Supplementary Advice on Conservation Objectives for North-East Faroe-Shetland Channel Nature Conservation Marine Protected Area

April 2018

JNCC

jncc.defra.gov.uk

Contents

Introduction

What the conservation advice package includes

The information provided in this document sets out the site's supplementary advice on conservation objectives set for this site. This forms part of JNCC's conservation advice package for the site and must be read in conjunction with all parts of the package as listed below:

- Background document explaining where to find the advice package, JNCC's role in the provision of conservation advice, how the advice has been prepared, when to refer to it and how to apply it;
- Conservation Objectives setting out the broad ecological aims for the site;
- Statements on:
    - the site's protected feature condition;
    - conservation benefits that the site can provide; and
    - conservation measures needed to support achievement of the conservation objectives set for the site.
- Supplementary Advice on Conservation Objectives (SACO) providing more detailed and site-specific information on the conservation objectives (this document); and
- Advice on Operations providing information on those human activities that, if taking place within or near the site, could impact it and hinder the achievement of the conservation objectives stated for the site.

The most up-to-date conservation advice for this site can be downloaded from the conservation advice tab in the Site Information Centre (SIC) accessible on JNCC's website.

The advice presented here describes the ecological characteristics or 'attributes' of the site's protected features: Deep-sea sponge aggregations, Offshore subtidal sands and gravels, Offshore deep-sea muds, an area of the Faroe-Shetland Channel continental slope and Geodiversity features representative of the West Shetland Margin Paleo-Depositional System, Miller Slide and Pilot Whale Diapirs Key Geodiversity Areas. These attributes are: extent and distribution, structure and function and supporting processes.

Figure 1 illustrates the concept of how a feature's attributes are interlinked: with impacts on one potentially having knock-on effects on another e.g. the impairment of any of the supporting processes on which a feature relies can result in changes to its extent and distribution and structure and function.

Collectively the attributes set out in Tables 1 - 4 below, along with the objectives set for each of them, describe the desired ecological condition (favourable) for the site's protected features. Each feature within the site must be in favourable condition as set out in the site's conservation objectives. All attributes listed in the tables below must be taken into consideration when assessing impacts from an activity.

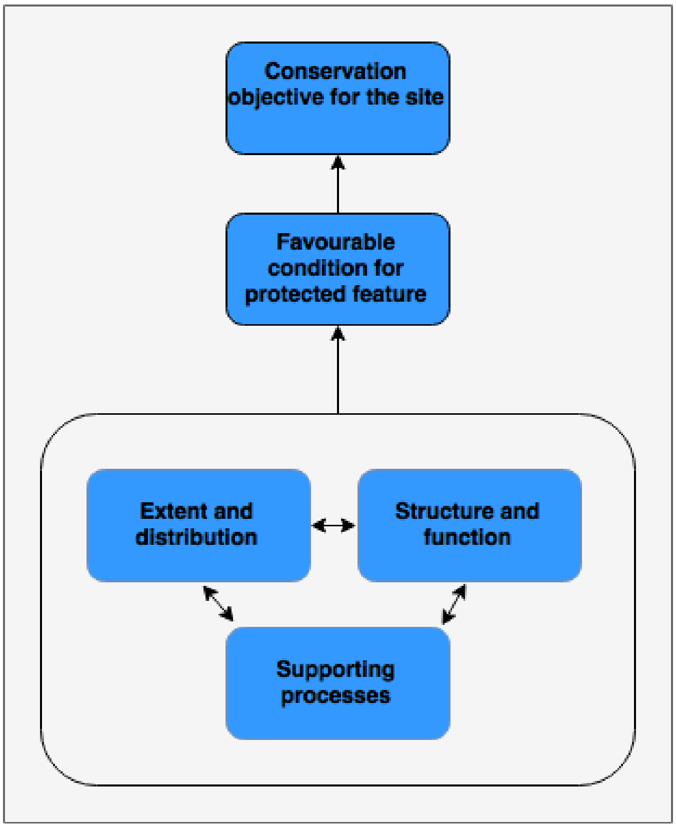

Figure 1. Conceptual diagram showing how a feature's attributes are interlinked and collectively describe favourable condition and contribute to the conservation objectives stated for the site.

The objectives listed in Tables 1 - 4 below reflect our current understanding of each protected feature's condition e.g. where evidence indicates some of a feature's extent is lost and needs to be recovered or that extent is not lost and needs to be conserved in order to ensure the feature is in overall favourable condition. The rationale for setting each objective is also provided in the explanatory notes, along with reference to supporting evidence from the site. Note that where it is not practical through human intervention to recover a feature's attribute, a conserve objective is set, accompanied by a statement to reflect the impracticality of restoration. Note also that when a conserve objective is set, this does not preclude the need for management now or in the future. Please see the conservation measures relating to those activities JNCC consider may require additional management.

Table 1. Supplementary advice on the conservation objectives for Deep-sea sponge aggregations within North-East Faroe-Shetland Channel NCMPA

Attribute: Extent and distribution
Objective: Recover ***JNCC advise a recover objective*** *based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities. Our confidence in this objective would be improved with longer term monitoring. It is important to note however that recovery is expected to occur over a long timeframe in the order of decades or centuries depending on the degree of impact and the suitability of prevailing environmental conditions to support recovery. Activities should look to minimise, as far as is practicable, removal or dislodgement of sponges within the potential extent of Deep-sea sponge aggregations within the site.*
Explanatory notes Deep-sea sponge aggregations are known to have a naturally patchy distribution, influenced by suitable habitat type and wider environmental conditions. Evidence underpinning Deep-sea sponge aggregations are typically point records. It is therefore not possible to map or calculate an area of feature extent within a site. For Deep-sea sponge aggregations extent will be a description of where in the site the conditions are suitable for the feature to occur. The focus for Deep-sea sponge aggregations is on its distribution, i.e. how it is spread out within the site and the factors underpinning its distribution. A reduction in distribution has the potential to alter the biological and physical functioning of the habitat. The distribution of a biogenic habitat such as Deep-sea sponge aggregations can be important in relation to the health and resilience of the feature (JNCC, 2004b). The loss of patches of sponges within the full known distribution of Deep-sea sponge aggregations should be kept to a minimum. A Deep-sea sponge aggregation is a biogenic habitat characterised by the presence of structural sponges that occur above a specified density threshold (OSPAR, 2010a; Henry and Roberts, 2014): • More than 0.5 individuals per m^{-2}; • Registering as at least 'frequent' on the SACFOR scale; or • If bycatches of sponges exceed 400 kg, based on the ICES recommendation (ICES, 2013) for the identification of Vulnerable Marine Ecosystems[1].

[1] While there are occurrences of deep-sea sponge aggregations in UK waters that have been identified through bycatch records, JNCC does not recommend that trawl surveys are used to search for new instances of deep-sea sponge aggregations or monitor known deep-sea sponge aggregations.

In UK waters, four different subtypes of Deep-sea sponge aggregations have been identified (Henry and Roberts, 2014):

1. **Boreal ostur sponge aggregations –** which are characterised by large structural geodiid sponges. Other erect and encrusting sponges may also be present.
2. **Glass sponge fields** – dominated by a single type of glass sponge (Hexactinellidae). Usually these are bird's nest (*Pheronema carpenteri*) sponge fields, but could be formed by aggregations of other species of glass sponges.
3. **Encrusting sponge dominated aggregations** - characterised by low lying massive and encrusting sponges.
4. **Stalked sponge grounds –** characterised by enhanced densities of stalked sponge species, typically on muddy sediments.

Evidence suggests that the sponges comprising Deep-sea sponge aggregation habitat have limited potential to recover from removal, dislodgement, crushing or repeated exposure to significant sediment loading (ICES, 2009). Any recovery of extent will be influenced by the method of reproduction, dispersal potential and the relative location of a potential source population of reproductive adult sponges. Generally, there is little information on the reproduction, recruitment, growth rates and longevity of deep-water sponges (Hogg *et al.*, 2010; Maldonado *et al.*, 2016).

Geodia barretti, which can characterise boreal ostur aggregations, release gametes once or twice a year but less than 30% of the population is involved in reproduction each year (Spetland *et al*., 2007). Number of larvae produced and their dispersal ability varies between shallow water sponge species (Uriz *et al*., 1998; Mariani *et al*., 2006). There is no information on the dispersal and larvae survival of deep-sea sponges, however small sponges within Boreal ostur aggregations are relatively rare suggesting successful reproduction is infrequent (Klitgaard and Tendal, 2004). Sexual reproduction has not been observed in Bird's nest sponges and aggregations are likely to be formed by asexual budding (Maldonado *et al.,* 2016).

Sponge growth rates differ between species, season and environmental conditions (Leys and Lauzon, 1998; Turon *et al.,* 1998*;* Cebrian *et al.*, 2003; McMurray *et al.*, 2008; Duckworth *et al.*, 2012), and larger sponges tend to grow slower than smaller ones (Leys and Lauzon, 1998; McMurray *et al.*, 2008). Based on annual growth rates it is predicted that individual structural sponges can take decades to reach average sizes within the population (Leys and Lauzon, 1998; Klitgaard and Tendal, 2004). The life-history traits of individual sponges indicate that recovery in extent of deep-sea sponge aggregations after mortality or removal of adult sponges may take decades or centuries (ICES, 2009; Hogg *et al.*, 2010).

Extent and distribution within the site

The known extent and distribution of Deep-sea sponge aggregations within the site is available to view via JNCC's Interactive MPA Mapper. The site protects examples of boreal ostur sponge aggregations, typically dominated by *Geodia barretti, Geodia macandrewi, Geodia atlantica, Isops phlegraei, Stryphnus* ponderosus and *Stelletta normani* (Bett 2001; Howell *et al.,* 2007; Howell *et al.,* 2010; Bett, 2012; Henry and Roberts *et al.,* 2014).

Within the site, survey data has recorded sponges occurring in a particularly narrow 'sponge belt' concentrated around the 450 m depth contour in an area of dynamic mixing, where warmer Atlantic waters flow over cooler Arctic waters (Henry and Roberts *et al.,* 2014; O'Connor *et al.,* 2017). The presence of boreal ostur sponge aggregations has been reported with high confidence between the 425 and 475 m depth contours in the south of the site (Henry and Roberts *et al.,* 2014). Further survey work in 2017 also confirmed the presence of Deep-sea sponge aggregations to the left and right of the southerly protruding site boundary following the 425-475 m depth contour (O'Connor *et al.,* 2017).

VMS data from 2009-2015 indicates that demersal trawling occurs within the site along the depth contours associated with the Deep-sea sponge aggregations. Additionally, static gear activity (hooks, lines and gill nets) from UK and non-UK fleets has increased between 2009 and 2015 along the south-east edge of the site. Demersal fishing activities can result in sponges being dislodged and displaced, crushed or brought up to the surface, all of which can kill the sponges (ICES, 2009). Sponges may become caught or entangled in static gears and damaged on the seabed, or brought to the surface. These activities can therefore have a direct impact upon the extent and distribution of deep-sea sponges within the site.

JNCC understands that the site includes locations where offshore infrastructure has been installed. Such installation and decommissioning practices often result in physical damage, smothering and mortality through the introduction of concrete mattresses, cuttings piles and rock dump. This type of activity has the potential to reduce or alter the extent and distribution of deep-sea sponge aggregations within the site.

Whilst future decommissioning activities that do not require rock dump may result in habitat being introduced for deep-sea sponge aggregations that is suitable for colonisation (once oil and gas operations within a site have ceased), this is likely to be a slow process due to the life-history traits of the species (ICES, 2009; Hogg *et al.*, 2010).

Evidence indicates that activities are occurring which are capable of impacting the extent and distribution of the feature within the site. Therefore, **JNCC advise a recover objective**. Our confidence in this objective would be improved with longer-term monitoring and a better understanding of how activities impact the feature. The life-history traits of sponges mean that Deep-sea sponge aggregations develop over decades or centuries (ICES, 2009; Hogg *et al.*, 2010) and therefore extent may not easily be restored through management intervention. Activities should look to minimise, as far as is practicable, removal or dislodgement of sponges within the potential extent of Deep-sea sponge aggregations within the site (425 – 475 m).

For further information on activities capable of affecting the Deep-sea sponge aggregations, please see the Advice on Operations Workbook.

Attribute: Structure and function

Objective: Recover

JNCC consider that there are occurring within the site that can impact the structure and function of Deep-sea sponge aggregations. As such, a recover objective is set for the sub-attributes; sponge composition, sponge abundance, characteristic communities and function. Overall, ***a recover objective is advised*** *for this attribute as a whole and is based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities. Our confidence in this objective would be improved with longer-term monitoring. It is important to note however that recovery is expected to occur over a long timeframe in the order of decades or centuries depending on the degree of impact and the suitability of prevailing environmental conditions to support recovery. Activities should look to minimise, as far as is practicable, further removal, dislodgement or injury of sponges within the potential extent of Deep-sea sponge aggregations within the site.*

Explanatory notes

Structure

Structure with respect to Deep-sea sponge aggregations encompasses:

- **Sponge composition**: namely the species, shape and size of the individual sponges that form the aggregation;
- **Sponge abundance** within the Deep-sea sponge aggregation;
- the presence of **spicule mats**, which have a strong influence on other species; and
- **Characteristic communities** present.

Sponge composition

Sponges are a highly diverse group of organisms and have a range of different morphotypes depending on species and/or environmental conditions (e.g. Fig. 2; Schönberg and Fromont, 2014). Other benthic organisms live on the surface of sponges or within the canals in the sponge's tissue. Sponge morphotype influences the abundance, diversity and composition of organisms living on or in the sponge (Neves and Omena, 2003; Montenegro-González and Acosta, 2010). A significant relationship has been observed between the structural complexity of biogenic structures, such as sponges and corals, and the number of taxa they support (Buhl-Mortensen and Mortensen, 2005; Buhl-Mortensen, 2010). Structural complexity of a sponge could be related to both its morphotype and size. Biodiversity may be increased by enhanced structural complexity because of an increase in the heterogeneity of habitats available for other benthic organisms e.g. providing elevated perches for other filter feeders (Bett and Rice, 1992; Bell, 2008) or refuges from predators (Freese and Wing, 2003). The communities of organisms living on or within individual sponges can also vary between different species of sponge with similar morphologies, possibly due to differences in the structure of the sponge tissue and/or the secondary metabolites the sponges produce (Skilleter *et al.*, 2005; Kersken *et al.*, 2014).

Key species form a part of the habitat structure or help to define a biotope. For Deep-sea sponge aggregations, the habitat structure is formed by the sponge species themselves, and therefore sponges are the key species in this habitat type. The ICES Working Group on Deep-Water Ecology has released a list of structural sponge species frequently found in Deep-sea sponge aggregations in the North Atlantic (see ICES, 2009).

A study of organisms living on stalked sponges found interspecific differences in the height above the seabed that species occupied (Beaulieu, 2001). This indicates that the size of sponges in a Deep-sea sponge aggregation can also influence the associated community, independently of sponge species and morphotype, and that a reduction in the height of sponges within an aggregation could lead to the loss of species from the community.

The diversity of sponge species, morphotypes and sizes within a Deep-sea sponge aggregation will influence the associated community and therefore it is important that these aspects of the structure of the Deep-sea sponge aggregation should be conserved.

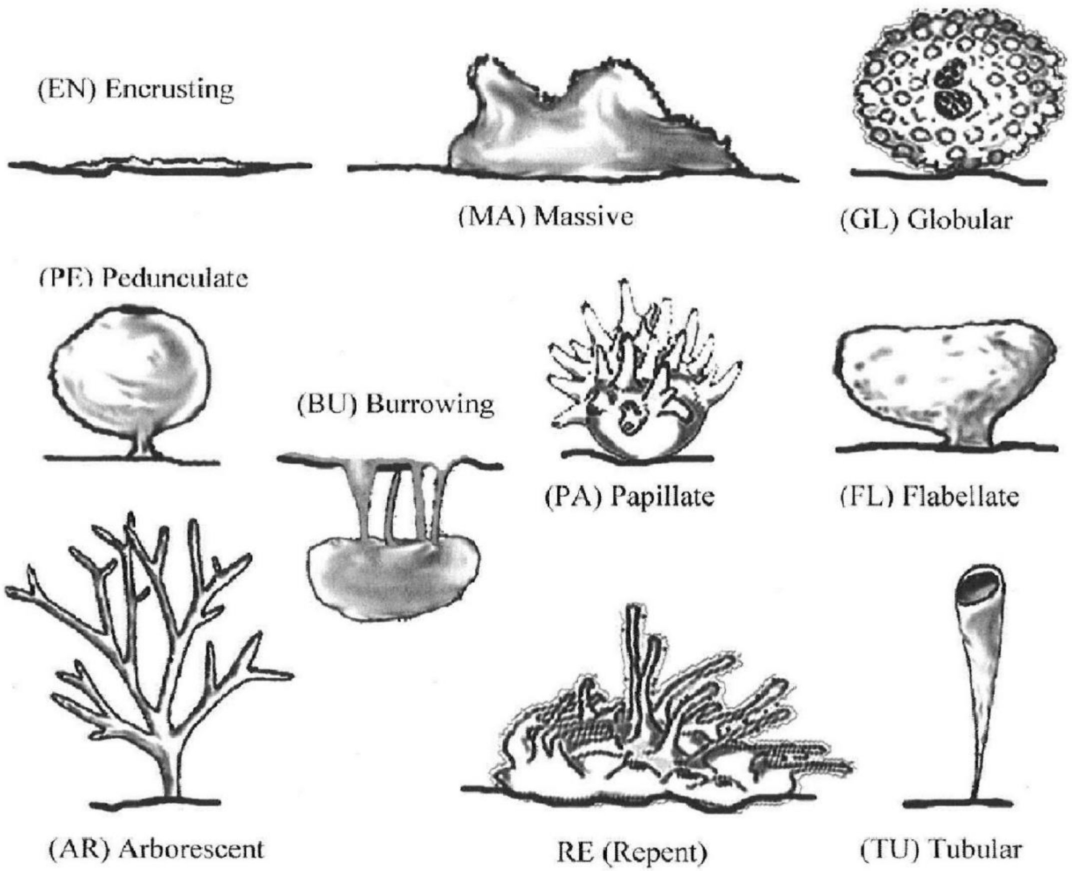

Figure 2. An example range of sponge morphotypes (from Berman *et al*., 2013).

