Assessment of Coral Carbonate Mounds in the OSPAR area and the development of a monitoring program

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1. Background Information

1.1. Name of feature: Coral carbonate mounds

1.2. Definition of feature

The text defining carbonate mounds in OSPAR (2005a) reads as follows;

Carbonate mounds are distinct elevations of various shapes, which may be up to 350 m high and 2 km wide at their base (Weering et al., 2003). They occur offshore in water depths of 500-1100 m with examples present in the Porcupine Seabight and Rockall Trough (Kenyon et al, 2003). Carbonate mounds may have a sediment veneer, typically composed of carbonate sands, muds and silts. The cold-water reef-building corals Lophelia pertusa and Madrepora oculata, as well as echiuran worms are characteristic fauna of carbonate mounds. Where cold-water corals (such as L. pertusa) are present on the mound summit, coral debris may form a significant component of the overlying substratum.

Due to ambiguities of usage and definition, the unequivocal term ‘coral carbonate mounds’ is now considered preferable to distinguish these features from mounds that build up through the growth of other calcareous organisms, such as algae and bryozoans. Coral carbonate mounds are thought to develop through periods of interglacial/interstadial coral framework growth, interspersed with periods of glacial sedimentation over timescales of 1-2 million years (Roberts et al. 2006; Kano et al. 2007). **Coral Carbonate Mounds are defined here as features which have formed by successive periods of coral reef development, sedimentation and (bio)erosion.** In all known cases to date, these feature are large (up to 350 m tall and often >100 m) and old (>10, 000 years).

Coral carbonate mounds may or may not support contemporary reefs and so can be referred to as active (with live coral reefs) or retired (without live coral reefs) mounds (Huvenne et al., 2005). They can be entirely buried through sedimentation and no longer affect the topography of the seabed (Henriet *et al.,* 1998; De Mol et al. 2002; Huvenne et al., 2003, 2007; Van Rooij et al. 2008). Here we focus on coral carbonate mounds that stand >50 m above the surrounding seabed.

To avoid confusion, it is worth noting that the Darwin Mounds are small sand mounds (up to 75 m diameter and 5 m high) that are colonized by cold-water corals (Masson et al. 2003, Wheeler et al., 2008) and so are not coral carbonate mounds as defined here. Neither are the giant coral reefs that occur off Norway, as they are not the result of periodic growth and dormancy and do not predate the Holocene.

1.3. Correlation with habitat classification scheme

The EUNIS classification (2004 version; http://eunis.eea.eu.int/eunis/habitats.jsp) gives carbonate mounds the code A6.75; they are not included in the National Marine Habitat Classification for Britain and Ireland (Connor *et al*., 2004).

1.4. Common characteristics of coral carbonate mounds

Coral carbonate mounds are geological features that typically provide a range of habitats associated with different substrate types including stabilised sediment, mobile sediments, cobble grounds, coral rubble, coral reef and consolidated carbonate hard-grounds, each supporting distinct faunal assemblages. The composition of this patchwork of habitats can vary considerably between mounds (Wheeler et al., 2005), mainly due to differences in hydrodynamic conditions and the growth and activity stages the mounds are in (Wienberg et al., 2008).

Wienberg et al., (2008) classified habitats present on Franken Mound on Rockall Bank, an active coral carbonate mound with live stands of scleractinian coral. They identified five distinct faunal assemblages associated with discrete live coral colonies, dense coral framework coverage, two different classes of coral debris fields and soft sediment. Discrete coral colonies were mainly made up of octocorals, antipatharian and scleractinian corals, accompanied by sponges, hydroids, and actinians. On dense coral reef these assemblages consisted mainly of live and dead scleractinians, octocorals, actinians and sponges. The two classes of coral debris fields were dominated by sponges and cnidarians growing on *Lophelia* debris and bioturbation of soft sediment areas indicated the presence of infaunal assemblages. All habitats were utilized by mobile megafauna including echinoderms, crustaceans and fish. Further detail of faunal assemblage of active coral carbonate mounds can be found under the ‘ecological significance’ criterion in the original Texel-Faial evaluation in section 2.3.

Some coral carbonate mounds do not support live coral reefs, and typically have low abundances of filter feeding benthos. Research is at an early stage but it is thought that unfavourable hydrodynamic conditions at these so called ‘retired mounds’ cause limited food supply or excessively strong currents lead to erosion of the coral framework. While some of these retired mounds are in the process of being buried and covered by thick layers of sediment (De Mol et al., 2005), others appear more speciose than surrounding seabed areas by offering distinct coral rubble and hardground habitats that in some cases is even more biodiverse than live coral habitats (Jensen & Frederiksen, 1992, Mortensen et al., 1995). The sponge assemblage diversity has been negatively correlated with live coral cover (van Soest et al., 2007). Hence, the absence of live coral reefs does not make coral carbonate mounds less significant in terms of conservation priorities.

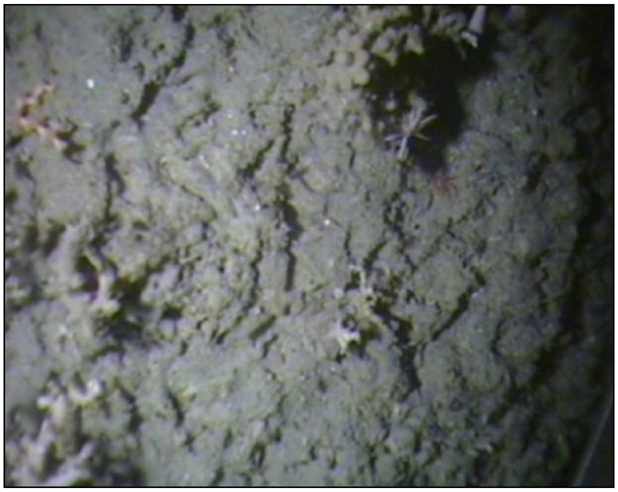

Figure 1.1. Detail of retired coral carbonate mound showing coral rubble habitats distinct from off-mound habitats. Picture for a north Porcupine Bank coral carbonate mound, September 2008

2. Original Evaluation against the Texel-Faial selection criteria

2.1. List of OSPAR Regions where the feature occurs:

Regions I, V; biogeographic zones: 21, 23, 35

2.2. List of OSPAR Regions and Dinter biogeographic zones where the feature is under threat and/or in decline

None

2.3. Original evaluation against the Texel-Faial criteria for which the feature was included on the Initial OSPAR List

Carbonate mounds were nominated in a joint submission by three Contracting Parties citing decline, rarity, sensitivity, and ecological significance with information also provided on threat. The nomination was for Region V.

