Supplementary Advice on Conservation Objectives for Fulmar MCZ

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Contents

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 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 and General Management Approach;
  - conservation benefits that the site can provide; and
  - conservation measures needed to further the conservation objectives stated 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) on JNCC's website.

The advice presented here describes the ecological characteristics or 'attributes' of the site's protected features: Subtidal mixed sediments, Subtidal sand, Subtidal mud and Ocean quahog (*Arctica islandica*) specified in the site's conservation objectives. These attributes are: extent and distribution, structure and function and supporting processes.

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 Tables 1 and 2 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 Tables 1 and 2 must be taken into consideration when assessing impacts from an activity.

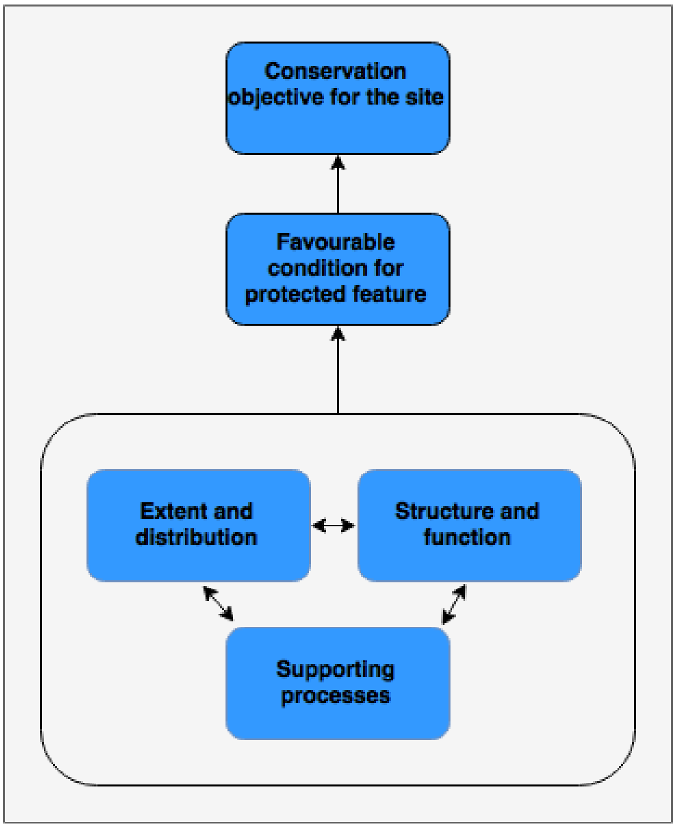

Figure 1. Conceptual diagram showing how a feature's attributes are interlinked and collectively describe favourable condition and contribute to the conservation objectives stated for the site.

The objectives listed in Tables 1 and 2 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 maintained 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 management to recover a feature's attribute, a maintain objective is set, accompanied by a statement to reflect the impracticality of restoration. Note also, that when a maintain 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 protected sedimentary broad-scale habitats (Subtidal sand, Subtidal mud, Subtidal mixed sediments) within Fulmar MCZ.

Attribute: Extent and distribution

Objective: Subtidal mud (maintain), Subtidal sand (maintain), Subtidal mixed sediments (maintain)

JNCC advise a maintain objective *for the Subtidal mud, Subtidal sand and Subtidal mixed sediments, as we are not aware of any activities occurring which would result in a significant change to their extent and distribution. These objectives are based on expert judgment, specifically our understanding of feature sensitivity to pressures associated with ongoing activities. Our confidence in these objectives would be improved with long term monitoring and better access to information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, changes in substrata and biological communities 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, 2004). The extent of the Subtidal sedimentary habitats within the site must be maintained 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; 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). Maintaining 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:

- *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).
- *A5.3 Subtidal mud* - 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).
- *A5.4 Subtidal mixed sediments* – Comprises of mixed sediments found from extreme low water to deep, offshore circalittoral habitats. These habitats include a range of sediments, such as heterogeneous muddy gravelly sands and mosaics of cobbles and pebbles embedded in or lying upon sand, gravel or mud. Mixed sediments include mosaic habitats, such as superficial waves or ribbons of sand on a gravel bed or areas of lag deposits with cobbles/pebbles embedded in sand or mud and are less well defined, sometimes overlapping other habitat or biological subtypes. These habitats may support a wide range of infauna and epibionts, including polychaetes, bivalves, echinoderms, anemones, hydroids and bryozoans (Connor *et al.,* 2004). Subtidal mixed sediments are classed by a range sediment sizes, predominantly more than 0.063 mm, but mud may also be present (McBreen and Askew, 2011).

Extent and distribution within the site

The site map for Fulmar MCZ is available to view on JNCC's Interactive MPA Mapper. The site area is calculated to be 2,437 km^2 with the EUNIS habitat A5.3: Subtidal mud extending across most of the site and large patches of A5.2: Subtidal sand of >30 km^2 to the north-east and >110 km^2 to the east of the site respectively. There are small patches of A5.4: Subtidal mixed sediments located in the centre and to the south-west of the site. This site contains approximately 6% of A5.2: Subtidal sand, 93% A5.3: Subtidal mud, and 1% A5.4: Subtidal mixed sediment.

