A1a.2 Benthos

A1a.2.1 Introduction

Available information relating to the benthos of the UKCS has been reviewed in successive SEAs – where appropriate in terms of three divisions; offshore, nearshore (to approximately 5km) from shore, and intertidal (littoral). These distinctions also correspond broadly to differences in survey methods and the coverage of both individual studies and regional programmes. In recent years there have been a number of additional data compilations and analyses, notably the Marine Natural Area profiles (Jones *et al*. 2004a-f) by English Nature (now Natural England), the UKSeaMap marine landscape classification (Connor *et al.* 2006), the Mapping European Seabed Habitats (MESH) programme (MESH 2008), and the EUSeaMap (EMODnet Seabed Habitats project) which in a second phase (EUSeaMap2) extending the coverage to all European seas and improving the existing maps. Similarly, there have been developments in terms of conservation with OSPAR establishing a list of threatened and/or declining species and habitats in the north-east Atlantic (OSPAR 2009), revisions to the UK Biodiversity Action Plan (succeeded by the UK Post-2010 Biodiversity Framework in 2012), and new UK marine site designations made possible through new country legislation. Increasing attention has also been focused on the assessment of changes in benthic community structure and function in relation to the effects of regional climate change. Some of the most recent and current large research projects are focussing on potential impacts from CO_2 leakage in the marine environment (Blackford *et al.* 2008, 2009, Connelly *et al.* 2012, Murray *et al.* 2013) and from wet renewable energy devices (e.g. the FLOWBEC project and O'Carroll *et al*. 2014).

A1a.2.2 UK context

Over a period of nearly one hundred years, the biology of the seabed has been studied in the context of fisheries ecology and, latterly, in relation to biogeographical patterns of species distribution. Over the last forty years numerous smaller spatial scale investigations of the seabed have been carried out, concerned primarily with environmental monitoring of various industrial activities (e.g. oil and gas developments, aggregate extraction, sewage sludge dumping and marine renewable energy developments. Industry funded surveys include not only the small-scale work around specific sites, but also a number of regional assessments e.g. west of Shetland (the oil industry's Atlantic Frontier) and the northern, central and southern North Sea regions.

Benthic communities identified by various authors show consistency at a high level and strong correlation with habitat (or substrate) type. Benthic communities in deeper water, soft sediment habitats tend to be spatially distributed over large scales, with distinctive species assemblages associated with particular substrate types and present over large areas. However, depending on the intensity and spatial extent of sampling, localised community types or more subtle variations may be distinguished, often associated with topographic features. The spatial scale of habitat and community variability in shallow water is generally much finer.

The Marine Nature Conservation Review (MNCR) was started in 1987 by the Nature Conservancy Council and, subsequent to the Environment Protection Act 1990, was continued by the JNCC on behalf of the country conservation agencies (CCW, EHS, SNH, Natural England (formerly English Nature)) up to its completion in 1998. The focus of MNCR work was on benthic habitats and their associated communities, which together are described as 'biotopes' in inshore areas and were described initially by Connor *et al*. (1997a & b). Hiscock (1998) provides a review of information describing seabed habitats and communities in the north-east Atlantic and inshore areas within each of the 15 MNCR coastal sectors around Great Britain.

JNCC's UKSeaMap project (Connor *et al.* 2006; McBreen *et al.* 2011) used available geological, physical and hydrographical data, combined where possible with ecological information, to produce simple broadscale and ecologically relevant maps of the dominant seabed and water column features for the whole sea area under UK jurisdiction. UKSeaMap 2006 also classified 32,000 benthic samples to habitat type according to the updated National Marine Habitat Classification (Connor *et al.* 2004), before assessing their ecological validity against the predicted landscape types. Coastal physiographic features and topographic features on the shelf were very well validated overall; however, there was significant variability across the modelled landscape types, with some appearing to be well validated, whilst others (e.g. Shallow coarse sediment plains and Shelf coarse sediment plains) were poorly correlated against ecological information. The 2010 project update (McBreen *et al*. 2011) filled gaps in the UK coverage and additional data input enabled improved confidence in the predictive maps.

UKSeaMap distinguishes between a total of 24 sediment plain landscapes, using criteria of sediment type (coarse, mixed, sand and mud); water depth (shallow, shelf and deep); tidal velocity and (for deep-water) temperature. In comparison, the Marine Habitat Classification for Britain and Ireland (v05.05) distinguishes between 77 biotopes in sublittoral sediments – excluding macrophyte-dominated communities (e.g. maerl, kelp and seaweeds on sediment, and seagrass beds) and an additional eight biogenic reef biotopes on sediment (including *Sabellaria, Serpula, Modiolus* and *Mytilus* reefs/beds). The hierarchical classification is based on four sediment classes, and in large part on the presence of large (>5mm), visible bivalves and epifauna. The recognised biotopes are also strongly numerically dominated by shallow water examples (only 12 are offshore sediment biotopes). A further and the most recent revision of the MNCR biotope classification (Connor *et al*. 2004) includes a set of deep sea biotopes provided by Parry *et al*. (2015). This draws on both infaunal community data (Bett 2012, Nickell *et al*. 2013) and epifaunal assemblages (Piechaud & Howell 2013, Howell *et al*. 2010a, Howell 2015); it is based on the three relevant biogeographical zones (Atlantic, Atlanto-Arctic and Arctic) which are subdivided by depth range (upper, mid and lower bathyal; upper, mid and lower abyssal) and substrate into a further 66 biotopes. A large amount of spatial data on habitats and biological communities/assemblages of the deep sea which has contributed to this classification is a product of the 'Mapping the Deep' project carried out by the Marine Institute at Plymouth University as a partner in the MAREMAP project (also see below).

At a finer mapping scale, the four year project Developing a Framework for Mapping European Seabed Habitats (MESH) established a framework for mapping marine habitats by developing internationally agreed protocols and guidelines for seabed habitat mapping and generating the first compiled marine habitat map for north-west Europe. The project covered the entire marine areas of Ireland, the UK, Netherlands, Belgium and France from the Belgian border to southern Loire on the Atlantic Coast.

The MESH map of seabed habitats for north-west Europe was derived from a library of over 1,000 data sets. Habitat prediction models were developed either to fill the gaps where existing survey data were not available, or to help understand the distribution of specific habitats using survey data. The same modelling approach was used to create two different types of map: those showing the likely occurrence of EUNIS habitats and those showing the distribution of more broadly defined marine landscapes. The MESH data is now available within the EMODnet[1] website (www.emodnetseabedhabitats.eu) which provides access to the ICES habitat mapping metadata catalogue. The portal presents predicted broad-scale habitat maps

[1] European Marine Observation and Data Network

from surveys produced and collated by the MESH (2004-2008), MESH Atlantic (2010-2014) and EMODnet Seabed Habitats (2009-2016) projects.

Using multibeam echo sounders, detailed mapping of the seabed habitats and shallow geology is currently being taken forward by a major NERC funded multi-institute project, launched in 2010, the Marine Environmental Mapping Programme (MAREMAP, http://www.maremap.ac.uk/index.html). Two of the programme's seven themes are very relevant to the offshore energy sector: coastal and shelf geological and habitat modelling; deep water geological and habitat modelling. Maps are currently available for a total of eleven areas which are distributed over Regional Seas 1, 3, 4, 7, 8 and 10.

The passages of the *UK Marine and Coastal Access Act 2009* and Acts of the devolved administrations have empowered benthic research for the establishment of marine protected areas. Much effort has been concentrated by Defra (Cefas), Marine Scotland, JNCC and the country nature conservation agencies on gathering data to further the understanding and management of designated sites, together with searching for evidence to support and validate the new site proposals for Marine Protected Areas and their successful designation. In England, Wales and Northern Ireland these are called Marine Conservation Zones (MCZs), while in Scotland they are known as Nature Conservation Marine Protected Areas (NCMPAs) – see Appendix 1j. In July 2014, 30 Nature Conservation MPAs were designated, 13 of which are offshore and the remainder nearshore/coastal. The first suite of MCZs, designated in 2013, comprised 27 inshore sites and five offshore. These were followed in January 2016 by a second tranche of 23 site designations, which comprised of inshore sites, five offshore sites and two sites which span the on/offshore 12nm boundary. A 2012 Cefas-led survey to close information gaps on the broadscale habitat extents present in recommended Marine Conservation Zones (rMCZs) has resulted in numerous survey and post-survey publications (Defra 2014a-d, 2015a-d) which are available through the Defra website.

When considering impacts from the offshore energy sector and reviewing sustainable energy generation sites, important environmental considerations will be enhanced by knowledge gained in the ongoing NERC funded FLOWBEC project. The FLOWBEC (Flow and Benthic Ecology 4D) project aims to investigate the potential impacts that tidal and wave energy harnessing devices may have on the marine environment; for example by gaining understanding of how changes to water flow and turbulence introduced by tidal technology might affect the various types of marine wildlife. FLOWBEC uses a range of measurement and modelling systems including sonar technology, radar and shore observations to monitor the interaction of hydrodynamics and wildlife including fish and diving seabirds and how they interact with the installation. The tools developed in FLOWBEC may enable further direct simulations and evaluation of ecosystem impacts related to a large variety of factors, such as pollution from human activities, CO_2 leaks arising from carbon capture and storage and marine renewable energy devices. Suggestions that marine renewable energy installations have the potential to contribute to local biodiversity enhancement must also be considered in the context of artificial reefs and Fish Aggregating Devices (FADs) (Inger *et al.* 2009).

A1a.2.3 Ecological context

The seabed and benthos are fundamental parts of the marine ecosystem, critical to nutrient cycling and of major importance as a food resource for man, fish, birds and other animals. The seabed is the spawning ground of several commercially important species and is the ultimate sink for discharged and spilled materials. Quantitative studies of the biology of the seabed have been undertaken for the last 100 years, initially in the context of fisheries ecology and biogeographical patterns of species distribution. In addition there have been a range of benthic studies undertaken of specific habitats, for assessments of conservation status and for documentation of the biodiversity of an area.

Benthic fauna exhibit a diversity of feeding methods, the primary modes being filter feeding (where particulate food is taken from the overlying water), deposit feeding (where food deposited on the seabed or incorporated into sediments is swallowed, sometimes along with large quantities of sediments), grazing (of algae and other marine plants in shallow waters and bacterial mats in deeper waters), carnivory (predation on other animals) and carrion/detritus feeders. In addition, there are parasitic, commensal and symbiotic species. Benthic animals and plants can significantly affect the seabed in terms of sediment stability (increasing through the effects of e.g. tubes and roots, or decreasing through burrowing activity), sediment accumulation (e.g. fine material in the interstices of mussel beds), habitat creation (e.g. low biogenic reefs formed by the activities of methane metabolising bacteria, aggregations of *Sabellaria spinulosa* tubes or horse or blue mussels can provide hard surfaces in sedimentary areas), and habitat complexity (e.g. through seabed armouring by large dead shells allowing fine sediment retention in tide swept areas).

The majority of benthic species are adapted to function in/on specific substrata or a narrow range of substrata and associated hydrodynamic conditions. Future developments using wet renewable energy devices have the potential to affect local hydrodynamics with concomitant changes to benthic communities, hence research projects such as MaREE (Marine Renewable Energy and the Environment; 2010 - 2013) and collaborative research through organisations such as SuperGen UKCMER[2] provide useful input to this developing knowledge base. MaREE explored the environmental issues related to marine renewable energy development within the Highlands & Islands region of Scotland, and has looked at potential seabed habitat change following energy extraction (Shields *et al*. 2011) and habitat mapping in the Pentland Firth (Harenzda *et al*. 2011).

A1a.2.4 Features of Regional Sea 1

Stephen's surveys in the 1920s (Stephen 1923, 1930) represent the first large-scale survey of the offshore areas in the northern North Sea, with over 1,000 sublittoral samples as well as littoral sampling, and provide a good historical baseline for further studies. Later, McIntyre (1958) extended the investigations of the benthos of fishing grounds with surveys off the east coast of Scotland, in Aberdeen Bay, St Andrews Bay, and the Smith Bank at the outer reaches of the Moray Firth. Subsequent studies include a series of surveys combined to give North Sea wide coverage coordinated by ICES (Künitzer *et al*. 1992; Kroncke *et al*. 2011).

The MESH map of seabed habitats for Regional Sea 1 is shown in Figure A1a.2.1. Regional Sea 1 is predominantly deep circalittoral sand, with a large area of finer sediments – deep circalittoral mud – in the northern North Sea. Nearshore and in scattered offshore patches there are areas of deep circalittoral coarse sediment. Around the Northern Isles the nearshore circalittoral seabed is predominantly moderate energy rock interspersed with coarse sediments.

MAREMAP has recently covered the approaches to the Firth of Forth which brings more detail to the MESH depiction of a circalittoral mix of sandy mud, fine mud and moderate energy rock. Seabed mapping of biotopes has also been carried out at two NCMPA locations: Firth of Forth (Sotheran & Crawford-Avis 2014) and Wee Bankie to Goudon (Sotheran & Crawford-Avis 2013).

Detailed habitat descriptions of areas of conservation interest, acquired recently by acoustic/ground truthing within the MPA/MCZ programmes, do not always agree with the broad brush MESH maps. For example, the Farnes East MCZ site, surveyed in 2014 by Cefas/JNCC

[2] SuperGen UK Centre for Marine Energy Research

was originally believed to be approximately 50% moderate energy circalittoral rock, but the new data (Defra 2014b, Whomersley 2012) shows the majority of the site to be subtidal sands and gravel, with a much reduced area of rock present and interestingly – a fairly large presence of subtidal mud.

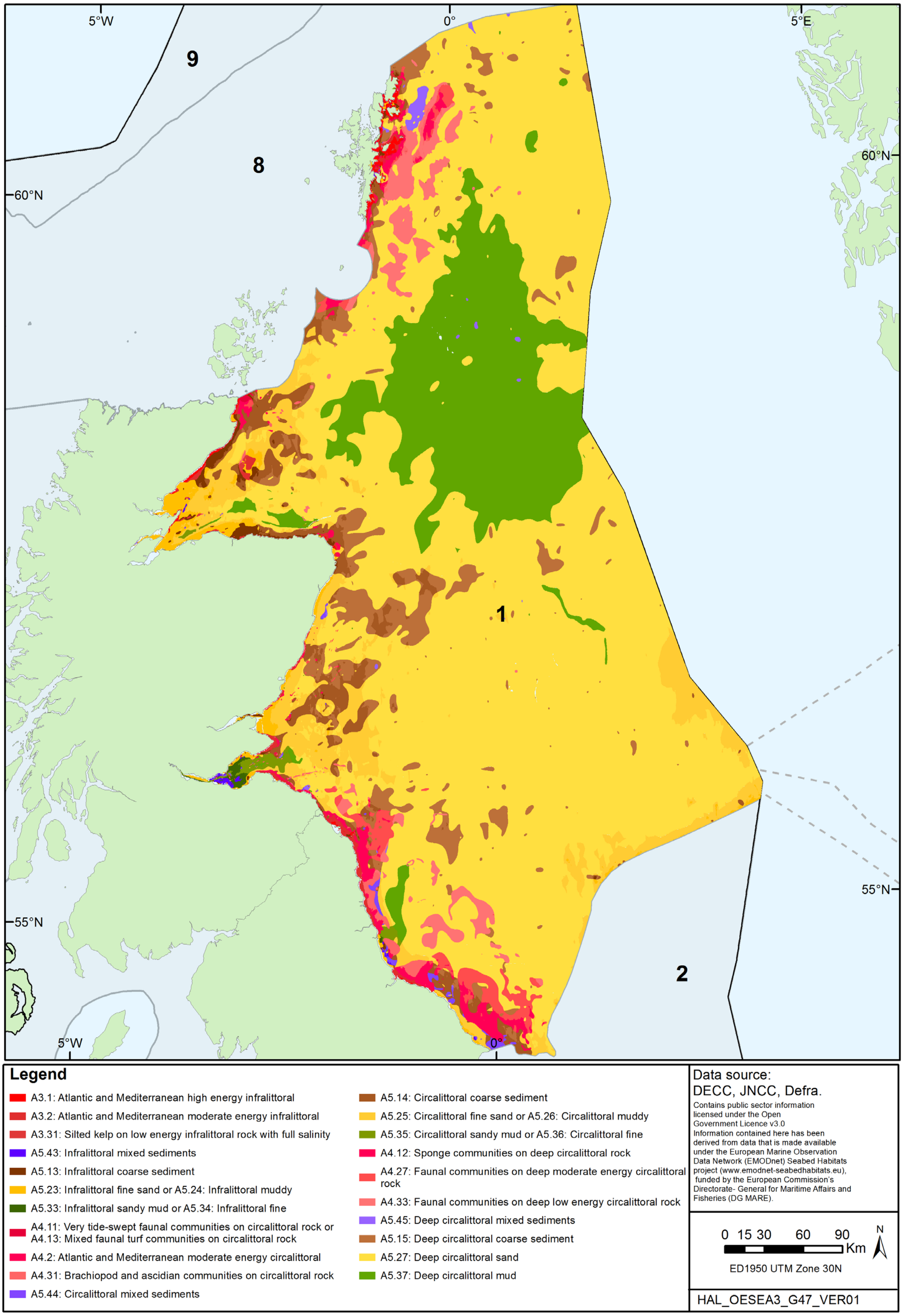
Some of the coastal SACs (see Section A1j) have benthic qualifying features e.g. Sullom Voe (boreal–Arctic species rich communities which are restricted to Shetland voes), while more recent survey evidence of offshore Annex 1 habitats, has led to the creation of three offshore sites: Braemar Pockmarks SAC, Scanner Pockmark SAC and Pobie Bank Reef SCI (Foster-Smith *et al*. 2009). More recent still, a number of NCMPAs have been designated in Scottish offshore waters: Central Fladen, East of Gannet and Montrose Fields, Firth of Forth Banks Complex, Turbot Bank and the Norwegian Boundary Sediment Plain. In English offshore waters there are three offshore MCZs (Fulmar, North East of Farnes Deep and Swallow Sand), three inshore MCZs (Aln Estuary, Coquet to St Mary's & Runswick Bay) and one which straddles the 12nm offshore/inshore boundary (Farnes East MCZ).

The MPA research programme (Marine Scotland 2011) to provide justification for designations and guidance for management has produced a number of publications which are highlighted where relevant in the following habitats and species sections.

A1a.2.4.1 Offshore habitats and species

The benthic infauna of the offshore northern North Sea in general is characterised by its tendency towards higher diversities than the central or southern areas (Künitzer *et al.* 1992, Kroncke *et al*. 2011). While these results may be attributable, in part, to the use of finer sieves (typically 0.5mm in the northern area as opposed to 1mm elsewhere), the gradual increase in diversity northward through the southern and central areas would suggest that this gradient does exist. There may be a relationship between this increase and changes in depth and productivity in the area, but the variability of the data makes it difficult to discern clear divisions on smaller scales. Eleftheriou *et al*. (2004) provide a review of community types described from the SEA 5 area, also making major distinctions between areas north and south of 57°30'N (i.e. well to the north of the Regional Sea Areas 1-2 boundary). Broadscale patterns of offshore macrofaunal distribution are described by Glémarec (1973), Basford *et al.* (1990), Duineveld *et al*. (1990), Künitzer *et al*. (1992) and Jennings *et al*. (1999).

Figure A1a.2.1: MESH classification of marine biotopes, Regional Sea 1



Early studies of benthic epifauna recovered in fishing trawls have been followed by photographic surveys (using a camera attached to the headline of a demersal trawl) (Dyer *et al.* 1982, 1983; Cranmer *et al*. 1984), while Basford *et al.* (1989, 1990) investigated epifaunal community assemblages using a 2m Agassiz trawl, at 38 stations in the area north of Peterhead. Statistical analysis of the latter distinguished two groups of stations in the area:

- fauna inhabiting moderately sorted, coarse sediments with relatively low silt and organic carbon levels; characterised by sponges, the bryozoan *Flustra foliacea*, the anemone *Bolocera tuediae*, and the crab *Hyas coarctatus*, typically in the sandy areas extending south of Fair Isle to off Peterhead
- the deeper, finer sediments of the Fladen Ground and its northern extensions where the fauna was typified by the echinoderms *Asterias rubens, Astropecten irregularis* and *Brissopsis lyrifera*.

The latter group was further subdivided giving a deeper mud-dwelling group in the Fladen area characterised by the seapen *Pennatula phosphorea* and a shallower group in the surrounding area typified by the hermit crab *Pagurus bernhardus*, the shrimp *Crangon allmanni*, the purple heart urchin *Spatangus purpureus* and the gastropod *Colus gracilis*. Similarly, the first group was divided into a shallower (70m), coarser sediment group typified by the presence of sponges and occurring between Orkney and Shetland and off the Buchan coast; and a deeper (100m), finer sediment group typified by tunicates and the shrimp *Spirontocaris lilljeborgi* and associated with the intermediate area of the Outer Moray Firth. The majority of the stations south of 57°30'N were grouped together based on the presence of sponges, tunicates, *Spirontocaris lilljeborgi* and the hermit crab *Pagurus bernhardus*.

Infaunal community distribution in the area is relatively well described over broad scales. From 1980 to 1985, Basford *et al*. (1989, 1990) took macrofaunal and sediment samples every 15 miles in a grid extending across the North Sea from just north of Shetland to the Firth of Forth. Analysis of this data in conjunction with the sediments produced two major groups according to the amount of silt present in the sediments.

The major group of stations containing less than 20% silt was sub-divided into three groups: a fine sand group, inhabited by *Abra prismatica*, *Ophelina neglecta*, *Travisia forbesii*, *Bathyporeia elegans* and *Eudorellopsis deformis*; an inshore, coarser sandy sediment group (near Shetland) where *Hesionura elongata*, *Protodorvillea kefersteini, Protomystides bidentata* and *Tellina pygmea* were present; and a finer (medium to very fine sand) group, which was characterised by *Spiophanes kroyeri, Myriochele heeri, Harpinia antennaria* and *Aricidea wassi.*

A second major group of stations defined by containing more than 20% silt was geographically located in the Fladen Ground. The seabed fauna of the muddy sediments of the Fladen Ground is generally regarded as uniform with moderate species richness and faunal densities and with moderately high productivity but low biomass. The low biomass may be in part an artefact of inadequate sampling of deep burrowing species such as the crustaceans *Nephrops* and *Calocaris*, and the hagfish *Myxine* which, although contributing substantial biomass, are generally poorly sampled by grab and core samplers (DTI 2001)[3].

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3 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197798/SEA2_Assessment_Document.pdf

Basford *et al*. (1990) reported on additional sampling extending from off Orkney to the inner Moray Firth. These samples indicated a gradient of infaunal density from less than 3,000 individuals/m^2 offshore increasing to 6,000 in the outer Moray Firth. Species richness varied from 30 to 60 species per station with no detectable pattern. The initial division shown in the analysis of the data revealed an inshore group of species and an offshore group. These groups were subdivided into a siltier group characterised by the polychaete *Pisione remota* and a coarser silt group typified by the bivalve *Nucula tenuis*. The offshore group was further subdivided with the polychaete *Spiophanes bombyx* representative of the shallower, less silty group and the amphipod *Eriopisa elongata, Thyasira* spp. and other bivalves, and the polychaetes *Lumbrineris gracilis* and *Ceratocephale loveni* representative of the deeper siltier samples.

Several areas in Regional Sea 1 (both offshore and nearshore) were surveyed in 2003 as part of the SEA Programme, in order to address identified data gaps. These included Fair Isle, outer Moray Firth, Pobie Bank, Smith Bank, Sandy Riddle and Southern Trench; they are summarised in Section 6 of the SEA 5 Environmental Report (DTI 2004[4]).

As part of the MPA programme, a number of surveys have taken place between 2011 and 2015 in order to gather data with which to underpin offshore site designations and their management. These have involved collaboration between MSS, Cefas, JNCC and BGS and fall within Defra's MB0120 data collection programme for rMCZs - reports (Defra 2014a-d, 2015a-d) are cited below where relevant.

A total of nine offshore areas were designated in 2014 as either NCMPAs (Central Fladen, Norwegian Boundary Sediment Plain, Turbot Bank, Firth of Forth Banks Complex, East of Gannet and Montrose Fields) or MCZs (Swallow Sands, NE Farnes Deep and Fulmar). Site details can be found at http://jncc.defra.gov.uk/page-5201. Sea bed samples, photographic imagery and acoustic data acquired from these sites by MSS and JNCC in 2011 have been analysed by Goudge & Morris (2014) and Pearce *et al.* (2014b) and habitats and biotopes have been mapped by Southeran & Crawford-Avis (2014 a & b). The biological features that these NCMPA sites aim to protect are burrowed mud (Central Fladen), offshore deep sea muds (East of Gannet & Montrose Fields), subtidal sands and gravels (Firth of Forth Banks Complex, Norwegian Boundary Sediment Plain), shelf banks and mounds (Firth of Forth Banks Complex), aggregations of *Arctica islandica* (East of Gannet & Montrose Fields, Firth of Forth Banks Complex, Norwegian Boundary Sediment Plain) and sand eels (Turbot Bank).

Burrowed mud at the Fladen Ground is rich in the common seapens *Pennatula phosporea* and *Virgularia mirabilis*; the tall seapen *Funiculina quadrangularis,* which is nationally uncommon, is also present in low numbers (Allan *et al*. 2012). Subtidal sand and gravel is the preferred habitat of *Arctica islandica*, an OSPAR threatened/declining species (OSPAR 2009). It is widespread in the North Sea north of 53°30'N and data from 1970-2000 analysed by Witbaard & Bergman (2003) give densities of up to 286/m^2 in the northern North Sea (Fladen Ground) and as low as 0.07/m^2 in the south-eastern part of its range. These numbers partially reflect the varying size distributions with low density areas dominated by large adults. Sand and gravel habitats also support sandeels – an important functional species in the North Sea, which is in serious decline. This habitat occupies a large area of the Firth of Forth Banks Complex NCMPA, including the Berwick, Scalp and Montrose Banks and the Wee Bankie shelf banks and mounds. Large numbers of sandeels have also been found in the sandy sediments of the

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/195060/SEA5_Section_6.pdf

Turbot Bank NCMPA. *Modiolus* beds and Annex 1 stony reefs have also been recorded from the Firth of Forth Banks Complex (Allen *et al.* 2014a).

The biological features of the three designated MCZs include sandy sediments with patches of coarse sediment, mixed sediment and also mud. The sites lie approximately 55km (North East of Farnes Deep), 100km (Swallow Sands) and 224km (Fulmar) off the Northumberland coast, with depths generally ranging from 50-100m. The Swallow Sands site includes a drop down to 150m in a channel described as Swallow Hole Glacial Tunnel Valley. Sediments at all sites are stable and support a diverse range of marine flora and fauna. Photographic and acoustic data acquired in 2012 and 2014 by JNCC/Cefas have not yet been fully reported, however a total of 410 infaunal species including *Arctica islandica* and 39 epifaunal species, were recorded for the North East of Farnes Deep site. The Fulmar site comprises sand and mixed sediments which support Venus communities, while a range of worms, cockles, urchins, sea cucumbers, burrowing anemones, brittlestars inhabit the softer mud areas of seabed. Of special conservation interest are the records of sea pen *Pennatula phosphorea* and the long-lived bivalve *Arctica islandica*.

A1a.2.4.2 Pockmarks

Pockmarks are a widespread feature in muddy sediments in the central and northern North Sea that have only recently begun to be explored in detail. The macrofaunal ecology of an active Fladen Ground pockmark (the Scanner pockmark in block 15/25, within Regional Sea 1) was described by Dando *et al.* (1991), who found that the fauna of sediments within the pockmark was characterised by the bivalve *Thyasira sarsi* (known to contain symbiotic sulphur-oxidising bacteria) and a mouthless and gutless nematode, *Astomonema southwardorum*, which also contains symbiotic bacteria. Methane derived authigenic carbonate (MDAC) blocks, deposited through a process of precipitation during the oxidation of methane gas, lie in the base of the pockmark and support fauna more typically associated with rocky reef. These carbonate structures were notably colonised by large numbers of anemones (*Urticina felina* and *Metridium senile*) and squat lobsters (Dando *et al*. 2001). This pockmark area is now a designated Site of Community Importance (SCI) containing the Annex I habitat “Submarine structures made by leaking gases”. The northern section of the site contains the Scotia pockmark complex with two deep sections and active methane seeps. A recent survey of the Scanner Pockmark SAC area (Gafeira & Long 2015a) confirmed the presence of 61 pockmarks, four of which were large in area (>72,000m^2) and deep ($\geq$12m). A second pockmark SAC, the Braemar Pockmarks (Gafeira & Long 2015b), consists of a series of crater-like depressions on the sea floor (Gafeira & Long 2015b). In this location, large blocks, pavements slabs and smaller fragments of MDAC have been deposited. Although Gafeira & Long (2015a & b) make use of data from a Cefas/JNCC survey in 2012, further biological reports from this survey are still awaited.

Another manifestation of gas seepage, the formation of carbonate cemented columns, has been found in the Kattegat (eastern North Sea) by Jensen *et al.* (1992). Such features are not known to occur in UK parts of Regional Sea 1.

A1a.2.4.3 Nearshore and coastal habitats and species

A geographical summary of nearshore benthic habitats and communities of the east coasts of Scotland and England north of Flamborough Head was presented within SEAs 2, 3 & 5; this was drawn largely from MNCR coastal sector reports and JNCC Coastal Directories. From primarily the same sources, the English Nature Marine Area Profile for Mid North Sea (Jones *et al*. 2004e) characterised nearshore benthic habitats of the English part of the area as being composed predominantly of muddy sand, whereas further offshore the sediment was mainly sand with patches of gravelly sand and muddy sand. To support SEA 5, a synthesis of current information on the benthic environment and the benthic communities and associations was produced by Eleftheriou *et al*. (2004); this synthesis covered nearshore habitats and species of the Scottish part of Regional Sea 1.

The major firths of the Scottish east coast – the Moray Firth and Firths of Tay and Forth – together with other significant inlets on the mainland coast (e.g. the Ythan estuary, Montrose Basin) all support habitats which may be characterised as estuarine and sheltered from wave action. These habitats include extensive intertidal sand- and mudflats which are of ecological and conservation importance and sub-littoral habitats which are distinct from those of adjacent coastal areas. Reed beds and saltmarsh are also characteristic of upper estuary locations. South of the border, the coastline of north-east England has a number of small rivers entering the North Sea, of which the Aln and Coquet are of noted conservation value. Sheltered muddy gravels, intertidal mud, coastal saltmarshes and saline reedbeds are present in the Aln Estuary which also presents the unusual feature of sheltered estuarine rock habitat. Larger rivers and estuaries – Blyth, Tyne, Wear and Tees – have typically industrialised altered environments, although sheltered mudflats and saltmarsh provide important habitat resources for waders, wildfowl and in certain locations seals. Teesmouth, a designated SPA and Ramsar site, is particularly rich in these habitats.

Open coastlines of the Regional Sea 1 area provide a range of intertidal habitats from bedrock shores, boulders and cobbles, to extensive sandy beaches. Shallow subtidal habitats are predominantly sands, gravels, or a mixture of the two, although extensive areas of exposed rock also occur, with characteristic epifaunal communities. Reasonable survey coverage of rocky intertidal and shallow subtidal habitats in the area has been produced, in part due to work related to the MNCR (Hiscock 1998, Bennett & Foster-Smith 1998). On a UK-wide basis, this work has been the basis for a classification of biotopes (i.e. distinctive habitat with associated flora and fauna) and regional reports. However, Eleftheriou *et al.* (2004) note that for important stretches of hard substrata on the east coast of Scotland there is little or no information available.

New data sought in conjunction with the MPA and MCZ projects in Scotland and England/Wales respectively are based on the newly designated and currently proposed sites described in Section A1a.2.4 above. A number of peat and clay exposures are present or believed to be present at a number of sites e.g. Farnes East MCZ, Coquet to St Mary MCZ; this habitat is usually colonised by boring species such as bivalve piddocks and although not common around the UK, piddocks are also associated with the softer chalk rocks of the east and south coasts of England. Areas of finer sediments – sandy muds and mud – supporting sea pen and burrowing megafauna communities are present at Farnes East MCZ. A broad range of rock, sediment and boulder habitats of varying wave exposures are present off Runswick Bay, where species of conservation interest include native oysters, spiny lobster, the pink sea fan *Eunicella verrucosa*, the Ross worm *Sabellaria spinulosa* and *Arctica islandica*. A number of important commercial fish species use the nearshore habitats off Runswick Bay for spawning.

A1a.2.5 Features of Regional Sea 2

The MESH map of seabed habitats for Regional Sea 2 is shown in Figure A1a.2.2. Furthest offshore the seabed is predominantly circalittoral fine sand and sandy mud, with the large shallower infralittoral fine sand area of Dogger Bank in the north of the regional sea and numerous sand banks aligned parallel to the shore through much of the nearshore waters. Among the offshore sandbanks there are four SCI sites: Dogger Bank; Haisborough, Hammond and Winterton; Inner Dowsing, Race Bank and North Ridge; North Norfolk Sandbanks and Saturn Reef.

Along the coast there are several large estuaries – Humber, Blackwater, Medway and Thames – and the extensive sheltered marine embayment of the Wash. This range of features provides a wide variety of coastal marine habitats, some of which have received protection through designation as conservation sites. Three inshore MCZs were designated in 2013 (Blackwater, Crouch, Roach and Colne Estuaries; Medway Estuary; Thanet Coast) and a further three in 2016 (Holderness Inshore; Cromer Shoal Chalk Beds and the Swale Estuary). More detailed descriptions and GIS data of the macrofaunal communities and biotopes within three nearshore areas have been acquired through Defra's Regional Environmental Characterisations which were funded by the Marine Aggregate Levy Sustainability Fund as a part of Cefas' Marine Environmental Protection Fund. The three areas are: off the Humber (Tappin *et al*. 2011), the Norfolk/Suffolk coast (Limpenny *et al*. 2011) and off the Thames estuary (EMU Ltd & University of Southampton 2009).

As with the eastern English Channel, the seabed fauna of the southern North Sea has colonised and developed over the last 6-11,000 years, in the process being subject to a change from Arctic to more temperate Boreal conditions.

