



Background Document for  
*Lophelia pertusa* reefs



## OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

## Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

## Acknowledgement

This report has been prepared by Jason M. Hall-Spencer & Kilian M. Stehfest, Marine Institute, University of Plymouth, Plymouth PL4 8AA, UK on behalf of the UK Joint Nature Conservation Committee (JNCC), Monkstone House, Peterborough, PE1 1UA, UK with additional funding from the Esmée Fairbairn Foundation.

We thank Álvaro Altuna, Jeff Ardron, Boris Dorschel, Nicola Chapman, Sabine Christiansen, Amelia Curd, Eilif Gaard, Brigitte Guillaumont, Jean-Pierre Henriet, Martin Hoveland, Jan Helge Fosså, Lisbeth Jonsson, Eamonn Kelly, Dave Long, Gui Menezes, Pål Buhl Mortensen, Steinunn Hilma Ólafsdóttir, Kate Sanderson, Alberto Serrano and Andy Wheeler for help with improving this report, but any mistakes remain our own. We also thank the Esmée Fairbairn Foundation for grant aid in support of the DC-UK Programme, devoted to enhancing the conservation status of deep water habitats.

Photo acknowledgement:

Cover page: *Lophelia pertusa*, Wikipedia

# Contents

<b>Background document on <i>Lophelia pertusa</i> reefs .....</b>	<b>4</b>
Executive summary.....	4
Récapitulatif .....	4
1. Background information .....	5
Name of habitat .....	5
Definition of habitat.....	5
Correlation with habitat classification schemes.....	5
Common characteristics of habitat .....	5
2. Original evaluation against the Texel-Faial selection criteria.....	7
OSPAR Regions and biogeographic zones where the feature occurs .....	7
OSPAR Regions and biogeographic zones where the feature is under threat and/or in decline.....	7
Original evaluation against the Texel-Faial criteria for which the feature was included on the initial OSPAR List .....	7
3. Current status of <i>Lophelia pertusa</i> reefs.....	8
Distribution in OSPAR maritime area .....	8
Habitat extent (current trends/future prospects).....	10
Condition (current/trends/future prospects).....	11
Limitations in knowledge .....	12
4. Evaluation of threats and impacts.....	13
5. Existing management measures.....	14
6. Conclusion on overall status .....	15
7. Action to be taken by OSPAR .....	16
Action/measures that OSPAR could take, subject to OSPAR agreement.....	16
Brief summary of proposed monitoring system.....	17
<b>Annex 1: Overview of data and information provided by Contracting Parties .....</b>	<b>18</b>
Summaries of country-specific information provided .....	18
<b>Annex 2: Detailed description of the recommended monitoring and assessment strategy .....</b>	<b>24</b>
Rationale for proposed monitoring.....	24
Use of existing monitoring programmes .....	24
Synergies with monitoring of other species or habitats .....	24
Assessment criteria.....	24
Techniques/approaches.....	24
Selection of monitoring locations .....	25
Timing and frequency of monitoring.....	25
<b>Annex 3: References .....</b>	<b>26</b>

# Background document on *Lophelia pertusa* reefs

## Executive summary

This background document on *Lophelia pertusa* reefs has been developed by OSPAR following the inclusion of this habitat on the OSPAR List of threatened and/or declining species and habitats (OSPAR agreement 2008-6). The document provides a compilation of the reviews and assessments that have been prepared concerning this habitat since the agreement to include it in the OSPAR List in 2003. The original evaluation used to justify the inclusion of *Lophelia pertusa* reefs in the OSPAR List is followed by an assessment of the most recent information on its status (distribution, extent, condition) and key threats prepared during 2008-2009. Chapter 7 provides recommendations for the actions and measures that could be taken to improve the conservation status of the habitat. In agreeing to the publication of this document, Contracting Parties have indicated the need to further review these proposals. Publication of this background document does not, therefore, imply any formal endorsement of these proposals by the OSPAR Commission. On the basis of the further review of these proposals, OSPAR will continue its work to ensure the protection of *Lophelia pertusa* reefs, where necessary in cooperation with other competent organisations. This background document may be updated to reflect further developments or further information on the status of the habitat which becomes available.

## Récapitulatif

Le présent document de fond sur les Récifs de *Lophelia pertusa* a été élaboré par OSPAR à la suite de l'inclusion de cet habitat dans la liste OSPAR des espèces et habitats menacés et/ou en déclin (Accord OSPAR 2008-6). Ce document comporte une compilation des revues et des évaluations concernant cet habitat qui ont été préparées depuis qu'il a été convenu de l'inclure dans la Liste OSPAR en 2003. L'évaluation d'origine permettant de justifier l'inclusion des Récifs de *Lophelia pertusa* dans la Liste OSPAR est suivie d'une évaluation des informations les plus récentes sur son statut (distribution, étendue et condition) et des menaces clés, préparée en 2008-2009. Le chapitre 7 fournit des propositions d'actions et de mesures qui pourraient être prises afin d'améliorer l'état de conservation de l'habitat. En se mettant d'accord sur la publication de ce document, les Parties contractantes ont indiqué la nécessité de réviser de nouveau ces propositions. La publication de ce document ne signifie pas, par conséquent que la Commission OSPAR entérine ces propositions de manière formelle. A partir de la nouvelle révision de ces propositions, OSPAR poursuivra ses travaux afin de s'assurer de la protection des Récifs de *Lophelia pertusa* le cas échéant avec la coopération d'autres organisations compétentes. Ce document de fond pourra être actualisé pour tenir compte de nouvelles avancées ou de nouvelles informations qui deviendront disponibles sur l'état de l'habitat.

## 1. Background information

### Name of habitat

*Lophelia pertusa* reefs

### Definition of habitat

*Lophelia pertusa* (L., 1758), a cold-water, reef-forming coral, has a wide geographic distribution ranging from 55°S to 70°N, where water temperatures typically remain between 4 - 8°C. These reefs are generally subject to moderate current velocities (0.5 knots). The majority of records occur in the North-east Atlantic. The extent of *L.pertusa* reefs varies, with examples off Norway several km long and more than 20 m high. These reefs occur within a depth range of 200 -> 2000 m on the continental slope, and in shallower waters in Norwegian fjords and Swedish west coast. In Norwegian waters, *L.pertusa* reefs occur on the shelf and shelf break off the western and northern parts on local elevations of the sea floor and on the edges of escarpments. The biological diversity of the reef community can be three times as high as the surrounding soft sediment (ICES, 2003), suggesting that these cold-water coral reefs may be biodiversity hotspots. Characteristic species include other hard corals, such as *Madrepora oculata* and *Solenosmilia variabilis*, the redfish *Sebastes viviparous* and the squat lobster *Munida sarsi*. *L.pertusa* reefs occur on hard substrata; this may be *Lophelia* rubble from an old colony or on glacial deposits. For this reason, *L.pertusa* reefs can be associated with iceberg plough-mark zones.

