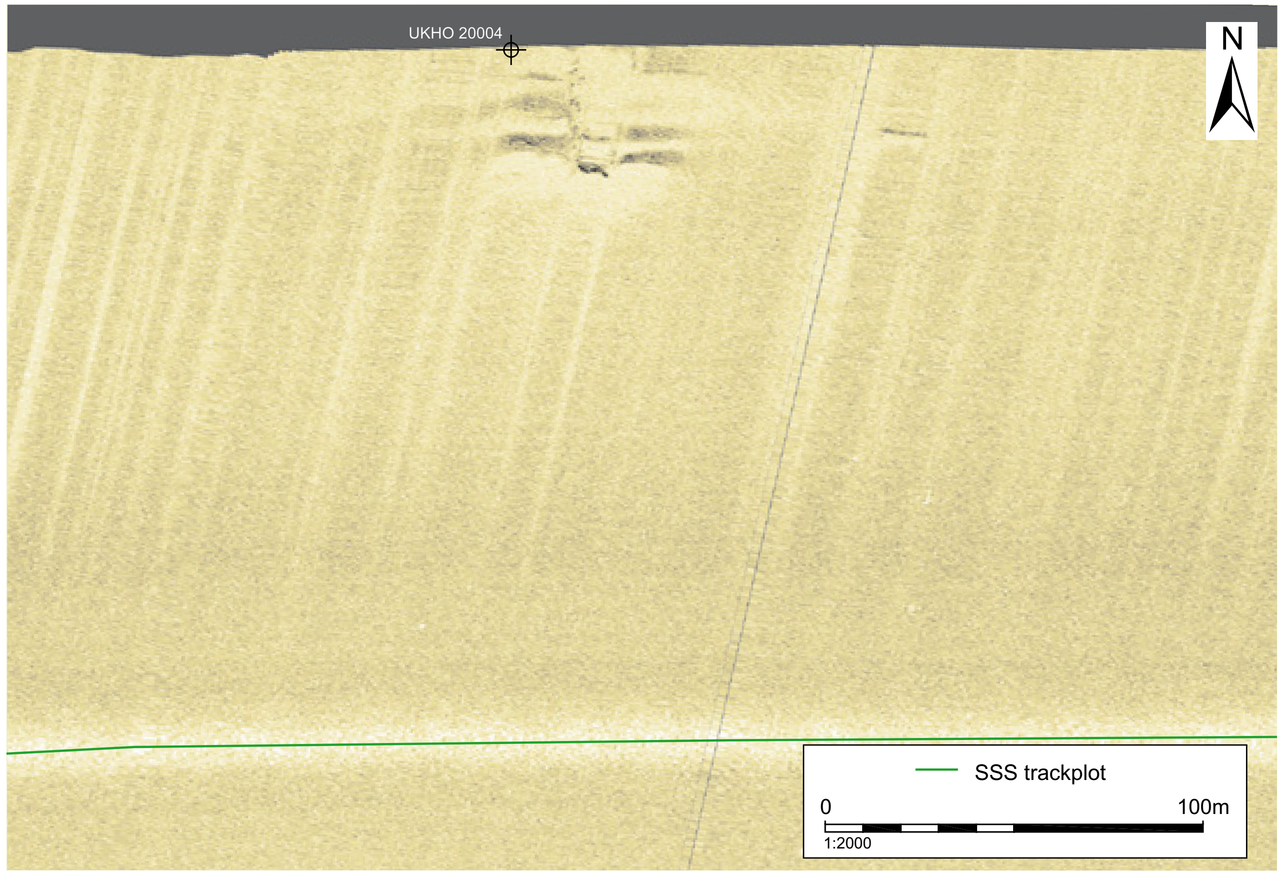




Magnetic profile shows an anomaly of 34.3nT adjacent to the wreck location.

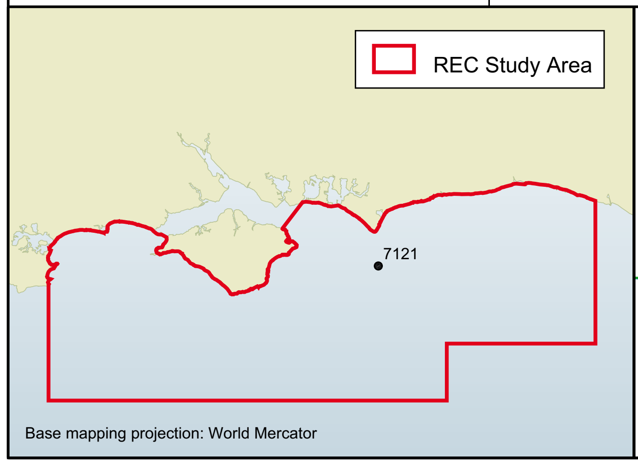
Figure 5.27: WA ID 7121 — *LCT (A)-2428* (currently charted as unidentified) UKHO 20004

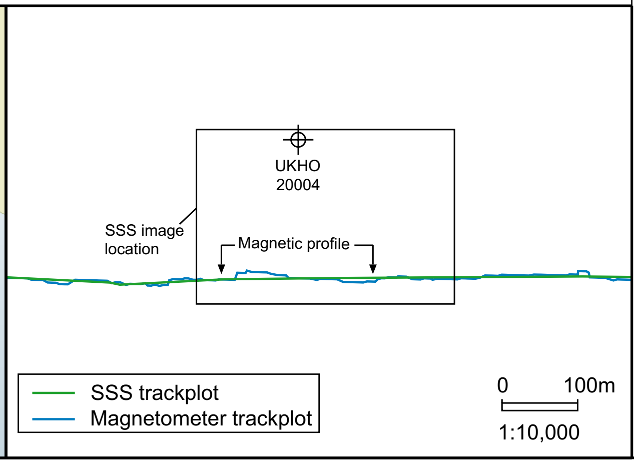
Location		657470 E 5611817 N (UTM 30N) 50 38.22 N 00 46.39 W (WGS84)	**Region** 2
Archaeological Importance		High	
Geophysical survey dimensions and notes		21.7m length x 9.2m width x 0m height. Wreck, extends off range so length particularly underestimated. Some internal structure visible. Surrounded by an area of disturbed seafloor measuring 41.2x28.2x0.0m. Located 12m E of 20004. Object of debris (6.6x0.7x0.0m) located 30m east of wreck. Not covered by bathymetry.	
Build	**Type**	Landing Craft Tank (Armoured) Mark 5	
	Construction	All steel	
	Dimensions	34.8m overall length x 10.0m beam x 0.9m draft; 286 short tons	
	Shipyard	Built as LCT-428 by the New York Shipbuilding Corp. in Camden, New Jersey, USA prior to June 1944	
Loss	**Cause**	Sunk by gunfire after capsizing	
Extent of Survival		This wreck is recorded by UKHO as being approximately 60m long, 4m high and orientated 165/345°. It is recorded as having a sonar length of 25m, a width of 5m and a height of 2.5m on a sandy seabed. The wreck is described as intact, inverted and almost buried. It is identified as a barge or LCT (landing craft (tank)). The geophysical data is consistent with an inverted partially buried metal flat bottomed craft. The internal structure that is apparent is probably the result of large holes in the bottom. Approximately 450m to the south are the positions for two NMR monument reports, 767316 and 911186, both flat bottomed wrecks. 767316 is described as a 20th century self-propelled steel barge wreck. 911186, just 4m away is described as a barge wreck. The similar description and position suggest these are duplicate records. Their proximity and descriptive similarity to 7121 suggest they are records of the same wreck. The sidescan data shows sandwaves have built up alongside the wreck, with the crests perpendicular to the length of the wreck. There may also be some scour around the southwest end of the wreck.	
BGS Sediment Characterisation		Rock with thin sediment / Sandy sediment	

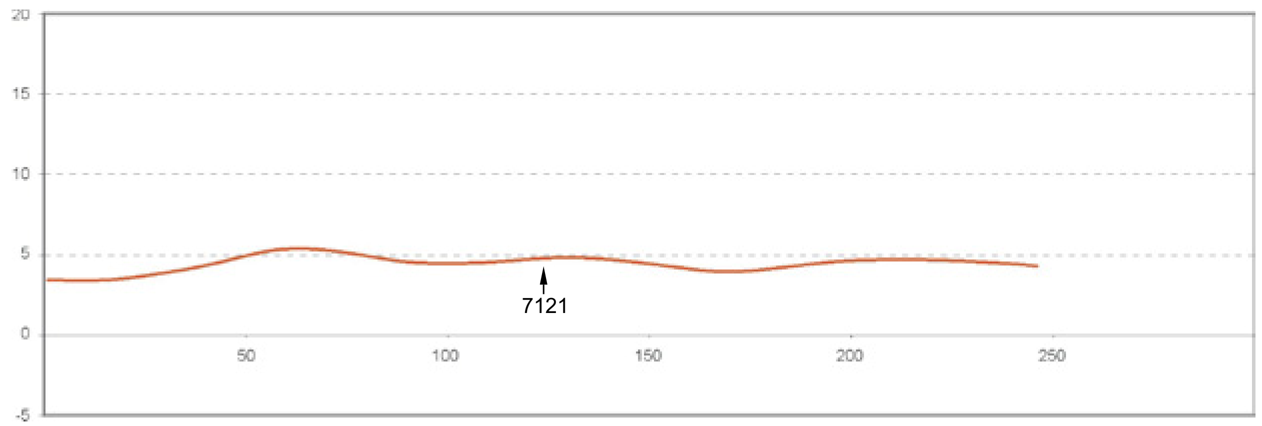


Mosaiced sidescan sonar image shows an intact, partially buried wreck.

This site was not covered by multibeam bathymetry.



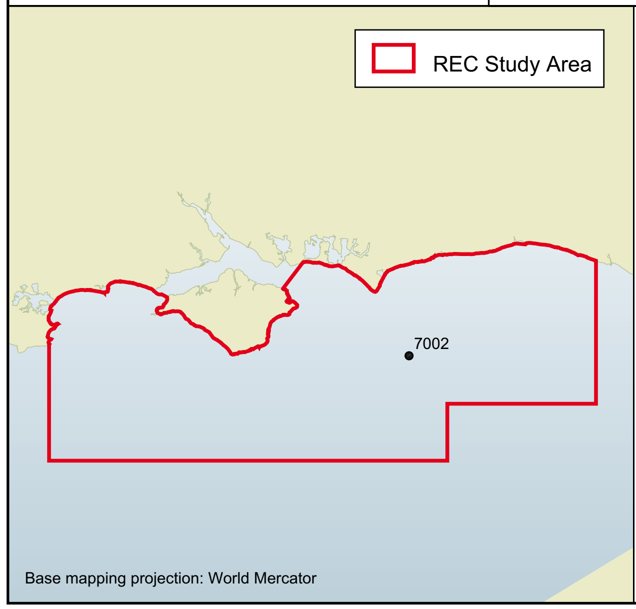


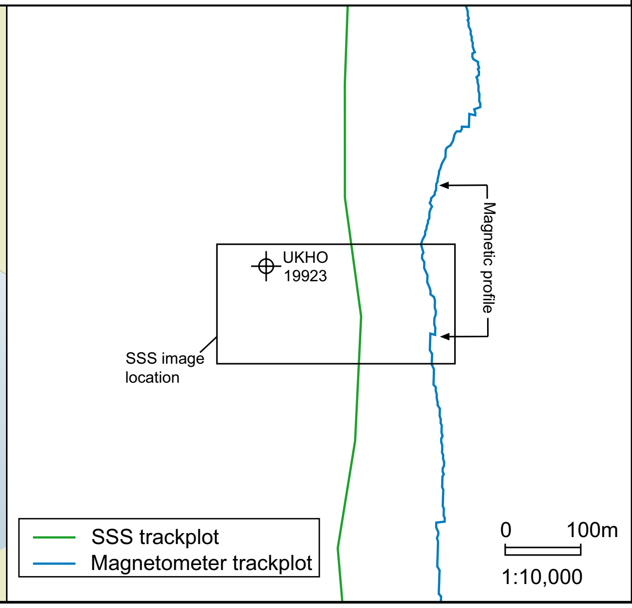


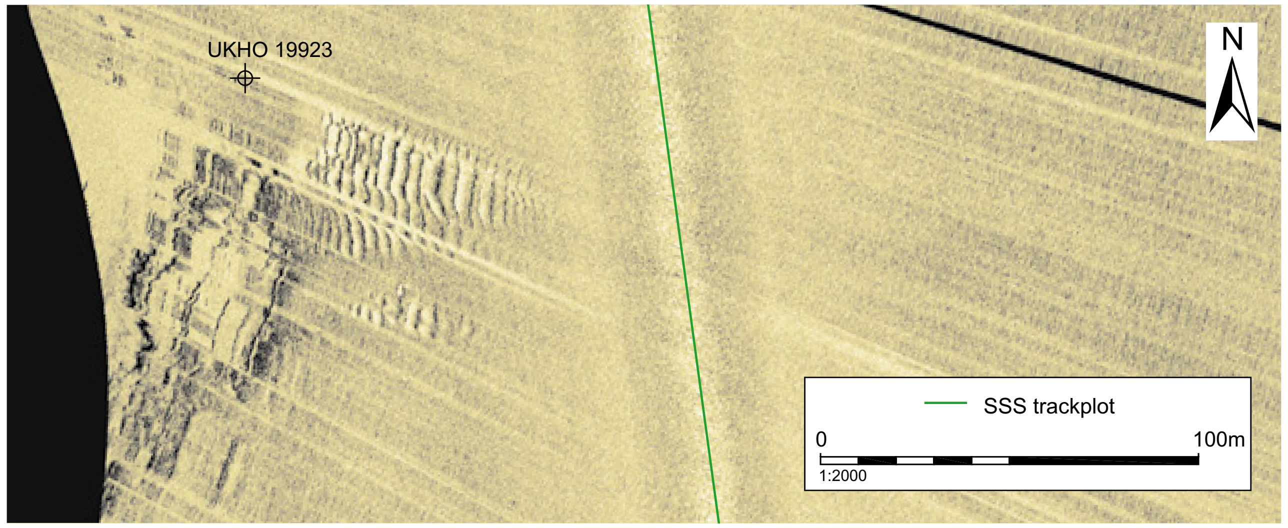
Magnetic profile shows no anomaly adjacent to the wreck location.

Figure 5.28: WA ID 7002 — Unidentified wreck UKHO 19923/NMR 767302 and 911166

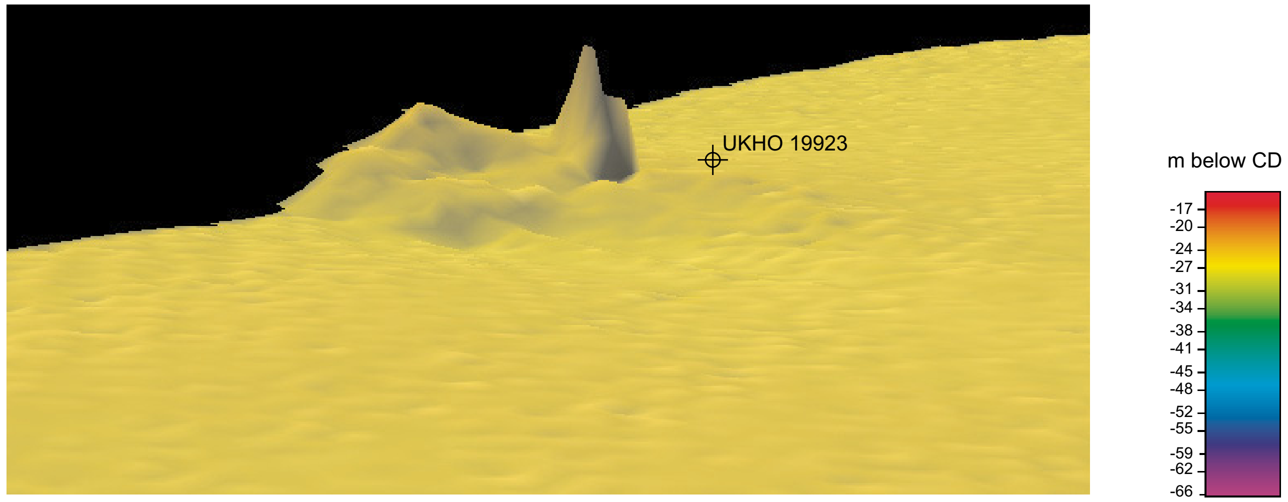
Location		665178 E 5604292 N (UTM 30N) 50 34.03 N 00 40.05 W (WGS84)	**Region**	2
Archaeological Importance		Medium		
Geophysical survey dimensions and notes		66m length x 30m width x 3.3m height. Broken up wreck. Poor SSS data, distorted. Bathy shows wreck orientation to be 050/230° but wreck extends off data to west. Wreck contains one particularly upstanding feature that measures 12m EW by 4m NS. It projects 2m up from the bulk of the wreck. Lies 8m south of 19923 position.		
Build	**Type**	Probable requisitioned steam trawler		
	Construction	Unknown		
	Dimensions	Unknown		
	Shipyard	Unknown		
Loss	**Cause**	Unknown		
Extent of Survival		The UKHO record this wreck as being 90m long, well broken up with a depth of 19.5m in a general depth of 26m. Orientation is described as 040/220°. A scour with a depth of 1m is recorded. Seabed type is described as sandy. Diver reports suggest that this wreck is 88m long and "very broken". The stern is reported to be the most intact section, lying on its port side with a large iron propeller still attached. A spare propeller is lying by a boiler. The wreck is reported to be a probable First World War casualty. The project geophysical data confirms previous reports that this wreck is well broken up. However it does not assist in further characterising the wreck beyond the description provided by diver reports. There is no scour evident in the geophysical data but 2 areas of sand ripples or sandwaves, with crests oriented N-S, can be seen adjacent to the north-east of the wreck.		
BGS Sediment Characterisation		Sandy sediment		



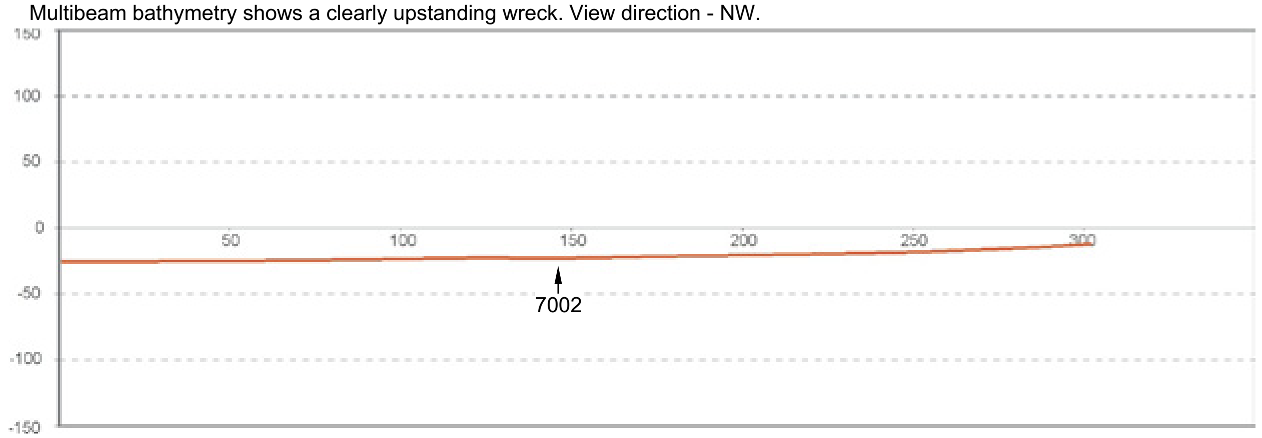




Mosaiced sidescan sonar image shows a broken up wreck.



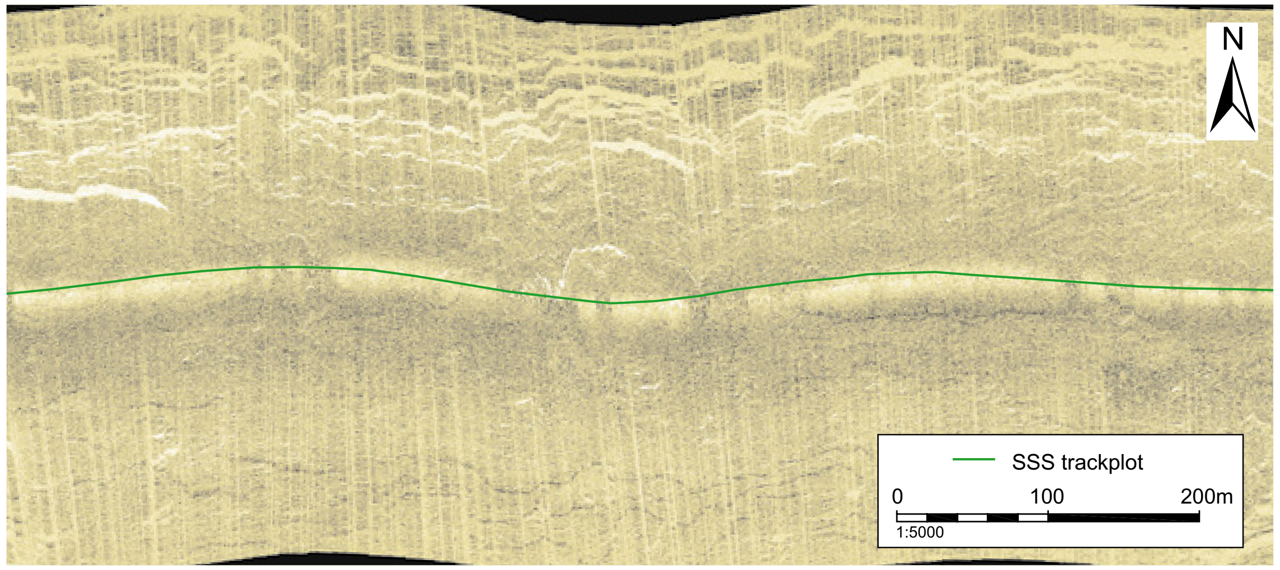
Multibeam bathymetry shows a clearly upstanding wreck. View direction - NW.



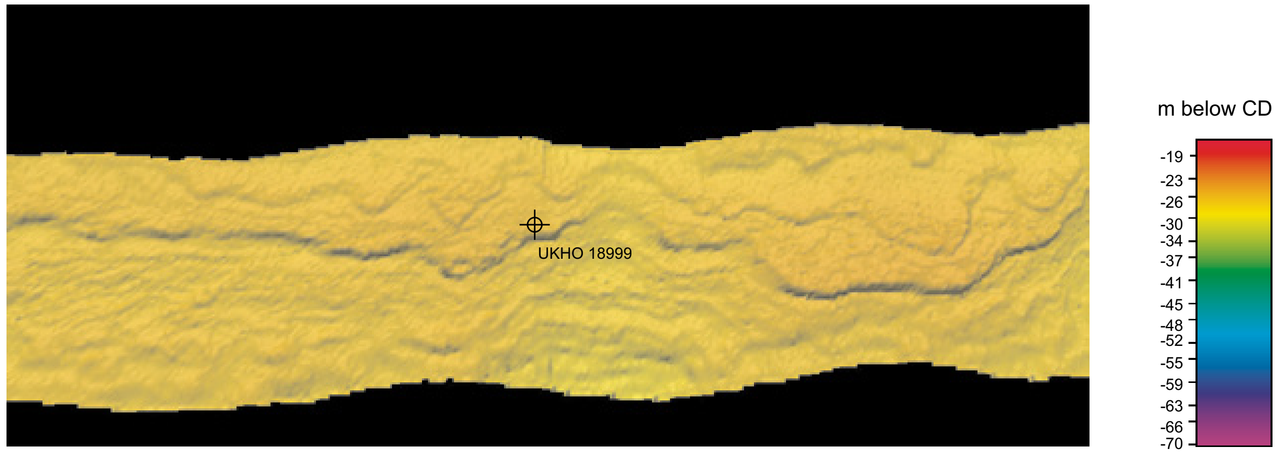
Magnetic profile shows no anomaly adjacent to the wreck location.

Figure 5.29: WA ID 7224 — Possible uncharted wreck UKHO 18999

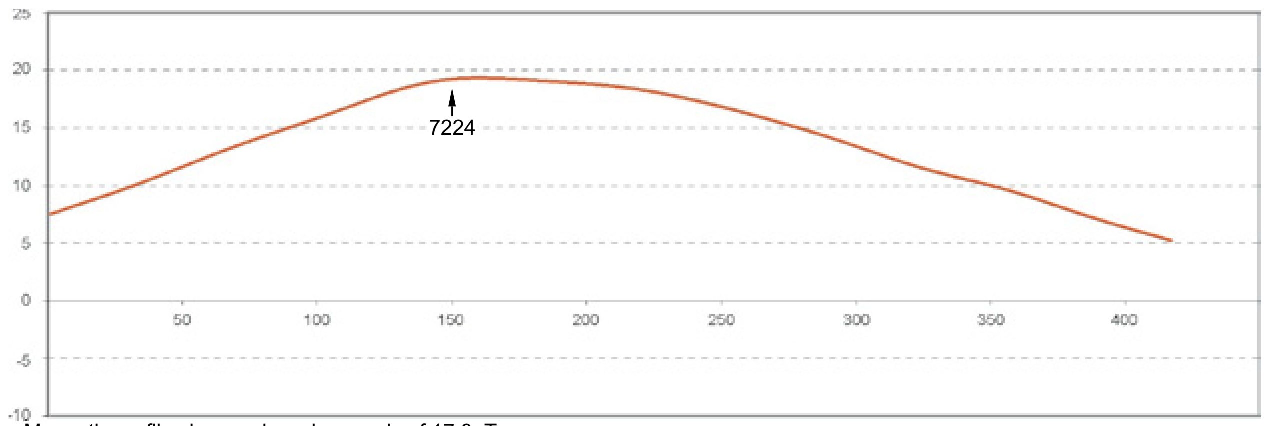
Location		637460 E 5602340 N (UTM 30N) 50 33.41 N 01 03.56 W (WGS84)	**Region**	2
Archaeological Importance		Low		
Geophysical survey dimensions and notes		Magnetometer anomaly, amplitude 17.80nT. Possible buried wreck or debris. 290m NE of 18999, the wreck of a coaster. Not seen in bathymetry data.		
Build	**Type**	Small metal object or wooden shipwreck		
	Construction	Unknown		
	Dimensions	Unknown		
	Shipyard	Unknown		
Loss	**Cause**	Unknown		
Extent of Survival		Not detected in sidescan sonar data and may be buried		
BGS Sediment Characterisation		Rock and thin sediment		



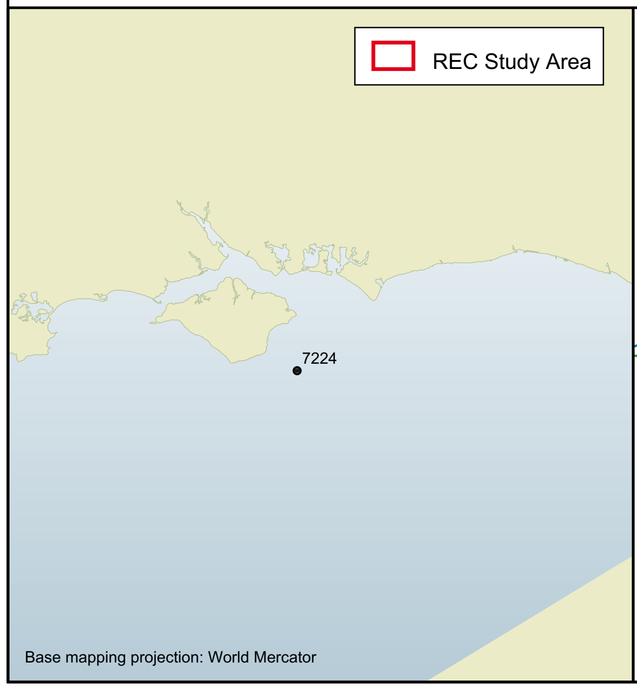
Mosaiced sidescan sonar image shows no features at anomaly location.



Multibeam bathymetry shows no features at anomaly location. View direction - S.



Magnetic profile shows a broad anomaly of 17.8nT.



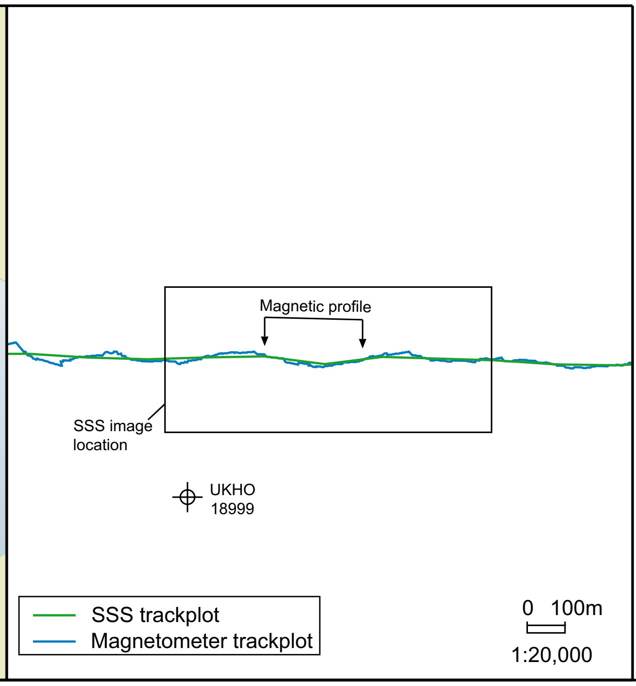
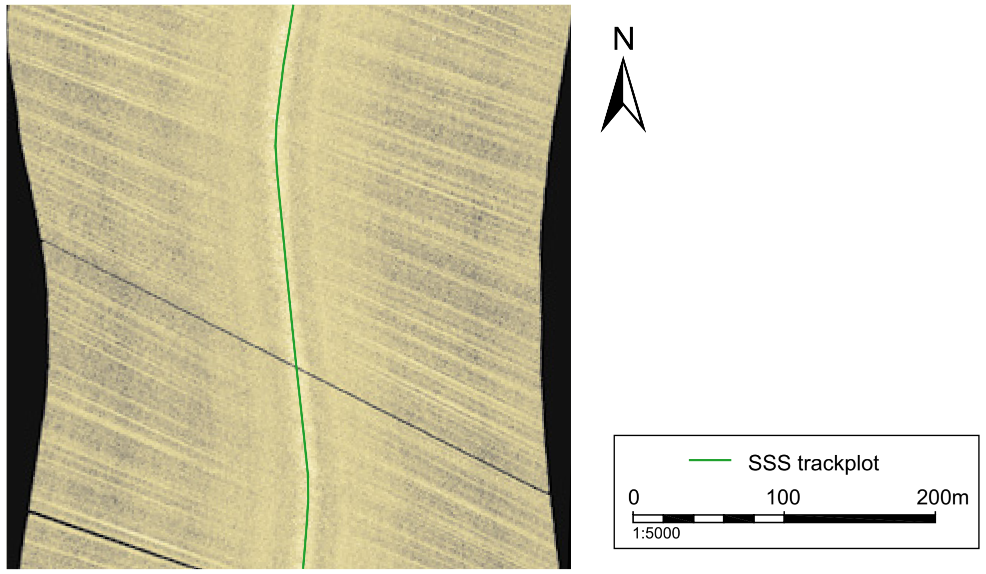
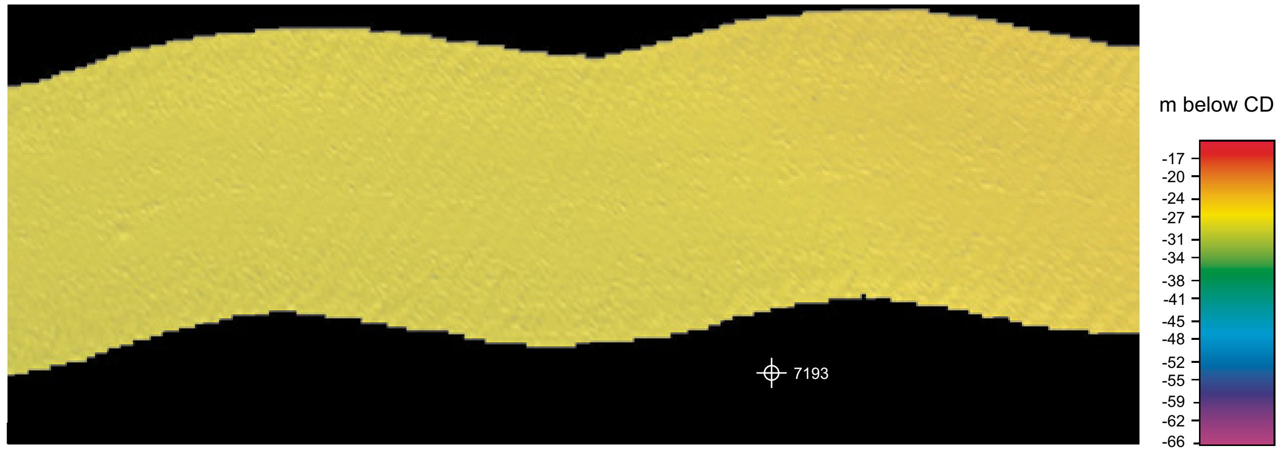


Figure 5.30: WA ID 7193 — Possible uncharted wreck

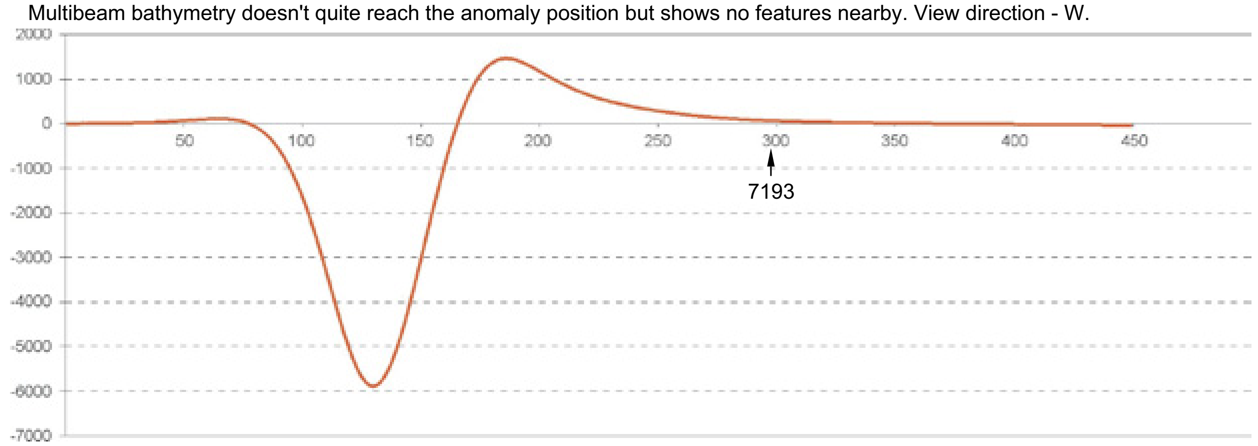
Location	665336 E 5604042 N (UTM 30N) 50 33.89 N 00 39.92 W (WGS84)	**Region**	2
Archaeological Importance	Uncertain		
Geophysical survey dimensions and notes	Magnetometer anomaly of 9274.32nT; Very large anomaly suggestive of a buried wreck. NMR 911731 is 12m to the south and NMR 767302 and NMR 911166 lie 270m to the southwest but all appear to be inaccurate positions for SS *Lola* (7000), which lies to the north. Nothing visible in sidescan here. May be associated with unidentified wreck 7002, which is 260m to the NW. Not covered by bathymetry data. No pipelines or other fixed infrastructure in vicinity.		
Build – **Type**	Unknown		
Build – **Construction**	Unknown		
Build – **Dimensions**	Unknown		
Build – **Shipyard**	Unknown		
Loss – **Cause**	Unknown		
Extent of Survival	Not possible to tell as the feature was only detected in the magnetometer data.		
BGS Sediment Characterisation	Sandy sediment		



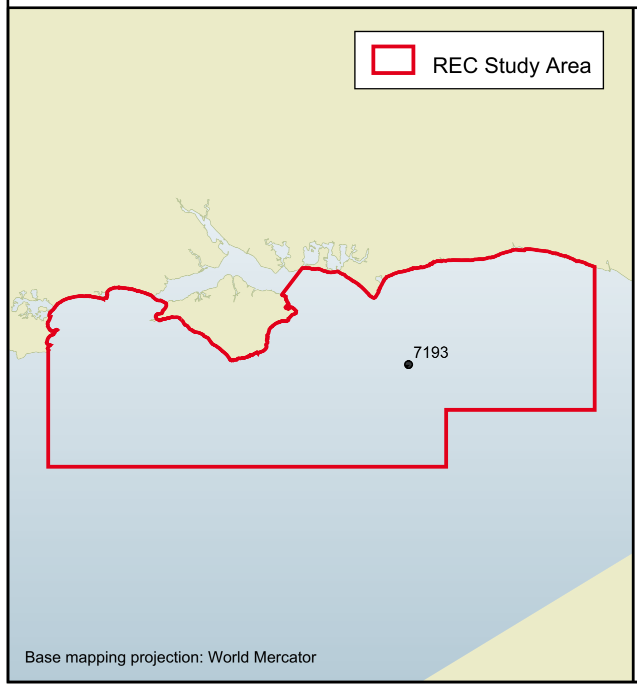
Mosaiced sidescan sonar image shows no visible feature at the anomaly posiiton.



Multibeam bathymetry doesn't quite reach the anomaly position but shows no features nearby. View direction - W.



Magnetic profile shows a large anomaly of 9274.3nT.



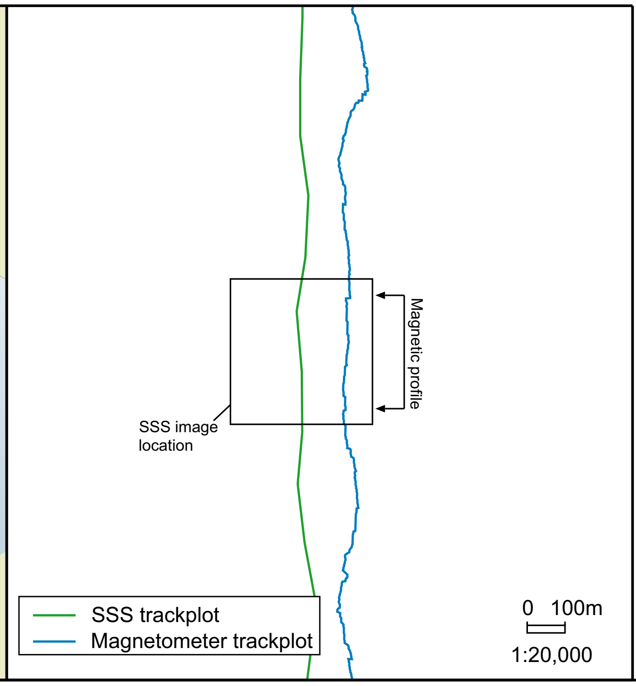
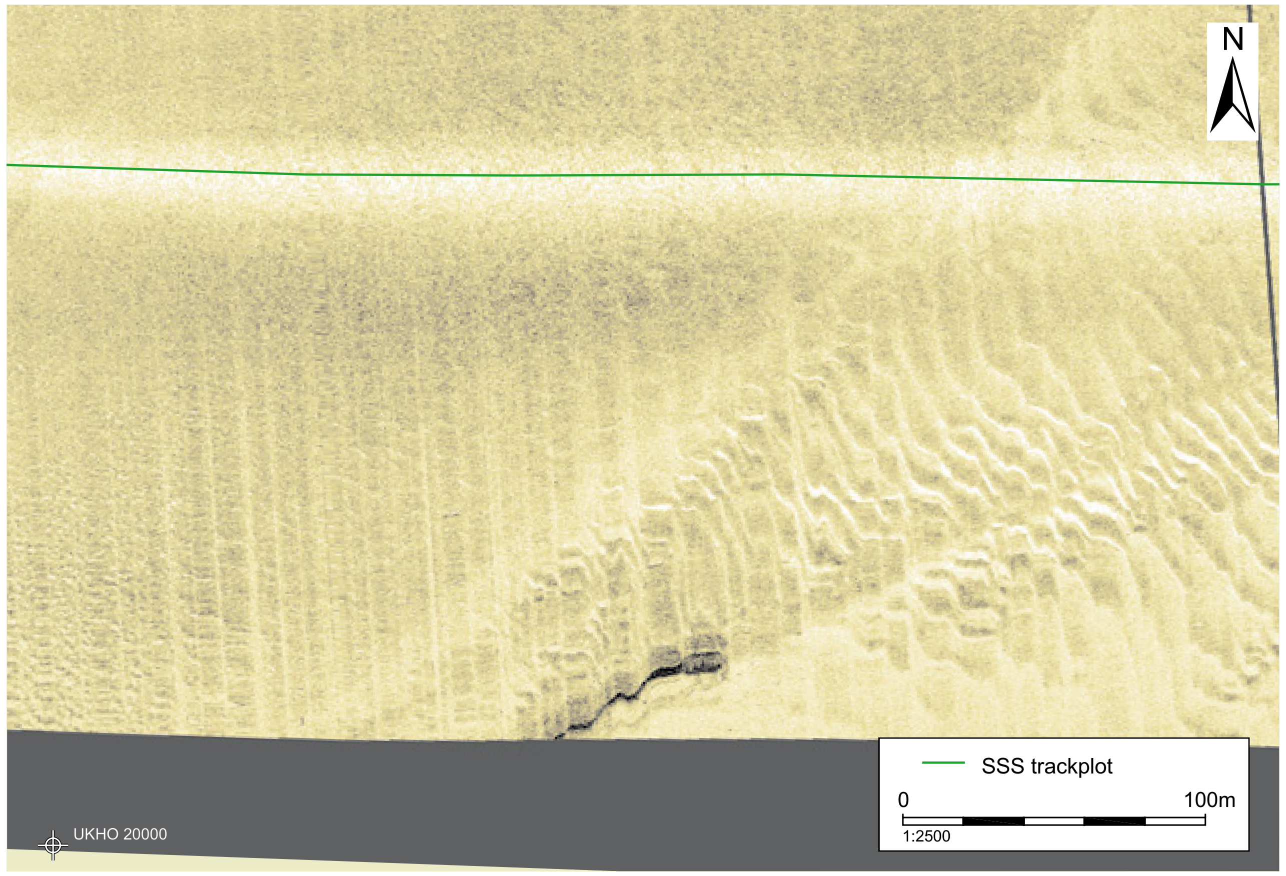


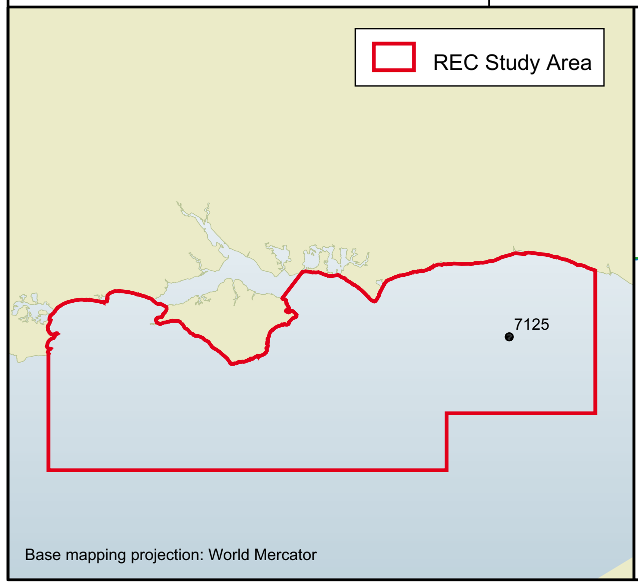
Figure 5.31: WA ID 7125 — *Quail* UKHO 20000

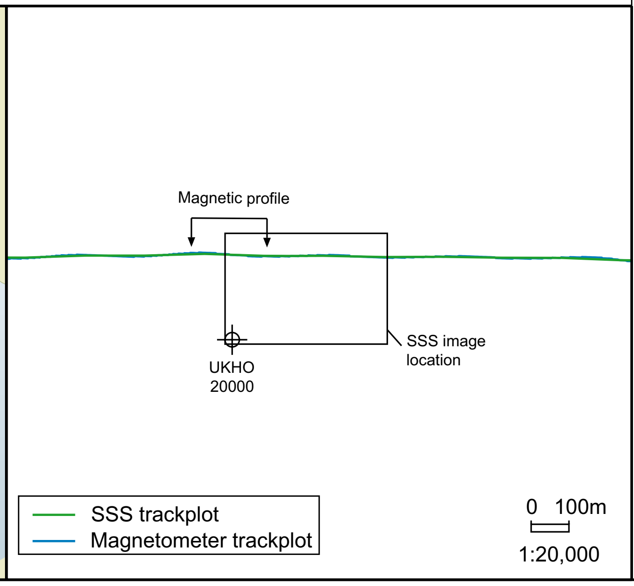
Location		690433 E 5612674 N (UTM 30N) 50 38.09 N 00 18.42 W (WGS84)	**Region** 3
Archaeological Importance		Medium	
Geophysical survey dimensions and notes		40.8m x 19.3m x 0m (height not determinable). Possible wreck. Contains a dark reflector (38.4x6.5x0.0m) that extends off range. 100m NE of 20000. Not covered by bathymetry.	
Build	**Type**	Steam ship; probable early tramp vessel	
	Construction	Possibly iron	
	Dimensions	68.3m length x 8.5m beam x 5.2m draught; 924 gross tons	
	Shipyard	Built 1870 by Palmers Shipbuilding and Iron Company, Jarrow.	
Loss	**Cause**	Collision	
Extent of Survival		The UKHO charted position is approximately 100m from the geophysical anomaly, which extends off range towards the charted position. This is consistent with them being the same wreck. UKHO describe the wreck as being in two pieces, with a "small forward part" on its side and the "after part" upright. Orientation is given as 80° and the sonar dimensions as being 79.8m long, 9.1m wide and 6.5m high. General depth is 36m. The wreck is reported by divers to be upright with its bow broken off and lying with its port side to the west and its large counter-stern lying to the east. There is reported to be no sign of its superstructure and masts, although one or both of the engines can be seen (McDonald 1999: 102). The project geophysical survey data is neither consistent nor inconsistent with this description because the anomaly extends off range and the height of the object cannot be determined. The close proximity of the anomaly and the lack of other charted wrecks do however suggest that 7125 is part of the *Quail*. The sidescan data shows the *Quail* to lie in an area of sand ripples, possibly on a sandbank. No scouring is apparent.	
BGS Sediment Characterisation		Sandy sediment	

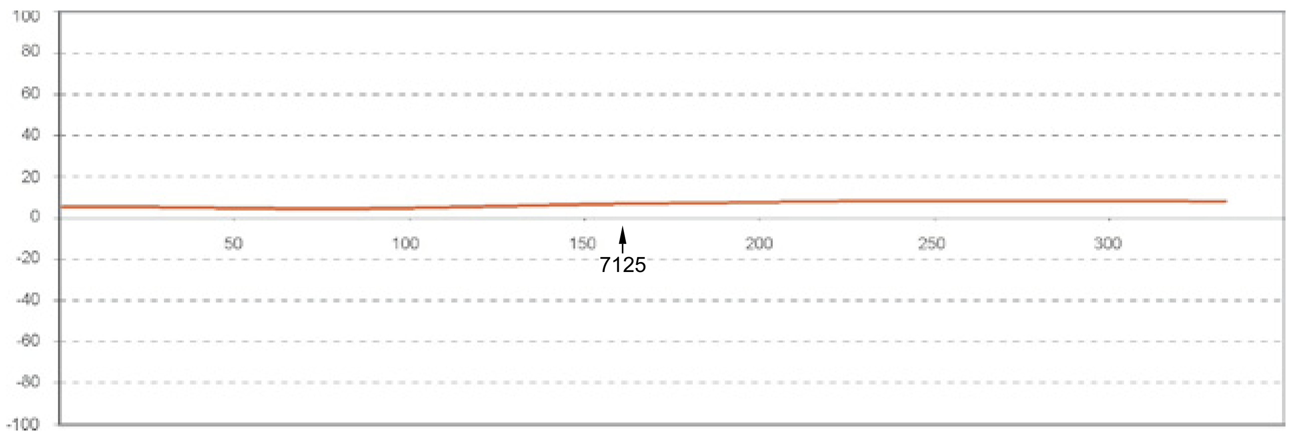


Mosaiced sidescan sonar image shows a distorted dark reflector extending off the range.

This site was not covered by multibeam bathymetry.







Magnetic profile shows no anomaly adjacent to the wreck location.

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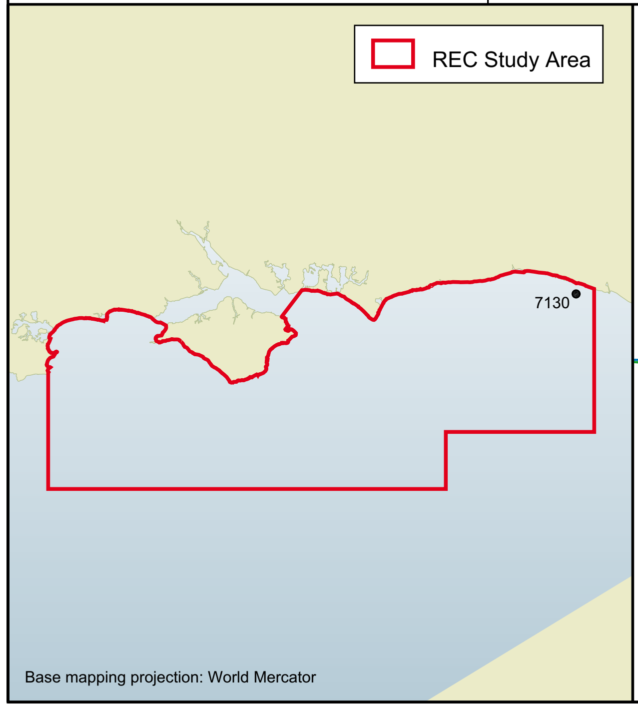
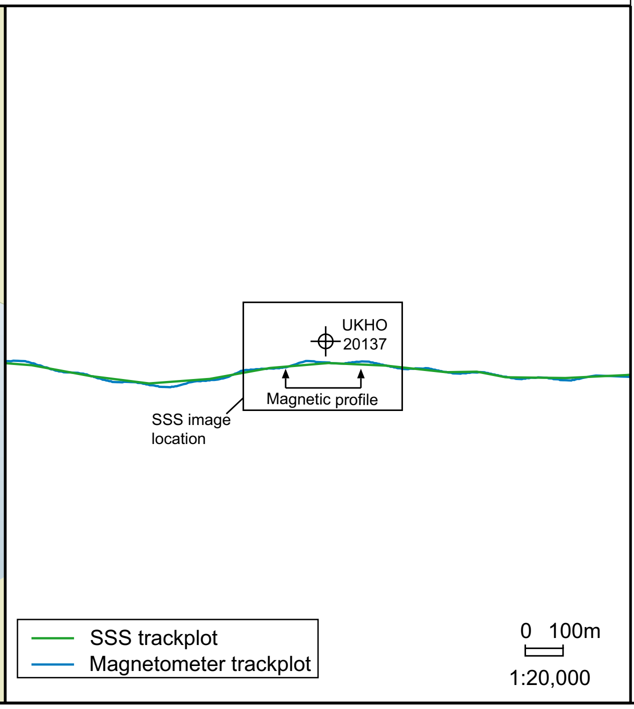
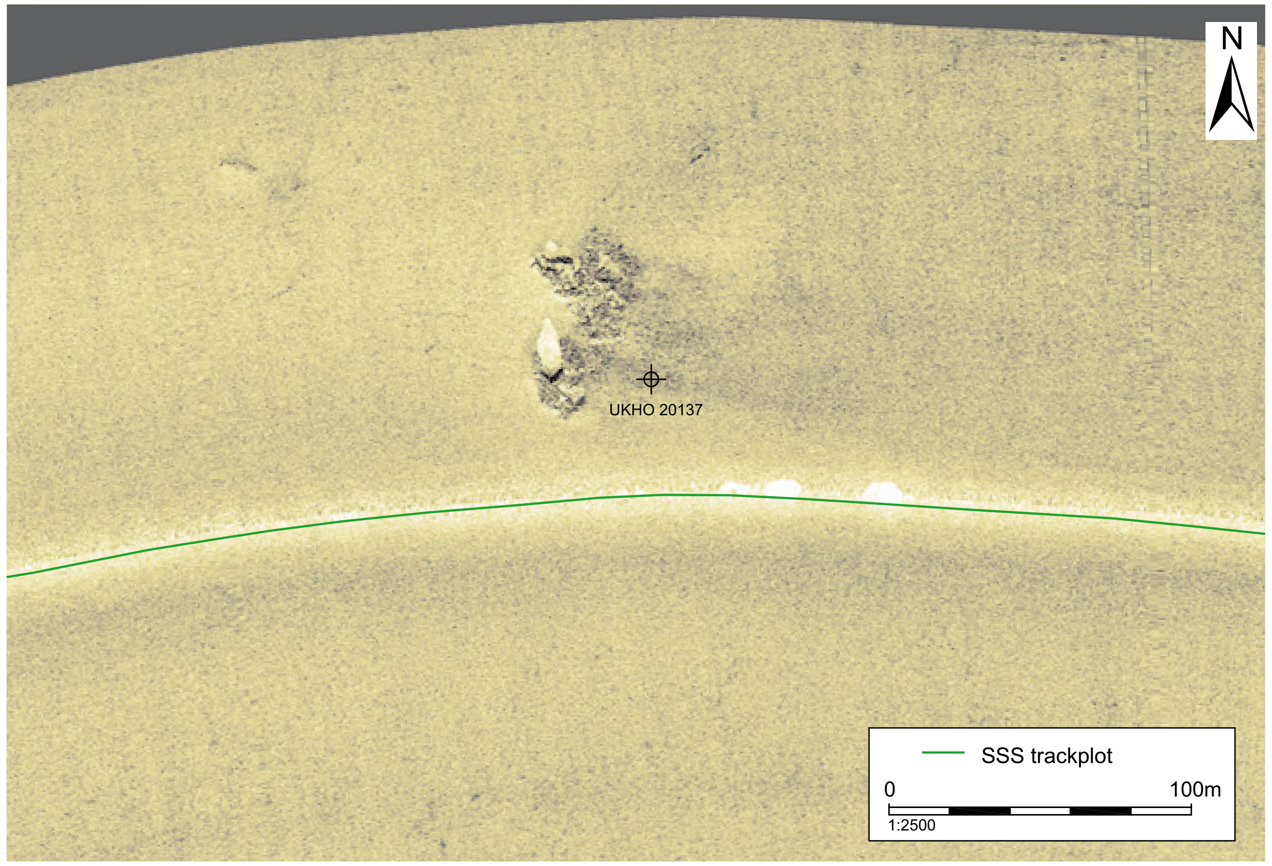
Figure 5.32: WA ID 7130 — HMT *Inverclyde* UKHO 20137

Location		707111 E 5628881 N (UTM 30N) 50 46.48 N 00 03.74 W (WGS84)	**Region**	3
Archaeological Importance		Medium		
Geophysical survey dimensions and notes		41.6m length x 25.1m width x 0m height. Broken up wreck 6m W of 20137. Contains 3 items of debris, 2 at the southern end (4.8x2.6x2.8m and 6.6x2.5x0.9m) and one near the northern end (7.0x1.4x0.0m). Not covered by bathymetry.		
Build	**Type**	Requisitioned trawler		
	Construction	Possibly steel		
	Dimensions	36.9m long x 6.7m beam x 3.7m draught; 215 tons		
	Shipyard	Built 1914 as *Perihelion*		
Loss	**Cause**	Sank under tow		
Extent of Survival		Surveyed by UKHO as having a sonar length of 36m and a sonar width of 30m, with a 1.5m deep scour. A debris field 30m long is noted. General depth is 12m with a least depth of 10.6m and the seabed is recorded as sand. Described as an "area of scattered wreckage which lies in scour". It is recorded as having 3 feet of mast showing in March 1943. Recorded as having been dispersed in 1946 and swept to 13.7m. The project geophysical data is consistent with diver descriptions of a dispersed wreck and the position and dimensions of 7130 are consistent with it being identified as HMT *Inverclyde*. No bedforms or scours are apparent in the geophysical data next to the wreck.		
BGS Sediment Characterisation		Sandy sediment		

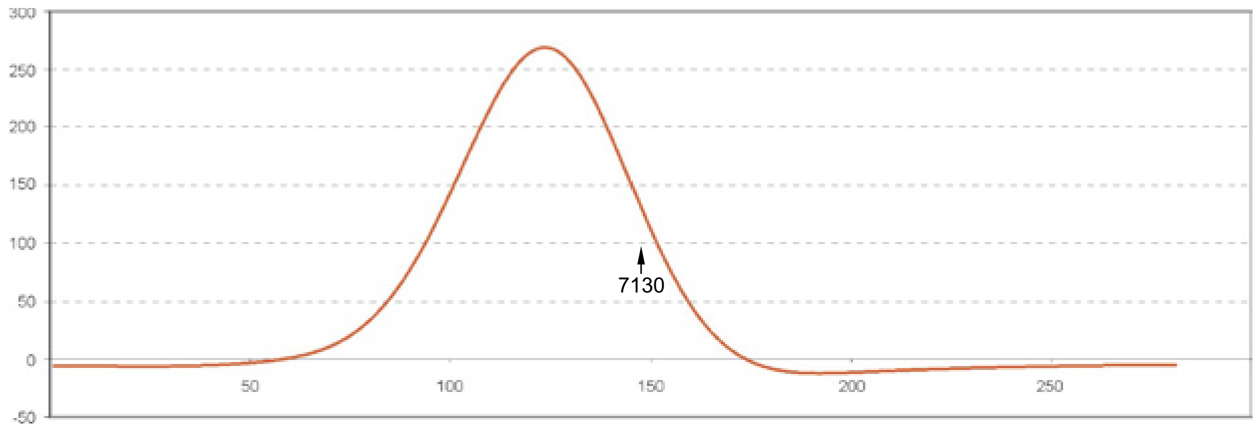






Mosaiced sidescan sonar image shows a broken up wreck.

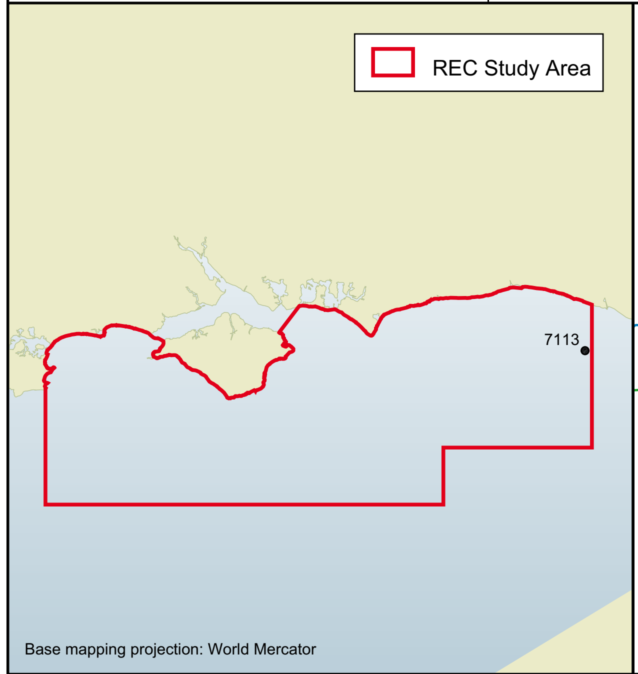
This site was not covered by multibeam bathymetry.

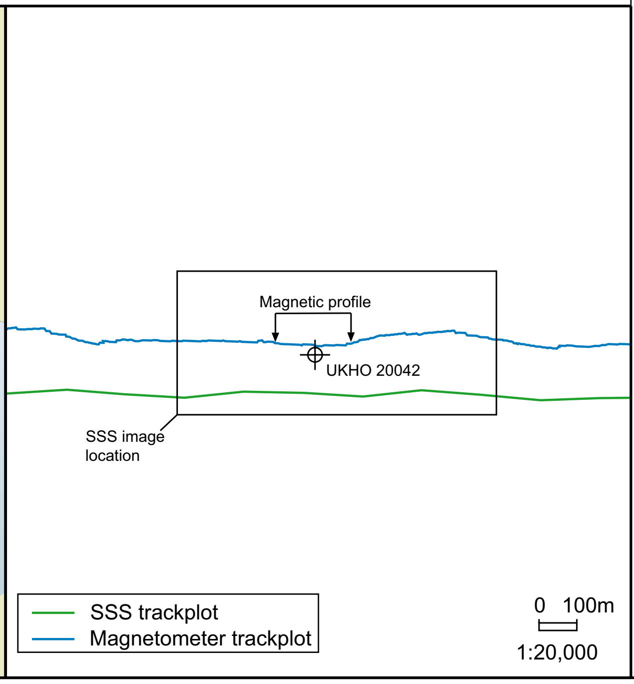


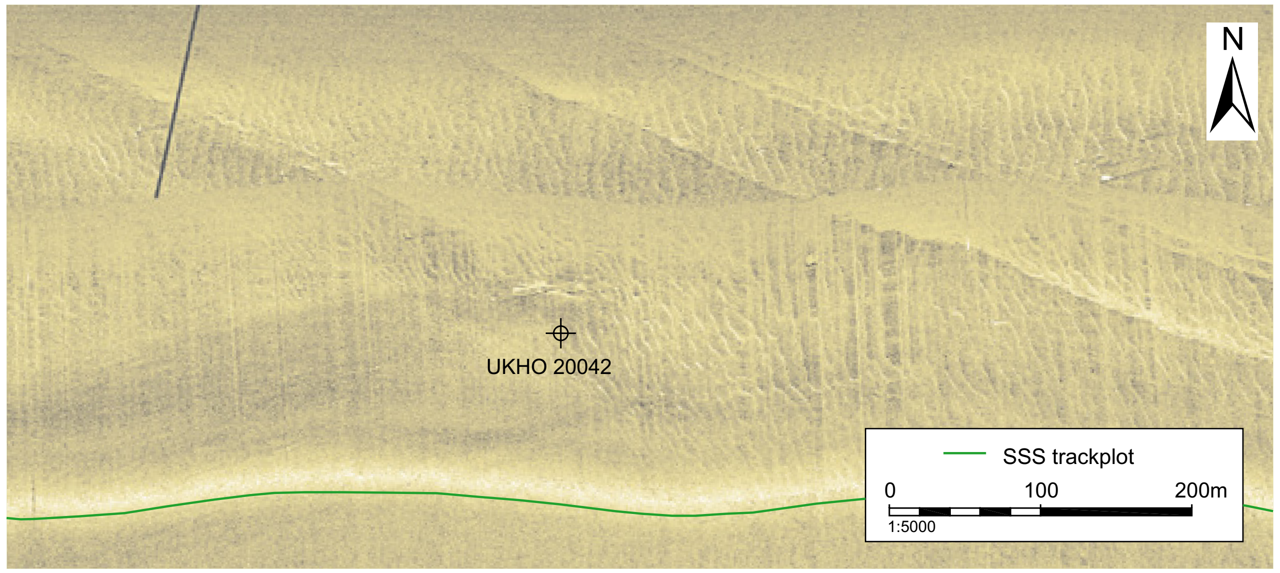
Magnetic profile shows an anomaly of 328.4nT adjacent to the wreck location.

Figure 5.33: WA ID 7113 — *Girlvine* UKHO 20042

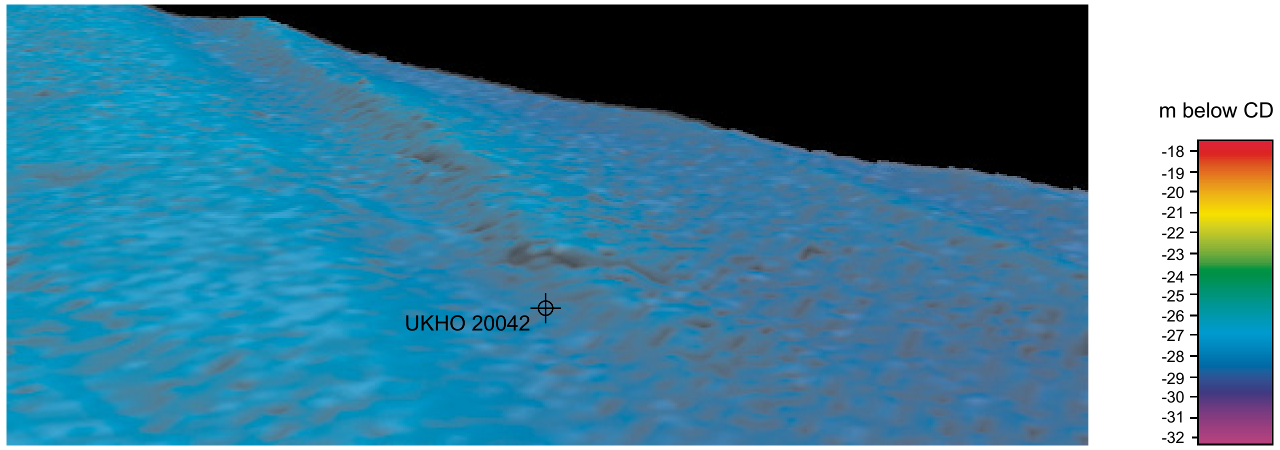
Location		710189 E 5618518 N (UTM 30N) 50 40.83 N 00 01.48 W (WGS84)	**Region**	3
Archaeological Importance		Medium		
Geophysical survey dimensions and notes		32m length x 7m width x 0.4m height; wreck, possibly partially buried. No obvious superstructure. Hard reflector on near side measures 14.7 x 3.0 x 0.4m. Not seen in bathy data. Just appears as a change in a sandbank, possibly due to resolution.		
Build	**Type**	Believed to be a motor fishing vessel (type unknown)		
	Construction	Steel		
	Dimensions	Unknown		
	Shipyard	Unknown		
Loss	**Cause**	Foundered, cause unknown		
Extent of Survival		The wreck is recorded by UKHO as having a minimum depth of 26.5m in a general depth of 29m with a sonar height of 1.6m. It is visited by recreational divers who describe it a being a small fishing vessel. As of 1999 the hull was intact and upright but the deck had collapsed. This is consistent with the geophysical data, which also suggests collapse of the superstructure and partial burial by sand. It was also reported to be partially buried in 1980. The geophysical data shows the wreck to lie on a sandbank or sandwave in an area of sand ripples. No scours are apparent.		
BGS Sediment Characterisation		Sandy sediment		



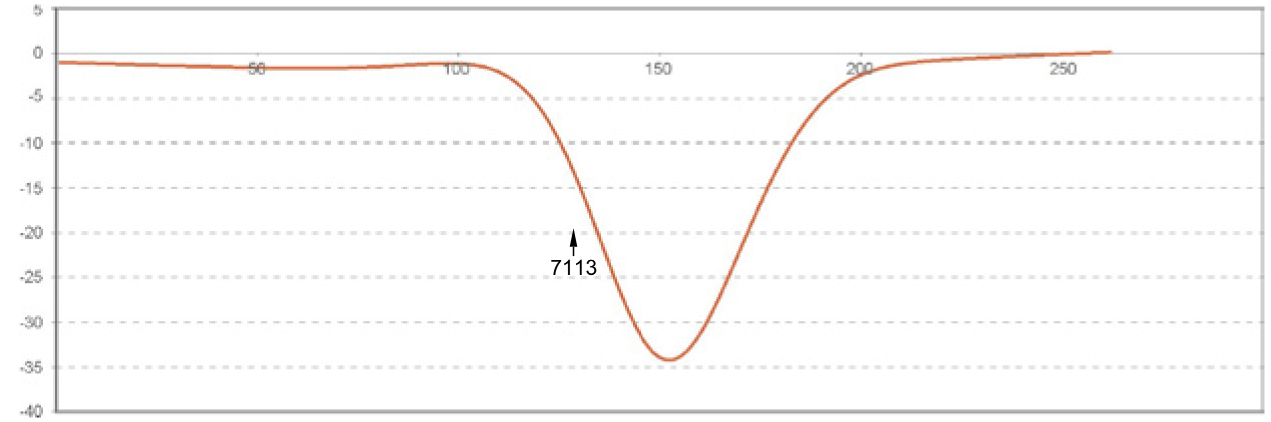




Mosaiced sidescan sonar image shows a broken up and scattered wreck.



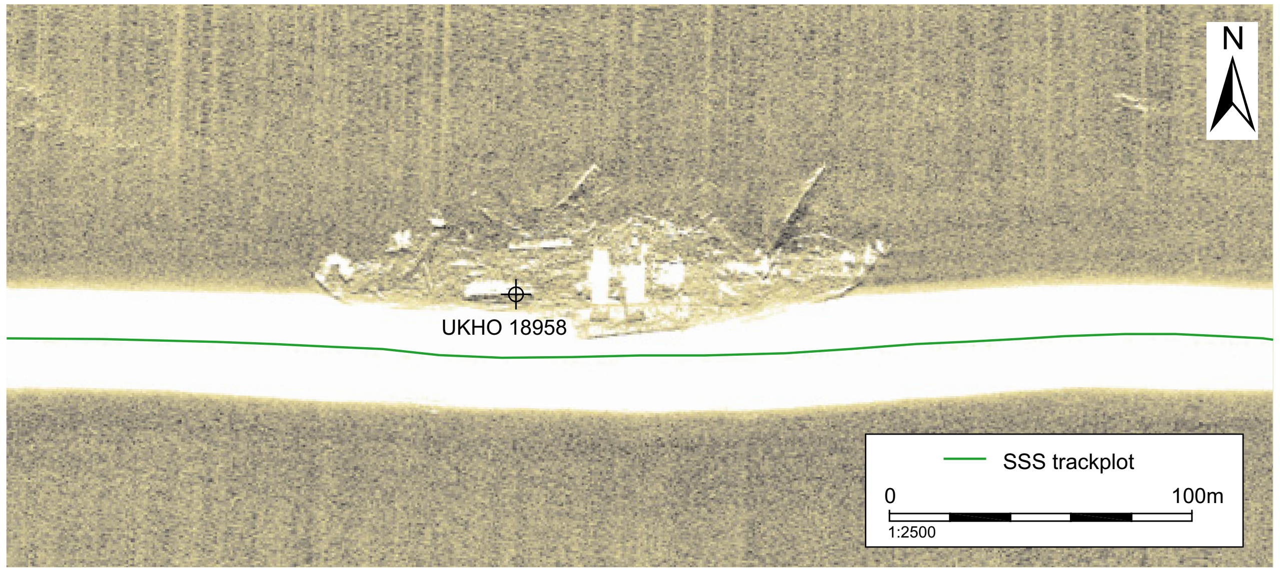
Multibeam bathymetry shows a change in a sandbank but no clear wreck. View direction - NW.



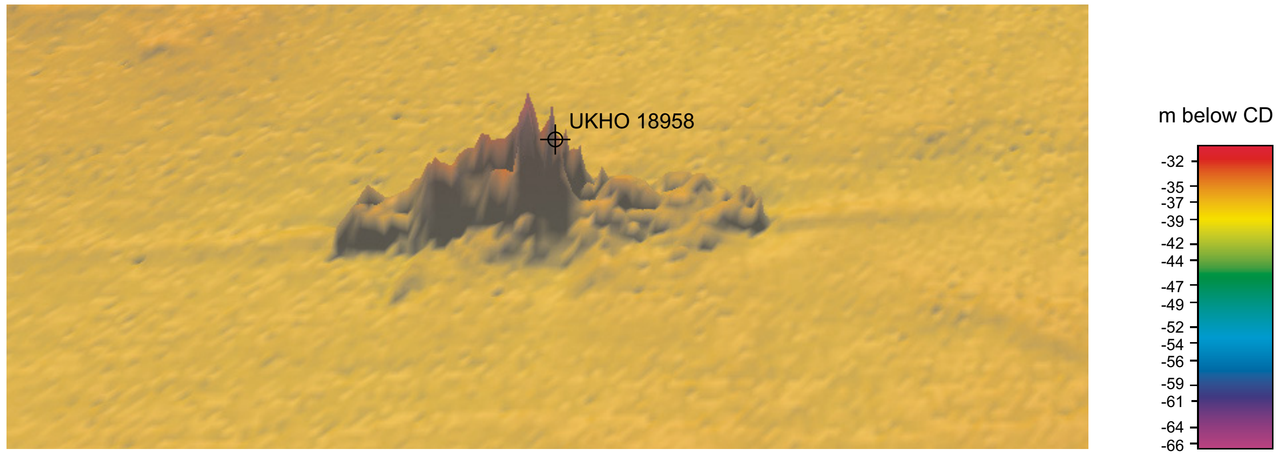
Magnetic profile shows an anomaly of 33.6nT adjacent to the wreck location.

Figure 5.34: WA ID 7089 — SS *Mendi* UKHO 18958

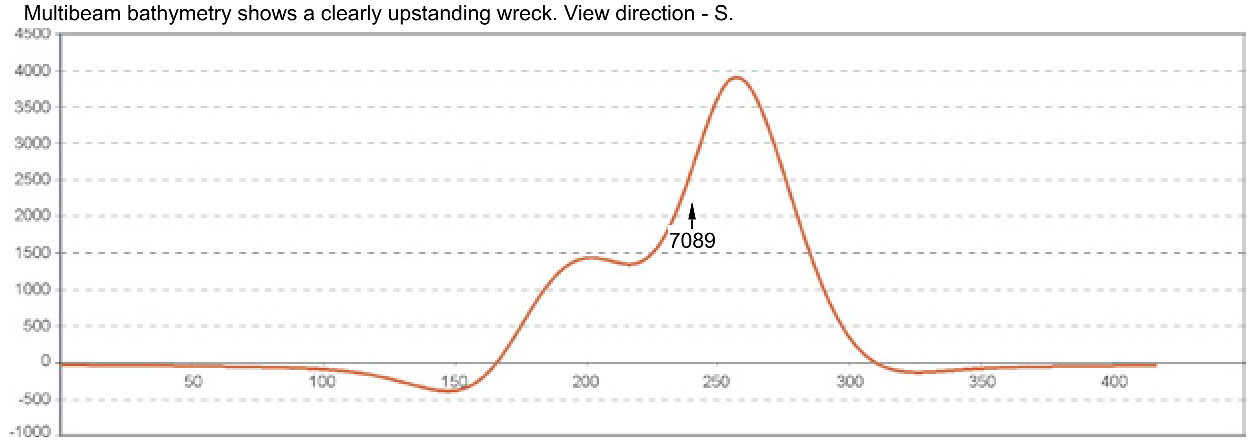
Location		618247 E 5590915 N (UTM 30N) 50 27.50 N 01 20.05 W (WGS84)	**Region**	4
Archaeological Importance		High		
Geophysical survey dimensions and notes		124m length x 41m width x 6m height. Broken up wreck. Orientation 85/265°. Minimum depth 30.6m. Seabed depth 36.5m. At location of 18958. An area of debris measuring 9.4m x 4.5m x 0.0m is situated 54m NE of the wreck.		
Build	**Type**	Merchant steam ship (cargo-liner).		
	Construction	Riveted clinker steel shell plate and framed construction, typical of the early 20th century.		
	Dimensions	112.84m length x 14.08m breadth x 8.22m depth of hold; 4230 gross registered tonnes.		
	Shipyard	Built 1905 by Alexander Stephen & Sons Ltd of Linthouse in the Govan area of Glasgow.		
Loss	**Cause**	Collision		
Extent of Survival		Diver investigation since 1974 appears to have demonstrated that the entire length of the hull survived the sinking intact. The superstructure and upper decks had collapsed but much artefactual evidence appears to have survived (WA 2007). The site has been subject to a comprehensive desk-based archaeological assessment (WA 2007) and a subsequent geophysical survey (WA 2008). That geophysical assessment suggested that the condition of the site had changed since the wreck was wire swept in 2003, with the trend being that of rapid collapse. The above geophysical description is consistent with this. No bedforms or scour are apparent adjacent to the wreck in the geophysical data.		
BGS Sediment Characterisation		Rock and thin sediment		



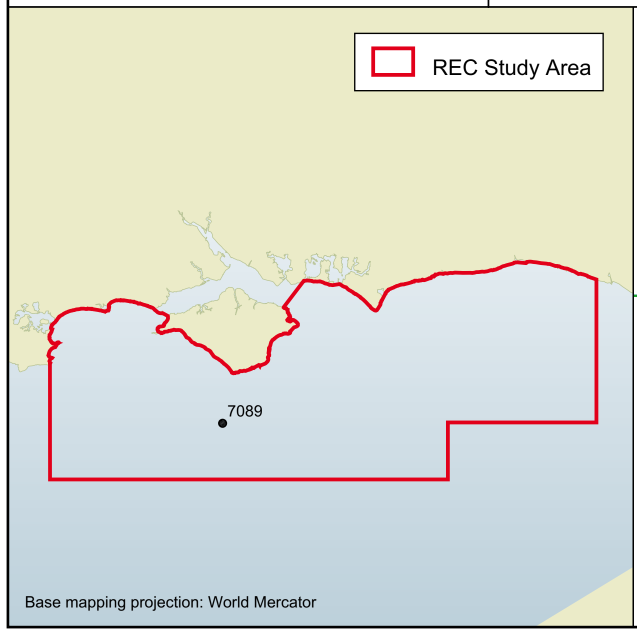
Mosaiced sidescan sonar image shows a broken up but largely coherent wreck (water column intentionally not removed).



Multibeam bathymetry shows a clearly upstanding wreck. View direction - S.



Magnetic profile shows a large anomaly of 5872.6nT adjacent to the wreck location.



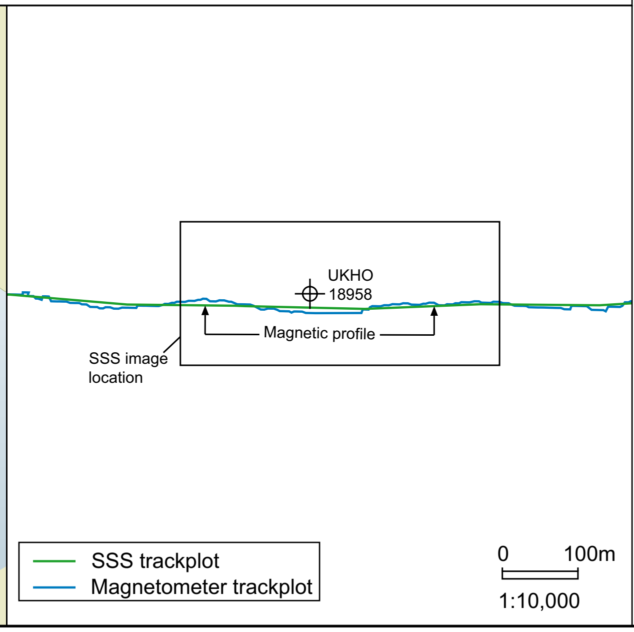
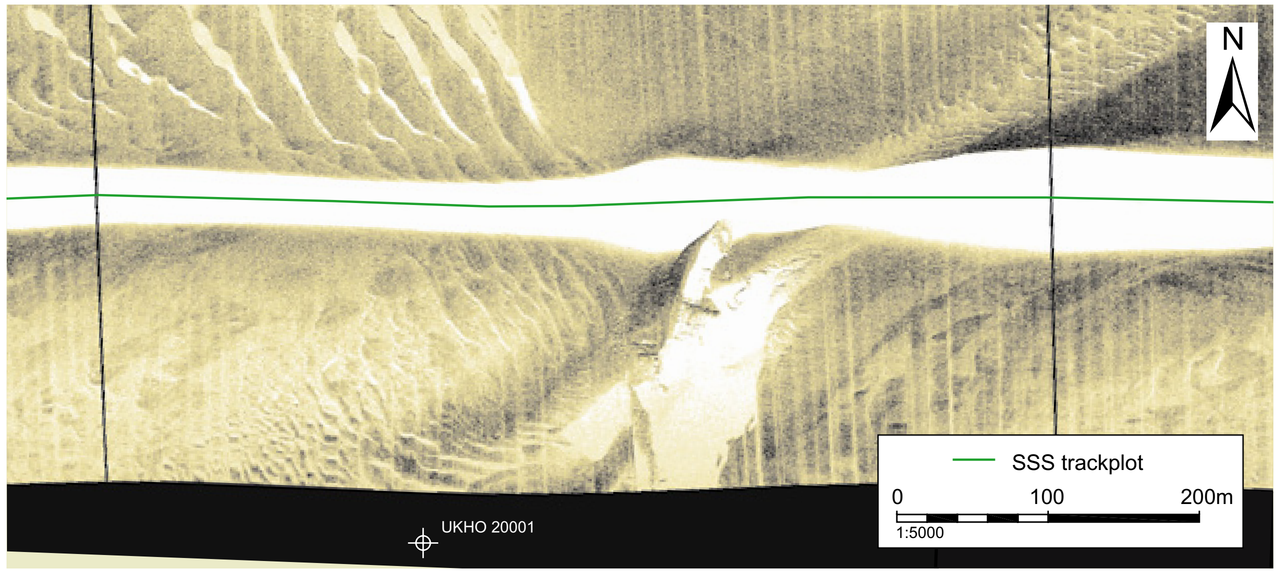
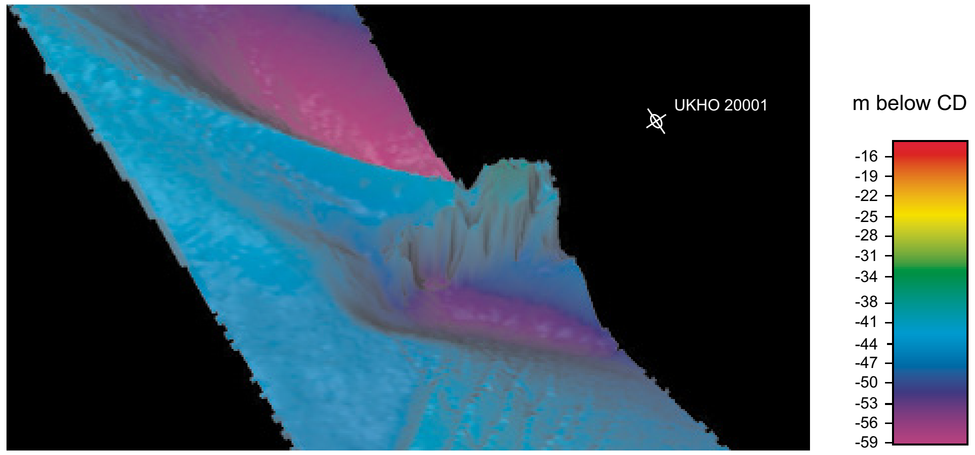


Figure 5.35: WA ID 7126 — SS *Pagenturm* UKHO 20001

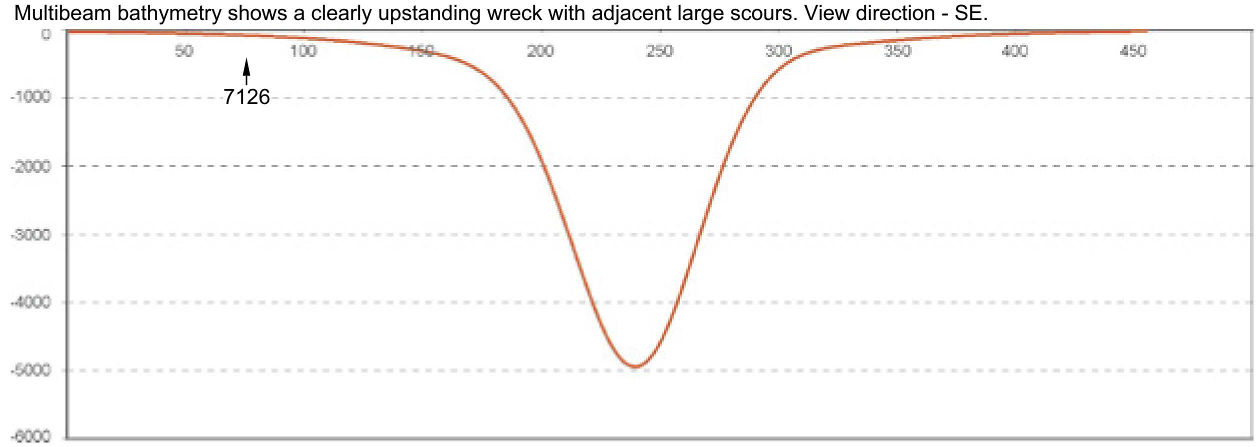
Location		696795 E 5612942 N (UTM 30N) 50 38.10 N 00 13.02 W (WGS84)	**Region**	5
Archaeological Importance		Medium		
Geophysical survey dimensions and notes		82m x 28m x 13m. Wreck extends beyond data coverage so length is underestimated. Protrusion partway along vessel, probably superstructure. 73m NE of 20001. Magnetic anomaly of 5828.1nT at northern end of wreck. Small object of debris (4.3 x 1.5 x 0.0m) on eastern side. Sinuous dark reflector (16.8 x 6.8 x 0.0m) in the wreck shadow may be an object of debris. Another item of debris (11.4 x 0.8 x 0.0m) situated 52m SW of the wreck. Overall debris field measures 130 x 60m. Orientation of wreck 20/200°.		
Build	**Type**	Armed merchant steam ship; probable tramp		
	Construction	Possibly steel		
	Dimensions	122.2m x 15.8m x 8.5m; 5000/3160 gross/net tons		
	Shipyard	Built 1909 by J.C. Tecklenborg A.G. in Geestemünde, Germany		
Loss	**Cause**	Enemy action; torpedoed		
Extent of Survival		Diver descriptions vary in reporting the orientation of the wreck, with some stating the stern is to the north and others reporting the bow is to the north. Sonar length is described by the UKHO as being 110.5m, with a width of 25.3m and a height of 20.5m in a general depth of 44m. Orientation of 15° is recorded (roughly N-S). A scour depth of 5m is recorded. The project geophysical survey data is consistent with the dimensions of the *Pagenturm* and the description given by divers, with the vessel being at least partially on its side. The wreck may be partly buried by a sand bank. There are deep scours each side of the wreck and sand bank. That to the east has a maximum depth of approximately 14m; the western scour has a maximum depth of approximately 7m.		
BGS Sediment Characterisation		Sandy sediment		



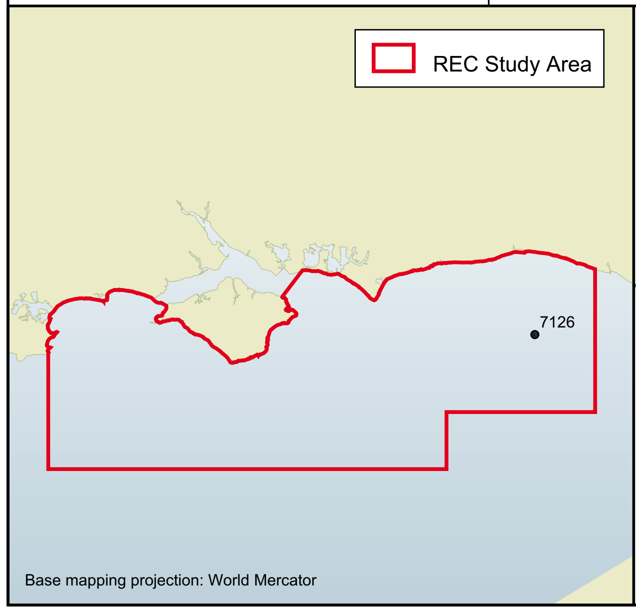
Mosaiced sidescan sonar image shows a clearly upstanding, relatively intact wreck (water column intentionally not removed).



Multibeam bathymetry shows a clearly upstanding wreck with adjacent large scours. View direction - SE.



Magnetic profile shows a large anomaly of 5828.1nT adjacent to the wreck location.



