Supplementary Advice on Conservation Objectives for Norwegian Boundary Sediment Plain Nature Conservation MPA

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Contents

Introduction

What the conservation advice package includes

The detail provided in this document offers background information on JNCC's conservation advice package for this offshore Nature Conservation Marine Protected Area (hereafter referred to as the 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, can 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 feature: Ocean quahog aggregations (and sands and gravels as their supporting habitat) 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 Table 1 below, along with the objectives set for each of them, describe the desired ecological condition (favourable) for the site's feature. Each feature within a site must be in favourable condition as set out in the site's conservation objective. All attributes listed in Table 1 must be taken into consideration when assessing impacts from an activity.

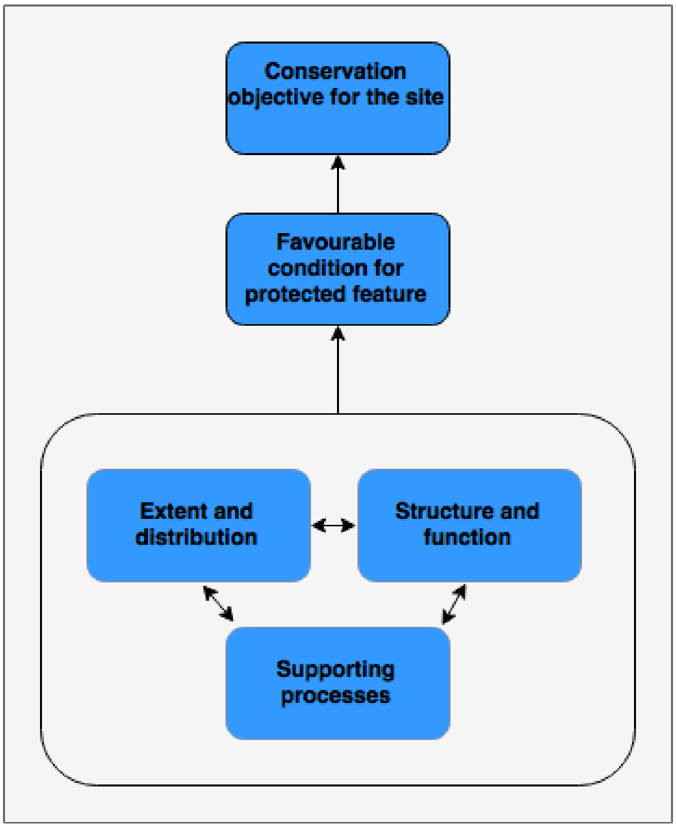

Figure 1. Conceptual diagram showing how a feature's attributes are interlinked and collectively describe favourable condition and contribute to the conservation objectives stated for the site.

In Table 1 below, the attributes for Ocean quahog aggregations are listed and a description provided in explanatory notes. An objective of recover or conserve is set for each feature attribute. The objective reflects our current understanding of a feature's condition e.g. where evidence indicates some of a feature's extent is lost and needs to be recovered or that extent is not lost and needs to be conserved in order to ensure the feature is in overall favourable condition. The rationale for setting an objective is also provided in the explanatory notes, along with reference to supporting evidence from the site. Note that where it is not practical through human intervention to recover a feature's attribute, a conserve objective is set, accompanied by a statement to reflect the impracticality of restoration.

Note also that when a conserve objective is set, this does not preclude the need for management in the future. Please see the conservation measures regarding our advice on those activities occurring in or near the site which may require additional management.

Table 1. Supplementary advice on the conservation objectives for Ocean quahog aggregations in Norwegian Boundary Sediment Plain Nature Conservation MPA

Attribute: Extent and distribution

Objective: Conserve

The feature is exposed to activities associated with pressures to which Ocean quahog aggregations are considered to be sensitive. Despite this, ***JNCC advises a conserve objective*** *due to substantial uncertainty around the ability of any site-based measures to support recovery of the extent and distribution of the feature within the site. This is also 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 aggregations within the site. Our confidence in the setting of this objective would be improved by a better understanding of the extent and distribution of Ocean quahog aggregations 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 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 within the site
The known extent and distribution of Ocean quahog aggregations and suitable habitat within the site is available to view via JNCC's Interactive MPA Mapper. It should be noted that ocean quahog supporting habitat is also available to view on this map and is discussed under Supporting processes further down. The map will be updated to include data from the 2015 survey of the site in due course.