Oil and gas activity within the site overlaps with the mapped Subtidal mud habitat, with several wells and associated infrastructure located in this broad-scale habitat, however the extent and distribution of this impact is currently unknown so a maintain objective is advised. We are not aware of any activities occurring in the areas of mapped Subtidal sand and Subtidal mixed sediment which could impact the extent and distribution of these broad-scale habitats.

JNCC understand that the activities occurring in the area of Subtidal mud habitat have resulted in a change to the extent and distribution of the protected broad-scale habitat within the site. Installation and/or removal of infrastructure may have a continuing effect on extent and distribution. As such, **JNCC advise a maintain objective** for Subtidal mud, Subtidal sand and Subtidal mixed sediments' extent and distribution. These objectives are based on expert judgment, specifically our understanding of feature sensitivity to pressures associated with ongoing activities. Our confidence in these objectives would be improved with long 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 the protected features of the site, please see the Advice on Operations workbook.

Attribute: Structure and function

Objective: Subtidal mud (Maintain), Subtidal sand (Maintain), Subtidal mixed sediments (Maintain)

JNCC advise a maintain objective *for the Subtidal mud, Subtidal sand and Subtidal mixed sediments, 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 as sub-attributes under Structure 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 maintained (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.

Physical structure: Finer scale topography within the site
JNCC is not aware of any discernible examples of fine-scale topographic features present within the site. There is no evidence to indicate that the finer scale topography in the site has been impacted and so **JNCC advise a maintain objective**. This is based on expert judgement; specifically, our understanding of the feature's sensitivity to pressures exerted by the activities present. Our confidence in this objective would be improved by long term monitoring and a better understanding of the finer scale topography within the site.

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 maintained (Cooper *et al.,* 2011; Coates *et al.,* 2015; 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. Several habitat types are present at the site, including A5.2: Subtidal sand, A5.3: Subtidal mud and A5.4: Subtidal mixed sediments. Although A5.3: Subtidal mud dominates, A5.2: Subtidal sand and A5.4: Subtidal mixed sediments are patchily distributed through-out the site, with verified patches of sand distributed to the north-east and east of the site, and mixed sediment towards the centre and south-west of the site.

Grain sizes reported for Subtidal mud 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 Subtidal sand 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). Grain sizes reported for Subtidal mixed sediment within the site are on average 20.28 ± 10.32%, 51.95 ± 15.26%, and 27.78 ± 17.13% (gravel, sand and silt/clay respectively).

It is expected that sedimentary habitat composition within the site could change naturally over time as a result of wider environmental processes, but it is clear from available survey data that A5.3: Subtidal mud is the dominant habitat type. Subtidal mud within the site has been subjected to activities that may have resulted in a change to the sediment composition of Subtidal mud within the site but the extent and distribution of the impact is unknown so a recover objective cannot be set. Installation and/or removal of infrastructure may have a continuing effect on sediment composition. As such, **JNCC advise a maintain objective** for the Subtidal mud, Subtidal sand and Subtidal mixed sediments, as currently these broad-scale habitats have not been subjected to activities that have resulted in a change their sediment composition. These objectives are based on expert judgment, specifically our understanding of feature sensitivity to pressures associated with ongoing activities. Our confidence in these objectives would be improved with long 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 the protected features of 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, 2004). It is important to maintain 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).

Biological structure: Key and influential species within the site

A variety of bioturbators, predators and grazers have been recorded from surveys within the Fulmar MCZ, such as Ocean quahog (*Arctica islandica*), king scallop (*Pecten maximus)*, burrowing tube anemones (*Cerianthus lloydii*), polychaete worms (*Paramphinome jeffreysii*), nemertean worms, brittle stars (*Amphiura filiformis*) and the holothurian (*Labidoplax digitate*), as well as sea urchins, gastropods (Family Buccinidae), hermit crabs and other unidentified crustaceans. It is possible that these species play a critical role in maintaining the structure and functioning of the protected Subtidal sedimentary habitats. However, no further information is currently available to draw conclusions with any degree of certainty.

There is insufficient information available to support an understanding of the significance of the role which these species play in maintaining 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, 2004). It is therefore important to maintain 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).

