Supplementary Advice on Conservation Objectives for North Norfolk Sandbanks and Saturn Reef Special Area of Conservation

December 2017

JNCC

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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 qualifying features condition;
  - conservation benefits that the site can provide; and
  - conservation measures needed to support achievement of the conservation objectives set for the site.
- Supplementary Advice on Conservation Objectives (SACO) providing more detailed and site-specific information on the conservation objectives (this document);
- 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.

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 qualifying features: Annex I Sandbanks slightly covered by seawater all the time and Annex I Reefs, specified in the site's conservation objectives. These attributes include 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 features. The condition of each feature contributes to its favourable conservation status more widely, as well as the site's integrity. All attributes listed in Tables 1 and 2 must be taken into consideration when assessing impacts from an activity.

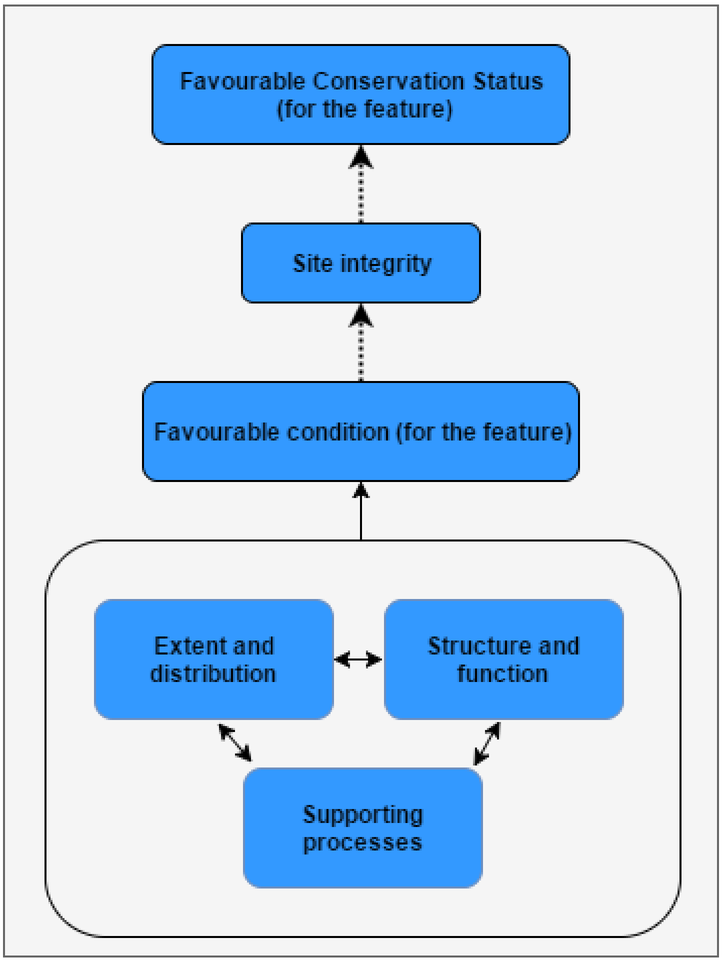

Figure 1. Conceptual diagram showing how feature attributes are interlinked, describe favourable condition and contribute to site integrity and wider favourable conservation status.

In Tables 1 and 2 below, the attributes description for Annex I Sandbanks slightly covered by seawater all the time and Annex I Reefs are provided in the explanatory notes. An objective of restore or maintain 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 restored 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 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 restore 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 for further detail regarding managing activities.

Table 1. Supplementary advice on conservation objectives (SACO): Annex I Sandbanks slightly covered by seawater all the time.

Attribute: Extent and distribution

Objective: Restore

JNCC understands that the site has been subjected to activities that have resulted in a change to the extent and distribution of the feature within the site. Installation and/or removal of infrastructure may have a continuing effect on extent and distribution. As such, JNCC advise a restore objective which is based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. oil and gas sector activities and cabling. Our confidence in this objective would be improved with longer-term monitoring and access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, changes in substratum and the biological assemblages within the site to minimise further impact on feature extent and distribution.

Explanatory notes

Extent refers to the total area in the site occupied by the qualifying feature and must include consideration of its distribution i.e. how it is spread out within the site. A reduction in extent has the potential to alter the biological and physical functioning of sedimentary habitat types (Elliott *et al.,*1998). The distribution of a habitat influences the component communities present, and can contribute to the health and resilience of the feature (JNCC, 2004a). The extent within the site must be conserved to the full known distribution.

Annex I sandbanks are defined and delineated (Duncan, 2016) by:

- ***large-scale topography*** which is elevated, elongated, rounded or irregular, permanently submerged and predominantly surrounded by deeper water (EC, 2013);
- ***sediment composition*** that is mainly sandy sediments (sand is defined as sediment particles between 2 and 0.0625 mm in diameter and sandy sediment must be composed of less than 30 % gravel and have more sand than mud). Other sediment types including boulders, cobbles or mud may also be present on a sandbank; and
- ***biological assemblages***. See JNCC's Marine Habitat Correlation Table for more detail about the range of biological communities (biotopes) that occur on Annex 1 sandbanks.

Loss of large scale topography would constitute loss of the sandbank feature extent. Loss of characterising sandbank biological assemblages or sandbank sediments from an area of the feature would constitute loss of sandbank habitat and a reduction in overall feature extent.

In the UK offshore area, there are two different types of sandbank:

1. Sandy mound sandbanks: created by glacial processes which have long since stopped acting on the feature. While surface sediments may be mobilised, the extent and distribution of the sandbanks as a whole remain broadly unaffected by ongoing hydrodynamic processes. It is important to note that we would not expect large scale topography or the underlying immobile substrates to recover, should they be physically impacted. The sandbank communities, however, are capable of recovering from impacts but this will be dependent on prevailing environmental conditions, the influence of human activities i.e. the scale of any current impacts, species life history traits, environmental connectivity between populations and habitat suitability (Mazik *et al.,* 2015);
2. Open shelf ridge sandbanks: can be relatively mobile with their extent and distribution being actively influenced by ongoing hydrodynamic processes and subsequently changing naturally over time. Recovery from physical impacts for these types of sandbanks is possible but again dependent on the range of factors mentioned in 1 above.

Extent and distribution within the site

The site map in Annex A shows the extent and distribution of the sandbank feature within North Norfolk Sandbanks and Saturn Reef SAC. The site is a representative example of the Annex I feature Sandbanks which are slightly covered by sea water all the time, and is considered to represent the most extensive system of open shelf ridge sandbanks in the UK (Graham *et al*., 2001). JNCC consider the entire site to represent an integrated sandbank system, with feature extent occupying the entirety of the site. The physical delineation of the sandbank contained within this site is supported by the original Site Assessment Document (JNCC, 2010) and has been further validated by recent biological community analysis (Parry *et al*., 2015). The total sandbank area is 3,603 km^2.

The innermost sandbanks in the site, known collectively as ‘the inner banks’, are examples of sandbanks developed in stronger tidal currents. The outer banks, further offshore, are known as the ‘Indefatigables’ and are the best example of open sea, tidal sandbanks in a moderate current strength in UK waters. The sandbanks have a north-west to south-east orientation and are thought to be progressively, though very slowly, elongating in a north-easterly direction (JNCC, 2010).

Based on our current understanding, JNCC do not consider it likely that human activities taking place within the site have the potential to permanently impact on the large-scale topography of the North Norfolk sandbanks. They could, however, have an impact on the other variables that help define the extent and distribution of a sandbank, namely sediment composition and biological assemblages.
A considerable number of predominantly gas extraction activities take place within the site, much of this now involved in decommissioning of the associated infrastructure. Of particular note are activities associated with the deposition of material (rock dump) or other alteration of surface sediment (e.g. drill cuttings and cabling operations) that may lead to a persistent change in substrate which is not suitable habitat for characterising sandbank communities. Aggregates dredging is occurring within the site but JNCC understand that this activity operates in such a way as to ensure that the distribution of surface sediments is not changed and so the feature's extent would remain unimpacted.

A restore objective is advised for extent and distribution of the sandbank feature. This objective is based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. those associated with the oil and gas industry and cabling. Our confidence in this objective would be improved with longer-term monitoring and access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, changes in substratum and the biological assemblages within the site to minimise further impact on feature extent and distribution. Further information on the impacts associated with human activities on Annex I Sandbanks slightly covered by seawater all the time can be found in the Advice on Operations workbook for the site.

