# Supplementary Advice on Conservation Objectives for Braemar Pockmarks Special Area of Conservation

**February 2018**

# 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 feature 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); and
- Advice on Operations providing information on those human activities that, if taking place within or near the site, can impact it and present a risk to the achievement of the conservation objectives.

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 feature: Annex I Submarine structures made by leaking gases 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 Table 1 below, along with the objectives set for each of them, describe the desired ecological condition (favourable) for the site's feature. The condition of the feature contributes to its favourable conservation status more widely, as well as the site's integrity. All attributes listed in Table 1 must be taken into consideration when assessing impacts from an activity.

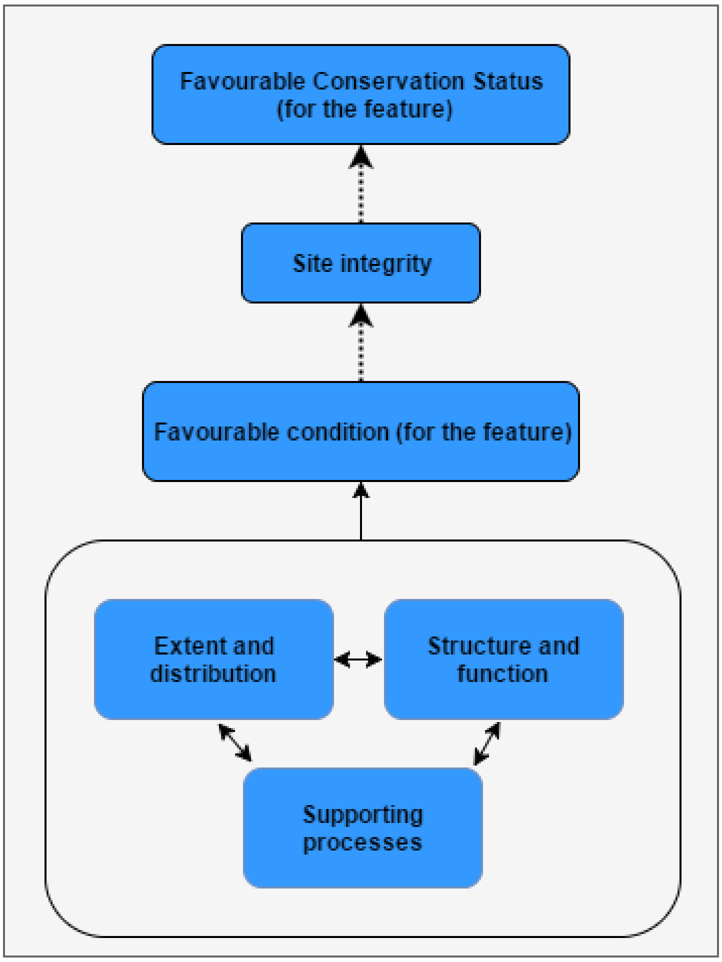


**Figure 1. Conceptual diagram showing how feature attributes are interlinked, describe favourable condition and contribute to site integrity and wider favourable conservation status.**

In Table 1 below, the attributes for the Annex I Submarine structures made by leaking gases are listed and a description provided in 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 the conservation objectives for Annex I habitat 1180 Submarine structures made by leaking gases in Braemar Pockmarks SAC.**

## Attribute: Extent and distribution

**Objective: Maintain**

*JNCC understands that sidewall slumping and subsequent infilling has happened in some of the pockmarks within the site. However, it is unclear whether this has resulted in burial of the feature i.e. a reduction in its extent and distribution. It is also unclear if the sidewall slumping is natural or the result of impacts from ongoing human activities. Regardless, a maintain objective is advised as it is not considered feasible through management intervention to restore Submarine structures made by leaking gases if they have been buried. Activities must look to minimise, as far as is practicable, impacts on feature extent and distribution.*