Biological structure: Characteristic communities within the site

Three types of characteristic biological communities have been identified within Fulmar MCZ (Jones *et al.,* 2016):

- *Paramphinome jeffreysii*, *Thyasira* spp. and *Amphiura filiformis* in offshore circalittoral sandy mud (A5.376) - Characterised by a range of polychaetes, including *Paramphinome jeffreysii*, brittlestars *Amphiura filiformis,* nemertean worms and the holothurian *Labidoplax digitate,* with the bivalve *Thyasira* recorded at some stations. This biotope was reported as widespread across the three sedimentary features;
- *Virgularia mirabilis* and *Ophiura spp*. with *Pecten maximus* on circalittoral sandy or shelly mud (A5.354) - Dominated by sea-pens (identified as Pennatulacea, most likely to be *Virgularia mirabilis*), brittlestars, which could be *Ophiura*, and hermit crabs. Scallops (potentially *Pecten maximus*) were also recorded in a small number of transects. This biotope was recorded predominantly in areas comprising A5.3 Subtidal mud; and
- Circalittoral mixed sediments (A5.44) – Not possible to match this to an existing biotope within the habitat classification system for Britain and Ireland. This habitat was found to be present in small patches within the wider area of A5.3 Subtidal mud.

The hydroid *Corymorpha nutans*, anemone *Bolocera tuediae,* gastropods of the family Buccinidae, unidentified sea urchins and crustaceans also occurred at several stations. In addition, patches of horse mussels (*Modiolus modiolus*) were recorded at the centre of the site but were not considered to be dense enough to constitute beds and they did not dominate the habitat where they occurred.

The OSPAR threatened and/or declining species Ocean quahog, is also present within Fulmar MCZ and is a protected feature within the site (see Table 2 for more information).

Based on expert judgment of the sensitivity of the characterising communities present to pressures associated with activities taking place within the site, **JNCC advise a maintain objective** for this sub-attribute as the extent and distribution of potentially damaging activities are currently unknown. Our confidence in the setting of this objective would be improved by long-term monitoring information and better access to information on the activities taking place within the site. Further information on the impacts associated with human activities on the protected broad-scale habitats can be found in 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); 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 broad-scale habitats within the site

The broad-scale habitats within the site supports a wide variety of fauna, including burrowing anemones, brittle stars, slender sea pens and ocean quahog. These in turn may provide important feeding opportunities for commercially important and other fish species, which may in turn support foraging behaviour in marine mammals and seabirds (Camphuysen *et al.,* 2011).

Seabirds, such as gannets, have been shown to forage in the region (Hamer *et al.,* 2000). However, to our knowledge there is no direct evidence of Fulmar MCZ being especially important for seabirds' due to the depth of the site and distance from coast. Published evidence does indicate that the area around Fulmar MCZ may perform some supporting function for grey seals (Camphuysen *et al.,* 2011; Jones *et al.,* 2013). Individuals that travel to the region from haul out sites on the east coast of Scotland and England are most likely to be using these areas to forage (McConnell *et al.,* 1999; Camphuysen *et al.,* 2011). Other studies suggest that this region more broadly may be important for marine mammals such as harbour porpoise (Hammond *et al.,* 2002; McLeod *et al.,* 2008; Russell and McConnell 2014), but there is no evidence suggesting the site is especially important for marine mammals.

Given that a maintain objective is advised for characteristic communities on which these functions rely, **JNCC advise a maintain objective** for this sub-attribute. Our confidence in the objectives would be improved by long term monitoring and a better understanding of the role which biological communities play in the function and health of the feature. Further information on the impacts associated with human activities on the protected broad-scale habitats can be found in the Advice on Operations workbook.

Attribute: Supporting processes

Objective: Maintain

JNCC consider there is limited evidence to suggest that supporting processes are being impeded with respect to supporting the function of the protected broad-scale habitats within the site. As such, ***JNCC advise a maintain objective*** *and that 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 statements on conservation benefits, 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

It is this eastward current bringing fine material (mud) from the areas of muddy seabed found to the west of the site that is thought to be responsible for the dominance of A5.3: Subtidal mud in Fulmar MCZ (BGS, 2011). It is therefore likely that the currents operating around the site have a significant role to play in surface sediment composition.

The effect of episodic storm events on the site is unknown, but due to the depth range recorded within the site, it is unlikely that any part of the site is above the storm-wave base. However, storm events have been shown to mobilise sediment up to the particle size of medium sand in 60 m water depth in the North Sea (Klein *et al.,*1999) and so the composition of the protected broad-scale habitats within the site may be effected by natural disturbance events.

While infrastructure known to be present may be having a localised effect on the hydrodynamic regime within the site, it is not thought that this is having an adverse impact on the conservation status of the protected broad-scale habitats present. As such, **JNCC advise a maintain 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.

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.

Water quality within the site

The cool Atlantic waters to the north of the site exhibit seasonal stratification during spring and summer, which increase the prevalence of phytoplankton communities (Salomons *et al.,* 1988; Weston *et al.,* 2005). The site is also likely to be affected by the warmer central North Sea water to the south, although more data on the site's physicochemical properties is required.

Available evidence indicates relatively low suspended sediment concentrations in the deeper regions (below 50 m) of the North Sea of less than 5 g/m^3 (Eleveld *et al.,* 2004). Phytoplankton production in the North Sea throughout the year results in chlorophyll *a* levels up to 5.8 $\mu g\ L^{-1}$ (Brockmann & Wegner 1985; Brockmann *et al.,* 1990), supporting a high biomass of species at higher trophic levels year-round and creating a region that is biologically unique in the North Sea (Kröncke and Knust 1995).