Attribute: Structure and function

Objective: Restore

JNCC understands that the site has been subjected to activities that have resulted in a change to the structure and function of the feature within the site. Installation and/or removal of infrastructure may have a continuing effect on structure and function, specifically the finer scale topography, sediment composition and distribution of characteristic communities. As such, ***JNCC advise a restore objective*** *which is based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. demersal fishing, oil and gas sector activities and cabling. Our confidence in this objective would be improved with longer-term monitoring, access to better information on the activities taking place within the site and a better understanding of the species which can play key and influential roles in determining the feature's function and health. Activities must look to minimise, as far as is practicable, disturbance and changes to the sediment composition, finer scale topography and biological communities within the site.*

Explanatory notes

Structure

Structure encompasses both the physical structure of a habitat type together with the biological structure. **Physical structure** refers to **finer scale topography** and **sediment composition and distribution** Physical structure can have a strong influence on the hydrodynamic regime at varying spatial scales in the marine environment, as well as the presence and distribution of biological communities (Elliot *et al.,* 1998). This is particularly true of features like sandbanks which are large-scale topographic features. The biological structure refers to the **key and influential species** and **characteristic communities** present. Biological communities are important in not only characterising the sandbank feature but supporting the health of the feature i.e. its conservation status and the provision of ecosystem services by performing functional roles.

Physical structure: finer scale topography

Sandbank topography can be characterised by finer scale bedforms such as sand waves, mega-ripples and mounds which are driven by hydrodynamic processes. These bedforms can support different sediment types and associated communities (Elliott *et al.,* 1998; Barros *et al.,* 2004; Limpenny *et al.,* 2011). Where finer bedforms are known to be naturally present on a sandbank feature they should be conserved.

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

The sandbanks in this site are subject to a wide range of water current strengths which influences their fine-scale topography. Within the site, currents are strongest on the banks closest to shore and reduce gradually in strength with increasing distance offshore (Collins *et al*., 1995). The inner banks appear to be more pronounced, exhibiting taller crests and deeper troughs, than the outer banks. Sandbanks within the site are asymmetric in profile with their steeper slope (up to 7°) facing away from the coast and towards the northeast.

Sandwaves are present, being best developed on the inner banks indicating the sediment surface is regularly mobilised by tidal currents, while the outer banks have small or no sandwaves associated with them (Collins *et al*.,1995). Mega-ripples have been recorded in the site with height and wavelength scales of the order of 1 metre (Sanay *et al*., 2007) but can reach up to 40 m in some places (Fugro, 2013a). Other surveyed areas show megaripples with average amplitudes of 0.3 m and an average wavelength of 13 m (Fugro, 2013b; 2013c). Historical differences in bank elevation have been observed within the inner banks, with reduced elevation at the southern edges and deposition at the northerly edges, which suggests these banks are moving in a north easterly direction (Cooper *et al*., 2008; Jenkins *et al*., 2015). Furthermore, there are indications of sand transportation in an offshore direction between the banks, which is thought to be the process by which the sandbank structures (crests, flanks and troughs) are maintained.

There are activities occurring within the site which are capable of impacting the feature's finer scale topography. Evidence indicates that given the prevailing higher energy hydrodynamic regime within the site, the presence of widespread infrastructure and the introduction of material over the feature can result in scour pits affecting finer scale topography for quite some distance from source. These scour pits may persist or become periodically covered as the sandbanks system naturally progresses. Demersal fishing and aggregate dredging may also impact finer scale topography although the impacts are anticipated to be relatively short-lived and are therefore not considered further under this attribute

Overall, JNCC consider finer-scale topography of the feature may be impacted by the activities occurring within the site and therefore **need to be restored**. This objective is based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. cabling and oil and gas industry. Our confidence in this objective would be improved with longer-term monitoring, access to better information on the activities taking place within the site and a better understanding of the significance of the key and influential roles which species can play in supporting the feature's function and health. Activities must look to minimise, as far as is practicable, disturbance and changes to the sediment composition, finer scale topography and biological communities within the site. Further information on the impacts associated with human activities on Annex I Sandbanks slightly covered by seawater all the time can be found in the Advice on Operations workbook for the site.

Physical structure: sediment composition and distribution

Sediment composition of sandbanks is highly dependent on the level of energy experienced by the environment. It can be varied but in the offshore tends to be limited to primarily circalittoral sand but also circalittoral coarse sediments and to a lesser extent, circalittoral mixed sediments where finer sediment fractions (mud, silt/clay) are present. Coarser sediments tend to be located in higher energy environments that are subject to strong prevailing currents. Conversely, finer sediment types are typically associated with lower energy environments. Storm conditions however can mobilise all sediment types including coarser fractions. Furthermore, it is important to note that the composition and spatial distribution of sediments can change naturally over time.

Many functional ecological groups have specific niche sedimentary requirements; some species occur on all types of sediment, but most are restricted to a type and therefore limited in their distribution. Particle composition (including grain size and type) is a key driver influencing biological community composition (Cooper *et al.,* 2011; Coates *et al.,* 2015; 2016; Coblentz *et al.,* 2015) and the distribution and extent of these communities (JNCC, 2004a). The natural range of sedimentary habitats known to be present within a sandbank along with their composition and distribution, should be conserved.

Physical structure: sediment composition and distribution of the feature within the site
Recent evidence from survey confirms that the feature is comprised predominantly of circalittoral sand with areas of circalittoral mixed sediments and coarse sediments. Circalittoral mixed sediments and coarse sediments are found mainly in flanks and troughs and in places coincident with records of *Sabellaria spinulosa* reef (Parry *et al*., 2015). For further details on *S. spinulosa* reef please see Table 2.

Differences were observed between the sediment composition on the crests in comparison with the troughs during survey work. The sand fraction dominates the particle size composition of samples located on 'crests' consistently comprising >80% sand, whilst stations in the troughs were more heterogeneous showing a slightly wider range of sediment grades, but still typically contained 70-80% sand (Parry *et al*., 2015). Particle size distributions, grouped according to position on bank (i.e. crest, flank and trough), showed greatest variability within the troughs of the sandbanks in comparison with crests and flanks (Jenkins *et al*., 2015). The differences between particle size distribution found on the inner and outer banks were significant from a statistical point of view, but the differences found were relatively small. Sand grain sizes reported for the inner banks within the site ranged from 280mm (crests) to 429mm (troughs), and 275mm (crests) to 477mm (troughs) for the outer banks (Jenkins *et al*., 2015).

Some of the activities occurring at the site such as aggregate extraction, cabling and activities associated with the oil and gas industry e.g. decommissioning, are capable of changing the substratum in the site. Of particular note are activities associated with the deposition of material e.g. rock dump. As previously mentioned, aggregates dredging is occurring within the site but we understand that this activity operates in such a way as to ensure that the distribution of surface sediments is not changed and so the feature's sediment composition and distribution would remain unimpacted.

A restore objective is advised for the sediment composition and distribution within the site based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities, i.e. cabling and oil and gas sector activity.

Our confidence in this objective would be improved with longer-term monitoring and access to better information on the activities taking place within the site. Further information on the impacts associated with human activities on the sandbank feature can be found in the Advice on Operations workbook for the site.

Biological structure: key and influential species

Key species form a part of the habitat structure or help to define a biotope. Influential species are those that have a core role in the structure and function of the habitat. For example, species that are bioturbators which are benthic organisms that forage and burrow bottom tunnels, holes and pits in the seabed, help to cycle nutrients and oxygen between seawater and the seabed supporting organisms that live within and above the sediment. Grazers, surface borers, predators or other species with a significant functional role linked to the habitat can also be influential species. Changes to the spatial distribution of communities across the feature could indicate changes to the overall feature (JNCC, 2004a). It is therefore important to conserve the key natural structural and influential species of the sandbank within the site to avoid diminishing biodiversity and ecosystem functioning within the habitat and to support its health (Hughes *et al.,* 2005).

Biological structure: key and influential species of the feature within the site

S. spinulosa is a key and influential species in this site due to its ability to create biogenic reefs and in doing so, influence the finer scale topography and increase the species diversity associated with the wider sandbank feature in the site. *S. spinulosa* biogenic reef is another qualifying feature of this site. Further information is available in Table 2.

Burrowing species such the bivalves *Artica islandica*, *Abra alba, Fabulina fabula*, *Tellina fabula*, echinoderms such as *Echinocardium cordatum,* and polychaetes such as *Ophelia borealis*, *Spiophanes bombyx, Scoloplos armiger*) are present within the site. Predatory species such as *Nephtys cirrosa*, *Sthenelais limicola, Nephtys hombergii*, *Aglaophamus rubella*, *Glycera fallax*, *Anaitides* spp. and *Sigalion mathildae* and Pennant's swimming crab (*Portumnus latipes*) and the common necklace shell *Euspira nitida*, are also all present in the site (Ellis *et al*., 2010; Jenkins *et al*., 2015). Higher numbers of predatory species have been observed in the troughs of sandbanks compared to the crests and flanks (Ellis *et al*., 2010).

As mentioned, the bivalve ocean quahog (*Arctica islandica*), a notable species and listed OSPAR threatened or declining species, is present in the site (UKOOA, 2001). Records of the species are mostly from the troughs, however very little is currently known about the wider abundance, population structure and distribution of the species within the site.