**Explanatory notes**

Annex 1 Submarine structures made by leaking gases form over geological time scales. The slow formation of the carbonate structures that characterise the physical structure of this habitat is dependent upon the migration of gases (methane) to the seabed and is mediated by a unique community of microbial organisms. These communities undertake the anaerobic oxidation of methane (AOM) at the sulphate-methane interface, which is most commonly close beneath the seabed surface (Boetius *et al*., 2000). AOM leads to the precipitation of a carbonate cement that binds the seabed sediments to form Methane-Derived Authigenic Carbonate (MDAC) (Niemann *et al*., 2005). It is the MDAC feature itself that is directly equivalent to the qualifying feature Annex 1 Submarine structures made by leaking gases.

There are two main types of Submarine structures made by leaking gases known to occur in UK waters:

1. **Bubbling reefs**: formed by carbonate cement resulting from the AOM (known as MDAC) (Interpretation Manual - EUR28, 2013). Bubbling reef structures are elevated from the surrounding seabed to form various topographic features. Extent is determined by the physical area occupied by the MDAC (JNCC, 2016).
2. **Submarine structures associated with pockmarks**: Pockmarks are depressions or craters in the seabed formed by the expulsion of fluids. To be considered a pockmark associated submarine structure, MDAC must be present within a pockmark. In the case of this type of the Annex I feature, it is the physical area occupied by the MDAC within a pockmark that represents the extent of the Annex I habitat of interest, as opposed to the area of the pockmark (Interpretation Manual - EUR28, 2013).

A variation in feature extent has the potential to alter the biological functioning of the habitat. Feature extent may change naturally over time, for example by the temporary or permanent covering or infilling of the feature by mobile sediments. In the case of submarine structures associated with pockmarks, the periodic expulsion of large volumes of methane (Hong *et al.*, 2017) may expel sediments from within pockmarks that in turn results in the uncovering of buried MDAC.

Due to the slow formation of MDAC, to restore feature extent once lost is difficult or impossible. Accretion of the feature may be on-going or may have ceased – dependent on whether or not gas is still migrating to the seabed from the underlying sediments/rocks, and the presence of the mediating microbial communities. However, it is important to note that the feature does not have to be actively accreting to be considered an example of the Annex 1 feature.

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**Extent and distribution within the site**

The Braemar Pockmarks SAC protects an example of the pockmarks type of Annex I submarine structures made by leaking gases as described above. The site includes 23% of the total known resource of pockmark type qualifying feature in UK waters (based on verified and potential records from acoustic data). The site map for Braemar Pockmarks SAC showing the extent and distribution of the qualifying feature is available to view on JNCC's Interactive MPA mapper, comprising both verified and potential records.

Forty-eight pockmarks covering 0.2 $km^2$ have been identified within the site (Gafeira and Long, 2015). Six of the pockmarks within the site covering 0.1 $km^2$ have verified examples of MDAC present. A further 14 pockmarks show strong acoustic reflectance indicative of potential MDAC and cover 0.1 $km^2$. The size, volume and distribution of pockmarks are not uniform across the site; one notably large pockmark occurs to the north of the site within the SAC boundary.

Nearly a quarter of the mapped pockmarks have evidence of sidewall slumping, with one event occurring sometime between the 2005 and 2012 site surveys. Pockmark sidewall slumping can obscure the venting of natural gas from the seabed and result in burial of the feature located at its base, reducing the extent and distribution of the feature within the site. The burial of MDAC has not been confirmed within Braemar Pockmarks SAC, however this has been observed in nearby Scanner Pockmark (Gafeira and Long, 2015). The cause of pockmark sidewall slumping within the site is unknown and could be attributed to either anthropogenic activities, such as demersal trawling known to occur in the site, or due to natural processes (Gafeira and Long, 2015). Regardless of the cause of sidewall slumping, it is not considered practicable to restore the extent and distribution of the feature once buried. While there is evidence of active gas seepage interpreted from acoustic anomalies on side-scan and backscatter datasets within the site (Gafeira and Long, 2015), the recovery of the feature is highly uncertain.