Within the North Atlantic, boreal ostur sponge aggregations are typically composed of large structural sponges, including *Geodia atlantica, G. barretti, G.macandrewii, G. phlegraei, Phakellia sp* and *Stelletta normani* (Howell *et al.,* 2010; Maldonado *et al.*, 2016; OSPAR, 2010a). Other erect, massive and encrusting sponges can also occur within boreal ostur aggregations (Howell *et al.,* 2010; Henry and Roberts, 2014).

If a sponge species can reproduce asexually, fragmentation of larger sponges could potentially increase the population of sponges in a

Deep-sea sponge aggregation but will also reduce the size of the individuals (Hogg *et al.*, 2010). Consequently, although the extent of a Deep-sea sponge aggregation will not be reduced, the structure of the habitat may be altered. Sponges differ in their dispersal ability (Uriz *et al*., 1998; Mariani *et al*., 2006), growth rates (Duckworth *et al.,* 2012), ability to regenerate damaged tissue (Duckworth, 2003; Henry and Hart, 2005) and sensitivity to increased suspended sediment (Schönberg, 2016). These differences can be due to species, morphotype and/or life stage. These factors will all influence the ability of Deep-sea sponge aggregations to recover physical structure after damage and the sponge composition of the habitat if any recovery does occur.

Growth to repair damaged tissue can be significantly faster than normal growth rates (Leys and Lauzon, 1998). However, although individual sponges can repair damage this does not indicate that recovery of the habitat structure from damage will be as rapid (ICES, 2009). Damaged *Geodia* can regrow to their original weight in a few weeks under laboratory conditions (Hoffmann *et al.,* 2003) but within a natural aggregation no evidence of repair is seen a year after damage (Freese, 2001). It is important to conserve the range of sponge species present in a Deep-sea sponge aggregation to increase the likelihood that some recovery may occur.

Biological structure: Sponge composition within the site
The site protects examples of boreal ostur sponge aggregations (Bett, 2001; Howell *et al.,* 2010; Bett, 2012; Henry and Roberts *et al.,* 2014; O'Connor *et al.,* 2017). Up to 50 sponge species can be found within the sponge fields, many of which are different to those found in the surrounding areas.

In the site, the boreal ostur aggregations contain a mix of primarily large structural geodiid sponges, such as the globular *Geodia barretti* and *G. macandrewi, G. atlantica*, and *G. phlegraei*, as well as numerous other lobose and encrusting species (Henry and Roberts *et al.,* 2014). The encrusting sponges recorded in the Faroe-Shetland Channel are described as white, green, orange, cream and yellow *Porifera* morphospecies, blue (potentially *Hymedesmia curvichela*), and red encrusting sponges (Howell *et al.,* 2010; O'Connor, 2017). However, massive, globular, flabellate (potentially *Phakellia sp.*) and arborescent sponges have also been recorded (O'Connor, 2017). The age structure, growth rates and reproductive viability of the sponge aggregations located within the site are currently unknown.

Offshore infrastructure and bottom-contacting fishing gear (demersal trawling and demersal static fishing) occur in parts of the site where Deep-sea sponge aggregations occur. The species composition, size and morphology of the sponges could be affected by pressures exerted by these activities. As the complexity and variety of sponge morphotypes present will influence the associated community, it is important that these aspects of Deep-sea sponge aggregation structure be conserved.

Evidence indicates that activities are occurring which are capable of impacting the feature. Therefore, **JNCC advise a recover objective**. Our confidence in this objective would be improved with a better understanding of how activities impact the feature. Due to differences between sponge species in sensitivity to pressures and ability to recover, the species composition of the recovered habitat may be different to undisturbed Deep-sea sponge aggregations within the site. Activities should look to minimise, as far as is practicable, further physical damage to individual sponges within the potential extent of Deep-sea sponge aggregations within the site (425 - 475 m).

For further information on activities capable of affecting the Deep-sea sponge aggregations, please see the [Advice on Operations Workbook].

Biological structure: Sponge abundance
The abundance of sponges within a Deep-sea sponge aggregation can influence the characteristic biological communities that are present. Beazley *et al.* (2015) found a positive relationship between the density of structural sponges and the biological diversity of other invertebrate taxa. The biomass and abundance of some fish species, such as shortnose snipe eel (*Serrivomer beanii*), deep-sea cat shark (*Apristurus profundorum*) and eelpout (*Lycodes* spp.) have also been shown to be higher in areas of a high sponge biomass (Kenchington *et al.*, 2013). Changes in the abundance of sponges may therefore have an impact on the characteristic biological communities and the biodiversity that a site can support. Sponge morphotype and available survey methods may influence how this attribute is described. If individual sponges can be identified on videos or stills, then abundance could be density of individual sponges. As the functions of sponges are directly linked to their biomass, the volume or biomass of sponges is valuable way of quantifying the abundance of larger sponges (Wulff, 2001), however non-destructive survey methods, such as 3D camera technology, would be required. For some morphotypes e.g. encrusting sponges, distinguishing individuals is difficult and abundance should be described as area occupied or number of patches.

Deep-sea sponge aggregations can vary in how the individual sponges are distributed within an aggregation, e.g. sponges can be randomly distributed or clustered (Uriz *et al.*, 1998). Sponges or clumps of sponges have communities of other organisms associated with them. Within a Deep-sea sponge aggregation, communities associated with one patch of sponges are likely to be more similar to communities on other nearby patches of sponges compared to patches that are located further away (Mayer *et al.*, 2016). Therefore, the spatial distribution of sponges or patches of sponges within the Deep-sea sponge aggregation could impact the overall diversity of associated organisms in the site.

It is important therefore to conserve the density and spatial distribution of sponges within a Deep-sea sponge aggregation to maintain the richness and diversity of the characteristic biological communities that may be present. Moreover, the spatial distribution of sponges may also effect how well the Deep-sea sponge aggregation can recover from a loss of individuals, as recovery could depend on the relative location of reproductive adults.

Biological structure: Sponge abundance within the site
In the boreal ostur Deep-sea sponge aggregations recorded in the site, the majority of sponges have been recorded from around the 450 m depth contour to the south of the site, specifically particularly between the 425 m and 475 m depth contours. In this narrow deep-sea sponge belt, sponge densities have been recorded as ranging from 0.001-0.818 sponges per m^2 (Axelsson, 2003). In 2017, survey results also indicated higher sponge aggregation densities to the south-west as opposed to the south-east of the site and closer to the 475 m than the 425 m depth contour (O'Connor, 2017).

Oil and gas extraction and bottom contacting fishing gear (demersal trawling and demersal static fishing) occur in parts of the site where Deep-sea sponge aggregations occur. Sponge abundance can be affected by pressures exerted by these activities. Research undertaken within the Faroe-Shetland Channel indicates that sponge abundance is reduced in areas around wells where there are patches of drill cuttings visible on the sea-bed, possibly as a result of smothering (Jones *et al.,* 2006). This impact is generally observed within 100 m of the well, but the actual area of impact will depend on the hydrodynamics and type of drilling (Jones *et al.,* 2006; Jones *et al.,* 2007). Immediately after a drilling event, most surviving sponges within the area of disturbance occur on larger boulders that protrude above the level of smothering (Jones *et al*., 2006), however three years later the same boulders no longer supported sponges, indicating a more long-term effect on sponge abundances (Jones *et al.*, 2012). Therefore, the sponge abundance in Deep-sea sponge aggregations within a hundred metres of active or recently drilled wells may have been reduced by the activity.

In addition, bottom-contact fishing practices can reduce the abundance of sponges within a Deep-sea sponge aggregation through mortality, due to dislodgement and displacement, crushing and bringing sponges up to the surface as by-catch (ICES, 2009).

Evidence indicates that activities are occurring which are capable of affecting the abundance of sponges with the Deep-sea sponge aggregations feature of the site. **JNCC therefore advise a recover objective**. Our confidence in this objective would be improved with better understanding of how activities impact the feature. Due to differences between sponge species in sensitivity to pressures and ability to recover, the species composition and abundance of the recovered habitat may be different to undisturbed deep-sea sponge aggregations within the site.

The life-history traits of sponges mean that Deep-sea sponge aggregations develop over decades or centuries (ICES, 2009; Hogg *et al.,* 2010) and therefore abundance may not easily be restored through management intervention. Activities should look to minimise, as far as is practicable, removal or dislodgement of sponges within the potential extent of Deep-sea sponge aggregations within the site (between 425 m and 475 m).

For further information on activities capable of affecting the Deep-sea sponge aggregations, please see the Advice on Operations Workbook.

Biological structure: Spicule mats
Many species of sponges support their tissues with skeletal structures known as spicules (Hogg *et al.*, 2010). The spicules that form the skeleton of sponges can accumulate on the sea-bed in Deep-sea sponge aggregations, forming spicule mats. The presence of spicule mats alters the benthic community (Bett and Rice, 1992; Barrio Froján *et al*., 2012), possibly because they provide a hard substrate for attachment, act as refugia or enhance food availability to filter feeders; brittlestars and ascidians use the spicule mats as perches to access food particles in the higher flow rates above the sediment boundary layer (Bett and Rice, 1992). The numbers of polychaetes and brittlestars are positively correlated with the volume of spicules in the spicule mat (Bett and Rice, 1992), and these organisms are likely to be prey for fish and other benthic organisms. Spicule mats result in a hard surface on the seabed which inhibits colonisation by infaunal organisms (Gubbay, 2002). It is therefore important to conserve the presence and extent of spicule mats within Deep-sea sponge aggregations as they influence the characteristics of the habitat type. Where spicule mats are present, it is important that their extent and distribution is conserved.

Dense spicule mats are generally associated with glass sponges, however significant accumulations of spicules do occur in sponge aggregations dominated by *Geodia* sp and are associated with distinctive benthic communities (Klitgaard and Tendal, 2004; Barrio Froján *et al.*, 2012, Murillo *et al.*, 2016).

Biological structure: Spicule mats within the site
There is no information available on the presence or extent of spicule mats of the boreal ostur aggregation representing the Deep-sea sponge aggregations within the site.

JNCC advise conserve objective, however further information is needed. While evidence indicates that activities are occurring which are capable of affecting the extent and distribution of spicule mats within the site, there is insufficient information available to support a view as to the nature or scale of any impacts. Our confidence in this objective would be improved with better understanding of how the activities impact spicule mats.

Biological structure: Characteristic communities

The variety of communities present make up the habitat and reflect the habitat's overall character and conservation interest. Characteristic communities include, but are not limited to, representative communities, for example, those covering large areas and notable communities, those that are nationally or locally rare or scarce e.g. listed as OSPAR threatened or declining, or particularly sensitive. Deep-sea sponge aggregations are listed on the OSPAR threatened and declining habitats list, and this includes the characteristic communities associated with them (OSPAR, 2010a). Deep-sea sponge aggregations have also been recognised as Vulnerable Marine Ecosystems (VMEs) by the International Convention for the Exploration of the Sea (ICES, 2013), who make recommendations for the protection of instances of the feature from fishing activity where they occur.

The biological communities characteristic of Deep-sea sponge aggregations can vary depending on the structure of the Deep-sea sponge aggregation and other large-scale variables such as depth and current speed (Beazley *et al.*, 2015), as well as fine-scale physical, chemical and biological processes. The characteristic communities of Deep-sea sponge aggregations are generally epibenthic fauna typical of hard substrates (Gubbay, 2002) and tend to have relatively high biodiversity (Bett and Rice, 1992; Beazley *et al.*, 2013; Beazley *et al.*, 2015). Brittlestars are often associated with Deep-sea sponge aggregations (Henry and Roberts, 2014), which use the sponges and spicule mats as elevated perches to improve feeding (Bett and Rice, 1992).

It is important to conserve the natural spatial distribution, composition, diversity and abundance of the main characterising biological communities of the Deep-sea sponge aggregation within the site to avoid diminishing biodiversity and ecosystem functioning within the habitat and to support its health (Hughes *et al.*, 2005).

Biological structure: Characteristic communities within the site

Only one community, Boreal ostur, has been associated with the Deep-sea sponge aggregations observed in the site (Howell *et al.*, 2010; Henry and Roberts, 2014). The Deep-sea sponge aggregations found in the site conform to the OSPAR definition of a Threatened and/or Declining habitat (OSPAR, 2010a). They are also classed as a Vulnerable Marine Ecosystem (VME) according to FAO international guidelines. Therefore, this site makes a contribution to global commitments to protect Vulnerable Marine Ecosystems. Along with the key sponge species mentioned above, this community is also characterised by brittlestars (e.g. *Ophiactis balli*), brachiopods, squat lobster (*Munida sp.*) and tube-building polychaetes (*Sepulidae*) (Howell *et al.,* 2010).

Oil and gas extraction and bottom contacting fishing gear (demersal trawling and demersal static fishing) occur in parts of the site where Deep-sea sponge aggregations occur. Characteristic communities associated with Deep-sea sponge aggregations can be affected by pressures exerted by these activities. Research undertaken from within the Faroe-Shetland Channel indicates that sponge abundance is reduced in areas around wells where there are patches of drill cuttings visible on the sea-bed, possibly as a result of smothering (Jones *et al.,* 2006). This impact is generally observed within 100 m of the well, but the actual area of impact will depend on the hydrodynamics and type of drilling (Jones *et al.,* 2006; Jones *et al.,* 2007). Immediately after a drilling event, most surviving sponges within the area of disturbance occur on larger boulders that protrude above the level of smothering (Jones *et al*., 2006), however three years later the same boulders no longer supported sponges, indicating a more long-term effect on sponge abundances (Jones *et al.*, 2012). Therefore, the key species characterising the community is modified within a hundred metres of active or recently drilled wells.

In addition, bottom-contact fishing practices are capable of affecting the characteristic communities through removing benthic species and damaging or killing them by abrasion.

Evidence indicates that activities are occurring which are capable of affecting the characteristic communities of the Deep-sea sponge aggregations feature of the site. **JNCC therefore advise a recover objective**. Our confidence in this objective would be improved with better understanding of how activities impact the feature. Due to differences between sponge species in sensitivity to pressures and ability to recover, the species composition and abundance of the recovered habitat may be different to undisturbed deep-sea sponge aggregations within the site.

The life history traits of sponges mean that Deep-sea sponge aggregations develop over decades or centuries (ICES, 2009; Hogg *et al.,* 2010) and therefore abundance may not easily be restored through management intervention. Activities should look to minimise, as far as is practicable, removal or dislodgement of sponges within the potential extent of Deep-sea sponge aggregations within the site (between 425 m and 475 m).

For further information on activities capable of affecting the protected features of the site, please see the Advice on Operations workbook.

Function

Functions are ecological processes that include sediment processing, secondary production, habitat modification, supply of recruits, bioengineering and biodeposition. These functions rely on natural supporting processes and the growth and reproduction of sponges, and associated biological communities, and provide a variety of functional roles within it (Bell, 2008).

These functions can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services locally and to the wider marine environment (ETC, 2011). Ecosystem services that might typically be provided by Deep-sea sponge aggregations include:

- Nutrition: Sponges filter feed organic matter out of the water column, therefore Deep-sea sponge aggregations are a potentially important link in the flow of nutrients between the pelagic and benthic environment (Maldonado *et al*., 2012; Cathalot *et al.*, 2015). For example, cold-water corals can secrete mucus which becomes a source of dissolved and particulate organic matter (Wild *et al., 20*08). Sponges feed on the organic matter produced by cold-water corals and it is incorporated into sponge tissue, which is then shed and can be consumed by higher trophic levels (Rix *et al., 20*16). This may serve to increase the availability of prey species to predators through enhancement to levels of biological diversity, potentially act as spawning grounds and provide refugia from predators for commercially important fish species;
- Silicon regulation: by providing a long-term sink for silicon (Maldonado *et al.,* 2012, Tréguer and Rocha, 2013); and
- Provision of biochemical and biotechnological products: Sponges and their associated microbes produce a diverse array of chemicals, many of which have been shown to have applications in drug development (Laport *et al.,* 2009; Ebada *et al.*, 2010; Sawadogo *et al.*, 2015; Indraningrat *et al.*, 2016). Sponges may also have wider biotechnological applications (Hogg *et al.*, 2010), e.g. chitin networks from one species of sponge are effective at absorbing uranium contamination (Schleuter *et al.*, 2013). Sponge species typically found in Deep-sea sponge aggregations may also prove to have useful applications in the future.

