JNCC Report
No: 508

Applying the OSPAR habitat definition of deep-sea sponge aggregations to verify suspected records of the habitat in UK waters

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February 2014

ISSN 0963 8901

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This report should be cited as:

Henry, L.A. &*e* Roberts, J.M. 2014. Applying the OSPAR habitat definition of deep-sea sponge aggregations to verify suspected records of the habitat in UK waters. *JNCC Report* No. 508

Summary

There is currently a limited knowledge of the biodiversity and ecological functioning of deep-sea habitats such as the OSPAR listed habitat “deep-sea sponge aggregations”; however the growing perception is that vulnerable marine ecosystems such as these play an important role in supporting the provision of goods and services from our seas.

Deep-sea sponge aggregations are a habitat type listed on the OSPAR list of Threatened and/or Declining species and habitats (OSPAR agreement 2008-07). An OSPAR background document has been produced which characterises these habitats and records their known distribution across the North-East Atlantic (OSPAR Commission, 2010).

In order to improve our knowledge of this habitat in UK waters, a study was undertaken to further characterise and verifiy suspected records of deep-sea sponge aggregations by applying the habitat definition provided by OSPAR (OSPAR, 2010). A total of 111 suspected records were assessed from areas including the Faroe-Shetland Channel, Wyville Thomson Ridge, Rockall Bank, Rosemary Bank Seamount, Hatton Bank, the Hebrides continental slope, George Bligh Bank and the Hatton-Rockall Basin.

Using the habitat definition from the OSPAR background document for deep-sea sponge aggregations, three criteria were derived against which suspected records were assessed:

- *Density* – Do suspected records conform to the densities of key sponge species as outlined by OSPAR?
- *Habitat* – Do suspected records conform most closely to a ‘deep-sea sponge aggregation’ or would it be better characterised as another habitat type based on the key species present?
- *Ecological function* – Do suspected records support a biological assemblage considered typical of a deep-sea sponge aggregation?

It was considered that density was an important criterion in verifying the presence of deep-sea sponge aggregations. Therefore if suspected records did not meet this criterion they were excluded from further consideration. A suspected record received a tick if just the density criterion was met, two ticks if the density and one other criterion were met, and three ticks if all three criteria were met. The number of ticks correlated to the confidence score assigned to each suspected record, with one tick equating to low confidence, two to medium confidence, and three to high confidence.

The data collation and verification exercises demonstrated numerous records of deep-sea sponge aggregations in UK waters that conform to density, habitat and ecological function criteria. Verified high confidence records were determined in the Faroe-Shetland Channel including the West Shetland Slope, on the Wyville Thomson Ridge, Rosemary Bank, Hatton Bank, the Hebrides continental slope, and in the Hatton-Rockall Basin.

Notably, these aggregations not only included boreal ostur and *Pheronema* grounds as sub-types of the deep-sea sponge aggregation habitat, but also what could be characterised as ‘stalked sponge grounds’, ‘encrusting sponge fields’ and ‘erect glass sponge aggregations’. As such, this study suggests further sub-types of deep-sea sponge aggregations are present in UK waters.

The results from this study will be used to assist in the identification of Marine Protected Areas in UK waters for deep-sea sponge aggregations, as well as in the development of further work areas concerning the conservation of habitats in UK waters.

Contents

1 Background

1.1 OSPAR habitat definition for deep-sea sponge aggregations

Over 80% of the OSPAR area is in 'deep-sea' waters greater than 200m water depth. This makes it challenging to study and manage the effects of natural and man-made perturbations on marine species and habitats in the deep-sea. There has also been a basic lack of knowledge about the biodiversity and ecological functioning of deep-water habitats such as cold water coral reefs, coral gardens and deep-sea sponge aggregations, making these vulnerable to human disturbances because they lack effective management. However the growing perception has been that these vulnerable marine ecosystems supply some of the richest biological diversity in the ocean and perform vital ecosystem goods, services and functions such as providing fisheries and performing key biogeochemical cycles (Hogg *et al* 2010).

OSPAR set out to protect and conserve these resources by developing a list of species and habitats considered to be priorities for protection in the North East Atlantic. The OSPAR List of Threatened and/or Declining Species and Habitats includes the deep-sea habitats, *Lophelia pertusa* reefs, coral gardens and deep-sea sponge aggregations, and case reports were prepared detailing their qualification for inclusion on the list, along with definitions for each. Not only do the case reports consider management plans for species and habitats on the list, but they also set out to identify and map occurrences of these features to help parties to the OSPAR convention develop, for example, MPA networks.

Deep-sea sponge aggregations were formally put forward on the list of Threatened and/or Declining species and habitats (OSPAR agreement 2008-07) and a provisional document was set out to characterise these habitats. The document (OSPAR 2010) defines deep-sea sponge aggregations as occurring in the deep sea (typically > 250m water depth), which are primarily characterised by the presence of structure-forming (usually megabenthic) glass sponges (Class Hexactinellida) or demosponges (Class Demospongiae) in relatively high densities typically ranging from 0.5–24 sponges/m^2 (OSPAR 2010). These habitats are broadly distributed across the globe: in the northeast Atlantic, ranging from densely packed mostly boreal or cold-water 'ostur' (mainly demosponges), to clusters of hexactinellids such as *Pheronema carpenteri* and *Asconema setubalense* that create underlying clay-rich sediment matrices of spicules. A variety of other large (>5cm diameter) sponge species also inhabit the aggregations (ICES 2012) and may contribute to habitat formation.

1.2 Ecological importance of deep-sea sponge aggregations

Although they are patchily distributed across space and time (Gutt & Starmanns 2003), when present, deep-sea sponge aggregations support a high biological diversity including habitats that help sustain fish at various stages in their life cycles (Klitgaard 1995; Bett & Rice 1992; Miller *et al* 2012). Deep-sea sponge aggregations seem to occur in environmental settings similar to those inhabited by cold-water coral reefs and coral gardens across the wider OSPAR region. Interactions between complex topography, strong currents and re-suspension of organic matter are extremely important to feeding, respiration and metabolism in sessile suspension-feeding organisms such as corals and sponges (OSPAR 2010).

A wider global review of deep-sea sponge grounds was also recently prepared for the United Nations Environment Programme's Regional Seas series by Hogg *et al* (2010). Apart from the high three-dimensional structural complexity of many deep-sea sponge aggregations, the role of spicule mats created by the senescence and death of hexactinellid sponges like *Pheronema carpenteri* are also biodiversity hotspots, and may even function to reduce sediment erosion in the deep sea (Black *et al* 2003). The diversity of bioactive compounds and structural elements found in the Phylum Porifera has also attracted bioprospectors and engineers to deep-sea sponge aggregations for pharmaceutical and fibre optic design technology (Hogg *et al* 2010). The importance of sponge grounds to early life history stages of many species of fish such as the redfish *Sebastes* (Miller *et al* 2012) and crabs is also notable as these have significant socioeconomic importance.

1.3 Methodological advances in the identification and delineation of deep-sea sponge aggregations

The OSPAR (2010) definition relied heavily on ground-truthed observations via box core sampling, commercial and survey fisheries bycatch data and photographic/video stations to identify records of the habitat. The majority of known records are currently from OSPAR Region I (Iceland and Norway). However the utility of predictive species and habitat modelling is being rapidly explored, and new models that predict and explain sponge assemblages, such as those formed by *Pheronema carpenteri* (Ross & Howell 2012), may be useful in identifying and spatially mapping other areas of sponge aggregations across the wider OSPAR area.

For now, considerable variation exists in the predictability of sponge assemblages across different models (Huang *et al* 2011), and thus observation-based data still remain the most efficient in delineating these grounds. Canadian fisheries survey data for example have excellent spatial coverage, allowing high densities and biomass of corals and sponges to be identified (Kenchington *et al* 2009; Murillo *et al* 2010; Murillo *et al* 2012). However, most regions in the OSPAR area lack these data, thus defining a vulnerable marine ecosystem such as deep-sea sponge aggregations will be strongly case-specific, dependent on the kind of data available for each region (Auster *et al* 2011).

1.4 Suspected deep-sea sponge aggregations in UK waters

To date, the only verified records of deep-sea sponge aggregations in UK waters held by the Joint Nature Conservation Committee (JNCC) come from the West Shetland Slope in the Faroe-Shetland Channel, although predictive mapping suggest other occurrences along the Wyville Thomson Ridge (Howell *et al* 2011). This dense sponge ‘belt’ occurs in 400–600m water depth in association with glacial iceberg ploughmarks (Bett, 2000, 2001, 2012) and likely forms a near-continuous habitat into Faroese waters. These dense but patchy aggregations of boreal ostur are thought to reflect favourable food supply conditions created by strong currents and high availability of re-suspended organic matter.

However the spatial patchiness of vulnerable marine ecosystems such as deep-sea sponge aggregations in the wider North East Atlantic region (Kenchington *et al* 2009), combined with on-going bottom fisheries impacts and a lack of targeted UK scientific deep-sea sponge surveys across fine and broad scales (ICES 2011), has resulted in a lack of understanding about the present-day occurrence of these habitats in British waters.

Predictive habitat mapping seeks to alleviate some of these problems (Howell *et al* 2011), and mapping work has predicted ostur aggregations on the Wyville Thomson Ridge and the Faroe Shetland Channel, as well as potential *Pheronema carpenteri* aggregations from George Bligh Bank to the Darwin Mounds and between the Hebrides Terrace Seamount and the European continental slope (Ross & Howell 2012). However the history of scientific exploration in British waters is rich with endeavours to understand the deep-sea environment, particularly the north and west of Scotland; therefore an exhaustive review of these data may help reveal an even wider geographical range of deep-sea sponge aggregations in UK waters, and uncover habitat-forming sponge fauna other than ostur and *Pheronema*.

Scientific surveys conducted over a decade ago for the oil and gas industry, during the Atlantic Frontier Environmental Network (AFEN) Atlantic Margin Environmental Surveys (AMES) and surveys by individual operators revealed potential deep-sea sponge aggregations in UK waters (Roberts *et al* 2000; Bett 2001; Axelsson 2003; Henry & Roberts 2004; Bett & Jacobs 2007; Bett 2012). More recent directed multibeam/sidescan habitat mapping, photographic and video surveys (e.g. Strategic Environmental Assessments of the SEA4 and SEA7 regions (Jacobs 2006; Narayanaswamy *et al* 2006; Howell *et al* 2007; Roberts *et al* 2008; Howell *et al* 2010), FRS, JNCC and British Geological Survey expeditions (Narayanaswamy *et al* 2006; Howell *et al* 2009), and the RRS *James Cook* JC060 cruise (Huvenne *et al* 2011) also revealed further potential records of this habitat type. Many suspected records may exist throughout offshore UK waters on Hatton and Rockall Banks, in the Hatton-Rockall Basin, on seamounts in the Rockall Trough, along the Hebrides continental slope and Wyville Thomson Ridge and west of Shetland particularly in the Faroe Bank and Faroe-Shetland Channels. To date there has been no regional scale overview of how this broad range of sponge taxa from across the UK may potentially form deep-sea sponge aggregations, their densities, or their ecological function. Thus, the aim of the present work was to collate these data to provide a regional assessment of suspected sponge aggregations that were then applied to the OSPAR (2010) definition for verification.

2 Identifying deep-sea sponge aggregations in UK waters

2.1 Collating suspected deep-sea sponge aggregation records

In contrast to the well-developed time-series and spatial coverage of some vulnerable marine ecosystems, such as deep-sea sponge aggregations off the eastern Canadian shelf and slope, there are no systematic benthic surveys of sponge bycatch in UK waters. Thus, the identification of suspected deep-sea sponge aggregations around the UK will represent highly conservative estimates of the spatial extent of this habitat.

Due to the lack of standardised fisheries survey data that would have had the greatest spatial extent, verification of records of deep-sea sponge aggregations in UK waters were found through the Geodatabase of Marine Features, Scotland (GeMS) database, as well as publications and data derived through the surveys and cruise reports outlined in Section 1.4. All these data were examined in order to tabulate records of suspected deep-sea sponge aggregations. Although the current OSPAR definition identifies the 250m water depth contour as being around the upper limit of deep-sea sponge aggregation occurrence, it is notable that aggregations of the same species can occur in shallow waters e.g. *Geodia barretti* from Swedish fjords. This bathymetric uncertainty can be avoided if Gage and Tyler's definition of the deep-sea is adopted (i.e. greater than 200m water depth (after Gage & Tyler 1991) which is approximately the depth contour of the shelf break); thus for the purposes of this report, only records from greater than 200m water depth were included.