There is insufficient information available to support an understanding of the significance of the role which these species play in maintaining the structure and function of the sandbanks within the site. 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 communities present make up the habitat and reflect the habitat's overall character and conservation interest. Characteristic communities include, but are not limited to, representative communities, for example, those covering large areas, and notable communities, for example, those that are nationally or locally rare or scarce such as those listed as OSPAR threatened or declining, or known to be particularly sensitive.

The biological communities typical of sandbanks will vary greatly depending on location, sediment type and depth, as well as fine-scale physical, chemical and biological processes. Communities found on sandbank crests are predominantly those typical of mobile sediment environments and tend to have relatively low diversity. Fauna such as polychaetes (worms) and amphipods (shrimp-like crustaceans) thrive in this environment as they are able to rapidly bury themselves. Animals like hermit crabs, flatfish and starfish also live on the surface of the sandbanks. Deeper areas more sheltered from prevailing currents or wave action can have reduced sediment movement. Such areas tend to have a higher diversity of burrowing species and often can support an abundance of attached bryozoans, hydroids and sea anemones, particularly on stones and dead shells.

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

Biological structure: characteristic communities of the feature within the site

There is considerable overlap in species composition of the biological communities present on sandbank crests, flanks and troughs in the site, with sediment type found to have the greatest influence on the composition of biological communities present rather than topography i.e. flank, crest and trough (Parry *et al*., 2015).

Benthic communities within the site are characterised by the presence of polychaetes of the genus *Ophelia borealis* and ribbon worms. The dominant sandy biotope, A5.233 - *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand, tends to occur in shallower water areas but found consistently on crests, flanks and troughs within the site. The coarse and mixed sediment biotopes tend to occur in troughs, but also sometimes on sandbank flanks. Coarse and mixed sediment biotopes in the troughs have many of the same species as the sand sediment habitat, however in higher abundances. Coarse sediment areas have some of the same characterising species as mixed sediment e.g., polychaetes such as the bristleworm *Mediomastus fragilis*, the ross worm *S. spinulosa*, the T headed worm *Scalibregma inflatum* and other polychaetes of the species *Notomastus* sp., but in lower abundances. Mixed sediment within the site hosts some different characterising polychaete species e.g. *Anobothrus gracilis* and *Ampharete lindstroemi,* and a much higher average abundance of more diverse taxa than other substrate types (Parry *et al*., 2015).

Epifauna occur on areas of sand where a small number of pebbles and cobbles are present, as well as on coarser sediment and areas where *S. spinulosa* reef are present. See Table 2 for more detail on epifauna specifically associated with *S. spinulosa* reef. Species such as the soft coral *Alcyonium digitatum*, bryozoans including *Alcyonidium diaphanum* and *Flustra foliacea*, the hydroid *Nemertesia antennina*, the anemone *Urticina felina* and the seastar *Asterias rubens* were found throughout the site associated with mixed and coarser sediments. Sandeels (*Ammodytes* sp.) are known to spawn in this region of the southern North Sea between November and February (Coull *et al*., 1998) and some individuals were recorded at a number of locations within the site during the 2013 survey (Jenkins *et al*., 2015).

Evidence shows that numbers of taxa, abundance and species diversity generally increases with increasing depth in both nearshore and offshore banks (Jenkins *et al.,* 2015). Samples taken from the inner bank crests contained fewer taxa, but similar abundances compared to the outer banks. Samples representing the troughs of the inner banks showed greatest variability in the number of taxa, abundance and diversity.

Demersal fishing and to a much lesser extent aggregate extraction occurring within the site can impact characteristic communities of the feature through pressures such as abrasion and the removal of non-target species. In addition, the activities which are considered to be impacting sandbank sediment composition i.e. cabling and oil and gas activities can also impact the characteristic communities.

A restore objective is advised for characteristic communities of the feature within the site based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities, i.e. demersal fishing, cabling and oil and gas sector activities. Our confidence in this objective would be improved with longer-term monitoring and access to better information on the activities taking place within the site. Further information on the impacts associated with human activities on Annex I Sandbanks slightly covered by seawater all the time can be found in the Advice on Operations workbook for 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 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. **key and influential species** and **characteristic communities**

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 typically provided by Annex 1 sandbanks include:

- Nutrition: due to the level of primary and secondary productivity on or around sandbanks, a range of fish species use these areas as feeding and nursery grounds. Some will migrate to certain parts of the habitat for feeding and breeding e.g. cod, plaice, dab, sole (Ellis *et al.,* 2012), whilst others are more resident e.g. sandeels (Frederiksen *et al.*, 2005; SNH and JNCC, 2012) making the conservation of sandbanks important to the fishing industry;
- Bird and whale watching: foraging seals, cetaceans and seabirds may also be found in greater numbers in the vicinity of sandbanks due to their shallower nature that enhances the availability of their typical prey items (e.g. Daunt *et al.,* 2008; Scott *et al,* 2010; Camphuysen *et al.,* 2011; McConnell *et al.,* 1999, Jones *et al.,* 2013);
- Climate regulation: by providing a long-term sink for carbon within sedimentary habitats.

The prevailing hydrodynamic regime and sedimentary composition have a strong influencing effect on the recovery potential of the functional components of subtidal sedimentary habitats – with higher-energy, coarser sedimentary habitats showing greater recovery potential following impact than lower-energy, finer sedimentary habitats (Dernie *et al.,* 2003). Recovery of populations of individual species or communities also depends on life history traits of species (e.g. their growth rate, longevity), and interactions with other species including predators. Furthermore, the environmental connectivity between populations or species patches, the suitability of the habitat (e.g. substrate type), depth, water and sediment quality (Mazik *et al.,* 2015) will also influence the recovery potential of features.

The natural range of sandbank communities within the site should be conserved to ensure the functions they provide support the health of the feature and the provision of ecosystem services to the wider marine environment.

Function of the feature within the site

The ecosystem services that may be provided by sandbanks within the site include:

- **Nutrition** - by providing a feeding area where prey is more biologically available for a variety of species of commercial importance, spawning areas for plaice (*Pleuronectes platessa*) and spawning and nursery grounds for young commercial fish species, such as sandeels (*Ammodytes* spp.) the common dab (*Limanda limanda*), sole (*Solea solea),* lemon so*le (Microstomus kitt)* and sprat (*Sprattus sprattus)* (JNCC, 2010; MALSF, 2009; Coull *et al*.,1998; Ellis *et al*., 2010);

- **Bird and whale watching** - by providing feeding grounds for marine birds and marine mammals. Evidence shows that during the breeding season black-legged kittiwakes (*Rissa tridactyla*) have a high usage within the site (Wakefield *et al.,* 2017). Other marine bird species have maximum foraging ranges which overlap the site limits, and therefore might use the site as well (Thaxter *et al.,* 2012). The site falls within the Southern North Sea candidate Special Area of Conservation, which suggests that this site may contribute to wider support for the southern North Sea population of harbour porpoise (*Phocoena phocoena)* (JNCC, 2017). Marine mammals such as harbour seals have been recorded travelling out to the site from haul out sites on the east coast of England (Jones *et al.,* 2013); and

- **Climate regulation** – the range of sedimentary habitats and associated communities in the site perform known ecological processes common to sandbanks such as deposition and burial of carbon in seabed sediments through bioturbation, living biomass and calcification of benthic organisms sinks (Hattam *et al*., 2015).

Given that a recover objective is advised for characteristic communities on which these functions rely, JNCC also advise a **recover objective** for this sub-attribute. Our confidence in this objective 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 Annex I Sandbanks slightly covered by seawater all the time can be found in the Advice on Operations workbook for the site.

Attribute: Supporting processes

Objective: Maintain

A maintain objective is advised for supporting processes based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities. Our confidence in this objective would be improved with long-term monitoring, specifically of contaminant levels within the site and a better understanding of the hydrodynamic regime within the site. Activities must look to avoid, as far as is practicable, impairing the hydrodynamic regime within the site and exceeding Environmental Quality Standards set out in the relevant section below.

Explanatory notes

The sandbank feature relies on a range of supporting natural processes to support the functions (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, 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 resource and propagules, influence water properties by distributing dissolved oxygen, and facilitating 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 structure and sorting of sediment particles. Shape and surface complexity within sandbank features can be influenced by coarse as well as finer-scale oceanographic processes, supporting the formation of topographic bedforms. The hydrodynamic regime plays a critical role in the natural formation and movement of mobile sandbanks.

Hydrodynamic regime within the site
The water within the site is a mixture of both northern Fair Isle and southern English Channel waters. The site presents a complex pattern of currents, that are at present not well understood. Water movement is influenced by the local topography, with strongest currents measured on the near-shore sandbanks and decreasing with distance offshore (Jenkins *et al.,* 2015). For example, on one of the banks, near-bed residual tidal currents have been observed to be strongest towards the crestline and in opposing directions on either side of the bank (Caston and Stride 1970; Caston, 1972).