The natural range of Deep-sea sponge aggregation communities within the site should be conserved to ensure that the functions they provide support the health of the feature and the provision of ecosystem services to the wider marine environment.

Function within the site

The ecosystem services provided by Deep-sea sponge aggregations in the site could include:

- Nutrition – the Faroe-Shetland Channel supports demersal fish species which are of commercial interest, e.g. Greenland halibut (*Reinhardtius hippoglossoides*, Bullough *et al.,* 1998; Gordon, 2001). The Deep-sea sponge aggregations and associated characteristic communities could help to support these species.

There is no specific data on the contribution that sponges in the site make to the global silicon cycle and the aggregation is not currently exploited for biochemical or biotechnological products.

Given that a recover objective is advised for all but one of the other sub-attributes under structure and function, and that these sub-attributes will be closely coupled with the functional significance of Deep-sea sponge aggregations within the site, **JNCC advise a recover objective** for this sub-attribute.

Further information on the impacts associated with human activities on the Deep-sea sponge aggregations can be found in the Advice on Operations workbook.

Attribute: Supporting processes

Objective: Conserve

There is limited evidence to suggest that supporting processes of importance to the conservation of Deep-sea sponge aggregations are being impeded. ***JNCC advise a conserve objective****. This is based on expert judgment, specifically our understanding of the feature's sensitivity to pressures associated with ongoing activities. Our confidence in this objective would be improved with long-term monitoring and with better understanding of tolerance of Deep-sea sponge aggregations to different contaminants. Activities must avoid, as far as practicable, exceeding Environmental Quality Standards and the disruption, obstruction or removal of supporting habitat for Deep-sea sponge aggregations within the site.*

Explanatory notes

Deep-sea sponge aggregations rely on a range of natural supporting processes to support ecological processes (functions) and recovery from any impacts. For the site to fully deliver the conservation benefits set out in the statement on conservation benefits, the following supporting processes must remain largely unimpeded: hydrodynamic regime; supporting habitat; water quality; and sediment quality.

Hydrodynamic regime

Hydrodynamic regime refers to the speed and direction of currents, seabed shear stress and internal and surface wave exposure. These mechanisms circulate larvae and organic material, and influence water properties by distributing dissolved oxygen and transferring it from the surface to the seabed (Hiscock *et al.*, 2004; Mienis *et al.*, 2007; Hosegood & van Haren, 2004; Wagner *et al.*, 2011).

Deep sea sponge aggregations require hydrographic conditions that result in a continuous supply of particulate and dissolved organic matter to the seabed that the sponges can feed on. Deep-sea sponge aggregations are thought to occur near areas where topology leads to the creation of internal waves (Howell *et al*., 2016), which would result in resuspension of food particles. Gamete release in the sponge *Geodia barretti* appears to coincide with phytoplankton blooms (Spetland *et al*., 2007), which suggests that hydrodynamic regime may also influence reproduction of sponges in Deep-sea sponge aggregations.

Hydrodynamic regime within the site
Five different water masses flow and converge within the Faroe-Shetland Channel where this site is located. The North Atlantic Water, Modified North Atlantic Water and Arctic Intermediate/North Icelandic Water masses flow in a north-easterly direction through the channel, while the Norwegian Sea Arctic Intermediate Water and Faroe-Shetland Channel Bottom Water masses flow in a south-westerly direction (Bett, 2012). The Modified North Atlantic Water, Arctic Intermediate/North Icelandic Water and Norwegian Sea Arctic Intermediate Water all occur between 500 and 600 m depth within the site, while the North Atlantic Water is shallower than 500 m and the Faroe-Shetland Channel Bottom Water occurs deeper than 600 m (Bett, 2012). The layering of these water masses which have contrasting characteristics interacts with the continental slope to create internal mixing of the water masses close to the seabed within the site (Bett, 2012; Mckenna *et al.,* 2016).

Deep-sea currents below 600 m predominantly travel north-east to south-west along the Faroe-Shetland Channel and more shallow currents (above 600 m) predominantly travel in the opposite direction. Between 400 and 600 m this mixing of water masses leads to turbulent mixing resuspending and providing nutrients to the water column for deep-sea sponges to feed upon. This mixing zone is thought to significantly increase the abundance and diversity of species found in the site and explain the highly biologically diverse communities found there.

It is also likely that the currents operating around the site have a significant role to play in surface sediment composition. The installation or maintenance of infrastructure or the removal of sediment that causes a change in current speed or direction may have a detrimental effect on the abundance and diversity of species within the site and alter the distribution or composition of sediments across the site.

While the infrastructure present in the site may be having a localised effect on the hydrodynamic regime, it is not thought that this is having an adverse impact on the conservation status of the protected Deep-sea sponge aggregations. As such, **JNCC advise a conserve objective** for this sub-attribute. This is based on expert judgment, specifically our understanding of the feature's sensitivity to pressures associated with ongoing activities. Our confidence in this objective would be improved with a better understanding of the hydrodynamic regime within the site and its influence on the feature's conservation status.

Further information on the impacts associated with human activities on the Deep-sea sponge aggregations can be found in the Advice on Operations workbook.

Supporting habitat

The preferred seabed type of Deep-sea sponge aggregations varies between the different subtypes. It is therefore important to conserve the seabed sediment types and sediment distributions within a site, to ensure that there are favourable conditions for new sponge recruits to settle and maintain the spatial distribution of sponges in Deep-sea sponge aggregations.

Supporting habitat within the site

Species of *Geodia* settle on rocky substrates (Cárdenas and Rapp, 2015). Therefore, boreal ostur aggregations tend to develop where coarse sediment, and cobbles and boulders are present on the sea-bed. At depths of 400-600 m, the combination of seabed type and plentiful supply of nutrients are ideal for the establishment of deep-sea sponges.

Offshore infrastructure occurs within the site. Such installation (and decommissioning) practices often result in a change of substrata on the seafloor through the introduction of concrete mattresses, cuttings piles and rock dump. This type of activity has the potential to reduce or alter the natural extent of supporting habitat for Deep-sea sponge aggregations within the site. Further detail on the composition of the sediment habitats within the site is provided in Table 2 under the structure attribute.

Deep-sea sponge aggregations are thought to have a high sensitivity to physical change to or loss of habitat. It is therefore important to conserve the extent and distribution of supporting habitats within the site to maintain Deep-sea sponge aggregations and provide the best chance of potential recovery from disturbance. **JNCC advise a conserve objective**, noting it is not possible to recover the extent and distribution of the supporting habitat for Deep-sea sponge aggregations. However, activities must look to minimise, as far as is practicable, further disruption, obstruction or removal of supporting habitats within the site.

Further information on the impacts associated with human activities on the Deep-sea sponge aggregations can be found in the Advice on Operations workbook.

Water and sediment quality

Contaminants may also impact the ecology of a Deep-sea sponge aggregation by having a range of effects on different species within the habitat, depending on the nature of the contaminant (JNCC, 2004b; UKTAG, 2008; EA, 2014). It is important therefore to avoid changing the natural water and sediment quality properties of a site and as a minimum ensure compliance with existing Environmental Quality Standards (EQS) as set out below.

Environmental Quality Standard (EQS)

The targets listed below for water and sediment contaminants in the marine environment are based on existing targets within OSPAR or the Water Framework Directive (WFD) and require concentrations and effects to be kept within levels agreed in the existing legislation and international commitments. These targets are set out in The UK Marine Strategy Part 1: The UK Initial Assessment 2012).

Aqueous contaminants must comply with water column annual average (AA) Environmental Quality Standards (EQSs) according to the amended Environmental Quality Standards Directive (EQSD) (2013/39/EU), or levels equating to (High/Good) Status (according to Annex V of the Water Framework Directive (WFD) (2000/60/EC), avoiding deterioration from existing levels.

Surface sediment contaminants (<1 cm from the surface) must fall below the OSPAR Environment Assessment Criteria (EAC) or Effects Range Low (ERL) threshold. For example, mean cadmium levels must be maintained below the ERL of 1.2 mg per kg. For further information, see Chapter 5 of the OSPAR Quality Status Report (OSPAR, 2010b) and associated QSR Assessments.

There are little data on the impact of aqueous and sediment contaminants on Deep-sea sponge species, therefore no tolerance thresholds have been established for Deep-sea sponge aggregations. The general standards described above apply to this feature until more habitat specific information is available.

The following sources provide information regarding historic or existing contaminant levels in the marine environment:

- Marine Environmental and Assessment National Database (MERMAN);
- The UK Benthos database available to download from the Oil and Gas UK website;
- Cefas Green Book;
- Strategic Environmental Assessment Contaminant Technical reports available to download from the British Geological Survey

website; and

- Charting Progress 1: The State of the UK Seas (2005) & Charting Progress 2: The State of the UK Seas (2014).

Water quality

The water quality properties that influence Deep-sea sponge aggregations include salinity, pH, temperature, suspended particulate concentration, dissolved organic matter, silicate concentration, nutrient concentrations and dissolved oxygen. They can act alone or in combination to affect habitats and their communities in different ways, depending on species-specific tolerances. In fully offshore habitats these parameters tend to be relatively more stable, particularly so for deeper waters, although there may be some natural seasonal variation. They can influence the abundance, distribution and composition of Deep-sea sponge aggregations and associated communities at relatively local scales. Changes in any of the water quality properties, because of human activities, may impact habitats and the communities they support (Elliot *et al.*, 1998; Little, 2000; Gray and Elliot, 2009). Increased concentrations of fine sediment in the water column can have a negative impact on Deep-sea sponges by blocking feeding structures, reducing other physiological processes and damaging the surface of the sponges by abrasion of larger particles (Bell *et al.*, 2015).

Sponges consume organic matter that they filter out of passing seawater. The diet of sponges includes bacteria and other small planktonic organisms (Yahel *et al*., 2007; Hadas *et al*., 2009; Perea-Blázquez *et al*., 2012; Kahn *et al*., 2015). Sponges may have a preference for particles smaller than 10 µm (Witte *et al*., 1997) but they can feed on larger particles (Frost, 1981; Yahel *et al*., 1998; Ribes *et al*., 1999). Dissolved organic matter is also an important food source for sponges (de Geoji *et al.,* 2008a; de Geoji *et al*., 2008b; van Duyl *et al*., 2008; Rix *et al*., 2017). As a result, deep sea sponge aggregations require a continuous supply of particulate and dissolved organic matter to the seabed. Changes to water quality that reduces the supply of suspended particulate or dissolved organic matter to the sponges may also be detrimental. It is important therefore to avoid changing the natural water quality of a site as a minimum to ensure compliance with existing EQS as set out above until thresholds specific to Deep-sea sponge aggregations have been identified.

Water quality within the site

Sponges require dissolved silicon to create their skeletons. The presence of *Geodia barretti, G. atlantica* and *G. phlegraei*, which are key species in boreal ostur aggregations, is determined by silicate concentrations near the seabed (Howell *et al*., 2016). There also appears to be a minimum bottom salinity of 34.3 – 34.6 ‰ below which important boreal ostur species cannot grow (Knuby *et al.*, 2013). G barretti, has an upper temperature tolerance of ~10°C and/or is unable to survive rapid temperature changes (Guihen *et al*., 2012; Howell *et al*., 2016).

The five different water masses that converge within the Faroe-Shetland Channel where this site is located have contrasting characteristics (Bett, 2012; Mckenna *et al.*, 2016). All five water masses have salinity values above the minimum threshold suggested by Knuby *et al.* (2013). The temperature range of the water masses are also all generally below 10°C (Mckenna *et al.*, 2016). The silicate concentration within the North Atlantic Water, Modified North Atlantic Water and the Arctic Intermediate/North Icelandic Water masses is between 2.5 and 7.5 µM l^{-1}, however the colder Norwegian Sea Arctic Intermediate Water and the Faroe-Shetland Bottom Water have higher silicate concentrations, 9.6- 12.3 µM l^{-1} (Mckenna *et al.*, 2016).

The concentration of suspended particles and dissolved organic matter in the water column are properties of water quality. There are no site-specific data on the type and quantity of particulate and dissolved organic matter that sponges in the site consume. *G. barretti* exhibits a rapid 86% decline in respiration rate when exposed to a short burst of suspended sediment at a concentration of 100 mg L^{-1} (Tjensvoll *et al.*, 2013). Extended exposure of increased levels of suspended sediments that naturally occur on the seabed had no effect on the respiration rate of *G. barretti,* whereas continued cyclical exposure to crushed rock particles can lead to a permanent decrease in respiration rates within a month (Kutti *et al.*, 2015). Exposure to suspended sediments containing barite, which is found in drilling muds released during oil and gas extraction, have been shown to damage the cells of *G. barretti* (Edge *et al.*, 2016). Recovery from the short-term exposure to increased concentrations of suspended sediments that naturally occur on the seabed can be rapid; *G. barretti* returned to normal respiration rates within four hours (Tjensvoll *et al.*, 2013). However, repeated and long-term exposure may reduce the ability of sponges to grow and reproduce, particularly if the sediment is contaminated or not naturally found within the habitat (Kutti *et al.*, 2015).

Offshore oil and gas extraction occurs within the site, which can result in the release of chemicals, including heavy metals and polyaromatic hydrocarbons, and suspended sediments into the water column (BP, 2010). While this information identifies possible sources of contamination, there is currently no information available to indicate that water quality in the site is falling below EQSs. Indeed, the Charting Progress 2 reports that the open seas are little affected by pollution and levels of monitored contaminants continue to fall, albeit slowly in many cases.

Therefore, **JNCC advise a conserve objective** and that aqueous contaminants must be restricted to comply with water column annual average limits according to the amended environmental quality standards Directive (2013/39/EU) or levels equating to high/good status (Annex V of the Water Framework Directive 2000/60/EC), avoiding deterioration from existing levels. Our confidence in this objective would be improved with longer-term monitoring, a better understanding of contaminant levels in the site and how contaminants can impact the Deep-sea sponge aggregations present.

For further information on activities capable of affecting Deep-sea sponge aggregations and their supporting habitat, please see the Advice on Operations Workbook.

Sediment quality
Studies on shallow water sponges have shown that exposure to contaminants such as Copper or polyaromatic hydrocarbons (PAHs) can have a negative impact on sponges' feeding rates, settlement or survival, however the response varies between different sponge species (Cebrian *et al*., 2006; Cebrian and Uriz, 2007). The impact of a particular contaminant on sponges can be enhanced if other contaminants are also present (Cebrian and Uriz, 2007). Sponges filter large volumes of food particles, therefore even if contaminants do not impact the sponge, chemicals such as Aluminium, Iron, Nickel, Lead, PAHs and poly-chlorinated biphenyls (PCBs) can bioaccumulate within the sponge tissue (Gentric *et al*., 2006). Although impacts of contamination and bioaccumulation have not been studied in deep-water sponges, various contaminants are also likely to affect the species that live in or on Deep-sea sponge aggregations. Bioaccumulation in biogenic habitats can impact colonisation and settlement by mobile and sessile epifauna species sensitive to particular contaminants, (e.g. heavy metals), and lead to accumulation in species at higher trophic levels (Roberts *et al*., 2008; OSPAR, 2009; OSPAR, 2010b; OSPAR, 2012). This can alter the structure of communities within a site e.g. lowering species diversity or abundance.

It is important therefore to avoid changing the natural sediment quality of a site and as a minimum ensure compliance with existing EQSs as set out above until thresholds specific to Deep-sea sponge aggregations have been identified.

Sediment quality within the site
As a benthic species, sediment quality of supporting habitats is key to the establishment and maintenance of Deep-sea sponge aggregations within the site.

Evidence from the Charting Progress 2 report indicated that while the site is distant from terrestrial sources of pollution, climatic variability may affect ecological function of the site. The extent to which sediment quality is currently impacted by anthropogenic activity is unclear and information on pollution levels by heavy metals or other contaminants is currently unknown. While this information identifies possible sources of contamination, there is no information available to indicate that sediment quality in the site is falling below EQSs.

Due to the lack of evidence on sediment quality affecting Deep-sea sponge aggregations and their potential limited recovery rates to anthropogenic activities within the site, **JNCC advise a conserve objective** and that activities must look to avoid, as far as is practicable, exceeding EQSs set out above.

Our confidence in this objective would be improved with longer-term monitoring, a better understanding of contaminant levels in the site and how contaminants can impact the Deep-sea sponge aggregations present.

For further information on activities capable of affecting deep-sea sponge aggregations and their supporting habitat, please see the Advice on Operations Workbook.

Table 2. Supplementary advice on the conservation objectives for Offshore deep-sea muds and Offshore subtidal sands and gravels within North-East Faroe-Shetland Channel NCMPA

Attribute: Extent and distribution

Objective: Conserve

JNCC advise conserve objectives *for Offshore deep-sea muds and Offshore subtidal sands and gravels, however further information is needed. While evidence indicates that activities are occurring which are capable of affecting the extent and distribution of the protected habitats within the site, there is insufficient information available to support a view as to the nature or scale of any impacts. Activities must look to minimise, as far as is practicable, reductions to the extent and distribution of the protected habitats within the site.*

Explanatory notes

Extent refers to the total area in the site occupied by Subtidal sedimentary habitats and must include consideration of their distribution i.e. how spread out they are within a site. A reduction in extent has the potential to alter the biological and physical functioning of Subtidal sedimentary habitat types (Elliott *et al.,* 1998; Tillin and Tyler-Walters, 2014). The distribution of a habitat influences the component communities present, and can contribute to the health and resilience of the feature (JNCC, 2004b). The extent of the Subtidal sedimentary habitats within the site must be conserved to their full known distribution.