### Correlation with habitat classification schemes

The EUNIS habitat classification (2007 version; <http://eunis.eea.europa.eu/habitats.jsp>) subdivides *L.pertusa* reefs into two habitat types depending on whether they occur in the circalittoral (A5.631) or deep-sea (A6.611). In the National Marine Habitat Classification for Britain and Ireland this habitat has been assigned the code SS.SBR.Cri.Lop (Connor *et al.*, 2004). *Lophelia pertusa* is known to also occur on seamounts, knolls and banks (A6.72), on carbonate mounds (A6.75) and on canyons, channels, slope failures and slumps on the continental slope (A6.81).

### Common characteristics of habitat

*L.pertusa* is one of six coral species known to form extensive cold-water reefs. Unlike many warm-water corals it lacks symbiotic algae and so does not require light. It has a cosmopolitan distribution in the Atlantic, Pacific and Indian Oceans and also occurs in the Mediterranean (Zibrowius, 1980; Cairns, 1994).

Sars (1865) noted that *L.pertusa* builds reefs but other terms have since been used to describe these habitats, such as 'massifs', 'banks', 'mounds', and 'bioherms'. *L.pertusa* reefs are defined here as biogenic structures formed by *L.pertusa* that alter sediment deposition, provide complex structural habitat, and are subject to the processes of growth and (bio)erosion (Davies *et al.*, 2008). Colonies about 1.5 m high are thought to be about 250 years old but the reefs are believed to build up 1.3 – 3 m per 1000 years (Wilson, 1979; Freiwald *et al.*, 1999; Mortensen, 2000), as approximately 86% of the corallite growth rate is lost to bioerosion and other factors (Freiwald & Wilson 1998). Southern parts of the OSPAR area (Region V) had conditions suitable for coral growth during glacial times, as well as the interglacial periods and here periodic reef growth has formed mounds that are more than a million years old. Northern parts of the OSPAR area (Region I) were unfavourable for coral growth during the last ice age but even here reefs are up to 10 000 years old (Schröder-Ritzrau *et al.* 2005).

*L.pertusa* larvae require hard substrata to settle and its reefs mainly occur at depths where temperature varies less than in surface waters, in areas with strong currents and sloping bathymetry which enhance the supply of organic material for reef growth, namely settling and resuspended

phytodetritus, faecal pellets and zooplankton (Frederiksen *et al.*, 1992; Duineveld *et al.*, 2004; Thiem *et al.*, 2006). *L.pertusa* requires temperatures between 4 - 13 °C and salinities of about 35 - 38 psu, with oxygen concentrations  $>3 \text{ ml l}^{-1}$  in waters saturated with aragonite (Freiwald *et al.*, 2004; Taviani *et al.*, 2005; Dodds *et al.*, 2007; Davies *et al.*, 2008). It grows from single polyps to form colonies which merge to form patch-reefs several metres across (Wilson, 1979). If favourable conditions prevail, this process can continue to form large reefs (typically 50 m wide, 3 m high) and also giant reefs such as Rost Reef, a 35 km long reef complex off Norway (Figure 1). *L.pertusa* reefs also contribute to the development of coral carbonate mounds, which are features (up to 350 m high) formed by successive periods of coral reef development, sedimentation and (bio)erosion (Hovland *et al.*, 1998; De Mol *et al.*, 2002; Foubert *et al.*, 2008).



**Figure 1:** *Lophelia pertusa* reef (showing the white and orange colour morphs) at 400 m depth off Rost, Norway, the largest known cold-water coral reef on Earth. (Photograph taken on Polarstern Cruise ARK-XXII © Jago/IFM Geomar 2007)

The reef-forming coral *Madrepora oculata* often occurs amongst *L.pertusa* reefs which trap sediment and create carbonate-rich deposits to form isolated habitats of high benthic biomass. Their diversity can be three times that of surrounding sediments (Le Danois, 1948; Jensen & Frederiksen, 1992; Jonsson *et al.*, 2004; Henry & Roberts, 2007) as the reefs commonly harbour abundant sessile suspension feeders and a multitude of grazing, scavenging and predatory invertebrates such as echinoderms (*e.g.* *Bonellia* sp.), molluscs (*e.g.* *Acesta excavata*), crustaceans (*Pandalus* spp., *Munida* spp.) and echinoderms (*e.g.* *Cidaris* spp., *Gorgonocephalus* sp.) (Freiwald *et al.*, 2004; Hovland, 2008; Roberts *et al.*, 2006, 2008). There is a growing inventory of species that are known to associate with these reefs in the OSPAR area; the current tally stands at over 1300 species, several of which are new to science (Myers & Hall-Spencer, 2004; Mortensen & Fosså, 2006, Henry & Roberts, 2007; Guerra-Garcia, 2008). The species that associate with *L.pertusa* reefs change from one biogeographic province to another with an overall reduction in diversity from south to north coupled with a shift towards a more northern fauna (Hall-Spencer *et al.*, 2002, 2007; Roberts *et al.*, 2008).

The conservation importance of *L.pertusa* reefs is increasingly recognised, not only because of their longevity and high biodiversity, but also due to potential benefits for commercial fisheries. Although functional relationships have not been demonstrated so far, the reefs are presumed to act as breeding grounds for commercial species such as redfish (*Sebastes* spp.), which hide amongst the complex 3-dimensional structure, and provide hunting territory for demersal predators such as monkfish, cod, ling, saithe and tusk (Husebo *et al.*, 2002; Costello *et al.*, 2005).

## 2. Original evaluation against the Texel-Faial selection criteria

### OSPAR Regions and biogeographic zones where the feature occurs

OSPAR Regions: all

Dinter (2001) biogeographic zones:

Norwegian Coast - Finmark

Norwegian Coast – West Norway

Norwegian Coast - Skaggerak

South Iceland – Faeroe Shelf

Boreal

Boreal-Lusitanian

Lusitanian-Boreal

Lusitanian – cool

Lusitanian – warm (north)

Lusitanian – warm (south)

Macaronesian

### OSPAR Regions and biogeographic zones where the feature is under threat and/or in decline

OSPAR Regions: All where they occur.

Dinter (2001) biogeographic zones: All where they occur.

### Original evaluation against the Texel-Faial criteria for which the feature was included on the initial OSPAR List

**Global/regional importance:** The OSPAR area appears to be particularly important for *L.pertusa* because of the high proportion of the known occurrences of these reefs in the North-east Atlantic. There is still uncertainty about how well the distribution of *L.pertusa* has been mapped in other oceans because of the widely scattered reported occurrences elsewhere.

**Sensitivity:** The delicate structure of *L.pertusa* makes these coral reefs particularly vulnerable to physical damage. The growth rate is thought to be about 6 mm per year implying that normal-sized colonies of about 1.5 m 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. The effects of drill cuttings, water-based and synthetic drilling muds, and the variety of chemicals and contaminants including dissolved and dispersed oil which is known to

enter the environment around offshore oil operations may have lethal and sub-lethal effects on corals, but there are few studies on this as yet (Rogers, 1999).

**Decline:** A number of studies have estimated the extent of *L.pertusa* in parts of the North-east Atlantic and the changes that have taken place in recent years. This has been summarised by the ICES Study Group on mapping the occurrence of cold-water corals (ICES 2002a). In the Norwegian EEZ, for example, *L.pertusa* is estimated to cover somewhere between 1500 and 2000 km<sup>2</sup> of seabed, mostly concentrated between depths of 200 - 400 m (Fosså *et al.*, 2000). Analysis of information collected by direct observation and fishermen's interviews suggest that between one third and one half of the total reef area of Norway has been damaged to an observable extent (Ottensen *et al.*, 2000). The current and past distribution of *L.pertusa* reefs around the Faroe Islands also show changes, and these are thought to be due to fishing (ICES 2002a).