Based on what is known about the habitat preferences of Ocean quahog (Witbaard and Bergman, 2003), >99% (~164 km^2) of the seabed habitats present within the site are 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. A collaborative survey between JNCC and Marine Scotland in 2015 shows that the depth at which Ocean quahog aggregations have been recorded across the site ranges between 80 m-120 m (O'Connor, 2016).

Samples taken during surveys for oil and gas developments between 1979 – 1993 provide evidence of Ocean quahog aggregations in the northern half of the site. The 2015 survey gives further evidence of Ocean quahog aggregations within the site, with the highest numbers sampled in the southern half of the site (O'Connor, 2016).

Offshore infrastructure, such as oil platforms and pipelines, which occur within the site could impact the extent and distribution of Ocean quahog aggregations. Such installation practices can result in localised physical damage, smothering and mortality through the introduction of concrete mattresses, cuttings piles and rock dump. Additionally, vessel monitoring system (VMS) data from 2009 to 2015 indicate that the Ocean quahog aggregations within the site are exposed to demersal trawling to which the feature is known to be sensitive. This activity impacts the sediment and is physically abrasive and has the potential to cause damage and result in mortality of individuals. These activities have the potential to reduce or alter the extent and distribution of Ocean quahog aggregations within the site.

Whilst decommissioning activities not requiring rock dump may result in habitat being introduced that is suitable for Ocean quahog 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).

Ocean quahog aggregations within the site are being exposed to damaging pressures associated with oil and gas operations and fishing activities and this may be impacting the feature's extent and distribution. Despite this, **JNCC advises a conserve objective** acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site; and also 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, disturbance to individuals that may result in a change to the extent and distribution of Ocean quahog aggregations within the site.

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

Attribute: Structure and function

Objective: Conserve

The feature is being exposed to activities associated with pressures to which Ocean quahog aggregations are considered to be sensitive. Despite this, ***JNCC advises a conserve objective*** *acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site an 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 the setting of this objective would be improved by long-term monitoring information on the population of Ocean quahog aggregations throughout the site.*

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.

Structure within the site

Information contained within UKBenthos shows 55 Ocean quahog individuals were sampled between 1979 – 1993 from the site. In 2015, a JNCC and Marine Scotland Science survey sampled 24 Ocean quahog individuals in 22 of 120 sample stations throughout the site (O'Connor, 2016). A maximum sample size of 2 individuals were recorded in a single station, with the greatest number of grab sample records taken in the south of the site. Assuming that the near full extent of the site contains habitat suitable for Ocean quahog aggregation colonisation (Witbaard and Bergman, 2003), average density of the Ocean quahog aggregations recorded across the site in 2015 was 0.13 individuals per km^2. This is significantly lower than documented averages from the northern North Sea (16 ind/m^2) (Witbaard, 1997; Witbaard and Bergman, 2003). However, the 2015 survey used a Hamon grab, which is not as effective in assessing ocean quahog density compared to trawl-based sampling methods (such as those used by Witbaard and Bergman, 2003) or box coring. There is currently not enough evidence available to attribute a cause for the observed decline in density in the northern North Sea.

More data are required to develop a time series of Ocean quahog population structure to identify any changes to the feature in the site over time. As there are no time series data for Ocean quahog aggregations within the site, it is unclear whether the population is declining, being conserved or increasing in the site. The age structure, growth rates and reproductive viability of the population located within the site are also currently unknown.

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).

Vessel monitoring system (VMS) data from 2009 to 2015 indicate that the Ocean quahog aggregations within the site are exposed to demersal trawling to which the feature is known to be sensitive. The feature is also being exposed to damaging pressures associated with oil and gas operations. Oil and gas activity can often result in localised physical damage, smothering and mortality through the introduction of concrete mattresses, cuttings piles and rock dump. These activities may be impacting the feature's structure within the site. Despite this, **JNCC advises a conserve objective** acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site and 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 the setting of this objective would be improved by long-term monitoring information on the population of Ocean quahog aggregations throughout the site.

For further information on activities capable of affecting Ocean quahog aggregations, 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 a range 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 of ecosystem services being provided by Ocean quahog aggregations within the site, 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 Ocean quahog aggregations are being exposed to activities with associated pressures that the feature is considered sensitive to and that this may be impacting the feature's function. Despite this, **JNCC advise a conserve objective**, acknowledging the substantial uncertainty around the ability of any site-based measures to support restoration of the feature within the site and 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 the setting of this objective would be improved by long-term monitoring information on the population of Ocean quahog aggregations throughout the site.