For these reasons, **JNCC advise a maintain objective** noting it is not possible for the feature to be recovered by management intervention. Activities must look to minimise, as far as is practicable, further impact on the feature's extent and distribution within the site. Further information on the impacts associated with human activities on Submarine structures made by leaking gases can be found in the Advice on Operations workbook.

## Attribute: Structure and function

### Objective: Restore

*JNCC advises a restore objective for structure and function, specifically the characterising communities and function. This is based on our understanding of the sensitivity of the feature's biological communities to pressures associated with demersal trawling occurring within the site, specifically to the pressures removal of target and non-target species and abrasion. Our confidence in this advice would be improved with a better understanding of the degree to which burial of the feature and its biological communities has occurred within the site. Activities must look to minimise, as far as is practicable, impacts on the physical structure and biological assemblages within the site.*

**Explanatory notes**

**Structure**

Structure encompasses both the physical structure of a habitat type together with the biological structure. 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). The biological structure refers to the key and influential species and characteristic communities present. Biological communities are important in not only characterising the feature but supporting its health i.e. its conservation status and the provision of ecosystem services by performing functional roles.

**Physical structure**

Similar to bubbling reefs, the Methane-Derived Authigenic Carbonate (MDAC) associated with pockmarks provides a hard substrate differing to the surrounding seabed. The physical structure of MDAC outcroppings from the seabed commonly takes the form of blocks, pavements and slabs. Created by the expulsion of fluids, pockmarks are large seabed depressions which may or may not contain MDAC created by the anaerobic oxidation of methane (AOM). The physical structure of pockmarks can change naturally over time e.g. through the slumping of sidewalls, or by continued fluid escape activity resulting in continuing AOM, formation of MDAC, and hydrogen sulphide release. Changes to the physical structure of the pockmark, such as sidewall slumping, may serve to bury existing MDAC and therefore will determine whether the structures are exposed and fully functional as a feature. Sidewall slumping may be attributed to either natural or anthropogenic influences but either cause can alter the structure of the Annex I feature structure by covering this with a layer of sediment. Although the feature of interest itself is the MDAC, it is also important to conserve the pockmark feature associated with the Annex I feature to avoid infilling from anthropogenic causes.

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**Physical structure within the site**

Within the site, the feature has been recorded as large blocks, slabs and smaller fragments of MDAC exposed at the base of six of the 48 pockmarks recorded and may be present within a further 14 (Hartley, 2005; Gafeira and Long, 2015; Rance *et al*., 2017). Rance *et al.* (2017) conclude that all carbonate samples they collected were shown to be abraded and well-worn with rounded edges. This suggests that MDAC within the site may be subject to natural erosion. As mentioned previously, nearly a quarter of the mapped pockmarks have evidence of sidewall slumping, which can potentially bury the physical structure of the feature at the base of the pockmark.

The carbonate structures within the site provide a habitat for marine fauna which are usually associated with rocky reef, and chemosynthetic organisms (Dando, 2001, Judd, 2001; Rance *et al.,* 2017). Existing evidence suggests that MDAC structures at the Braemar Pockmarks SAC are more abundant and diverse in form than those at the Scanner Pockmark SAC and appear to be characterised by slightly different species assemblages (JNCC, 2017). Further information on the species associated with the feature is provided under the key and influential species and characterising communities attributes.