Decline

The occurrence of carbonate mounds in the OSPAR Maritime Area is not fully known. Because of this there is little information on any changes in the extent of the habitat and associated species. If mounds occur in areas targeted by demersal fisheries the habitat and associated epifauna may suffer physical damage.

Rarity

Carbonate mounds are widely distributed on the eastern margin of the North Atlantic from the Iberian Peninsula to offshore Norway in water depths of 50m to perhaps 2,000m, (Masson *et al.,* 1998). They generally occur in small, localised clusters. The findings of deep sea surveys undertaken in the last few years suggest that the European slopes of the Rockall and Porcupine Basins may be the most prolific area for the formation of carbonate mounds in the world (Anon, 1999). Recent discoveries include a giant cluster of reefs including hundreds of buried mounds off south-west Ireland (Kenyon *et al.,* 1998) and a new field of seafloor mounds in 1000m of water in the northern Rockall Trough (Masson *et al.,* 1998). The full extent of these features in the OSPAR Maritime Area is not known at the present time.

Sensitivity

Sampling of the biological communities associated with carbonate mounds have revealed that they are often dominated by suspension feeders and can support rich deepwater coral communities. Living corals have colonised some of these mounds and debris from the deep-water colonial coral (*Lophelia* sp.) have been recovered from cores as well as the surface of mounds (Kenyon *et al.,* 1998). As the biological communities on carbonate mounds are dominated by filter feeding communities they are likely to be sensitive to siltation. Physical damage by fishing gear is known to break up corals that colonise this habitat. The delicate structure and slow growth rate of *Lophelia* makes this coral particularly vulnerable to physical damage. The growth rate is thought to be about 6mm per year implying that normal sized colonies of around 1.5m high are about 250 years old, and the reef structures seem to be relatively stable within a time scale of hundreds of years (ICES, 1999). The potential for *Lophelia* to recover after physical damage is uncertain but is probably dependent on the severity of damage and the size of the surviving coral fragments.

Ecological significance

The elevation and substrate of carbonate mounds provide a suitable surface for colonisation for many species that require hard surfaces for attachment. Because of this they can be areas of high species diversity in the deep sea and therefore of particular ecological significance. Surveys of the Porcupine Bank and Rockall Bank, have indicated that the summits and upper slopes of most of carbonate mounds and knolls identified on sidescan sonar were covered by a carpet of coral debris. Living coral was also present with the most abundant species being the colonial corals *Lophelia pertusa* and *Madrepora oculata* which formed colonies up to 30cm high. The solitary coral *Desmophyllum cristagalli* and the octocoral *Stylaster* sp. were also occasionally present and nearby areas of cobbles and small boulders provided a surface for settlement of individual coral colonies (Wilson & Vina Herbon, 1998).

Sampling of the fauna from Porcupine Basin carbonate mounds revealed that although most of the animals were suspension feeders there were also deposit feeding, carnivorous or omnivorous species (Sumina & Kennedy, 1998). The branching structure of dead coral underlying the living colonies provided a surface for settlement which was also elevated from the seabed and was extensively colonised by sponges, bryozoans, hydroids, soft corals, ascidians, calcareous tube worms, zoanthids, crinoids and bivalves. Many large eunicid worms and sipunculids were also found burrowing inside the coral material perhaps using the coral for shelter. The suspension feeding ophiuroid *Ophiactis balli* was also abundant sheltering in the dead coral material and the suspension feeding bivalve *Astarte* sp. abundant in the sediment underlying the thickets at some sites.

The area around carbonate mounds can also support an abundance of species. In the case of the Porcupine Basin there was extensive evidence of the working of the sediment apparently by echiuran worms, cerianthid anemones and caridean shrimps (Wilson & Vina Herbon, 1998). The tail-like features downstream of carbonate mounds in the northern Rockall Trough showed high densities of the xenophyophore *Syringammina fragilissima* compared to numbers in the background sediments. There was also a slight increased in the density of metazoan invertebrates on the tails and mounds relative to the background (Masson *et al.,* 1998). The reason for this clustering is unclear at the present time.

Threat

Although information about carbonate mounds and the associated communities is limited it can be expected that demersal trawling operations have a physical impact. Fishing activity is very intensive in some of the areas where mounds occur and repeated trawling does not allow time for the continual growth of coral colonies. Recovery may therefore only be possible over a long period of time, if at all.

ICES evaluation

ICES requested that further information on the biological communities associated with carbonate mounds be cited in the nomination. This has been provided in the section on ecological significance. They note there is no evidence that carbonate mound substrates are at any greater risk than other reef-supporting substrates but that they may be at lower risk than other features such the sand mounds underlying the Darwin Mounds to the west of Shetland (ICES, 2002). In particular, ICES consider there is no evidence of direct "clear and present" threats to the mounds but that there is evidence of a threat to biota growing on the mounds from fishing activities.

ICES concluded that there was insufficient evidence for the nomination so it is necessary to determine whether there is a strong enough case for the nomination on the basis of expert judgement.

3. Current status of the species or habitat

3.1. Distribution in OSPAR maritime area

In the light of changes in the definition of this feature outlined in section 1.2., coral carbonate mounds are only known to occur along shelf slopes in OSPAR region V to depths of 1500 m. They were first reported in this area by Hovland et al. (1994) and later by Henriet et al. (1998) who hypothesised that these features are associated with hydrocarbon seepage. While hydrodynamic conditions such as ocean currents and water column structure are now considered to be the main drivers of mound formation (Eisele et al., 2008), the original hypothesis stimulated intensive mapping and further geological investigations by the hydrocarbon exploration industry, vastly increasing the knowledge of the distribution of coral carbonate mounds in the OSPAR area (Wheeler et al. 2007). They occur on the European continental slope (Hovland et al., 1994, Kenyon et al., 2003), where they tend to be clustered in areas commonly referred to as mound provinces. The Hovland, Magellan, Belgica and Pelagia mound provinces occur along the continental slope off Ireland. Off the west coast of Scotland, Rockall Bank is flanked by the Logachev mounds and the west Rockall Bank mounds and there is strong evidence for coral carbonate mounds on Hatton Bank (Roberts et al. 2008).