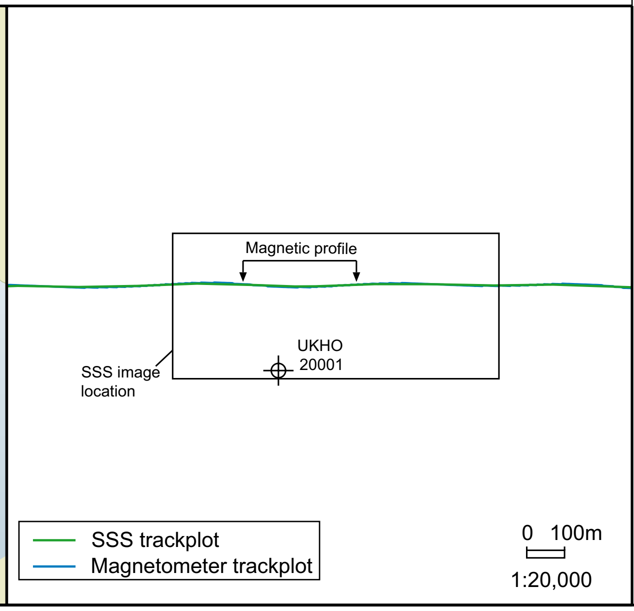
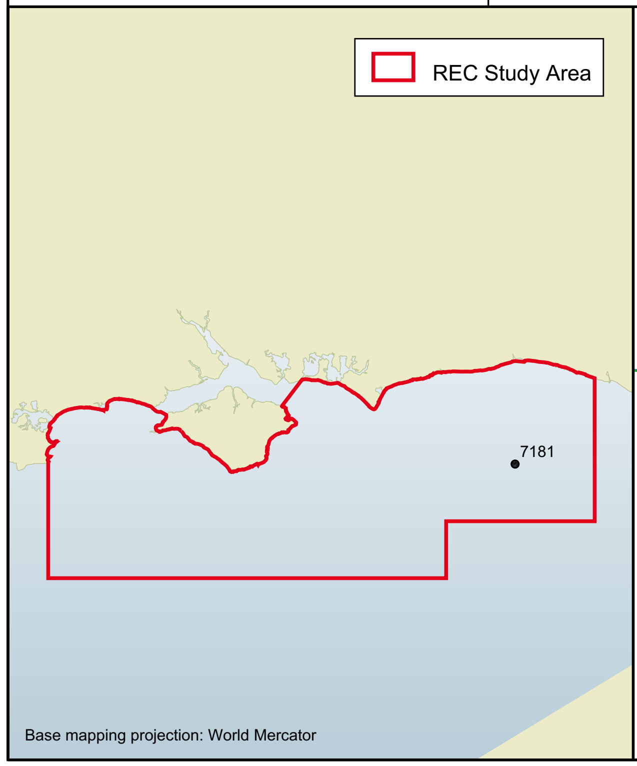
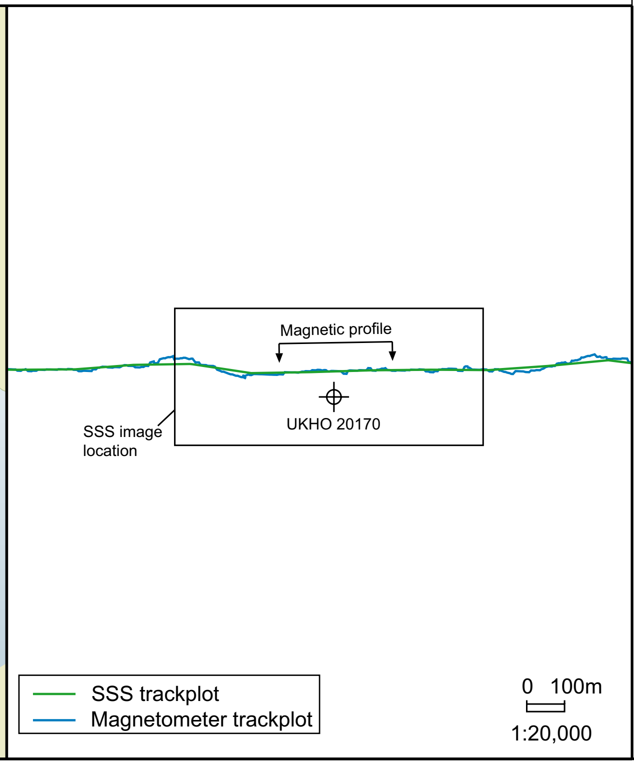
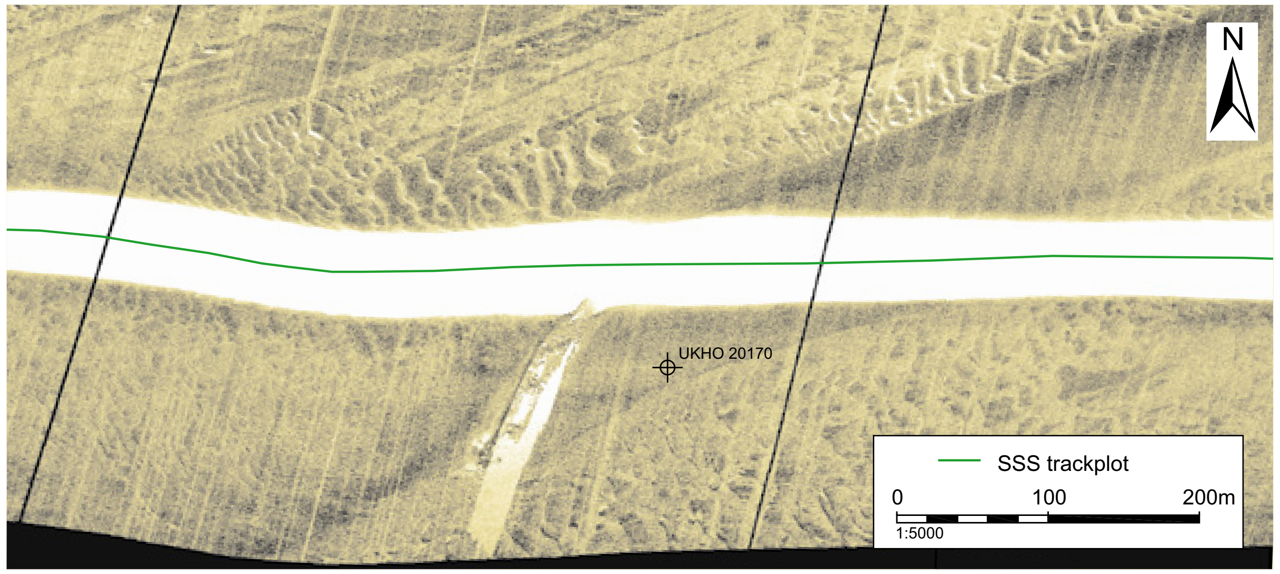


Figure 5.36: WA ID 7181 — Unidentified wreck UKHO 20170

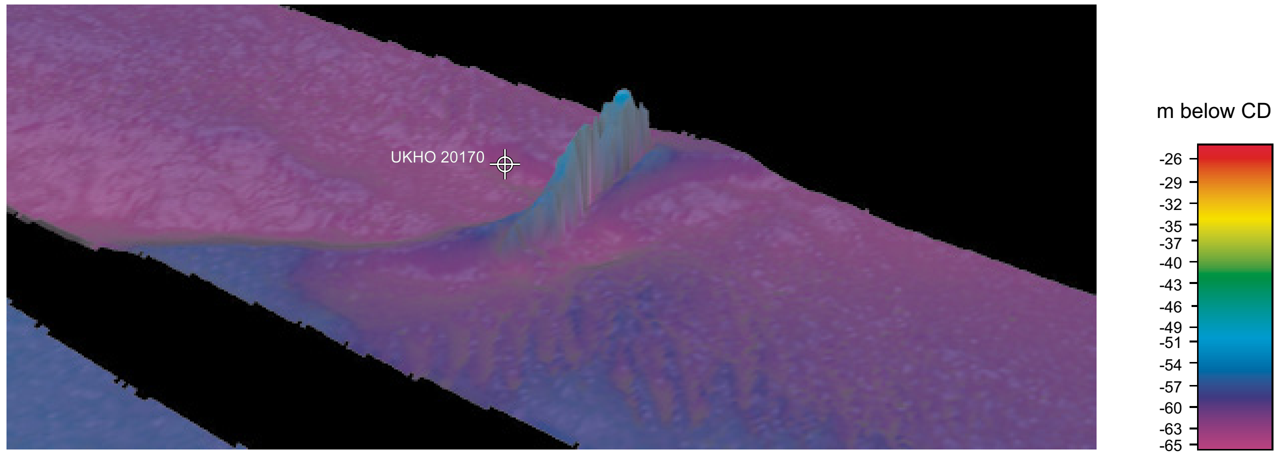
Location		692238 E 5607737 N (UTM 30N) 50 35.39 N 00 17.04 W (WGS84)	**Region**	5
Archaeological Importance		Medium		
Geophysical survey dimensions and notes		96m length x 17.1m width x 8m height; Fairly coherent wreck. 35m W of 20170. Magnetic anomaly of 2387.0nT lies 12m N of wreck. 6 other features adjacent to southern end of wreck, on western side. 2 items of debris (1.5x0.8x0.4m and 1.6x0.7x0.5m), 3 bright reflectors (4.3x3.7x0.0m, 3.6x2.7x0.0m and 3.3x2.9x0.0m) and one depression (5.8x3.2x-0.6m). Wreck orientation 10/190°. Minimum depth 52.4m. Seabed depth 61m.		
Build	**Type**	Unknown		
	Construction	Unknown		
	Dimensions	Unknown		
	Shipyard	Unknown		
Loss	**Cause**	Unknown		
Extent of Survival		The UKHO record this wreck as having a sonar length and width of 26m and 13.7m respectively, with a depth of 51m in a general depth of 62m. Orientation is described as 13°. Seabed type is described as sand and gravel. From the geophysics it is apparent that sediment appears to have built up into an arcing sandbank crossing the wreck. Scours either side of this up to 1.5m deep.		
BGS Sediment Characterisation		Sandy sediment		



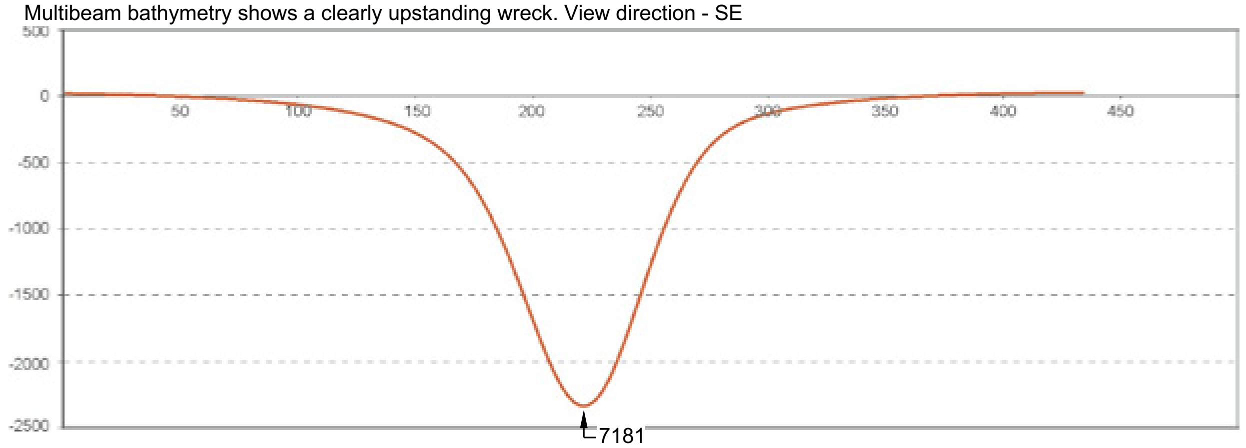




Mosaiced sidescan sonar image shows a coherent wreck (water column intentionally not removed).



Multibeam bathymetry shows a clearly upstanding wreck. View direction - SE



Magnetic profile shows a large anomaly of 2387.0nT adjacent to the wreck location.

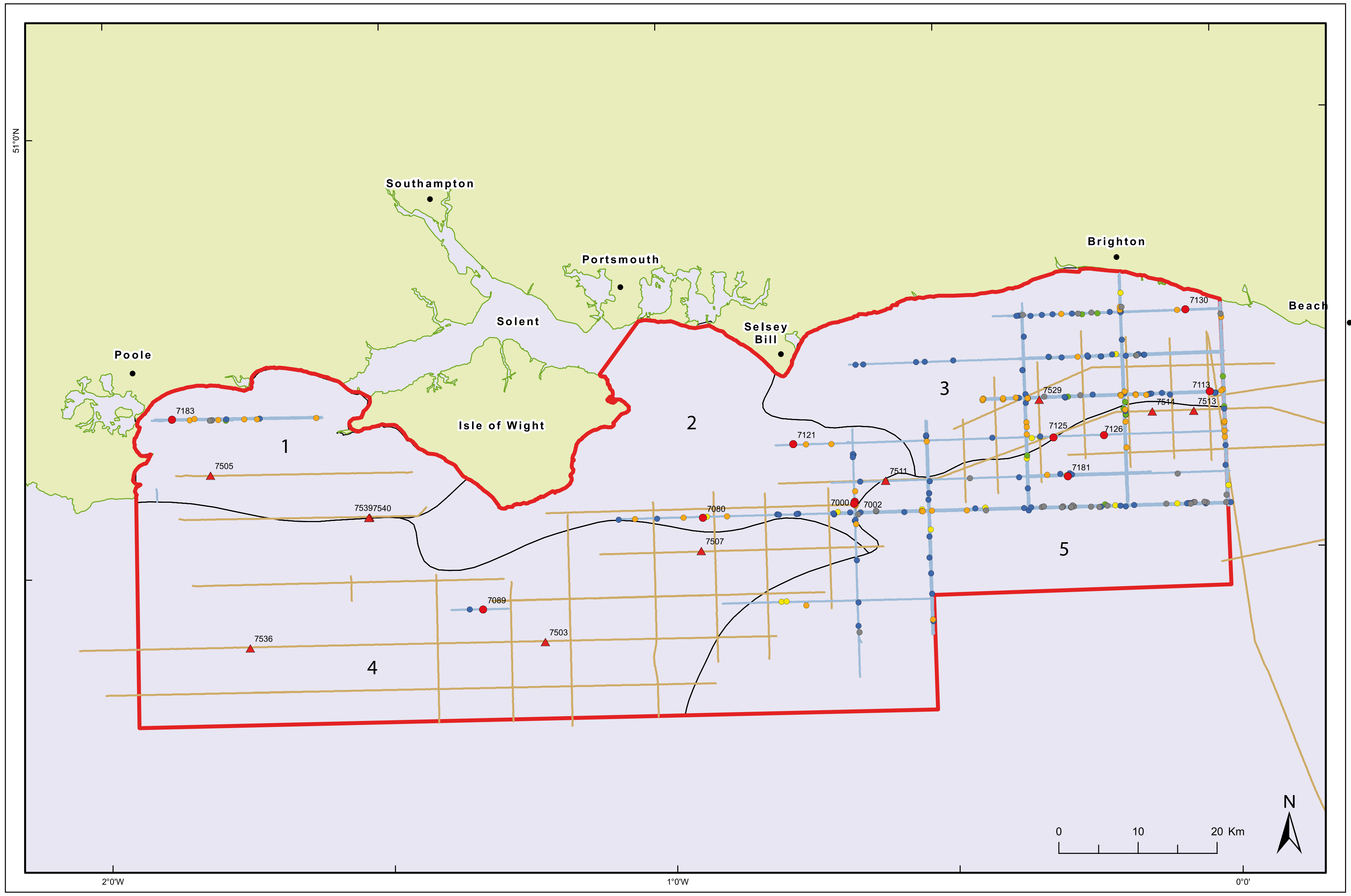


Figure 5.37: Geophysical anomalies.

The identity of the wreck was established by divers who recovered a nameplate from the donkey boiler. The wreck is described by divers as being in about 25 m of water on a gravel sea bed. It is reported to lie approximately west-east and to be upright, 'though rotting through' (Wendes, 2006). The stern is described as leaning to port. The bow is described as pointing upwards after having broken and the engine is reported to have fallen over. The highest parts of the wreck are the main and donkey boilers. Petrol engines are described as having been seen.

The wreck was discovered by recreational divers in the 1980s and has been a very popular dive site for many years (Hinchcliffe, 1999). As a result, a considerable number of artefacts have been salvaged from it, including portholes, deck fittings and brass parts of the helm (NMR 895838). Salvaged artefacts are believed to be dispersed in private ownership and some may have been disposed of. In 2004 the wreck was adopted by the University of London Sub-Aqua Club under the Nautical Archaeology Society's 'Adopt-a-Wreck' scheme.

Sites **7539** and **7540** are sidescan sonar anomalies which are 149 m apart, with dimensions of 66 m by 20 m and 113 m by 75 m respectively. Both anomalies are characterised as possible wrecks. They are respectively approximately 120 m north-west and 240 m west of the charted position of UKHO wreck 19003.

19003 is recorded by UKHO as having a sonar length of 50 m and a vertical height of 6.5 m in a general depth of 38 m. A pebble sea bed is described by UKHO. The wreck has been visited by recreational divers who reported it in 1999 as having a vertical stern and 'generally collapsing'. It is elsewhere described as lying half over on its port side and partly broken up. A high bank in the sea bed has been observed to the east of the wreck (Wendes, 2006). The position given for the wreck in a regional dive guide is about 100 m to the north-east of the charted position and 140 m from **7539**.

The date on the salvaged bridge steering pedestal has enabled 19003 to be identified as the 1913 South Shields built 3207 ton steel screw steamship SS *Westville*. En route for Blaye from Blythe with a cargo of 5200 tons of coal, this armed collier was torpedoed and sunk by *UB-35* on 31 December 1917. There was no loss of life. The *Westville* was the last ship to be sunk by a U-boat in 1917.

The sonar dimensions of **7539** correspond very approximately with those of 19003. Given the close proximity, **7539** may therefore be the *Westville*. The proximity of both anomalies to 19003 suggests an association.

NMR record 804944 is for a wreck described as 'possibly *Westville*'. This record is for a position over 6 km to the east which does not correspond with any UKHO charted wreck.

5.3.9 Physical Region 3

7529 is a sidescan sonar anomaly with dimensions of 43 m by 7 m and a height of 3 m. It has the characteristics of a broken up but fairly coherent wreck.

This site corresponds with the charted position of UKHO 20059 and is 500 m north of NMR 911208. 20059 is recorded as having sonar dimensions of 42.1 m by 17.5 m and a height of 4.4 m in a general depth of 22 m. It is described as a trawler but is not identified beyond this. 911208 is a trawler wreck and appears to be 20059. A report was made to UKHO by visiting scuba divers in 1984, describing it as an approximately 120 foot long trawler lying on its starboard side with about half the beam buried. The wreck is described as being very corroded. Portholes were described as being recovered. In 1977 the wreck was described by divers as a very old trawler partly on its side with a 6–8 feet diameter iron prop, a large winch amidships and a small amount of superstructure aft (NMR 911208). It has been described as a steam drifter in a regional dive guide and it has been subject to salvage of artefacts and fittings (McDonald, 1999).

Steam trawlers were introduced late in the 19th century and steam drifters at the end of the century. Assuming that **7529** was powered by a steam engine, it can therefore be dated to the late 19th century or the first half of the 20th. Otherwise it is not identified.

5.3.10 Physical Region 4

Site **7503** comprises two sidescan anomalies classified as wreck material with sonar lengths of 30 m and 68 m and heights of 7 m and 3m respectively. It lies approximately 140 m west of the charted position of UKHO wreck 61782 which is described by UKHO as a wreck lying on its starboard side with its bow end to the west. The bows are described as missing and the wreck is recorded as having a sonar length of 42 m with a height of 3.4 m in a general depth of 33 m. It appears to have been discovered as a physical snag and it has been investigated by recreational divers.

It is not known whether 61782 has been identified but it does appear to be the wreck of a large metal ship of the late 19th or more probably of the first half of the 20th century.

7507 is a sidescan anomaly that is classified as a debris field and possible wreck. It has sonar dimensions of 22 m and 15 m, with a height of 2 m. It lies 160 m west of the UKHO charted wreck 6339 which is described as debris or a well buried small wreck with sonar dimensions of 10 m by 5 m and a height of 1.3 m. It is also described as a slight magnetometer anomaly. The sea bed here is described as sandy with a general depth of 27 m. It was found as a physical snag but is not recorded as being identified. There is a discrepancy between the size of the anomalies and their positions and it is not therefore certain that they are the same debris field or wreck. **7507** is probably anthropogenic but is not identified.

7536 is a sidescan sonar anomaly with sonar dimensions of 69 m by 24 m, with no definable height. It has the characteristics of a possible broken up wreck.

It is 290 m south-east of UKHO charted wreck 61785. This has sonar dimensions of 18 m by 4 m with a vertical height of 3.4 m in general depth of 37 m on a gravel sea bed. It has been identified by recreational divers as a result of being located as a physical snag and is described as a partially intact and listing steam trawler with its bow buried and a machinery aft design. The wreck is further identified as possibly being the 1909 Dundee built *Neree*, a 36.7 m long 226 gross ton Belgian steam trawler lost in 1926. Given the proximity, **7536** is likely to be 61785 and has probably broken up further since originally being discovered.

5.3.11 Physical Region 5

7511 is a site with dimensions of 25 m by 21 m and a height of 3 m and has been characterised as a wreck. It is not associated with a charted wreck, the nearest being 2.4 km to the south-west with significantly different sonar dimensions. **7511** is a probable wreck but is not identified and no diver description has been traced.

7513 is a sidescan anomaly with dimensions of 30 m by 10 m and a height of 5 m. It has the characteristics of a wreck. It is not closely associated with a charted wreck. The nearest is UKHO 20021, the *Leachs Romance*, a 44 ton fishing vessel lost in 1940 as a result of striking a mine. This is 1.4 km to the south-east, although the wreck is listed as dead and the charted position is a reported sinking position only. However, *Leachs Romance* would probably be smaller than **7513**, particularly after striking a mine.

7513 is probably a metal shipwreck of the late 19th or 20th century. No diver description has been traced and it is currently unidentified.

7514 is a sidescan sonar anomaly which has dimensions of 55 m by 9 m, with a height of 4.5 m. It has the characteristics of a wreck but does not correspond with the position of any UKHO charted wreck.

7514 is 470 m south-east of NMR 911777, the recorded loss position of the screw steamship *Ikeda*, a 4761 gross ton cargo vessel built in 1917 and sunk by a torpedo in 1918 by the submarine *UB-40*. However, the NMR position for this loss matches no charted wreck position or any of three UKHO positions for the *Ikeda*. Furthermore the sonar dimensions of **7514** do not match the dimensions of the *Ikeda*, which was over twice as long as the length of the anomaly. It therefore seems unlikely that **7514** is the *Ikeda*.

UKHO charted wreck 20025 lies just over 1 km to the south. This record is for a reported sinking in 1949 rather than a located wreck on the sea bed and the position is unlikely to be precise. It is therefore possible that the vessel reported as having sunk at the position given is actually at **7514**. However no further details concerning 20025 are available for comparison with **7514**.

Although **7514** appears to be a wreck and could be 20025, it is currently unidentified. The sonar dimensions suggest a metal wreck of the late 19th — early 20th century.

5.3.12 Archaeological characterisation

A total of 250 anomalies were identified from the South Coast REC 2007 Survey data as being of potential anthropogenic origin, of which 188 were detected by sidescan sonar, 55 by magnetometer and seven by both sidescan sonar and magnetometer (Figure 5.37). Average density per km² of survey corridor was 1.68 overall and 1.31 for anomalies detected by sidescan sonar.

Data searches have produced only 15 NMR and 20 UKHO records for the survey corridors, and average density of only 0.1 and 0.13 per km² respectively. Even taking into account the likelihood that individual scattered wrecks or obstructions may be represented by more than one anomaly and the possibility that some of the anomalies have been wrongly categorised as being of probable anthropogenic origin, it seems likely that the density of anthropogenic material on the sea bed is greater than is indicated by either the UKHO or the NMR.

A total of 14 anomalies were identified as wrecks or probable wrecks, or just under 6% of the total number of geophysical anomalies. These wrecks can be analysed by date as shown in Table 5.9.

Period	Number of wrecks	
	By date of build	By date of loss
Pre-1508 AD	-	-
1509-1815	-	-
1816-1913	5	1
1914-1945	3	8
Post 1946	1 (probable)	1
Undated	5	4

Table 5.9: Geophysical anomalies identified from the REC data as wrecks listed by date.

The earliest vessel identified is the *Quail*, built in 1870. The earliest identified loss event was in 1886.

The wrecks are dominated by the two World Wars of the 20th century, with 50% being lost between 1914–18 and 1939–45. One of the vessels lost during this period, the internationally important SS *Mendi* **(7089)** in Region 4, has been accepted for designation as a protected place under the Protection of Military Remains Act 1986. Three other 20th century wartime losses in the South Coast REC area have already been designated as protected places (*HMS Acheron*, *HMS Swordfish* and *HMS Loyalty*) with a fourth (U-81) being designated a controlled site. However, none of these sites were covered by the survey data.

The survey has been generally successful in characterising late 19th century and 20th century maritime activity within the REC area, finding evidence of both warships and their victims and typical merchant ships and fishing vessels. However, in terms of characterising the whole REC area, the South Coast REC geophysical survey data has not produced results that are representative of earlier periods.

The environs of the South Coast REC area contain ports that have been important since at least the medieval period and loss records suggest that large numbers of vessels sank within the area in the 18th and early 19th centuries. Evidence exists for fairly extensive and continuous maritime activity within the REC area from at least as early as the Bronze Age.

The South Coast REC area and its environs (most notably the Solent) also have one of the densest concentrations of pre-1850 historic shipwrecks in the UK. Notable examples include the following vessels, which are all designated under the Protection of Wrecks Act (1973):-

- *Grace Dieu*, a major warship of Henry V's navy, lost in 1439 in the River Hamble (environs of the REC area);
- A small armed, possibly Iberian merchant ship lost in about 1520 in Studland Bay (Region 1);
- Probable 16th century armed vessel, lost at Brighton (Region 3);
- A late 16th or early 17th century merchant ship, probably Spanish, lost at Yarmouth in the Solent (environs of the REC area);
- A large armed, possibly Dutch merchant ship lost in the early 17th century in the approaches to Poole Harbour (Region 1);
- *Hazardous*, a 4th Rate English warship lost in 1706 (Region 2);
- *Assurance*, a 5th Rate English warship lost in 1738 on the Needles (Region 1);
- *Invincible*, 74 gun English warship lost in 1758 (Region 2).
- *Pomone*, a 5th Rate English warship lost in 1811 on the Needles (Region 1).

None of this pre-1850 maritime activity is apparent in the survey results.

The absence of recognisable shipwreck material pre-dating the late 19th century is perhaps not surprising. Wrecks of the modern period tend to be relatively large, made of metal that is comparatively robust in the medium-short term and relatively recently exposed to the marine environment. Pre-modern wrecks tend to be smaller, are made of less robust wood and have been exposed to the marine environment for longer. As a result they are much less likely to have significant mass exposed above the sea bed and therefore are less obviously recognisable in sidescan survey data. The smaller quantity of ferrous metal used in their construction and fittings also makes them less obvious magnetometer anomalies. It is conceivable that some of the 236 other geophysical anomalies identified during the survey relate to earlier maritime activity, but without further field assessment this is entirely speculative.

The identified wrecks were distributed as shown in Table 5.10. This distribution is, in one way, unsurprising in archaeological terms and the density of recorded sites clearly shows that most wreck sites are located in the eastern Solent; Region 2. This Region contains the approaches to Southampton and Portsmouth, the most significant 19th and 20th century ports in the environs of the South Coast REC area, and was identified as a 'high hazard' area by the ALSF funded Navigational Hazard Project (Merritt *et al*., 2007). However, a very significant proportion of the losses that have occurred in the area have occurred close to or within the inter-tidal zone, which was not surveyed in the course of the REC study.

A density analysis of the wreck distribution (Figure 5.38) also shows a high number of sites in the area around Poole Harbour and at the entrance to the western Solent, near the Isle of Wight, which is again to be expected given the maritime activity and 'high hazards' in these areas (Merritt *et al*., 2007).

All of the wrecks identified from the REC survey data appear to have been lost as a result of collision, foundering or enemy action. One loss mechanism which appears very frequently in historic loss records is stranding, when a vessel is lost as a result of going aground, for example on a sandbank or the shore. This is not represented in the survey results, because none of the survey corridors included locations in which strandings are likely to have occurred. Stranding has been responsible for a very significant proportion of maritime losses. For example, statistics produced by the Board of Trade for 1879–80 indicate that 60% of the total shipping losses in the UK were the result of strandings.

Regions	Number of shipwrecks or probable wrecks
1	1
2	6
3	4
4	1
5	2
Total	**14**

Table 5.10: Distribution of geophysical anomalies identified as wrecks by region.

The scarcity of wrecks detected in Region 1, which contains the western approaches to the Solent, the approaches to the historic port of Poole, as well as four of the nine designated wrecks listed above is perhaps not as significant as it seems. The Region does not contain major shipping routes of either of the two World Wars of the 20th century and the concentration of recorded sites per km as shown in Table 5.11 is in any event broadly comparable with that in Regions 2 and 3.

	Region 1	Region 2	Region 3	Region 4	Region 5
Concentration of recorded sites per km	3.11	3.66	3.28	1.29	2.21

Table 5.11: Concentration of recorded UKHO and NMR sites per line kilometre of survey corridor.

The distribution patterns of anomalies are thought unlikely to have an environmental basis.

Survey corridors within Regions 2, 3 and 5 all contain anomalies within each of the three sea bed character types: coarse sediment; rock and thin sediment; and sandy sediment. However, the corridor in Region 1 includes only rock and thin sediment (either coarse or sandy), whereas Region 4 contains both coarse sediment and rock and thin sediment. Geophysical anomalies in this Region have only been detected in the latter category.

Aside from wreck sites the assessment of the geophysical data identified 236 other anomalies of possible anthropogenic origin (Table 5.12). The anomalies identified from the sidescan sonar data have been classified as: 17 Bright reflectors, 18 Dark reflectors, 107 Debris, 39 Seafloor Disturbances. Data examples of anomalies from each of these classifications are shown in Figures 5.39–5.42.

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5
Bright Reflector	0	3	4	0	10
Dark Reflector	1	0	11	0	6
Debris	3	17	49	1	36
Seafloor Disturbance	4	0	9	0	32
Magnetic	6	8	28	0	12
Total	14	28	101	1	96

Table 5.12: Distribution of geophysical anomalies in the South Coast REC area.

As it is often difficult to assess the anthropogenic or archaeological potential of an anomaly these descriptions are not on their own definitive. A single small but prominent anomaly may be part of a much more extensive feature that is largely buried. Similarly, a scatter of minor anomalies may define the edges of a buried but intact feature, or it may be all that remains as a result of past impacts on a once larger site.

Some of these anomalies may prove to be natural or of modern origin. These anomalies would require further investigation, either by a more detailed geophysical survey or by diver or ROV inspection, in order to accurately assess their archaeological potential.

There is no correlation between the types of anomalies identified from the data and the sea bed sediment classification. Nor is there any significant variation in the number of anomalies found per kilometre. The majority of anomalies were found in Regions 3 and 5 but this simply reflects the bias in data coverage of these Regions.

The majority of magnetic anomalies for which there was no corresponding sidescan sonar anomaly were found in areas of rock and thin sediment or sandy sediment indicating that even where there is little sediment there is potential for buried material to be present. As might be expected, no magnetic anomalies were identified in areas of sea bed identifiied as rock.

While all of the wrecks identified from the sidescan sonar data were expected to have magnetic anomalies it was only possible to identify these for 8 of the 14 sites. This is thought to be because the magnetometer towfish did not pass sufficiently close to the sites to detect the magnetic anomaly in these cases. This underlines the point that magnetometer only surveys are unlikely to provide comprehensive coverage unless very narrow line spacings are adopted.

5.4 Aviation archaeology

Evidence of the UK's aviation heritage normally occurs on the sea bed in the form of aircraft crash sites, the result of crashes or controlled ditching. Evidence can also occur in the form of objects lost or jettisoned from aircraft in flight, such as munitions.

The vast majority of aircraft losses at sea have been of military aircraft and date from the Second World War of 1939–45. Most have occurred along the south and east coasts of England.

With very few exceptions the aircraft crash sites and recorded losses connected with aviation that have been traced in the South Coast REC area are all of military aircraft. Consistent with the national picture, they are also overwhelmingly of the period 1939–45.

Although they received little attention from marine archaeologists until recently, aircraft crash sites, particularly those of historic military aircraft, are increasingly regarded as important archaeological sites. All military aircraft crash sites are automatically protected by UK legislation under the Protection of

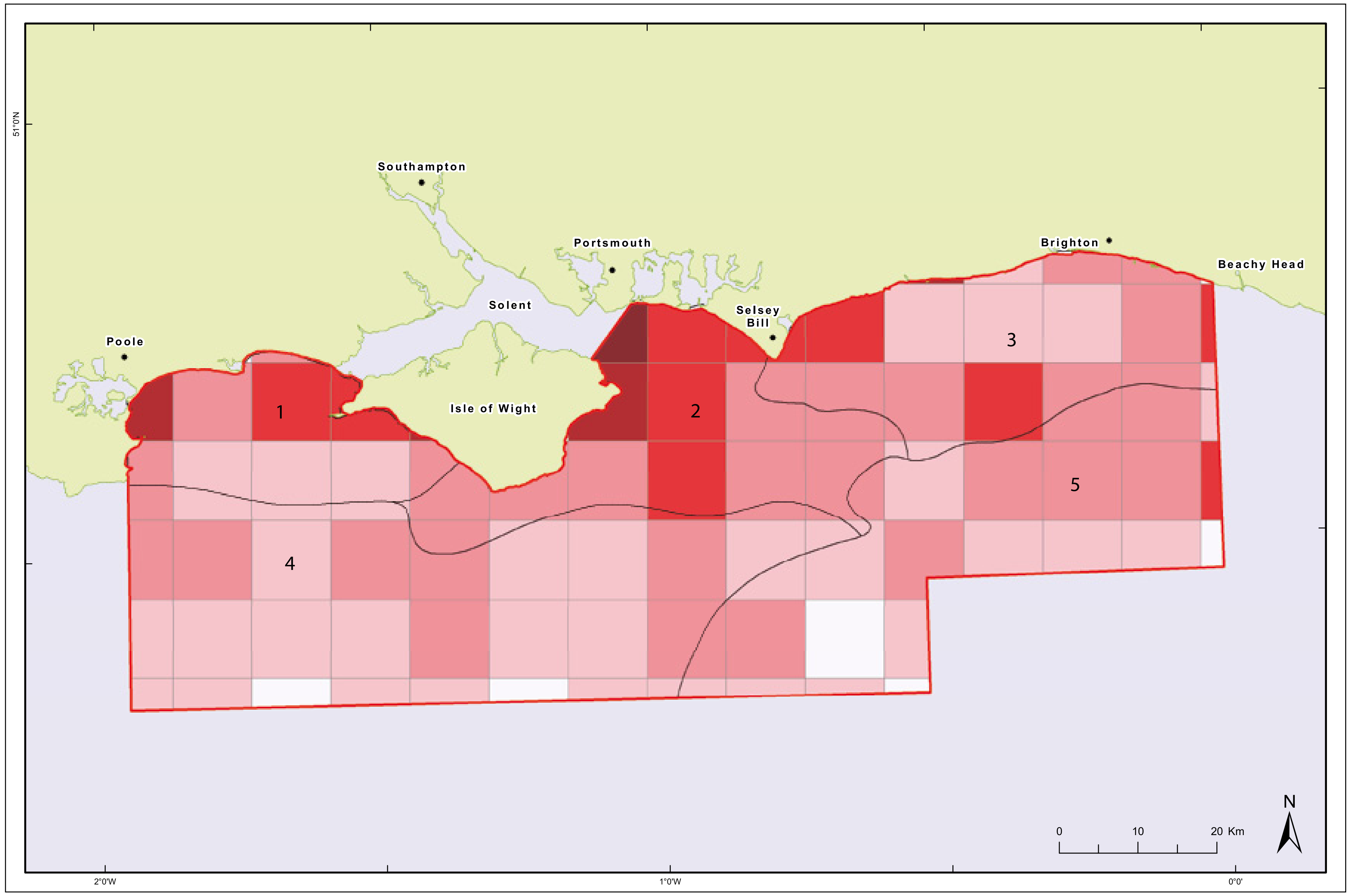


Figure 5.38: Density of UKHO charted wrecks and obstructions per km² within the South Coast REC area, illustrated in 10 km cells.

Military Remains Act 1986 and (once found) a licence is required for any disturbance or works. Military aircraft crash sites are now also subject to archaeological and management guidance issued by English Heritage (2002) and by the Ministry of Defence (Service Personnel and Veterans Agency, 2009).

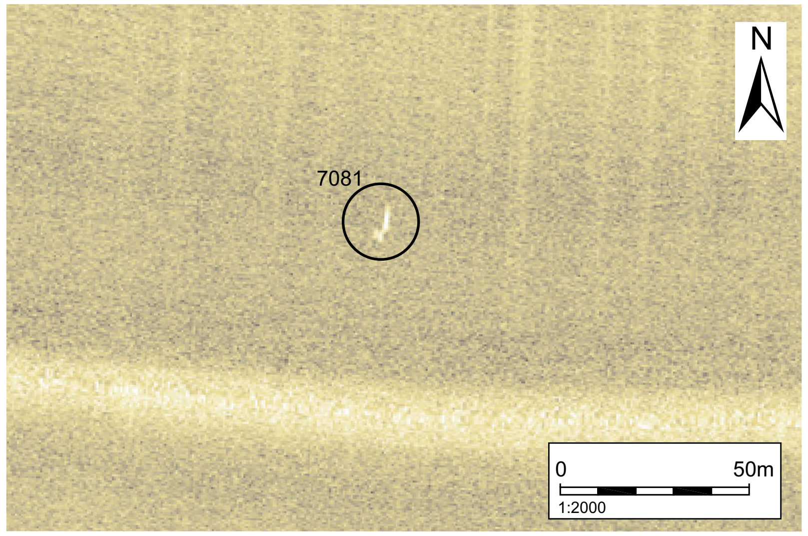
5.4.1 Background

Physically, aircraft wrecks are relatively fragile compared to shipwrecks. Although the processes that influence the formation and survival of aircraft crash sites on the sea bed are as yet only poorly understood, it may reasonably be stated that most aircraft wrecks are relatively ephemeral. This is because aircraft frequently break up when they crash or ditch. It is also because their fragility makes them particularly vulnerable to damage and dispersion as a result of natural processes including corrosion and the physical impacts of human intervention such as trawling and dredging. Evidence of significant damage and deterioration, largely caused by trawling is present in relation to **7135** in Region 3. Such damage is widely believed to be consistent with the national picture.

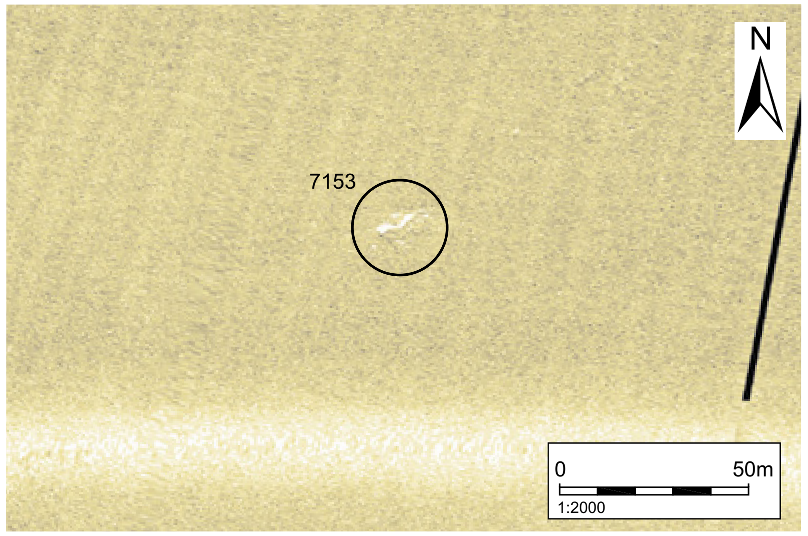
This fragility and the relatively small size of aircraft wrecks compared to shipwrecks also makes them very hard to find and characterise during geophysical surveys. Even large aircraft can be hard to recognise in sidescan sonar data unless they are intact and fully exposed. For example, one English Channel anomaly identified by UKHO as being a probable wooden shipwreck was subsequently identified during ROV inspection as a partially intact Consolidated B-24 Liberator four engined bomber (Wessex Archaeology, 2007c). As a result it is possible that some anomalies characterised as either natural features or as shipwreck material could in fact be aircraft-related.

The recent ALSF scoping study Aircraft Crash Sites at Sea (Wessex Archaeology, 2008e) concluded that there was a very

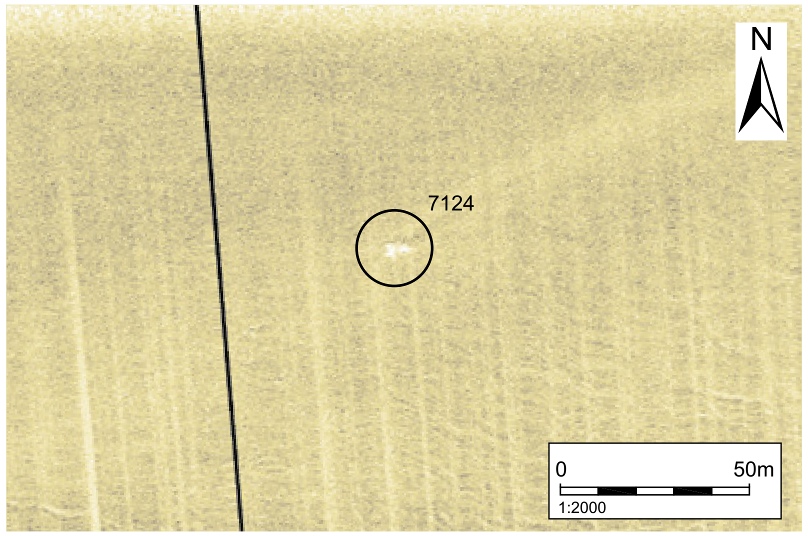
Figure 5.39: Sidescan Sonar Anomaly Types – Bright Reflector



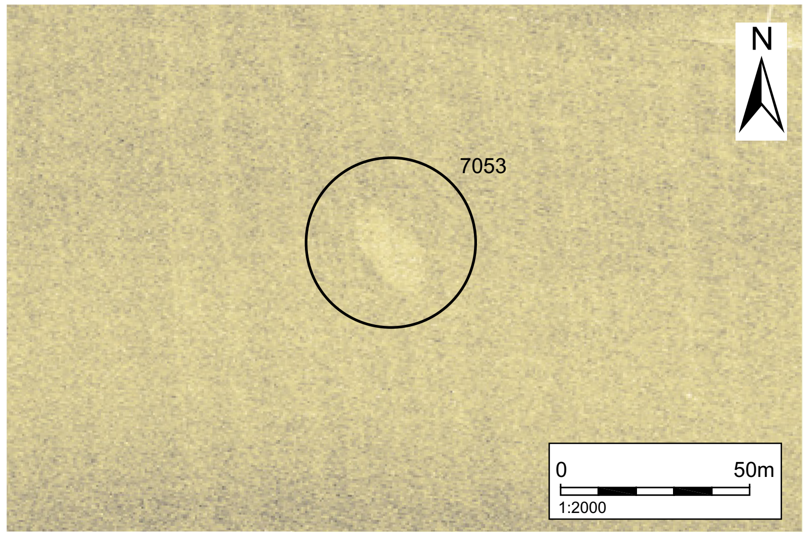
7081 – Region 2 – 6.4m x 1.7m x 0m. Linear bright reflector.



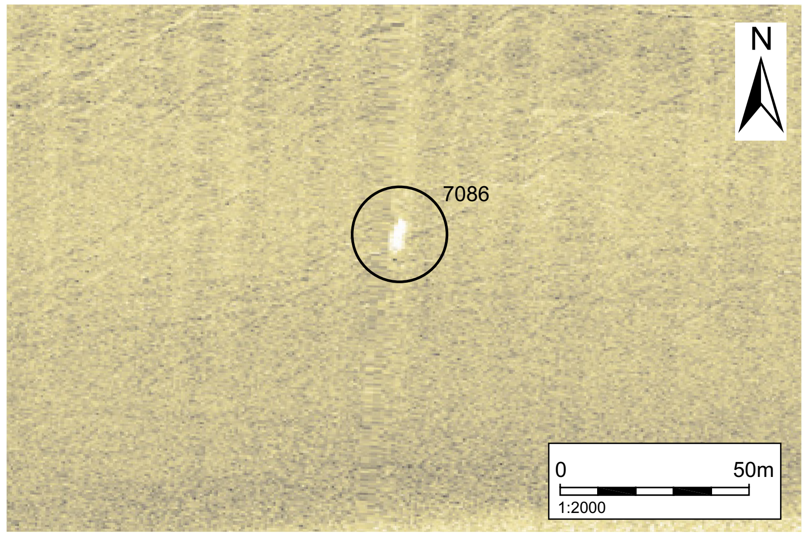
7153 – Region 2 – 7.9m x 2.1m x 0m. Irregularly-shaped bright reflector.



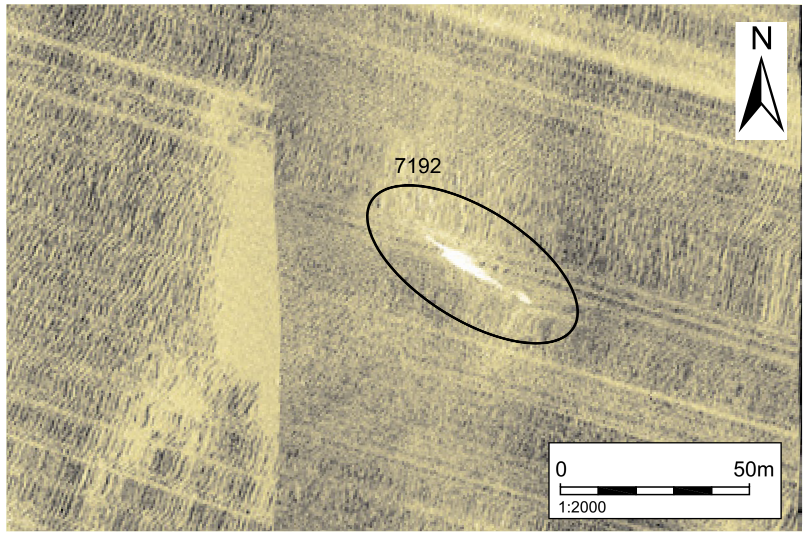
7124 – Region 3 – 4.4m x 2.1m x 0m. Irregularly-shaped bright reflector.



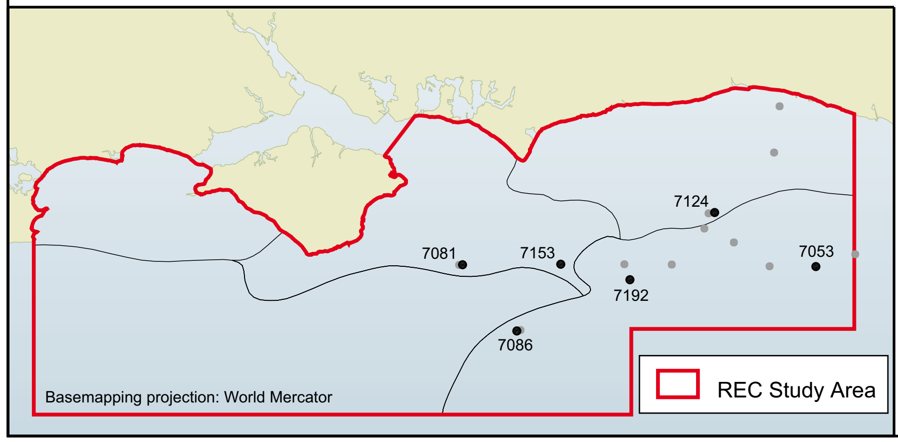
7053 – Region 5 – 17.8m x 10.2m x 0m. Elliptical. Clear outline.



7086 – Region 5 – 5.7m x 1.4m x 0m. Oval-shaped bright reflector.



7192 – Region 5 – 20.6m x 2.8m x 0m. Irregularly-shaped large bright reflector in two sections.

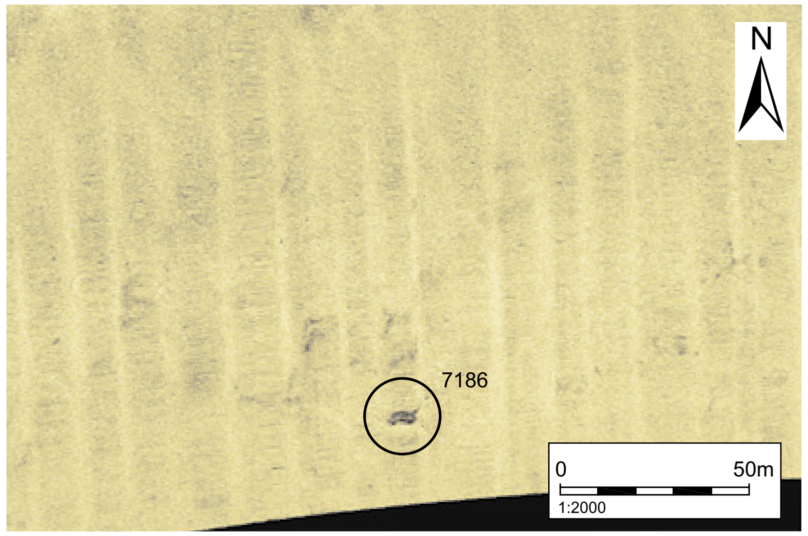


Bright reflectors are areas of low reflectivity. They may be hard edged or diffuse. Shadows are an extreme example where no acoustic energy is returned to the sidescan sonar towfish. Only bright reflectors that are not shadows are of interest.

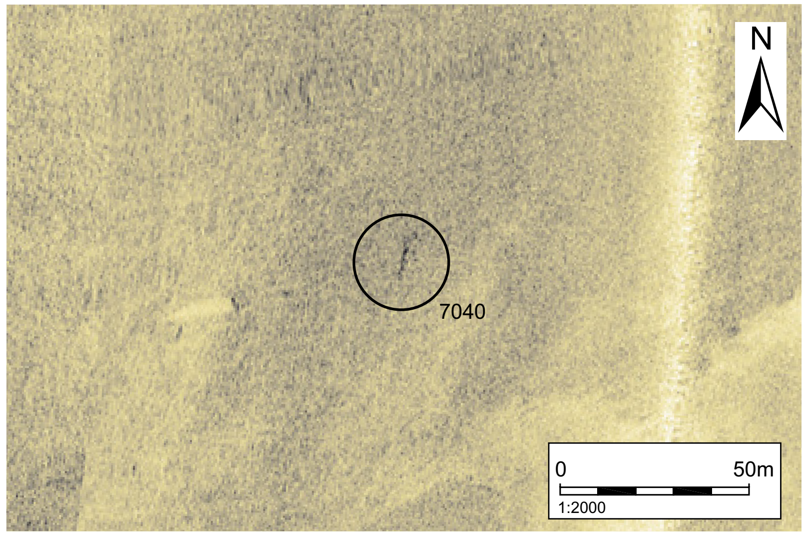
Distribution of bright reflectors across the physical regions

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Bright Reflector	0	3	4	0	10	**17**

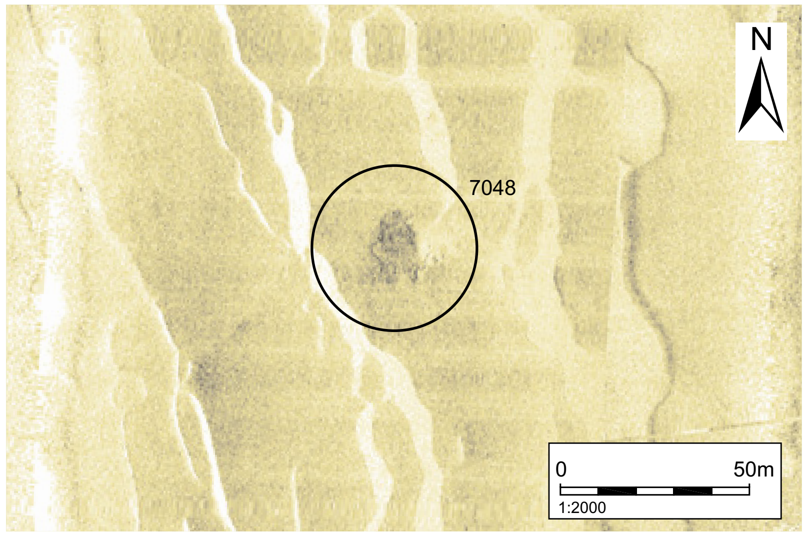
Figure 5.40: Sidescan Sonar Anomaly Types – Dark Reflector



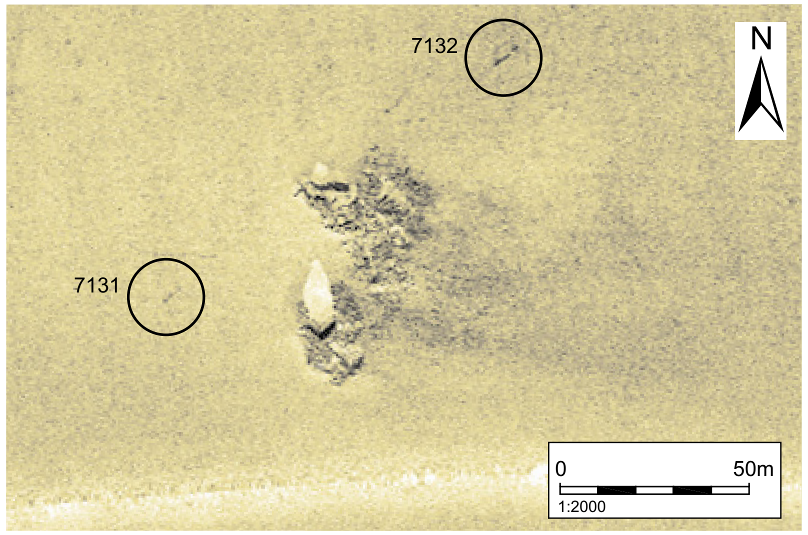
7186 – Region 1 – 3.7m x 2m x 0m. Irregularly shaped.



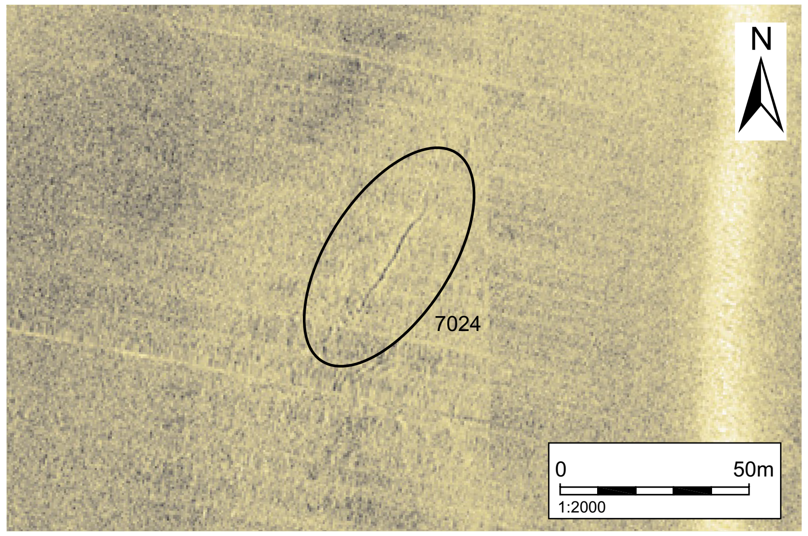
7040 – Region 3 – 6.6m x 0.8m x 0m. Indistinct dark reflector.



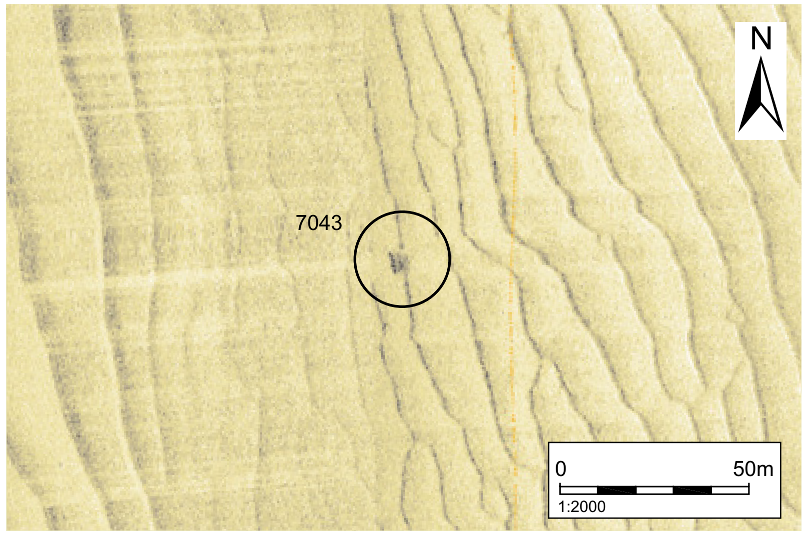
7048 – Region 3 – 14.7m x 11.3m x 0m. Diffuse dark reflector in an area of sand ripples.



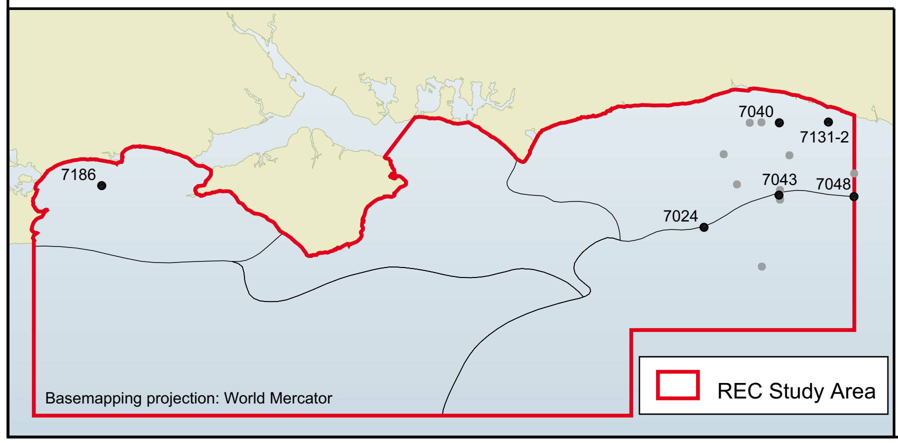
7131 & 7132 – Region 3 – 7131: 15.2m x 0.4m x 0m. Possible debris. Linear. 17m W of wreck 7130. 7132: 5.6m x 0.5m x 0m. 26m NE of 7130.



7024 – Region 5 – 27.1m x 0.9m x 0m. Linear. Possibly debris.



7043 – Region 5 – 4.4m x 3.9m x 0m. Dark reflector near the crest of a sandwave or ripple. May be part of a partially buried object.

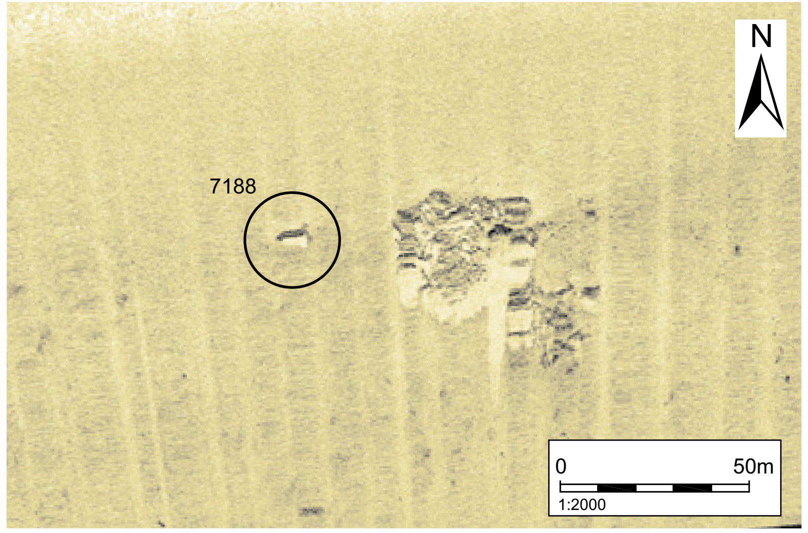


Dark reflectors are areas of high reflectivity. They may be objects with or without height and may have hard edges or be diffuse.

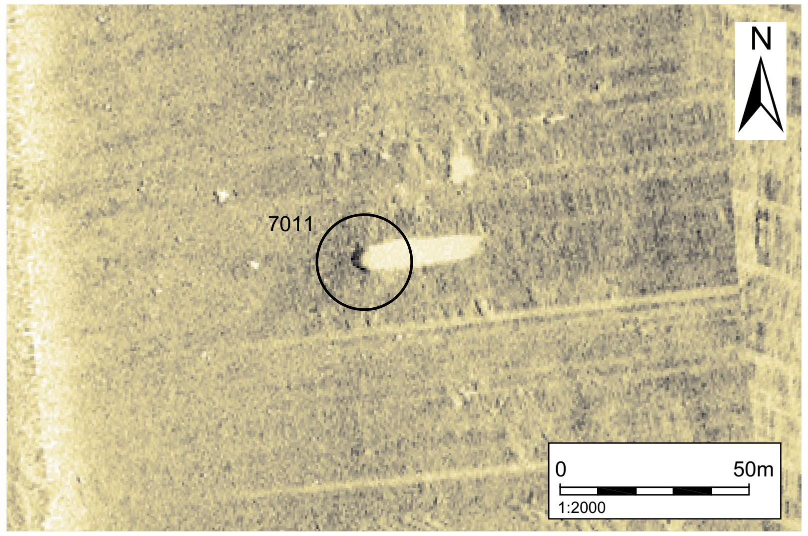
Distribution of dark reflectors across the physical regions

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Dark Reflector	1	0	11	0	6	**18**

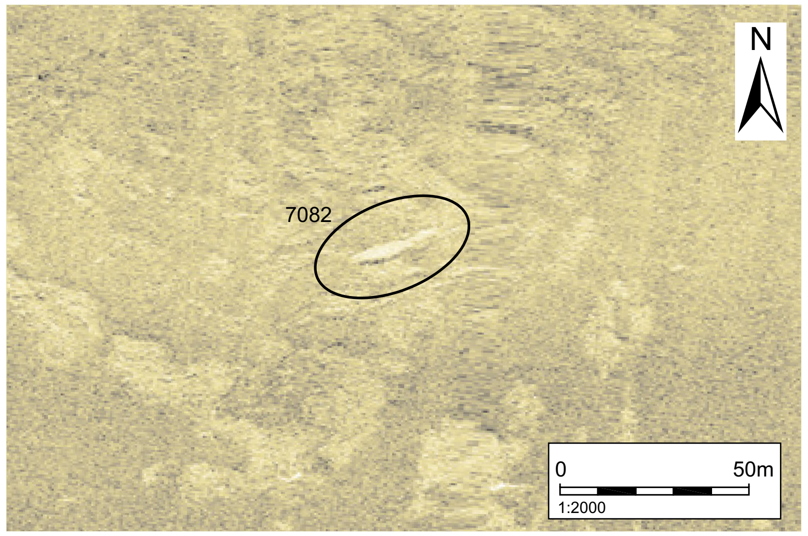
Figure 5.41: Sidescan Sonar Anomaly Types – Debris



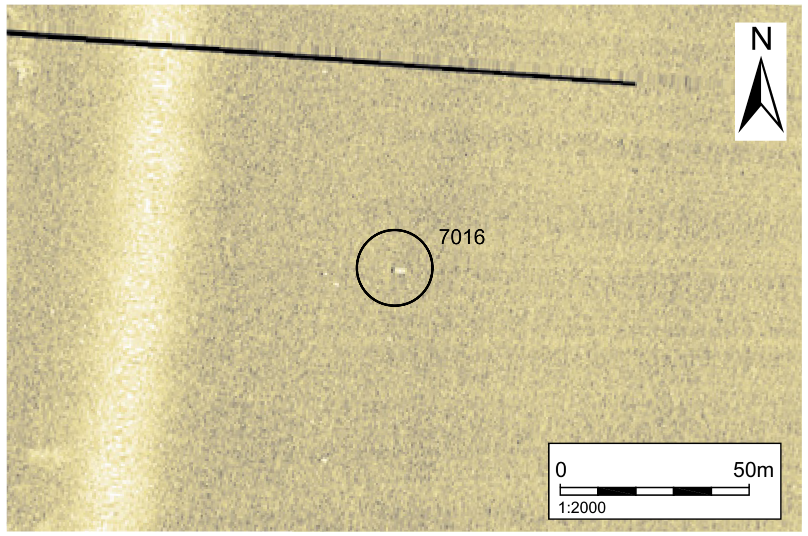
7188 – Region 1 – 5.4m x 1.3m x 0.5m. 16m west of seafloor disturbance 7187.



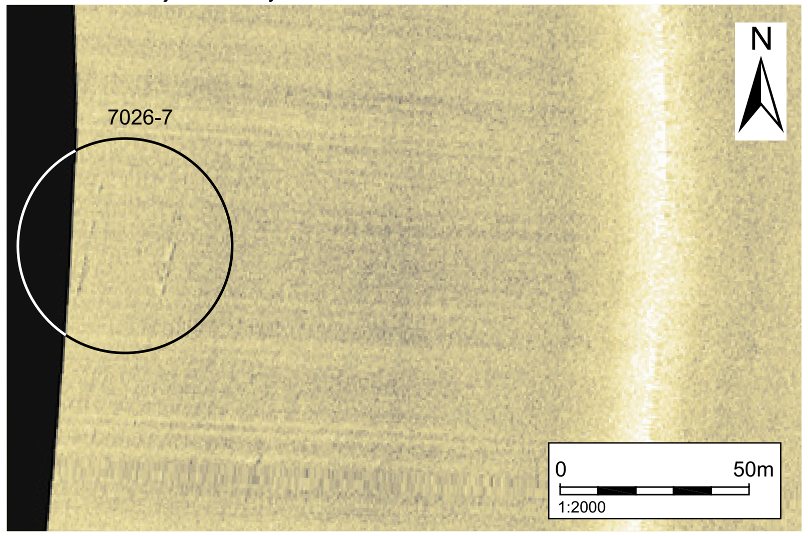
7011 – Region 2 – 5.5m x 2.9m x 3.1m. May be geological but very angular. Other smaller objects nearby.



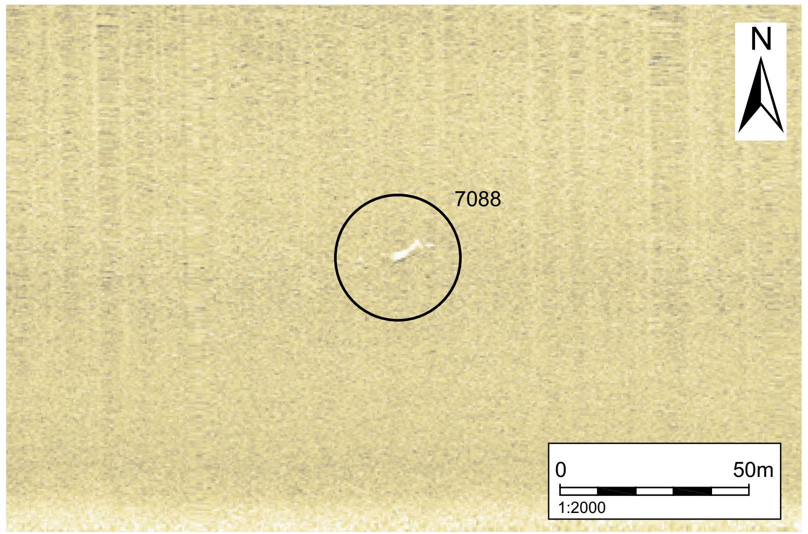
7082 – Region 2 - 13.9m x 1.6m x 0.5m. Upstanding irregularly shaped object.



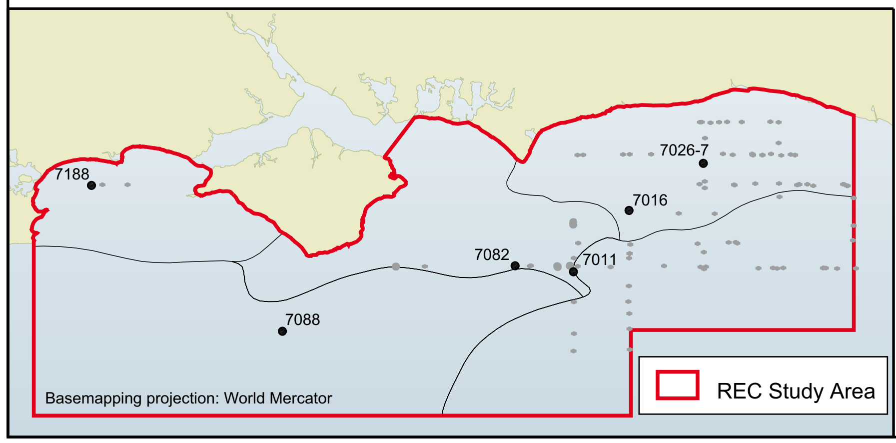
7016 – Region 3 – 4m x 1.2m x 0.8m. Upstanding object.



7026 & 7027 – Region 3 – 7026: 9.1m x 0.5m x 0.1m. Linear. Indistinct.
7027: 19.7m x 0.5m x 0.1m. Linear. Indistinct.



7088 caption: 7088 – Region 4 – 7.7m x 0.2m x 0.3m. Linear.

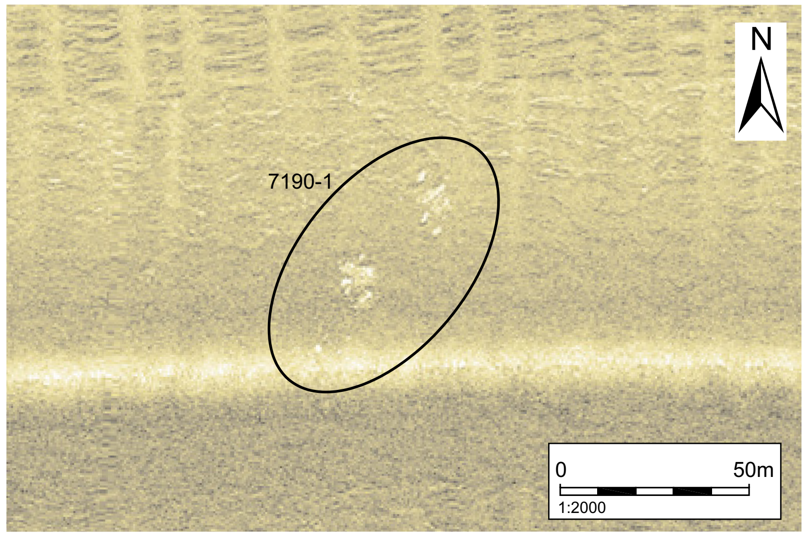


Debris are objects on the seabed, generally with height or with evidence of structure, that are potentially of anthropogenic origin. They may occur singly or in groups.

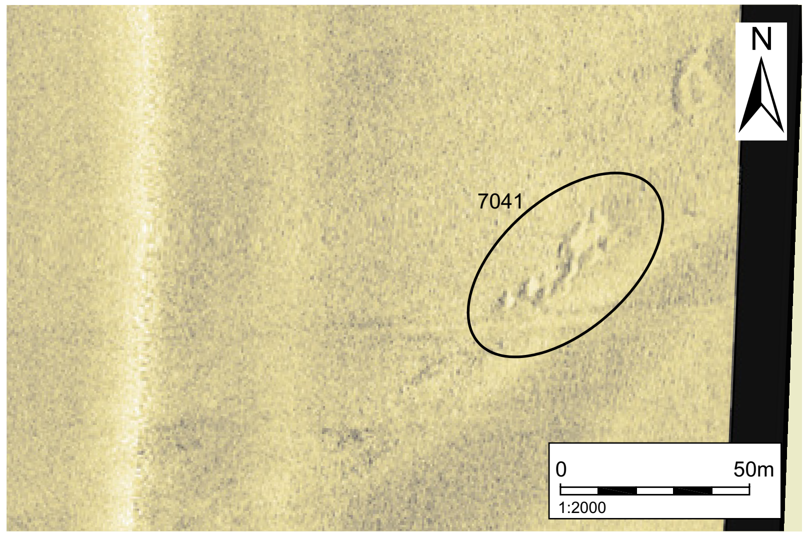
Distribution of debris across the physical regions

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Debris	3	17	50	1	36	**107**

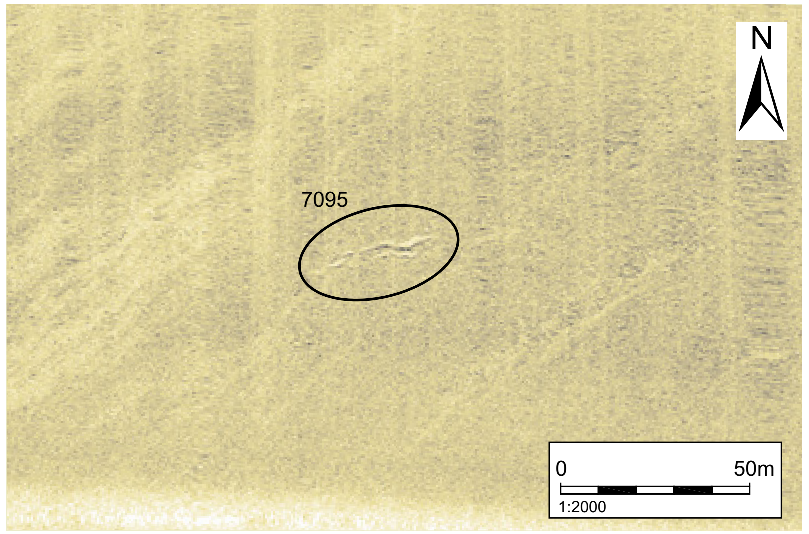
Figure 5.42: Sidescan Sonar Anomaly Types — Seafloor Disturbance



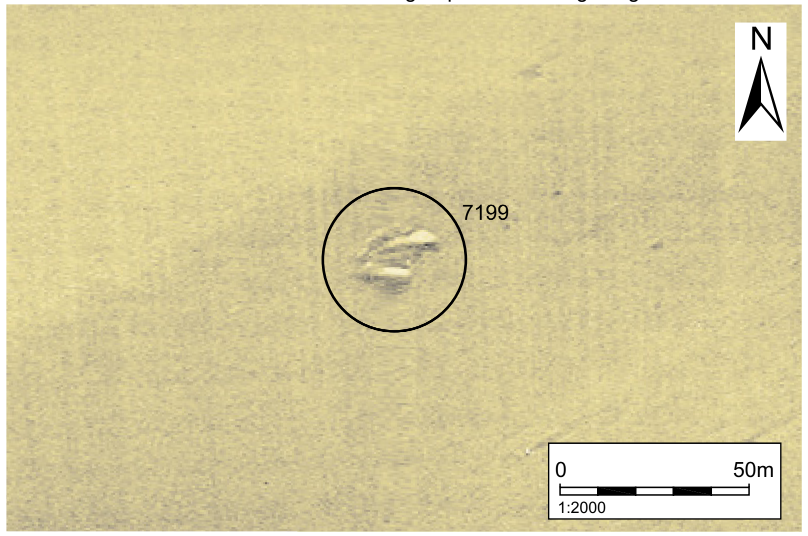
7190 & 7191 – Region 1 – 7190: 10.9m x 5.9m x 0m. Mound/group of debris or geological features. 7191: 9.1m x 6.2m x 0m. Mound/group of debris or geological features.



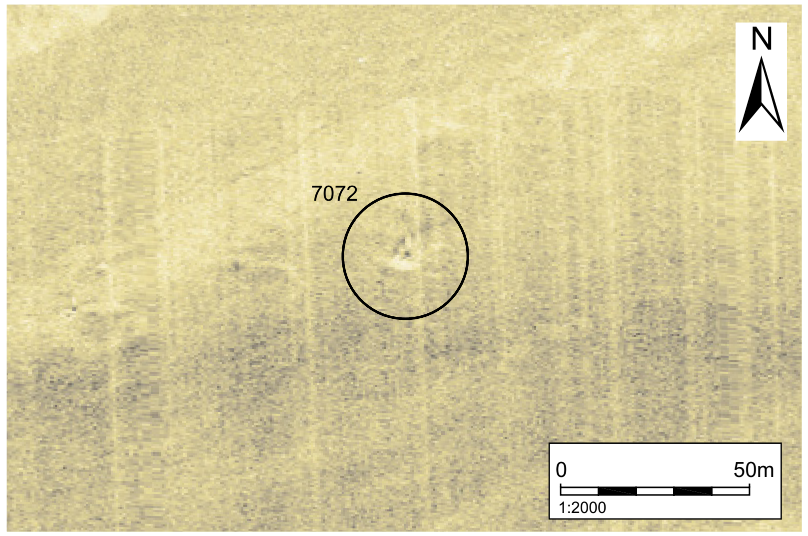
7041 – Region 3 – 23.6m x 9.6m x 0m. Possibly a group of debris.



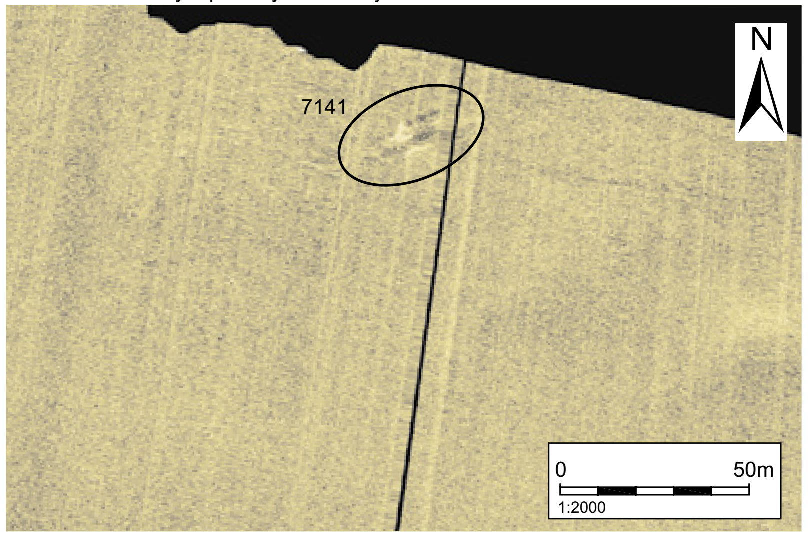
7095 – Region 3 – 18.4m x 3.5m x 0m. Patch of dark reflectors surrounded by bright reflectors. Possibly a partially buried object.



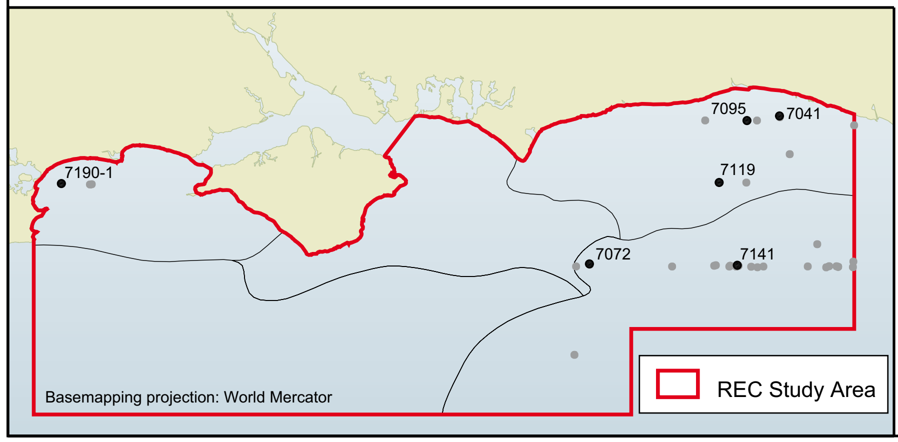
7119 – Region 3 – 12.2m x 10m x 0m. Possible group of debris.



7072 – Region 5 – 7.5m x 6.8m x 0m. Patch of bright and dark reflectors. 250m SW of of NMR 1027939, an unidentified seabed obstruction reported by fishermen.



7141 – Region 5 – 12.4m x 6.7m x 0m. Patch of dark and bight reflectors.



An area of seabed that appears disturbed, potentially by a buried or partially-buried wreck or debris of archaeological interest. These types of features may be groups of what is apparently debris or may be more ephemeral and consist solely of a patch of bright and dark reflectors distinct from the surrounding seabed.

Distribution of seafloor disturbance across the physical regions

Anomaly Type	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Seafloor Disturbance	4	0	8	0	26	38

large discrepancy between the number of aircraft losses that are known to have occurred and the number of aircraft crash sites that have actually been located. Most aircraft casualties have only a general location associated with them. Given that many thousands of aircraft are known to have crashed in UK territorial and continental shelf waters, there is arguably greater potential for any given area of sea bed to contain unknown aircraft crash sites than unknown shipwrecks.

5.4.2 Casualties (recorded losses)

Current estimates suggest that c.1000 losses of German aircraft occurred off the British coast with most of these occurring in the English Channel and south-east. However, many NMR and SMR/HER records are based on named loss locations, in other words where aircraft are reported to have been lost rather than a located wreck on the sea bed. Often these loss locations are approximate and can be very general indeed, such as the 253 losses recorded by the NMR as being associated with the Isle of Wight. Co-ordinates assigned to these losses are somewhat arbitrary and can also be subject to error on the part of the database compilers. For example, of the seven losses recorded by the NMR in Region 5, three appear to have been actually lost in Region 3 and the other four are recorded simply as having been lost off the Sussex coast. As a result NMR and SMR/HER records are not necessarily a reliable guide to the location of aircraft crash sites on the sea bed. Furthermore, comparison of the loss location descriptions and the measure of precision assigned to co-ordinates in a sample of records for the study area suggests that the quoted precision cannot always be relied upon.

Table 5.13 shows the number of NMR records for each of the five Regions within the South Coast REC area.

As a general guide to distribution NMR and SMR/HER records are probably reasonably reliable. However, it should be noted that Regions 1, 2, 4 and the western part of Region 3 have been subject to SMR/HER enhancement exercises in respect of crash sites that have resulted in many more aircraft losses being added. The remainder of Region 3 and Region 5 have not and the density of aircraft losses shown in Figure 5.43 may not therefore be representative of the number of aircraft that have crashed there. It may be expected that more aircraft have crashed there than is shown.

The majority of these records date from 1939–45 and include Allied fighters and German fighters and bombers that are consistent with offensive German operations against both land and maritime targets in the period 1940–43/44. They also include British and Allied bombers, air sea rescue aircraft and fighter bombers, consistent with the movement of aircraft to and from areas of Allied offensive operations in continental Europe. These records also include two unidentified aircraft in Region 3 and 14 unidentified aircraft in Region 4, all of which are believed to have been lost in 1939–45.

In Regions 4 and 5 the small number of recorded losses is probably consistent with the comparatively offshore locations of these Regions, for a number of reasons. For example, most combat interceptions of German aircraft would be expected to have occurred closer to the coast. The crews of damaged aircraft that had to ditch would also have sought to get as close to the coast as possible to maximise their chances of survival. In addition, more investigative diving by recreational divers has traditionally occurred in shallower inshore waters.

Most of the losses in Region 4 are of RAF Hurricanes and Spitfires. There is only a single German aircraft, a Junkers 88, and 14 unidentified aircraft. In contrast, the losses in Region 5 include: an RAF Hurricane Mark I and a Spitfire Mark I; a Horsa Mark I heavy transport glider that ditched during D-Day; an RAF Manchester heavy bomber returning from a raid on Le Havre; two RAF Beaufighter twin engined fighter bombers and a Heinkel He 111 German bomber.

5.4.3 Aircraft wrecks

Only eight UKHO records within the South Coast REC area are known to relate to aircraft losses: three in Region 3; two in Region 2 and one in each of the remaining Regions (Table 5.13). However, only one site in Region 3 was covered during the South Coast REC 2007 geophysical survey. No other geophysical anomalies were identified as aircraft remains from the South Coast REC geophysical data.

5.4.4 Physical Region 1

Within Region 1, UKHO wreck number 19432 is recorded by the UKHO as the wreck of an RAF Whitley bomber on the basis of information supplied by recreational divers in 1981. The same site is recorded by the NMR as 832521.

Region	Number of aircraft casualties (NMR)	Number of aircraft wrecks (UKHO)
1	125	1
2	131	2
3	86	3
4	35	1
5	7	1
Total	384	8

Table 5.13: Aircraft casualties and known aircraft wrecks in the South Coast REC study area.

An aircraft wreck is also recorded as having been found by recreational divers at a position only 94 m to the south of 19432 (Hinchcliffe, 1999). However, it is described as being a 'World War Two bomber' and 'almost certainly a Halifax'. Due to their close proximity, they are unlikely to be separate aircraft. The Armstrong Whitworth Whitley was a twin engined bomber in service with the RAF at the start of the war. It was the first full production RAF heavy bomber and was used in that role until replaced by the Halifax. Subsequently it was used in the maritime patrol role during the Battle of the Atlantic and later as a glider tug and paratroop transport. The four engined Handley Page Halifax was a later heavy bomber. It was an Allied aircraft, mostly flown by the RAF.

No Halifax or Whitley is recorded as crashing at this location by the online Dorset Air Crashes database. On the basis that the non-UKHO report is later and on the basis that more than two engines have probably been seen by divers in order to identify it as a Halifax, it is probably the case that this aircraft is in fact a Halifax. That aircraft was introduced in 1940, mainly as a heavy bomber but also in specialised roles such as a glider tug and also with RAF Coastal Command. As a bomber it took part in all of the major Bomber Command raids. In the maritime patrol role it was not retired until 1952. The likelihood is that it was lost during 1940-45.

If the wreck is that of a Whitley then it is 'extinct', in that no preserved, instructional or derelict examples are known to survive. As such it would be of very high archaeological importance even

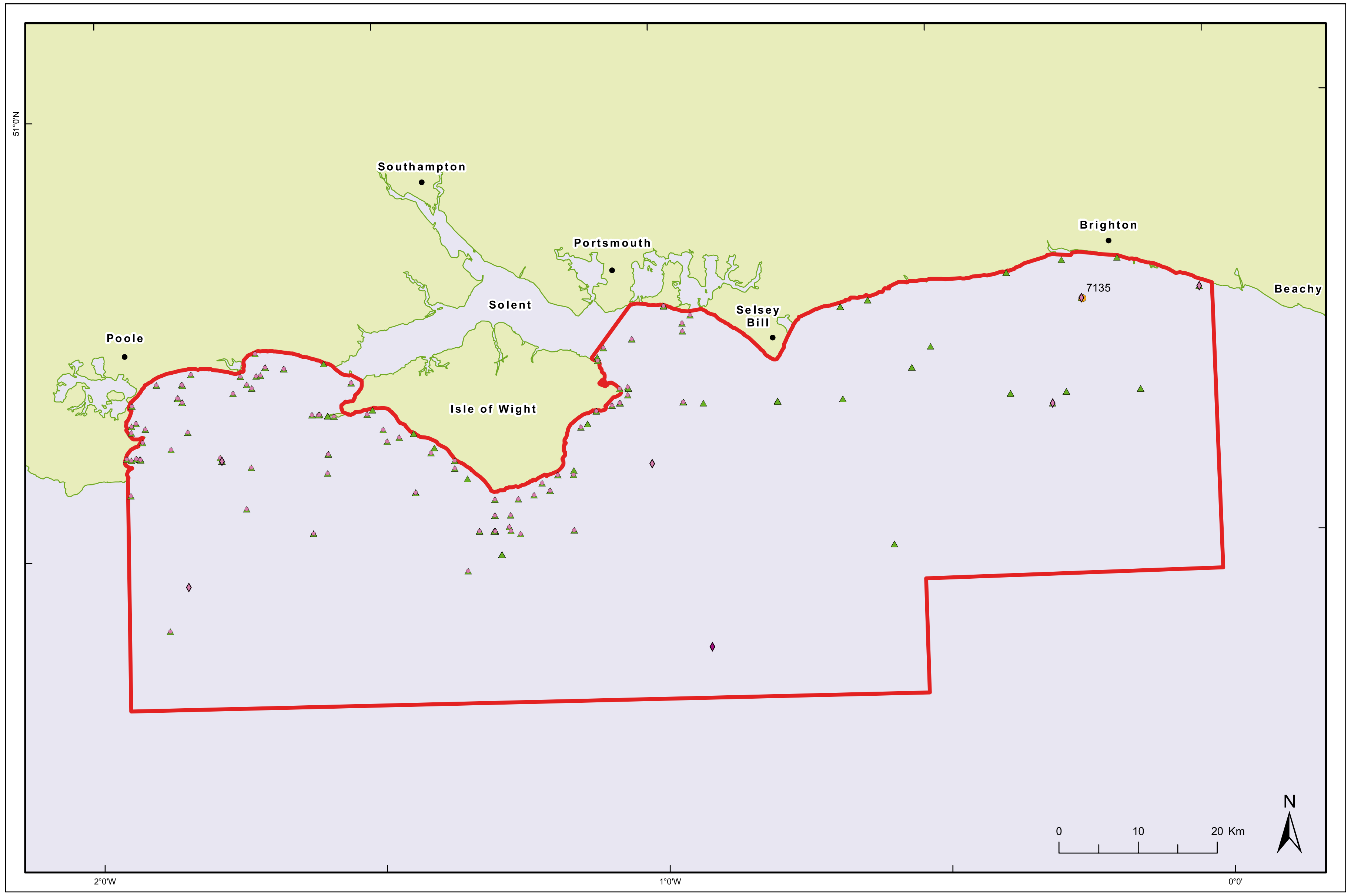


Figure 5.43: Known and potential aircraft crash sites.

if in a highly degraded condition. If it is a Halifax then it is not as significant because the aircraft type is not extinct, examples of the type having survived. Importance would probably be regarded as being medium-high, depending upon the degree of preservation.

5.4.5 Physical Region 2

Within Region 2, UKHO wreck number 19021 is that of a Piper light aircraft, registration G-ARLS, that lost power and was forced to ditch on either 29 July 1975 (UKHO) or 31 July 1975 (McDonald and Pritchard, 2001). No deaths were associated with this wreck. It was subsequently disturbed by the pot lines of a fishing boat. It is not considered to be archaeologically significant. It is not recorded by the NMR and the South Coast REC geophysical survey did not cover the position of this wreck.

The partially intact wreck of a C-47 Skytrain is known to lie close to an outfall in Sandown Bay, Isle of Wight. The site, which appeared as an anomaly and was categorised by UKHO as a small wreck or rock pinnacle was investigated in advance of the development of the outfall (Wessex Archaeology, 1997a-b). The aircraft has not been identified conclusively but it has however been suggested that it is a C-47 of the US 95 Troop Carrier Squadron that ditched after suffering flak damage over France on 7 June 1944 (Key Publishing Ltd Aviation Forums, 2009).

The C-47, more famously known as the Dakota, was the principal US transport and troop carrier during the Second World War and was heavily involved in the D-Day and Arnhem airborne operations. After the war thousands of C-47s were converted for civilian use. Due to their robust nature a very large number survive, including some still in commercial use. Nevertheless, as a partially intact C-47 possibly lost during the D-Day operations, this wreck is of high importance.

5.4.6 Physical Region 3

The only possible aircraft crash site, **7135**, located during the South Coast REC geophysical survey is in Region 3 (Figure 5.44). It was detected by sidescan sonar and characterised as a seafloor disturbance. Its sonar dimensions were 5.1 m by 4.3 m with no significant height.

The anomaly is approximately 340 m north-east of the UK charted wreck of a four engined bomber (UKHO 20138). This has been identified as possibly being BF455, a Short Stirling Mark III four engined heavy bomber lost whilst returning from a raid on Frankfurt on the night of 10–11 April 1943. The aircraft, of the 75 (New Zealand) Squadron, based at Newmarket, had been damaged by flak and attacked by night fighters and was forced to ditch, reportedly about 3 miles off Shoreham. All of the crew were subsequently rescued.

The distance between the anomaly and the charted position of the aircraft wreck is considerable and casts some doubt on whether the anomaly is in fact associated with the aircraft. Its apparently small size in comparison with a Stirling bomber and this positional discrepancy suggest that it may not be the aircraft itself, only part of it.

Diver reports made to UKHO indicate that the charted aircraft wreck, which is in a general depth of about 9 metres, was subject to trawling in the 1970s. It was also missing one wing. By 1999 diver reports suggested that the wreck had become widely scattered as a result of trawling and/or storm waves.

This reported scattering of the aircraft wreck means an association between the anomaly and the aircraft wreck is possible, although this it is unlikely to be provable without a visual inspection. If it is associated, then it is likely to be a fairly large section of the wreck as seen in the 1970s or alternatively the remains of the missing wing. If the latter, it may have become detached at the time of ditching.

The Short Stirling bomber was the first of the RAF's four engined heavy bombers to enter service. It is 'extinct'. As a result, if **7135** is part of a Short Stirling then even in a degraded and fragmentary condition it is of very high archaeological importance.

Furthermore BF455 was a significant aircraft in that it carried the famous Canadian brothers Richard Douglas Tod and Robert Ernest Tod. These twins enlisted on the same day, went overseas together, were assigned to the same squadron together and finally and extremely unusually were assigned to the same aircraft. Robert Tod was the radio operator and his conduct during the loss earned him the Distinguished Flying Medal. After the loss of BF455 the brothers were assigned to another Stirling and were tragically lost together when this aircraft was shot down by a German night fighter later in 1943.

There are two further UKHO charted aircraft wrecks in Region 3 but neither were covered by the geophysical survey.

UKHO 20174 is recorded as being a German aircraft, presumed WWII. The charted position is approximately 20 km south of Shoreham, West Sussex. The UKHO survey details record that it was dived in 1991, presumably by recreational divers, who describe it as being the broken up and largely buried remains of an aluminium aircraft with a single V-12 engine and a panel instrument with writing in German. It is recorded as standing 2 m high, with a 1 m deep scour. No mention of this wreck appears in regional dive guides.