**Threat:** The principal threat to *L.pertusa* reefs is physical damage by fishing gear. There are documented cases of damage in north-west European waters but these are most likely a minute fraction of the number of instances where such reefs have been damaged, given how widespread trawling has been, and the amount of habitat that is potentially suitable for corals in the North-east Atlantic (ICES, 2002a). Petroleum industry developments with associated discharges of drilling mud and drill cuttings may also negatively affect the corals. Given the slow growth rate of the reefs, they may take centuries to recover from damage, if at all.

In summary, the original evaluation noted that *L.pertusa* reefs were under considerable threat due to the dramatic effects of trawling damage and the widespread occurrence of this activity throughout OSPAR Regions I-V (OSPAR 2005).

**ICES evaluation:** The ICES review of this nomination found that there was good evidence of decline and threat to *L.pertusa* reefs. In particular, ICES reported that there was good evidence of decline in OSPAR Regions I, II, III, and V. Occurrence in Region IV is not well known, but given the distribution of deep-water trawling it is likely that damage/decline has occurred there as well. ICES also noted that there is good evidence that the principal current threat comes from bottom trawling. As the technology to undertake such trawling in hard habitats develops further, areas of *L.pertusa* reefs have come under threat (ICES, 2002b).

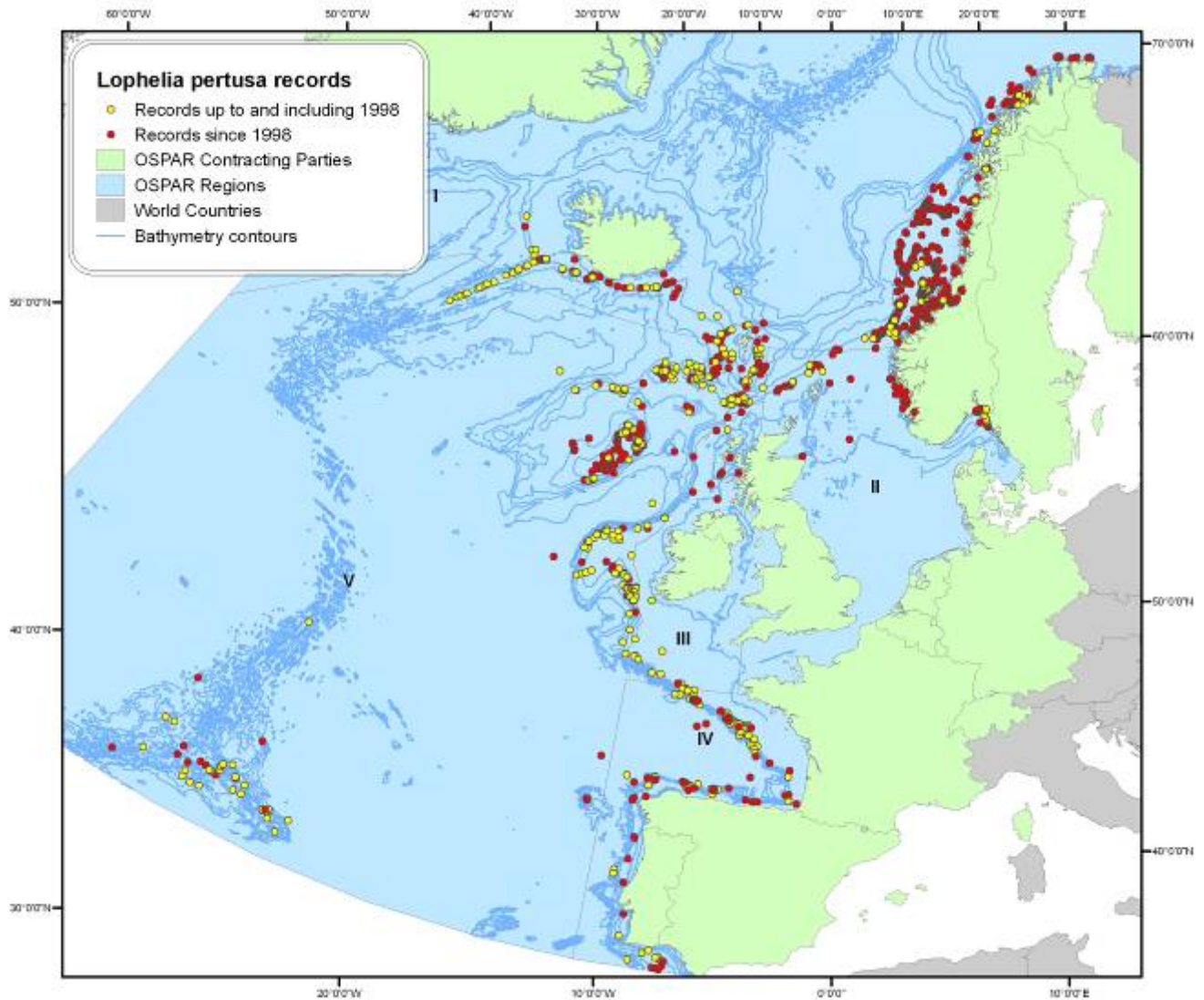
### 3. Current status of *Lophelia pertusa* reefs

#### Distribution in OSPAR maritime area

*L.pertusa* has not been found in the coldest parts of the OSPAR area (the Deep Sea Arctic, shelf areas off Greenland, North Iceland, the High Arctic Maritime and the Barents and White Seas (see Dinter 2001 for a map of these biogeographic regions). *L.pertusa* does not occur in the warm surface waters of the southern OSPAR region but is found in deep waters of the Macaronesian-Azores biogeographic region and occurs all along the European continental shelf up to Finnmark.

This review incorporates over 2000 records of *L.pertusa* from the OSPAR area, including records within the waters of Iceland, Norway, Sweden, Faroe Islands, UK, Ireland, France, Spain and Portugal, and in areas beyond national jurisdiction (Figure 2). Due to uncertainties in many of the records it is not always clear how many of these represent current reef habitats (David Connor, JNCC, *pers com.* 2008).