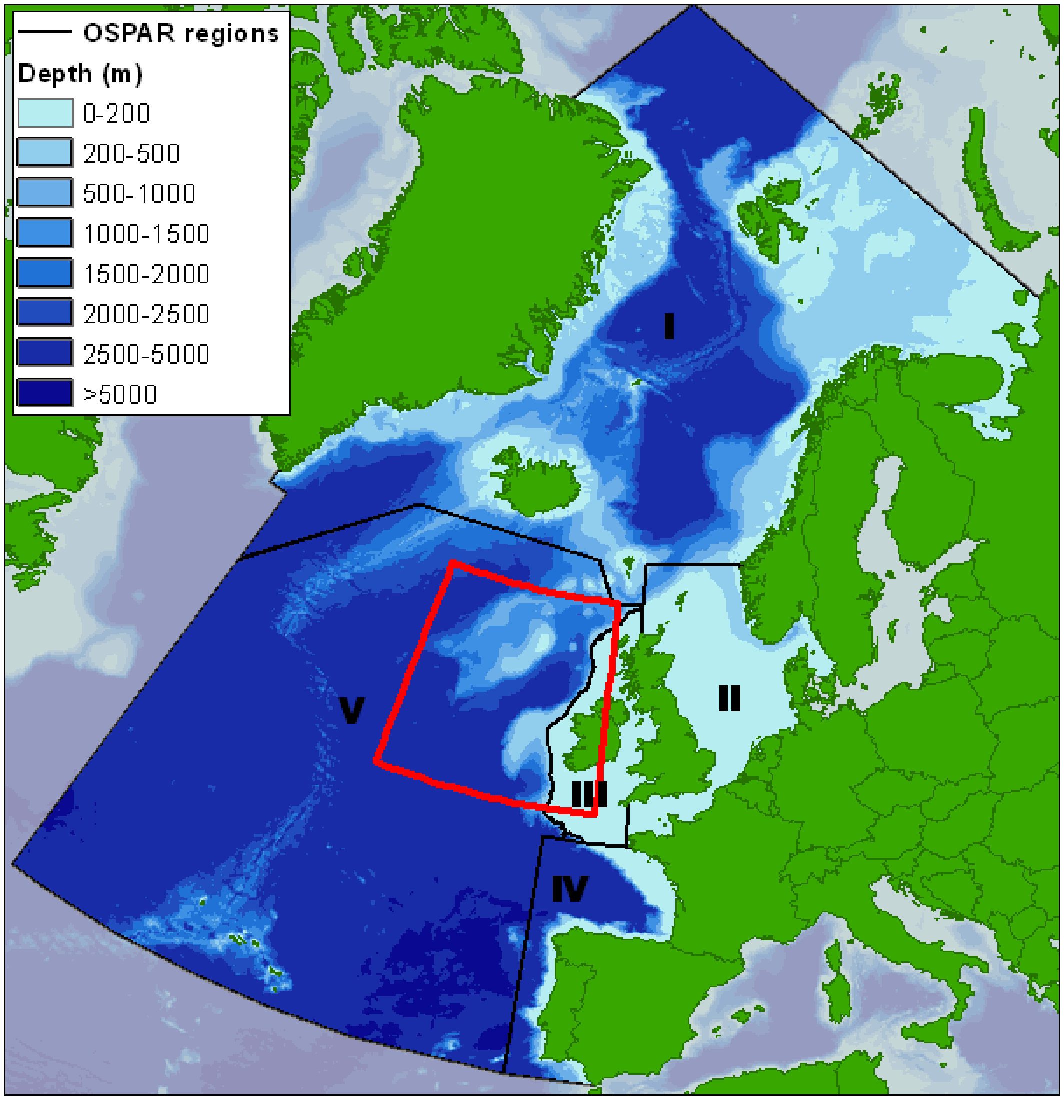

Figure 3.1. Overview of the OSPAR area. Black lines indicate boundaries of the OSPAR regions. The red frame indicates the extent of the map in Fig. 3.