Subtidal sedimentary habitats are defined by:

- ***Sediment composition*** (grain size and type) (e.g. Cooper *et al.,* 2011; Coates *et al.,* 2015; Coates *et al.,* 2016; Coblentz *et al.,* 2015). Some species can inhabit all types of sediment, whereas others are restricted to specific types; and
- ***Biological assemblages*** - See JNCC's Marine Habitats Correlation Table for more detail about the range of biological communities (biotopes) that characterise Subtidal sedimentary habitats in the UK marine environment. In offshore environments, note that Subtidal sedimentary habitats are not typically dominated by algal communities.

A significant change in sediment composition and/or biological assemblages within an MPA could indicate a change in the distribution and extent of Subtidal sedimentary habitats within a site (see UK Marine Monitoring Strategy for more information on significant change). Reduction in extent has the potential to affect the functional roles of the biological communities associated with Subtidal sedimentary habitats (Elliott *et al.,* 1998; Tillin and Tyler-Walters, 2014) e.g. a change from coarser to finer sediment would alter habitat characteristics, possibly favouring deposit feeders over suspension feeders (Tillin and Tyler-Walters, 2014). Conserving extent is therefore critical to maintaining or improving conservation status of Subtidal sedimentary habitats.

A general description of the different types of Subtidal sedimentary habitats found in the UK offshore marine environment of relevance to this MPA is provided below:

- *Offshore deep-sea muds* - Comprises of mud and cohesive sandy mud. This habitat is predominantly found in stable deeper/offshore areas where the reduced influence of wave action and/or tidal streams allow fine sediments to settle. These habitats are often dominated by polychaetes and echinoderms, such as *Amphiura* spp., sea-pens, such as the slender sea-pen (*Virgularia mirabilis*), and burrowing megafauna, such as the Norway lobster (*Nephrops norvegicus*) (Connor *et al.,* 2004), although polychaetes, sea spiders, molluscs, crustaceans and fish are also found. Bathymetry, current velocity, bottom water-mass distribution and particle size of the mud (clay, silty or sandy) have a significant influence on the distribution and composition of the seabed communities present. Subtidal mud is defined by a ratio of mud to sand being greater than 4:1, with particle sizes of less than 0.063 mm for mud and 0.063 mm to 2 mm for sand (McBreen and Askew, 2011). On the continental shelf, the Priority Marine Feature (PMF) Offshore deep-sea muds directly equates to the EUNIS habitat A5.3 Subtidal mud, but the PMF also covers deep-water examples that occur on or beyond the continental slope (Tyler-Walters *et al.,* 2016).
- *Offshore subtidal sands and gravels* - Offshore subtidal sands and gravels are more stable than their shallower equivalents, with diverse infaunal communities dominated by polychaetes, hatchet shells and small bivalves. Offshore fine to muddy sands support a variety of tube-building polychaetes, burrowing brittlestars and bivalves, while medium sands support the Pea urchin (*Echinocyamus pusillus*) and fine sands host amphipods. Mobile predators present in this habitat include flatfish, starfish, crabs and hermit crabs. On the continental shelf; Offshore subtidal sands and gravels are equivalent to the EUNIS habitats A5.1: Subtidal coarse sediments, A5.2: Subtidal sand, and A5.4: Subtidal mixed sediments, but the Priority Marine Feature also covers deep-water examples of the habitat which occur on or beyond the continental slope in Scotland (Tyler-Walters *et al.,* 2016).

Extent and distribution within the site

The site map for North-East Faroe-Shetland Channel NCMPA is available to view on JNCC's Interactive MPA Mapper. The site area is calculated to be 23,682 km^2 with the Priority Marine Feature Offshore deep-sea muds extending across most the site (approximately 75%) and large patches of Offshore subtidal sands and gravels to the north, west and south of the site (approximately 25%).

JNCC are not aware of any activities occurring in the site that could impact the extent and distribution of these protected habitats. As such, **JNCC advise a conserve objective**. Our confidence in this objective would be improved with better access to information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, reductions to the extent and distribution of the protected habitats within the site.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds within the site, please see the Advice on Operations workbook.

Attribute: Structure and function

Objective: Conserve

JNCC advise a conserve objective *for the Offshore deep-sea muds and Offshore subtidal sands and gravels, as currently these broad-scale habitats have not been subjected to activities that have resulted in a change to their structure and function. Fine-scale topography and key and influential species are not considered in the setting of these objectives due to a current lack of understanding of their influence on the broad-scale habitat features. Our confidence in the setting of this objective would be improved by long-term monitoring information. Activities must look to minimise, as far as is practicable, changes in substrata within the site.*

Explanatory notes

Structure refers to the physical structure of a Subtidal sedimentary habitat and its biological structure. Physical structure refers to finer scale topography and sediment composition. Biological structure refers to the key and influential species and characteristic communities present.

Physical structure: Finer scale topography

The topography of Subtidal sedimentary habitats may be characterised by features, such as mega-ripples, banks and mounds, which are either formed and maintained by ongoing hydrodynamic processes (active bedforms) or the result of long since passed geological processes (relict bedforms). As these bedforms support different sedimentary habitats and associated communities compared to the surrounding seabed, it is important that they are conserved (Elliott *et al.,* 1998; Barros *et al.,* 2004; Limpenny *et al.,* 2011). Recovery of active bedforms is likely so long as the prevailing hydrodynamic regime remains largely unimpeded, noting that the reverse is true for relict bedforms.

Physical structure: Finer scale topography of the feature within the site

The site includes several relict sedimentary topographical features: a prograding wedge, contourite deposits; Pilot Whale diapirs and slide deposits, which are all recognised as protected geodiversity features within the site (see Table 4). While evidence indicates that activities are occurring which are capable of affecting some of the relict sedimentary topographical features, it is not feasible to recover reflect sedimentary topographical features through management intervention. Therefore, **JNCC advise a conserve objective**. Our confidence in the condition of the sedimentary topographical features would be improved by longer-term monitoring. Activities should avoid the deposition of artificial substrata in areas where these finer scale topographic features occur.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds within the site, please see the Advice on Operations workbook.

Physical structure: Sediment composition

On the continental shelf, sediment composition is highly dependent on the prevailing hydrodynamic regime. Coarser sediments tend to dominate in high energy environments that are subject to strong prevailing currents. Conversely, finer sedimentary habitats are typically associated with lower energy environments. However, storm conditions can mobilise all sediment types, including the coarser fractions, most notably in shallower waters (Green *et al.,* 1995).

In deeper waters, bottom currents may impact sediment composition through erosional and depositional processes (Sayago-Gil *et al.,* 2010). The continental shelf edge and upper continental slope (>200 m) have been shown to be impacted by currents, influencing sediment composition by depositing finer particles in deeper waters (Hughes, 2014). Indeed, mud content can increase exponentially with depth as hydrodynamic influence is reduced (Bett, 2012).

As sediment composition may be a key driver influencing biological community composition it is important that natural sediment composition is conserved (Cooper *et al.,* 2011; Coates *et al.,* 2015; Coates *et al.,* 2016; Coblentz *et al.,* 2015).

Physical structure: Sediment composition within the site

Sediment composition within the site can be seen in the site map available to view on JNCC’s interactive MPA mapper. Although Offshore deep-sea muds dominate, Offshore subtidal sands and gravels are patchily distributed through-out the site, with verified patches distributed to the north, west and south, and Offshore deep-sea muds towards the centre of the site.

Grain sizes reported for Offshore deep-sea muds within the site are on average 0.90 ± 0.89%, 72.07 ± 4.21%, and 27.02 ± 4.14% (gravel, sand and silt/clay respectively). Grain sizes reported for Offshore subtidal sands and gravels within the site are on average 0.57 ± 0.59%, 82.91 ± 1.27%, and 16.52 ± 1.29% (gravel, sand and silt/clay respectively).

To our knowledge, these protected habitats have not been subjected to activities that have resulted in a change to their sediment composition. Therefore, **JNCC advise a conserve objective** for this sub-attribute. Our confidence in this objective would be improved with longer-term monitoring and better access to information on the activities taking place within the site. Activities should look to minimise, as far as is practicable, changes in substrata within the site.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds within the site, please see the Advice on Operations workbook.

Biological structure: Key and influential species

Key and influential species are those that have a core role in determining the structure and function of Subtidal sedimentary habitats. For example, bioturbating species (animals that forage and burrow tunnels, holes and pits in the seabed) help recycle nutrients and oxygen between the seawater and the seabed supporting the organisms that live within and on the sediment. Grazers, surface borers, predators or other species with a significant functional role linked to the Subtidal sedimentary habitats can also be classed as a key or influential species. Changes to the spatial distribution of communities across a Subtidal sedimentary habitat could indicate changes to the overall feature and as a result how it functions (JNCC, 2004b).

Due to the prevailing influence of the hydrodynamic regime, higher energy, coarser sedimentary habitats show greater recovery potential following impact than lower energy, finer sedimentary habitats (Dernie *et al.,* 2003). Recovery of the feature is thought to be largely dependent on the scale of the disturbance and action of remaining key and influential species, such as burrowers. However, recovery of the communities associated with Subtidal sedimentary habitats also depends on the life-history traits of the species themselves (e.g. their growth rate, longevity) and their interactions with other species, including predators and prey. Furthermore, the environmental connectivity between populations or species patches, the suitability of the habitat (e.g. substrate type), depth, water and sediment quality will also influence the recovery potential of Subtidal sedimentary habitats (Mazik *et al.,* 2015).

It is important to conserve the key and influential species of a site to avoid diminishing biodiversity and the ecosystem functioning provided by the protected Subtidal sedimentary habitats, and to support their conservation status (JNCC, 2004b; Hughes *et al.,* 2005).

Biological structure: Key and influential species of the feature within the site
A variety of bioturbators, predators and grazers have been recorded from surveys within the site, such as burrowing tube anemones (*Cerianthus lloydii*), sabellids, hydroids, seastars, sea cucumbers and various fish species, as well as sea urchins, gastropods, crabs and other unidentified crustaceans. It is possible that these species play a critical role in maintaining the structure and functioning of the protected habitats Offshore subtidal sands and gravels and Offshore deep-sea muds. However, there is no scientific information available to support this.

There is insufficient information available to support an understanding of the significance of the role which these species play in conserving the function and health of the protected Subtidal sedimentary habitats. Therefore, it is not possible to set an objective for this sub-attribute and it is not considered further in our advice.

Biological structure: Characteristic communities
The variety of biological communities present, make up the habitat and reflect the habitat's overall character and conservation interest. Characteristic communities include, but are not limited to, representative communities, such as those covering large areas, and notable communities, such as those that are nationally or locally rare or scarce, listed as OSPAR threatened and/or declining, or known to be particularly sensitive to anthropogenic activities.

Biological communities within Subtidal sedimentary habitats vary greatly depending on location, sediment type and depth, as well as other physical, chemical and biological processes. Burrowing bivalves and infaunal polychaetes thrive in coarse sedimentary habitats where the sediment is well-oxygenated with animals, such as hermit crabs, flatfish and starfish, living on the seabed. In deeper and more sheltered areas, the effects of wave action and prevailing currents may be diminished, resulting in finer sedimentary habitats where burrowing species may have a key role to play in maintaining the biological diversity of the habitat.

Changes to the spatial distribution of biological communities across a Subtidal sedimentary habitat could indicate changes to the overall feature (JNCC, 2004b). It is therefore important to conserve the natural spatial distribution, composition, diversity and abundance of the main characterising biological communities of the Subtidal sedimentary habitats within a site to avoid diminishing biodiversity and ecosystem functioning within the habitat and to support its health (JNCC, 2004b; Hughes *et al.,* 2005).

Similar to the biological structure of key and influential species, the recovery of characterising species' function is dependent on the influence of prevailing environmental conditions, life-history traits and interactions between species, with environmental connectivity between populations or species patches, the suitability of the habitat (e.g. substrate type), depth, water and sediment quality further influencing the recovery potential of Subtidal sedimentary habitats (Mazik *et al.,* 2015).

Biological structure: Characteristic communities of the feature within the site

Four broad characteristic communities have been recorded in the site (Bett, 2012). These are broadly defined by the families of polychaete worms present:

- Spionidae – Syllidae – Syllidae in Atlantic sand and muddy sand (100-300 m): Characterised by polychaetes from the families Spionidae and Syllidae. This biotope is distinguished from other biotopes in the area by the abundance of Syllidae.
- Spionidae – Capitellidae - Syllidae in Atlanto-Arctic sand and muddy sand (300-600 m): Characterised by species of polychaetes from the families: Spionidae, Capitellidae, Terebellidae and Oweniidae, and distinguished from other biotopes in the region by the abundance of the Syllidae. The biotope was generally found in parts of the site shallower than 600 m where the sediment is coarser and the water temperature is highly variable.
- Cirratulidae – Maldanidae – Maldanidae in Arctic sand and muddy sand (600-1200 m): Characterised by polychaetes from the families Cirratulidae, Maldanidae, Amphinomidae, Terebellidae, and Spionidae. High abundances of Maldanidae distinguish the biotope from other biotopes identified in the region. This biotope occurs in deeper parts of the site where the water temperature is more stable and the sediment has a higher silt content.
- Oweniidae – Capitellidae – Maldanidae in Arctic mud and sandy mud (>1200 m): Characterised by polychaetes from the families Oweniidae and Capitellidae, and distinguished from other biotopes in the area by the abundance of Maldanidae.

The following characteristic habitats have also been recorded from the wider Faroe-Shetland Channel (including from imagery taken within the site) and are described as follows (Howell *et al.,* 2010):

- Halcampid anemones in rippled Arctic Deep-sea sand;
- Lanice beds (potentially *Lanice conchilega*) in Atlantic Deep-sea sand;
- Ophiuroids in Atlantic Deep-sea sand;
- Sabellids, white encrusting sponges and ophiuroids in Arctic/Atlantic Deep-sea mixed substrates;
- Cyclostomes, ophiuroids and white encrusting sponges in Arctic Deep-sea mixed substrates;
- *Ophiactis abyssicola* and white encrusting sponges in intermediate/Atlantic Deep-sea mixed substrates; and
- White encrusting sponges and serpulids in Arctic/Atlantic/Intermediate Deep-sea mixed substrates.

Notably, community composition in Faroe-Shetland Channel changes with depth down the continental slope (Howell *et al.,* 2007; Bett, 2012; Jones *et al.,* 2012).

Some demersal trawling occurs over the Offshore subtidal sands and gravels feature along the length of the site between around 500 and 700 m depth (Marine Scotland, 2017). Demersal trawling is capable of impacting the characteristic communities through removing benthic species and damage or mortality from abrasion. There are also three plugged oil wells within the site. However, as fishing activity and oil and gas operations are limited within the site to a small geographic area and the intensity of impact is low, **JNCC advise a conserve objective**. This is based on expert judgement; specifically, our understanding of the features sensitivity to pressures exerted by the activities present. Our confidence in this objective would be improved with longer-term monitoring of the condition of the characteristic biological communities of Offshore subtidal sands and gravels and Offshore deep-sea muds within the site. Activities must look to minimise, as far as is practicable, changes in substrata and biological communities within the site.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds within the site, please see the Advice on Operations workbook.

Function
Functions are ecological processes that include sediment processing, secondary production, habitat modification, supply of recruits, bioengineering and biodeposition. These functions rely on the supporting natural processes and the growth and reproduction of those biological communities which characterise the habitat and provide a variety of functional roles within it (Norling *et al.,* 2007), i.e. the key and

influential species and characteristic communities present. These functions can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services locally and to the wider marine environment (ETC, 2011).

Ecosystem services that may be provided by Subtidal sedimentary habitats include:

- Nutrition: Different sediment types offer habitat for breeding and feeding for various commercial species, which in turn are prey for larger marine species, including birds and mammals (FRS, 2017);
- Bird and whale watching: Foraging seals, cetaceans and seabirds may also be found in greater numbers near some Subtidal sedimentary habitats due to the common occurrence of prey for the birds and mammals (e.g. Daunt *et al.,* 2008; Scott *et al,* 2010; Camphuysen *et al.,* 2011; McConnell *et al.,* 1999, Jones *et al.,* 2013); and
- Climate regulation: Providing a long-term sink for carbon within sedimentary habitats.

Similar to the biological structure of key and influential species and characterising species, function is dependent on the influence of prevailing environmental conditions, life-history traits and interactions between species: environmental connectivity between populations or species patches, the suitability of the habitat (e.g. substrate type), depth, water and sediment quality further influencing the recovery potential of Subtidal sedimentary habitats (Mazik *et al.,* 2015). It is critical to ensure that the extent and distribution of Subtidal sedimentary habitats within a site, along with the composition of any key and influential species and characteristic biological communities, are conserved to ensure the functions they provide are maintained.