**Figure 2:** *Lophelia pertusa* records in the OSPAR area, based on data in the OSPAR habitat database from Contracting Parties and other sources up to December 2008.<sup>1</sup>

The shallowest live *L.pertusa* record is at 40 m depth in Trondheimfjord, Norway (Strømgren 1971). Most Norwegian records are from the continental shelf and slope, at 200 – 400 m depth (Dons, 1944; Mortensen *et al.*, 1995; Hovland *et al.*, 1998; Freiwald *et al.*, 1999; Fosså *et al.*, 2002; Hovland, 2008). Off Iceland reefs occur along the southern shelf slope and the Mid-Atlantic Ridge at 114 - 800 m depth (Copley *et al.*, 1996) and they are widespread on shelf slopes off the Faroes (Bruntse & Tendal, 2001). The continental margin off the UK and Ireland has hundreds of *L.pertusa* reefs at 650 - 1000 m depth (Wilson, 1979; De Mol *et al.*, 2002; Wheeler *et al.*, 2007; Roberts *et al.*, 2008). *L.pertusa* has been recorded all along the continental shelf margin of the Bay of Biscay between 150 - 1800 m depth with most records shallower than 400 m, where more scientific sampling effort has been carried out (Reveillaud *et al.*, 2008) although Le Danois (1948) noted that fishermen encountered *L.pertusa* most frequently around 800 m depth in the Bay of Biscay. In the southern part of the OSPAR area, *L.pertusa* has been recorded frequently on seamounts around the Azores and along the Iberian Shelf at 200 - 2000 m depth (Hall-Spencer *et al.*, 2007). Within the OSPAR area there is a report from

<sup>1</sup> The coastline and bathymetry are derived from the GEBCO digital atlas. The map is projected in the North Pole Lambert Azimuthal Equal Area projection (Central Meridian 0.000000, Latitude of origin 90.000000).

2875 m depth in a canyon in the Straits of Gibraltar although this could have been a dead colony (Zibrowius 1980).

Detailed maps of *L.pertusa* records for different parts of the OSPAR area, which also show protected areas, can be found in Annex 1.

### **Habitat extent (current trends/future prospects)**

**Current extent:** The extent of live *L.pertusa* reefs increases from south to north along the continental margins of Europe with the largest reefs reported from areas to the south-west of Ireland (De Mol *et al.*, 2002), off North-west Scotland (Roberts *et al.*, 2008), the Faroes (Bruntse & Tendal, 2001) and along the continental slope and off Norway (Fosså *et al.*, 2005), where abundant reefs are found scattered along the mid-Norwegian continental shelf and inside local depressions in the seafloor (Hovland, 2008). Southwards, along the Bay of Biscay and along the Iberian shelf, *L.pertusa* reefs appear to only occur in smaller formations (Duineveld *et al.*, 2004; Alvarez-Perez *et al.*, 2005) although extensive reefs formed in these areas during the Pleistocene (de Mol *et al.*, 2005). The largest present day reefs occur in recently glaciated parts of the OSPAR area, such as on the Sula Ridge off Norway, where they colonise iceberg plough mark zones in current-swept areas (Freiwald *et al.*, 1999; Fosså *et al.*, 2005). Such extensive reefs appear to be rare and attachment substrata can also be small, such as mollusc shells or cobbles, seeding the development of patch reefs (Wilson, 1979; Mortensen *et al.*, 1995, 2001). At the deepest limits of *L.pertusa* growth, reefs will probably be small, sparsely distributed colonies that are limited by low aragonite concentrations (from which it builds its skeleton), low current speeds and inconsistent food supply. The current and past extent of *L.pertusa* distribution in key parts of the OSPAR area is described in more detail in Annex 1.

The total extent of *L. pertusa* reef habitat in the OSPAR area is not yet known.

**Trends in extent:** The extent of *L.pertusa* reefs is undergoing an overall decline due to mechanical damage by demersal fishing gear in all OSPAR areas (Hall-Spencer *et al.* 2001; Fosså *et al.* 2002, 2005; ICES 2005, 2007; Grehan *et al.* 2005; Wheeler *et al.* 2005; Reveillaud *et al.* 2008) although new individual *L.pertusa* colonies have been recorded on oil rigs in ICES Regions I and II (Bell & Smith, 1999; Gass & Roberts 2006). Knowledge of the amount of *L.pertusa* reef lost is poor, except for in Sweden and Norway where it is estimated that up to 50% of this habitat has been impacted (Fosså *et al.*, 2002; Figure 4, Annex 1). Surveys off the UK and Ireland reveal that patch reefs and colonies attached to boulders may have been reduced in extent to a greater degree than large reefs as they present less of an obstacle to fishing with rock-hopper gear (Wheeler *et al.*, 2005; Davies *et al.*, 2007). This ties in with reports that demersal trawlers avoid large reefs due to the damage this causes to the gear (Joubin, 1922a; Hall-Spencer *et al.*, 2001, in press; Armstrong & van den Hove, 2008).

**Future prospects for the extent of *L.pertusa* reefs:** Over the next 10 years unprotected reefs, especially small patch reefs, are expected to continue to decline in extent due to the ongoing impacts of demersal fishing. If recent fisheries closures are complied with then a network of protected areas off the Azores and the Mid-Atlantic Ridge and on the continental shelves off Iceland, the Faroes, Norway, Sweden, the UK and Ireland can be expected to protect the reefs they contain and allow them to recover from past fishing impacts (see section 5 Existing Management Measures). Effective enforcement of these closures will be key to their success. Concerns have been raised that even protected *L.pertusa* reefs may reduce in extent in OSPAR Region I over the course of this century due to reductions in aragonite saturation levels due to anthropogenic increases in CO<sub>2</sub> (Guinotte *et al.*, 2007). Additional concerns are that climate-driven changes in oceanographic circulation may reduce food supply and lead to declines in the extent of established reefs throughout the OSPAR area (Davies *et al.*, 2007).

### Condition (current/trends/future prospects)

**Current condition:** Those *L.pertusa* reefs that are in good condition can be breathtaking examples of pristine habitat in the OSPAR area which mirror the descriptions of high biodiversity and biomass first described in pioneering studies of the ecology of these reefs (Le Danois, 1948). Rost Reef (Fosså *et al.*, 2005), Sula Ridge reef (Freiwald *et al.* 2002) and some of the reefs on Hatton Bank (Roberts *et al.*, 2008) and off South-west Ireland (Wheeler *et al.*, 2005) have escaped major habitat degradation, presumably because large reefs are difficult grounds to trawl (Hall-Spencer *et al.*, 2001; Armstrong & van den Hove, 2008). Such reefs are characterised by areas of high live coral cover with intact structural integrity and they support a diverse array of high-biomass, long-lived sessile biota. Despite escaping direct physical damage the biological communities of some reefs in “good condition” can still be impacted by the decline of stocks of migratory fish that utilise these habitats (Gordon *et al.*, 2003). Low coral cover does not necessarily mean that reefs are in poor condition as some reefs have a naturally low live-coral cover but provide a highly biodiverse coral rubble habitat (Henry & Rogers, 2008). Reefs that are in poor condition often have low live-coral cover together with evidence of mechanical damage such as coral smashed by towed gear, buried in sediment or tangled with litter.