Evidence from the Charting Progress 2 report indicates that while the site is distant from terrestrial sources of pollution, enrichment of southern water masses due to riverine inputs and climatic variability are thought to affect ecological function of sites in the North Sea. Atmospheric deposition in the North Sea has been highlighted as a major source of contamination of trace metals (cadmium, lead, copper and zinc; Injuk *et al.,* 1992).

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 maintain 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.

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.

Sediment quality within the site
It is unclear as to whether sediment quality is currently being impacted within the site. In relation to pollution by heavy metals, available information is contradictory and not available from the site. For example, studies from 1992 indicated no evidence of pollution accumulation by heavy metals in North Sea sediments (Chapman, 1992; Chapman *et al.,* 1992), whereas other studies showed evidence of areas in the North Sea with high concentrations of heavy metals in sediments that were bioavailable to benthic organisms (Salomons *et al.,* 1988; Scholten *et al.,* 1998; Langston *et al.,* 1999).

More recent literature has noted that the exploration of North Sea oil and gas reserves has resulted in the accumulation of large quantities of drill cuttings on the seabed surrounding drill sites (Breuer *et al.,* 2004). These drill cuttings contain higher concentrations of certain metals (barium, cadmium, copper, nickel, lead and zinc) and hydrocarbons than found in natural sediments (Breuer *et al.,* 2004). As there are oil and gas exploration operations taking place within the site, drill cuttings may present a local pollution pathway at the site.

As available evidence is sparse and inconclusive, **JNCC advise a maintain objective**. This objective is based on expert judgement, specifically our understanding of the feature's sensitivity to pressures associated with ongoing activities. Activities must look to avoid, as far as is practicable, exceeding sediment EQSs set out above. Our confidence in this objective would be improved with long term monitoring and a better understanding of contaminant levels in the site.

Table 2. Supplementary advice on the conservation objectives for Ocean quahog within Fulmar MCZ.

Attribute: Extent and distribution

Objective: Maintain

The feature is being exposed to damaging pressures associated with oil and gas operations and this may be impacting the feature's extent and distribution. Despite this, ***JNCC advise a maintain objective*** *acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site, in light of wider environmental impacts such as climate change and the feature's limited capacity to recruit or reproduce as described in the explanatory notes. Activities should look to minimise, as far as is practicable, disturbance to individuals that may result in a change to the extent and distribution of Ocean quahog within the site. Our confidence in the setting of this objective would be improved by a better understanding of the distribution of Ocean quahog throughout the site and monitoring of their condition.*

Explanatory notes

Extent describes the occurrence of *Arctica islandica* (herein referred to as Ocean quahog), with distribution providing a more detailed overview of the species location(s) and pattern of occurrence within a site. It is important to consider the life histories and environmental preferences of the species as this will have a strong influence on extent and distribution.

Ocean quahog is found around all British and Irish coasts, as well as offshore. The species has also been recorded from the Baltic, Iceland, the Faroe Islands, Onega Bay in the White Sea to the Bay of Biscay and from Labrador to North Carolina (Tyler-Walters and Sabatini, 2017). Benthic surveys have shown a reduction in North Sea distribution between 1902-1986 (Rumohr *et al.,* 1998). The same surveys also show a reduction in species abundance between 1972-1980 and 1990-1994.

It is thought that UK waters are likely to be a sink of new recruits, with larval settlement events originating from Iceland separated by long periods without successful recruitment (Witbaard and Bergman, 2003). These recruits are thought to be carried down the east coast of the UK and into the mid and southern North Sea where the slower moving waters inside gyres allow settlement to occur. Temperature is also thought to play an important role in the successful recruitment of Ocean quahog, with increasing temperatures attributed as the cause of low recruitment success in North Sea populations (Witbaard and Bergman, 2003). As the seas around the UK warm, it is expected that southerly populations of Ocean quahog may experience increased recruitment failure resulting in a range contraction. Recovery of the feature within a site is therefore likely to be reliant on an infrequent and unpredictable supply of recruits from elsewhere and highly dependent on wider environmental pressures, such as climate change.

As a burrowing species, extent and distribution of supporting habitats will be important in governing the extent and distribution of the species. Ocean quahog has been found in a range of sediments, from coarse clean sand to muddy sand in a range of depths typically from 4 m to 482 m deep, but most commonly between 10 m to 280 m (Thorarinsdóttir and Einarsson, 1996; Sabatini *et al.,* 2008; OSPAR, 2009; Tyler-Walters and Sabatini, 2017). Ocean quahog is thought to have a high sensitivity to physical loss of habitat (Tyler-Walters and Sabatini, 2017). It is therefore important to maintain the extent and distribution of supporting habitats to provide the best chance of any potential settlement for new recruits and to retain existing individuals.