While there is evidence of active gas seepage within the Braemar Pockmarks SAC interpreted from acoustic anomalies on side-scan and backscatter datasets within the site (Gafeira and Long, 2015), the slow accretion rate of MDAC means that the feature forms over geological time scales. As mentioned previously, the burial of MDAC from sidewall slumping has not been confirmed within Braemar Pockmarks SAC. The cause of pockmark sidewall slumping within the site is unknown and could be attributed to either anthropogenic activities, such as demersal trawling known to occur in the site, or due to natural processes (Gafeira and Long, 2015). Regardless of the cause of sidewall slumping, it is not considered practicable to restore the physical structure of the feature once buried. For this reason, **JNCC advise a maintain objective** for characterising communities. Activities must look to minimise, as far as is practicable, impact on the feature's physical structure within the site. Further information on the impacts associated with human activities on Submarine structures made by leaking gases can be found in the Advice on Operations workbook.

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**Key and influential species**

MDAC is formed as a consequence of the anaerobic oxidation of methane (AOM) at the sulphate-methane interface that most commonly occurs within a few tens of centimetres beneath the seafloor. AOMs; consortia of methanotrophic archaea and sulphate-reducing bacteria (Boetius *et al*., 2000; Niemann *et al.*, 2005) are fundamental to the formation of Annex I Submarine structures formed by leaking gases

(MDAC). In addition to the precipitation of MDAC, AOM activity leads to the release of hydrogen sulphide; consequently, mats of thiotrophic (sulphide-oxidising) bacteria (e.g. *Beggiatoa spp.*) often occur in the immediate vicinity (probably restricted to a few centimetres) of where there is active AOM, and can therefore be used as evidence of active gas seepage. Sulphide-rich sediments are toxic to ‘normal’ benthic organisms, but may host specialist organisms, for example those with chemosynthetic symbionts.

Species associated with Annex I Submarine structures formed by leaking gases can be either categorised as; i) those associated with AOM and the presence in the sediments of methane and hydrogen sulphide; or ii) those associated with the hard-substrate provided by MDAC. Either or both categories may be found in both types of the feature.

The biological communities that live within and around the active methane seepage and MDAC are important not only in characterising Submarine structures made by leaking gases but also in supporting the provision of ecosystem services by performing functional roles. Certain species may form a key component of the habitat’s structure (e.g. encrusting and reef-forming species). Influential species are likely to have a key role affecting the structure and function of the habitat such as grazers, surface borers, predators or other species with a significant functional role linked to the habitat.

Pockmarks may be characterised by species typically associated with sedimentary habitats. However, on or around MDAC may be colonised by species requiring a hard substrate (something rarely present in the types of sediment suitable for pockmark formation). Thiotrophic bacterial mats, where present, indicate active gas seepage, AOM and the potential presence of specialist organisms with chemosynthetic symbionts (Hovland *et al.,* 2012).

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**Key and influential species in the site**

There is limited information regarding the key and influential species that play a critical role in the formation of Annex I habitat Submarine structures made by leaking gases within the site. The observation of chemosynthetic bacterial mats across multiple surveys indicates active gas seepage (Hartley, 2005; Judd and Hovland, 2007; Gafeira and Long, 2015) that could also be linked to contributing to the accretion of MDAC itself (O’Reilly *et al.,* 2014). JNCC are not aware of any other key or influential species that play a critical role in setting the foundations for colonisation of characterising communities associated with MDAC within the Braemar Pockmarks SAC. Due to the insufficient information available, it is not possible to set an objective for this sub-attribute and it is not considered further in our advice.

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**Characteristic communities**

A variety of communities may be found living within and upon MDAC and reflect its overall character and conservation interest. The biological communities typical of the feature may vary greatly depending on the physical structure of the MDAC itself, depth and fine-scale physical, chemical and biological processes and also the general oceanographic context (water depth, current strength etc.). AOMs and specialist communities may be present within the immediate vicinity of active methane seepage pathways, in either bubbling reefs or pockmark associated structures.