3.2. Habitat extent (current trends/future prospects)

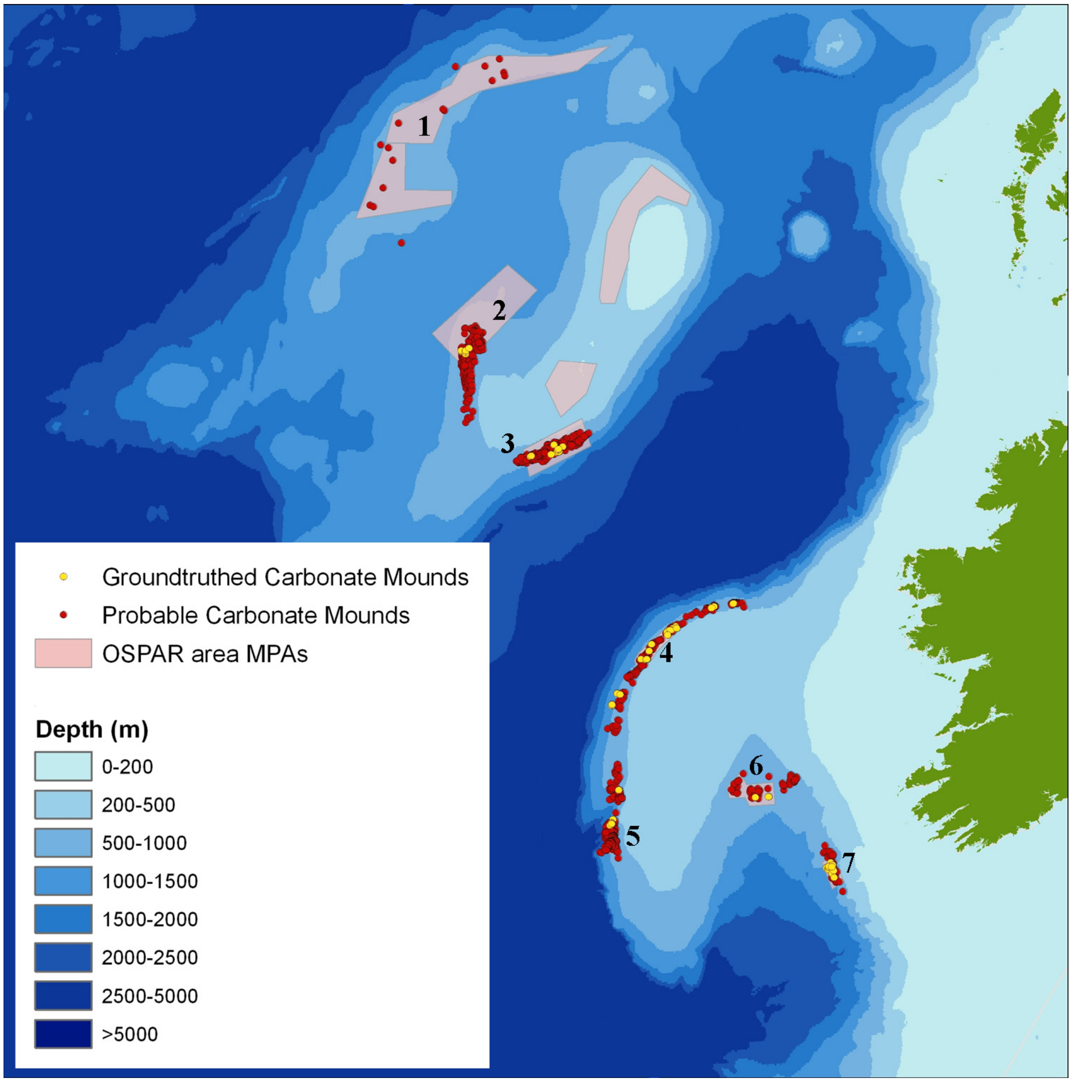

Figure 3.2. Carbonate mounds in the NE Atlantic. Yellow dots indicate cold water coral carbonate mounds groundtruthed by high resolution seismic, ROV, OPHOS or hopper camera footage, box cores, gravity cores or grab samples recorded and collected during various research cruises between 1999 and 2007. Red dots represent seafloor elevation features that are, due to their proximity to groundtruthed coral carbonate mounds and the context of their setting, probably also coral carbonate mounds. The clustered occurrence of coral carbonate mounds in provinces such as the Belgica Mound province in the Porcupine Seabight further supports this assumption. Pink areas indicate marine protected areas:

1. **Hatton Bank NEAFC closure**, total area: 1099000 Ha, date closed: 01/2007
2. **West Rockall Mound NEAFC closure**, total area: 97000 Ha, date closed: 01/2007
3. **Logachev Mound NEAFC closure**, total area: 217000 Ha, date closed: 01/2007
4. **North-West Porcupine SAC**, total area: 71000 Ha, date closed: 10/2007
5. **South-West Porcupine SAC**, total area: 32400 Ha, date closed: 10/2007
6. **Hovland Mound Province SAC**, total area: 105000 Ha, date closed: 10/2007
7. **Belgica Mound Province SAC**, total area: 40300 Ha, date closed: 10/2007

Human activities have not altered the extent of coral carbonate mounds themselves as they have not been subject to activities, such as mining, that would impact their structural integrity. The habitats that occur on coral carbonate mounds, however, such as cold-water coral reefs are undergoing an overall decline due to mechanical damage from demersal fishing gear (Hall-Spencer et al., 2001, Grehan et al., 2005, Wheeler et al., 2005). The decline of these habitats is not limited to OSPAR region V, where coral carbonate mounds occur, as their distributions are not restricted to these features.

3.3. Condition (current/trends/future prospects)

The condition of coral carbonate mounds is not impacted by human activities. However, habitats that occur on certain mounds are impacted, most significantly by demersal fishing. Knowledge of the proportion of habitats present on coral carbonate mounds that have been impacted by fishing is scant, since the majority of these features have not been surveyed visually. However, many of the mounds that have been surveyed visually show signs of trawling damage such as smashed corals, overturned boulders and ghost nets (Hall-Spencer et al., 2001; Grehan et al., 2005; Wheeler et al., 2005; Rogers et al. 2008). Additionally, analyses of vessel monitoring system (VMS) data indicates intensive demersal trawling activitiy in all of the areas where coral carbonate mounds are known to occur (Hall-Spencer et al., in press, Rogers et al., 2008). On the edge of the Porcupine Bank off the west coast of Ireland, part of that fishing effort has been attributed to fishing vessels targeting orange roughy (*Hoplestethus atlanticus*) which aggregate on these features to spawn (Shephard and Rogan, 2006).

3.4. Limitations in knowledge

So far *L. pertusa* reefs and deep sea sponge aggregations are the only habitats associated with coral carbonate mounds that have been nominated for the OSPAR (2006a,b) list of threatened and/or declining species and habitats, with the latter's evaluation greatly limited by a lack of data. No comprehensive classification and evaluation of other habitats found on coral carbonate mounds such as crinoid, octocoral, gorgonian or antipatharian aggregations have been carried out to date. Hence the distribution, status and sensitivity of these habitats to anthropogenic impacts are uncertain.

4. Evaluation of threats and impacts

Table 4.1. Summary of key threats and impacts to habitats associated with coral carbonate mounds.

Type of impact	Cause of threat	Comment	Scale of threat
Habitat loss/ degradation through physical damage	Demersal fisheries	Bottom trawling acts by removing fish and damaging the more fragile benthic species causing shifts in benthic community structure. Thus bottom trawling has direct and indirect impacts. Large, slow-growing species such as antipatharians are particularly vulnerable to trawling disturbance. Differential vulnerability to trawling leads to lower biomass and production of communities in heavily trawled areas and a dominance by smaller, faster growing individuals and species (Jennings et al., 2001).	High
Habitat loss/ alteration	Infrastructure development (cable laying, oil & gas exploitation)	Offshore oil rigs and other oil installations can cause a variety of disturbances such as smothering of benthic fauna due to disposal of drill cuttings, localised disturbance of sediments due to anchors and rig feet implacement and trench digging for pipelines.	Low
Habitat alteration through community shifts	Climate change	Climate change could lead to shifts in surface water productivity and the supply of food to habitats on coral carbonate mounds. Retired mounds may benefit and their suspension feeding communities flourish whereas active mounds may enter a period of decline.	Unknown
Habitat loss/ alteration	Scientific study	There is an established code of practice to mitigate against damage to vulnerable NE Atlantic ecosystems (OSPAR, 2008)	Low
Habitat loss/ alteration	Ocean acidification	A shoaling of the Aragonite Saturation Horizon due to increased levels of anthropogenic CO_2 in seawater is expected to lead to the reduction and in deeper or more northern mounds the cessation of calcification by reef building corals (Guinotte et al., 2006).	Unknown