Additional suspected records of deep-sea sponge aggregations in UK waters were identified based on expert judgement by conducting an exhaustive literature review to collate data. For this exercise, records were included if scientific experts had noted that sponges occurred in high densities, if they formed 'characteristic', 'dominant' or 'conspicuous' parts of the benthic fauna in an image or video transect, or if they have been recorded as at least 'frequent' using the SACFOR scale of abundance.

As video and stills imagery data had not yet been formally analysed by cruise scientists, an even more conservative approach to identifying potential deep-sea sponge aggregations was used in the case of using the unpublished density data collected from the Rockall-Hatton Basin during the JC060 cruise (Huvenne *et al* 2011). Data on sponge abundance per stills image frame were available, with some annotations on the SACFOR abundance of some species. Only records with scores of 'Frequent' or more abundant were included. This ensured in a conservative way that encrusting and low-lying massive forms could be considered as potential deep-sea sponge aggregations. In the case of the hexactinellid bird's nest sponge *Pheronema carpenteri* that is known worldwide to form deep-sea sponge aggregations, only the top three highest abundances were included as a conservative approach to identify high densities of this species.

2.2 Verification of deep-sea sponge aggregation records

Each record identified through the collation exercise outlined in section 2.1 was examined in closer detail to verify if the OSPAR definition of deep-sea sponge aggregations (OSPAR 2010) could be applied. This was achieved using a series of criteria (Figure 1) that combined available density data (published or available through video and images provided to JNCC), comparisons with potentially similar habitats, and information as to what extent the sponge records suggest that the aggregation serves an ecological function through the provisioning of habitat to other species (section 2.3). Each record was then assigned a confidence score (section 2.4) to assess the likelihood that a record truly represents a deep-sea sponge aggregation *sensu* OSPAR (2010).

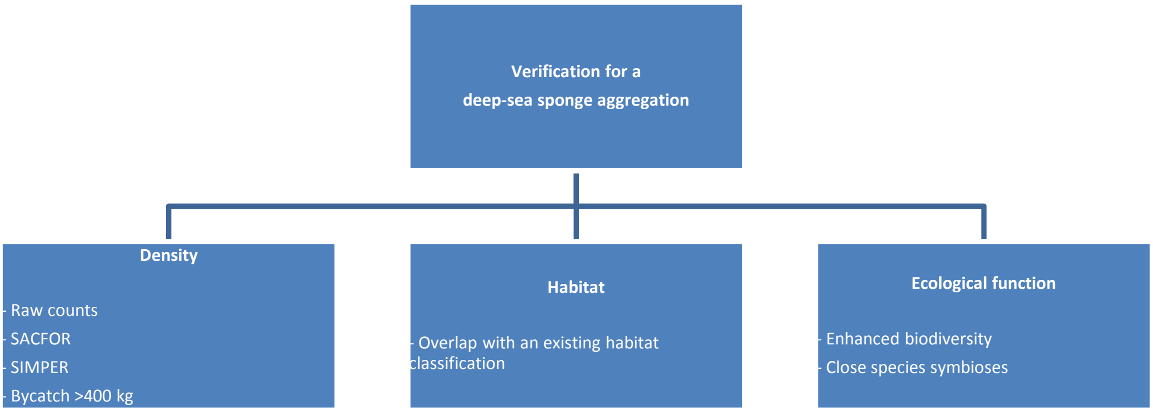

Figure 1. Criteria used to verify suspected records of deep-sea sponge aggregations.

2.3 Criteria for verifying records

Each record was individually reviewed and passed through three criteria for *density*, *habitat* and *ecological function* (described below) to verify whether the OSPAR habitat definition for deep-sea sponge aggregations can be applied in each case (Figure 1).

2.3.1 Density criterion

The OSPAR definition outlines sponge aggregations as having densities ranging from 0.5 – 1 sponge/m^2 in the case of massive forms of demosponges, and at least 4–5 sponges/m^2 for glass sponges such as *Pheronema carpenteri*. It is important to note that densities of morphospecies such as stalked sponges have not been taken into consideration by the OSPAR definition. However, aggregations do not need to exhibit high sponge species diversity, but should possess high densities of a few large species that could be detectable by the naked eye during photo and video surveys or as identifiable fisheries bycatch.

Therefore in some cases, such as with stalked sponges or with presence/absence data, raw counts of abundance or density could not be or were not estimated during analysis. Instead, in order to constitute a sponge aggregation as per the OSPAR definition, records had to demonstrate that sponges were visually detected as the main feature of that habitat using other quantitative methods.

Because collated records were already filtered in section 2.1 to ensure that sponges formed the most ‘characteristic’, ‘dominant’ or ‘conspicuous’ parts of the benthic fauna in a given record, a record passed the density criterion if this density assessment was made using a more quantitative methodology. This could include:

- raw measurements of abundance/density that equal or exceed densities reported in the OSPAR definition (2010), which are generally between 0.5–24 sponges/m^2
- assessments of occurrence categorised as at least ‘frequent’ according to the Marine Nature Conservation Review’s SACFOR scale of abundance
- using the multivariate similarity of percentages (SIMPER) metric to determine that sponges were truly characteristic of an assemblage
- using current (ICES 2012) recommendations that bycatches of sponges exceeding 400kg likely indicate a deep-sea sponge aggregation

The outputs of using SIMPER and biomass estimates to define potential deep-sea sponge aggregations are somewhat problematic. ‘Characteristic’ species according to SIMPER depends on the spatial distribution of the organisms in question, how abundances or occurrences were measured, the type of data transformation used, which similarity metric was employed, or in the case of biomass from fishing bycatch, dry/wet weight standardised to area fished. However although it is not perfect, the ‘tick’ system was employed in order to weight the evidence in support of an area being characterised by high densities of sponges.

2.3.2 Habitat criterion

The OSPAR listed habitat deep-sea sponge aggregations must be identifiable as such. Although community composition of sponge taxa varies between OSPAR regions, the habitat is itself best characterised by one or a set of large (>5cm diameter) sponge species that may or may not dominate the community biomass (OSPAR 2010). Therefore, a sponge record passed the habitat criterion if it could be determined that the assemblage could not be described as anything other than a potential deep-sea sponge aggregation. This was done by determining whether the sponge record could potentially conform to other deep-water habitats. This included habitats structured by OSPAR habitat-forming fauna such as corals, seapens, cerianthid anemones, or *Lanice* polychaetes.

The record received a tick if it could be confirmed that is was characterised by sponges (this is usually done using a SIMPER analysis but could also be via sponges dominating the biomass) or that it did not co-occur with corals, seapens, cerianthids, or *Lanice* polychaetes. If it did co-occur, then the only ways for the record to receive a tick would be if there was an accompanying SIMPER analysis to demonstrate that sponges characterised the assemblages more than other habitat-forming fauna, or if the sponges clearly dominated the biomass over the other habitat-forming fauna. These assessments were determined using the expert annotations and associated fauna information, as detailed in Table 1 and by examining published SIMPER results.

Assessment of the habitat criterion was particularly relevant in distinguishing records of potential deep-sea sponge aggregations from cold-water coral reefs formed by *Lophelia pertusa*. The two habitats often overlap in their environmental niches, although typically sponges are more diverse in areas with reduced live coral coverage (van Soest *et al* 2007). In these cases, assessment of the habitat criterion was made alongside a review of available images and/or video that accompanied each record to determine whether sponges or live *Lophelia* were more representative of the habitat across the entire image or video transect. This is not to say that the two habitats cannot co-exist; typically patchy aggregations of fauna such as coral gardens taxa or sponges can inhabit the dead coral framework zone of cold-water coral reefs (Roberts *et al* 2008). However, only records that could quantifiably demonstrate that sponges more strongly characterised the habitat than live *Lophelia* were given a tick.

2.3.3 Ecological function criterion

The OSPAR (2010) habitat definition identified deep-sea sponge aggregations as supporting rich macrofaunal assemblages, with particular emphasis on their roles as habitats for fauna such as echinoderms (particularly ophiuroids), crustaceans, other sessile epifauna such as hydroids and attached polychaetes, and fish. The ecological function criterion was used to demonstrate that a sponge record appears to be associated with a biologically diverse group or elevated richness of associated species. This was determined by examining the associated fauna column of Table 1 to look for these fauna or by identifying other fauna determined by SIMPER as characteristic of that assemblage represented by that record. This filter also reinforces the concept that a deep-sea sponge aggregation must be defined by its functional role, which can be measured as the extent to which the suspected record has evidence to suggest it supports an associated biological assemblage.

2.4 Confidence

The ‘fit’ of each record was individually assessed as a tick-box exercise using a best-fit assessment matrix. If a record passed at least one of the quantitative density criteria, the record was given a tick. Additional ticks were provided if the record passed the habitat and ecological function criteria. A total of 3 ticks indicated a ‘high’ confidence level, and strongly support the notion that the OSPAR definition of deep-sea sponge aggregations can be applied in that case. Two ticks suggested a ‘medium’ confidence, while records with 0–1 ticks were assigned a low level of confidence.

3 Suspected deep-sea sponge aggregations by region

Table 1 summarises all relevant georeferenced records of suspected deep-sea sponge aggregations available for analysis. This table includes information on depth, dominant substratum, and any biological associations noted at the time.

Adopting the data collation methodology outlined in Section 1.4 a total of 111 suspected records were identified from:

- Faroe Plateau, Faroe Bank Channel, Faroe-Shetland Channel and north of Shetland (n=34)
- Wyville Thomson Ridge (n=8)
- Rockall Bank (n=37)
- Rosemary Bank (n=6)
- Hatton Bank and Hatton Drift (n=10)

- the Hebrides continental slope (n=1)
- George Bligh Bank (n=7) and
- Hatton-Rockall Basin (n=8).

Many records included annotations about a rich biological diversity associated with the sample (video, image or benthic sample), including potential symbioses such as ophiuroids with an encrusting sponge on East Rockall Bank (Howell *et al* 2009).

Although most records were not associated with cold-water coral reefs, there were 23 records of potential deep-sea sponge aggregations that overlapped with outcrops and reefs of the scleractinian framework-forming coral *Lophelia pertusa* on Rockall, Rosemary and George Bligh Banks (Narayanaswamy *et al* 2006; Howell *et al* 2007; Roberts *et al* 2008; Howell *et al* 2009; unpublished data from Marine Scotland Science survey 2011). Additionally, 35 suspected records occurred alongside gorgonians, antipatharians, scleractinian cup corals, hydrocorals and seapens, which could indicate multiple overlaps with Coral Gardens habitat in UK waters.

Table 1. Suspected records of deep-sea sponge aggregations in UK waters by geographic area (full details are provided in Appendix I). Associated fauna are also noted (NI refers to no information on associated fauna were available).