It is likely that the engine is a Daimler Benz DB 600, 601 or 605 and that UKHO 20174 is therefore the wreck of a German Bf 109 fighter, lost between 1939 and 1945. It is not possible to say with certainty which Bf 109 variant it is and when exactly it was lost, although German fighter operations in this area typically occurred between the fall of France in 1940 and the liberation of France in 1944. It is also not possible with the available data to identify the actual aircraft, although further research may allow this to be done.

As a broken up Bf 109, 20174 would have medium archaeological importance. There are believed to be 45 surviving Bf 109s worldwide, some of which are airworthy.

UKHO 20143 is recorded as being a single seater low wing mono-plane. The charted position is approximately 2 km off Peacehaven, East Sussex (Figure 5.43). It is recorded as having been identified by divers removing a snagged trawl in 1956. The UKHO survey notes indicate that it could not be found in 2001 and was believed to be buried. As it had clearly been impacted by trawling and does not appear in regional dive guides it is possible that it has been dispersed.

UKHO 20143 is recorded by the NMR as 911540. The NMR record is associated with an aircraft wreck listed in a regional dive guide (McDonald, 1999) notwithstanding the fact that the positions quoted in that guide are different from the charted position. Given that the dive guide description is similar to the UKHO's they may be the same wreck. The dive guide describes the aircraft as being a Spitfire, which is consistent with the UKHO description but this is not conclusive. Regardless, that description does suggest that it is likely to be a fighter lost in 1939–45.

The archaeological importance of UKHO 20143 will depend upon which aircraft type it is and its current condition.

5.4.7 Physical Region 4

A single aircraft wreck is recorded by UKHO in Region 4, wreck number 19372. This is a light aircraft, Apache GASFF which ditched south-west of the Needles in 1980. A survivor is reported as having been recovered at the time. The UKHO position relies upon a report made at the time and appears to be approximate. The UKHO record no survey of the position as having been undertaken. The charted position lay to the west of the survey lines run during the project. The wreck is not considered to be archaeologically significant.

5.4.8 Physical Region 5

UKHO wreck number 20197 was recorded by the UKHO as being a wooden shipwreck. However ROV investigation in 2006 identified the wreck as being a partially intact Consolidated B-24 Liberator heavy bomber (Wessex Archaeology, 2007c). The four engined Liberator was produced in greater numbers than any other American combat aircraft and was operated by the RAF and the US 8th Air Force during the Second World War. Serving in the anti-submarine war the long-ranged Liberator enabled RAF Coastal Command to close the mid-Atlantic 'air gap', paving the way for victory in the Battle of the Atlantic.

The actual aircraft has not been identified but the loss probably occurred in 1941–45. A total of 15 Liberators survive in preservation worldwide, some still airworthy. Nevertheless this wreck must be regarded as being of high importance.

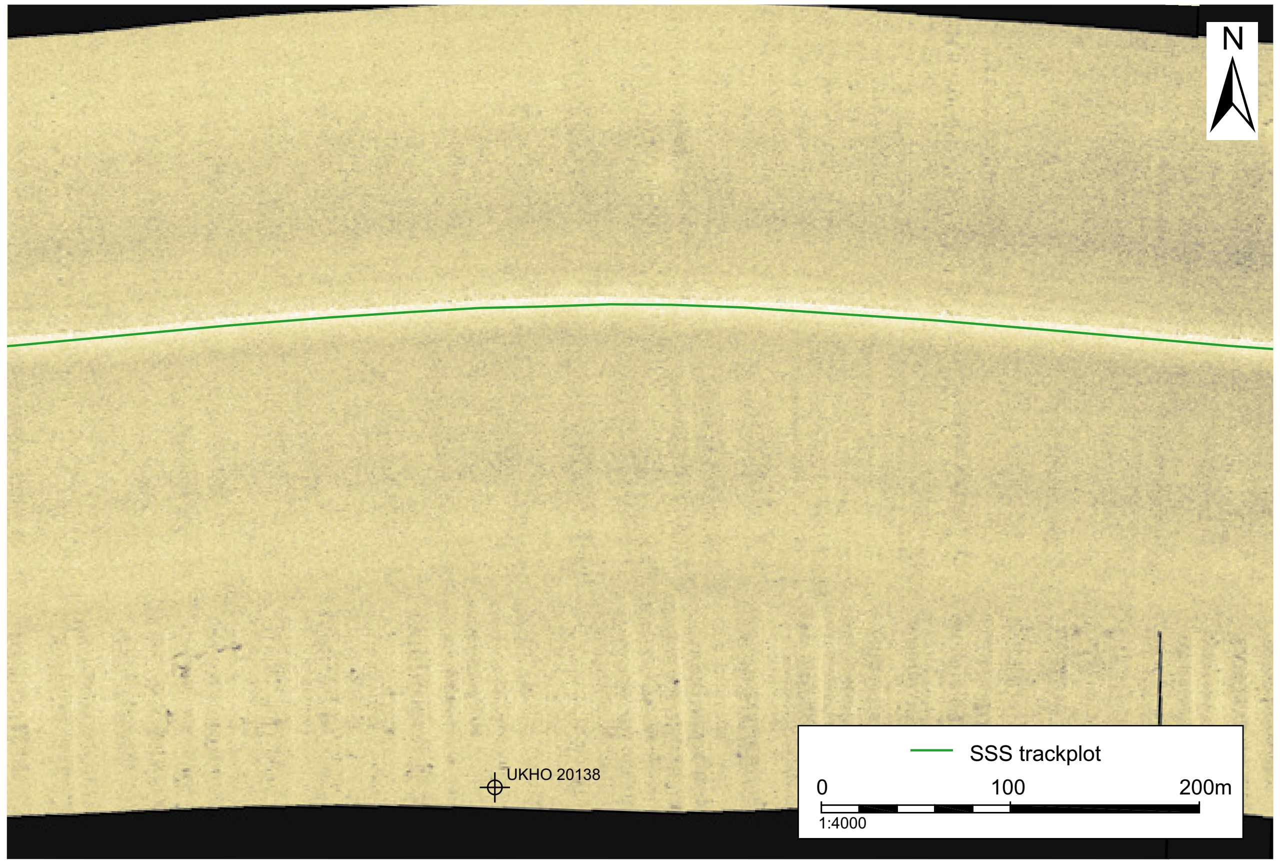
5.5 Summary

5.5.1 Prehistoric archaeology

Operations involving interference with the seabed will inevitably, in archaeological terms, always involve working 'blind'. The precise location of prehistoric archaeological material offshore is simply

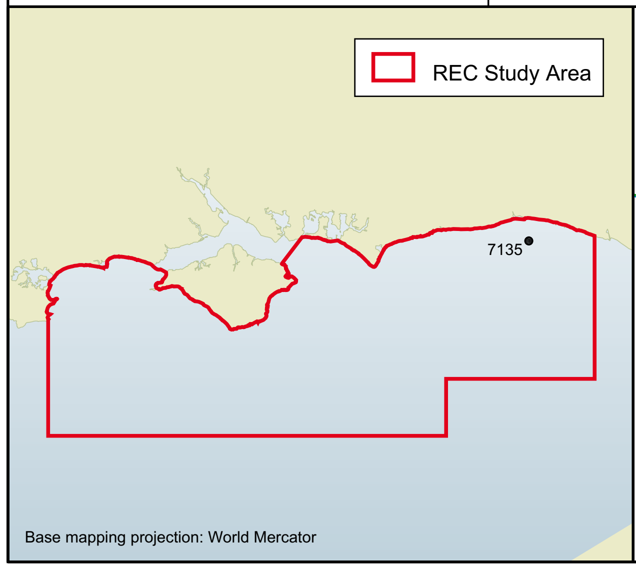
Figure 5.44: WA ID 7135 — Possible aircraft wreck (possibly BF455 of 75 (NZ) Squadron UKHO 20138

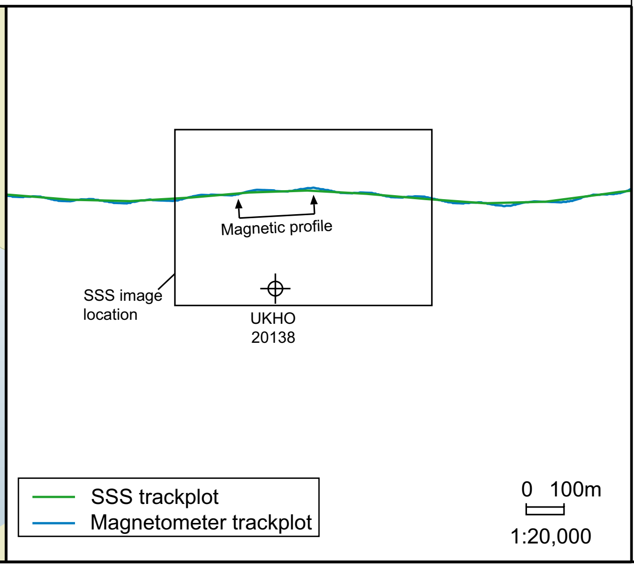
Location		695210 E 5628469 N (UTM 30N) 50 46.51 N 00 13.87 W (WGS84)	**Region**	3
Archaeological Importance		High if part of UKHO 20138, otherwise low		
Geophysical survey dimensions and notes		5.1m x 4.3m x 0m. 350m NE of 20138. Possible aircraft wreck. Not covered by bathymetry.		
Build	**Type**	Possible Short Stirling Mark III heavy bomber		
	Construction	All metal airframe		
	Dimensions	Wingspan 30.2m; length 26.59m; height 6.93m; wing area 135.63 square metres; weight empty 19,595kg.		
	Factory	Unknown		
Loss	**Cause**	Ditched due to flak damage and/or shortage of fuel		
Extent of Survival		In 1970 the UKHO received a report from recreational divers of the wreck of a four engined bomber in the charted position in 8.8m water depth. 7135 is 343m NE of the charted position of the aircraft. Furthermore, 7135 is not resolved in sufficient detail by the sidescan data to determine whether it is an aircraft or part of one. This would ordinarily give rise to some doubt as to whether 7135 was the aircraft, particularly as it is also about 325m away from an alternative position for the wreck given in a regional dive guide, which is also off range and within 130m of the charted position (McDonald 1999: 96). However, the same regional dive guide states that by 1999 the wreck was "widely scattered". Therefore 7135 could be a large section of the aircraft wreck as originally seen or alternatively could be the wing that was originally seen to be missing. Alternatively 7135 could be another object not associated with the aircraft. Approximately 725m south of 7135 is the position recorded by the NMR for the loss of a Second World War British Halifax bomber. No scours or bedforms are apparent in the geophysical data next to the possible wreck.		
BGS Sediment Characterisation		Rock and thin sediment		

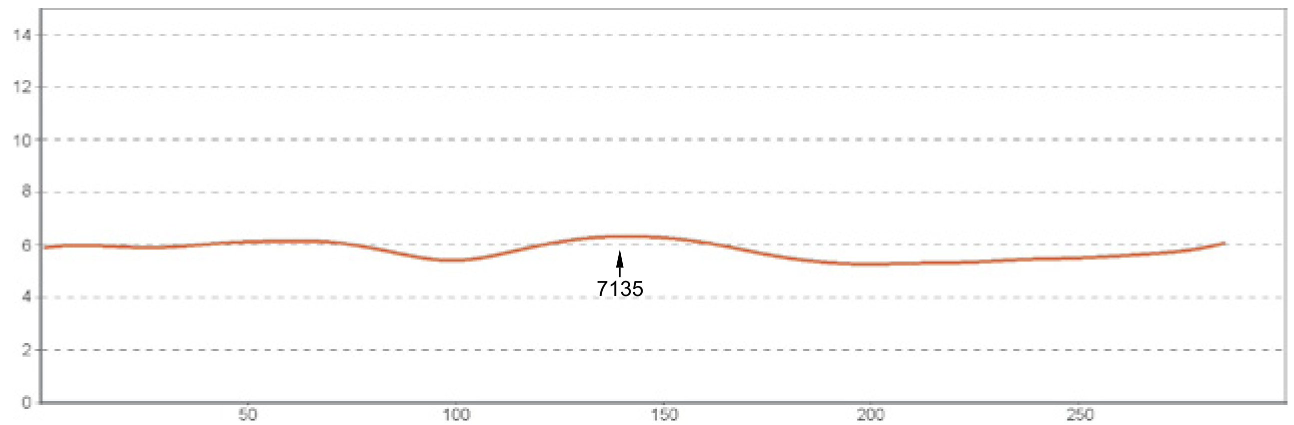


Mosaiced sidescan sonar image shows a seafloor disturbance.

This site was not covered by multibeam bathymetry.







Magnetic profile shows no anomaly adjacent to the wreck location.

unknown at present and we can do no more than highlight areas where there is a comparatively higher potential for the resource to survive. To a large extent, the lack of chronological control is outweighed by the intrinsic significance of any artefacts and organic sediments that may be encountered in future, as our understanding of the human use of the South Coast REC area is currently extremely limited. The scenarios presented above indicate that, under the appropriate preservational conditions, there is potentially a very large resource that could be recorded, in however serendipitous a manner.

The BMAPA initiative for recording dredged finds (BMAPA, 2005) has resulted in the reporting, since 2005, of few potentially early finds though these do include red deer antler and unidentified animal bone from licence areas in the general vicinity of the Protosolent channel south of Chichester (Areas 122/3 and 395) and a mammoth tooth to the west of the Isle of Wight (Area 127). Even these limited recorded finds are encouraging.

The characterisation of the South Coast REC area through the methods described above has involved the amalgamation of archaeological knowledge and theory with geological and geophysical interpretation. This approach focussed on identifying offshore the types of landscape features where archaeological material is found on land. It is not possible to provide definitive maps of the landscape at various times in the past as there is not enough evidence to do so based on the modern bathymetry with little knowledge of the changes undergone through time. However, it is certainly possible to highlight areas of the sea bed where the potential of archaeological material remaining is higher than that of the sea bed as a whole.

5.5.2 Maritime archaeology

The results of the survey have produced a more reliable guide to the density of maritime archaeological material on the sea bed than is currently available in other data sets, including the NMR and UKHO. Many more sites of potential archaeological interest were identified in the survey area than the UKHO and NMR records indicate are present.

The survey has successfully characterised the maritime archaeological resource of the South Coast REC area in respect of the late 19th century and more recently. However, it has failed to find evidence for earlier periods. This may be because of the relatively ephemeral nature of the remains of vessels of these periods and the relative difficulty of detecting them with current geophysical methodologies and equipment. Therefore, no conclusion can be drawn about the volume, distribution or character of the pre-19th century maritime activity in the REC area on the basis of the geophysical data.

The distribution of anomalies, identified from the archaeological assessment of the data appears unlikely to have an environmental basis. However, no firm conclusions can be reached on the South Coast REC data alone which did not cover inter-tidal or shallow water areas. The distribution of the survey corridors means that vessels that have been lost as a result of being stranded are not represented in the survey results. This is likely to be a significant bias in terms of characterising maritime activity in the South Coast REC area.

Evidence of wreck sites and associated debris has been identified in the survey data. However, it is not possible to say whether definitive evidence of the second type of maritime site, resulting from deliberate or accidental loss of material from a vessel, is present amongst the anomalies.

5.5.3 Aviation archaeology

Analysis of the UKHO and NMR databases for records of aircraft wrecks revealed that very few sea bed positions are known and the vast majority have only very approximate positions of the location of the aircraft when it was lost, before it came to rest on the sea bed. The distribution of aircraft wrecks in the REC area is therefore unknown and likely to be seriously underestimated, particularly as so many aircraft were lost in the English Channel during the course of the Second World War.

Aircraft wrecks are much more difficult to detect using current geophysical technologies and methods than shipwrecks, particularly modern shipwrecks, owing to their relative fragility and small size. Although only one known aircraft wreck was covered by the survey, and has potentially been located, it is possible that other geophysical anomalies identified from the survey data may also be related to aircraft wrecks rather than those of vessels.

6 Biological Characterisation

The biological resources in the South Coast REC study area were sampled using a combination of sampling gear (Chapter 3). A 0.1 m^2 mini Hamon grab was used to collect quantitative samples of the fauna living within and on the surface of the sediment deposits. Larger animals living on the sediment surface, including mobile invertebrates and demersal fish were sampled using a 2 m scientific beam trawl and underwater imagery was utilised to gain information about the biotopes present. The biological communities sampled across the REC study area using these three methods are described below.

6.1 Benthic macrofauna

Collectively, the benthic macrofauna sampled across the area were relatively rich with a total of 609 taxa being recorded across 67 samples. Mollusca dominate the benthos in terms of weight (Figure 6.1), accounting for over 65% of the total biomass recorded (g Ash Free Dry Weight, gAFDW). Annelida (primarily polychaetes) dominate the study area in terms of abundance accounting for over 40% of the total abundance recorded, closely followed by Crustacea which account for 27%. Annelida, Crustacea and Miscellania (mostly epifaunal species) contribute more or less equally to the taxonomic diversity across the area with fewer species of molluscs and echinoderms present. Elsewhere, annelids often exhibit a much greater dominance in terms of benthic diversity than has been observed in the South Coast REC study area (EMU, 2009; Robinson *et al*., 2009). In the study area, crustacean and epifaunal species also make a significant contribution to diversity which is a reflection of the environmental heterogeneity, and in particular the presence of rock and coarse substrates.

Figure 6.2 shows the ten most abundant species recorded in grab samples taken across the South Coast REC study area. The barnacle *Balanus crenatus* (Crustacea) was the most abundant species with a total of 2183 individuals recorded. *B.crenatus* is one of the most common sublittoral barnacles in the UK colonising a wide range of substrata, including cobbles and shells. *B. crenatus* release their larvae into the water column between February and September and very high numbers have been recorded in the waters of the Solent between February and May (Muxagata *et al*., 2004). The gregarious settlement behaviour of this species (Miron *et al*., 1996) means that high abundances are not uncommon in areas where suitable attachment surfaces are readily available (Kenny and Rees, 1994).

The sea squirt, *Dendrodoa grossularia*, was the second most abundant species recorded and, like *B. crenatus*, is widely distributed around the British coast. *D. grossularia* is gregarious in nature and is often found in high numbers attached to rock and coarse substrates. Kenny and Rees (1994) found high abundances of both *B. crenatus* and *D. grossularia* off the north Norfolk coast soon after the cessation of gravel extraction. This indicates that the larvae of these species are relatively cosmopolitan in their distribution. That these two species have been recorded together in several geographically separate areas indicates that there may be some overlap in the niche which they occupy.

The third most abundant macrofaunal species recorded in the South Coast REC study area is the American slipper limpet, *Crepidula fornicata*, a large gastropod which dominates the biomass. *C. fornicata* is an introduced species which is now widely distributed in the UK. It can tolerate a wide range of environmental conditions but is found in higher densities in wave protected areas such as bays, estuaries or the sheltered sides of wave exposed islands. This species is found on a variety of substrata but is most abundant in muddy or mixed muddy areas (de Montaudouin *et al*., 1999; de Montaudouin *et al*., 2001).

Other abundant species include the tubiculous polychaetes, *Pomatoceros lamarcki* and *Sabellaria spinulosa*. Both of these species build tubes attached to hard substratum including rocks, pebbles and shells. The high abundance of *P. lamarcki* and *S. spinulosa* across the REC study area further reflects the dominance of rock and coarse sediments. Conversely, high abundances of the pea urchin, *Echinocyamus pusillus*, and the interstitial polychaetes, *Notomastus latericeus* and *Lumbrineris*

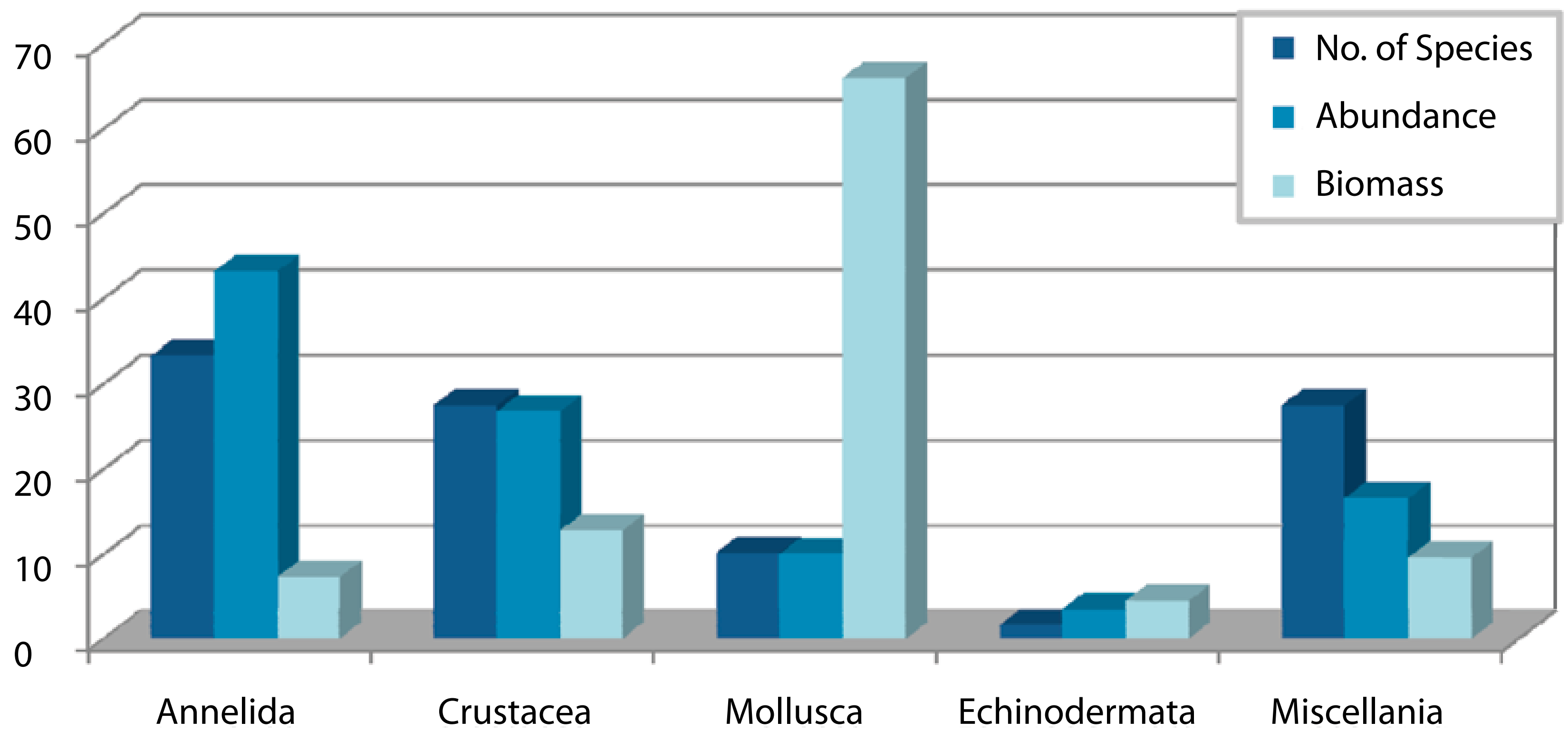


Figure 6.1: Relative contributions of major phyla to the number of species (diversity), abundance and biomass (g AFDW) recorded from 0.1 m^{-2} Hamon grab samples taken across the South Coast REC area.

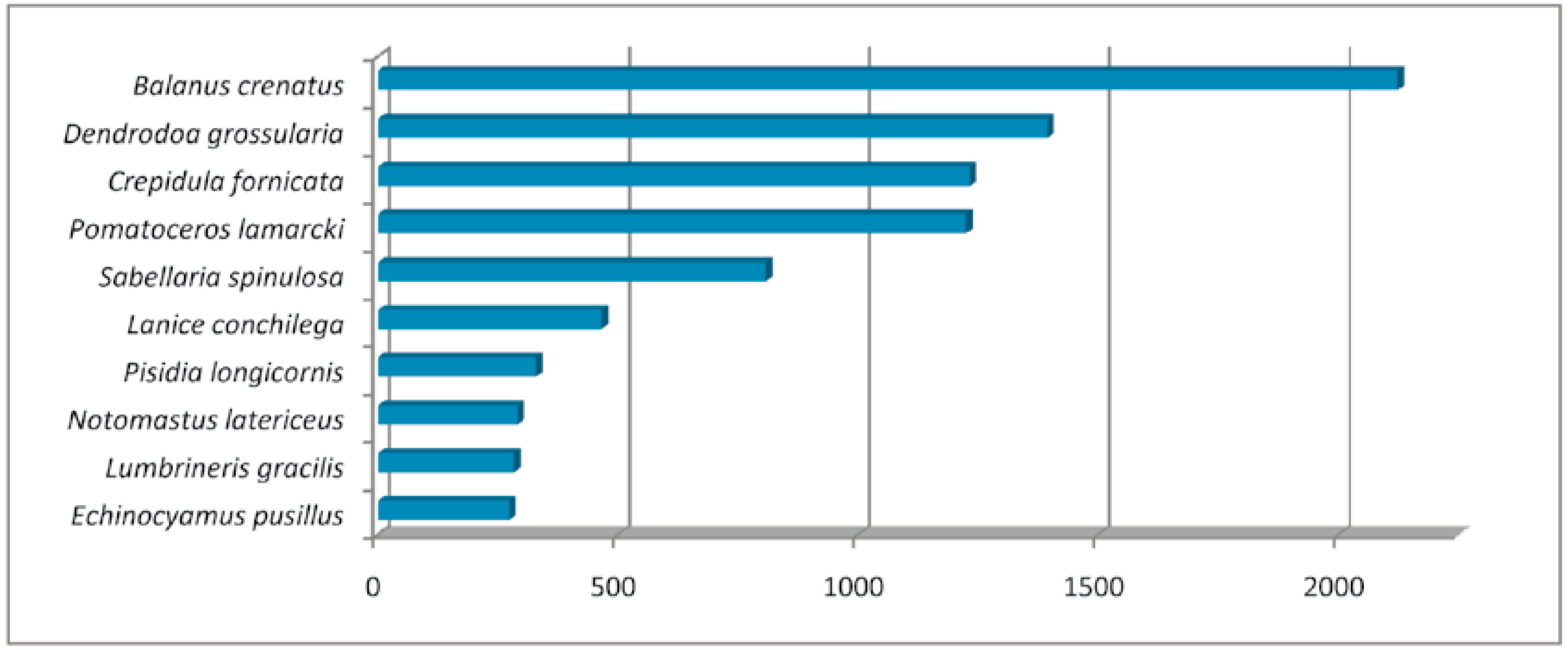


Figure 6.2: The ten most abundant benthic species recorded in 0.1 m^{-2} Hamon grab samples taken across the South Coast REC area, and the total number counted across all 67 samples.

gracilis, reflect the presence of sand. From the evidence presented above it is clear that the complex and wide ranging environmental conditions across the South Coast REC study area support a diverse suite of fauna.

6.1.1 Benthic macrofaunal composition and diversity

Figure 6.3, 6.4 and 6.5 show the relative diversity (no. of species), abundance and biomass (g AFDW) recorded from grab samples taken across the South Coast REC study area. The diversity of the benthos is relatively consistent across the area with the exception of the far eastern section of the Selsey — West Sussex Coastal Platform (Region 3) where diversity is notably reduced. The abundance of benthic fauna is similarly uniform with elevated abundance in sheltered areas, either side of the Isle of Wight and further offshore on the South Wight Platform (Region 4). This pattern is also reflected in the biomass with the highest values recorded inshore. There is a reasonable correspondence between abundance, biomass and diversity across the REC study area with the lowest values being recorded in the eastern sections of Regions 3 and 5.

To further investigate patterns of biological diversity across the South Coast REC study area a number of standard diversity measures were calculated for each of the grab samples. These are represented in Figures 6.6 to 6.8. The first of these, Simpson's Diversity Index (1-λ) is derived from the number and abundance of species present. A high Simpson's Diversity Index (approaching 1) indicates high biodiversity. The majority of grab samples had an Index between 0.75 and 1 (Figure 6.6) indicating a high diversity of benthic macrofauna.

Figure 6.7 shows the relative evenness (Pielou's Evenness, J') of the macrobenthic communities across the South Coast REC study area. Evenness is a measure of how similar species are in their abundance. A high evenness value (approaching 1) indicates that the majority of species are equally abundant. Conversely a low value indicates that one or more species dominates the community in terms of abundance. The majority of grab samples from the area exhibit high evenness but areas of lower evenness (<0.7) are observed around the Isle of Wight indicating that one or more species is particularly dominant.

Taxonomic Distinctness (Δ*) describes the average relatedness of species in a sample. In this case an assemblage in which species are distributed amongst several families will be more diverse than another, with identical richness and relative abundance, where species originate from a single family or genus (Warwick and Clarke, 2001). This is perhaps the most useful and instinctive measure of biodiversity. Taxonomic Distinctness is high across much of the South Coast REC study area (83–100) again indicating that the study area supports a high diversity of benthic macrofauna (Figure 6.8). Lower Δ* values are observed in the northeast of the area which is unsurprising since the abundance, biomass and number of species recorded here were low (Figure 6.3 to 6.5).

6.1.2 Benthic macrofaunal assemblages

Multivariate analysis of the benthic abundance data has been used to identify natural groupings which exist within the South Coast REC study area. Since the aim of this research is to provide a broad characterisation data were left untransformed meaning that the resulting groups are driven by the more abundant species. Figure 6.9 shows the results of a SIMPROF test on the group average sorting dendrogram. This reveals 13 discrete groups of samples (P<0.05%), which can usefully be considered as benthic assemblages.

The corresponding multi-dimensional scaling (MDS) ordination is shown in Figure 6.10. This illustrates that whilst the fauna in the South Coast REC study area can be considered as 13 discrete assemblages there is considerable overlap between them and they are likely to share a number of component taxa. The MDS ordination has been overlaid with the 13 faunal assemblages and coloured according to broader groupings based on similarities in the fauna and sediments. Groups coloured pale green are characterised by species which are indicative of pure sand deposits; those coloured dark green are characterised by species which are indicative of mixed sand deposits (sand containing some coarse sediment); groups coloured blue are characterised by species which are indicative of mixed deposits (sandy gravel and gravelly sand) and those coloured red are characterised by species indicative of coarse sediments (gravel with very little sand or silt). Figure 6.10 shows that there is a greater overlap in the 'coarse' sediment assemblages than the 'sand' assemblages and which is

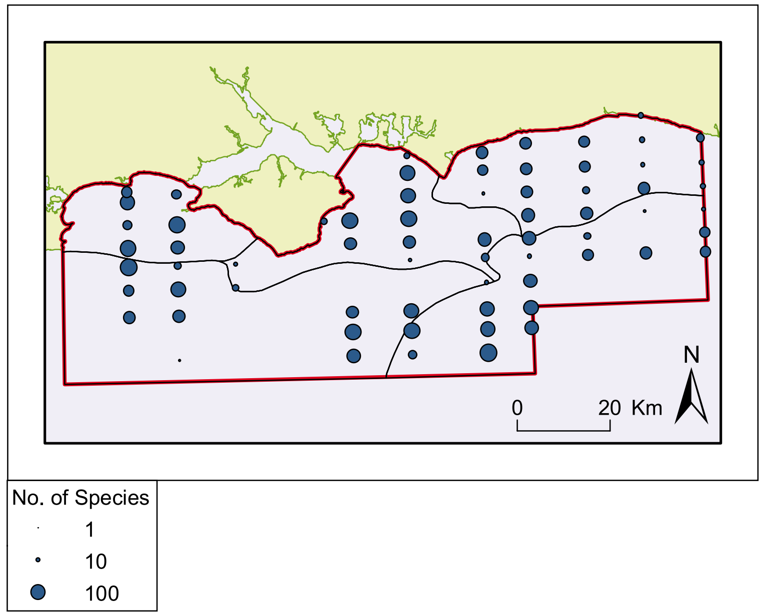


Figure 6.3: Total number of species recorded per 0.1 m^{-2} Hamon grab sample taken from within the South Coast REC area.

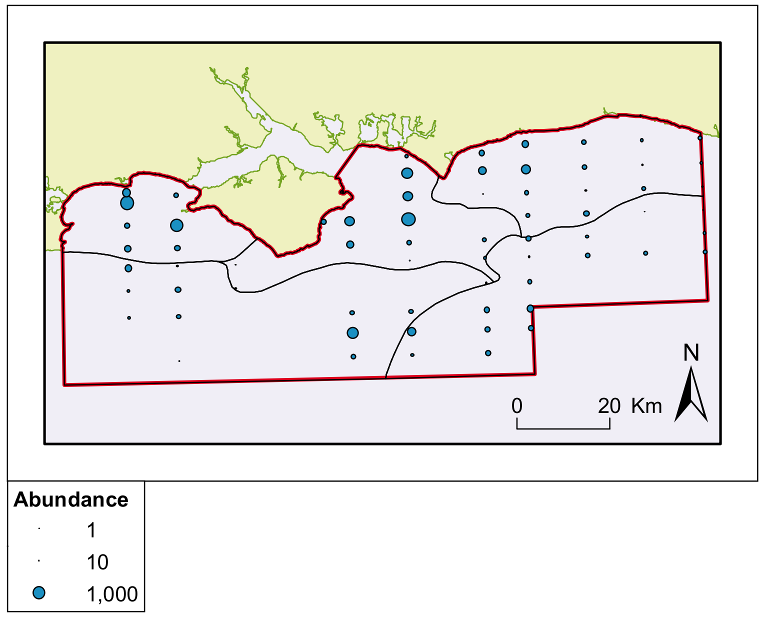


Figure 6.4: Total abundance of animals recorded per 0.1 m^{-2} Hamon grab sample taken from within the South Coast REC area.

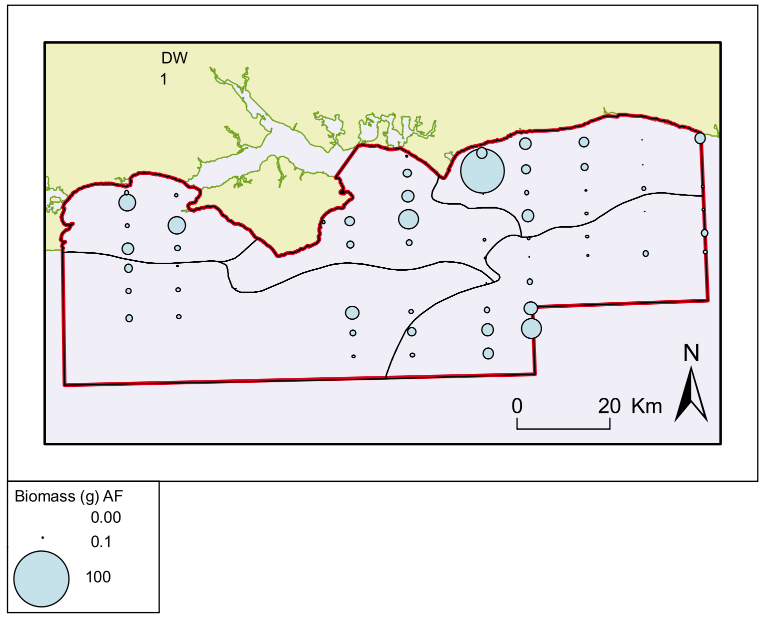


Figure 6.5: Total biomass (g Ash Free Dry Weight) recorded per 0.1 m^{-2} Hamon grab sample taken from within the South Coast REC area.

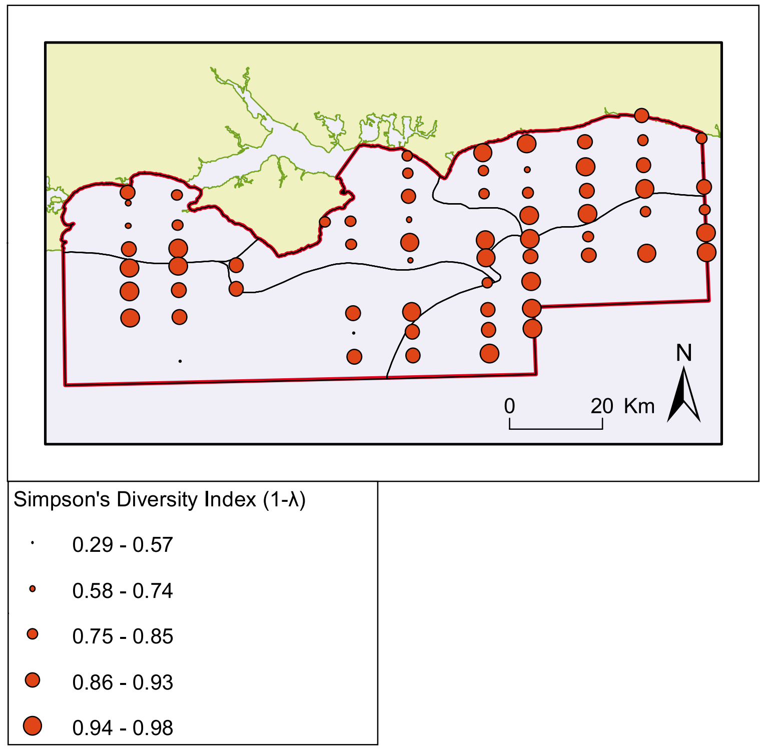


Figure 6.6: Simpson's Dominance (1-λ) calculated per 0.1 m^{-2} Hamon grab sample taken from within the South Coast REC area.

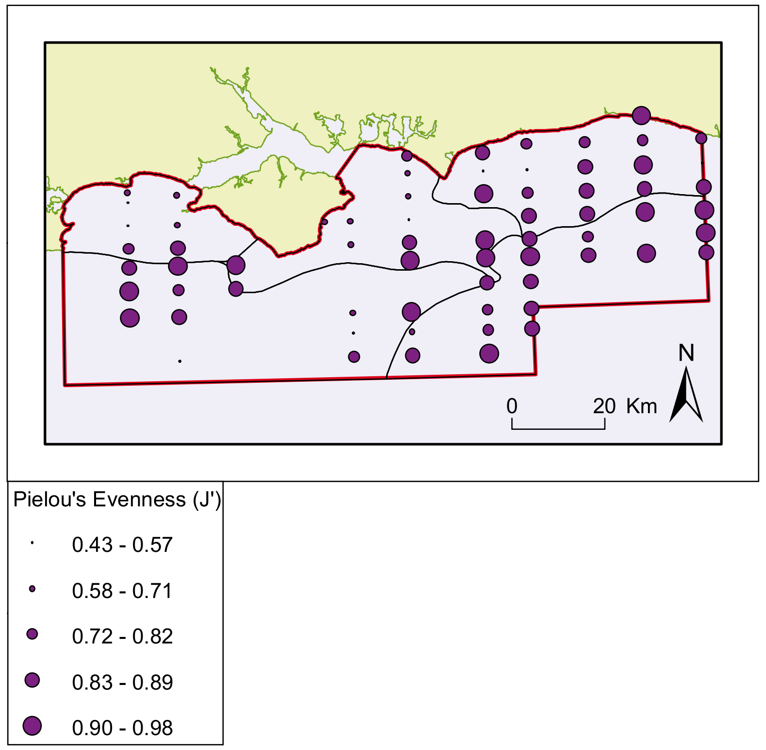


Figure 6.7: Pielou's Evenness (j') calculated per 0.1 m^{-2} Hamon grab sample taken from within the South Coast REC area.

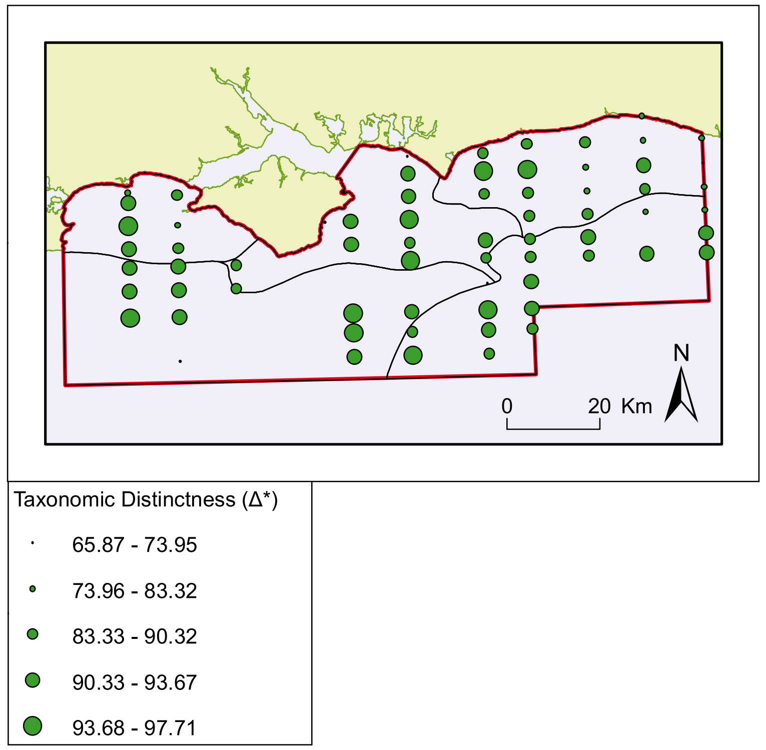


Figure 6.8: Taxonomic Distinctness (Δ*) calculated per 0.1 m^{-2} Hamon grab sample taken from within the South Coast REC area.

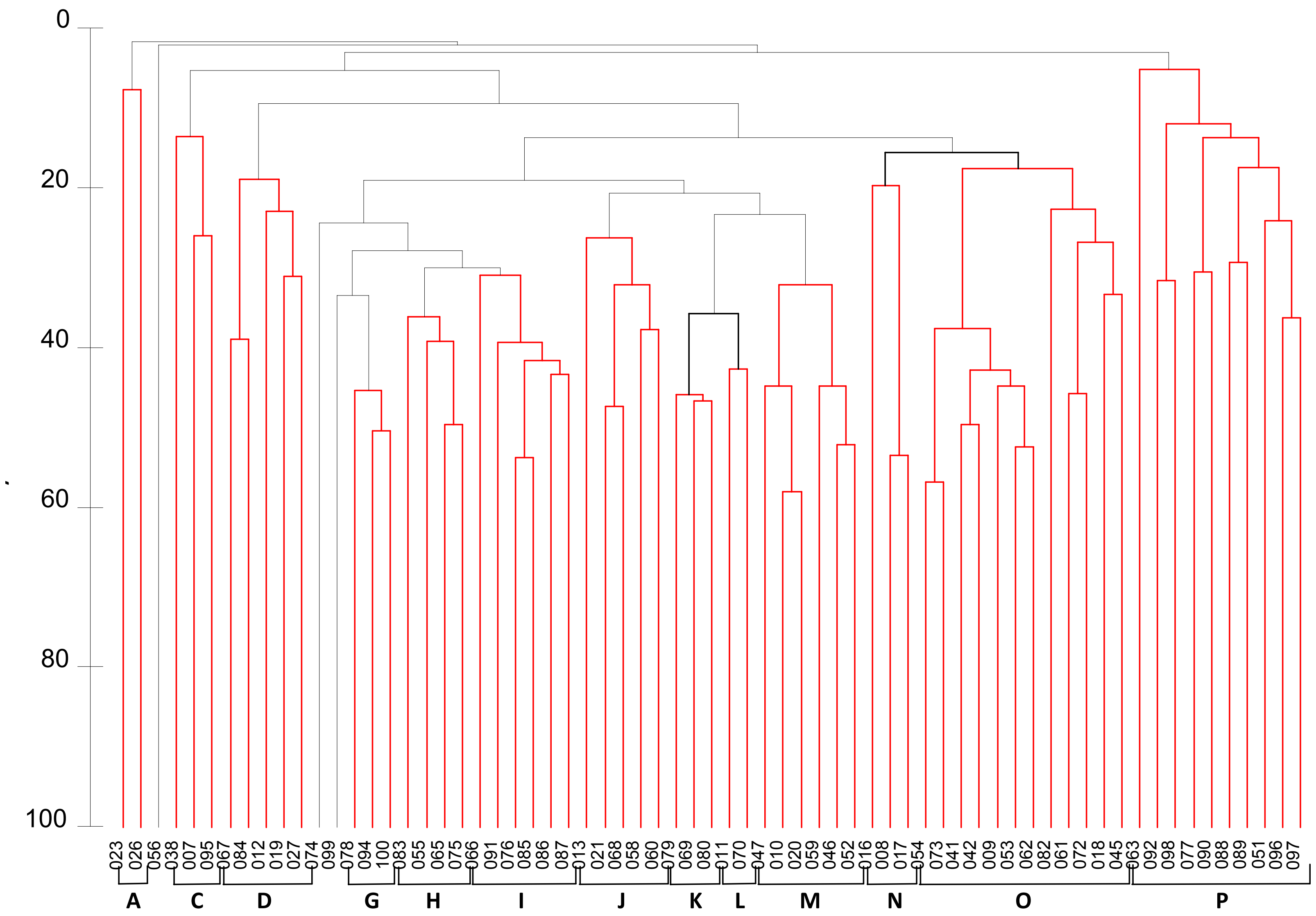


Figure 6.9: A group average sorting dendrogram, based on Bray-Curtis similarity of the benthos (untransformed abundance data) recorded across the South Coast REC area. Clusters of stations which are not significantly different from one another (P<0.05) are highlighted in red.

not unusual since benthic fauna tend to be much sparser in sand deposits. The distribution of the benthic groups identified in Figures 6.9 and 6.10 is illustrated in Figure 6.11. The benthic assemblages group well geographically indicating that their composition is driven strongly by the environmental conditions in the study area.

The distribution, characteristic species (identified through SIMPER analysis), diversity attributes and sediment composition of the faunal assemblages identified through multivariate analysis (Figure 6.9) are described in the following thirteen benthic assemblage summaries.

Stations 56, 38, 99 and 78 did not fall into any of the benthic assemblages identified as the fauna was significantly different to that recorded at all other sites (P<0.05%). Close inspection of the raw data (See South Coast REC 2007 survey acquisition report in Appendix A1) shows that the grab sample taken at station 56 was close to afaunal with only 5 individuals recorded. Station 99 is also characterised by a sparse faunal complement, relative to the rest of the study area.

High abundances of *Ampelisca brevicornis* and *Ampelisca diadema* were observed at Station 38, 77 and 54 respectively.

Both of these species belong to the family Ampeliscidae; tubiculous Amphipods which are known to occur in dense patches or beds (Hastings, 1981; Dauvin, 1988). *Ampelisca* beds are likely to be very small-scale features on the seabed and hence are rarely sampled using traditional methods. Very little is known about the influence that these features have on the seabed, or the associated fauna. That this sample is significantly different from all others in the South Coast REC area is an indication that dense aggregations of *Ampelisca* may significantly alter the benthic macrofauna.

Moderate abundances of the squat lobster *Galathea intermedia*, the colonial anemone *Epizoanthus couchii* and the polychaete *Laonice bahusiensis* were recorded at Station 99. All of these species have been recorded elsewhere in the study area and it is the low abundance, or complete lack, of other species which make this station unique.

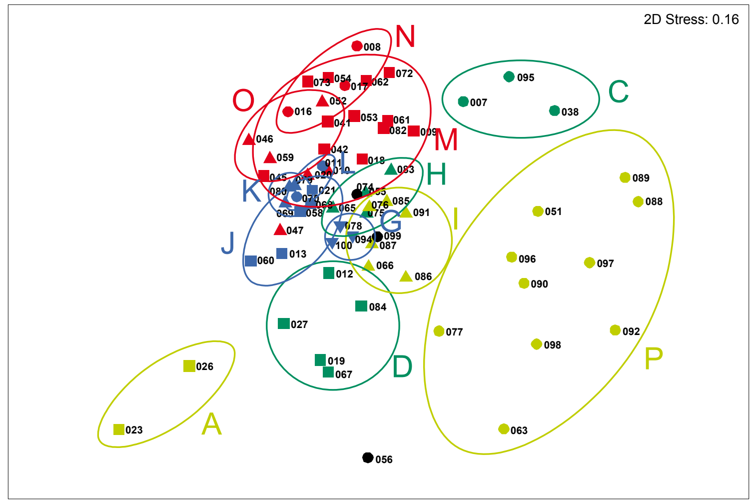


Figure 6.10: A multi-dimensional scaling (MDS) ordination based on Bray-Curtis similarity illustrating the similarity between the benthos (untransformed abundance data) recorded across the South Coast REC area, superimposed with the benthic assemblages identified in Figure 6.9.

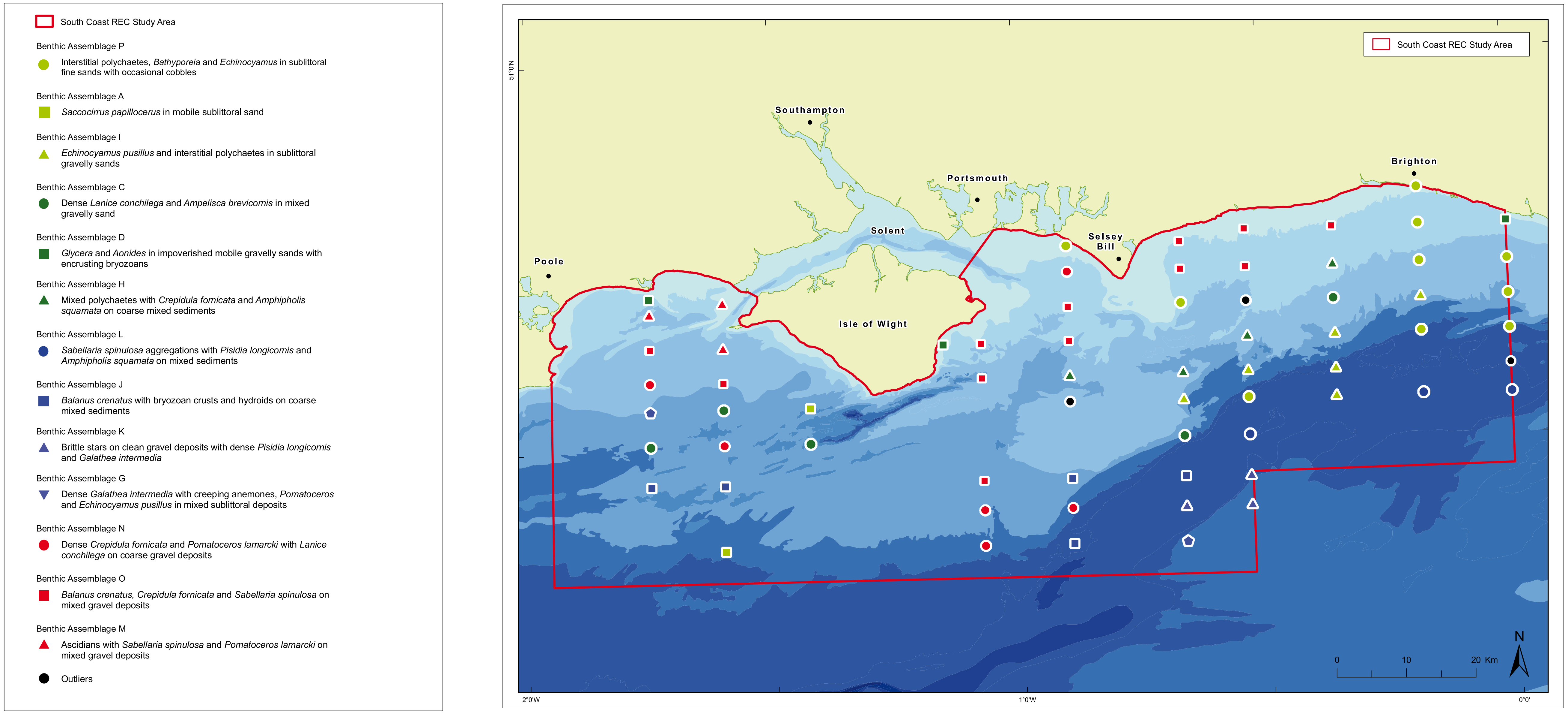
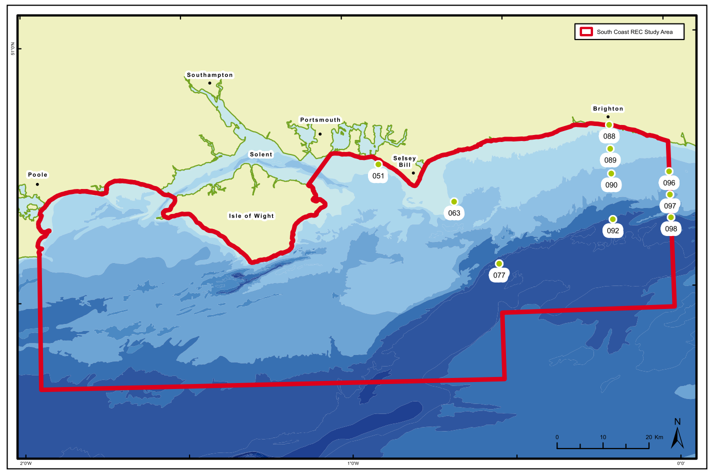


Figure 6.11: Distribution of benthic assemblages identified through multi-variate analysis of grab sample data (Figure 6.9 and 6.10).

Benthic Assemblage P (n=10)

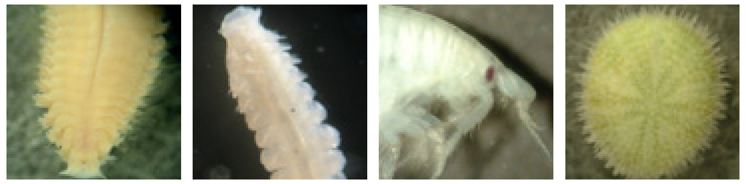
Interstitial polychaetes, *Bathyporeia* and *Echinocyamus* in sublittoral fine sands with occasional cobbles.



Location of samples assigned to Benthic Assemblage P.

Most characteristic taxa (with % contribution to similarity)

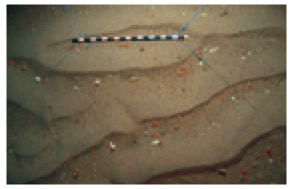
- *Nephtys* (27.98%)
- *Spiophanes bombyx* (27.91%)
- *Nephtys cirrosa* (15.07%)
- NEMERTEA (5.34%)
- *Magelona johnstoni* (4.38%)
- *Bathyporeia elegans* (3.96%)
- *Echinocyamus pusillus* (3.18%)
- *Bathyporeia guilliamsoniana* (2.63%)
- *Ophelia borealis* (2.01%)
- *Lagis koreni* (1.22%)



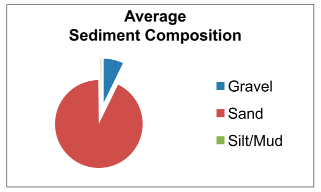
Photographs of representative fauna from Benthic Assemblage P. Interstitial polychaetes *Nephtys* sp. (a) and *Spiophanes bombyx*, the amphipod crustacean, *Bathyporeia* sp (c) and the pea urchin, *Echinocyamus pusilus* (d). © www.seasurvey.co.uk

Grab sample taken at Station 92 (Assemblage P).

Total Species	72
Average No. Species	12
Average Abundance	37
Average Biomass (g AFDW)	0.1066
Simpson's Diversity (1-λ)	0.91
Pielou's Evenness (J')	0.75
Taxonomic Distinctness (Δ*)	80.4

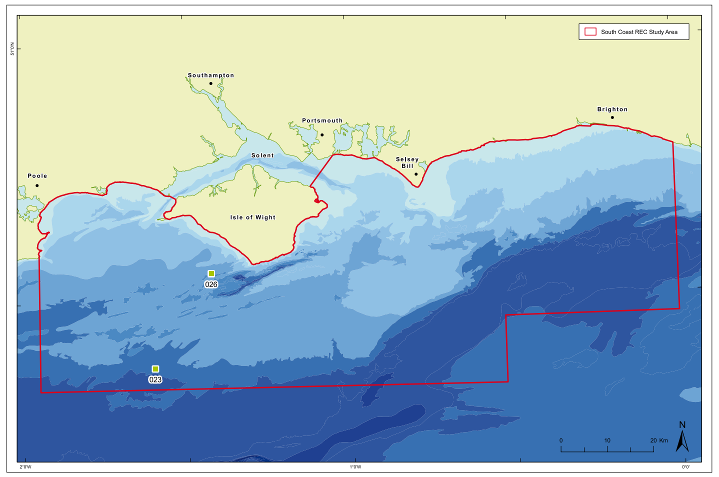


Seabed image taken at Station 92 (Assemblage P).



Benthic Assemblage A (n= 2)

Saccocirrus papillocercus in mobile sublittoral sand.



Location of samples assigned to Benthic Assemblage A.

Most characteristic taxa (with % contribution to similarity)

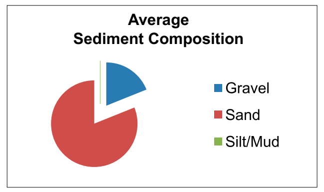
- *Saccocirrus papillocercus* (100%)

Photographs of representative fauna from Benthic Assemblage A. The interstitial polychaete, *Saccocirrus papillocercus* (a) © www.seasurvey.co.uk

Grab sample taken at Station 23 (Assemblage A).

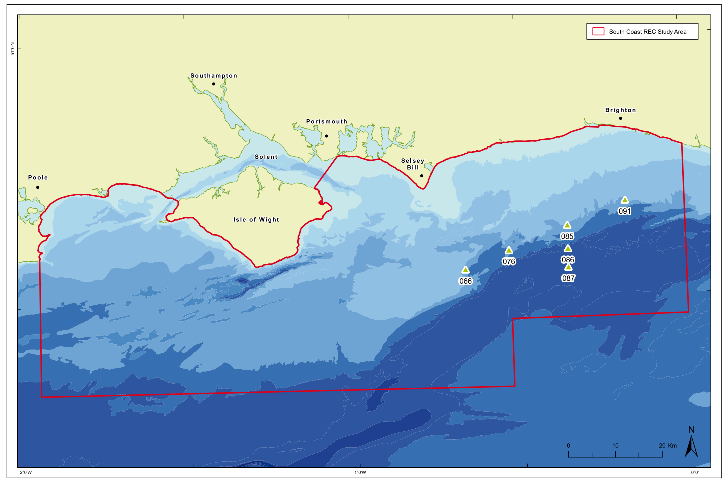
Total Species	12
Average No. Species	7
Average Abundance	13
Average Biomass (g AFDW)	0.0027
Simpson's Diversity (1-λ)	0.78
Pielou's Evenness (J')	0.81
Taxonomic Distinctness (Δ*)	83.96

Seabed image taken at Station 23 (Assemblage A).



Benthic Assemblage I (n=6)

Echinocyamus pusillus and interstitial polychaetes in sublittoral gravelly sands.



Location of samples assigned to Benthic Assemblage I.

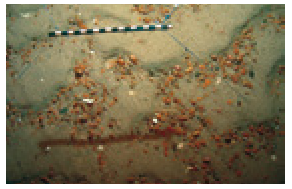
Most characteristic taxa (with % contribution to similarity)

- *Echinocyamus pusillus* (38.15%)
- *Lumbrineris gracilis* (8.42%)
- *Notomastus latericeus* (6.55%)
- *Aonides paucibranchiata* (4.17%)
- *Glycera* (3.84%)
- NEMERTEA (3.75%)
- Maldanidae (2.96%)
- *Glycera lapidum* (2.75%)
- *Pomatoceros lamarcki* (1.9%)
- *Polycirrus* (1.46%)

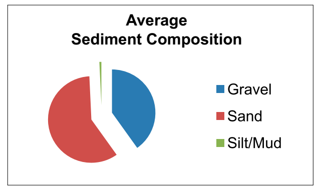
Photographs of representative fauna from Benthic Assemblage I, the pea urchin, *Echinocyamus pusilus* (a) and the interstitial polychaetes, *Lumbrineris* sp. (b), *Notomastus latericeus* (c) and *Aonides paucibranchiata* (d). © www.seasurvey.co.uk

Grab sample taken at Station 86 (Assemblage I).

Total Species	166
Average No. Species	55
Average Abundance	155
Average Biomass (g AFDW)	0.3712
Simpson's Diversity (1-λ)	0.94
Pielou's Evenness (J')	0.78
Taxonomic Distinctness (Δ*)	89.82

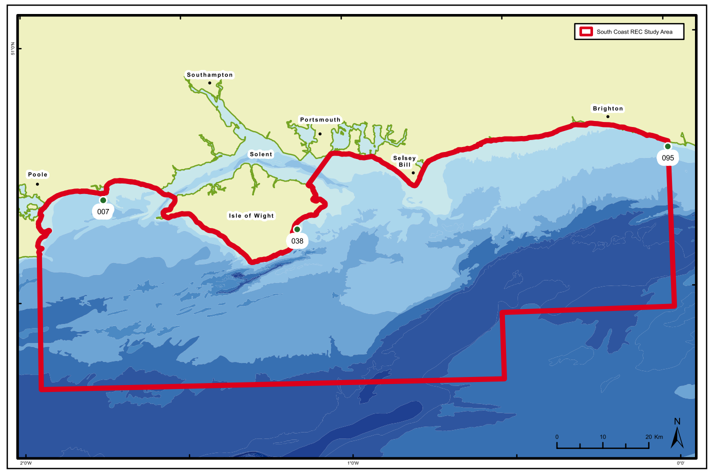


Seabed image taken at Station 86 (Assemblage I).



Benthic Assemblage C (n=3)

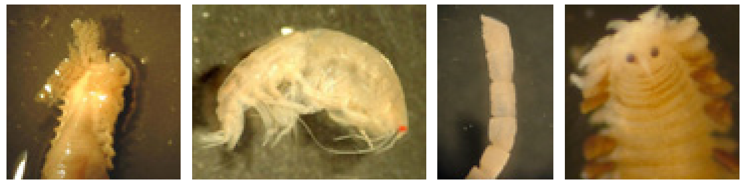
Dense *Lanice conchilega* & *Ampelisca brevicornis* in mixed gravelly sand.



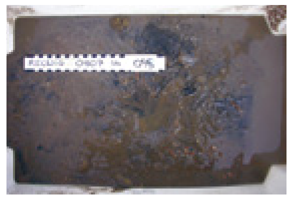
Location of samples assigned to Benthic Assemblage C.

Most characteristic taxa (with % contribution to similarity)

- *Lanice conchilega* (37.95%)
- *Ampelisca brevicornis* (30.32%)
- *Euclymene* (5.44%)
- *Eumida bahusiensis* (3.81%)
- *Spiophanes bombyx* (3.43%)
- *Ampelisca* (3.43%)
- *Nephtys* (2.9%)
- *Nucula nitidosa* (1.72%)
- *Caulleriella alata* (1.27%)
- *Nephtys kersivalensis* (0.64%)

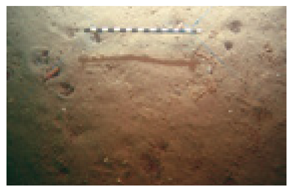


Photographs of representative fauna from Benthic Assemblage C, the sand mason, *Lanice conchilega* (a), the tube dwelling Amphipod, *Ampelisca* sp. (b) and the interstitial polychaetes *Euclymene* (c) and *Eumida bahusiensis* (d). © www.seasurvey.co.uk



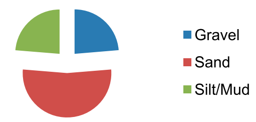
Grab sample taken at Station 95 (Assemblage C).

Total Species	91
Average No. Species	40
Average Abundance	268
Average Biomass (g AFDW)	1.7478
Simpson's Diversity (1-λ)	0.92
Pielou's Evenness (J')	0.71
Taxonomic Distinctness (Δ*)	81.92



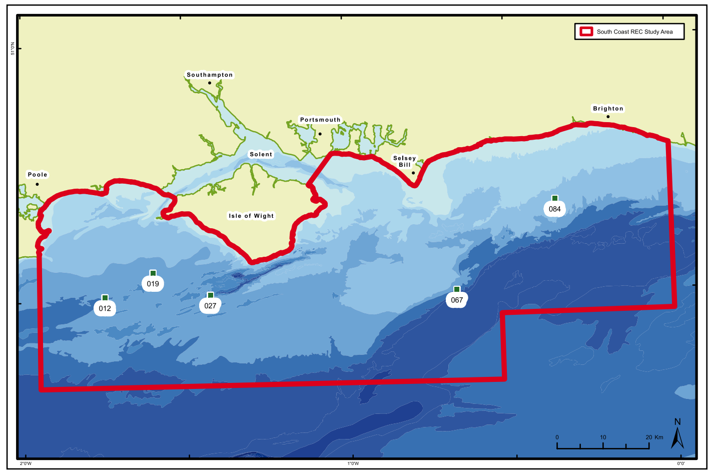
Seabed image taken at Station 95 (Assemblage C).

Average Sediment Composition



Benthic Assemblage D (n=5)

Glycera and *Aonides* in impoverished mobile gravelly sand with encrusting bryozoans.

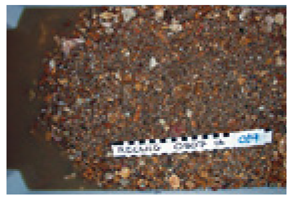


Location of samples assigned to Benthic Assemblage D.

Most characteristic taxa (with % contribution to similarity)

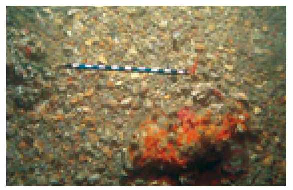
- *Glycera* (25.13%)
- *Aonides paucibranchiata* (14.46%)
- *Eunereis longissima* (11.64%)
- *Schizomavella auriculata* (10.01%)
- *Escharella immersa* (5.36%)
- *Escharella* (3.43%)
- *Amphipholis squamata* (3.32%)
- *Verruca stroemia* (2.94%)
- *Nereididae* (2.75%)
- *Pyura tessellata* (2.75%)

Photographs of representative fauna from Benthic Assemblage D, the interstitial polychaetes, *Glycera* sp. (a) and *Aonides paucibranchiata* (b) and the encrusting bryozoan, *Schizomavella* sp. (c). © www.seasurvey.co.uk



Grab sample taken at Station 19 (Assemblage D).

Total Species	95
Average No. Species	28
Average Abundance	47
Average Biomass (g AFDW)	0.2809
Simpson's Diversity (1-λ)	0.97
Pielou's Evenness (J')	0.88
Taxonomic Distinctness (Δ*)	87.28

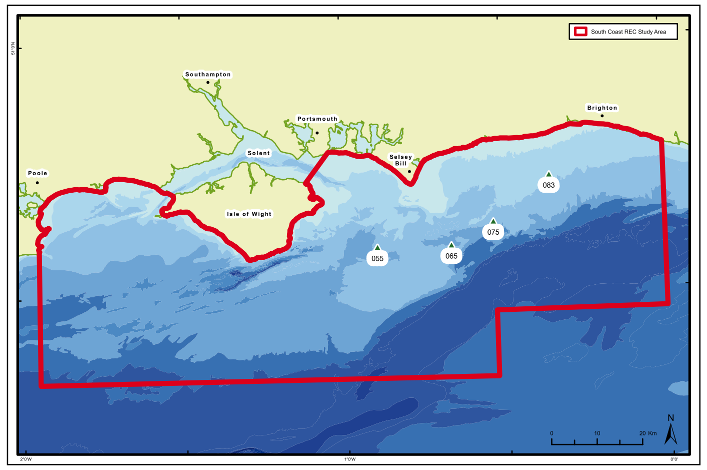


Seabed image taken at Station 19 (Assemblage D).

Average Sediment Composition

Benthic Assemblage H (n=4)

Mixed polychaetes with *Crepidula fornicata* and *Amphipholis squamata* on coarse mixed sediments.



Location of samples assigned to Benthic Assemblage H.

Most characteristic taxa (with % contribution to similarity)

- *Lumbrineris gracilis* (13.04%)
- *Sabellaria spinulosa* (8.78%)
- *Pomatoceros lamarcki* (8.78%)
- Maldanidae (7.57%)
- NEMERTEA (5.93%)
- *Notomastus latericeus* (4.76%)
- *Crepidula fornicata* (4.24%)
- *Amphipholis squamata* (4.06%)
- *Mediomastus fragilis* (4.02%)
- *Caulleriella alata* (3.08%)

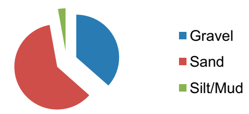
Photographs of representative fauna from Benthic Assemblage H, the interstitial polychaete, *Lumbrineris* sp. (a), the American slipper limpet, *Crepidula fornicata* (b) and the brittle star, *Amphipholis squamata* (c). © www.seasurvey.co.uk

Grab sample taken at Station 55 (Assemblage H).

Total Species	161
Average No. Species	69
Average Abundance	178
Average Biomass (g AFDW)	2.1379
Simpson's Diversity (1-λ)	0.98
Pielou's Evenness (J')	0.85
Taxonomic Distinctness (Δ*)	87.45

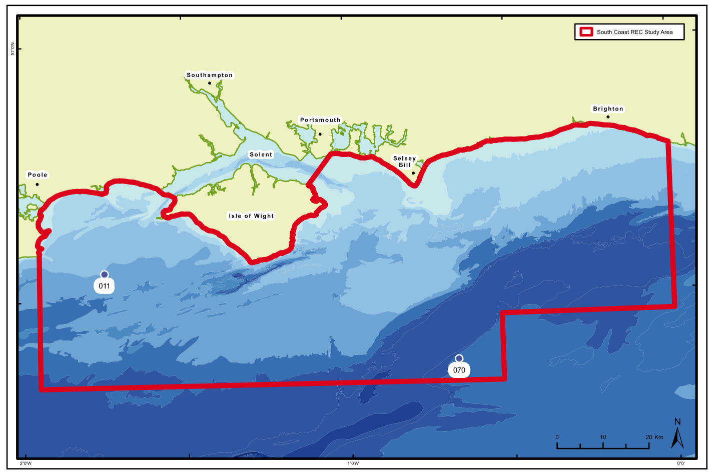
Seabed image taken at Station 55 (Assemblage H).

Average Sediment Composition



Benthic Assemblage L (n=2)

Sabellaria spinulosa aggregations with *Pisidia longicornis* and *Amphipholis squamata* on mixed sediments.



Location of samples assigned to Benthic Assemblage L.

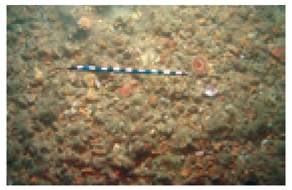
Most characteristic taxa (with % contribution to similarity)

- *Sabellaria spinulosa* (11.33%)
- *Pisidia longicornis* (9.33%)
- *Harmothoe* (8%)
- *Lumbrineris gracilis* (6%)
- *Amphipholis squamata* (6%)
- *Unciola crenatipalma* (4.67%)
- *Notomastus latericeus* (3.33%)
- *Nucula nucleus* (3.33%)
- *Typosyllis* (2.67%)
- NEMATODA (2%)

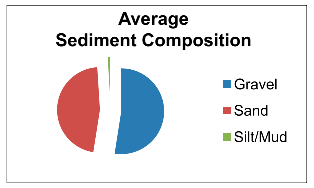
Photographs of representative fauna from Benthic Assemblage L, the Ross worm, *Sabellaria spinulosa* (a) the porcelain crab, *Pisidia longicornis* (b) and the brittle star, *Amphipholis squamata* (c). © www.seasurvey.co.uk

Grab sample taken at Station 11 (Assemblage L).

Total Species	204
Average No. Species	133
Average Abundance	352
Average Biomass (g AFDW)	3.0272
Simpson's Diversity (1-λ)	0.98
Pielou's Evenness (J')	0.87
Taxonomic Distinctness (Δ*)	90.5

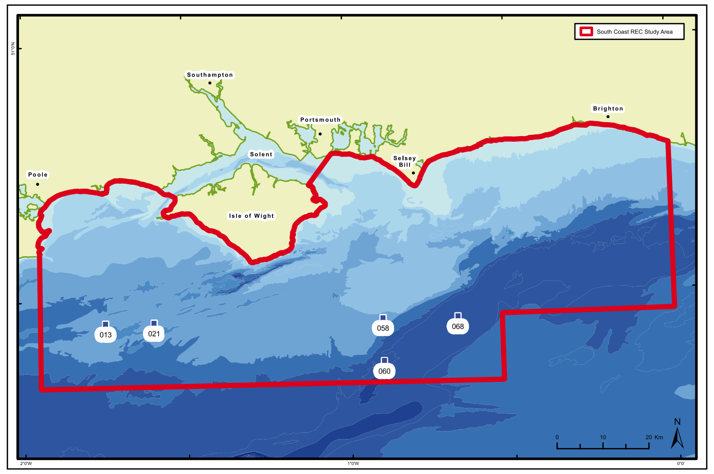


Seabed image taken at Station 11 (Assemblage L).



Benthic Assemblage J (n=5)

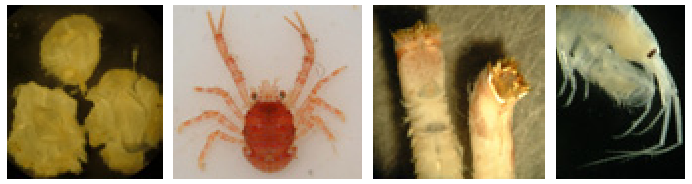
Balanus crenatus with bryozoan crusts and hydroids on coarse mixed sediments.



Location of samples assigned to Benthic Assemblage J.

Most characteristic taxa (with % contribution to similarity)

- *Balanus crenatus* (29.28%)
- *Galathea intermedius* (10%)
- *Amphipholis squamata* (4.02%)
- *Sabellaria spinulosa* (2.87%)
- *Maera othonis* (2.46%)
- *Aonides paucibranchiata* (2.2%)
- *Disporella hispida* (2.15%)
- *Electra pilosa* (2.15%)
- *Escharella immersa* (2.15%)
- *Typosyllis* (1.62%)

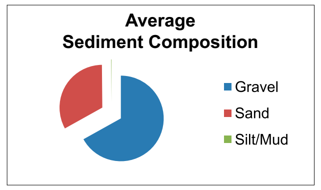


Photographs of representative fauna from Benthic Assemblage J, the barnacle, *Balanus crenatus* (a), the squat lobster, *Galathea intermedius* (b), the Ross worm, *Sabellaria spinulosa* (c) and the Amphipod, *Maera othonis* (d). © www.seasurvey.co.uk

Grab sample taken at Station 13 (Assemblage J).

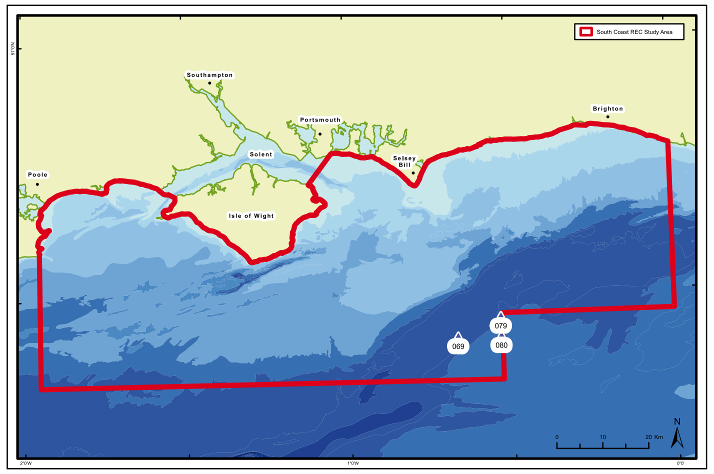
Total Species	184
Average No. Species	69
Average Abundance	155
Average Biomass (g AFDW)	1.0609
Simpson's Diversity (1-λ)	0.95
Pielou's Evenness (J')	0.82
Taxonomic Distinctness (Δ*)	93.57

Seabed image taken at Station 13 (Assemblage J).



Benthic Assemblage K (n=3)

Brittle stars on clean gravel deposits with dense *Pisidia longicornis* and *Galathea intermedia*.



Location of samples assigned to Benthic Assemblage K.

Most characteristic taxa (with % contribution to similarity)

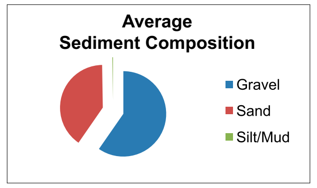
- *Pisidia longicornis* (21.49%)
- *Galathea intermedius* (11.1%)
- *Amphipholis squamata* (6.47%)
- *Laonice bahusiensis* (6.08%)
- *Harmothoe* (4.54%)
- *Pomatoceros lamarcki* (4.41%)
- *Notomastus latericeus* (2.79%)
- *Psamathe fusca* (2.6%)
- *Scalibregma celticum* (2.21%)
- *Janiridae* (2.16%)

Photographs of representative fauna from Benthic Assemblage K, the porcelain crab, *Pisidia longicornis* (a), the squat lobster, *Galathea intermedius* (b) and the brittle star, *Amphipholis squamata* (c). © www.seasurvey.co.uk

Grab sample taken at Station 69 (Assemblage K).

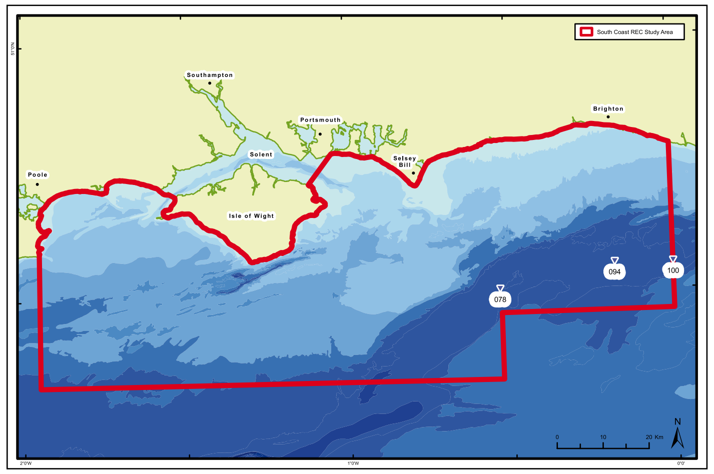
Total Species	172
Average No. Species	93
Average Abundance	335
Average Biomass (g AFDW)	8.9537
Simpson's Diversity (1-λ)	0.96
Pielou's Evenness (J')	0.81
Taxonomic Distinctness (Δ*)	90.89

Seabed image taken at Station 69 (Assemblage K).



Benthic Assemblage G (n=3)

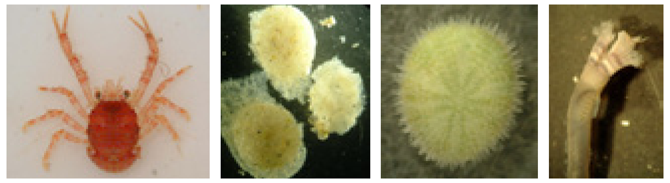
Dense *Galathea intermedia* with creeping anemones, *Pomatoceros* and *Echinocyamus pusilus* in mixed sublittoral deposits.



Location of samples assigned to Benthic Assemblage G.

Most characteristic taxa (with % contribution to similarity)

- *Galathea intermedia* (14.31%)
- *Epizoanthus couchii* (13.8%)
- *Echinocyamus pusillus* (11.75%)
- *Pomatoceros lamarcki* (8.2%)
- *Laonice bahusiensis* (7.01%)
- *Amphipholis squamata* (4.46%)
- *Notomastus latericeus* (3.08%)
- *Glycera lapidum* (2.2%)
- *Maera othonis* (1.84%)
- *Lumbrineris gracilis* (1.78%)

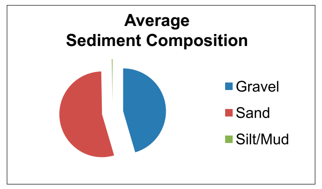


Photographs of representative fauna from Benthic Assemblage G, the squat lobster, *Galathea intermedius* (a), the creeping anemone, *Epizoanthus couchii* (b), the pea urchin, *Echinocyamus pusilus* (c) and the tubiculous polychaete, *Pomatoceros lamarcki* (d). © www.seasurvey.co.uk

Grab sample taken at Station 78 (Assemblage G).

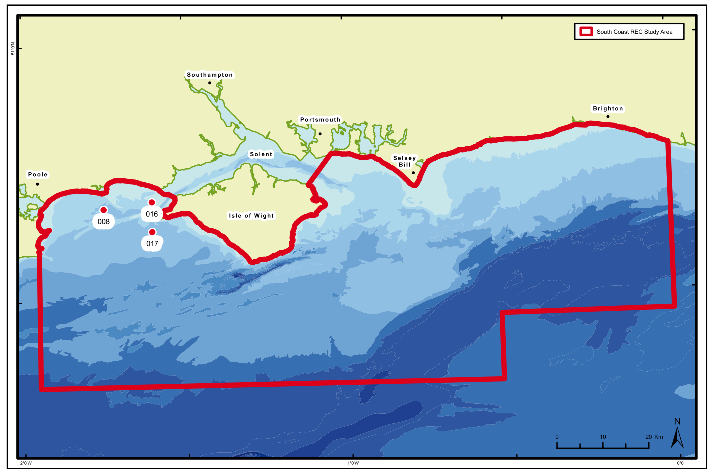
Total Species	131
Average No. Species	68
Average Abundance	159
Average Biomass (g AFDW)	1.0017
Simpson's Diversity (1-λ)	0.96
Pielou's Evenness (J')	0.83
Taxonomic Distinctness (Δ*)	92.87

Seabed image taken at Station 78 (Assemblage G).



Benthic Assemblage N (n=3)

Dense *Crepidula fornicata* and *Pomatoceros lamarcki* with *Lanice conchilega* on coarse gravel deposits.



Location of samples assigned to Benthic Assemblage N.

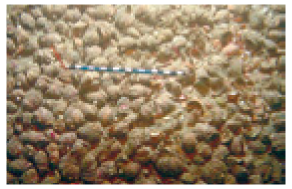
Most characteristic taxa (with % contribution to similarity)

- *Pomatoceros lamarcki* (60.01%)
- *Lanice conchilega* (4.9%)
- *Pisidia longicornis* (4.77%)
- *Crepidula fornicata* (4.71%)
- *Pomatoceros* (4.38%)
- *Notomastus latericeus* (3.31%)
- *Mediomastus fragilis* (1.07%)
- *Ampelisca spinipes* (0.79%)
- *Polycirrus* (0.79%)
- *Nephtys* (0.75%)

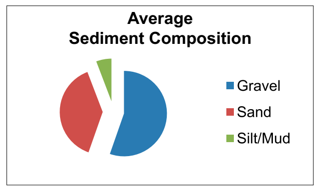
Photographs of representative fauna from Benthic Assemblage N, the tubiculous polychaete, *Pomatoceros lamarcki* (a), the American slipper limpet, *Crepidula fornicata* (b) and the sand mason, *Lanice conchilega* (c). © www.seasurvey.co.uk

Grab sample taken at Station 17 (Assemblage N).

Total Species	173
Average No. Species	86
Average Abundance	832
Average Biomass (g AFDW)	6.6794
Simpson's Diversity (1-λ)	0.82
Pielou's Evenness (J')	0.55
Taxonomic Distinctness (Δ*)	86.94

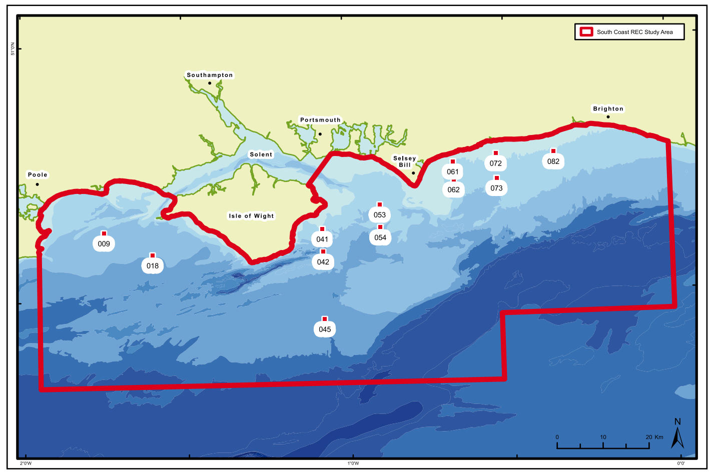


Seabed image taken at Station 17 (Assemblage N).



Benthic Assemblage O (n=12)

Balanus crenatus, Crepidula fornicata and *Sabellaria spinulosa* on mixed gravel deposits.



Location of samples assigned to Benthic Assemblage O.

Most characteristic taxa (with % contribution to similarity)

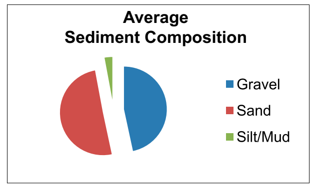
- *Balanus crenatus* (37.85%)
- *Crepidula fornicata* (16.57%)
- *Lanice conchilega* (5.58%)
- *Sabellaria spinulosa* (4.99%)
- *Notomastus latericeus* (3.25%)
- *Mediomastus fragilis* (2.8%)
- *Polycirrus* (2.13%)
- *Lumbrineris gracilis* (1.9%)
- *Pomatoceros lamarcki* (1.64%)
- *Harmothoe* (1.11%)

Photographs of representative fauna from Benthic Assemblage O, the barnacle, *Balanus crenatus* (a), the American slipper limpet, *Crepidula fornicata* (b) and the Ross worm, *Sabellaria spinulosa* (c). © www.seasurvey.co.uk

Grab sample taken at Station 41 (Assemblage O).

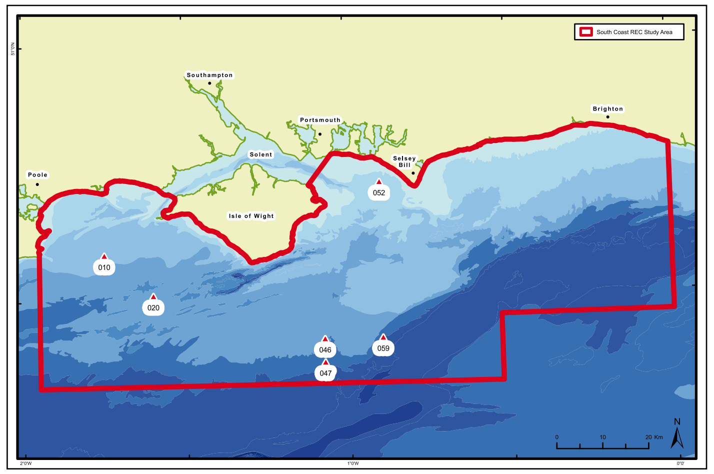
Total Species	278
Average No. Species	103
Average Abundance	505
Average Biomass (g AFDW)	2.0411
Simpson's Diversity (1-λ)	0.81
Pielou's Evenness (J')	0.60
Taxonomic Distinctness (Δ*)	92.73

Seabed image taken at Station 41 (Assemblage O).



Benthic Assemblage M (n=6)

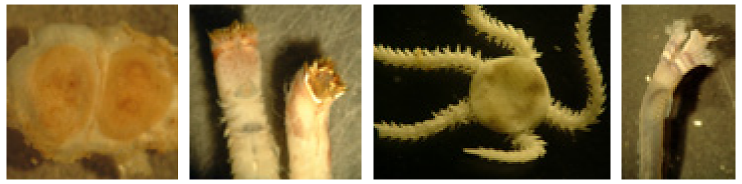
Ascidians with *Sabellaria spinulosa* and *Pomatoceros lamarcki* on mixed gravel deposits.



Location of samples assigned to Benthic Assemblage M.

Most characteristic taxa (with % contribution to similarity)

- *Dendrodoa grossularia* (51.94%)
- *Sabellaria spinulosa* (5.95%)
- *Amphipholis squamata* (2.39%)
- Maldanidae (2.11%)
- *Pomatoceros lamarcki* (1.64%)
- *Lumbrineris gracilis* (1.41%)
- *Laonice bahusiensis* (1.17%)
- NEMATODA (1.04%)
- *Thelepus cincinnatus* (1.03%)
- *Verruca stroemia* (0.99%)

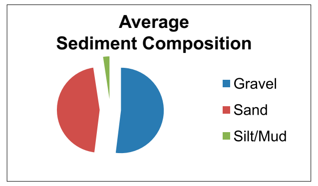


Photographs of representative fauna from Benthic Assemblage M, the ascidian *Dendrodoa grossularia* (a), the Ross worm, *Sabellaria spinulosa* (b), the brittle star, *Amphipholis squamata* (c) and the tubiculous polychaete, *Pomatoceros lamarcki* (d). © www.seasurvey.co.uk

Grab sample taken at Station 40 (Assemblage M).

Total Species	337
Average No. Species	75
Average Abundance	460
Average Biomass (g AFDW)	8.9088
Simpson's Diversity (1-λ)	0.86
Pielou's Evenness (J')	0.60
Taxonomic Distinctness (Δ*)	93.54

Seabed image taken at Station 40 (Assemblage M).



Variable	Source	Data Type	Details
Water Depth	REC	Numerical	Water depth at which sample was collected (6-65m)
Easting	REC	Numerical	Recorded position of sample (Easting)
Northing	REC	Numerical	Recorded position of sample (Northing)
% Sand	REC	Numerical	% sand (by weight) recorded from the Hamon grab samples. Note that % Gravel was not used in the analysis since there was a high correlation between %Sand and %Gravel. % Sand should therefore be taken a proxy for %Gravel.
% Silt & Clay	REC	Numerical	% Silt & Clay (by weight) recorded from the Hamon grab samples.
SAND_MODE	REC	Numerical	Modal (most frequently occuring) sand fraction (phi) recorded from Hamon grab samples (Folk & Ward, 1957) - Bimodal values were removed from the matrix
Mean	REC	Numerical	Mean (arithmatic average) particle size (phi) recorded from Hamon grab samples (Folk & Ward, 1957). Note that Median grain size was excluded from the analysis since there was a near perfect correlation between Mean and Median. Mean grain size should therefore be taken as a proxy for Median grain size.
Sorting	REC	Numerical	Sorting (standard deviation) of the grain sizes (phi) recorded from Hamon grab samples (Folk & Ward, 1957)
Skewness	REC	Numerical	Skewness (assymetry) of the sediment composition (phi) recorded from Hamon grab samples (Folk & Ward, 1957)
Solid Geology Category	BGS Solid Geology Map - DigRock250	Categorical	Underlying solid geology: Barton Group (1), Bracklesham Group (2), Lambeth Group (3), London Clay Formation (4), Lower - Upper Greensand (5), Chalk (6), Wealdon Group (7) and White Chalk Sub-group(8)
Rock Category	BGS LexRock database - DigRock250	Categorical	Rock Composition: Mudstone and Siltstone (1), Chalk (2), Clay, Silt and Sand (3), Mudstone (4), Sandstone and interbedded Mudstone and Siltstone (5), Sandstone and Mudstone (6)
Bedforms	REC	Categorical	Bedforms: Rock and thin sediments (1), Rock Outcrop (2), Sand waves and megaripples (3), Sand banks (4), Sediment sheet (5), Channel fill sediments (6) and Pallaeovalley sediments (7)
Sea bed character	REC	Categorical	Regional sea bed character: Rock and thin sediments (1), Coarse Sediments (2), Sandy Sediments (3)
Current Velocity	Proudman Oceanographic Laboratory	Modelled Numerical	Maximum amplitude of the depth averaged mean spring tidal current (m/s)
Photic Zone	Cefas	Modelled Categorical	Photic zone, area exposed to sufficient sunlight for photsynthesis to occur (light reaching the seabed is ≥ 1% of the surface irradiance, calculated from the light attenuation coefficient (Kd)). Photic (1), Aphotic (0).