Tides over the area are controlled by a progressive tidal wave, moving down the coastline of England. Episodic currents over the wider area of Norfolk Banks induced by storm surges cause sand to be transported in directions other than those caused by the tidal currents alone (Flather, 1987). The former, combined with observed tidal flows (Venn and D'Olier, 1983), is expected to transport sand oblique to the tidal currents and towards the northeast up to about 100 km to seaward, contributing to the sandbank feature's natural progression in this direction (Stride, 1988).

A hydrodynamic model developed by CEFAS, currently unpublished, indicates that ocean current flow is predominantly in a south-eastly direction with predicted velocities at seabed reaching a maximum of 2.7m/s. The wave regime in the site has a marked seasonality. Wave height ranges from 0.5 m to greater than 4 m, with the largest waves being seen in the winter months when waves of over 3 m height are regularly recorded (Draper, 1968; Marshall, 1997).

While there is evidence to suggest hydrodynamic regime is impacted locally by human activities within the site i.e. aggregate extraction, cabling and oil and gas sector activities, it is unclear whether this is occurring on such as scale as to impact the natural formation and movement of the sandbank feature within the site.

A maintain objective is advised for the hydrodynamic regime based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities. Our confidence in this objective would be improved with long-term monitoring and specifically a better understanding of the effects which human activities have on the hydrodynamic regime within the site and its influence on the formation and movement of the feature. Further information on the impacts associated with human activities on Annex I Sandbanks slightly covered by seawater all the time can be found in the Advice on Operations workbook for the site.

Water and sediment quality

Contaminants may also impact the ecology of a sandbank feature through a range of effects on different species within the habitat, depending on the nature of the contaminant (JNCC, 2004a; UKTAG, 2008; EA, 2014). It is important therefore to avoid changing the natural:

Water quality
and
Sediment quality

Environmental Quality Standards (EQS)

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

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

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

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

- Marine Environmental and Assessment National Database (MERMAN);
- The UK Benthos database available to download from the Oil and Gas UK website;
- Cefas Green Book;
- Strategic Environmental Assessment Contaminant Technical reports available to download from the British Geological Survey website;
- 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 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. Water quality properties can influence the abundance, distribution and composition of communities at relatively local scales. Changes in any of the water quality properties can impact habitats and the communities they support (Elliott *et al.,*1998; Little, 2000; Gray and Elliott, 2009). Changes in suspended sediment in the water column may have a range of biological effects on different species within the habitat; affecting the ability to feed or breathe. A prolonged increase in suspended particulates for instance can have a number of 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 have sub-lethal and lethal impacts on fish and infaunal and epifaunal communities (Best *et al.,* 2007). Concentrations of contaminants in the water column must not exceed the EQS listed above.

Water quality within the site

There is not much known about the quality of the water within the site. Most of the information which is available is on the wider southern North Sea area. The planktonic assemblage in the southern North Sea area is largely influenced by inflows of northeast Atlantic water which is gradually mixed with North Sea water (HR Wallingford, 2002). Rates of primary production increase significantly in the spring months followed by a smaller peak in abundance in the autumn, influenced to some extent by vertical mixing, stratification of the water column and light availability (Johns and Reid, 2001).

Surface temperatures in the region can be highly variable, with temperatures ranging from 8 to 14.6°C during May alone (MALSF, 2009). Salinity for the site falls under typical values for the North Sea with no significant seasonal variation and little variation in depth, with values at approximately 34.8 parts per thousand at the surface and 34.6 parts per thousand at the seabed in both summer and winter (BODC, 1998). Available evidence indicates that sediment suspension varies widely between summer (0 to 5 mg/l) and winter months (around 5 mg/l) (Dolphin *et al*., 2011).

A considerable number of predominantly gas exploration developments have taken place within the site. The main contaminants associated with this activity come from produced water and drill cuttings. Higher quantities of corrosion inhibitors, gas treatment products and scale inhibitors are discharged into the North Sea than chemicals of any other functional group. While possible sources of contamination are present on site, there is no information available to indicate whether water quality within the site is falling or above below Environmental Quality Standards (EQSs). However, 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. JNCC therefore advise that aqueous contaminants must be maintained below the annual average (AA_EQS) according to the amended Environmental Quality Standards Directive (EQSD) (2013/39/EU) or levels equating to (High / Good) Status (according to Annex V of the Water Framework Directive (WFD) (2000/60/EC).

A maintain objective is advised for water quality based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities. Our confidence in this objective would be improved with longer-term monitoring, specifically of contaminants within the site. Further information on the impacts associated with human activities on Annex I Sandbanks slightly covered by seawater all the time can be found in the Advice on Operations workbook for the site.

Sediment quality

Various contaminants are known to affect the species that live in or on the surface of sediments. These include heavy metals like Mercury, Arsenic, Zinc, Nickel, Chrome and Cadmium, polyaromatic hydrocarbons (PAHs), poly-chlorinated biphenyls (PCBs), organotins (TBT) and pesticides such as hexachlorobenzene. These metals and compounds can impact species sensitive to particular contaminants (e.g. heavy metals) and bioaccumulate within organisms thus entering the marine food chain (e.g. PCBs) (OSPAR 2009; 2010; 2012). This contamination can alter the structure of communities within a site e.g. lowering species diversity or abundance. It is important therefore to avoid changing the natural sediment quality of a site and as a minimum ensure compliance with existing EQS as set out above. Sediment contaminants must not exceed the EQS listed above.

Sediment quality within the site

Trends in the concentration and distribution of contaminants in sediments in the wider southern North Sea, including hydrocarbons (HCs), are similar as those described for surface water contamination i.e. higher concentrations in the immediate vicinity of installations with concentrations generally falling to background levels within a very short distance from discharge (Hartley Anderson Ltd., 2001). Gross contamination of sediments by metals extends no further than 500 m downstream from production platforms except for Barium, which shows evidence of elevated levels in the area within 500 to 1,000 m of platforms (Hartley Anderson Ltd., 2001). There are, however, some notable exceptions. For example, the levels of certain metals (Lead, Vanadium, Copper and Iron) appear higher in the southern North Sea compared to the northern North Sea. Work on seasonal current circulation patterns within the southern North Sea suggests that this may be due to coastal contamination transported offshore without being widely dispersed (Hartley Anderson Ltd., 2001).

Where concentrations of total hydrocarbons (THCs) are found to be higher than Environmental Quality Standards (EQS) expected for the offshore, these are in the immediate vicinity of installations with concentrations generally falling to background levels within a very short distance from discharge.

A maintain objective is advised for sediment quality based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. oil and gas sector activities. While evidence indicates there may be elevated levels of contaminants in the site, exceeding EQLs, a maintain objective is advised as restoration of contaminants in the offshore is not currently feasible. Our confidence in this objective would be improved with longer-term monitoring, specifically contaminants within the site. Further information on the impacts associated with human activities on Annex I Sandbanks slightly covered by seawater all the time can be found in the Advice on Operations workbook for the site.

Table 2. Supplementary advice on conservation objectives (SACO): Annex I Reefs - *Sabellaria spinulosa* biogenic reef.

Attribute: Extent and distribution

Objective: Restore

JNCC understands that the site has been subjected to activities that have resulted in a change to the extent and distribution of the feature within the site. Installation and/or removal of infrastructure may have a continuing effect on extent and distribution of the biogenic reef within the site. As such, ***JNCC advise a restore objective*** *which is based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. those associated with the oil and gas industry and demersal fishing. Our confidence in this objective would be improved with longer-term monitoring and access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, damaging the established i.e. high confidence reef within the site.*

Explanatory notes

Extent refers to the area of the site occupied by the feature and must consider how the feature is distributed across the site as this influences the component communities present and can contribute to the health and resilience of the feature (JNCC, 2004a). Annex I reefs include biogenic concretions, such as *Sabellaria spinulosa* reef, which arise from the sea floor in the sublittoral and littoral zone (ECDG Environment, 2007). The extent and distribution of *S. spinulosa* reef is defined and delineated in terms of reef elevation, area and patchiness (Gubbay, 2007). These factors are all considered important to the definition of examples of the actual feature as there is a natural graduation from solitary individuals, to small clusters or crusts, to areas of confirmed reef.

In UK waters, *S. spinulosa* reef is typically found from 3 m to over 40 m deep (Jessop and Stoutt, 2006; JNCC, 2010a; JNCC, 2010b). The extent of *S. spinulosa* reefs are highly variable and subject to physical and biological pressures such as those created by storms and predation. *Sabellaria* reefs are naturally ephemeral (capable of forming, decaying and disappearing from an area over just a few years) and shift in spatial distribution (occasionally forming cohesive expanses of reef up to several hectares, but often demonstrating a high degree of patchiness) (Hendrick *et al.,* 2011; Benson *et al.,* 2013; Roberts *et al.,* 2016). Due to the cyclical nature of reef formation and decay, it is important to conserve the feature's overall extent within a site, and that this approach includes conserving both established reef and areas of potential reef. Assessments should focus on reef extent occurring at that specific point in time, therefore a repeat survey may be required at the point of assessment.