5. Existing Management measures

While there are no management measures specific to coral carbonate mounds other than the listing by OSPAR, a number of mounds are protected under the category of 'biogenic reefs', listed in Annex I of the EU habitats directive. Eamonn Kelly (Dept. Environment, Heritage & Local Government, Ireland) reports that Ireland currently has four mound sites in the Irish EEZ designated as special areas of conservation (SACs) under this directive (Fig. 3.2.), aimed at protecting *L. pertusa* and *M. oculata* reef habitat that occurs on the mounds. The principle threats to the reef habitat in these areas were identified as commercial fisheries, oil & gas development and marine scientific research. In response to these threats all bottom fishing was banned at the sites in 2007 and a notification system for access by pelagic fishing vessels has been put in place. Ireland also decided not to open two of the sites to oil/gas exploration during the 2007 offshore Strategic Environmental Asessment (SEA) and two further sites are under consideration during the current 2008 SEA process. Furthermore, the Irish government has created a permit system and code of practice for marine scientific research activities in the SACs. Human usage and adherence to management arrangements at the sites are being monitored and it is envisaged that visual inspection of key coral communities within each of the four sites will be conducted on a regular basis during each Natura 2000 reporting cycle.

In addition to the Irish SACs, three areas closed to demersal fishing by the North East Atlantic Fisheries Commission (NEAFC) to protect deep water coral reefs contain confirmed or probable coral carbonate mounds (Hatton Bank, West Rockall Mound, Logachev Mound).

6. Conclusion on overall status

The following sections draw on parts 3-5 of this report to provide an updated evaluation of coral carbonate mounds against the Texel-Faial criteria cited in the nomination of the habitat.

Decline

The original evaluation states that carbonate mounds and associated epifauna may suffer from physical damage caused by demersal fishing gear. However, since coral carbonate mounds are robust geological features their numbers will not decline as a result of human activity although habitats associated with the mounds have been damaged by demersal fishing. The different habitats that occur on coral carbonate mounds will differ in the degree to which they are affected by anthropogenic impacts. It is therefore preferable to identify and assess the decline of individual habitats associated with coral carbonate mounds separately, as has been done for *Lophelia pertusa* reefs which are on the OSPAR (2005a,b) list of threatened and/or declining habitats and species.

Rarity

The findings of deep-sea surveys to date have confirmed the original evaluation that coral carbonate mounds as defined in this document are rare worldwide and the OSPAR area is globally important for this feature as it contains the greatest concentration of coral carbonate mounds in the world as well as the largest examples. The Florida-Hatteras slope is the only other area with comparably high concentrations of this feature (Grasmueck et al., 2006).

OSPAR region V is of high regional importance as coral carbonate mounds only occur in this part of the OSPAR area.

Sensitivity

As geological features, coral carbonate mounds are sensitive only to activities that might compromise their structural integrity such as mining, which at present do not occur where they are located. The original evaluation mainly elaborates on the sensitivity of *Lophelia pertusa* to trawling, however *Lophelia pertusa* reef habitat is listed separately on the OSPAR list. It does not occur on all coral carbonate mounds in the OSPAR area and is not restricted to coral carbonate mounds. Further research is needed to assess other habitats associated with carbonate mounds.

Ecological significance

Following a recommendation by ICES, a detailed description of the ecology of coral carbonate mounds was added to the original evaluation under the criterion of ecological significance. This description highlights the great ecological heterogeneity some mounds exhibit but also implies that not all mounds are of equally high ecological significance. While this evaluation is still valid, recent research furthermore suggests that the mounds are of ecological significance for orange roughy (*Hoplostethus atlanticus*) stocks, which aggregate on elevated seabed features to spawn (Shephard and Rogan, 2006).

Threat

Coral carbonate mounds, as defined in this document, are neither declining nor sensitive to anthropogenic impacts and are therefore not considered under threat. However, habitats associated with some carbonate mounds are threatened by demersal fishering so many of the coral carbonate mounds that occur in the OSPAR area have now been closed to these fisheries.

7. Action should be taken at an OSPAR level?

7.1. Action/measures that OSPAR could take, subject to OSPAR agreement

Coral carbonate mounds were initially nominated for inclusion on the list of threatened and/or declining species and habitats in the OSPAR maritime area based on the criteria of ‘decline’, ‘sensitivity’ and ‘threat’ (OSPAR, 2006a,b). Recent geological coring and ROV surveys have led to a more tightly-defined description of these features. Based on this research, it is recommended that coral carbonate mounds are removed from the OSPAR list as they do not represent one habitat type and ICES advises that there is no evidence of ‘clear and present’ threats to the mounds themselves. While there is evidence that species and habitats that are present on some of the mounds are threatened by ongoing fishing activities, mounds are not always home to these habitats or species. Where carbonate mounds harbour habitats and species of conservation interest, such as *Lophelia* reefs and orange roughy, then measures targeting those species would implicitly protect the mounds that support them.

The Irish, UK and NEAFC areas that are closed to demersal fishing activities to protect *L. pertusa* and *Madrepora oculata* reefs should also protect active coral carbonate mounds and are sufficiently large to encompass and protect adjacent areas of boulder, coral rubble and sediment habitats that flank the coral carbonate mounds. OSPAR must now assess whether these existing management measures are effective (using VMS and standard fisheries surveillance methods) and facilitate a synthesis of recent acoustic mapping efforts regarding these features in OSPAR Region V. Research into coral carbonate mounds is in its infancy so OSPAR should encourage surveys of unexplored mounds. Assessments should also be made of whether current management measures provide adequate protection to the species and habitats that are present on coral carbonate mounds. OSPAR should solicit research into other organisms that form habitats on coral carbonate mounds such as sponges, *Madrepora oculata,* gorgonians and antipatharians.