Table 6.1: Summary of the environmental variables used to investigate the links between biological communities and environmental conditions in the South Coast REC area.

6.1.3 Linking benthic communities with environmental conditions

The relationship between biological communities and the environment is a central theme of marine research (Seiderer and Newell, 1999; Newell *et al*., 2001; Robinson *et al*., 2005; Rodil *et al*., 2009). Understanding how environmental conditions influence marine fauna is of key importance to conservation management since it helps predict the likely distribution of sensitive species and biodiversity hotspots as well as the impacts of natural and anthropogenic induced change.

The links between biological communities and the environmental conditions across the South Coast REC study area were investigated using a range of environmental variables calculated for each of the REC sample stations. The variables used are summarised in Table 6.1 along with the data source and type. The univariate descriptors of sediment composition (Sorting, Skewness, Mean etc) were calculated according to methods set out in Folk and Ward (1957). % gravel content was found to correlate highly with % sand, so just the latter was used in the analysis and can be regarded as a proxy for % gravel. Similarly median grain size correlated highly with mean grain size and was also removed from the analysis.

RELATE Test results	
Sample statistic (Rho)	0.524
Significance level of sample statistic	0.03%
Number of permutations	9999
Number of permuted statistics greater than or equal to Rho	2

Table 6.2: Summary of RELATE results carried out on benthic assemblage group averaged, untransformed benthic abundance data and normalised environmental variables (Table 6.1).

Benthic assemblages

The relationship between the benthic assemblages identified through multivariate analysis (Figure 6.9) and the environmental conditions were investigated using routines in the PRIMER (V6) multivariate analysis program. The untransformed benthic abundance data were averaged across the assemblages and were compared with the normalised environmental data (Table 6.1) which were also averaged across the benthic assemblages. Table 6.2 shows the results of a RELATE test which compares the resemblance between samples in terms of the fauna and the environmental variables. This confirms that there is a statistically significant relationship between biology and environment within the South Coast REC study area at the 0.03% level.

The BIO-ENV routine was employed to investigate which environmental variables, individually and in combination, correlate best with the patterns observed in the benthic assemblages (Table 6.3). The highest correlation (ρs=0.825) was obtained from a five variable combination of; Easting, % Sand, Sorting, Rock Category and Current Velocity. With the exception of Easting these factors also gave highest individual correlations (ρs=0.258–0.648). The positional attribute (Easting) may be acting as a proxy for other unmeasured, but geographically important, variables. A longitudinal gradient in the fauna of the English Channel was reported in the early habitat mapping work of Norman Holme (1961; 1966; 1985). The faunal gradient in the central and eastern Channel has more recently been linked to broadscale sorting of sediments around a bedload parting zone (Figure 2.10) between the Isle of Wight and the Cotentin peninsula (Coggan *et al*., 2009). The strong relationship between the benthic assemblages and sediment composition is clearly illustrated in Table 6.3 with % sand and sorting contributing to all of the highest correlations.

No. of Variables	Correlation (ρs)	Variables
5	0.825	Easting, % Sand, Sorting, Rock Category & Current Velocity
	0.812	% Sand, Sorting, Rock Category, Current Velocity & Sea Bed Character
	0.805	Easting, % Sand, Mean, Sorting & Rock Category
	0.794	% Sand, Mean, Sorting, Rock Category & Current Velocity
	0.793	% Sand, Sorting, Rock Category, Current Velocity & Photic Zone
3	0.792	% Sand, Rock Category & Current Velocity
	0.779	% Sand, Sorting & Current Velocity
	0.765	Sorting, Rock Category & Current Velocity
	0.752	Mean, Sorting & Rock Category
	0.72	% Sand, % Silt % Clay & Rock Category
1	0.648	Sorting
	0.561	% Sand
	0.411	Mean
	0.385	Current Velocity
	0.259	Rock Category

Table 6.3: Summary of BIO-ENV results carried out on benthic assemblage group averaged, untransformed benthic abundance data and normalised environmental variables (Table 6.1).

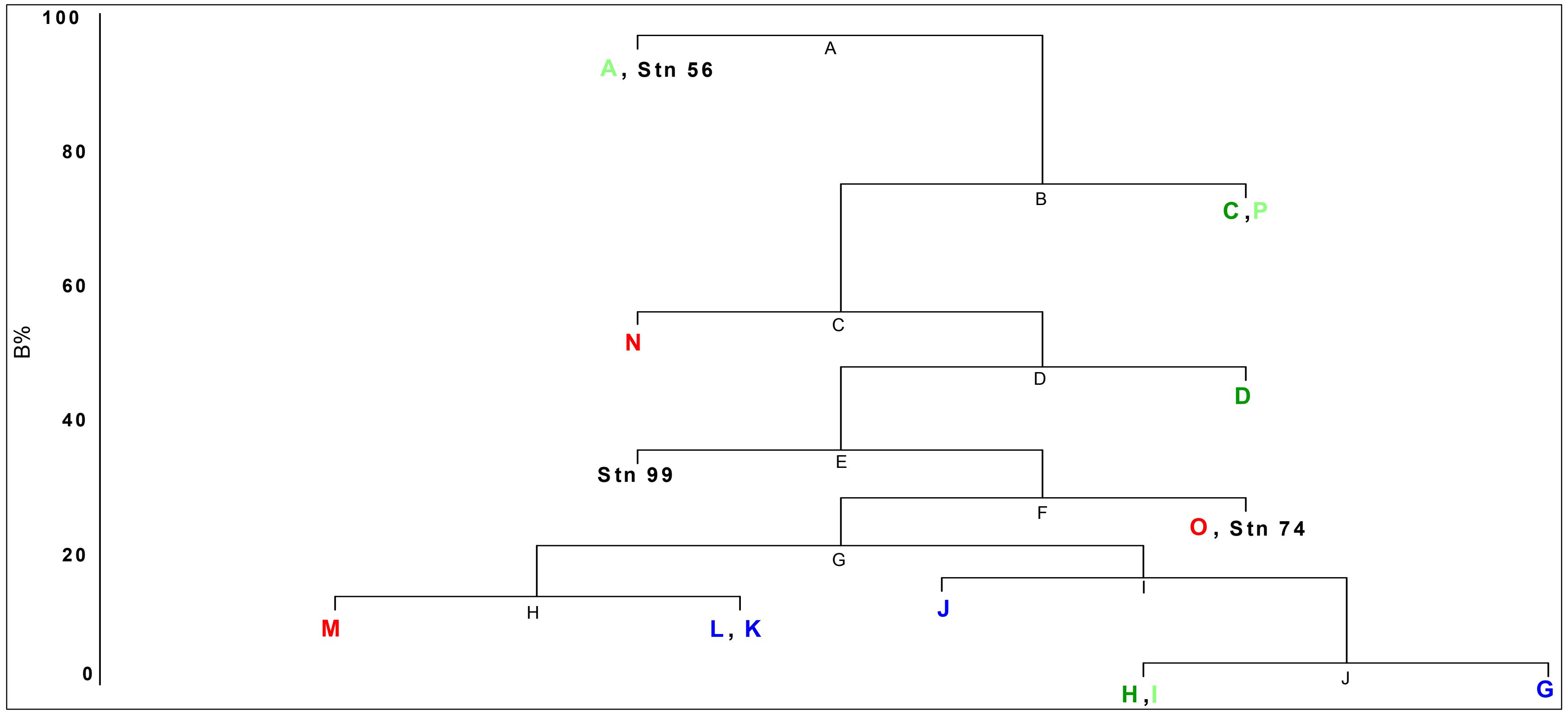
The absence of Depth and Northing in Table 6.3, indicates that other environmental variables are more significant in determining the composition of the benthos. This is counterintuitive given the longstanding theories of zonation but is unsurprising given the variability which exists within each of the depth bands across this area. Within the shallow infralittoral zone of the South Coast REC study area there are sand wave and megaripple fields, rock outcrops and channel fill sediments. Each of these sediment types influences the wave energy and turbidity in a different way and provides a habitat for different groups of species. Rock outcrops provide anchorage and settlement surfaces for a range of sessile organisms whilst the mobile sand waves provide fluid sediments in which interstitial polychaetes can thrive. Such high variation across the depth ranges will invariably override or mask any depth gradients although these will certainly exist for individual species.

In subsequent sections of this report attempts will be made to map the South Coast study area in terms of the Biotopes present, a concept first advocated by Ernst Haeckel (1876). The biotope concept has evolved over time and is now a well developed management tool which describes broad biological assemblages in combination with environmental conditions under which they occur, namely sediment type, energy (water currents) and their biological zonation (Infralittoral/Circalittoral etc) (Connor *et al*., 2004). The BIO-ENV results given in Table 6.3 indicate that this combination of environmental variables, or proxies thereof (% Sand, Sorting, Rock Category, Current Velocity & Photic Zone), correlate highly with the benthic assemblages in the area (ρs=0.793). The use of the EUNIS biotope classification is therefore likely to result in a good representation of the biological and environmental conditions of this area.

BIO-ENV analysis identifies the 'best' overall multivariable correlation, or explanatory environmental variables. However, in order to use the variables as predictors of biological assemblages it is necessary to explore the species-environment relationships in more detail, and for this we have used a LINKTREE analysis. The LINKTREE algorithm splits the biotic samples (or in this case assemblages) in a series of divisions chosen to maximise the degree of separation between the groups (the ANOSIM R Statistic). The abiotic variables which best describe each split are given alongside the ANOSIM R and absolute difference between groups (B%). The LINKTREE can therefore be used, much like a dichotomous key, to predict benthic assemblages in areas where the environmental conditions are known. The LINKTREE for the benthic assemblages identified in the South Coast REC study area is presented in Figure 6.12 alongside the explanatory notes for each split in the tree. For ease of interpretation the average data for the benthic assemblages identified in Figure 6.9 have been used and the environmental variables have been back–transformed so that they appear in their native units.

Biodiversity

The previous section investigated the relationships between benthic assemblages and environmental conditions but biodiversity can also be used to interpret species-environment relationships. For example, a recent study of the sublittoral benthos of the Outer Thames Estuary (EMU, 2009) identified a strong positive correlation between sediment diversity (H') and the number of species. Similarly, Robinson *et al*., (2009) found that faunal diversity increased with increasing gravel content in the Irish Sea. The taxonomic distinctness (Δ*) of quantitative benthic samples has been used to investigate how the environmental conditions within the South Coast REC study area influence biological diversity. Figure 6.13 shows the relationship between taxonomic distinctness (hereafter referred to as diversity) and sediment composition which is consistent with the observations of Robinson (2009). There is a positive correlation between diversity and % gravel and a converse negative correlation with % sand. However, neither relationship is especially strong, with gravel and sand accounting for 16% and 19% of the variation in diversity respectively. The relationship between diversity and % Silt and Clay and Sorting (Phi) was found to be weaker still with less than 6% of the variation in diversity accounted for in both cases.



Split	R	B%	Characterising Environmental Conditions	
			Left	Right
A	0.92	97	Sorting <0.598 or % Silt & Clay <0.003	Sorting >0.994 or % Silt & Clay >0.125
B	0.92	75	Mean < -0.256 or Northing < 5617233.572 or Current Velocity > 0.758	Mean >1.380 or Northing > 5618968.867 or Current Velocity <0.691
C	0.75	56	Easting <587407.401 or % Silt & Clay > 5.778 or Current Velocity < 0.758 or Sorting >3.191 or Water Depth <17.432	Easting >626511.531 or % Silt & Clay < 2.858 or Current Velocity >0.913 or Sorting < 2.960 or Water Depth >20.539
D	0.76	47	Rock Category 1-3	Rock Category 4-6
E	0.54	35	Sea bed character = 3 or Skewness> 0.640 or Easting >712540.619 or % Sand >67.466	Sea bed character =1 or Skewness <0.353 or Easting <695725.843 or % Sand <60.622
F	0.53	28	Photic Zone <0.500 or Water Depth >25.921 or Northing <5612094.949 or Current Velocity >1.109	Photic Zone >0.667 or Water Depth <20.904 or Northing >5614731.520 or Current Velocity <1.086
G	0.63	21	SAND_MODE <0.867	SAND_MODE >1.180
H	1.00	13	Solid Geology Category 1-6 or Water Depth <33.917 or Photic Zone >0.167 or Northing >5596490.753 or Sea bed character 2-3 or % Silt & Clay >1.985 or Current Velocity <1.474 or Easting <626511.531	Solid Geology Category = 8 or Water Depth >41.901 or Photic Zone < 0 or Northing < 5591822.946 or % Silt & Clay < 0.988 or Current Velocity >1.489 or Easting >627215.406
I	1.00	16	Skewness <-1.262 or Solid Geology Category 7-8 or Northing <5589267.087 or Easting <630500.153 or Current Velocity >1.642 or Rock Category 4-6 or % Sand < 32.894 or Mean <-2.447 or Sea bed character = 1 or Sorting < 2.240 or SAND_MODE <1.180 or % Silt & Clay <0.173	Skewness >0.1 or Solid Geology Category 1-3 or Northing >5602154 or Easting >668743.993 or Current Velocity <1.164 or Rock Category 1-2 or % Sand >54.237 or Mean >-1.297 or Sea bed character 2-3 or Sorting >2.364 or SAND_MODE >1.217 or % Silt & Clay >0.309
J	1.00	3	Bedform 1-3 or Water Depth <44.243 or Mean >-0.383 or Northing > 5608758.880 or Easting <683408.042 or Sorting <2.485 or % Sand >59.102 or Rock Category 2-6 or Solid Geology Category 2-8 or % Silt & Clay > 47.831 or Current Velocity <1.147	Bedform = 7 or Water Depth >60.440 or Mean <-1.297 or Northing <5602154 or Easting >695725.843 or Sorting >2.746 or % Sand < 54.237 or Rock Category =1 or Solid Geology Category =1 or % Silt & Clay <45.957 or Current Velocity >1.164

Figure 6.12: Benthic assemblage LINKTREE diagram using environmental variables as detailed in Table 6.1. Variable values have been back-transformed so that they are presented in their correct units.

We can therefore conclude that % Silt and Clay and Sorting are not important, on their own, in promoting biological diversity in this area. Examination of diversity relative to geographical position (Easting), depth and water current shows that these variables also have little influence on biodiversity when examined in isolation (Figure 6.14). There is no relationship between diversity and depth or geographical location (Easting) but a weak positive correlation is evident between current velocity and diversity. The positive correlation between current velocity and diversity is unsurprising given the dominance of filter feeding organisms including the American slipper limpet, *Crepidula fornicata*, the barnacle, *Balanus crenatus* and the *tubiculous polychaetes*, *Pomatoceros lamarcki* and *Sabellaria spinulosa*. These species and many others present in the area, feed on organic matter suspended in the water column which is more readily suspended in areas of strong water movements.

Figure 6.15 shows the relationship between diversity (Δ*) and the rock category, seabed character and photic zone. The rock category does not show any clear relationship with diversity, it is likely therefore that whilst the faunal composition (particularly that of the epibenthos) may vary according to the underlying rock composition, a similar number and range of species are always present. The relationship between seabed character and diversity reflects the pattern seen previously with sediment composition (Figure 6.13). There is a decrease in diversity associated with sandier sediments although interestingly a similar decrease in diversity is associated with the rocky areas. This and previous figures illustrate that there are no strong relationships between any of the environmental variables, in isolation, and the benthic diversity which is thought to be an indication of the complexity which exists in the study area. Coarse sediment deposits, exposed to strong water currents support the highest benthic diversity in this area but the relationships are weak and this is in part due to the consistently high diversity observed throughout the area.

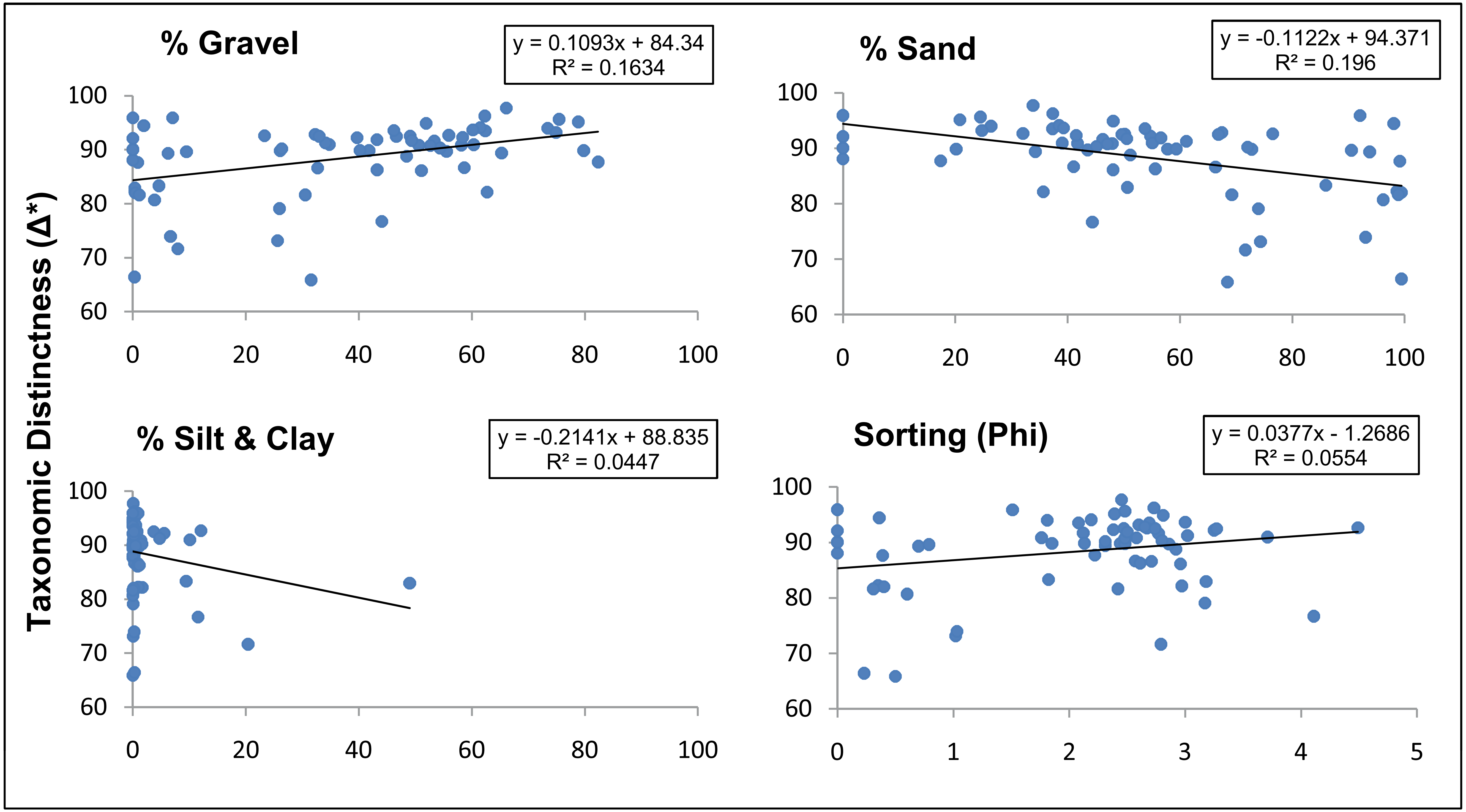


Figure 6.13: Relationship between sediment composition (% Gravel, % Sand, % Silt & Clay and Sorting) and benthic diversity (Taxonomic Distinctness, Δ*).

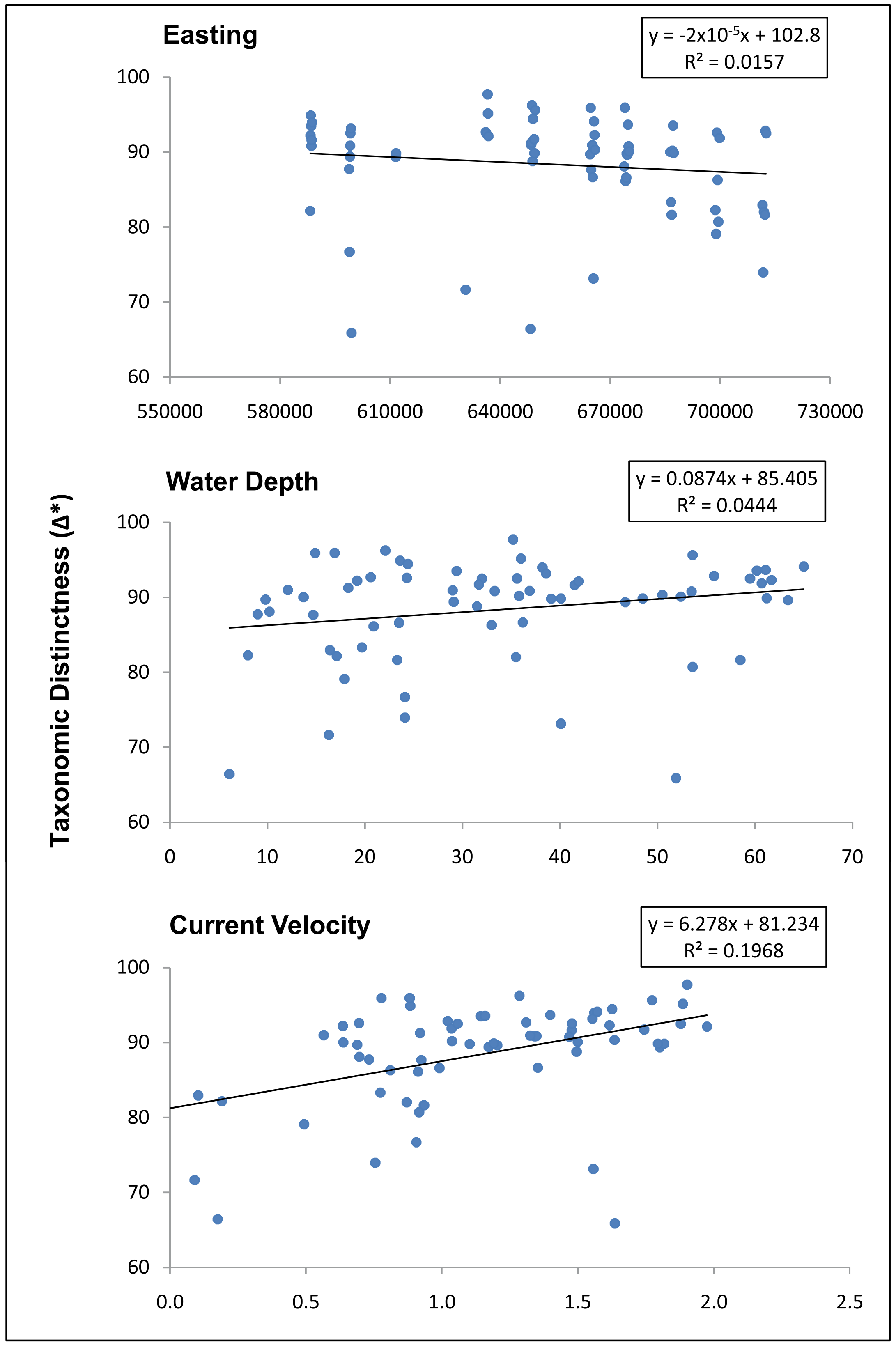


Figure 6.14: Relationship between Easting, Water Depth (m) and Current Velocity and benthic diversity (Taxonomic Distinctness, Δ*).

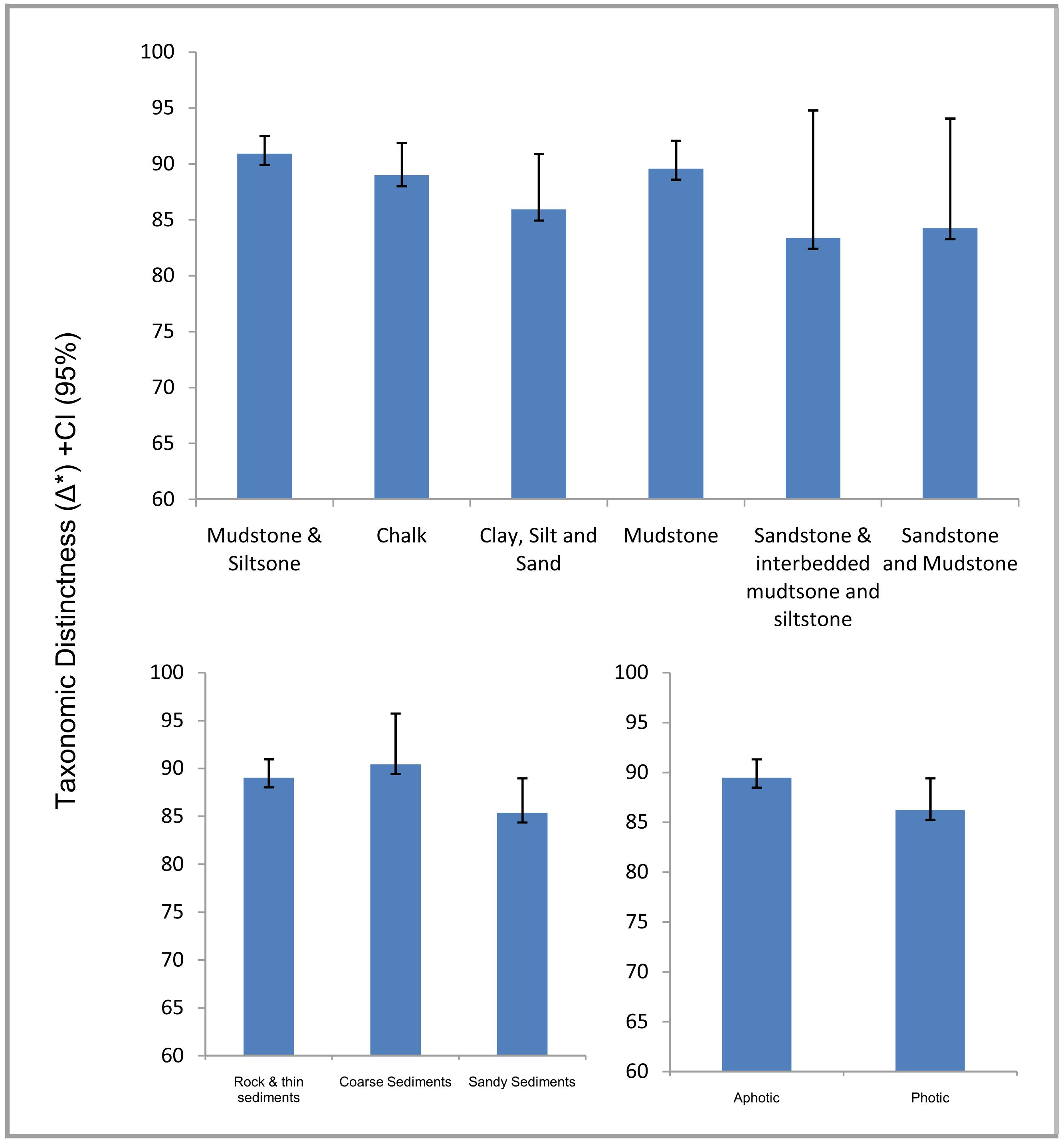


Figure 6.15: Relationship between the underlying rock composition (Rock Category), the sea bed character and the photic zone, and benthic diversity (Taxonomic Distinctness, Δ*).

6.2 Epibenthic fauna

The epibenthic fauna sampled across the South Coast REC study area was, like the benthos, relatively rich, with a total of 260 taxa recorded across 24 samples. Echinoderms and molluscs dominated the epifauna in terms of weight (Figure 6.16), accounting for 40% of the 34% total biomass (g Wet Weight, WW) respectively. Miscellania (mostly colonial organisms) dominate the area in terms of diversity accounting for over 45% of the total number of species recorded. Crustacea and Mollusca also contribute significantly (18% and 16% respectively) to the diversity of epibenthic species found.

Echinodermata, Crustacea and Mollusca contribute more or less equally to the abundance of epifauna with fewer Miscellania, Fish and Annelida. This is in part a reflection of the sampling gear used. 2 m beam trawls are designed to sample animals living on or close to the seabed and do not, therefore, adequately sample infaunal animals such as Annelids or very mobile animals including fish. The apparent disparity between the diversity, abundance and biomass of Miscellania is an artefact of the way in which colonial animals (which make up the bulk of this group) are recorded. Due to the inherent difficulties of enumerating colonial animals they are included only in terms of presence (1) or absence (0). Many colonial species, particularly encrusting bryozoans which may be strongly attached to the surface of the substrata, are difficult to weigh and hence may also be under represented in the biomass data. That the miscellaneous fauna dominated the epifaunal diversity is a reflection of the coarse nature of sediments over large tracts of the South Coast REC study area (Figure 4.10).

Figure 6.17 shows the ten most abundant species recorded in trawl samples taken across the South Coast REC study area. The American slipper limpet, *Crepidula fornicata*, was the most abundant, with a total of 4579 individuals. This species was also highly abundant in the grab samples and video footage taken across the South Coast REC study area highlighting how well established it has become.

The brittle star, *Ophiothrix fragilis*, was the second most abundant species recorded; it is gregarious by nature, often forming dense beds (Morgan and Jangoux, 2004, 2005). The presence of *O. fragilis* beds in the English Channel has frequently been reported both in the English (Ellis and Rogers, 2000; Kaiser and Spence, 2002;

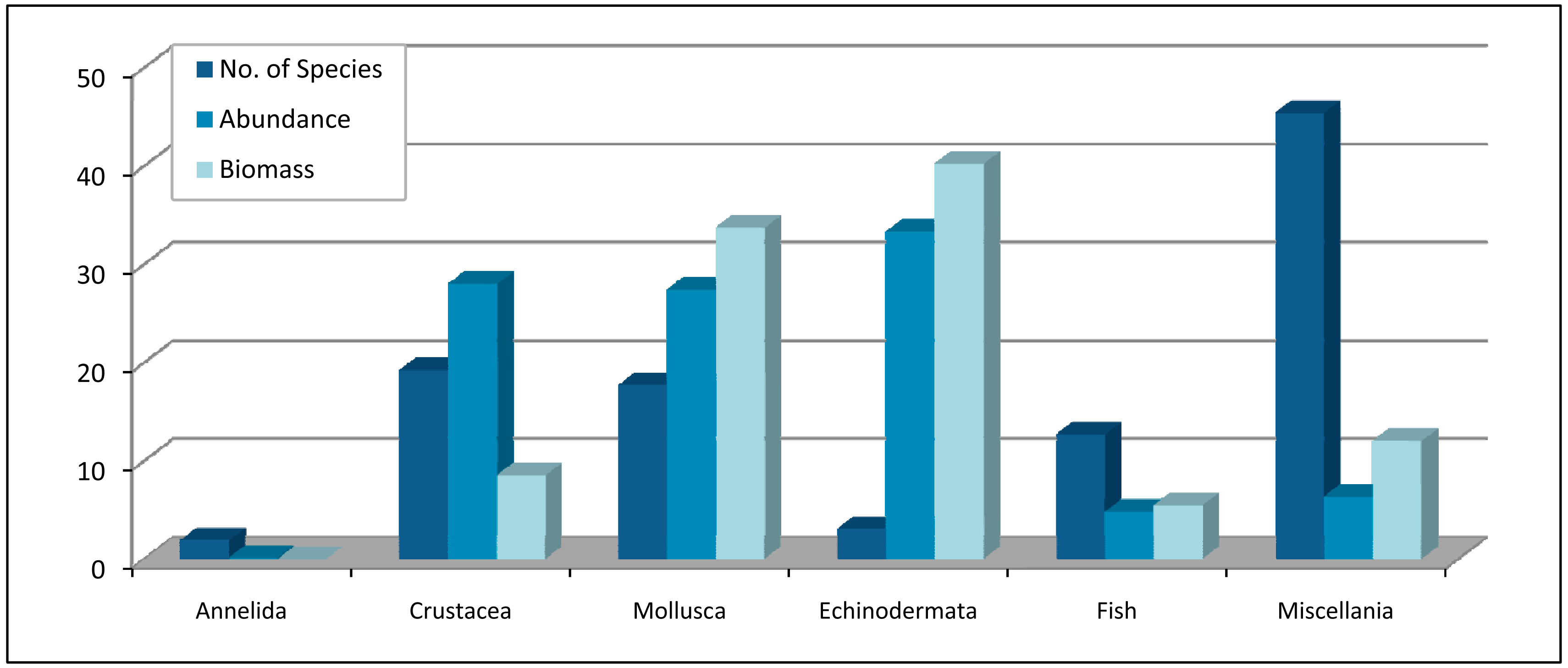


Figure 6.16: Relative contribution of major phyla to the number of species (diversity), abundance and biomass (g Wet Weight) recorded from 2 m beam trawl samples taken across the South Coast REC area.

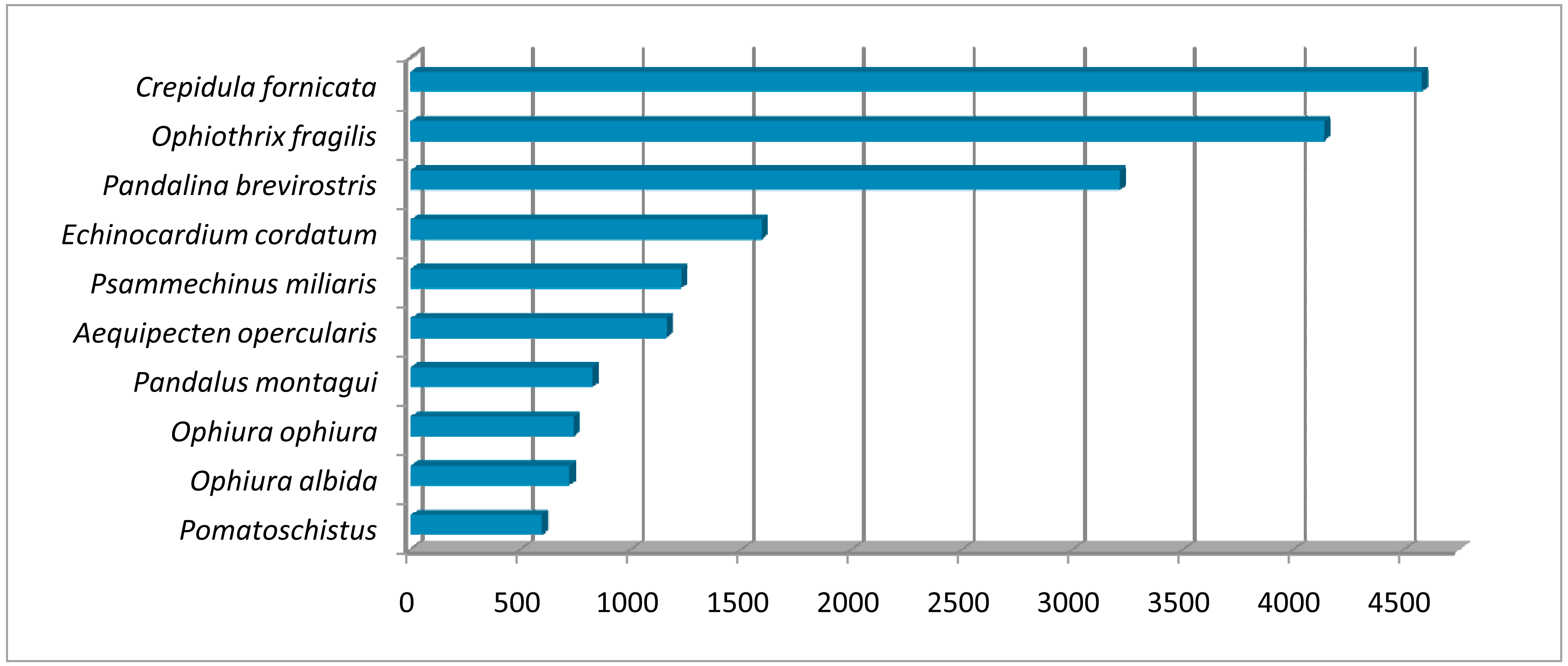


Figure 6.17: The ten most abundant species recorded in 2 m beam trawl samples taken across the South Coast REC area, and the total number counted across all 23 samples.

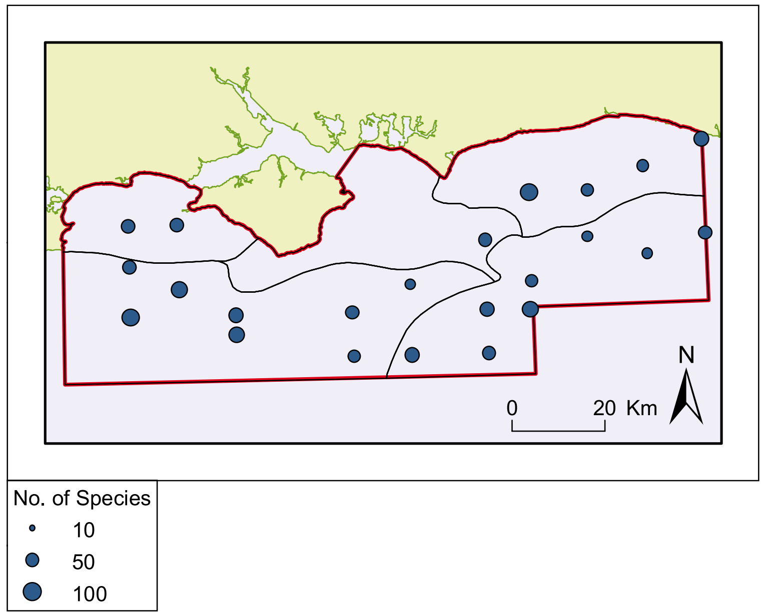


Figure 6.18: Total number of species recorded per 2 m beam trawl sample taken from within the South Coast REC area.

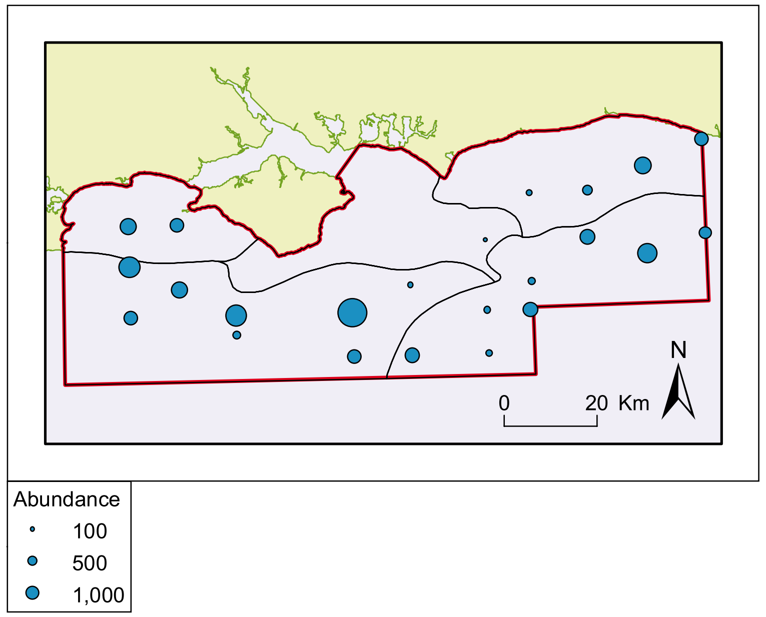


Figure 6.19: Total abundance of animals recorded per 2 m beam trawl sample taken from within the South Coast REC area.

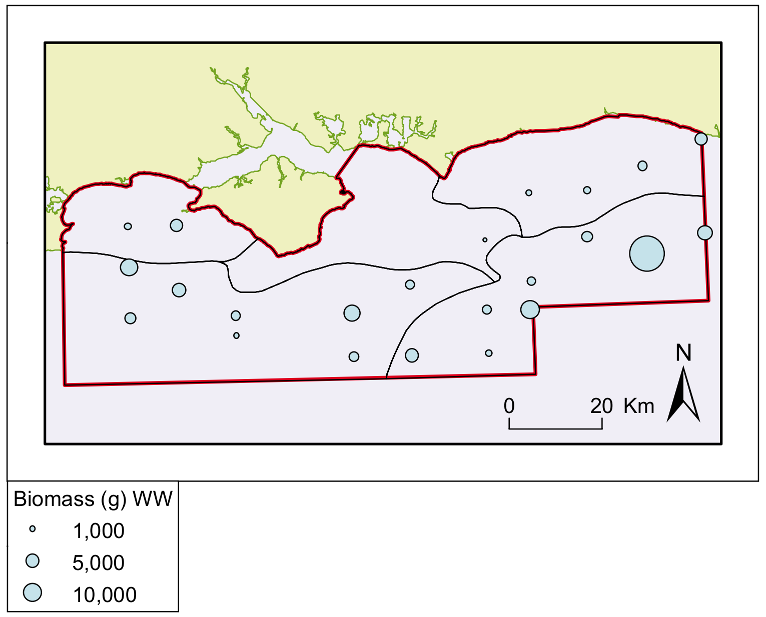


Figure 6.20: Total biomass (g Wet Weight) recorded per 2 m beam trawl sample taken from within the South Coast REC area.

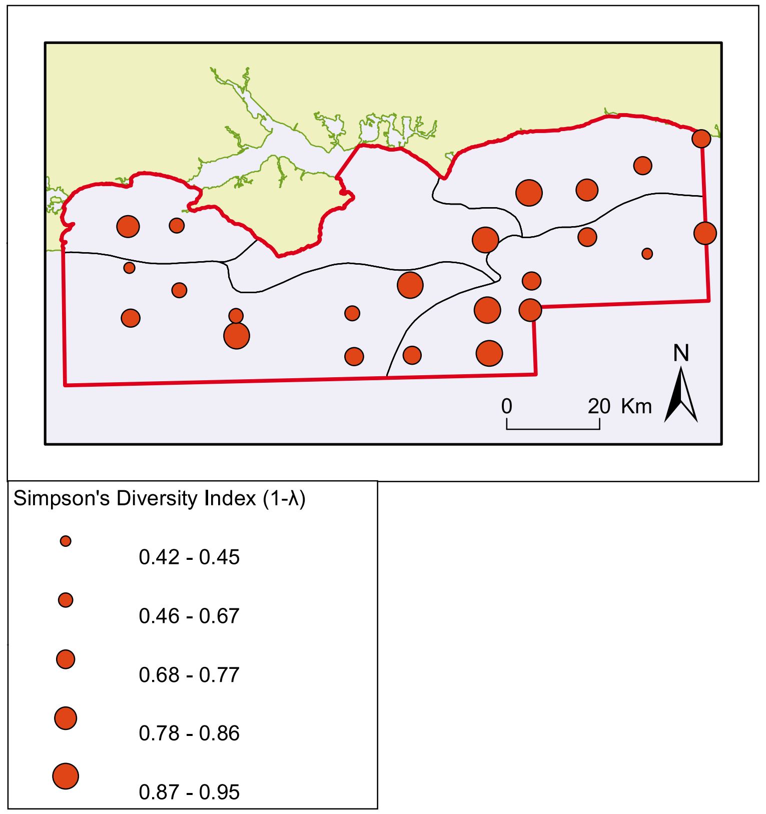


Figure 6.21: Simpson's Dominance (1-λ) calculated per 2 m beam trawl sample taken from within the South Coast REC area.

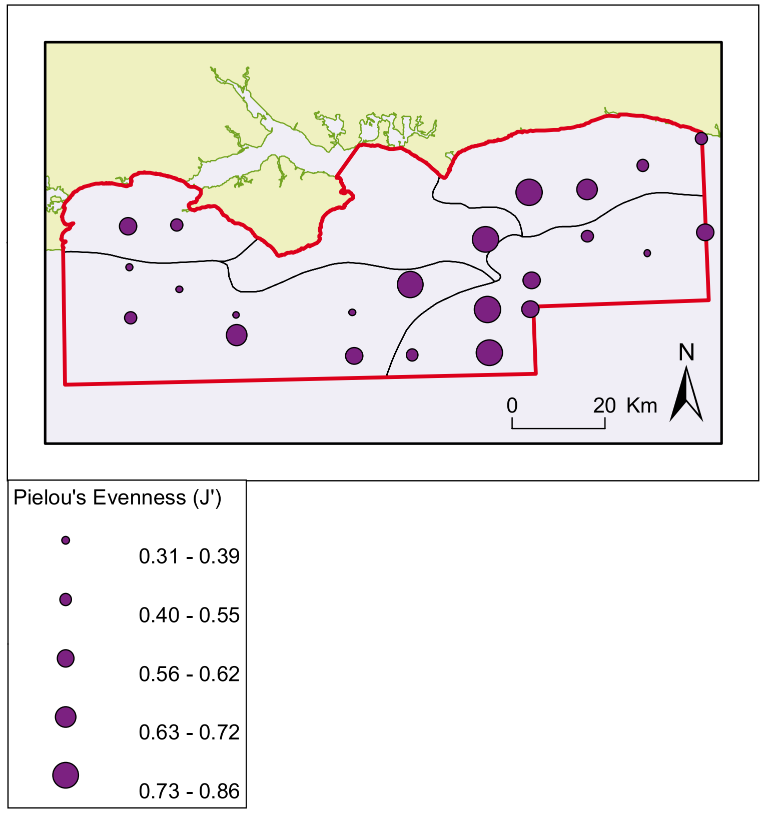


Figure 6.22: Pielou's Evenness (j') calculated per 2 m beam trawl sample taken from within the South Coast REC area.

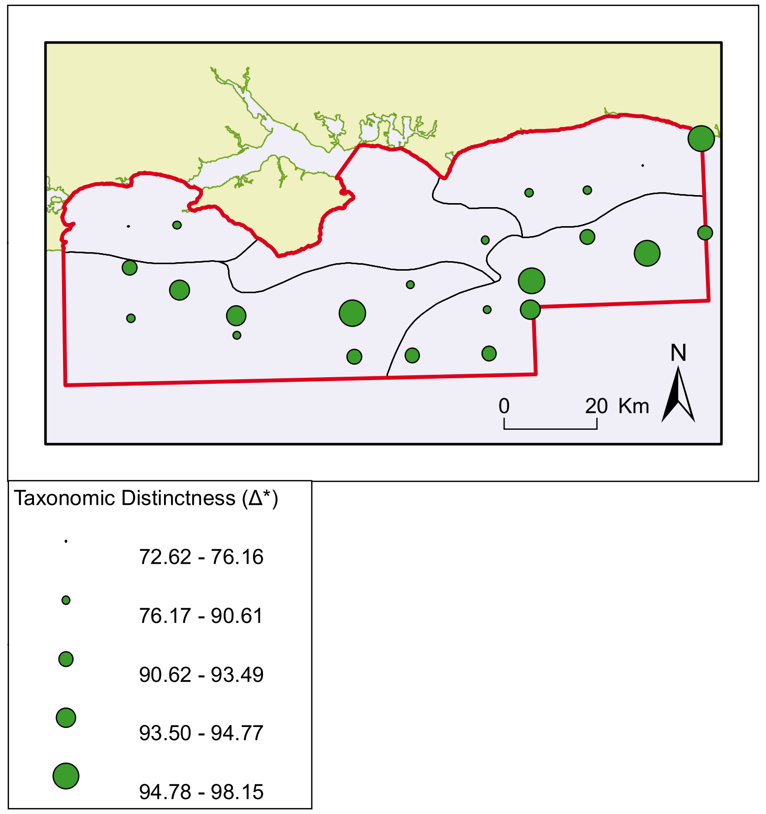


Figure 6.23: Taxonomic Distinctness (Δ*) calculated per 2 m beam trawl sample taken from within the South Coast REC area.

South Coast REC Study Area

Epibenthic Assemblage I

- *Pandalina brevirostris* and *Crepidula fornicata* on sublittoral mixed sediments with occasional cobbles and red seaweeds

Epibenthic Assemblage II

- *Ophiothrix fragilis* beds and *Crepidula fornicata* on mixed cobbley sediments

Epibenthic Assemblage III

- *Chlamys* and *Aequipecten* on coarse sublittoral sediments

Epibenthic Assemblage IV

- *Pagurus bernhardus*, gobies and *Callionymus* on sublittoral sands with echinoderms

Epibenthic Assemblage V

- *Aequipecten opercularis*, *Psammechinus miliaris* and *Liocarcinus holsatus* on mixed sediments

Epibenthic Assemblage VI

- Dense *Aequipecten opercularis* and *Psammechinus miliaris* on mixed sediments
- Outliers

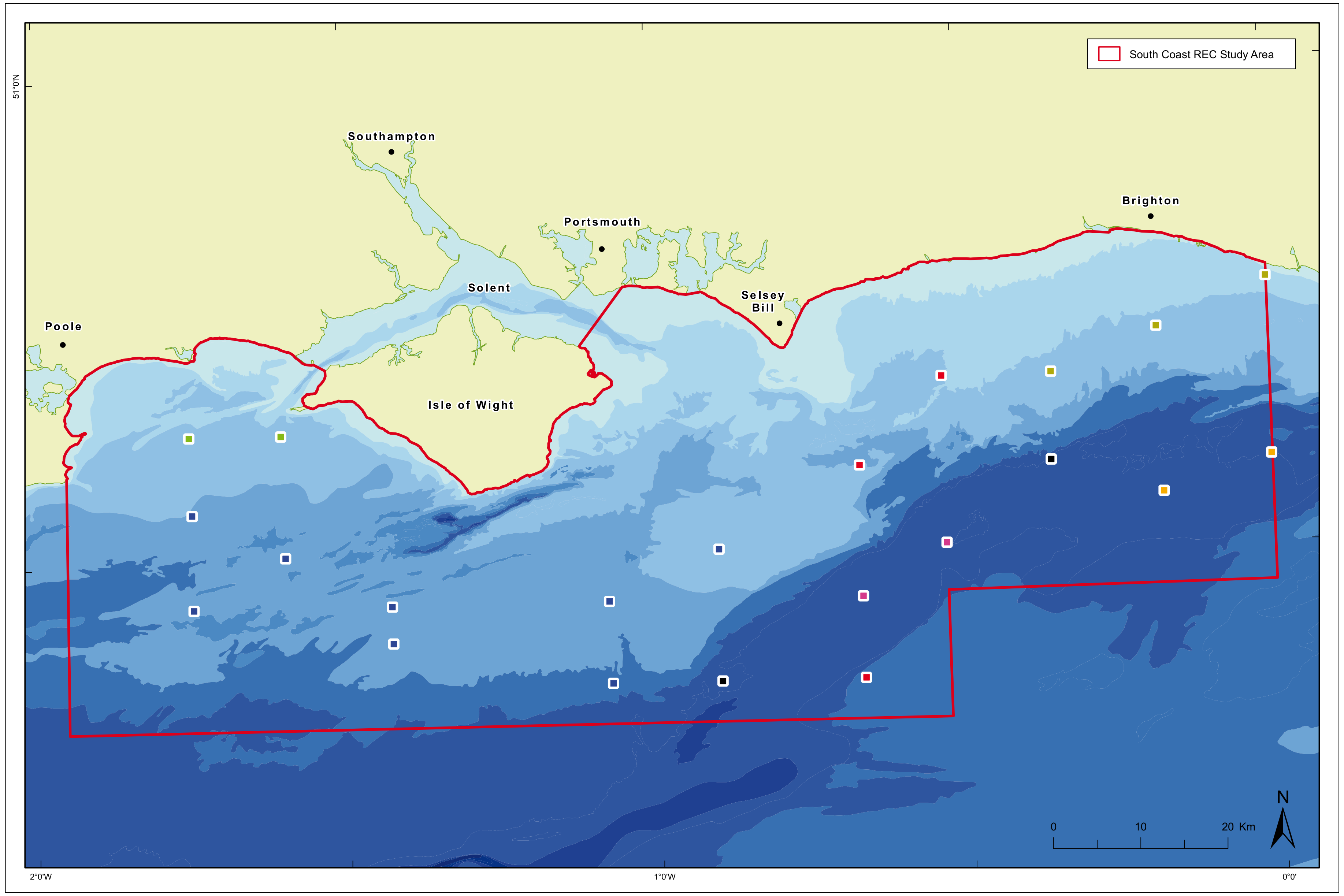


Figure 6.26: Distribution of epibenthic assemblages identified through multi-variate analysis of trawl sample data (Figures 6.24 and 6.25).

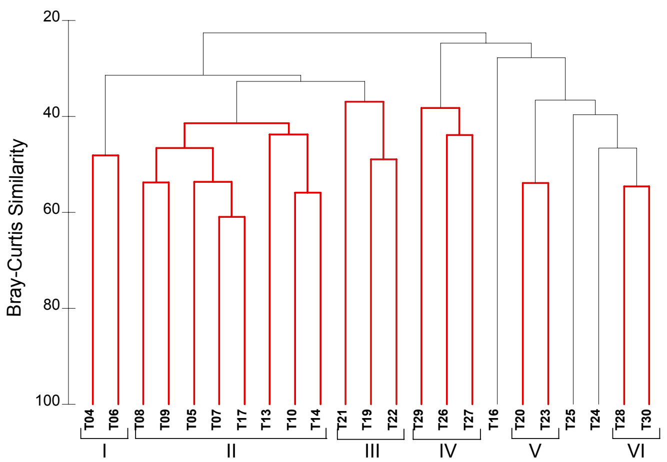
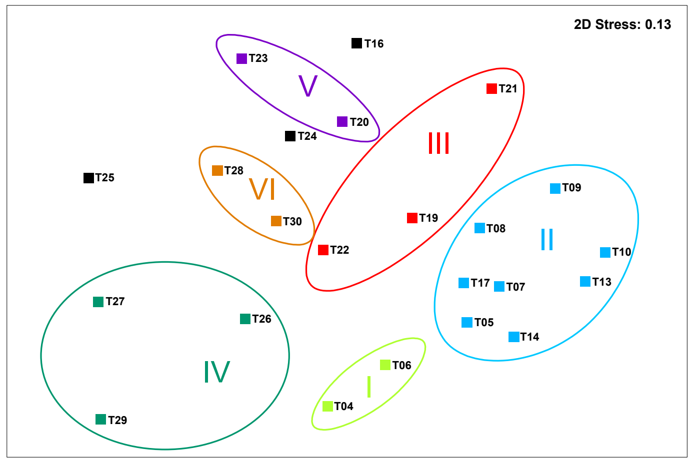


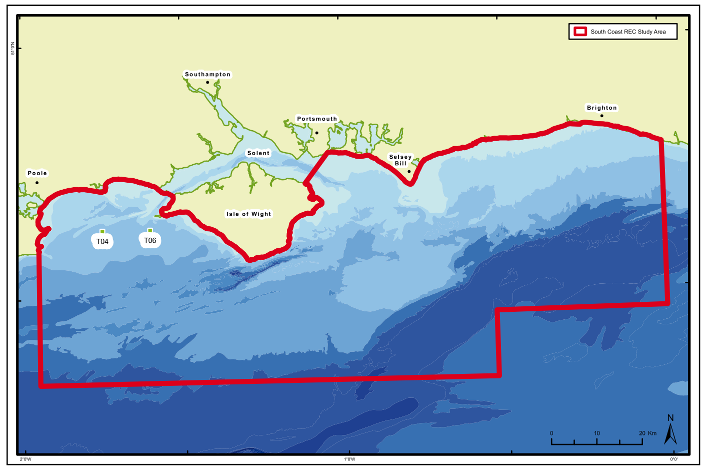
Figure 6.24: *(left)* A group average sorting dendrogram, based on Bray-Curtis similarity of the epibenthos (square root transformed abundance data) recorded across the South Coast REC area. Clusters of stations which are not significantly different from one another (P<0.05) are highlighted in red.

Figure 6.25: *(right)* A multi-dimensional scaling (MDS) ordination based on Bray-Curtis similarity illustrating the similarity between the epibenthos (square root transformed abundance data) recorded across the South Coast REC area, superimposed with the benthic assemblages identified in Figure 6.24.



Epibenthic Assemblage I (n=2)

Pandalina brevirostris and *Crepidula fornicata* on sublittoral mixed sediments with occasional cobbles and red seaweeds.



Location of samples assigned to Epibenthic Assemblage I.

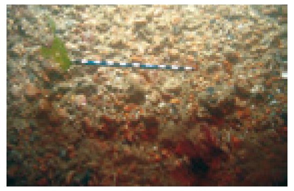
Most characteristic taxa (with % contribution to similarity)

- *Pandalina brevirostris* (60.21%)
- *Crepidula fornicata* (14.85%)
- *Inachus dorsettensis* (6.19%)
- *Macropodia rostrata* (3.09%)
- *Callionymus lyra* (3.09%)
- *Aequipecten opercularis* (1.65%)
- *Pagurus prideaux* (1.44%)

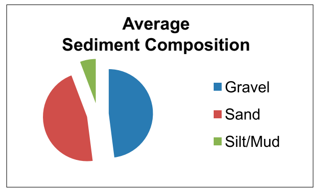
Photographs of representative fauna from Epibenthic Assemblage I. The prawn, *Pandalina brevirostris* (a) the American slipper limpet, *Crepidula fornicata* (b) and the small crab *Inachus* sp. (c). © www.seasurvey.co.uk

Trawl sample 4 taken at station 9 (Assemblage I).

Total Species	70
Average No. Species	50
Average Abundance	1782
Average Biomass (g Wet Weight)	4801
Simpson's Diversity (1-λ)	0.71
Pielou's Evenness (J')	0.45
Taxonomic Distinctness (Δ*)	91.19

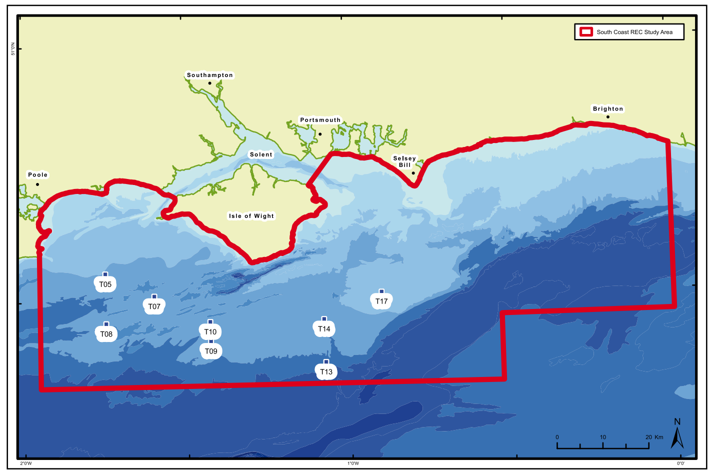


Seabed image taken at station 17 (Assemblage I).



Epibenthic Assemblage II (n=8)

Ophiothrix fragilis beds and *Crepidula fornicata* on mixed cobbley sediments.



Location of samples assigned to Epibenthic Assemblage II.

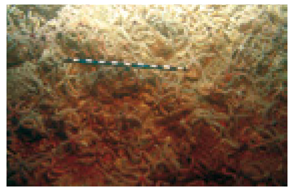
Most characteristic taxa (with % contribution to similarity)

- *Pandalina brevirostris* (42.97%)
- *Crepidula fornicata* (14.03%)
- *Ophiothrix fragilis* (8.92%)
- *Pandalus montagui* (7.01%)
- *Polycarpa pomaria* (3.67%)
- *Pilumnus hirtellus* (3.5%)
- *Chlamys varia* (2.96%)
- *Microcosmos claudicans* (2.11%)
- *Pyura tessellata* (1.8%)
- *Ciliata septentrionalis* (1.09%)

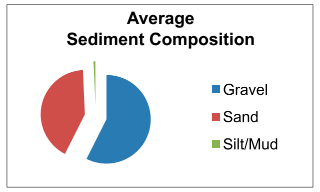
Photographs of representative fauna from Epibenthic Assemblage II. The prawn, *Pandalina brevirostris* (a) the American slipper limpet, *Crepidula fornicata* (b) and the brittle star, *Ophiothrix fragilis* (c). © www.seasurvey.co.uk

Trawl sample 14 taken at station 45 (Assemblage II).

Total Species	165
Average No. Species	61
Average Abundance	1528
Average Biomass (g Wet Weight)	3699
Simpson's Diversity (1-λ)	0.80
Pielou's Evenness (J')	0.45
Taxonomic Distinctness (Δ*)	95.29

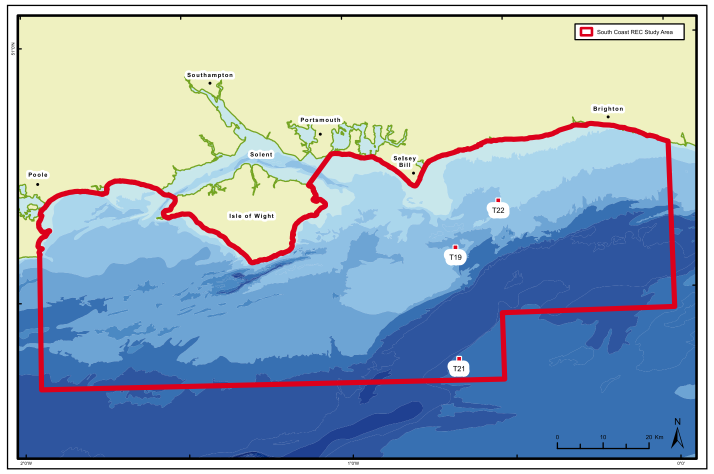


Seabed image taken at station 28 (Assemblage II).



Epibenthic Assemblage III (n=3)

Chlamys and *Aequipecten* on coarse sublittoral sediments.



Location of samples assigned to Epibenthic Assemblage III.

Most characteristic taxa (with % contribution to similarity)

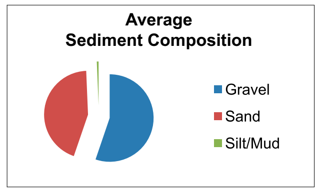
- *Chlamys varia* (12.35%)
- *Aequipecten opercularis* (10.49%)
- *Crepidula fornicata* (9.35%)
- *Macropodia rostrata* (6.33%)
- *Ocenebra erinacea* (6.22%)
- *Calliostoma zizyphinum* (5.21%)
- *Pagurus bernhardus* (4.09%)
- *Pilumnus hirtellus* (3.66%)
- *Buccinum undatum* (3.63%)
- *Chlamys distorta* (3.16%)

Photographs of representative fauna from Epibenthic Assemblage III. The queen scallop, *Aequipecten opercularis* (a) the spider crab, *Macropodia* sp.(b) and the American slipper limpet, *Crepidula fornicata* (c). © www.seasurvey.co.uk

Trawl sample 19 taken at station 65 (Assemblage III).

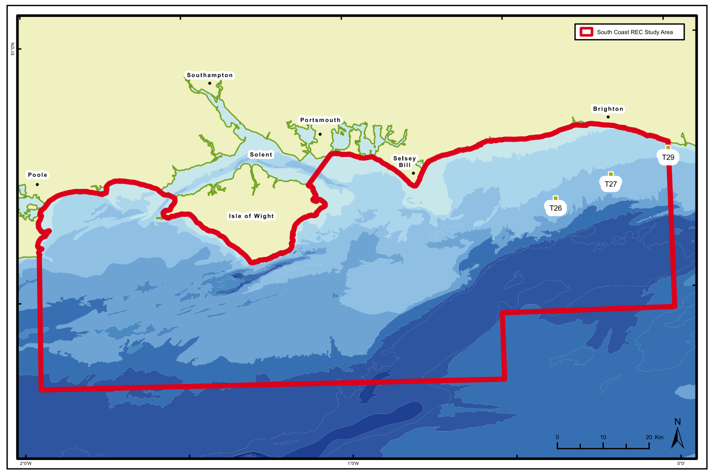
Total Species	121
Average No. Species	61
Average Abundance	187
Average Biomass (g Wet Weight)	1463
Simpson's Diversity (1-λ)	0.97
Pielou's Evenness (J')	0.83
Taxonomic Distinctness (Δ*)	90.43

Seabed image taken at station 70 (Assemblage III).



Epibenthic Assemblage IV (n=3)

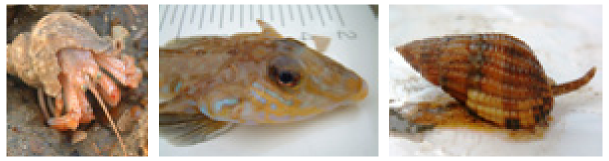
Pagurus bernhardus, gobies and *Callionymus* on sublittoral sands with echinoderms.



Location of samples assigned to Epibenthic Assemblage IV.

Most characteristic taxa (with % contribution to similarity)

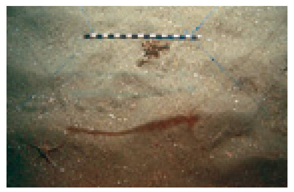
- *Pagurus bernhardus* (20.77%)
- *Pomatoschistus* (20.34%)
- *Callionymus lyra* (15.99%)
- *Hinia reticulata* (13.73%)
- *Crepidula fornicata* (7.53%)
- *Pagurus prideaux* (3.65%)
- *Adamsia carciniopados* (2.57%)
- *Anapagurus laevis* (2.08%)
- *Ophiura albida* (1.62%)
- *Buccinum undatum* (1.4%)



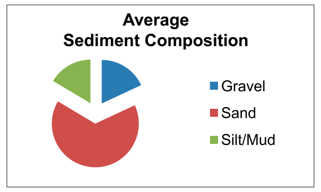
Photographs of representative fauna from Epibenthic Assemblage IV. The hermit crab, *Pagurus bernhardus* (a) the dragnet, *Callionymus lyra* (b) and the netted dogwhelk, *Hinia reticulata* (c). © www.seasurvey.co.uk

Trawl sample 29 taken at station 95 (Assemblage IV).

Total Species	66
Average No. Species	38
Average Abundance	1376
Average Biomass (g Wet Weight)	12116
Simpson's Diversity (1-λ)	0.80
Pielou's Evenness (J')	0.54
Taxonomic Distinctness (Δ*)	90.52

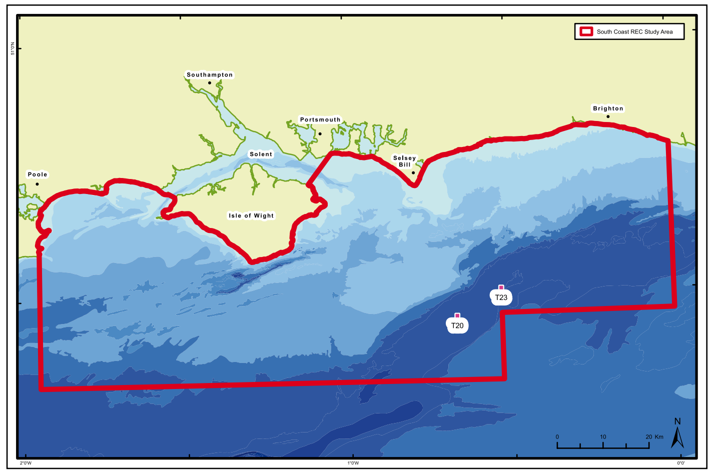


Seabed image taken at station 90 (Assemblage IV).



Epibenthic Assemblage V (n=2)

Aequipecten opercularis, *Psammechinus miliaris* and *Liocarcinus holsatus* on mixed sediments.



Location of samples assigned to Epibenthic Assemblage V.

Most characteristic taxa (with % contribution to similarity)

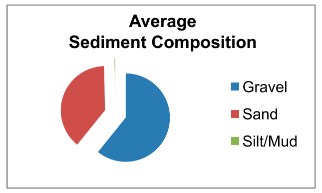
- *Aequipecten opercularis* (37.68%)
- *Psammechinus miliaris* (18.12%)
- *Liocarcinus holsatus* (12.32%)
- *Ophiothrix fragilis* (4.35%)
- *Pagurus bernhardus* (3.62%)
- *Pyura squamulosa* (3.62%)
- *Macropodia rostrata* (2.9%)
- *Pomatoschistus* (2.9%)
- *Buccinum undatum* (2.17%)
- *Ciliata* (1.45%)

Photographs of representative fauna from Epibenthic Assemblage V. The queen scallop, *Aequipecten opercularis* (a) the sea urchin, *Psammechinus miliaris* (b) and the swimming crab, *Liocarcinus holsatus* (c). © www.seasurvey.co.uk

Trawl sample 23 taken at station 78 (Assemblage V).

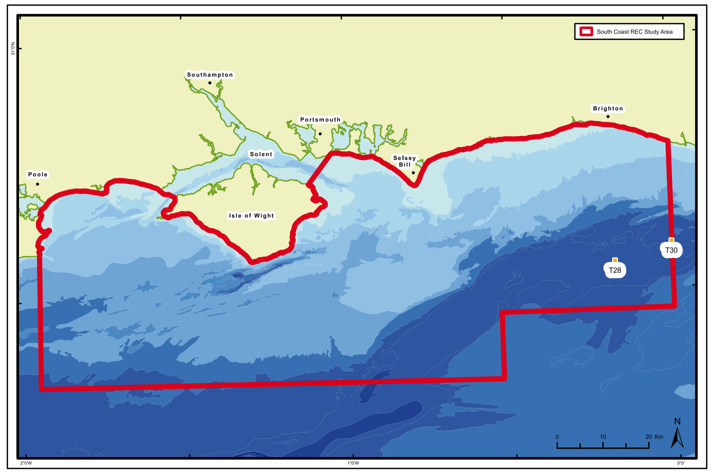
Total Species	65
Average No. Species	45
Average Abundance	284
Average Biomass (g Wet Weight)	1703
Simpson's Diversity (1-λ)	0.85
Pielou's Evenness (J')	0.67
Taxonomic Distinctness (Δ*)	95.30

Seabed image taken at station 78 (Assemblage V).



Epibenthic Assemblage VI (n=2)

Dense *Aequipecten opercularis* and *Psammechinus miliaris* on mixed sediments.



Location of samples assigned to Epibenthic Assemblage VI.

Most characteristic taxa (with % contribution to similarity)

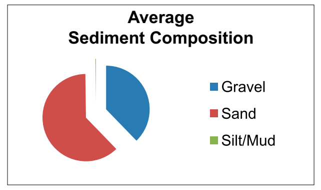
- *Aequipecten opercularis* (34.83%)
- *Psammechinus miliaris* (27.97%)
- *Pomatoschistus* (12.93%)
- *Ophiothrix fragilis* (3.43%)
- *Pandalina brevirostris* (2.64%)
- *Asterias rubens* (2.64%)
- *Crangon allmanni* (2.11%)
- ACTINIARIA (1.32%)
- *Inachus dorsettensis* (1.32%)
- *Macropodia rostrata* (1.32%)

Photographs of representative fauna from Epibenthic Assemblage VI. The queen scallop, *Aequipecten opercularis* (a) the sea urchin, *Psammechinus miliaris* (b) and the brittle star, *Ophiothrix fragilis* (c). © www.seasurvey.co.uk

Trawl sample 30 taken at station 99 (Assemblage VI).

Total Species	75
Average No. Species	53
Average Abundance	846
Average Biomass (g Wet Weight)	4959
Simpson's Diversity (1-λ)	0.84
Pielou's Evenness (J')	0.58
Taxonomic Distinctness (Δ*)	95.69

Seabed image taken at station 94 (Assemblage VI).



Morgan and Jangoux, 2004) and the French literature (Davoult, 1990; Migne and Davoult, 1997; Lefebvre *et al*., 2003; Dauvin and Ruellet, 2008). *O. fragilis* is a suspension-feeding species found in hydrodynamically active areas rich in suspended sediments (Morgan and Jangoux, 2004). They have also been reported to show a preference for coarse sediments (Lefebvre *et al*., 2003), making the South Coast REC study area an ideal habitat for this species.

Two other brittle star species occur across the study area in high abundance, *Ophiura ophiura* and *Ophiura albida*. These brittle stars do not aggregate into beds in the same way as *O. fragilis* but are often recorded in high densities. Both species are found sublittorally, on a variety of soft substrata but mainly fine muddy sands. Similarly, the heart urchin, *Echinocardium cordatum*, which is also abundant, is found in sandy sediments where it lives in a permanent burrow (Nakamura, 2001). *E. cordatum* is common on all UK coasts where there is a good food supply and suitable sandy sediments (Wieking and Kronke, 2003). Other species recorded in high abundance in the trawl samples include the prawns *Pandalina brevirostris* and *Pandalus montagui*, the queen scallop *Aequipecten opercularis* and the sea urchin *Psammechinus miliaris*. These four species are most commonly found in association with sublittoral mixed or coarse sediments which again reflects the physical heterogeneity of this area.

6.2.1 Epibenthic composition and diversity

Figure 6.18, 6.19 and 6.20 show the relative diversity (no. of species), abundance and biomass (g WW) recorded in trawl samples from the South Coast REC study area. The diversity of the epibenthos is relatively consistent across the study area but the abundance and biomass vary considerably between sites. There is no real pattern or gradient in the biomass or abundance across the study area but there is a relatively high level of correspondence between the two. Stations which exhibit low abundance of epifauna also have low biomass and high abundances are also echoed with high biomass.

To further investigate patterns of biological diversity across the study area the same suite of standard diversity measures applied to the benthic data were calculated for each of the trawl samples. These results are represented in Figure 6.21 to 6.23. The majority of trawl samples had a high Simpson's Diversity Index (1-λ), with values ranging between 0.68 and 1 (Figure 6.21) indicating the area supports a high diversity of epibenthic fauna. Figure 6.22 shows the relative evenness (Pielou's Evenness, J') which was again high for the majority of trawl samples though areas of lower evenness (J'<0.5) are observed on the South Wight Platform (Region 4) indicating that one or more species is particularly dominant in this area.

Taxonomic Distinctness (Δ*, Figure 6.23) of the epifauna was between 76 and 100 across much of the South Coast REC study area, indicating that this area supports a moderate to high diversity of epibenthic fauna. Lower Δ* values were observed in the inshore areas which corresponds with areas of low abundance and biomass identified in Figure 6.19 and 6.20.

6.2.2 Epibenthic assemblages

Multivariate analysis of the epibenthic abundance data has been used to identify natural groupings which exist within the South Coast REC study area. The aim of this research is to provide a broad characterisation and hence the data were only subject to a mild transformation (Square Root) meaning that the resulting groups are driven by the more abundant species. Figure 6.24 shows the results of a SIMPROF test on the group average sorting dendrogram. This reveals 6 discrete groups of samples, at the 0.42% significance level, which can usefully be considered as epibenthic assemblages.

The corresponding multi-dimensional scaling (MDS) ordination is shown in Figure 6.25. This shows that in contrast to the benthic assemblages, there is little overlap between the epibenthic assemblages and they form six quite discrete groups. The distribution of the epibenthic groups identified in Figures 6.24 and 6.25 is illustrated in Figure 6.26. The epifaunal assemblages group well geographically indicating that their composition is driven strongly by the environmental conditions in the study area.

The distribution, characteristic species (identified through SIMPER analysis), diversity attributes and sediment composition of the epifaunal assemblages identified through multivariate analysis (Figure 6.24) are described in the following six epibenthic assemblage summaries.

Trawls 16, 24 and 25 did not fall into any of the epifaunal assemblages as the fauna was significantly different to that recorded at all other sites (P<0.05%). Close inspection of the raw data (See South Coast REC 2007 survey acquisition report in Appendix A1) shows that the trawl sample 16 (Station 60) was characterised by a very sparse fauna. The fauna that were present in this sample include the hermit crab, *Pagurus bernhardus*, the whelk, *Buccinum undatum* and the toad crab *Hyas coarctatus*.

High abundances of the queen scallop, *Aequipecten opercularis*, the sea urchin, *Psammechinus miliaris*, and the small spider crab, *Macropodia rostrata*, were recorded in trawl sample 24 (Station 79) and similarly high abundances of the shrimp, *Crangon almanni* and the brittle star, *Ophiura albida* were recorded from Trawl 25 (Station 86) making these samples unique within the study area.

6.2.3 Linking epibenthic communities with environmental conditions

The epibenthic assemblages identified through multivariate analysis of the trawl data (Figure 6.24) are composed in-part by mobile invertebrates and fish which may utilise a variety of habitats during different times of the day and during different stages of their life. It is likely therefore that the relationship of these assemblages is less correlated with the environmental conditions than the benthic assemblages were found to be. Multivariate analysis of this data was carried out following the same methods used for benthic assemblages in order to test this hypothesis. Square root transformed trawl abundance data, averaged across the assemblages, was compared with the normalised environmental data (Table 6.1). The resulting RELATE test results, presented in Table 6.4, shows that the there is, in fact, a strong correlation (ρs=0.629) between the epibenthos and the environmental conditions in the South Coast REC area. This relationship is stronger than the relationship observed between the benthos and the environment which is perhaps a reflection of the abundant sessile epifauna in this area.

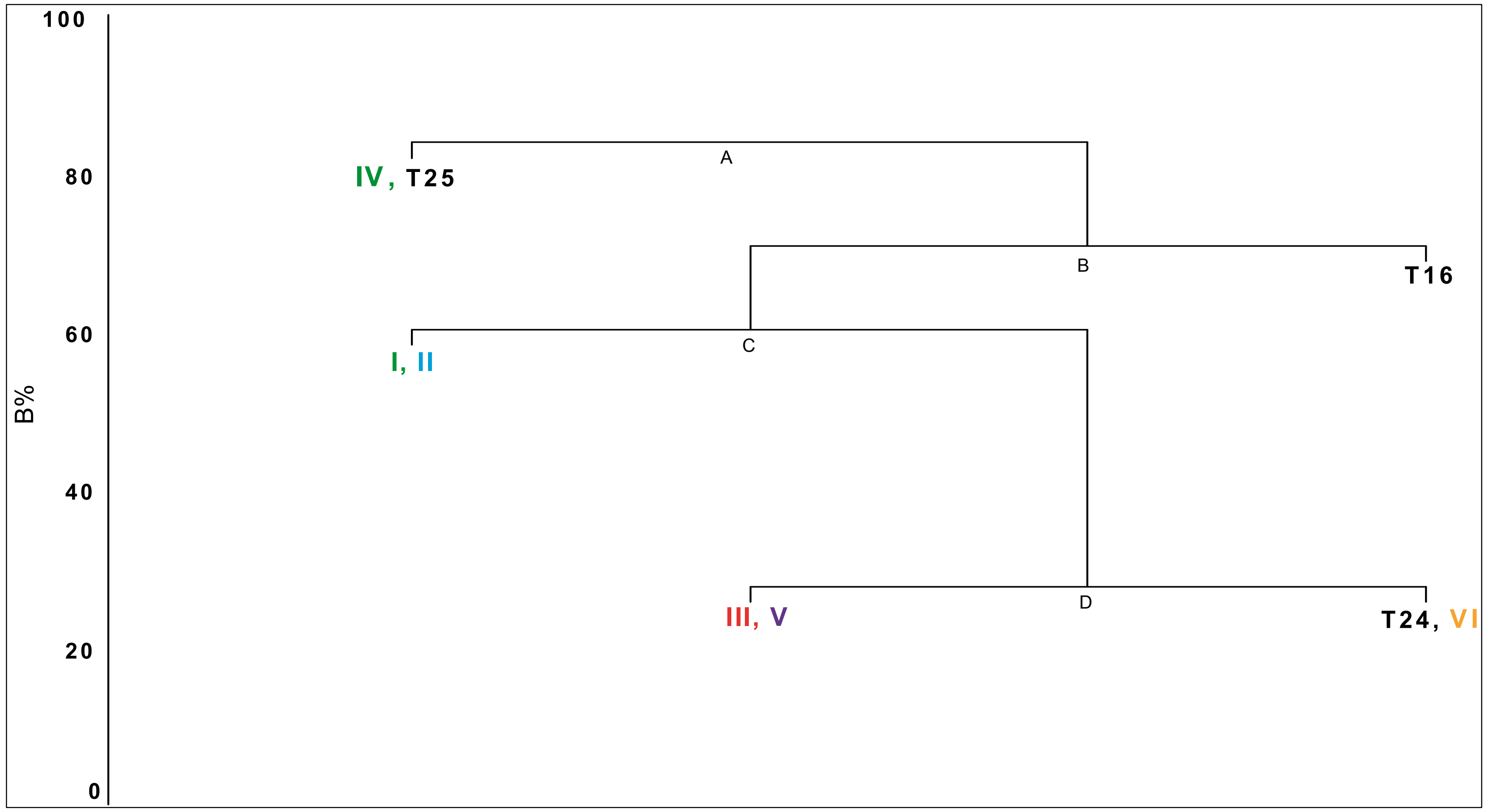
RELATE Test results	
Sample statistic (Rho)	0.629
Significance level of sample statistic	0.42%
Number of permutations	9999
Number of permuted statistics greater than or equal to Rho	41

Table 6.4: Summary of RELATE results carried out on epibenthic assemblage group averaged, square root transformed epibenthic abundance data, and normalised environmental variables (Table 6.1).

The BIO-ENV routine was employed in order to investigate which environmental variables, individually and in combination, correlate most strongly with the patterns observed in the epibenthic assemblages (Table 6.5). The highest correlation (ρs = 0.848) was obtained from a five variable combination of; % Silt & Clay, SAND_MODE, Mean, Rock Category, Bedform. Several of these variables were also responsible for the highest individual correlations. Interestingly, two of the variables which describe the geology and morphology of the seabed (Bedform and Rock Category) exhibit a strong correlation with the epibenthos in the study area. These variables did not exhibit a strong correlation with the benthic assemblages because benthic organisms, by definition, live within the sediments whereas epibenthic organisms live on its surface. The dominance of % Sand in the Benthic BIO-ENV analysis and Beform/Rock Category in the epibenthic analysis is a good reflection of this.

No. of Variables	Correlation (ρs)	Variables
5	0.848	% Silt & Clay, SAND_MODE, Mean, Rock Category, Bedform
	0.84	Water Depth, Easting, Mean, Rock Category, Current Velocity
	0.84	Water Depth, % Silt & Clay, SAND_MODE, Mean, Rock Category
	0.836	Water Depth, % Silt & Clay, Mean, Skewness, Rock Category
	0.835	Water Depth, %Sand, SAND_MODE, Mean, Rock Category
3	0.806	Water Depth, Mean, Rock Category
	0.79	Water Depth, Easting, Mean
	0.788	Water Depth, Easting, Northing
	0.777	Water Depth, Easting, Current Velocity
	0.77	Water Depth, SAND_MODE, Mean
1	0.665	% Silt & Clay
	0.549	SAND_MODE
	0.545	Water Depth
	0.504	Rock Category
	0.488	Photic Zone

Table 6.5: Summary of BIO-ENV results carried out on epibenthic assemblage group averaged, square root transformed epibenthic abundance data, and normalised environmental variables (Table 6.1).



R	B%	Characterising Environmental Conditions: Left	Right
57	84	Mean >-0.479	Mean <-0.681
56	71	Northing >5592041.616 or Mean >-1.879 or % Sand >31.669 or Current Velocity <1.652	Northing <5582320.455 or Mean <-2.823 or % Sand <24.393 or Current Velocity >1.776
79	60	Rock Category 4-6 or Easting <609840.227	Rock Category =1 or Easting >665653.174
75	26	Skewness <-0.063 or % Sand <44.079 or Easting <668409.893 or Mean < -1.716 or SAND_MODE <1.467	Skewness > 0.109 or % Sand >47.066 or Easting >675026.017 or Mean >-1.520 or SAND_MODE >1.5

Figure 6.27: Epibenthic assemblage LINKTREE diagram using environmental variables as detailed in Table 6.1. Variable values have been back-transformed so that they are presented in their correct units.

Depth, which did not show a strong correlation with the benthic assemblages, correlates highly with the epibenthic assemblages both individually and as a component of group of variables (Table 6.5). % Silt and Clay is also an important environmental variable for these assemblages, and this is perhaps because a number of the most dominant epibenthic species are filter feeders and % Silt and Clay could feasibly be considered as a proxy for suspended organic matter, which they feed upon and also create as pseudo-faeces. SAND-MODE, which did not feature as an important variable in the benthic analysis, shows a strong correlation with the epibenthic assemblages. This variable describes the most frequently occurring (modal) sand fraction in the sediment deposits. Where the sand fraction of a deposit is bimodal it has two values, both of which were excluded from the analysis. The bimodality of sands therefore seems to be an important environmental factor in determining the distribution of the epibenthos in this area although the reasons for this are not immediately clear.

Analysis of the relationships between the epibenthic assemblages and the environmental conditions revealed a strong correlation between the standard biotope descriptors used in the EUNIS

EUNIS	MNCR	Description	Frequency
A3.116	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock	1
A3.215	IR.MIR.KR.XFoR	Dense foliose red seaweeds on silty moderately exposed infralittoral rock	1
A4.111	CR.HCR.FaT.BalTub	*Balanus crenatus* and *Tubularia indivisa* on extremely tide-swept circalittoral rock	1
A4.13	CR.HCR.XFa	Mixed faunal turf communities	1
A4.131	CR.HCR.XFa.ByErSp	Bryozoan turf and erect sponges on tide-swept circalittoral rock	1
A4.1312	CR.HCR.XFa.ByErSp.DysAct	Mixed turf of bryozoans and erect sponges with *Dysidia fragilis* and *Actinothoe sphyrodeta* on tide-swept wave-exposed circalittoral rock	1
A4.1342	CR.HCR.XFa.FluCoAs	*Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock	1
A4.138	CR.HCR.XFa.Mol	*Molgula manhattensis* with a hydroid and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock	2
A4.213	CR.MCR.EcCr.UrtScr	*Urticina felina* and sand-tolerant fauna on sand-scoured or covered circalittoral rock	3
A4.2141	CR.MCR.EcCr.FaAlCr.Flu	*Flustra foliacea* on slightly scoured silty circalittoral rock	2
A4.241	CR.MCR.Cmus.Cmyt	*Mytilus edulis* beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock	1
A5.13	SS.SCS.ICS	Infralittoral coarse sediment	1
A5.14	SS.SCS.CCS	Circalittoral coarse sediment	6
A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	10
A5.231	SS.SSa.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna	5
A5.234	SS.SSa.IFiSa.TbAmPo	Semi-permanent tube-building amphipods and polychaetes in sublittoral sand	1
A5.25	SS.SSa.CFiSa	Circalittoral fine sand	9
A5.43	SS.SMx.Imx	Infralittoral mixed sediment	1
A5.431	SS.SMx.IMx.CreAsAn	*Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment	17
A5.44	SS.SMx.CMx	Circalittoral mixed sediment	17
A5.444	SS.SMx.CMx.FluHyd	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	13
A5.445	SS.SMx.CMx.OphMx	*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment	2
A5.52	SS.SMp.KSwSS	Kelp and seaweed communities on sublittoral sediment	2
A5.521	SS.SMp.KSwSS.LsacR	*Laminaria saccharina* and red seaweeds on infralittoral sediments	1
		Total	100

Table 6.6: EUNIS and MNCR codes for biotopes assigned in video analysis.

classification system, as was the case for the benthic assemblages, with a correlation of ρs=0.84 being obtained for a similar combination of variables (Water Depth, Easting, Mean, Rock Category, Current Velocity). However, the frequent occurrence of rock in the BIO-ENV results (Table 6.26) highlights that the type of rock is important in determining natural biotic assemblages, something that is overlooked in the current EUNIS classification scheme.

The LINKTREE algorithm has been used to explore the species-environment relationships in more detail and the resulting tree diagram is presented in Figure 6.27 alongside the explanatory variables. The variables identified at each node can be used for predictive purposes, presenting the possibility of predicting the probable composition of epibenthic assemblages at new stations within or adjacent to the South Coast REC study area, so long as appropriate environmental data are available.

6.3 Video results

A total of 100 video segments were analysed, there being 92 video stations (Figure 3.4), eight of which had two substrate types within their length.

A total of 24 EUNIS biotope classes were assigned (Table 6.6, Figure 6.28), seven at Level 4, fourteen at Level 5 and three at Level 6 (Figure 6.29). Eleven were rock biotopes (A3=infralittoral, A4 = circalittoral), the most frequent being A4.213 '*Urticina felina* and sand-tolerant fauna on sand-scoured or covered circalittoral rock, which occurred three times.

The remaining thirteen were sedimentary biotopes, three each for coarse sediments and sand, five for mixed sediments and two macrophyte dominated communities on sediment (Figure 6.30). The most common sediment biotopes were A5.431 '*Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment' and A5.44 'Circalittoral Mixed Sediments', both of which occurred at 17 of the 92 stations. Biotope class A5.444 '*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment' was assigned at 13 stations and A5.141 '*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles' at 10 stations.

Nearly half of all video stations were assigned biotopes from the coarse sediment class (Figure 6.31), while rock, coarse and sand

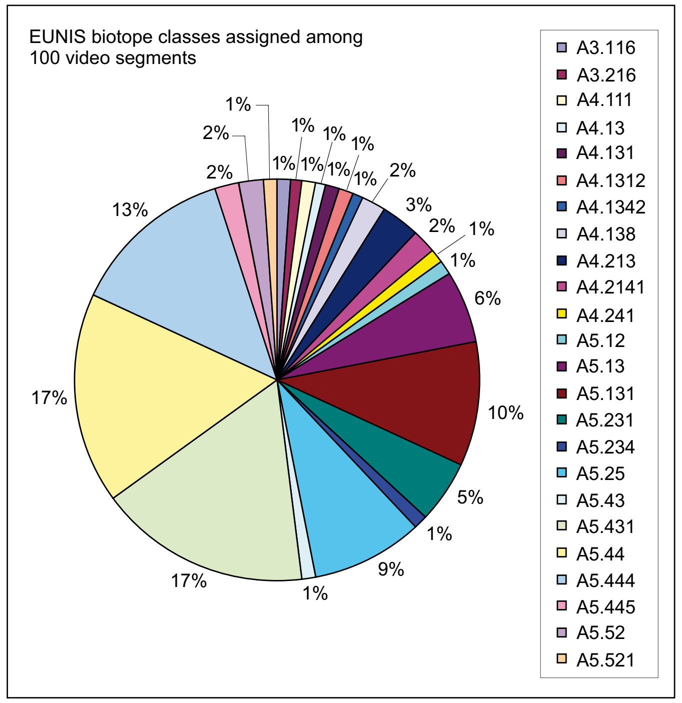


Figure 6.28: EUNIS biotope classes assigned from the analysis of underwater video and stills images.

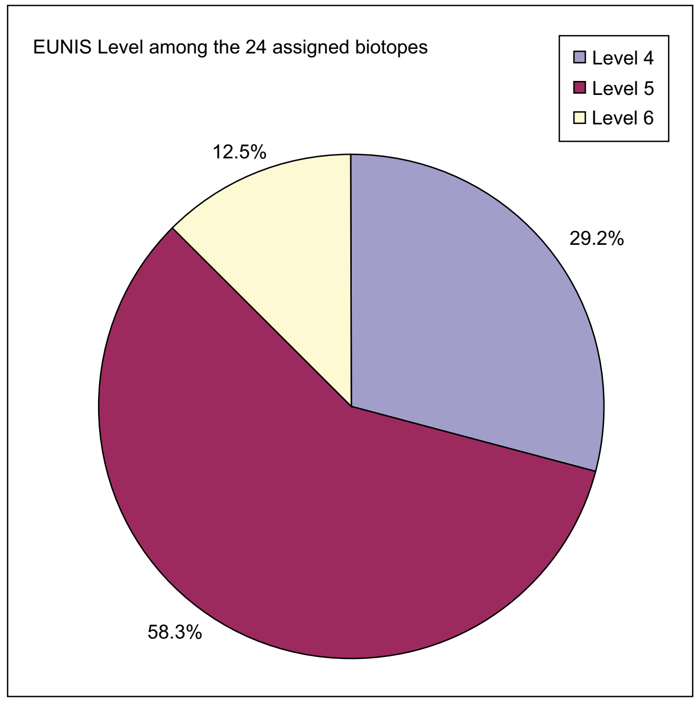


Figure 6.29: EUNIS class level among the 24 biotopes assigned during the analysis of underwater video and stills images.