Record	Sponge species or expert annotation	Associated fauna (other than sponges)	Reference
Faroe-Shetland Channel, Faroe Bank Channel, Faroe Plateau, and north of Shetland (n=34)			
1	‘fan sponges’	squat lobster	Bett and Axelsson 2000
2	‘extensive sponge growth’	*Munida*, cidarids, asteroids, spatangids	Bett and Axelsson 2000, Axelsson 2003
3	‘extensive sponge growth’	cushion starfish	Bett and Axelsson 2000, Axelsson 2003
4	‘sponge zone’	echinoids and asteroids	Bett and Axelsson 2000, Axelsson 2003
5	‘massive sponges’	NI	Bett and Axelsson 2000
6	‘large sponge’	NI	Bett and Axelsson 2000
7	‘extensive seabed cover of close-encrusting sponges’	NI	Bett and Axelsson 2000
8	‘well developed sponge fauna’	cidarid urchins and sea cucumbers, fish including *Helicolenus* sp.	Bett and Jacobs 2007
9	‘high density populations of stalked sponges’	burrows, pycnogonids, seastars, fish	Bett and Jacobs 2007
10	‘dominated by…tubular white sponges’	rays (elasmobranchs), seastars, pycnogonids, octocorals, fish	Bett and Jacobs 2007
11	‘branched sponges common’	ling, urchins, geryonid crabs, modest epifauna	Bett and Jacobs 2007
12	‘massive sponges common’	stone crabs, gastropods, cidarids, brachiopods, ling	Bett and Jacobs 2007
13	‘fauna dominated by…sponges’	crinoids, fish, pycnogonids, cerianthid anemones	Bett and Jacobs 2007

14	'abundant population of stalked sponges'	sabellids, seapens, hydroids, pycnogonids, cerianthid anemones, fish	Bett and Jacobs 2007
15	'dense populations of stalked sponges'	many burrows in sediments, enteropneusts, pycnogonids, hydroids, seapens, anemones, octocorals, fish	Bett and Jacobs 2007
16	'abundant populations of stalked sponges'	sabellid-type worms, pycnogonids, seapens, hydroids, enteropneusts, fish	Bett and Jacobs 2007
17	'fair number of rocks with…branched white sponges'	octocorals, ophiuroids, sabellids, seastars, anemones, tunicates, pycnogonids, fish	Bett and Jacobs 2007
18	'better developed epifauna…[including] sponges'	ophiuroids, fish, sabellids, seapens, octocorals, tunicates, crinoids, anemones, pycnogonids	Bett and Jacobs 2007
19	'sponges (massive, tubular and bottle-brush)…the most evident fauna'	octocorals and fish	Bett and Jacobs 2007
20	'tubular sponge frequent'	octocorals, seapens, seastars, gastropods, hydroids and fish	Bett and Jacobs 2007
21	'highly abundant [one sponge /m^2] stalked sponge population'	NI	Bett 2007
22	an abundance of…sponges…throughout'	*Myxine glutinosa*, burrowing anemones	Howell *et al* 2007, 2010
23	abundance of...encrusting and erect sponges'	ophiuroids, tunicates, bryozoans, hydroids	Howell *et al* 2007, 2010
24	dominated by sponges'	saddle oysters, serpulids, *Munida rugosa, Cidaris cidaris, Helicolenus dactylopterus*, *Parastichopus tremulus*	Howell *et al* 2007, 2010
25	fauna...dominated by sponges'	saddle oysters, serpulids, *Munida rugosa, Cidaris cidaris, Helicolenus dactylopterus, Parastichopus tremulus*	Howell *et al* 2007, 2010
26	fauna…dominated by sponges…in high densities'	saddle oysters, stylasterids, *Caryophyllia, Munida rugosa,* bryozoans, sea stars, urchins	Howell *et al* 2007, 2010
27	fauna…dominated by sponges'	saddle oysters, *Caryophyllia*, serpulids, *Munida rugosa, Cidaris cidaris*, brachiopods, seastars, ophiuroids	Howell *et al* 2007, 2010
28	fauna…dominated by sponges…in high densities'	saddle oysters, serpulids, *Munida rugosa, Cidaris cidaris*, brachiopods, seastars, *Helicolenus dactylopterus*	Howell *et al* 2007, 2010
29	typical fauna…were…sponge'	hydroids, brachiopods, seastars, soft corals	Howell *et al* 2007, 2010

30	dominant fauna were...sponges'	hydroids, brachiopods, *Cidaris cidaris*, squat lobsters	Howell *et al* 2007, 2010
31	'typical fauna were…sponges'	sea stars, urchins	Howell *et al* 2007, 2010
32	'typical fauna were…sponges'	sea stars, ophiuroids	Howell *et al* 2007, 2010
33	fauna were predominantly encrusting sponges'	hydroids, ophiuroids, *Stichastrella rosea*, hagfish	Howell *et al* 2007, 2010
34	particularly with an abundance of sponges' including *Geodia*	hydroids, *Cidaris cidaris*, brachipods, sea stars, squat lobsters	Howell *et al* 2007, 2010
Wyville Thomson Ridge (n=8)			
35	erect lobe-shaped whitish sponges (possibly *Phakiella* spp.) were frequently encountered', including *Phakellia robusta*	*Cidaris cidaris*, rich epifauna inlcuding bryozoans, hydroids, polychaetes, isopods, ophiuroids, bivalves, octocorals, barnacles	Henry and Roberts 2004
36	‘plentiful seafloor covering of…sponges’	ophiuroids, anemones, crinoids, tube worms	Jacobs 2007
37	dominant fauna were encrusting and erect sponges'	*Cidaris cidaris*, anemones, squat lobsters, stylasterids, soft corals	Howell *et al* 2007, 2010
38	numerous morphospecies	ophiuroids, polychaetes, hydroids, actinaria, *Caryophyllia*, urchins, stylasterids, brachiopods	Howell *et al* 2007, 2010
39	frequently observed including many morphospecies of encrusting sponge,…erect sponge'	ophiuroids, erect bryozoans, anemones, soft corals, hydroids, sea stars	Howell *et al* 2007, 2010
40	characteristic fauna inlcuded…sponges'	saddle oysters, *Caryophyllia, Munida rugosa, Helicolenus dacylopterus*	Howell *et al* 2007, 2010
41	'characteristic fauna inlcuded…sponges'	saddle oysters, stylasterids, *Caryophyllia, Munida rugosa, Helicolenus dacylopterus*	Howell *et al* 2007, 2010
42	numerous morphospecies of…sponge'	*Caryophyllia*, anemones, stylasterids, bryozoans, sea stars, squat lobsters, *Helicolenus dactylopterus*	Howell *et al* 2007, 2010
Rockall Bank (n=37)			
43	‘deep-sea sponge aggregations’	holothurians	Rockall Bank 2011 survey
44	‘deep-sea sponge aggregations’	holothurians, actinarians, *Lophelia*	Rockall Bank 2011 survey
45	‘deep-sea sponge aggregations’	holothurians, actinarians, *Lophelia*	Rockall Bank 2011 survey
46	‘deep-sea sponge aggregations’	epifauna	Rockall Bank 2011 survey
47	‘deep-sea sponge aggregations’	epifauna	Rockall Bank 2011 survey

48	'deep-sea sponge aggregations'	NI	Rockall Bank 2011 survey
49	'deep-sea sponge aggregations'	NI	Rockall Bank 2011 survey
50	'deep-sea sponge aggregations'	NI	Rockall Bank 2011 survey
51	'possible deep-sea sponge aggregations'	epifauna, possible *Lophelia*	Rockall Bank 2011 survey
52	'deep-sea sponge aggregations	epifauna, possible *Lophelia*	Rockall Bank 2011 survey
53	'deep-sea sponge aggregations'	epifauna, possible *Lophelia*	Rockall Bank 2011 survey
54	'deep-sea sponge aggregations'	gorgonians, *Lophelia*	Rockall Bank 2011 survey
55	'deep-sea sponge aggregations'	*Lophelia*	Rockall Bank 2011 survey
56	'deep-sea sponge aggregations'	*Lophelia*	Rockall Bank 2011 survey
57	'deep-sea sponge aggregations'	*Lophelia*	Rockall Bank 2011 survey
58	'deep-sea sponge aggregations'	gorgonians, *Lophelia*	Rockall Bank 2011 survey
59	'deep-sea sponge aggregations'	gorgonians, epifauna, possible *Lophelia*	Rockall Bank 2011 survey
60	'deep-sea sponge aggregations'	*Lophelia*	Rockall Bank 2011 survey
61	'deep-sea sponge aggregations, rather sparse'	epifauna	Rockall Bank 2011 survey
62	'deep-sea sponge aggregations, rather sparse'	epifauna	Rockall Bank 2011 survey
63	'sparse deep-sea sponge aggregations'	epifauna	Rockall Bank 2011 survey
64	'sparse deep-sea sponge aggregations'	antipatharians, *Lophelia*	Rockall Bank 2011 survey
65	'sparse deep-sea sponge aggregations'	epifauna	Rockall Bank 2011 survey
66	'sparse deep-sea sponge aggregations'	epifauna	Rockall Bank 2011 survey
67	'sparse deep-sea sponge aggregations'	epifauna	Rockall Bank 2011 survey
68	'…globose sponge forms…dominate the image'	hydrozoans, bryozoans, serpulids	Howell *et al* 2009; Long *et al* 2010
69	'heavily encrusted with at least five species of encrusting sponge'	ophiuroids, *Munida*, caryophyllids, serpulids, brachiopods	Howell *et al* 2009; Long *et al* 2010
70	'large white erect lobose sponge is the most conspicuous element'	ophiuroids, *Munida*, bryozoans	Howell *et al* 2009; Long *et al* 2010
71	'yellow, erect, globose sponge is a conspicuous…element'	hydroids, *Munida*, bryozoans, ophiuroids	Howell *et al* 2009; Long *et al* 2010

72	'pale yellow erect globose sponge is of note with at least three other morphospecies'	bryozoans, brachiopods, serpulids, *Munida,* ophiuroids	Howell *et al* 2009; Long *et al* 2010
73	'most conspicuous…is a large…branching sponge…and at least five other species'	anemones, caryophyllids, bryozoans, *Munida*, ophiuroids	Howell *et al* 2009; Long *et al* 2010
74	'most conspicuous elements are…patches of a yellow globose sponge'	*Lophelia*, shrimp, caryophyllid, bryozoans	Howell *et al* 2009; Long *et al* 2010
75	'most conspicuous is a large..encrusting…sponge'	ophiuroids, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
76	'most conspicuous is a large..encrusting…sponge'	ophiuroids, *Munida*, bryozoans	Howell *et al* 2009; Long *et al* 2010
77	'most conspicuous is a large..encrusting…sponge'	ophiuroids, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
78	'conspicuous forms include the encrusting sponge'	ophiuroids, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
79	'most prominent features are…sponge'	hydrocoral, ophiuroids, anemones, caryophyllids, echinoids, scallop, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
Rosemary Bank (n=6)			
80	'white encrusting sponges...Hexactinellida sp.'	*Cidaris cidaris*, anemones, decapods	Rosemary Bank MSS survey: Axelsson *et al* 2012
81	'white encrusting sponges...Hexactinellida sp.'	*Cidaris cidaris*, *Munida*, anemones	Rosemary Bank MSS survey: Axelsson *et al* 2012
82	'white encrusting sponges...Hexactinellida sp.'	burrows, high abundance of amphiurid urchins	Rosemary Bank MSS survey: Axelsson *et al* 2012
83	conspicuous fauna included…sponges'	*Cidaris*, *Phelliactis*, *Psolus*	Howell *et al* 2007
84	blue encrusting sponge,…cup sponges	decapods*, Psolus*, *Madrepora*, stylasterids, anemones, *Lepidion*	Howell *et al* 2007, 2010
85	conspicuous fauna included encrusting sponges'	*Lophelia, Psolus, Stichopathes, Madrepora, solitary corals*	Howell *et al* 2007, 2010
Hatton Bank and Hatton Drift (n=10)			
86	*Craniella* sp., Hexactinellida	*Trachyrhynchus murrayi*, *Macrourus berglax*	Durán Muñoz *et al* 2009
87	sponge bycatch (1), mostly geodiids	gorgonians, seapens	Durán Muñoz *et al* 2012
88	sponge bycatch (2), mostly geodiids	seapens	Durán Muñoz *et al* 2012
89	sponge bycatch (3), mostly geodiids	seapens	Durán Muñoz *et al* 2012
90	sponge bycatch (4), mostly geodiids	gorgonians, seapens	Durán Muñoz *et al* 2012
91	'several distinctive vase-shaped sponges…abundant'	*Psolus*, galatheid crab	Narayanaswamy *et al* 2006; Roberts *et al* 2008

92	‘several distinctive vase-shaped sponges…abundant’	*Psolus*, ophiuroids	Narayanaswamy *et al* 2006; Roberts *et al* 2008
93	‘several distinctive vase-shaped sponges…abundant’	*Stichopathes*, *Psolus*, ophiuroids	Narayanaswamy *et al* 2006; Roberts *et al* 2008
94	‘several distinctive vase-shaped sponges…abundant’	solitary corals, actinarians, *Psolus*	Narayanaswamy *et al* 2006; Roberts *et al* 2008
95	‘several distinctive vase-shaped sponges…abundant’	NI	Narayanaswamy *et al* 2006; Roberts *et al* 2008
Hebrides slope (n=1)			
96	‘*Hyalonema* sp…conspicuous megafauna’	epizootic zoanthids	Roberts *et al* 2000
George Bligh Bank (n=7)			
97	*Aphrocallistes bocagei*	*Stichopathes*, ascidians, *Lophelia*	Narayanaswamy *et al* 2006
98	*Aphrocallistes bocagei*	*Stichopathes*, ascidians, *Lophelia*	Narayanaswamy *et al* 2006
99	*Aphrocallistes bocagei*	*Stichopathes*, ascidians, *Lophelia*	Narayanaswamy *et al* 2006
100	*Aphrocallistes bocagei*	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006
101	*Aphrocallistes bocagei*	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006
102	*Aphrocallistes bocagei*, *Pheronema carpenteri*	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006
103	*Aphrocallistes bocagei*, *Pheronema carpenteri*	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006
Hatton-Rockall Basin (n=8)			
104	‘cream encrusting Porifera’	*Graneledone* octopus, sabellids, serpulids, *Caryophyllia*, actinaria, ophiuroids, *Munida*, Majidae	Huvenne *et al* 2011
105	green and grey encrusting sponges, boring, lamellate and globose sponges	actinaria, *Caryophyllia*, ophiuroids, Majidae, sabellids, ascidians, *Lanice*	Huvenne *et al* 2011
106	‘grey encrusting Porifera’	actinaria, ophiuroids, crinoids, Majidae, ascidians	Huvenne *et al* 2011
107	‘grey encrusting Porifera’ and 'Porifera massive globose sp. 2'	crinoids, scleractinians, *Graneledone* octopus, ophiuroids, Majidae, actinarians, *Lanice*	Huvenne *et al* 2011
108	*Pheronema carpenteri*	holothurians, sabellids, ascidians, *Munida*, ophiuroids, seastars	Huvenne *et al* 2011
109	*Pheronema carpenteri*	ascidians, sabellids, cerianthids	Huvenne *et al* 2011
110	*Pheronema carpenteri*	cerianthids, ascidians, *Munida*, hydroids, sabellids	Huvenne *et al* 2011
111	dominated numerically by...*Pheronema carpenteri*’	foraminifera, polychaete tubes, galatheid crabs, cerianthids	Hughes and Gage 2004

4 Verified deep-sea sponge aggregations

The verification exercise of section 2.3 and the corresponding confidence assignment outlined in section 2.4 produced many records that could be verified as deep-sea sponge aggregations in UK waters with high confidence, including all records already listed in GeMS (Table 2).