Extent and distribution within the site

The known extent and distribution of Ocean quahog and suitable habitat within the site is available to view via the JNCC's Interactive MPA Mapper. Based on what is known about the habitat preferences of Ocean quahog (Witbaard and Bergman, 2003) the full extent of the site (2,437 km^2) is considered suitable for Ocean quahog colonisation. These habitats are important for the life cycle of Ocean quahog as they offer suitable areas for larval settlement. Survey data suggests that Ocean quahog are distributed throughout Fulmar MCZ, but that they can be found in higher densities to the north of the site (Curtis *et al.,* 2015 and third-party sources).

JNCC understands that the site includes locations where offshore infrastructure has been installed, such as oil platforms and pipelines. Such installation and decommissioning practices can often result in localised 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 Ocean quahog within the site.

Whilst future decommissioning activities that do not require rock dump may result in habitat being introduced for Ocean quahog that is suitable for colonisation (once oil and gas operations within a site have ceased), this is likely to be a very slow process due to the long-lived, slow reproducing and vulnerable nature of the species (Butler *et al*., 2012; Brix, 2013; Ridgeway and Richardson, 2010; Tyler-Walters and Sabatini, 2017).

The feature is being exposed to damaging pressures associated with oil and gas operations and this may be impacting the feature's extent and distribution. Despite this, **JNCC advises a maintain objective** acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site, in light of wider environmental impacts such as climate change and the feature's limited capacity to recruit/reproduce. Activities should look to minimise, as far as is practicable, a change in substrata that may result in a change to the natural extent of the ocean quahog's supporting habitat within the site.

For further information on activities capable of affecting Ocean quahog and their supporting habitat, please see the Advice on Operations Workbook.

Attribute: Structure and function

Objective: Maintain

*The feature is being exposed to damaging pressures associated with oil and gas operations and this may be impacting the feature's structure and function. Despite this, **JNCC advise a maintain objective** acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site, in light of wider environmental impacts such as climate change and the feature's limited capacity to recruit or reproduce as described in the explanatory notes. Activities should look to minimise, as far as is practicable, disturbance to individuals within the site. Our confidence in setting of this objective would be improved by long-term monitoring information of Ocean quahog condition within the site.*

<u>Explanatory notes</u>

Structure

Structure refers to the densities and age classes of individuals from a population found within a site. Ocean quahog are more prevalent in the northern North Sea than the southern North Sea. Recorded Ocean quahog densities typical in the North Sea are outlined in the table below.

Ocean quahog / m^2	Geographic location	Sampling method	Reference
Northern North Sea		Box coring	De Wilde *et al.* (1986)
12	Central Fladen grounds		
286	Northern Fladen	Triple D-dredge	Witbaard and Bergman (2003)
23	Southern Fladen		
Southern North Sea			
0.07	Oyster grounds		
0.14-0.17	North of Dogger Bank		
0.35	Central Oyster ground		

The structure of Ocean quahog populations tends to be highly skewed in the North Sea, with populations containing either adults or juveniles, as opposed to representatives of both age classes (AquaSense, 2001; Witbaard and Bergman, 2003; OSPAR, 2009). Sporadic recruitment and the detrimental effect of increasing temperature on juveniles is expected to have a significant effect on successful Ocean quahog recruitment. Recovery of a population within a site is likely to be reliant on an infrequent supply of recruits from elsewhere and the influence of wider environmental temperature changes brought about by climate change.

It is important to note that distinguishing between adult and juvenile Ocean quahog is difficult without in-depth analysis of shell growth, and that individuals of similar size may vary greatly in age. For example, individuals ranging from 50-179 years old showed little discernible difference in mean length (Ropes and Murawski, 1983). However, what is known is that growth rates are relatively fast during the juvenile stage between 3-7 years of age but slow down after 15 years (Thompson *et al.,* 1980; Cargnelli *et al.,* 1999; Tyler-Walters and Sabatini, 2017). Both sexes have highly variable shell lengths at sexual maturity, between 24 mm and 49 mm reported (Thompson *et al.,* 1980; Cargnelli *et al.,* 1999). Shell length is therefore not a reliable indicator of age for this species.

Recovery of Ocean quahog populations is hard to monitor and likely to be extremely slow (over centuries) due to the long-lived (up to 507 years recorded; Brix, 2013), slow-growing, low density, irregularly recruiting, high juvenile mortality and low fecundity of the species (Ridgeway and Richardson, 2010; Butler *et al*., 2012). For the UK, this is compounded by the fact that any recovery would likely be dependent on a supply of recruits from elsewhere. It is therefore important that the number and age class of individuals is maintained in the long-term to maintain the population within the site.

Structure within the site

Between 1902 and 2012, a total of 52 individual Ocean quahog were sampled from across the site, with the highest numbers obtained from the north of the site that coincide with the sedimentary habitat A5.3: Subtidal mud. Based on sampling records to date, and the assumption that the full extent of the site contains habitat suitable for Ocean quahog colonisation (Witbaard and Bergman, 2003), the average density of Ocean quahog recorded across the site is 0.02 individuals per km^2 or in the highest density area in the north of the site 0.86 individuals per km^2. This average density is significantly lower than documented for the southern North Sea (0.14-0.35 individuals per m^2) (Witbaard, 1997; Witbaard and Bergman, 2003). However, the surveys used Hamon grabs and drop-down video sampling techniques, which are not as effective in assessing ocean quahog density compared to trawl-based sampling methods (such as those used by Witbaard and Bergman, 2003). There is currently not enough evidence available to attribute a cause for the observed decline in density in the southern North Sea.