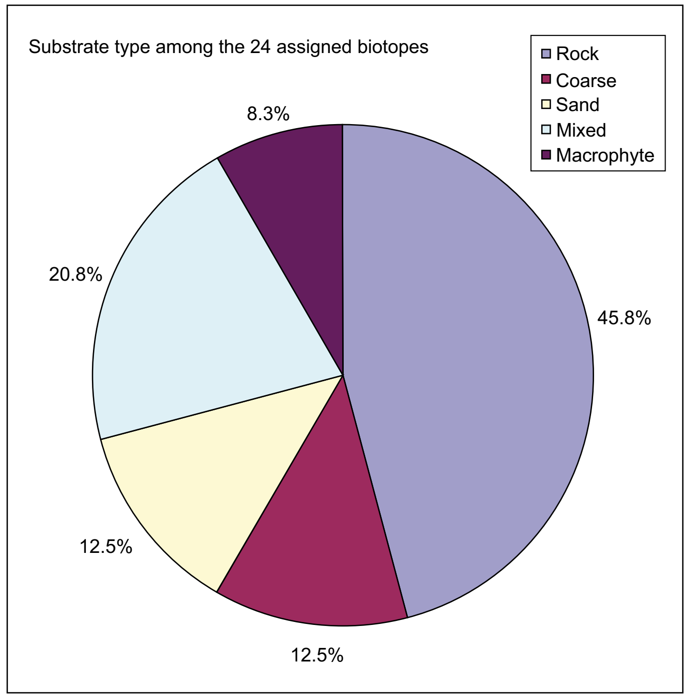


Figure 6.30: Proportion of substrate types among the 24 biotope assignments made during the analysis of underwater video and stills images.

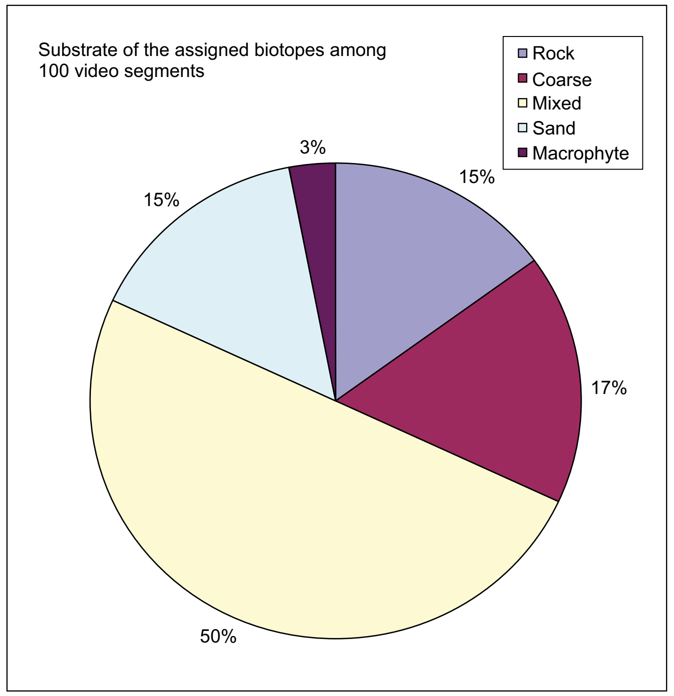


Figure 6.31: Substrate type of the assigned biotope classes among the 100 video segments.

substrates were fairly evenly distributed among the remainder. Macrophyte communities on sediment (A5.52) were encountered at three nearshore stations in Region 3 between Selsey Bill and Brighton (Stations 61, 62 and 81).

Mapped outputs of the biotope assignments are not presented in this chapter, as some assignments were modified during the integrated analysis which considered the evidence of both video and grab analysis to determine the final biotope assignment for each station. The results of the integrated analysis can be found in Chapter 7.

6.4 Rare and alien species

One of the main objectives of nature conservation management is to avoid species extinctions and rarity is one of the key factors which might determine a species risk of extinction. Thus identifying the presence of rare species is an important component of conservation management. The Joint Nature Conservation Committee (JNCC) developed criteria for the assessment of the rarity of marine benthic species in 1996 (Sanderson, 1996). The criteria includes Nationally Rare species; those which have been recorded in eight or fewer of the 1 546 ten kilometre squares of the Ordinance survey national grid and Nationally Scarce species; those occurring in 9 to 55 ten kilometre squares. A small number of benthic and epibenthic species (including fish) are listed in the OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR, 2009).

Another key objective of nature conservation is to monitor and where necessary, control the spread and associated impacts of introduced species. Thousands of marine animals, plants and algae are transported from their native range across bio-geographical boundaries to colonise 'new' areas through the transport and discharge of ballast water, as fouling organisms on ships hulls or through aquaculture. The term 'alien' is given to non-native species which have established self-perpetuating populations in the UK, which can displace native species. Where non-native species have not established self-perpetuating populations or their origin is not clear they are classified as cryptogenic. This classification is particularly useful as it prevents introduced species from being described as new or rare species. Environmental changes also give rise to new introductions, for example climate change is responsible

Species	Phylum	Description	Status	Grab Samples			Trawl Samples		
				Records	Abundance	Samples	Records	Abundance	Samples
Obelia bidentata	Cnidaria	Errect colonial hydroid	Nationally Rare	1	Present	45	0	0	
Elminius modestus	Crustacea	Barnacle	Alien	1	3	54	0	0	
Rissoides desmaresti	Crustacea	Mantis shrimp	Nationally Scarse	1	1	73	1	3	5
Apherusa clevei	Crustacea	Amphipod	Nationally Rare	1	1	65	0	0	
Jassa falcata	Crustacea	Tubiculous amphipod	Cryptogenic	1	1	17	0	0	
Jassa marmorata	Crustacea	Tubiculous amphipod	Cryptogenic	1	3	79	0	0	
Monocorophium insidiosum	Crustacea	Amphipod	Cryptogenic	1	1	8	0	0	
Nucella lapilus	Mollusca	Dogwhelk	OSPAR Listed	0	0	~	1	1	9
Thecacera pennigera	Mollusca	Sea slug	Cryptogenic; Nationally scarce	0	0	~	1	1	4
Crepidula fornicata	Mollusca	American slipper limpet	Alien	30	1232	7-11, 13, 16-18, 20, 21, 41, 42, 45, 46, 52-55, 58, 61, 62, 65, 72-76, 82, 83	16	4579	4-9, 14, 17, 19, 22, 24, 26-30
Hincksina flustroides	Bryozoa	Errect colonial bryozoan	Nationally Rare	11	Present	10, 12, 20, 21, 45, 47, 55, 65, 68, 70, 75	4	Present	7, 8, 10, 21
Styela clava	Chordata	The leathery sea squirt	Alien	1	1	73	3	6	6, 22, 24
Microcosmos claudicans	Chordata	Sea squirt	Nationally Rare	6	17	11, 13, 20, 46, 47, 59	8	127	5, 7, 8, 9, 10, 13, 17, 21
Raja montagui	Chordata	Spotted Ray	OSPAR Listed	0	0	~	1	1	25

Table 6.7: Summary of the status and records of rare and alien species within the South Coast REC area (Sanderson, 1996; Pinnion *et al.*, 2007; OSPAR, 2009).

for the extension of the natural range or distribution of numerous species including the kelp, *Laminaria ochroleuca*, which is thought to have crossed the English Channel during the warm period prior to 1940 (Eno *et al*., 1997).

A number of rare and alien species were identified in the South Coast REC grab and trawl samples and these are summarised in Table 6.7.

6.4.1 Nationally rare species

A number of nationally rare species were identified in the South Coast REC study area, perhaps the most notable being the sea squirt, *Microcosmos claudicans*, which was recorded in significant numbers in both grab (n=17) and trawl (n=127) samples. The abundances recorded in the study area indicate that this could be an important habitat for this species, though it is also possible that this species has, until now, been under-recorded in the UK, possibly because of its preference for coarse substrata which can be difficult to sample. The rare colonial bryozoan, *Hincksina flustroides* was also relatively abundant across the study area; recorded from 11 grab samples and 4 trawls.

6.4.2 Non-native species

Three established alien species were identified in the South Coast REC study area, the most conspicuous being the American slipper limpet, *Crepidula fornicata*. The leathery sea squirt, *Styela clava* and the barnacle, *Elminius modestus* were also recorded, albeit in very low numbers (Table 6.7).

Crepidula fornicata is perhaps the best-known alien species on British shores, in part because of the detrimental impact this introduction has had on oyster fisheries (Davidson, 1976; Key and Davidson, 1981). The first recorded occurrence of this species in Europe was in Liverpool Bay in 1872 when it was introduced with the American hard shelled clam, *Mercenaria mercenaria* (Eno *et al*., 1997). The *C. fornicata* population of Liverpool has since died off and it is likely that other populations introduced with *M. mercenaria* may have suffered the same fate (McMillan, 1938). Since this time *C. fornicata* has been introduced in other locations in association with the American oyster, *Crassostrea virginica* and the American hard shelled clam, *M. mercenaria* (Eno *et al*., 1997) and it is now common throughout Europe.

The leathery sea squirt *Styela clava* was also identified across the South Coast REC study area, albeit in much lower abundance than *C. fornicata*. This species is native to the north-western Pacific and was first recorded in Plymouth, Devon, in 1953 (Carlisle, 1954). It is thought to have been transported on the hulls of warships following the end of the Korean War in 1951. Since its introduction *Styela clava* has spread rapidly along the coast of England, reaching Southampton Water in 1959 and Wales and France by 1968. The species is now found as far north as Cumbria and certain parts of Scotland (Eno *et al*., 1997). Although the method of dispersal is not fully understood, *S. clava* is a fouling pest and may have been transported around the UK and Europe on ships' hulls or through the relocation of oysters. The success of *Styela clava* is attributed to its ability to withstand salinity changes and temperature fluctuations although it is reported to only be able to spawn in waters above 15°C (Eno *et al*., 1997). In areas where *Styela clava* populations become large there may be competition for food between individuals and other species (Eno *et al*., 1997). The main impact of this invasive ascidian is, however, as a fouling organism on oyster beds and ships' hulls.

The final alien recorded in the South Coast REC study area is the barnacle *Elminius modestus*. *E. modestus* was first recorded in Chichester Harbour in 1945, where it was believed to have been introduced from Australasia between 1940 and 1943 (Crisp, 1958; Bishop and Barnes, 1960). *E. modestus* grows rapidly and is able to withstand reduced salinity, high turbidity and lower temperatures than some native barnacle species (Eno *et al*., 1997). This species reproduces several times in a year and its larvae have been recorded in very high numbers in the nearby Solent Waters (Muxagata *et al*., 2004) indicating that this population is now very well established. *E. modestus* is distributed all around the UK coast (Southward, 2008) and is thought to have been spread mostly through shipping, as fouling adults and as pelagic larvae in ballast water (Eno *et al*., 1997). Only 3 individuals were recorded within the South Coast REC study area and it is likely that this species is more prevalent in the adjacent harbours and the Solent (Muxagata *et al*., 2004).

7 Integrated Assessment of Habitats and Biotopes

7.1 Introduction

In the context of this report the term habitat and biotope are compatible and interchangeable. Both terms are used for describing and mapping the physical characteristics of the sea bed environment and its associated biological community, thus combining the abiotic and biotic elements of the marine environment (Connor *et al*, 2004; Foster-Smith *et al*, 2007).

Within the South Coast REC study area the detail, volume and coverage of data available to characterise the physical nature of the marine habitat is relatively more extensive than the data available to characterise its biological nature. The former includes comparatively detailed morphology of the sea bed surface (Figure 4.1 and 4.2) enabling the major physical bedforms to be accurately mapped and their occurrence to be correlated, in many cases, with the geology underlying the sea bed. The physical nature of the sea bed in terms of sediment particle size has also been sampled at over 900 stations (Figure 3.6) enabling a range of sediment attributes to be mapped and modelled (Figure 4.27, 4.29–4.33) including modelled sea bed sediment distribution based on the Folk classification (Figure 4.25).

In comparison detailed biological analysis for this study has only been undertaken at the 92 sample stations completed during the South Coast REC 2007 sampling survey (Figure 7.1); sea bed imagery was available at all stations but grab samples only at 67 stations. All this data has been used in the integrated assessment outlined in this chapter. That assessment is somewhat hindered by the incomplete coverage of the South Coast REC 2007 geophysical survey (Figure 3.1), where only 13 of the 92 ground-truthing stations had any sidescan, multibeam or sub-bottom seismic coverage. Other geophysical survey line data has been utilised in the interpretation (Figure 3.5) but none of these lie directly over any of the 92 stations.

7.2 Biotope classifications

Biotope classes have been assigned to each of the South Coast REC sample stations according to the European Nature Information Service (EUNIS) habitat classification system developed by the European Environment Agency (http://eunis.eea.europa.eu/habitats.jsp). The marine section of this classification has direct equivalents in the UK's own system 'The Marine Habitat Classification for Britain and Ireland (Connor *et al*, 2004) http://www.jncc.gov.uk/MarineHabitatClassification/, the present version of which was developed during the JNCC's Marine Nature Conservation Review and hence their system of biotope coding has become known as the MNCR biotope codes. Expert judgement was used to assign biotope classes to each of the sampling stations, based on an integrated assessment of the available environmental, geophysical and biological information. The results of this assessment are presented in tabular form in Table 7.1 and in mapped form in Figure 7.1.

The EUNIS scheme has a hierarchical structure, with progressive layers (1 to 7) dealing with different habitat features or characteristics. Level 1 splits marine (denoted 'A') from the terrestrial environments, and down to Level 3 for rock, and Level 4 for sediment, the differentiation between classes is entirely based on physical and environmental characteristics, namely substrate type (rock and sediment, which is subsequently further subdivided into coarse sediment, sand, mud and mixed sediment), biological zone (littoral, circalittoral etc) and exposure to currents and waves (high, moderate and low energy). Hence, the term 'habitat' is commonly applied to Level 3 for rock and Level 4 for sediment substrates. Beyond this, the classification takes account of the species compositions of the faunal communities to further discriminate the classes, so the terms 'biotope' and 'sub-biotope' are more frequently used. At EUNIS level 2, A1 and A2 relate to littoral (shoreline) habitats and so are not relevant to this study while A3 and A4 respectively refer to infralittoral rock and circalittoral rock habitats; marine algae dominate the shallower infralittoral zone but not the deeper circalittoral zone as this becomes a-photic. The Level 2 code A5 deals with sublittoral sediments, i.e. those permanently covered by seawater. In a similar fashion, the MNCR codes represent hierarchical levels, with the each level separated by a period (.). The letters of the code abbreviate the full meaning, so for example CR.HCR represents Circalittoral Rock, High Energy Circalittoral Rock and SS.SSa.IFiSa represents Sublittoral Sediments, Sublittoral Sands, Infralittoral Fine Sand.

7.3 Development of a modelled biotope map using GIS

As the EUNIS system uses purely physical and environmental characteristics in its upper hierarchical levels, there is opportunity to develop a modelled EUNIS level 3 map using the available environmental and geological data. The process involves modelling the distribution of the EUNIS substrate classes (rock, coarse sediment, sand, mud, and mixed sediment) and then overlaying these with information relating to the environmental parameters relevant to the EUNIS system. A combination of light penetration and depth was used to model the photic and aphotic zones (approximating the boundary between the infralittoral and circalittoral zones) while an estimation of current speed (e.g. maximum current during spring tides) modelled the relative energy status at the seabed (high, moderate or low energy). Spatial join queries were then used in the GIS to map the various EUNIS Level 3 classes.

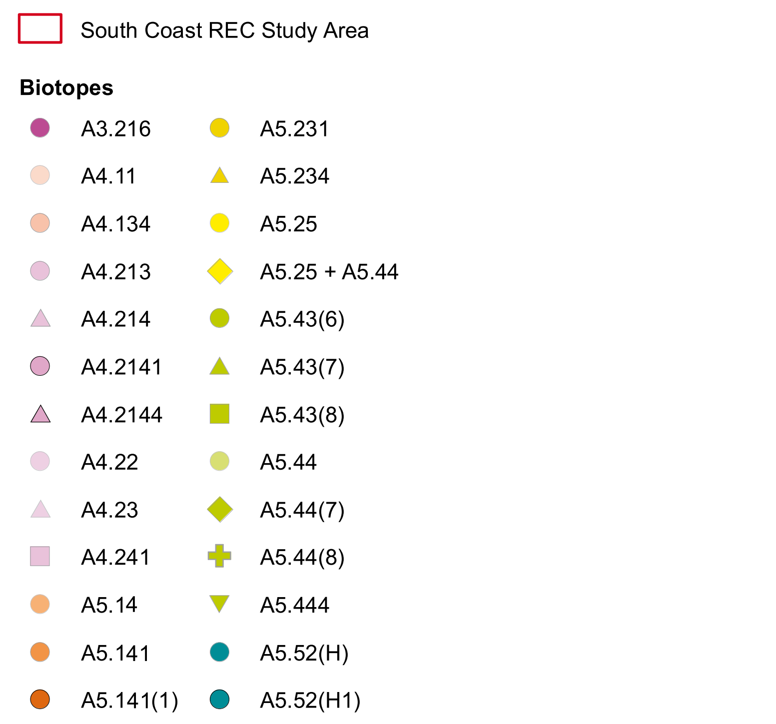
The initial stage of creating the modelled biotope map for the South Coast REC study area required the generation of a sea bed sediment (SBS) map. This was based on the Folk sediment classification system (Folk, 1954) and simplified into the four more general sediment classes used in the EUNIS classification scheme (Figure 7.2).

7.3.1 Folk based sea bed map

Within ArcMap 9.3 GIS software, contours showing % gravel were generated from the available sample station PSA data (Figure 3.4), with contour values of 80, 30, 5 and 1% to reflect the % gravel divisions in the Folk classification.

Contours showing the sand:mud ratio were generated from the combined % sand and % mud raster layers, converted to show contours for the 1:9, 1:1 and 6:1 ratio divisions in the Folk classification. A 6:1 sand:mud ratio was used as the boundary for sand substrates as this was considered to better reflect the descriptions of sublittoral sand biotopes that appear in the EUNIS classification than the 9:1 ratio in the published Folk classification (Folk,1954).

The % gravel and sand/mud ratio contour shapefiles were combined to produce a layer of polygons each with % gravel and sand/mud ratio values which were then assigned to one of the four



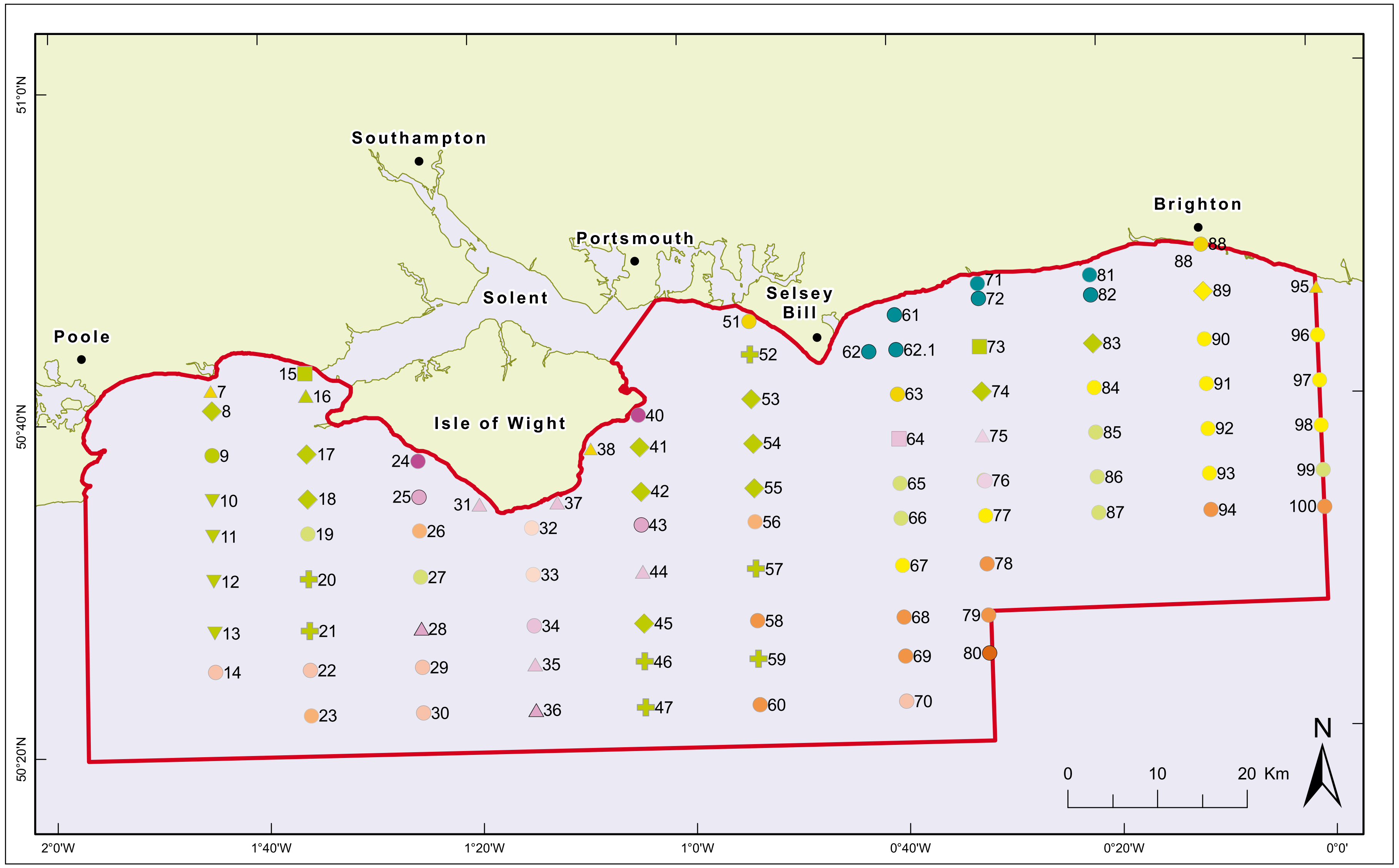


Figure 7.1: EUNIS habitat classes for the South Coast REC sample stations.

Assigned using expert judgement based on an integrated assessment of the available physical, environmental and biological information. Symbol colour reflects EUNIS Level 3 classes (e.g. green = A5.4). Symbol shape, shade and borderline colour (black, grey) discriminate between different biotopes at EUNIS Level 4 and higher.

EUNIS sediment classes. The boundaries of these four classes were tested at different % gravel and sand:mud ratio boundaries for consistency with the sediments described within a range of EUNIS biotopes and with the visual and physical evidence from the South Coast REC sample stations and geophysical data. The boundaries drawn in Figure 7.2 were considered the most appropriate fit. Compared to the boundaries shown in the UK SeaMap (Connor *et al*., 2006) EUNIS sediment classification (Figure 7.3) our EUNIS sediment classification has a narrower coarse sediment spectrum (>80% gravel only) and a wider spectrum for mixed sediment, and sand.

Finally, polygons for rock and thin sediment were extracted from the sea bed character map (Figure 4.17a, b) and overlaid on top of the EUNIS sediment class shapefile to produce a map of EUNIS sediment class and rock outcrop.

7.3.2 Modelled biotope map

To complete the modelled biotope map two more variables were required to be added to the sea bed map, namely tidal current velocity and photic/aphotoc zones.

The photic and aphotic zone data has been taken from Coggan & Diesing (2009) and their method statement states:-

The infralittoral, circalittoral and deep circalittoral were modelled using wave and light data. The infralittoral is the zone dominated by photosynthetic organisms. Its lower limit is approximated by the depth at which light reaching the seabed is 1% of surface irradiance. The lower limit of the circalittoral can be approximated by the depth of water at which the passage of a wave is still able to disturb the seabed. This 'wave base' is commonly equal to half the wave length.

We obtained a map of the average light attenuation coefficient (Kd) for August 2007 covering the Channel area (provided by R. Forster, Cefas). From the average map we calculated the 1% irradiance

Station Number	Assigned EUNIS biotope	Equivalent MNCR biotope	Description of assigned biotope	Assigned EUNIS Level 3	Modelled EUNIS Level 3
7	A5.234	SS.SSa.IFiSa.TbAmPo	Semi-permanent tube-building amphipods and polychaetes in sublittoral sand	A5.2	A3.3
8	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A5.4
9	A5.43(6)	SS.SMx.IMx.(BriHydLanBal)	Tide swept, infralittoral mixed sediments with erect bryozoans and hydroids, dense *Lanice conchilega* and *Balanus crenatus*	A5.4	A3.2
10	A5.444	SS.SMx.CMx.FluHyd	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	A5.4	A4.2
11	A5.444	SS.SMx.CMx.FluHyd	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	A5.4	A4.2
12	A5.444	SS.SMx.CMx.FluHyd	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	A5.4	A4.2
13	A5.444	SS.SMx.CMx.FluHyd	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	A5.4	A4.1
14	A4.134	CR.HCR.Xfa.FluCoAs	*Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock	A4.1	A4.1
15	A5.43(8)	SS.SMx.IMx.(SabCrepPomB)	Infralittoral mixed sediments with clumps of *Sabellaria*, *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A5.4
16	A5.43(7)	SS.SMx.IMx.(PomAl)	Infralittoral mixed sediments with *Pomatoceros* and occasional foliose red and green algae	A5.4	A5.1
17	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and Pomatoceros	A5.4	A5.4
18	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A5.4
19	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A4.2
20	A5.44(8)	SS.SMx.CMx.(AsSabCr)	Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna	A5.4	A4.2
21	A5.44(8)	SS.SMx.CMx.(AsSabCr)	Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna	A5.4	A4.1
22	A4.134	CR.HCR.XFa.FluCoAs	*Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock	A4.1	A4.1
23	A5.14	SS.SCS.CCS	Circalittoral coarse sediment	A5.1	A4.1
24	A3.215	IR.MIR.KR.XFoR	Dense foliose red seaweeds on silty moderately exposed infralittoral rock	A3.2	A3.3
25	A4.2141	CR.MCR.EcCr.FaAlCr.Flu	*Flustra foliacea* on slightly scoured silty circalittoral rock	A4.2	A4.2
26	A5.14	SS.SCS.CCS	Circalittoral coarse sediment	A5.1	A4.1
27	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A4.1
28	A4.2144	CR.MCR.EcCr.FaAlCr.Bri	Brittlestars on faunal and algal encrusted exposed to moderately wave-exposed circalittoral rock	A4.2	A4.1
29	A4.134	CR.HCR.XFa.FluCoAs	*Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock	A4.1	A4.1
30	A4.134	CR.HCR.XFa.FluCoAs	*Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock	A4.1	A4.1
31	A4.214	CR.MCR.EcCr.FaAlCr	Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock	A4.2	A3.2
32	A4.11	CR.HCR.FaT	Very tide-swept faunal communities on circalittoral rock	A4.1	A4.1
33	A4.11	CR.HCR.FaT	Very tide-swept faunal communities on circalittoral rock	A4.1	A4.1
34	A4.213	CR.MCR.EcCr.UrtScr	*Urticina felina* and sand-tolerant fauna on sand-scoured or covered circalittoral rock	A4.2	A4.1
35	A4.214	CR.MCR.EcCr.FaAlCr	Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock	A4.2	A4.1
36	A4.2144	CR.MCR.EcCr.FaAlCr.Bri	Brittlestars on faunal and algal encrusted exposed to moderately wave-exposed circalittoral rock	A4.2	A4.1
37	A4.214	CR.MCR.EcCr.FaAlCr	Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock	A4.2	A3.2

Station Number	Assigned EUNIS biotope	Equivalent MNCR biotope	Description of assigned biotope	Assigned EUNIS Level 3	Modelled EUNIS Level 3
38	A5.234	SS.SSa.IFiSa.TbAmPo	Semi-permanent tube-building amphipods and polychaetes in sublittoral sand	A5.2	A3.3
40	A3.215	IR.MIR.KR.XFoR	Dense foliose red seaweeds on silty moderately exposed infralittoral rock	A3.2	A3.3
41	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A3.2
42	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A4.1
43	A4.2141	CR.MCR.EcCr.FaAlCr.Flu	*Flustra foliacea* on slightly scoured silty circalittoral rock	A4.2	A4.1
44	A4.214	CR.MCR.EcCr.FaAlCr	Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock	A4.2	A4.1
45	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A5.4
46	A5.44(8)	SS.SMx.CMx.(AsSabCr)	Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna	A5.4	A5.4
47	A5.44(8)	SS.SMx.CMx.(AsSabCr)	Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna	A5.4	A4.1
51	A5.231	SS.SSa.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna	A5.2	A3.3
52	A5.44(8)	SS.SMx.CMx.(AsSabCr)	Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna	A5.4	A3.2
53	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A3.2
54	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A5.4
55	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of Sabellaria, dense Crepidula and encrusting barnacles and Pomatoceros.	A5.4	A4.1
56	A5.14	SS.SCS.CCS	Circalittoral coarse sediment	A5.1	A5.4
57	A5.44(8)	SS.SMx.CMx.(AsSabCr)	Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna	A5.4	A4.1
58	A5.141	SS.SCS.CCS.PomB	Pomatoceros triqueter with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.1
59	A5.44(8)	SS.SMx.CMx.(AsSabCr)	Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna	A5.4	A4.1
60	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.1
61	A5.5211(1)	SS.SMp.KSwSS.LsacR.CbPb.(Crep)	Red seaweeds and dense *Crepidula* on tide-swept mobile infralittoral cobbles and pebbles	A5.5	A3.2
62	A5.5211(1)	SS.SMp.KSwSS.LsacR.CbPb.(Crep)	Red seaweeds and dense *Crepidula* on tide-swept mobile infralittoral cobbles and pebbles	A5.5	A3.2
62.1	A5.5211(1)	SS.SMp.KSwSS.LsacR.CbPb.(Crep)	Red seaweeds and dense *Crepidula* on tide-swept mobile infralittoral cobbles and pebbles	A5.5	A3.2
63	A5.231	SS.SSa.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna	A5.2	A3.2
64	A4.241	CR.MCR.Cmus.Cmyt	*Mytilus edulis* beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock	A4.2	A3.2
65	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.2
66	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A4.2
67	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A5.2
68	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.1
69	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.1

Station Number	Assigned EUNIS biotope	Equivalent MNCR biotope	Description of assigned biotope	Assigned EUNIS Level 3	Modelled EUNIS Level 3
70	A4.134	CR.HCR.XFa.FluCoAs	*Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock	A4.1	A4.1
71	A5.5211	SS.SMp.KSwSS.LsacR.CbPb	Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles	A5.5	A3.3
72	A5.5211(1)	SS.SMp.KSwSS.LsacR.CbPb.(Crep)	Red seaweeds and dense *Crepidula* on tide-swept mobile infralittoral cobbles and pebbles	A5.5	A3.2
73	A5.43(8)	SS.SMx.IMx.(SabCrepPomB)	Infralittoral mixed sediments with clumps of *Sabellaria*, *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A5.4
74	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A3.2
75	A4.23	CR.MCR.SfR	Communities on soft circalittoral rock	A4.2	A3.2
76	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A4.2
76.1	A4.22	CR.MCR.Csab	*Sabellaria* reefs on circalittoral rock	A4.2	A4.2
77	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A5.2
78	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.2
79	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.2
80	A5.141(1)	SS.SCS.CCS.PomB.(Oph)	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.2
81	A5.5211	SS.SMp.KSwSS.LsacR.CbPb	*Laminaria saccharina* and red seaweeds on infralittoral sediments	A5.5	A3.3
82	A5.5211(1)	SS.SMp.KSwSS.LsacR.CbPb.(Crep)	Red seaweeds and dense *Crepidula* on tide-swept mobile infralittoral cobbles and pebbles	A5.5	A3.2
83	A5.44(7)	SS.SMx.CMx.(SabCrepPomB)	Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*	A5.4	A5.2
84	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A3.2
85	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A5.2
86	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A5.4
87	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A5.4
88	A5.231	SS.SSa.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna	A5.2	A5.2
89	A5.25 + A5.44	SS.SSa.CFiSa + SS.SMx.CMx	Circalittoral fine sand	A5.2	A5.2
90	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A3.2
91	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A4.2
92	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A5.2
93	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A5.2
94	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A5.4
95	A5.234	SS.SSa.IFiSa.TbAmPo	Semi-permanent tube-building amphipods and polychaetes in sublittoral sand	A5.2	A5.2
96	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A5.2
97	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A5.2
98	A5.25	SS.SSa.CFiSa	Circalittoral fine sand	A5.2	A5.2
99	A5.44	SS.SMx.CMx	Circalittoral mixed sediments	A5.4	A5.4
100	A5.141	SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	A5.1	A4.2

Table 7.1: EUNIS biotopes, and their MNCR equivalent codes, assigned to the South Coast REC sample stations during the integrated assessment. EUNIS and MNCR codes having elements in parenthesis indicate potential new biotopes classes identified by this study. Also a comparison at EUNIS level 3 between the assigned and modelled biotopes (see Figure 7.4) with agreements highlighted in yellow.

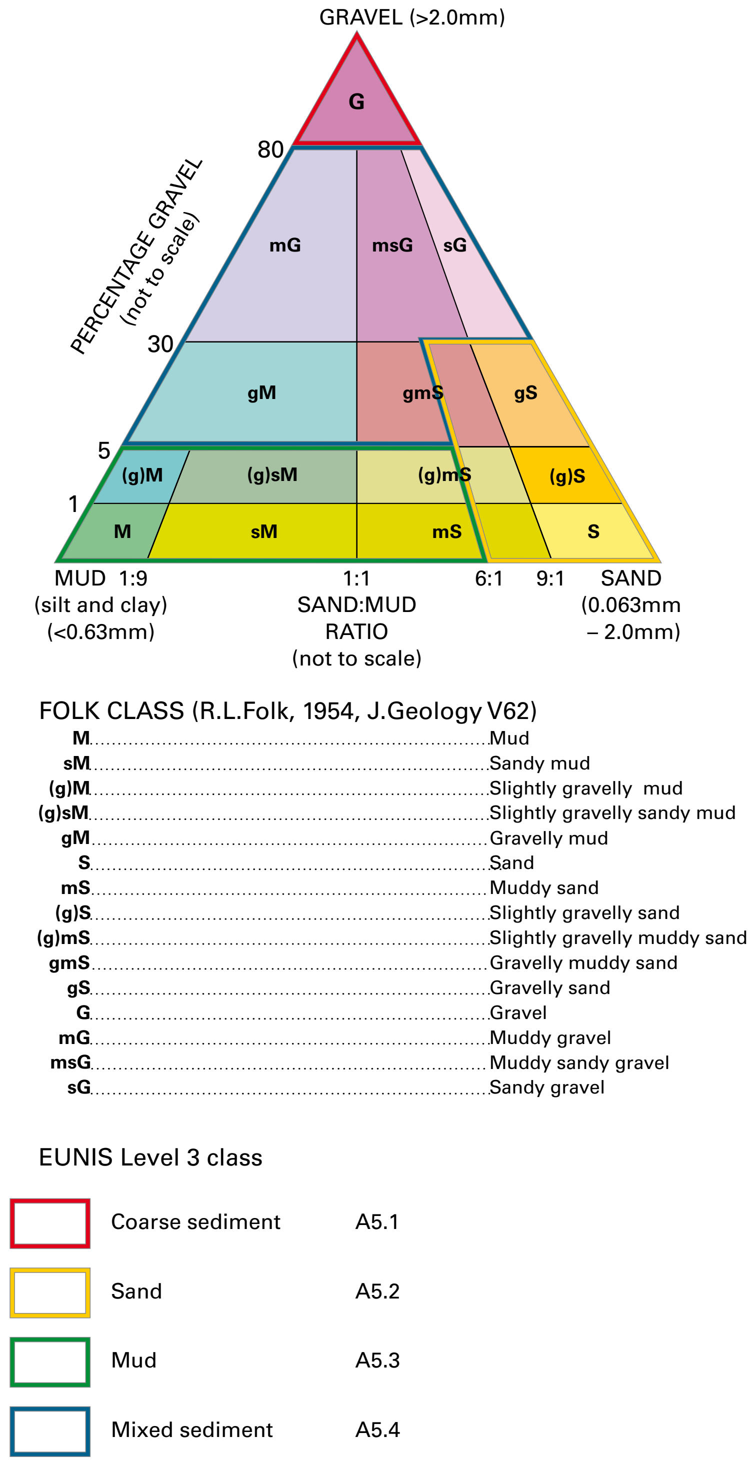


Figure 7.2: Division of modelled EUNIS classes within Folk classification.

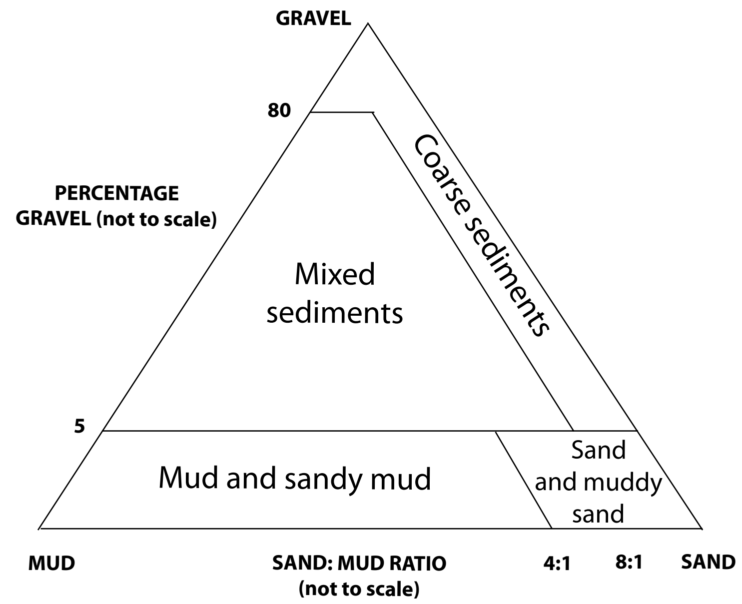


Figure 7.3: Division of UK SeaMap EUNIS classes within Folk classification (Connor *et al.*, 2006).

depth for each pixel as Z = ln(100)/Kd. The map of 1% depth was compared to the GEBCO (General Bathymetric Chart of the Oceans, http://www.gebco.net/) 30 arc-second bathymetry in order to derive photic (infralittoral) and aphotic (circalittoral plus deep circalittoral) zones.

Tidal current velocity contours were derived from raster data modelling the mean spring tidal current (Figure 2.7) (pers comm. M J Howarth, Proudman Oceanographic Laboratory). Contour values of 0.5 m/s and 1.5 m/s were used, being the levels set by the EUNIS system to differentiate low (<0.5 m/s), moderate (0.5–1.5 m/s) and high (>1.5 m/s) current speeds. The tidal velocity contours and the photic zone layer were overlaid on top of the modelled sea bed map to produce a layer of polygons each with a EUNIS sediment class or rock, photic zone, and tidal velocity attribution. An additional field was added to the attribute table of this layer to hold the final EUNIS classification. For polygons classified as rock, the EUNIS classification attribute was determined using the photic zone and tidal velocity values (i.e. high, moderate or low energy infralittoral or circalittoral rock). For all other polygons the EUNIS sediment class was used as the attribution. The completed model is shown in Figure 7.4.and the area covered by each modelled EUNIS class is listed in Table 7.3. Figure 7.5 shows the completed model draped over the sea bed morphology model.

7.4 Discussion

The limited agreement at EUNIS level 3 between the assigned and modelled biotopes (Table 7.1) was investigated further. There was agreement at 30 stations, but a discrepancy at the remaining 62 stations. The reasons for these discrepancies lay primarily in the modelled biotope map and fell into six broad categories as follows:

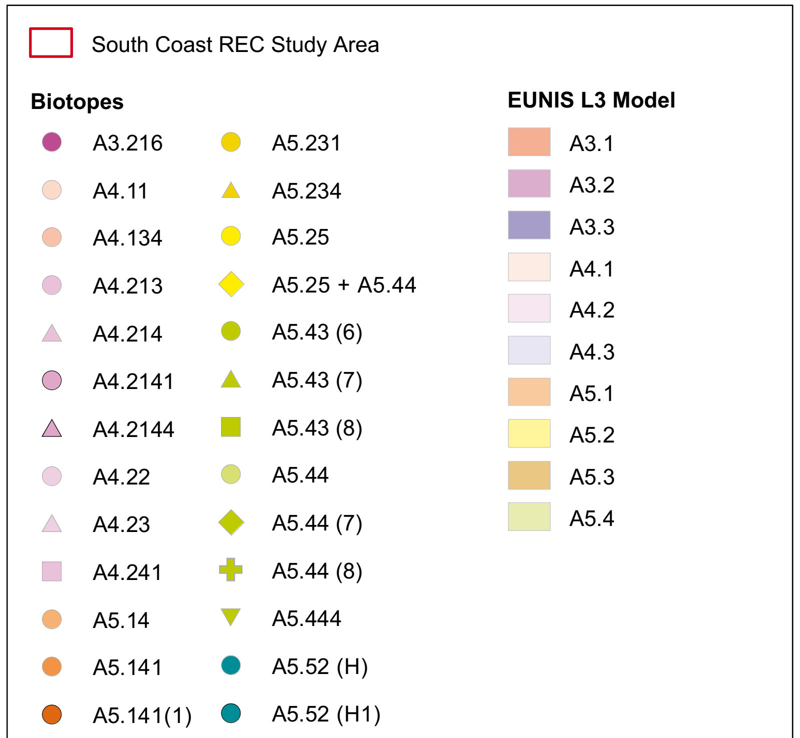
Resolution of sediment thickness at sea bed

This is where the model predicted a rock habitat but the sample station observations assigned a sediment habitat and the discrepancy could be primarily attributed to the inability of the acoustic and seismic technologies to discriminate whether or not rock at the sea bed surface has a thin covering of sediment. Sediment layers less than approximately 0.5 – 1 m depth can not be detected by sub-bottom seismic systems (James *et al*, 2007), yet these are certainly suitable habitats for benthic infauna (organisms that burrow into sediments) and can be sampled by grabs for both faunal and PSA analysis. This limitation was considered to account for nearly half (29/62) of all the discrepancies indicated in Table 7.1, as summarised in Table 7.2.

This could be resolved to some extent with a denser grid of multibeam, sidescan and sub-bottom seismics and numerous video camera transects but the fundamental resolution problem associated with the acoustic properties of the sub-bottom system would remain. It may be more appropriate to modify the EUNIS classification system to take account of this type of rock and thin sediment substrate which is very common in the English Channel and elsewhere in UK waters.

Spatial resolution of the sediment map

This is essentially a near miss, where a biotope polygon on the modelled map does not quite extend far enough to envelop a sampling station that has been assigned to the same substrate class. For example, station 65 was assigned to a sediment class but lies just 10 metres outside a sediment polygon on the modelled biotope map. Using a buffer of 500 metres, seven of the remain-



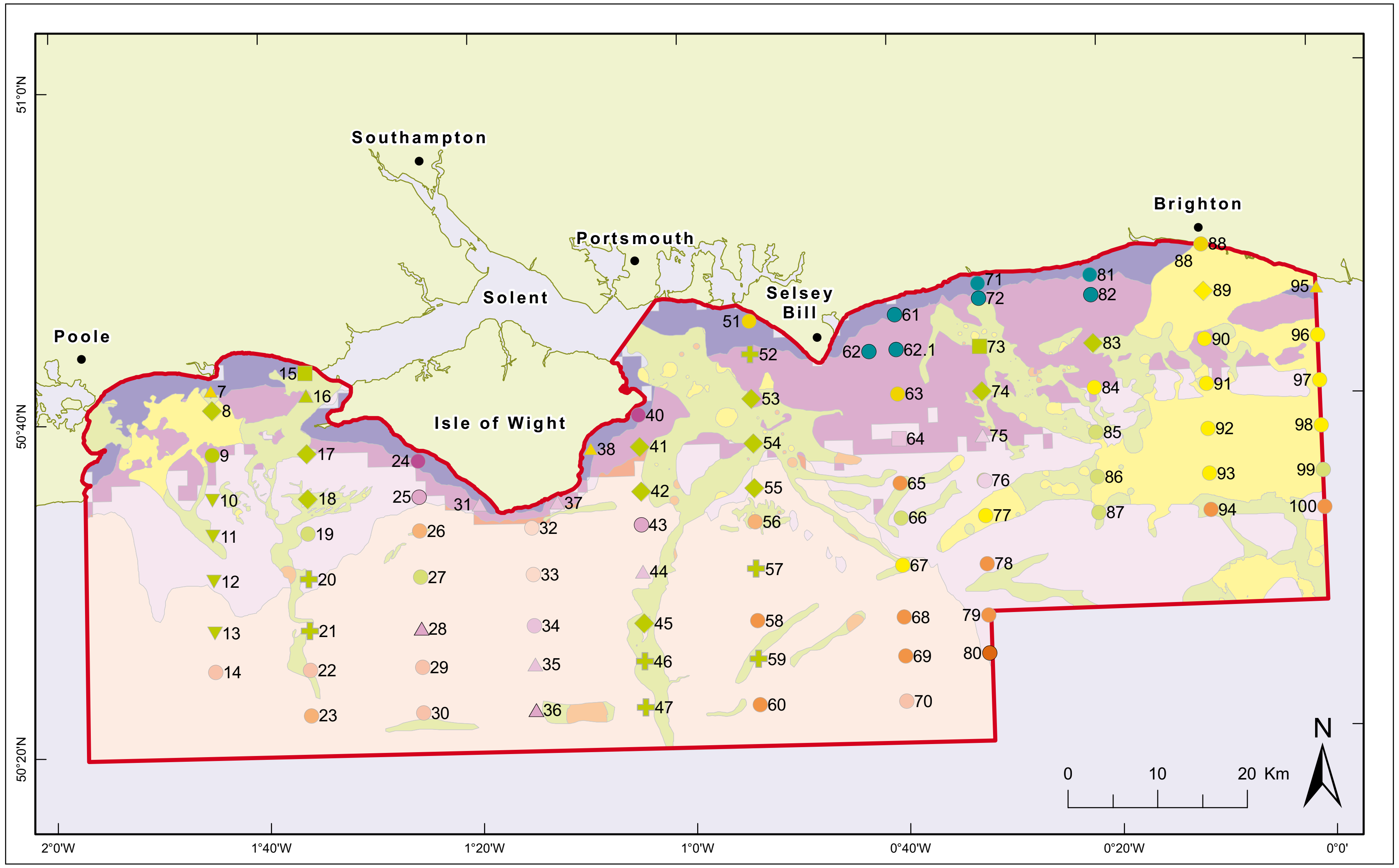


Figure 7.4: Modelled biotope map at EUNIS level 3 overlain with the assigned EUNIS biotopes at South Coast REC sample stations.

ing 33 discrepancies were accounted for (stations 11, 20, 21, 26, 43, 59, and 65, 91). Again, these discrepancies could be almost entirely eliminated if a full coverage acoustic survey of the site had been available, or if the survey design had targeted sampling sites at identifiable sea bed features.

Spatial resolution of the photic/aphotic zone model

The photoic/aphotic zone model was derived from irradiance and bathymetry data, and inspection of Figure 2.15 shows the layer has a resolution of about 10 sq km. There are a number of limitations with this layer, as it does not account for the varying turbidity of water across the study area (data were not available) and it only approximates the division between littoral and circalittoral zones, which itself is a gradient rather than a sharp boundary. Mismatches between infralittoral (A3) and circalittoral (A4) rock habitats accounted for four of the remaining 25 discrepancies (stations 31, 37, 64 and 75). Despite this, the approach taken to modelling the photic-aphotic boundary was far more advanced than using bathymetry alone. Greater spatial resolution for bathymetry, irradiance and turbidity data would improve the model.

Discrimination among energy states

There were eight instances where the discrepancies could be primarily attributed to differences between the assigned and modelled energy levels of the biotope. Four of these are considered to be attributable to the resolution of the data on current speed, resulting in discrepancies between moderate and low energy infralittoral rock (A3.2 cf A3.3) at stations 24 and 40, and between moderate and high energy circalittoral rock (A4.2 cf A4.1) at stations 28 and 43. The other four cases are considered to be errors in assigning the correct energy level to the biotope, based on the fauna present. Review of the seabed imagery for

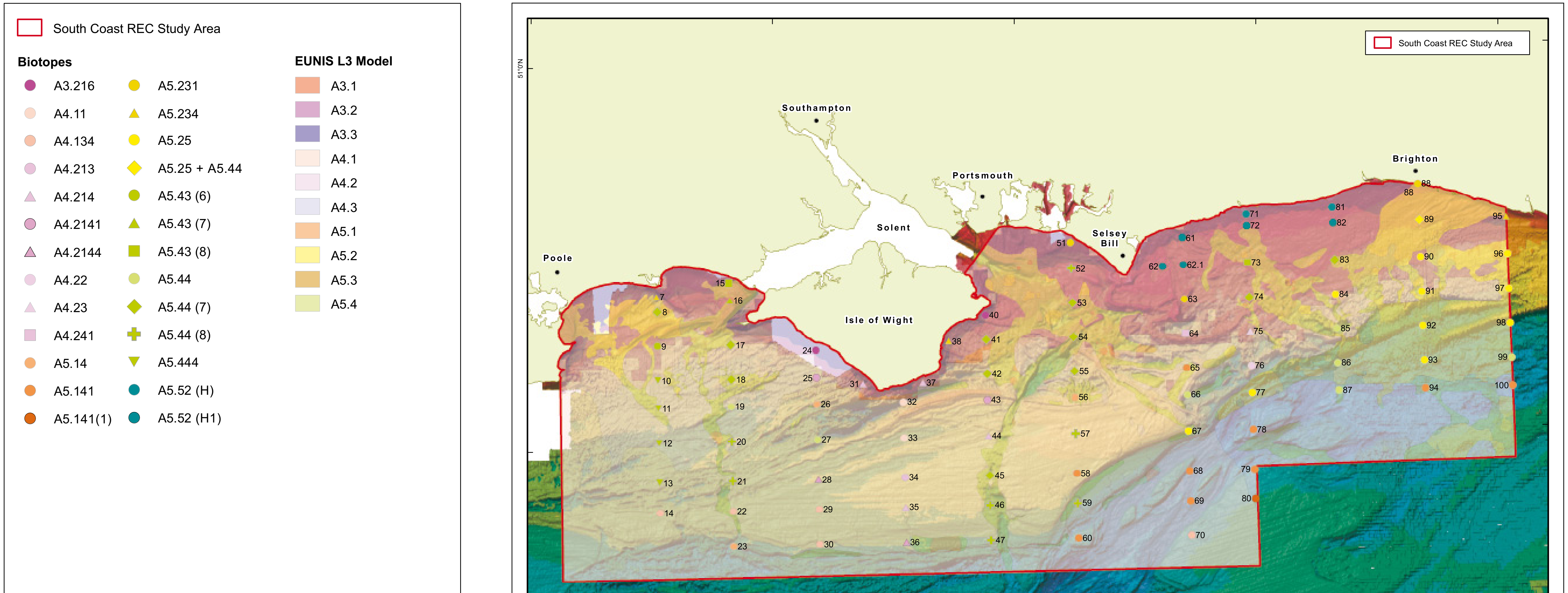


Figure 7.5: Modelled biotope map at EUNIS level 3 overlain with the assigned EUNIS biotopes at South Coast REC sample stations draped on sea bed morphology.

stations 34, 35, 36 and 44 showed the presence of sponges and Tubularia, taxa that are characteristic of high energy rock biotopes. However, these same taxa also occur in moderate energy environments and the mis-assignment is a consequence of the subjective nature of the assessment and is somewhat trivial.

Assignment and classification of cobble/pebble substrates to sediment or rock classes

There were nine instances where the discrepancy between the assigned and modelled biotopes related primarily to whether cobble substrates were regarded as rock or sediment habitats This EUNIS class A5.5 relates to macrophyte (i.e. seaweed) dominated sediments and was assigned at seven nearshore stations (61, 62, 62.1, 71, 72, 81 and 82) where the substrate comprised cobble and pebble in a consolidated matrix, with some sand and/or mud also present. The consolidated nature of the cobble and pebble presents a stable surface on which seaweeds can grow, but the substrate is still classed as sediment, though it could be argued to perform as a rock and so align with the predicted substrate according to the modelled biotope map. Interestingly clumps of the slipper limpet, *Crepidula fornicata*, also provided hard surface for growing algae, so these areas could potentially be regarded as biogenic reefs. In a similar fashion, two deeper stations (47 and 57) had substrate of consolidated cobbles, and were assigned to sediment classes though they could equally be regarded as rock. These discrepancies highlight an area of difficulty in interpreting the current EUNIS habitat classes and call for some modification of the system so that it specifies consolidated cobble as a rock habitat, yet includes

Assigned Biotope		Modelled Biotope		Discrepancies	
EUNIS level 3	MNCR code	EUNIS level 3	MNCR code	Number	Sample Stations
A5.1	SCS	A4.1	HCR	5	23, 58, 60, 68, 69
A5.1	SCS	A4.2	MCR	4	78, 79, 80, 100
A5.2	SSa	A3.2	MIR	3	63, 84, 90
A5.2	SSa	A3.3	LIR	3	7, 38, 51
A5.4	SMx	A3.2	MIR	5	9, 41, 52, 53, 74
A5.4	SMx	A4.1	HCR	4	13, 27, 42, 55
A5.4	SMx	A4.2	MCR	5	10, 12, 19, 66, 76

Table 7.2: Summary of discrepancies at EUNIS level 3 between modelled rock biotopes and assigned biotopes at 29 sample stations.

accounts of the interstitial infauna that can be collected from such substrates using grab sampling techniques.

Discriminating different sediment classes

There were three instances where a discrepancy between the assigned and modelled biotope primarily concerned the discrimination between sediment classes. At station 16 the observations showed a mixed sediment but the model showed a coarse one, and at stations 83 and 85 the observations showed a mixed sediment but the model predicted sand. This is, in fact, quite a low rate of discrepancy given that sediments in the area are quite mobile and the model included PSA data collected over several decades. A small percentage change in the sand:mud ratio can flip a sample between the coarse and mixed classes and the migration of sand waves or sand ribbons across an area can change the base sediment type from sand to mixed over short periods of time (i.e. several days or weeks). Hence, these discrepancies are not regarded as a serious issue; they are to be expected with this type of modelling work. Once again, greater classification and spatial accuracy could be achieved in the model if full coverage acoustic surveys had been available.

To summarise, it is rather alarming to read a statistic indicating that there is only about 30% agreement at EUNIS level 3 between the modelled biotope map and the biotope classes assigned to the stations as a result of detailed examination of sea bed samples. However, closer examination of the discrepancies reveals one or two factors relating to data density and quality that could greatly

Modelled EUNIS level 3	Habitat description	Area within REC sq km (%)
A3.1	Atlantic and Mediterranean high energy infralittoral rock	12 (<0.2)
A3.2	Atlantic and Mediterranean moderate energy infralittoral rock	681 (12)
A3.3	Atlantic and Mediterranean low energy infralittoral rock	305 (5)
A4.1	Atlantic and Mediterranean high energy circalittoral rock	2287 (40)
A4.2	Atlantic and Mediterranean moderate energy circalittoral rock	962 (17)
A4.3	Atlantic and Mediterranean low energy circalittoral rock	14 (<0.2)
A5.1	Sublittoral coarse sediment	648 (12)
A5.2	Sublittoral sand	550 (10)
A5.3	Sublittoral mud	0.16 (<0.001)
A5.4	Sublittoral mixed sediments	215 (4)
A5.5	Sublittoral macrophyte dominated sediment	0

Table 7.3: EUNIS habitat classification level 3 codes and descriptions with modelled area coverage in the South Coast REC study area. (The four codes highlighted in yellow only occurred in the model, the seven codes in pale blue occurred in both the modelled biotope map and in among the biotope assignments based on sample data).

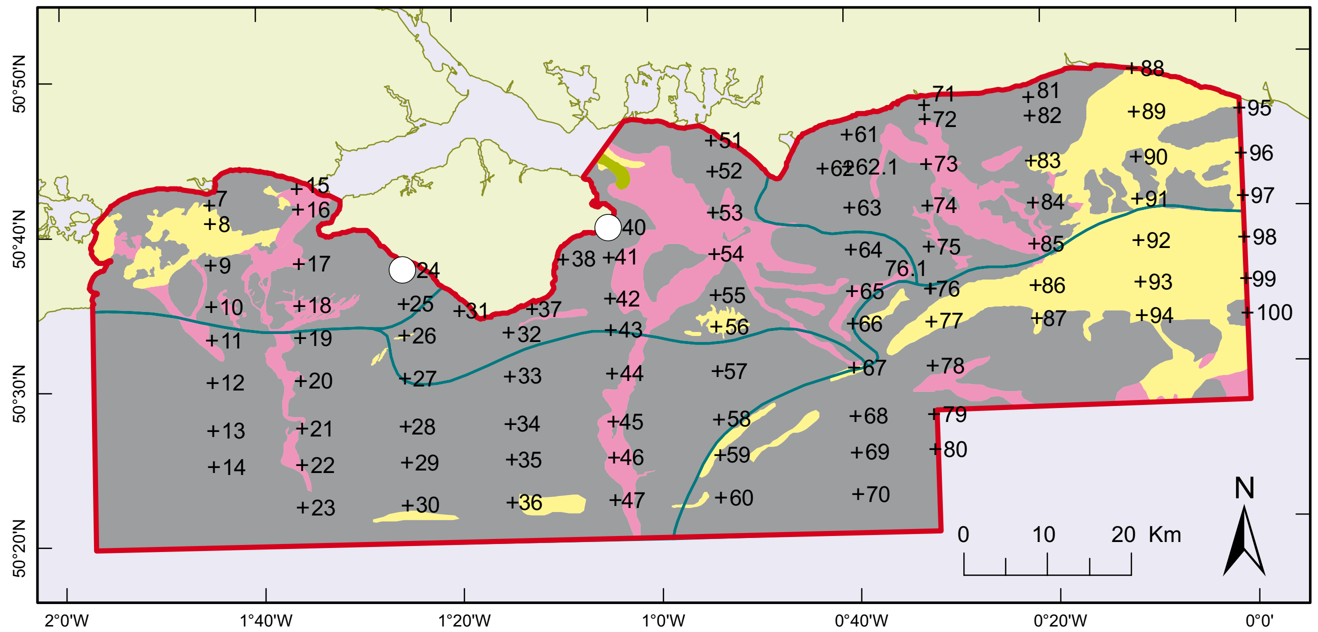
improve the modelled layer, and highlights the fact that some of the discrepancies are minor, if not trivial. There are significant issues of scale to be considered when comparing assigned with modelled habitat classes, particularly as the digital terrain model shows a complex seabed morphology in this area with different rates of variability over a range of spatial scales. Video and grab techniques sample the sea bed on a metre or sub-metre scale while the model deals with matters on a scale of several kilometres. It should be recognised that the two exercises address different questions, the model helping to show the spatial distribution of the main habitat characteristics in the area and the sea bed sampling providing fine detail on the nature and range of biotopes that the area supports.

7.5 Biotope summaries

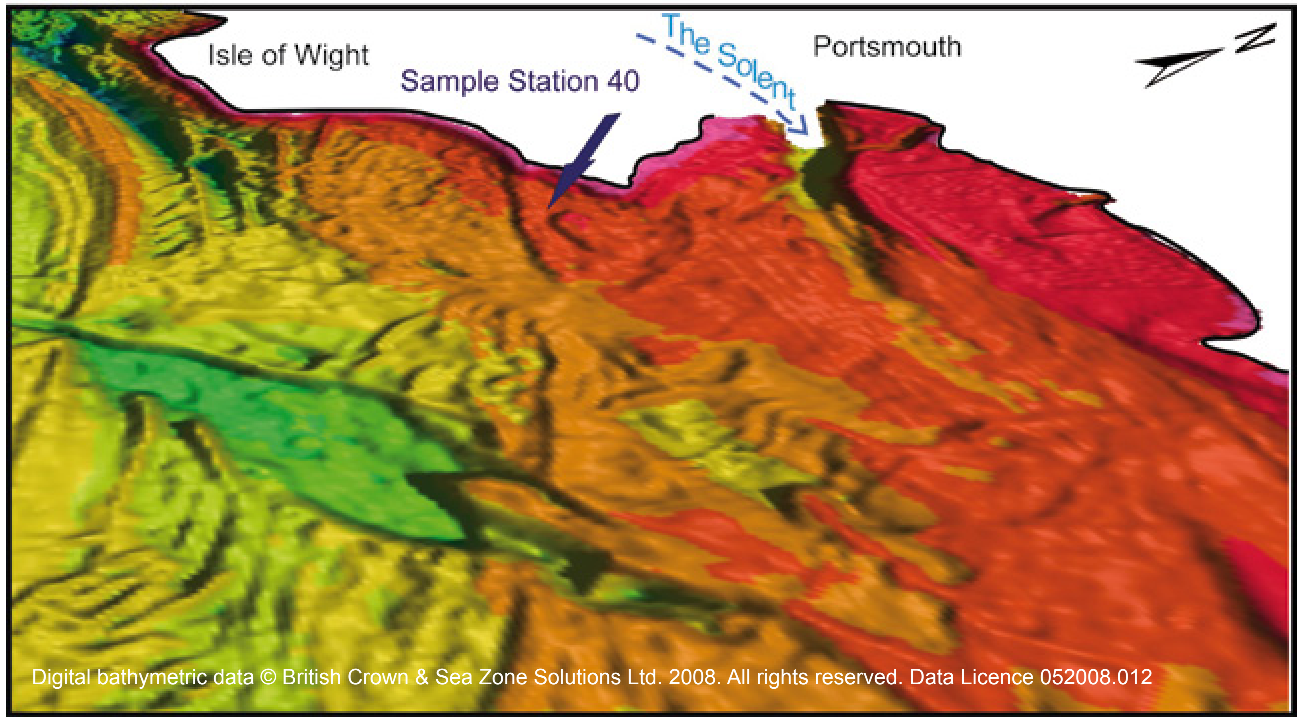
The biotope summaries for each of the seven EUNIS Level 3 classes and their associated higher levels from 4 to 7 are outlined below. They include a brief description of the physical and biological characteristics of each biotope, illustrated with relevant sea bed photographs. The summaries include, where available, illustrations of multibeam, sidescan sonar and boomer sub-bottom at selected stations or in close proximity. There is also a histogram of the mean grain size distribution for the collective samples within each of the seven classes. EUNIS and MNCR codes having elements in parenthesis indicate potential new biotopes classes identified by this study. These have such an unusual combination of taxa that they are considered to be significantly different to the biotopes and sub-biotopes currently listed in the EUNIS habitat classification scheme. Some may be considered local variants of existing biotopes.

Marine Aggregate Levy Sustainability Fund MALSF

A3.2 — Atlantic and Mediterranean moderate energy infralittoral rock (IR.MIR)



Location of stations assigned to the EUNIS Level 3 Habitat A3.2 (white circles), in relation to sea bed character.



Sea bed morphology.

Geophysical data

There are no South Coast REC 2007 Survey geophysical lines over the two A3.2 stations at 24 and 40.

Solid geology

Station 40 lies just offshore of Whitecliff Bay which is a classic area of Chalk and Tertiary rocks where the Wight–Bray monocline crosses the shore. The Chalk cored rampart associated with the Monocline Rampart Enclosure is south of Station 40 on the isometric sea bed morphology figure. The steep near vertical dips of rocks associated with the monocline mean that individual formations and groups have a relatively narrow extent some <100 m, therefore to pinpoint the bedrock beneath Station 40 is difficult although its position suggests it may more likely be Tertiary Barton Group and comprises silty muds with some beds of sand.

Station 24 lies just offshore of the west coast of the Isle of Wight in Brighstone Bay . It is in an open location, exposed to the prevailing south westerlies. It is in an area of sea where Lower Cretaceous Wealden Group rocks crop out in the cliffs of Brighstone Bay and extend offshore across the southern half of Region 1. The Wealden Group comprises predominantly red mudstones with subordinate sandstones but also includes, in part, lenses of grey silty or sandy clay with plant debris and also fossil material such as crocodile, turtle and dinosaur bones. It also includes dark grey mudstones and siltstones with some sandstones in part.

Sea bed character

Rock and thin sediment is interpreted as underlying both stations. At Station 40 the sea bed is strewn with isolated pebbles and cobbles with no rock exposure apparent. By contrast large ledges of rock are apparent at Station 24 with boulders and cobbles although these appear to be covered by a very thin veneer of fine sediment.

A3.2 modelled coverage

The modelled A3.2 biotope has an extent of 681 km^2 in the South Coast REC study area. This is about 12% of the study area.

A3.2 — Atlantic and Mediterranean moderate energy infralittoral rock (IR.MIR)

Level 4 (Biotope Complex)

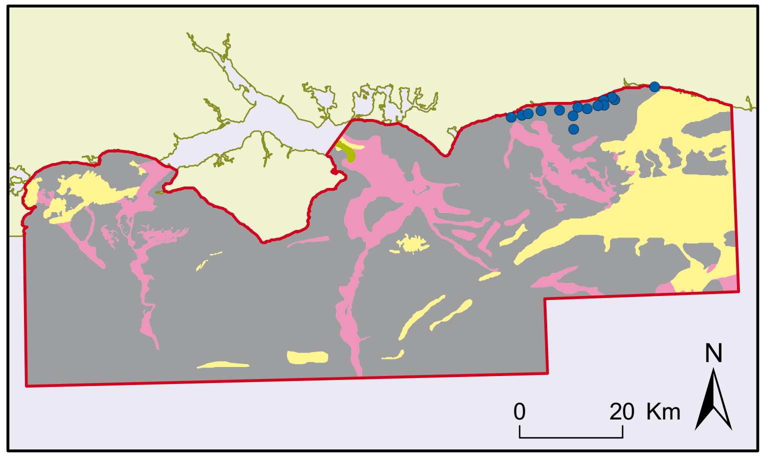
A3.21 = IR.MIR.KR
Kelp and red seaweeds (moderate energy infralittoral rock)

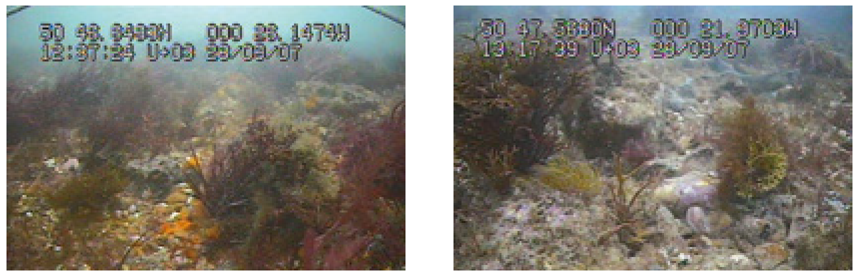
No sites were assigned to this Level 4 biotope complex, though it is likely to exist in the REC area as biotopes at the more detailed Level 5 were recorded. These observations generally showed a distinct lack of kelp, and hence they were assigned to the Level 5 biotope which has a more dominant red seaweed component.

The EUNIS description for this Level 4 biotope complex is as follows:

'Infralittoral rock subject to moderate wave exposure, or moderately strong tidal streams on more sheltered coasts. On bedrock and stable boulders there is typically a narrow band of kelp (Laminaria digitata) in the sublittoral fringe which lies above a *(Laminaria hyperborea)* forest and park. Associated with the kelp are communities of seaweeds, predominantly reds and including a greater variety of more delicate filamentous types than found on more exposed coasts (A3.11). The faunal component of the under storey is also less prominent than in A3.11'.

The SSFC inshore survey recorded this Level 4 biotope complex quite frequently on the Selsey — West Sussex coastal platform (Clarke, 2008). The MNCR equivalent of this habitat, IR.MIR.KR is recorded widely around the UK coastline, including many places along the South Coast (Connor *et al*, 2004).

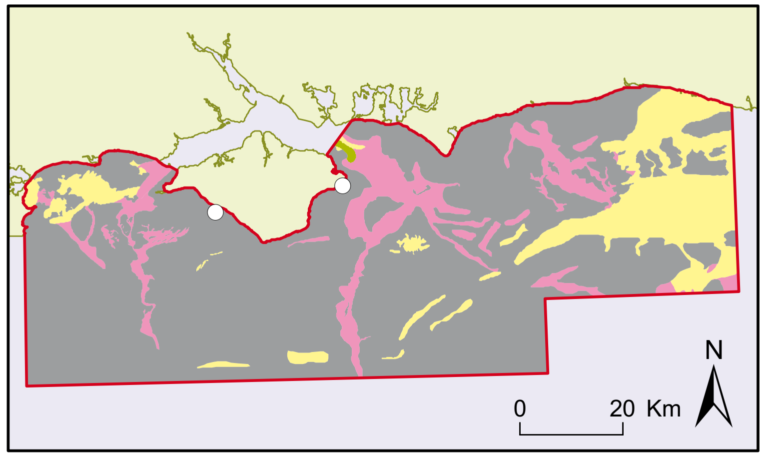




Records of A3.21 biotope from the SSFC inshore survey, with example seabed photos (SSFC Stations GV81 and GT82. Images © SSFC).

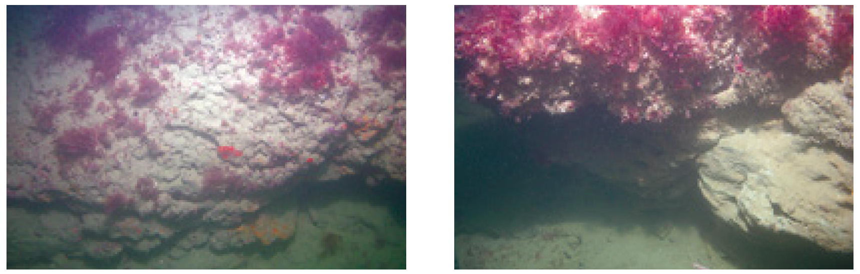
Level 5 (Biotope)

A3.215 = IR.MIR.KR.XFoR
Dense foliose red seaweeds on silty moderately exposed infralittoral rock



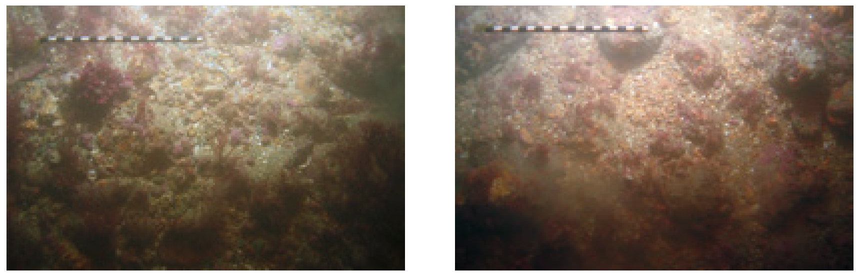
Location of stations assigned to the EUNIS A3.215 biotope (white circles), in relation to sea bed character.

This biotope is characterised by red seaweeds on silted rock. At Station 24 the rock occurred as an extensive, rugged outcrop, rising several metres above the seabed, but was clearly heavily silted. There was a good cover of foliose red algae, but no kelp. Faunal cover was sparse.

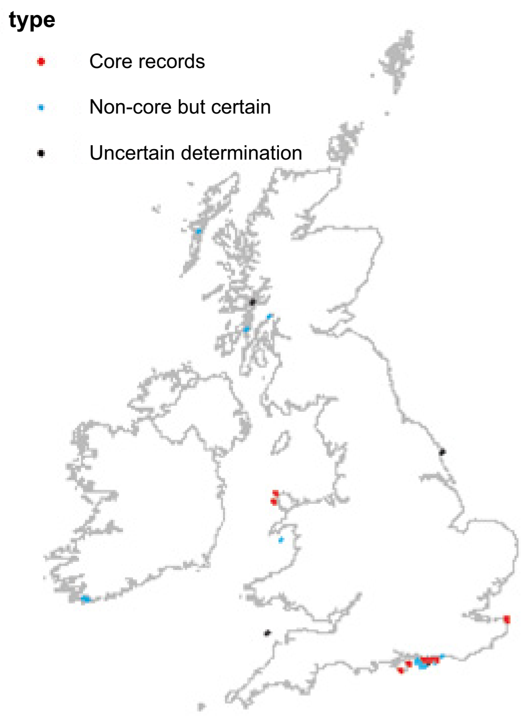


Seafloor image at Station 24 showing silted outcropping rock with dominance of red seaweed.

At Station 40 the rock was in the form of large cobbles, again supporting red algae, but also with some sponge and hydroid turf. The presence of silt significantly reduced the visibility on the video observations.



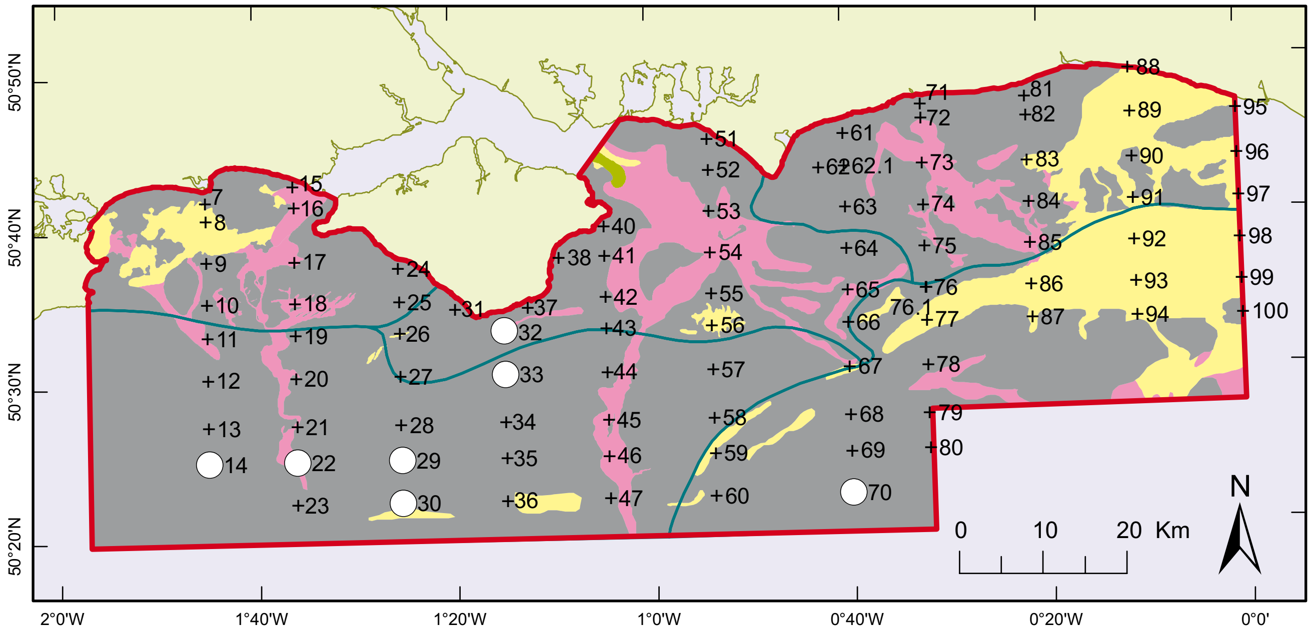
Seafloor image at Station 40 showing red seaweeds and some sponge on cobbles.



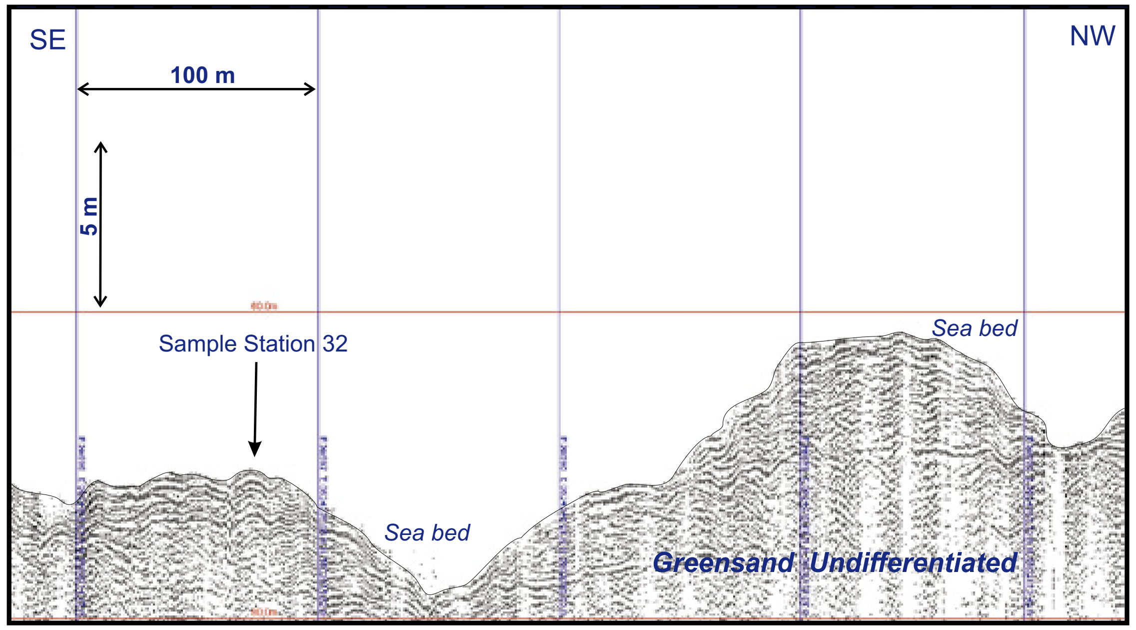
Distribution of KR.XFoR (= A3.215) biotope around UK shores. (Connor *et al* 2004. Internet version, accessed 24/11/2009. © JNCC).

It is notable that this particular biotope has a fairly restricted geographical distribution, with a cluster of known records appearing within the area covered by the South Coast REC.

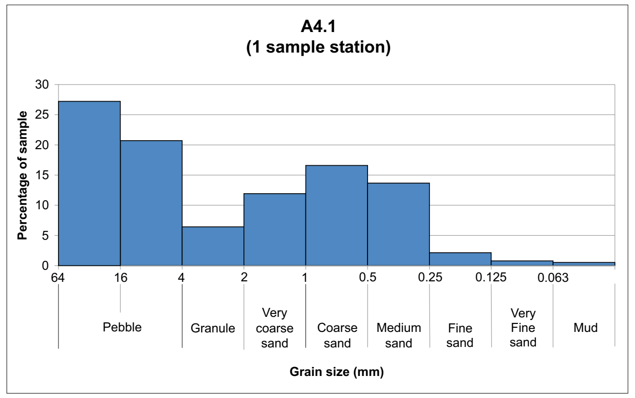
A4.1 — Atlantic and Mediterranean high energy circalittoral rock (CR.HCR)



Location of stations assigned to the EUNIS Level 3 Habitat A4.1 (white circles), in relation to sea bed character.



Seismic section.



Geophysical data

There are no South Coast REC 2007 Survey geophysical lines over the seven stations identified as A4.1. The seismic line section at station 32 is from a South Coast Dredging Association funded survey for regional environment assessment.

Solid Geology

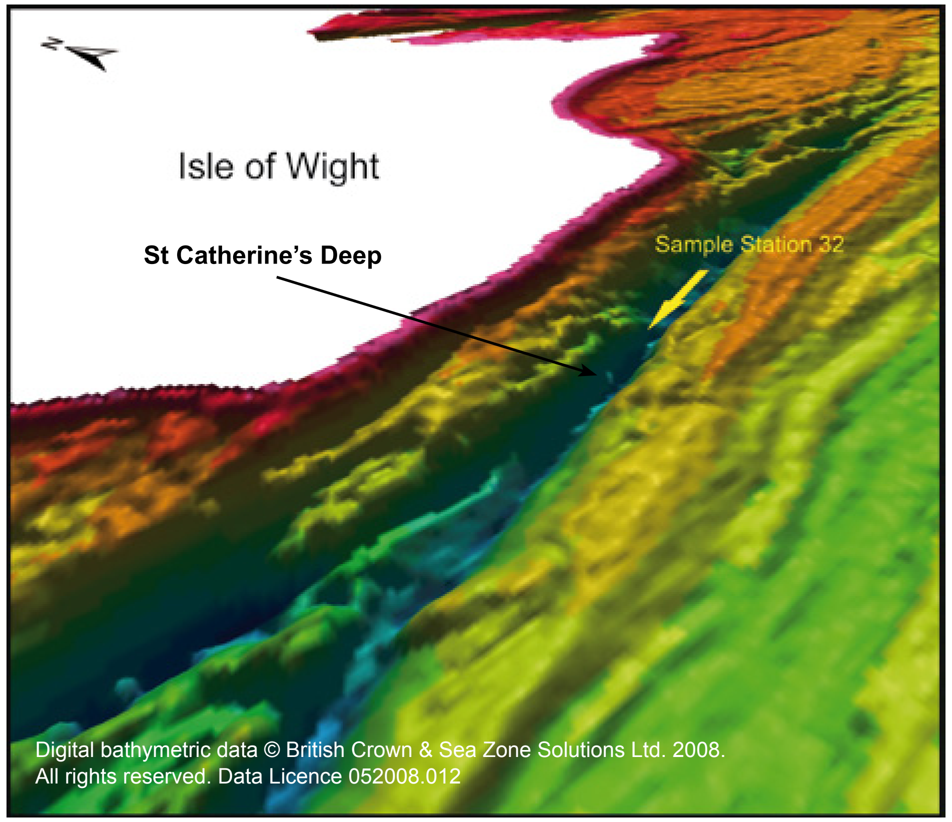
With the exception of station 32, which lies at the bottom St Catherine's Deep and rather anomalous in terms of the A4.1 biotope in the study area as a whole, all the A4.1 stations are on Chalk of the South Wight Platform region and Chalk on the terrace platform east of the Northern Palaeovalley channel. Station 32 is in Lower Greensand, which comprises grey-green and green glauconitic muddy sands, some are very fossiliferous. It also includes brown grey, silty muds, silts and fine sands and there may be thin conglomerates.

Sea bed character

Rock and thin sediment is interpreted as underlying all stations. Video and geophysical evidence indicates the sea bed is a thin coarse lag gravel with rock outcropping at or close to the surface. The angularity, abundance of cobbles and boulders, local and in-situ provenance indicates that much of the gravel 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.

A4.1 modelled coverage

The modelled A4.1 biotope has an extent of 2287 km² in the South Coast REC study area. It is the most extensive biotope covering 40% of the study area.

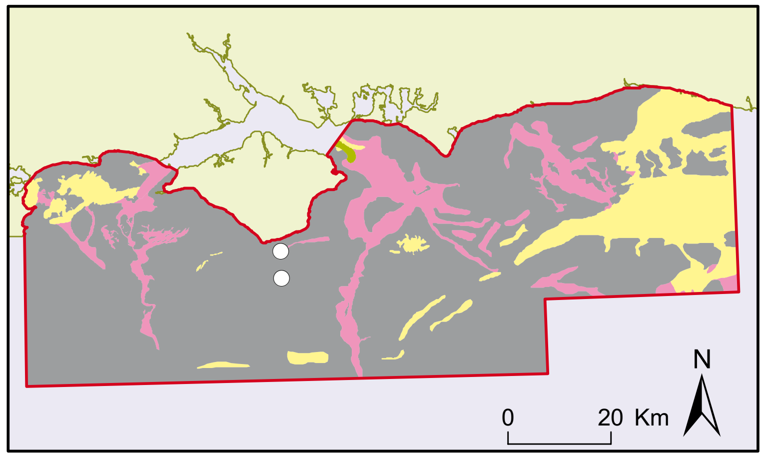


Sea bed morphology.

A4.1 — Atlantic and Mediterranean high energy circalittoral rock (CR.HCR)

Level 4 (Biotope Complex)

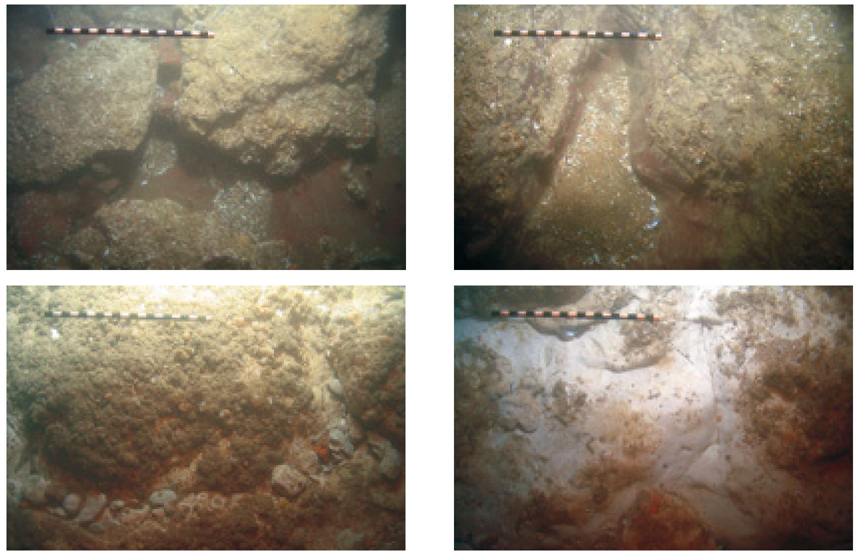
A4.11 = CR.HCR.FaT
Very tide-swept faunal communities on circalittoral rock



Location of stations assigned to the EUNIS A4.11 biotope (white circles), in relation to seabed character.

Stations 32 and 33 were assigned to this Level 4 biotope complex. Station 32 was in the St Catherine's deep, at 74 metres water depth, where there was bedrock (some red in colour) and boulders, with gravelly sand and pebbles. The rocks were encrusted with barnacles, ascidians and some sponge. Stone crabs (*Maja squinado* and *Ebalia* sp.) and some fish were seen.

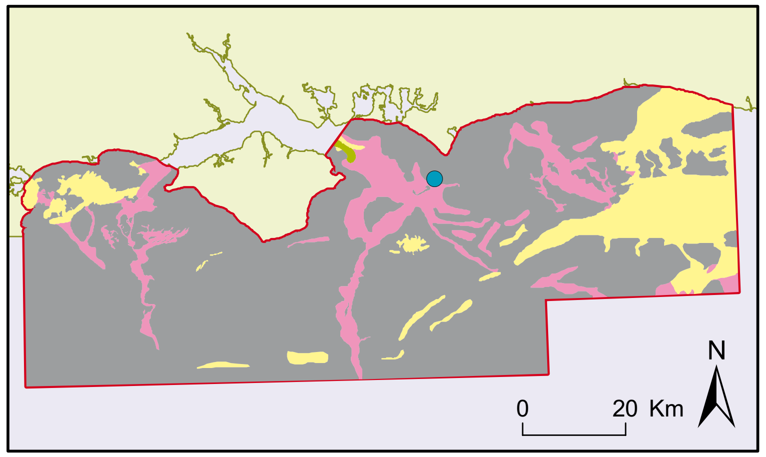
Station 33 was shallower, at 40 metres, with light coloured bedrock (chalk) and cobbles, mostly covered by a hydroid and bryozoan turf. Abundant *Urticina felina* and ascidians indicated there were strong currents. The whelk *Buccinum undatum* and the keelworm *Pomatoceros* sp, were also seen.



Seabed photos from Stations 32 (top) and 33 (bottom) showing bedrock with barnacles and faunal turf.

Level 4 (Biotope Complex)

A4.13 = IR.MIR.KR.XFoR
Mixed faunal turf communities on circalittoral rock

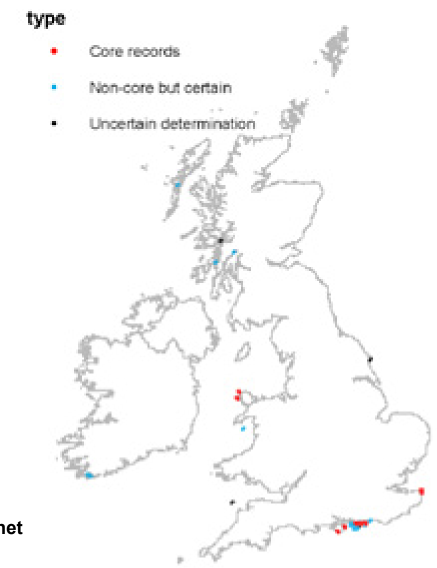


Records of A4.13 biotope from the SSFC inshore survey (SSFC Station GV42).

None of the South Coast REC sample sites were assigned to this Level 4 biotope complex, though five sites were assigned to the higher Level 5 biotope (see next column). However, the SSFC inshore survey recorded this biotope complex at one of the 270 sites sampled on the Selsey — West Sussex Coastal Platform.

The EUNIS description for this biotope complex indicates that it occurs on wave-exposed circalittoral bedrock and boulders, subject to tidal streams ranging from strong to moderately strong, and that the biota are characterised by a diverse range of hydroids, bryozoans and sponges, and the red seaweed *Dysidea fragilis* forming an often dense, mixed faunal turf.

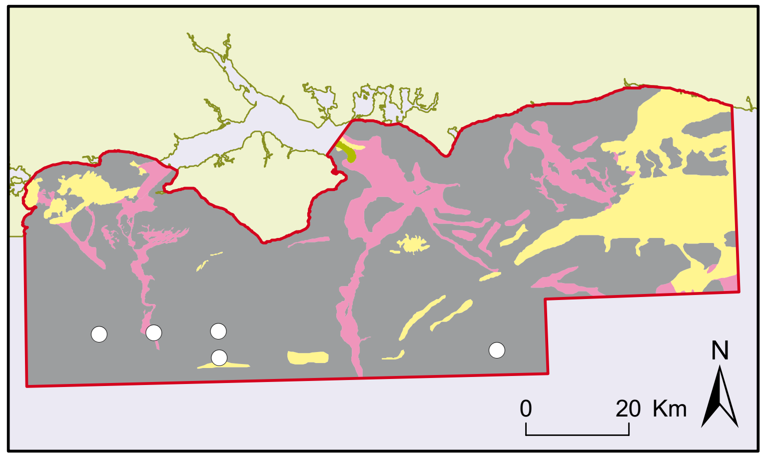
A cluster of records for the MNCR equivalent of this habitat, IR.MIR.KR.XFoR, occurs near the Isle of White.



Distribution of KR.XFoR (= A4.13) biotope around UK shores. (Connor *et al* 2004. Internet version, accessed 26/11/2009. © JNCC).