A1a.2.5.1 Offshore habitats and species

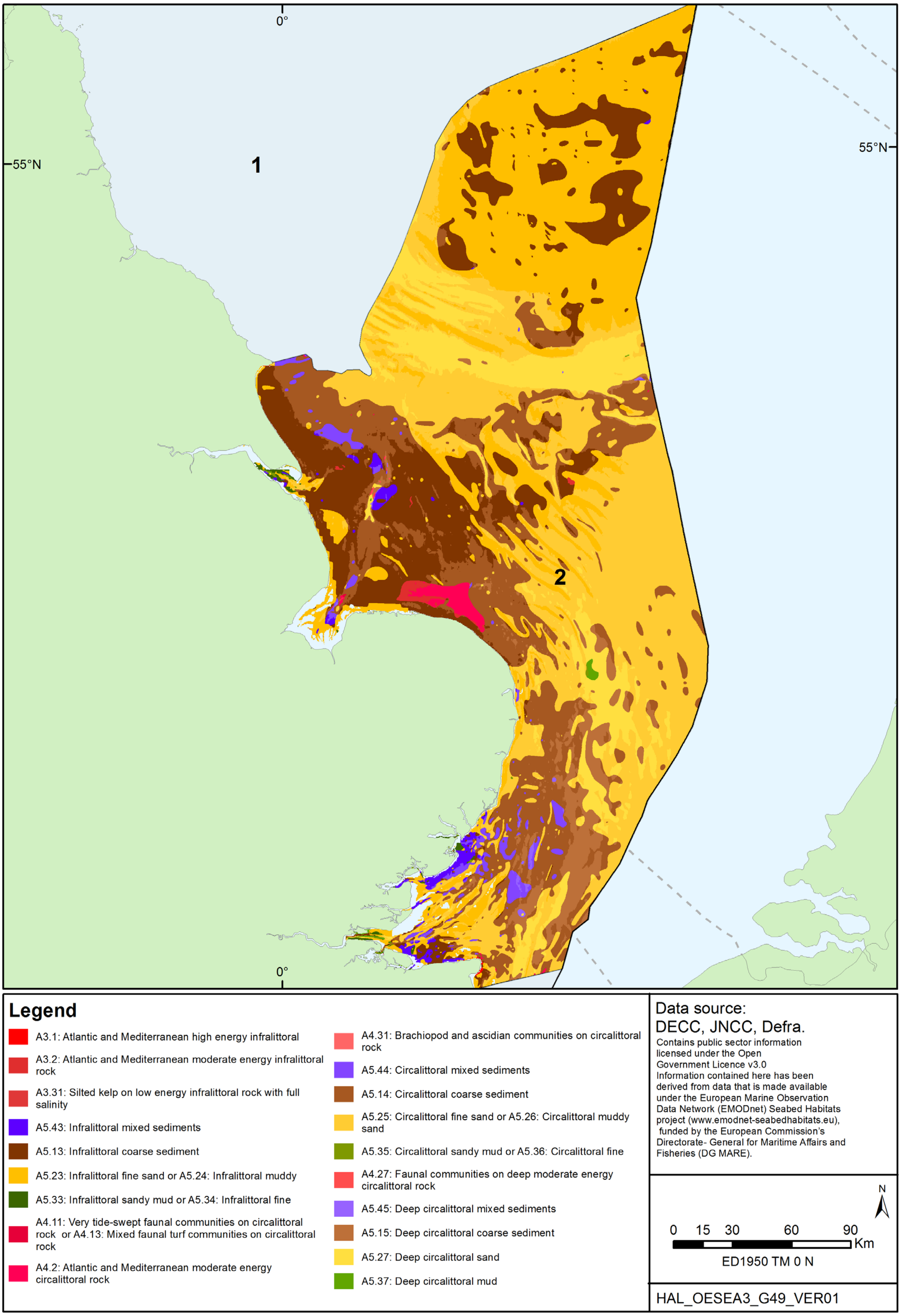
In terms of broad community distribution, the ICES survey reported by Künitzer *et al*. (1992; 2011) provide a good picture of community distribution in the southern North Sea. Four main communities were distinguished, corresponding to the following habitats:

- fine sands in 50-70m with a fauna typified by the polychaetes *Ophelia borealis* and *Nephtys longosetosa*
- muddy fine sands in 30-50m with the bivalve *Nucula nitidosa*, the shrimp *Callianassa subterranea* and the cumacean crustacean *Eudorella truncatula*
- coarse sediments mainly in less than 30m (1) with the polychaete *Nephtys cirrosa*, the sea urchin *Echinocardium cordatum* and the amphipod crustacean *Urothoe poseidonis*
- coarse sediments mainly in less than 30m (2) with the polychaetes *Aonides paucibranchiata* and *Pisione remota* and the amphipod crustacean *Phoxocephalus holbolli*

Dyer *et al.* (1983) conducted cluster analyses of trawled (primarily epi-) fauna from MAFF groundfish surveys over the whole North Sea, showing the area could be divided into four northern and three southern groups. The southern groups corresponded to the northern slopes of the Dogger Bank (S3), the shallowest part of the Dogger Bank and other shallow stations on the western side of the North Sea (S2), and the broad area of muddy fine sands off the Dutch coast forming group S1.

By contrast, the cluster analysis performed by Jennings *et al.* (1999) indicated that the epifauna of the entire North Sea south of the Dogger Bank was similar and formed a single cluster. Contrasting again, Rees *et al.* (1999) concluded that the area could be divided into 6 groupings based on sediment type and epifauna.

Figure A1a.2.1: MESH classification of marine biotopes, Regional Sea 2



A1a.2.5.2 Offshore sandbanks

A series of sandbanks and tidal sand ridges (the Norfolk Banks) extends over large areas of the southern North Sea. As part of the SEA process, the DTI (now DECC) commissioned detailed surveys of these potential Annex I habitats within the SEA 2, SEA 3 and adjacent areas. Four sandbank areas have subsequently been designated as SCIs (Haisborough, Hammond and Winterton; Inner Dowsing, Race Bank and North Ridge; North Norfolk Sandbanks and Saturn Reef, and Dogger Bank. All four sites represent the conservation feature 'sandbanks slightly covered by water at all times'; and all but Dogger have associated reefs of *Sabellaria spinulosa* (also protected). JNCC provides a selection assessment document for each cSAC (JNCC 2010a, b, c & 2011) and a number of additional reports provide evidence of the habitats and biological communities present within the sites; for example Diesing *et al.* (2009) on the Dogger Bank. JNCC/Cefas survey work in 2011 on the Haisborough, Hammond and Winterton SCI and the Inner Dowsing, Race Bank and North Ridge SCI has not yet been reported.

The North Norfolk Sandbanks and Saturn Reef SCI includes the Leman, Ower, Inner, Well, Broken, Swarte Banks and four banks called, collectively, the Indefatigables. The banks are considered to support communities of polychaete worms, isopods, crabs and starfish typical of sandy sediments in the southern North Sea such as (JNCC 2007).

Studies by Vanosmael *et al*. (1982) on the Kwinte Bank of Belgium, suggested that the fauna of offshore linear sandbanks is distinctive in a number of features, in particular the very high densities of interstitial (that is living in the interstices between sediment grains) polychaetes present. These species show very high variability between sampling stations, reflecting either (or both) patchiness of distribution or very tightly defined habitat requirements, so that a small alteration in location of samples results in a large difference in the fauna recorded.

It is clear that there are major sediment and faunal differences between the offshore linear sandbanks (the Norfolk Banks) and the banks in the approaches to the Wash. The Wash approach banks (Galahad field, Dudgeon Shoal, Cromer Knoll and the western end of the Haddock Bank) are composed of stony and coarse shell sediment with extensive epifauna and infauna. In contrast, the offshore linear banks are sandier with a fauna typified by the sea urchin *Echinocardium cordatum* and the bivalve *Tellina fabula* with sandeels (two species) common.

The SEA survey samples of the Dogger Bank indicated a richer (more and larger animals of a range of species) fauna than that found on the sandbanks to the south. At the 5mm material level, no major differences were discerned between the various stations sampled across the Dogger Bank (SEA 2). Predominant species were *Echinocardium cordatum, Fabulina fabula* and a range of worms including the sand mason *Lanice conchilega* and *Owenia fusiformis*. Sonnewald & Türkay (2012) describe five distinct macrofauna communities on Dogger Bank, which show similar spatial distribution throughout the twentieth century. They note biodiversity reduction over this long term period, including a decline in the dominant species *Spisula / Mactra* in the 1950s.

The fauna recorded during the DTI survey of the southern SEA 2 sandbanks accords closely in terms of species distribution with previous surveys of the area. Banks off the south Norfolk, Suffolk and Essex coasts are likely to support similar faunal communities.

Multibeam acoustic survey of the North Norfolk Sandbanks and Saturn Reef SCI in 2014 (Cefas/JNCC) successfully mapped the sandbank profiles and procured grab samples, however results are not yet reported.

A1a.2.5.3 Nearshore habitats and species

SEA 3 presented a geographical summary of nearshore benthic habitats and communities of the east coast of England south of Flamborough Head – largely drawn from MNCR coastal sector reports and JNCC Coastal Directories (Irving 1995a, b, 1998). From primarily the same sources, the English Nature Marine Area Profile (Jones *et al*. 2004c) characterised benthic habitats of the area as composed predominantly of sandy gravel closer to the shore, whereas further offshore the sediment is mainly sand with patches of gravel, sandy mud and sandy gravel. The regional environmental classification work carried out by the aggregates industry EMU Ltd & University of Southampton 2009; Limpenny *et al*. 2011) describes four benthic groups based on the sediment categories 'sublittoral coarse sediment' and sublittoral sands and muddy sand'. Site specific work around the Gabbard Banks off the Suffolk coast (Harwich) (GGOWL[5] 2005) found five main biotopes:

- Infralittoral mobile clean sand with sparse fauna
- Impoverished infralittoral mobile gravel and sand with *Glycera lapidum*
- Circalittoral coarse sand and gravel with *Mediomastus fragilis, Lumbrineris* spp and venerid bivalves
- *Sabellaria spinulosa* on stable circalittoral mixed sediment; and
- *Scalibregma* dominated sand/muddy sand.

Further work in this area for the Galloper Offshore Wind Farm (RWE *et al*. 2011) supports these descriptions. Details of selected coastal/nearshore habitats have also been acquired through the MCZ programme (https://consult.defra.gov.uk/marine/tranche2mczs).

Close inshore and extending northward from Spurn Head within the Holderness Coast rMCZ, variation from the nearshore high and moderate energy sediment habitats is provided by subtidal rubble and some circalittoral rock which support encrusting cup corals, sea fans, anemones and sponges, together with starfish, brittlestars and sea urchins. High and moderate energy hard substrate is also present on the inshore Norfolk coast at the Cromer Shoal Chalk Beds MCZ, where exposed chalk beds with many crevices and holes provide attachment sites for encrusting tubeworms, sea squirts and anemones, together with protection for juvenile crab, lobster and fish species. A second MCZ, the Swale Estuary, comprises low and moderate energy rocky intertidal and sublittoral sediments, with an excellent example of exposed clay.

Towards the southern end of the southern North Sea a discontinuous belt of gravel and sandy gravel extends offshore from Aldeburgh in Suffolk to the vicinity of Clacton-on-Sea in Essex. To the north of the area many of these sediments generally form a surface layer less than 1 metre thick, with the underlying glacial deposits or bedrock often exposed locally. The gravel habitats found in deeper offshore areas (>30m) generally tend to be less perturbed by natural disturbance than those found closer inshore. These areas also tend to support a diverse marine fauna which may include a wide range of anemones, polychaetes, bivalves and amphipods, and both mobile and sessile epifauna.

[5] Greater Gabbard Offshore Winds Limited (*GGOWL*)

Sand habitats are very widespread throughout the southern North Sea and are the dominant habitat type found in the North Sea. They tend to be mobile but accumulate in areas of moderate to strong tidal currents; in such situations the sands are coarse and clean with little silt/mud. More mobile sand habitats tend to be characterised by robust and sometimes impoverished faunas, dominated by organisms which are capable of rapid burrowing, such as certain mobile polychaete worms, burrowing amphipods and thick-shelled bivalves.

Chalk reefs occur at two locations within the southern North Sea, in the south within the Thanet coast SAC and MCZ; and in the north within the Flamborough Head SAC. Chalk reef habitats characteristically support a wide range of species, some of which are unique to this type of substrata. Subtidal chalk at Thanet is bored by piddocks *Barnea* spp., *Pholas dactylus, Hiatella arctica* and *Petricola pholadiformis*; this piddock-dominated habitat is the most widespread biotope on the subtidal reef and is considered to be scarce in Britain. The chalk reefs at Flamborough support kelp *Laminaria hyperborea* forests with an associated fauna that typically colonises the holdfasts. These kelp communities are considered to be a key structural and functional component of the chalk reefs at Flamborough Head. The chalk reefs at Flamborough also support a variety of faunal 'turf' communities, ranging from low encrusting forms, such as sea mats and sponges, to tall erect forms, such as soft corals and sea fans, plus mobile organisms such as crustaceans, echinoderms, molluscs and fish.

There are larger numbers and a wider range of cave habitats at Flamborough Head SAC than at any other chalk site in Britain; over 200 caves have been recorded at Flamborough Head, although a proportion of these are above Mean Low Water. Flamborough Head is particularly important for its specialised encrusting and filamentous algal communities which include *Hildenbrandia rubra, Pseudendoclonium submarinum, Sphacelaria nana* and *Waerniellina lucifuga*. The bedrock floors of the caves are characterised by abundant *Sabellaria alveolata* and sponges such as *Leucosolenia* spp. or the chalk-boring yellow sponge *Cliona celata* and *Polydora* spp. worms, characteristic of the chalk habitats.

A1a.2.5.4 Estuarine habitats and species

The Wash is a large (66,000ha), wide mouthed marine embayment, about half of it exposed at low water in the form of sand and mudflats, an area comparable in Britain only to Morecambe Bay. In the outer reaches there are deep channels between the sandbanks, the greatest depth (47m) being recorded from the Lynn Deeps, midway between Hunstanton and the Friskney shore. The intertidal flats, amounting to around 40% of the total area of the Wash, consist mainly of fine sands supporting a community characterised by the lugworm *Arenicola marina*, with cockle *Cerastoderma edule*, Baltic tellin *Macoma balthica*, mussel *Mytilus edulis*, the gastropod *Hydrobia ulvae*, the crustacean *Corophium volutator* and the polychaete worm *Nephtys hombergii* (English Nature 1994).

Major river estuary channels, e.g. the Humber and Thames, where tidal scour may be considerable, generally consist of mixed mud, muddy sand and gravel, with a fauna comprised predominantly of capitellids, oligochaetes, nematodes and the polychaete *Polydora* sp. The diversity and quantity of species present is related primarily to salinity and water quality (i.e. organic pollution loading).

Rees *et al.* (1982) describe five main community types in the Humber estuary:

- Impoverished marine sand, in the central channel from Immingham to the mouth, influenced by tidal action and characterised by *Nephtys* spp., mysid shrimps, *Spio filicornis* and *Spiophanes bombyx*.

- 'Transitional' muddy sand, mostly from Barton to Immingham on the south side, influenced by tidal current action, with *Capitella capitata*, *Polydora* sp., mysid shrimps, Gammaridae and *Nephtys* spp.
- Impoverished estuarine muddy sand, from the upper estuary to Paull Roads on the north side, influenced by tidal current action. Sparse fauna, distinguished from transitional muddy sand by the absence of polychaetes.
- Marine sand, at the southern mouth, containing a rich fauna in areas which were presumed to be less exposed than those of impoverished marine sand in the main channel. Characteristic species include *Spiophanes bombyx* and *Spio filicornis*.
- Nearshore mud, off Immingham and Grimsby, with a rich mud fauna including *Polydora* sp. and *Pygospio elegans*.

The sea bed of much of the Thames estuary consists of gravel, pebbles, clay or chalk, with silt and mud occurring in areas of deposition. A 1972 study by MAFF of the sea bed around the sewage sludge disposal sites in the outer Thames estuary was described by Talbot *et al*. (1982), who identified nine faunal and sediment associations, the most common ones being dominated by the polychaete worms *Nephtys* spp., *Spio* spp. and *Spiophanes* spp., bivalves *Tellina* spp. and amphipods. A survey of 218 sites between Gravesend Reach and the Black Deep approach channel to the outer Thames estuary was carried out in 2001, together with a trawl survey and assessment of the age structure and commercial significance of cockle (*Cerastoderma edule*) populations, as part of an environmental assessment of the proposed London Gateway Port project (Newell *et al*. 2001). In general, the communities were found to be rich in species (for this type of habitat), with high biomass values especially in the intertidal mudflats of the upper estuary. Epifauna was dominated by the swimming crab *Liocarcinus holsatus*, prawn *Pandalus montagui* and brown shrimp *Crangon crangon* with colonial bryozoa *Alcyonidium diaphanum* and hydroids *Sertularia cupressina*. Multivariate analysis of macrofaunal community structure distinguished at least five communities, corresponding to variation in sediment, water depth, salinity and current velocity. Large scale grab and trawl surveys in support of offshore wind farm developments further out in the region of the Long Sand and Kentish Knock sandbanks (London Array Limited 2005) and the Inner Gabbard and Galloper sandbanks (GGOWL 2005) found broadly similar communities; species-poor worm and amphipod communities dominated shallow sandy areas and richer polychaete dominated communities occurred on more stable, often deeper, areas where sediments were usually coarser.

The native oyster *Ostrea edulis* is sufficiently abundant to form an important fishery in some shallow inshore areas of the Thames estuary, notably in areas of mixed shell and gravel over mud, for example off the north Kent coast between Whitstable and Herne Bay. The introduced slipper limpet *Crepidula fornicata* is also common in similar areas.

A1a.2.5.5 Biogenic habitats

Sabellaria reefs are present within the southern North Sea, described from two areas in particular: offshore from the Wash on sandy gravel substratum (see Foster-Smith & Hendrick 2003) and nearshore off the north Norfolk coast (Pearce *et al*. 2011) where a series of reefs were discovered in 2008 by the East Coast Regional Environmental Characterisation Survey (Limpenny *et al*. 2011). Epifaunal/mobile species associated with the reefs included *Pandalus montagui, Necora puber, Aequipecten opercularis, Asterias rubens, Mytilus edulis* and Ascidiacea sp.; fauna identified from grab and trawls also included *Crepidula fornicata, Polydora* sp. *Nucula nucleus, Abra alba, Kurtiella bidentata* and *Balanus crenatus*. *Sabellaria spinulosa* reef has also been found in an aggregate licence area (401/2) approximately 13 nautical miles east of Great Yarmouth (Newell *et al*. 2000). Here, the area surrounding the *Sabellaria* reef was characterised by stable coarse, gravelly sand and it is likely that this habitat is present in the surrounding offshore waters. An offshore area of *Sabellaria spinulosa* reef discovered as part of a survey in 2002 on behalf of ConocoPhillips (BMT Cordah 2003) was located in the sandbank area between Swarte and Broken banks. It is now named Saturn Reef and is included within the North Norfolk Sandbanks and Saturn Reef SCI. Samples from the reef indicated an associated community dominated by polychaetes (most abundant species were *Pholoe synophthalmica* and *Mediomastus fragilis*) and epifaunal species otherwise associated with crevice habitats (e.g. *Galathea intermedia*). The gastropod mollusc, *Noemiamea dolioliformis*, believed to an ectoparasite of *Sabellaria spinulosa* (see Killeen & Light 2000) was also recorded (BMT Cordah 2003). In 2002, the Saturn reef covered an area approximately 750m by 500m just to the south of Swarte Bank, varying in density over this area (JNCC 2007). More recent survey in the area (JNCC/Cefas 2013) did not appear to find the extensive reef of 2002, but the full survey analysis is yet to be reported. Whether absence/reduction in area is a result of damage to the reef structure (e.g. by bottom trawling) or whether such reefs are naturally ephemeral is not yet known. However, formation of such a substantial reef of *Sabellaria spinulosa* in this area in 2003 indicates favourable conditions for reef formation.

The ecology of *Sabellaria* reefs, commonly cited as being species rich and offering a complex three dimensional structure, was investigated by Pearce *et al*. (2011) who found that, in comparison to surrounding sediments, the reefs were characterised by a high abundance of fauna (≤ five-fold), but showed no difference in numbers of epibenthic or infaunal species. Evidence of reef dominance by a few species, was surmised by the fact that evenness of species in/on the reefs was lower than in/on surrounding sediment. They were also able to demonstrate that *S. spinulosa* reefs have a detectable influence on the diet of several demersal fish species either directly e.g. Dover sole, dab and plaice or indirectly e.g. lesser weever, northern rockling and dab, which were found to feed on benthic species likely to be present in high numbers in reef habitats.

S. spinulosa aggregations also occur regularly in the outer Thames estuary (e.g. GGOWL 2005, London Array Limited 2005) and as far upstream as Canvey Island (Attrill *et al*. 1996), but do not appear to be so extensive or well developed as around the Wash.

Sabellaria alveolata reefs are present off the Essex coast within the Blackwater, Crouch, Roach and Colne Estuary MCZ, together with native oyster (*Ostrea edulis*) beds and mussel (*Mytilus edulis*) beds.

Intertidal mussel beds formed by *M. edulis* are extensively distributed and commercially exploited within Regional Sea 2. Occasionally complex biogenic reefs of mixed *M. edulis* and *S. spinulosa* occur intertidally as in the Thanet Coast MCZ.

A1a.2.6 Features of Regional Sea 3

Prior to OESEA (DECC 2009), Regional Sea 3 (the eastern English Channel) had not previously been assessed by the SEA programme. Benthic habitats and species of the area had been reviewed in the Marine Natural Area profile (Jones *et al.* 2004f) and habitat mapping had been carried out under the UKSeaMap marine landscape classification (Connor *et al*. 2006), the MESH programme (MESH 2008) and most recently the Dover Straits area has been mapped by MAREMAP. To date, marine energy exploitation is confined to a single R3 consented wind farm (Rampion) off the Worthing coast for which benthic data is available (E.ON Climate & Renewable 2012). Other data sources include the South Regional Environmental Characterisation (MALSF) and the MCZ programme.

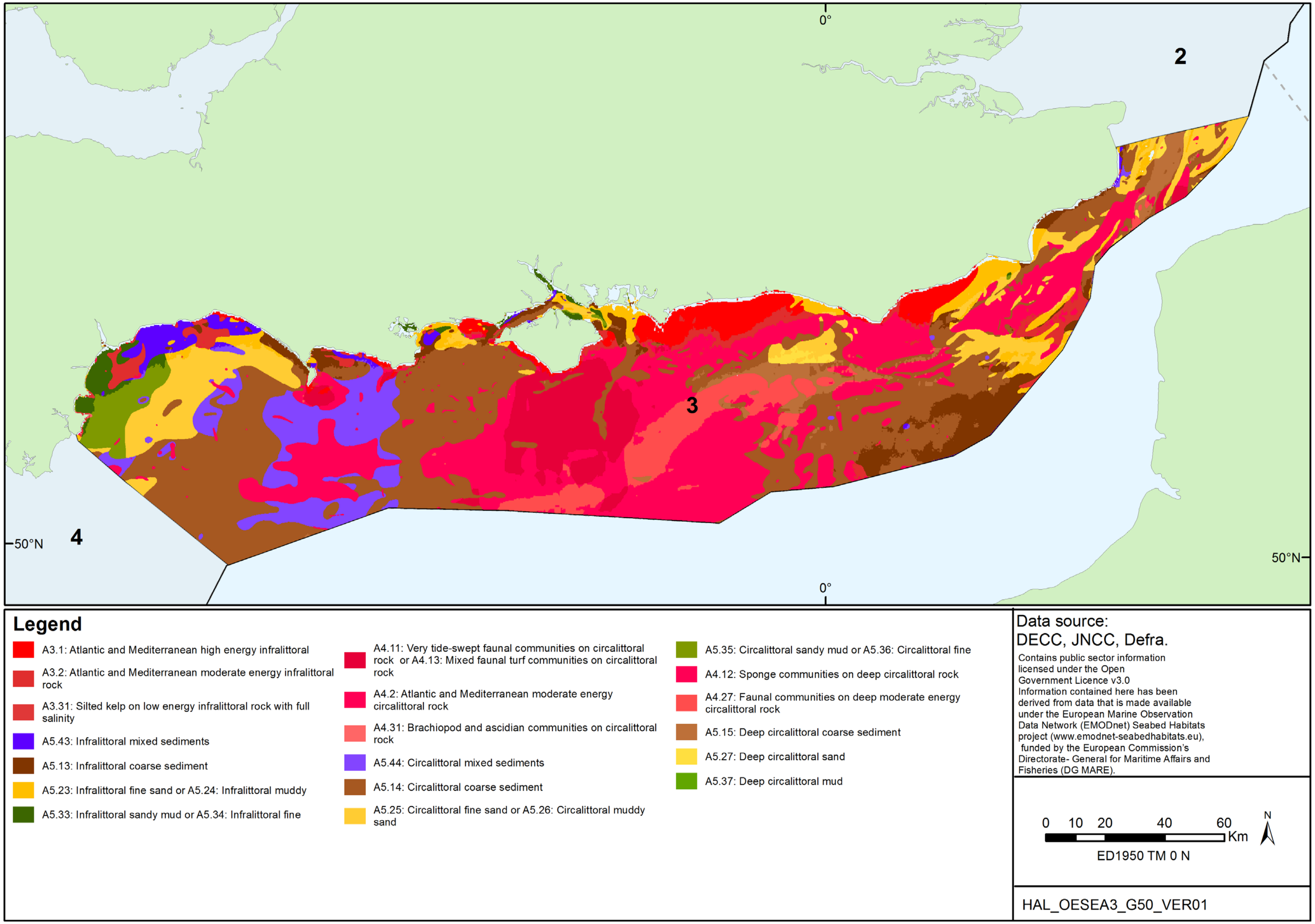
The MESH map of seabed habitats for Regional Sea 3 is shown in Figure A1a.2.3.

Within the Quaternary period (which encompasses the most recent 2.6 million year), the topography of the English Channel has been modified by the action of numerous eroding marine transgressions and palaeo-rivers active during glacial low-stands. It has also been postulated that a large proglacial lake to the north-east of the Weald-Artois Anticline ridge developed and subsequently caused the failure which produced a significant outflow of water into the English Channel, probably in the mid-Pleistocene. The most recent major change in status took place about 6,000 years ago when the Flandrian transgression occurred. As with the southern North Sea, therefore, the seabed fauna of the eastern English Channel has colonised and developed over the last 6 to 11,000 years, in the process being subject to a change from Arctic to more temperate Boreal conditions.

Current coastal topography includes a number of sheltered shallow inlets/harbours in the central part of the English Channel: Pagham, Chichester, Langstone, Portsmouth, several within the Solent and Poole. There are many small estuaries in the eastern Channel and several larger ones in the western Channel: Exe, Teign and the Dart. All are dominated by fine sand and mud habitats with characteristic fauna and a number of *Zostera* beds (Black & Kochanowska 2004).

Offshore protected sites include Bassurelle Sandbank and Wight-Barfleur Reef - designated as European SCIs in 2011 and 2013 respectively. A suite of eight inshore MCZs were designated in 2013 – Folkestone Pomerania, Beachy Head West, Kingmere, Pagham Harbour, Chesil Beach and Stennis Ledges, Poole Rocks, South Dorset and Torbay – and a further six MCZ as part of the 2nd tranche of proposals. Four of these most recent designations are nearshore/coastal: Dover to Deal, Dover to Folkestone, Utopia and the Needles; and two are offshore: Offshore Brighton and Offshore Overfalls.

Figure A1a.2.3: MESH classification of marine biotopes, Regional Sea 3



A1a.2.6.1 Habitats and species

Primarily drawn from MNCR coastal sector reports and JNCC Coastal Directories (Barnes 1996, 1998a, b), the English Nature Marine Area Profile (Jones *et al.* 2004f) characterised coastal benthic habitats of the area as being composed of an assortment of mixed sediments (especially gravel and shells) with sand and, in sheltered locations, mud. There are also occasional, sometimes extensive, exposures of bedrock and boulder reefs, mostly occurring off headlands such as Beachy Head, Selsey Bill and the Purbeck coast. Further offshore in the deeper waters of the western Channel, the seabed is dominated by sediments, mainly of sand, sandy gravel and gravel.

In offshore areas of the eastern Channel there are extensive deposits of gravel to the south and east of Selsey Bill. Further west there are also significant banks known as the Dolphin and Shingles Banks (within the western approaches to the Solent), the Solent, Brambles and Ryde Middle Banks (Solent), the Horse and Dean and Medmerry Banks (eastern approaches to the Solent), and banks in Poole Bay. In addition to these banks there are several large gravel areas present, some of which exceed 2 metres in height; and several banks of sandy gravel of 'veneer' thickness, i.e. <0.5m thick. The gravel habitats found in deeper offshore areas (>30 metres) have, in general, low levels of natural mobilisation (through wave and current action), and support diverse marine fauna which may include a wide range of anemones, polychaetes worms, bivalves and amphipods and both mobile and sessile epifauna.

Nearshore 'mixed sediments' are 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, particularly during the summer months, settlement and subsequent growth of a rich variety of plant and animal species occurs. The slipper limpet *Crepidula fornicata* is a characteristic species of the Solent region (Collins & Mallinson 2000). This non-native species is commonly associated with gravel and its shells can form the main hard substrate in areas of soft sediments. Nearshore finer sediments - sand habitats – support *Zostera* beds in a range of locations and are conservation features of two of the designated MCZs: Pagham Harbour and Torbay.

Extensive brittlestar beds are frequently encountered in deep water (30-50m) in the eastern Channel (Ellis & Rogers 2000), although they are also occasionally found closer to the coast. Collins (2002) found an *Ophiothrix fragilis* bed approximately 2km off Kimmeridge Bay, to the west of Swanage, Dorset.

Sand habitats are found in regions of moderate to strong tidal currents and are characterised by robust and sometimes impoverished faunas, typically venerid bivalves, amphipods (shrimps), polychaetes worms and heart urchins, with sparse or absent epifauna. The Rampion wind farm development location (E-On Climate & Renewables, 2012) comprises mainly sands and gravelly sands, with lesser amounts of sandy gravel and siltier sediments. Some sediments were found to be thin and superficial overlying chalk bedrock. Four ecologically identifiable groups were identified from grab samples, the most common being characterised by the polychaetes *Mediomastus fragilis* and *Lumbrineris* spp. with Venerid bivalves in circalittoral coarse sand or gravel. The circalittoral fine sands were dominated by the urchin *Echinocyamus pusillus,* the *polychaete Ophelia borealis* and the bivalve *Abra prismatica.* Cobble and pebbles amongst the coarse sediments were colonised by *Pomatoceros triqueter*, barnacles and bryozoan crusts.

The Offshore Overfalls MCZ site, located 18km to the east of the Isle of Wight and extending to straddle the 12nm boundary, is a good example of coarse sediments, sand and mixed sediments in a depth range from 1-35m. Of particular scientific interest in this site is the actual overfalls feature which comprises sandwaves of mixed sediment, sands and gravels of importance for a wide range of fish species. Biological data was collected by Cefas during 1998-2004 and in 2012.

Detailed infaunal data was acquired for an area off the west corner of the Isle of Wight and directly south of Poole Bay, as part of a baseline survey carried out for the Navitus offshore wind development whose planning application was rejected in September 2015 (Fugro Emu Ltd 2014). The seabed was found to be predominantly coarse sediments – in line with the MESH predicted habitats – with some additional patches of muddy sandy gravels. Coarse sediments of well sorted sand were predominantly *Nephtys cirrosa* and *Bathyporeia* dominated, with a number of samples also rich in *Lanice conchilega*. Coarse gravels with strong tidal streams were dominated by the polychaete *Protodorvillea kefersteini* and a number of muddy sandy gravels sported abundant *Crepidula fornicata*. *Sabellaria spinulosa* was present in mixed sediments, but no reef structures were observed.

In areas of lower tidal currents or sheltered from prevailing winds, sediments of muddy sand are widespread. In Lyme Bay, the muddy sand seabed supports a community dominated by the bivalve *Corbula gibba*, the polychaete worms *Chaetozone setosa* and *Magelona filiformis* and the amphipod *Bathyporeia tenuipes* (Ambios Environmental Consultants 1995). Other notable species records from Lyme Bay include the worm anemone *Scolanthus callimorphus*, the polychaete *Sternaspis scutata* and the mantis shrimp *Rissoides desmaresti*. Most of the rias[6] within the region have areas of shallow or intertidal sandbanks, often with areas of subtidal muddy gravel. On the south coast of Devon, the seabed of Tor Bay is of relatively uniform muddy sand that supports a diverse burrowing community dominated by bivalves, brittlestars and anemones. A small yet important population of the burrowing red band fish *Cepola rubescens*, which appears to be more or less restricted to Regional Sea 3 in British waters, was discovered in the Bay (Devon Wildlife Trust 1995), with other small populations reported from Brixham Harbour (as well as from more muddy sediments).

Sandbanks within Regional Sea 3 tend to be in shallow water and the communities they support are determined by the sediment type and a variety of other physical factors, including geographical location, the relative exposure of the coast and differences in the depth, turbidity and salinity of the surrounding water. These sandbanks provide important nursery grounds for young commercial fish species, including plaice, cod and sole (Brown *et al*. 1997). Patches of a very dense tube mat biotope were found by Rees *et al*. (2005) during fish habitat studies in the eastern Channel. At three locations in the lows between linear sand banks off the French coast an undescribed small polychaete, *Chaetopterus* sp., occurred with small *Lanice conchilega* as an enriched sediment stabilizing biotope. This biotope was distinct though with similarities to other tide swept sub-tidal biotopes dominated by *L. conchilega*. Using cameras and side-scan sonar it was seen to overlay heterogeneous cobbles and shell hash with intermittent rippled sand veneer. The patchiness of this enriching biogenic feature contributed to the variability in trawl catches of fish.

The Bassurelle Sandbank SCI, typical of the offshore sandbank habitat in this regional sea, straddles the UK/French boundary line in the Dover Strait; it is an open shelf ridge sandbank 15km in length with a maximum height of 15m, formed by tidal currents. Sandwaves and mega ripples up to 2.5m high are abundant on part of the bank whose infauna is dominated by polychaetes, including species such as *Lagis koreni* and *Spiophanes bombyx*, and the bivalves *Moerella pygmaea* and *Ensis* sp. In places on Bassurelle Sandbank, and on the margin of the wider sandwave field, the sediment is slightly more gravelly and shelly, with the coarser

[6] drowned river valleys, resulting from post-glacial rise in relative sea level.

sediment often collecting in the troughs between sandwaves. In these areas, a slightly different infaunal community of polychaete worms is found.

The epifaunal community present on the Bassurelle Sandbank is typical of a sand and gravelly sand habitat. On the bank itself, the hermit crab Pagurus bernhardus, brittlestar *Ophiura* spp. and the hydroid *Hydrallmania falcata*, have all been observed. The sand eel (*Ammodytes tobianus*) and weever fish (*Echiichthys*) were characteristically present, although these were absent from the sandy areas surrounding the bank. The region is a nursery area for lemon sole, mackerel and sand eel and a spawning area for cod, lemon sole, sole, plaice, sand eel and sprat.

Mud-dominated sediments in Regional Sea 3 are located in estuarine harbours and in deeper water 'troughs' or 'deeps' (although these are not deep in the context of other Regional Sea areas). The fauna of muddy sediments in this area is generally dominated by polychaete worms, bivalve molluscs such as cockles, and brittlestars. Of particular note are the soft muddy areas within the Folkestone Pomerania MCZ, which support biogenic reefs of both ross worm, *S. spinulosa*, and honeycomb worm, *S. alveolata*. The MCZ is located 6km from the south-east Kent coastline in the narrowest part of the Channel.