7.2. Brief Summary of monitoring system to be implemented (c.f. annex 2)

- Monitor fishing activities around coral carbonate mounds
- Assess and report on compliance with closed areas
- Assess and seek to mitigate against any damaging effects of planning proposals (e.g. for oil and gas) likely to affect the habitats which occur on these features
- Compile evidence on the species and habitats that form on coral carbonate mounds and assess which are threatened by ongoing fishing activities.
- Carry out periodic video assessments (e.g. 6 years) of habitat condition at selected sites, including evidence of trawling damage, ghost fishing and percentage cover of live and dead or destroyed coral communities.

Annex.1 Overview of data and information provided by Contracting Parties

Table 2. Information provided by contracting parties

Contracting Party	Feature occurs in CP's Maritime Area	Contribution made to the assessment (e.g. data/information provided)	National reports References or weblinks
Belgium	N	Y	Jean-Pierre Henriet pers. comm. Foubert et al. (2008)
Denmark	N	N	
European Commission	Y	N	
France	N	N	
Germany	N	N	
Iceland	N	N	
Ireland	Y	Y	Boris Dorschel pers. comm.
Netherlands	N	Y	Henk de Haas pers comm., Furu Mienis pers. comm.
Norway	N	N	
Portugal	N	N	
Spain	N	N	
Sweden	N	N	
UK	Y	Y	Dave Long (British Geological Survey) pers. comm.

Annex 2. Description of the recommended monitoring and assessment strategy

1. Rationale for the proposed monitoring

Certain coral carbonate mounds have associated habitats that are known to be impacted, and therefore threatened by, demersal fishing. There is now abundant evidence of the high impact of demersal trawling to shelf-slope habitats. Although fishing closures fall within the remits of fisheries organisations, rather than OSPAR, monitoring resources could be used to support any relevant measures introduced, such as the surveying of areas that are closed to demersal fishing and the assessment of areas with coral carbonate mounds that remain open to demersal fishing. Where protective measures such as fishery closures have been brought in, monitoring is needed to assess their effectiveness.

2. Use of existing monitoring programmes

The Irish and UK authorities continuously monitor national and EU fisheries activities around coral carbonate mounds within their EEZs and the North East Atlantic Fisheries Commission (NEAFC) collates fisheries surveillance data from those nations that fish on or around coral carbonate mounds in the High Seas parts of the OSPAR area. These monitoring programmes should be closely integrated with the design, management and monitoring of areas that are closed to protect those vulnerable species and habitats that are known to occur on coral carbonate mounds.

OSPAR should also support projects that utilise survey data from the hydrocarbon industry to provide information on the status of species and habitats on coral carbonate mounds, such as the SERPENT (Scientific and Environmental ROV Partnership using Existing iNdustrial Technology) project. The SERPENT project makes opportunistic use of Remotely Operated Vehicles in operational settings during periods of stand-by time and the wider utilisation of data collected as part of routine offshore work and environmental assessment studies.

3. Synergies with monitoring of other species or habitats.

Deep-sea surveys are usually expensive due to their remote location so coral carbonate mound monitoring should be combined with assessments of other deep-sea habitats (e.g. *Lophelia pertusa* reefs, sponge habitats) and species (e.g. Orange Roughy, Black Scabbardfish, Roundnose Grenadier) where possible. Monitoring of other features, such as canyons and seamounts, could be carried out together with coral carbonate mound monitoring in some cases.

The opportunity should be taken to obtain physical and chemical data wherever possible in addition to habitat specific assessments to maximise the use of ship-time. Remote monitoring methods, such as VMS should be improved to allow more precise calculations of the effects of fishing (Rogers et al., 2008; Hall-Spencer et al., in press).

4. Assessment criteria

Visual surveys of active coral carbonate mounds should quantify the amount of live and dead coral and its associated sessile macrofauna and be tailored to the main threats to the habitats on the mounds selected. If, for example, the mounds can be fished then visual surveys should monitor trawl scars, entangled nets, ghost fishing, and mechanical damage. If the mounds are sampled scientifically using destructive techniques then the sampling should meet with OSPAR protocols to minimise damage. If the mounds are adjacent to oil/gas drilling then the onus should be placed on the industry to monitor the effects of drill cuttings, sediment disturbance and infrastructure. Inactive coral carbonate mounds will not have *L. pertusa* reefs but may have habitats such as sponge fields, highly biodiverse coral rubble grounds or stands of antipatharians that are of conservation importance so the occurrence and status of the range of habitats that occur on coral carbonate mounds should be assessed.

5. Techniques/approaches:

The design and execution of monitoring programmes will be site-specific and depend on depth, location, available technologies and prevailing threats. Acoustic techniques are needed to determine the extent of coral carbonate mounds - Foubert et al. (2008) provide a summary of these. Visual surveys of mounds may be required to monitor their status. Roberts et al. (2006) review visual techniques (e.g. drop-down digital video and high-resolution still photography) which can be applied to the range of habitats that characterise coral carbonate mounds. Rogers et al. (2008) set out recent and emerging techniques available for monitoring human impacts to coral carbonate mounds (e.g. satellite surveillance, electronic vessel logbooks). As a minimum these should be used to closely monitor and manage all human activities (demersal fisheries, oil & gas development and marine scientific research) likely to affect protected mounds. For example, fisheries should be continuously monitored remotely using satellite technology, ideally in combination with onboard observers, patrol vessels and overflight surveys where required. It would be desirable to also monitor and manage human activities likely to affect coral carbonate mounds in all unprotected areas where these features have been reported to occur.

6. Selection of monitoring locations

In situ monitoring is required for sites holding coral carbonate mounds that are Special Areas of Conservation under the EU's Habitats Directive, such as the NW Porcupine, SW Porcupine, Hovland Mound Province and Belgica Mound Province in Irish waters. Remote monitoring using fisheries surveillance techniques may be sufficient to monitor fisheries closures on carbonate mounds such as the Logachev Mounds and Hatton Bank closures set up by NEAFC. A compilation and synthesis of fisheries and benthic surveys is now needed to determine the likely extent and status of mound features in areas that have been closed to demersal fishing activities. It would be desirable to also obtain acoustic survey data for all areas with coral carbonate mounds within the territorial waters of Contracting Parties to OSPAR. Once priority areas of recorded coral carbonate mound occurrence have undergone baseline surveys, acoustic surveys could then be made of relatively unexplored regions that are likely to support coral carbonate mounds. On the basis of these surveys, targeted visual surveys should then be made of likely coral carbonate mound habitats.