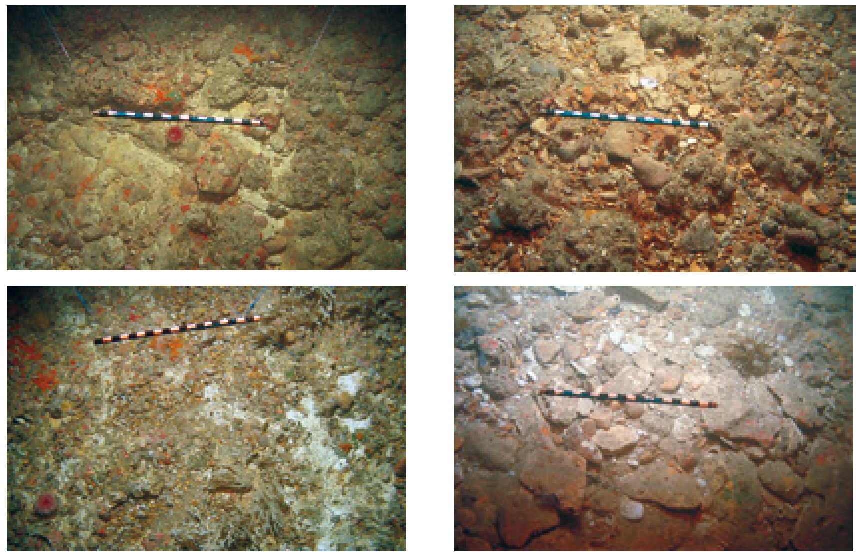
Level 5 (Biotope)

A4.134 = CR.HCR.Xfa.FluCoAs
Flustra foliacea and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock



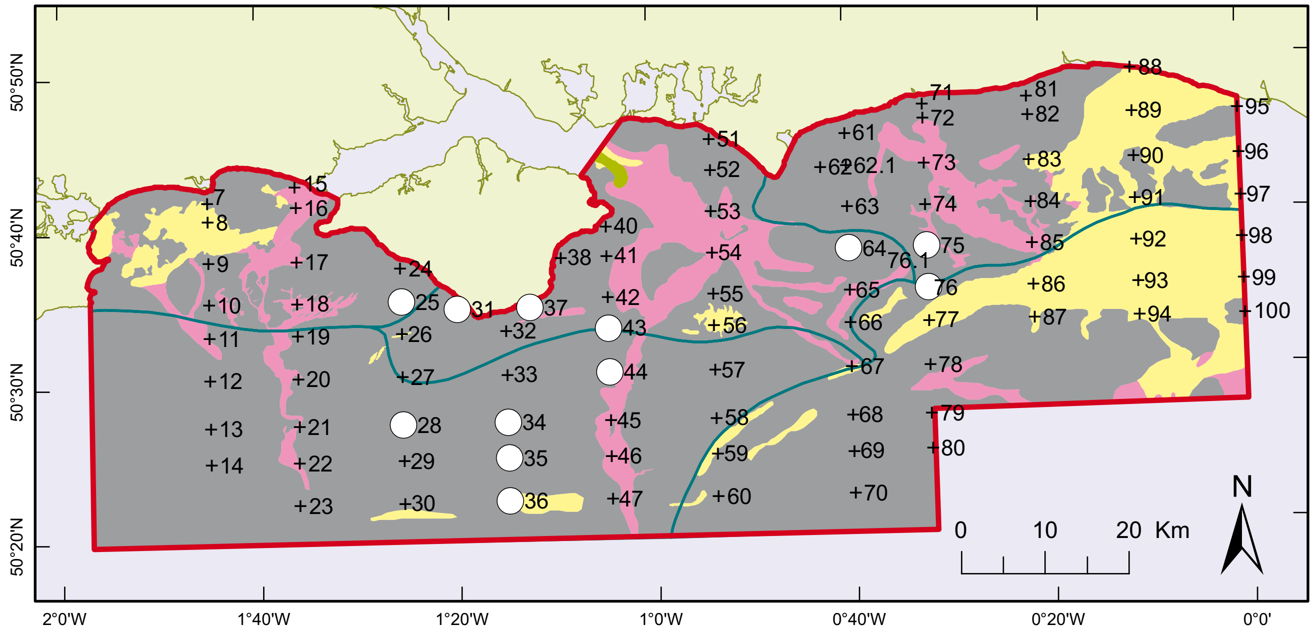
Location of stations assigned to the EUNIS A4.134 biotope (white circles), in relation to seabed character.

This biotope was recorded at Stations 14, 22, 29, 30 and 70. These all lie over chalk bedrock with Station 70 being divided from the others by the Northern Palaeovalley. All of these stations typically had a thin layer of mobile, coarse gravel and cobbles overlying bedrock, which was sometimes exposed and occasionally scoured bare. *Flustra*, encrusting sponges and *Urticina* were prominent in the video, with the stills showing an abundance of ascidians, usually occurring in aggregations covered by hydroids and hence quite cryptic. Starfish occurred occasionally (*Henricia* sp., *Asterias rubens, Crossaster papposus*) but no urchins or holothurians. There were also a few small stone crabs (*Ebalia* sp.)

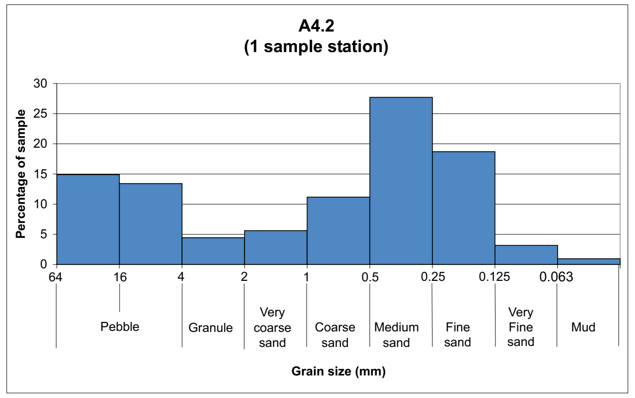


Seabed photos from Stations 14, 22, 30 and 70 (clockwise from top left) showing rock and thin sediment with mixed encrusting fauna.

A4.2 — Atlantic and Mediterranean moderate energy circalittoral rock (CR.MCR)



Location of stations assigned to the EUNIS Level 3 Habitat A4.2 (white circles), in relation to sea bed character.



Geophysical Data

South Coast REC 2007 Survey geophysical lines cover three of the twelve stations identified as A4.2. The geophysical line figure opposite is at the crossover of corridor 9 and 27 where sample station 64 is located.

Solid Geology

The A4.2 biotope is underlain by both Cretaceous and Tertiary rocks. Six stations are on the Chalk platform of Region 4. Three are near shore off the south coast of the Isle of Wight in Lower Greensand and Wealden Group. Whilst the remaining three are in an area of Barton Group rocks around Hooe Bank on the border of Region 2 and 3. Station 64 is one of these Barton Group based stations in an area with strong structural control with significant scarps and ridges.

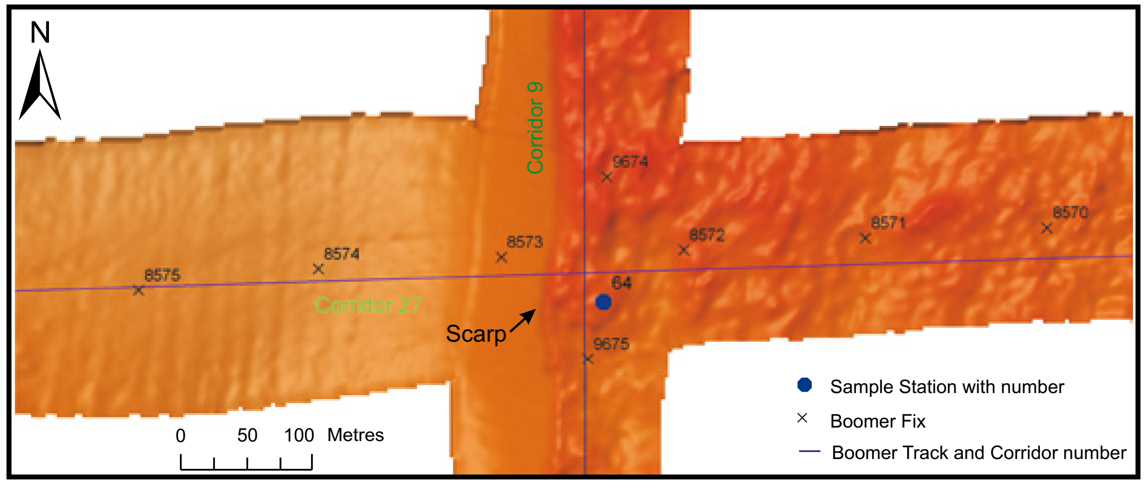
Lower Greensand comprises grey-green and green glauconitic muddy sands, some are very fossiliferous. It also includes brown grey, silty muds, silts and fine sands and there may be thin conglomerates. The Wealden Group comprises predominantly red mudstones with subordinate sandstones but also includes, in part, lenses of grey silty or sandy clay with plant debris and also fossil material such as crocodile, turtle and dinosaur bones. It also includes dark grey mudstones and siltstones with some sandstones in part. Tertiary Barton Group comprises silty muds with some beds of sand.

Sea bed character

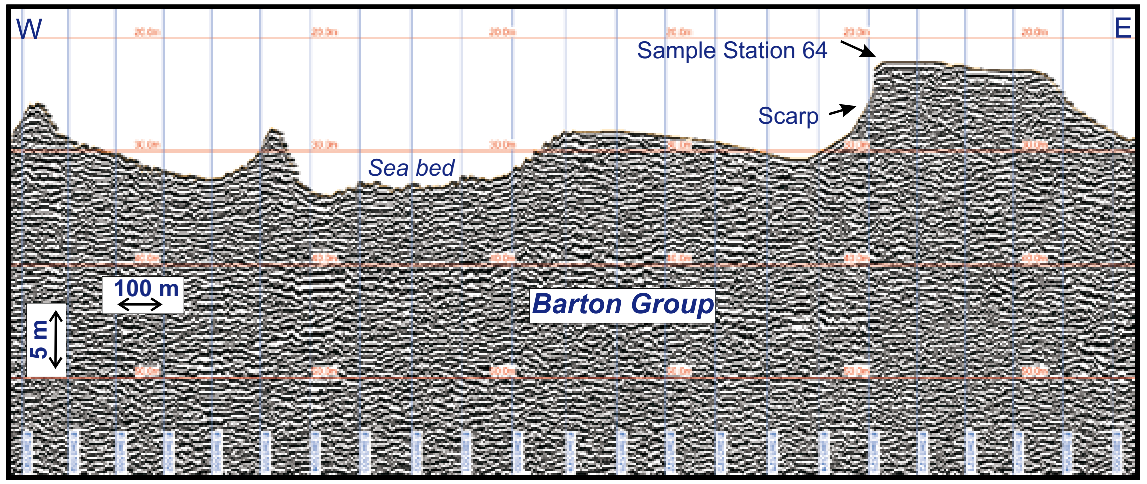
Rock and thin sediment is interpreted as underlying all stations. Video and geophysical evidence indicates the sea bed on the Chalk platform is a thin coarse lag gravel with rock outcropping at or close to the surface. The angularity, abundance of cobbles and boulders, local and in-situ provenance indicates that much of the gravel 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. All three stations around the Isle of Wight have extensive areas of exposed bedrock and some large boulders. Similarly with the Tertiary based stations, large boulders are lacking although station 64 has some cobbles.

A4.2 modelled coverage

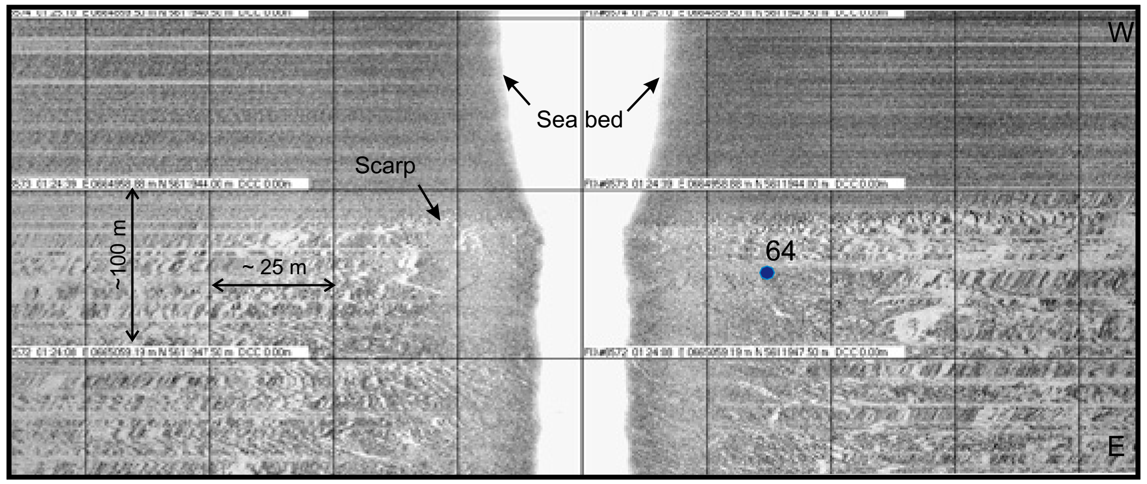
The modelled A4.2 biotope has an extent of 962 km² in the South Coast REC study area and covers 17% of the study area.



Multibeam swath corridors.



Seismic section.

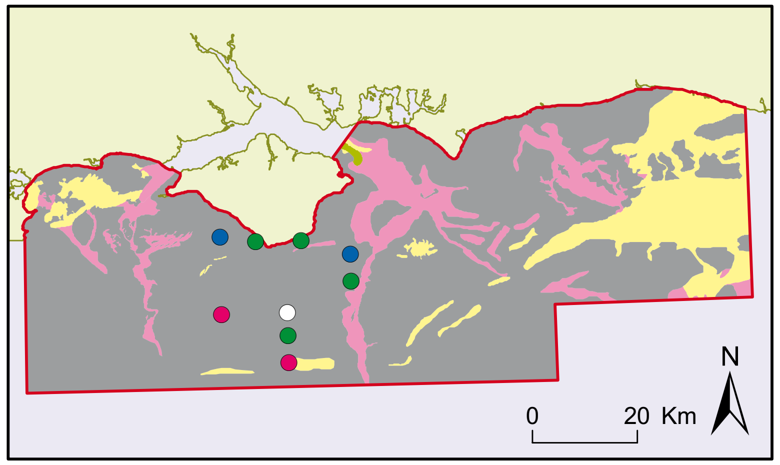


Sidescan sonar record.

A4.2 — Atlantic and Mediterranean moderate energy circalittoral rock (CR.MCR)

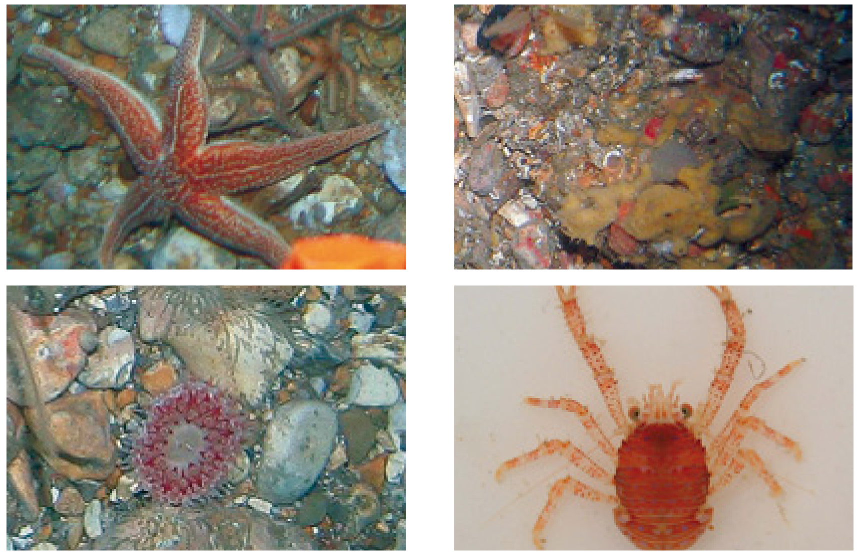
Level 4 ('Biotope Complex')

A4.21 = CR.MCR.EcCr
Echinoderms and crustose communities on circalittoral rock



Location of stations within the EUNIS A4.21 biotope complex, in relation to seabed character. Circle colours: white = A4.213, green = A4.214, blue = A4.2141, pink = A4.2144.

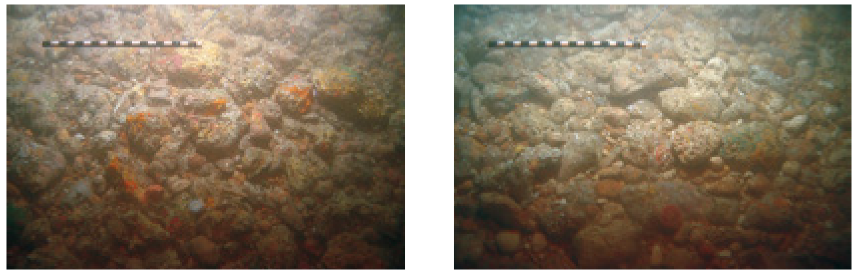
Nine of the South Coast REC stations were assigned under this biotope complex, mostly in association with chalk rock. The presence of characteristic species and life forms always enabled a more precise classification at EUNIS level 5 or 6, so A4.21 does not itself occur among the South Coast REC records. The EUNIS description is s follows: 'Mainly occurs on exposed to moderately wave-exposed circalittoral bedrock and boulders, subject to moderately strong and weak tidal streams. This habitat type contains a broad range of biological subtypes, from echinoderms and crustose communities (A4.21) to Sabellaria reefs (A4.22) and circalittoral mussel beds (A4.24)'.



Specimen photographs of *Asterias rubens* (top left), crustose community (top right), *Urticina felina* (bottom left) and *Galathea* sp. (bottom right, © MES).

Level 5 (Biotope)

A4.213 = CR.MCR.EcCr.UrtScr
Urticina felina and sand-tolerant fauna on sand-scoured or covered circalittoral rock

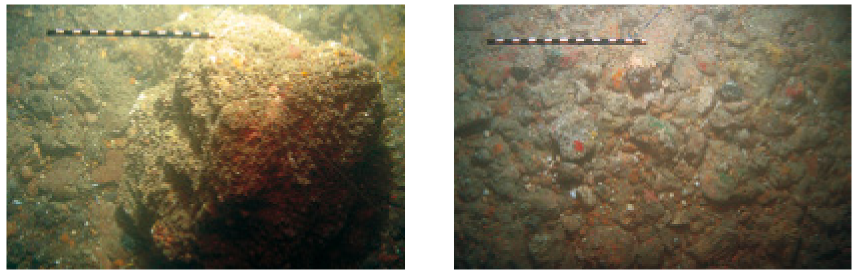


Seabed images from Station 34 showing cobbles & pebbles thinly overlaying bedrock. The substrate is encrusted with sponges and barnacles.

Recorded at Station 34, this biotope typically occurs in tide-swept areas where rock is associated with mobile sand or gravel, and is noted for its scour-tolerant species. It frequently occurs as a narrow band at the rock-sediment interface of outcropping rock. However, in this location it appeared to be more widespread due to the general flatness of the chalk platform. Superficially the seabed looks a poorly sorted mixture of cobble, pebble and gravel, but occasional exposures of chalk bedrock were seen. The cobbles are rounded, some smooth (like flint nodules) and some pitted. Barnacles were common; the small squat-lobster *Galathea* and the gastropod *Calliostoma* were recorded.

Stations 31 and 37 were very close to the southern shore of the Isle of Wight and showed exposed

A4.214 = CR.MCR.EcCr.FaAlCr
Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock

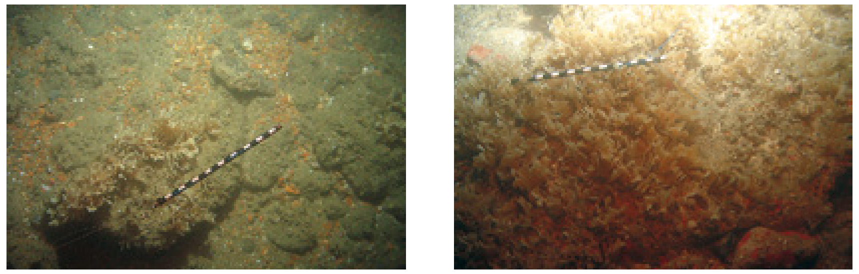


Seabed images from Stations 37 (left) and 35 (right) showing exposed bedrock formations, overlain with boulders, cobbles and gravel, with thick covering of faunal turf and occasional tufts of red algae.

rock formations with thick faunal 'turf', while stations 35 and 44 were on the chalk platform where the rock was covered by coarse (cobble/pebble) substrate and faunal cover was more patchy. Small ascidians, the worm *Bispira* an the crab *Maja squinado* featured on the nearshore stations while sponges and hydroid turf were more prominent offshore.

Level 6 ('Sub-biotope')

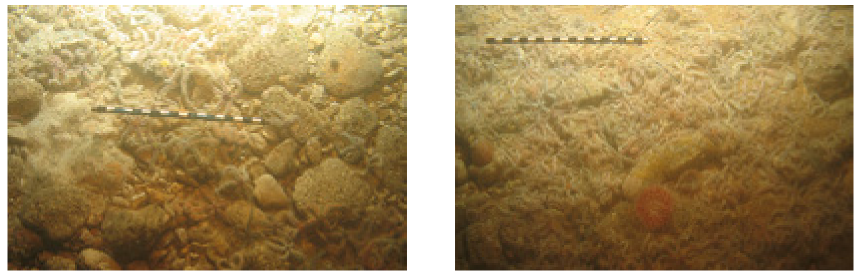
A4.2141 = CR.MCR.EcCr.FaAlCr.Flu
Flustra foliacea on slightly scoured silty circalittoral rock



Seabed images from Stations 25 (left) and 43 (right) showing silted rock outcrops with boulders, cobbles and some gravel. *Flustra foliacea* colonises upper surfaces.

This sub-biotope occurs on the upper surfaces of exposed rock and features moderate to heavy covering of the foliose bryozoan *Flustra foliacea* (Hornwrack). It was found at Station 25 on dark coloured mudstone and Station 43 on much lighter coloured sandstone. Both stations featured rock exposures in a series of ridges of about 1 m elevation. Sedentary taxa included encrusting sponges, anemones and the bryozoan *Pentapora foliacea* (Ross coral), while motile forms included the starfish *Henricia* sp. and the gastropod *Calliostoma* sp.

A4.2144 = CR.MCR.EcCr.FaAlCr.Bri
Brittlestars on faunal and algal encrusted exposed to moderately wave-exposed circalittoral rock



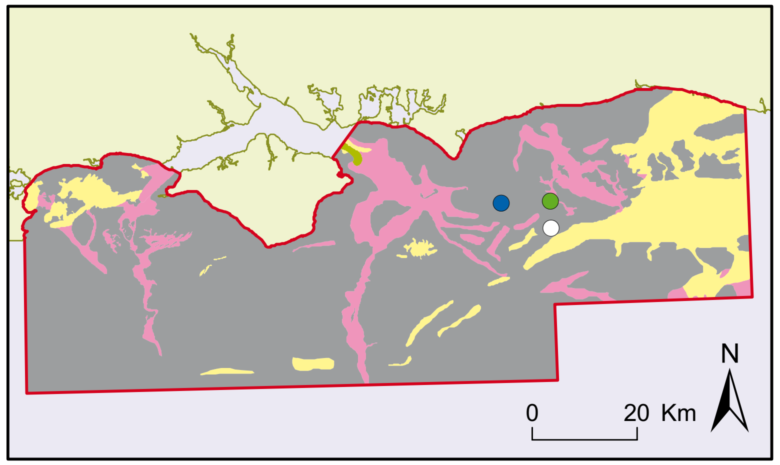
Seabed images from Stations 28 (left) and 36 (right) showing brittlestars on exposed rock and cobble surfaces with patchy encrusting life forms.

This second sub-biotope was recognised on the basis of having dense aggregations of the brittlestar *Ophiothrix fragilis*, although at these two stations the cover of encrusting fauna was much reduced, but still present in patches (not visible in the selected photographs). The bryozoan *Alcyonidium diaphanum* and the anemone *Urticina felina* were among the sessile forms while the sun-star *Crossaster paposus* and hermit crabs and gastropods were among the motile firms.

A4.2 — Atlantic and Mediterranean moderate energy circalittoral rock (CR.MCR)

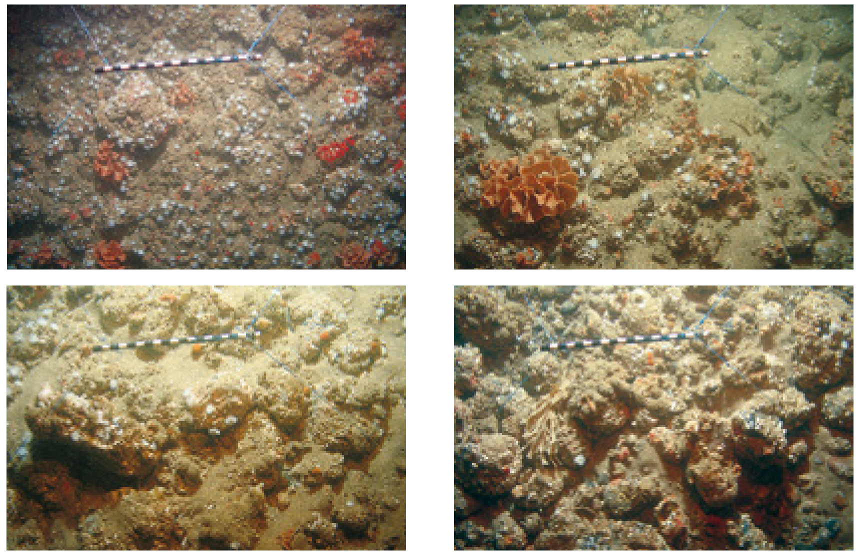
Level 4

A4.22 = CR.MCR.CSab
Circalittoral Sabellaria reefs (on rock)



Location of stations assigned to EUNIS A4.22 in relation to seabed character. Circle colours: white = A4.22, green = A4.23, blue = A4.241.

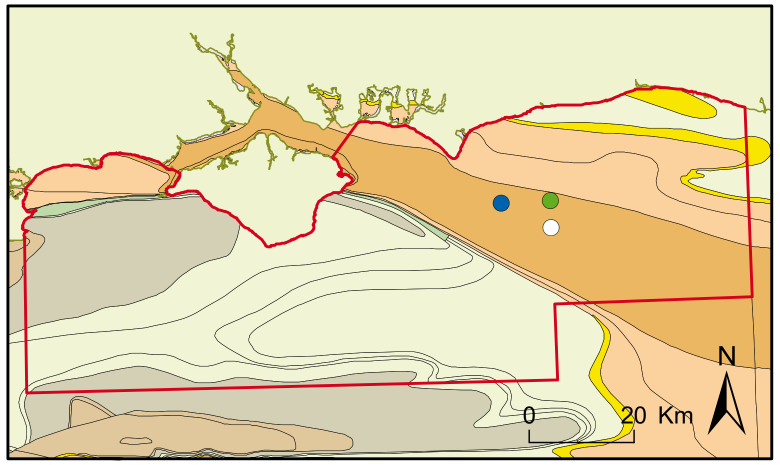
This biotope complex occurred at a single station, 76 M (=76.1) the small mound recognised during the acoustic survey, adjacent to Station 76. The ground here can generally be described as consolidated cobble rubble with a high content of mobile sand. The upper faces of the cobbles were colonised by barnacles, and there were relatively dense patches of the small white anemone, *Actinothoe* sp. and frequent occurrences of the Ross coral, *Pentapora fascialis*. Small clumps of *Sabellaria* tubes were observed among the cobbles.



Seabed photographs from Station 76 M showing consolidated cobble rubble (top left), *Pentapora, Actinothoe* and *Sabellaria* tubes (top right), Encrusting barnacles (bottom left) and *Flustra foliacea* (bottom right).

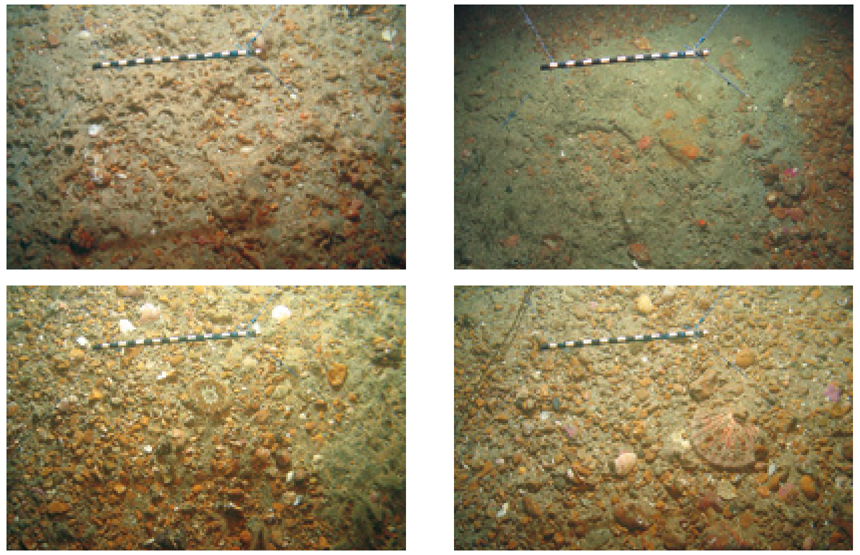
Level 4

A4.23 = CR.MCR.SfR
Soft rock communities



As of Figure 7.46, but showing the stations in relation to solid geology.

This biotope complex was assigned at station 75, but is likely to be more widespread in the REC area reflecting the dominance of the softer rock types, such as chalk and the sand- and mud-stones. Flat bedrock exposures at the seabed were characterised by a honeycomb of small holes, indicating he presence of boring bivalve molluscs (e.g. the paddock, *Pholas dactylus*). Thin layers of mobile sandy and lag-gravel smothered and/or scoured the rock surface, hence only a few scour tolerant taxa were recorded, notably *Urticina* and *Nemertesia*. The king scallop *Pecten maximus* and the Queen scallop *Aequipecten opercularis*.

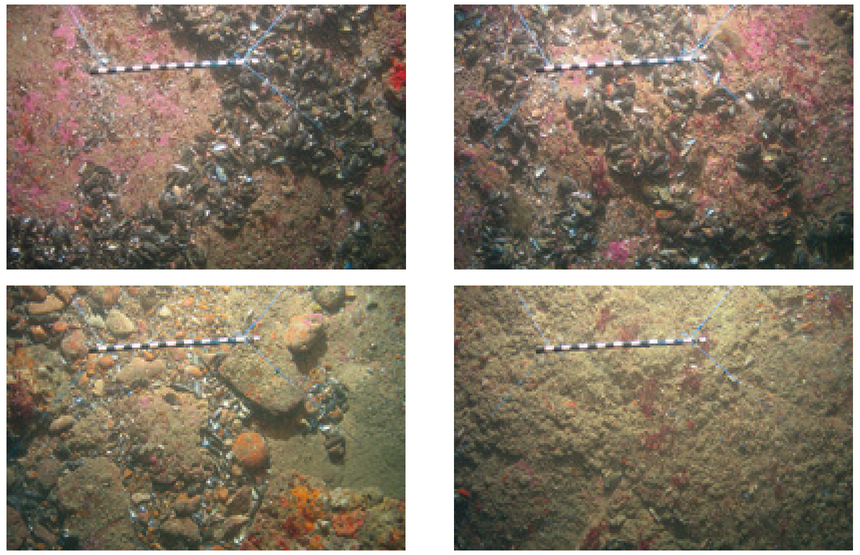


Seabed photographs from Station 75 showing honeycomb of holes in soft rock (top left and right), *Urticina felina* (bottom left) and *Pecten maximus* (bottom right).

Level 5

A4.241 = CR.MCR.CMus.CMyt
Mytilus edulis beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock

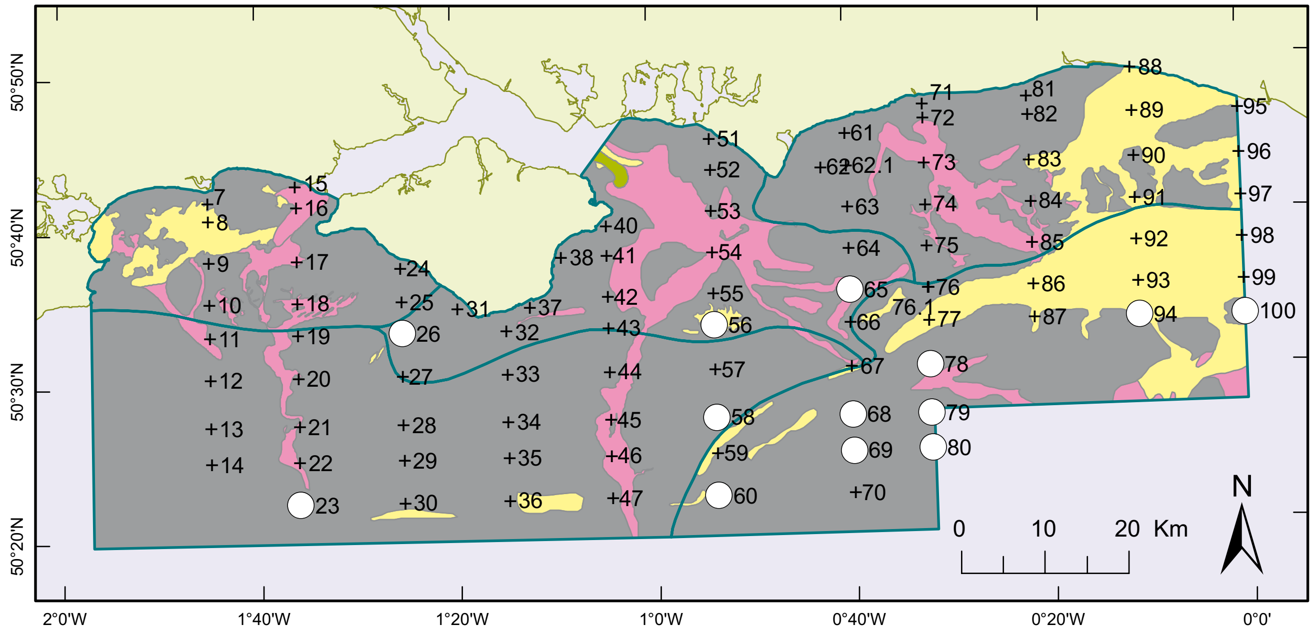
This biotope complex was assigned at Station 64 which featured exposed bedrock and cobbles supporting beds of the mussel *Mytilus edulis.* Although not listed in the EUNIS description of this biotope, red and coralline algae, and encrusting sponges were prominent; as detailed in the EUNIS description for the related biotope A4.242 which features the mussel *Musculus discors*. Large aggregations of ascidians covered many upper surfaces of the rock, giving the appearance of a 'fur covering' in seabed images.



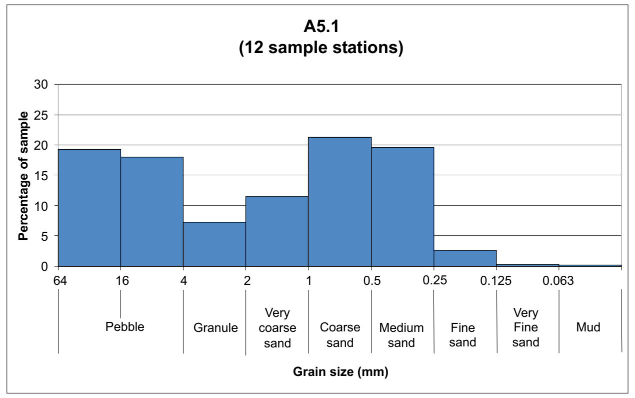
Seabed photographs from Station 64 showing clumps of mussels, with red and coralline alga (top left and right), Encrusting sponge on rocks (bottom left) and bedrock with a 'fur covering' of ascidians (bottom right).

Marine Aggregate Levy Sustainability Fund MALSF

A5.1 — Sublittoral Coarse Sediment (SS.SCS)



Location of stations assigned to the EUNIS Level 3 Habitat A5.1 (white circles), in relation to seabed character.



Geophysical Data

South Coast REC 2007 Survey geophysical lines cover six of the twelve stations identified as A5.1. The geophysical line figure opposite is on corridor 18 where sample station 94 is located.

Solid Geology

The A5.1 biotope is underlain by both Cretaceous and Tertiary rocks. One station –58, is on the Chalk platform of Region 4.

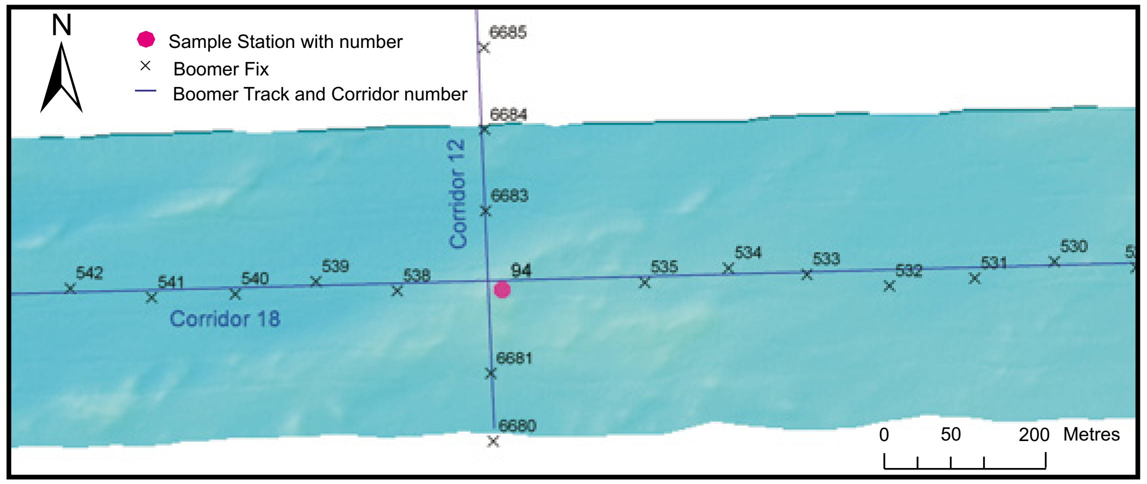
Station 26 is on the Wealden–Lower Greensand boundary south west of the Isle of Wight. Station 56 is also on Lower Greensand at the Overfalls within the Monocline Rampart Enclosure. Lower Greensand at the southern margin of the South Wight Platform underlies station 23. The remaining eight stations are either within or at the margins of the Northern Palaeovalley underlain by Chalk and Tertiary rocks.

Sea bed character

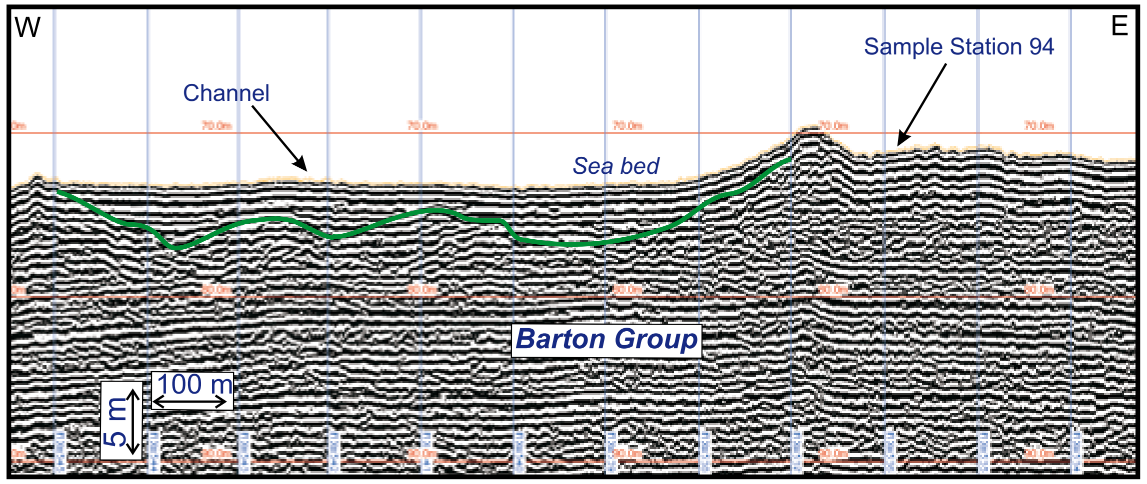
Although virtually all stations are classified as rock and thin sediment from geophysical evidence, the video and sample station data shows the sea bed to be a bimodal sandy gravel with medium to coarse sand and pebbles. However even though the sediments are not well sorted they appear to have undergone some degree of reworking and transport, not unlikely as the majority of them are associated with the main channel of the Northern Palaeovalley. Flint is the most common gravel component

A5.1 modelled coverage

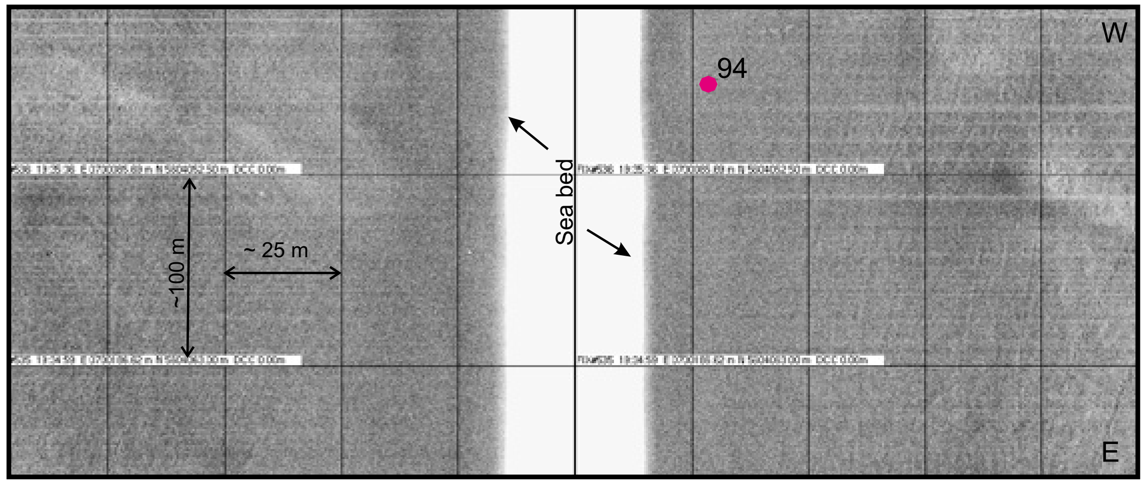
The modelled A5.1 biotope has an extent of 648 km² in the South Coast REC study area and covers 11% of the study area.



Multibeam swath corridor.



Seismic section.

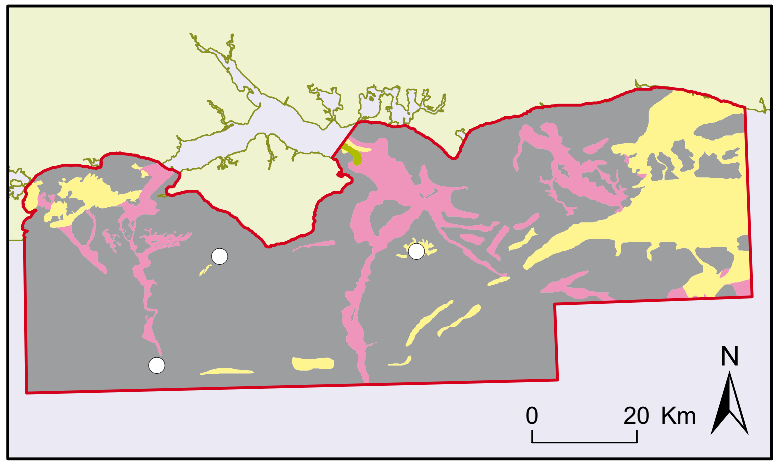


Sidescan sonar record.

A5.1 — Sublittoral Coarse Sediment (SS.SCS)

Level 5 (Biotope)

A5.14 = SS.SCS.CCS
Circalittoral coarse sediment

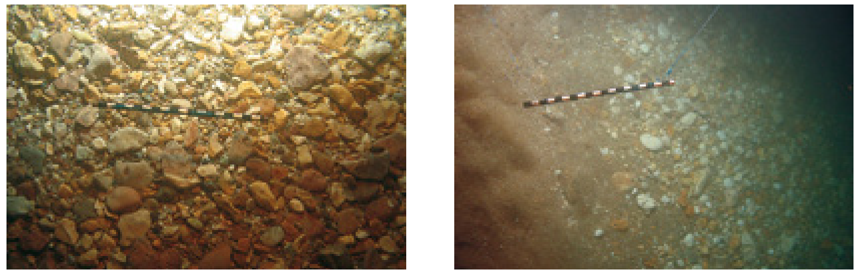


Location of stations assigned to the EUNIS A5.14 biotope (white circles), in relation to seabed character.

This is a common biotope complex, covering a total of thirteen of the South Coast REC stations. Three stations (23, 26 & 56) were assigned at this level (4), and the other ten at higher levels (5 & 6). In the 200411 version of EUNIS, this biotope complex had the code A5.13.

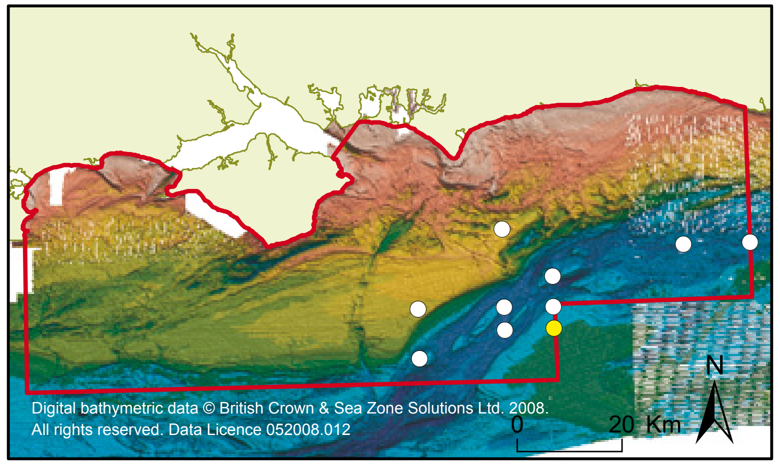
The substrate was typically poorly sorted, mobile, lag gravel (including cobbles and pebbles) with sand, the latter sometimes occurring as superficial sheets. Selection of the 'coarse' sediment class reflects a lack of silt/mud, which is a characteristic of 'mixed' sediment.

These stations were effectively barren of epifauna, with only a few small gadoid fish and occasional hydroid tufts observed in video and still images. There was no evidence of emergent fauna (e.g. worm tubes). Grab samples were also depauperate, with only 31 individuals in 16 taxa recorded over all three stations. These were mostly errant worms, with 10 of the 21 individuals recorded being *Saccocirrus papillocercus*. The bivalve *Goodallia triangularis* occurred at station 26.



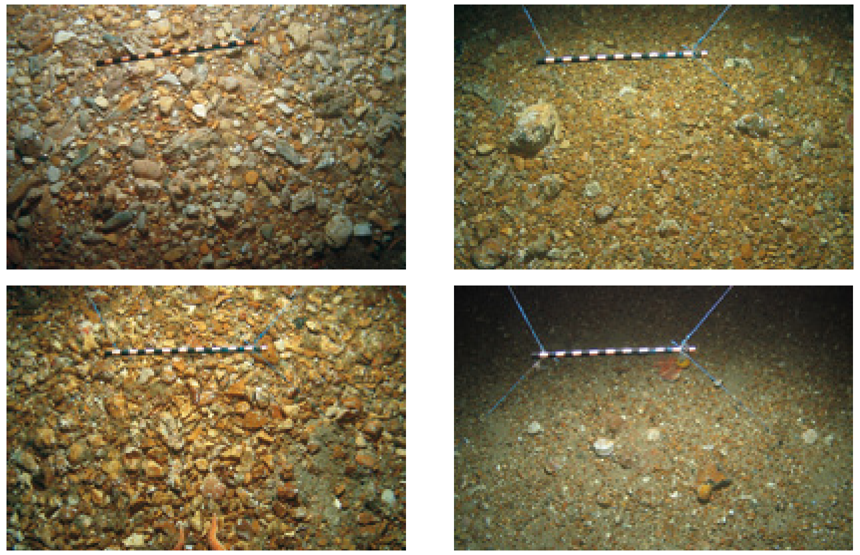
Seabed photos from Stations 23 (top) and 56 (bottom) with examples of typical fauna (right).

A5.141 = SS.SCS.CCS.PomB
Pomatoceros triqueter with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles



Records of A5.141 (white circles) and A5.141(1) (yellow circle) in relation to seabed topography.

This biotope was assigned at nine stations (58, 65, 68, 69, 78, 79, 94, 100), seven of which were on the floor of the Northern Palaeovalley, and two on its margins. The sediment appeared to be better sorted than for A5.14, with a dominance of 'fluvial' type sub-rounded, golden coloured gravel particles, occasional cobbles and little sand. The keelworm *Pomatoceros* and barnacles encrusted the larger stone particles and scallop shells, and were characteristic of this biotope. Other epibenthic megafauna seen in video and stills included the starfish *Asterias rubens* and *Crossaster papposus*, the anemone *Urticina felina*, the hydroid *Hydrallmania falcata* and the queen and king scallop, *Aequipecten opercularis* and *Pecten maximus*.



Seabed photos for a transect of stations running west to east along the floor of the northern palaeovalley: stations 60 (top left), 68 (top right), 79 (bottom left) and 100.

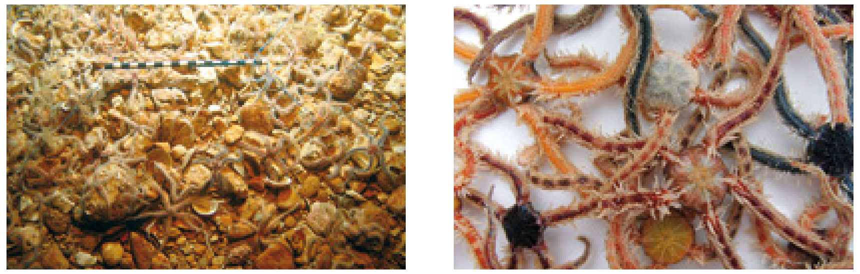
Level 5 & Level 6 (Sub-biotope)

The grab samples from the A5.141 stations were rich in fauna, with 280 different taxa identified. The squat lobster *Galathea intermedia* was the most abundant species, being common at all stations, while the long clawed porcelain, *Pisidia longicornis*, was only abundant at Station 69 and 79.
Other commonly occurring taxa included the ophiuroid *Amphipholis squamata*, the worm *Laonice bahusiensis*, and the green sea urchin *Echinocyamus pusillus*.

Specimens of *Galathea intermedia* (top left), *Pisidia longicornis* (top right), *Amphipholis squamata* (bottom left) and *Laonice* sp. (bottom right). (© MES).

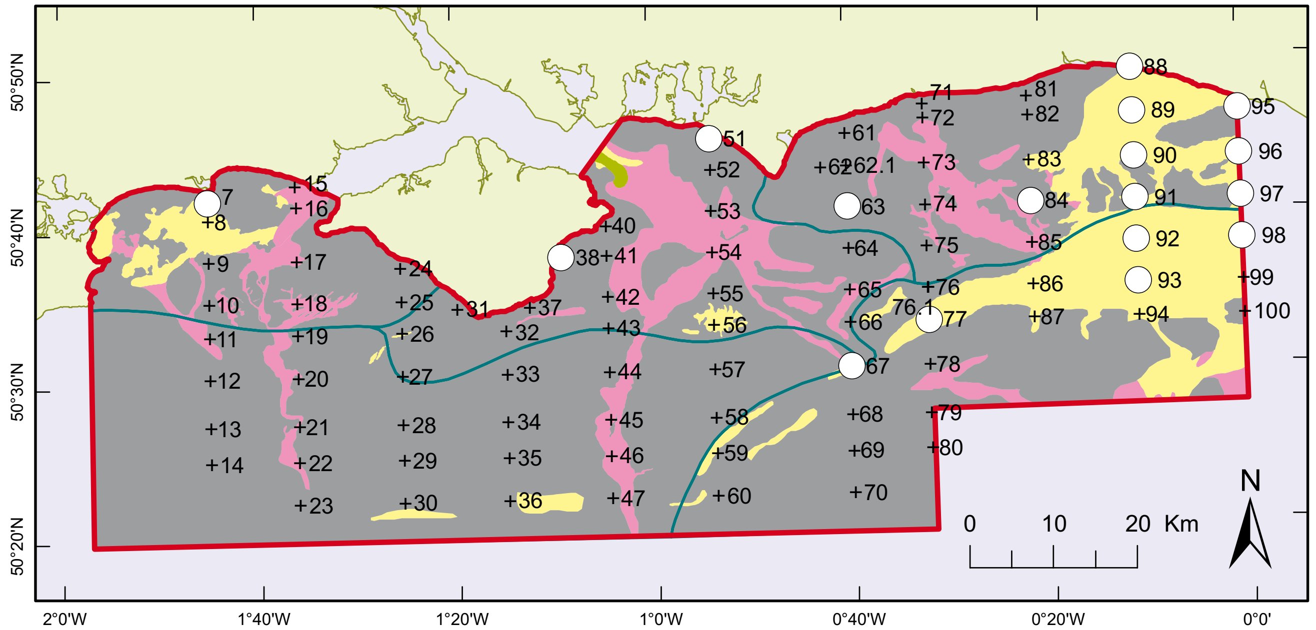
A5.141(1) = SS.SCS.CCS.PomB.(Oph)
Ophiothrix fragilis beds overlying circalittoral cobbles and pebbles encrusted with Pomatoceros, barnacles and bryozoan crusts

At station 80, a bed of *Ophiothrix fragilis* was found in association with A5.141. Currently, EUNIS only lists Ophiothrix beds in associatoin with mixed sediment, not coarse sediment; hence we propose this new sub-biotope. The ophiuroids were present at densities in the order of 100 individuals per square metre in seabed photographs from this site.

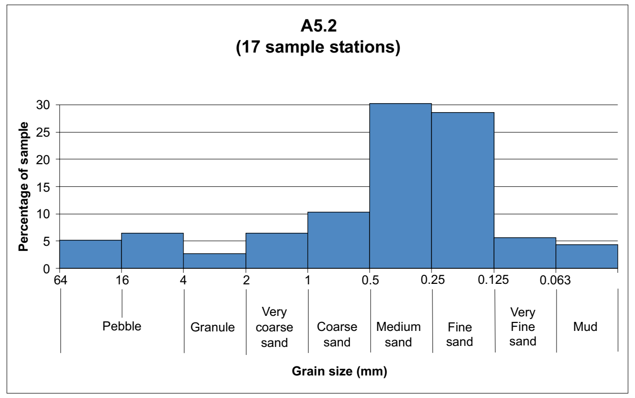


Seabed photo from Station 80s (left) and specimen photograph of *Ophiothrix fragilis* (right, © MES).

A5.2 — Sublittoral Sand (SS.SSa)



Location of stations assigned to the EUNIS Level 3 Habitat A5.2 (white circles), in relation to seabed character.



Geophysical Data

South Coast REC 2007 Survey geophysical lines cover eleven of the seventeen stations identified as A5.2. The geophysical line figure opposite is on corridor 26 where sample station 91 is located.

Solid Geology

The A5.2 biotope is underlain by both Cretaceous and Tertiary rocks with the latter underlying the largest number of stations.

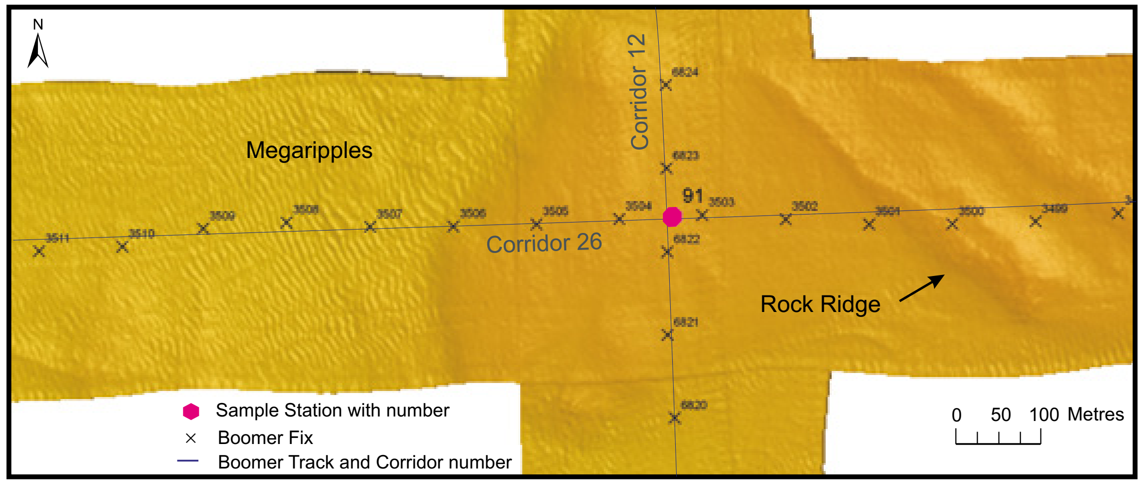
Although A5.2 is a sandy biotope solid geology can impact the occurrence of sand by controlling the alignment of sand between rock ridges or rock based channel margins such as the Northern Palaeovalley.

Sea bed character

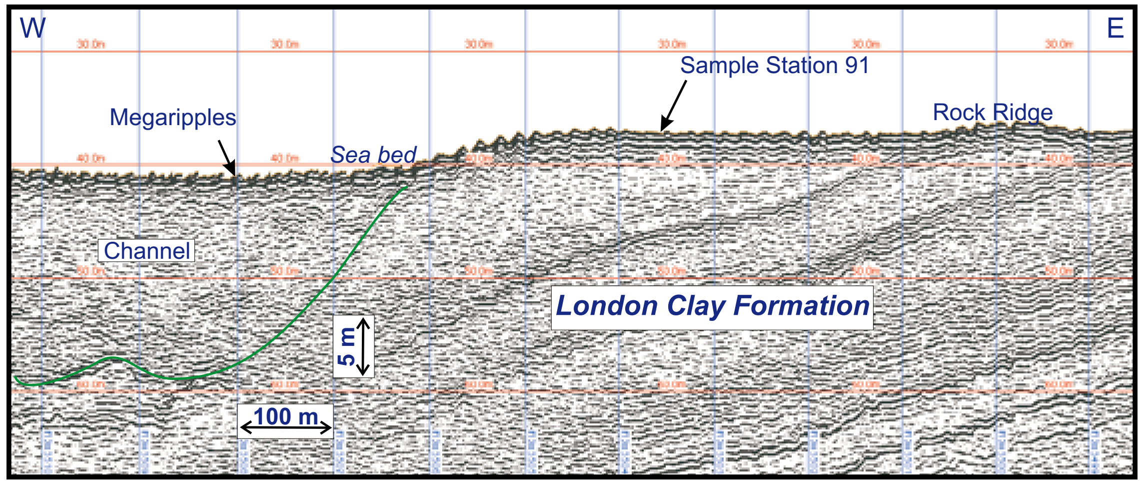
The majority of the sample stations are on substrates that are classified as sandy sediment. Only one station–7, is west of the Isle of Wight, all others are east of the Isle of Wight associated with the sand sheets on the Selsey–West Sussex platform which have well developed megaripples and minor sand waves with cross profile asymmetry to the east and the sand banks of the Northern Palaeovalley Banks. These are the result of eastern transport of sediment against the Palaeovalley margin which has created two large linear sand banks. The outer bank is well developed with a single virtually straight crest line over 16 km long which is attached at its eastern end to the coastal platform. The inner bank in total length is about 28 km.

A5.2 modelled coverage

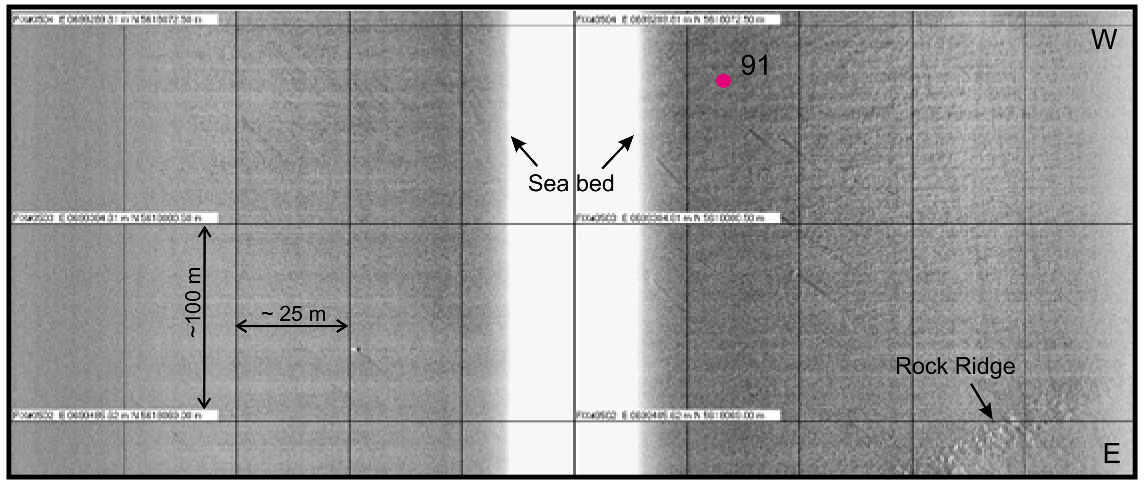
The modelled A5.2 biotope has an extent of 550 km^2 in the South Coast REC study area and covers 10% of the study area.



Multibeam swath corridors.



Seismic section.

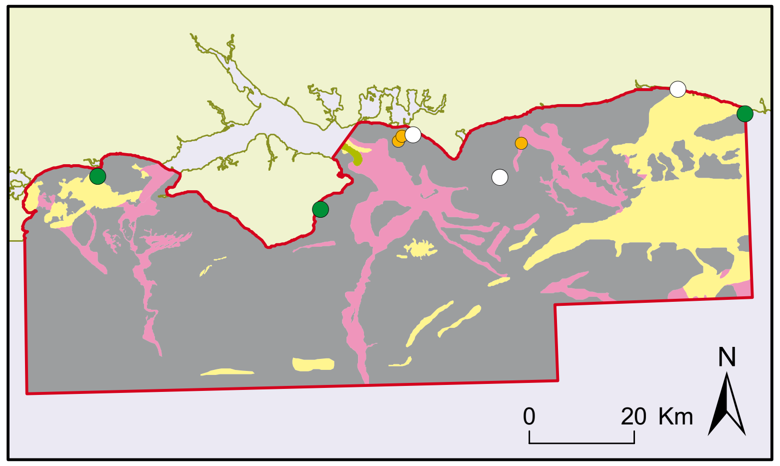


Sidescan sonar record.

A5.2 — Sublittoral Sand (SS.SSa)

Level 4 (Biotope Complex)

A5.23 = SS.SSa.IFiSa
Infralittoral fine sand

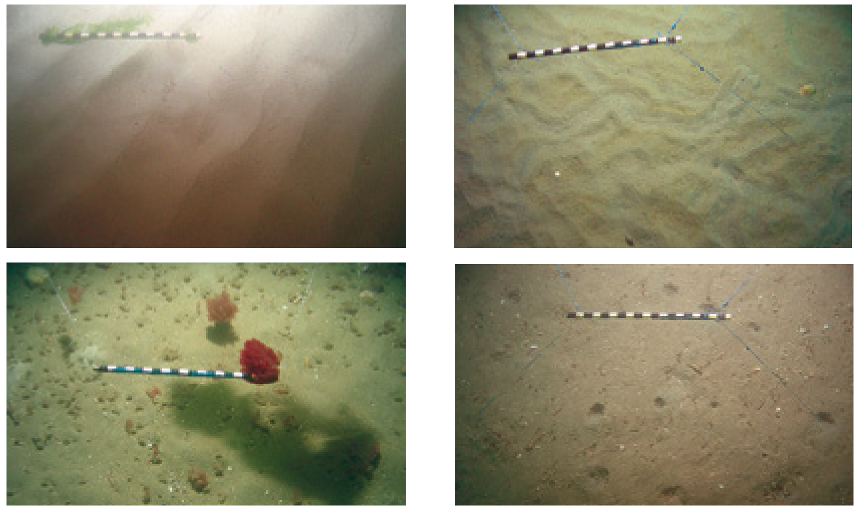


Location of stations assigned under the A5.23 biotope complex, in relation to seabed character. Circle colours: white = A5.231, green = A5.234, gold = A5.23 from SSFC inshore survey.

This is a common biotope complex, covering a total of thirteen of the South Coast REC stations. Three stations (23, 26 & 56) were assigned at this level (4), and the other ten at higher levels (5 & 6). In the 200411 version of EUNIS, this biotope complex had the code A5.13

This is a relatively uncommon biotope complex in the South Coast REC survey, with only six stations, five of which were on the coast. All were assigned to higher Level 5 biotopes. The SSFC inshore survey recorded this complex at only 3 of the 270 stations sampled (Clarke, 2008).

Seabed images showed clean, rippled sand, sometimes having a hard, compacted appearance, and rarely including pebbles and small cobbles.



Seabed photos from Stations 51 (top left), 88 (top right), 7 (bottom left) and 95 (bottom right).

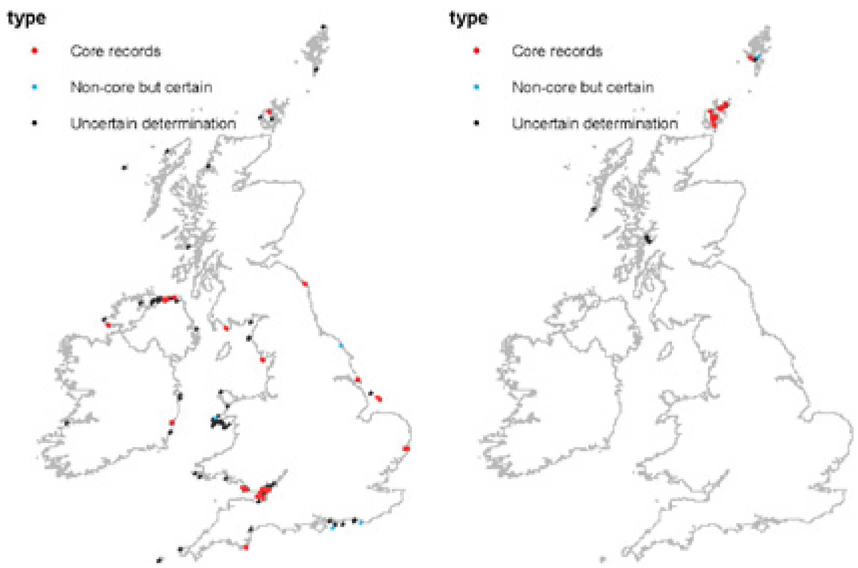
Level 5 (Biotope)

A5.231 = SS.SSa.IFiSa.IMoSa
Infralittoral mobile clean sand with sparse fauna

EUNIS describes this biotope complex as ‘clean sands which occur in shallow water, either on the open coast or in tide-swept channels of marine inlets. The habitat typically lacks a significant seaweed component and is characterised by robust fauna, particularly amphipods *(Bathyporeia)* and robust polychaetes including *Nephtys cirrosa* and *Lanice conchilega*’.

Specimen photographs of *Spiophanes* (left) and *Nephtys* (right) (© MES).

Stations 51, 63, 88 were assigned to this biotope. Seabed images were typically void of life-forms, though a few gastropods *(Hinia)* and hermit crabs were seen at Station 88. Grab samples contained little fauna, with the three stations in total yielding 73 errant worms, eight amphipods and one bivalve, gastropod and hermit crab. The most common worms were *Spiophanes* and *Nephtys* species.



Distribution maps for IFiSa.IMoSa (= A5.231) (left) and IFiSa.TbAmPo (= A5.234) (right) (Connor *et al* 2004. Internet version, accessed 26/11/2009, © JNCC).

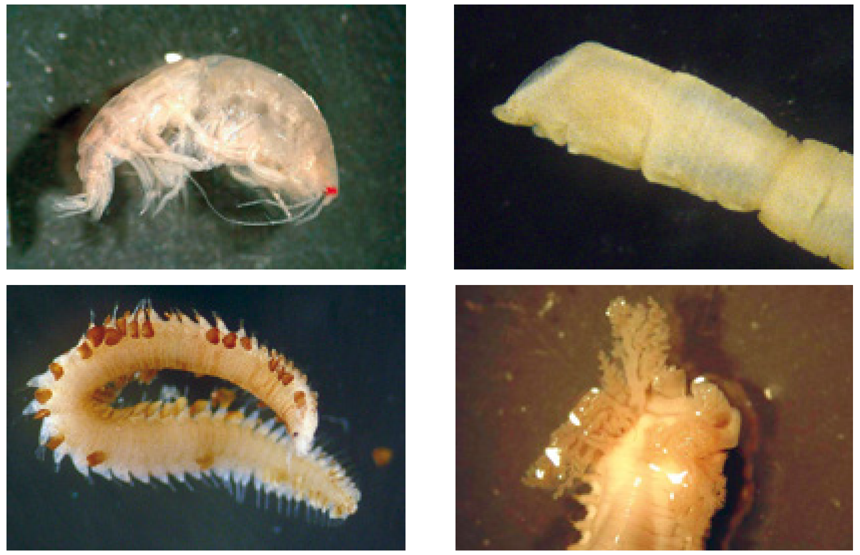
Level 5 (Biotope)

A5.234 = SS.SSa.IFiSa.TbAmPo
Semi-permanent tube-building amphipods and polychaetes in sublittoral sand

The MHCBI distribution maps for these two biotopes are given in Figure 7.83 and show that whilst the infralittoral mobile clean sand biotope (IMoSa) has been recorded at many places around the UK, records of the biotope with tube building amphipods and polychaetes (TbAmPo) have previously been limited to Scotland.

Stations 7, 38, 95 were assigned to this biotope, the seabed images clearly showing the presence of small tubes emerging from the sand (Fig 7.81); burrow holes were also noted, among with some empty bivalve shells and broken urchin tests. Small clumps of *Crepidula* were present at Station 7.

Grab samples were characterised by large numbers of errant worms, tub-building worms and amphipods, and a few bivalves. The errant worms were mostly from common shallow water polychaetes families including the Phyllodocidae *(Eumida, Anaitides)*, Nephtydae *(Nephtys)*, Spionidae *(Spio, Spiophanes)*, Maldanidae *(Euclymene)*, Oweniidae *(Galathowenia)* and Pectinariidae *(Lagis)*. The tube building worms ware almost exclusively *Lanice conchilega (Terebellidae)*, the tubes being clearly visible in many of the seabed images as individual tufts emerging from the sans, often with a few strands of filamentous red algae attached (See Figure 7.81). Other smaller tubes are built but the tube-dwelling amphipod, *Ampelisca brevicornis*, which was also numerous at Stations 7 and 38.

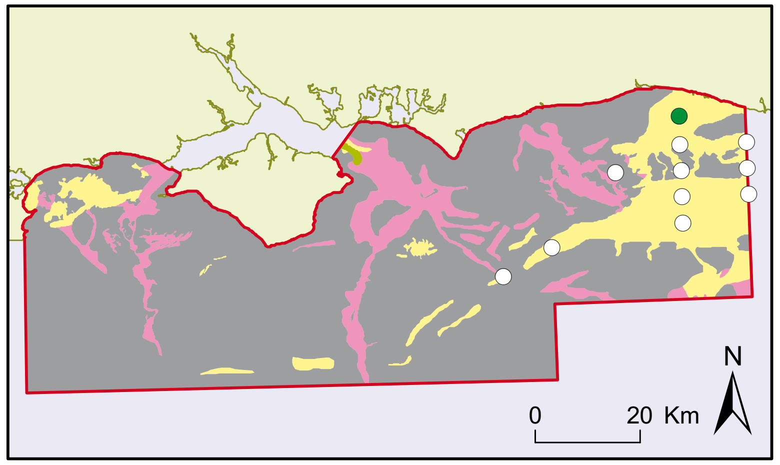


Specimens of taxa characteristic of A5.234. *Ampelisca* (top left), *Euclymene* (top right), *Eumida* (bottom left) and *Lanice* (bottom right). (© MES).

A5.2 — Sublittoral Sand (SS.SSa)

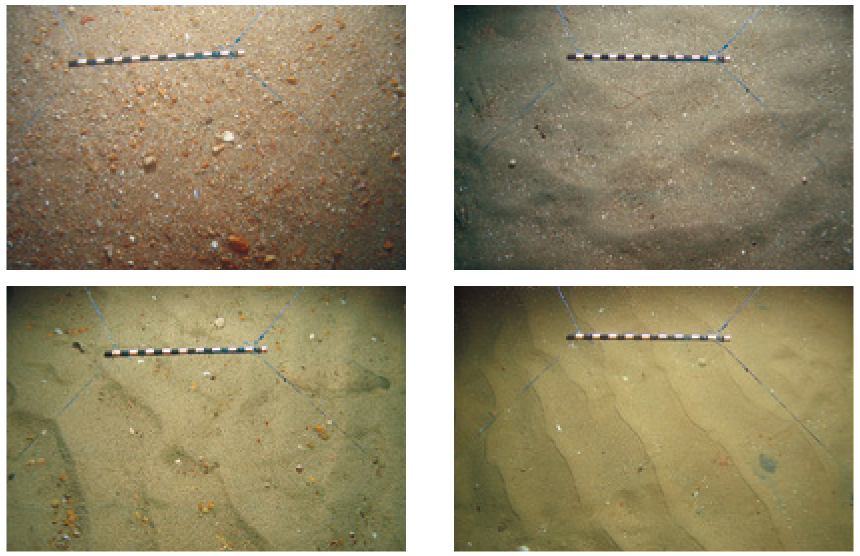
Level 4 (Biotope Complex)

A5.25 = SS.SSa.CFiSa
Circalittoral fine sand



Location of stations assigned to the A5.25 biotope complex, in relation to seabed character. Circle colours: white = A5.25, green = mosaic of A5.25 & A5.44.

Eleven stations were assigned to this biotope complex. Stations 67 and 77 are associated with the margin of the Northern Palaeovalley where sand becomes banked up against the valley wall. The remaining nine stations were associated with the extensive sand field in the east of the region, which also extends into the floor of the Northern Palaeovalley. A mosaic of sediment types was found at station 89, alternating between sand and coarse sediment, providing evidence of the mobility of the sand in that area. Patches of coarse sediment was seen on the video at a number of other stations, consistent with a thinning of the sand cover in the troughs between sand waves.



Seabed photos from Stations 67 (top left), 90 (top right), 93 (bottom left) and 97 (bottom right).

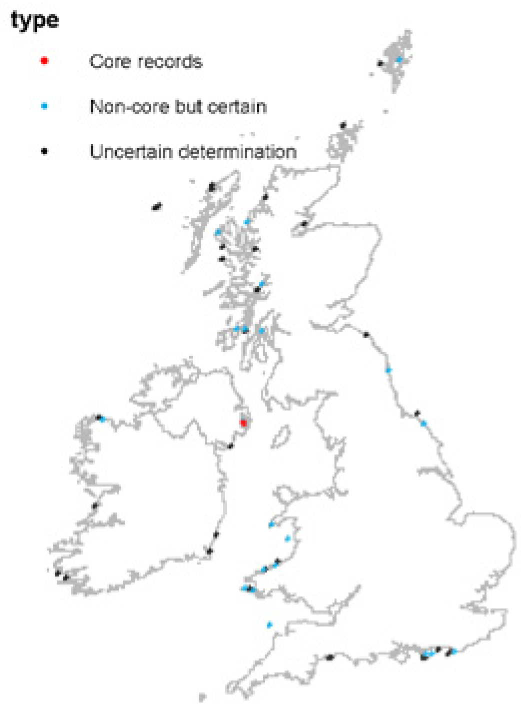
Epibenthic megafauna were rarely seen on video. On still images, tan coloured brittle stars (ophiuroids) were regularly seen laying on the surface of the sand, though never in great aggregations. These were identified as *Ophiura ophiura* and *O. albida*. Hermit crabs were frequently present, though not abundant, and some gastropods (*Buccinum* and *Polinices*) were recorded. In places where there were some hard surfaces at the sediment-water interface or slightly covered by sand, attached fauna such as the hydroid *Hydrallmania*, and the bryozoan *Alcyonidium* were present. Exposed cobbles or pebbles frequently had Barnacles and/or *Pomatoceros* growing on them.

Specimens of *Ophiura ophiura* (left) and *ophiura albida* (right) (© Crown).

In grab samples, the infauna was dominated by errant worms, with the families Glyceridae *(Glycera)*, Nephtydae *(Nephtys)* and Spionidae *(Spiophanes bombyx)* being the most abundant and common. The small sea urchin *Echinocyamus pusillus* was also characteristic, but was mostly restricted to the shallower waters of stations in the Selsey-West Sussex Coastal Platform.

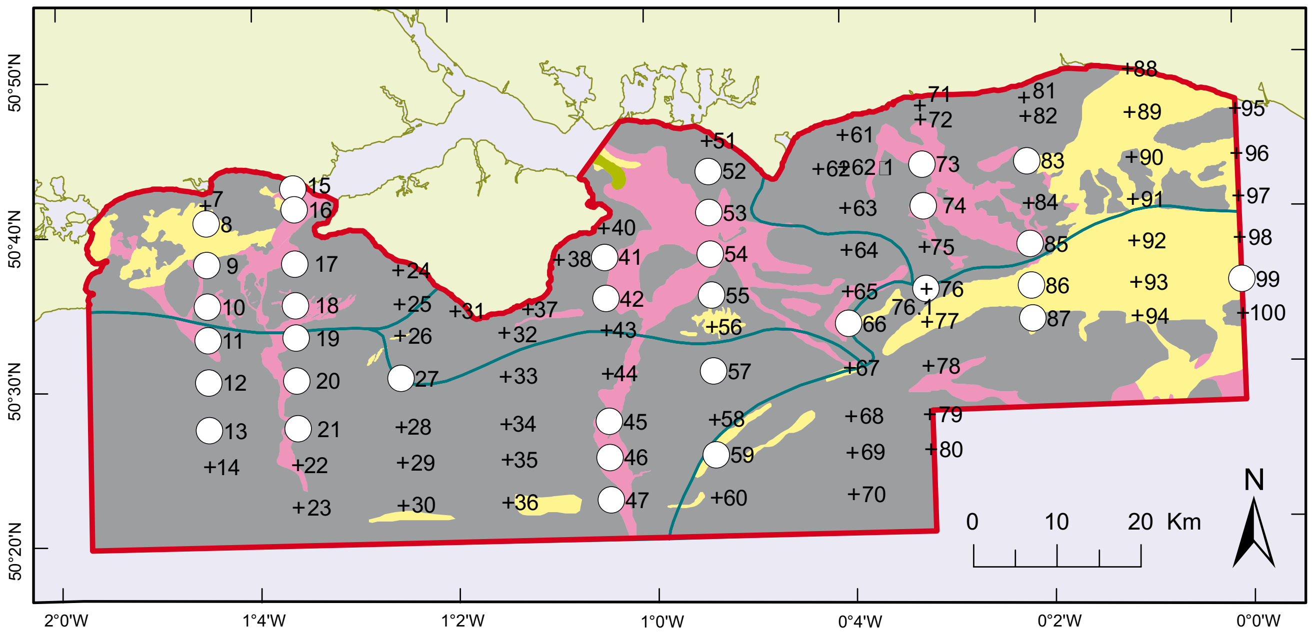
Specimen photos of *Glycera* (top left), *Nephtys* (top right), *Spiophanes* (bottom left) and *Echinocyamus* (bottom right). (© IMARES and MES).

The MHCBI distribution map for this biotope complex shows that although it has not been extensively recorded, it does not appear to be restricted to any one particular part of the UK coast.

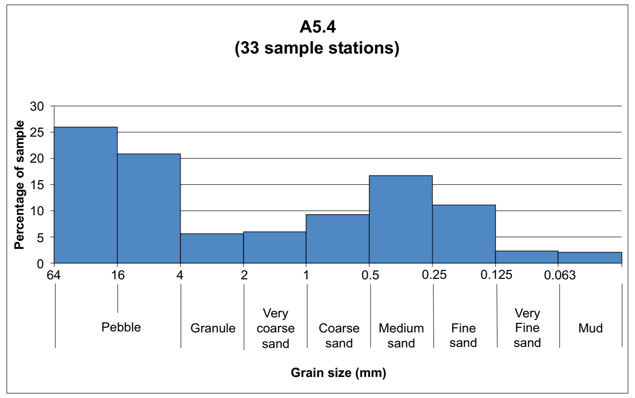


Distribution maps for SS.SSa.IFiSa.IMoSa (left) and SS.SSa.IFiSa.TbAmPo (right) (Connor *et al* 2004. Internet version, accessed 26/11/2009, © JNCC).

A5.4 — Sublittoral mixed sediments (SS.SMx)



Location of stations assigned to the EUNIS Level 3 Habitat A5.4 (white circles), in relation to seabed character.



Geophysical Data

South Coast REC 2007 Survey geophysical lines cover only nine of the thirty four stations identified as A5.4. The geophysical line figure opposite is on corridor 25 where sample station 73 is located.

Solid Geology

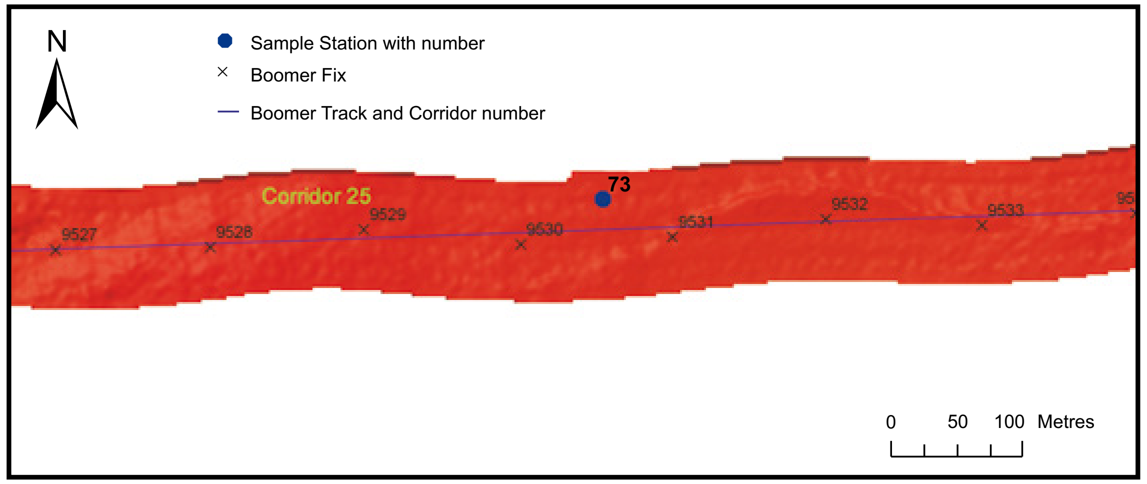
The A5.4 biotope is underlain by the whole range of Cretaceous and Tertiary rocks within the study area and is found across all five regions. This reflects to some extent the heterogeneous nature of the biotope.

Sea bed character

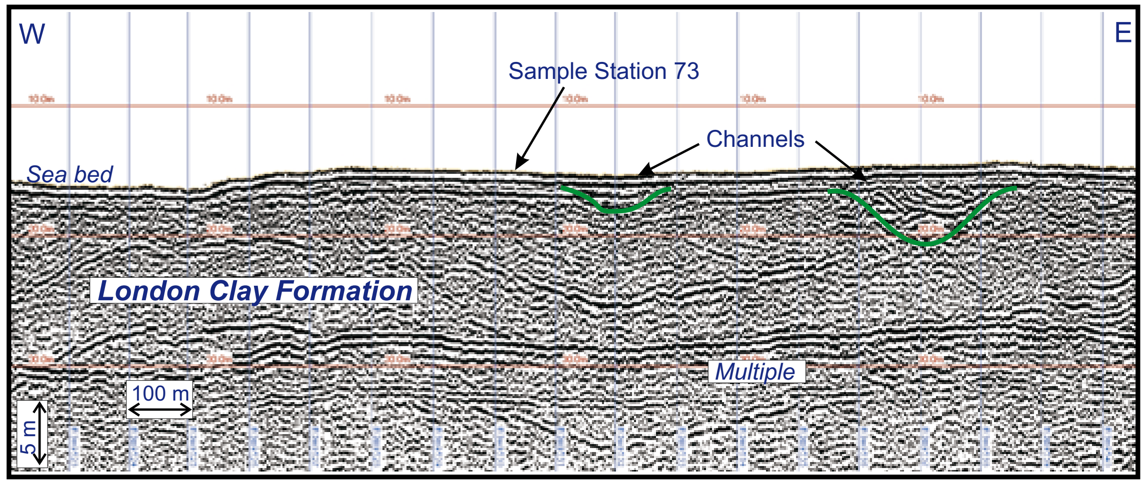
The biotope lies on all three of the major substrates including rock and thin sediment, coarse sediment and sandy sediment. It extends from the nearshore both east and west of the Isle of Wight out to the southern margins of the study area. It is interesting to note that 33 of the 34 A5.4 biotope stations were sampled for PSA by the Hamon Grab indicating that the mix of sediments is biased towards the pebble sand spectrum which is readily sampled by the Hamon Grab rather than a winnowed cobble, boulder and rock substrate which is not easily sampled by the Hamon Grab. An observation which is confirmed by the bimodal nature of the sediment sampled and the evidence from sea bed imagery where sandy gravels are dominant.

A5.4 modelled coverage

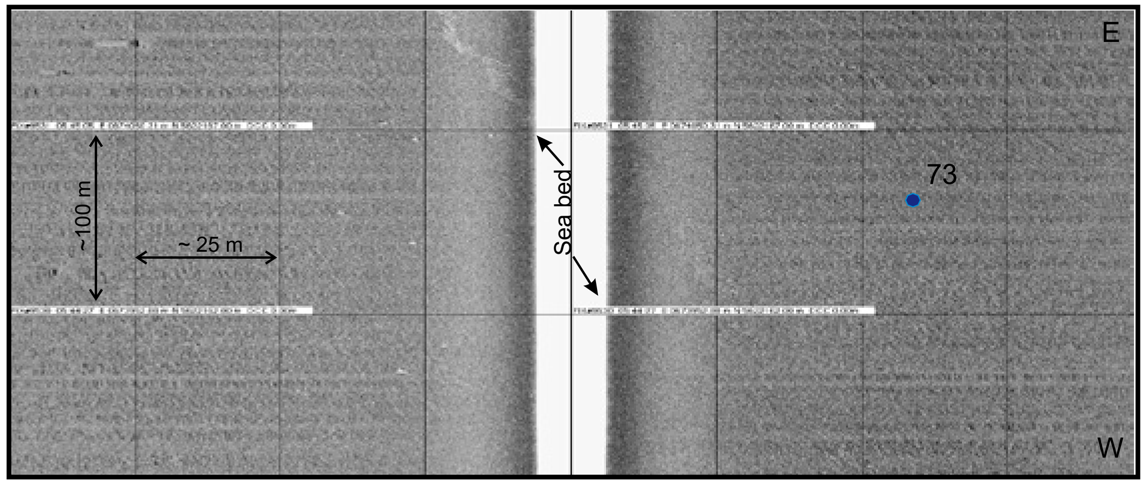
Although the A5.4 biotope has the largest number of sample stations in the study area this is not reflected in its modelled extent which is only 215 km² and covers 4% of the study area.



Multibeam swath corridor.



Seismic section.

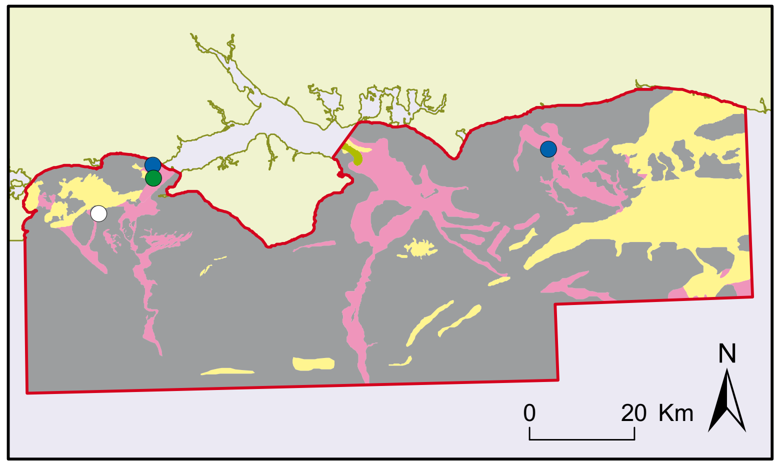


Sidescan sonar record.

A5.4 — Sublittoral mixed sediments (SS.SMx)

Level 4 (Biotope Complex)

A5.43 = SS.SMx.IMx
Infralittoral mixed sediments

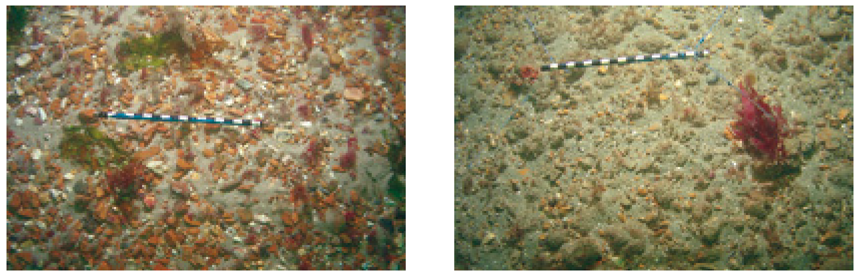


Location of stations within the EUNIS A5.43 biotope complex, in relation to seabed character. Circle colours: white = A5.43(6), green = A5.43(7), blue = A5.43(8).

This biotope complex occurred in shallower, infralittoral waters and hence tended to be found fairly near the coast. The sediments typically comprised a mixture of muddy sand with pebble sized gravel particles, and occasional cobbles (if at all). The gravel component appeared to be of a fluvial origin (rather than lag-gravel) being fairly well sorted, rounded in shape and predominantly golden in colour. The sediment surface appeared to be a little silty and moderately tide-swept

Filamentous and foliose red and green algae were a feature, though they were not 'luxuriant' in their growth or cover. Together with hydroids, barnacles (Cirripedia) and keel worms (Serpulidae) they colonised the sediment surface. The slipper limpet, *Crepidula fornicata*, was also present and sometimes abundant. The infauna was characterised by errant and tube-building bristle worms (Polychaeta).

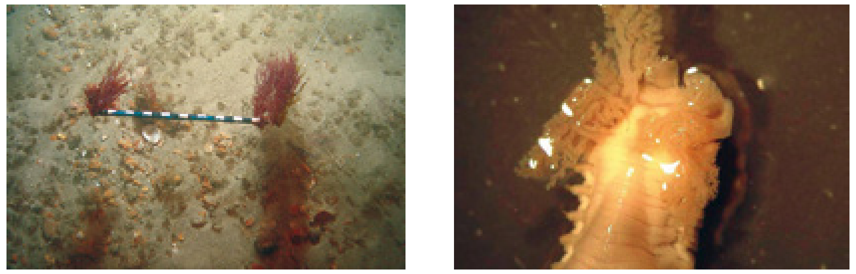
This biotope complex is fairly poorly discriminated at Level 5 in the current EUNIS classification, having only five biotopes (A5.431–A5.435) and infaunal records for only one of these. The observed combinations of flora and fauna were considered to be sufficiently different to the existing biotopes to warrant the generation of three new biotope classes.



