Supplementary Advice on Conservation Objectives for North East of Farnes Deep Marine Conservation Zone

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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 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); and
- 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, Subtidal sand, Subtidal mud, Subtidal mixed sediments and Ocean quahog (*Arctica islandica*) specified in the site's conservation objective. 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 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 Tables 1 and 2 must be taken into consideration when assessing impacts from an activity.

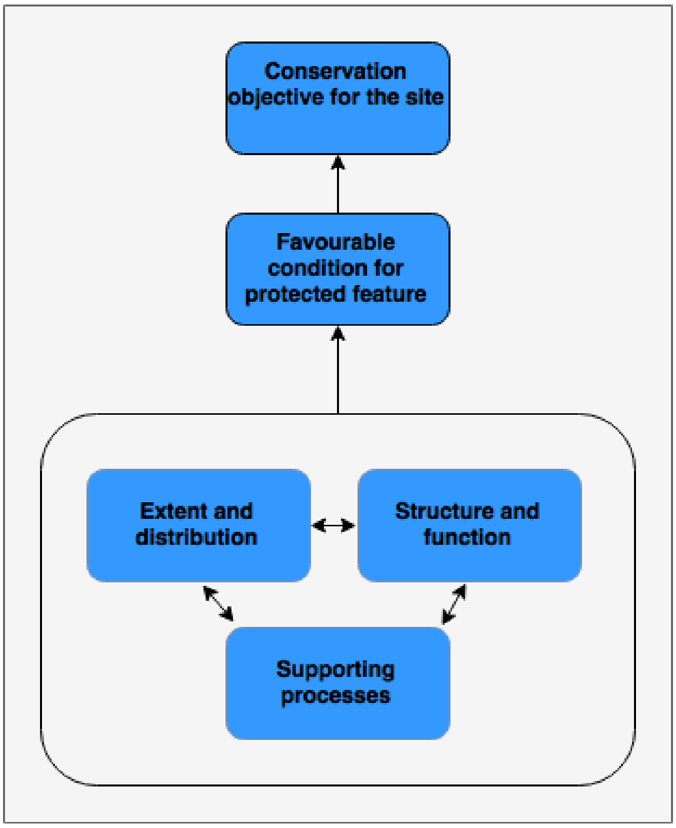

Figure 1. Conceptual diagram showing how a feature's attributes are interlinked and collectively describe favourable condition and contribute to the conservation objectives stated for the site.

In Table 1 below, the attributes for the broad-scale habitats (Subtidal coarse sediment, Subtidal sand, Subtidal mud and Subtidal mixed sediments) are listed and a description provided in explanatory notes. In Table 2 the attributes for Ocean quahog (*Arctica islandica*) are listed with descriptions 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.

Table 1: Supplementary advice on the conservation objectives for protected broad-scale habitats (Subtidal coarse sediment, Subtidal sand, Subtidal mud and Subtidal mixed sediments) in North East of Farnes Deep MCZ.

Attribute: Extent and distribution
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 for further site-specific information on this attribute.
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 conserved to their full known distribution. Subtidal sedimentary habitats are defined by: • ***Sediment composition*** (grain size and type) (e.g. Cooper *et al.,* 2011; Coates *et al.,* 2015; 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:

- *A5.1 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).
- *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). On the continental shelf, the Priority Marine Feature (PMF) Offshore deep-sea muds directly equates to the EUNIS habitat A5.3 Subtidal mud, but the PMF also covers deep-water examples that occur on or beyond the continental slope (Tyler-Walters *et al.,* 2016).
- *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 of the broad-scale habitats within the site

The designated features for this site are Subtidal coarse sediment, Subtidal sand, Subtidal mud and Subtidal mixed sediments. The extent and distribution of the protected broad-scale habitats 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 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.

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).

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).

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

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); 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.

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 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).

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.

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.

Supporting processes 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).

Table 2: Supplementary advice on the conservation objectives for Ocean quahog in North East of Farnes Deep MCZ.

Attribute: Extent and distribution

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 for further site-specific information on this attribute.

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 conserve 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 of Ocean quahog (*Arctica islandica*) within the site

The extent and distribution of Ocean quahog (*Arctica islandica*) 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 for further site-specific information on this attribute.

Explanatory notes

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 conserved in the long-term to maintain the population within the site.

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, 2013); and
- Carbon cycling and nutrient regulation: Maintaining healthy and productive ecosystems through the laying down of carbonate during shell growth and filter-feeding.

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 for further site-specific information on this attribute.

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 statement on conservation benefits (hyperlink is provided in the box at the top of this document), 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.

Supporting habitats
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 loss of habitat (Tyler-Walters and Sabatini, 2017). It is therefore important to conserve the extent and distribution of supporting habitats within the site to conserve Ocean quahog populations and provide the best chance of any potential settlement for new recruits.

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) and Contaminant Status of the Irish Sea' Report (2005).

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; 2014). 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 conserve 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.

Supporting processes 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).

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