The depth at which Ocean quahog have been recorded in 2007, 2009 and 2011 were between 78 m and 85 m deep. As there are no time series data available for Ocean quahog within the site, it is unclear whether the population is declining, being maintained or increasing in the site. The age structure, growth rates and reproductive viability of the population located within Fulmar MCZ are also currently unknown.

Evidence indicates that the prevailing sea temperatures is having a significant effect on the likely survivorship and recruitment potential of Ocean quahog (Cargnelli *et al.,* 1999; Witbaard and Bergman, 2003; Tyler-Walters and Sabatini, 2017) and the reported widespread declines in the abundance of this species through-out the North Sea (Rumohr *et al.,* 1998).

The feature is being exposed to damaging pressures associated with oil and gas operations and this may be impacting the feature's structure. Despite this, **JNCC advise a maintain objective** acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site, in light of wider environmental impacts such as climate change and the feature's limited capacity to recruit or reproduce as described in the explanatory notes. For further information on activities capable of affecting Ocean quahog and its supporting habitat, 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 supporting natural processes and the growth and reproduction of Ocean quahog. These functions can occur at several 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 Ocean quahog include:

- Nutrition: Providing food for a broad range of fish and invertebrate species, including commercially important fish species, e.g. cod and haddock (Brey *et al.,* 1990; Rees and Dare, 1993; Cargnelli *et al.,* 1999);
- Regulatory processes: Providing a bentho-pelagic link by removing plankton and detritus from the water column;
- Scientific study: Ocean quahog longevity enables the construction of 'master chronologies' over hundreds of years to study climatic and environmental change (Butler *et al.,* 2012; Schöne, 2013). Ocean quahog also provide a key role in ageing research and are an indicator of heavy metal pollution in sediments and historical environmental change (Weidman *et al.*, 1994; Zettler *et al.,* 2001; Liehr *et al.,* 2005; Schöne, 2005); and
- Carbon cycling and nutrient regulation: Maintaining healthy and productive ecosystems through the laying down of carbonate during shell growth and filter-feeding.

Function within the site

Whilst there is no direct evidence on the ecosystem services provided by the species in Fulmar MCZ, Ocean quahog are filter feeders and remove plankton and detritus from the water column, playing a role in carbon cycling and nutrient regulation (Tyler-Walters and Sabatini, 2017). The longevity of Ocean quahog also enables scientists to construct 'master chronologies' over tens or hundreds of years to study changes in climate and environmental change using the biogenic carbonates stored in the growth rings of Ocean quahog (Schöne, 2013). This data can be used to: investigate the mechanisms driving ocean circulation and temperature variability in North Atlantic waters over the past millennia; understand the significance of external forcing (solar and volcanic), internal variability and climate oscillations (North Atlantic Oscillation and Atlantic Multidecadal Oscillation) in a coupled ocean-atmosphere model of the last 1000 years; and to research the mechanisms of longevity to better understand human ageing.

JNCC acknowledge the significant effect of prevailing sea temperatures on the likely survivorship and recruitment potential of Ocean quahog aggregations (Cargnelli *et al.,* 1999; Witbaard and Bergman, 2003; Tyler-Walters and Sabatini, 2017) and the reported widespread declines in the abundance of this species throughout the North Sea (Rumohr *et al.,* 1998).

The feature is also being exposed to damaging pressures associated with oil and gas operations and this may be impacting the feature's function. Despite this, **JNCC advise a maintain objective** acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site, in light of wider environmental impacts such as climate change and the feature's limited capacity to recruit or reproduce as described in the explanatory notes. For further information on activities capable of affecting Ocean quahog and their supporting habitat, please see the Advice on Operations Workbook.

Attribute: Supporting processes

Objective: Maintain

JNCC consider there to be limited evidence to suggest that supporting processes are being impeded with respect to supporting the Ocean quahog within the site. As such, ***JNCC advise a maintain objective*** *and that activities must look to avoid, as far as is practicable, exceeding Environmental Quality Standards set out below, as well as change in substrate extent and distribution. 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 Ocean quahog.*

Explanatory notes

Ocean quahog rely on a range of supporting natural processes to support function (ecological processes) and help any recovery from adverse impacts. Supporting processes can be physical, biological and chemical in nature (Alexander *et al.,* 2014). In the case of Ocean quahog, these are the environmental conditions that can affect species persistence, growth and recruitment. For the site to fully deliver the conservation benefits set out in the statements on conservation benefits: hydrodynamic regime, supporting habitat and water and sediment quality must remain largely unimpeded.