**Trends in condition:** During the last ice age extensive reefs developed in the Mediterranean but were absent from northern parts of the OSPAR area (Taviani *et al.*, 2005). Through the Holocene *L.pertusa* distribution shifted northwards and most Mediterranean *L.pertusa* reefs gradually died off. Now the most extensive examples of this habitat thrive off the coast of Norway (Fosså *et al.*, 2005; Lindberg *et al.*, 2007; Hovland, 2008). Over the past 10 years reductions in the condition of *L.pertusa* reefs have been well documented for Norway, Sweden, Iceland, the UK and Ireland (Hall-Spencer *et al.*, 2001; Fosså *et al.*, 2005; Grehan *et al.*, 2005; Wheeler *et al.*, 2005) with old records of human impacts to *L.pertusa* reefs off France (Joubin, 1922a). All activities which affect water quality, productivity, hydrodynamics and sediment processes can be expected to alter the condition of *L.pertusa* reefs as they have well known constraints on conditions for growth (Davies *et al.* 2007, 2008). Thus mining and dumping have the potential to reduce the condition of established reefs and changes related to present day climate shifts can be expected to improve conditions for reef development in some areas but reduce reef condition in others. 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. The effects of drill cuttings, water-based and synthetic drilling muds, and the variety of chemicals and contaminants including dissolved and dispersed oil which enter the environment around offshore oil operations may have lethal and sublethal effects on corals (Gass & Roberts, 2006). The International Research Consortium on Continental Margins and the International Research Institute of Stavanger are conducting research into the impact of oil and gas exploration on corals which is expected to be completed by 2010. All the evidence for reductions in *L.pertusa* reef condition recorded over the past decade show that demersal fishing is the cause, based on by-catch records, *in situ* video and acoustic images of trawl tracks through reefs.

**Future prospects:** Over the next 10 years small, unprotected reefs <1500 m depth are expected to decline in condition due to the ongoing impacts of demersal fishing since current fishing does not extend deeper than 1500 m. It is possible that over the next 100 years the condition of *L.pertusa* reefs in OSPAR Region I will decline due to reductions in aragonite saturation levels (Guinotte *et al.*, 2007) and changes in oceanographic circulation may benefit some reef areas but not others across all OSPAR Regions (Davies *et al.*, 2007).

### Limitations in knowledge

Figure 2 includes old records (e.g. Duncan, 1873; Jourdan, 1890, 1895; Gravier 1915, 1920) and should not be interpreted as showing the current distribution of *L.pertusa* reef habitat, as some records may have been from isolated colonies, rather than reefs, other records may be of subfossil reefs or from reef habitat that has subsequently been altered (either naturally or by man). Many areas that appear suited to *L.pertusa* reef development, such as northern seamounts, have not been adequately surveyed (Hall-Spencer *et al.*, 2007; Davies *et al.*, 2008). Several countries (Norway, Sweden, Faroes, Ireland, UK, and France) have commissioned surveys to begin to address these limitations in knowledge and determine where reefs are currently present. The current EU project CoralFISH aims to i) develop essential methodologies and indicators for baseline and subsequent monitoring of closed areas, ii) incorporate fish into coral ecosystem models to better understand coral fish carrying capacity, iii) evaluate the distribution of deep-water bottom-fishing effort to identify areas of potential interaction and impact upon coral habitat, iv) use genetic fingerprinting to assess the potential erosion of genetic fitness of corals due to long-term exposure to fishing impacts, v) construct bio-economic models to assess management effects on corals and fisheries to provide policy options, and vi) produce as a key output, habitat suitability maps both regionally and for OSPAR Region V to identify areas likely to contain vulnerable habitat.

There is firm evidence that fishing activity is the current cause of widespread *L.pertusa* reef degradation but knowledge is incomplete about where damaging fishing practices are ongoing or have taken place in the past. Although widespread trawling damage is known from waters off Ireland north to Norway, *L.pertusa* reef decline has not been documented along the Mid Atlantic Ridge or in French, Spanish or Portuguese waters. It is highly likely that trawling damage has occurred in these areas, in light of what is known about fishing activities in these areas (Hall-Spencer *et al.*, 2007; Reveillaud *et al.*, 2008), but reefs in the Bay of Biscay, for example, may be less vulnerable to deep-sea trawling than on fishing grounds further north as there the reefs mainly occur in deep canyons where bottom trawling is difficult (Brigitte Guillaumont, Ifremer, *pers.com.*). Around the Azores *L.pertusa* specimens were not present in by-catch from monitored trawl fisheries, probably because this fishery operates shallower than the main occurrence of the coral (Sampaio *et al.*, 2008).

In coastal zones, spotter planes, patrol vessels and onboard observers supply data on fisheries activity. However, applying these methodologies to offshore areas is expensive and time-consuming. A cost-effective method is the emerging use of the vessel monitoring scheme (VMS) via satellite surveillance (Murawski *et al.*, 2005; Hall-Spencer *et al.*, in press). However, there can be uncertainty over the type of fishing taking place, which requires corroborative evidence such as visual sightings (Kuruc, 2005), and VMS can be blocked or falsified leading some government authorities to investigate the use of remotely-sensed imagery as a complementary tool to support VMS evidence (Kourti *et al.*, 2005). The strong potential for satellite surveillance to be used as a tool to protect *L.pertusa* reefs has recently been illustrated using the Darwin Mounds, Rockall Bank and Hatton Bank closed areas as examples (Davies *et al.*, 2007; Rogers *et al.*, 2008; Hall-Spencer *et al.* in press).

## 4. Evaluation of threats and impacts

**Table 1:** Summary of the main threats and impacts to *Lophelia pertusa* reefs

Human activity	Pressure
Fishing	Damage or loss of species; Physical damage to habitat
Oil and gas exploration	Substratum change; contamination
Dumping of solid waste and dredged material	Increased siltation (deposited sediment)
Land-based activities (emissions and input from agriculture, forestry, industry, urban waste water)	Nutrient changes (eutrophication); hazardous substance & heavy metal contamination
Tourism and recreation activities (diving tourism in shallow areas)	Physical damage to reef
Research (scientific sampling)	Physical damage to reef

OSPAR (2005), the UN Secretary General (UNGA, 2006) and the International Council for the Exploration of the Seas (ICES, 2005) are agreed that the most threatened and easily impacted systems are ones that are both readily disturbed and are very slow to recover, or may never recover. An ongoing and continued threat to *L.pertusa* reefs in the OSPAR area has been verified and impacts have been documented by ICES (1999, 2002a, 2002b; 2005, 2007).

**Fishing:** Cold-water coral reefs are widely recognised as threatened marine ecosystems because they are slow-growing habitats that are easily impacted by the mechanical effects of fishing gear, especially bottom trawls but also gillnets, pots and benthic longlines (Freiwald *et al.*, 2004, Rogers *et al.*, 2008). Examples are documented from Ireland to Iceland and northern Norway where *Lophelia* is reported in commercial by-catch and side-scan sonar images reveal the extent of reef impacts including trawl door furrows and broken coral strewn on the seabed and photographs record ghost fishing nets tangled with corals and crushed reef systems (Rogers *et al.*, 2008).

In the past 20 years trawling, gillnetting, potting and longlining activities have extended into deeper waters and now occur to <1500 m depth leading to documented declines in the extent and status of this habitat in the following biogeographic zones; Deep Sea Atlantic (Hall-Spencer *et al.*, 2001), South Iceland – Faroe Shelf (ICES, 2002a, 2005), Norwegian Coast-West Norway (Fosså *et al.*, 2002, 2005; Fosså & Alvsvåg, 2003), Norwegian Coast-Skagerrak (Armstrong & van den Hove, 2008), Boreal-Lusitanian (Hall-Spencer *et al.*, 2001; Grehan *et al.*, 2005; ICES, 2003, Wheeler *et al.*, 2005) and Lusitanian-Boreal (Reveillaud *et al.*, 2008). Although no declines in *L.pertusa* reef habitat have been documented in the Lusitanian Warm North, Lusitanian Cool, Lusitanian Warm South and Macaronesian Azores biogeographic regions it is highly likely that damage has occurred in areas that lie outside the no-trawling region of the Azores (Hall-Spencer *et al.*, 2007). Fosså *et al.* (2000) estimated that *L.pertusa* covered 1500 - 2000 km<sup>2</sup> of seabed in the Norwegian EEZ and that 30 - 50% of the total reef area had been damaged by demersal fishing. Damage from fishing is predicted to remain a threat to *L.pertusa* reefs over the next decade throughout the OSPAR area.