Table 2. Verification of suspected records of deep-sea sponge aggregations in UK waters applying the three criterion and associated confidence level.

Record (from Table 1)	Density	Habitat	Ecological function	Confidence
Faroe Bank Channel, Faroe-Shetland Channel, Faroe Plateau, north of Shetland				
1		✓	✓	MEDIUM
2	✓	✓	✓	HIGH
3	✓	✓	✓	HIGH
4	✓	✓	✓	HIGH
5		✓		LOW
6				LOW
7		✓		LOW
8		✓	✓	MEDIUM
9		✓	✓	MEDIUM
10			✓	LOW
11		✓	✓	MEDIUM
12		✓	✓	MEDIUM
13			✓	LOW
14			✓	LOW
15			✓	LOW
16			✓	LOW
17			✓	LOW
18			✓	LOW
19				LOW
20			✓	LOW
21	✓	✓		MEDIUM
22			✓	LOW
23			✓	LOW
24	✓	✓	✓	HIGH
25	✓	✓	✓	HIGH
26	✓	✓	✓	HIGH
27			✓	LOW
28	✓	✓	✓	HIGH
29	✓	✓	✓	HIGH
30		✓	✓	MEDIUM
31		✓	✓	MEDIUM
32			✓	LOW
33			✓	LOW
34		✓	✓	MEDIUM

Wyville Thomson Ridge				
35			✓	LOW
36			✓	LOW
37		✓	✓	MEDIUM
38		✓	✓	MEDIUM
39	✓	✓	✓	HIGH
40	✓	✓	✓	HIGH
41	✓	✓	✓	HIGH
42	✓	✓	✓	HIGH
Rockall Bank				
43		✓	✓	MEDIUM
44			✓	LOW
45			✓	LOW
46		✓	✓	MEDIUM
47		✓	✓	MEDIUM
48		✓		LOW
49		✓		LOW
50		✓		LOW
51			✓	LOW
52			✓	LOW
53			✓	LOW
54			✓	LOW
55			✓	LOW
56			✓	LOW
57			✓	LOW
58			✓	LOW
59			✓	LOW
60			✓	LOW
61		✓	✓	MEDIUM
62		✓	✓	MEDIUM
63		✓	✓	MEDIUM
64			✓	LOW
65		✓	✓	MEDIUM
66		✓	✓	MEDIUM
67		✓	✓	MEDIUM
68			✓	LOW
69			✓	LOW
70			✓	LOW
71			✓	LOW
72			✓	LOW
73			✓	LOW
74			✓	LOW
75			✓	LOW
76			✓	LOW
77			✓	LOW
78			✓	LOW
79			✓	LOW
Rosemary Bank				
80		✓	✓	MEDIUM
81		✓	✓	MEDIUM
82		✓	✓	MEDIUM
83		✓	✓	MEDIUM

84	✓	✓	✓	HIGH
85	✓	✓	✓	HIGH
Hatton Bank				
86	✓		✓	MEDIUM
87	✓	✓	✓	HIGH
88	✓	✓	✓	HIGH
89	✓	✓	✓	HIGH
90	✓	✓	✓	HIGH
91	✓	✓	✓	HIGH
92	✓	✓	✓	HIGH
93	✓	✓	✓	HIGH
94	✓	✓	✓	HIGH
95	✓	✓	✓	HIGH
Hebrides continental slope				
96	✓	✓	✓	HIGH
George Bligh Bank				
97			✓	LOW
98			✓	LOW
99			✓	LOW
100			✓	LOW
101			✓	LOW
102			✓	LOW
103			✓	LOW
Hatton-Rockall Basin				
104	✓		✓	MEDIUM
105	✓		✓	MEDIUM
106	✓	✓	✓	HIGH
107	✓		✓	MEDIUM
108	✓	✓	✓	HIGH
109	✓	✓	✓	HIGH
110	✓	✓	✓	HIGH
111	✓	✓	✓	HIGH

4.2 Geographic variation in deep-sea sponge aggregations

Verified high confidence records were determined for the Faroe-Shetland Channel including the West Shetland Slope, the Wyville Thomson Ridge, Rosemary Bank, Hatton Bank, the Hebrides continental slope, and in the Hatton-Rockall Basin (Table 2). These are shown in Figure 2 symbolised by deep-sea sponge aggregation sub-type and level of confidence. Notably, these aggregations not only included boreal ostur (e.g. Klitgaard & Tendal, 2004) and *Pheronema* grounds (e.g. "*Holtenia* ground" *Pheronema carpenteri*, Thomson, 1873), but also what could be characterised as stalked sponge grounds (e.g. "*Hyalonema* ground" *Stylocordyla borealis*, Thomson, 1873 – see Bett 2012), encrusting sponge fields and erect glass sponge aggregations. Boreal ostur aggregations are for the first time also verified at deeper depths and outside their more familiar setting on the Faroe-Shetland Channel/Wyville Thomson Ridge using bycatch fishing records on the eastern slope of Hatton Bank. All records are described in more detail below by geographic area, including those that scored low to medium confidence, as additional survey work may reveal new data to advance these records to a higher confidence level in which they constitute deep-sea sponge aggregations.

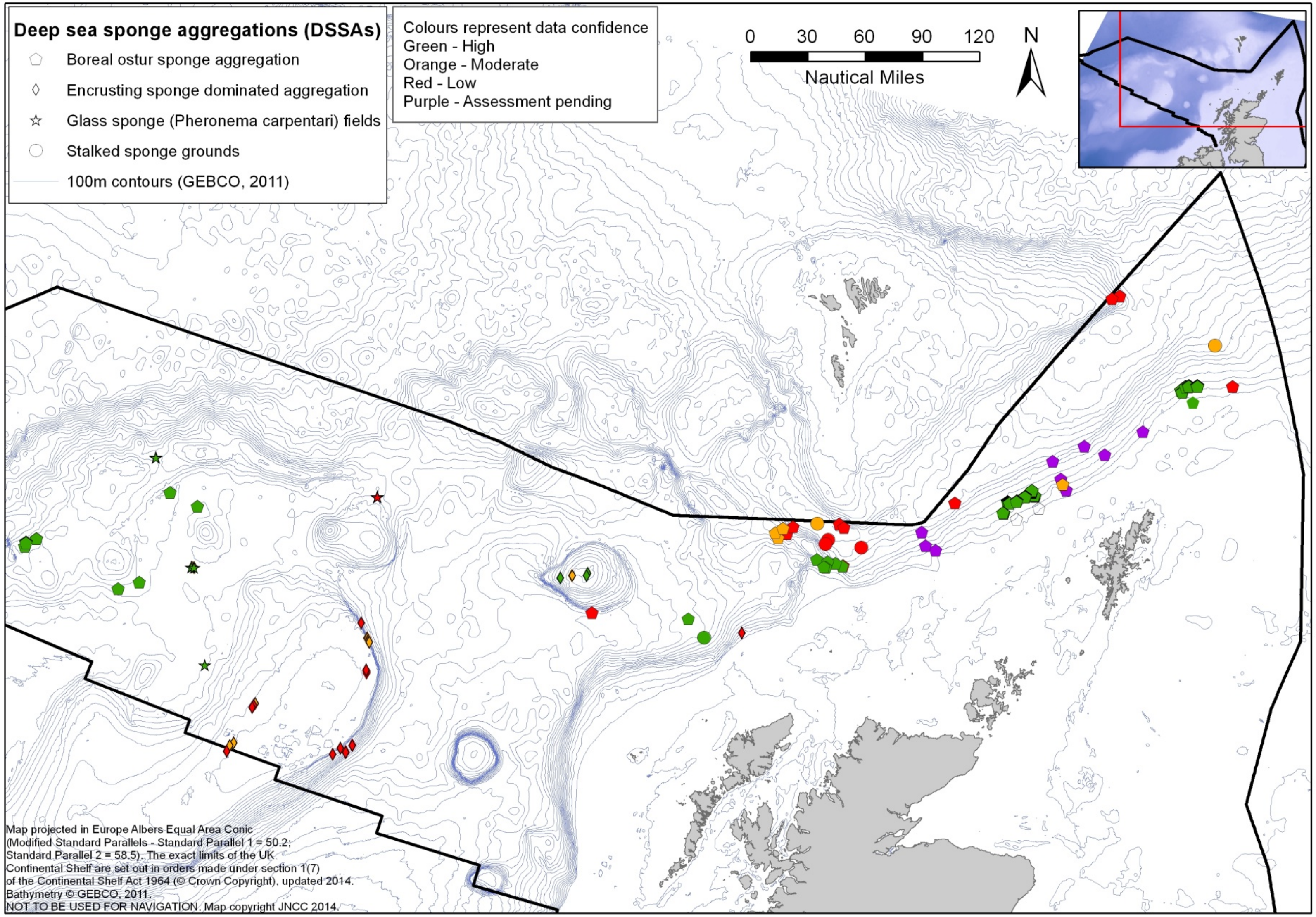

Figure 2. Deep-sea sponge aggregation sub-types in UK waters symbolised by confidence

4.2.1 Faroe Bank Channel, Faroe Plateau, Faroe-Shetland Channel, north of Shetland

Verified high confidence deep-sea sponge aggregation records were already held in GeMS from previous habitat analyses and predictive habitat models (Axelsson, 2003; Howell *et al* 2010, 2011), which the present verification exercise supported (Table 2). This confirmed that sponge grounds occur in the Faroe-Shetland Channel, including the West Shetland Slope (Bett, 2001) as well as in an area north of Shetland (Bett, 2001). These occur in a particularly narrow 'sponge belt' centered around the 500m bathymetric contour and are associated with iceberg ploughmarks on mixed gravelly sediments and occasional boulders in waters that range in temperate from about -2 to 8°C. Densities of sponges in the sponge belt ranged from 0.001–0.818 sponges/m^2 (Axelsson, 2003).

These aggregations in the Faroe-Shetland Channel, including the West Shetland Slope, conform to the description of boreal ostur (Klitgaard & Tendal, 2004; Figure 3): a mix of primarily large structural geodiid sponges such as *Geodia barretti*, *G. macandrewi*, *G. atlantica*, and *G. phlegraei* (synonym for *Isops phlegraei*) as well as numerous other lobose and encrusting species.