Where AOMs are present, thiotrophic bacterial mats (e.g. *Beggiatoa spp.*) are likely to be present on the seabed in the immediate vicinity (probably restricted to a few centimetres) of active seep vents. In the presence of hydrogen sulphide the 'normal' benthic communities are likely to be depleted, but organisms hosting symbiotic chemosynthesisers such as the gutless nematode *Astomonema southwardorum,* bivalves *Thyasira sarsi* and *Lucinoma borealis* may be present *(*Hovland *et al.,* 2012; Hartley, 2005; Gafeira and Long 2015)*.*

MDAC located in pockmarks provide hard substrate which differs from the surrounding, typically muddy, seafloor. This provides more ecological niches for the colonisation of a range of marine species (Judd, 2001). Invertebrate specialists of hard substrate occurring on MDAC within pockmarks can include Hydrozoa, Anthozoa, Ophiuroidea and Gastropoda (Interpretation Manual - EUR28, 2013). Examples of likely species could include the deeplet sea anemone (*Bolocera tuediae)*, Dahlia anemone (*Urticina felina)*, plumose anemone (*Metridium senile), Common whelk Buccinum undatum* and the brittlestar *Ophiura albida* on the carbonate structures. The carbonate structures can provide shelter for fish species such as wolf fish (*Anarhichas lupus)* (Dando, 2001).

It is important to conserve the natural spatial distribution, composition, diversity and abundance of the characterising biological communities of the feature within the site to avoid diminishing biodiversity and ecosystem functioning of the habitat (JNCC, 2004a; Hughes *et al.,* 2005).

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**Characteristic communities within the site**

Evidence suggests that the MDAC structures and the pockmark depressions with which they are associated have attracted a range of fish species (cod, monk-fish, haddock, wolf-fish and conger eel) within the site by providing shelter (Hartley, 2005; Rance *et al.,* 2017). In addition, the frequent occurrence of whelk egg masses on the MDAC within the site has been noted (Hartley, 2005). The faunal communities within Braemar Pockmarks SAC are representative of those present on Submarine structures made by leaking gases within pockmarks, consisting of anemones (*Cerianthus lloydii*) and hydroids, as well as organisms dependent on the chemosynthesis of natural gas including the pogonophoran polychaete (S*iboglinum fiordicum*) (Hartley, 2005). The ocean quahog (*Arctica islandica*) has been recorded at the Braemar

Pockmarks SAC, an OSPAR Threatened and/or Declining species, as well as sea-pen species indicative of the OSPAR Threatened and/or Declining habitat 'Sea-pen and burrowing megafauna communities'. (Rance *et al*., 2017).

As mentioned previously, the burial of MDAC from pockmark sidewall slumping has not been confirmed within Braemar Pockmarks SAC. The cause of pockmark slope failure within the site is unknown and could be attributed to either anthropogenic activities, such as demersal trawling known to occur in the site, or due to natural processes (Gafeira and Long, 2015). Trawl scars from fishing have been identified throughout the SAC, with the majority of activity located in the north of the site (Rance *et al*., 2017). There have also been faint channels close to an abandoned wellhead identified through the interpretation of acoustic data that are likely to emanate from anchor mooring cables associated with oil and gas operations (Rance *et al*., 2017). JNCC considers that these activities can directly impact the feature's characterising communities through associated pressures i.e. the removal of target species and abrasion.

As previously mentioned these activities can also cause sidewall slumping and burial of the MDAC and its associated communities. While there is evidence of active gas seepage interpreted from backscatter acoustic anomalies on side-scan and backscatter datasets within the site (Gafeira and Long, 2015), there is no evidence to suggest gas seepage will unbury MDAC and its associated communities. Consequently, in contrast to the direct impacts on communities from demersal trawling which are associated with removal of non-targets species and abrasion, burial from sidewall slumping is not an impact which management intervention is capable of reversing. It is not considered practicable to unbury the feature nor its associated biological communities, where they have been buried.