**Other threats:** Fishing is the only threat that has led to a documented decline in *L.pertusa* reefs to date, but other threats include mining of deep-sea mineral resources and the more localised disturbances associated with hydrocarbon exploitation and carbon capture and storage, the effects of

dumping, the damage that can occur through scientific sampling and the effects of diving tourism in shallow areas. Additionally, where reefs are located in close proximity to the coast, most notably in Norway and Sweden, they are likely to be impacted by terrestrial inputs of nutrients and particulate matter, which might have contributed to the decline of *L.pertusa* reefs off the Swedish coast (Lisbeth Johnson, Tjarno Marine Lab., *pers com.* 2008.). Each of these potential threats needs to be considered if the *L.pertusa* reef habitats are to be managed effectively. There are also concerns that global increases in anthropogenic CO<sub>2</sub> and shifting ocean currents will alter the ecology of the OSPAR area and threaten *L.pertusa* reefs that have built-up over millennia (Davies *et al.*, 2007).

## 5. Existing management measures

Laws for the protection of *L.pertusa* reefs were developed by Norway in 1999 (Armstrong & van den Hove, 2008) and this initiative has been built on by the work of ICES (2002a, 2005, 2007) and the United Nations (Rodgers *et al.*, 2008), facilitating the establishment of a series of OSPAR-wide management measures designed to protect this habitat (Annex 2). So far 24 closed areas with known *L.pertusa* occurrences have been established in the OSPAR area, covering a total area of approximately 578 000 km<sup>2</sup>, approximately seven times the size of Ireland. Three closures within Icelandic waters, three closures in Faroes waters and six closures in Norwegian waters have been implemented at the national level (Annex 1). Certain *L.pertusa* reefs in areas under EU jurisdiction have been designated as Special Areas of Conservation under the Habitats Directive, as is the case with the four closures in the Irish EEZ. Restrictions to harmful fishing gear have either been adopted through an amendment to EC Regulation No 850/98 of the Common Fisheries Policy, as was the case with *L.pertusa* reefs on the Darwin Mounds (UK) and around the Azores (Portugal) or through the annual Council Regulations fixing the fishing opportunities and associated conditions. The latter route was chosen for the time being to protect the four reefs in Irish waters and on North West Rockall Bank. (Annex 1).

Parts of the OSPAR area outside national or EU fishing limits fall under the jurisdiction of the North-East Atlantic Fisheries Commission (NEAFC) which has closed seamounts, parts of the Mid Atlantic Ridge and five areas along the UK and Irish continental shelf through regulatory measures for the protection of deep-water corals (Annex 1).

As regards hydrocarbon exploration, Norway and the UK have offshore oil and gas industries that operate in areas of known *L.pertusa* habitat with similar developments planned off Ireland. National regulatory authorities for these industries require Strategic Environmental Assessment (SEA) and Impact Assessment (IA) in advance of new developments.

The last decade has seen a raft of *L.pertusa* reef mapping programmes carried out in Iceland, the Faroes, Norway, Sweden, UK, Ireland, France, Spain and monitoring of fishing activities around areas closed to protect *L.pertusa* habitat occurs as a regular part of fisheries control measures. To date there have been no prosecutions for violations of closures although preliminary analyses based on VMS indicate high levels of compliance with these closures (Davies *et al.*, 2007; Armstrong & van den Hove, 2008).

## 6. Conclusion on overall status

The following sections draw on parts 3-5 of this report to provide an updated evaluation of *L.pertusa* reefs against the Texel-Faial criteria.

**Table 2:** 2008 evaluation of *Lophelia pertusa* reefs against the Texel-Faial selection criteria

Texel-Faial criteria	Updated evaluation (2008)
Global importance	Globally important
Regional importance	Does not qualify
Rarity	Does not qualify
Sensitivity	' <b>very sensitive</b> ' to the effects of demersal trawling ' <b>sensitive</b> ' to the localised effects of oil and gas exploitation
Ecological significance	' <b>very important</b> '
Decline	' <b>significant decline</b> '
Threat	' <b>currently threatened</b> '

**Global Importance:** The ratio between known numbers of *L.pertusa* records within and outside the OSPAR area is similar to the previous evaluation of the habitat (OSPAR, 2005) and so this area is therefore still considered to be 'globally important'. At present 92% of global records for *L.pertusa* occur in the OSPAR area; there are 2072 records in the OSPAR area (Figure 2) and a database compiled by Freiwald *et al.* (2004) has a further 180 records for this species recorded from outside the OSPAR area. Although some of this difference in recorded numbers might be attributed to the fact that the deep-sea fauna in the OSPAR area is probably the best known worldwide, the high saturation levels of aragonite that occur in the OSPAR area are thought to make this area globally important for *L.pertusa* reef development (Guinotte *et al.*, 2006; Davies *et al.*, 2008).

**Regional Importance:** Regional importance was not considered in the OSPAR (2005) evaluation but Figure 2 shows that the importance of *L.pertusa* reefs varies between regions. Norway has all of the world's most extensive *L.pertusa* reefs and also has the shallowest known examples of this habitat, so OSPAR Region I is important for this reason. The reefs are also important in OSPAR Regions II-V as they provide habitat for assemblages of associated species that change depending on depth and biogeographic region. In Region V their periodic growth over the past 1 - 2 million years has led to the formation of coral carbonate mounds up to 350 m high. As the habitat occurs throughout the OSPAR area, it does not qualify for this criterion.

**Rarity:** The rarity of *L.pertusa* reefs was not assessed in the last Texel-Faial evaluation and is difficult to determine for the OSPAR area as a whole due to the high regional variability in abundance and in some cases lack of knowledge of whether live reefs are still present at the sites of historical records. This habitat is absent in Arctic waters and despite the greater ease of sampling at shallow depths <0.1% of *L.pertusa* records are from <50 m and it is 'rare' at depths <87 m as only 2% of records are known from these depths. As *L.pertusa* is known from numerous locations around the Azores and on the Reykjanes Ridge south of Iceland it seems likely that it will occur in suitable parts of the Mid Atlantic Ridge. *L.pertusa* is known to occur all along the European shelf from Gibraltar to Finnmark and of the 1407 *L.pertusa* records that give precise depth information for the OSPAR area, 75% are from 190 – 880 m depth. This habitat is 'rare' (<2% of records) below 1400 m depth but is not considered rare in the OSPAR area as a whole (David Connor, JNCC, *pers.com.* 2008).