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 transferring oxygen 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, which as filter-feeders could affect the feeding behaviour, growth and survival of Ocean quahog. Alterations to the natural movement of water and sediment could affect the presence and distribution of Ocean quahog, particularly given the reliance on larvae from Icelandic waters to re-stock populations in the North Sea (Witbaard and Bergman, 2003). The natural movement of water and sediment should therefore not be hindered.

Hydrodynamic regime within the site

It is likely that the predominantly eastward current that passes through this site carries Ocean quahog spat down from Iceland, which seeds Fulmar MCZ along with other populations in the southern North Sea (OSPAR, 2000; Witbaard and Bergman, 2003; Holmes *et al.,* 2003). Maintaining the hydrodynamic regime within the site is therefore critical to maintaining the supply of new recruits as well as ensuring a sufficient flow of water across the siphons of Ocean quahog to support respiratory and feeding processes. While infrastructure known to be present may be having a localised effect on the hydrodynamic regime within the site, it is not thought that this is having an adverse impact on the conservation status of Ocean quahog which are present. As such, **JNCC advise a maintain objective** for this sub-attribute and that activities must, look to avoid, as far as is practicable, altering the hydrodynamic regime. Our confidence in this objective would be improved with long-term monitoring, a better understanding of the hydrodynamic regime in the site and its impact on Ocean quahog.

Supporting habitat

The extent and distribution of supporting habitat plays an important role in determining the extent and distribution of the species. As a burrowing species, Ocean quahog has been found in a range of sediments, from coarse clean sand to muddy sand in a range of depths typically from 4 m to 482 m deep, but most commonly between 10 m to 280 m (Thorarinsdóttir and Einarsson, 1996; Sabatini *et al.,* 2008; OSPAR, 2009).

Ocean quahog are thought to have a high sensitivity to physical change to or loss of habitat (Tyler-Walters and Sabatini, 2017). It is therefore important to maintain the extent and distribution of supporting habitats within the site to maintain Ocean quahog populations and provide the best chance of any potential settlement for new recruits.

Supporting habitats within the site

As previously mentioned the extent and distribution of supporting habitat is available to view via the JNCC's Interactive MPA Mapper. Based on what is known about the habitat preferences of Ocean quahog, the full extent of the site (2,437 km^2) is considered suitable for Ocean quahog colonisation (Witbaard and Bergman, 2003). JNCC understands that the site includes locations where offshore infrastructure has been installed, such as oil platforms, subsea structures and pipelines. 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 Ocean quahog within the site. Further detail on the composition of the sediment habitats within the site is provided in Table 1 under the structure attribute.

Whilst future decommissioning activities that do not require rock dump may result in habitat being introduced for Ocean quahog that is suitable for colonisation (once oil and gas operations within a site have ceased), this is likely to be a very slow process due to the long-lived, slow reproducing and vulnerable nature of the species (Butler *et al*., 2012; Brix, 2013; Ridgeway and Richardson, 2010; Tyler-Walters and Sabatini, 2017). Therefore, **JNCC advise a maintain objective** for this attribute and that, as far as is practicable, changes in substrata within Fulmar MCZ is kept to an absolute minimum. For further information on activities capable of affecting Ocean quahog and their supporting habitat, please see the Advice on Operations Workbook.

Water and sediment quality

Ocean quahog is considered not sensitive to contaminants at Environmental Quality Standards (EQS) levels (Tyler-Walters and Sabatini, 2017). However, above this baseline, some contaminants may impact the conservation status of Ocean quahog depending on the nature of the contaminant (UKTAG, 2008; EA, 2014). Ocean quahog has a medium sensitivity to other water qualities, such as increases in temperature (Tyler-Walters and Sabatini, 2017). It is important therefore to avoid changing water and sediment quality properties of a site and as a minimum ensure compliance with existing 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).

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

- Marine Environmental and Assessment National Database (MERMAN);
- An Analysis of UK Offshore Oil and Gas surveys 1975-1995;
- Cefas' Green Book; and
- Cefas' Containment Status of the North Sea Report (2001).

The water quality properties that influence Ocean quahog include salinity, pH, temperature, suspended particulate concentration, nutrient concentrations and dissolved oxygen. These parameters can act alone or in combination to affect Ocean quahog according to 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. Changes in any of the water quality properties through human activities may impact habitats and the communities they support (Elliot *et al.,* 1998; Little, 2000; Gray and Elliot, 2009).

Salinity does not appear to be a limiting factor for the distribution of Ocean quahog, since the species is found in the Baltic Sea at 16 ppt (OSPAR, 2009), in the mid-Atlantic Bight at 32-34 ppt (Cargnelli *et al.,* 1999) and Oeschger and Storey (1993) successfully kept adult quahog at 22 ppt in the laboratory for several weeks.

Experimental evidence has shown that lower pH (380-1120 µatm pCO_2), has no effect on shell growth or crystalline microstructure in Ocean quahog as Ocean quahog can actively pump protons to drive increased calcification (Stemmer *et al.,* 2013; Stemmer, 2013). This suggests that although Ocean quahog can buffer against the effects of short-term acidification, longer-term acidification may have energetic consequences and ultimately restrict growth and/or reproductive output.