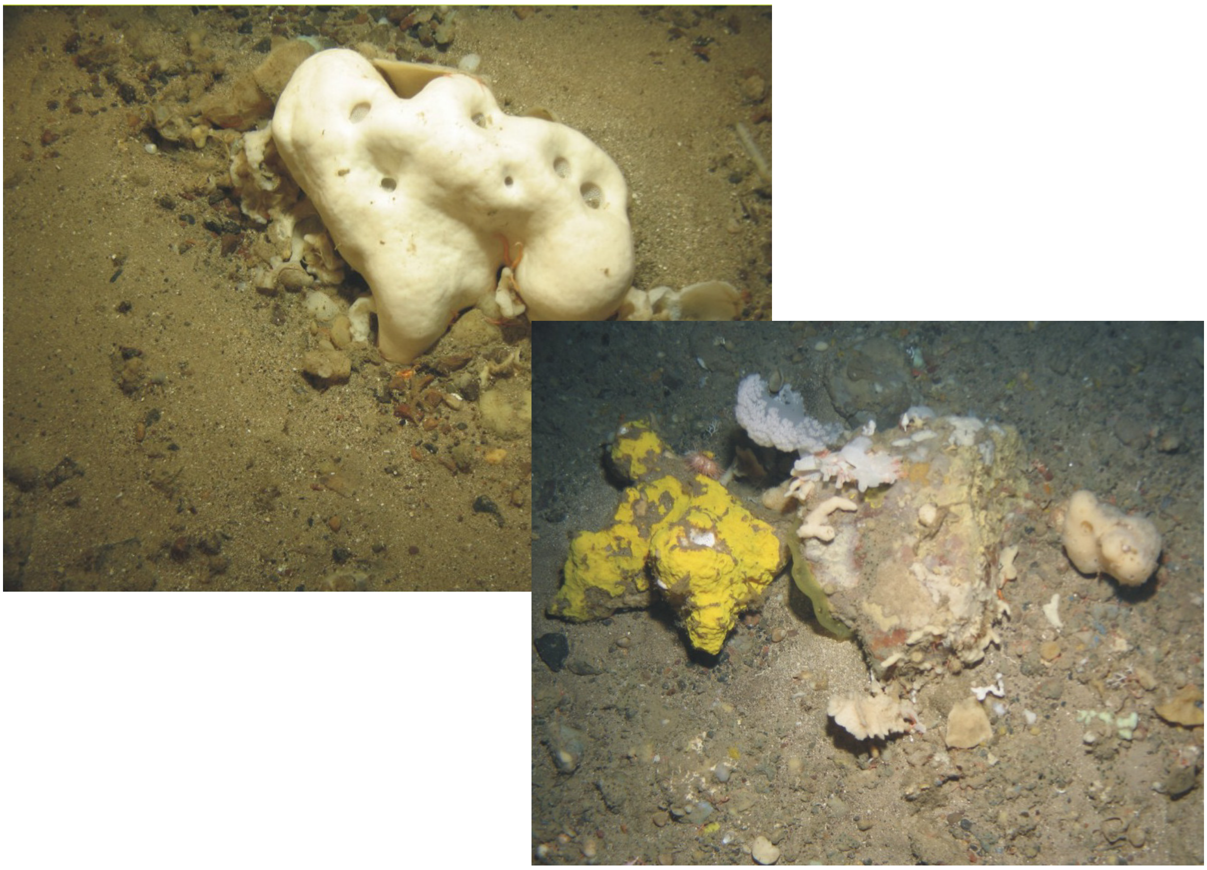

Figure 3. Boreal ostur on the West Shetland slope dominated by large geodiids (upper image), globose and encrusting species such as the yellow *Aplysilla sulfurea* in the lower image (photo credits SEA/SAC 2007 Department of Business, Innovation and Skills).

Boreal ostur in this region supports a high biodiversity of associated species, including *Munida* crabs, ophiuroids such as *Ophiactis balli*, and sessile tubiculous polychaetes (Howell *et al* 2010). Grab sampling of these habitats in UK waters (Bett, 2001) and in Faroese waters (Klitgaard & Tendal, 2004) substantiates the important role of boreal ostur in enhancing macofaunal biodiversity.

Other notable records in this region were records with medium confidence of abundant stalked sponge populations in the eastern end of the Faroe Bank Channel and the southern end of the Faroe-Shetland Channel in waters 963–1045m deep, as well as a population north of Shetland occurring in densities of 1 sponge/m2 (Bett, 2007; Bett & Jacobs, 2007) e.g. “contourite and other deep sand features” in Bett (2012) Enhanced densities (but not high enough to correspond to the OSPAR definition) of the stalked demosponge *Stylocordyla borealis* in the southern Faroe-Shetland Channel (Jones *et al* 2007) suggest that the sponge field identified by the verification exercise as an aggregation (with low to medium confidence) may be structured by this species (as originally recognised by Wyville Thomson in 1873 – see Bett, 2012). However confirmation of these as sponge grounds requires additional density data, habitat classification and/or associated biodiversity information.

There are two other areas in the SEA4 region that may contain ostur (B. Bett, personal communication), but additional quantification is required. The first is the Fugloy Ridge on the northeastern part of the Faroe Plateau at depths of approximately 1000–1500m water depth. Here, gravel is common with cobbles and boulders that may too be present with well-developed epifauna including octocorals and sponges but these instead may conform more to the definition of stony reefs. The second area, on the southern part of the Faroe Plateau in water depths of approximately 800–1200m where the seabed has high cover of gravel and cobble with occasional boulders, is also colonised by well-developed sponge and coral epifauna (Bett, 2007).

4.2.2 Wyville Thomson Ridge

Habitat classifications using SIMPER analyses and predictive habitat modelling identified or predicted deep-sea sponge aggregations structured primarily by boreal ostur on the northern side of the Wyville Thomson Ridge (Howell *et al* 2010, 2011). The verification exercise supports this classification, and identified with high confidence two areas in 457–788m water depth with numerous morphospecies of sponges that characterised the assemblages (Table 2). Cobbles and boulders are the primary substrata for these aggregations in this region, with subzero temperatures at depths >600m.

Examination of the images from the SEA7/SAC report demonstrate the role of large demosponges structuring the habitat, but being accompanied by numerous lobose, lamellate and encrusting species (Figure 4) that may be associated with ostur.

Figure 4. Boreal ostur on the northern side of the Wyville Thomson Ridge is comprised of large demosponges (upper image) as well as numerous other sponge morphospecies. Note the local enhancement of ophiuroids associated with the large demosponge (photo credits SEA/SAC 2007 Department of Business, Innovation and Skills).

4.2.3 Rockall Bank

The verification exercise did not identify any of the 37 records of deep-sea sponge aggregations on the eastern part of Rockall Bank with high confidence (Table 2).

Video sequences from seabed tows conducted by Marine Science Scotland surveys in 2011 were examined that showed the patchy distribution of sponges along the seabed. Quantification of sponge encounters, combined with assemblage analyses e.g. using SIMPER, would provide a robust tool to determine whether sponges characterise the assemblages and if the assemblage is best described as a deep-sea sponge aggregation.

The verification exercise assigned a low to medium confidence level for these records, which according to the video seemed to be comprised of yellow and white lobose sponges on two types of substrata. The first were associated with bioturbated muddy sands, and the occasional cobble ground and boulder in waters 201–257m deep. Typically holothurians, anemones and the occasional *Lophelia* colony were present in these records. The second type of potential aggregation occurred approximately in the same depth band in waters 213–222m deep, but more on hard gravelly sands, cobbles and boulders, and were colonised by epifaunal organisms including *Lophelia* and gorgonians. Only sparse patches of sponges were observed in deeper areas of the survey beyond 775m water depth where boulders were draped in sediments.

Encrusting and lobose white and yellow sponges were also observed along the eastern flank of Rockall Bank (Howell *et al* 2009), on coarse sands, cobbles, boulders, on bedrock and biogenic debris in waters 421–578m deep. These assemblages supported a rich epifaunal community characterised by ophiuroids, *Munida*, Caryophyllidae, and serpulid polychaetes. However, the lower densities of sponges relative to indicator taxa of coral gardens (Long *et al* 2010) suggest these assemblages conform more closely to the *Munida–Caryophyllia* deep-sea mixed substratum assemblage associated with cold-water coral reef communities sensu Howell *et al* (2010), see Figure 5. Thus these likely correspond more closely to other habitats and are unlikely to represent deep-sea sponge aggregations.

Figure 5. Patches of a pale yellow lobose sponge on the eastern flank of Rockall Bank in association with the cold-water coral *Lophelia pertusa* (photo credit JNCC).

Rich sponge assemblages are found along the southwestern flank of Rockall Bank in Irish waters (van Soest *et al* 2007) in association with dead coral framework. These may also represent a variant of deep-sea sponge aggregation types, provided that date could be gathered to establish that the cover or density of live coral does not exceed that of the sponges.

4.2.4 Rosemary Bank

Nearly half of the records from Rosemary Bank were verified as deep-sea sponge aggregations with high confidence (Table 2). These did not conform to the more familiar aggregations of either boreal ostur or *Pheronema* grounds, but instead are comprised mostly of low-lying massive and encrusting fields of yellow, blue, grey and white sponges (Figure 6). These ranged in depth from 842–867m water depth on mostly pebble, cobble and boulder substrata in waters averaging 8°C (Howell *et al* 2007, 2010). *Psolus* were often found in these assemblages, along with the bright orange anemone *Phelliactis*, and occasionally with scleractinian corals including *Lophelia*, *Madrepora* and solitary corals as well as the coiled red-orange antipatharian *Stichopathes*. Although this overlap with indicator species of cold-water coral reefs or coral gardens might seem to preclude these assemblages as deep-sea sponge aggregations, SIMPER identified sponges as being the most characteristic fauna rather than corals in two of these records (Howell *et al* 2010).

Figure 6. An encrusting sponge field comprised of several morphospecies of sponges on Rosemary Bank (photo credit SEA/SAC 2007 Department of Business, Innovation and Skills).

Other potential sponge aggregations may occur on Rosemary Bank, these being primarily characterised by hexactinellid sponges and white encrusting sponges (Axelsson *et al* 2012) and identified as having medium confidence with regards to their designation as deep-sea sponge aggregations due to the lack of density data for these records (Table 2). These aggregations were found in waters 430–760m depth, typically on gravelly mud, sand and sandy gravel in association with *Cidaris cidaris*, *Munida* and *Psolus* as with the encrusting sponge fields identified with high confidence from similar depths during the SEA7 survey (Howell *et al* 2007).

4.2.5 Hatton Bank

Nine out of 10 records from Hatton Bank were verified with high confidence as deep-sea sponge aggregations (Table 2).

Four of these were derived from fisheries bycatch data during Spanish surveys (Durán Muñoz *et al* 2011; 2012), which constitute aggregations that conform to boreal ostur. Bycatches in excess of the recommended ICES limit (ICES 2012) of 400kg were identified, made up mostly of geodiid sponges such as *Geodia* spp. (Figure 7) as well as the occasional catch of axinellids and the glass sponge *Pheronema carpenteri* (Durán Muñoz *et al* 2012). These aggregations were found along the eastern slope of Hatton Bank in waters 1064–1248m deep on a contourite deposit of sands and muds. Seapens and gorgonians were also caught along with boreal ostur, but their biomass was relatively minor in comparison to sponge catches ranging from 404–3000kg and thus these appear to form an associated fauna with these grounds.

Figure 7. Black and white image of large bycatch of geodiid sponges forming boreal ostur along the eastern slope of Hatton Bank (photo credit P. Durán Muñoz, IEO).

A second type of deep-sea sponge aggregation was identified with high confidence from photographic surveys of Hatton Bank (Narayanaswamy *et al* 2006; Roberts *et al* 2008), with densities of vase-shaped glass sponges (possibly *Aphrocallistes bocagei*) approximately 0.3855 sponges/m^2 (Bullimore *et al* 2013). These were found in waters 836–841m deep on mud-draped boulders, pebbles and cobbles. These assemblages supported a high biological diversity of epifauna including *Stichopathes*, *Psolus* and ophiuroids and anemones (Figure 8), which are characterised mostly by sponges and not other habitat-forming fauna (Bullimore *et al* 2013).

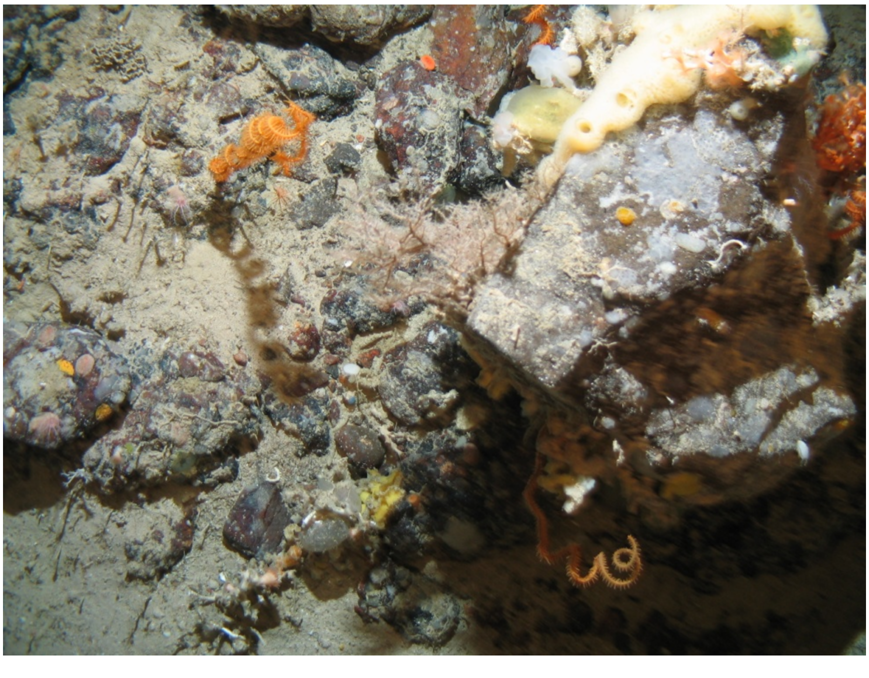

Figure 8. Glass sponge aggregation on Hatton Bank (photo credit SEA/SAC 2007 Department of Business, Innovation and Skills).