**JNCC advise a restore objective,** noting that this refers specifically to the restoration of characteristic biological communities associated with MDAC that have been subject to removal or abrasion pressures associated with demersal trawling. It does not refer to the restoration of characteristic biological communities that have already been subjected to burial through pockmark sidewall slumping, as such restoration is impossible. Our confidence in this advice would be improved with access to better information on the activities taking place within the site, their impacts on the site's characteristic communities and the degree to which sidewall slumping has occurred within the site. Activities must look to minimise, as far as is practicable, further impact on the feature's characterising communities within the site. Further information on the impacts associated with human activities on Submarine structures made by leaking gases can be found in the Advice on Operations workbook.

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**Function**

Functions are ecological processes e.g. sediment processing, secondary production, habitat modification, supply of recruits, bioengineering and biodeposition. Biological communities associated with habitats may contain species that perform key functional roles that help to maintain conservation status. Functions are reliant on natural supporting processes and the growth and reproduction of biological communities which characterise the habitat and as mentioned previously, providing a variety of functional roles within it (Norling *et al.,* 2007). These can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services (ETC, 2011) locally and to the wider marine environment. Ecosystem services which Annex 1 Submarine structures made by leaking gas can provide include:

- Climate regulation: by providing a natural storage capacity for greenhouse gases e.g. methane; and
- Nutrition: by providing habitat a food source as well as refugia for a variety of fauna, including a range of commercially important fish species.

Both bubbling reefs and submarine structures associated with pockmarks provide a habitat that differs from the surrounding seabed. The physical structure of MDAC support a more diverse range of epifaunal marine species as the physical structure of MDAC provides a surface for attachment. Submarine structures may also provide a refugia for a variety of fish species, but it is presently unclear as to whether this is a result of the hard substrate of the MDAC or the pockmarks in the case of submarine structures associated with pockmarks. Active gas seeps and associated structures may have ecological significance because of the utilisation of methane and its by-product, hydrogen sulphide, by chemosynthesisers (Judd 2001).

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**Function of the feature within the site**

The ecosystem services provided by Braemar Pockmarks SAC include:

- Climate regulation - The observation of chemosynthetic bacterial mats across multiple surveys indicates active gas seepage (Hartley, 2005; Judd and Hovland, 2007; Gafeira and Long, 2015). Chemosynthetic organisms metabolise natural gas and its derivatives including methane – serving to contribute to the regulation of climate. The Methane Derived Authigenic Carbonate (MDAC) structures themselves are storage units of methane, being derived from the anaerobic oxidation of methane.
- Nutrition - by providing a habitat for a variety of fauna, including commercially important fish such as cod, monk-fish, haddock, wolf-fish and conger eel (Hartley, 2005, Rance *et al.*, 2017).

**JNCC advises a restore objective** because, as mentioned previously, removal of species and abrasion associated with demersal trawling can impact the feature's biological communities, including commercial fish species listed under nutrition above. Consequently, the site's capacity to provide nutrition as an ecosystem service may be reduced and require restoration. Activities must look to minimise, as far as is practicable, impact on the feature's biological communities within the site. Further information on the impacts associated with human activities on Submarine structures made by leaking gases can be found in the Advice on Operations workbook.

**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, a better understanding of the source of the natural gas seepages within the site and the influence it has on the formation and change in distribution of the feature, 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 natural gas seepage, MDAC accretion and hydrodynamic regime within the site and exceeding Environmental Quality Standards set out in the relevant section below.*

**Explanatory notes**

The feature relies on a range of natural processes to support ecological functioning. Supporting processes are the physical, biological and chemical controls that give rise to a habitat, shaping its characteristics and determining its faunal composition (Alexander *et al*., 2014). For the site to fully deliver the conservation benefits set out in the statement on conservation benefits, the following supporting processes must remain largely unimpeded:

natural gas seepage and MDAC accretion;
hydrodynamic regime;
water quality and sediment quality.