Function of the feature within the site

The ecosystem services provided by Offshore subtidal sands and gravels and Offshore deep-sea muds in the site could include:

- Nutrition – the Faroe-Shetland Channel supports demersal fish species which are of commercial interest, e.g. Greenland halibut (*Reinhardtius hippoglossoides,* Bullough *et al.,* 1998; Gordon, 2001). The offshore subtidal sands and gravel communities could help to support these species.
- Bird and whale watching - There are enhanced feeding conditions for cetaceans within the wider Faroe-Shetland Channel and it is thought to be an important migratory pathway for certain cetacean species, e.g. fin and sei whales (Stone, 1988; Weir et al., 2001; Swift *et al*., 2002; Hastie *et al.,* 2003; Macleod, 2004; Macleod *et al*., 2006). The sedimentary habitat communities could help to support their prey species.
- Climate regulation - sedimentary habitats provide a long-term carbon sink (Alonso et al., 2012), so are important for climate regulation.

Given that a conserve objective is advised for the characteristic biological communities on which these functions are dependent, **JNCC also advise a conserve objective** for this sub-attribute. Our confidence in this objective would be improved with longer-term monitoring of the condition of the characteristic biological communities of the protected habitats within the site and the role that such communities play in mediating the delivery of the ecosystem services identified.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds within the site, please see the Advice on Operations workbook.

Attribute: Supporting processes

Objective: Conserve

There is limited evidence to suggest that supporting processes are being impeded with respect to supporting the function of Offshore subtidal sands and gravels and Offshore deep-sea muds within the site. As such, ***JNCC advise a conserve objective*** *which is based on expert judgment, specifically our understanding of the feature's sensitivity to pressures associated with ongoing activities. Our confidence in this objective would be improved with long term monitoring, specifically of contaminant levels within the site and a better understanding of the hydrodynamic regime within the site. Activities must look to avoid, as far as is practicable, exceeding Environmental Quality Standards set out below.*

Explanatory notes

Subtidal sedimentary habitats and the communities they support rely on a range of natural processes to support function (ecological processes) and help any recovery from adverse impacts. For the site to fully deliver the conservation benefits set out in the statement on conservation benefits (hyperlink is provided in the box at the top of this document), the following natural supporting processes must remain largely unimpeded - Hydrodynamic regime and Water and sediment quality.

Hydrodynamic regime

Hydrodynamic regime refers to the speed and direction of currents, seabed shear stress and wave exposure. These mechanisms circulate food resources and propagules, as well as influence water properties by distributing dissolved oxygen, and facilitate gas exchange from the surface to the seabed (Chamberlain *et al.,* 2001; Biles *et al.,* 2003; Hiscock *et al.,* 2004; Dutertre *et al.,* 2012). Hydrodynamic regime also effects the movement, size and sorting of sediment particles. Shape and surface complexity within Subtidal sedimentary habitat types can be influenced by hydrographic processes, supporting the formation of topographic bedforms (see finer scale topography). Typically, the influence of hydrodynamic regime on Subtidal sedimentary habitats is less pronounced in deeper waters, although contour-following currents (e.g. on the continental slope) and occasional episodes of dynamic flows can occur (Gage, 2001).

Hydrodynamic regime within the site

Five different water masses flow and converge within the Faroe-Shetland Channel where this site is located. The North Atlantic Water, Modified North Atlantic Water and Arctic Intermediate/North Icelandic Water masses flow in a north-easterly direction through the channel, while the Norwegian Sea Arctic Intermediate Water and Faroe-Shetland Channel Bottom Water masses flow in a south-westerly direction (Bett, 2012). The Modified North Atlantic Water, Arctic Intermediate/North Icelandic Water and Norwegian Sea Arctic Intermediate Water all occur between 500 and 600 m depth within the site, while the North Atlantic Water is shallower than 500 m and the Faroe-Shetland Channel Bottom Water occurs deeper than 600 m (Bett, 2012). The layering of these water masses which have contrasting characteristics interacts with the continental slope to create internal mixing of the water masses close to the seabed within the site (Bett, 2012; Mckenna *et al.,* 2016).

Deep-sea currents below 600 m predominantly travel north-east to south-west along the Faroe-Shetland Channel and more shallow currents (above 600 m) predominantly travel in the opposite direction. Between 400 and 600 m this mixing of water masses leads to turbulent mixing resuspending and providing nutrients to the water column for deep-sea sponges to feed upon. This mixing zone is thought to significantly increase the abundance and diversity of species found in the site and explain the highly biologically diverse communities found there.

It is also likely that the currents operating around the site have a significant role to play in surface sediment composition. The installation or maintenance of infrastructure or the removal of sediment that causes a change in current speed or direction may have a detrimental effect on the abundance and diversity of species within the site and alter the distribution or composition of sediments across the site.

While the infrastructure present in the site may be having a localised effect on the hydrodynamic regime, it is not thought that this is having an adverse impact on the conservation status of the protected sedimentary habitats. As such, **JNCC advise a conserve objective** for this sub-attribute. This is based on expert judgment, specifically our understanding of the features sensitivity to pressures associated with ongoing activities. Our confidence in this objective would be improved with a better understanding of the hydrodynamic regime within the site and its influence on the features conservation status.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds within the site, please see the Advice on Operations workbook.

Water and sediment quality

Contaminants may affect the ecology of Subtidal sedimentary habitats through a range of effects on different species within the habitat, depending on the nature of the contaminant (JNCC, 2004b; UKTAG, 2008; EA, 2014). It is therefore important to avoid changing the natural water quality and sediment quality in a site and, as a minimum, ensure compliance with existing Environmental Quality Standards (EQSs).

The targets listed below for water and sedimentary contaminants in the marine environment and are based on existing targets within OSPAR or the Water Framework Directive (WFD) that require concentrations and effects to be kept within levels agreed in the existing legislation and international commitments as set out in The UK Marine Strategy Part 1: The UK Initial Assessment (2012). Aqueous contaminants must comply with water column annual average (AA) EQSs according to the amended EQS Directive (2013/39/EU) or levels equating to (High/Good) Status (according to Annex V of the WFD (2000/60/EC), avoiding deterioration from existing levels).

Surface sediment contaminants (<1 cm from the surface) must fall below the OSPAR Environment Assessment Criteria (EAC) or Effects Range Low (ERL) threshold. For example, mean cadmium levels must be maintained below the ERL of 1.2 mg per kg. For further information, see Chapter 5 of the Quality Status Report (OSPAR, 2010b) and associated QSR Assessments.

The following sources of information are available regarding historic or existing contaminant levels in the marine environment:

- Marine Environmental and Assessment National Database (MERMAN);
- The UK Benthos database available to download from the Oil and Gas UK website;
- Cefas' Green Book;
- Strategic Environmental Assessment Contaminant Technical reports available from the British Geological Survey website; and
- Charting Progress 1: The State of the UK Seas (2005) and Charting Progress 2: The State of the UK Seas (2014).

Water quality

The water quality properties that influence the communities living in or on Subtidal sedimentary habitats include salinity, pH, temperature, suspended particulate concentration, nutrient concentrations and dissolved oxygen. They can act alone or in combination to affect habitats and their communities in different ways, depending on species-specific tolerances. In fully offshore habitats, these parameters tend to be relatively more stable, particularly so for deeper waters, although there may be some natural seasonal variation. In deeper waters, dissolved oxygen levels are generally lower due to stratification of the water column and the isolation of bottom water masses (Greenwood *et al.,* 2010). Salinity also increases with depth, peaking about 50 m down, after which the salinity decreases with increasing depth to a minimum around 1000 m in North Atlantic waters (Talley, 2002).

Water quality can influence habitats and the communities they support by affecting the abundance, distribution and composition of communities at relatively local scales (Elliott *et al.,* 1998; Little, 2000; Gray and Elliott, 2009). For example, a prolonged increase in suspended particulates can also have several implications, such as affecting fish health, clogging filtering organs of suspension feeding animals and affecting seabed sedimentation rates (Elliott *et al.,* 1998). Low dissolved oxygen can also have sub-lethal and lethal impacts on fish, infauna and epifauna (Best *et al.,* 2007). Conditions in the deep-sea are typically more stable than in shallower habitats, therefore deep-sea organisms are expected to have a lower resilience to changes in abiotic conditions (Tillin *et al.,* 2010). Concentrations of contaminants in the water column must not exceed the EQS.

Water quality within the site

The five different water masses that flow through the site have contrasting characteristics (adapted from Bett, 2012; Mckenna *et al.*, 2016):

	Temperature (°C)	Salinity (ppt)	Phosphate (µM L^{-1})	Nitrate (µM L^{-1})	Silicate (µM L^{-1})
North Atlantic Water	>8	35.35 - 35.45	0.6 - 1.1	9 - 16	2.5 - 7.5
Modified North Atlantic Water	6.5 - 8	35.1 - 35.3	0.6 - 1.1	9 - 16	2.5 - 7.5
Arctic Intermediate/North Icelandic Water	2 - 5.5	34.76 - 34.99	0.85 - 0.97	12.1 - 13.2	5.8 - 7.3
Norwegian Sea Arctic Intermediate Water	0.5 - -0.5	34.89 - 34.91	0.9 - 1.1	13.2 - 14.9	9.6 - 12.3
Faroe-Shetland Channel Bottom Water	< -0.5	34.91	0.8 - 1.1	9.6 - 14.8	11.77

The properties of the water masses influence the spatial distribution of the characterising communities within the site. In shallower parts of the site, where the North Atlantic Water, Modified North Atlantic Water and Arctic Intermediate/North Icelandic Water masses are present at the seabed, there is more mixing and the temperature of the water is highly variable. This leads to communities typical of Atlanto-Arctic Bathyl Sand (Bett, 2012). The Norwegian Sea Arctic Intermediate Water and Faroe-Shetland Channel Bottom Water are in contact with the sea-bed sediments in parts of the site below 600 m, here the water temperature is colder and much more stable. The two deeper water masses result in Arctic bathyl muddy sand communities (Bett, 2012).

Background data on dissolved oxygen, dissolved and particulate organic and inorganic carbon, nitrogen and silicate are not currently available. However, the mixing of the five water masses between 400-600 m is likely to result in local fluctuations in temperature, salinity and nutrient levels. The amount of dissolved and particulate nutrients available to sponges in this depth band is currently unknown, however the 2017 survey collected conductivity, temperature and depth data, that once analysed will provide further information on this.

Evidence from the Charting Progress 2 report, that used decadal time-series data indicated that air temperature, sea temperature and ocean acidification are increasing, but that suspended particulate matter, turbidity and salinity were neither increasing nor decreasing. The Charting Progress 2 report also indicates that while the site is distant from terrestrial sources of pollution, climatic variability may affect ecological function of the site. The extent to which water quality is currently impacted by anthropogenic activity is unclear and information on pollution levels by heavy metals or other contaminants (such as atmospheric deposition of trace metals) is currently unknown. While this information identifies possible sources of contamination, there is no information available to indicate that water quality in the site is falling below EQSs.

JNCC advise a conserve objective and that activities must look to avoid, as far as is practicable, exceeding EQSs set out above. Our confidence in this objective would be improved with long term monitoring, a better understanding of contaminant levels in the site and how contaminants can impact communities characteristic of the protected habitats.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds, please see the Advice on Operations Workbook.

Sediment quality

Various contaminants are known to affect the species that live in or on the surface of Subtidal sedimentary habitats. These include heavy metals like mercury, arsenic, zinc, nickel, chromium and cadmium, polyaromatic hydrocarbons, polychlorinated biphenyls, organotins (such as TBT) and pesticides (such as hexachlorobenzene). These metals and compounds can impact species sensitive to contaminants, degrading the community structure (e.g. heavy metals) and bioaccumulate within organisms thus entering the marine food chain (e.g. polychlorinated biphenyls) (OSPAR, 2009; OSPAR, 2010; OSPAR, 2012). The biogeochemistry of mud habitats in particular is such that the effects of contaminants are greater (Sciberras *et al.,* 2016) leading in some cases to anoxic or intolerant conditions for several key and characterising species and resulting in a change to species composition. It is therefore important to ensure sediment quality is maintained by avoiding the introduction of contaminants and as a minimum ensure compliance with existing EQS as set out above, particularly in mud habitats.

Sediment quality within the site

Evidence from the Charting Progress 2 report indicated that while the site is distant from terrestrial sources of pollution, climatic variability may affect ecological function of the site. The extent to which sediment quality is currently impacted by anthropogenic activity is unclear and information on pollution levels by heavy metals or other contaminants is currently unknown. While this information identifies possible sources of contamination, there is no information available to indicate that sediment quality in the site is falling below EQSs.

Due to the lack of evidence on sediment quality affecting the biological communities associated with Offshore subtidal sand and gravels and Offshore deep-sea muds within the site, **JNCC advise a conserve objective** and that activities must look to avoid, as far as is practicable, exceeding EQSs set out above. Our confidence in this objective would be improved with longer-term monitoring, a better understanding of contaminant levels in the site and how contaminants can impact the biological communities associated with the protected habitat types present.

For further information on activities capable of affecting Offshore subtidal sands and gravels and Offshore deep-sea muds, please see the Advice on Operations Workbook.

Table 3. Supplementary advice on the conservation objectives for the area of Continental slope protected within the North-East Faroe-Shetland Channel NCMPA

Attribute: Extent and distribution

Objective: Conserve

As a large-scale geological feature, it is not considered that any activities currently taking place, or that may take place in the future, are capable of affecting the extent and distribution of the area of the Faroe-Shetland Channel continental slope protected within this site. ***JNCC advise a conserve objective*** *based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities.*

Explanatory notes

In the context of a large-scale feature, extent and distribution refers to area the large-scale feature occupies within a site.

Site advice

The entire area of the site covers a section of the Faroe-Shetland Channel continental slope. As a large-scale geological feature, it is not considered that any activities currently taking place, or that may take place in the future, are capable of affecting the extent and distribution of the area of the Faroe-Shetland Channel continental slope protected within this site. As such, **JNCC advise a conserve objective**.

Attribute: Structure and function

Objective: Conserve

As a large-scale geological feature, it is not considered that any human activities are capable of affecting the physical nature of the area of the Faroe-Shetland Channel continental slope protected within this site. Moreover, there is no evidence to suggest that the functional role of the Faroe-Shetland Channel continental slope has been impaired. ***A conserve objective is advised*** *based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities.*

Explanatory notes

In the context of a large-scale feature, structure refers to the physical structure of the feature and the functional role it plays in supporting the wider health and biodiversity of Scotland's seas.

Structure within the site

The Faroe-Shetland channel continental slope is a gradient of bedrock overlain with sediment that divides the Scottish continental shelf from the deeper waters of the Faroe-Shetland Channel. As a large-scale geological feature, it is not considered that any human activities are capable of affecting the physical nature of the area of the Faroe-Shetland Channel continental slope protected within this site. As such, **JNCC advise a conserve objective**.

Function within the site

Functions provided by large-scale features can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services locally and to the wider marine environment (ETC, 2011). Ecosystem services that may be the provided by the area of the Faroe-Shetland Channel continental slope protected within the site include:

- Whale and dolphin watching - The interaction between hydrographic processes and the continental slope may enhance feeding conditions through the aggregation of principle prey items (e.g. squid, herring, blue whiting and krill) for several species of cetacean, including sperm whale, minke whale, orca, fin whale, long-finned pilot whale and Atlantic white-sided dolphin (Stone, 1988; Weir *et al.,* 2001; Swift *et al*., 2002; Macleod, 2004; Macleod *et al.,* 2006). In addition, the topography of the Faroe-Shetland Channel continental slope and wider channel is thought to be of functional significance as a migratory pathway/corridor for several cetacean species. Of these, based on the data available, fin and sperm whales are the most regular users of the route. These cetacean species seem to use the channel as a passageway to move through into colder, temperate waters to the north to feed in the early summer months whilst some remain in the channel (e.g. Macleod *et al.,* 2006) before travelling.
- Nutrition – The same process outlined above is also true for fish assemblages; many of which are of commercial importance (Bullough *et al., 19*98; Gordon, 2001).
- Enhanced levels of biological productivity - The diversity and abundance of species present within the site has been linked to the presence of the mixing zone at the intermediate water masses which act against the continental slope. For example, benthic fauna indicates a diversity and abundance maximum at the intermediate water masses (Bett, 2000; Bett, 2001; Narayanaswamy *et al.*, 2005; Narayanaswamy *et al.*, 2010).

There is no evidence to suggest that the functional role of the Faroe-Shetland Channel continental slope has been impaired as a result of human activity. As such, **JNCC advise a conserve objective**.

Attribute: Supporting processes

Objective: Not Set

The Faroe-Shetland Channel continental slope is a relict geological feature. As such, consideration of supporting processes is not of relevance.

Explanatory notes

In the context of large-scale features, supporting processes refers to the role that the hydrodynamic regime plays in maintaining the functional significance of the feature within a site.

Supporting processes within the site

The Faroe-Shetland Channel continental slope is a relict geological feature. As such, consideration of supporting processes is not of relevance.