A third type of sponge aggregation may also occur on the fine sand sedimentary habitats of the Hatton Drift along the western flank of Hatton Bank. Catches of the spherical demosponge *Craniella* occur along with glass sponges, which characterise bottom trawls at

1298m water depth along with the longsnout and roughnose grenadiers *Trachyrhynchus murrayi* and *Macrourus berglax* (Durán Muñoz *et al* 2009), although the exact locations of these catches are not published. Furthermore indicator species of coral gardens co-occur at depths <1300m on the Hatton Drift, such as *Paragorgia*, *Solenosmilia*, antipatharians and seapens. Similarity analyses revealed these to be characterised by sponges not corals, and therefore the verification exercise would have scored these as deep-sea sponge aggregations with high confidence (Table 2). However the catch per unit effort for sponges on the Hatton Drift is substantially lower than the recommended ICES threshold of >400kg (see Figure 6A in Durán Muñoz *et al* 2012), thus the designation of these as aggregations with high confidence was conservatively scaled back to medium confidence and should remain so until definitive density estimates are known. Future surveys may indeed elevate this area into the High category if bycatch can be standardised or if other density estimates are measured.

4.2.6 Hebrides continental slope

Only one suspected record of deep-sea sponge aggregations exists on the continental slope west of the Hebrides. The verification exercise confirmed this with high confidence as an aggregation, and it seems to comprise yet another type of sponge aggregation in UK waters. Locally enhanced densities, up to 0.11 sponge/m^2 of the stalked hexactinellid *Hyalonema* occur on the slope in waters 1295m deep, on muddy sediments (Roberts *et al* 2000). Although xenophyophores are perhaps generally more characteristic of the wider area (Bett, 2001), *Hyalonema* sp. occurred in 37% of the images analysed by Roberts *et al*, and were thus more characteristic than other habitat-forming fauna found on the slope such as seapens or bamboo corals (Roberts *et al* 2000). These aggregations seem to form an important habitat for epizootic zoanthids, in a large area of the Scottish seabed otherwise devoid of hard substrata (Figure 9).

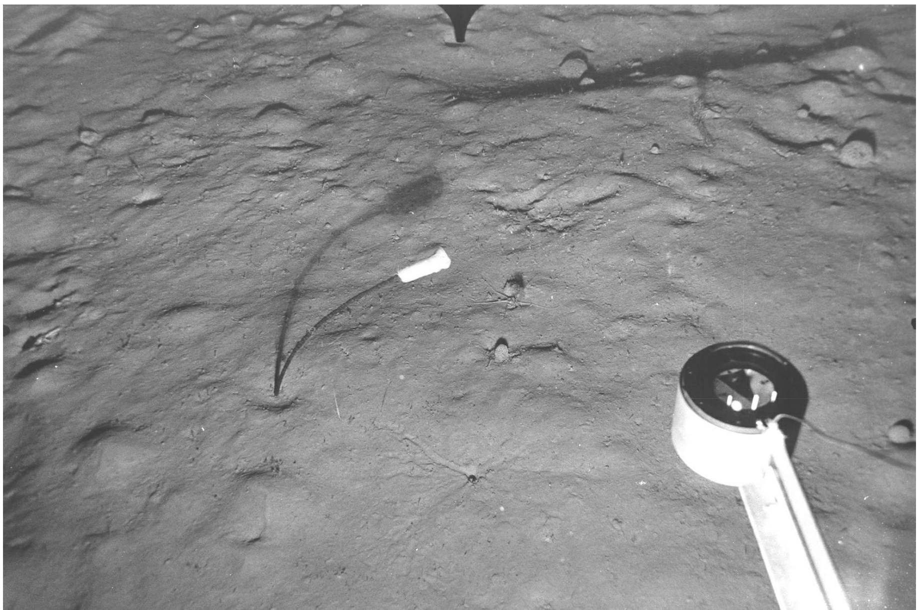

Figure 9. The hexactinellid stalked sponge *Hyalonema* on the Hebrides continental slope, as habitat for a dark coloured epizootic zoanthid on its stem (photo credit Enterprise Oil & JM Roberts).

4.2.7 George Bligh Bank

None of the seven suspected records of deep-sea sponge aggregations on George Bligh Bank could be verified with high or even medium confidence (Table 2), due primarily to a lack of available density or habitat classification data. These potential aggregations are comprised mostly of the hexactinellid *Aphrocallistes* and *Pheronema* in waters 855–1115m deep, on coral framework and boulders interspersed by sandy patches (Narayanaswamy *et al* 2006). These are associated with other habitat-forming fauna such as *Stichopathes*, *Lophelia* and *Keratoisis*, which may represent overlap with cold-water coral reefs and coral gardens. In this respect, these potential aggregations appear similar to those verified with high confidence for Hatton Bank (Narayanaswamy *et al* 2006; Roberts *et al* 2008; Bullimore *et al* 2013). However density data combined with SIMPER analyses could provide a more robust verification.

4.2.8 Hatton-Rockall Basin

The Hatton-Rockall Basin is predicted to support dense aggregations of the bird's nest sponge *Pheronema carpenteri* (Ross & Howell 2012). The verification exercise adopted a conservative approach using photographic and video survey data that supports this prediction, with four records of areas that contain such aggregations particularly in areas with polygonal fault gullies that were not predicted by habitat models. These occur in a narrow depth range in the basin from 1100–1161m water depth on mud, sand and lebenspurren-marked seabed (Figure 10).

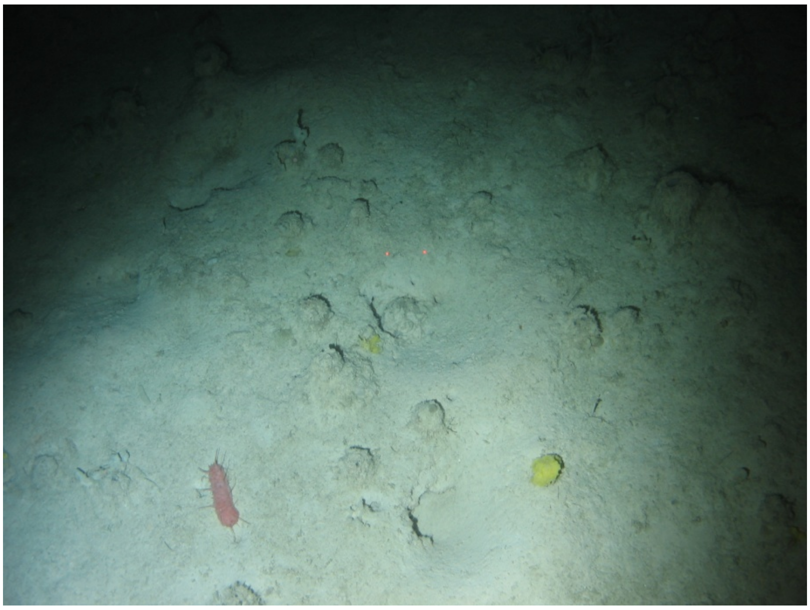

Figure 10. A dense aggregation of the bird's nest sponge *Pheronema carpenteri* (mound shapes in the picture) in the Hatton-Rockall Basin, in association with holothurians, *Lanice* and sabellid polychaetes (laser distance = 10cm apart; photo credit JNCC/JC060 cruise).

Although density data from the most recent survey during the 2011 JC060 cruise (Huvenne *et al* 2011) are unpublished, examination of the images with the top three highest abundance counts in each image frame showed that densities ranged in these three records between 8–10 sponges/m^2, which exceeds that as defined in the OSPAR definition. Densities estimated during the BENBO surveys in the basin measured an average of 1.53 sponges/m^2 (Hughes & Gage, 2004), which is still greater than other aggregations as defined by OSPAR. Although two of these records co-occur with other habitat-forming species such as burrowing cerianthid anemones, from the images these do not seem to be more dense than *Pheronema*, thus it is likely these other fauna are associated with the sponge aggregation and not the other way around.

As they do in the Porcupine Seabight (Bett & Rice 1992), the surrounding sediments appear to host a rich biological diversity including foraminifera, ascidians, terebellid and sabellid polychaetes, cerianthids, hydroids, and *Munida* (Hughes and Gage, 2004; B. Bett unpublished data from the JC060 cruise in Huvenne *et al* 2011). The clay-rich spicule mats produced by *P. carpenteri* aggregations in the Hatton-Rockall Basin also function to help reduce sediment erosion in an otherwise current-swept regime (Black *et al* 2003) that may help further stabilise the biological communities inhabiting these mats.

A second type of deep-sea sponge aggregation verified with high confidence was identified in more shallow waters in the Hatton-Rockall basin in waters around 1170m water depth from images obtained during the JC060 cruise (Huvenne *et al* 2011). This assemblage was characterised by an encrusting grey sponge, which was estimated as occurring as frequent according to the SACFOR scale of abundance (Table 2). A rich associated fauna was found to occur in this image including anemones, ophiuroids, crinoids, and ascidians (Figure 11).

Figure 11. An aggregation of sponges in the Hatton-Rockall basin comprised of numerous encrusting, lamellate and massive globose sponge morphospecies (laser distance = 10cm apart; photo credit JNCC/JC060 cruise).

5 Conclusions

The data collation and verification exercises demonstrated numerous records of deep-sea sponge aggregations in UK waters that conform to density, habitat and ecological function criteria. These range from the more familiar boreal ostur (Klitgaard & Tendal, 2004) and *Pheronema carpenteri* aggregations (Thomson, 1873) to other types of aggregations including stalked sponge grounds (Thomson, 1873) and encrusting sponge fields.

Aggregations of boreal ostur were verified on the north side of the Wyville Thomson Ridge, in the Faroe-Shetland Channel and on Hatton Bank with densities at least as high as 0.818 sponges/m^2, and bycatches of over 3000kg per tow. *Pheronema carpenteri* aggregations were verified in the Hatton-Rockall basin. Fields of encrusting sponges represent a new type of deep-sea sponge aggregation, which were found to occur on Rosemary Bank and in the Hatton-Rockall basin. The sponge species that constitute these aggregations likely differ between these geographic areas, a problem that cannot be resolved using stills image analyses. Furthermore their associated fauna seems to differ, implying distinct associated communities, which further suggests that the two geographic areas each possess a sub-type of encrusting deep-sea sponge aggregation. Finally, although more sparsely distributed than other deep-sea sponge aggregations, locally enhanced abundances of stalked *Hyalonema* sponge populations on the Hebrides continental slope represent a fourth type of aggregation in UK waters that may include Thomson's "*Hyalonema* ground" (*Stylocordyla borealis*) (Thomson, 1873; Bett, 2013). There is also the possibility of "cold-water" ostur sensu Klitgaard & Tendal (2004) on the Faroe Plateau.

The distinction of these types is important, as these aggregations inhabit different environmental niches, support different associated fauna and likely provide unique ecosystem functions. The rich microbial diversity hosted by the boreal ostur component species *Geodia barretti* provides important ecosystem functions such as nitrification (Hoffman *et al* 2009; Radax *et al* 2012), which further supports the idea that deep-sea sponge aggregations play important roles in ocean biogeochemical cycling as nitrogen sinks.

However the distribution of deep-sea sponge aggregations and thus the ecosystem functions they provide are susceptible to environmental changes. Even short-term pulses of warming seawater temperature threaten populations of boreal ostur in fjoridic settings structured by *Geodia barretti*, which greatly reduce live sponge tissue cover (Guihen *et al* 2012). Thus oceanographic trends can play a role in creating temporally heterogenous occurrences of boreal ostur and likely other sponge aggregation types in the wider OSPAR region. Attempts to develop robust models that predict the distribution of sponge fauna and habitats should therefore account for this variability.