**Natural gas seepage and MDAC accretion**

Natural gas migration plays a fundamental role in the accretion of Methane-Derived Authigenic Carbonate (MDAC) as a result of anaerobic oxidation of methane (AOM) below the seabed surface (Niemann *et al*., 2005). Consequently, AOM within the site will be reliant on a supply of natural gas. It is important that this process remains unhindered, noting that gas seepage may be naturally intermittent (Judd, 2001).

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**Natural gas seepage and MDAC accretion within the site**

Faint traces of gas release were identified through the acquisition of side scan sonar data during the 2012 survey, showing streams of bubbles being released into the water column (Rance *et al*., 2017). This suggests there are likely to be active natural gas seeps within the Braemar Pockmarks SAC. Similarly, observations from the video and stills data of 'presumed chemosynthetic' white bacterial mats on the seabed surface further supports the view that natural gas seeps within this area are currently active, although further evidence is required to confirm this, such as additional side scan sonar data with confirmed groundtruthing in areas where previous gas seeps have been observed (Rance *et al*., 2017).

There is anecdotal evidence to suggest that the presence of MDAC is sustained by shallow biogenic gas seepage (Hartley, 2005); however, if deeper petrogenic gas supports the structures, there is potential for a reduction in seepage if the underlying reservoir is depleted through commercial activities (Oil & Gas UK 2008). Currently there are no active wells within the site (1 plugged and abandoned well within the north of the site and 1 completed well ~100m outside of the boundary to the south of the site).

The infilling of pockmarks from sidewall slumping that has been identified within the site may bury the feature and bacterial mats although this hasn't been confirmed. However, survey evidence suggests that gas migration from the seabed has not been interrupted within the site. As such, **JNCC advises a maintain objective**. Activities must look to minimise, as far as is practicable, impacts on natural gas seepage and therefore MDAC accretion within the site. Our confidence in this objective would be improved with long-term monitoring, better access to information on activities within the site, and a better understanding of the source of the natural gas seepages within the site and the influence it has on the formation and change in distribution of the feature. Further information on the impacts associated with human activities on Submarine structures made by leaking gases can be found in the Advice on Operations workbook.

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**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 and influence water properties by distributing dissolved oxygen, transferring it from the surface to the seabed (Dutertre *et al.,* 2012; Hiscock *et al.,* 2004; Biles *et al.,* 2003; Chamberlain *et al.,* 2001). Hydrodynamic regime also effects the movement, size and sorting of sediment particles.

MDAC is formed at the sulphate-methane interface, which is normally located beneath the seabed (except where gas flow is sufficient for sulphate utilisation during AOM to exceed supply, in which case it may rise to the seabed). Consequently, overlying sediments must have been removed (e.g. by erosion by strong currents, or fluid expulsion during pockmark activity) for MDAC to be present at or above the normal seabed. Moreover, the hydrodynamic regime interacts with the physical structure of pockmarks, serving to reduce bottom currents below a critical minimum. This allows for increased larval settlement from the water column into these areas (Snelgrove, 1994).

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**Hydrodynamic regime within the site**
Sediment migration is thought to be relatively limited in this part of the North Sea. This has resulted in the persistence of impacts to seafloor sediments such as trawl and anchor scars, and the persistence of elevated levels of hydrocarbons from exploratory oil-well discharges which remained close (up to 200m) to the source point (Gafeira and Long, 2015).

There is no evidence to suggest the hydrodynamic regime within the site is impacted by human activities. It is important to maintain the regional hydrodynamic regime around the Braemar Pockmarks SAC to ensure that key processes such as the interaction of currents with the physical structure of pockmarks, resulting in increased larval settlement and deposition of organic material, remain unimpacted. As such, **JNCC advise a maintain objective**.

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**Water and sediment quality**
Contaminants may also impact the conservation status of the biological communities associated with MDAC by having a range of 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 natural water and sediment quality properties of a site and as a minimum ensure compliance with existing Environmental Quality Standards (EQS) as set out below.