A1a.2.6.2 Rock and rock reefs

Offshore, the eastern Channel basin is dominated by a large expanse of varied bedrock habitat, with gravel and bedrock outcrops. The water depths in the vicinity are generally between 50-75m, with the exception of a linear deep that reaches 100m. The extremely heterogeneous nature of the habitat is due to the complex geology of the region, where folded bedrock is overlain by coarse sediment patches (gravel, pebbles, cobbles and boulders), and both may be covered in more mobile sandy sediments. The current strengths are sufficient to mobilise fine gravel, which results in a highly disturbed environment. Epibenthic fauna, such as barnacles and bryozoans, have been found encrusting sampled cobbles from here (Graham *et al*. 2001).

The coastline of the south-east of England is well known for its chalk cliffs. Chalk is also present in the shallow subtidal, occurring as three main forms which may all be classified as reefs (in the context of the Habitats & Species Directive; Jones *et al*. 2004f). These are (1) gently shelving platforms which extend from the shore beyond Low Water Mark; (2) low-lying nearshore outcrops; and (3) sections of low-lying subtidal cliffs. These nearshore chalk exposures occur at Shakespeare Cliff, between Dover and Folkestone (outcrops); between Beachy Head and Seaford Head (platforms); between Newhaven and Brighton (platforms); off Hove and Worthing (cliffs); off Culver Cliff on the east side of the Isle of Wight (outcrops), at the Needles on the west side (outcrops); and at White Nothe on the east side of Ringstead Bay in Dorset (outcrops).

Chalk is a relatively soft rock and a number of species that are capable of boring into the rock tend to dominate the associated subtidal communities. These species include bivalve piddocks (in particular *Pholas dactylus, Hiatella arctica, Barnea* spp. and *Petricola pholadiformis*), polychaete worms (especially spionids) and sponges. 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. The growth of the kelp *Laminaria hyperborea*, which typically grows as 'forests' on shallow parts of reefs elsewhere, is considerably restricted in the eastern Channel due to the high turbidity and the consequent restricted light penetration. However, there are often lush growths of various red seaweeds such as *Calliblepharis ciliata, Delesseria sanguinea* and *Halurus flosculosus* and, slightly deeper, a variety of faunal turf communities. These latter are likely to feature low encrusting forms such as sea mats and sponges as well as tall erect forms such as soft corals and hydroids, plus mobile organisms such as crustaceans, echinoderms, molluscs and fish. Chalk reefs/outcrops appear to be an important component of nesting areas for black seabream. A number of the newly designated MCZ sites include chalk features: Kingmere, Beachy Head and South Dorset.

Following the underlying geology, there is an east/west divide with sandstone reefs occurring from Beachy Head to Selsey Bill and limestone reefs being more commonly encountered in the west, e.g. at Bembridge on the Isle of Wight and off Durlston, Kimmeridge, Lulworth and Portland in Dorset. In shallow water, both sandstone and limestone bedrock and boulder surfaces are covered (often up to 80%) by foliose algae, with occasional kelp plants *Laminaria* spp. also present. In slightly deeper water, several species of sponge are likely to be conspicuous, including *Esperiopsis fucorum* and *Dysidea fragilis*. *Pentapora fascialis*, a coral-like bryozoan which may grow in clumps up to 40cm tall, is often conspicuous on bedrock outcrops. Overhangs may be dominated by a variety of sea squirts, bryozoans, hydroids, anemones and the soft coral *Alcyonium digitatum*.

In Lyme Bay, between 3 and 8km offshore, a number of discrete, bedrock reefs emerge from sediment. They support rich faunal communities with some conspicuous, though rarely encountered, Mediterranean-Atlantic species. These include the bryozoan *Pentapora fascialis*, dense stands of the pink sea fan *Eunicella verrucosa* and a population of the rare solitary coral *Leptopsammia pruvoti* (at Saw Tooth Ledges). The occurrence of these last two species is of national importance (Barne *et al*. 1996d).

The nearshore Folkestone Pomerania MCZ site has high energy circalittoral rock ledges and boulder-strewn platforms which support rich communities of fragile sponges and anthozoans. Rocky outcrops in the shallow sublittoral just outside Poole Harbour entrance have a rich and diverse fauna and form part of the Poole Rocks MCZ.

Offshore south of the Isle of Wight, the newly designated Wight-Barfleur Reef SCI is an area of bedrock and stony reef (Annex I feature) between St Catherine's Point and Barfleur Point on the Cotentin Peninsula in northern France. The site is approximately 65km long (east to west) and up to 26km wide. The reef area supports a diverse encrusting community including sponges, tube worms, anemones and sea squirts. The south-eastern area of the site contains part of a large geological feature known as a palaeochannel, which forms a major channel running roughly in a north-east to south-west direction across the English Channel. Recent survey work by Cefas includes Coggan *et al*. (2009) and the latest 2013 work which is still to be reported.

Mudstone, with its hard, clay-like consistency, may be present as smooth, horizontal exposures in a number of nearshore areas and is often partially covered by mixed sediments (which scour the surface of the mudstone smooth). In the eastern Solent it is often found below a layer of limestone cap rock, large chunks of which can break off and form boulder slabs as a result of erosion. Soft clay is commonly encountered in nearshore areas off Selsey Bill, most dramatically as the near vertical cliff forming the Mixon Hole. Although little life is obvious on the cliff itself, the clay face is riddled with holes of the piddock *Pholas dactylus*, with various species of crustacean present on the horizontal ledges (Irving 1999).

Within Sandown Bay and elsewhere on the eastern side of the Isle of Wight, discrete areas of soft mud support reef-like 'beds' that are formed by thousands of mud tubes inhabited by the amphipod crustacean *Ampelisca* spp. The tubes are packed tightly together to completely cover the underlying substratum, which may be smooth bedrock or consolidated mixed sediments. Each individual 'bed' rarely covers more than about 25m^2 of the seabed. Few other organisms are specifically associated with these *Ampelisca* 'beds'.

A1a.2.7 Features of Regional Sea 4

Benthic habitats and species of the area have been reviewed in the Marine Natural Area profiles for the South Western Peninsula (Jones *et al.* 2004a) and Western Approaches (Jones *et al*. 2004b), and mapped by the UKSeaMap marine landscape classification (Connor *et al.* 2006) and the MESH programme (MESH 2008). There has been extensive sampling of coastal and nearshore habitats in the English Channel and Bristol Channel. The MESH map of seabed habitats for Regional Sea 4 is shown in Figure A1a.2.4.

The pioneering studies of Le Danois in the first half of the 20th Century were described in the 1948 publication “Les Profondeurs de la Mer”, characterising the marine fauna occurring in the Celtic Sea and Bay of Biscay, from south-western Ireland to the Cantabrian Sea.

The benthic invertebrate fauna of the English Channel has been sampled intermittently from 1899. The longest continuous datasets are those collected by Holme from 1959-1985 (Holme 1966) that have more recently been assessed for quality of the data and potential for resurvey (Genner *et al.* 2001). Holme made a point of resurveying historic sites, e.g. Eddystone Grounds, which had been originally surveyed between 1895 and 1898 and again from 1931 to 1932. Three datasets were produced: 1) survey of seabed species, 2) brittlestar survey and 3) death assemblages. The seabed species dataset comprises a qualitative faunal record of echinoderms and molluscs from anchor dredge samples from 324 stations distributed throughout the English Channel. In addition Holme compiled reference lists from comparable historic MBA surveys as far back as 1895. The brittlestar survey used a mini-Agassiz, and provided a quantitative record of all echinoderms from 329 stations on the south coast of England. Death assemblages are a record of all dead-shell material retained in anchor dredges. Offshore areas of the English Channel were further investigated using towed video and still cameras by Holme & Wilson (1985). The area studied, about 37km south of the Dorset coast, was predominantly of hard substrata often with transitory sand cover.

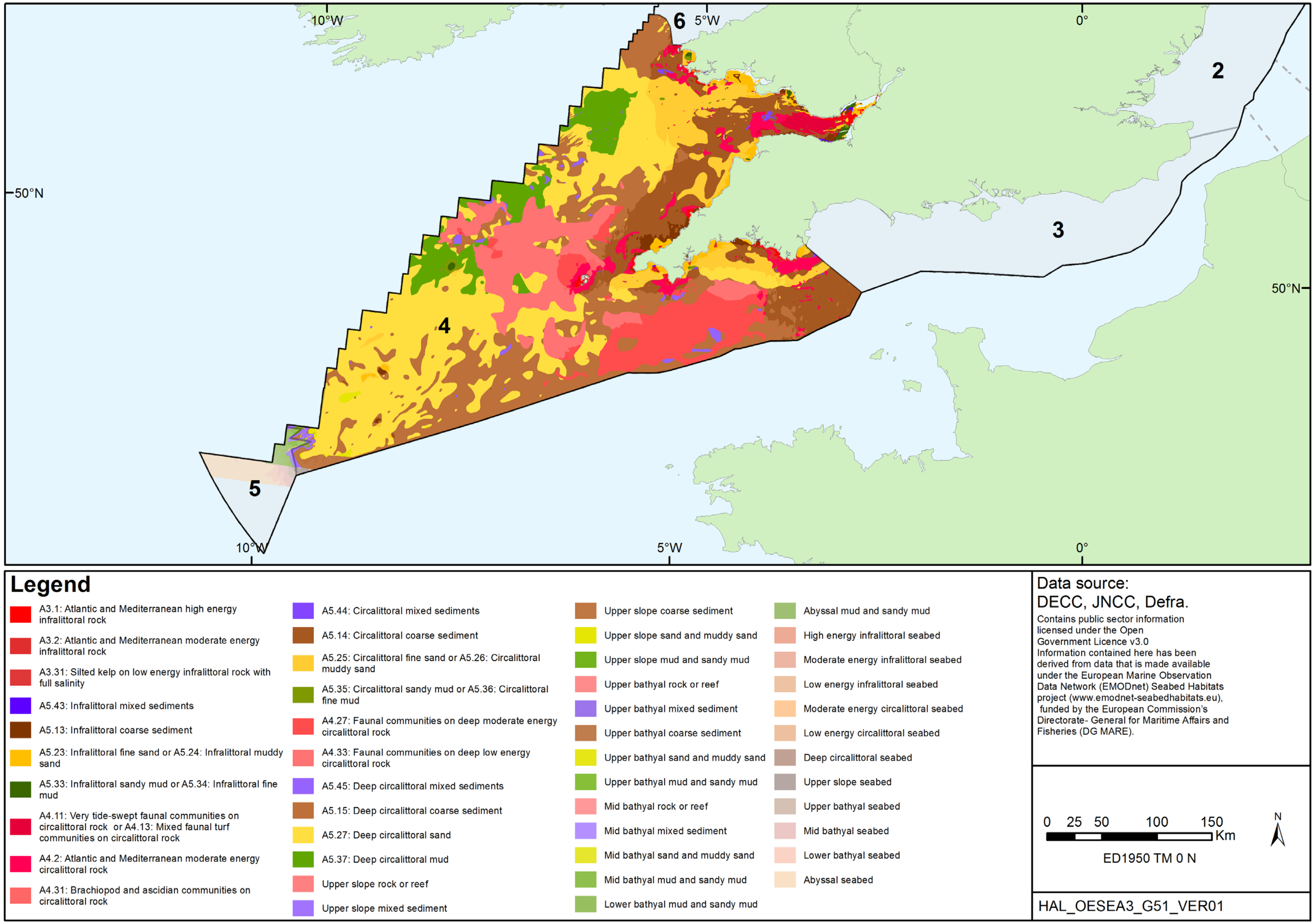
Regional mapping of sedimentary macrobenthic communities in the English Channel has also been described by Cabioch *et al*. (1977).

In the offshore Celtic Sea, other than epibenthic trawling undertaken by Cefas during groundfish surveys of the area, there have been no published quantitative studies of the benthic assemblages (Marine Institute 1999), although details of the molluscs from a regional benthic survey (Hartley & Dicks 1977) have been published (Hartley 1979) and there is work relating to benthic communities in the adjacent Irish Sea and St. Georges Channel (Mackie *et al*. 1995; Ellis *et al*. 2000) and more extensively to the Porcupine Bank and Goban Spur (Lampitt *et al.* 1986, Flach *et al*. 1998, Flach & Bruin 1999).

MAREMAP has also covered areas of seabed within Regional Sea 4 – Southwest Approaches to the English Channel.

Recent collaborative surveys by JNCC and Cefas in 2011, 2012 and 2015 acquired groundtruthing, video and still photographic images and some particle size data in the offshore waters between the north Cornish coast and the UK/Ireland boundary line.

Figure A1a.2.4: MESH classification of marine biotopes, Regional Sea 4



The diversity and richness of the region's offshore and nearshore benthos are reflected in the large number of sites (13 offshore and 22 nearshore) initially proposed for MCZ candidature by the Finding Sanctuary Regional MCZ project (Lieberknecht *et al.* 2011). Of these, two offshore and eight inshore sites became designated MCZs in 2013; and a further eight sites were designated in the 2016 2nd Tranche. All are cited where relevant in the subsequent habitats and species sections.

A1a.2.7.1 Offshore habitats and species

In the deep offshore waters of Regional Sea 4, the seabed is dominated in terms of spatial area by sediment habitats which are formed mainly of sand, or mixtures of sand and gravel. Gravel occurs in the east and south of the area, grading to more muddy habitats in the north, and tends to be less perturbed by natural disturbance than that found in shallower coastal waters.

Offshore relict tidal sand-banks occur across offshore areas as large bedforms, which may be up to 50km long, approximately parallel to the tidal direction (Heathershaw & Codd 1985). Although there are very sparse data, it is likely that these areas of sand are characterised by a fauna comprising polychaetes, molluscs, echinoderms and crustaceans, with the species present varying according to the sediment type.

The most extensive published survey of the benthic fauna of the Celtic Sea is that undertaken in 1974 and 1975 by the Field Studies Council Oil Pollution Research Unit (Hartley & Dicks 1977, Hartley 1979). The fauna at most sites was typical of a 'deep Venus community' as described by Mackie (1990). At the edge of the Celtic Deep, the communities were typical of a 'boreal deep mud association' and included the brittlestars *Amphiura chiajei* and *Amphiura filiformis*, the bivalves *Nucula sulcata, Nucula tenuis, Thyasira flexuosa* and *Abra nitida*, and polychaetes *Myriochele heeri, Lagis koreni* and *Amphicteis gunneri*.

For the northern Celtic Sea adjacent to the St. Georges Channel, McBreen *et al*. (2008) analysed data from Mackie *et al.* 1995 and Wilson *et al*. 2001 and some unpublished HABMAP results in a study of sediment characteristics as predictors of benthic biological communities. This indicated that biological assemblages were not only linked to particle size but also to the chemical properties of the sediments, and that the use of particle size as a proxy for biological assemblages in biological habitat mapping risked overlooking distinct and representative habitats.

During the period 2000-2006, approximately 150 tows with a 2m-beam trawl have been undertaken by Cefas in the Celtic Sea. Ellis *et al*. (2002) used multivariate community analyses to describe two distinct macro-epibenthic assemblages; one dominated by the anemone *Actinauge richardi* found along the edge of the Celtic Shelf and another characterised primarily by the hermit crab *Pagurus prideaux* and its commensal anemone *Adamsia palliata*, but with 3 sub categories and dominated by a wider range of species, found in the Celtic Sea.

Warwick *et al*. (1986) and Warwick & Joint (1987) investigated the size distribution of taxa (pelagic and benthic) at a site in the Celtic Sea (CS2, 50º30'N 07º00'W), in relation to community ecology and the evolutionary constraints on species body size.

Building on these earlier records, recent surveys under Defra's MB0120 programme have acquired acoustic and photographic data of a range of habitats comprising particularly interesting or representative species, in order to support the designation of offshore MCZs. Six offshore MCZ sites have now been designated and 6 are rMCZs. Ten of the offshore MCZ/rMCZs are grouped around four features: Haig Fras, SW Deeps, Jones Bank and the Celtic Deep.

Haig Fras is a reef of considerable size and is described below in Section A1a.2.7.2. To the east of Haig Fras and the Greater Haig Fras area, and lying approximately 67km north of Land's End, a third site – East of Haig Fras – was designated as an offshore MCZ in 2013 following dedicated habitat description survey work by JNCC/Cefas (Defra 2014a). This site lies in 50-100m water depth and comprises three main habitats: a mosaic of muddy gravelly sand with cobbles and pebble; mud; and exposures of moderate energy circalittoral rock. 'Subtidal sands and gravels' and 'mud habitats in deep water' are both habitat features of conservation interest (FOCI) present in the site.

SW Deeps: two sites of interest lie to the east and west of the SW Deeps which are in waters of 100-200m depth approaching the shelf edge in the South-west Approaches. The SW Deeps West MCZ site lies 230km from Land's End and extends along the shelf edge; it consists primarily of sand with small areas of both coarse and mixed sediments. To the east of the Deeps, the extensive SW Deeps East rMCZ site abuts the UK/France boundary; here coarse sediments are also present, but there are considerable patches of finer muds which support sea pens and can be described as a deep sea bed. At both sites there are very extensive Celtic Sea relict sandbanks.

Jones Bank: there are newly-researched sites to the east and west of the shallowing sedimentary Jones Bank feature west of Land's End at the UK/Ireland boundary. The NW of Jones Bank MCZ contains sea-pens, burrowing megafauna communities and subtidal mud. Subtidal mud is an important habitat for a number of species including worms, cockles, urchins and sea cucumbers. Burrowing fireworks anemones and brittlestars can also be found as well as luminous sea-pens which protrude from the surface of the mud. Designation of this site will also protect subtidal sediment habitats, which support a range of burrowing animals such as worms and shrimps, as well as scavenging animals that occupy the surface of the seabed such as crabs and fish. NW of Jones Bank has also been identified as an important nursery and spawning area for fish.

Celtic Deep: is a seabed depression close to the UK/Ireland continental shelf boundary reaching 200m water depth. Seabed sediments with the Deep are primarily fine muds which are rich in sea-pens and burrowing megafauna communities, but a range of sedimentary habitats (mixed sediments, coarse sediments, mud and rock outcrops) are found in surrounding waters. Four recommended MCZ sites have been described: Celtic Deep, South of Celtic Deep; North of Celtic Deep & East of Celtic Deep (Defra 2014c). A summer frontal system with its associated high planktonic productivity is associated with the general Celtic Deep area.

A1a.2.7.2 Offshore reefs

Haig Fras is a significant area of offshore rocky reef within Regional Sea 4. It is a distinct topographical feature located approximately 150km offshore in the Celtic Sea, south-west of Cornwall, consisting of a granite outcrop approximately 45x15km, rising from a surrounding seabed depth of 100-110m to within 38m of the surface. A remote camera survey (Rees 2000) demonstrated that the bedrock on the peak has three distinct deep-water reef biotopes associated with it, with a further, more complex and less well-defined biotope present where boulders and cobbles were partly embedded in sediment at the base of the shoal. The biotopes are:

- Biotope dominated by jewel anemones *Corynactis viridis*
- Biotope dominated by Devonshire cup corals *Caryophyllia smithii*
- Biotope characterised by cup sponges and erect branching sponges

- Complex biotope with red encrusting sponge, *Caryophyllia smithii* and featherstars (crinoids) on boulders with the bryozoan *Pentapora fascialis*, squat lobster *Munida* sp. and brittlestars (ophiuroids) also common

Haig Fras is now a designated SAC; its surrounding area, Greater Haig Fras, was investigated in 2012 and 2015and is now a MCZ.

A1a.2.7.3 Nearshore habitats and species

As described by Jones *et al.* (2004a), the nearshore benthic habitats of the South Western Peninsula Natural Area are varied, ranging from the fine muds of sheltered estuaries and rias, to exposures of granite bedrock, and to a lesser extent sandstone, limestone, shales and mudstone. In general, the nearshore seabed is composed of an assortment of mixed sediments (especially gravel and shells) with sand and, in sheltered locations, mud. There are also occasional and sometimes extensive exposures of bedrock and boulder reefs, often occurring off headlands. In deeper water, which may not be that far from the shore, the seabed is dominated by sediments, mainly of sand, sandy gravel and gravel. Nearshore rocky reefs extend along the north coast of Cornwall and Devon, particularly adjacent to hard cliffs and shores. The reefs around the Isles of Scilly and the island of Lundy are of particular importance.

In the western Channel off Start Point, where Regional Seas 3 and 4 meet, the seabed is composed of areas of mobile sand and gravel, interspersed with bedrock outcrops covered in a rich turf of animal species (Barne *et al*. 1996d). In general, the gravel habitats found in deeper offshore areas (>30m) tend to be less affected by natural disturbance than those found closer inshore and are therefore likely to support a more stable and diverse fauna; sea cucumbers (*Holothuria forskali*) and sea fans (*Eunicella verrucosa*) are common.

In estuarine locations e.g. the Upper Fowey and Pill Point MCZ sites, a wide range of estuarine habitats and associated species may include intertidal coarse sediment, intertidal mud, low energy intertidal rock, saltmarshes and saline reedbeds, estuarine rocky habitats and sheltered muddy gravels. The Fal Estuary supports what is probably the best developed maerl bed in UK waters outside of Scotland (Perrins *et al*. 1995; Anon 1999).

Sand habitats are widespread, particularly in the west of Lyme Bay, in the large embayment between Salcombe and the Lizard, in Mount's Bay, to the south-west of the Isles of Scilly, off Port Isaac Bay, in Bideford Bay and in the approaches to the outer Bristol Channel. The communities which these sand areas support are determined by a number of factors including the exact nature of the sediment, the relative exposure of the coast and differences in the depth, turbidity and salinity of the surrounding water. More mobile sand habitats tend to be characterised by robust fauna and sometimes impoverished faunas; venerid bivalves, amphipods (shrimps), polychaetes (worms) and heart urchins are particularly characteristic. Inshore areas of sand may support *Zostera* beds, e.g. Mounts Bay MCZ; within the Isles of Scilly MCZs and off Whitsand & Looe Bay MCZ. Two stalked jellyfish of conservation interest (*Haliclystus auricula* and *Lucernariopsis campanulata*) are found attached to seagrass at the latter site with a third species*, L. cruxmelitensis*, recorded in Mounts Bay.

Subtidal sediments consisting of muddy sand are either restricted to areas sheltered from the prevailing winds and currents (e.g. the western side of Lyme Bay), or to areas of seabed deeper than 50m where there is little or no wave action (such as in the approaches to the outer Bristol Channel).

A small area of fine sand and mud sediment off Whitsand Bay to the west of Plymouth Sound supports infaunal communities dominated by polychaetes but including burrowing sea cucumbers *Leptosynapta inhaerens* and *Trachythyone elongata* and the burrowing shrimp *Callianassa subterranea*. A number of the sediment-dwelling species that occur off the south coast of Devon and Cornwall have a distribution which is limited to south-western waters. Of particular note is the rich shell fauna, including southern species such as the bivalve *Callista chione*. Areas of clean sand off Plymouth Sound support an infaunal community featuring *Dosinia exoleta* and *Abra prismatica* (Hiscock & Moore 1986).

Subtidal rock in the western end of Lyme Bay consists largely of rocky reefs which fringe the coastline, particularly adjacent to hard cliffs and shores. Off Start Point, the Skerries Bank and Surrounds MCZ site has been designated for a range of sediment habitats surrounding the moderate and high energy rocky habitats of the Bank. Species of note here are the pink sea fan *Eunicella verrucosa* and the spiny lobster *Palinurus elephas*.

The south coasts of both Devon and Cornwall have a number of **inshore rocky outcrops** which comprise varied habitats. Many fall within the definition of Annex 1 reefs and are now part of SACs such as Plymouth Sound and Eddystone SAC (East Rutts, Hatt Rock, Hands Deep, Eddystone, Hilsea Point, Mewstone), Fal and Helford SAC, Lizard Point SAC, Lands End and Cape Bank SAC. The East Rutts rock outcrop rises from the seabed at 35m to 9m below the surface just west of Salcombe. It is unusual in being limestone rather than the more usual granite; piddocks are abundant and the rarer foliose bryozoan *Chartella papyracea* is present. A granite sub-surface outcrop occurs a little further west at the Eddystone Rocks, which is some 20km south of Plymouth Sound and is formed of flat-faced, angular vertical cliffs with overhangs, colonised by a turf of bryozoans, hydroids, anemones and extensive patches of jewel anemones *Corynactis viridis* on cliff faces and with plumose anemones dominating underwater headlands. *Eunicella verrucosa* is common throughout. A high proportion of southern species are present with similar communities being found off Hands Deep, a rock outcrop to the north west of Eddystone. The spiny lobster, *Palinurus elephas*, is a southern species which has decreased in abundance in recent years and is now a protected feature of some of the inshore MCZs e.g. the Manacles; Skerries Bank and Surrounds. The Manacles MCZ is a small group of rocks about 2km offshore between the Helford River and Lizard Point characterised by dense growths of sponges, hydroids and sea squirts.

In the Isles of Scilly, subtidal bedrock reefs fringe the coastline, particularly adjacent to rocky shores, though there are also reefs further offshore which emerge from sediment. Off the sheltered east coast of St Mary's, in depths of 25-35m, several south-west species of nature conservation importance are found, including the branching sponge *Axinella dissimilis*, the corals *Leptopsammia pruvoti* and *Hoplangia durotrix*, and the pink sea fan *Eunicella verrucosa*. Eighteen sub-types of subtidal rock habitat have been identified around the islands (Hiscock 1984), reflecting the wide range of environmental conditions present. The Isles of Scilly is a designated SAC with Annex 1 reef habitat as one of its qualifying features (Eggleton & Meadows 2013). The recent designation of 11 separate MCZs within and abutting the existing SAC gives added protection to a suite of intertidal habitats, high energy circalittoral rock and a number of vulnerable species: pink sea fan, spiny lobster and two species of stalked jellyfish.

Much of the coastline of south Devon and Cornwall is wave exposed, although further offshore in deeper water, the wave stress is lower and extremely rich animal communities are present, often with spectacular growths of dead man's fingers *Alcyonium digitatum, Eunicella verrucosa*, jewel anemones *Corynactis viridis* and Devonshire cup corals *Caryophyllia smithii*. Similarly, along the north Cornwall coast, rock may extend into the sublittoral zone adjacent to rocky shores; with communities in the infralittoral zone dominated by algae (most noticeably the brown algae *Dictyopteris membranacea* and *Dictyota dichotoma*) to depths in excess of 20m.

Extensive bedrock reefs are present off the west and north coasts of Cornwall e.g. Cape Bank rMCZ, with smaller outcrops occurring in Mount's Bay, south west Cornwall. These high energy infralittoral and circalittoral rocks habitats are designated features of a number of inshore MCZ sites e.g Padstow Bay and Surrounds on the north Cornish coast and Skerries Bank and Surrounds on the south Devon coast just off Start Point.

At Lundy, the granite or slate bedrock reefs range from west-facing bedrock reefs, which are very exposed to wave action, to more sheltered east-facing reefs. Each contains a diverse range of features, such as vertical surfaces, overhangs, gullies and upward-facing silted surfaces; there are also sheltered boulder slopes close to the east coast of the island. This diversity of habitats leads to a wide range of marine life, including many south-western species which have a limited occurrence elsewhere in the area (English Nature 1997c). All five British species of stony coral are found here: *Caryophyllia smithii, Balanophyllia regia, Caryophyllia inornata, Hoplangia durotrix* and *Leptopsammia pruvoti*. A more detailed description of benthic habitats and communities around Lundy is given in Barne *et al.* (1996a). Lundy's ecological importance is recognised in its SAC and MCZ designations.

Benthic descriptions of the seabed to the north and east of Lundy have been made by Channel Energy Ltd (2013) in support of the proposed Atlantic Array Offshore Wind Farm. Five biotopes were identified, ranging from tideswept mobile clean sands with a sparse infauna of opportunistic polychaetes and crustacea, to deeper circalittoral gravels, coarse sands, medium sands and shell gravels which all supported communities rich in polychaetes - *Mediomastus fragilis, Lumbrineris* sp., *Sabellaria spinulosa* and *Glycera* sp. – together with the urchin *Echinocyamus pusillus* and a number of Venerid bivalves – *Kurtiella bidentata, Spisula, Timoclea ovata* and *Tellina* spp. Within these extremes were well-sorted medium and fine sands with *Nephtys cirrosa, Bathyporeia* spp. and sandeels; cohesive sands and muddy sands dominated by *Amphiura filiformis* and *Kurtiella bidentata*; and lastly stable, compacted fine sands with *Tellina fabula, Abra alba, Kurtiella bidentata, Spiophanes bombyx, Chaetozone, Magelona* and *Bathyporeia tenuipes*.

The Severn Estuary and Bristol Channel are well studied; both intertidally and subtidally. The Severn Estuary contains a variety of intertidal habitats, which together with the very large tidal range makes it one of the largest and most important intertidal zones in Britain. Thirteen community types have been identified from areas of littoral sediment here (Severn Tidal Power Group 1989). Their distribution appears to be determined primarily by sediment type and the level of consolidation, with salinity being of lesser importance. Communities within sediments are characterised by polychaete worms (the most dominant species being ragworms *Nereis* spp. and *Neanthes* spp. and the lugworm *Arenicola marina*) and amphipod crustacea (*Corophium* spp. and *Bathyporeia* spp.); epifaunal communities are characterised by gastropod molluscs (in particular the spire shell *Hydrobia ulvae*). The abundant invertebrate biomass of these extensive intertidal sediment flats supports internationally important numbers of wading birds.

The sublittoral habitats and communities of the Bristol Channel and the Severn Estuary are also well studied and SEA 8 includes a comprehensive review (Pinnion *et al.* 2007). The deep sub-tidal channels in the Severn Estuary itself comprise an insignificant area of benthic habitat compared with the inter-tidal and are species poor because of frequent anoxia coupled with the extreme mobility of the substrata and scouring by mobile sediments (Warwick & Somerfield 2010). Grab and dredge sampling on a grid of 155 stations in 1972/3 provided information on the composition and distribution of communities within the system (Warwick & Davies 1977). These were divided into five main community types indicated in Table A1a.2.1.

Table A1a.2.1: Sublittoral communities of the Bristol Channel and Severn Estuary

Community	Habitat Description	Notes/associated species
Bivalve Venus community	Sands, especially in the outer Bristol Channel	A bivalve Tellina community on hard- packed sand, and a bivalve Spisula community on loose sands.
Bivalve Abra community	On silty or mixed bottoms in the outer Channel	The bivalve *Abra alba*, the polychaetes *Scalibregma inflatum* and *Lagis koreni*, and others
Horse mussel Modiolus Community	On hard substrate, mostly in the central Channel	The hermit crab *Pagurus bernhardus*, the scaleworm *Lepidonotus squamatus*, the brittlestar *Ophiothrix fragilis*, and others
Reduced species diversity hard substrate community	On rocky substrate subjected to strong tidal scour, mostly in the inner part of the Channel	The polychaetes *Typosyllis armillaris, Eulalia tripunctata, Sabellaria alveolata, Sabellaria spinulosa* and others
Reduced species diversity soft substrate community	In fluid muds of the inner Channel	The polychaetes *Tharyx marioni, Nephtys hombergii* and *Peloscolex* spp.

Source: after Warwick & Davies (1977)

Sampling by the Severn Tidal Power Group (1989) identified ten species associations within the Severn Estuary, being determined again largely by sediment type and exposure to tidal currents. Coarse sediments of consolidated gravel, pebbles and cobbles were dominated by the reef-building polychaetes *Sabellaria* (mainly *S. alveolata*, although some *S. spinulosa* was also recorded). These *Sabellaria* reefs may cover extensive areas of the sea bed, particularly where there are tide-swept hard substrata affected by turbid water – a feature rarely found in other UK estuaries. Indeed, the richest association of species within the estuary (up to 25 species per sample) was associated with these reefs. Areas of medium/fine sand in shallower water close to both north and south coasts were characterised by a mix of bivalves, amphipods and polychaetes.

A major integrated survey of the geology, sediments and fauna of the outer Bristol Channel was undertaken between 2003 and 2005 (Mackie *et al.* 2006). The seabed was mapped using multibeam and sidescan sonar and sub-bottom profiling, augmented with groundtruthing video and camera tows, beam trawl and grab sampling of sediments and fauna. The survey area could be divided into 4 main physical regions, Carmarthen Bay and its approaches, the outer Bristol Channel sands (divided into 2 sub-regions, the north with extensive fields of sandwaves up to 19m in height, and the south where there were few sandwaves over a gravelly sediment pavement), the Lundy platform and the Morte platform (off Ilfracombe), both with significant rock outcrops. Nearly 1,000 species were found in the surveys including a number of rarities (see for example Holmes *et al.* 2006). Faunal analysis revealed 5 main benthic assemblages which corresponded to 8 infaunal and 3 epifaunal biotopes:

- Infaunal
    - Infralittoral mobile clean sand with sparse fauna
    - Infralittoral sand with *Nephtys cirrosa* and *Bathyporeia* spp.
    - Infralittoral compacted fine muddy sand with *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods

    - Circalittoral muddy sand or slightly mixed sediment with *Abra alba* and *Nucula nitidosa*
    - Offshore circalittoral sand or muddy sand with *Owenia fusiformis* and *Amphiura filiformis*
    - Infralittoral mobile coarse sand with interstitial polychaete worms notably *Hesionura elongata* and *Microphthalmus similis*
    - Circalittoral coarse sand or gravel with *Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves
    - Offshore mixed sediment with a polychaete rich deep Venus community
- Epifaunal
    - Stable circalittoral mixed sediment with *Sabellaria spinulosa*
    - Tide-swept circalittoral mixed sediment with *Flustra foliacea* and *Hydrallmania falcata*
    - Tide-swept sublittoral sand with cobbles or pebbles and *Sertularia cupressina* and *Hydrallmania falcata*

There is comparatively little offshore information available for the Cornish coast but studies for the proposed WaveHub facility some 20km off St Ives provide detailed information from seabed mapping, sampling and photography for the offshore area and potential cable routes to shore (SWRDA 2006). Multivariate analysis of grab samples indicated 4 statistically significant clusters each with characterising species, as follows:

- Cluster A comprised inshore cable route stations characterised by taxa typically observed in shallow sublittoral sandy sediments, including three amphipod crustaceans, *Urothoe poseidonis, Bathyporeia guilliamsoniana* and *Bathyporeia tenuipes* and the polychaetes *Chaetozone setosa* and *Nephtys cirrosa*.
- Cluster B included stations on the cable route with very poorly sorted pebble sediments. Characteristic species included the crab *Pisidia longicornis*, encrusting serpulid polychaetes and the polychaete *Typosyllis* sp.
- Cluster C included WaveHub and other offshore stations with poorly sorted pebble sediments. Characteristic species were as for cluster B but were present at higher densities.
- Cluster D included WaveHub and other offshore stations with coarse to very coarse sand. The fauna was dominated by polychaetes *Glycera lapidum, Typosyllis* sp., *Eunice* sp., *Kefersteinia cirrata, Ehlersia cornuta, Protodorvillea kefersteini* and *Polygordius* sp.