**Sensitivity:** None of the research into *L.pertusa* reefs that has been published since OSPAR (2005) alters the evaluation of this habitat as 'very sensitive' to the effects of demersal trawling. These habitats are easily damaged and recovery is likely to be achieved only over a very long period (>25 years), if at all. The reefs are also 'sensitive' to the localised effects of oil and gas drilling and scientific research sampling as they can be damaged by mechanical impacts and disturbed sediment and recovery is likely to take a long time (>5 years) to occur. Knowledge of the sensitivity to chemical discharges from hydrocarbon exploration is still limited; however there are currently studies by both the International Research Consortium on Continental Margins and the International Research Institute of Stavanger underway which are expected to be completed in 2010 to address this issue (Lisbeth Johnson, Tjarno Marine Lab., *pers.com.* 2008). There are no data on the sensitivity of these reefs to climate change, although concerns have been raised that reefs in OSPAR Region 1 will be lost over the next 100 years due to ocean acidification.

**Ecological significance:** Although the OSPAR (2005) assessment noted the much higher biodiversity of *L.pertusa* reefs relative to surrounding areas, ecological significance was not explicitly assessed. These habitats are high in biodiversity (>1300 spp listed from OSPAR *L.pertusa* reefs to date), studies are ongoing and revealing a growing inventory of species that are new to science. Hence, *L.pertusa* reefs are 'very important' with regards to their ecological significance. Furthermore they support species and ecosystem processes over a much wider area than the habitat itself. For example, they are spawning grounds for invertebrates, they offer refuge to diurnally migrating crustaceans and provide feeding areas for fish.

**Decline:** There has been a 'significant decline' in extent and quality of *L.pertusa* reefs in OSPAR Region I (30 – 50% of reefs are impacted off Norway) and similar levels of decline are thought to have occurred in OSPAR Regions II-V. Since OSPAR (2005), pilot assessments using VMS have been made on behalf of NEAFC, ICES and IUCN which show intense deep-sea trawling effort in regions of known *L.pertusa* occurrence in the years 2005 - 2007 (ICES 2007; Rogers *et al.*, 2008; Hall-Spencer *et al.*, in press). Declines in the extent and quality of *L.pertusa* reefs have been brought about by commercial fishing activities historically on shelf areas and more recently to depths of 1500 m. An OSPAR-wide assessment of bottom fishing activities likely to impact vulnerable marine ecosystems has not been done, but individual studies show this varies greatly between regions with little known impact around the Azores, for example, but high impact along the continental slope from Ireland north to Norway (Hall-Spencer *et al.*, 2001).

**Threat:** The habitat is considered 'currently threatened' as the present rate of *L.pertusa* reef decline linked directly to human activity exceeds that which can be expected from what is known about long-term natural variability and resilience in *L.pertusa* habitats. The past few years have seen NEAFC, Iceland, Norway, the Faroes, the EU and some EU member states (Sweden, the UK and Ireland) set up areas to restrict the use of bottom gear to protect *L.pertusa* reef habitat (see Annex 1). Assessments of fishing activities are needed to determine whether these protected areas are working and assessments are needed to determine how much *L.pertusa* reef habitat lies outside the protected areas and is threatened.

## 7. Action to be taken by OSPAR

### Action/measures that OSPAR could take, subject to OSPAR agreement

As set out in Article 4 of Annex V of the Convention, OSPAR has agreed that no programme or measure concerning a question relating to the management of fisheries shall be adopted under this Annex. However where the Commission considers that action is desirable in relation to such a question, it shall draw that question to the attention of the authority or international body competent for



that question. Where action within the competence of the Commission is desirable to complement or support action by those authorities or bodies, the Commission shall endeavour to cooperate with them.

It has been agreed by OSPAR that *L.pertusa* reefs face grievous threat and are declining due to destructive fishing practices. Some of the areas with known *L.pertusa* reefs have now been closed to particular types of fishing in OSPAR waters.

As further supportive and complementary actions it is proposed that the OSPAR Commission should

- amend the title of the habitat on the OSPAR List to reflect the inclusion of other corals, such as *Madrepora oculata*, which are within the scope of this habitat type;
- agree on what percentage of known *L.pertusa* reef area it is desirable to protect;
- assess whether existing management measures for the protection of *L.pertusa* reefs are effective, and what further measures, if any, might be needed to assess the key threats;
- urge EU Member States to consider the designation of further *L.pertusa* reefs in their waters as Special Areas of Conservation under the Habitats Directive;
- recommend that Contracting Parties intensify their work to identify, select and effectively manage sites where *L.pertusa* reefs are known to exist as OSPAR Marine Protected Areas;
- contact relevant fisheries management authorities to:
  - urge further consideration of the need for measures to protect *L.pertusa* reefs in the OSPAR area;
  - ask them to facilitate access to VMS data to allow comparison of the geographical distributions of *L.pertusa* and fishing activities;
- contact national and international research funding agencies to urge that they:
  - support and facilitate acoustic mapping to locate *L.pertusa* reefs (only Ireland has a complete set of modern charts);
  - support and facilitate visual surveys of reefs and report on their status.

#### **Brief summary of proposed monitoring system**

Minimum recommended:

- Monitor fishing activities around *L.pertusa* reefs;
- Assess and report on compliance with closed areas;
- Assess and seek to mitigate any damaging effects of planning proposals (e.g. for oil and gas) likely to affect habitat.

Preferably include:

- Monitor changes in carbonate chemistry at selected reefs in OSPAR Region I;
- Carry out periodic (e.g. every 6 years) assessments of habitat extent through acoustic surveys at selected sites;
- Carry out periodic video assessments (e.g. 6 years) of habitat condition at selected sites, including percentage cover of live and dead or destroyed coral.

