

# Supplementary Advice on Conservation Objectives for South West Deeps (East) MCZ

January 2021



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## Introduction

### What the conservation advice package includes

The information provided in this document sets out JNCC's supplementary advice on the conservation objectives set for this site. This forms part of JNCC's formal 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 features condition and General Management Approach;
  - 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);
- [Advice on Operations](#) providing information on those human activities that, if taking place within or near the site, can impact it and present a risk to 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) on JNCC's website.

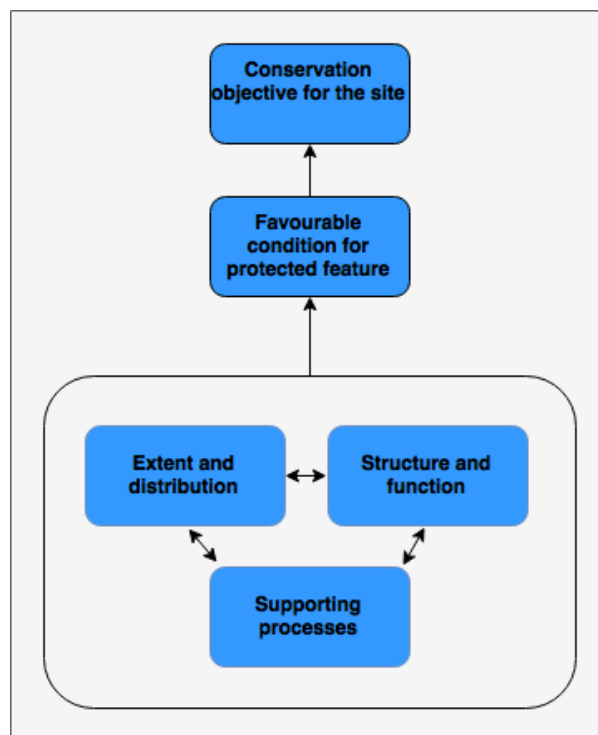
The advice presented here describes the ecological characteristics or 'attributes' of the site's protected features: **Subtidal coarse sediment and Subtidal sand** specified in the site's conservation objective. These attributes are: extent and distribution, structure and function and supporting processes.

Supplementary advice on the conservation objectives for the site's broad-scale habitat feature: **Deepsea bed** and geomorphological feature: **Celtic Relict Sandbanks** is not yet available. Three habitats have been identified with high confidence as being present within the extent of the wider Deep-sea bed feature: Deep-sea rock, Deep-sea mud and Deep-sea bioherms. Advice on activities capable of affecting these three habitats is available in the Advice on Operations workbook for this site. Further information regarding this feature can

be found on the [Site Information Centre](#) or by contacting JNCC at [OffshoreMPAs@jncc.gov.uk](mailto:OffshoreMPAs@jncc.gov.uk).

Figure 1 below 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 the following tables describe the desired ecological condition (favourable) for the site's features. Each feature within the site must be in favourable condition as set out in the site's conservation objective. All attributes listed in the following tables 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.**

In Table 1 below, the attributes for the Deep-sea bed, Subtidal coarse sediment and Subtidal sand are listed and a description provided in explanatory notes.

Please note our current understanding of whether the available evidence indicates that each attribute needs to be recovered or maintained is not provided. However, links to available

evidence for the site are provided in the tables below and should you require further site-specific information on the attributes listed for the site's features, please contact JNCC at [OffshoreMPAs@jncc.gov.uk](mailto:OffshoreMPAs@jncc.gov.uk).

**Table 1: Supplementary advice on the conservation objectives for broad-scale habitats (Deep-sea bed, Subtidal coarse sediment and Subtidal sand) in South West Deeps (East) MCZ.**

<p><b>Attribute: Extent and distribution</b></p>
<p><b>Objective:</b>  An objective has not been set for this attribute. Links to available evidence are provided below. Please contact JNCC at <a href="mailto:OffshoreMPAs@jncc.gov.uk">OffshoreMPAs@jncc.gov.uk</a> for further site-specific information on this attribute.</p>
<p><b><u>Explanatory notes</u></b></p> <p>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 <i>et al.</i>, 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, 2004). The extent of the Subtidal sedimentary habitats within the site must be conserved to their full known distribution.</p> <p>Subtidal sedimentary habitats are defined by:</p> <ul style="list-style-type: none"> <li>• <b>Sediment composition</b> (grain size and type) (e.g. Cooper <i>et al.</i>, 2011; Coates <i>et al.</i>, 2015; 2016; Coblenz <i>et al.</i>, 2015). Some species can inhabit all types of sediment, whereas others are restricted to specific types; and</li> <li>• <b>Biological assemblages</b> - See <a href="#">JNCC's Marine Habitats Correlation Table</a> 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.</li> </ul> <p>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 <a href="#">UK Marine Monitoring Strategy</a> 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 <i>et al.</i>, 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). Maintaining extent is therefore critical to maintaining or improving conservation status of Subtidal sedimentary habitats.</p>