Multivariate analysis of trawl samples showed 3 statistically significant clusters across the survey area as follows:

- Cluster A of trawl stations on fine sands within St Ives Bay characterised by a sparse epifauna with low numbers of fish including sand gobies *Pomatoschistus* spp. and sole *Solea solea*.
- Cluster B comprised trawls from the southern offshore area as well as the nearshore and offshore cable route and was characterised by *Pisidia longicornis* and the brittlestar *Ophiothrix fragilis*.

- Cluster C included trawls from the northern parts of the offshore area and was dominated by queen scallops *Aequipecten opercularis* and the hermit crab *Pagurus prideaux*.

There is little information on the north coast of the Bristol Channel; a number of SACs (Pembrokeshire Marine; Carmarthen Bay) are designated for their range of coastal and inshore habitats including many subtidal sandbanks and reefs. South-western species such as the scarlet and gold star coral *Balanophyllia regia* are often present.

A1a.2.8 Features of Regional Sea 5

Regional Sea 5 comprises deep water at the most westerly end of the South-western Approaches and is delineated from Regional Sea 4 due to the contrast of habitat found at this extreme depth. The region is bounded to the east by the shelf break and extends westwards in to the north-east Atlantic. The seabed is generally composed of fine material. The water is oceanic in origin, with negligible coastal influences, low turbidity and is stratified. While comparable to the other deep water Regional Seas, influences from the Mediterranean current are stronger in this region leading to Lusitanian species being present in the water column. The area is intersected by submarine canyons, characterised by the upwelling of nutrient-rich deep waters and with cold-water corals present.

Very little information from this offshore area was available until the MESH survey (Davies *et al*. 2008) which identified three canyons (Explorer, Dangaard and Whittard) and has been followed up by very recent work (research cruise JC125, August 2015) on the Whittard Canyon carried out as part of the CODEMAP[7] programme. The aims of cruise JC125 were threefold: to provide robust, integrated and fully 3D methodology (using sideways multibeam) to map complex deep sea habitats using combination of acoustic and visual; to revisit key habitats in the Whittard Canyon in order to establish potential changes over the last 6 years; and to measure the water column structure in the eastern branch of Whittard Canyon, to allow the inclusion of oceanographic parameters in the predictive habitat models. Since the Whittard Canyon is in close proximity to the newly designated (2014) The Canyons MCZ, the new information will be very relevant to further understanding of the MCZ habitats and ecology. Whittard Canyon lies slightly north-west of the Canyons MCZ in Irish territorial waters. Canyons at the Celtic Margin (approximately 320km south of Cork and south-west of Land's End) were examined as part of the MESH South West Approaches Canyons Survey (MESH Cruise 01-07-01) (Davies *et al.* 2008). It was predicted that these canyons may contain bedrock and biogenic reefs formed by cold water corals (two of the three sub-types for Annex I reef). As this area is more influenced by southerly 'warmer' water bodies, it may contain biological communities very different from those Annex I reefs occurring in the far north-west of the UK offshore area which are influenced by 'cold' Arctic waters. Deep sea biotope definition carried out by Howell *et al*. (2010a) analysed 873 images acquired from Dangaard and Explorer Canyons in conjunction with a further 1,114 images from other deep sea features in Regional Seas 8, 10 and 11 to describe epifaunal assemblages. Further biotope definition of these canyons and mini-mounds in the South-west Approaches is given by Davies *et al.* (2014) and Stewart *et al*. (2014).

[7] Complex Deep-sea Environments: Mapping habitat heterogeneity As Proxy for biodiversity (CODEMAP) searches for alternative methods to quantify deep-sea biodiversity. The aim is to develop a robust, integrated and fully 3D methodology to map complex deep-sea habitats, using a combination of acoustic and visual techniques. The CODEMAP project is supported by the European Research Council (ERC).

The Canyons MCZ lies at the shelf edge, which drops away steeply to the oceanic abyssal plain at 2,000m, giving rise to features such as deep-sea bed and cold-water coral reef. There are two large canyons within the site, which add to its topographic complexity: the Dangaard Canyon to the north and the Explorer Canyon below it. A patch of live deep-water coral reef (*Lophelia pertusa*) has been found on the northernmost wall of the Dangeard Canyon.

A1a.2.8.1 Offshore habitats & species

Submarine canyons are major incisions into the continental slope. They act as transport channels for moving sediment, organic carbon and other nutrients from the continental shelf to the deep ocean floor. Canyons are highly dynamic zones, swept by regular tidal currents and sporadic sediment flows that create a highly variable seafloor, often supporting vibrant and complex ecosystems.

The canyon interfluves, or canyon tops, at Dangeard and Explorer canyons were found to comprise numerous mounds (≤400) up to 10m in height and ~80m in diameter (Stewart *et al*. 2014). These mini-mound features were not identified within the shallow sub-surface imaged by the seismic data and it was concluded that they are modern features possibly forming through colonisation and subsequent growth on a relict sea bed rather than accumulation over time. Significant amounts of coral rubble were observed coincident with these mounds. It is likely that this area once hosted diverse carbonate mounds similar to those found on Porcupine Bank (Roberts *et al*. 2003, 2008) and the northern Rockall Trough (Masson *et al*. 2003, Roberts *et al.* 2003) and that they have since been destroyed by fishing which is known to have occurred in this area (Stewart *et al*. 2014).

Dangeard and Explorer canyons both exhibit a diverse array of substratum types supporting a range of large epifaunal species including sea cucumbers (Holothurians), squat lobster (*Munida rugosa*), numerous anemone and several starfish species, sea pens, shell debris and fish species. Multivariate analysis of biological data by Howell *et al.* (2010a, b) identified six clusters which were used to define new habitat types according to the EUNIS classification hierarchy. Ten new biotopes were defined from these six clusters, with video observation providing further faunal detail. A further three biotopes were identified from video observations alone, making a total of thirteen biotopes described from the canyons; of these, six were proposed as new EUNIS habitat types.

The thirteen biological communities or biotopes observed in and around the canyons (see below) were similar to those observed at comparable depths and temperatures on other deep-sea features in the UK's offshore area. However, the hard substrate communities observed at other offshore areas in the NW of Britain were, in general, more species-rich than those observed in the canyons of the South-west Approaches. It is possible that this may be a sampling error resulting from the poor-resolution images of bedrock and coral reef obtained in this survey and the limited observations of reef habitat obtained. However, video observations suggest sediment scour and smothering may prevent many species from colonising the available hard substrate. Importantly, one biotope observed in the SW canyons has not been observed during surveys of other deep-sea features. This biotope was found on muddy sand and characterised by the seapen *Kophobelemnon* sp. and ceriantid anemones. This biotope was similar to that of the shallow EUNIS habitat type Circalittoral fine mud, which is characterised by the seapens *Virgularia mirabilis* and *Pennatula phosphorea* together with the burrowing anemone *Cerianthus lloydii* and the ophiuroid *Amphiura* spp. This newly described biotope could be considered a deep-water version of this shallower habitat type.

- Biotope 1 Sand/mud with burrowing (*Amphiura* sp.) and surface dwelling ophiuroids

- Biotope 2 Mud with sea pens (*Kophobelemnon* sp.), seastars (*Pseudarchaster* sp.), anemones (*Bolocera* sp.) and holothurians (*Benthogone* sp.)
- Biotope 3 Bedrock ledges with annelids/hydroids and anemones
- Biotope 4 *Lophelia pertusa* reef, with predominantly sediment clogged *L. pertusa* and live *Madrepora oculata*
- Biotope 5 Coral rubble with squat lobsters (*Munida* sp.), ophiuroids and crinoids
- Biotope 6 Mixed sediments with squat lobsters (*Munida* sp.), ophiuroids and crinoids
- Biotope 7 Bedrock with a sand veneer, little visible fauna
- Biotope 8 Bedrock /boulders with little visible fauna
- Biotope 9 Bedrock with sand veneer, with anemones
- Biotope 10 Bedrock with barnacles (poss. *Bathylasma* sp.)
- Biotope 11 Mud/sand with signs of bioturbation and occasional cerianthid anemones
- Biotope 12 Mud with abundant cerianthids, and little other fauna
- Biotope 13 Bedrock with reef like fauna (corals/crinoids)

Recent surveys (2012, 2015) (JC36, JC125) have acquired a wealth of physical and photographic data of the seabed in the Whittard Canyon. A new deepwater biotope on a vertical wall, described by Johnson *et al.* (2013), comprised a good variety of species including solitary coral *Desmophyllum dianthus*, cerianthid anemones, crinoids, the gastropod *Margarites* sp., the portunid crab *Bathynectes longispina* were all common; other less common species of coral, urchin, crab and fish; but the community was dominated by high densities of the large bivalve *Acesta excavata* and the deep-sea oyster *Neopycnodonte zibrowii*.

Vertical and overhanging cliffs within the canyons have been mapped and shown to provide the perfect substratum for cold water coral communities (Huvenne *et al.* 2011).

Canyon processes include locally enhanced internal tides and focussed downslope organic carbon transport, which provide a food-rich habitat for filter feeding species.

Annex I biogenic reef (biotope 4), reef rubble (biotope 5) and bedrock reef (biotopes 3 and 13 and limited examples of biotope 6) were all observed within the canyons of the SW Approaches. Annex I stony reef was not observed. Cold water coral (*Lophelia pertusa*) reef was observed within and at the seaward entrance to the Explorer Canyon between depths of 743-925m. It was associated with areas of sediment covered and exposed bedrock on the canyon flanks. In addition, areas of reef rubble were observed in the vicinity of intact reef within the canyon but more commonly on the interfluves of Dangaard Canyon associated with mini-mound structures. It is likely that these mound structures support or once supported live *Lophelia* reef. Bedrock supporting reef-like fauna was observed in all canyons. Bedrock reef communities were observed at the heads, on the flank and on the canyon floor from 237-1,030m. The megabenthic fauna of the bedrock reef areas appear similar to bedrock reef areas on other UK offshore features at similar depths (Narayanaswamy *et al.* 2006; Howell *et al*. 2007) although a combined analysis of both datasets would be required to establish this conclusively. In addition, much of the encrusting fauna of bedrock reef habitat was difficult to identify below phylum level without physical samples. Thus faunal differences may exist that are undetectable at the resolution achievable with video and image sampling.

A1a.2.9 Features of Regional Sea 6

Regional Sea 6, the Irish Sea between St George's Channel and the North Channel, corresponds closely to the SEA 6 area and benthic habitats and species were reviewed as part of the SEA process in 2005. A variety of reports and survey work was commissioned to support SEA 6 including:

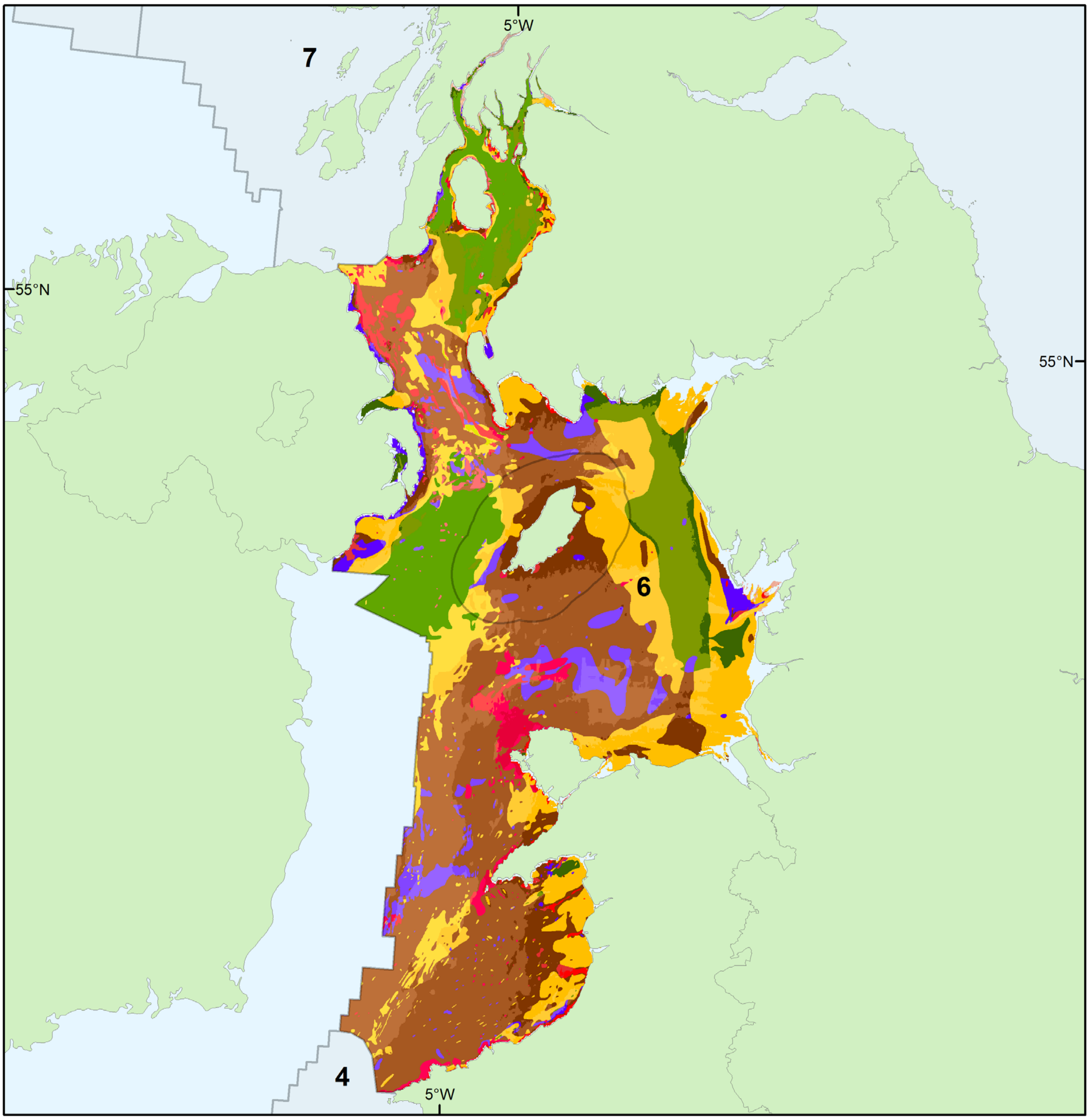
- A synthesis of current information on the benthic environment and the benthic communities and associations of the SEA 6 area (Wilding *et al*. 2005a).
- A synthesis of information on the benthos of SEA 6 Clyde Sea area (Wilding *et al*. 2005b).
- Survey report assessing the status of horse mussel beds in the Irish Sea off North West Anglesey (Rees 2005).
- Survey report detailing the distribution and extent of methane-derived authigenic carbonate within the SEA 6 area (Judd 2005).

Additional sources of information include:

- A variety of survey work commissioned by oil and gas operators, including broadscale seabed surveys and drilling surveys in the vicinity of the Isle of Man and St George's Channel and pre and post development surveys of oil and gas facilities in the Liverpool Bay area
- BIOMÔR reports 1 and 2, benthic biodiversity studies in the southern and south-west Irish Sea
- Output from the Irish Sea Study Group, in particular the Irish Sea environmental review
- Reports detailing rare species/communities including scientific papers detailing the file shell *Limaria hians* presence within the SEA 6 area and the atlas of marine Biodiversity Action Plan produced for the Countryside Council for Wales
- CCW intertidal habitat mapping studies.
- Survey reports commissioned by SNH to search for Features of Conservation Interest and to map habitats and species within potential and designated NCMPA sites.
- Habitat mapping by JNCC

The MESH map of seabed habitats for Regional Sea 6 is shown in Figure A1a.2.5.

Figure A1a.2.5: MESH classification of marine biotopes, Regional Sea 6



Legend

- A3.1: Atlantic and Mediterranean high energy infralittoral rock
- A3.2: Atlantic and Mediterranean moderate energy infralittoral rock
- A3.31: Silted kelp on low energy infralittoral rock with full salinity
- A5.43: Infralittoral mixed sediments
- A5.13: Infralittoral coarse sediment
- A5.23: Infralittoral fine sand or A5.24: Infralittoral muddy sand
- A5.33: Infralittoral sandy mud or A5.34: Infralittoral fine mud
- A4.11: Very tide-swept faunal communities on circalittoral rock or A4.13: Mixed faunal turf communities on circalittoral rock
- A4.2: Atlantic and Mediterranean moderate energy circalittoral rock
- A4.31: Brachiopod and ascidian communities on circalittoral rock
- A5.44: Circalittoral mixed sediments
- A5.14: Circalittoral coarse sediment
- A5.25: Circalittoral fine sand or A5.26: Circalittoral muddy sand
- A5.35: Circalittoral sandy mud or A5.36: Circalittoral fine mud
- A4.12: Sponge communities on deep circalittoral rock
- A4.27: Faunal communities on deep moderate energy circalittoral rock
- A4.33: Faunal communities on deep low energy circalittoral rock
- A5.45: Deep circalittoral mixed sediments
- A5.15: Deep circalittoral coarse sediment
- A5.27: Deep circalittoral sand
- A5.37: Deep circalittoral mud
- Upper slope rock or reef
- Upper slope mixed sediment
- Upper slope coarse sediment
- Upper slope sand and muddy sand
- High energy infralittoral seabed
- Moderate energy infralittoral seabed
- Low energy infralittoral seabed
- Moderate energy circalittoral seabed
- Low energy circalittoral seabed
- Deep circalittoral seabed

Data source:
DECC, JNCC, Defra.

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Information contained here has been derived from data that is made available under the European Marine Observation Data Network (EMODnet) Seabed Habitats project (www.emodnet-seabedhabitats.eu), funded by the European Commission's Directorate- General for Maritime Affairs and Fisheries (DG MARE).

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A1a.2.9.1 Offshore habitats and species

Available information on offshore benthic communities of the Irish Sea is well summarised in Mackie (1990) where source references are also provided. In addition, benthic biodiversity of the southern Irish Sea from Anglesey to the Celtic Deep was surveyed in 1989 and 1991 by Mackie *et al.* (1995) during the BIOMÔR 1 project. An abundant and diverse polychaete dominated fauna, comparable to that of other deep water communities, was found at depths below 80m, which included a number of new species and species previously unrecorded in UK waters. The BIOMÔR 2 project (Wilson *et al*. 2001) surveyed the south-west Irish Sea but also included areas to the north of Anglesey, part of Cardigan Bay, St. Bride's Bay and the Celtic Deep.

Offshore seabeds in the Irish Sea are predominantly sedimentary, many of glacial origin consisting mostly of sands and muddy sands (Figure A1a.2.6). Much of the benthos in the central and southern deeper parts is described as either 'deep Venus/hard' or 'deep Venus' by Mackie (1990). The deep Venus community is characterised by the urchin *Spatangus purpureus* and the bivalves *Glycymeris* sp., *Astarte sulcata* and *Venus* spp. in depths of 40-100m. In sand wave areas the communities also often contain elements of both shallow (*Spisula* sub-communities) and deep *Venus* communities. These two communities are the most dominant in the offshore benthic environment of Regional Sea 6. Other reports confirm the generalisations made by Mackie (1990). For example, to the east of Tremadog Bay, the seabed is varied but dominated by current swept coarse cobbles sustaining, in places, minimal epifauna (Rees 1993). However, in areas with micro-relief (formed by the presence of cobbles protruding into the current) the bivalve *Glycymeris glycymeris* was common. Accumulations of *Glycymeris* have also been recorded from the St. Georges Channel (Rees 2004). Descriptions by Dalkin (2008) in the vicinity of the UK/Irish median line at 53°N include a sand wave field in depths <90m transitioning northwards to coarse sandy sediments at 90m depth. Shell debris, mostly comprising dead *Modiolus modiolus* and tough shelled *Glycymeris,* was apparent in troughs between the sand waves.

On deeper ground, more stable mixed sediments with encrusting barnacles and serpulid worms became dominant and a more diverse fauna, with bryozoans and hydroids - *Flustra foliacea* and *Hydrallmania falcata* – was present on tide-swept circalittoral mixed sediment. Characterising species here also included a hydroid/bryozoan turf of *Nemertesia antennina*, *Sertularella* sp, *?Aglaophenia sp., Flustra foliacea, Bugula sp.,* and *Cellaria* sp. A range of anemones including *Urticina felina, Sagartia spp, Mesacmaea mitchellii* and *Aureliania heterocera* (=*Capnea sanguinea*) was present both on stable cobbles and burrowing in the coarse silty sediment. The most stable substratum supported the branching and encrusting sponges *?Raspalia hispida* and *?Esperiopsis fucorum* together with dead man's fingers *Alcyonium digitatum*. Dalkin described these offshore mixed sediments as being a polychaete-rich deep *Venus* community.

Areas of slightly silty sand supported no conspicuous epifauna.

Mixed sediments deeper than 98m were recorded in the deeper eastern section and also southern trough of Mackie's 'North Box'. The more stable cobble areas present sparse sponges, *Nemertesia* spp. and *Alcyonidium diaphanum*. All of the samples recorded could be considered as silty habitats, with fine sediment resuspended and deposited on each tidal cycle, as observed in the photographic record.

More rocky areas were grazed by *Echinus* sp. and supported pink shrimps, possibly *Pandalus* sp, *Cancer pagurus* and *Inachus* sp.

The southern Irish Sea is considered to represent a boundary between different biogeographical regions with several species reaching their distribution limits and is regarded as a significant source of benthic biodiversity (Mackie *et al.* 1995). During the BIOMÔR 1 project, Mackie *et al*. (1995) recorded four dominant assemblages, arranged in a continuum of overlapping mosaics. One of the assemblages refers to the deep soft muds of the Celtic Trough and is described in Section A1a.2.9. A second assemblage was primarily associated with inshore sands and muddy sands and showed similarity to the 'Amphiura' and 'shallow Venus' communities. The richest assemblage and that with the most extensive geographical coverage, was associated with gravelly sediments; it included conspicuous serpulids, other large polychaetes (*Polydora* spp.), an exclusive tubiculous ampharetid species and the amphipod *Guernea coalita*. A fourth less strongly defined assemblage appeared to be associated with shallow stony ground in Cardigan Bay and included polychaetes, gastropods, bivalves and crustaceans, none of which were exclusive to the assemblage.

Megafaunal burrowing communities are present in the deep muds of the northern Irish Sea (Swift 1993, Hughes & Atkinson 1997) and south in the Celtic Deep (Mackie *et al.* 1995); they produce considerable biogenic topography on the seabed and the fauna includes the seapens *Virgularia mirabilis* and *Pennatula phosphorea*, together with several burrowing crustaceans (*Calocaris macandreae, Callianassa subterranea* and *Goneplax rhomboides*). Several epibenthic species are also common and include *Amphiura* spp., *Asterias rubens, Pagurus bernhardus* and *Liocarcinus depurator*. The habitat is exemplified by the South Rigg MCZ site in the northern Irish Sea which consists of a rocky outcrop arising from deep burrowed mud where sea pens, *Echinocardium* and *Nephrops* are all common. *Arctica islandica* has also been recorded, most notably for juveniles thus evidencing the only known breeding population in the Irish Sea (Wildlife Trusts 2015).

Just beyond – and straddling – the inshore/offshore 12nm line to the north and west of Anglesey, four areas have been surveyed by JNCC in collaboration with the HABMAP project (Blyth-Skyrme *et al*. 2008) in order to confirm or negate BGS's earlier prediction of reefs (Graham *et al*. 2001). HABMAP's predicted seabed biotope maps for the southern Irish Sea (Robinson *et al.*, 2007) predicted these study areas to be dominated by tideswept mixed sediment with *Flustra foliacea* and *Hydrallmania falcata*; the video tows of Blythe-Skyrme *et al*. revealed boulder, rock and gravel habitats in moderate tidal streams, with typical encrusting faunas of bryozoan and hydroids, *Alcyonium digitatum* and *Pomatoceros*. The coarse sand and gravel lying between the boulder/cobble reefs supported a community similar to Mackie's (2005) 'Deep Venus' dominated by the polychaetes *Mediomastus fragilis, Lumbrineris* spp and venerid bivalves. *Mytilus edulis* was also present, however no records of *Modiolus* beds was taken.

In the western Irish Sea within the north-west mud basin and approximately midway between the Isle of Man and the coast of Northern Ireland there is an area of hard substrate, the Pisces Reef Complex cSAC/SCI. The area consists of an extensive mud plain through which three areas of Annex I bedrock and boulder-dominated stony reef protrude. The average seabed depth here is approximately 100m with a maximum of 150m and a minimum of 70m at the peaks of the rocky reef outcrops. The deepest depths are within the scour pits which encircle the outcropping rocky reefs. The reefs support a diverse animal community, including hydroids (e.g *Diphasia nigra*), a range of sponges, including the cup sponge *Axinella infundibuliformis,* echinoderms, for example the cushion star fish *Porania pulvillus* and various crustaceans, for example the edible crab *Cancer pagurus* and squat lobster *Munida rugosa.* Additionally, the reef may provide shelter for juvenile fish, including blue whiting, bib, red gurnard and wrasse. In particular, the mosaic of bedrock and stony reef provide a myriad of ledges and habitat niches. Of note is the occurrence of the *Diphasia alata* hydroid community which is considered rare.

This rocky outcrop was first identified within an area of soft muddy sediments during geophysical survey of the Irish Sea in 2004 as part of SEA 6 (Judd 2006). Additional video and still image data of the reef was collected in 2012 and 2014 by Cefas and JNCC respectively; both surveys are yet to report.

A large broadscale seabed survey carried out in 1997 by the University of Liverpool, on behalf of BP (Holt *et al.* 1997), in the region east of the Isle of Man identified the area as being relatively uniform, probably consisting of fine and medium sands with various amounts of stones and shell. Sidescan sonar and video survey identified widespread areas of fine scale sand waves or ripples. A total of 475 taxa were recorded during this survey (Holt *et al*. 1997). Video analysis indicated that the areas of fine/medium sands were colonised by *Spatangus purpureus*, *Asterias rubens, Pagurus bernhardus* and *Astropecten irregularis* whilst coarser areas of seabed were commonly inhabited by *Ophiothrix fragilis*. The sand waves/ripples identified consisted of much coarser sands, stones and gravel often with very large amounts of dead shell material including *Ensis, Modiolus* and *Glycymeris*. Living fauna varied from smaller numbers of *Modiolus* to dense feeding aggregations of *O. fragilis* on the tops of ridges. Areas of rich epifauna abundance were extremely rare and limited to small areas of coarse sand with stone, gravel or shell.

Muddy ground exists in only a few patches in the area, the largest of which occurs to the west of the Isle of Man and supports a substantial *Nephrops* fishery. Smaller pockets occur locally, for example to the south-west of the Lleyn Peninsula and off the Cumbrian coast. Deep water offshore bedrock outcrops are also uncommon, examples can be found west and north-west of Anglesey (Pisces Reef Complex) and off Strangford Lough (Barne *et al*. 1995d).

In recent years the Liverpool Bay area has been subject to both aggregate extraction and considerable oil and gas exploration and production activity; consequently there is a wide variety of data available on the benthic communities of the area (e.g. Holt & Shalla 2002, Westminster Gravels Ltd 2006). Seabed surveys carried out around five of the main production installations in Liverpool Bay in 2001 recorded nearly 400 different taxa. Sampling identified slightly differing benthic compositions at each site although annelids were recorded as being the most abundant group at each often comprising around half of the total taxa found (Holt & Shalla 2002).

Survey of offshore areas north-west of Lleyn Peninsula indicated that the seabed is varied but dominated by current swept coarse cobbles sustaining minimal epifauna. In areas with micro-relief (formed by the presence of cobbles protruding into the current) the long lived bivalve *Glycymeris glycymeris* was common (Rees 1993).

In offshore parts of Cardigan Bay, finer sediments dominate the substratum. The sedimentary environment off Aberystwyth, where some of the earliest grab sampling work in the UK was done (Laurie & Watkin 1922), consists of muddy sand and is locally referred to as the ‘Gutter’. The ground here supports an Amphiura type community (Rees 1993). The benthic biotopes of Cardigan Bay consist of fine sediments hosting Amphiura and shallow Venus communities while muddier areas contain spionid polychaetes, the tubicolous ampharetid *Melinna palmata, Amphiura filiformis* and the bivalve *Abra alba* (Mackie 1990). In addition, the large burrowing crustacea *Upogebia deltaura* and *Callianassa* sp. have been recorded. Further offshore the community resembles the deep Venus communities typical of a coarse gravel/shell substratum exemplified by the presence of tubeworms such as *Hydroides norvegica, Pomatoceros lamarckii* and *Sabellaria spinulosa* and the ascidian *Dendrodoa grossularia*.

Investigations in the St George’s Channel area by Mackie *et al.* (1995) identified that gravelly sediments sampled had the richest fauna and suggested that species richness increased from east to west toward the deeper offshore gravels of the channel. In addition, the number of taxa also increased in a northerly direction from the Celtic Deep towards the southern Irish Sea.

Mackie *et al.* (2005) suggest that the Irish Sea gravels (with an average of 145 species per $0.2m^2$) represent one of the richest shelf habitats currently known. However, it is worth noting that equivalent richness has been reported elsewhere in the UK e.g. from the North Sea (Hartley 1984) and Shetland (May & Pearson 1995) and in such cases the richness can be interpreted as a reflection of the habitat complexity introduced by the presence of large bivalve shells (Hartley 1984). Outwith the Irish Sea area, comparable gravelly sediments and faunal communities are described from the English Channel (Holme & Wilson 1985, Kaiser & Spence 2002) and Fair Isle Channel (Wilson 1986). Two candidate conservation zones have been identified in the southern Irish Sea: the Mid St George's Channel rMCZ and the North St George's Channel rMCZ. The Mid St George's Channel rMCZ is described as having a typical sand and gravel fauna of polychaete worms, bivalves and crustacea; with areas of cobble supporting a rich epifauna of anemones, hydroids and sponges. It lies within the location of a seasonal thermal front, the Celtic Front (see Section A1d: Water Environment) which gives rise to high productivity and rich filter feeding communities. The North St George's Channel rMCZ is in an area of relict glacial drumlins and carbonate slabs which are described in Section A1a.2.9.4.

Benthic epifauna, including demersal fish species, were surveyed using beam trawls in the Irish Sea, St Georges Channel and Bristol Channel by Ellis *et al.* (2000). They described six major assemblages; those in the inshore areas of the northern Irish Sea were generally ascribed to their "*Pleuronectes-Limanda* (plaice-dab) assemblage", where the hermit crab *Pagurus bernhardus*, the sand star *Astropecten irregularis* and flatfish species dab *Limanda limanda* and solenette *Buglossidium luteum* were important discriminators. Beyond the 20m contour in Liverpool Bay, they found a "*Microcheirus-Pagurus* assemblage" dominated by starfish *Asterias rubens*, sole *Solea solea* and dragonet *Callionymus lyra*, with the thickback sole *Microcheirus variegatus* and the hermit crab *Pagurus prideaux* as important discriminating species; a single site north east of Llandudno was dominated by dead man's fingers *Alcyonium digitatum*, *A. rubens* and *L. limanda*, with high catches of species typical of hard or stony ground such as the anemone *Metridium senile* (Alcyonium assemblage).

A1a.2.9.2 Nearshore habitats and species

Due to the bathymetry of the area, the inshore waters of the Irish Sea, including littoral areas, occupy a proportionately large spatial area within Regional Sea 6 in comparison to other regions of the UKCS. Many intertidal and inshore areas are of conservation interest and the large number of designated sites includes nine inshore marine SACs within the Welsh jurisdiction and two NCMPA sites within Scottish waters. A summary of the nearshore habitats and species is given below.

Nearshore habitats along the west coast of Wales from the Lleyn Peninsula in the north to Milford Haven in the south are characterised by a mixture of sandy gravel and gravel. Near shore sediments in the northern limits of the area comprise mainly sand and gravel. Further south in the Cardigan Bay area, sediments are primarily sandy in nature. Large glacial features known as sarns in the north of Cardigan Bay consist of long (>10km), narrow ridges of poorly sorted glacial outwash and moraine, frequently 6-8m in height and up to 500m across. Sarn environments are occasionally exposed during low spring tides and as a consequence the associated biota is somewhat ephemeral in nature. Most of the coastline is exposed or very exposed, the one exception being Milford Haven which is very sheltered, although with strong tidal currents in places. Nearshore sediments in the south-west Pembrokeshire area are generally of a coarse nature, composed of gravel and sand although the substratum around Skomer between St Annes Head and Strumble Head is rock as a result of extreme tidal scouring. The coast around Strumble Head and Skomer consists of a series of bays separated by headlands characterised by a relatively impoverished fauna determined by the degree of exposure. There are a large number of subtidal sandbanks around the Pembrokeshire islands.

The nearshore environment of the Lleyn to Strumble Head area is relatively current swept and consequently composed of bedrock with coarse sedimentary cover. Benthos is typical of the substratum, characterised by dense coverings of bryozoans, sea squirts, the hydroid *Nemertesia antennina*, the crinoid *Antedon bifida*, dead man's fingers *Alcyonium digitatum* and the sponge *Cliona celata* (Ellis & Rogers 2000). According to Ellis & Rogers (2000) the south-west entrance to the Menai Strait SAC contains the highest number of sea cucumbers (Holothuroidea) in the Irish Sea. Menai Straits and Conwy Bay, Anglesey, the Lleyn peninsula, Carmarthen Bay and a large section of the Pembrokeshire coast (Pembrokeshire Marine) all have SAC status. Reefs and sandbanks are features common to all; with intertidal mudflats and sandflats being qualifying features in all but Cardigan Bay. The Pembrokeshire Marine SAC has six geographically distinct areas of reef recognisable within the SAC (CCW 2005). In the shallowest areas the sublittoral reefs are dominated by *Laminaria* forest, with rich understories of red algae and a variety of animals and fish. Moore (2004) carried out a "tidal rapids survey" of Wales in many of these reef areas and described a variety of mostly animal dominated communities, with numerous sponges, hydrozoans, encrusting and foliose bryozoans, and tunicates (sea squirts). He also reported considerable cover of foliose red algae such as *Delesseria sanguinea* and *Erythroglossum laciniatum* on upward facing rocks even at depths of 15-20m. Sanderson (1995) noted that in comparison to most parts of the UK, nationally rare and/or scarce seabed species were very numerous in the general area of west Pembrokeshire; however the majority were from the well-studied areas of the Pembrokeshire Marine SAC in the immediate vicinity of Skomer or from within Milford Haven. Many are simply southern species close to their northern limit of distribution in the British Isles, for example the pink sea fan *Eunicella verrucosa*.

Strangford Lough, situated in County Down, is a shallow, glacially formed sea lough 24km long, 4-8km wide and linked to the Irish Sea via the 'narrows'. It is the UK's largest sea inlet and has a rich history of marine research which continues today. The lough is a complex tidal estuary and tidal flows through the narrows can reach 4.1 metres/second (Nunn 1994). Hydrographic and bathymetric conditions have created an exceptional variety of habitats, including tidal stream habitats and undisturbed muddy areas. It is an area of high biological diversity with more than 2,000 marine species identified[8], some typically Arctic, others of southern distribution. A former marine nature reserve, it is now a designated MCZ and SAC.