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Appendix 1

Details of ‘suspected’ and ‘verified’ deep-sea sponge aggregation records analysed

Sponge species or expert annotation	Latitude	Longitude	Depth (m)	Gear	Substratum	Associated fauna (other than sponges)	Reference
Faroe-Shetland Channel, Faroe Bank Channel, Faroe Plateau, and north of Shetland (n=22)							
‘fan sponges’	60.95667	-2.44733	425	epibenthic sledge station 53927#1	mixed sediments	squat lobster	Bett & Axelsson 2000
‘extensive sponge growth’	61.266	-1.78483	486	WASP station 53921#1	mixed sediments	*Munida*, cidarids, asteroids, spatangids	Bett & Axelsson 2000, Axelsson 2003; GEMS object ID 11699
‘extensive sponge growth’	60.99283	2.493	506	WASP station 53925#1	mixed sediments	cushion starfish	Bett & Axelsson 2000, Axelsson 2003, GEMS object ID 11700
‘sponge zone’	60.96	2.413333	410	WASP station 53916#1	mixed sediments with trawl mark	echinoids and asteroids	Bett & Axelsson 2000, Axelsson 2003, GEMS object ID 11701
‘massive sponges’	62.035	0.315	389	WASP station 54501#1	mixed sediments		Bett & Axelsson 2000
‘large sponge’	58.92667	-9.89333	1886	WASP station 54597#1	boulder		Bett & Axelsson 2000
‘extensive seabed cover of close-encrusting sponges’	59.09833	-7.35833	354	WASP station 54623#1	coarse gravel/boulders		Bett & Axelsson 2000
‘well developed sponge fauna’	59.97867	-7.149833	582	WASP station 55003#1	mixed gravel, cobble, boulder	cidarid urchins and sea cucumbers, fish including *Helicolenus* sp.	Bett & Jacobs 2007

'high density populations of stalked sponges'	60.181	-6.542833	1191	WASP station 55005#2	muddy sands	burrows, pycnogonids, seastars, fish	Bett & Jacobs 2007
'dominated by…tubular white sponges'	60.105	-6.943	883	WASP station 55007#1	large rocks and boulders	rays (elasmobranchs), seastars, pycnogonids, octocorals, fish	Bett & Jacobs 2007
'branched sponges common'	60.0155	-7.21533	476	WASP station 55011#1	dense gravel to rocky ground	ling, urchins, geryonid crabs, modest epifauna	Bett & Jacobs 2007
'massive sponges common'	60.072	-7.1065	522	WASP station 55012#4	iceberg ploughmarks, boulders to open gravel	stone crabs, gastropods, cidarids, brachiopods, ling	Bett & Jacobs 2007
'fauna dominated by…sponges'	60.2225	-6.173167	1167	WASP station 55015#1	variable cobble, gravel, boulders	crinoids, fish, pycnogonids, cerianthid anemones	Bett & Jacobs 2007
'abundant population of stalked sponges'	60.065	-5.709333	963	WASP station 55020#1	sandy, no ripples	sabellids, seapens, hydroids, pycnogonids, cerianthid anemones, fish	Bett & Jacobs 2007
'dense populations of stalked sponges'	60.06417	-6.296667	1045	WASP station 55022#1	muddy sands	many burrows in sediments, enteropneusts, pycnogonids, hydroids, seapens, anemones, octocorals, fish	Bett & Jacobs 2007
'abundant populations of stalked sponges'	60.02567	-6.327333	990	WASP station 55023#1	sandy	sabellid-type worms, pycnogonids, seapens, hydroids, enteropneusts, fish	Bett & Jacobs 2007
'fair number of rocks with…branched white sponges'	62.67083	-2.017333	1352	WASP station 55056#2	muddy sand, sandy muds	octocorals, ophiuroids, sabellids, seastars, anemones, tunicates, pycnogonids, fish	Bett & Jacobs 2007

‘better developed epifauna…[including] sponges’	62.635167	-2.147167	1078	WASP station 55057#1	gravel, rocks	ophiuroids, fish, sabellids, seapens, octocorals, tunicates, crinoids, anemones, pycnogonids	Bett & Jacobs 2007
‘sponges (massive, tubular and bottle-brush)…the most evident fauna’	60.20083	-6.0785	1196	WASP station 55016#1	gravel, cobbles, occasional boulders	octocorals and fish	Bett & Jacobs 2007
‘tubular sponge frequent’	60.61867	-4.266	1022	WASP station 55043#1	gravelly sand with rocks and boulders	octocorals, seapens, seastars, gastropods, hydroids and fish	Bett & Jacobs 2007
‘highly abundant [1 sponge /m^2] stalked sponge population’	62.370167	-0.114167	991	WASP station 55345#1	silty sandy contourite		Bett 2007
an abundance of…sponges…through out'	60.676283 to 60.672383	-3.69515 to -3.60955	626-630	WSC_10	mixed boulder and pebble/cobble	*Myxine glutinosa*, burrowing anemones	Howell *et al* 2007, 2010
abundance of...encrusting and erect sponges'	60.6868 to 60.684083	-3.66823 to -3.674983	628-629	WSC_11	pebbles, cobbles, boulders	ophiuroids, tunicates, bryozoans, hydroids	Howell *et al* 2007, 2010
dominated by sponges'	60.61221 to 60.61598	-3.387916 to -3.3959	454-460	WSC_14	sandy gravel, pebbles, cobbles	saddle oysters, serpulids, *Munida rugosa, Cidaris cidaris, Helicolenus dactylopterus*, *Parastichopus tremulus*	Howell *et al* 2007, 2010
fauna...dominated by sponges'	60.80875 to 60.81402	-2.894467 to -2.9147667	422-442	WSC_15	cobbles	saddle oysters, serpulids, *Munida rugosa, Cidaris cidaris, Helicolenus dactylopterus, Parastichopus tremulus*	Howell *et al* 2007, 2010

fauna…dominated by sponges…in high densities'	60.83703 to 60.85558	-2.9619 to - 2.970217	486- 518	WSC_16	sandy gravel, cobbles, pebbles	saddle oysters, stylasterids, *Caryophyllia, Munida rugosa,* bryozoans, sea stars, urchins	Howell *et al* 2007, 2010
fauna…dominated by sponges'	60.796317 to 60.787983	-3.060767 to -3.068683	479- 491	WSC_17	sandy gravel, cobbles, pebbles	saddle oysters, *Caryophyllia*, serpulids, *Munida rugosa, Cidaris cidaris*, brachiopods, seastars, ophiuroids	Howell *et al* 2007, 2010
fauna…dominated by sponges…in high densities'	60.74197 to 60.73272	-3.19803 to - 3.20092	485- 494	WSC_18	sandy gravel, cobbles, pebbles	saddle oysters, serpulids, *Munida rugosa, Cidaris cidaris*, brachiopods, seastars, *Helicolenus dactylopterus*	Howell *et al* 2007, 2010
typical fauna…were…sponge'	61.93502 to 61.93675	-0.6072 to - 0.615267	441- 449	WSC_E_1	cobbles, boulders	hydroids, brachiopods, seastars, soft corals	Howell *et al* 2007, 2010
dominant fauna were...sponges'	61.92738 to 61.92267	-0.5843 to - 0.58953	423- 437	WSC_E_2	cobbles, pebbles, sand	hydroids, brachiopods, *Cidaris cidaris*, squat lobsters	Howell *et al* 2007, 2010
typical fauna were…sponges'	West Shetland Channel	West Shetland Channel		WSC_E_3	cobbles/pebbles boulders on muddy sands	sea stars, urchins	Howell *et al* 2007, 2010
'typical fauna were…sponges'	61.98843 to 61.98073	-0.48205 to - 0.486583	477- 481	WSC_E_4	cobbles/pebbles boulders on muddy sands	sea stars, urchins	Howell *et al* 2007, 2010
'typical fauna were…sponges'	62.02718 to 62.0158	-0.45095 to - 0.457367	514- 530	WSC_E_5	cobbles/pebbles muddy sands	sea stars, ophiuroids	Howell *et al* 2007, 2010
fauna were predominantly encrusting sponges'	West Shetland Channel	West Shetland Channel		WSC_E_9	cobbles/pebbles boulders on muddy sands	hydroids, ophiuroids, *Stichastrella rosea*, hagfish	Howell *et al* 2007, 2010

particularly with an abundance of sponges' including *Geodia*	West Shetland Channel	West Shetland Channel		WSC_E_10	cobbles/pebbles boulders on muddy sands	hydroids, *Cidaris cidaris*, brachipods, sea stars, squat lobsters	Howell *et al* 2007, 2010
Wyville Thomson Ridge (n=8)							
erect lobe-shaped whitish sponges (possibly *Phakiella* spp.) were frequently encountered', including *Phakellia robusta*	60.03222	-7.0216667	~540	RVL04#1	pebbles, dropstones	*Cidaris cidaris*, rich epifauna inlcuding bryozoans, hydroids, polychaetes, isopods, ophiuroids, bivalves, octocorals, barnacles	Henry & Roberts 2004
'plentiful seafloor covering of…sponges'	59.8763	-5.9467	800	images, station WTRN_7	bedrock, boulder, rubble	ophiuroids, anemones, crinoids, tube worms	Jacobs 2007
dominant fauna were encrusting and erect sponges'	59.87653 to 59.87438	-6.41057 to -6.421583	462-557	WTR_1	boulders, cobbles, biogenic debris and gravel	*Cidaris cidaris*, anemones, squat lobsters, stylasterids, soft corals	Howell *et al* 2007, 2010
numerous morphospecies of sponge	59.870183 to 59.86647	-5.952717 to -5.959033	626-698	WTR_4	cobble, pebble, boulder	ophiuroids, polychaetes, hydroids, actinaria, *Caryophyllia*, urchins, stylasterids, brachiopods	Howell *et al* 2007
frequently observed including many morphospecies of encrusting sponge,…erect sponge'	59.8815 to 59.8861	-6.0827 to -6.0781	766-788	WTR_5	sand-draped cobbles and boulders	ophiuroids, erect bryozoans, anemones, soft corals, hydroids, sea stars	Howell *et al* 2007
characteristic fauna inlcuded…sponges'	59.87653 to 59.88125	-6.2188 to -6.21937	473-477	WTR_7	cobbles, boulders	saddle oysters, *Caryophyllia, Munida rugosa, Helicolenus dacylopterus*	Howell *et al* 2007, 2010
'characteristic fauna inlcuded…sponges'	59.82785 to 59.82322	-6.22823 to -6.221033	458-462	WTR_11	cobbles, boulders	saddle oysters, stylasterids, *Caryophyllia, Munida rugosa, Helicolenus dacylopterus*	Howell *et al* 2007, 2010

numerous morphospecies of…sponge'	59.82706 to 59.82263	-6.2605 to -6.25935	457-460	WTR_12	cobbles, boulders	*Caryophyllia*, anemones, stylasterids, bryozoans, sea stars, squat lobsters, *Helicolenus dactylopterus*	Howell *et al* 2007, 2010
Rockall Bank (n=37)							
‘deep-sea sponge aggregations’	57.26376	-14.702278	257	Tow2_1	bioturbated muddy sand, cobbles, boulders	holothurians	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.2437	-14.71448	238	Tow2_2	bioturbated muddy sand, cobbles, boulders	holothurians, actinarians, *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.2249	-14.726971	256	Tow2_3	bioturbated muddy sand, cobbles, boulders	holothurians, actinarians, *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	56.8775	-14.811545	201	Tow3_10	bioturbated muddy sand, cobbles, boulders	epifauna	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	56.84335	-14.856246	214	Tow3_15	bioturbated muddy sand, cobbles, boulders	epifauna	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	56.78938	-14.869414	228	Tow3_19	bioturbated soft sediment with boulders and cobbles		Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.07169	-13.256524	659	Tow6_10	boulders, cobbles, pebbles		Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.14375	-13.170746	683	Tow6_17	boulders, cobbles, pebbles		Rockall Bank 2011 survey