7. Timing and Frequency of monitoring.

To manage coral carbonate mounds effectively, continuous assessment needs to be made of fishing activities in mound areas throughout OSPAR Region V as these activities are known to be the main threat to the habitats that occur on these features. There is a risk that destructive fishing activities present an ongoing conflict with the conservation status of coral carbonate mound habitats even within protected areas.

After baseline surveys are complete repeat surveys should target areas where there is good reason for concerns over a reduction in conservation status. Examples may include fisheries infringements or pollution events. From a logistic point of view weather conditions are unlikely to be favourable for monitoring in winter. It would be desirable for visual surveys to be made of protected areas once every 6 years to enhance ecological knowledge of the systems, assess their status and to record long-term changes in condition, including percentage cover of live and dead or destroyed coral, at selected sites. Policing of closures is a highly important element of monitoring, if this attains full compliance then repeated visual surveys of all coral carbonate mounds and the habitats they support will not be necessary.

Annex 3: References

Anon, 1999. Carbonate Mounds and deep water corals on the European Margin. A framework for cost-shared and concerted RTD Actions under FP5. Dublin meeting Jan 8-9th, 1999.

De Mol, B., Van Rensbergen, P., Pillen, S., Van Herreweghe, K., Van Rooij, D., McDonnell, A., Huvenne, V., Ivanov, M., Swennen, R. and Henriet, J.P., 2002. Large deep-water coral banks in the Porcupine Basin, southwest of Ireland. Marine Geology 188, 193-231.

De Mol, B., Henriet, J.P. and Canals, M., 2005. Development of coral banks in Porcupine Seabight: do they have Mediterranean ancestors? In: Cold-water Corals and Ecosystems. Edited by Freiwald, A. and Roberts, J.M., Springer, Berlin. pp. 515-533.

Eisele, M., Hebbeln, D. and Wienberg, C., 2008. Growth history of a cold-water coral covered carbonate mound – Galway Mound, Porcupine Seabight, NE-Atlantic. Marine Geology 253, 160-169.

Foubert, A., Depreiter, D., Beck, T., Maignien, L., Pannemans, B., Frank, N., Blamart, D. and Henriet, J.-P., 2008. Carbonate mounds in a mud volcano province off north-west Morocco: Key to processes and controls. Marine Geology 248, 74-96.

Grasmueck, M., Eberli, G. P., Viggiano, D. A., Correa, T., Rathwell, G. and Luo, J., 2006. Autonomous underwater vehicle (AUV) mapping reveals coral mound distribution, morphology, and oceanography in deep water of the Straits of Florida. Geophysical Research Letters 33, L23616.

Grehan, A.J., Unnithan, V., Olu-Le Roy, K. and Opderbecke, J., 2005. Fishing impacts on Irish deep-water coral reefs: making the case for coral conservation. In: Benthic habitats and the effects of fishing. Edited by Barnes, P.W. and Thomas, J.P., American Fisheries Society Symposium 41, Bethesda, MD, USA. pp. 819-832.

Guinotte, J.M., Orr, J., Cairns, S., Freiwald, A., Morgan, L. and George, R., 2006. Will human-induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals? Front. Ecol. Environ. 4, 141–146.

Hall-Spencer, J.M., Allain, V. and Fosså, J.H., 2001. Trawling damage to North-east Atlantic ancient coral reefs. Proceedings of the Royal Society, London 269, 507–511.

Hall-Spencer, J.M., Tasker, M., Christiansen, S., Rogers, S. and Hoydal, K., 2008. The design of Marine Protected Areas on High Seas and territorial waters of Rockall. ICES J. Mar. Sci. (in press).

Henriet, J.P., De Mol, B., Pillen, S., Vanneste, M., Van Rooij, D., Versteeg, W and Croker, P.F., 1998. Gas hydrate crystals may help build reefs. Nature 391, 648-649.

Hovland, M., Croker, P.F. and Martin, M., 1994. Fault-associated seabed mounds (carbonate knolls?) off western Ireland and north-west Australia. Marine & Petroleum Geology 11, 232-246.

Huvenne, V. A. I., Bailey, W. R., Shannon, P. M., Naeth, J., di Primio, R., Henriet, J. P., Horsfield, B., De Haas, H., Wheeler, A. and Olu-Le Roy, K., 2007. The Magellan mound province in the Porcupine Basin. International Journal of Earth Sciences 96, 85-101.

Huvenne, V. A. I., De Mol, B. and Henriet, J. P., 2003. A 3D seismic study of the morphology and spatial distribution of buried coral banks in the Porcupine Basin, SW of Ireland, Marine Geology 198, 5-25.

Huvenne, V. A. I., Beyer, A., de Haas, H., Dekindt, K., Henriet, J. -P., Kozachenko, M., Olu-Le Roy, K., Wheeler, A. and the TOBI/Pelagia 197 and CARACOLE Cruise Participants, 2005. The seabed appearance of different coral bank provinces in the Porcupine Seabight, NE Atlantic: results from sidescan sonar and ROV seabed mapping. In Cold-water Corals and Ecosystems. Edited by Freiwald, A. and Roberts, J.M., Springer, Berlin, pp. 535-569.

ICES, 1999. Ecological functioning and integrity of marine ecosystems L.pertusa reefs. IMPACT 99/4/Info.3-E. Submitted by Norway. ICES Working Group on Impacts on the Marine Environment. Brest, 15019 November, 1999.

ICES, 2002. Report of the Working Group on Ecosystem Effects of Fisheries. Advisory Committee on Ecosystems. ICES CM 2002/ACE:03.

Jennings S., Pinnegar J.K., Polunin N.V.C. and Warr K.J., 2001. Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. Marine Ecology Progress Series 213, 127-142.

Jensen, A. and Frederiksen, R., 1992. The fauna associated with the bankforming deepwater coral *Lophelia pertusa* (Scleractinia) on the Faroe shelf. Sarsia 77, 53–69.