Table 4. Supplementary advice on the conservation objectives for the geodiversity features protected within the North-East Faroe-Shetland Channel NCMPA

Terminology

- *Geodiversity features* – a collective term for geological and geomorphological features.
- *Key Geodiversity Area* – a collective term for geodiversity features that in combination make up the key geodiversity interests of a site.
- *Relict* – a category of geodiversity features which have been formed by geological processes which are no longer taking place e.g. iceberg plough marks formed by glacial movement during the last ice age.
- *Active* – a category of geodiversity features which are formed and maintained by natural processes that are still taking place e.g. sand and sediment wave fields which are maintained by the prevailing hydrodynamic regime.

Overview of the protected geodiversity features of the site

The site protects geodiversity features comprising Key Geodiversity Areas within Scotland's seas:

- **The North Sea Fan –** comprising the relict geomorphological components: prograding wedge, slide deposits
- **The Miller Slide -** comprising the relict geomorphological components: slide deposits
- **The West Shetland Margin Paleo-Depositional System –** comprising active geomorphological components contourite sand/silt
- **The Pilot Whale Diapirs** – comprising relict geomorphological components mud diapirs

There is no direct information on the condition of the protected geodiversity features within the site. Consequently, the conservation objective attributes have been set based on JNCC's understanding of the sensitivity of the protected geodiversity features to pressures associated with human activities to which the features are considered to be sensitive (based on Brooks *et al*., 2013). It is important to note that only physical pressures (such as abrasion to the seabed surface and the physical removal or deposition of material) are considered to pose a threat to the integrity of relict protected geodiversity features of the site. For active protected geodiversity features, changes to the prevailing hydrodynamic regime may also pose a threat to the conservation status of these features.

Attribute: Extent and distribution

Objective: Conserve

While evidence indicates that activities are occurring which are capable of impacting the protected geodiversity features, it is not feasible to *recover reflect geodiversity features once impacted through management intervention. In addition, JNCC are uncertain as to whether any localised hydrodynamic changes may be taking place, for instance because of the installation of infrastructure associated with oil and gas extraction, which may have or be hampering the maintenance of the active geodiversity features.* ***A conserve objective is therefore advised****. Our confidence in the condition of the protected geodiversity features would be improved by longer term monitoring. Activities should avoid the deposition of artificial substrata in areas where contourite deposits have been recorded or activities that lead to disruption, obstruction or removal of the relict geodiversity features: prograding wedge, Miller Slide, North Sea Slide and The Pilot Whale Diapirs.*

Explanatory notes

In the context of the protected geodiversity features of the site, extent and distribution refers to the area occupied within a site. Any significant loss of extent to relict geodiversity features may be more significant than for active geodiversity features because the processes that led to the formation of relict features are no longer taking place. The extent and distribution of the protected geodiversity features within the site is shown on JNCC's Interactive MPA Mapper.

Extent and distribution within the site

The North Sea Fan and Miller Slide

Prograding wedge and slide deposits

There is a prograding wedge covering around 60% of the site to the east, which forms a key part of the North Sea Fan Key Geodiversity Area. The Miller Slide complex is one of the largest submarine palaeo-slides identified in Scottish waters with a lateral extent of over 50 km and is thought to have failed approximately 200,000 years ago (Long *et al.,* 2003). The Miller Slide is located to the west and covers approximately 40% of the site.

Prograding wedges and slide deposits are relict features. As such, they have been defined as having no resilience to pressures associated with physical disturbance. However, owing to the very large scale of the features, any impacts arising from physical pressures associated with human activities are considered negligible (Brooks, 2013). As such, **JNCC advise a conserve objective** for these protected geodiversity features. Activities must look to minimise, as far as is practicable, reductions to the extent and distribution of the prograding wedges and slide deposits within the site.

The West Shetland Margin Paleo-Depositional System

Contourite deposits: sand/silt

The contourite deposits west of Shetland form a complex of sandy bedforms that are unique in UK waters (Brooks *et al.,* 2013). Contourites are the deposits formed by oceanic boundary currents that flow along the contours at depths determined by the water density. The currents maintaining these deposits, build up extensive and thick, fine grained bodies of sediment called drifts. Within the site, there are four known areas of contourite deposits along the continental slope, covering an area around 2,840 km^2.

These protected geodiversity features are actively maintained by hydrodynamic processes and so extent of these features may well change naturally over time. Pressures such as a physical change to another seabed type or artificial changes to topography may cause localised disruption to flows (and associated patterns of sediment transport) that could result in the loss of distribution and extent of the feature in the immediate vicinity of the obstruction. There is increasing interest in the site for oil and gas exploration activities and such activity may have already affected the extent and distribution of these protected geodiversity features (although direct evidence of such impacts is not available).

JNCC are uncertain as to whether any localised hydrodynamic changes may be taking place, for instance as a result of the installation of infrastructure associated with oil and gas extraction, which may have or be hampering the maintenance of the active geodiversity features. A **conserve objective is therefore advised**. Our confidence in the condition of the protected geodiversity features would be improved by longer term monitoring. Activities should avoid the deposition of artificial substrata in areas where contourite deposits have been recorded.

The Pilot Whale Diapirs

Mud diapirs

The Pilot Whale Diapirs are a series of relict deep water diapiric sediment mounds that measure 2-3 km across and rise to more than 70 m above the seabed. Within the site, the Pilot Whale Diapirs have been recorded from slightly west of the centre of the site and are patchily distributed over an area of around 420 km^2.

The Pilot Whale Diapirs are relict features. As such, they have been defined as having no resilience to pressures associated with physical disturbance. However, owing to the very large scale of the features, any impacts arising from physical pressures associated with human activities are considered negligible (Brooks, 2013). As such, **JNCC advise a conserve objective** for these protected geodiversity features. Activities must look to minimise, as far as is practicable, reductions to the extent and distribution of The Pilot Whale Diapirs.

Attribute: Structure and function

Objective: Conserve

While evidence indicates that activities are occurring which are capable of impacting the protected geodiversity features, it is not feasible to recover relict geodiversity features once impacted through management intervention. In addition, JNCC are uncertain as to whether any localised hydrodynamic changes may be taking place, for instance because of the installation of infrastructure associated with oil and gas extraction, which may have or be hampering the maintenance of the active geodiversity features. ***A conserve objective is therefore advised****. Our confidence in the condition of the protected geodiversity features would be improved by longer term monitoring. Activities should avoid the deposition of artificial substrata in areas where contourite deposits have been recorded or activities that lead to disruption, obstruction or removal of the relict geodiversity features: prograding wedge, Miller Slide, North Sea Slide and The Pilot Whale Diapirs.*

Explanatory notes

In the context of the protected geodiversity features of the site, structure refers to the physical nature of protected geodiversity features and function as both the scientific importance of the features in their own right, as well as the role they play in supporting biological functioning.

Structure within the site

The North Sea Fan and Miller Slide

Prograding wedge and slide deposits

Prograding wedges are stacked accumulations or glacial deposited sediments that are typically 200-400 m thick (Stoker, 1995; Brooks *et al.*, 2013). Many of the slide deposits in Scottish waters have been buried and therefore are not visible on the surface of seabed (Brooks *et al.*, 2013); although both the Miller Slide and North Sea Slide are exposed at the seabed.

These are relict features and as such, they have been defined as having no resilience to pressures associated with physical disturbance. However, owing to the very large scale of the feature (in terms of both geographical extent and sediment thickness), any impacts arising from physical pressures associated with human activities are considered negligible (Brooks, 2013). As such, **JNCC advise a conserve objective** for this protected geodiversity feature. Activities must look to minimise, as far as is practicable, changes to the structure and function of the prograding wedges and slide deposits within the site.

The West Shetland Margin Paleo-Depositional System

Contourite deposits: sand/silt

Contourites are the deposits formed by oceanic boundary currents that flow along the contours at depths determined by the water density. The currents usually operate over very great periods of time, and build up extensive and thick, fine grained bodies of sediment called drifts. The sands on the upper slope of the Faroe-Shetland Channel within the site are thin, low and mainly isolated sand waves and sand ribbons (Brooks *et al.,* 2013). Later surveys have showed that the southwards flowing currents, beneath the Upper Slope Current that exit the Arctic Ocean through the Faroe-Shetland Channel and its extension, the Faroe Bank Channel, also transport sand (Masson, 2001). These sands form about half a dozen thin isolated sheets and some waveforms, including southwards directed barchan waves (Wynn *et al.,* 2002). They occur in depths of between about 800 m and 1,100 m (Brooks *et al.,* 2013). One of the sheets has been investigated in detail and shown to be less than 40 cm thick though about 60 km long (Brooks *et al.,* 2013).

The eastern slope of the Faroe-Shetland Channel within the site exhibits examples of both muddy drifts and rare examples of sandy contourites on the upper slope, transported northwards by the upper slope current that sweeps the margin between southern Ireland and the Barents Sea, as well as sandy contourites on the lower slope that are swept southwards by the Norwegian Sea deep water. The bulk of the fine-grained drift associated with the eastern side of the Faroe-Shetland Channel is between 200 m and 400 m thick and was deposited between about 4 and 0.5 million years ago (Knutz and Cartwright, 2003; Knutz and Cartwright, 2004). The sequence also contained climbing sediment waves typical of contourite drifts (Knutz and Cartwright, 2003; Knutz and Cartwright, 2004).

These protected geodiversity features are actively maintained by hydrodynamic processes and so the structure of these features may well change naturally over time. Pressures such as a physical change to another seabed type or artificial changes to topography may cause localised disruption to flows (and associated patterns of sediment transport) that could result in the loss of structure of the feature in the immediate vicinity of the obstruction. There is increasing interest in the site for oil and gas exploration activities and such activity may have already affected the structure of these protected geodiversity features (although direct evidence of such impacts is not available).

JNCC are uncertain as to whether any localised hydrodynamic changes may be taking place, for instance as a result of the installation of infrastructure associated with oil and gas extraction, which may have or be hampering the maintenance of the active geodiversity features. A **conserve objective is therefore advised**. Our confidence in the condition of the protected geodiversity features would be improved by longer term monitoring. Activities should avoid the deposition of artificial substrata in areas where contourite deposits have been recorded.

The Pilot Whale Diapirs
Mud diapirs
The Pilot Whale Diapirs are the collective term for the field of seabed mud mounds located to the south-west of the site. The largest of these occur over a buried anticline and they are set in sediment debris flows that originated from grounded ice and submarine landslides. Other diapirs and mud mounds are sited on and adjacent to the north-east plunging Fugloy Ridge and buried transfer fault zones within a region subject to modern earthquakes. The pilot whale diapirs measure 2 km to 3 km across and rise to more than 70 m above the surrounding seafloor.

These are relict features and as such, they have been defined as having no resilience to pressures associated with physical disturbance. However, owing to the very large scale of the feature (in terms of both geographical extent and sediment thickness), any impacts arising from physical pressures associated with human activities are considered negligible (Brooks, 2013). As such, **JNCC advise a conserve objective** for this protected geodiversity feature. Activities must look to minimise, as far as is practicable, changes to the structure and function of the Pilot Whale Diapirs within the site.

Function within the site

Miller Slide and North Sea Fan
Prograding wedge and slide deposits
Functions provided by geodiversity features can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services locally and to the wider marine environment (ETC, 2011). Ecosystem services that may be the provided by the protected geodiversity features of The Miller Slide and North Sea Fan Key Geodiversity Area include:

- Scientific importance: The Miller Slide complex is regarded as scientifically important because it represents one of the largest submarine palaeo-slides identified in Scottish waters and is thought to have failed approximately 200,000 years ago (Long *et al.,* 2003). It is regarded as a particularly good example of a submarine mass movement because unusually for a palaeo-slide complex, a complete picture can be obtained of both the erosional and depositional areas of the slide (Evans *et al.,* 2005). The North Sea Fan is a large example of a trough-mouth fan system and is one of the largest such features identified on the north-east Atlantic margin. It is considered scientifically important since it holds a detailed archive of information on the Pleistocene glacial history of the British and Fennoscandian ice sheets stretching back to at least 1.1 Ma.

Whilst JNCC consider that there may be activities taking place that are capable of affecting the conservation status of the protected geodiversity features that comprise these Key Geodiversity Areas, it is not possible to recover them through human intervention. As such, **JNCC advise a conserve objective** and recommend that activities that result in the physical removal of unconsolidated material or obscuring of the surfaces of the prograding wedge or slide deposits within the site are kept to a minimum.

West Shetland Margin Paleo-depositional system

Contourite deposits: sand/silt

Functions provided by geodiversity features can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services locally and to the wider marine environment (ETC, 2011). Ecosystem services that may be the provided by the protected geodiversity features of the West Shetland Margin paleo-depositional system Key Geodiversity Area include:

- Scientific importance: all the protected geodiversity features of the West Shetland Margin paleo-depositional system Key Geodiversity Area form part of a palaeo-depositional system that was active during the last glacial period and so represent a valuable record of the glacial history of the area (Brooks *et al.*, 2013). The contourite deposits can be used to track current flow back from present day current measurements (e.g. Hansen and Østerhus, 2007), by using cores and seismic profiles (e.g. Hohbein and Cartwright, 2006). They have also been the focus of detailed studies of scientifically important sedimentary facies and have a critical role to play in furthering understanding of Neogene palaeoceanography and associated climatic changes. Furthermore, Sandy contourites are less well studied but are of greater economic significance since the discovery that they can form hydrocarbon reservoirs (Viana e*t al.,* 2007).
- Habitat provision: The protected geodiversity features of this Key Geodiversity Area may be considered to be of functional importance as a settlement point for Deep-sea sponge aggregations; a protected biodiversity feature of the site that provide ecosystem services (see Table 1).

These protected geodiversity features are actively maintained by hydrodynamic processes and so may well change naturally over time. Pressures such as a physical change to another seabed type or artificial changes to topography may cause localised disruption to flows (and associated patterns of sediment transport) that could result in the loss of function of the feature in the immediate vicinity of the obstruction. There is increasing interest in the site for oil and gas exploration activities and such activity may have already affected the function of these protected geodiversity features (although direct evidence of such impacts is not available).

JNCC are uncertain as to whether any localised hydrodynamic changes may be taking place, as a result for instance due to the installation of infrastructure associated with oil and gas extraction, which may have or be hampering the maintenance of the active geodiversity features. A **conserve objective is therefore advised**. Our confidence in the condition of the protected geodiversity features would be improved by longer term monitoring. Activities should avoid the deposition of artificial substrata in areas where contourite deposits have been recorded.

The Pilot Whale Diapirs
Mud diapirs
Functions provided by geodiversity features can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services locally and to the wider marine environment (ETC, 2011). Ecosystem services that may be the provided by the protected geodiversity features of The Pilot Whale Diapirs Key Geodiversity Area include:

- Scientific importance: The pilot whale diapirs are unusual in that they are the only known example of diapirs found in UK waters that breach the seabed surface and provide scientists with a rare opportunity to directly sample mid-Cenozoic age sediments at the seabed. Notably, the contourite deposits and mud diapirs were both selected for protection due to their scientific importance.

Whilst JNCC consider that there may be activities taking place that are capable of affecting the conservation status of the protected geodiversity features that comprise these Key Geodiversity Areas, it is not possible to recover them through human intervention. As such, **JNCC advise a conserve objective** and recommend that activities that result in the physical removal or obscuring of the surfaces of the Pilot Whale Diapirs within the site are kept to a minimum.

Attribute: Supporting processes

Objective: Conserve

Supporting processes are not considered to be of relevance to the protected geodiversity features that comprise The Miller Slide, North Sea Fan or Pilot Whale Diapirs Key Geodiversity Areas because they are all relict features. However, the protected geodiversity features comprising the West Shetland Margin contourite deposits are actively maintained by the prevailing hydrodynamic regime. JNCC do not believe there is any evidence to suggest that the prevailing hydrodynamic regime has been affected by human activities. As such, ***JNCC advise a conserve objective****.*

Explanatory notes
In the context of the protected geodiversity features of the site, supporting processes refers to the role that the prevailing hydrodynamic regime plays in maintaining the integrity of active protected geodiversity features within the site.

Supporting processes within the site

The Miller Slide, The North Sea Fan and The Pilot Whale Diapirs
All of the protected geodiversity features comprising these Key Geodiversity Area are relict features. As such, consideration of supporting processes is not of relevance to the conservation status of the protected geodiversity features.

West Shetland Margin contourite deposits
Five different water masses converge in the Faroe-Shetland Channel that includes this site. The North Atlantic Water, Modified North Atlantic Water and Arctic Intermediate/North Icelandic Water masses flow in a north-easterly direction through the channel, while the Norwegian Sea Arctic Intermediate Water and Faroe-Shetland Channel Bottom Water masses flow in a south-westerly direction (Bett, 2012). The layering of these water masses which have contrasting characteristics interacts with the continental slope to create internal mixing of the water masses close to the seabed within the Faroe-Shetland Sponge Belt NCMPA (Bett, 2012; Mckenna *et al.*, 2016).

Current speeds of between 0.05 to 0.3 m s^{-1} have been recorded near the seabed within the site (Jones *et al.*, 2006; BP, 2010). Internal waves, known as solibores, travel up the continental slope near the seabed in the site (Hosegood and van Haren, 2004). The velocities of these waves are over 0.1 m s^{-1} (Hosegood and van Haren, 2004). The internal waves occur intermittently but have a significant impact on sediment transport, resuspending sands and gravels on the seabed and transporting them up the continental slope (Hosegood and van Haren, 2004).