Seafloor images from Station 16 (left) and 73 (right) illustrating 'mixed' substrate. The presence of both red and green algae indicates the stations lie in the 'infralittoral' (photic) zone.

Level 5 (Biotope)

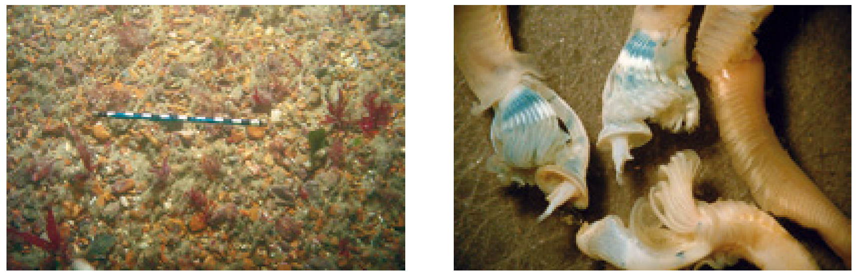
A5.43(6) = SS.SMx.IMx.(BriHydLanBal)
Tide swept, infralittoral mixed sediments with erect bryozoans and hydroids, dense *Lanice conchilega* and *Balanus crenatus*



Seafloor image at Station 9 (left) showing many tubes *Lanice conchilega* (right).

This biotope variant was recorded at Station 9. Visually, the most prominent feature was the peppering of the seabed surface with the emergent tubes of the Sand Mason worm, *Lanice conchilega*, among sparse tufts of red and green algae and more frequent tufts of hydroids and bryozoans. Barnacles covered some of the larger pebbles and a variety of small crabs were recorded *(Ebalia, Pagurus, Macropodia)*. Errant polychaetes occurring in the grab sample included the genera *Syllis, Polydora, Spio, Spiophanes* and *Notomastus*.

A5.43(7) = SS.SMx.IMx.(PomAl)
Infralittoral mixed sediments with *Pomatoceros* and occasional foliose red and green algae

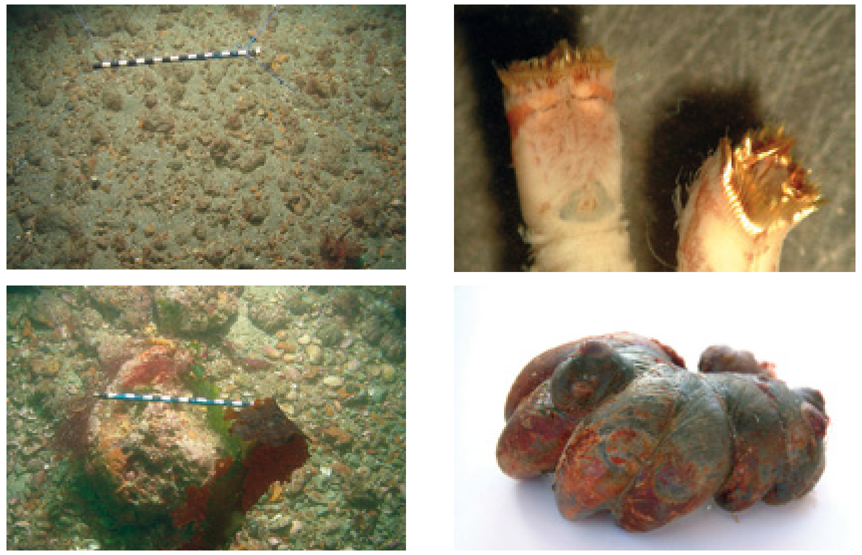


Seafloor image at Station 16 (left) where many of the pebbles had the calcareous tubes of the Serpulid worm, *Pomatoceros triqueter* (right, © MES).

Sediment at Station 16 contained a high proportion of gravel, which appeared to be relatively stable, as small tufts of red and green algae occurred in patches and the white tubes of the keel worm *Pomatoceros* were common on the gravel and pebbles. Errant polychaetes occurring in the grab sample included the genera *Schistomeringos, Spio, Notomastus*, and *Scalibregma*; the tubeworm *Lanice* was also present. Other taxa present in some numbers included the Amphipod *Melita hergensis*, the small crab *Pisidia longicornis*, the slipper limpet *Crepidula fornicata* and the bivalve *Tapes rhomboides*.

Levels 5 (Biotope)

A5.43(8) = SS.SMx.IMx.(SabCrepPomB)
Infralittoral mixed sediments with clumps of *Sabellaria*, *Crepidula* and encrusting barnacles and *Pomatoceros*



Seafloor images from Stations 73 (top) and 15 (bottom) with specimen photographs of *Sabellaria* (top) and *Crepidula* (bottom) (© MES).

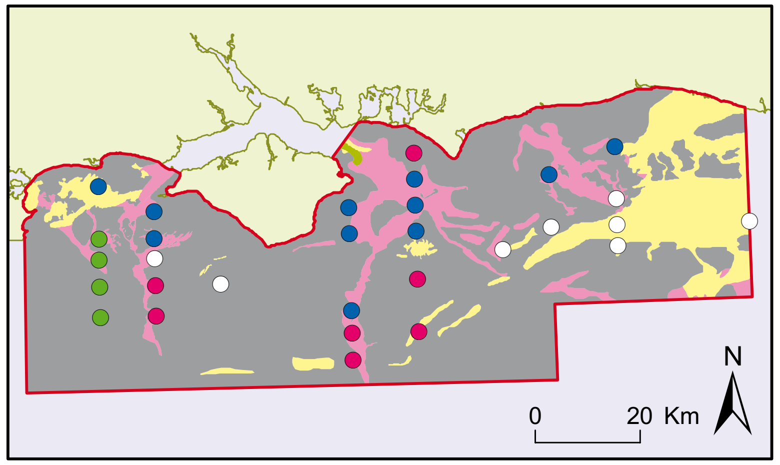
This biotope was described primarily on the samples from Station 73 which lies well to the east of Selsey Bill. Here, the seabed is relatively flat, with mixed muddy sediments supporting a low density cover of red algae and hydroid turf. Small hummocks on the surface are likely to be tubes of *Sabellaria spinulosa*, there being 178 individuals recorded in the single grab sample. Solitary ascidians, 'top-shell' gastropods (Trochidae) and the scour tolerant anemone *Urticina felina* were recorded as 'Frequent' in the stills images. A total of 71 taxa were identified in the grab sample, those occurring in numbers >1 included the scale-worm *Harmothoe*, the errant polychaetes *Syllis, Eunereis, Lumbrineris, Spiophanes, Caulleriella, Mediomastus* and *Notomastus*, the tube-dwelling worms *Lanice* and *Nicolea*, and the rock-boring worm *Perkinsiana*. Other numerous taxa included barnacles (373), *Pomatoceros*, four species of amphipod, ten species of ascidian, a few bivalves and *Crepidula fornicata*.

Station 15 was originally assigned to a similar habitat from deeper, circalittoral waters (A5.44(7) below), but re-assigned here in view of the density of red and green algae, belying its location in shallow waters adjacent to the coast. The habitat was clearly a *Crepidula* bed in mixed substrate (including cobbles and fine mud) with a diverse encrusting community including barnacles, *Pomatoceros* and the bryozoan *Pentapora* recorded by video & stills. The substrate proved too coarse for grab sampling.

A5.4 — Sublittoral mixed sediments (SS.SMx)

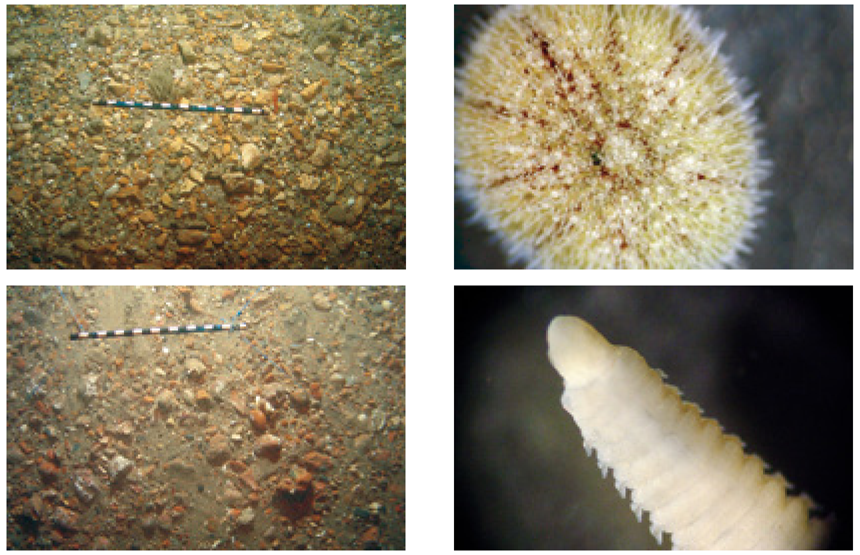
Level 4 ('Biotope Complex')

A5.44 = SS.SMx.CMx
Circalittoral mixed sediments



Location of stations within the A5.44 biotope complex, in relation to seabed character. Circle colours: white = A5.44, green = A5.444, blue = A5.44(7), pink = A5.44(8).

This biotope complex was recorded at 31 stations. The sediment comprised 'lag'- and 'fluvial'-gravel, sand and some mud. With low light levels, the habitat fell in the circalittoral zone. Stations 19, 27, 66, 76, 85, 86, 87 & 99 were assigned at Level 4, with those in the east having more sand than those in the west. Faunal cover was generally sparse and patchy, with ephemeral hydroids, *Pomatoceros*, and the scour tolerant anemone *Urticina*, featuring widely. Scallops (*Pecten* and *Aequipecten*) were present at low levels in the east. Grab samples showed a lower faunal richness in the west, with 24 taxa at Stations 19 & 27 compared to 82 and 86 taxa at the Stations 65 & 76 respectively. The urchin *Echinocyamus pusillus* was the most abundant taxon and the polychaetes *Lumbrineris*, *Aonides* and *Notomastus* occurred at most stations.



Mixed substrate at Stations 19 (top) & 85 (bottom) and two infaunal taxa, *Echinocyamus* (top) and *Lumbrineris* (bottom) (© Crown, MES).

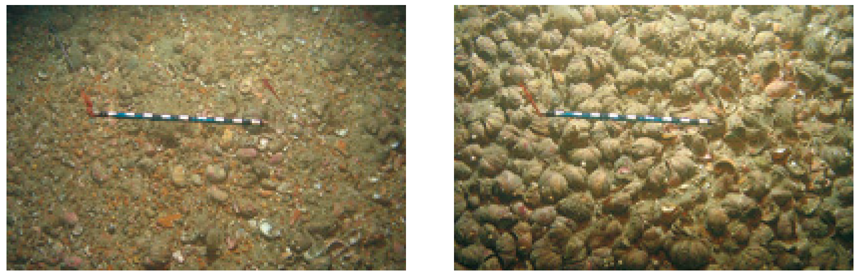
Level 5 (Biotope)

A5.444 = SS.SMx.CMx.FluHyd
Flustra foliacea and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment

The seabed at Station 12 (left) and the polychaete *Notomastus* (right, © MES).

This group of four stations (10, 11, 12 & 13) in the west notably featured stands of the foliose bryozoan *Flustra*, and a thin turf of hydroids over the harder substrate. The anemone *Urticina* and both erect and encrusting sponges were present. Some patches of ground were nearly devoid of epifauna. In the grab samples, the polychaete worms *Notomastus*, *Nereididae*, *Thelepus* and *Glycera* occurred at all stations, as did the barnacle, *Verruca*, and a variety of ascidians (e.g. *Dendrodoa*, *Polycarpa* and *Pyura*).

A5.44(7) = SS.SMx.CMx.(SabCrepPomB)
Circalittoral mixed sediments with clumps of *Sabellaria*, dense *Crepidula* and encrusting barnacles and *Pomatoceros*

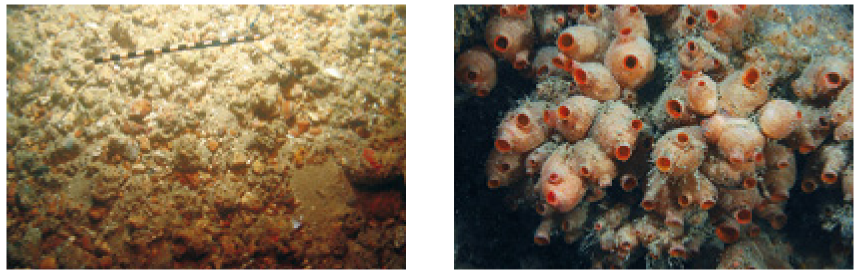


Seabed images from Station 8 showing mixed sediment (left) and a patch obscured by a dense aggregation of the slipper limpet, *Crepidula fornicata* (right).

Stations 8, 14, 18, 41, 42, 45, 53, 54, 55, 74 and 83 were assigned to this new biotope class, which is a variant featuring both *Sabellaria* and *Crepidula*, and so may currently be restricted to this geographic area, where *Crepidula* have something of a stronghold (530 in a single grab at |Station 8). *Pomatoceros* and barnacles colonised the hard substrata, including the *Crepidula* shells. *Flustra* was fairly common. Grab samples contained a wide variety of errant polychaetes, typically including *Harmothoe*, *Lumbrineris*, *Polydora*, *Mediomastus* and *Notomastus*, and the tube-dwelling worms *Lanice*, *Polycirrus* and *Thelepus*. Few bivalve species occurred, *Nucula* being the most prominent. Other notable macrofauna included the small crab *Pisidia* and the ascidian *Dendrodoa*.

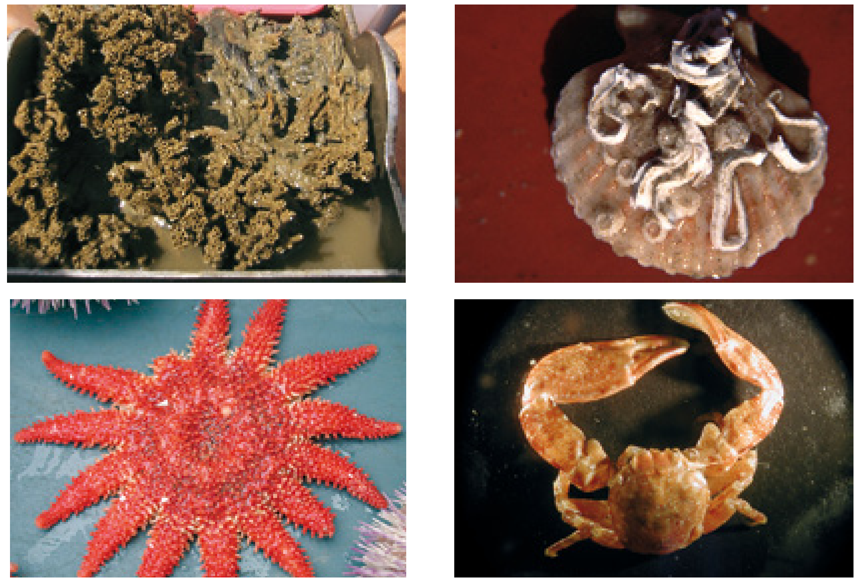
Levels 5 ('Biotope')

A5.44(8) SS.SMx.CMx.(AsSabCr)
Circalittoral mixed sediments with ascidians, *Sabellaria* clumps and encrusting fauna



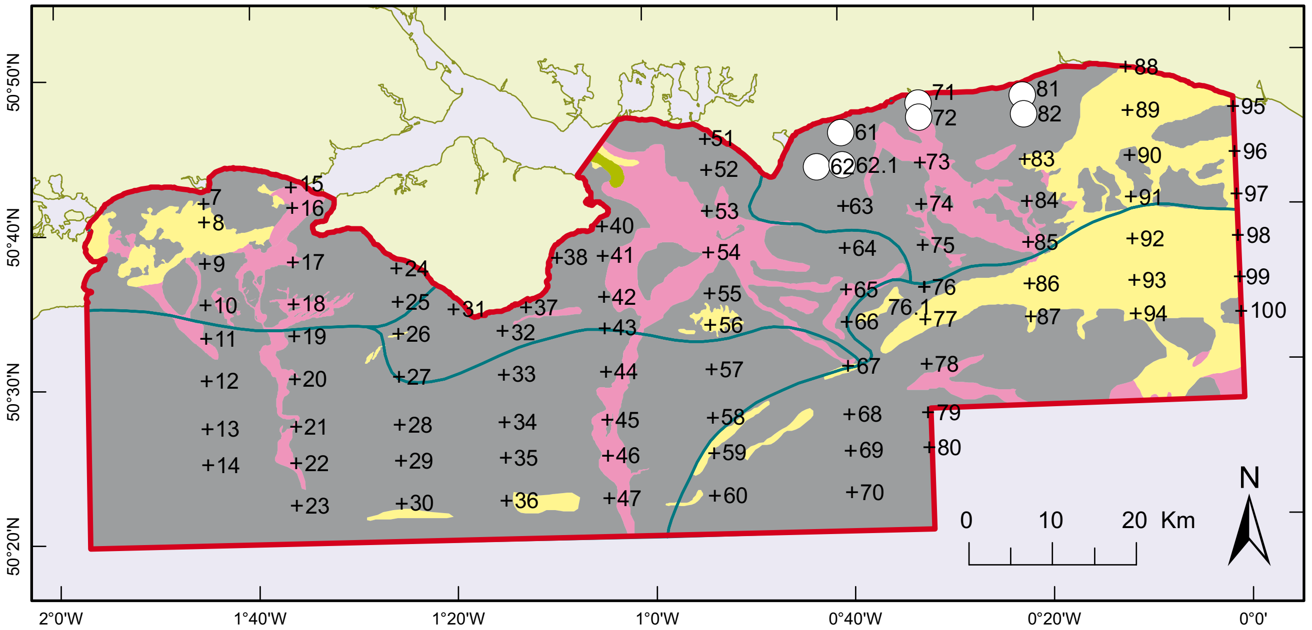
Seabed image from Station 59 (left) and close up of the gregarious sea squirt *Dendrodoa grossularia* (right, © Keith Hiscock).

This new variant of the circalittoral mixed sediment was assigned to Stations 20, 21, 46, 47, 52, 57 & 59, the first four of which were associated with palaeochannels. Sediment in this biotope is less muddy than in A5.44(7) with a higher proportion of pebbles & cobbles, the greater stability allowing a rich encrusting fauna to establish. Solitary and gregarious ascidians were a feature, especially *Dendrodoa* which occurred in large numbers (~500 per grab) but were not resolved on video/stills among the other encrusting fauna which included hydroids, bryozoans, sponges, barnacles and *Pomatoceros*. *Flustra*, *Urticina* and *Crepidula* are also present and larger cobbles supported the hydrozoans *Tubularia*, *Actinothoe*, *Epizoanthus* and *Corynactis*. Epibenthic fauna included the starfish *Crossaster* and *Amphipholis* and the crabs *Cancer, Maja, Galathea, Pisidia, Ebalia* and *Liocarcinus*. Grab samples showed the infauna to have few bivalves but a wide range of polychaetes including *Sabellaria* (10's per grab), *Syllis, Nereididae, Lumbrineris, Laonice, Capitellids* and *Maldanidae*.

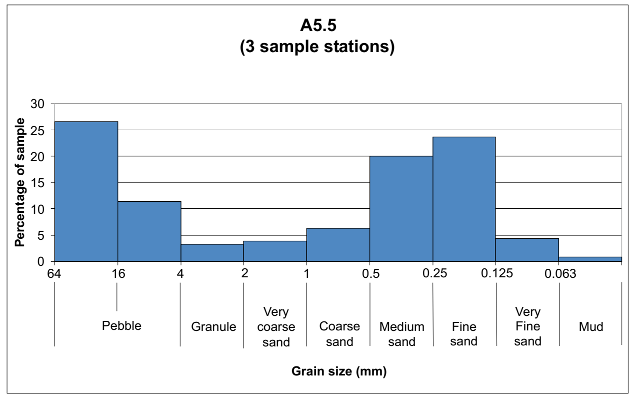


Epibenthic taxa typical of mixed substrates. Clockwise: *Sabellaria* tubes, *Pomatoceros* tubes, *Pisidia longicornis* and *Crossaster papposus* (© Crown, MES).

A5.5 — Sublittoral Macrophyte dominated sediment (SS.SMp)



Location of stations assigned to the EUNIS Level 3 Habitat A5.5 (white circles), in relation to seabed character.



Geophysical Data

South Coast REC 2007 Survey geophysical lines cover four of the seven stations identified as A5.5. The geophysical line figure opposite is on corridor 25 where sample station 62 is located.

Solid Geology

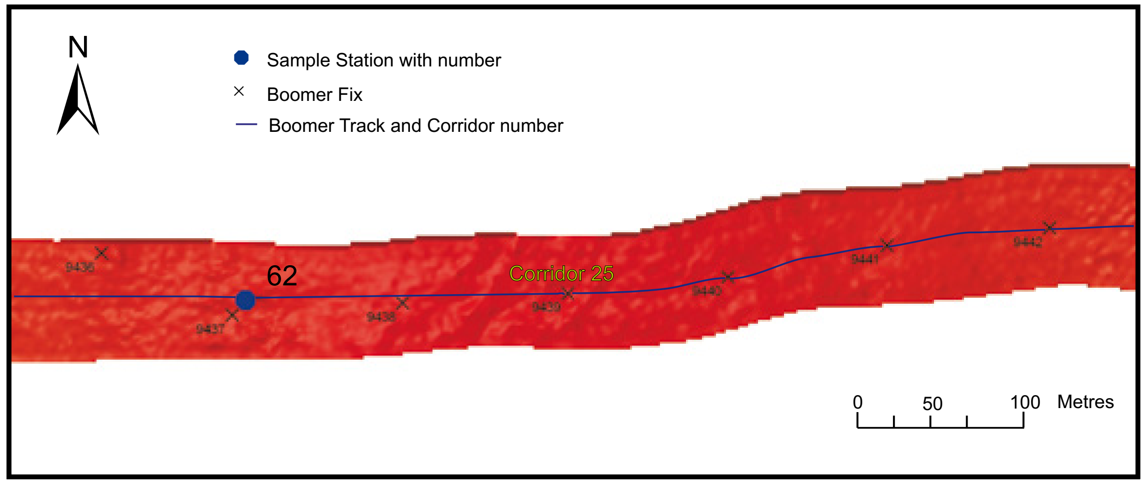
The nearshore occurrence of this biotope on the Selsey–West Sussex Platform is in an area with a shallow east-west trending synclinal axis which allows Chalk to underlie much of the nearshore and four of the seven stations lie on Chalk. The three stations furthest west off Selsey Bill are underlain by London Clay Formation or Bracklesham Group rocks.

Sea bed character

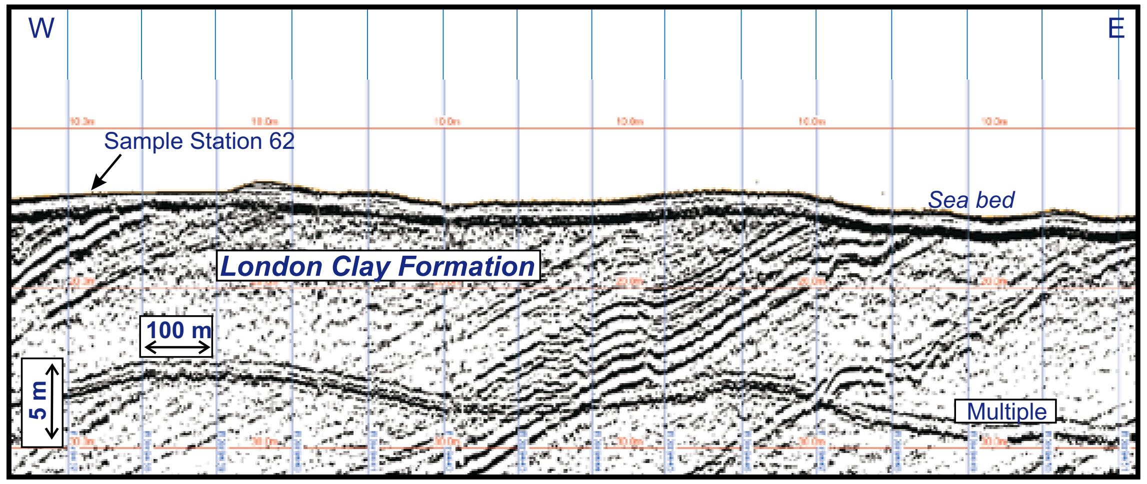
All seven stations are on rock and thin sediment. The seismic profile at station 62 is an excellent example of rock and thin sediment substrate with dipping London Clay reflectors reaching the sea bed and the resistant beds creating linear ridges which are recorded in the red coloured multibeam corridor. The sampled sediment is a bimodal mix of fine to medium sand with large pebbles which is confirmed by the sea bed imagery.

A5.5 modelled coverage

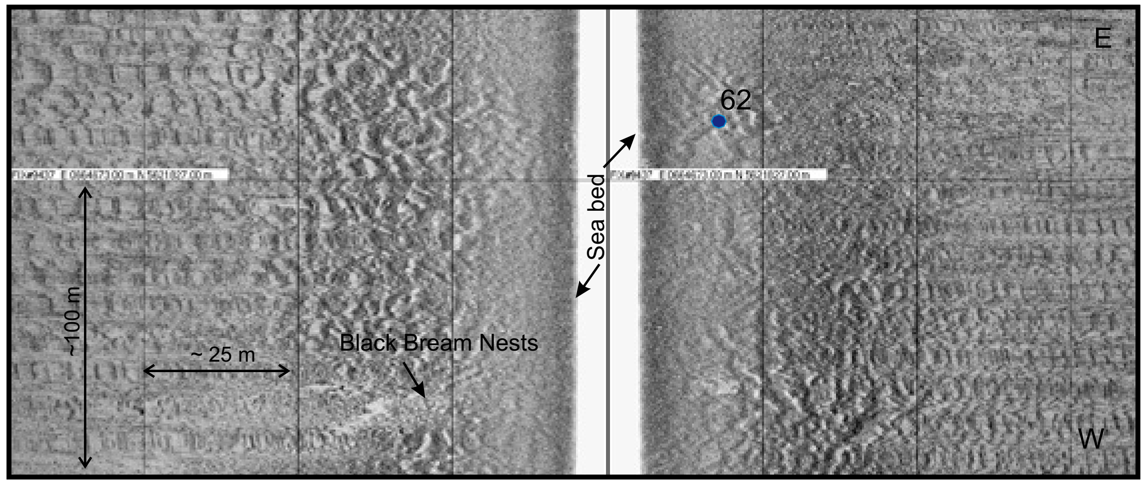
This biotope has not been included in the modelling because it is not a sediment or rock based biotope. A methodology needs to be created which would allow a biologically based biotope to be modelled.



Multibeam swath corridor.



Seismic section.

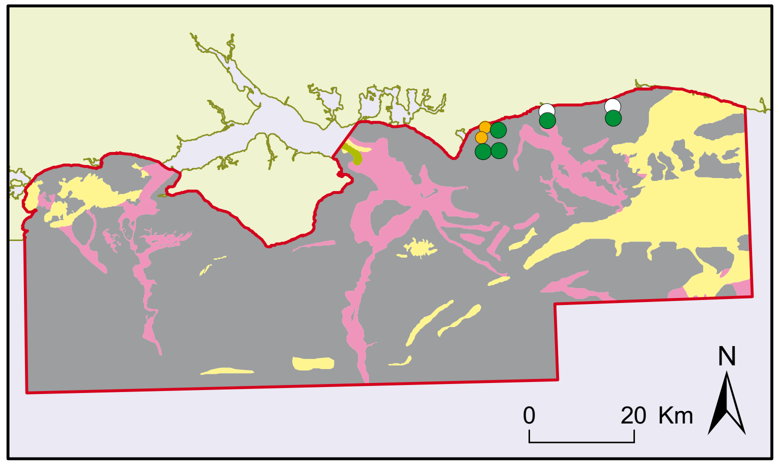


Sidescan sonar record.

A5.5 — Sublittoral Macrophyte dominated sediment (SS.SMp)

Level 4 (Biotope Complex)

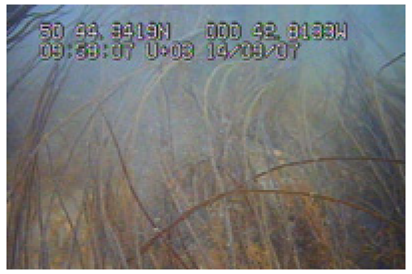
A5.52 = SS.SMp.KSwSS
Kelp and seaweed communities on sublittoral sediment

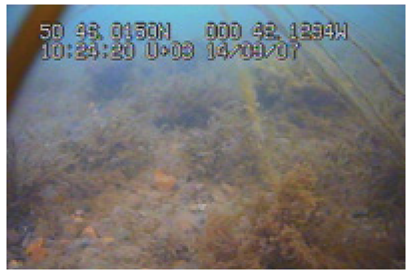


Location of stations assigned under the A5.52 biotope complex, in relation to seabed character. Circle colours: white = A5.5211, green = A5.5211(A), gold = A5.52 from SSFC inshore survey.

Seven of the South Coast REC stations were assigned under this biotope complex, all occurring along the shallow coastal waters of the Selsey — West Sussex Coastal Platform. The SSFC inshore surveys assigned two sites to this Level 4 biotope complex (Figures 7.90 & 7.91). It can be regarded as a transition between rock and sediment habitats in the infralittoral zone, with the substrate comprising coarse and or mixed sediment that is stable enough to allow the attachment and significant growth of kelp and other macro algae. In the examples recorded in the South Coast REC survey, kelp was not prominent, so the biotope assignments have been made at higher EUNIS levels (6 and 7).

The EUNIS description for this biotope complex is: 'shallow sublittoral sediments which support seaweed communities, typically including the kelp *Laminaria saccharina*, the bootlace weed *Chorda filum* and various red and brown seaweeds, particularly filamentous types. The generally sheltered nature of these habitats enables the seaweeds to grow on shells and small stones which lie on the sediment surface; some communities develop as loose-lying mats on the sediment surface'. It is fairly widespread around the UK (Figure 7.93) and particularly common in the sheltered inshore waters along the west coast of Scotland.





Video grabs from SSFC stations GV43 (left) and GV86 (right) assigned to A5.52, showing the bootlace weed *Chorda filum* and other algae growing on coarse sediment (© SSFC).

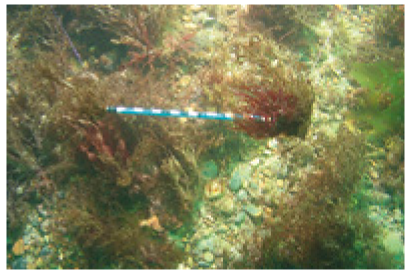
Levels 5 (Biotope) & 6 (Sub-biotope)

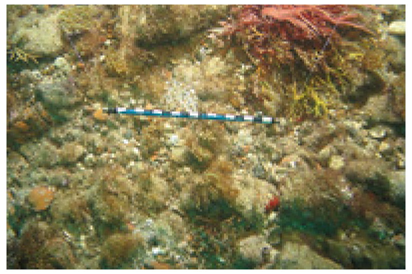
A5.521 = SS.SMp.KSwSS.LsacR
Laminaria saccharina and red seaweeds on infralittoral sediments

This biotope class is characterised by the kelp *Laminaria saccharina*. As this was rarely seen at the South Coast REC stations, none were assigned to this biotope.

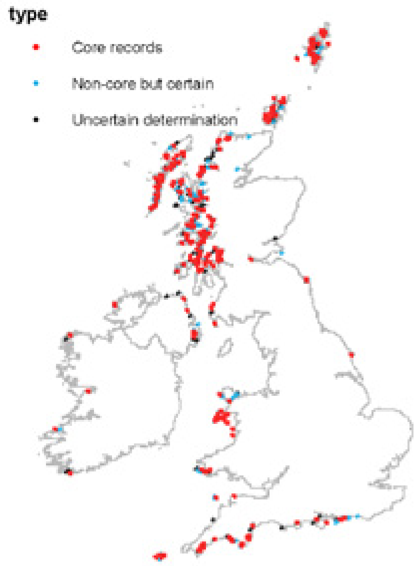
A5.5211 = SS.SMp.KSwSS.LsacR.CbPb
Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles

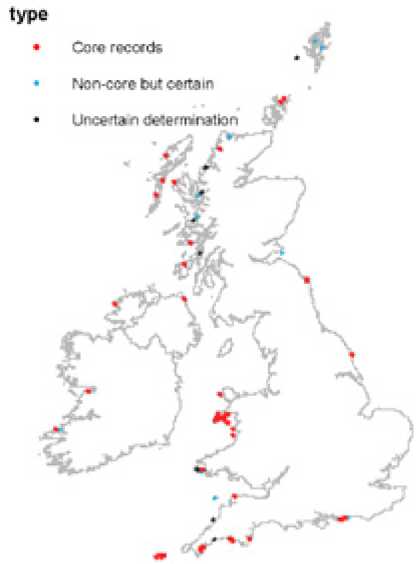
Stations 71 and 81 were assigned to this biotope. Water depth was less than 10 metres and the substrate comprised poorly sorted gravel, including pebbles and cobbles. This supported a substantial growth of red and brown foliose algae, including *Calliblepharis ciliata* and *Chondrus crispus*.
The Snakelocks anemone, *Anemonia viridis*, was common and some stone crabs (Majidae) and gastropods *(Calliostoma)* were noted. At Station 71 the substrate between clumps of seaweed was usually bare, but at Station 81 it was covered by a thick hydroid turf (Figure 7.92). The ground was too hard for grab sampling.





Seabed photos from Stations 71 (left), 81 (right) showing stands of red and brown algae growing on cobbles and pebbles.



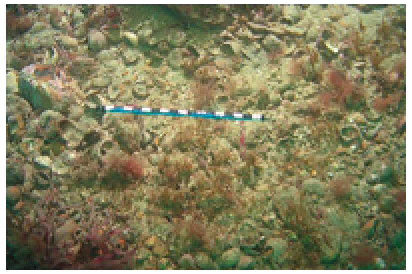


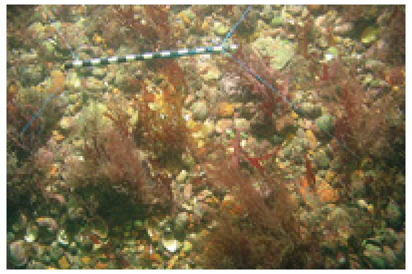
Distribution maps for KSwSS (= A5.52) (left) and KSwSS.LsacR.CbPb (=A5.5211) (right) (Connor *et al* 2004. Internet version, accessed 26/11/2009, © JNCC).

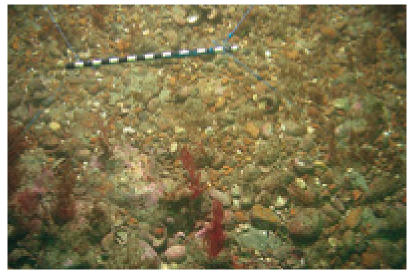
Level 7 (sub-biotope variant)

A5.5211(A) = SS.SMp.KSwSS.LsacR.CbPb.(Crep)
Red seaweeds and dense *Crepidula* on tide-swept mobile infralittoral cobbles and pebbles

This new biotope has been generated to account far variant A5.5211 in which the slipper limpet *Crepidula fornicata* is common and may dominate the substrate between stands of red and brown seaweeds. The substrate is mixed, rather than coarse, so grab sampling is usually effective. In common with other *Crepidula* habitats, the substrate contains a significant proportion of fines (mud/silt).







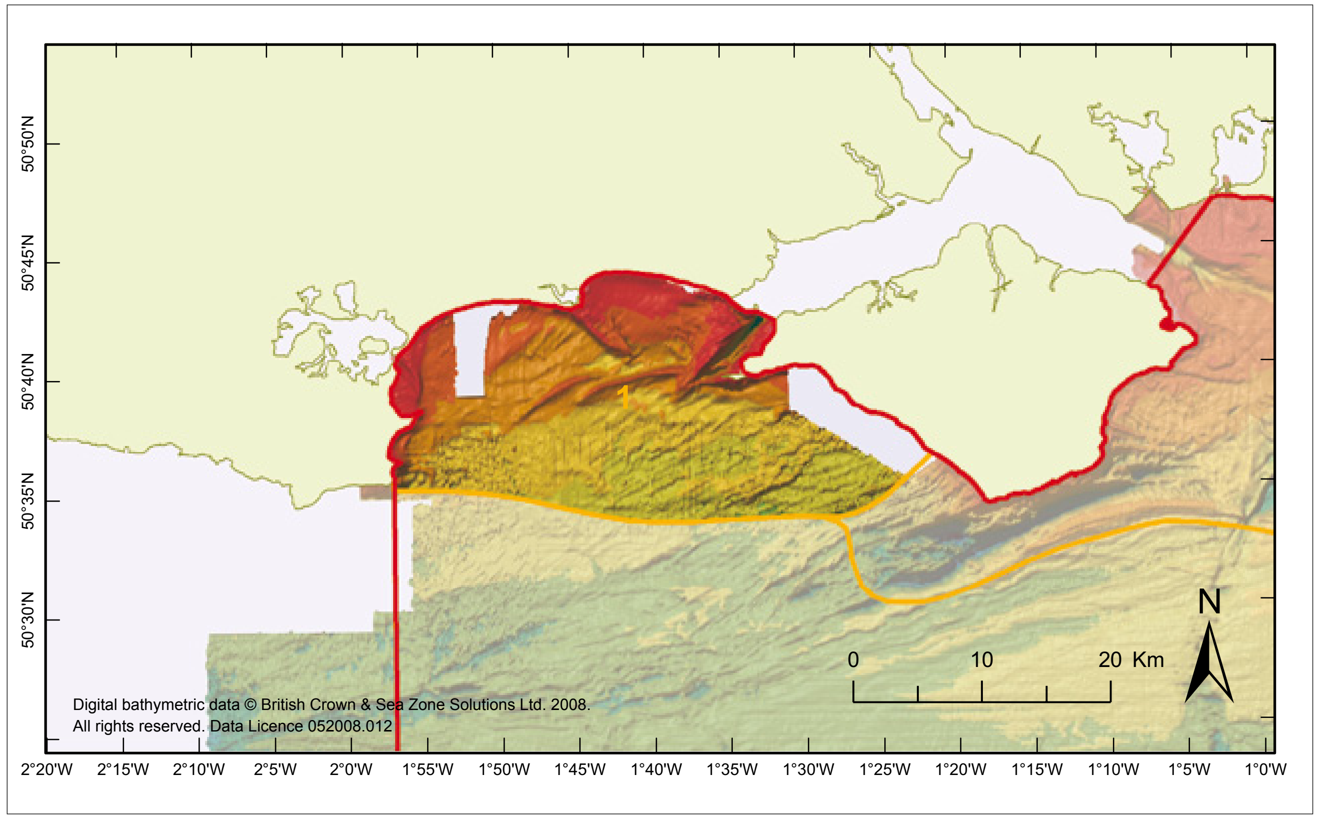
Seabed photos from Stations 61 (top left), 62 (top right), 72 (bottom left) and 82 (bottom right) showing mixed substrate with seaweeds and *Crepidula fornicata*.

Grab samples revealed an abundant infauna, dominated by polychaete worms and amphipods, but with few decapods or bivalves. Errant worms include the Capitellids *Mediomastus* and *Notomastus*, while the tube worms *Lanice conchilega* and *Polycirrus* also featured. Barnacles and *Pomatoceros* encrusted many of the stones and *Crepidula* clumps. Several genera of gammaridean amphipods occurred in significant numbers including *Dexamine, Ampelisca, Abludomelita, Maera* and *Cheirocratus*.

Specimen photographs of *Crepidula fornicata* (left) and *Lanice conchilega* (right) (© MES).

7.6 Habitat summaries

Physical Region 1 — Greater Poole and Christchurch Bay
Habitat Summary



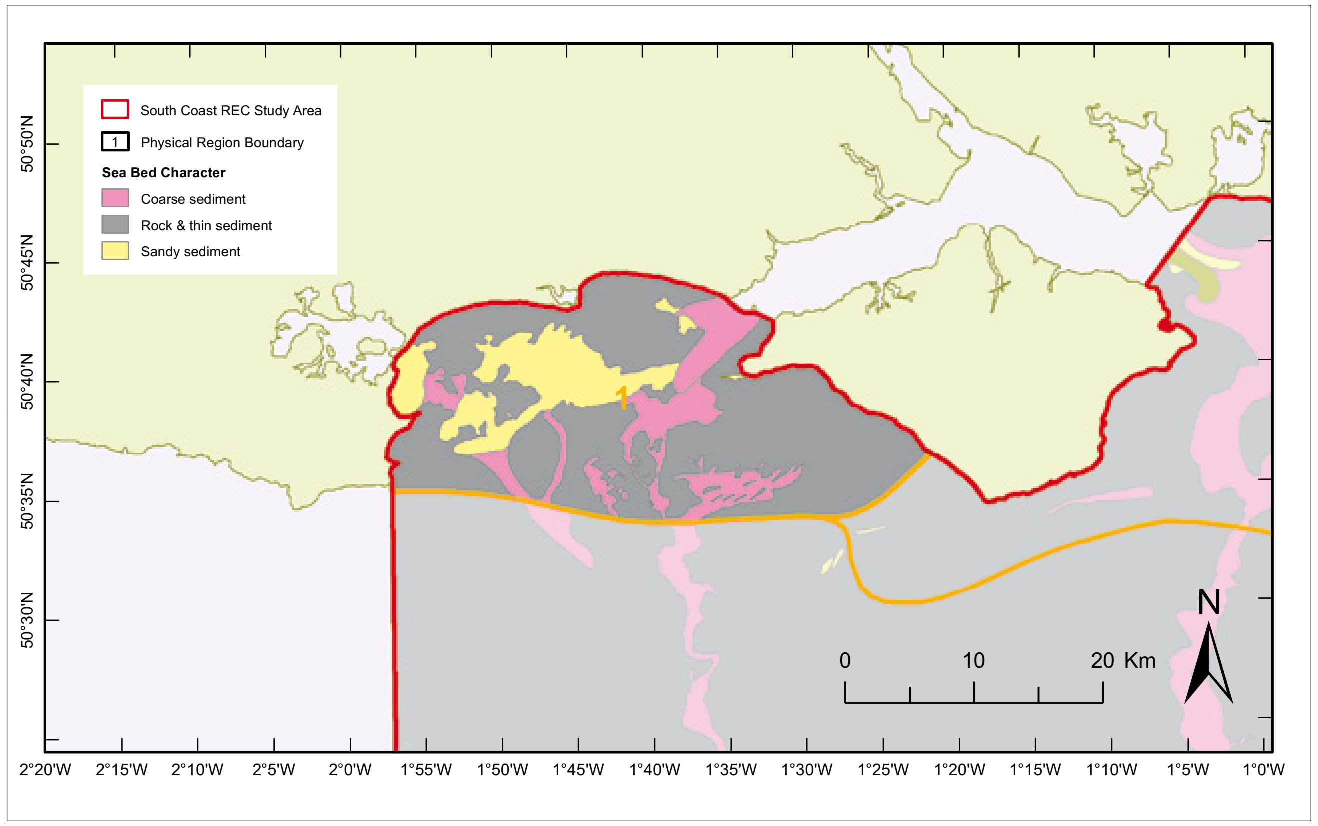
Water Depth (m)
0–40 m

Area (km²)
570

Grab stations
7

Trawl stations
2

Video locations
10



Geology and Sediments

Region 1 has a relatively complex sea bed character which includes three sand banks, a gravel bank, a sand wave field and prominent rock scarp and ledge. These are within the northern half of the Region bounded to the south by a line from the Needles to Handfast Point (Figure 4.2). The smallest of these sand banks is Hook Sand in the east of Poole Bay. It is <4 km long and aligned at almost a right angle to the entrance of Poole Harbour.

The distance from Handfast Point to the Needles is 25 km and the sand banks of Dolphin Sand and Dolphin Bank underlie 14 km of this stretch of sea bed They are aligned in a slightly offset en-echelon form, virtually east-west. Their crests are at a depth of 8 to 13 m, they also have an asymmetrical cross profile with steep south facing lee slopes up to 14 m high.

Christchurch Ledge has a south-west facing rock scarp 10–12 m high which extends offshore for about 6 km from the high cliffs of Hengistbury Head. The back of the ledge is relatively flat at a depth of 4 to 6 m.

Shingle Bank at the western entrance to the Solent is a north-east to south-west trending gravel bank about 7 km long. It is attached onshore to the gravel based Hurst Spit and derives gravel from Hurst Spit as part of the eastward longshore transport of sediment around Christchurch Bay.

The southern half of the region is a slightly undulating surface of coarse sediment and rock and thin sediment. There are some linear north-east to south-west trending ridges up to 8 m high and these parallel the strike of the underlying Wealden Group rocks. However, there is also evidence of coarse sediment associated with thin sediment sheets and small channels.

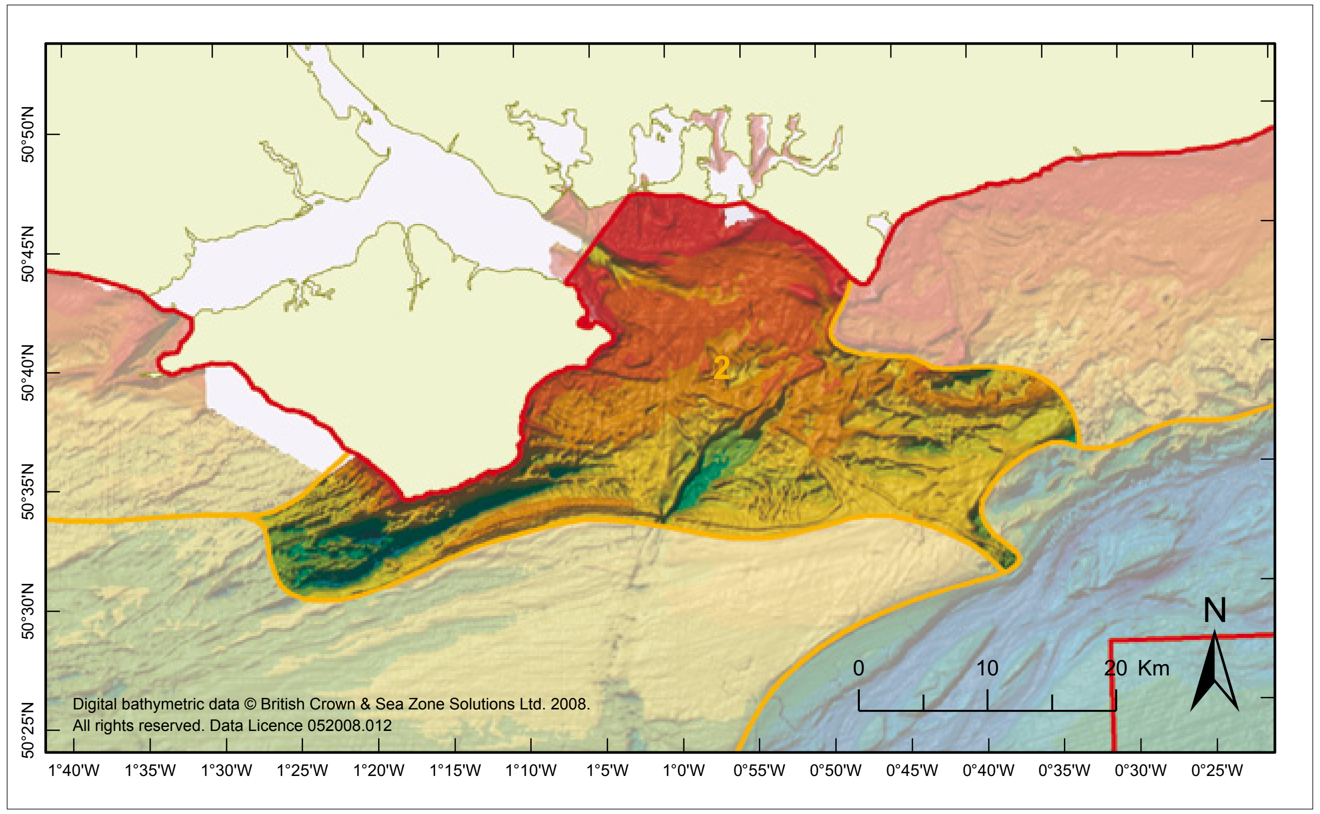
Broad Habitat

Region 1 mainly comprises moderately sheltered inshore waters in the 0–40 m depth zone, though most of the area is in the 10–30 m range. The northern part, from Swanage to The Needles and down the west coast of the Isle of Wight, is in the photic zone, so supports infralittoral rock habitats, while the southern part is in the aphotic zone and supports circalittoral rock habitats. The nearshore environment is sheltered to between 1 and 3 miles offshore, but then becomes moderately exposed to fully exposed, leading to a change from low to moderate to high energy habitats moving offshore. For the most part, rock is very close to the seabed surface but has a covering of mixed sediment comprising coarse lag gravel, sand and some mud. This covering becomes thicker along the southwest extension of the Solent and the south east extension of Poole Harbour, and between the two there is a substantial accumulation of sand. This variety of environmental conditions and layering of substrates, leads to a wide variety of potential habitats, including moderate and low energy infralittoral rock (A3.2 & A3.3), high, moderate and low energy circalittoral rock (A4.1, A4.2 & A4.3), and sublittoral coarse, sand and mixed sediments (A5.1, A5.2 and A5.4 respectively).

At seven of the ten sampling sites the habitat was determined to be sublittoral mixed sediment (A5.4); the epibiota notably including red and green algae in the infralittoral and *Flustra* in the circalittoral. *Crepidula* were a common feature and the worms *Lanice* and *Sabellaria* were sometimes abundant. *Barnacles* and *Pomatoceros* frequently encrusted pebbles and cobbles. The two sites in the southeast corner (Stations 25 & 25) were rocky reef habitats, suggesting that a substantial reef system exist s in this area. Only one site (Station 7, off Christchurch) was sublittoral sand, but given the large sand sheet in the centre of the region this habitat is likely to be more prevalent than indicated by the limited sampling programme.

Benthic Assemblages M, N & O occurred here, and Epibenthic Assemblage I was unique to this Region.

Physical Region 2 — East Wight and St Catherine's Deep
Habitat Summary



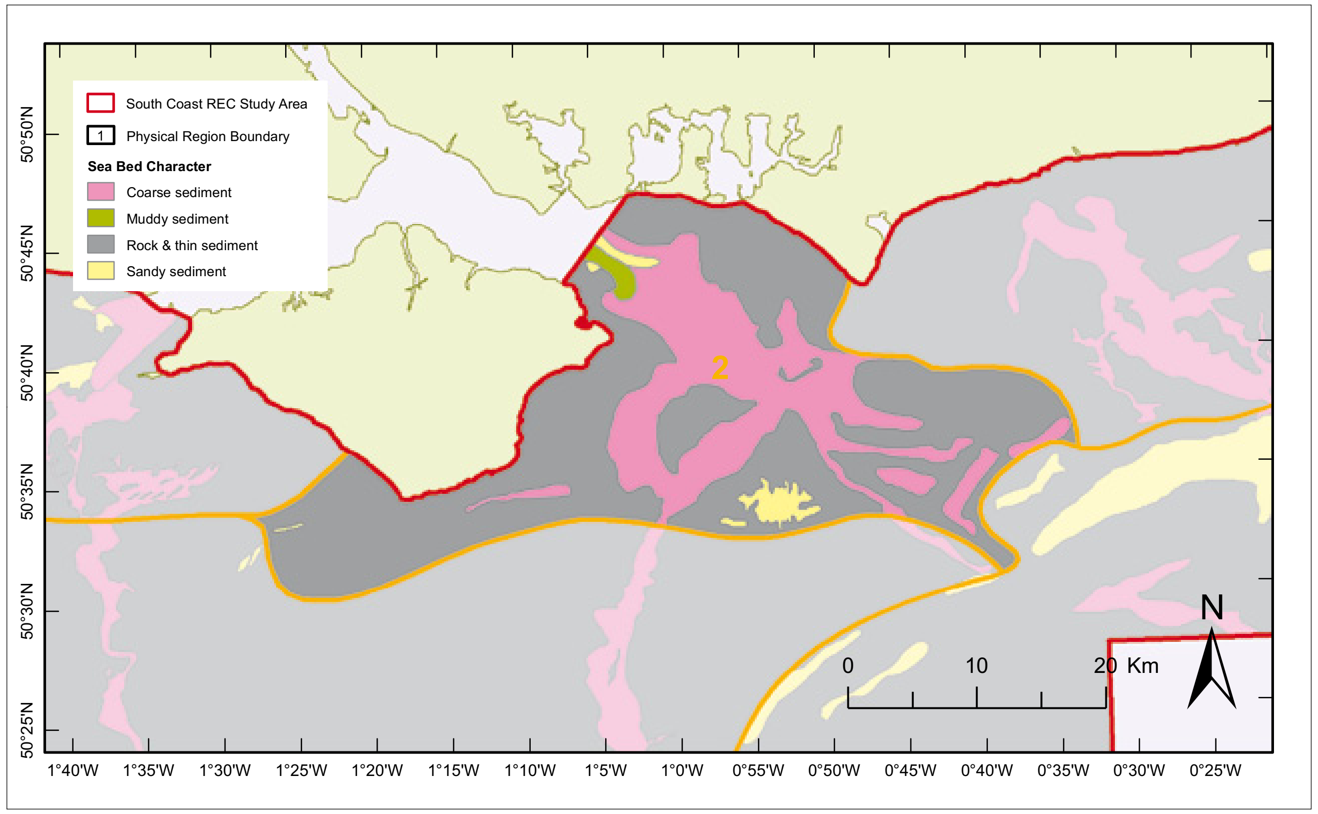
Water Depth (m) 0–80 m

Area (km²) 876

Grab stations 13

Trawl stations 1

Video locations 19



Geology and Sediments

Region 2 can be divided into two distinctive northern and southern sea bed areas. The northern area is an extension of the eastern Solent and trends north-west to south-east down to the Northern Palaeovalley (Figure 4.2). It has a central channel system with coarse sediment dominating its centre flanked to the north in Bracklesham Bay by rock and thin sediment. The Horsetail sand bank, at the entrance to the Solent, also flanks the central channel. The rock-based floor to Bracklesham Bay has a gentle southern decline that appears to mirror the low southern dip of the underlying Tertiary. Within Nab Hole in the central channel a small sand wave field has formed.

South of Pullar Bank a number of linear east-west rock ridges 8 to 14 m high appear in the central channel forcing the break up of the central coarse sediment deposit into discrete linear occurrences in the depressions between these ridges.

The southern flank of the central channel is formed by the limestone of the Bembridge Ledge in the north–west and rock and thin sediment continues along the Chalk based northern margin of the Monocline Rampart Enclosure and beyond to the Northern Palaeovalley.

The southern area is the distinctive Monocline Rampart Enclosure. Coarse sediment here is associated with the two Palaeoolent channel systems that cross the floor of the Enclosure before merging and exiting through a narrow gap in the southern wall of the Rampart. The Enclosure includes linear east-west ridges of rock up to 4 m high. These ridges become higher > 20 m in the south-west of the Enclosure where the sea bed descends in to St Catherine's Deep.

Sand waves occur within a small sand wave field in the south-east corner of the Enclosure in what appears to be a unique occurrence. This sand wave field is known as the Overfalls. St Catherine's Deep is characterised by rock and thin sediment. It has an undulating rough sea bed. The Deep, on its north side, is backed by the 300 m high cliffs of the Isle of Wight.

Broad Habitat

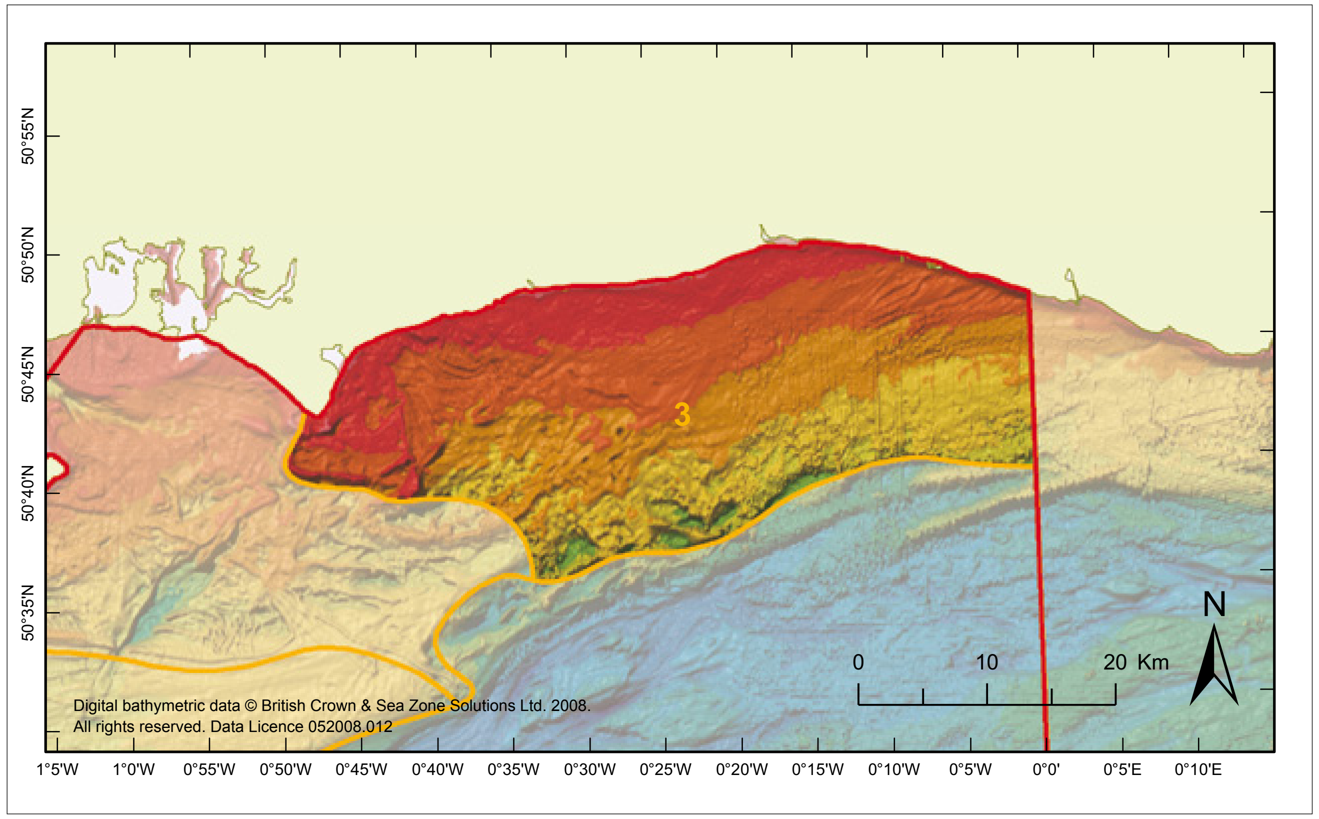
Region 2 is mostly open and moderately sheltered inshore waters in the 0–80 m depth range and so includes the infralittoral, circalittoral and deep circalittoral biological zones. The western part is very variable in habitat type, ranging from the relatively flat shallow sandy seabed off the west of the Isle of Wight to the 80 metre deep rock canyon of St Catherine's Deep that has a narrow base and near vertical walls in some areas. The east-facing beaches are the most sheltered areas, with sublittoral sand habitat (A5.2) off Sandown Bay giving way to moderately energy infralittoral rock off Whitecliff Bay and Bembridge. The southern tip of the Isle of Wight is exposed and steeply shelving, leading to a dominance of high and moderate energy sublittoral rock habitats (A4.2), but this modifies to sublittoral coarse and mixed sediment habitats around both the western and eastern margins of St Catherine's Deep.

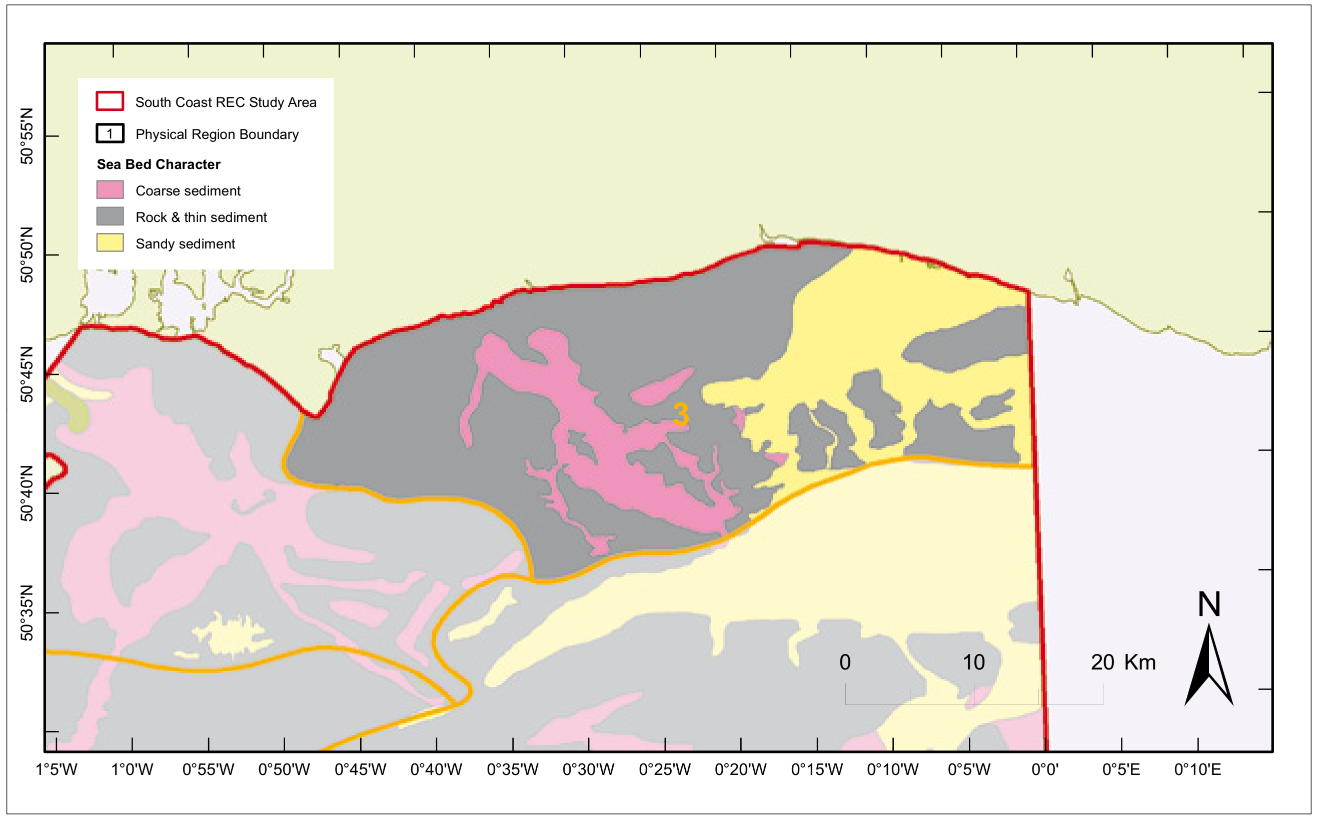
The eastern part of region 2 is dominated by the sublittoral sediments associated with the ancient and modern outflow of the eastern Solent. This is mostly mixed sediment, with records indicating an increasing proportion of mud towards the northwest. Some sand habitats were recorded off the western shore of Selsey Bill and occur in small patches on the EUNIS modelled map. Coarse sediment habitats were found at two sites in the southeast corner of region 2, and again appear in small patches on the EUNIS modelled map. Moderate energy circalittoral rock habitats were recorded in the southeast and southern margins of the region, at Stations 64 and 43, both associated with strongly linear, positive topographic features that suggest ridges of rocky reef.

Five stations (41, 42, 53, 54 & 55) in the centre of the region were assigned to A5.44(7), a new biotope class characterised by *Sabellaria*, *Crepidula*, *Pomatoceros* and barnacles, and this appears t be typical of the mixed muddy-sandy-gravely sediment that covers much of the area.

Benthic Assemblages A, C, D, H & O occurred here, as did Epibenthic Assemblage III.

Physical Region 3 — Selsey–West Sussex Coastal Platform
Habitat Summary





Water Depth (m)
0–40 m

Area (km^2)
969

Grab stations
18

Trawl stations
4

Video locations
21

Geology and Sediments

The Selsey–West Sussex Coastal Platform comprises a large platform of rock and thin sediment with abundant rock structural lineations of bedding and scarps, particularly in the west off Selsey Bill where the Mixon, Boulder Bank, Pullar Bank and the Shoal of Lead (Figure 4.2) form substantial rock ridges of Bracklesham and Barton Group with their tops at depths of around 5 m. These extend to a maximum distance of 10 km offshore. Rock structural lineations associated with bedding dip slopes and scraps are common in The Park and Outer Owers and along the southern boundary of the Region with the Northern Palaeovalley. The Park and Inner Owers are within a shallow 10 km wide embayment that cuts back into the Platform towards Pagham Harbour, possibly an indicator of an ancient fluvial system flowing from the back of Selsey Bill. However, the limited seismic lines hereabouts have not shown a significant sediment filled channel within the embayment, it appears to be rock and thin sediment, with the embayment floor being sandy in part.

Coarse sediment is associated with the Palaeoarun channel system which cuts across the Platform to the Northern Palaeovalley. These include river terrace deposits and channel fill. To the east of the Palaeoarun the rock platform has a gentle decline but minor rock lineations caused by bedding in the relatively steeply dipping underlying rock are common.

Further east an extensive sheet of sandy sediment with windows of rock and thin sediment covers the platform. The sand sheet has well developed megaripples and minor sand waves with cross profile asymmetry to the east (Figure 4.24).

Broad Habitat

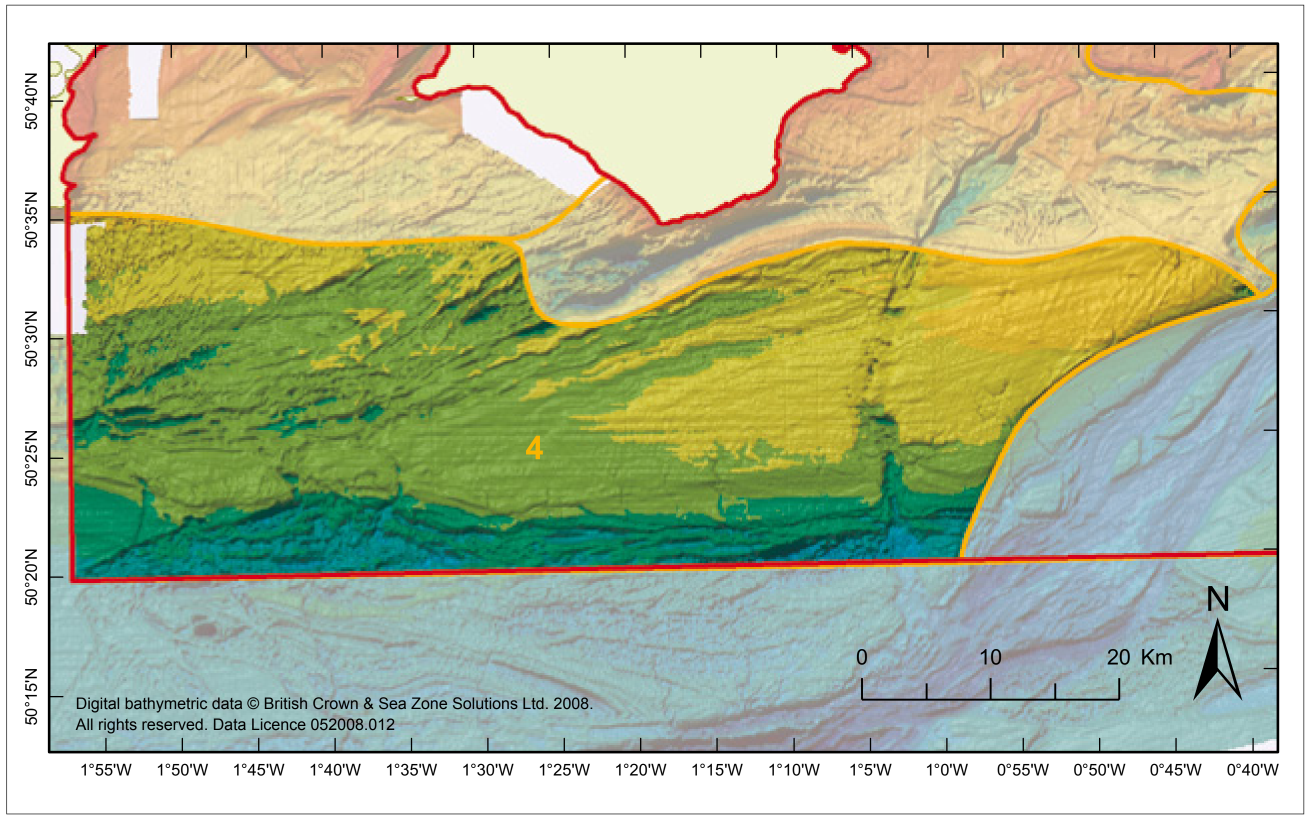
Region 3 comprises moderately exposed nearshore waters in the depth range 0–40 m, so includes the infralittoral and circalittoral biological zones. As its name suggest, this coastal platform is relatively flat and gently shelving. Bedrock is close the surface over much of the region but a significant sand wave field exists in the east, possibly the only part where a rock outcrop is unlikely to be found. For the remainder, rock habitats could be found at the seabed surface almost anywhere, but are usually modified to mixed sediment habitats on account of lag gravel or thicker deposits of the same type of mixed sediment that dominated region 2.

The nearshore waters are in the photic zone, and being reasonably sheltered seaweeds are able to grow on the larger more stable cobbles and pebbles, so along the coast from Selsey Bill to just beyond Shoreham there is an uncommonly extensive area of macrophyte dominated subtidal sediment (A5.5). Kelp was not noted here at sites in the infralittoral zone. Green brown and red algae were common, with the red algae in particular extending to sites in the upper circalittoral; roughly the 10–20 m depth zone in this area, and up to about 3 miles offshore. In places there was also a significant proportion of *Crepidula* among the algae and they seemed to favour the more silty sediments. *Crepidula* were also a feature of many of the mixed sediment sites that were focused in the centre of the region. A soft-rock community (A4.23) was identified in the southwest (Station 7), rock exposures being characterised by many small pits, likely to be of biogenic origin.

Nine of the 21 sampling stations were sublittoral sand habitats (A5.2) and these supported a reduced faunal assemblage characterised by errant worms, amphipods, the 'pea' urchin *Echinocyamus*, Hermit crabs and dragonets. Fine sand habitats (A5.25) were characteristic of the sand wave field in the southeast, which extends in to the northern palaeovalley. Ophiuroids were noted from these habitats in trawls, grabs and on video. Benthic Assemblages C, D, H, I, O and P occurred here, and Epibenthic Assemblages III and IV.

Marine Aggregate Levy Sustainability Fund MALSF

Physical Region 4 — South Wight Platform
Habitat Summary



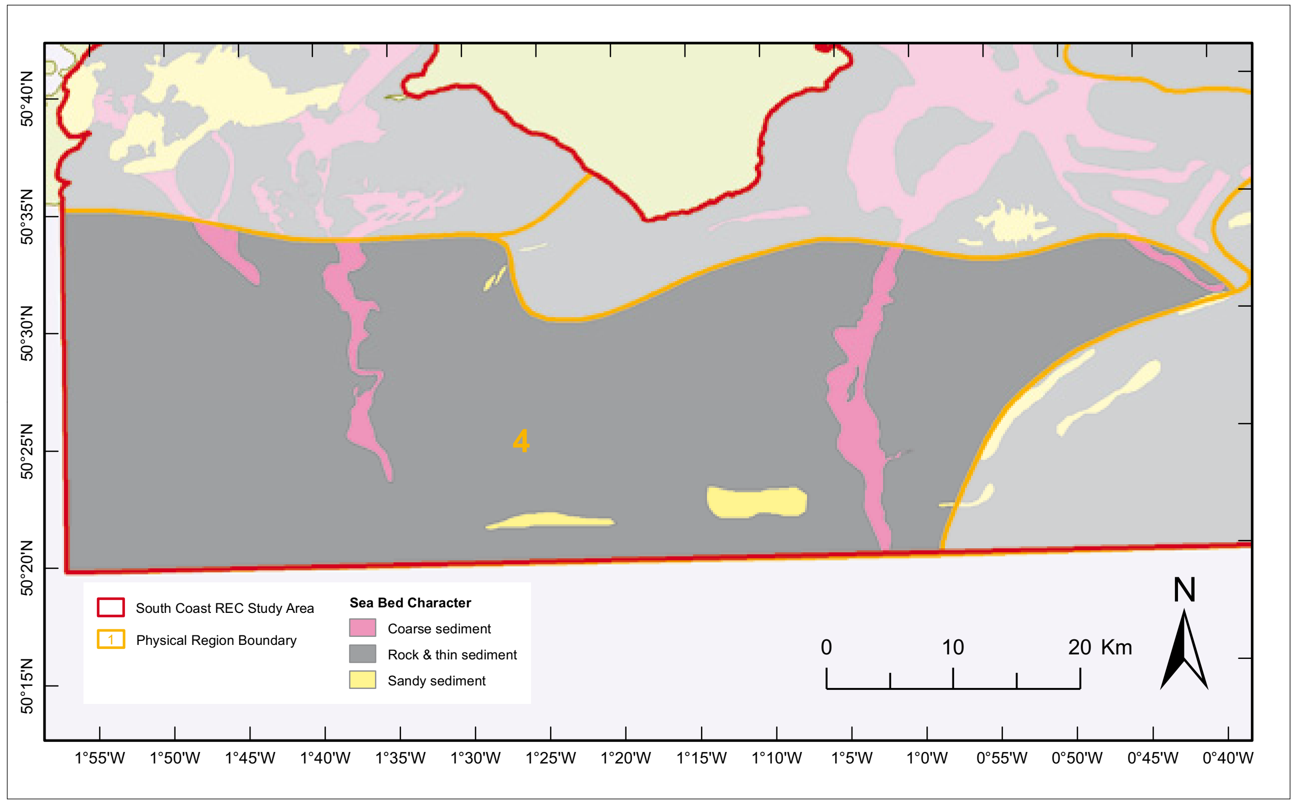
Water Depth (m) 30–60 m

Area (km²) 1919

Grab stations 11

Trawl stations 8

Video locations 23



Geology and Sediments

The region is dominantly a platform of rock and thin sediment. There are two narrow north-south areas of coarse sediment overlying palaeochannels in the west and east.

The central and eastern half of the region is a remarkably flat and relatively smooth sea bed surface underlain by horizontally bedded Chalk. In the north-west of the region where the sea bed is underlain by Lower Greensand and Wealden rocks the slightly steeper dips, thinner bedding and variable lithological properties create a sea bed of linear rock ridges up to 4 m high. These rock types also occur along the southern margin of the region where intensive folding associated with the Central English Channel Monocline (Figure 4.2) has produced significant scarps at the Chalk-Lower Greensand boundary and prominent linear ridges. These scarps have also been cut through by small rivers which have left open channels in the sea bed surface.

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. The angularity, abundance of cobbles and boulders, local and in-situ provenance 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 only significant sand deposits that are apparent on the limited seismic data are sand patches with megaripples aligned at the foot of the southern Chalk scarp where sand is trapped as it migrates eastward.

Broad Habitat

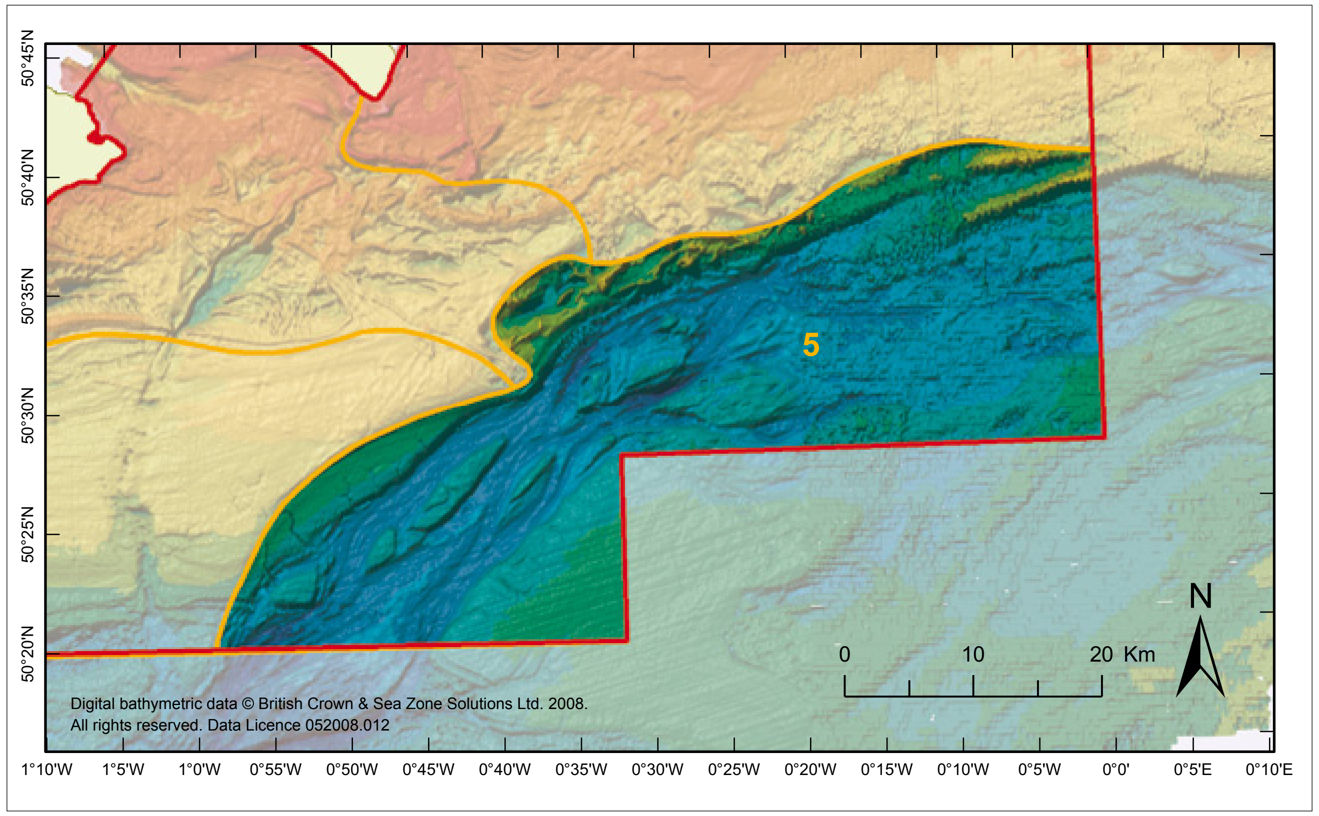
Region 4 is a fully exposed area of offshore water, most of which lies beyond the 6 nautical mile line. Depths range from 20–60 metres, so the area is primarily in the circalittoral zones but extends into the deep circalittoral in the south, where the seabed lies below the wave-base. The region is dominated by rock habitats; less than half the stations were successfully sampled by grab. Those that were lay away from the central area, in the west and east, and most of these were associated with sediment infill of palaeochannels. A small amount of coarse sediment occurs, in patches, mostly in the south of the region.

Video records showed rocky reef at many of the sites in this region, usually with some low-elevation rock outcrops, reflecting the broad flat nature of the underlying chalk platform that dominates the eastern and central parts. Much of the hard seabed, including small boulders and cobbles, supported faunal and algal crusts, with the bryozoan *Flustra*, the anemone *Urticina* and the brittlestar *Ophiothrix fragilis* being characteristic. Encrusting and erect sponges were also seen. The high rugosity of the rock-rubble seabed surface is suitable for a wide range of more cryptic taxa including several types of crabs and gastropods. Habitats on the western extension of the rock platform (Stations 14, 22, 29 & 30) appeared to be a higher energy status (A4.1) than those further east (A4.2).

The western and eastern palaeochannels in the region formed distinct mixed sediment habitats, some characterised by *Crepidula* and others by clumps of *Sabellaria* (A5.44(8) at Stations 20, 21, 46 and 47). A single sand habitat was sampled in the extreme east of the region and is associated with the margin of the Northern Palaeovalley where mobile sands bank up against the valley wall.

Benthic Assemblages A, D, J and M occurred here. Epibenthic Assemblage II was exclusive to this region and accounted for all the stations sampled by trawl.

Physical Region 5 — Northern Palaeovalley and Margin
Habitat Summary



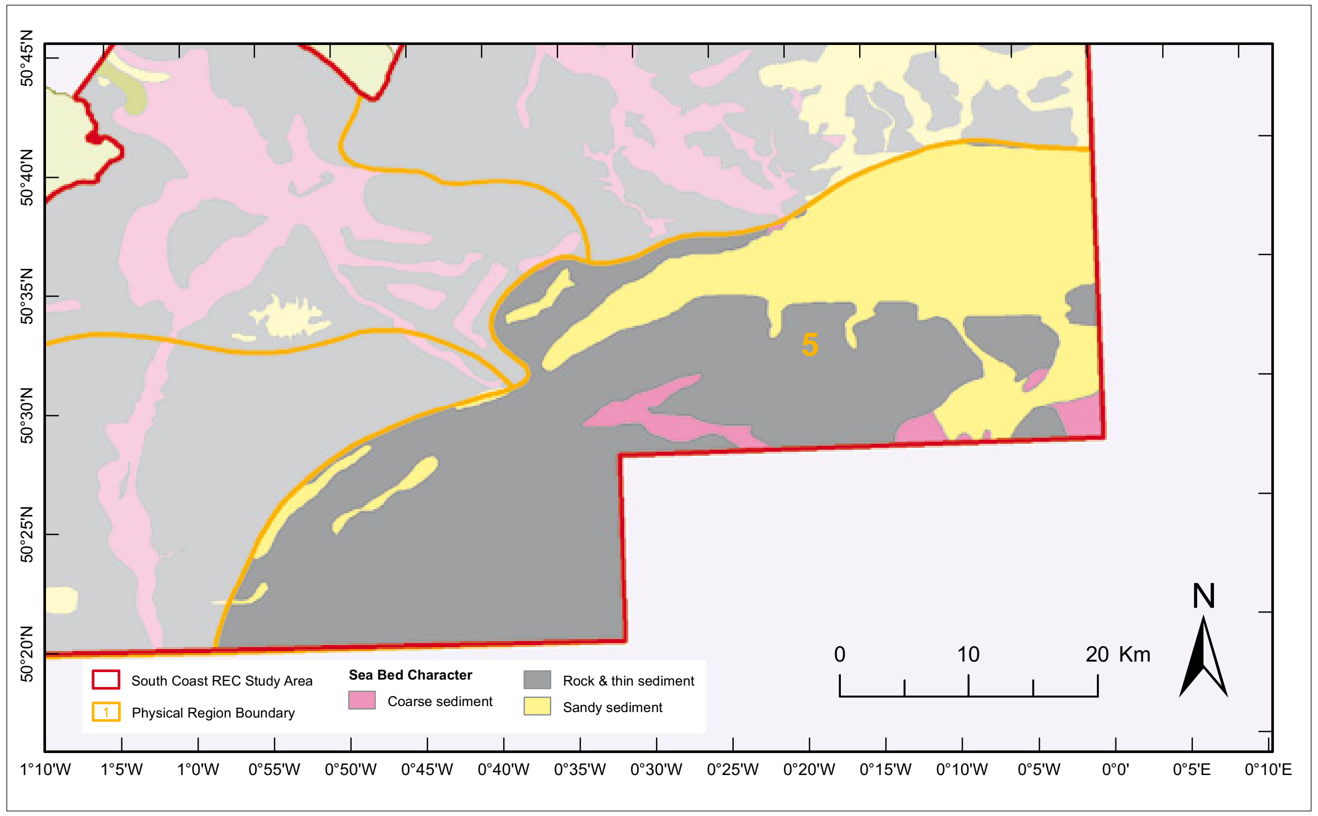
Water Depth (m)
50–70 m

Area (km²)
1340

Grab stations
17

Trawl stations
8

Video locations
17



Geology and Sediments

The Northern Palaeovalley is a significant regional feature in this part of the English Channel (Figure 4.2). In the west of the region it includes a number of classic fluvial morphology features such as a channel margin terrace and a number of flow elongated flat topped bars within the main channel. Both the terraces and one of the bars have small dendritic stream channels etched in their surfaces. However, the limited seismic data available suggests that the channel floor, terrace and central bars are all underlain by rock and thin sediment, there is no evidence for significant channel fill or terrace sediments on the seismic line. Linear sheets of megarippled sand are aligned along the break of slope at the northern margin of the main channel and the scarp at the back of the channel terrace. These linear sand sheets become much more extensive east of the Wight–Bray Monocline pinch point where the main channel narrows to 8 km. The wider and thicker sands, which remain banked against the northern margin of the Palaeovalley, support east facing sand waves up to 4 m high.

Immediately east of the pinch point the main channel floor is overdeepened between a central channel bar but further east the channel floor becomes wider and loses its bars. The accumulation of sand becomes much more extensive and extends across the channel floor. However, the build up of sand, associated with eastern transport of sediment, against the Palaeovalley margin has created two large linear sand banks, the Northern Palaeovalley Banks. The outer bank is well developed with a single virtually straight crest line over 16 km long, which is attached at its eastern end to the coastal platform. The inner bank in total length is about 28 km. It is not as well developed through its entire length. As with the outer bank its eastern end is attached to the coastal platform.

East of the pinch point there are some over deepened hollows within the rock and thin sediment of the Palaeovalley margin and also relatively smooth tilted bedding plane surfaces are extensively developed as low angled slopes in the margin where Barton Group and older Tertiary rocks outcrop at the sea bed.

Broad Habitat

Region 5 comprises offshore waters, mostly beyond the 12 nautical mile limit, with depths in the range 50–70 metres, so includes the lower circalittoral and deep circalittoral biological zones. The majority of the seabed is below the wave base, so will not be disturbed by storm events. The floor or the Northern Palaeovalley dominates the region, with coarse sediment in the south and southwest and a sand-wave field in the northeast. The coarse sediment areas are fairly uniform in habitat, eight of the sample stations being assigned to A5.141. They comprise smaller gravel and pebble particles swept by string tidal currents, so the epifauna are fairly sparse, with few attached fauna other than barnacles and *Pomatoceros*. The queen scallop Aequipecten and the sun-star *Crossaster* are characteristic motile epifauna, and dense ophiuroid beds occurred at Station 80. The gravel substrate supports a rich and varied infauna, dominated by interstitial taxa, especially small arthropods such as the squat lobster *Galathea* and the porcelain crab *Pisidia*, and errant polychaete worms.

Mobile substrates bank up against the northern margin of the palaeovalley, so mixed and sandy substrate habitats were recorded here (Stations 59, 77, 86, 87; A5.44 & A5.25). In contrast, in the southern most part of the region the palaeovalley margin rises onto a rock platform, with high energy circalittoral rock habitat (A4.134; Station 70) characterised by consolidated, stable cobbles supporting rich epifaunal growth and featuring many kinds of sponge.

In the northeast of the region the mixed substrate of the palaeovalley floor and margin has been smothered by a substantial sand-wave field, causing a dramatic change in habitat and biota. The fine sands support little epifauna, apart from ophiuroids and a few hermit crabs, but the infauna are quite varied and characterised by the errant polychaetes *Nephtys, Spiophanes* and *Magelona*, the amphipod *Bathyporeia* and pea-urchin *Echinocyamus*.

Benthic Assemblages G, I, J, k, L, M and P occurred here, and Epibenthic Assemblages III, V and VI, the latter two being exclusive to this region.

8 Features of Interest – 1

Annex I Habitats

What are 'Annex I Habitats'?

Annex I of the EC Habitats Directive (European Commission, 1992) list habitats that are subject to special requirements for conservation under EU law. This also applies in UK law since, as a member of the EU, the UK has transposed the Habitats Directive into national legislation.

Eight of the 189 habitats listed in Annex I of the Habitats Directive are marine and seven of these occur in UK waters, namely:

- Sandbanks which are slightly covered by sea water all the time
- Estuaries
- Mudflats and sandflats not covered by seawater at low tide
- Coastal lagoons
- Large shallow inlets and bays
- Reefs
- Submarine structures made by leaking gases

Within the context of the South Coast REC, it is the sandbanks and reefs that are of stakeholder interest. Definition of these features has become complex as a result of the need to define them in law; much assistance being provided by a guidance document published by the European Commission and a subsequent updated version (European Commission 2007a, b; see also 'Web Resources' below).

The JNCC provide more accessible summaries of the habitat definitions, which for sandbanks and reefs are as follows (material sourced from JNCC website, accessed 06/12/2009):

'Annex I sandbanks slightly covered by seawater all the time occur where areas of sand are predominantly surrounded by deeper water and where the top of the sandbank is in less than 20 metres water depth. However, the sides of these sandbanks, particularly in offshore waters, can extend into waters deeper than 20 m'.

'Reefs are rocky marine habitats or biological concretions that rise from the seabed. They are generally subtidal…… Two main types of reef can be recognised: those where animal and plant communities develop on rock or stable boulders and cobbles, and those where structure is created by the animals themselves (biogenic reefs)'.

Why are 'Annex I Habitats' important?

The list of Annex I habitats represent key environments that are considered important for the maintenance of the marine ecosystem. Some have important roles in animal life cycles such as breeding and nursery grounds while others may include fragile or vulnerable biotopes with little resilience to anthropogenic disturbance. A few are simply rare, as far as was known when the Directive was developed.

Sandbanks include four main sub-types; a) gravelly and clean sands, b) muddy sands, c) eelgrass beds and d) maerl beds, and provide habitat for a variety of taxa. Eelgrass and maerl beds are particularly noted as relatively rare biotopes supporting a high diversity of species but, as far as we can establish, neither is found in the South Coast REC study area. Shallow sandy areas are regarded as important feeding grounds for many fish and birds, supporting good populations of shrimps, prawns, worms, bivalves and small fish. They are also nursery grounds for many commercial species of fish, especially the flatfish.

Rocky reefs are commonly regarded as biodiversity hot-spots, having both a great diversity and abundance of species. Their structural complexity provides many niche habitats occupied by specialist species, for example, communities of steep rock faces are very different to those on flatter surfaces. The many nooks and crannies provide shelter for a multitude of cryptic, crepuscular and nocturnal species, which in turn are predated by larger taxa attracted to the rich source of food, such as fish and man. Importantly the rock substrate gives a foothold for marine plants, mainly macro-algae, which can form extensive 'kelp forests' in the infralittoral zone. These are areas of high productivity and provide habitat and shelter for many marine taxa. Below the photic zone, tide swept cobble substrates provide habitat for sponges, which come in encrusting and erect forms and add to the structural complexity of the ecosystem, providing yet more habitat for yet more fauna. Finally, soft rock supports a specialist community of organisms capable of boring into rock, including bivalves, worms, and sponges.