Adult Ocean quahog have a medium sensitivity to increases in water temperature. Evidence suggests that the optimal temperature for Ocean quahog survival, spawning and recruitment is 6-16°C (Loosanoff, 1953; Merrill *et al.,* 1969; Golikov and Scarlato, 1973; Jones, 1981; Mann, 1989; Cargnelli *et al.,* 1999; Harding *et al.,* 2008). Temperature change can be local (associated with localised effects, such as warm-water effluents, are highly unlikely to have a significant impact in offshore environments) or global (associated with climate change). The impacts on habitats and species from global temperature change can be direct, e.g. changes in breeding or growing seasons, predator-prey interactions, symbiotic relationships and species' physiologies, or indirect, e.g. changes in habitat conditions (Begum *et al.,* 2010). Many uncertainties exist in predicting our future climate and the impacts on habitats and species (EC, 2013).

Temperature has been attributed as the cause of low recruitment in North Sea populations, potentially increasing larval mortality and consequently restricting their southernmost extent (Witbaard and Bergman, 2003; Harding *et al.,* 2008). Temperature-induced changes in phytoplankton communities can also have knock-on effects on zooplankton communities, which can in turn impact filter-feeding organisms, such as Ocean quahog (Witbaard *et al.,* 2003). Witbaard *et al.* (2003) found that at high densities, copepods associated with warming seas intercept the downward flux of food particles to Ocean quahog, leading to slower shell growth. It is therefore important to maintain the natural temperature regime of the water column as far as is practicable against wider environmental pressures.

Ocean quahog are thought to have a low sensitivity to deoxygenation, nutrient enrichment, organic enrichment, changes in suspended sediments and smothering (Tyler-Walters and Sabatini, 2017). Although low levels of smothering via siltation events are unlikely to affect Ocean quahog, high levels of smothering could restrict the ability of Ocean quahog to feed or breathe (Elliot *et al.,* 1998; Morton, 2011). Adult Ocean quahog can switch from aerobic to anaerobic respiration and will be able to resurface post-smothering (Sabatini *et al.,* 2008). Powilleit *et al.* (2009) documented a high burrowing potential in Ocean quahog after experimental burial, successfully burrowing to the sediment surface through a covering layer of 32-41 cm. Although Ocean quahog can survive low dissolved oxygen levels, it could have sub-lethal and lethal affects under long-term anoxia (Taylor, 1976; Weigelt, 1991; Strahl *et al.,* 2011).

Ocean quahog are not considered sensitive to organic and inorganic pollutants (Tyler-Walters and Sabatini, 2017). However, JNCC advise that aqueous contaminants should 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. It is important therefore to carefully consider any proposals or human activity that could change the natural water quality properties affecting a site and as a minimum ensure compliance with existing EQS.

Water and sediment quality within the site

It is unclear whether water or sediment quality is impacted to the extent that it may affect the conservation status of Ocean quahog. Information on pollution by heavy metals is sparse with considerably more data required. Studies from 1992 indicated no evidence of pollution accumulation by heavy metals in North Sea sediments (Chapman, 1992; Chapman *et al.,* 1992), whereas older studies showed evidence of high concentrations of heavy metals in North Sea sediments, except in the central North Sea (Salomons *et al.,* 1988).

The cool Atlantic waters to the north of the site exhibit seasonal stratification during spring and summer, which increase phytoplankton communities (Salomons *et al.,* 1988; Weston *et al.,* 2005). The site is also likely to be affected by the warmer central North Sea water to the south, although more data on the site's physicochemical properties is required.

Available evidence indicates relatively low suspended sediment concentrations in the deeper regions (below 50 m) of the North Sea of less than 5 g/m^3 (Eleveld *et al.,* 2004). Phytoplankton production in the North Sea throughout the year results in chlorophyll *a* levels up to 5.8 $\mu g\ L^{-1}$ (Brockmann and Wegner, 1985; Brockmann *et al.,* 1990), supporting a high biomass of species at higher trophic levels year-round and creating a region that is biologically unique in the North Sea (Kröncke and Knust, 1995).

Evidence from the Charting Progress 2 report indicates that while the site is distant from terrestrial sources of pollution, enrichment of southern water masses due to riverine inputs and climatic variability may affect ecological function of sites in the North Sea. Atmospheric deposition in the North Sea has been highlighted as a major source of contamination of trace metals (cadmium, lead, copper and zinc; Injuk *et al.,* 1992).

While this information identifies possible sources of contamination, there is currently no information available to indicate that water or sediment quality in the site is falling below EQSs. Due to the lack of evidence on water and sediment quality affecting Ocean quahog within the site, **JNCC advise a maintain 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 Ocean quahog. For further information on activities capable of affecting Ocean quahog and their supporting habitat, please see the Advice on Operations Workbook.

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