Infrastructure associated with oil and gas extraction are present within the mapped extent of the feature, and there is likely to be continuing interest in oil and gas extraction in the future. The presence of this infrastructure can have an extremely localised effect on the hydrodynamic regime within the site. These protected geodiversity features are actively maintained by the prevailing hydrodynamic regime, and are therefore potentially affected by such changes. JNCC do not believe there is any evidence to suggest that the prevailing hydrodynamic regime has been affected by human activities. As such, **JNCC advise a conserve objective**. Activities must look to minimise, as far as is practicable, changes to the hydrodynamics within the site.

References

Axelsson, M.B. (2003). *The deep-seabed environment of the UK continental margin – integration and interpretation of geological and biological data*. University of Southampton, Ph.D. thesis.

Barrio Froján, C.R.S., MacIsaac, K.G., McMillan, A.K., Sacau Cuadrado, M.M., Large, P.A., Kenny, A.J., Kenchington, E. and de Cárdenas González, E. (2012). An evaluation of benthic community structure in and around the Sackville Spur closed area (northwest Atlantic) in relation to the protection of vulnerable marine ecosystems. *ICES Journal of Marine Science*, 69: 213-222.

Barros, F., Underwood, A.J. and Archambault, P. (2004). The Influence of troughs and crests of ripple marks on the structure of subtidal benthic assemblages around rocky reefs. *Estuarine, Coastal and Shelf Science*, 60: 781-790.

Beaulieu, S.E. (2001). Life on glass houses: sponge stalk communities in the deep sea. *Marine Biology,* 138: 803-817.

Beazley, L.I., Kenchington, E.L., Murillo, F.J. and Sacau, M. (2013). Deep-sea sponge grounds enhance diversity and abundance of epibenthic megafauna in the Northwest Atlantic. *ICES Journal of Marine Science,* 70: 1471–1490.

Beazley, L., Kenchington, E., Yashayaev, I. and Murillo, F.J. (2015). Drivers of epibenthic megafaunal composition in the sponge grounds of the Sackville Spur, northwest Atlantic. *Deep-Sea Research I,* 98: 102–114.

Bell, J.J. (2008). The functional roles of marine sponges. *Estuarine, Coastal and Shelf Science,* 79: 341–353.

Bell, J.J., McGrath, E., Biggerstaff, A., Bates, T., Bennett, H., Marlow, J. and Shaffer, M. (2015). Sediment impacts on marine sponges. *Marine Pollution Bulletin,* 94: 5-13.

Berman, J., Burton, M., Gibbs, R, Lock, K., Newman, P., Jones, J. and Bell, J. (2013). Testing the suitability of a morphological monitoring approach for identifying temporal variability in a temperate sponge assemblage. *Journal for Nature Conservation,* 21: 173-182.

Best, M.A., Wither, A.W. and Coates, S. (2007). Dissolved oxygen as a physicochemical supporting element in the Water Framework Directive. *Marine Pollution Bulletin*, 55: 53-64 [online]. Available at: http://www.sciencedirect.com/science/article/pii/S0025326X06003171 [Accessed 20 September 2017].

Bett, B.J. (2000). Benthic ecology of the Faeroe-Shetland Channel. Section 4.3.1 in Environmental Surveys of the Seafloor of the UK Atlantic Margin, Atlantic Frontier Environmental Network [CD-ROM]. ISBN 09538399-0-7. Available from Geotek Limited, Daventry, UK.

Bett, B.J. (2001). UK Atlantic Margin Environmental Survey: introduction and overview of bathyal benthic ecology. *Journal of Continental Shelf Research,* 21: 917–956.

Bett, B.J. (2012). Seafloor biotope analysis of the deep waters of the SEA4 region of Scotland's seas. JNCC Report No. 472 [online]. Available at: http://jncc.defra.gov.uk/pdf/472_web.pdf [Accessed 12 January 2018].

Bett, B.J. and Rice, A.L. (1992). The influence of hexactinellid sponge (*Pheronema carpenteri*) spicules on the patchy distribution of macrobenthos in the Porcupine Seabight (bathyal NE Atlantic). *Ophelia,* 36: 217–226.

Biles, C.L., Solan, M., Isaksson, I., Paterson, D.M., Emes, C. and Raffaelli, G. (2003). Flow modifies the effect of biodiversity on ecosystem functioning: an in-situ study of estuarine sediments. Journal of Experimental Marine Biology and Ecology, 285: 165-177.

Brooks, A.J., Kenyon, N.H., Leslie, A., Long, D. and Gordon, J.E. (2013). Characterising Scotland's marine environment to define search locations for new Marine Protected Areas. Part 2: The identification of key geodiversity areas in Scottish waters. Scottish Natural Heritage Commissioned Report No. 432. Available at: http://www.snh.org.uk/pdfs/publications/commissioned_reports/432.pdf [Accessed 12 January 2018].

Buhl-Mortensen, L., Vanreusel, A., Gooday, A.J., Levin, L.A., Priede, I.G., Buhl-Mortensen, P., Gheerardyn, H., King N.J. and Raes, M. (2010). Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. *Marine Ecology,* 31: 21-50.

Buhl-Mortensen, L. and Mortensen, P.B. (2005). Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. In: Freiwald A., Roberts J.M. (eds) Cold-Water Corals and Ecosystems. Erlangen Earth Conference Series. Springer, Berlin, Heidelberg.

Bullough, L.W., Turrell, W.R., Buchan, P. and Priede, I.G. (1998). Commercial deep-water trawling at sub-zero temperatures: Observations from the Faroe-Shetland Channel. *Fisheries Research*, 39: 33-41.

Camphuysen, K., Scott, B. and Wanless, S. (2011). Distribution and foraging interactions of seabirds and marine mammals in the North Sea: A metapopulation analysis [online]. Available at: http://www.abdn.ac.uk/staffpages/uploads/nhi635/ZSLpaper-kees.pdf [Accessed 20 September 2017].

Cárdenas, P. and Rapp, H.T. (2015). Demosponges from the Northern Mid-Atlantic Ridge shed more light on the diversity and biogeography of North Atlantic deep-sea sponges. *Journal of the Marine Biological Association of the United Kingdom,* 95: 1475–1516.

Cathalot, C., Van Oevelen, D., Cox, T.J.S., Kutti, T., Lavaleye, M., Duineveld, G. and Meysman, F.J.R. (2015). Cold-water coral reefs and adjacent sponge grounds: hotspots of benthic respiration and organic carbon cycling in the deep sea. *Frontiers in Marine Science*, 2:37. doi: 10.3389/fmars.2015.00037.

Cebrian, E. and Uriz, M.J. (2007). Contrasting effects of heavy metals and hydrocarbons on larval settlement and juvenile survival in sponges. *Aquatic Toxicology,* 81: 137-143.

Cebrian, E., Agell, G, Marti, R and Uriz, M.J. (2006). Response of the Mediterranean sponge *Chondrosia reniformis* Nardo to copper pollution. *Environmental Pollution,* 141: 452-458.

Chamberlain, J., Fernandes, T.F., Read, P., Nickell, D. and Davies, I.M. (2001). Impacts of biodeposits from suspended mussel (*Mytilus edulis* L.) culture on the surrounding surficial sediments. *ICES Journal of Marine Science*, 58: 411-416.

Coates, D.A., Alexander, D., Stafford, R. and Herbert, R.J.H. (2015). Conceptual ecological modelling of shallow sublittoral mud habitats to inform indicator selection. JNCC Report No. 557 [online]. Available at: http://jncc.defra.gov.uk/PDF/Report%20557_web.pdf [Accessed 20 September 2017].

Coates, D.A., Alexander, D., Herbert, R.J.H. and Crowley, S.J. (2016). Conceptual ecological modelling of shallow sublittoral sand habitats to inform indicator selection. JNCC Report No. 585 [online]. Available at: http://jncc.defra.gov.uk/pdf/Report_585_web.pdf [Accessed 20 September 2017].

Coblentz, K.E., Henkel, J.R., Sigel, B.J. and Taylor, C.M. (2015). Influence of sediment characteristics on the composition of soft-sediment intertidal communities in the northern Gulf of Mexico. PeerJ 3: e1014. [online]. Available at: https://dx.doi.org/10.7717/peerj.1014 [Accessed 20 September 2017].

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. (2004). The Marine Habitat Classification for Britain and Ireland, Version 04.05.

Cooper, K.M., Curtis, M., Wan Hussin, W.M.R., Barrio F.C.R.S., Defew, E.C., Nye, V. and Paterson, D.M. (2011). Implications of dredging induced changes in sediment particle size composition for the structure and function of marine benthic macrofaunal communities. *Marine Pollution Bulletin*, 62: 2087-2094.

Daunt, F., Wanless, S., Greenstreet, S.P.R., Jensen, H., Hamer, K.C. and Harris, M.P. (2008). The impact of the sandeel fishery on seabird food consumption, distribution and productivity in the north-western North Sea. *Canadian Journal of Fisheries and Aquatic Science*, 65: 362-81.

Dernie, K.M., Kaiser, M.J. and Warwick, R.M. (2003). Recovery rates of benthic communities following physical disturbance. *Journal of Animal Ecology*, 72: 1043-1056.

Duckworth, A.R. (2003). Effect of wound size on the growth and regeneration of two temperate subtidal sponges. *Journal of Experimental Biology and Ecology,* 287: 139-153.

Duckworth, A., West, L., Vansach, T., Stubler, A. and Hardt, M. (2012). Effects of water temperature and pH on growth and metabolite biosynthesis of coral reef sponges. *Marine Ecology Progress Series*, 462: 67-77.

Dutertre, M., Hamon, D., Chevalier, C. and Ehrhold, A. (2012). The use of the relationships between environmental factors and benthic macrofaunal distribution in the establishment of a baseline for coastal management. *ICES Journal of Marine Science*, 70: 294-308.

Ebada, S.S., Lin, W.H. and Proksch, P. (2010). Bioactive Sesterterpenes and Triterpenes from marine sponges: Occurance and pharmacological significance. *Marine Drugs,* 8: 313-346.

Edge, K.J., Johnston, E.L., Dafforn, K.A., Simpson, S.L., Kutti, T. and Bannister, R.J. (2016). Sub-lethal effects of water-based drilling muds on the deep-water sponge *Geodia barretti. Environmental Pollution*, 212: 525-534.

Elliott, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. and Hemingway, K.L. (1998). Intertidal sand and mudflats and subtidal mobile sandbanks volume II. An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. UK Marine SACs Project. Oban, Scotland, English Nature.

Environment Agency (EA) (2014). Water Framework Directive: Surface water classification status and objectives [online]. Available at: http://www.geostore.com/environmentagency/WebStore?xml=environment-agency/xml/ogcDataDownload.xml [Accessed 20 March 2017].

Evans, D., Harrison, Z., Shannon, P.M., Laberg, J.S., Nielsen, T., Ayers, S., Holmes, R., Houlta, R.J., Lindberg, B., Haflidason, H., Long, D., Kuijpers, A., Andersen, E.S. and Bryn, P. (2005). Palaeoslides and other mass failures of Pliocene to Pleistocene age along the Atlantic continental margin of NW Europe. *Marine and Petroleum Geology*, 22: 1131-1148.

European Topic Centre (ETC) (2011). Assessment and reporting under Article 17 of the Habitats Directive. Explanatory notes and guidelines for the period 2007-2012 [online]. Available at: https://circabc.europa.eu/sd/a/2c12cea2-f827-4bdb-bb56-3731c9fd8b40/Art17%20-%20Guidelines-final.pdf [Accessed 20 September 2017].

Foden, J., Rogers, S.I. and Jones, A.P. (2010). Recovery of UK seabed habitats from benthic fishing and aggregate extraction-towards a cumulative impact assessment. *Marine Ecology Progress Series*, 411: 259-270.

Freese, J.L. (2001). Trawl induced damage to sponges observed from a research submersible. *Marine Fisheries Review*, 63(3): 7-13.

Freese, J.L. and Wing, B.L. (2003). Juvenile red rockfish, *Sebastes sp*., associations with sponges in the Gulf of Alaska. *Marine Fisheries Review,* 65: 38-42.

Fisheries Research Services (FRS) (2017). Sandeels in the North Sea. Scottish Government [online]. Available at: http://www.gov.scot/Uploads/Documents/ME01ASandeels.pdf [Accessed 10 October 2017].

Gage, J.D. (2001). Deep-sea benthic community and environmental impact assessment at the Atlantic Frontier. *Continental Shelf Research*, 1: 957-986.

Gentric, C., Rehel. K., Dufour, A and Sauleau, P. (2016). Bioaccumulation of metallic trace elements and organic pollutants in marine sponges from the South Brittany Coast, France. *Journal of Environmental Science and Health, Part A,* 51: 213-219.

Gordon, J.D.M. (2001). Deep-water fisheries at the Atlantic Frontier. *Continental Shelf Research*, 21: 987-1003.

Gray, J. and Elliott, M. (2009). Ecology of Marine Sediments: From Science to Management, Second Edition, Oxford Biology.

Greenwood, N., Parker, E.R., Fernand, L., Sivyer, D.B., Weston, K., Painting, S.J., Kröger, S., Forster, R.M., Lees, H.E., Mills, D.K. and Laane, R.W.P.M. (2010). Detection of low bottom water oxygen concentrations in the North Sea; implications for monitoring and assessment of ecosystem health. *Biogeoscience*, 7: 1357-1373.

Gubbay, S. (2002). The Offshore Directory *Review of a selection of habitats, communities and species of the north-east Atlantic.*

Guihen, D., White, M. and Lundälv, T. (2012). Temperature shocks and ecological implications at a cold-water coral reef. *Marine Biodiversity,* 5: e68.

Hansen, B. and Østerhus, S. (2007). Faroe bank channel overflow 1995–2005. *Progress in Oceanography*, 75(4): 817-856.

Hastie, G.D., Swift, R.J., Slesser, G., Thompson, P.M. and Turrell, W.R. (2005). Environmental models for predicting oceanic dolphin habitat in the Northeast Atlantic. *ICES Journal of Marine Science*, 62(4): 760-770.

Henry, L.A. and Hart, M. (2005). Regeneration from injury and resource allocation in sponges and corals–A review. *International Review of Hydrobiology,* 90: 125–158.

Henry, L.A. and 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. JNCC, Peterborough.

Hiscock, K., Southward, A., Tittley, I. and Hawkins, S. (2004). Effects of changing temperature on benthic marine life in Britain and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 14: 333-362

Hogg, M.M., Tendal, O.S., Conway, K.W., Pomponi, S.A., Van-Soest, R.W.M., Krautter, M. and Roberts, J.M. (2010). Deep-sea sponge grounds: reservoirs of biodiversity. *UNEP-WCMC Biodiversity Series No. 32*, UNEP-WCMC, Cambridge.

Hohbein, M. and Cartwright, J. (2006). 3D seismic analysis of the West Shetland Drift system: Implications for Late Neogene palaeoceanography of the NE Atlantic. *Marine Geology*, 230: 1–20.

Hosegood, P. and van Haren, H. (2004). Near-bed solibores over the continental slope in the Faeroe-Shetland Channel. *Deep-Sea Research Part II*, 51: 2943-2971.

Howell, K.L., Davies, J.S., Hughes, D.J. and Narayanaswamy, B.E. (2007). SEA/SAC Survey 2007. Photographic analysis report. DTI.

Howell, K.L., Davies, J.S. and Narayanaswamy, B.E. (2010). Identifying deep-sea megafaunal epibenthic assemblages for use in habitat mapping and marine protected area design. *Journal of the Marine Biological Association of the UK,* 90: 33-68.

Howell, K.L., Piechaud, N., Downie, A.L. and Kenny A. (2016). The distribution of deep-sea sponge aggregations in the North Atlantic and implications for their effective spatial management. *Deep-sea Research 1,* 115: 309-320.

Hughes, T.P., Bellwood, D.R., Folke, C., Steneck, R.S. and Wilson, J. (2005). New paradigms for supporting the resilience of marine ecosystems. *Trends Ecological Evolution*, 20: 380-386.

Hughes, D.J. (2014). Benthic habitat and megafaunal zonation across the Hebridean Slope, western Scotland, analysed from archived seabed photographs. *Journal of the Marine Biological Association of the UK*, 94: 643-658.

ICES (2009). Report of the ICES-NAFO Working Group on Deep-Water Ecology (WGDEC), 9–13 March 2009. ICES Advisory Committee http://vme.ices.dk/download/WGDEC_2009.pdf [Accessed July 2017].

ICES (2013). Report of the ICES-NAFO Joint Working Group on Deep-Water Ecology (WGDEC), 11–15 March 2013. ICES Advisory Committee, Floedevigen, Norway. http://ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2013/WGDEC/wgdec_2013.pdf [Accessed July 2017].

Indraningrat, A.A.G., Smidt, H. and Sipkema, D. (2016). Bioprospecting sponge-associated microbes for antimicrobial compounds. *Marine Drugs,* 14: doi:10.3390/md14050087.

Irving, R. (2009). The identification of the main characteristics of stony reef habitats under the Habitats Directive. *JNCC Report No. 432*. JNCC, Peterborough.

Joint Nature Conservation Committee (2004a). Common Standards Monitoring Guidance for Littoral Rock and Inshore Sublittoral Rock Habitats. [online]. Available at: http://jncc.defra.gov.uk/PDF/CSM_marine_rock.pdf [Accessed 17 January 2018].