‘possible deep-sea sponge aggregations’	57.83807	-13.160128	215	Tow7_1	boulders and cobbles, gravelly sands	epifauna, possible *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations	57.84175	-13.164327	222	Tow7_3	boulders and cobbles, gravelly sands	epifauna, possible *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.84423	-13.16729	217	Tow7_5	boulders and cobbles, gravelly sands	epifauna, possible *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.84998	-13.17354	223	Tow7_13	boulders and cobbles, gravelly sands	gorgonians, *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.8534	-13.177585	216	Tow7_17	boulders and cobbles, gravelly sands	*Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.85627	-13.18105	215	Tow7_22	boulders and cobbles, gravelly sands	*Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	57.85906	-13.184556	218	Tow7_24	boulders and cobbles, gravelly sands	*Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	58.23468	-13.514346	222	Tow7_28	cobbles, boulders	gorgonians, *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	58.12584	-13.336934	217	Tow7_34	cobbles, boulders	gorgonians, epifauna, possible *Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations’	58.12233	-13.331546	213	Tow7_36	boulders and cobbles, gravelly sands	*Lophelia*	Rockall Bank 2011 survey
‘deep-sea sponge aggregations, rather sparse’	58.1269	-13.33905	794	Tow9_4	silty sediment-draped boulders	epifauna	Rockall Bank 2011 survey
‘deep-sea sponge aggregations, rather sparse’	58.12422	-13.33434	775	Tow9_6	silty sediment-draped boulders	epifauna	Rockall Bank 2011 survey

‘sparse deep-sea sponge aggregations’	58.11454	-13.31658	819	Tow9_9	gravelly sands, pebbles, cobbles, boulders and silty sediments in between	epifauna	Rockall Bank 2011 survey
‘sparse deep-sea sponge aggregations’	58.1106	-13.30782	820	Tow9_10	bedrock, boulder, silty sediments and pebbles	antipatharians, *Lophelia*	Rockall Bank 2011 survey
‘sparse deep-sea sponge aggregations’	58.10917	-13.30482	804	Tow9_11	silty sediments with dense pebble cover, in between boulder and bedrock	epifauna	Rockall Bank 2011 survey
‘sparse deep-sea sponge aggregations’	58.10112	-13.29109	820	Tow9_12	silty sediments with dense pebble cover, in between boulder and bedrock	epifauna	Rockall Bank 2011 survey
‘sparse deep-sea sponge aggregations’	58.09826	-13.28586	816	Tow9_13	silty sediments with dense pebble cover, in between boulder and bedrock	epifauna	Rockall Bank 2011 survey
‘…globose sponge forms…dominate the image’	57.12887400	-13.0715478	421.5	ER-O#1_08	coarse sands with bedrock outcrop	hydrozoans, bryozoans, serpulids	Howell *et al* 2009; Long *et al* 2010
‘heavily encrusted with at least five species of encrusting sponge’	57.12593920	-13.0697900	483.3	ER-O#1_39	coarse sands, pebbles, cobbles	ophiuroids, *Munida*, caryophyllids, serpulids, brachiopods	Howell *et al* 2009; Long *et al* 2010
‘large white erect lobose sponge is the most conspicuous element’	57.12402820	-13.0686327	518	ER-O#1_52	coarse sand, cobbles, boulders	ophiuroids, *Munida*, bryozoans	Howell *et al* 2009; Long *et al* 2010
‘yellow, erect, globose sponge is a conspicuous…element’	57.12249600	-13.0676210	557	ER-O#1_66	coarse sands, coral rubble, cobbles,	hydroids, *Munida*, bryozoans, ophiuroids	Howell *et al* 2009; Long *et al* 2010

					pebbles		
'pale yellow erect globose sponge is of note with at least three other morphospecies'	57.12241420	-13.0676621	568	ER-O#1_69	coarse sands and bedrock (or boulders)	bryozoans, brachiopods, serpulids, *Munida,* ophiuroids	Howell *et al* 2009; Long *et al* 2010
'most conspicuous…is a large…branching sponge…and at least five other species'	57.12238500	-13.0676695	568.8	ER-O#1_70	coarse sands, biogenic debris, pebbles, cobbles, bedrock	anemones, caryophyllids, bryozoans, *Munida*, ophiuroids	Howell *et al* 2009; Long *et al* 2010
'most conspicuous elements are…patches of a yellow globose sponge'	57 12.23690	-13.0677179	578	ER-O#1_71	bedrock	*Lophelia*, shrimp, caryophyllid, bryozoans	Howell *et al* 2009; Long *et al* 2010
'most conspicuous is a large..encrusting… sponge'	57.20116750	-13.0063014	446.3	ER-N#1_17	coarse sands, biogenic rubble, pebbles, cobbles	ophiuroids, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
'most conspicuous is a large..encrusting… sponge'	57.20049330	-13.0050403	548.3	ER-N#1_21	coarse sands, biogenic rubble, cobbles	ophiuroids, *Munida*, bryozoans	Howell *et al* 2009; Long *et al* 2010
'most conspicuous is a large..encrusting… sponge'	57.20059730	-13.0050807	545.8	ER-N#1_23	biogenic debris, cobbles	ophiuroids, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
'conspicuous forms include the encrusting sponge'	57.20040140	-13.0044815	559.3	ER-N#1_24	cobbles, pebbles, biogenic debris	ophiuroids, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
'most prominent features are…sponge'	57.19947740	-13.0024923	563	ER-N#1_40	*Lophelia* fragments, biogenic debris, boulders	hydrocoral, ophiuroids, anemones, caryophyllids, echinoids, scallop, serpulids, bryozoans	Howell *et al* 2009; Long *et al* 2010
Rosemary Bank (n=6)							
'white encrusting sponges...Hexactinellida sp.'	59.18767333	-10.3917733	450	video ROSE07403 #1	sandy gravel	*Cidaris cidaris*, anemones, decapods	Rosemary Bank MSS survey: Axelsson *et al* 2012

‘white encrusting sponges...Hexactinellida sp.’	59.18805000	-10.3912000	430	video ROSE07403 #3	sandy gravel	*Cidaris cidaris*, *Munida*, anemones	Rosemary Bank MSS survey: Axelsson *et al* 2012
‘white encrusting sponges...Hexactinellida sp.’	59.18853667	-10.3883016	760	video ROSE07403 #4	gravelly mud, sand	burrows, high abundance of amphiurid urchins	Rosemary Bank MSS survey: Axelsson *et al* 2012
conspicuous fauna included…sponges'	59.248183 to 59.24375	-10.14568 to -10.14702	443-469	RB_1_1	cobbles	*Cidaris*, *Phelliactis*, *Psolus*	Howell *et al* 2007
blue encrusting sponge,…cup sponges	59.177566	-10.56708	842	RB_2_1_008	pebbles, cobbles	decapods, *Psolus*, *Madrepora*, stylasterids, anemones, *Lepidion*	Howell *et al* 2007, 2010
conspicuous fauna inlcuded encrusting sponges'	59.142466	-10.5758	867	RB_2_2_030	coarse pebbles, cobbles	*Lophelia, Psolus, Stichopathes, Madrepora, solitary corals*	Howell *et al* 2007, 2010
Hatton Bank and Hatton Drift (n=10)							
Craniella sp., Hexactinellida	Hatton Drift	Hatton Drift	1298	Hatton Drift bycatch		*Trachyrhynchus murrayi*, *Macrourus berglax*	Durán Muñoz *et al* 2009
sponge bycatch (Geodiids, *Pheronema*, hexactinellids)	57.76666	-17.446666	1247.5	eastern slope	sand, mud contourite deposits	gorgonians, seapens	Durán Muñoz *et al* 2012
sponge bycatch (Geodiids, *Pheronema*, hexactinellids)	57.88833	-17.17	1153.5	eastern slope	sand, mud contourite deposits	seapens	Durán Muñoz *et al* 2012
sponge bycatch (Geodiids, *Pheronema*, hexactinellids)	58.691666	-16.74	1181	eastern slope	sand, mud contourite deposits	seapens	Durán Muñoz *et al* 2012
sponge bycatch (Geodiids, *Pheronema*, hexactinellids)	58.713333	-17.25	1064	eastern slope	sand, mud contourite deposits	gorgonians, seapens	Durán Muñoz *et al* 2012
‘several distinctive vase-shaped sponges…abundant’	58.94897117	-17.6976271	837.5	HB_E&F#1_45	mud-draped rock	*Psolus*, galatheid crab	Narayanaswamy *et al* 2006; Roberts *et al* 2008

'several distinctive vase-shaped sponges…abundant'	58.94896433	-17.6973330	836.8	HB_E&F#1_46	mud, cobbles	*Psolus*, ophiuroids	Narayanaswamy *et al* 2006; Roberts *et al* 2008
'several distinctive vase-shaped sponges…abundant'	58.94880733	-17.6975355	839.2	HB_E&F#1_47	mud, cobbles, rock	*Stichopathes*, *Psolus*, ophiuroids	Narayanaswamy *et al* 2006; Roberts *et al* 2008
'several distinctive vase-shaped sponges…abundant'	58.94863667	-17.6974816	838.8	HB_E&F#1_48	mud-draped rock, cobbles, boulders	solitary corals, actinarians, *Psolus*	Narayanaswamy *et al* 2006; Roberts *et al* 2008
'several distinctive vase-shaped sponges…abundant'	58.94827133	-17.6971675	841	HB_E&F#1_52	mud, pebbles, cobbles, boulders		Narayanaswamy *et al* 2006; Roberts *et al* 2008
Hebrides slope (n=1)							
'*Hyalonema* sp…conspicuous megafauna'	58.977667	-7.9566667	1295	photo transect A	muddy sediments	epizootic zoanthids	Roberts *et al* 2000
George Bligh Bank (n=7)							
Aphrocallistes bocagei	59.32148133	-13.9540645	855.5	photo GB_A#7_0051	coral framework	*Stichopathes*, ascidians, *Lophelia*	Narayanaswamy *et al* 2006
Aphrocallistes bocagei	59.31869183	-13.9539501	902.7	photo GB_A#7_0072	coral framework	*Stichopathes*, ascidians, *Lophelia*	Narayanaswamy *et al* 2006
Aphrocallistes bocagei	59.31769683	-13.9538496	921.3	photo GB_A#7_0080	coral framework	*Stichopathes*, ascidians, *Lophelia*	Narayanaswamy *et al* 2006
Aphrocallistes bocagei	59.31975767	-13.9554883	1115	photo GB_E#1_0028	boulders, flat shelly sand in between	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006
Aphrocallistes bocagei	59.31976417	-13.9553843	1100	photo GB_E#1_0029	boulders, flat shelly sand in between	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006
Aphrocallistes bocagei, *Pheronema carpenteri*	59.31742867	-13.9552798	1076.7	photo GB_F#1_006	boulders, flat shelly sand in between	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006
Aphrocallistes bocagei, *Pheronema carpenteri*	59.31739550	-13.9551841	1104.5	photo GB_F#1_007	boulders, flat shelly sand in	*Lophelia, Keratoisis*	Narayanaswamy *et al* 2006

					between		
Hatton-Rockall Basin (n=8)							
‘cream encrusting Porifera’	58.1844855	16.420574	1175.6	IMG_7872	boulder, mud	*Graneledone* octopus, sabellids, serpulids, *Caryophyllia*, actinaria, ophiuroids, *Munida*, Majidae	Huvenne *et al* 2011
green and grey encrusting sponges, boring, lamellate and globose sponges	58.18016058	16.45642175	1171.5	IMG_7306	boulder, sand	actinaria, *Caryophyllia*, ophiuroids, Majidae, sabellids, ascidians, *Lanice*	Huvenne *et al* 2011
‘grey encrusting Porifera’	58.18449933	16.4210905	1170.0	IMG_7879	boulder, mud	actinaria, ophiuroids, crinoids, Majidae, ascidians	Huvenne *et al* 2011
‘grey encrusting Porifera’ and 'Porifera massive globose sp. 2'	58.18441567	16.42088217	1174.1	IMG_7899	boulder, cobbles	crinoids, scleractinians, *Graneledone* octopus, ophiuroids, Majidae, actinarians, *Lanice*	Huvenne *et al* 2011
Pheronema carpenteri	58.17665184	16.46437225	1168.1	IMG_7805	mud, sand	holothurians, sabellids, ascidians, *Munida*, ophiuroids, seastars	Huvenne *et al* 2011
Pheronema carpenteri	58.176755	-16.4661493	1167.3	IMG_7839	mud, sand	ascidians, sabellids, cerianthids	Huvenne *et al* 2011
Pheronema carpenteri	58.18439233	-16.4231672	1166.8	IMG_7976	mud, sand	cerianthids, ascidians, *Munida*, hydroids, sabellids	Huvenne *et al* 2011
dominated nuemrically by...*Pheronema carpenteri*'	57.425	-15.683333	1100	BENBO station B	lebensspuren', sponge debris and other biogenic sediments and many burrows	foraminifera, polychaete tubes, galatheid crabs, cerianthids	Hughes & Gage 2004