Established areas of reef that persist over time form more elevated structures or consistently recolonise the same areas and are especially important for conservation of the feature's extent (Roberts *et al.,* 2016). Please see explanatory notes under the supporting processes attribute relating to supporting habitats for further information.

Extent and distribution within the site

The extent and distribution of high confidence Annex I *S. spinulosa* biogenic reef feature and areas of potential reef are shown in the site map provided in Annex A. To better visualise the different extents and distributions of the high confidence and potential reef within the site an extract of the site map is provided in Annex B. High confidence reef has been observed at several locations within the site, hosting examples of biogenic reef in an open, tide-swept situation on sand and gravelly sand habitat (Vanstaen and Whomersley, 2015). Areas of potential reef shown in the map can provide supporting habitats for the establishment of new Annex I *S. spinulosa* biogenic reef. Advice is provided on these areas under the Supporting processes attribute.

During a 2003 survey (BMT Cordah, 2003) an extensive area of reef named Saturn Reef, was identified between Swarte and Broken banks. The extent of Saturn Reef was estimated to cover an area of 0.375km^2, with a core area (0.125km^2) of near continuous (90% coverage of the core area) and high elevation reef (>10cm high). Areas of patchy reef (<10-50% coverage of reef extent) were also observed in the same area. In follow-up surveys in 2006 (Limpenny *et al*., 2010) and 2013 (Vanstaen and Whomersley, 2015) no substantial reef structures were found in the Saturn reef area. It is not understood whether the loss was a result of damage (e.g. from bottom trawling), or due to the ephemeral nature of this feature. Further work is needed to investigate potential causes of reef disappearance to distinguish between natural or anthropogenic environmental drivers (Vanstaen and Whomersley, 2015). Nonetheless, formation of such a substantial reef of *S. spinulosa* in the area of Saturn Reef in 2003 indicates the presence of favourable conditions for reef formation. Please see explanatory note on supporting habitats under supporting processes for more information on favourable conditions within the site for reef formation.

In the 2013 survey, a new area of *S. spinulosa* reef was recorded and mapped as high confidence reef (Ellwood, H., 2013) to the west of the Saturn reef area and at several other locations throughout the site such as the northern sections of the Swarte and Well Banks (troughs and flanks) and the troughs in the southern sections of Inner and Leman banks (Vanstaen and Whomersley, 2015). The depth at which *S. spinulosa* have been recorded across the site varies between -20m and -40 m. The total area is estimated to be approximately 115 hectares (Vanstaen and Whomersley, 2015), but it is important to understand that the boundaries of areas of *S. spinulosa* that have been mapped and presence confirmed by video analysis should be considered as a coarse demarcation rather than a sharp boundary.

Vessel Monitoring System (VMS) data shows demersal fishing activity occurring over Annex I biogenic reef. Fishing activity can result in impacts to the feature extent through abrasion. Aggregate extraction and predominantly gas extraction activities are also operating in areas where *S. spinulosa* reef has been found. These activities are capable of exerting pressures to which the feature is sensitive to e.g. habitat physical change, obstruction and siltation rates changes and have the potential to impact the extent and distribution of the biogenic reef feature. Our understanding is that the aggregate industry operates under a policy of avoiding impacting areas where *S. spinulosa* is found. Therefore, there is no evidence to suggest that *S. spinulosa* reef within the site is impacted by this specific activity.

A restore objective is advised however, for extent and distribution based on expert judgment, specifically our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. demersal fishing and oil and gas sector activities. Our confidence in this objective would be improved with long-term monitoring and access to better information on the activities occurring in the site. Activities must look to avoid, as far as is practicable, damaging established reef within the site. Further information on the impacts associated with human activities on Annex I *S. spinulosa* biogenic reef can be found in the Advice on Operations workbook.

Attribute: Structure and function

Objective: Restore

JNCC understands that the site has been subjected to activities that have resulted in a change to the structure and function of the feature within the site. Installation and/or removal of infrastructure may have a continuing effect on structure and function, specifically the characteristic communities and sediment composition and distribution. As such, ***JNCC advise a restore objective*** *which is based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. those associated with the oil and gas industry and demersal fishing. Our confidence in this objective would be improved with long-term monitoring and access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, damage and disturbance to the physical structure of established reef within the site and its associated biological communities.*

Explanatory notes

Structure

Structure encompasses both the physical and biological structure of a habitat type.

Physical structure

Physical structure relates to topography and surface complexity of the feature and can itself influence the prevailing hydrodynamic regime at varying spatial scales. Biological structure refers to the presence and abundance of key and influential species and the characteristic communities present and the population structure of associated species assemblages. Biological communities are important in characterising the nature of the feature and in describing the health of the feature, i.e. defining its conservation status and those ecosystem services it provides.

Physical structure

Sabellaria spinulosa worms use sand and shell fragments to build tubes, which they attach to the underlying substrate. When conditions are favourable, dense aggregations of individuals form reef structures rising above the surrounding seabed (Jackson, 1977; Chisholm and Kelley, 2001; OSPAR, 2013). These elevated aggregations characterise the biogenic reef feature and themselves provide attachment surfaces for other epifauna and crevices that afford protection to fauna from predation, physical disturbance and physiological stress (Hendrick *et al.,* 2011). The structure provided by *S. spinulosa* reef is valuable in soft sediment areas by maintaining a higher faunal diversity than the surrounding substrate, by virtue of the epifauna attached to or within the reef. It is therefore important that the physical structure of the feature is conserved to conserve epibenthic diversity.

It is important to note that the physical structure of the reef can naturally be highly variable. Elevation of the feature (average tube height) varies naturally across the reef with low, medium and high reef tentatively considered as between 2-5 cm, 5-10 cm and 10-20 cm respectively (Gubbay, 2007). High densities of *S. spinulosa* can also form crusts or sheets and although not widely considered to be reef, these areas can be considered stages in reef development and should be considered in assessments (Gubbay, 2007; see the advice under supporting habitats for more information). Densities of *S. spinulosa* aggregations are also known to vary widely from 120 tubes per m^2 recorded in Belfast Lough, Northern Ireland to more than 4500 tubes per m^2 in the Wash on the east coast of England (Hendrick and Foster-Smith, 2006).

Whilst some aggregations may be short-lived, with the reef disintegrating and disappearing soon after the death of the reef-builders, in other cases the reefs may repeatedly develop and decline in regular succession through resettlement after each successive generation has died. The physical structure of the reef can also naturally bioerode or become covered by mobile sediments, leading to patchy distributions of *S. spinulosa* reefs interspersed with patches of underlying sediment (Hendrick and Foster-Smith, 2006; Limpenny *et al.,* 2010).

It is likely that if prevailing conditions and the timing of disturbance are favourable, i.e. disturbance/damage does not occur during a spawning/reproduction event, *S. spinulosa* reefs can recover their physical structure relatively quickly (within 16-24 months) from short-term or intermediate levels of physical impact/abrasion (Pearce *et al.,* 2007; Gibb *et al.,* 2014). Recovery will be accelerated where some of the reef is left intact as this will assist larval settlement of new recruits of the species (Vorberg, 2000; Cooper *et al.,* 2007; Pearce *et al.,* 2007; Savage *et al.,* 2008).

Physical structure within the site

The density of *S. spinulosa* biogenic reef varied across the area of Saturn Reef when identified in 2003. A core section of near continuous and high profile reef (10cm high) with very dense coverage (90% of the seabed) was identified, with some sections rising to up to 25cm above the seabed. Also observed were patchier reef areas with 10-50% coverage and even sparser reef patches with less than 10% coverage. Reef patches were either broken by various 'holes' or were elongated strips, raised above surrounding seabed with surrounding sediment included both tube debris and non-tube sediment consisting of silty sand/stones (BMT Cordah, 2003).

Further surveys were undertaken by JNCC and Cefas in 2013 in five discreet areas across the site where video and acoustic data were collected. Tube elevation was taken into account using the Gubbay 2007 measure of reefiness, whereby >10cm in height was considered as high reefiness. The best examples of *S. spinulosa* reef in terms of coverage and height were found to the west of the Saturn Reef. This area contained the highest number of *S. spinulosa* individuals when compared to other discreet sampling areas (Vanstaen and Whomersley, 2015).

The human activities taking place in the site i.e. demersal fishing and activities associated with the oil and gas industry have the potential to impact the physical structure of the established biogenic reef in the site. Again, our understanding is that the aggregate extraction occurring in the area where *S. spinulosa* is found operates under a policy of avoiding impacting areas where reef is present. Therefore, there is no evidence to suggest that *S. spinulosa* reef within the site is impacted by this specific activity.