Sediments around the Isle of Man are predominantly sand and gravel mixed with various quantities of shell fragments (Bradshaw *et al*. 2003) or exposed bedrock.

The inshore designated NCMPA sites of Clyde Sill and South of Arran reflect habitat variety which was investigated and described by Allen (2013). A sediment gradation from coarse sand and gravel to fine sandy mud is found along the Clyde Sill as a result of the fast tide-swept waters of the North Channel meeting the sheltered and warmer waters of the Clyde. The species of the bivalve-polychaete infaunas change in relation to particle size. The sea mouse *Aphrodita aculeata* together with hermit crabs are common epifauna on the coarse sediments. Around Arran a mosaic of coarse shell gravels, maerl, burrowed mud and *Zostera* have been described; burrowed mud communities include *Nephrops*, sea pens, squat lobsters and *Arctica islandica*. On the east coast of Arran, mapping has revealed biotopes of fine sands with the bivalves *Abra alba* and *Nucula* sp.in the central and south Lamlash Bay; in the northern part of the Bay and the northern Channel, coarser mixed sediments support four biotopes including brittlestar beds and maerl and the bivalve *Kurtiella bidentata* (Axelsson *et al.* 2009, 2010).

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[8] www.doeni.gov.uk/niea/121submap

The coastal area from the Mull of Galloway and the Solway Firth to Morecambe Bay, the Ribble Estuary, Liverpool Bay, the Dee Estuary, Colwyn Bay and the northern entrance to the Menai Strait encompasses a range of habitats but is predominantly sedimentary in nature and includes some of the UK's most extensive sand/mud flats. The designated sites of Cumbria Coast, Flyde, Allonby Bay, West of Walney and other identified rMCZ sites such as Mud Hole – reflect the habitat variation.

Exposed and moderately exposed cliffs and intertidal rocky platforms with boulders, interspersed with extensive sandy beaches are found in the Cumbria Coast MCZ where Sabellaria reefs also occur. An extensive area of subtidal sediment habitats typical of the eastern side of Liverpool Bay is protected by the Flyde MCZ lying adjacent to the Shell Flat and Lune Deep SAC. Rich in bivalves, it is an important feeding ground for birds and nursery and spawning grounds for several commercially important fish species including sole (*Solea solea*), plaice (*Pleuronectes platessa*) and whiting (*Merlangius merlangus*).

The richness of various other areas of subtidal sediments are recognised by the Allonby Bay MCZ and West of Walney MCZ. Allonby Bay in the Solway Firth is an extensive area of shallow sublittoral sands extending from the coast out to 5.5km, but maintaining a maximum depth of only 6m. A range of exposure conditions of both rocky and sedimentary habitats are present and there are large areas of nationally important biogenic reefs of both *Sabellaria alveolata* and *Mytilus edulis*. West of Walney MCZ comprises subtidal sand with cockles, Echinocardium, *Holothuria forskali* and extends to deeper water (33m) where mud habitats support burrowing megafauna communities which include brittlestars, sea-pens and *Nephrops* (Swift 1993). Deeper water (35m) muddy habitats are also found in the Mud Hole rMCZ which lies 21km off the west coast of Cumbria close to Isle of Man waters. It supports *Nephrops*, the crab *Goneplax*, shrimp (*Callianassa subterranea*), sea pens, hydroids, sea urchins and a variety of molluscs and polychaetes (Lumb 2011).

In general, polychaete and cockle communities dominate much of the central intertidal area of Morecambe Bay and form the basis of an extensive fishery. Numerous recent surveys in connection with proposed and actual offshore wind farm developments, notably off the north Wales and Wirral coasts (e.g. COWL 2002, Seascape Energy 2002, NPower Renewables 2005, Dong 2013a & b), but also extending to the Solway Firth (E.ON 2013), have added further detail. Since some of these surveys extend out almost to the area of the Liverpool Bay oil and gas related surveys, the Liverpool Bay area is arguably now one of the most intensively surveyed sediment areas in UK waters. These later surveys have broadly confirmed previous understanding of the habitats and communities, these being largely sands containing variants of the "shallow Venus" community, interspersed with sparser polychaete and amphipod communities, often with dense heart urchins *Echinocardium cordatum*, in more mobile sandy areas, and with richer pockets of gravelly or muddy sediments (e.g. Mackie 1990). For example, the coarse to sandy gravels off the Dee Estuary (Dong 2013a) were dominated by the polychaete worms *Spiophanes bombyx, Spio armata, Polycirrus* spp. and *Ophelia borealis*, with venerid and tellin bivalves occurring in deeper water. The finer sandy infralittoral areas here were more impoverished and dominated by the polychaete *Nephtys cirrosa* and amphipods *Bathyporeia* spp. Deeper circalittoral fine sediments were often dominated by either the bivalve *Kurtiella bidentata*, the polychaete *Lagis koreni*, or the brittlestar *Amphiura filiformis*. *Abra alba* and *Nucula nitidosa* were abundant in circalittoral muddy sand or slightly mixed sediments. One of the most recent surveys carried out in 2011/12 for the Walney III extension wind farm (Dong 13b) recorded 260 taxa from 72 grab samples and found all species and communities to be typical of the eastern Irish Sea. Grouped by taxa, the polychaetes were dominant; whereas grouped by individuals the molluscs were most abundant, followed by polychaetes and phoronid worms. The five most abundant species were *Phoronis* spp*, Amphiura filiformis, Nucula nitidosa, Kurtiella bidentata* and *Thyasira flexuosa.* Seabed sediments in the project area comprised three distinct zones, moving from finer muds in the east, through medium/fine sand with shell fragments in the majority of the site and with coarser gravelly sand in the west of the site. From a conservation standpoint, no Annex 1 habitats were recorded and a single juvenile *Arctica islandica* was identified.

Loose, well-sorted medium sands off the north Wales coast are the preferred habitat for the thumbnail crab *Thia scutellata*. This species has a limited distribution in Wales and the U.K. (Rees 2001), possibly because the precise conditions it prefers are limited even within fields of sand waves. CCW considers it to be a "species of concern" (Moore 2002). Rees (2001) considered the main UK populations to be 6-12 miles offshore from the north Wales coast, but recent surveys have identified important populations closer inshore, especially off Rhyl and Prestatyn (e.g. NPower Renewables 2002, Cowl 2002) and off the Dee Estuary (Dong 2013).

A1a.2.9.3 Biogenic habitats

A number of biogenic habitats were identified by SEA 6 as being of potential conservation significance.

Modiolus communities have been identified in a variety of locations in Regional Sea 6. Pre and post drilling surveys in block IOM 112/29, north-east of the Isle of Man, identified a community based around *Modiolus* which appeared to have formed an extensive network of reefs raised up to around 0.5 or 1m above the surrounding seabed, occupying an area of approximately 6km^2 (Holt & Shalla 1997). A dedicated survey to assess the status of *Modiolus* beds in the Irish Sea off north-west Anglesey was also commissioned for the SEA6 assessment. This survey identified *Modiolus* in four localities within the survey area, Blocks 109/12, 13, 16 and 22, in sufficient quantities to be considered as beds (Rees 2005). *Modiolus* probably occurred in other areas however due to the patchiness of communities they could have been easily missed on side-scan. The survey identified that *Modiolus* from very tide swept hard ground were noticeably smaller than those identified in areas subject to less current stress. This variance in growth may to be due to possible sand/grit scour in more extreme environments. Similar variation in size is commonly seen in the mussel *Mytilus edulis* growing intertidally, with very small individuals associated with very wave exposed rock faces and larger ones on sheltered shores. Previously extensive *Modiolus* communities off the south-east Isle of Man (Jones 1951) are now much reduced in extent, possibly due to the effects of scallop dredging (Holt *et al*. 1998). *Modiolus* reefs are also present in Strangford Lough.

Another reef forming species of conservation significance identified in the SEA 6 area is the file shell *Limaria hians*. Although recorded distribution of *L. hians* is patchy it is known to occur on the west coast of the British Isles, in particular Scotland where isolated areas with *L. hians* have been found in the Clyde Sea and Mull of Kintyre area. At present there is insufficient data to describe the current status of *L. hians*, but it is likely that its numbers and distribution have declined dramatically over recent decades (Hall-Spencer & Moore 2000). Available data suggest that these bivalves have now disappeared from previous strongholds in the Clyde such as Skelmorlie Bank, Stravanan Bay and the Tan Buoy where only their dead shells remain. Scallop dredging is the likely cause of their decline. *L. hians* was recorded in the Liverpool Bay area during a 2001 survey where two individuals were identified in a post drilling survey at sample stations around the Douglas platform. The numbers found in this survey were however very low and not indicative of an important population (Holt & Shalla 2002).

Aggregations of the tube-building worm *Sabellaria spinulosa* may form dense subtidal reefs which can stabilise cobble, pebble and gravel habitats, providing a biogenic habitat that allows many other associated species to become established. Although there are numerous records of this species off the coast of Wales and the Isle of Man[9], evidence of reefs is less common. A thick clump of *S. spinulosa* tubes was collected by E.I.S. Rees west of Anglesey in the 1960s and seabed video footage taken by CCW in 2011/2012 (now held by Natural Resources Wales) from an area north of Lleyn Peninsula also showed some large clumps of tubes that appeared to *S. spinulosa*. More recently, the SEA 6 survey of the north-west Anglesey coast to assess *Modiolus* distribution (Rees 2005) also identified areas of *S. spinulosa* within Blocks 109/17, 18, 19 and 22. Reportedly there were previously dense areas of *S. spinulosa* at the entrance to Morecambe Bay, loss of which was attributed to the activities of prawn fishing in the approach channels to the Bay (Mistakidis 1956, Taylor & Parker 1993) although based on southern North Sea experience, natural change may be a significant factor in apparent appearance/disappearance of aggregations of the species (Gibb *et a*l. 2014).

The related species *Sabellaria alveolata* forms extensive intertidal reefs in many parts of the region, particularly in much of Cardigan Bay, the Cumbrian coast (notably Allonby Bay) and parts of the Scottish Solway coast (Holt *et al.* 1998). Elsewhere in the UK extensive reefs are found in Regional Seas 3 and 4. These reefs can sometimes have a stabilising function on unconsolidated sediments, thus adding considerably to the biodiversity of the shore. Off some parts of the Cumbrian coast they can extend for considerable distances in the shallow subtidal down to several metres below LAT.

Intertidal mussels, *Mytilus edulis*, can also form reefs in low energy environments as recorded in Allonby Bay.

A1a.2.9.4 MDAC Reefs

One further community of conservation significance within the Irish Sea is that associated with methane-derived authigenic carbonates (MDAC). These MDAC ‘reefs’, as they are known, are formed as a consequence of the anaerobic oxidation of methane by consortia of microbes. Prior to SEA6, there were no previously published reports of MDAC in the area. However, carbon isotope data have confirmed that the cemented hard grounds of two areas studied for SEA6, Texel 11 and Holden’s Reef, are composed of MDAC (Judd 2005). They are colonised by a variety of benthic fauna in marked contrast to the surrounding seabed sediments. The abundant fauna of the Texel 11 ‘reefs’ includes bryozoans, hydroids, sponges, anemones, starfish, urchins, lobster, and squat lobster (*Munida* sp.). By contrast in some places close to Holden’s Reef, sediments were discoloured by the presence of sulphides (black) and associated bacterial mats (white), assumed to be the sulphide-oxidiser *Beggiatoa*. Apart from the benthic macrofauna attracted to the hard substrate (the MDAC), it is likely that there are benthic micro-, meio-, and macro-faunal communities associated with the anaerobic methane oxidation which has resulted in MDAC formation.

At the northern entrance to St George’s Channel approximately 30km west of Anglesey, a site identified as The Croker Carbonate Slabs SCI comprises a total area of over 800ha of the Annex I feature “submarine structures made by leaking gases”. The site lies in 70m water depth in the north descending down to approximately 100m at the south-west corner. As described above, the seabed habitats created by these MDAC structures are distinctive, supporting a diverse range of marine species that are absent from the surrounding seabed characterised by coarse sediment. Areas of ‘high relief’ MDAC support a diverse range of soft corals, erect filter feeders, sponges, tube worms (*Sabella* and *Sabellaria*) and anemones (*Sagartia troglodytes*) whilst the ‘low relief’ MDAC is colonised with scour-resistant, lower-lying

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[9] https://data.nbn.org.uk

hydroids and bryozoans. These two contrasting categories are potential new biotopes (Whomersley *et al*. 2010). Species not previously associated with habitats in the Irish Sea such as the Ross coral *Pentapora fascialis* and the hydroid *Lytocarpia myriophyllum* have also been recorded (JNCC 2012). *Sabellaria spinulosa* was very abundant, often covering the exposed MDAC surface entirely. The surrounding sediment is highly mobile and consists of poorly sorted sand (from fine to coarse grained) with a large proportion of broken shell gravel and whole shells interspersed with rippled sand. Blue-grey clay was also commonly seen towards the southern end of the site. Data collected by Cefas and BGS in 2008 (Milodowski *et al*. 2009) and during a Cefas/JNCC survey in 2008 are summarised in Whomersley *et al*. (2010). Twenty two video tows were collected from which 79 species and six biotope complexes were identified; the area of MDAC was assessed from acoustic results to cover an area up to 40km^2. A larger area incorporating the Croker Carbonate slabs SCI and named as North St George's Channel rMCZ has been proposed, but not yet put forward as a candidate MCZ. As well as the carbonate slabs, the rMCZ site contains glacial drumlins and a mixture of sediment habitats – mixed sediments, sands and gravels – and its rich biodiversity includes a current count of more than 500 species.

The Pisces Reef complex SAC falls within another recommended MCZ, Slieve na Griddle, which lies between Northern Ireland and the Isle of Man. Pisces is a series of reefs made up of protruding rocky mounds rising to 15-35m from the seafloor. The habitat creates a complex solid surface that protects many species from physical abrasion and predation; these include brachiopods, tunicates, bryozoan, hydroids and fish. Between the rocky mounds lies a plateau of mud and sediment, a sheltered area for Dublin Bay prawns, brittlestars and other species to settle in the relative protection of the outcrops. This combination of the muddy areas of the MCZ and the rocky mounds of the SAC makes the area unique and of very high biodiversity.

A1a.2.10 Features of Regional Sea 7

The benthic communities present in the coastal region of Regional Sea 7 are complex and varied and are described by Hiscock (1998), and summarised in SEA 7[10]. The benthic environment of this area was also reviewed by SAMS in support of the Scottish Marine Renewables SEA (Wilding *et al*. 2005c). The complex coastline of the mainland and islands supports a wide range of habitats from those characteristic of extremely exposed conditions to extremely sheltered conditions. There is considerable local variation with for example the Loch Duich, Alsh and Long complex holding deep mud and rock communities in extreme shelter from wave action and tidal streams but with narrows areas having typical tidal stream-swept communities. In many of the sheltered locations on the west coast, deep water extends close inshore and many deep-water species occur in rocky habitats near to the coast. Distinctive communities are also present in areas of very strong tidal streams such as the Gulf of Corryvreckan, the Sound of Mull and the Sound of Jura (Hiscock 1998).

Inshore waters have been extensively surveyed through the Marine Nature Conservation Review (e.g. the sealoch survey programme led by CM Howson, 1988-92), preceding NCC work, and subsequent work by SNH to support SAC designations and other conservation initiatives. In 2014 eight coastal sites were designated as NCMPAs: Wester Ross, Lochs Duich, Long and Alsh, Small Isles, Loch Sunart, Loch Creran, Loch Sunart to the Sound of Jura, Loch Sween, Upper Loch Fyne and Loch Goil. Three additional NCMPA site designations were also submitted to the UK government in 2014 (SNH 2014); these all lie within the Minches – the Sea of Hebrides, North East Lewis and Shiant East Bank - and are noted further below.

[10] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/194382/SEA_7_Appendix_3_-_Environmental_Baseline.pdf

The Minch seabed has been surveyed mainly as a part of fisheries investigations and a programme of studies using acoustic survey and ground-truthing by video and grab sampling was initiated by the SOAEFD Marine Laboratory in 1995. Acoustic mapping to determine the presence of cold water corals provided further details of seabed biotopes in the Minch and Sea of the Hebrides (Roberts *at al*. 2005). The survey concentrated on an area to the east of the island of Mingulay where prominent mounds (up to 5m high and 15m in diameter) were found along seabed ridges (water depths varying between 72-215m). Seabed video showed the mounds to be characterised by extensive areas of live *Lophelia pertusa* coral interspersed with dead reef framework and coral rubble.

The MESH map of seabed habitats for Regional Sea 7 is shown in Figure A1a.2.7.

MAREMAP has also covered areas of seabed within Regional Sea 7 – the Western Approach to the Small Isles; and Canna to the Point of Sleat.

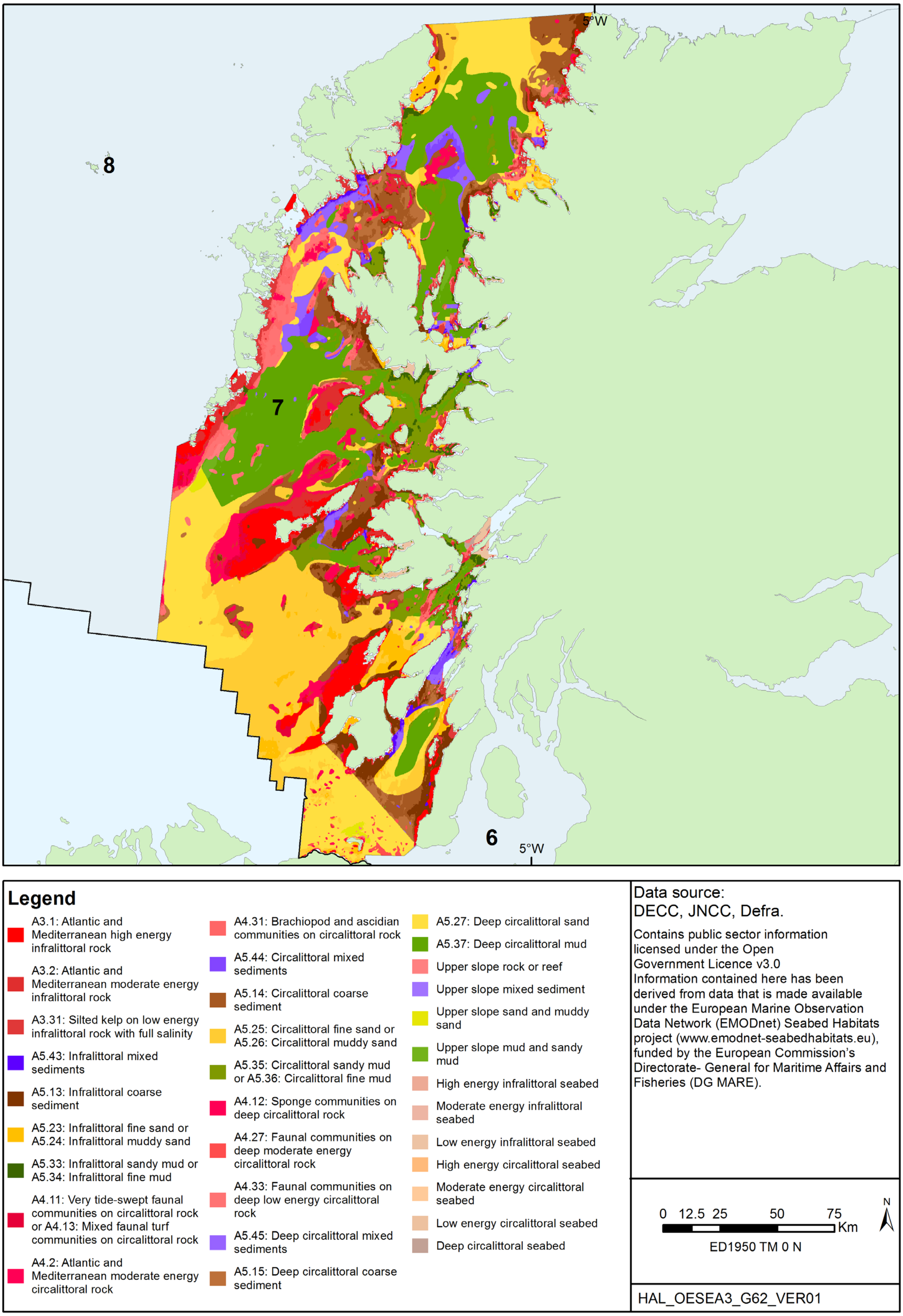
A1a.2.10.1 Habitats and species

In the Minch, four broad groupings (or biotopes) have been identified and related to sediment types (Pinn 1998). Gravel substratum, characterised by Community A, was dominated by the featherstar *Leptometra celtica*. Also present, but in lower numbers, were the cloaked hermit crab *Pagurus prideaux* with its commensal anemone *Adamsia palliata*, the cushion star *Porania pulvillus* and the squat lobster *Munida rugosa*. Soft mud, characterised by Community B, was dominated by burrowing decapods such as the mud shrimp *Calocaris macandreae* and *Nephrops norvegicus*, with the seapen *Virgularia mirabilis*, the echiuran *Maxmuelleria lankesteri* and the polychaete *Sabella pavonina* also commonly observed. Mixed sediments supported a variable fauna, Community C, of which the hydroid cnidarian *Abietinaria abietina* was the most commonly observed; other common epifauna were *Pagurus prideaux*, *Adamsia palliata*, the encrusting sponge *Myxilla incrustans, Echinus esculentus* and *Munida rugosa*. Boulders and bedrock, characterised by Community D, were dominated by the echinoderms *Ophiothrix fragilis, Ophiocomina nigra, Asterias rubens* and *Echinus esculentus*.

In the area of the Mingulay mounds, Roberts *et al*. (2005) found a substrate of dead reef framework and coral rubble, where suspension-feeding megafauna were abundant, in particular the stalkless crinoids *A. bifida* and *Leptometra celtica*, various erect sponges (*Axinella* sp., *Phakellia* sp.); many rocks also had a dense cover of zoanthids (*Parazoanthus anguicomus*). The large cerianthid anemone *Pachycerianthus multiplicatus* was often seen in sediment-filled areas in the rubble surrounding the reef mounds. In deeper areas, heavily bioturbated muddy sediments were found with *Nephrops* present as well as the smaller mud-burrowing shrimp *C. macandreae* (Roberts *et al*. 2005). At other areas mapped as part of this study, west of Skye and the Sound of Rum, crinoids were abundant on hard substrata, and areas dominated by sponges and zoanthids were also seen.

As noted above, MNCR coverage of coastal habitats in Regional Sea 7 is extensive, with a correspondingly large number and variety of biotopes recorded. Spatial complexity of habitat distribution is high, in response to wide variations in depth, salinity, seabed topography and composition, wave exposure and tidal current regime. Specific areas noted by Wilding *et al*. (2005c) in the context of wave and tidal power generation, included the Sounds of Harris and Barra in the Western Isles; Kyle Rhea between the mainland and Skye; Sound of Mull; Falls of Lora in Loch Etive; Firth of Lorne and surrounding area (including Corryvreckan); Sound of Islay and the area west of Islay. This selection emphasises the distribution of habitats and communities associated with high tidal stream velocities.

Figure A1a.2.7: MESH classification of marine biotopes, Regional Sea 7



The MNCR sealoch survey programme, *reported as a series of Nature Conservancy Council CSD studies and summarised by Howson et al.* (1994), surveyed a wider range of habitats from fjordic and fjardic systems, including soft muds typical of sealoch basins and deeper parts of the Minch and Hebridean Sea. However, as elsewhere around the UK, rock habitats (especially in the form of spectacular vertical wall formations – see Figure A1a.2.8) have attracted disproportionate survey effort by SCUBA (and recently ROV survey), and a correspondingly detailed distinction of biotopes.

In addition, as noted by Wilding *et al.* (2005c), a majority of the species data reported in MNCR documents are based on visual surveys. Visual surveys are subject to bias, particularly in those surveys conducted underwater using divers, which, in addition, are expensive to conduct and logistically difficult. The logistical problems are exacerbated in areas that are remote particularly where exposed to waves and/or tidally driven currents. In particular, mobile, coarse and sandy sediments may offer little to the observer in terms of recordable megafauna. This makes them ‘unattractive’ and, consequently, they are often undersampled.

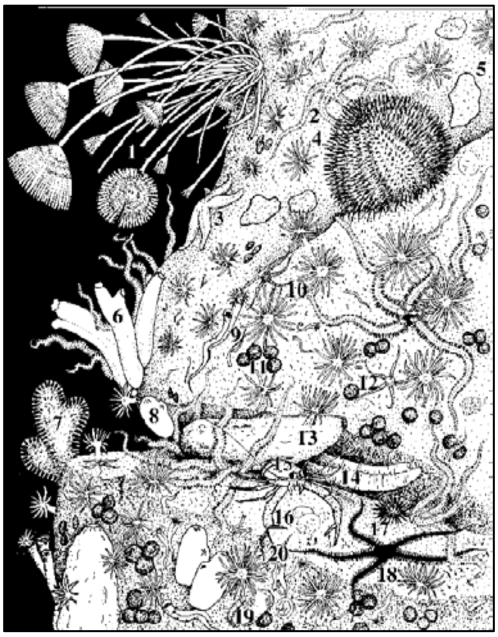


Figure A1a.2.8: Rock wall circalittoral community typical of fjordic sea lochs

The illustration is based on locations in Loch Duich. Species illustrated include: 1. Sabella pavonina, 2. Ophiothrix fragilis, 3. Asterias rubens, 4. Echinus esculentus, 5. Parasmittina trispinosa, 6. Ciona intestinalis, 7. Alcyonium digitatum, 8. Serpula vermicularis, 10. Protanthea simplex, 11. Neocrania anomala, 12. Ophiura albida, 13. Ascidia mentula, 14. Chaetopterus variopedatus, 15. Munida rugosa, 16. Terebratulina retusa, 17. Psammechinus miliaris, 18. Ophiocomina nigra, 19. Corella parallelograma, 20. Pomatoceros triqueter. From Howson, Connor & Holt (1994). (Drawing by Sue Scott.)

Monitoring studies, for example the historic work in relation to the Loch Eil pulp mill discharge (a series of papers by Pearson, most recently Feder & Pearson 1988), or more recent work in connection with the effects of organic enrichment and of medicine residues from aquaculture sites, have provided quantitative (and in many cases more statistically robust) descriptions of macrobenthic community structures in soft sediment habitats, which are considerable more spatially extensive than hard substrates within this Regional Sea. As a representative example, Pearson (1970, 1971) divided the sediment communities of Loch Eil/upper Loch Linnhe into six main community types influenced by substratum, depth and current-speed:

- a deep mud fauna characterised by *Amphiura chiajei, Myrtea spinifera* and *Terebellides stroemi*
- an inner loch transition fauna with *Eupolymnia nebulosa*
- a sandy mud fauna with *Turritella communis* and *Corbula gibba*
- a sand fauna containing *Venus striatula* (now *Chamelea gallina*), *Echinocardium cordatum* and *Cucumaria* (now *Trachythyone*) *elongata*
- a medium depth transition fauna with *Lucinoma borealis*

- a hard ground fauna with *Ophiopholis aculeata, Ophiothrix fragilis, Psammechinus miliaris, Astarte elliptica* and *Eunice pennata*.

The bivalve mollusc *Thyasira gouldi* was believed to be endangered and restricted in distribution to a few west of Scotland sea-lochs and so a UK Biodiversity Action Plan was developed for the species. However, a study into the identity of all the species of *Thyasira* found on the UK shelf (Oliver & Killeen 2002) has shown that the species is more common and widespread that previously thought and thus the species no longer appears on the UK List of Priority Species and Habitats.

A1a.2.10.2 Biogenic habitats

As noted above, the reef-forming coral *Lophelia pertusa* has been recorded from sites with Regional Sea 7, notably at the Mingulay mounds site in the Sea of the Hebrides.

Modiolus communities have been also identified in a variety of locations in Regional Sea 7, including areas designated as SACs (e.g. Loch Creran SAC, Lochs Alsh, Long and Duich SAC).

Loch Creran, situated at the northern end of the Firth of Lorn, is particularly notable for biogenic reefs of the calcareous tube-worm *Serpula vermicularis*, which occur in shallow water around the periphery of the loch (Figure A1a.2.9). This species apparently has a world-wide distribution but the development of reefs is extremely rare; reefs previously found in Loch Sween are now known to be dead (JNCC), leaving Loch Creran as the only known site in the UK to contain living *S. vermicularis* reefs; there are no known occurrences of similarly abundant reefs in Europe.

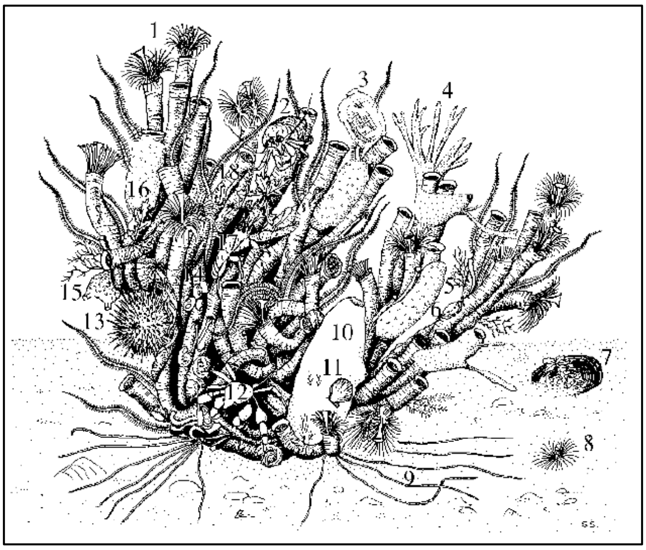


Figure A1a.2.9: A small reef of the calcareous tube-worm *Serpula vermicularis* with associated fauna

1. Serpula vermicularis, 2. Pagurus prideaux, 3. Corella parallelograma, 4. Esperiopsis fucorum, 5. Didemnidae indet.*, 6. Pisidia longicornis, 7. Modiolus modiolus, 8. Chone infundibuliformis, 9.* Terebellidae indet.*, 10. Ascidiella aspersa, 11. Chlamys distorta, 12. Inachus dorsettensis, 13. Psammechinus miliaris, 14. Dendrodoa grossularia, 15. Pyura sp., 16. Phycodrys rubens, 17. Galathea sp., 18. Pomatoceros triqueter. (Drawing by Sue Scott.)*

A1a.2.11 Features of Regional Sea 8

Regional Sea 8 extends in continental shelf depths from the Irish median line to the Norwegian median line and is considered by JNCC (2004) to represent two distinct biogeographic provinces (Lusitanian and Boreal) south and north of the Fair Isle Channel respectively. This contrasts with the major division in deeper water faunas, which are clearly different on either side of the Wyville Thomson Ridge, associated with a major separation of water masses.

The MESH map of seabed habitats for Regional Seas 8 and 9 is shown in Figure A1a.2.10.

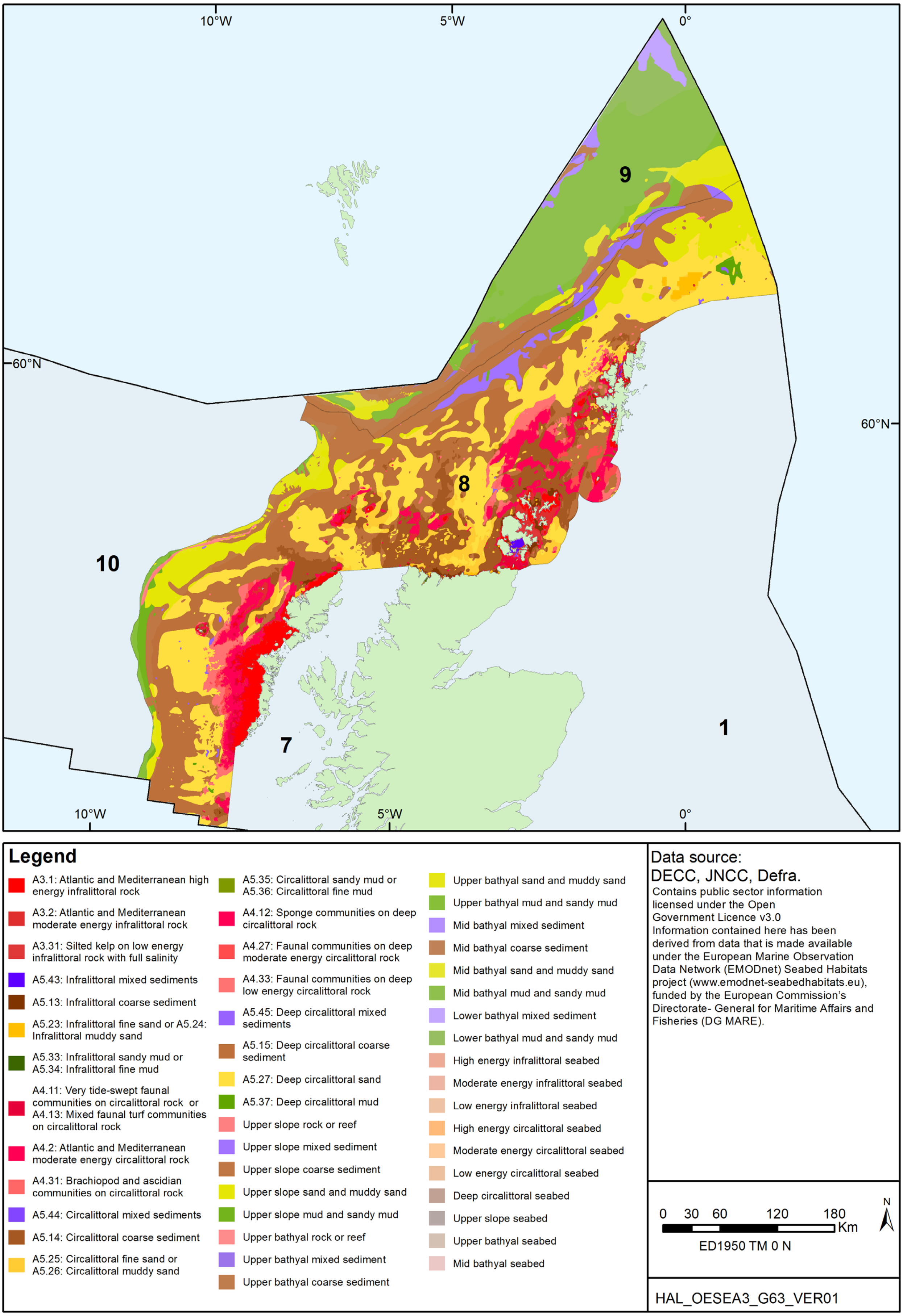
The southern part of Regional Sea 8 – i.e. south of the Wyville Thomson Ridge, west of the Western Isles – remains one of the least well-characterised areas of the UKCS in terms of benthic communities, with the exception of the immediate vicinity of St Kilda and the Stanton Banks SAC which have both now been extensively surveyed for shallow-water biotopes. Sealochs on the west coast of the Western Isles (e.g. Loch Roag) have been surveyed by the MNCR programme and subsequent work by SNH. Marine habitats at North Rona SAC have also been surveyed (SNH 2006d); however, there remains virtually no information on the benthic communities of the offshore Hebrides shelf. The Regional Sea 8/10 boundary follows the 1,000m isobath, and the Hebrides slope has been sampled by transects at depths below *ca*. 400m (Gage 1986, Gage *et al*. 2000). Seabed photographs show a clear transition of sediment type with depth, with shallower stations dominated by coarser sediments and deeper stations having much finer sediments. A large number of these earlier seabed photographs captured during a number of cruises during 1988, 1995,1996 and 1998 on the Hebridean Slope of the Scottish shelf edge were re-examined in a habitat and taxonomic analyses by Hughes *et al*. (2014). Their work confirmed the broad trends in bathymetric variation and habitat type described by Gage (1986) and gives further details / assessment of zonation in the wider Hebrides Slope area.