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:

- *A5.1 Subtidal coarse sediment* – Comprises of coarse sand, gravel, pebbles, shingle and cobbles. These sediments typically have low silt content and are characterised by robust fauna, including venerid bivalves (Connor *et al.*, 2004). The particle sizes of Subtidal coarse sediments are classed as more than 0.063 mm but predominantly contain grains sizes in excess of 2 mm (McBreen and Askew, 2011).
- *A5.2 Subtidal sand* – Comprises of clean medium to fine sands or non-cohesive slightly muddy sands. Such habitats are often subject to a degree of wave action or tidal currents which restrict the silt and clay content to less than 15%. This habitat is characterised by a range of taxa including polychaetes, bivalve molluscs and amphipods (Connor *et al.*, 2004). Subtidal sand is defined by the ratio of mud to sand being lower 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).

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#### **Extent and distribution of the broad-scale habitats within the site**

The designated features for this site are Deep-sea bed, Subtidal coarse sediment and Subtidal sand. The extent and distribution of these features within the site is shown in the [site map](#). For further site specific information please see the [Site Information Centre](#).

For information on activities capable of affecting the protected features of the site, please see the Advice on Operations workbook (hyperlink is provided in the box at the top of this document).

#### **Attribute: Structure and function**

##### **Objective:**

**An objective has not been set for this attribute. Links to available evidence are provided below. Please contact JNCC at [OffshoreMPAs@jncc.gov.uk](mailto:OffshoreMPAs@jncc.gov.uk) for further site-specific information on this attribute.**

##### **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. However, the reverse is true with regards to relict bedforms.

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**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; 2016; Coblentz *et al.*, 2015).

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**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, 2004). 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, 2004; Hughes *et al.*, 2005).

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).

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#### **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, 2004). 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, 2004; Hughes *et al.*, 2005).

Similar to the biological structure of key and influential species, the recovery of characterising species 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).

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### **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 various commercial species, for instance mud habitats can be suitable for Norway lobster (Sabatini and Hill, 2008) and shallow sandy sediments can offer habitat for sand eels (Rowley, 2008), 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);
- 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 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.

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### **Structure and function of the feature within the site**

For further site-specific information on the structure and function of the feature within the site, please see the [Site Information Centre](#).

For information on activities capable of affecting the protected features of the site, please see the Advice on Operations workbook (hyperlink is provided in the box at the top of this document).

## **Attribute: Supporting processes**

### **Objective:**

**An objective has not been set for this attribute. Links to available evidence are provided below. Please contact JNCC at [OffshoreMPAs@jncc.gov.uk](mailto:OffshoreMPAs@jncc.gov.uk) for further site-specific information on this attribute.**

### **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).

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#### **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, 2004; 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 2010](#)) 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.

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### **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; 2010; 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.

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### **Supporting process for the feature within the site**

For further site-specific information on the natural processes which support the feature within the site, please see the [Site Information Centre](#).

For information on activities capable of affecting the protected features of the site, please see the Advice on Operations workbook (hyperlink is provided in the box at the top of this document).

## References

- 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.
- Best, M.A., Wither, A.W. and Coates, S. (2007). Dissolved oxygen as a physicochemical supporting elements 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. (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](http://jncc.defra.gov.uk/pdf/472_web.pdf) [Accessed 10 October 2015].
- 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.
- 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].
- 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](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](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.
- 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.
- 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].
- 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].
- 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.
- Gray, J. and Elliott M. (2009). Ecology of Marine Sediments: From Science to Management, Second Edition, Oxford Biology.
- Green M.O., Vincent C.E., McCave I.N., Dickson R.R., Rees J.M., Pearsons N.D. (1995). Storm sediment transport: observations from the British North Sea shelf. *Continental Shelf Research*, 15: 889-912
- 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., 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.

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.

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.

Joint Nature Conservation Committee (JNCC) (2004). Common standards monitoring guidance for inshore sublittoral sediment habitats [online]. Available at: [http://jncc.defra.gov.uk/PDF/CSM\\_marine\\_sublittoral\\_sediment.pdf](http://jncc.defra.gov.uk/PDF/CSM_marine_sublittoral_sediment.pdf) [Accessed 20 September 2017].

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].

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.

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](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.

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.



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

OSPAR Commission (2010). Quality status report 2010. London.

Rowley, S.J. (2008). *Ammodytes tobianus* Lesser sand eel. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews. Plymouth: Marine Biological Association of the United Kingdom [online]. Available from: <http://www.marlin.ac.uk/species/detail/2067> [Accessed 10 October 2017].

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.

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.

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](http://jncc.defra.gov.uk/PDF/Report%20512-A_phase1_web.pdf) [Accessed 10 October 2017].