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

Attribute: Supporting processes

Objective: Conserve

JNCC consider there is limited evidence to suggest that supporting processes are being impeded with respect to supporting the Ocean quahog aggregations within the site. As such, ***JNCC advise a conserve 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 aggregations.*

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, 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

The hydrodynamic regime in the site is seasonally stratified (van Leewen *et al.,* 2015), with thermal stratification occurring in the spring as the air temperatures start to increase, reducing mixing of the water. The water masses remain stratified through-out summer until autumn when falling air temperatures and high winds cause a mixing of the water column (Sündermann and Pohlmann, 2011; van Leewen *et al.,* 2015). The low air temperature and pressure during winter results in continuous mixed hydrodynamic conditions in this region of the North Sea. Seasonal stratification results in a seasonal pattern of nutrient availability and therefore food supply for Ocean quahog aggregations varies throughout the year (Witbaard, 1996).

Within this region of the North Sea the mean spring tidal range is recorded as between one and two meters (Holgate *et al.,* 2013; PSMSL, 2016). Ocean current within the area stems from well mixed coastal water along the Atlantic inflow from the north and the Fair Isle/ Dooley current which flows from north of Orkney, as a result turbidity is moderate (SEA3, 2016; Sundermann and Pohlmann, 2011). The flow recorded in this region of the North Sea is ~0.2 m/s in a southerly direction (Shell UK LTD, 2017). Movement of the water masses from the North East Atlantic to central North Sea could help carry recruits of new Ocean quahog populations into the area from locations around Iceland (Sündermann and Pohlmann, 2011). The depth of the site is 80-120 m (below the storm base) suggesting that it is unlikely to be affected by storm events.

While infrastructure known to be present within the site may be having an extremely localised effect on the hydrodynamic regime, it is not thought that this is having an adverse impact on the conservation status of Ocean quahog aggregations. As such, **JNCC advise a conserve objective** for this sub-attribute.

For further information on activities capable of affecting Ocean quahog aggregations, please see the Advice on Operations Workbook.

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 change to or 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.

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. It should be noted that this will be updated to include data from the 2015 survey of the site in due course. Based on what is known about the habitat preferences of Ocean quahog (Witbaard and Bergman, 2003), >99% (~164 km^2) of the seabed habitats present within the site are considered suitable for Ocean quahog colonisation (based on UKSeaMap modelled habitat data; JNCC, 2016).

JNCC understands that the site includes locations where offshore infrastructure has been installed, such as oil platforms, subsea structures and pipelines. Such installation practices often result in a change in substrate 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 aggregations within the site.

Whilst decommissioning activities not requiring rock dump may result in habitat being introduced that is suitable for Ocean quahog 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).

A conserve objective is advised, however further information is needed. While evidence indicates that activities are occurring which are capable of affecting the composition of the supporting habitat for Ocean quahog within the site, there is insufficient information available to support a view as to whether the nature or scale of any impacts occurring is sufficient to prevent it being suitable for Ocean quahog. Our confidence in this objective would be improved with better understanding of how the activities taking place are affecting the availability of supporting habitat. Activities must look to minimise, as far as is practicable, further reductions to the extent and distribution of the supporting habitat for Ocean quahog within the site.

For further information on activities capable of affecting Ocean quahog aggregations, 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) 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.

Water and sediment quality within the site

The site lies within the central North Sea in an area of relatively high human activity. Oil and gas activity occur within the site and could impact water quality. Offshore oil and gas extraction can result in release of hydrocarbons into the water column, with discharges from offshore installations in the North Sea amounting to 16,000-17,000 tonnes of oil per year (Walday and Krogland, 2017).

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 μg 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 (Kröncke and Knust, 1995).

Evidence 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 (Wieking and Kröncke, 2005). 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). 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). It is unclear whether sediment quality is impacted to the extent that it may affect the conservation status of Ocean quahog aggregations. 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). There is no evidence available to reach a conclusion on the impact of hydrocarbons on Ocean quahog aggregation within the site.

There is limited information available on the sediment contaminant levels within the site. According to Clean Seas Environment Monitoring Program (CSEMP), samples taken in the Fladen Ground monitoring station adjacent to the site suggest the sediment is below background levels for all monitored contaminants and will have limited impact on marine life (CSEMP, 2014).

Additional literature has also noted that the exploration and exploitation of North Sea oil and gas reserves has also 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 infrastructures within the site, drill cuttings may present a previously unexplored pollution pathway at a local scale.

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. **JNCC advise a conserve objective**, due to lack of evidence to suggest that contamination of water or sediment is impacting Ocean quahog aggregations within the site. JNCC advise 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 aggregations and their supporting habitat, please see the Advice on Operations Workbook.

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