Two relatively recent surveys included both the intertidal and subtidal habitats around St Kilda. The first, conducted by SNH in 1997, involved a complete mapping of the intertidal biotopes for all the islands and the main stacks, together with broadscale mapping of the seabed in the areas adjacent to the islands using a RoxAnn acoustic ground discrimination system with ground truthing provided by scuba diver observations, underwater video and grab samples. A second survey in 2000 by SNH and the Fisheries Research Services Laboratory, Aberdeen mapped the areas of seabed between the islands and an area to the northwest of Soay. This survey employed a range of acoustic survey techniques including RoxAnn, multibeam swathe bathymetry and sidescan sonar together with towed video and ROV and grab sampling in the areas of soft sedimentary seabed (St Kilda World Heritage Site Management Plan 2003-2008 (2003)).

Five surveys have been conducted which confirm the presence of rocky reef and identify the biological communities present within the Stanton Banks SAC (JNCC 2008b). A British Geological Survey (BGS) manned submersible survey of an area within the Stanton Banks confirmed the presence of reef habitat and described characteristic reef fauna (Eden *et al*. 1971). A collaborative survey between JNCC and DARDNI (Department for Agriculture and Rural Development, Northern Ireland) was undertaken in 2003 (Service & Mitchell 2004). Two areas of Stanton Banks (Stanton 1 and 2) were surveyed using RoxAnn acoustic ground discrimination system (AGDS) and multibeam to characterise the physical properties/morphology of the seabed. Biological ground truthing of these areas using video tows and stills camera images confirmed the presence of bedrock reef and identified the major faunal communities. Further survey was undertaken by the North Western Shelf consortium, as part of the MESH2 project in 2005 and 2006 (MESH 2005, 2006). This included multibeam survey of three further areas (Stanton 1, 3 and 4) and biological ground truthing of Stanton 4 using drop-down video and ROV (remotely operated vehicle).

The newly designated (2014) Geikie Slide and Hebridean Slope NCMPA is a geological marine landslide with three key biological features: burrowed mud with seapens and burrowing fauna; offshore subtidal sands and gravels; and offshore deep sea muds.

Figure A1a.2.10: MESH classification of marine biotopes, Regional Seas 8 and 9



The Wyville Thomson Ridge became a designated SCI in 2011. The site has a minimum water depth of around 400m and has been the subject of several recent surveys: AFEN in 1996 & 1998; in 1999, 2000 and 2006 as part of the SEA programme (JNCC 2008a); and in 2012 by JNCC/MSS to gather evidence on the presence and extent of Annex 1 reef features in support of the MPA programme. Sidescan sonar, multibeam swathe bathymetry and video tows were all successfully collected.

To the north-east of the Wyville Thomson Ridge, extensive regional mapping and habitat assessment on the continental shelf west of Shetland has been carried out under the AFEN and SEA programmes; however, intensive seabed sampling data exists only towards the most northerly part of this area in the vicinity of oil & gas developments and pipeline routes. Very little biological data for the continental shelf seabed west of Orkney was available until recently when data additions to the south-east of the Wyville Thomson Ridge were made in support of two newly designated NCMPAs: West Shetland Shelf NCMPA and NW Orkney NCMPA.

The Solan Bank Reef SCI is also a newly designated NCMPA. Surveys were undertaken in 2008 (JNCC/Cefas) and 2014 (JNCC/MSS). The 2008 data helped to characterise the biological communities associated with the Annex I reef feature and identified encrusting fauna (bryozoans and corallines), an unusual cup coral and rare sponges (Whomersley *et al*. 2010). The aim of the 2014 survey was to gather seabed evidence to inform development of a national indicator of 'Good Environmental Status' for sponge and other epifaunal communities as part of the UK's obligations under the Marine Strategy Framework Directive (MSFD). The survey, undertaken by MSS, conducted assessments of the number of sponges and their body shapes (morphologies).

Lying to the north of Scotland in offshore waters, the West Shetland Shelf NCMPA comprises offshore subtidal sands and gravels – a UK BAP priority habitat - with diverse fauna. It overlaps with the Windsock Fisheries Area which is managed by Marine Scotland for the recovery of cod stocks. Although a relatively common habitat in Scotland waters, the range of different types of sand and gravel habitats present within the MPA support a particularly rich diversity of wildlife. On the surface, anemones, cup sponges (*Axinella infundibuliformis*) and several types of crustaceans including hermit crabs and squat lobster (*Munida rugosa*) can be found living between small rocks, whilst urchins and starfish (such as *Porania pulvillus* and *Asterias rubens*) are typical fauna living on the surface of the sandier sediments. Bryozoans and encrusting sponges are often found growing on the surface of cobbles and pebbles. Sea snails, bivalves such as scallops, keel worms and sand mason worms (*Lanice conchilega*) are adapted to living buried in the sand to avoid passing predators.

Many fish species have routinely been recorded within the area enclosed by the MPA including dragonet (*Callionymus lyra*), red gurnard (*Aspitrigla cuculus*), cod (*Gadus morhua*), plaice (*Pleuronectes platessa*), skate and rays (such as *Raja naevus*). Certain types of fishing are already managed within the overlapping Windsock Fisheries Area to help cod populations recover.

Work by MSS individually and in collaboration with JNCC has informed the evidence for this site designation and existing recent survey data was re-analysed to search and document priority habitats (Pearce *et al*. 2014b, Goudge & Morris 2014, Allen *et al*. 2014a).

Northwest Orkney NCMPA lies to the north and west of the Orkney Isles on the Scottish continental shelf in depths of 12-216m. The area is considered important as an export ground for sandeels – a mobile FOCI species. There are key geomorphological features (shelf tidal bedform features) which present as sediment wave fields, sand wave fields and sand banks which are active and are maintained under a specific range of tidal current conditions. The seabed is thus characterised by a mixed ground type (areas of rough substrate within the areas of sediment) which make it suitable for sandeel colonisation. A time series of larval abundance data beginning in the 1950s (Lynam *et al*. 2013) shows that newly hatched sandeel larvae from this region are exported by currents to sandeel grounds around Shetland and the Moray Firth (Proctor *et al*. 1998). The MPA therefore plays an important role in supporting wider populations of sandeels in Scottish waters.

Shallow water benthos of the west Shetland shelf (together with coastal littoral and sublittoral habitats of Orkney and Shetland) was reviewed for SEA 4 by Eleftheriou (2003).

In nearshore areas, the MNCR programme targeted a number of coastal sites in Orkney and Shetland and there has been more recent survey effort on behalf of SNH at SACs in Regional Sea 8 for which reef is a qualifying interest feature i.e. Sanday and Papa Stour. There has been long term survey and monitoring effort in connection with Sullom Voe in Shetland and Flotta in Orkney since the inception of the two oil transhipment terminals during the 1970's.

There are four newly designated nearshore/coastal MPAs, two of which are around Shetland: Fetlar to Haroldswick; Mousa to Boddam – and two around Orkney: Wyre and Rousay Sound; Papa Westray.

Fetlar to Haroldswick NCMPA has been designated to protect a mosaic of high energy seabed habitats including horse mussel beds, kelp and seaweed communities and maerl beds. The NCMPA also encompasses over 200km^2 of important black guillemot feeding grounds. Mousa to Boddam NCMPA will protect sandeels and the sandy seabed within which they live; Mousa itself is also known for its sea caves, reefs, harbour seals and Arctic terns. Wyre and Rousay Sound NCMPA includes shallow sublittoral kelp and seaweed communities on sand; also maerl beds with their associated rich biodiversity. Papa Westray NCMPA has been designated for reasons other than benthic (its black guillemot population and for its marine geomorphology, including a nearshore sand wave field). The site lies within the Orkney carbonate production area which is an internationally important example of a shelf carbonate system. The sand is rich in calcium carbonate that comes from the eroded shells and plant skeletons that once lived in or on the seabed, such as maerl and bivalve molluscs. These remains of sea creatures supply the sandy beaches of Orkney and underpin the development of small areas of coastal machair.

In the vicinity of Yell Sound on Shetland, Hartley Anderson (2001) described a varied fauna which reflected the varied seabed types. Epifaunal cover was typically extensive, with almost 100% of exposed surfaces colonised by hydroid turf, sponge and bryozoan mats. The best-developed encrusting fauna was seen in areas with limited sand presence. Where cobbles and boulders were part buried in sand, hydroid turf was the predominant fauna. In addition to encrusting animals, a range of erect sessile species was observed, including the bryozoan *Cellaria* sp., other bryozoans, the anemones *Hormathia digitata*, *Parazoanthus anguicomus* and *Bolocera tuediae*, several sponges and what were believed to be small hard corals (up to 2cm high). The hard seabed is also typified by a range of motile animals, the most common of which are the sea urchins *Cidaris cidaris* (slate pencil urchin) and *Echinus esculentus*, the starfish *Stichastrella rosea*, *Asterias rubens* and *Porania pulvillus* (cushion star), brittle stars including *Ophiothrix fragilis*, and squat lobsters *Munida rugosa*.

Patches of sand and gravel in the Yell Sound area supported a relatively uniform boreal shelf sand macrofaunal community dominated by tubicolous polychaetes such as *Galathowenia oculata*, a characteristic species of stable sediments, as well as polychaetes such as *Pisione remota* and *Hesionura elongata*, typical of more mobile, well sorted grades. On pebbles and gravel, starfish (*Porania*), brittlestars (*Ophiura*), anemones (*Bolocera tuediae*), encrusting and erect sponges and bryozoans were present, while on cobbles and pebbles there was a variable but well-developed epifauna consisting of erect and encrusting hydrozoans, sponges, anemones (*Parazoanthus anguicomus*), sea urchins (*Echinus*) and serpulid polychaetes.

Although the history of qualitative survey in Regional Sea 8 is rich, quantitative survey of the west Shetland shelf fauna did not commence until the work of Stephen (1923), who sampled a station (No.126 at 60°N 4'W at 144m depth) just southwest of the Clair oilfield and reported a fauna numerically dominated by the free living tube worm *Ditrupa arietina* (360/m^2), with the only other species recorded being the brittle star *Ophiura* sp. Stephen characterised the fauna as belonging to a "pure Ditrupa" community, which he had also found at a number of locations to the west and north of Shetland. Dyer *et al.* (1982) also recorded *Ditrupa* to the west of Shetland and included a photo of the seabed showing numerous tubes present.

On the basis of trawls and underwater photographs, Dyer (1983) described a sparse epifauna from the west Shetland shelf dominated by northern species such as the asteroids *Hippasteria phrygiana, Stichastrella rosea* and *Solaster endeca*, the anthozoan *Adamsia palliata*, the polychaete *Hyalinoecia tubicola*, and the sponges *Tetilla* and *Phakellia*; the echinoid *Echinus tenuispinus*, asteroids *Pteraster militaris* and *Pontaster tenuispinus* and the anthozoan *Hormathia digitata* were also dominant in the deeper northern stations. Cranmer *et al.* (1984) extended this work and noted the presence, in small densities, of the anthozoan *Actinauge richardi* (common around Shetland), the squat lobster *Munida rugosa* and the zoantharian *Epizoanthus incrustatus* (=*papillosus*) found in association with an anomuran crab. Basford *et al.* (1989) described epifauna from two stations west of Fair Isle as sparse and in low numbers, consisting of a few asteroids (*Asterias rubens, Porania pulvillus* and *Luidia ciliaris*) and echinoids such as *Spatangus purpureus* and both varieties of *Echinus acutus* (*E. a. flemingii* and *E. a. norvegicus*).

Macrofaunal samples from the Clair field (140m water depth) taken by grab were analysed by ERTSL (2001) and found a relatively uniform community dominated by tubicolous polychaetes characteristic of stable sediments. This interpretation may be influenced by the difficulties encountered in sampling the coarser sediments, or may reflect the tolerance of the dominant species to a range of sediment types. Faunal composition also suggested the presence of mixed or overlapping communities. An environmental survey of two prospective Foinaven-Sullom Voe pipeline routes which extend further west to the deeper water (360-500m) of the shelf edge, recorded species richness considerably lower than that recorded in the Clair area where over 500 taxa were found; the reasons for such a discrepancy remain unexplained (Hartley Anderson 2000). In deeper water (>100m), a generally sparse and patchy macrofaunal community was dominated by the tubicolous polychaetes *Myriochele (=Galathowenia) oculata* agg. and *Aonides paucibranchiata* which is consistent with the communities described from the AFEN and Clair baseline studies. Shallower stations generally had coarser sand substrate, and supported a community dominated by *Prionospio (Minuspio) cirrifera*, together with a number of surface-inhabiting species exploiting the greater niche heterogeneity of these sites which had more gravel.

In general, fauna of the west Shetland continental shelf varies according to the nature of the seabed sediments and is typical of a boreal mixed sediment community. Analysis of infaunal community data from Shetland sedimentary habitats (Pearson *et al*. 1994) suggests that they are comparable only in the most general terms with the infaunal communities, assemblages and associations described from subtidal sedimentary habitats elsewhere in boreal areas of western Europe; furthermore they are only loosely comparable to those defined for the North Sea as a whole. The difficulties in making comparisons between similar sedimentary habitats in boreal Europe result from the poorly sorted nature of sediments at the examined sites and the relatively high variability of habitats. Thus community types are frequently mixtures of two or more of the classical Petersen/Thorson community types (Gray 1981).

The seabed in nearshore waters off the north coast of mainland Scotland is dominated by rippled fine sand with a sparse epifauna. Empty shells of the priority marine feature *Arctica islandica* appear to be common in deeper water (>70m). Sand waves of coarser materials are widely distributed; rocky reef habitats of boulders and cobbles are predominantly in shallower depths (<45m).

A1a.2.11.1 Offshore islands and banks

The following description of benthic communities at St Kilda is derived from SNH advice under Regulation 33(2) of The Conservations (Natural Habitats, &c) Regulations 1994 (as amended) (SNH 2006a). The St Kilda SAC contains extremely wave-exposed reefs consisting of hard, igneous rock, forming steep and vertical reefs around the entire island group with few low-lying areas. Rock faces extend to over 300m above sea level, and reach sublittoral depths of between 60-80m on a subtidal plateau that encircles the island group. Typical intertidal reef communities extend several metres above mean high water into the littoral zone because of wave exposure. These reefs support characteristic populations of the exposed shore fucoids *Fucus distichus* and *Fucus spiralis var. nana*. Littoral communities of interest span a height range of 6 to 8m or more, with supralittoral green algae extending for tens of metres up the cliffs.

The clarity of the Atlantic sea water is high and sublittoral fringe communities dominated by *Alaria esculenta* reach depths of at least 15m. Below this zone, dense kelp forests of *Laminaria hyperborea* with a rich associated flora and fauna occur as deep as 35m; *Laminaria saccharina* replaces the *L. hyperborea* at a depth of 25m in some locations and *L. digitata* can reach depths of 50m in sparse kelp park. Circalittoral rock below 35m is dominated by diverse communities including large and colourful expanses of anemones, sponges and soft corals with hydroids and bryozoans characteristic of conditions in surge gullies. The invertebrates within this zone are primarily encrusting or low-growing species such as the jewel anemone *Corynactis viridis*, the dwarf form of the plumose anemone

Metridium senile, the anemone *Sagartia elegans*, polyclinid ascidians, sponges such as *Myxilla incrustans* and *Halichondria panicea*, and numerous thin encrusting species. Effectively the circalittoral zone found in this site is deeper than that found in any other of the suite of marine SACs, and the type of community found in this area is characterised by erect sponges such as *Axinella* spp. and *Phakellia* spp., as well as bryozoans, including *Porella* spp, along with associated encrusting sponges. Occasionally, at depths of 70m, there are patches of pink encrusting algae, which emphasise the uniqueness of this community, as littoral algal species are not usually found at these depths. There are also brittlestars *Ophiocomina nigra* and squat lobsters *Munida* spp. amongst the boulders on the bedrock plane, where the rarely recorded, erect coral-like cyclostome bryozoan *Coronapora truncata* was found. Overall these reefs provide some of the richest and most extensive examples of very exposed rock habitats in the EU.

Basalt and dolerite dykes throughout the island group have eroded to form caves and tunnels above and below the water which are a major feature of the islands, and are the most extensive of such systems in the UK. They support diverse communities that reflect the degree of surge to which they are exposed. In shallow water, within areas most affected by surge, little can survive other than the encrusting sponge *Myxilla incrustans*, which blankets the cave walls. With a reduction in surge, anemones such as the northern anemone *Phellia gausapata*, jewel anemone *Corynactis viridis* and *Sagartia elegans* are abundant along with thin encrusting sponges and bryozoans. Hydroids such as *Tubularia indivisa* dominate some of the larger systems; in all cases, there is a diverse fauna and flora associated with these characteristic dominant species. Microhabitats in the deeper caves show a wave exposure gradient with species usually found in more sheltered conditions, such as the fan worm *Sabella pavonina* and the burrowing anemone *Cerianthus lloydii*, present in the inner regions. Rarely recorded nocturnal species have also been found in the inner caves, most notably the crab *Bathynectes longipes* and the anemone *Arachnanthus sarsi*. The cave floors are typically lined with rounded boulders. The deeper caves show a wave exposure gradient with microhabitats comprising species typically found in more sheltered conditions present in the inner regions. The cave floors support communities dominated by the Devonshire cup-coral *Caryophyllia smithii*, calcareous tube worms and the urchin *Echinus esculentus*, with the squat lobsters *Galathea strigosa* and *Galathea nexa* living between the boulders.

North Rona SAC, Papa Stour SAC and Sanday SACs all provide a variety of littoral and subtidal reef habitats (SNH 2006b, c, d), supporting rich marine communities characteristic of conditions ranging from highly exposed (North Rona) to relatively sheltered (Sanday). The reefs support animal and algal species, which are highly influenced by wave exposure and water quality. The influence of the North Atlantic Drift is apparent in the presence of many southern species, but colder sub-arctic water accounts for the northern elements of the fauna and flora. The well developed sea caves found at North Rona and Papa Stour contain species characteristic of those found in northern latitudes, and associated communities that are representative of a range of exposures to wave action. Sanday SAC also supports sandbank, mudflat and sandflat Annex I habitats.

Quite close to North Rona lies the Solan Bank Reef, where a number of recent surveys (JNCC 2008, MSS/JNCC/Cefas 2014) have successfully gathered acoustic, photographic, video and grab sample data, some of which have been analysed (Whomersley *et al*. 2010) to determine the topographic, substrate and biological characteristics of the area. Current speed and direction have recently been obtained at three stations. Substrates vary from well-sorted sands through to creviced bedrock, and the Annex I reef feature was found to comprise both bedrock and stony reef. The majority of the reef was characterised by encrusting fauna, particularly bryozoans and corallines in shallow areas.

The 2014 survey also gathered seabed evidence to inform development of a national indicator of ‘Good Environmental Status’ for sponge and other epifaunal communities as part of the UK’s obligations under the Marine Strategy Framework Directive (MSFD). The survey, undertaken by MSS, conducted assessments of the number of sponges and their body shapes (morphologies). The 2014 survey completed 166 drop-frame video transects, together with measurements of current speed and direction at three stations. These data have not yet been reported.

The site represents the Annex I reef sub-types ‘bedrock’ and ‘stony’ reef. Bedrock outcrops create areas of high topography, with linear features (thought to be bedrock joint planes) forming cliffs of up to 10m in height above the surrounding seabed. Elsewhere the bedrock forms smooth and undulating features known as roches moutonnées, created by the scour effect of moving glacial ice. Stony reef comprised of boulders and cobbles with a sandy veneer occurs in ridges to the north-west and south-west of the site; these most likely represent glacial moraine ridges (the tracks of sediment carried by glacial ice). Boulders and cobbles also occur in the larger crevices in the bedrock while smaller rock fissures are filled with a mixture of coarse sand and shell/gravel veneer. A veneer of sand occurs over the flat bedrock surfaces, indicating that sediment scour is a significant factor across the site.

The reefs are characterised by encrusting fauna, mainly encrusting bryozoans and encrusting coralline algae in the shallower areas. Cup corals are present throughout the site, and brittlestars are common on both the bedrock and stony reef. Areas of flatter bedrock subject to sediment scour have a lower diversity of fauna than more sheltered areas. The highly scoured reef is mainly colonised by the keel worm *Pomatoceros triqueter* while a range of sponges, bryozoans and hydroids occur on less scoured reef areas. Water movement created by tidal streams and wave action is greater in shallower areas and here there is a higher abundance of species such as the soft coral *Alcyonium digitatum*, the cup coral *Caryophyllia smithii* and the jewel anemone *Corynactis viridis*. Foliose red algae and kelp grow in the shallowest locations where light penetrates the water.

On Stanton Banks SAC, survey by MESH (2005, 2006) confirmed that smooth, silty bedrock in the lower circalittoral zone was characterised by extensive encrusting coralline red algae, numerous barnacles, brittlestars, small sponge crusts (including *Hymedesmia paupertas*), axinellid sponges (*Axinella infundibuliformis*) and massive sponges (*Mycale lingua* and *Pachymatisma johnstonia*) (see Figure A1a.2.11). Sea urchins (*Echinus* sp.) and colonies of filamentous tubeworms (*Filograna* sp.) were also common. On the slopes, there was a transition from smooth bedrock to fissured rock outcrops, boulder and cobble with featherstars (*Leptometra celtica*), dead man's fingers (*Alcyonium digitatum*) and robust hydroids (*Tubularia* spp.). Cold water coral (*Lophelia pertusa*) has been observed on Stanton Banks but distinct biogenic reefs have not been identified (Roberts *et al*. 2003).

Figure A1a.2.11 – Stanton Banks habitats

Notes: Left: featherstars (Leptometra celtica), calcareous tube worms and the blue sponge crust Hymedesmia paupertas on bedrock and boulder reef. Right: boulder and bedrock reef habitat with Mycale lingua.
Source: MESH (2006)

A1a.2.12 Features of Regional Sea 9

Regional Sea 9, comprising the deep waters of the Faroe-Shetland Channel (below 600m water depth), was subject to early ground breaking studies exemplified by the popular accounts published by Wyville Thomson (1874) and Murray and Hjort (1912). To a large extent, later work has amplified rather than altered the general patterns identified by the early exploration. The seafloor of the channel was the subject of five major mapping and sampling cruises between 1996 and 2002, funded initially by the Atlantic Frontier Environmental Network (AFEN) and latterly by DECC as part of its SEA process. The AFEN and SEA surveys used a combination of seafloor mapping and physical or photographic sampling, which has allowed the broad distribution of habitats and species to be distinguished across the area. In addition, there have been a number of programmes of academic investigation of features identified by (or subjects highlighted by) the AFEN and SEA surveys (e.g. Grehan & Freiwald 2001). The most recent survey was conducted by JNCC/MSS in 2012 to make further investigations on the Wyville Thomson Ridge and Faroe-Shetland Channel proposed MPA sites. Video and camera imagery were collected to support evidence on the presence and extent of deep-sea sponge aggregations and offshore subtidal sands and gravels within the MPA (Morris *et al*. 2014).

Sediments in the Faroe-Shetland Channel are largely glacial in origin (Masson *et al*. 2003), and the band of numerous iceberg ploughmarks or scars along the upper slope between 200 and 450m provides evidence of past glacial activity. The sediments follow a general pattern of decreasing grain size from sand and gravel at the shelf break to mud in the deeper waters. The pattern is not uniform across the area since strong water currents occur at depth, resulting in the presence of coarser sediments than might be expected. In particular, the occurrence of large areas of gravel substrate on the continental slope and in places on the basin floor is regarded as unusual. A group of mud diapirs (mud “volcanoes”) are present in the north of the area. These are often associated with fluid escape or expulsion and on occasion with specialised seep biological communities, although no evidence of this has been found on these diapirs. No large reefs or colonies of cold water corals were found, which accords with the conclusions of Long *et al*. (1999) and Roberts *et al.* (2003).

The MESH map of seabed habitats for Regional Sea 9 is shown in Figure A1a.2.10 above.

AFEN (2000) and Bett (2001, 2003) have emphasised the biological importance of the hydrographic effects of the physical barrier presented by the Wyville Thomson Ridge, confirming the findings of the early studies described by Wyville Thomson (1874). To the north of the Wyville Thomson Ridge a major faunal division occurs at around 500m, reflecting the change from warm north Atlantic water near the surface to cold Faroe-Shetland Channel bottom water derived from the Norwegian Sea. Bett (2001) indicated that the cold water faunal group can be subdivided into three, reflecting stations below 1,200m, those between 500 and 1,200m to the north of Shetland, and those between 500 and 1,200m to the west of Shetland. Further work by Narayanaswamy *et al.* (2010) describes the deep-water macrofaunal diversity in the Faroe-Shetland region in relation to its unusual thermal regime.

Bett (2003) provided a range of seabed photographs selected to illustrate the variation of seabed composition and associated epibenthic communities within the Faroe-Shetland Channel. At the northern part of the Regional Sea in the mouth of the Faroe-Shetland Channel and the Norwegian Basin there are large areas of level-bottom “typical deep-sea” soft sediment habitat with the mud diapir province (see above) introducing local seabed habitat heterogeneity. In contrast to this, the deep waters (*ca.* 1,000-1,200m) of the southern end of the SEA 4 area (Faroe Bank Channel and southern reaches of the Faroe-Shetland Channel) are rather different in character, having sandier sediments that are home to a more abundant population of mega benthos – white stalked sponges being the most striking visual component of the fauna. Towards the lower slope of the southern edge of the Faroe Plateau, sediments become progressively coarser, indicative of significant bottom water currents, while barchan sand dune fields and sandy contourite deposits are also indicative of significant bottom water flows that result in the transporting away of fine sediments. Coarse sediment habitats are also widespread on the upper slope (*ca*. 300-500m) in a more-or-less continuous band throughout the region known as the “iceberg ploughmark zone”; during glacial periods, grounding icebergs gouged furrows in the seabed turning coarser sediments (cobbles and boulders) aside in an action similar to that of a plough harrow (see Belderson *et al*. 1973). The action of bottom currents has subsequently, at least partially, infilled the furrows with finer sediments. These processes have together created a complex, spatially heterogeneous, mosaic habitat that can repeatedly alternate from “piles of boulders” to open fine sediment areas. The coarse sediment (cobble and boulder) area can support diverse biological communities that exhibit significant local variation in their composition and abundance.

An extensive part of this region from approximately 62°23'N 2°32'W to the Norwegian boundary was designated in 2014 as the North East Faroe-Shetland Channel NCMPA. The habitats present here are strongly influenced by the wide depth range from the upper continental slope to the depths of the channel and associated environmental conditions. A dynamic mixing zone where warmer Atlantic waters flow over cooler Arctic waters is present, creating limits to species distribution. The continental slope plays an important role in funnelling ocean currents that bring valuable food and nutrients to the region. For example, at depths of 400-600m, the combination of seabed sediment and plentiful supply of nutrients create ideal conditions for the establishment of deep-sea sponges. Below 800m, the muddy seabed is home to those species that can tolerate the cooler Arctic-influenced waters, such as deep-sea worms. The MPA includes several different features of geological importance (see Section A1b), including the Pilot Whale Diapirs - a series of seabed sediment mounds which measure 2 to 3km across and rise to more than 70m above the surrounding seafloor.

Sponge aggregations are also protected by a second newly designated NCMPA – the Faroe-Shetland Sponge Belt NCMPA which lies just to the south of the NE Faroe-Shetland Channel NCMPA and straddles the boundary between Regional Seas 8 and 9. Biodiversity in the NCMPA is thought to be linked to the intermediate water masses and the peak in benthic diversity and abundance occurs within the same depth range. The higher current speeds and with the presence of cobbles and boulders (associated with iceberg ploughmarks) provide ideal conditions for sponges. Deep-sea sponge aggregations have been recorded in the channel between 400 and 600m depth. The type of deep-sea sponge aggregation which occurs within the Faroe-Shetland Sponge Belt MPA is boreal 'ostur'. Boreal 'ostur' sponge aggregations typically have a high abundance of species of giant sponge (Demospongiae), which local fishermen refer to as "Osturbunds" or "cheese-bottoms" due to their appearance. Within the UK, the boreal 'ostur' sponge aggregations are only known to occur within the biogeographic region which includes the Faroe-Shetland Channel.

There are two distinct sedimentary communities within the site representative of offshore subtidal sands and gravels; one is found between 300 and 600m which are characterised by a greater proportion of cobbles and boulders; and a second below 600m, characterised by finer sands and muddy sands. The two communities are dominated by contrasting families of polychaete worm.

A1a.2.12.1 Biogenic habitats

Deep sea sponge communities are characteristic of this region where up to 50 sponge species can be found within the sponge fields, many of which are different to those found in the surrounding areas (see Henry & Roberts 2014). Deep-sea sponge aggregations are an OSPAR threatened or declining habitat and a UK BAP Priority Habitat[11]. The sponges provide shelter for a range of small sea life and provide an elevated perch to enhance filter feeding for animals such as brittlestars.

A1a.2.13 Features of Regional Seas 10

Surveys reported in SEA 7 (BGS/NERC in 2003; DTI/Defra/JNCC in 2006) reported on the dramatic bathymetry of Regional Sea 10, where the deep sea abyssal plain is enhanced by various features on the shelf slope and by banks and sea mounts surrounding and rising from the deep sea Rockall Trough. One of these has been designated an SAC: Darwin Mounds, while a number of others have been designated SCIs, including: North West Rockall Bank,

[11] Also defined as Natural Environment & Rural Communities Act 2006 Habitat of Priority Importance

Anton Dohrn Seamount and East Rockall Bank. Two newly designated sites are the Rosemary Bank Seamount NCMPA and the Barra Fan and Hebrides Terrace NCMPA.

The Rockall Trough and Bank in water depths greater than 1,000m were described in SEA 7, with specific survey effort and technical studies (Davies *et al*. 2006) commissioned to support the assessment. MAREMAP has also covered areas of seabed within Regional Sea 10 – the Anton Dohrn Seamount and George Bligh Bank, which is also a seamount lying in the Rockall Trough to the north of Rockall Bank.

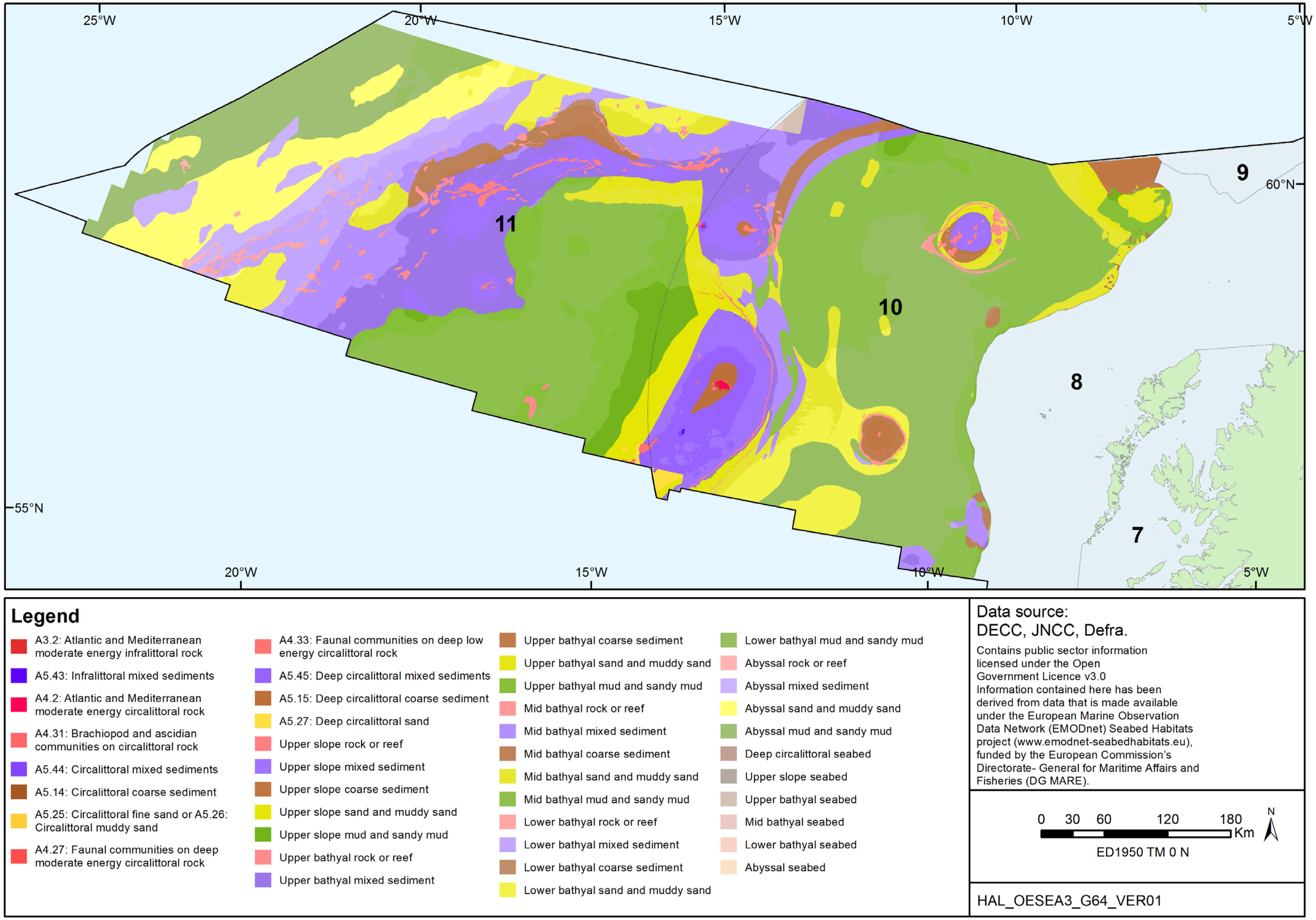
The MESH map of seabed habitats for Regional Seas 10 and 11 is shown in Figure A1a.2.12.