A restore objective is advised based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. demersal fishing and oil and gas industry activities. Our confidence in this objective would be improved with longer-term monitoring and access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, disturbance to the structure of established reef within the site. Further information on the impacts associated with human activities on Annex I *S. spinulosa* biogenic reef can be found in the Advice on Operations workbook.

Biological structure: Key and influential species
Key species form a part of the habitat structure or help to define a biotope. *S. spinulosa* as a species itself is key to the conservation of the reef's extent and physical structure. As mentioned under physical structure, these polychaete worms build tubes that often form dense aggregations characterising the feature and support the provision of ecosystem services, such as nutrition, carbon and nutrient cycling, water regulation and habitat provisioning. A study has identified a significant correlation between the density of living worms and reef biodiversity (Fariñas-Franco *et al.,* 2014). It is important therefore that living worm presence, abundance and density is conserved, acknowledging their ephemeral nature. Influential species are those that have a core role in the structure and function of the habitat, and can include grazers, surface borers and predators.

Biological structure: Key and influential species within the site
S. spinulosa is the key species of this feature responsible for building the tubular structures that make up the reef. Individual worms, using sediments from the surrounding habitats, build reef structures which can influence the finer scale topography and result in increased species diversity in comparison to surrounding areas. In some areas, *S. spinulosa* was found in high abundances, of up to 9000 individuals (Jenkins *et al.,* 2015).

Scavenger decapods, *Galathea intermedia*, *Ebalia cranchii* and *Pilumnus hirtellus* (BMT Cordah, 2003) as well as the gastropod mollusc *Noemiamea dolioliformis*, believed to be an ectoparasite of *Sabellaria* (Killeen and Light, 2000) are also associated with the reef in the site. However, the significance of their role in supporting the reef's function and health is not well understood and they are not considered further in our advice.

The activities taking place in the site e.g. those associated with the oil and gas sector and demersal fishing have the potential to impact the key and influential species of the feature, specifically *S. spinulosa* by way of damaging the physical structure of the reef. Our understanding is that the aggregate extraction occurring in the area where *S. spinulosa* is found operates under a policy of avoiding impacting those areas. Therefore, there is no evidence to suggest that *S. spinulosa* reef within the site is impacted by this specific activity.

A restore objective is advised based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. demersal fishing and oil and gas industry activities. Our confidence in this objective would be improved with longer-term monitoring, access to better information on the activities taking place within the site and a better understanding of the species which can play key and influential roles in the feature's function and health. Activities must look to minimise, as far as is practicable, disturbance to the *S. spinulosa* associated with established reef within the site. Further information on the impacts associated with human activities on Annex I *Sabellaria spinulosa* biogenic reef can be found in the Advice on Operations workbook.

Biological Structure: Characteristic communities

Changes to the spatial distribution and abundance of communities occurring on or within the feature could indicate changes to the overall feature (JNCC, 2004a). The species composition of communities includes a consideration of both the overall range of species present within the community, as well as their relative abundance. Species composition could be altered by human activities without changing the overall community type.

S*. spinulosa* reef structures support epifaunal and crevice-dwelling species, leading to distinct macrofaunal biotopes that are richer than the surrounding sediments (BRIG 2008; Fariñas-Franco *et al.,* 2014). This biodiversity is an indicator of the health of *S. spinulosa* reefs. The biological communities vary greatly depending on reef depth, the sediment type where the reef forms, and fine-scale physical, chemical and biological processes (OSPAR 2013; Fariñas-Franco *et al.,* 2014). The biotope most characteristic of *S. spinulosa* reef is *Sabellaria spinulosa* on stable circalittoral mixed sediment (SS.SBR.PoR.SspiMx; JNCC, 2015).

The diverse range of epifauna on *S. spinulosa* reefs includes mixed faunal turfs of bryozoans (*Flustra foliacea*, *Alcyonidium diaphanum*, *Cellepora pumicosa*) and hydroids, together with calcareous tubeworms (*Lanice conchilega, Pomatoceros triqueter*), sponges and tunicates. Additional epifauna known to occur include barnacles (*Balanus crenatus)*, starfish (*Asterias rubens)*, sea spiders (pycnogonids), hermit crabs (*Pagurus bernhardus)*, bivalves (*Abra alba* and *Nucula nitidosa*), gastropod molluscs (*Noemiamea dolioliformis, Gibbula cineraria*), shrimp (*Pandalus montagui*), the long-clawed porcelain crab (*Pisidia longicornis*) and squat lobster (Foster-Smith and Hendrick, 2003; JNCC, 2015, OSPAR, 2013). Typical infauna includes sublittoral polychaete species such as *Protodorvillea kefersteini, Harmothoe* spp, *Scoloplos armiger, Mediomastus fragilis*, and cirratulids, and tube building amphipods such as *Ampelisca* spp. (JNCC, 2015). It is important to conserve the natural spatial distribution, composition, diversity and abundance of the characterising communities associated with reef within the site to avoid diminishing biodiversity and ecosystem functioning within the habitat and to support its health (Hughes *et al.,* 2005; Fariñas-Franco *et al.,* 2014).

Biological structure: Characteristic communities within the site

In addition to S. spinulosa, polychaetes such as *Pholoe synophthalmic, Mediomastus fragilis, Scalibregma inflatum* and *Notomastus sp*, burrowing bivalves such as *Abra alba, Mysella bidentata*, *Tapes rhomboides* and *Mya truncate,* and *decapodes* such as *Upogebia deltuara,* are all associated with this feature within the site, and are believed to play a role in marine bioturbation (BMT Cordah, 2003). Other species associated with the *S. spinulosa* reef feature within the site included: several species of crustaceans e.g. squat lobster *Galathea intermedia*, edible crab *Cancer pagurus* and porcelain crab *Pisidia longicornis*, as well as worm species e.g. scaleworm family Polynoidae and polychaetes such as *Eteone longa*, *Phyllodoce mucosa*, *Eunereis longissima*, *Sthenelais boa* and *Glycinde nordmanii*, the shrimp-like amphipod *Abludomelita obtusata* and the brittlestar *Amphipolis squamata* (Jenkins *et al*., 2015).

The human activities taking place within the site, i.e. those associated with oil and gas sector activities and demersal fishing have the potential to impact the characterising species associated with the Annex I feature, *S. spinulosa* biogenic reef by damaging established reef. Again, our understanding is that the aggregate extraction operates under a policy of avoiding impacting those areas where the feature is known to occur. Therefore, there is no evidence to suggest that *S. spinulosa* reef within the site is impacted by this specific activity and it is not considered further under this attribute.

A restore objective is advised based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. demersal fishing and oil and gas sector activities. Our confidence in this objective would be improved with longer-term monitoring and access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, disturbance to the characterising species associated with established reef within the site. Further information on the impacts associated with human activities on Annex I *S. spinulosa* biogenic reef 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 that characterise the habitat and deliver a variety of functional roles within it (Norling *et al.,* 2007), i.e. key and influential species and characterising communities as mentioned. 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; Pearce *et al.*, 2011).

Ecosystem services provided by Annex I reefs include:

- Nutrition: enhanced levels of productivity occur on or around *S. spinulosa* reefs and *S. spinulosa* are a direct food source to several commercially important fish species, such as dab (*Limanda limanda)*, dover sole (*Solea solea)* and plaice (*Pleuronectes platessa).* Conserving *S. spinulosa* reefs can make an important contribution to fish stocks thus benefiting the fishing industry;
- Carbon and nitrogen cycling: maintaining healthy and productive ecosystems;
- Water regulation: *S. spinulosa* filters the water column maintaining healthy and productive ecosystems; and
- Habitat provisioning: *S. spinulosa* provides suitable living space for marine animals maintaining commercially important species.

Function of the feature within the site

Ecosystem services that may be provided by Annex I *S. spinulosa* reef within the site include:

- Nutrition: there is currently insufficient evidence available to provide further detail on nutrition provision by the feature at this site.
- Carbon and nitrogen cycling: there is currently insufficient evidence available to provide further detail on carbon and nitrogen cycling by the feature at this site.
- Water regulation: there is currently insufficient evidence available to provide further detail on water regulation by the feature at this site.
- Habitat provisioning: the abundance of certain characteristic taxa showed stronger relationships with both *S. spinulosa* abundance and reef volume than with sediment type (Jenkins *et al*., 2015). This could indicate that certain species are relying on the key and associated species associated with *S. spinulosa* reef as a food source.

Given that a recover objective is advised for characteristic communities on which these functions rely, JNCC also advise a **recover objective** for this sub-attribute. Our confidence in this objective would be improved by long-term monitoring and a better understanding of the role which biological communities play in supporting the function and health of the feature.

Further information on the impacts associated with human activities on Annex I *S. spinulosa* biogenic reef can be found in the Advice on Operations workbook.