**Environmental Quality Standard (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 as set out in The UK Marine Strategy Part 1: The UK Initial Assessment 2012).

Aqueous contaminants must comply with water column annual average (AA) 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 Quality Status Report (OSPAR 2010) and associated QSR Assessments.

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

- Marine Environmental and Assessment National Database (MERMAN)
- An Analysis of UK Offshore Oil and Gas surveys 1975-1995
- Cefas' Green Book
- Cefas' Containment Status of the North Sea Report (2001) & Contaminant Status of the Irish Sea' Report (2005)

**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. They can influence the abundance, distribution and composition of communities at relatively local scales. Changes in any of the water quality properties, as a result of human activities, may impact habitats and the communities they support (Elliot *et al.,* 1998; Little, 2000; Gray and Elliot, 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 (Elliot *et al.,* 1998). Low dissolved oxygen can have sub-lethal and lethal impacts on fish and infaunal and epifaunal communities (Best *et al.,* 2007).

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**Water quality within the site**

There is limited site-specific information available regarding water quality at the time of writing (February 2018). Historically, there has been oil and gas activity occurring within or in the near vicinity of the site. Several water toxicity studies have concluded that the necessary dilution to achieve a 'No Effect Concentration' would be reached at <10 to 100m and usually less than 500m from the discharge point depending on currents and water stratification (Gafeira and Long, 2015). The closest well (current status Completed), which could be considered a discharge point, is located 100m south of the site boundary and >500m from the nearest feature record. Therefore, there is minimal risk of water toxicity from this source.

The Charting Progress 2 reports that the open seas are little affected by pollution and levels of monitored contaminants continue to fall, albeit slowly in many cases. JNCC conclude that water contaminants within the site are unlikely to be exceeding EQS given the distance form sources of pollution. 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 Submarine structures made by leaking gases can be found in the Advice on Operations workbook.

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**Sediment quality**
Contaminants are known to have different effects on the species that live in or on the surface of sediments and hard substrate. 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 can impact species sensitive to particular contaminants, (e.g. heavy metals) and may bioaccumulate within organisms, entering the marine food chain (e.g. PCBs) (OSPAR Commission, 2009; 2010; 2012). This 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.

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**Sediment quality within the site**
Sediment migration is thought to be relatively limited in this part of the North Sea resulting in the persistence of elevated levels of hydrocarbons from exploratory oil-well discharges which have remained close (up to 200m) to the source point (UK Benthos Dataset in Gafeira and Long, 2015). This suggests that any contamination that occurs would persist for long periods of time. Historically, there has been oil and gas activity occurring within or in the near vicinity of the site.

Data from UK Benthos includes results from two surveys dated 1996 and 1997 conducted in the vicinity of a well located over 3km from the site boundary. The surveys analysed levels of hydrocarbon in sediments and provides a useful analogue for sediment movement near the Braemar Pockmarks SAC. High concentrations of hydrocarbons were generally found up to 200m from the well site and the combined data suggest that background levels exist up to 500m from the exploration well. This suggests that sediment migration and associated contamination is relatively confined to the source area (Gafeira and Long, 2015).

The closest well (current status Completed), which could be considered a discharge point, is located 100m south of the site boundary and >500m from the nearest feature record. Given sediment transport is very limited in the region and the well is far enough away from pockmarks in the site as to influence hydrocarbon levels in the sediments around the feature, there is no evidence to suggest contamination of the sediment associated with the qualifying feature.

There is limited information available to ascertain wider sediment contaminant levels within the site. Clean Seas Environment Monitoring Program (CSEMP) assessment of data supplied by the British Oceanographic Data Centre reveals levels for contaminants appear to be within expected background and EQS levels for this area. There is one data point located ~60km south west of the Braemar Pockmarks SAC site boundary which supports this (CSEMP, 2014).

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. 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 Submarine structures made by leaking gases can be found in the Advice on Operations workbook.

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