Recent survey and data gathering in the area includes:

- RRS James Clark Ross survey 2003 – The British Antarctic Survey-Natural Environment Research Council commissioned survey on the James Clark Ross was undertaken at Rosemary Bank Seamount delivering multibeam data that has helped to define the extent of the seamount.
- FRVMV Franklin Strategic Environmental Assessment/Special Area of Conservation survey 2006 – In 2006, a collaborative survey was undertaken by the Department for Trade and Industry and Defra (with staff participating from JNCC) as part of the SEA process. The survey data supported the presence of seamount communities and deep-sea sponge aggregations on the Rosemary Bank Seamount.
- Scotia Marine Scotland Science deepwater surveys 2007, 2012 – MSS survey data supported the presence of deep-sea sponge aggregations in the NCMPA.
- MB102 data collation contract – This Defra-led contract collated earlier records of hard corals on Rosemary Bank Seamount as part of the seamount communities protected feature from 1979 and 1987.

The Hatton and Rockall Banks and the Hatton-Rockall Basin were included in a recent workshop to identify ecologically or biologically significant marine areas (EBSAs) in the north-east Atlantic (OSPAR/NEAFC/CBD 2012).

Figure A1a.2.12: MESH classification of marine biotopes, Regional Seas 10 & 11



A1a.2.13.1 Hebrides slope

Observations made by the SEA 7 survey on the Hebrides slope (*ca*. 650-2,200m) largely supported existing datasets (Gage 1986, Gage *et al*. 2000), with some areas showing evidence of hydrodynamic activity at shallower stations with a relatively low megafaunal density and diversity. The most frequently seen species were the echinoid *Echinus acutus* and the ophiuroid *Ophiomusium lymani*. The dominant species present on the fine sediments of deeper stations of *ca*. 1,300m, were the octocoral *Acanella arbuscula*, pennatulids such as *Kophobelemnon stelliferum* and hexactinellid sponges such as *Hyalonema* sp. (Jones *et al.* 1998, Roberts *et al*. 2000). Although the majority of the community on the Hebrides slope followed the expected distributional patterns for the north-east Atlantic, some species were found at unusual depths; for example, *A. arbuscula* is usually found at depths greater than 1,500m (e.g. Hughes & Gage 2004), rather than 1,300m as here. These differences are most likely explained by the local hydrodynamic regime along with species association with the sediment types found throughout the area (Jones *et al*. 1998).

The macrofaunal community on the Hebrides slope is composed principally of polychaetes (accounted for *ca.* 53% of individual specimens and *ca.* 43% of all species collected), crustaceans (*ca.* 20% of individuals and *ca*. 34% of species) and molluscs (*ca*. 10% of individuals and *ca*. 12% of species) (Jones *et al*. 1998). Total macrofaunal biomass decreased linearly with increasing depth, falling within the established pattern for the continental margin worldwide (Rowe 1983). However, abundance deviated somewhat from the expected depth related trend, with polychaete abundance increasing by *ca*. 50% between 1,100-1,300m, potentially as a result of local hydrodynamic conditions and disturbance (Jones *et al.* 1998).

Dense fields of xenophyophores (possibly *Syringammina fragilissima*) were found on muddy sediments at 1,108m on the Hebrides slope, achieving densities of up to $10m^{-2}$ (Figure A1a.2.13). Xenophyophores are large protozoans found exclusively in the deep sea (Hughes & Gooday 2004). They agglutinate sediments to form elaborate tests which are often large (>25cm), either on or within sediments or on rock surfaces. The presence of xenophyophores appears to significantly increase the abundance of macrofauna and meiofauna in the immediate area (e.g. Hughes & Gooday 2004). *S. fragilissima* may perform many different roles, such as providing hard substrate for epifaunal species, elevating suspension feeders above the seafloor and increasing food available to deposit feeders resulting from the deposition of fine particles. The tests of xenophyophores may also passively trap larvae, leading to concentrated prey populations which may benefit predators, as well as forming a habitat for mating, reproduction and nursery functions (Hughes & Gooday 2004).

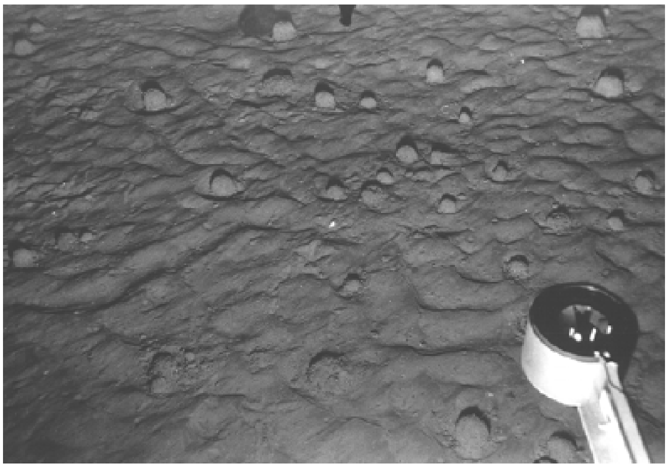


Figure A1a.2.13: Fields of the xenophyophore *S. fragilissima* on the Hebrides slope

Notes: Photographed at 1,108m (Enterprise Oil block 154/1).
Sources: Jones et al. (1998), Gage (2001)

Sponge beds may have many of the same effects on the benthic community as xenophyophores. The north-east Atlantic deep sea contains abundant aggregations of the hexactinellid sponge *Pheronema carpenteri* at depths of *ca*. 1,000-1,300m (e.g. Hughes & Gage 2004, Howell *et al*. 2013). The sponge aggregations appear to be directly related to increased abundance and richness of the macrofauna, particularly where there are large deposits of sponge spicules in the immediate area (e.g. Bett & Rice 1992). Dense spicule mats may have several effects on the benthic community, such as providing hard substrate, suitable for colonisation by species such as actinarians, hydroids and bryozoans (Bett & Rice 1992). Spicule mats and sponge bodies may also serve as refuge for prey species, as well as serving to trap particulate matter and phytodetritus.

A1a.2.13.2 Rockall Basin

At 1,920m depth, the Rockall Trough contains a community dominated by the octocoral *A. arbuscula* and the ophiuroid *O. lymani* (Hughes & Gage 2004). Sessile suspension feeders were most abundant, accounting for 77% of the total megafaunal standing stock biomass. Further west, Hughes & Gage (2004) sampled the Hatton-Rockall Basin at 1,100m. At this shallower site, the hexactinellid sponges (*P. carpenteri*) and ceriantharian anemones (species unspecified) were the most abundant, with mobile crustaceans such as *Munida tenuimana* relatively common. Sessile suspension feeders accounted for 92% of the total megafaunal biomass at this depth.

At all sites within the Rockall Trough and Hatton-Rockall Basin, polychaetes were the most abundant macrofaunal group, accounting for 55-58% of the total number of individuals and 57-79% of the biomass (Hughes & Gage 2004). In the Hatton Basin, small errant polychaetes (e.g. Hesionidae, Glyceridae, Amphinomidae, Nephtyidae) numerically dominated the fauna (69% of total individuals), but some other families e.g. Capitellidae, Chaetopteridae, Lumbrineridae, Polynoidae, Ampharetidae contained much larger individuals that dominated the overall biomass. On the Feni Ridge in the Rockall Trough, surface deposit and interface (species which can alternate between suspension and deposit feeding) feeders (e.g. Ampharetidae, Onuphidae, Cirratulidae) dominated the fauna (77% of total individuals). These community differences were most likely a result of differences in local hydrodynamic regime and food supply (Gage *et al*. 2000).

A1a.2.13.3 Banks and seamounts

Rockall Bank is the bathymetric expression of the underlying structural Rockall High. Its only expression above sea level is the granitic Rockall Island which is 18m high and approximately 25m in diameter. The granite has been dated as being about 55 million years old. On the eastern flank of the Bank in water depths of between 140 and 500m a number of linear scarps/ridges have been identified which are wave cut terraces formed when sea level was lower. Some local erosion and the development of ‘moats’, adjacent to the eastern margin of the Bank, suggest strong bottom currents are active. The eastern flank of Rockall Bank descends into the Rockall Trough, which is a broad deep-water sea way between Rockall Bank and the shallow water shelves adjacent to the UK and Ireland.

The Rockall Bank was the most intensively sampled area in the SEA 7 survey. Samples showed the bank to consist of different sedimentary regions. The south-east flank comprised mainly fine muddy sand with the echinoid *E. acutus* the most common mobile megafauna. The eastern flank of the bank had extensive areas of exposed bedrock with evidence of strong sediment scour (Narayanaswamy *et al*. 2006). Predicted coral reefs (Ross & Howell 2012) on the east Rockall Bank were confirmed by Howell *et al*. (2013).

On the north-west Rockall Bank several areas of live coral reef framework composed of *Lophelia pertusa* and *Madrepora oculata* were recorded (see Roberts *et al*. 2008), as reported from submersible observations from the 1970s when Wilson (1979) observed cold-water coral communities down to a depth of 1,000m. Thickets of *L. pertusa* and *M. oculata* occurred principally at depths between 150-400m; Wilson (1979b) also found large reef structures below 500m on the eastern flank of the bank which in June 2011 were re-discovered on the northern Rockall Bank (Howell *et al.* 2013). Occurrences of the *L. pertusa* reef framework biotope were confirmed by Howell *et al*. (2013) who noted the presence of large numbers of suspension feeders of various species and that the reefs also attract large schools of fish, suggesting their importance as habitat.

Further mapping has been carried out by Howell *et al*. (2009) of both broadscale habitats and the extent of the Annex I 'Reef' habitat.

The Anton Dohrn Seamount SCI is a former volcano centrally situated in the Rockall Trough and is roughly circular in shape. The slopes of the seamount are relatively steep and a moat-like depression surrounds the seamount, being slightly deeper around the north-west flank. The upper plateau surface has a diameter of approximately 40km and the highest point confirmed to date is about 650m below sea level. Narayanaswamy *et al*. (2006) found evidence of strong hydrodynamic activity on the flanks and plateau, where a sessile community was found to be composed primarily of brachiopods and barnacles; the mobile megafauna consisted primarily of echinoderms such as the echinoids *Calveriosoma cf. fenestratum* and *Cidaris cidaris*. No discoveries were made of large sessile epifauna such as gorgonians, corals or massive sponges. Benthic assemblages have been mapped most recently by Long *et al.* (2010) and Davies *et al.* (2015).

The Rosemary Bank Seamount NCMPA is located in the deep waters off western Scotland, north-east of the Rockall Trough. An extinct volcano, the Rosemary Bank Seamount is over 1,000m above the seafloor. The shallowest area within the MPA is approximately 400m below sea level on the crest of the seamount. In contrast, the deepest section of the MPA is 2,270m below sea level in the scour moat around the seamount.

Rising up from the surrounding sediments, the seamount provides a hard surface for marine life colonisation and also influences underwater currents, which bring a plentiful supply of food to the area to support rich communities dominated by suspension feeders. Survey data suggest four types of seamount communities are present: reef framework-forming colonial scleractinian corals, soft coral species, deep water sponges and seamount-associated sediments. Reef framework forming corals *L. pertusa* and *M. oculata* are a significant component of the seamount communities present. Deep-sea sponge aggregations, also a feature of the MPA, comprise low-lying massive and encrusting fields of yellow, blue, grey and white sponges. All of these species can take several decades to reach full size. Seamount communities (OSPAR 2010a), deep-sea sponge aggregations (OSPAR 2010b) and *L. pertusa* reefs (OSPAR 2010c) are all considered to be Threatened and/or Declining across the north-east Atlantic by the OSPAR Commission.

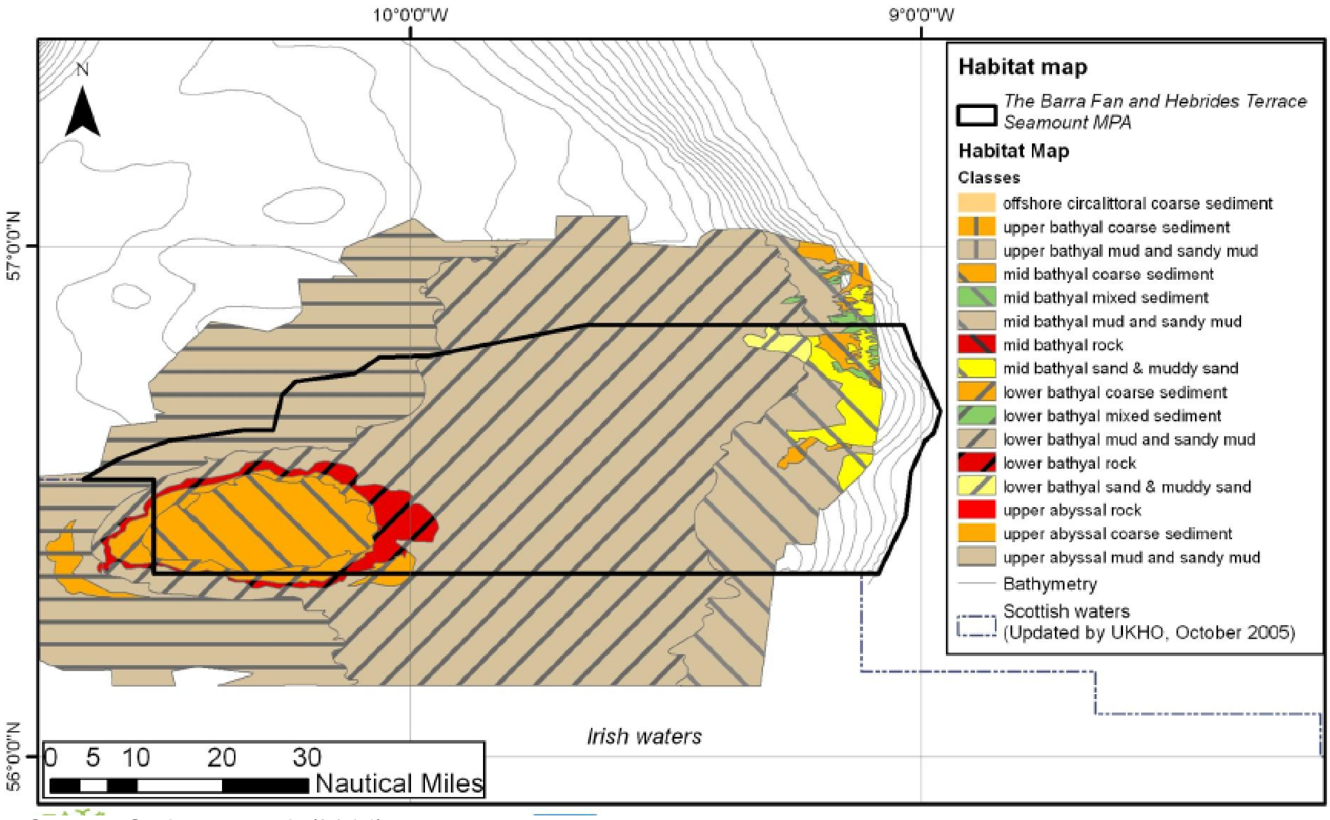
The **Hebrides Terrace Seamount** is a significant feature of the Barra Fan and Hebrides Terrace Seamount NCMPA. Situated to the west of Scotland, adjacent to the boundary with Irish waters, The Barra Fan and Hebrides Terrace Seamount NCMPA follows the seabed from the top of the Hebridean continental slope as it descends into the deep Rockall Trough and beyond. The 'Fan' is a geological protected feature of the site that was created when a large build-up of sediments underwent a series of submarine landslides which were then subjected to modification by water currents and gouging by icebergs. The seamount is the smallest in the UK deep sea area, arising from the seabed at 2,200m to approximately 1,000m at its summit.

On the continental slope part of the MPA, there are mud, sand and gravel habitats with a polychaete/bivalve/crustacean infauna. The base of the continental slope provides conditions for the establishment of burrowed mud habitat; specifically sea pens and burrowing megafauna communities (Allen *et al.* 2014b). Hughes *et al*. (2014) characterised the biological diversity of the Hebridean continental slope based on archived stills data from 1988-1998 (SEA 7 research project). The findings indicated five distinct biological zones, with associated communities that change with depth on the slope.

To the west of the site, the Hebrides Terrace Seamount rises to a height of almost 1km above the surrounding seabed and supports a diverse range of hard substrate colonising species including cold-water corals and deep sea sponges which represent OSPAR seamount communities (see Howell *et al*. 2010). The bathymetry causes enhanced currents which bring a rich food supply and diverse fish species including the long-lived deep-water orange roughy (*Hoplostethus atlanticus*) which is also associated with The Hebrides Terrace Seamount.

The Barra Fan and Hebrides Terrace Seamount area has been mapped from acoustic datasets (Sotheran *et al.* 2014). The resulting map (Figure A1a.2.14) shows the predominant seabed habitats to be mud and sandy mud within both the lower bathyal and upper abyssal biological zone regions. The seamount is characterised by rocky slopes in the lower bathyal area with coarser sediments on the broad peak within the mid bathyal region. The Barra fan area slopes from the offshore circalittoral with coarse sediments down to mud and sandy mud in the deeper areas. There is sand and muddy sand present on the slope and this material extends into the lower bathyal region, which is muddier.

Figure 1A1a.2.14: Habitat map for the Barra Fan and Hebrides Seamount area



Source: Sotheran et al. (2014)

Much that is known about this site has been gathered from recent video footage from two sources: data gathered by Heriot-Watt University in 2012 (Cross *et al.* 2014) as part of a study of the functional ecology of cold-water coral habitats; and data from MSS fish stock assessment surveys covering a nine year span (2000-2009) which were reviewed specifically for MPA Search Features in 2013 (Allen *et al*. 2014b).

The imagery analysed by Cross *et al*. – from two eastern transects and one across the summit of the seamount – showed biological communities attributable to the seamount communities MPA search feature to be present. They were able to identify six species clusters; a further five clusters were defined from video data (Table A1a.2.2).

Table A1a.2.2: Biotope definition of the Hebrides Seamount

Biotope definition from image data	Biotope definition from video data
Barnacles, ophiuroids and *Cidaris cidaris* on pebbles with sand	*Laetmogone* sp. and asteroids on muddy sand
Barnacles, antipatharians and encrusting sponges on sediment draped exposed bedrock and mixed substrate	Echinoids, anemones and crinoids on sand mixed with pebble/gravel
Xenophyophore fields – xenophyophores and barnacles on gravelly sands	Antipatharians, crinoids and sea pens on coarse sand mixed with pebble and cobbles
Xenophyophore fields – xenophyophores and sea pens on gravelly sands and mixed substrate	*Solenosmilia variabilis* reef framework with ascidians, lamellate sponges, echinoderms and octocorallia on coral rubble framework with underlying bedrock or cobbles
Antipatharian *Stichopathes cf. gravieri*, encrusting sponges, anemones, ascidians and cup corals on bedrock with sand veneer	Lamellate sponges and caryophyllids on sand mixed with gravel/pebbles and occasional boulders
Solenosmilia variabilis reef framework with crinoids, encrusting sponges, anthipatharians on coral rubble framework and bedrock with patches of sand.	

Source: Cross et al. (2014)

Allen *et al.* (2014b) identified four EUNIS habitats: boulders on deep-sea bed; deep-sea mixed substrata; deep-sea sand; deep-sea mud). Habitats and biotopes were also classified according to Howell *et al.* (2010) which identified them as: Atlantic upper slope coarse sediment; Atlantic upper slope mixed sediment; Atlantic upper slope sand; with two biotopes: '*Nephrops norvegicus* burrows with Geryonidae and anemones', and 'Halcampoid anemones in rippled sand'. Three MPA search features were observed: offshore subtidal sands and gravels, offshore deep sea muds and burrowed mud.

A1a.2.13.4 Biogenic habitats

The following biogenic habitats have been noted in Regional Sea 10:

- Deep sea sponge aggregations
- *Lophelia pertusa* reefs

A1a.2.14 Features of Regional Seas 11

The Hatton and Rockall Banks and associated slopes represent unique bathyal habitats (200 to 3,000m water depth) and constitute prominent features of the north-east Atlantic continental margin south of the Greenland to Scotland ridges. The banks are linked by the Rockall-Hatton Basin and are characterised by their gentle sloping bathyal bathymetry which contrasts to the more usual steep bathyal slopes on the north-east continental margin. There are strong environmental gradients down-slope on each of the banks, creating great habitat heterogeneity and supporting a wide variety of benthic and pelagic fauna. They are also locations of significant fishing, including bottom trawling, longlining, and midwater fisheries. New knowledge of this deep sea region is resulting in recognition not only of the need for protection within the UK's conservation mechanisms, but within UNEP's Convention on Biological Diversity (CBD) where a number of criteria e.g. vulnerability, uniqueness, biological diversity characterise The Hatton and Rockall Banks and the Hatton-Rockall Basin as a candidate Ecologically or Biologically Significant Marine Area (EBSA) within the north-east Atlantic (OSPAR/NEAFC/CBD 2012). The EBSA submission is based on the presence of two features: benthic and benthopelagic communities (cold water coral); pelagic communities. Within the UK jurisdiction, the Hatton Bank is a cSAC and the Hatton-Rockall Basin is a newly designated NCMPA.

The MESH map of seabed habitats for Regional Sea 11 is shown in Figure A1a.2.12 above.

The Hatton Bank and the George Bligh Bank located off its northern flank have been less studied than the Rockall Bank and Trough. However, both these areas have extensive live and dead coral framework comprised of *L. pertusa* and *M. oculata*, with a diverse associated community, including the cnidarian *Phelliactis* sp., the antipatharian coral *Stichopathes* sp., many hydroids/bryozoans, and mobile epifauna such as crustaceans and ophiuroids (Narayanaswamy *et al.* 2006). Frederiksen *et al.* (1992) reported great diversity of corals on the northern Hatton Bank, including *Paragorgia*, *Paramuricea*, Isididae and *Antipatharia* as well as the scleractinians *L. pertusa* and *M. oculata*. Since these early observations further records of coral frameworks have been noted throughout the Rockall, Hatton and George Bligh Banks (Narayanaswamy *et al.* 2013), including the Logachev Mounds and the Western Rockall Bank Mounds (Kenyon *et al.*, 2003; Roberts *et al.*, 2003; Narayanaswamy *et al.*, 2006; Howell *et al.*, 2007; Durán Muñoz *et al.* 2009).

Similar to the Rockall Trough, in the Hatton-Rockall Basin polychaetes were the most abundant macrofaunal group, accounting for 55-58% of the total number of individuals and 57-79% of the biomass (Hughes & Gage 2004). In the Hatton Basin, small errant polychaetes (e.g. Hesionidae, Glyceridae, Amphinomidae, Nephtyidae) dominated the fauna numerically (69% of total individuals), but some other families e.g. Capitellidae, Chaetopteridae, Lumbrineridae, Polynoidae, Ampharetidae contained much larger individuals that dominated the overall biomass.

The Hatton-Rockall Basin NCMPA site is located in water depths of ≥1000m and is designated to protect two features: deep-sea sponge aggregations and offshore deep sea mud habitats. The aggregations of deep-sea sponges comprise both encrusting sponges and fields of *Pheronema carpenteri*, both of which act as biodiversity hotspots (Howell *et al.*, 2013). For Pheronema fields, associated fauna include ascidians, foraminiferans, polychaetes and burrowing anemones, while the encrusting sponge aggregations are associated with anemones, ascidians, crinoids and ophiuroids. Howell *et al* (2013) describe the seabed in the area as littered with sponge spicules that inhibit the establishment of burrowing animals but allows surface-dwelling species e.g brittlestars to thrive. Geological faults – known as polygonal faults and included as a geological protection feature of the NCMPA– are present and manifest as cracks in the seafloor; these are thought likely to provide additional settlement substrate for deep sea sponges.

Howell *et al.* (2013) also predict the widespread presence of two different types of offshore deep-sea mud habitat. “Atlantic mid bathyal mud and sandy mud” is believed to dominate, with some patches of “Atlantic upper bathyal mud and sandy mud” also present. The limited survey data support the presence of habitat that is dominated by different species of burrowing anemone as well as echinoderms such as starfish, sea cucumbers and sea urchins.

Despite the current emphasis on photographic surveys for megafauna identification and biotope descriptions, macrofaunal investigations continue and indeed continue to discover new species, as evidenced by Oliver & Drewery (2013). They described two new species of chemosymbiotic bivalves from the Hatton-Rockall Basin, *Isorropodon mackayi* and *Thyasira scotiae*, the latter resembling *T. sarsi*. Since *Isorropodon* spp. and the larger thyrasirids – with the exception of *T. sarsi* – are typically found at hydrocarbon seeps associated with pockmarks and mud volcanoes, these new species suggest active sulphidic seepage in the Hatton-Rockall Basin.

In the northern Rockall Trough, in the area south of the Darwin Mounds there is a dense field of pockmarks but no chemosynthetic communities have been associated with them (Masson *et al*. 2003); however, as noted above Oliver & Drewery (2013) described new species of chemosymbiotic bivalves from a putative 'seep' in the Hatton–Rockall Basin. Evidence of fluid venting is widespread over the Porcupine Sea Bight and Rockall Plateau and has been implicated in the development of carbonate mounds and deep-water coral reefs (Hovland 1990, 2005). Despite the frequent co-occurrence of coral reefs and evidence of fluid venting, no direct evidence of active venting or of chemosynthetic communities had been reported in the Rockall or Porcupine regions (Roberts *et al*. 2009). In 2012 a research cruise on the FRV 'Scotia' (cruise 0712S) to the Hatton–Rockall Basin area investigated a series of trawling stations on soft sediments between the 400m and the 1,200m isobaths at depth intervals of approximately 100m. The new bivalve species were collected stations at 1,187-1,200m water depth.

A1a.2.15 Biogenic habitats

Although a range of biogenic habitats exist in UK coastal waters (e.g. maerl, kelp beds), four biogenic habitats are considered to be of particular relevance to this OESEA, because of distribution, statutory conservation designations and potential significant effects of the proposed activities – three associated with the reef-forming species *Sabellaria spinulosa*, *Modiolus modiolus* and *Lophelia pertusa* – and seagrass (*Zostera*) beds. Two additional reef-forming species – *Limaria hians* and *Serpula vermicularis* were noted above in Regional Seas 6 and 7 respectively and it is of interest that Moore *et al*. (2013) suggest that that *Modiolus modiolus* and *Lima hians* may be in completion for habitat space.

A1a.2.15.1 *Sabellaria* reefs

Dense, subtidal aggregations of the small, tube-building polychaete worm *Sabellaria spinulosa* can stabilise cobble, pebble and gravel habitats, providing a consolidated habitat for other species. *S. spinulosa* reefs are solid structures, at least several centimetres thick, raised above the surrounding seabed, which persist for many years and provide a biogenic habitat that allows many other associated species to become established (Farinas-Franco *et al.* 2014, Pearce *et al.* 2013). Reefs found in mixed sediment areas are important, as they allow fauna and crevice infauna to become established in areas where they would normally be absent. The MNCR biotope classification scheme (v04.05) defines a single *S. spinulosa* biotope: *Sabellaria spinulosa* on stable circalittoral mixed sediment (SspiMx). *S. spinulosa* reefs are on the OSPAR list of threatened or declining species and habitats and have become the subject of considerable work on their distribution, longevity and sensitivity to both natural and anthropogenic pressures (see for example Gibb *et al*. 2014).

S. spinulosa is naturally common around the British Isles. It is found in the subtidal and lower intertidal/sublittoral fringe with a wide distribution throughout the north-east Atlantic, especially in areas of turbid seawater with a high sediment load. However, in most parts of its geographical range *S. spinulosa* does not form reefs, but is solitary or in small groups encrusting pebbles, shell, kelp holdfasts and bedrock. It is often cryptic and easily overlooked in these habitats. Where conditions are favourable, much more extensive thin crusts can be formed, sometimes covering extensive areas of seabed. However, these crusts may be only seasonal features, being broken up during winter storms and quickly reforming through new settlement the following spring. There are extensive examples of this form of colony in the Berwickshire and North Northumberland Coast cSAC. These crusts are not considered to constitute true *S. spinulosa* reef habitats because of their ephemeral nature, which does not provide a stable biogenic habitat enabling associated species to become established in areas where they are otherwise absent.

Sabellaria reefs have been documented from Regional Seas 2, 3 and 4. In Regional Sea 1 there is evidence of aggregations rather, than reefs, off the Peterhead coast (CMACS 2013, referenced in Shell 2015).

In the southern North Sea (Regional Sea 2), *S. spinulosa* reefs are present offshore from the Wash on sandy gravel substratum and offshore from Skegness in the licence area of the Lincs Offshore Wind Farm (Centrica Energy 2007). They have also been reported within an aggregate licence area (401/2) which is approximately 13 nautical miles east of Great Yarmouth (Newell *et al*. 2000), in the Saturn Reef area included within the North Norfolk Sandbanks SAC and in the licence areas of the Thanet Offshore Wind Farm where Pearce *et al*. (2014a) have demonstrated reef recovery over an eight year period which they attribute partly to the habitat protection offered by the wind farm presence.

In Regional Sea 3 *S. spinulosa* biogenic reefs have been recorded 4km east of Swanage Pier in Dorset (Jones *et al.* 2004f), where the percentage coverage of *Sabellaria* on the seabed was estimated at between 5-80%. The reef was reported to be free of silt and many mollusc shells had been incorporated into the structure of the reef, particularly single valves of *Nucula* spp. and fragments of cockles and venerids. This would imply that currents capable of moving such items must affect the site from time to time. Farther east on the Hasting Shingle Bank reef status has been monitored in connection with the aggregate industry (Pearce *et al*. 2007).

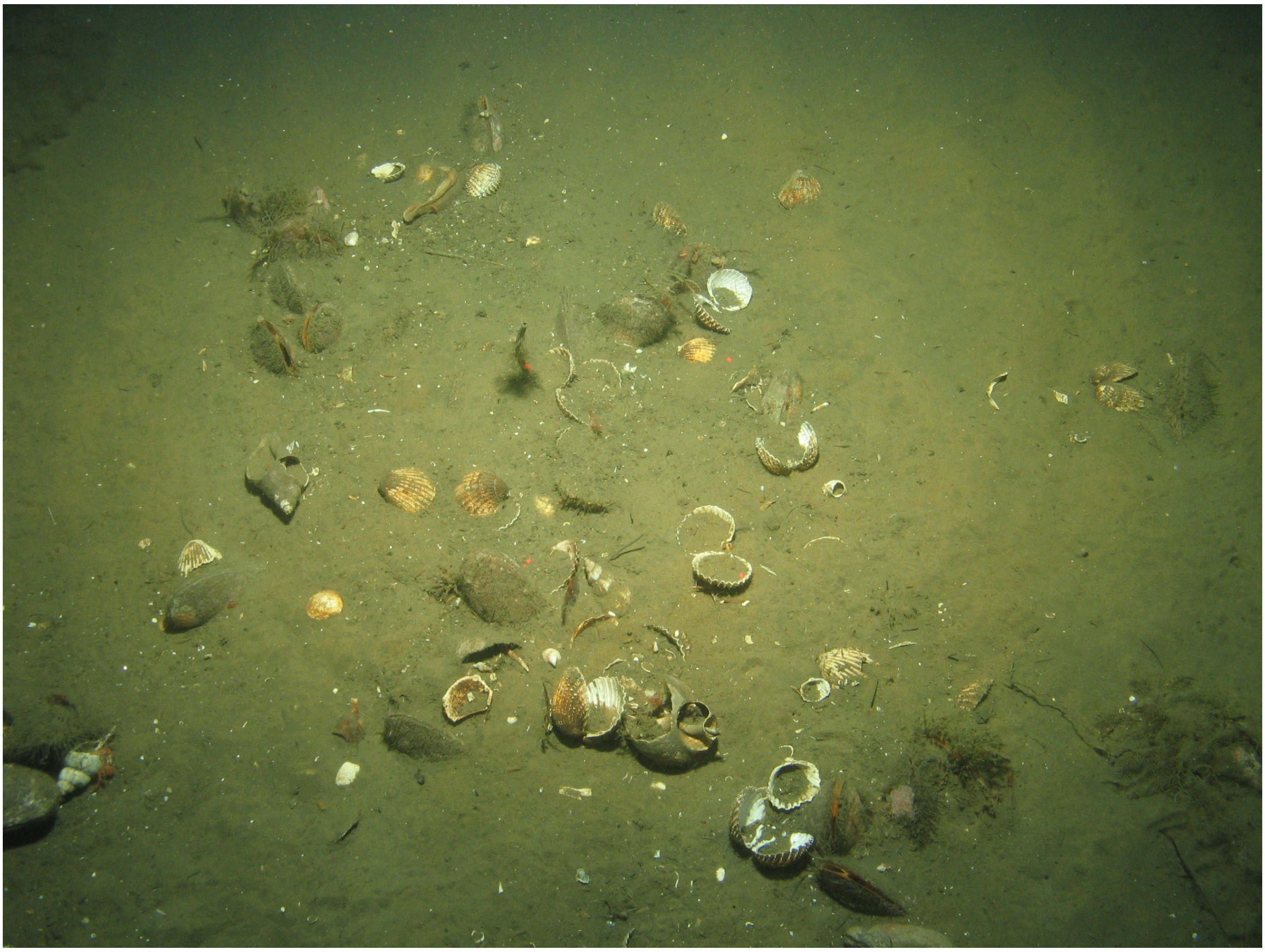
Extensive reefs formed by the congener *Sabellaria alveolata* have been described in the subtidal within Bridgwater Bay in the upper Bristol Channel (Regional Sea 4) and may be unique to the Bristol Channel (although *S. alveolata* reefs do penetrate some way into the subtidal off parts of the Cumbrian coast, whilst aggregations - mixed with *S. spinulosa* - have been seen in waters deeper than 10m off the Eastern Irish coast). These *S. alveolata* reefs may cover extensive areas of the seabed, particularly where there are tide-swept hard substrata affected by turbid water, which is the case further into the Severn Estuary.

A1a.2.15.2 *Modiolus* beds

The horse mussel (*Modiolus modiolus*) is a widely distributed species which in suitable conditions can establish dense and persistent beds. Although the species is not listed in the Annexes to the EU Habitats and Species Directive, it may be afforded protection under the Directive by virtue of forming biogenic reefs. These beds influence the seabed topography, sediment type and fauna present and can be considered as biogenic reefs.

Modiolus beds are recorded particularly from nearshore areas in Regional Seas 6, 7 and 8 (i.e. on the west coast from the Irish Sea north to Shetland). This habitat is represented in a number of coastal SACs. Their vulnerability to damage from trawling and scallop dredging has recently been evidenced by Cook *et al*. (2013) who recorded a significant reduction in the total number of epifaunal organisms following a single pass of a trawl (90%) or scallop dredge (59%) in experimental sites; the diversity of the associated community and the total number of *M. modiolus* also declined. At both sites declines in anthozoans, hydrozoans, bivalves, echinoderms and ascidians accounted for most of the change. In addition to defined reefs, *Modiolus modiolus* also occurs as scattered small groups of large individuals which can be several decades old; Figure A1a.2.15 shows such an aggregation in the central North Sea (Regional Sea 1) photographed during the DECC SEA monitoring survey in January 2016.