Attribute: Supporting processes

Objective: Restore

A restore objective is advised for the supporting habitat within the site and a maintain objective is advised for hydrodynamic regime and water quality within the site. These objectives are based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. demersal fishing and oil and gas sector activities. Our confidence in these objectives would be improved with longer-term monitoring, specifically of contaminants within the site. It would also be improved with access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, disturbance to the hydrodynamic regime within the site and the habitats which support the reef within the site. Activities must also look to avoid, as far as is practicable, exceeding Environmental Quality Standards for aqueous contaminants as set out below.

Explanatory notes

The *S. spinulosa* reef feature relies on a range of natural processes to support the functions (ecological processes) and help any recovery from adverse impacts. Physical, biological and chemical supporting processes affect reef development and persistence, and the faunal composition of reef communities (Alexander *et al.,* 2014). For the site to fully deliver the conservation benefits set out in the statement on conservation benefits, the natural supporting processes of hydrodynamic regime, supporting habitats and water 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, influence water properties by distributing dissolved oxygen, and facilitating gas exchange from the surface to the seabed (Chamberlain *et al.,* 2001; Biles *et al.,* 2003; Hiscock, 2005; Dutertre *et al.,* 2012). Hydrodynamic regime also effects the movement, size structure and sorting of sediment particles, which as filter-feeders could affect the feeding behaviour, growth and survival of *S. spinulosa*.

As filter-feeders requiring water movement, *S. spinulosa* inhabit areas of high turbidity, high sediment load, moderate currents and moderate suspended organic particulate load (Jones *et al.,* 2000; Foster-Smith, 2001; Hendrick *et al.,* 2011). These conditions provide sediment supply for tube building, food, oxygen, larvae for recruitment, waste removal and prevent sedimentation (Kirtley and Caline, 1992; Jones, 1999; Jackson and Hiscock, 2008). Reef communities of *S. spinulosa* have been found in areas with current velocities of 0.5m/s to 1.0m/s (Mistakidis, 1956; Jones *et al.,* 2000; Davies *et al.,* 2009).

It is important to maintain the hydrodynamic regime and a degree of sedimentation within the site to supply the sediment for the worms to build the tubes that form the reef structure. It is probable that *S. spinulosa* can tolerate smothering by sediment for up to several weeks. However, the rate of sediment deposition can influence the status of reef habitats and their associated communities. Sedimentation on reefs can influence community composition, alter species growth rates and potentially impact reproductive success by affecting larval recruitment.

Studies have noted the regular smothering of intertidal *Sabellaria* reefs, where a near complete kill occurred every winter (Miller, 2001). Nevertheless, recruitment was reported each spring, indicating that these intertidal reefs were essentially being maintained by more stable subtidal reefs (Fariñas-Franco *et al.,* 2014). While the susceptibility of subtidal reefs to smothering is not well understood, evidence indicates that increased sediments can present a potential threat to *S. spinulosa* with the species found to have a medium sensitivity to moderate smothering (Fariñas-Franco *et al.,* 2014; Tillin *et al.,* 2015). It is important therefore to conserve the natural sedimentation rates influencing reef environments.

Hydrodynamic regime within the site

The water within the site is a mixture of both northern Fair Isle and southern English Channel waters. The site presents a complex pattern of currents that are presently not that well understood. Water movement is influenced by the local topography, with strongest currents measured on the near-shore sandbanks and decreasing with distance offshore (Jenkins *et al.,* 2015). For example, on one of the banks, near-bed residual tidal currents have been observed to be strongest towards the crestline and in opposing directions on either side of the bank (Caston and Stride 1970; Caston, 1972).

Tides over the area are controlled by a progressive tidal wave, moving down the coastline of England. Episodic currents over the wider area of Norfolk Banks induced by storm surges, cause sand to be transported in directions other than those caused by the tidal currents alone (Flather, 1987). The former, combined with observed tidal flows (Venn and D'Olier, 1983) is expected to transport sand oblique to the tidal currents and towards the northeast up to about 100 km to seaward, contributing to the sandbank feature's natural progression in this direction (Stride, 1988).

A hydrodynamic model developed by CEFAS (currently unpublished), indicates that ocean current flow is predominantly in a south-easterly direction with predicted velocities at seabed reaching a maximum of 2.7m/s. The wave regime in the site has a marked seasonality. Wave height ranges from 0.5 m to greater than 4 m, with the largest waves being seen in the winter months when waves of over 3 m height are regularly recorded (Draper, 1968; Marshall, 1997).

While there is evidence to suggest hydrodynamic regime is impacted locally by human activities within the site e.g. aggregate extraction, cabling and oil and gas sector activities, it is unclear whether this is occurring on such as scale as to impact the natural formation and distribution of the biogenic reef within the site.

A maintain objective is advised based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities. Our confidence in this objective would be improved with longer term monitoring, specifically of the hydrodynamics within the site and its influence on the formation and distribution of biogenic reef. It would also be improved with access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, disturbance to the hydrodynamic regime within the site. Further information on the impacts associated with human activities on Annex I *S. spinulosa* biogenic reef can be found in the Advice on Operations workbook.

Supporting habitats

S. spinulosa reefs are completely reliant on the supporting habitat they colonise. Suitable supporting habitats can vary but in the offshore environment tend to be limited to sublittoral sand, mud and to a lesser extent mixed sediments (Savage *et al.,* 2008). Loss of suitable supporting habitats from an area could hinder the establishment or maintenance of reef and, consequently, the maintenance or recovery of the feature's overall extent.

Areas where there is evidence for the ability of reef to persist over time, forming more elevated structures or consistently recolonising, will be especially important for the conservation of the feature. Potential areas of reef outside persistent reef areas will also contribute towards the reefs' existing distribution. Identifying areas where *S. spinulosa* could colonise beyond the persistent reef areas provides evidence-based identification of supporting habitats within the site (Fariñas-Franco *et al.,* 2014).

Potential reef is defined as discrete areas where:

- low confidence reef exists that does not meet the criteria to be defined as high confidence reef;
- *S. spinulosa* reef has previously existed or dead reef is visible and prevailing environmental conditions are suitable for reef formation; or
- acoustic evidence predicts reef is present but there is insufficient ground truthing to validate the acoustic evidence.

The biotope associated with *S. spinulosa* reef is not considered sensitive to small-scale changes to the coarse sediment types, for example changes from gravel to sandy gravel (George and Warwick, 1985). However, the biotope can be negatively impacted by a change to the finest sediment class, for example a change in the sediment classification from sand to 'mud and sandy mud' (Long, 2006). Any changes in sediment type greater than one folk class should be considered when assessing the potential impact of a development on *S. spinulosa* reef. It is important to note that supporting habitats can naturally vary in their spatial distribution and extent where they are mobilised by prevailing currents. It is important to maintain the natural extent and distribution of areas suitable for reef formation.

Supporting habitats within the site

The site map available in Annex A shows the extent and distribution of both high confidence reef and potential reef within the site. To better visualise the different extents and distributions of the high confidence and potential reef within the site an extract of the site map is provided in Annex B. The areas of high confidence reef have been discussed under the preceding attributes; extent and distribution and structure and function. The areas of potential reef delineated in the site map are those parts of the site where evidence indicates that established reef has been recorded historically but since disappeared (Vanstaen and Whomersley, 2015; Ellwood, 2013). These areas represent supporting habitat for the reef feature in the site and are composed of the following sediment types; circalittoral sand, circalittoral mixed sediments and circalittoral coarse sediments.

Vessel Monitoring System (VMS) data shows demersal fishing activity occurring over areas mapped as potential reef. Aggregate extraction and gas well exploration are also operating within and close to areas where *S. spinulosa* potential reef is mapped. While we are aware of aggregates dredging operating in such a way as to ensure that established reef is undisturbed we are not aware of a similar practise to avoid impacting areas of supporting habitat and so both of these activities are capable of impacting areas of supporting habitat mainly through abrasion and habitat physical change and to a lesser extent siltation rate changes.

A restore objective is advised based on expert judgment, specifically our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities i.e. aggregates, demersal fishing and oil and gas sector activities. Our confidence in this objective would be improved with longer-term monitoring. It would also be improved with access to better information on the activities taking place within the site. Activities must look to minimise, as far as is practicable, disturbance to the supporting habitats as mapped. Further information on the impacts associated with human activities on Annex I *S. spinulosa* biogenic reef can be found in the Advice on Operations workbook.

Water quality

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

The targets listed below for water contaminants in the marine environment are based on existing targets within OSPAR or the Water Framework Directive (WFD) and require concentrations and effects to be kept within levels agreed in the existing legislation and international commitments. These targets are set out in The UK Marine Strategy Part 1: The UK Initial Assessment (2012). Aqueous contaminants must comply with water column annual average (AA) 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 provide information regarding historic or existing contaminant levels in the marine environment:

- Marine Environmental and Assessment National Database (MERMAN);
- The UK Benthos database available to download from the Oil and Gas UK website;
- Cefas' Green Book;
- Strategic environmental assessment contaminant technical reports downloadable 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).