Kano, A., Ferdelman, T.G., Williams, T., Henriet, J.P., Ishikawa, T., Kawagoe, N., Takahashima, C., Kakizaki, Y., Abe, K., Sakai, S., Browning, E.L., Li, X. and Integrated Ocean Drilling Program Expedition 307 Scientists, 2007. Age constraints on the origin and growth history of a deep water coral mound in the northeast Atlanticdrilled during Integrated Ocean Drilling Program Expedition 307. Geology 35, 1051-1054.

Kenyon, N.H., Ivanov, M.K. and Akhmetzhanov, A.M., eds., 1998. Cold water carbonate mounds and sediment transport on the Northeast Atlantic margin. Intergovernmental Oceanographic Commission technical series 52. UNESCO 1998.

Kenyon, N.H., Akmetzhanov, A.M., Wheeler, A.J., van Weering, T.C.E., de Haas, H. and Ivanov, M.K., 2003. Giant carbonate mud mounds in the southern Rockall Trough. Marine Geology 195, 5-30.

Masson, D.G., Bett, B.J., Jacobs, C.L. and LeBas, T.P., 1998. Distribution and biology of recently discovered carbonate mounds in the northern Rockall Trough. Poster presented at Atlantic Frontiers environmental Forum Aberdeen University, 6-7 October, 1998.

Masson, D.G., Bett, B.J., Billet, D.S.M., Jacobs, C.L., Wheeler, A.J., and Wynn, R.B., 2003. A fluid escape origin for deepwater coral-topped mounds in the northern Rockall Trough, NE Atlantic. Marine Geology 194, 159-180.

Mortensen, P.B., Hovland, M., Brattegard, T. and Farestveit, R., 1995. Deepwater bioherms of the scleractinian coral *Lophelia pertusa* (L.) at 64°N on the Norwegian shelf: structure and associated megafauna. Sarsia 80, 145–158.

OSPAR, 2003. Criteria for the identification of species and habitats in need of protection and their method of application (the Texel-Faial Criteria). OSPAR Commission, London (Reference Number: 2003-13).

OSPAR, 2006a. Case Reports for the Initial List of Threatened and/or Declining Species and Habitats in the OSPAR Maritime Area. London, OSPAR Commission. pp. 150.

OSPAR, 2006b. Descriptions of habitats on the initial OSPAR list of threatened and/or declining species and habitats. OSPAR Commission, London (Reference Number: 2004-07).

OSPAR, 2008. OSPAR convention for the protection of the marine environment of the North-East Atlantic. Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area OSPAR 08/7/5 Rev.1-E.

Roberts, J.M., Wheeler, A.J. and Freiwald, A., 2006. Reefs of the deep: the biology and geology of cold-water coral ecosystems. Science 312, 543-547.

Roberts, J.M., Henry, L.-A., Long, D. and Hartley, J.P., 2008. Cold-water coral reef frameworks, megafaunal communities and evidence for coral carbonate mounds on the Hatton Bank, north east Atlantic. Facies, (in press).

Rogers, A.D., Clark, M.R., Hall-Spencer, J.M. and Gjerde, K.M., 2008. A scientific guide to the FAO draft international guidelines (December 2007) for the management of deep-sea fisheries in the High Seas, IUCN, Gland, Switzerland. pp. 48.

Shephard, S. and Rogan, E., 2006. Seasonal distribution of orange roughy (*Hoplostethus atlanticus*) on the Porcupine Bank west of Ireland. Fisheries Research 77, 17-23.

Sumina, P. and Kennedy, R., 1998. Porcupine Seabight. Biological data. In: Cold water carbonate mounds and sediment transport on the Northeast Atlantic margin. Edited by Kenyon, N.H., Ivanov, M.K. and Akhmetzhanov, A.M., Intergovernmental Oceanographic Commission Technical Series 52. UNESCO 1998.

Van Rooij, D., Huvenne, V.A.I., Blamart, D., Henriet, J.-P., Wheeler, A. and de Haas, H., 2008. The Enya mounds: a lost mound-drift competition. Int J Earth Sci. (in press).

Van Soest, R.W.M., Cleary, D.F.R., Kluijver, M.J., Lavaleye, M.S.S., Maier, C. and van Duyl, F.C., 2007. Sponge diversity and community composition in Ifish bathyl coral reefs. Contributions to Zoology 76, 121-142.

Van Weering, T.C.E., de Haas, H., de Stiger, H.C., Lykke-Andersen, H. and Kouvaev, I., 2003. Structure and development of giant carbonate mounds at the SW and SE Rockall Trough margins, NE Atlantic Ocean. Marine Geology, 198, 67-81.

Wheeler, A. J., Beck, T., Thiede, J., Klages, M., Grehan, A. Monteys, F. X. and Polarstern ARK XIX/3a Shipboard Party, 2005. Deep-water coral mounds on the Porcupine Bank, Irish margin: preliminary results from Polarstern ARK-XIX/3a ROV cruise. In: Cold-water Corals and Ecosystems. Edited by Freiwald, A. and Roberts, J.M., Springer, Berlin, pp. 393-402.

Wheeler, A.J., Beyer, A., Freiwald, A., de Haas, H., Huvenne, V.A.I., Kozachenko, M., Olu-Le Roy, K. and Opderbecke, J., 2007. Morphology and environment of cold-water carbonate mounds on the NW European margin. Int J Earth Sci 96, 37-56.

Wheeler, A. J., Kozachenko, M., Masson, D. G. and Huvenne, V. A. I., 2008. The influence of benthic sediment transport on cold-water coral bank morphology and growth: the example of the Darwin Mounds, NE Atlantic. Sedimentology, (in press).

Wienberg, C., Beuck, L., Heidkamp, S., Hebbeln, D., Freiwald, A., Pfannkuche, O. and Monteys, X., 2008. Franken Mound: facies and biocoenoses on a newly-discovered 'carbonate mound' on the western Rockall Bank, NE Atlantic, Facies 54, 1-24.

Wilson, J. and Vina Herbon, C., 1998. Macrofaunas and Biogenic carbonates from the north slope of Porcupine Bank, south east slope of Rockall Bank and west of Faeroe Bank Channel. In: Cold water carbonate mounds and sediment transport on the Northeast Atlantic margin. Edited by Kenyon, N.H., Ivanov, M.K. and Akhmetzhanov, A.M., Intergovernmental Oceanographic Commission Technical Series 52. UNESCO 1998.

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