Biogenic reefs are commonly thought of as coral reefs, but are also formed by gregarious organisms such as mussels and some types of tube building worms. They again increase the physical complexity of the sea bed providing niches and substrate for other organisms to occupy, so they increase local biodiversity and productivity. Being static, they cannot avoid human pressures, so their presence alone can be indicative of an area where such pressures are relatively light and sustainable.

Where do they occur in the South Coast REC?

Sand banks

There are two areas of sand bank in the South Coast REC area, one in the west and one in the east (Figure 8.1). In the west, the distinct linear topographic features emerging from Poole Bay and Christchurch Bay are sand banks, including Dolphin Sand and Dolphin Bank (Figure 4.2). The area between them is shown on the EUNIS Level 3 map to be a sand substrate (Figure 7.4) and might be considered an integral part of these sand bank features under the detailed definition. Shingle Bank is a gravel bank at the western entrance to the Solent (Figure 4.20).

In the east there is a significant sand sheet on the Selsey — West Sussex Coastal Platform Region that extends down across the platform's southern margin into the Northern Palaeovalley where it merges with two distinct sand banks — the Northern Palaeovalley Banks. It is debateable whether these banks qualify under the Annex I criteria as they are generally shallower than about 40 metres.

Areas of sand waves in the west, centre and east of the South Coast REC area may be worthy of targeted surveys to establish their extent, form and elevation for comparison with the Annex I sand bank criteria.

Rocky reefs

Rocky reef habitats occur extensively over the REC area (Figure 8.1). Twenty one of the 100 sampling sites are identified as rocky reef habitats (A3.n and A4.n). A further seven sites are considered to qualify as stony reefs (A5.5). In addition, the morphology model of the area indicates many linear features attributable to bedrock near or at the sea bed surface, many abrupt changes in bathymetry and several areas of uneven sea bed, all of

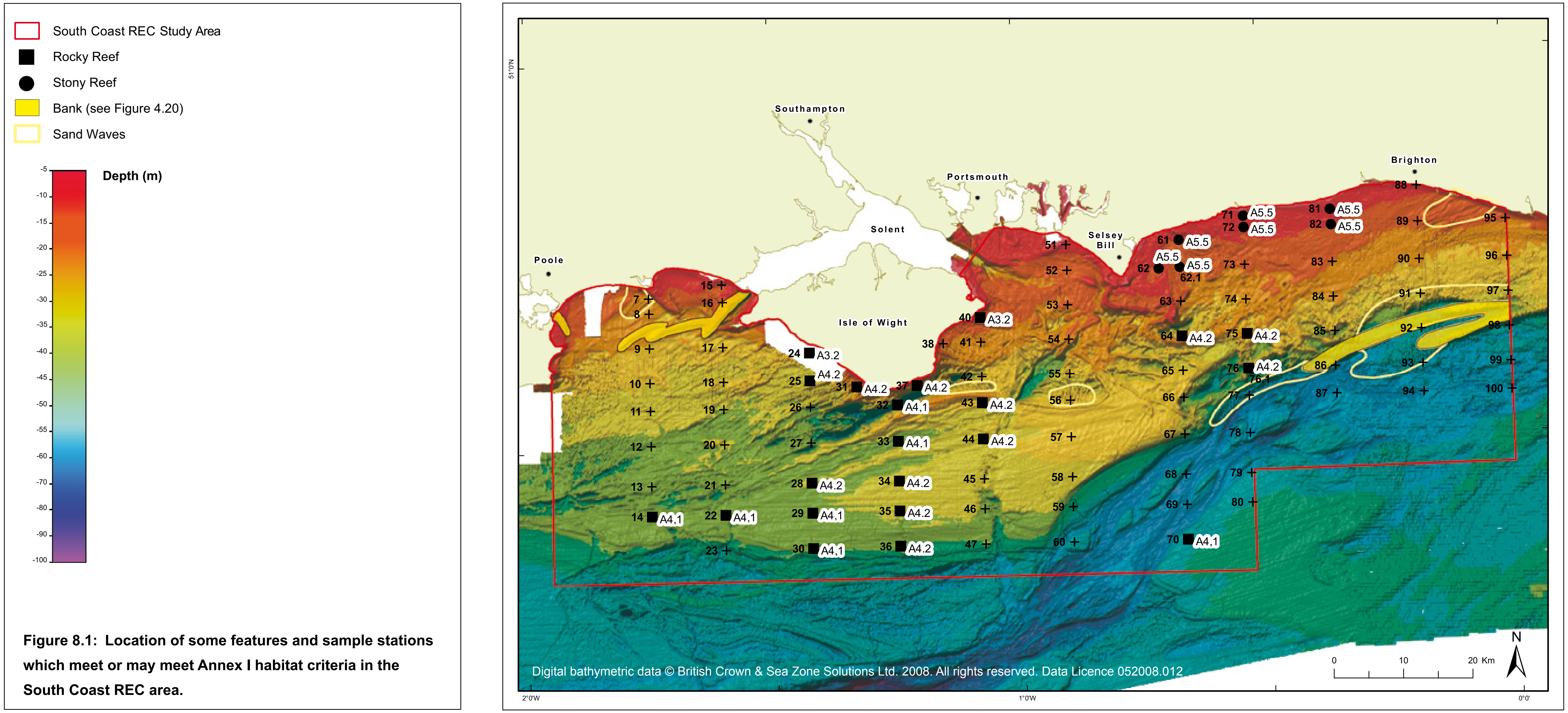
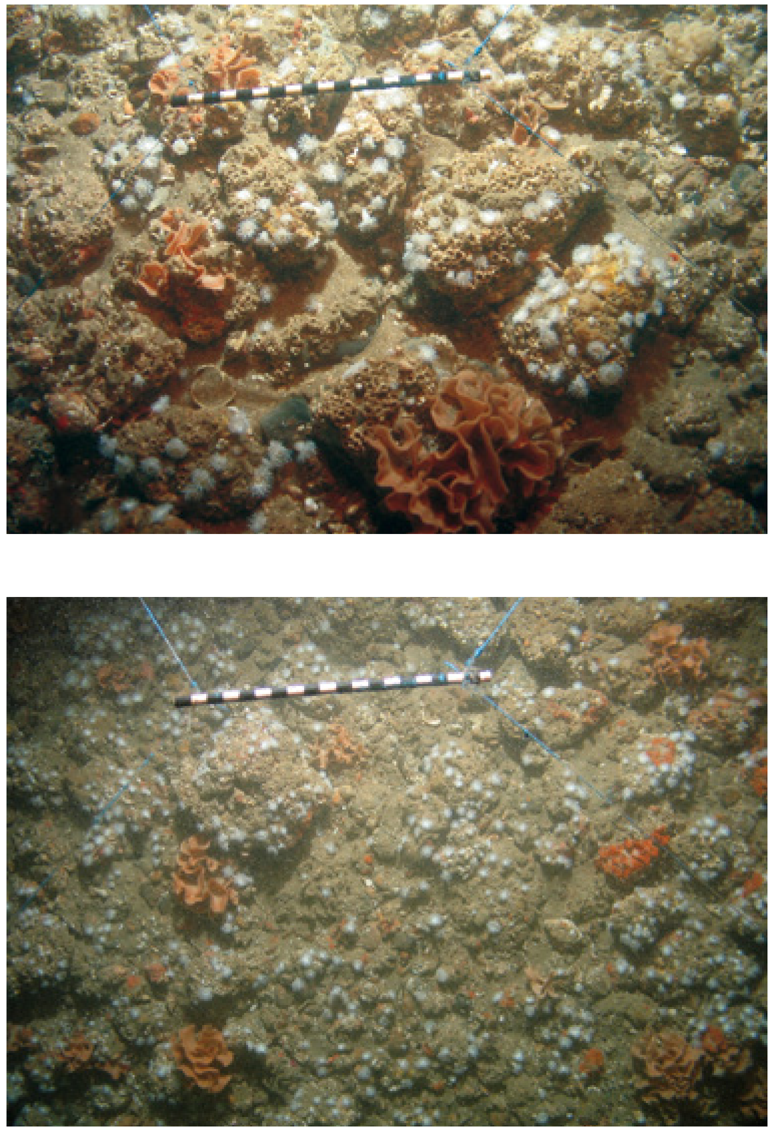


Figure 8.1: Location of some features and sample stations which meet or may meet Annex I habitat criteria in the South Coast REC area.

which are potential Annex I rocky reef features. The geomorphically complex area in to the south of the South Wight Platform that projects beyond the southern boundary of the REC forms part of the Wight-Barfleur reef system originally identified by Coggan *et al* (2009), which has now been proposed by the JNCC as an SAC under the Annex I site selection process (see Web Resources).

Other prominent features on the sea bed morphology model are also likely to qualify as Annex I rocky reefs and require further directed survey. These include all the rocky promontories extending from the shore into the sea, especially off Swanage, Christchurch, The Needles, Portsmouth, and Selsey Bill, the area around St Catherine's Deep and the chalk ledges two to three miles off the Sussex coast, including Kingmere Rocks, noted as marine Sites of Nature Conservation Importance (mSNCI).

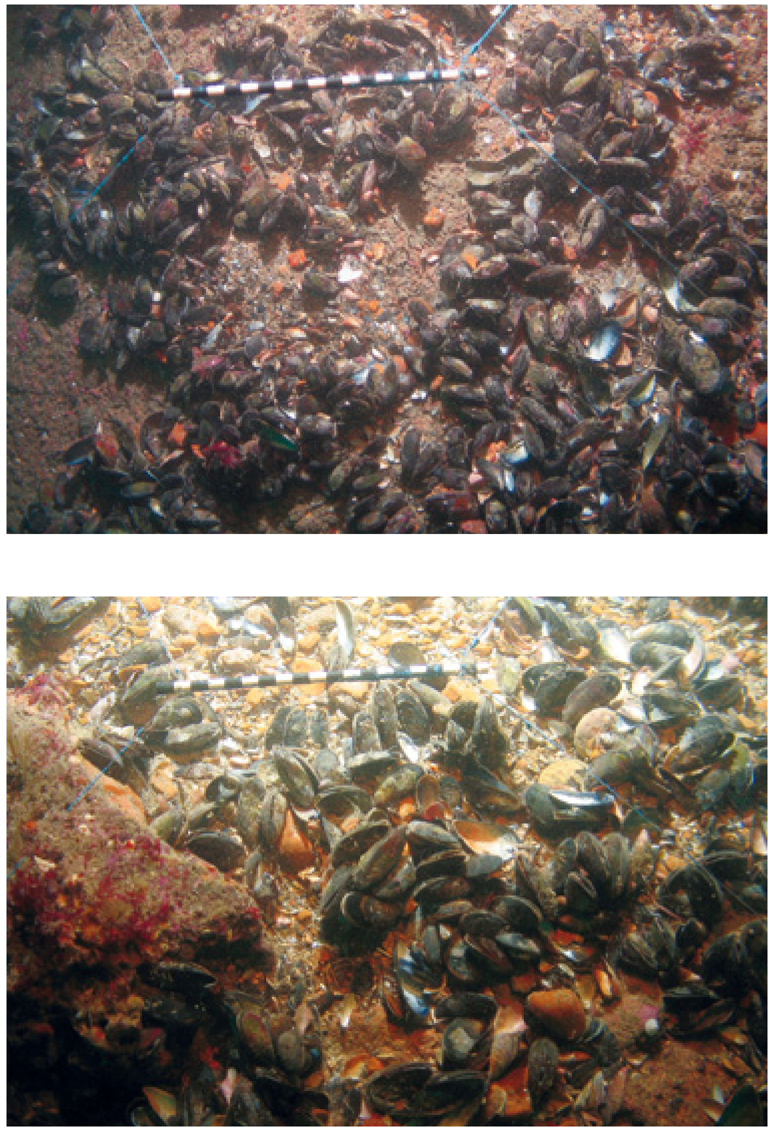
Station 76.1 (labelled 76M during the survey) is worthy of special note. This mound adjacent to Station 76 was targeted for an additional video drop. It appears to be made of rock rubble, now consolidated by biogenic concretions. It supports a notable density of white anemones, thought to be *Actinothoe sphyrodeta*, and, the foliose bryozoan *Pentapora fascialis* (Ross coral) and barnacles (Figure 8.2a, b). The highly rugose surface with interstices filled with sediment is unusual and likely to support a diverse mix of arthropods, hydrozoa, bryozoans and tube dwelling worms. As such, it merits further investigation.



Figures 8.2a, b: Seabed photographs from Station 76.1, a rubble mound with abundant white anemones and common Ross coral.

Biogenic reefs

One of the sampling sites in the REC area could be considered as biogenic reef, having a significant biogenic component. This is at Station 64 (Figure 8.3a, b) which was assigned to EUNIS A4.421 '*Mytilus edulis* beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock'. Expansive mussel beds were not apparent on the small part of this area sampled by video, but may exist in the vicinity. The presence of mussels imparts habitat characteristics that may qualify it as a biogenic reef.



Figures 8.3a, b: Seabed photographs from Station 64 showing clumps of mussels.

Summary

Although qualifying as rocky reefs, the question remains as to whether the conservation agencies would wish to include specific sites or wider areas as part of the Natura 2000 network and this will likely be influenced by how representative the sites are of certain biotope classes, and whether they would contribute to the connectivity of the overall network.

Web resources:

Pages from the JNCC website:

Annex I reefs (rocky and biogenic): http://www.jncc.gov.uk/protectedsites/sacselection/habitat.asp?FeatureIntCode=H1170

Annex I sandbanks: http://www.jncc.gov.uk/page-1452

Annex I reefs: http://www.jncc.gov.uk/page-1523

SAC site proposal for Wight-Barfleur reef: http://www.jncc.gov.uk/pdf/comm09p07.pdf

Pages from the European Commission:

EC Habitats Directive: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF

EC Interpretation Manual for EU Habitats: http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/2007_07_im.pdf

Update to EC Interpretation Manual for EU Habitats:

http://ec.europa.eu/environment/nature/natura2000/marine/docs/appendix_1_habitat.pdf

8 Features of Interest – 2

The American Slipper Limpet — *Crepidula fornicata*

Figure 8.4: The American Slipper Limpet, *Crepidula fornicata*
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The American slipper limpet, *Crepidula fornicata*, (Figure 8.4) is a North American gastropod whose natural range is reported from Escuminac Point on the Canadian coast (47°N) to the Caribbean islands (18°N) (Walne, 1956). It was introduced into the UK alongside intentional introductions of the American oyster *Crassostrea gigas* and the American hard clam *Mercenaria mercenaria* in the 1870s (McMillan, 1939; Utting and Spencer, 1992; Eno *et al.*, 1997). The American oyster and hard shelled clam were introduced to boost the English shellfish trade after the near collapse of native oyster, *Ostrea edulis*, stocks (Davidson, 1976; Eno *et al.*, 1997).

Crepidula fornicata was first observed in Liverpool Bay in 1872, although this population has since died out (McMillan, 1939). It was subsequently introduced on the east coast between 1887 and 1890, where it was reported to spread rapidly over native oyster beds (Crouch, 1895). The first observation on the south coast was made in 1913 in association with the Bosham oyster ponds in Portsmouth Bay (Cole, 1952) and then around 1930 in the Solent (Barnes *et al.*, 1973). The current UK distribution is given in Figure 8.5 (NBN, 2009) which closely matches the distribution reported by Blanchard (1997).

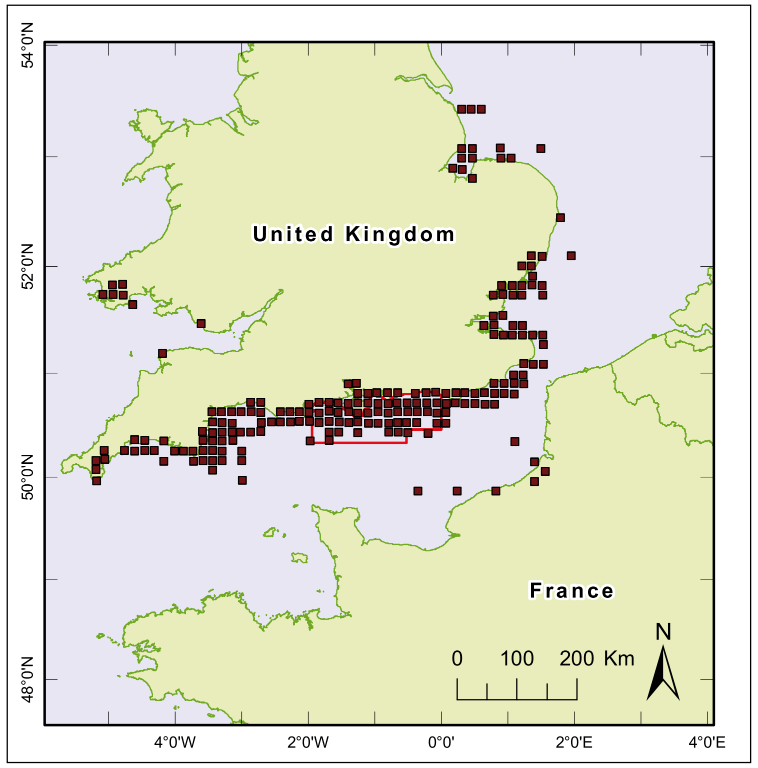


Figure 8.5: Distribution of the American slipper limpet, *Crepidula fornicata* (NBN, 2009).

Crepidula fornicata appears to be limited in its UK distribution to latitudes <54°N which is likely to be linked to water temperature. Thieltges *et al*,. (2004) reported high mortalities of *C. fornicata* in cold winters and concluded that sea temperature was responsible for the northern limit of their European distribution. Given that winter mortality is such a key factor in the population dynamics of *C. fornicata*, an increase in densities as well as an extension of their northern boundary is likely if climate change predictions are correct.

Crepidula fornicata does not occur in any abundance deeper than 30 metres (Barnes *et al.*, 1973), although the reasons for this are as yet undetermined. It can tolerate a wide range of environmental conditions but is found in higher densities in wave protected areas, as was observed in the South Coast REC area (Figure 8.6). *C. fornicata* can be found on a variety of substrata but is most abundant in muddy or mixed muddy areas (de Montaudouin *et al.*, 1999; de Montaudouin *et al.*, 2001). This may in part be due to its utilisation of suspended material for food but also as a result of its influence on the substrata. Faeces or pseudofaeces produced

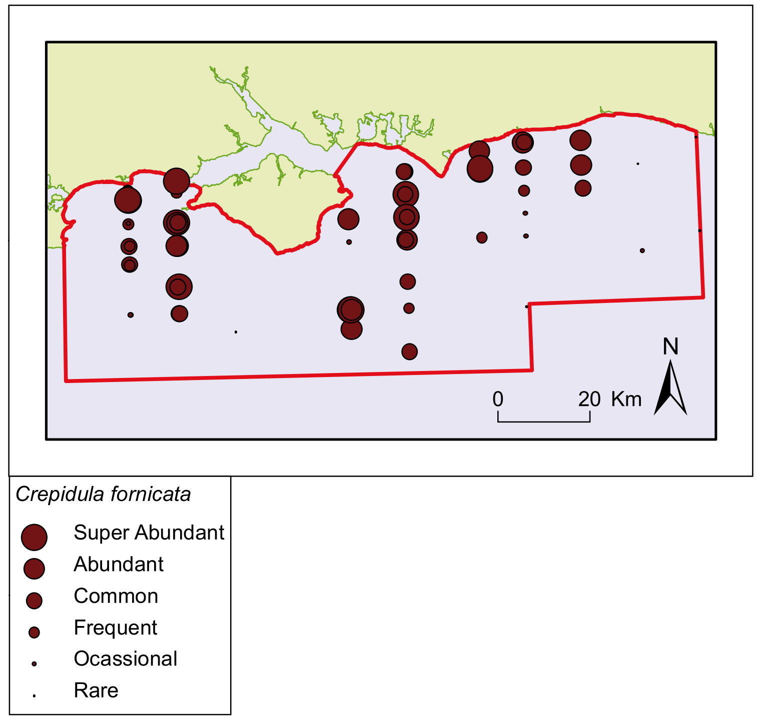


Figure 8.6: Distribution of the American slipper limpet, *Crepidula fornicata* across the South Coast REC study area. Abundances based on the SACFOR scale.

by *C. fornicata* accumulate where it is found in high densities, significantly altering the nature of the substratum, increasing the proportion of fine sediments (Barnes *et al.*, 1973).

The introduction of the American slipper limpet is thought to have had a detrimental effect on the native oyster population since it competes with them for food and space, whilst also depositing fine sediments which smothers them (Utting and Spencer, 1992). The accumulation of fine material by this species is also thought to render the substratum unsuitable for oyster settlement (Barnes *et al.*, 1973).

The American slipper limpet is a sequential hermaphrodite which forms long lived stacks composed of males, females, juveniles and individuals in transition, on the way from being male to becoming female (Coe, 1938). Fertilisation is internal with males transmitting sperm during mating. Dupont *et al.*, (2006) showed that the eggs of a given female are commonly fertilised by multiple males mostly found in the mother's 'stack' which they postulate helps to ensure reproductive success. Veliger larvae are released into the water column where they swim and feed for several weeks before metamorphosing (Le Cam *et al*., 2009). The reproductive success and dispersal potential of this species have no doubt contributed to its establishment in UK waters.

Crepidula fornicata was identified as a characterising species in both the grab and trawl samples from the South Coast REC study area and was also abundant in numerous seabed photographs. In order to better understand why this species has become so well established in this area the abundance recorded in grab samples was analysed in combination with the environmental data summarised in Table 6.1. A RELATE test on this data revealed a weak (Rho = 0.148) but significant relationship, at the 0.6% significance level, between *C. fornicata* abundance and the environmental conditions in the South Coast REC study area. This relationship was investigated further by plotting *C. fornicata* abundance against some of the key environmental variables (Figure 8.7) and also through BIO-ENV analysis (Table 8.1) using the full suite of variables recorded (Table 6.1).

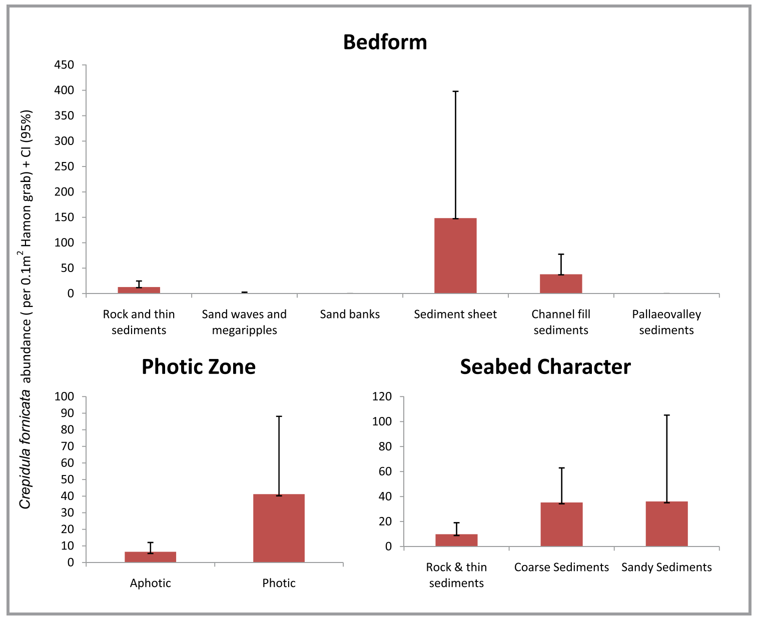


Figure 8.7: Relationship between bedforms, the photic zone, and sea bed character, and the abundance of the American slipper limpet, *Crepidula fornicata*, in grab samples from the South Coast REC study area.

Crepidula fornicata shows a clear preference for sediment sheets (Figure 8.8) in this area although its abundance on this bedform is highly variable. It was also present on channel fill sediments (Figure 8.9) and rock with thin sediments (Figure 8.10), albeit in much reduced numbers, but was notably absent from sandbanks, sand waves and the well sorted sediments of the Palaeovalley (Figure 8.7).

No. of Variables	Correlation (ps)	Variables
5	0.277	Water Depth, Northing, % Sand, Seabed Character and Bedform
	0.275	Water Depth, % Sand, Mean, Seabed Character and Bedform
	0.273	Water deepness, % Sand, Sorting, Seabed Character and Bedform
3	0.281	Water Depth, % Sand and Seabed Character
	0.277	Water Depth, % Sand and Bedform
	0.254	Water Depth, Seabed Character and Bedform
1	0.245	Water Depth
	0.148	% Sand
	0.128	Bedform

Table 8.1: Summary of BIO-ENV results carried out on untransformed *Crepidula fornicata* abundance data recorded in grab samples, and normalised environmental variables (Table 6.1).

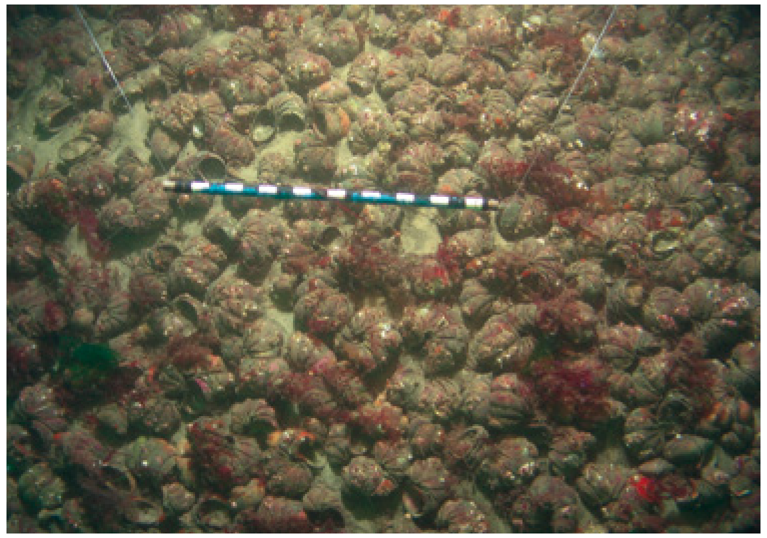


Figure 8.8: Dense sea bed cover of *Crepidula fornicata* at sample station 15 in Poole Bay – Region 1.

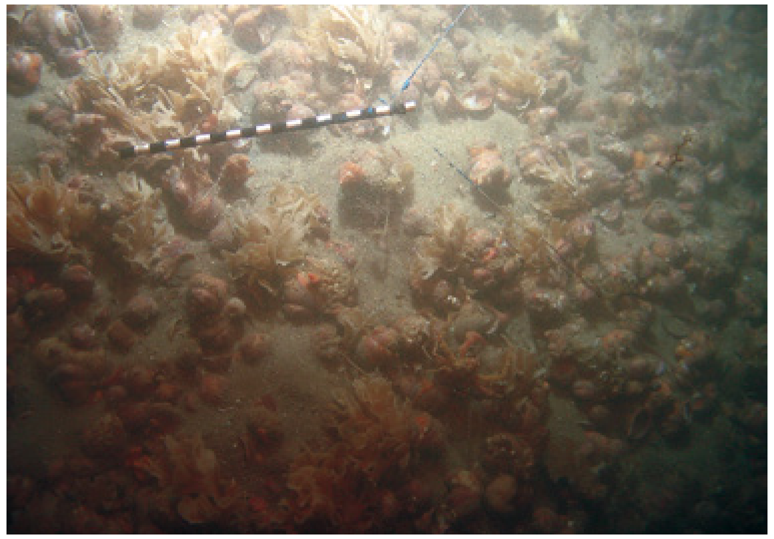


Figure 8.9: Discrete clusters of *Crepidula fornicata* associated with Hornwrack *Flustra foliacea* on sandy sea bed at sample station 54 – Region 2.

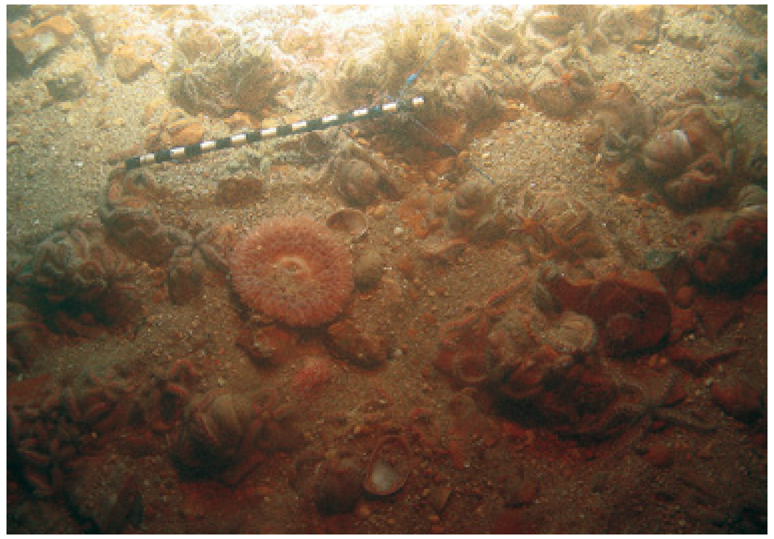


Figure 8.10: Discrete clusters of *Crepidula fornicata* associated with *Ophiothrix fragilis* on a gravelly sand sea bed at sample station 45 – Region 4.

8 Features of Interest – 3

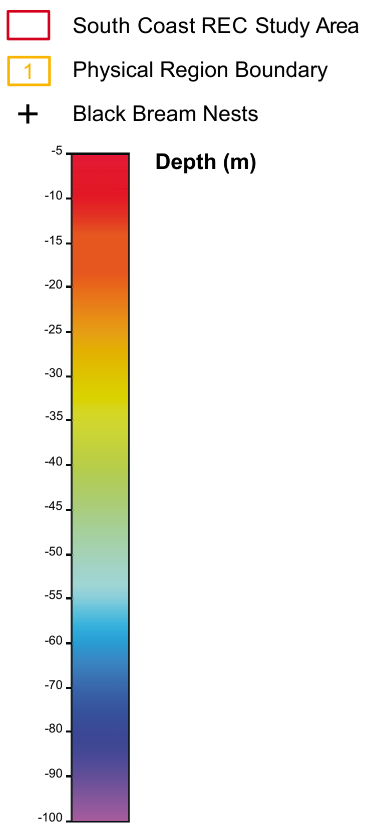
Black Bream (*Spondyliosoma cantharus* (L.))

The South Coast REC area is one of the few places in the UK that has been identified as being associated with black bream ‘nests’ (Figure 8.11). In spring each year black bream migrate from the wider English Channel, along the 9°C isotherm, to the shallow coastal waters within the South Coast REC area, once inshore the fish form spawning congregations. The larger male fish seek specific types of sea bed sediment where they ‘build’ or excavate individual ‘nests’ or depressions on the sea bed surface in the hope of attracting a mate (Figure 8.12).

In the process of building their ‘nests’ male black bream use their tail to remove the surface layer and expose the bedrock or compacted gravel beneath. In so doing male black bream may use their nests in intraspecific competition to attract a female.

Sea bed substrates and features which have been identified with bream nesting include thin sands and gravels and gravels on bedrock and adjacent to reefs and wrecks. The bedrock they have been noted on includes Chalk and the Tertiary Bracklesham Group. Bream nest sizes are typically between 1–2 m in width and 5–30 cm in depth, they create a distinctive group of pitted sea bed features that are clearly discernable on side scan sonar records. Figure 8.14 illustrates such groups on a sea bed of thin sediment on bedrock with the bedrock evident as thin ledges where bedding is exposed. It is through the use of this technique that the nesting sites in the South Coast REC area have been identified (Figure 8.11).

Once a female bream has selected a suitable nest she will lay her eggs in a thin layer within the nest; bream eggs are sticky and they become strongly attached to the substrate (Figure 8.13). After the female has laid her eggs the male fish will fertilise them, the male fish will then guard the eggs until they hatch to protect them from predators such as crustacean and to ensure siltation of the nest does not occur. This philopatry however makes the adults susceptible to fisheries overexploitation and exposes the eggs to trawl damage and the juvenile fish to trawl by-catch.



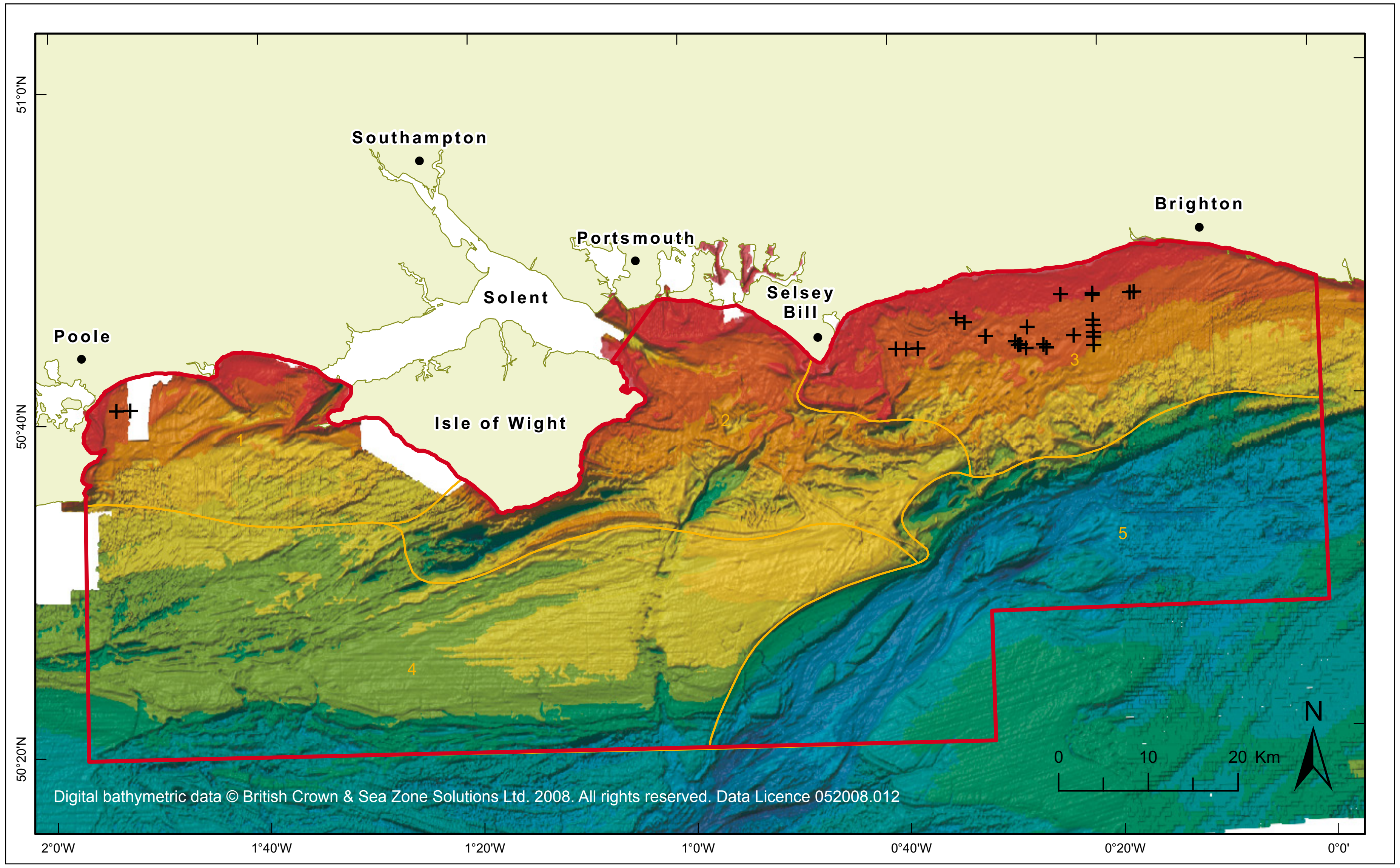


Figure 8.11: Distribution of Black Bream nests identified on South Coast REC 2007 Survey sidescan sonar records

(In addition includes monitoring area near Kingmere Rocks — location courtesy of Tarmac Marine & Hanson Marine).

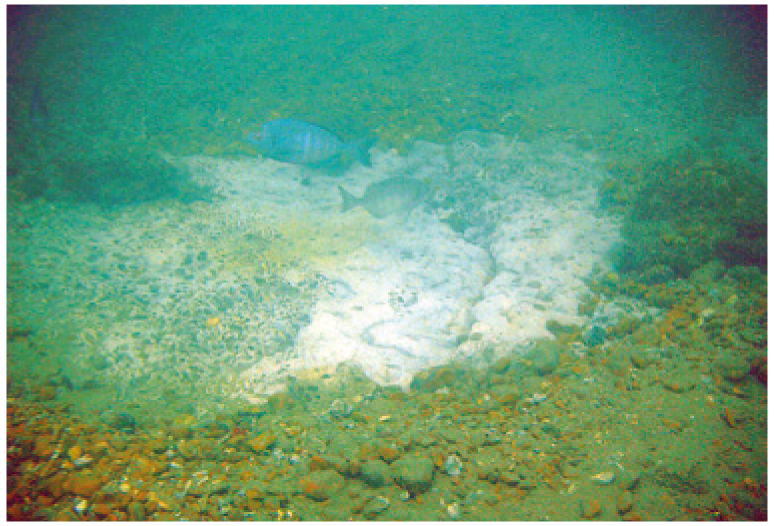


Figure 8.12: Sea bed photo of Black Bream nest on exposed bedrock surrounded by thin sand and gravel. Note two Black Bream swimming above nest © Alex Holmes with permission.

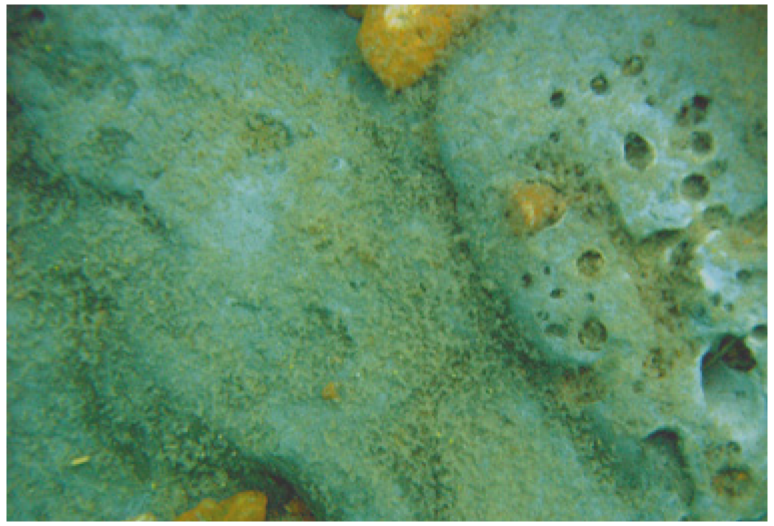


Figure 8.13: Sea bed photo of Black Bream eggs in nest on exposed bedrock © Alex Holmes with permission.

Unmolested juvenile bream will remain in the vicinity of the nest sites until they are 7–8 cm in length; they then disperse but remain in the inshore areas for 2–3 years (to reach approximately 20 cm in length).

Black bream are protogynous hermaphrodites; at sexual maturity they develop female sexual organs then later, as they grow, they become male. When the bream become sexually mature (as females) they recruit into the adult stock and range into the wider English Channel and South West Approaches to feed. It is expected that the bream exhibit site fidelity; returning to the same sites to spawn annually.

Black bream are not subject to ICES stock assessment, they are not classed as a pressure stock for EU fisheries management purposes and no Total Allowable Catch is prescribed. As a non-quota species the fish is fished inshore and offshore in net and trawl fisheries, notably in the South Coast REC area by pair trawlers. There is currently no minimum legal landing size for black bream under European Union Technical Regulations; as protogynous hermaphrodites such measures can have a counter productive effect. The vulnerability of the nesting sites means they are suitable candidates for protection through spatial management measures.

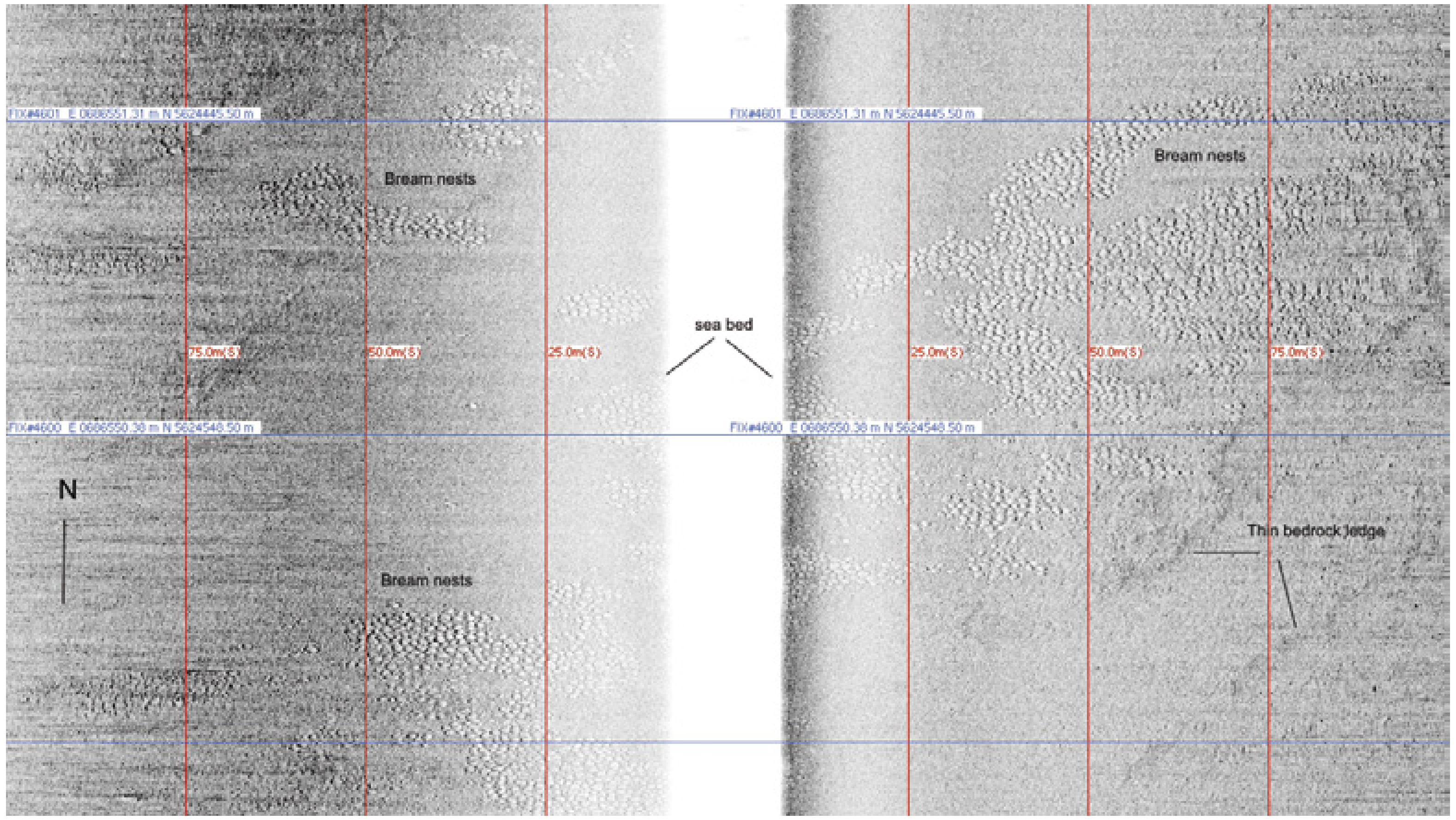


Figure 8.14: Sidescan sonar record of groups of Black Bream nests on thin sediment on bedrock. Corridor 11 of South Coast REC 2007 Survey.

8 Features of Interest – 4

Northern Palaeovalley Banks

The Northern Palaeovalley Banks are two large parallel sand banks aligned WSW-ENE along the northern margin of the Palaeovalley. Line 27 is a South Coast REC 2007 survey across both banks (Figures 8.15 and 8.17).

The outer bank is well developed with a single virtually straight crest line over 16 km long which is attached at its eastern end to the coastal platform. The crest lies at a depth of 30 to 35 m through much of its length, gradually descending to ~45 m as it peters out westward into the Palaeovalley floor. Throughout its length it has a relatively consistent width of around 2–3 km. It has a slightly rounded cross profile at its western end but gradually becomes more asymmetrical towards the east with its steeper south facing slope varying in height from 20 to 25 m. It has well developed megaripples from <0.5–~1.0 m high on both stoss and lee slopes indicating that its surface sand is mobile within at least this depth range.

The inner bank in total length is about 28 km. It is not as well developed through its entire length. As with the outer bank its eastern end is attached to the coastal platform with its crest at a depth of around 30 m. Its crest is relatively straight for about 10 km to the west and maintains a depth from 30 to 35 m and a width of around 2 km. Its south facing slope varies in height from 10 to 20 m with its north side no more than 12 m high and diminishing to the east as the bank gets closer to the coastal platform.

As it descends to the west the bank almost loses its classic bank cross profile in water depths of 45 to 50 m and for a length of about 4 km seems to reverse it asymmetry with a steeper north facing slope in parts, if only of a few metres up to 4 m in height. Hereabouts the rock based slope margin of the coastal platform which is up to 20 m high and lies behind the inner bank changes its alignment from ESE to WSW and becomes parallel to the inner bank. From this point and for the rest of its 14 km length the inner bank becomes attached to the coastal margin with the sediment banked against it. It maintains a consistent crest depth of around 45 m and also maintains a virtually straight south facing slope with a height of 15 to 20 m. This area of the bank has east facing sand waves up to 4 m high with abundant megaripples up to 1 m high.

Why are the banks in this location? The orientation and form of the margin of the coastal platform in this area appears to be controlled by folding of the underlying Tertiary and Chalk bedrock into a relatively steep anticline (Figure 8.16). The margin has eroded along this anticlinal axis which has turned at this point from ESE to WSW causing the Chalk coastal platform to extend out from Beachy Head. Net sand transport in this part of the English Channel is from west to east. This has been a long term process since sea level reached its current elevation over 5000 years ago with sand being transported eastward along the Northern Palaeovalley margin and being trapped against the Chalk cored extension of the coastal platform. It would appear that both banks are a form of banner bank attached to an immobile sea bed feature.

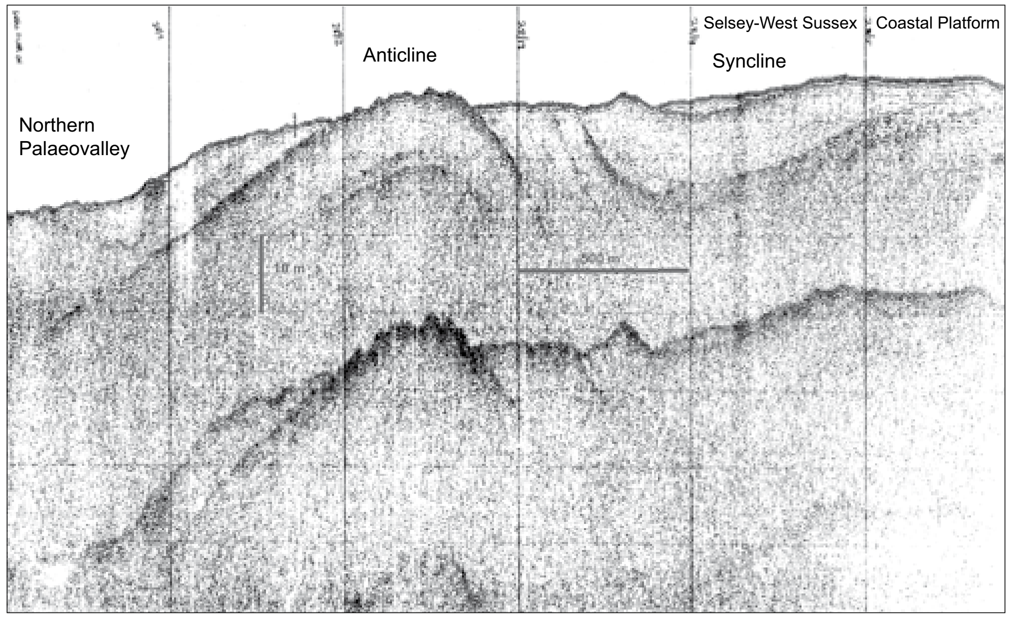


Figure 8.16: BGS seismic line 88/02-28 — N–S seismic section across margin of Northern Palaeovalley with coastal platform with anticline in Tertiary rocks backing slope of margin © NERC.

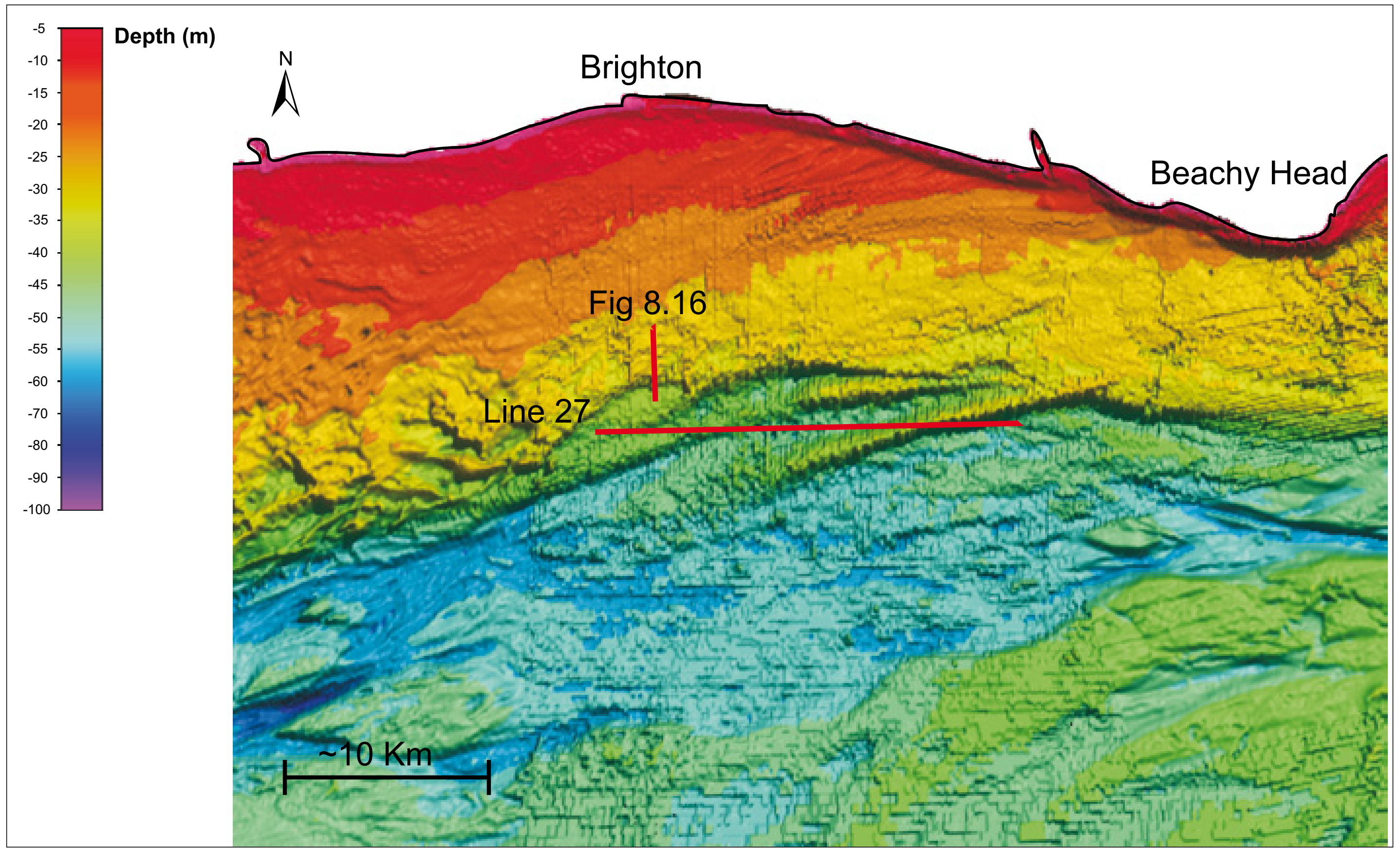


Figure 8.15: Sea bed morphology of area around Northern Palaeo-valley Banks. Digital bathymetric data © British Crown & Sea Zone Solutions Ltd. 2008. All rights reserved. Data Licence 052008.012.

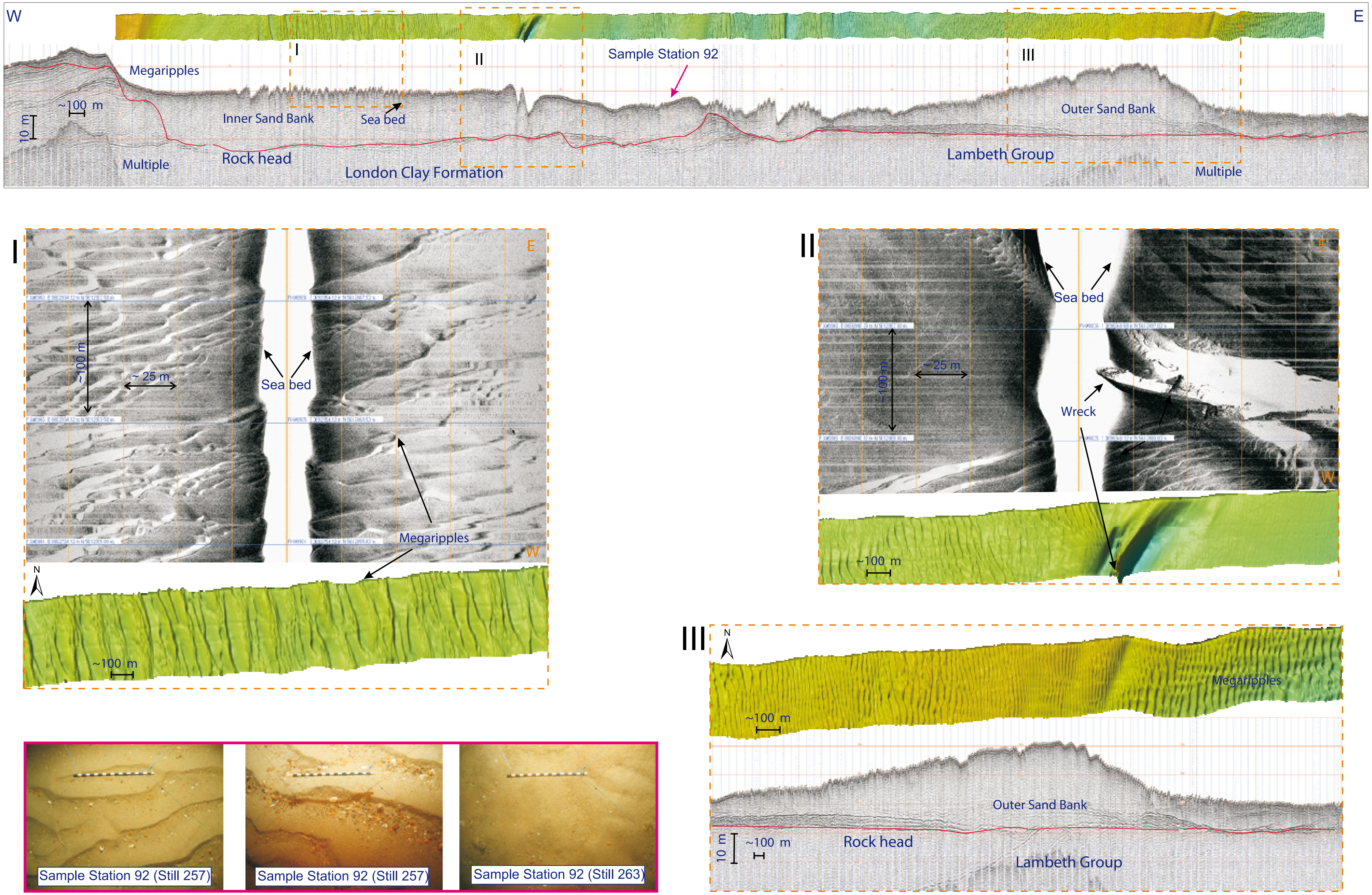


Figure 8.17: Line 27 — W–E seismic section across Northern Palaeovalley Banks with multibeam and sidescan images of sand bedforms and sea bed image of sand ripples at sample station 92.

8 Features of Interest – 5

Wreck of the SS *Mendi*

The wreck of the SS *Mendi* is a site of particular archaeological interest. Rammed in fog by the steamer SS *Darro*, she sank in February 1917 with the loss of 646 lives. Among their number were 607 servicemen of the 5th Battalion, South African Native Labour Corps bound for the Western front.

This disaster has largely slipped from public consciousness in the UK and has only recently become a focus of commemorative activity. In South Africa the *Mendi* occupies a more significant place in national remembrance. The regular subject of commemorative events, she was also closely associated with the anti-apartheid liberation struggle. It is largely South African influence that led to renewed interest in the UK and to the acceptance of the site for designation under the Protection of Military Remains Act 1986.

The site of the *Mendi* has significantly deteriorated since identification in 1974. In 2003 she was subject to a wire sweep, which may have led to the collapse of the superstructure and upper decks, as identified during an assessment of the REC geophysical data previously conducted by Wessex Archaeology (2008h). The general state of the wreck is now tending to rapid collapse as seen in the multibeam and sidescan sonar data acquired during the South Coast REC survey.

The treatment of relatives of the deceased and the recognition of the sacrifice of those on board are still current issues. Reconciliation events, such as the one led by the City Gate Church in Brighton in 2002, remain important. While the *Mendi* disaster is becoming a regular feature of Black History Month in the UK it is important to address how the site can best play a role in developing awareness, including considering how to protect the site from further deterioration and to recognise the wider historical significance of links between the UK and Africa.

The West Africa-Liverpool trade, of which the *Mendi* was a part, means that the *Mendi* can be understood not only as an event in the First World War but also as an important link between the UK and Africa. The *Mendi* reminds us that the history of the British Isles cannot be separated from the rest of the world.

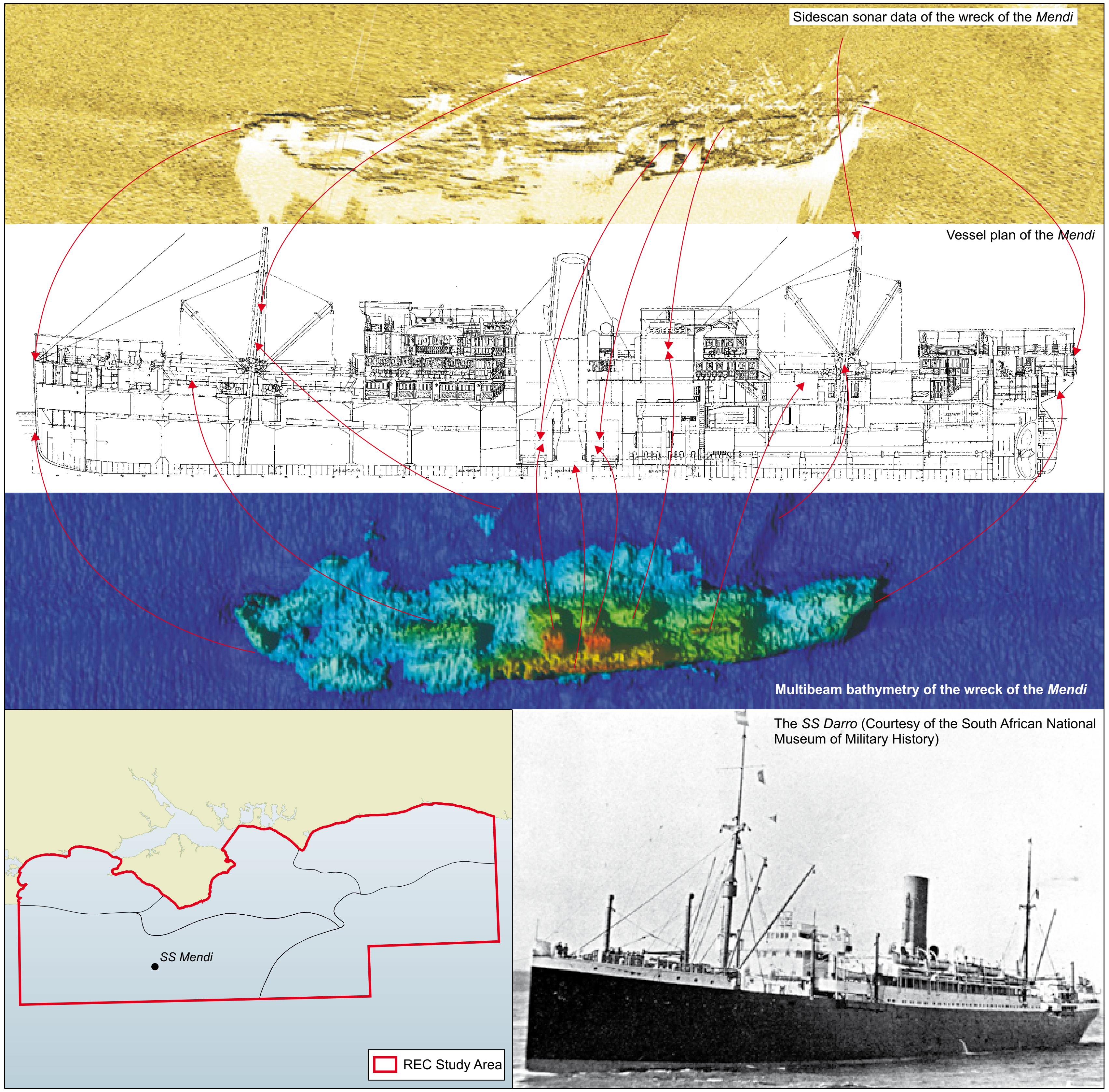


Figure 8.18: Multibeam bathymetry and sidescan sonar data of the wreck of the *Mendi* with vessel plan detailing the internal structure.

8 Features of Interest – 6

Palaeosolent

Generally speaking, palaeochannels provide an important archaeological resource for understanding prehistory. Artefacts such as worked flint and bone found on land are often in riverine deposits, generally redeposited and reworked prior to discovery. Extending the study of these river systems to offshore sites allows archaeologists to examine similar deposits largely unaffected by modern site formation processes. Through the study of submerged landscapes and palaeochannels it is possible to obtain archaeological material which has remained largely *in situ* and so improve our understanding of how the landscape was utilised.

The Palaeosolent is of particular interest in the study of palaeolithic Britain, with many handaxes being recovered from the Solent's gravel terraces. Although the Solent is an active water system, its palaeolithic course and extent are of great interest. Bathymetric and seismic datasets indicate where the course of the now partially infilled channel lies. These data indicate that it was a major tributary into the Northern Palaeovalley system that flowed between Britain and Continental Europe prior to a rise in sea level.

The course of the Palaeosolent is unlikely to have remained constant. For instance, its western tributary may have originally run from what is now Poole Harbour to join the main channel north of the Isle of Wight, this tributary became a separate system to the west. Some features identified along the channel, such as the elliptical basin to the south east of the Isle of Wight within the area of the monocline rampart enclosure (see Chapter 4), require further study to understand their context in the landscape. This feature is deeper and wider than other sections of the Palaeosolent to its south.

The Palaeosolent is of particular interest when studying encroaching sea levels and changes in coastal morphology. It is important to remember that the landscape has continually changed over the Pleistocene with sea level repeatedly rising and falling. Fluctuations in sea level would have forced early humans to re-locate and adapt to a changing climate. With modern society facing similar changes to our environment it is worth trying to understand how our ancestors may have coped as the world changed around them.

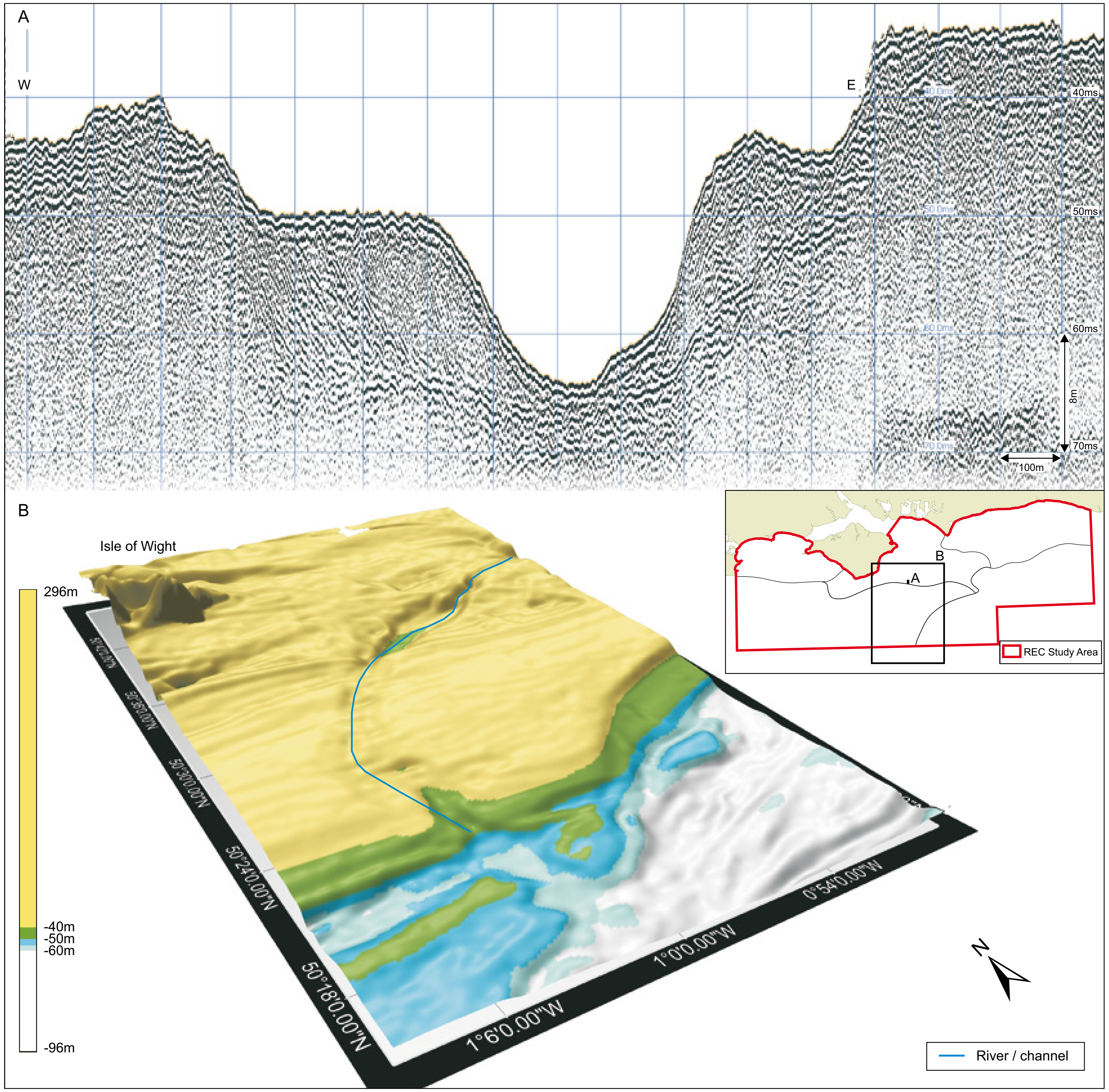


Figure 8.19: The course of the Palaeosolent, with a section across the remaining channel shown in sub-bottom profiler data.

8 Features of Interest – 7

Palaeoarun

The Palaeoarun is another example of an ancient river of archaeological interest. The partially infilled course of the river can still be seen offshore in bathymetric data, although it is harder to trace inshore where it is more heavily infilled. Study of these data and similar riverine systems has helped inform understanding of the landscape, and the processes which led to the formation of the English Channel (Gupta *et al*., 2007).

In 2003 the Palaeoarun was the focus of Wessex Archaeology's ALSF funded Seabed Prehistory project, which developed an understanding of how the landscape was used before the last marine transgression. This was done using bathymetric and sub-bottom profiler data to identify and model the Palaeoarun over a 1 km x 1 km area. Targeted vibrocore and grab samples provided material which could be processed to provide palaeo-environmental data, enabling reconstruction of the local habitat from 9000 years ago. This section of the Palaeoarun could then be considered as an inhabited landscape, based on evidence from terrestrial sites dating from the same period.

The South Coast REC has helped to map palaeochannels, like the Arun, within the study area; it is gravel terraces associated with these features that provide the resource for marine aggregate dredging. The dredging scars seen in the sub-bottom profiler data next to the Palaeoarun highlight the fact that as the aggregate areas are exploited they pose a threat to deposits of archaeological interest, as well as providing an opportunity for archaeologists to access these submerged sites and acquire archaeological data that would not otherwise be recorded.

As new areas are targeted for marine aggregate extraction in the South Coast REC area, archaeologists will be able to assess the threats to deeper parts of palaeochannels such as the Arun, which would have been inundated at earlier stages. This will further enhance our knowledge of how the now submerged landscape and character of the study area has changed over time.

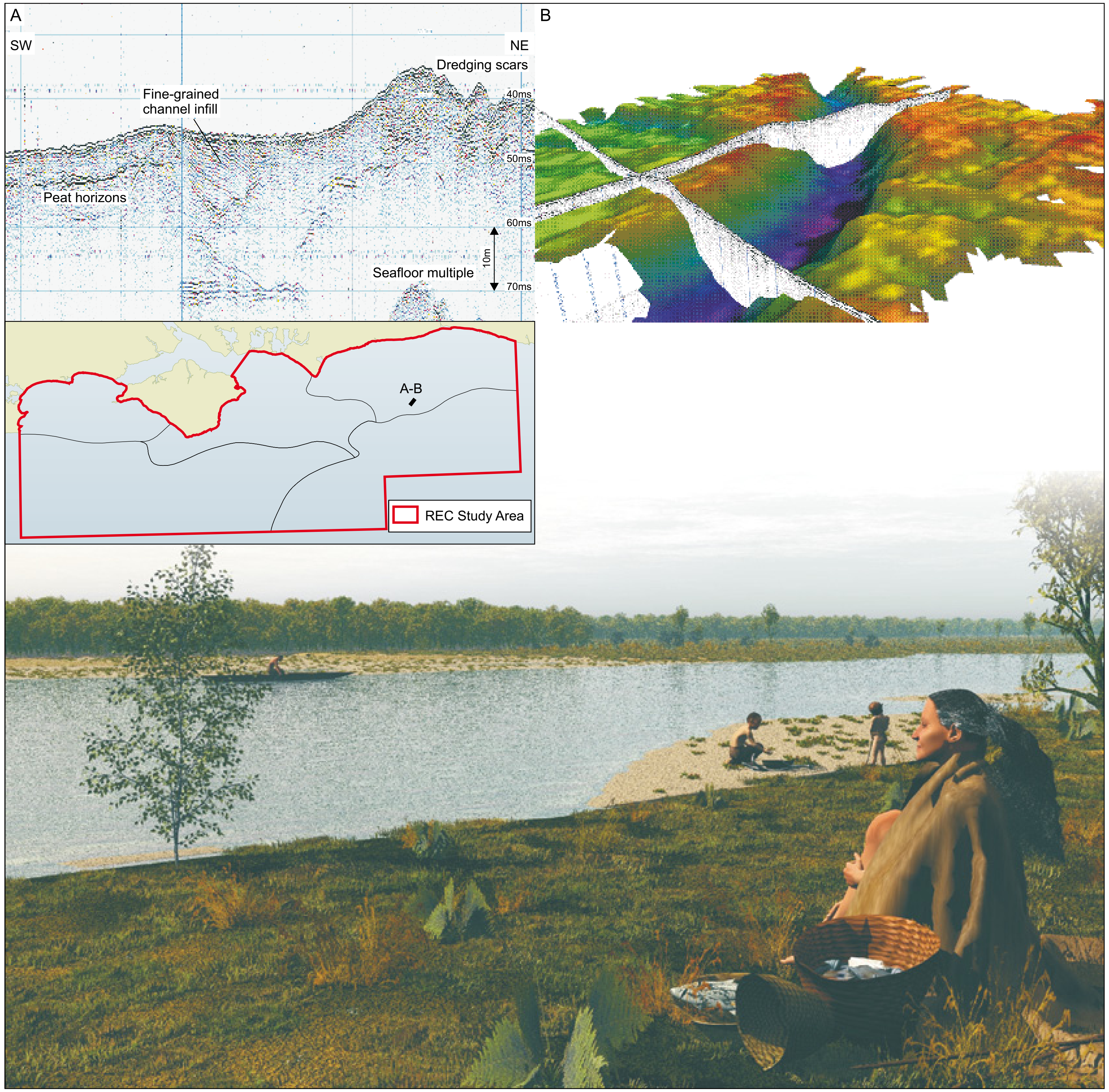


Figure 8.20: Geophysical data used to locate the Palaeoarun and a reconstruction of how the landscape surrounding the river could have looked 9000 years ago.

9 Gap Analysis

Gap Analysis — Survey Design and Data				
Issues	**Data Gaps**	**Implications for REC**	**Action**	**Current status**
Survey grid density	Seismic grid spread not systematic. Multibeam (MBES) & sidescan sonar (SSS) and magnetometer coverage <5% of the study area	Unable to systematically map Annex 1 habitats, channel systems or archaeology. Unable to produce stratigraphy or isopach maps for sub-surface Quaternary geology.	Used data from other sources	Spread increased but grid spacing wide 5–10 km. Not adequate to map Annex 1 habitats, stratigraphy, isopachs or archaeology. Able to indicate location of major channels
Survey grid coverage	Not all lines covered by complete suite of methods i.e. MBES, SSS magnetometer and sub-bottom	Unable to correlate all sea bed character types and sub-surface geology	Used data from other sources	Minimal MBES coverage. SSS and sub-bottom coverage increased to very wide grid across area. Significant gaps remain
Sample station density inadequate for mapping sediment distribution	Density 1 sample per 10 km²	Coarse interpretation of sediment distribution	Sourced other datasets and improved coverage in some areas to 5 samples per km²	Higher density skewed to areas of thicker sediment. Areas of rock relatively lacking in coverage
Sea bed morphology feature correlation	Seismic grid coverage not systematic. MBES, SSS and sub-bottom coverage <5% of sea bed area	Features interpreted on sea bed morphology cannot be identified or confirmed because of lack of seismic data across relevant features	Used data from other sources	Minimal MBES coverage. SSS and sub-bottom coverage increased to wide grid. Improved identification of features on sea bed morphology model. Significant gaps remain
Sample station density and placement inadequate for mapping biotope distribution	Sampling sites did not target observable seabed features	Biotope modelling can only use basic physical features, so limiting model to EUNIS level 3	None	As original — data status not improved
Biological sampling of rock habitats	No specimens collected from rocky reef habitats for quantitative samples	Species identification limited to taxonomic levels that can be positively identified on video & stills images	None	As original but diver surveys available in some shallow water
Biotope model	Low density of samples with biotope analysis	Limits model to level 3	None	As original — data status not improved
Vibrocores	No vibrocores completed in 2007 survey	No sediments for dating and corroborating stratigraphy and archaeology	None	As original — data status not improved
Sediment grabs	Not analysed for archaeology	No ground truthing for archaeology	None	As original — data status not improved
Magnetometer data	Magnetometer towed independently to sidescan (owing to shallow water depth) and hence data not co-located with the sidescan	Magnetic anomalies are not detected at all wrecks or other sites of archaeological interest covered by the sidescan. This is not always down to lack of magnetic signature, in some cases the magnetometer data does not cover the features. In addition, some magnetic anomalies are not covered by sidescan data and it is unknown whether they have a surface expression which would help determine their origin.	None	As original — data status not improved
Multibeam bathymetry survey corridor width coverage	Multibeam swath width narrower than that of the sidescan swath, comparative coverage unequal	Not all sites of archaeological interest in the sidescan data could be sought for in the multibeam data to enhance the sidescan interpretation	None	As original — data status not improved
Distribution of anomalies	Survey data not acquired in inter-tidal or shallow water areas	Cannot determine whether the distribution of archaeological anomalies has an environmental basis	None	As original — data status not improved
Distribution of aircraft wrecks	Difficult to detect with current geophysical methods	Number of aircraft wrecks likely to be seriously underestimated	None	As original — data status not improved
Vessel strandings	Survey corridors do not cover the inshore waters	Vessels lost through stranding are not represented in the survey results. Significant bias in terms of characterising maritime activity	None	As original — data status not improved

Gap Analysis — Non-Survey Data				
Issues	**Data Gaps**	**Implications for REC**	**Action**	**Current status**
Fisheries: effort	Limited data west & south of IOW and beyond 6 mile limit	Underestimating fisheries effort in these areas	Incorporated expert opinion within 6 mile limit	Quantitative data west & south of IOW and beyond 6 mile limit remains limited. New dataset currently (2010) in preparation at Cefas
Fisheries: breeding & spawning	Based on limited historic knowledge and data	Unable to accurately identify breeding and spawning areas	Sought data from Cefas but unavailable at this time	Revised breeding and spawning data currently (2010) in preparation at Cefas
Mammals	Data split over several databases (not centralised)	Underestimation of use of area by marine mammals	All available published sources acquired	Need unified database — single source of info
Birds	Disparate databases for nesting sites and seabird observations. Gaps in nesting site data	Underestimation of sea bird nesting sites	All available published sources acquired	Need a unified database for bird nesting sites and observations to aid the assessment of resource used by this group
Sharks	Very minimal shark sightings data available. Lack of consistent recording method	Insufficient data to estimate use of area by sharks	Data excluded from the review due to scarcity of records	Need a unified database for shark observations incorporating sport fishing catches and observations
Cables & pipelines	Limited published data	Possible underestimation of cables and pipelines in study area	All available published sources acquired	As original — data status not improved
Shipping usage of the study area	Remote logging of vessel movement using AIS does not account for all vessels and is biased toward commercial shipping	Usage of area by recreational boating was not reported, and is known to be high	None	As original — data status not improved

Gap Analysis — Interpretation and Data Analysis				
Issues	**Data Gaps**	**Implications for REC**	**Action**	**Current status**
EUNIS & MNCR Habitat/ Biotope Classification schemes	The EUNIS & MNCR classification schemes are incomplete, particularly for offshore waters	Unable to match some observed biotopes to those listed in the scheme, requiring some matches to be made at inferior levels in the hierarchy	Created eight new biotopes; more detailed variants of those already listed in the scheme	Issue unresolved; will take time to propose new biotope variants to relevant authorities
Modelling EUNIS Habitats using broadscale acoustic/ seismic survey data	The physical attributes used to discriminate habitats in the EUNIS scheme are not consistent with seabed character classes that can be discriminated in acoustic and seismic data	Systematic errors in deriving broadscale models of EUNIS level 3 & 4 biotope distribution that rely on acoustic/seismic interpretation	Highlight low correspondence between observed and modelled habitats/ biotopes.	Unresolved. Offshore mapping needs a new classification system, based on attributes that can be discriminated by acoustic & seismic techniques
Determination of photic zone (i.e. the lower limit of the infralittoral zone)	Absence of quantitative data on light penetration	Error in modelling the location of the photic/aphotic border, which subsequently defines the division between infralittoral and circalittoral habitat classes	Used best available data	As original — data status not improved
Wave data	Modelled 10 km grid	Too small a scale compared to other available oceanographic models such as current velocity and sea bed stress	None	As original — data status not improved
Pre-19th century maritime activity	Difficult to detect sites of these periods with current geophysical methodologies and equipment owing to their ephemeral nature	Volume, distribution and character of pre-19th century maritime activity not possible to determine	None	As original — data status not improved

10 Conclusions

- The active procurement by this study, of additional published and unpublished survey data has mitigated to a reasonable, if not complete, extent, the relative lack of geophysical data produced for the South Coast REC study from its dedicated geophysical survey in 2007. These geophysical datasets, the sample data from the successful South Coast REC 2007 sampling survey and additional sample and other relevant data has provided the basis for an adequate perspective of the regional character of the geology, biology and archaeology of the 5670 km^2 study area.

Geology and sediment

- The South Coast REC area is characterised by large expanses of rock and thin sediment, with approximately 75% of the sea bed dominated by habitats resting on a rock based foundation. Thick sediment is confined to channel systems, banks and sand sheets with about 14% of the study area covered by sandy sediment and 11% covered by coarse sediment. The coarse sediment is commonly associated with channel systems and the sands with banks and sheets. Marine aggregate extraction and prospecting is confined to these areas of thicker sediment, particularly coarse sediment, rather than across the REC area as a whole.
- Extensive areas of sand are confined to sand banks within the inner parts of Poole Bay and Christchurch Bay, and in the north east of the study area as banks on the margin of the Northern Palaeovalley and sand sheets and wave fields on the coastal platform off West Sussex.
- The sea bed south of the Isle of Wight is an area of relatively strong tidal currents with a winnowed sea bed comprising mostly immobile coarse sediment with cobbles and rock.
- The form and morphology of the sea bed is controlled by the structure of the underlying Chalk and Tertiary bedrock with features aligned roughly west–east parallel to the principal alignment of the major anticlines and synclines within these rocks.
- The east-west structural alignment has controlled the alignment of river systems such as the Solent and the Northern Palaeovalley. However, in both these cases they have actively eroded across the grain of these structures at some points in their development. Possibly as the result of inheriting drainage from an older overlying system whose rocks have been denuded.
- There is essentially no modern supply of sediment into the system and the overall sediment budget appears to be largely in equilibrium, so the sediment and rock character of the study area is not expected to change over decadal time scales.

Aggregates and dredge material

- There are currently, in 2009, twenty four licensed dredging areas in the South Coast Region. Over the ten-year period from 1998 to 2007, 48.581 Mt of marine sand and gravel was extracted from licensed dredging areas in the South Coast Region. The cumulative footprint of dredging during this ten-year period covered 78.21 km^2 of the sea bed which is 1.37% of the 5670 km^2 area encompassed by the South Coast REC study area. In 2008, 3.93 Mt of aggregate for construction purposes was dredged in the South Coast Region
- There are six sites in the REC area that are currently licensed for dredge material disposal. The most significant of these is the Nab Tower site, which lies to the east of the Isle of Wight, within a cluster of licensed aggregate extraction sites. This single disposal site has received just over 200 Mt of dredged material in the 9 years 2000–2008, representing 80% of all the dredged material deposited in the South Coast REC area. Annual disposal rates at Nab Tower range from 10 to 50 Mt per year.

Benthic resources

- Analysis of the benthic macrofauna from grab samples taken in the South Coast REC study area revealed 13 discrete assemblages. This is a relatively large number and a reflection of the geological and morphological diversity which exists in this area. The predominance of rock and coarse substrate, across much of the area, also plays an important role in shaping the benthic macrofauna in the study area which is evident in the high abundance of epilithic species identified. The most frequently recorded benthic assemblage (Benthic Assemblage O) can be described as *Balanus crenatus*, *Crepidula fornicata* and *Sabellaria spinulosa* on mixed gravel deposits.
- A number of benthic assemblages were associated with sand deposits and characterised by interstitial polychaetes and the pea urchin *Echinocyamus pusillus*. These were concentrated to the east of the study area in association with sandbanks and large sand wave features but were also found across the area in association with pockets of sand.
- Unusual assemblages identified in the study area include beds of the tubiculous amphipod, *Ampelisca* and the sand mason worm, *Lanice conchilega*.
- The benthic assemblages were found to be strongly correlated with environmental conditions. The highest correlation ($\rho s = 0.825$) was obtained from a five variable combination of: geographical position Easting, %Sand, Sorting, Rock Category and Current Velocity. The biodiversity of the macrobenthos did not correlate highly with any of the environmental variables, primarily because the study area was relatively uniform in terms of the diversity it supports.

Epibenthic resources

- Analysis of the epibenthic trawl samples taken across the South Coast REC study area revealed 6 discrete assemblages. As with the benthic macrofauna the high number of epibenthic assemblages identified is a reflection of the diverse environmental conditions within the study area. The influence of the rock and coarse sediments was also evident in the epibenthic trawl samples and, as in the grab samples, epilithic species formed an important component of the assemblages.
- Like the benthic assemblages, the epibenthic assemblages present in the study area were found to correlate strongly with environmental conditions. The highest correlation ($\rho s = 0.848$) was obtained from a five variable combination of; % Silt & Clay, SAND_MODE, Mean, Rock Category and Bedform.

Biotopes

- A few new biotopes were discovered in the South Coast REC area, these have such an unusual combination of taxa that they are considered to be significantly different to the biotopes and sub-biotopes currently listed in the EUNIS habitat classification scheme. Some may be considered local variants of existing biotopes, but still warrant recognition and amendment to the EUNIS scheme.

- A number of issues were encountered in regional biotope modelling using the EUNIS habitat classification system. A principal issue stemmed from the model prediction of a rock habitat in areas where sample station observations assigned a sediment habitat. The discrepancy resulted primarily from the inability of the acoustic and sub-bottom profiler technologies to discriminate whether or not rock at the sea bed surface has a thin covering of sediment. Sediment layers less than approximately 0.5–1 m depth can not be detected by sub-bottom profiler systems yet these are certainly suitable habitats for benthic infauna and can be sampled by grabs for both faunal and particle size analysis. This issue could be resolved to some extent with a denser grid of multibeam, sidescan and sub-bottom data and numerous video camera transects but the fundamental resolution problem associated with the acoustic properties of the sub-bottom profiler would remain. It may be more appropriate to modify the EUNIS classification system to take account of this type of rock and thin sediment substrate which is very common in the English Channel and elsewhere in UK waters.

Rare and invasive species

- A number of rare species were identified from the grab and trawl samples collected from the study area, the most notable being the sea squirt, *Microcosmos claudicans* and the colonial bryozoan, *Hincksina fulstroides*.
- The invasive American slipper limpet, *Crepidula fornicata*, was found to be very well established across the South Coast REC study area forming an important component of the benthic and epibenthic assemblages. An invasive species, it has been in the UK for over a century and in the Solent area since the 1930s; it is now regarded as a naturalised species. It is noteworthy as it occurs in great densities in the area, out-competes many native taxa and alters the local substratum, causing it to become more muddy. Seaweeds grow on many of the larger clumps of Crepidula shells, and in areas where it is extensive it could be regarded as a biogenic reef, in much the same way as mussel beds. Other alien species identified include the leathery sea squirt, *Styela clava* and the barnacle *Elminius modestus*.

Mammals

- The south coast region is of limited importance to marine mammals in a national and international context although the bottlenose dolphin, common dolphin, harbour porpoise, minke whale and long-finned pilot whale are all considered to be regular visitors.
- There is a recognised haul out site for harbour seals in Poole Harbour and the South Coast REC area is likely to form an important foraging resource for the local population of this species, particularly during the breeding season.

Birds

- The south coast region represents an important resource for numerous seabird species, many of which are considered to be threatened or declining in numbers. The heterogeneous coastline provides important nesting sites whilst the sea itself provides important food resources in the form of fish and invertebrates.

Conservation

- There are a large number of protected sites designated under International and European legislation but these are mostly limited to the coastal and nearshore areas. Twelve marine Sites of Nature Conservation Importance (mSNCI) occur offshore between Selsey Bill and Beachy Head. Surveys conducted for the South Coast REC have highlighted two other features of conservation interest within the area, namely rocky reefs and black bream nests. The reefs are listed under Annex I of the EU Habitats Directive, meaning they may at some time become targeted as candidate Special Areas of Conservation or be included in some other form of protected area. The black bream is a commercially important species that exhibits colonial nesting behaviour. The nesting sites occur on a characteristic ground-type, where bedrock is covered by a thin layer of gravel. As the nests are vulnerable to physical disturbance, they are being considered within local management plans and some are associated with the mSNCIs mentioned above.

Commercial fisheries

- Fisheries within the South Coast REC area are important in a local and national context. The fleet is largely inshore and multi-purpose, outside of the 6 nm limit however this fleet is joined by international fishers using mobile gear in suitable substrate.
- The spawning and nursery grounds of a number of commercially important finfish and shellfish extend into the South Coast REC area, including cuttlefish, edible crab, black bream and numerous flatfish. The region is also frequented by a number of shark species which may also use the region for breeding.

Marine archaeology

- The South Coast REC area is in a region rich in archaeology, with finds ranging from the Lower Palaeolithic to the Second World War. Archaeological material found on or beneath the sea bed can be broadly divided into prehistoric, maritime and aviation and all categories are present in abundance in the REC area. The results of the geophysical survey have produced a more reliable guide to the density of archaeological material on the sea bed than is currently available in other data sets, including the NMR and UKHO.
- The characterisation of the area in terms of prehistoric archaeology has involved the amalgamation of archaeological knowledge and theory with geological and geophysical interpretation. This approach focused on identifying offshore the types of landscape features where archaeological material is found on land. The precise location of prehistoric archaeological material offshore is simply unknown at present and we can do no more than highlight areas where there is a comparatively higher potential for the resource to survive. To a large extent, the lack of chronological control is outweighed by the intrinsic significance of any artefacts and organic sediments that may be encountered in the future, as our understanding of the human use of the South Coast REC area is currently extremely limited. The characterisation of this area indicates that, under the appropriate preservation conditions, there is potentially a very large resource of prehistoric archaeology present.

- The geophysical survey data has successfully characterised the maritime archaeological resource of the South Coast REC area in respect of the late 19th century and more recently. However, it has failed to find evidence for earlier periods and no conclusion can be drawn about the volume, distribution or character of the pre-19th century maritime activity in the area on the basis of the geophysical data. This may be because of the relatively ephemeral nature of the remains of vessels of these periods and the relative difficulty of detecting them with current geophysical methodologies and equipment.
- The close proximity of the South Coast REC area to the Continent and the presence of strategic targets including Southampton and Portsmouth has caused the area to be a major focus for both commercial and military aviation throughout the 20th century. The vast majority of aircraft sites date from the Second World War, when large numbers of aircraft were engaged in combat over UK waters. Most aircraft crash sites are recorded as named locations with an approximate position of the aircraft at the time of loss given. Few have been accurately located on the sea bed. Together with the difficulty of detecting and distinguishing aircraft on the sea bed with geophysical methods, as the sites are often ephemeral owing to aircraft commonly breaking up on impact with the sea, this has led to there being arguably greater potential for any given area of sea bed to contain unknown aircraft crash sites than unknown shipwrecks. The distribution and location of aircraft crash sites are likely to be seriously underestimated as a result.

Recommendations

- The tubiculous amphipod, *Ampelisca spp*. and the sand mason, *Lanice conchilega*, were both found to form bed features in this area, together and individually. Whilst these biogenic features would not be classified as biogenic reef under the current Annex I definition, they are certainly unusual and their influence on environment and associated fauna is not yet fully understood. A more detailed study on these small-scale biogenic features would be of value to both the scientific community and the conservation agencies.
- The fauna identified in the South Coast REC study area fitted relatively well into the EUNIS biotope classifications. However, large parts of the area are essentially thin sediments overlaying rock which are not adequately described in the classification hierarchy. A revision of the rock biotopes which incorporates rock with thin sediments should be considered.
- The complexity of the sediment filled channel systems which have been identified have not been adequately characterised during the study. A greater density of seismic lines would add greatly to our understanding of these channel systems which are the principal aggregate resource in the study area.

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