Figure A1a.2.15: Live *Modiolus modiolus* in central North Sea muddy sand; also visible are hydroids and sabellid polychaetes, and recently dead *Acanthocardia* shells



A1a.2.15.3 *Lophelia* reefs

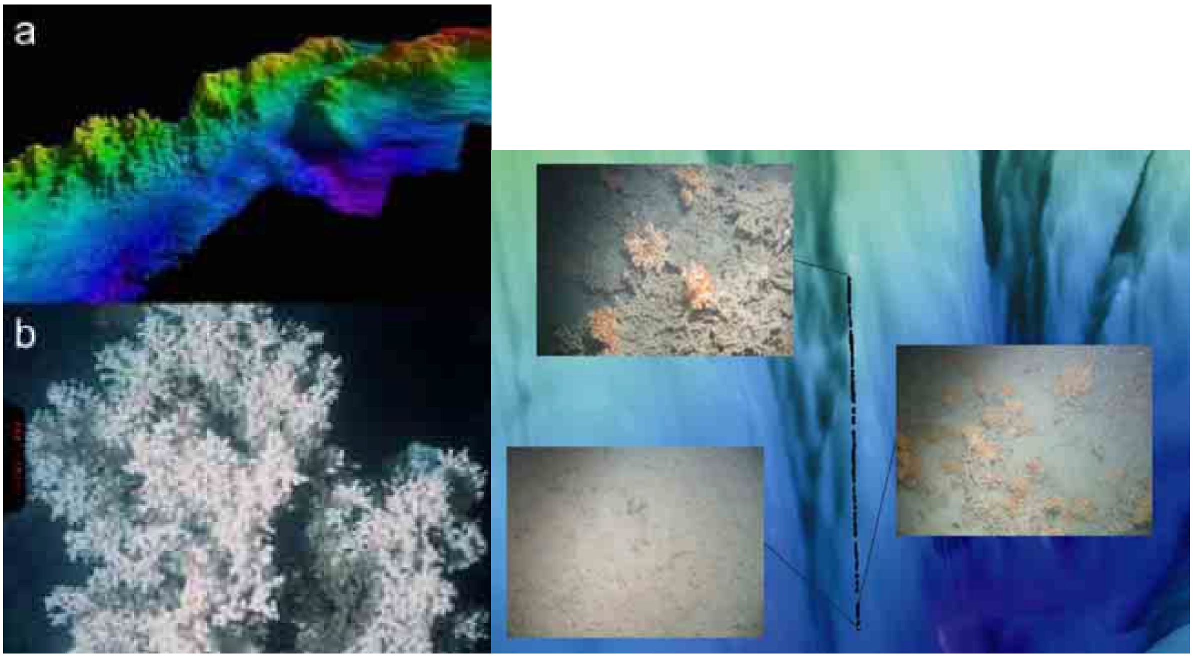
Lophelia pertusa is generally a relatively deep water species recorded in continental shelf edge areas in Regional Seas 4, 5, 8, 9, 10 and 11. A relatively shallow-water reef (the Mingulay complex) is present in the Sea of the Hebrides (Regional Sea 7) and there are scattered records of individual colonies in Regional Sea 1, notably from oil platforms.

L. pertusa reefs frequently occur on the exposed hard substrate of banks, seamounts and shelves usually between depths of 200-400m, but may occur in shallower and much deeper depths. *Lophelia* colonies are distributed sparsely to the west of Shetland, but are more abundant on the south and west flanks of the Rockall Bank (Wilson 1979, Howell *et al*. 2013), Wyville Thomson Ridge, Lousy Bank and Hatton Bank (Roberts *et al*. 2003, 2008); in the Sea of the Hebrides; and at the Celtic Margin (South West Approaches Canyons). During the SEA 7 survey *Lophelia* was also found in the northern part of the Rockall Bank as well as George Bligh Bank (Narayanaswamy *et al*. 2006). Adjacent to the UKCS, *Lophelia* is widely distributed around the Faroese plateau margin and in three well-delineated mound provinces in the Porcupine Seabight and on the Porcupine Bank (Irish waters): the Belgica Mounds (500-1,000m) on the eastern flank, the Hovland Mounds in the north and a large number of buried Magellan Mounds further to the northwest.

During the AFEN surveys of the northern Rockall Trough, colonies of *Lophelia* were discovered capping mounds, known as the Darwin Mounds, at depths of *ca*. 900-1,000m. These mounds are up to 75m in diameter and 5m high, and host an associated community of sessile suspension feeders that occur in close association with the coral (Masson *et al*. 2003), such as the xenophyophore *Syringammina fragilissima* at densities of up to $7m^{-2}$ (Bett 2001). In late 2015, the mounds were designated as an offshore Special Area of Conservation.

Lophelia and other cold-water corals such as *Madrepora oculata* and *Solenosmilia variabilis* create three-dimensional habitats in waters where the seafloor may be relatively featureless. In turn, these corals provide habitat for a wide variety of different species, including fish (Costello *et al.* 2005, Howell *et al*. 2013) and invertebrates (Jensen & Frederiksen 1992, Howell *et al*. 2013).

Figure A1a.2.16: Lophelia pertusa colonies in Regional Seas 5 and 7



Left: (a) Multibeam echosounder survey showing characteristic mounds formed by L. pertusa in the Sea of the Hebrides, (b) Seabed photograph of one of these L. pertusa mounds.
Source: Roberts et al. (2005)
Right: MESH South West Approaches Canyons survey camera tow of C_2_14 showing a biogenic reef, comprising dead and live Lophelia pertusa, with abundant live growths of Madrepora oculata.
Source: Davies et al. (2008)

Diverse invertebrate fauna have been recorded on living reefs, the dead coral framework and the adjacent coral rubble areas. Jensen & Frederiksen (1992) collected 25 blocks of *Lophelia* from the Faroe Shelf and found 4,626 individuals comprising 256 species, while a further 42 species were identified amongst coral rubble. Bullimore *et al.* (2013) attempted to characterise these distinctive coral communities. The Darwin Mounds support a macrofaunal community that appears to be taxonomically distinct from the majority of other sites within the north-east Atlantic. For example, several species such as *Porella laevis, Stegopoma plicatile* and *Eunice norvegica* occurred >75% of the time with *Lophelia* and were absent from neighbouring sites such as the Wyville Thomson Ridge and Faeroes Plateau (Henry & Roberts 2004).

Hall-Spencer *et al.* (2002) observed widespread damage to coral reefs caused by the trawls of commercial fishing vessels on the shelf edges of Ireland and Norway. The passage of the trawl may increase mortality of the coral by crushing, burying or wounding corals, thus increasing susceptibility to infection and epifaunal recruitment which may eventually smother corals (Fosså *et al.* 2002). The destruction of the coral reduces the three-dimensional structure to rubble, decreasing the complexity of the habitat with potential impacts on the associated community composition (Koslow *et al*. 2001, Fosså *et al*. 2002). In studies conducted on the Hebrides slope off Scotland, trawling marks were clearly visible in 2-12% (Roberts *et al*. 2000) and 5-47% of seabed photographs (Lamont & Gage 1998). A 2015 research cruise lead by Howell (Plymouth University) was able to compare an ROV transect over a coral mound on Porcupine Bank with one run 10 years earlier when evidence of trawl damage was observed. The 2015 observer did not note any signs of recovery of *Lophelia*, a point which underlines the species vulnerability and fragility.

A1a.2.15.4 *Zostera* beds

Seagrass beds develop in intertidal and shallow subtidal areas on sands and muds, and are present in all the coastal Regional Seas. They may be found in marine inlets and bays but also in other areas, such as lagoons and channels, which are sheltered from significant wave action. The current distribution and extent of seagrass beds is a small fraction of the historic coverage prior to widespread fungal wasting disease outbreaks in the 1920s-30s (Tubbs 1995).

Three species of *Zostera* occur in the UK, and all are considered to be scarce (present in 16-100 ten km squares; UKBAP). Dwarf eelgrass *Zostera noltii* is found highest on the shore, often adjacent to lower saltmarsh communities, narrow-leaved eelgrass *Zostera angustifolia* on the mid to lower shore and eelgrass *Zostera marina* predominantly in the sublittoral. The plants stabilise the substratum, are an important source of organic matter, and provide shelter and a surface for attachment by other species. Eelgrass is an important source of food for wildfowl, particularly brent goose and widgeon which feed on intertidal beds. Where this habitat is well developed the leaves of eelgrass plants may be colonised by diatoms and algae such as *Enteromorpha* spp, *Cladophora rectangularis, Rhodophysema georgii, Ceramium rubrum,* stalked jellyfish and anemones. The soft sediment infauna may include amphipods, polychaete worms, bivalves and echinoderms. The shelter provided by seagrass beds makes them important nursery areas for flatfish and, in some areas, for cephalopods. Adult fish frequently seen in *Zostera* beds include pollack, two-spotted goby and various wrasse. Two species of pipefish, *Entelurus aequoraeus* and *Syngnathus typhle* are almost totally restricted to seagrass beds, while the red alga *Polysiphonia harveyi*, which has only recently been recorded from the British Isles, is often associated with eelgrass beds.

Five different community types have been identified for seagrass beds from the southern North Sea and the Channel (UKBAP), and 16 microhabitats including the seagrass itself, sessile epifauna, infauna and free swimming animals not confined to a special part of the community. The diversity of species will depend on environmental factors such as salinity and tidal exposure and the density of microhabitats, but it is potentially highest in the perennial fully marine subtidal communities and may be lowest in intertidal, estuarine, annual beds.

Although there has been an identified requirement within the UKBAP action plan for seagrass beds (a priority UKBAP habitat) to compile and publish an up-to-date record of the extent, quality and distribution of seagrass around the UK, this has not yet been comprehensively achieved. Available information from the late-1990s was compiled by Davison (1997) and Davison & Hughes (1998). National distribution patterns for the three *Zostera* species are collated by the MarLIN database, showing patchy distribution within the southern North Sea coastal fringe. Maplin Sands is estimated to have the largest surviving continuous population of dwarf eelgrass in Europe (covering around 325ha).

A1a.2.16 Evolution of the baseline

Over recent geological timescales (*ca*. 11,000 years) seabed habitats around the UK have been subject to continuous processes of change associated with post-glacial trends in sea level, climate and sedimentation. In the shorter term, seasonal, inter-annual and decadal natural changes in benthic habitats, community structure and individual species population dynamics may result from physical environmental influences (e.g. episodic storm events; hydroclimatic variability and sustained trends) and/or ecological influences such as reproductive cycles, larval settlement, predation, parasitism and disease.

Kröncke (1995, 2011) reviewed a series of studies of long-term changes (1980's – 2000's) in North Sea benthos, concluding that consistent changes were evident (south of 58°N) for coastal regions and open sea (excepting the Wadden Sea):

- Increase in biomass (2.5 to 4-fold, peak values 8-fold)
- Increase of opportunistic, short-living species, mainly small polychaetes and bivalves, and ophiuroids and echinoids
- Decrease of long-living sessile species such as several bivalves

Although Krönke (1995) considered the potential effects of hydroclimatic factors, including storm frequency, sea surface temperature (SST) and Atlantic inflow, she concluded (at that time) that entirely natural factors did not explain the large-scale changes found in the communities of the entire North Sea. On the other hand, Krönke (1995, and earlier papers; and confirmed by more recent work in 2011) considered that there was evidence that the changes found were related to anthropogenic impacts such as increased fisheries, eutrophication (via diffuse inflow of nitrates from coastal regions or via the atmosphere) and pollution (point source and diffuse).

Austen *et al.* (1991) compared long-term (1971-88) trends in species abundance data for benthic communities off Northumberland and the Skagerrak, and pelagic data collected in corresponding areas (1958-88) by the Continuous Plankton Recorder (CPR). Statistical analysis (multi-dimensional scaling ordination) showed that changes in community structure at the two benthic stations showed a high degree of similarity, characterised by a transition in the late 1970s. There was a less marked transition between the 1970s and 1980s in pelagic community structure from the eastern North Sea, and no discernible temporal pattern in pelagic data from the Skagerrak. The main focus of the study was benthic-pelagic coupling, and there was no clear identification of the causal factors (including eutrophication and/or pollution).

Clark & Frid (2001) reviewed long-term changes in the North Sea ecosystem, at all trophic levels, and concluded that in the northern, western and central areas of the North Sea, long-term changes were predominantly influenced by climatic fluctuations. Primary productivity during a particular year was related to the effect of weather on the timing of stratification and the resulting spring bloom. In the southern and eastern North Sea, the lack of stratification and the large inputs of nutrients meant that primary productivity was more strongly influenced by variations in anthropogenic nutrient inputs, and was only weakly related to climatic variation. However, the weight of evidence shows that long-term changes in the ecosystem may ultimately be related to long-term changes in either climate or nutrients, although the long-term dynamics of certain taxa and communities do show evidence of being influenced by both anthropogenic factors and/or internal factors such as competition and predation. Many marine species have life cycles that are based upon particular thermal requirements and are therefore sensitive to changes in water temperatures. Temperature changes may also change the thermal or salinity stratification of water bodies, such that the mixing between surface and subsurface water layers is altered, affecting the supply of oxygen and nutrients. The Marine Climate Change Impacts Partnership Annual Report Card 2007-2008 Scientific Review - Seabed Ecology (Frid & Moore) concluded that:

- The available data show that climatic processes, both directly, e.g. winter mortality, and indirectly, via hydrographic conditions, influence the abundance and species composition of sea bed communities.

- These variations will directly affect the availability of food for bottom feeding fish such as cod and haddock, impact on shellfish populations (Nephrops and scallops/clams) and potentially alter patterns of biodiversity and ecological functioning.
- The alteration in the seafloor communities could alter rates and timing of processes such as nutrient cycling, larval supply to the plankton and organic waste assimilation.
- At local (although still large) spatial scales there is also evidence of effects resulting from fishing impacts and at smaller scales habitat modification e.g. wind farms, and impacts from contaminants e.g. oil and gas exploration, waste dumping.

The latest MCCIP Annual Report Card (2015) has a focus on the effects of climate change relevant to marine biodiversity legislation. Findings include the need for flexibility in management of protected areas since key species may disappear from sites in response to seawater temperature increase; biogenic habitats are particularly vulnerable. *Zostera* for example is likely to show increased growth and possibly an increased distribution in response to higher temperatures, whereas maerl is likely to suffer from ocean acidification and therefore decrease in abundance. *Modiolus* beds are predicted to decline in number significantly by 2050 and to be lost completely by 2100 (Gormley *et al.* (2013) as reported in MCCIP 2015). Since *Zostera* and other algae form active CO_2 stores, their protection will be of increasing importance.

As CO_2 levels in the atmosphere increase, the harmful effects of ocean acidification may be felt earlier in the Arctic because CO_2 dissolves more quickly in cold water, hence the northern parts of UK's Regional Seas 8 and 9 may be more at risk. As the acidity of the seawater rises, organisms with calcium carbonate shells, including cold-water corals, may have difficulty forming shells and skeletons. Recent projections suggest that this could start happening as early as 2016 in the Arctic winter, and throughout the year by 2026 (OSPAR 2010c). Over 85% of the UK's known cold water coral reefs are in waters which may be corrosive to them by 2060, with the result that only those within the East Mingulay SAC are predicted to be unaffected by 2099 (MCCIP 2015).

Defra's recent focus on the risk of climate change to ecosystem services (Brown *et al.* 2012) focuses on invasive non-native species and their likely detriment to native communities and ecosystems, the increased risk to species as their distributions shift of disease from new pathogens, and the impacts on areas of high biodiversity value in the coastal zone from increased storms and erosion.

Around UK waters, modelling of the velocity of climate change for sea surface temperature (MCCIP 2013) shows that the rate of increase over the last 50 years has been greater off the east coast than the west and that this pattern is projected to continue over the next 50 years. This modelling can be used to show how a species would need to shift its distribution to track its preferred thermal niche. There is reasonable scientific consensus that a regime change – a large, decadal-scale switch from one dynamic regime to another – took place in the North Sea in the period 1982-88 (Reid *et al*. 2001, Beaugrand 2004, Weijerman *et al*. 2005, van Nes *et al*. 2007). Similar regime shifts have been observed at a variety of scales, notably in the north Pacific in the mid-1970s. Biological and ecosystem indicators of regime shift include phytoplankton and zooplankton, benthic biomass, fish spawning stock biomass and fish recruitment, i.e. principally pelagic components of the ecosystem. It should also be noted that some studies (e.g. Taylor 2002) have found only weak evidence of regime shift at large geographical or ecological (i.e. across trophic levels) scales. It has been hypothesised (Beaugrand 2004 and references therein) that the regime shift resulted from the conjunction of three main (interlinked) features:

- A change in local hydro-meteorological forcing
- A displacement of oceanic biogeographical boundaries to the west of the European continental shelf
- An increase in oceanic inflow into the North Sea

Similar conclusions were reached by Weijerman *et al.* (2005), who described a comprehensive analysis of long-term data series on a wide range of physical and biological parameters from the 1960s to the mid 2000s, using principal component analysis, chronological clustering and regime shift analysis to identify the extent and timing of regime shifts in NW Europe. Their analysis – which included a wide range of pelagic, benthic, fisheries, bird and marine mammal data – indicated that substantial regime shifts occurred in the marine ecosystem in 1979 and 1988 and perhaps also in 1998, although results were less clear-cut in the latter case. These regime shifts were most evident among the biological data series, but they appeared to have been triggered by earlier shifts in a number of environmental factors. Salinity and weather conditions played an important role in the 1979 shift, while in the 1988 shift, temperature and weather conditions were the predominant factors. The North Sea and Wadden Sea results were consistent with a similar analysis of North Pacific data, with concomitant changes in physical and biological indices suggesting a shift in climate–ocean interactions throughout the entire temperate zone of the Northern Hemisphere. The role of the Atlantic Multidecadal Oscillation as an important factor in marine ecosystem changes has been addressed by Edwards *et al.* (2013).

Consideration of the relative importance and interactions between causal factors is based on a combination of statistical correlations, theoretical process interactions, and the sequential timing of supposed forcing factors and biological indicators. There are various conceptual and methodological problems in interpreting the data, and although Beaugrand (2004) speculates that observed changes over the last two decades are “likely to have had profound consequences for exploited resources and geochemical cycles”, the actual causes, significance, longevity and reversibility of regime shift remains uncertain.

Possible mechanisms for a “regime shift” in benthic communities at the Frisian Front in the southern North Sea, from a brittle star *Amphiura filiformis* dominated state to a burrowing mud shrimp *Callianassa subterranea* dominated situation, were modelled by van Nes *et al.* (2007). This study found no indications that food levels or other relevant conditions in this part of the North Sea had changed significantly, suggesting that the change represented a transition between alternative stable community states, possibly related to feedback between the benthic community and sediment stability causing both the shrimp dominated state and the brittle star dominated state to be stable under the same external conditions. Simulation of this mechanism indicated that a modelled system with alternative attractors can show a striking regime shift in response to a randomly fluctuating environment, even if no obvious trigger such as an environmental anomaly or fluctuation appears to be present.

In the western English Channel, fluctuations in benthos have been related to sea temperature, notably exceptionally cold winters, immigrant species, dinoflagellate blooms, and, increasingly, heavy fishing gear (Holme 1983). Fluctuations in western (cold water)[12] species e.g. *Munida rugosa, Echinus acutus* and *Dentalium entalis*) are likely to relate to temperature, as are fluctuations in Sarnian (warm water) species e.g. *Octopus vulgaris, Venus verrucosa* and *Dentalium vulgare*) (Holme 1966). However, the increased use of toothed scallop dredges and heavy chains on trawls to catch sole were recognised as increasingly important factors in determining benthic communities (Holme 1983). In 1998 selected benthic communities were resurveyed to test hypotheses regarding resilience of megabenthic species (*Glycymeris glycymeris* and *Paphia rhomboides*) to fishing disturbance (Kaiser & Spence 2002). Most sites showed temporal changes in bivalve and echinoderm communities, as would be expected over a 40-year period, although two out of ten did not, suggesting that a few areas of the seabed exist with a similar community composition to that before the general increase in bottom-fishing disturbance. These results reflect the patchy nature of benthic communities and highlight the need for further work in this area to interpret such spatial and temporal inconsistencies.

An additional aspect of the evolution of the baseline is the potential for new discoveries of small scale habitats and biotopes which may be of scientific, ecological and conservation importance and changes in perspectives on the relative importance of individual species or biotopes. The deployment of new seabed imaging techniques and methods of investigation such as benthic landers, ROVs and sclerochronology (the application of dendrochronological methods on marine bivalve (shell) growth) has resulted in several such discoveries/reassessments, and there is the expectation that more will follow in the future. For example, the ARAMACC[13] project is an EU-funded international collaboration whose scientific goal is to use the shells of the very long-lived molluscs, such as *Arctica islandica*, as a record of environmental change in the northeast Atlantic Ocean over the past thousand years. This work has already explored a correlation between the chronology of growth indices of *A. islandica* with the modelled inflow to the North Sea through the Fair Isle Channel (Estrella-Martinez *et a*l. 2015).

A1a.2.17 Environmental issues

A1a.2.17.1 Fishing

For some time, the extent and nature of changes at the seabed resulting from fishing activity have been apparent and the subject of reviews including de Groot & Lindeboom (1994), Jennings & Kaiser (1998) and Kaiser & de Groot (2000), with the bibliography of Dieter *et al.* (2003) listing 758 citations on the subject. Effects at the species level may be positive or negative for example, physical damage of large, long lived and fragile species e.g. deep water corals (Wheeler *et al.* 2005), can lead to mortality and potentially local extinction, while other species such as hermit crabs which survive trawling may increase in number, finding a rich supply of food in the discards of fish and killed or damaged benthic organisms. Impacts are greatest in areas with low levels of natural disturbance and are relatively low in areas with high rates of natural disturbance (OSPAR 2010d). At the ecosystem level e.g. seamounts (Clark & Koslow 2007) a shift towards a seabed community where shorter generation, more opportunistic species predominate has been proposed and for which evidence is beginning to accumulate e.g. Frid & Hall (1999) and Hiddink *et al*. (2006).

Virtually all parts of the worldwide continental shelf are, or have been, fished intensively and the types of seabed effects noted above are to be expected. On the shelf in Regional Seas 1 and

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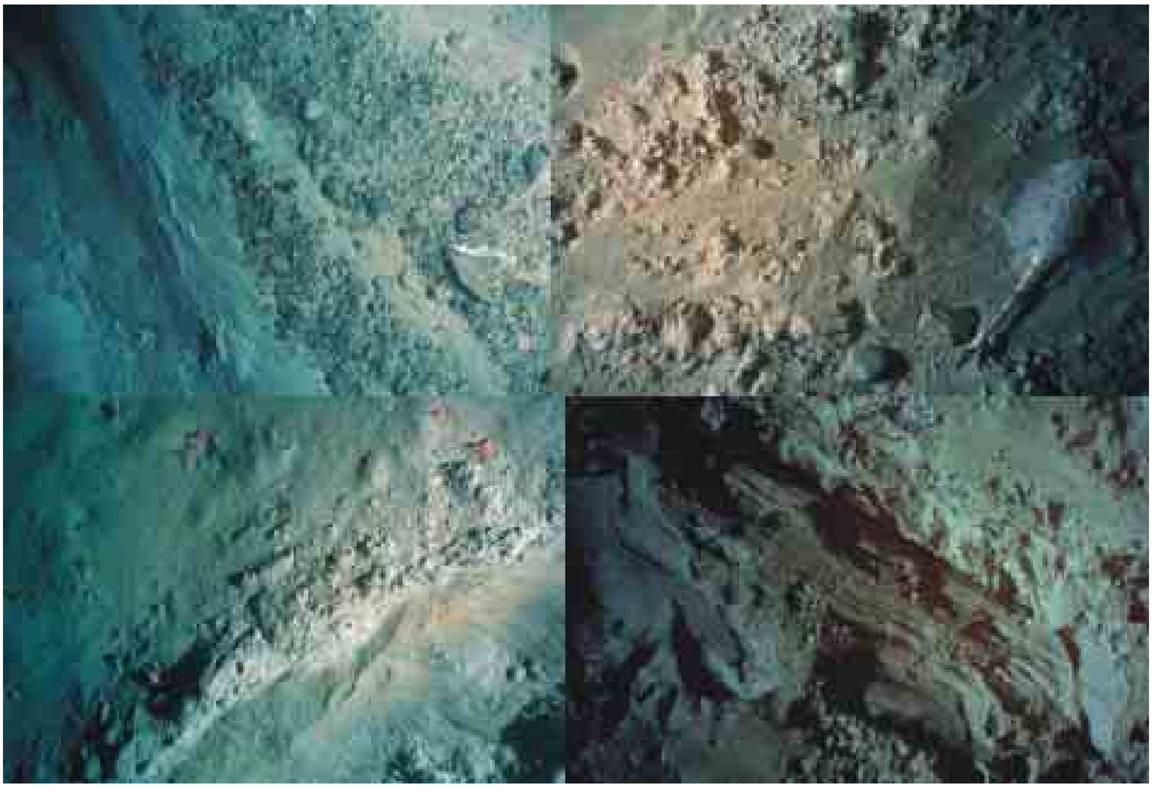
[12] As per Holme (1966), western species penetrate only a short distance into the western Channel; Sarnian species have a Channel Islands-centred distribution.
[13] Annually Resolved Archives of Marine Climate Change (http://aramacc.com/about-aramacc/)

2, beam trawling is reported to have reduced benthic biomass by 56% and benthic production by 21% compared to an unfished situation with recovery taking up to 15 years. Although shallower, coarser and higher energy sediments in general recover faster than deeper water muds, trawling on sandbanks has caused long-term changes and recovery (OSPAR 2010d). In the UK Regional Seas, only the oceanic (abyssal depths) seabed in Regional Seas 5 and 11 might be expected to be reasonably free of the effects of fishing. In Regional Sea 8 for example, Bett (2000) documented the observations of potential fishing impacts recorded during the AFEN 1996 and 1998 and DTI 1999 surveys – in the form of trawl marks and discarded/lost fishing gear observed on the seabed, and a core sample taken in (presumed) trawl disturbed ground. Fishing gear has also been recorded at the Darwin Mounds by Howell *et al*. (2013). The SEA 4 survey in 2000 recorded the presence of trawl marks in the iceberg ploughmark zone to the north of Shetland. The effects of deep-sea trawling on benthic communities is little known, though clearly is likely to be highly destructive to communities of sessile organisms (e.g. corals and sponges) (see Bett 2000 and Gage *et al*. 2005) and OSPAR (2010) notes the mechanical damage to fragile habitats in the deep sea as a concern. Certain vulnerable habitats, e.g. the Darwin Mounds where emergency measures were introduced in 2003/4 under the EU Common Fisheries Policy prohibiting 'bottom trawl or similar towed nets operating in contact with the bottom of the sea' which were succeeded by a permanent prohibition introduced in March 2004 (De Santo & Jones 2007). Some parts of the Rockall and Hatton Banks are also afforded protection by temporary closures to bottom fishing (OSPAR 2010d). The potential application of a lower depth limit of 600m to deep sea fishing is under discussion and is supported by the findings of Clarke *et al.* (2015) that trawling deeper than 600m causes great damage for a reducing benefit to fishermen. Data for this work was acquired through current MSS projects OFFCON, ECOSDEEP[14] and MOREDEEP.

Mapping the sensitivity of benthic habitats to fishing as documented by Hall *et al*. (2008) is another step towards positive management of UK seabed, especially when used in conjunction with management of the UK's MPA network.

[14] ECOSDEEP: ecosystem approach to conservation and contaminant status of Scottish deepwater fish.

Figure A1a.2.17: Seabed photographs showing physical disturbance ("trawl marks") of the seabed presumed to result from the action of demersal trawling in the Faroe-Shetland Channel



Source: Bett (2003)

A1a.2.17.2 Aggregate extraction

Aggregate extraction takes place at numerous discrete, licensed areas in the southern North Sea, English Channel, Bristol Channel and northern Irish Sea (Regional Seas 2, 3, 4 and 6) where sand and gravel is removed by dredger for use on land or for coastal replenishment. Such extraction removes the habitat, kills or disperses the seabed fauna and suspended particles impact the water column during dredging operations. The effects of this localised activity were reviewed by Newell *et al*. (1998) and appear to be similar to the effects of major storms where extensive sediment redistribution occurs followed by recolonisation and an ecological succession. There can be considerable variation in the time taken for complete recovery of communities following aggregate extraction depending upon the environmental conditions, with periods of 5-10 years sometimes being necessary in deeper, moderately stable areas (Newell *et al*. 1998, Robinson *et al*. 2005). The resulting benthic community may be different from that which existed previously as the sediment type may be different (e.g. muddy sand as opposed to clean sand as a result of the changed seabed topography). Characterisation and monitoring of aggregate extraction areas is undertaken by the industry and by industry sponsored funding through a levy system; see for example Tappin *et al.* (2011) Emu *et al*. (2009). James *et al.* (2007, 2010) in relation to Regional Seas 1, 2 and 3 respectively. Other research such as the effects of aggregate extraction on biogenic reefs (Hendrick *et al*. 2011, Pearce *et al.* 2011) is of relevance to operations in the offshore energy industry.

A1a.2.17.3 Disposal at Sea

Since the 1980s disposal at sea of radioactive wastes (stopped in 1982), industrial wastes (1992), colliery mine-stone (1995) and sewage sludge (1998) has been progressively reduced, and is now prohibited. Only the disposal of dredged material from ports, harbours and marinas is presently allowed and the majority of disposal licences are for maintenance operations. This activity is essential to maintain navigation in ports and harbours as well as for the development of new port facilities. There are marine disposal sites in all of the UK's coastal Regional Seas, i.e. with the exception of Regional Seas 5, 9, 10 and 11. In the OSPAR area, there were around 350 dump sites in 2005 (OSPAR 2010d), while in Scotland there are currently 66 open sites routinely used for disposal. A further 50 sites are either closed (not having been used for at least 10 years) or disused (not having been used for at least five years) (Scottish Government 2011). UK policy is to minimise seabed disposal and seek alternatives wherever feasible. During 2009 in Scotland, a total of 2,901,499 tonnes was dredged and deposited of a total of 5,743,882 tonnes that could be allowed under licence. The amount of disposal has remained relatively constant over time. Tonnages deposited are recorded by Marine Scotland and reported to OSPAR. Total UK-wide disposal is higher, with the most recent figures from 2012 total dry weight tonnage being 14,103,597 (OSPAR 2014).

Dredged material is assessed for contaminants before disposal to reduce environmental impacts. In general, dredged material with contaminant levels below a certain threshold can be disposed of at sea. Above this, but below a higher threshold, may require further consideration and testing before a decision can be made, whilst above the higher threshold there is a presumption against disposal at sea. Biologically inert or natural materials may also be considered for disposal. Fish waste (from land based processing) is sometimes disposed of intertidally under licence but this is by no means an annual occurrence. For example none took place in Scotland in the period 2005-2009 (Scottish Government 2011), however 976 tonnes of fish waste was deposited by the UK during 2012 (OSPAR 2014)

About 90% of all sediments dumped each year from OSPAR countries are dredged and dumped in the southern North Sea (QSR 2010). Sediments are part of the marine environment and relocation of non-contaminated sediments to the sea support the natural processes of the sediment balance. Dumping sediments on the seabed may smother and crush organisms living on the seafloor and may cause changes in benthic habitats and biological communities. Changes in community structure are restricted to within 5km of the dumpsite. Continuous maintenance dredging often takes place where navigation channels to ports have high sedimentation rates, such as in estuaries. Areas that are frequently dredged have a permanently changing benthic environment.

Historic disposal at sea consists of munitions dumping from World War I and II. Known dump sites comprise fourteen for conventional weapons located between Regional Seas 1, 2, 3, 4, 6 and 7; and up to four sites for chemical weapons in Regional Sea 10. The little data available on chemical contamination from these sources suggests that there is no detectable contamination of sediments, fish or shellfish from them (QSR, 2010).

A1a.2.17.4 General contamination of the North Sea

The North Sea (especially the southern part), and to some extent the English Channel, Irish Sea and Clyde, are surrounded by large centres of population, agriculture and industry and serviced by some of the busiest shipping lanes in the world. These have resulted in substantial diffuse inputs of nutrients, contaminants[15] and sediments either directly or from atmospheric fallout, which have resulted in a wide range of ecological effects. These effects range from sublethal changes in individuals (e.g. the endocrine disruption caused by tributyltin antifouling paints), to bioenergetic changes through enrichment of the seabed by enhanced phytoplankton

[15] Contaminants reported to OSPAR are cadmium, mercury, arsenic, chromium, copper, lead, nickel, zinc, oil, PAH, nitrogen and phosphorus.

productivity and to the asphyxiation of benthic animals by low concentrations of oxygen following intense phytoplankton blooms.

Such effects are well summarised in QSR (2010) and various OSPAR reports e.g. OSPAR (2014) and in general are viewed as declining in intensity as control measures take effect. They are also regarded as having no significant effect on the seabed fauna of offshore waters. Although Krönke (1992) suggests that the faunal changes noted on the Dogger Bank might be due to eutrophication the alternative explanation of system changes resulting from fisheries interaction is equally possible.

OSPAR Arctic Waters region, which includes part of Regional Sea 9, is the one OSPAR region where pressures from the offshore oil industry are expected to increase; this is in the context of some unacceptable concentrations of PAHs and PCBs already present in the region. In all other UK waters pollution from produced water, incidental spills and drill cuttings has reduced, although some pollution continues (QSR 2010).

A1a.2.17.5 Wrecks and artificial substrates

The deliberate and accidental placement of hard substrates where the seabed is predominantly sand and mud will allow the development of “island” hard substrate communities. Such “islands” occur naturally, for example on glacial dropstones and moraines, but the substantial expansion of the number of hard surfaces due to wrecks and other artificial substrates has a number of potential implications for seabed fauna. Firstly, the additional surfaces can provide “stepping stones” allowing species with short lived larvae to spread to areas where previously they were potentially excluded from. The rapid colonisation of new oil and gas platforms has been documented a number of times (e.g. Forteath *et al.* 1982) and such colonising species can have very rapid growth rates (e.g. the horse mussel *Modiolus modiolus*, Anwar *et al*. 1990), and cause slight enrichment at the seabed through dislodged animals and settlement of the wastes produced (Southgate & Myers 1979). Similarly rapid colonisation of monopiles associated with offshore wind turbines and meteorological masts has also been reported (e.g. Marineseen & CMACS 2004). As well as having a positive impact on habitat introduction and biodiversity, there are potential negative effects from the composition of the biofouling community. In a study to record the fouling marine non-native species in Scotland (Nall *et al.* 2015), nine out of 18 targeted species were found in harbours in the north of Scotland. Recognising the potential for facilitating the invasion of fouling marine non-native species through wet renewable devices, the effects of biofouling on wet renewables were addressed at the 2012 International Conference on the Environmental Interactions of Marine Renewable Energy Technologies and MacLeod (2013) discusses the developing use of software to predict all key characteristics of the biofouling community in any location using geographical area, tidal strength and deployment duration data. In the context of the natural availability of hard substrates (including extensive distribution of glacial dropstones over much of the continental shelf), such effects are only minor.

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