Joint Nature Conservation Committee (JNCC) (2004b). Common standards monitoring guidance for inshore sublittoral sediment habitats [online]. Available at: http://jncc.defra.gov.uk/PDF/CSM_marine_sublittoral_sediment.pdf [Accessed 17 January 2018].

Jones, D., Hudson, I.R. and Bett, B. (2006). Effects of physical disturbance on the cold-water megafaunal communities of the Faroe-Shetland Channel. *Marine Ecology Progress Series*, 319: 43-54.

Jones, D., Wigham, B., Hudson, I.R. and Bett, B. (2007). Anthropogenic disturbance of deep-sea megabenthic assemblages: a study with Remotely-Operated Vehicles in the Faroe-Shetland Channel, NE Atlantic. *Marine Biology*, 151. 1731-1741.

Jones, D., Gates, A. and Lausen, B. (2012). Recovery of deep-water megafaunal assemblages from hydrocarbon drilling disturbance in the Faroe-Shetland Channel. *Marine Ecology Progress Series,* 461: 71-82.

Jones, E., McConnell, B., Sparling, C. and Matthiopoulos, J. (2013). Grey and harbour seal density maps. Sea Mammal Research Unit to Marine Scotland Report [online]. Available at: http://www.scotland.gov.uk/Resource/0041/00416981.pdf [Accessed 20 September 2017].

Kahn, A.S., Yahel, G., Chu, J.W.F., Tunnicliffe, V. and Leys, S.P. (2015). Benthic grazing and carbon sequestration by deep-water glass sponge reefs. *Limnology and Oceanography,* 1-19.

Kenchington, E., Power D. and Koen-Alonso, M. (2013). Associations of demersal fish with sponge grounds on the continental slopes of the northwest Atlantic. *Marine Ecology Progress Series,* 477: 217–230.

Kersken, D., Göcke, C., Brandt, A., Lejzerowicz, F., Schwabe, E., Seefeldt, M.A., Veit-Köhler, G. and Janussen, D. (2014). The infauna of three widely distributed sponge species

(Hexactinellida and Demospongiae) from the deep Ekström Shelf in the Weddell Sea, Antarctica. *Deep Sea Research Part II: Topical Studies in Oceanography,* 108: 101-112.

Klitgaard, A.B. and Tendal, O.S. (2004). Distribution and species composition of mass occurrences of large-sized sponges in the northeast Atlantic. *Progress in Oceanography,* 61: 57-98.

Knudby, A., Kenchington, E. and Murillo, F.J. (2013). Modelling the Distribution of *Geodia* Sponges and Sponge Grounds in the Northwest Atlantic. *PLoS ONE,* 8: e82306.

Knutz, P.C. and Cartwright, J. (2003). Seismic stratigraphy of the West Shetland Drift: Implications for late Neogene paleocirculation in the Faeroe-Shetland gateway. *Paleoceanography*, 18(4).

Knutz, P.C. and Cartwright, J.A. (2004). 3D anatomy of late Neogene contourite drifts and associated mass flows in the Faroe-Shetland Basin. *Geological Society, London, Memoirs*, 29(1): 63-72.

Kutti, T., Bannister, R.J., Fosså, J.H., Krogness, C.M., Tjensvoll, I. and Søvik, G. (2015). Metabolic responses of the deep-water sponge *Geodia barretti* to suspended bottom sediment, simulated mine tailings and drill cuttings. *Journal of Experimental Marine Biology and Ecology,* 473: 64-72.

Laport, M.S., Santos, O.C.S. and Muricy, G. (2009). Marine Sponges: Potential sources of new antimicrobial drugs. *Current Pharmaceutical Biotechnology,* 10: 86-105.

Leys, S.P. and Lauzon, N.R.J. (1998). Hexactinellid sponge ecology: growth rates and seasonality in deep water sponges. *Journal of Experimental Marine Biology and Ecology*, 230: 111-129.

Limpenny, S.E., Barrio Frojan, C., Cotterill, C., Foster-Smith, R.L., Pearce, B., Tizzard, L., Limpenny, D.L., Long, D., Walmsley, S., Kirby, S., Baker, K., Meadows, W.J., Rees, J., Hill, K., Wilson, C., Leivers, M., Churchley, S., Russell, J., Birchenough, A. C., Green, S.L. and Law, R.J. (2011). The East Coast Regional Environmental Characterisation. MALSF. Cefas Report No. 08/04.

Little, C. (2000). The biology of soft shores and estuaries, Oxford University Press.

Long, D. and Bone, B.D. (1990). Sediment instability on the continental slope of north-western Britain. *Proceedings of Oceanology International 1990*, 2. Spearhead Exhibitions Ltd, Kingston upon Thames.

Macleod, K., Simmonds, M. and Murray, L. (2003). Summer distribution and relative abundance of cetacean populations off north-west Scotland. *Journal of the Marine Biological Association of the United Kingdom,* 83: 1187-1192.

Macleod, K. (2004). Abundance of Atlantic white-sided dolphin (*Lagenorhynchus acutus*) during summer off northwest Scotland. *Journal of cetacean research and management,* 6: 33-40.

Macleod, K., Simmonds, M. and Murray, L. (2006). Abundance of fin (*Balaenoptera physalus*) and sei whales (*B. Borealis*) amid oil exploration and development off northwest Scotland. *Journal of cetacean research and management,* 8: 247-254.

Maldonado, M., Ribes, M. and van Duyl, F.C. (2012). Nutrient Fluxes Through Sponges: Biology, Budgets, and Ecological Implications. In: Mikel A. Becerro, Maria J. Uriz, Manuel Maldonado and Xavier Turon, Editors: *Advances in Marine Biology,* 62.

Maldonado, M., Aguilar, R., Bannister, R.J., Bell, J.J., Conway, K.W., Dayton, P.K., Díaz, C., Gutt, J., Kelly, M., Kenchington, E.L.R., Leys, S.P., Pomponi, S.A., Rapp, H.T., Rützler, R., Tendal, O.S., Vacelet, J. and Young, C.M. (2016). Sponge Grounds as Key Marine Habitats: A Synthetic Review of Types, Structure, Functional Roles, and Conservation Concerns. *S. Rossi (ed.), Marine Animal Forests*, Springer International Publishing Switzerland.

Mariani, S., Uriz, M.J., Turon, X. and Alcoverro, T. (2006). Dispersal strategies in sponge larvae: integrating the life history of larvae and the hydrologic component. *Oecologia,* 149: 174-184.

Masson, D.G. (2001). Sedimentary processes shaping the eastern slope of the Faroe-Shetland Channel. *Continental Shelf Research,* 21: 825-857.

Mayer, K.S., Young, C.M., Sweetman, A.K., Taylor, J., Soltwedel, T. and Bergmann, M. (2016). Rocky islands in a sea of mud: biotic and abiotic factors structuring deep-sea dropstone communities. *Marine Ecology Progress Series,* 556: 45-57.

Mazik, K., Strong, J., Little, S., Bhatia, N., Mander, L., Barnard, S. and Elliott, M. (2015). A review of the recovery potential and influencing factors of relevance to the management of habitats and species within Marine Protected Areas around Scotland. Scottish Natural Heritage Report No. 771 [online]. Available at: http://www.snh.org.uk/pdfs/publications/commissioned_reports/771.pdf [Accessed 20 September 2017].

McBreen, F. and Askew, N. (2011). UKSeaMap 2010 Technical Report 3. Substrate Data. Joint Nature Conservation Committee, Peterborough.

McConnell, B.J., Fedak, M.A., Lovell, P. and Hammond, P.S. (1999). Movements and foraging areas of grey seals in the North Sea. *Journal of Applied Ecology,* 36: 573-90.

Mienis, F., de Stigter, H.C., White, M., Duineveld, G., de Haas, H. and van Weeringa, T.C.E. (2007). Hydrodynamic controls on cold-water coral growth and carbonate-mound development at the SW and SE Rockall Trough Margin, NE Atlantic Ocean. *Deep-SeaResearch I,* 54: 1655-1674.

Montenegro-González, J. and Acosta, A. (2010). Habitat preference of Zoantharia genera depends on host sponge morphology. *Universitas Scientarium,* 15: 110-121.

Murillo, F.J., Kenchington, E., Lawson, J.M., Li, G. and Piper, D.J.W. (2016). Ancient deep-sea sponge grounds on the Flemish Bank and Grand Bank, northwest Atlantic. *Marine Biology,* 163.

Narayanaswamy, B.E., Bett, B.J. and Gage, J.D. (2005). Ecology of bathyal polychaete fauna at an Arctic–Atlantic boundary (Faroe–Shetland Channel, North-east Atlantic). *Marine Biological Research,* 1: 20-32.

Narayanaswamy, B.E., Bett, B.J. and Hughes, D.J. (2010). Deep-water macrofaunal diversity in the Faroe-Shetland region (NE Atlantic): a margin subject to an unusual thermal regime. *Marine Ecology,* 31: 237-246.

Neves, G. and Omena, E. (2003). Influence of sponge morphology on the composition of the polychaete associated fauna from Rocas Atoll, northeast Brazil. *Coral Reefs,* 22: 123-129.

Norling, K., Rosenburg, R., Hulth, S., Gremare, A. and Bonsdorff, E. (2007). Importance of functional biodiversity and specific-specific traits of benthic fauna for ecosystem functions in marine sediment. *Marine Ecology Progress Series*, 332: 11-23.

O'Connor, J., Golding, N., Taylor, J., Drewery, J. and Boulcott, P. (2017). 1517S Cruise Report: Monitoring survey of North-east Faroe Shetland Channel NCMPA, Wyville Thomson Ridge SAC and West Shetland Shelf NCMPA. JNCC Report. Peterborough.

OSPAR Commission (2009). Agreement on coordinated environmental monitoring programme assessment criteria for the QSR 2010. Monitoring and Assessment Series. OSPAR Agreement 2009-2002.

OSPAR (2010a). Background document for Deep-sea sponge aggregations. OSPAR Commission

OSPAR (2010b). OSPAR Quality Status Report 2010. London: OSPAR Commission.

OSPAR Commission (2012). Coordinated environmental monitoring programme 2011 assessment report.

Roberts, D.A., Johnston, E.L. and Poore, A.G.B. (2008). Contamination of marine biogenic habitats and effects upon associated epifauna. *Marine Pollution Bulletin,* 56: 1057-1065.

Sawadogo, W.R., Boly, R., Cerella, C., Teiten, M.H., Dicato, M. and Diederich, M. (2015). A survey of marine natural compounds and their derivatives with anti-cancer activity reported in 2012. *Molecules,* 20: 7097-7142.

Sayago-Gil, M., Long, D., Hitchen, K., Díaz-del-Río, V., Fernández-Salas, L.M. and Durán-Muñoz, P. (2010). Evidence for current-controlled morphology along the western slope of Hatton Bank (Rockall Plateau, NE Atlantic Ocean). *Geo-Marine Letters*, 30: 99-111.

Schleuter, D., Günther, A., Paasch, S., Ehrlich, H., Kljajić, Z., Hanke, T., Bernhard, G. and Brunner, E. (2013). Chitin-based renewable materials from marine sponges for uranium absorption. *Carbohydrate Polymers,* 92: 712-718.

Schönberg, C.H.L. and Fromont, J. (2014). Sponge functional growth forms as a means for classifying sponges without taxonomy. Australian Institute Marine Science [online]. Available at: http://ningaloo-atlas.org.au/content/sponge-functional-growth-forms-means-classifying-spo [Accessed 17 January 2018].

Schönberg, C.H.L. (2016). Effects of dredging on filter feeder communities, with a focus on sponges. *WAMSI Dredging Science Node. Report, Theme 6, Project 6.1* Western Australian Marine Science Institution.

Sciberras, M., Parker, R., Powell, C., Robertson, C., Kroger, S., Bolam, S. and Hiddink, J. (2016). Impacts of Bottom Fishing on Sediment Biogeochemical and Biological Parameters in Cohesive and Non-Cohesive Sediments. *Limnology and Oceanography*, 61: 2076-2089.

Scott, B.E., Sharples, J., Ross, O.N., Wang, J., Pierce, G.J. and Camphuysen, C.J. (2010). Sub-surface hotspots in shallow seas: fine-scale limited locations of top predator foraging habitat indicated by tidal mixing and sub-surface chlorophyll. *Marine Ecology Progress Series*, 408: 207-26.

Skilleter, G.A., Russel, B.D., Degnan, B.M. and Garson, M.J. (2005). Living in a potentially toxic environment: comparisons of endofauna in two congeneric sponges from the Great Barrier Reef. *Marine Ecology Progress Series,* 304: 67-75.

Spetland, F., Rapp, H.T., Hoffmann, F. and Tendal, O.S. (2007). Sexual reproduction of *Geodia barretti* Bowerbank, 1858 (Porifera, Astrophorida) in two Scandinavian Fjords. In: Custódio M.R., Hajdu, E., Lôbo-Hajdu, G., and Muricy, G., Editors. *Porifera Research: Biodiversity, Innovation and Sustainability. Proceedings of the 7th International sponge symposium,* Rio de Janeiro, Brazil: Museu. Nacional: 613-620.

Stoker, M.S. (1995). The influence of glacigenic sedimentation on slope-apron development on the continental margin off Northwest Britain. In: The Tectonics, Sedimentation and Paleoceanography of the North Atlantic Region (eds R.A. Scrutton., M.S. Stoker, G.B. Shimmield, and A.W. Tudhope), Geological Society, London, Special Publications, 90: 159-177.

Stone, C.J. (1998). Cetacean observations during seismic surveys in 1997. JNCC Report 278. 57pp.

Swift, R.J., Hastie, G.D., Barton, T.R., Clark, C.W., Tasker, M.L. and Thompson, P.M. (2002). Studying the distribution and behaviour of cetaceans in the northeast Atlantic using passive acoustic techniques. Report for the Atlantic Frontier Environmental Network.

Talley, L.D. (2002). Salinity Patterns in the Ocean. The Earth System: Physical and Chemical Dimensions of Global Environmental Change 1: 629-640, in Encyclopedia of Global Environmental Change.

Tillin, H.M., Hull, S.C. and Tyler-Walters, H. (2010). Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Report to the Department of Environment, Food and Rural Affairs from ABPMer, Southampton and the Marine Life Information Network. Plymouth: Marine Biological Association of the UK. Defra Contract No. MB0102 Task 3A, Report No. 22 [online]. Available at: http://www.marlin.ac.uk/assets/pdf/MB0102_Task3-PublishedReport.pdf [Accessed 10 October 2017].

Tillin, H.M. and Tyler-Walters, H. (2014). Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities: Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes. JNCC Report No. 512B [online]. Available at: http://jncc.defra.gov.uk/PDF/Report%20512-A_phase1_web.pdf [Accessed 10 October 2017].

Tjensvoll, I., Kutti, T., Fosså, J.H. and Bannister, R.J. (2013). Rapid respiratory responses of the deep-water sponge *Geodia barretti* exposed to suspended sediments. *Aquatic Biology,* 19: 65-73.

Tréguer, P.J. and De La Rocha, C.L. (2013). The world ocean silica cycle. *Annual Review of Marine Science*, 5: 477-501.

Tyler-Walters, H., James, B., Carruthers, M. (eds.), Wilding, C., Durkin, O., Lacey, C., Philpott, E., Adams, L., Chaniotis, P.D., Wilkes, P.T.V., Seeley, R., Neilly, M., Dargie, J. and Crawford-Avis, O.T. (2016). Descriptions of Scottish Priority Marine Features (PMFs). Scottish Natural Heritage Commissioned Report No. 406 [online]. Available at: http://www.marlin.ac.uk/assets/pdf/406.pdf [Accessed 10 October 2017].

UK Technical Advisory Group on The Water Framework Directive (UKTAG) (2008). Proposals for Environmental Quality Standards for Annex VIII Substances. UK Technical Advisory Group on the Water Framework Directive.

Uriz, M.J., Maldonado, M., Turon, X. and Martí, R. (1998). How do reproductive output, larval behaviour, and recruitment contribute to adult spatial patterns in Mediterranean encrusting sponges? *Marine Ecology Progress Series,* 167: 137-148.

Viana, A.R., Almeida, W., Nunes, M.C.V. and Bulhões, E.M. (2007). The economic importance of contourites. *Geological Society, London, Special Publications*, 276(1): 1-23.

Wagner, H., Purser, A., Thomsen, L., Jesus, C.C. and Lundälv, T. (2011). Particulate organic matter fluxes and hydrodynamics at the Tisler cold-water coral reef. *Journal of Marine Systems,* 85: 19-29.

Weir, C.R., Pollock, C., Cronin, C. and Taylor, S. (2001). Cetaceans of the Atlantic Frontier, north and west of Scotland. *Continental Shelf Research*, 21: 1047-1071.

Witte, U., Brattegard, T., Graf, G. and Springer, B. (1997). Particle capture and deposition by deep-sea sponges from the Norwegian-Greenland Sea. *Marine Ecology Progress Series,* 154: 241-252.

Wynn, R.B., Masson, D.G. and Bett, B.J. (2002). Hydrodynamic significance of variable ripple morphology across deep water barchan dunes in the Faroe-Shetland Channel. *Marine Geology*, 192: 309-319.