The properties of water that influence biogenic reef habitats include salinity, pH, temperature, suspended particulate concentration, nutrient concentrations and dissolved oxygen. These parameters can act alone or in combination to affect habitats and their associated communities in different ways, depending on species-specific tolerances. In offshore habitats, these parameters tend to be relatively stable, particularly in deeper waters, although there may be some natural seasonal variation. Changes in any of these properties through human activities may impact habitats and the communities they support (Little, 2000; Gray and Elliot, 2009; Gibb *et al.,* 2014).

Changes in suspended sediment may have a range of biological effects on different species within the habitat, affecting the ability of species to feed or breathe (Elliott *et al.,* 1998; Gibb *et al.,* 2014). A prolonged increase in suspended particulates can affect fish health, clog the filtering organs of suspension feeders and affect seabed sedimentation rates (Elliot *et al.,* 1998; Gibb *et al.,* 2014). Specific impacts of changes in suspended sediment on *S. spinulosa* can include smothering by sediment (Gibb *et al.,* 2014). One study found *S. spinulosa* can survive short term, episodic sand burial of at least several centimetres for up to 32 days (Last *et al.,* 2011), but in other studies losses of Sabellarid reefs have been attributed to burial (Zale and Merrifield, 1989; Porras *et al.,* 1995). The maximum tolerance of *S. spinulosa* to burial by sedimentation is unknown (Hendrick *et al.,* 2011). *S. spinulosa* also need suspended sediment for tube-building. *S. spinulosa* are selective about the size of sediment particles that they build their tubes with, typically favouring medium-sized particles (120-500 µm diameter; Hendrick *et al.,* 2007). A substantial reduction in suspended sediment can therefore impede *S. spinulosa* reef formation/maintenance.

Low dissolved oxygen can have sub-lethal and lethal impacts on fish, infaunal and epifaunal communities (Best *et al.,* 2007). Concentrations of contaminants in the water column must, as a minimum, not exceed the EQS listed above. *S. spinulosa* reefs tend to be tolerant of adverse conditions such as polluted water, low salinity, low oxygen levels (Mistakidis, 1956; Jones *et al.,* 2000; Davies *et al.,* 2009). There is very little information on temperature tolerance for *Sabellari*a. The latitudinal distribution of *S. spinulosa* suggests broad temperature tolerance, although limited site-specific information mean some precaution is needed because any rapid local temperature change may have an impact (OSPAR, 2012; Fariñas-Franco *et al.,* 2014). Contaminants may impact *S. spinulosa* biogenic reefs, depending on the nature of the contaminant (UKTAG, 2008; EA, 2014). The sensitivity/tolerance of *S. spinulosa* to organic and inorganic pollutants is unknown. 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 quality within the site

There is not much known about the quality of the water within the site. Most of the information which is available is on the wider Southern North Sea area. The planktonic assemblage in the Southern North Sea area is largely influenced by inflows of northeast Atlantic water which is gradually mixed with North Sea water (HR Wallingford, 2002). Rates of primary production increase significantly in the spring months followed by a smaller peak in abundance in the autumn, influenced to some extent by vertical mixing, stratification of the water column and light availability (Johns and Reid, 2001).

Surface temperatures in the region can be highly variable, with temperatures ranging from 8 to 14.6°C during May alone (MALSF, 2009). Salinity for the site is in line with typical values for the North Sea with no significant seasonal variation and little variation in depth. Values have been recorded at approximately 34.8 parts per thousand at the surface and 34.6 parts per thousand at the seabed in both summer and winter (BODC, 1998). Available evidence indicates that sediment suspension varies widely between summer (0 to 5 mg/l) and winter months (around 5 mg/l) (Dolphin *et al*., 2011).

A considerable number of predominantly gas exploration developments occur within the site. The main contaminants associated with this activity come from produced water and drill cuttings. Higher quantities of corrosion inhibitors, gas treatment products and scale inhibitors are discharged into the North Sea than chemicals of any other functional group. While possible sources of contamination are present on site, there is no information available to indicate whether water quality within the site is falling or above below Environmental Quality Standards (EQSs). However, 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. JNCC therefore advise that aqueous contaminants must be maintained below the annual average (AA_EQS) according to the amended Environmental Quality Standards Directive (EQSD) (2013/39/EU) or levels equating to (High / Good) Status (according to Annex V of the Water Framework Directive (WFD) (2000/60/EC).

A maintain objective is advised for water quality based on expert judgment; specifically, our understanding of the feature's sensitivity to pressures which can be exerted by ongoing activities. Our confidence in this objective would be improved with longer-term monitoring, specifically contaminants within the site. Further information on the impacts associated with human activities on Annex I *S. spinulosa* biogenic reef can be found in the Advice on Operations workbook.

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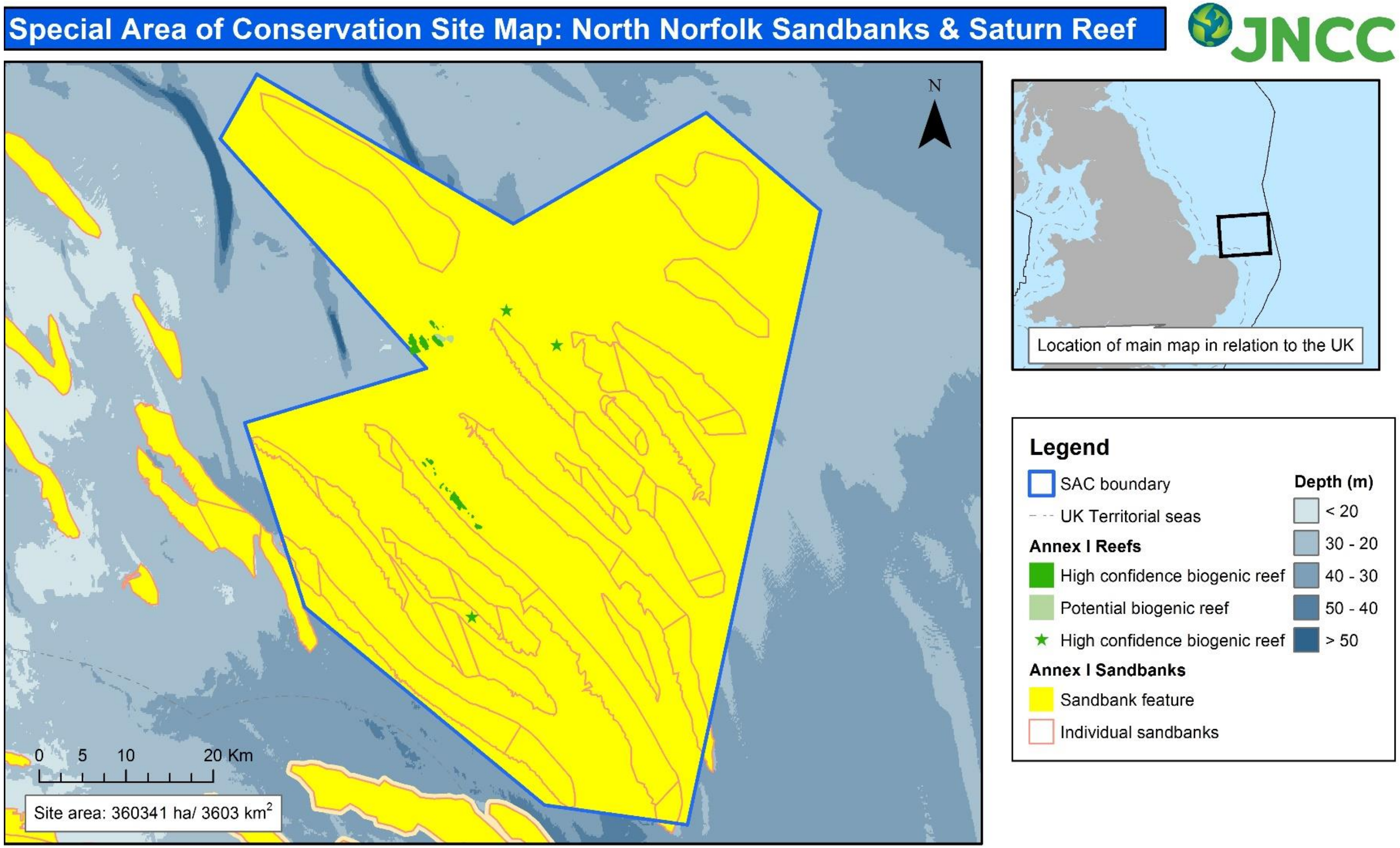
Annex A. Map of North Norfolk Sandbanks and Saturn Reef SAC showing high confidence and potential reef extent and distribution.



Annex B. Map extract of North Norfolk Sandbanks and Saturn Reef SAC showing high confidence and potential reef extent and distribution.