## Annex 1: Overview of data and information provided by Contracting Parties

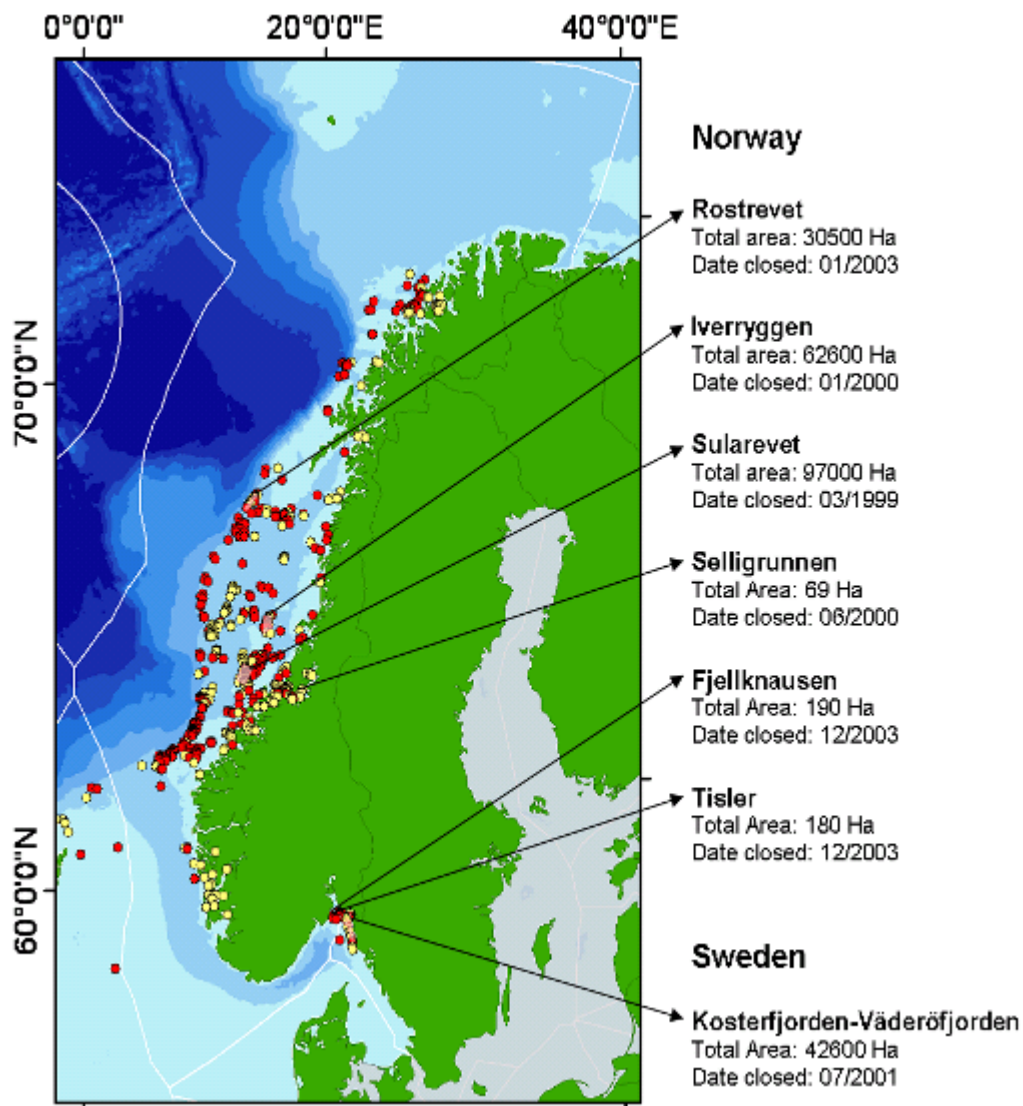
Contracting Party	Feature occurs in CP's Maritime Area	Contribution made to the assessment (e.g. data/information provided)	National reports References or weblinks
Belgium	N	Y	Jean-Pierre Henriët, University of Ghent
Faroës	Y	N	Eilif Gaard (Fisheries Research Services, Faroës). Ministry of Fisheries and Natural resources, 2008. Faroë Islands Fisheries and Aquaculture – Responsible Management for a Sustainable Future. <a href="http://www.faroeislands.org.uk/Default.aspx?ID=437&amp;M=News&amp;PID=1024&amp;NewsID=1329">http://www.faroeislands.org.uk/Default.aspx?ID=437&amp;M=News&amp;PID=1024&amp;NewsID=1329</a>
European Commission	Y	N	
France	Y	Y	<i>L. pertusa</i> database collected and formatted by F. Quemerrais (A-AMP) in partnership with Ifremer (B. Guillaumont, K. Olu, E. Le Guilloux), supplied by Amelia Curd (Agence pour les Aires Marines Protégées).
Germany	N	Y	Jeff Ardron (MCBI) and Sabine Christiansen (WWF)
Iceland	Y	Y	Steinunn Hilma Ólafsdóttir (Institute of Marine Research)
Ireland	Y	Y	Eamon Kelly (Department of the Environment, Heritage & Local Government (DEHLG)). Andrew Wheeler (University of Cork).
Netherlands	N	N	
Norway	Y	Y	Institute of Marine research, 2007. Cruise Report R/V G.O. Sars, Cruise No. 2007105, 2nd leg, 14th– 20th April 2007, Coral survey off Northern Norway, J.H. Fosså, P. Mortensen (Institute of Marine research, Bergen, Norway). & M. Hoveland (Statoil, Stavanger, Norway).
Portugal	Y	Y	<i>L. pertusa</i> records from the collection of the Department of Oceanography and Fisheries (Gui Menezes, University of the Azores, Portugal).
Spain	Y	Y	Unpublished <i>L. pertusa</i> data from Alberto Serrano (Instituto Español de Oceanografía, Centro Oceanográfico de Santander, Spain) and Álvaro Altuna Paseo de Arriola, San Sebastián, Spain
Sweden	Y	Y	Lisbeth Jonsson (Tjarnö Marine Lab.)
UK	Y	Y	Nikki Chapman (JNCC) background OSPAR documents and OSPAR <i>Lophelia</i> records. David Connor (JNCC) – advice.

*Lophelia pertusa* Reefs were originally nominated for inclusion in the OSPAR List in 2001 by Norway, UK and WWF.

### Summaries of country-specific information provided

**Norway and Sweden:** The Institute of Marine Research (Bergen, Norway) conducted a research survey aimed at verifying the occurrence of *L. pertusa* off the coast of Finnmark, northern Norway and found that *L. pertusa* was not present at sites east of 23°E (Pål Mortensen, IMR, *pers.com.* 2008). However *L. pertusa* was recorded previously in this location (records submitted to the OSPAR habitats database from Dons, 1935, 1944; Fosså *et al.*, 2000; IMR database).

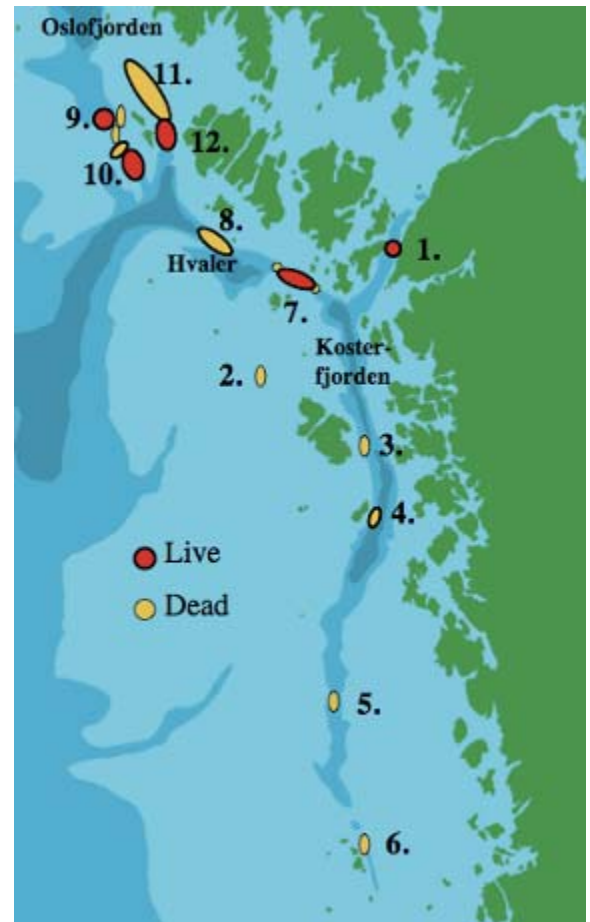
Recent microbial research shows that *L.pertusa*, and some of its associated fauna, relies on locally produced chemosynthetic microbes, which are independent of photosynthesis (Jensen et al., 2008; Martin Hoveland, Statoil, Norway, pers.comm. 2008).



**Figure 3.** Occurrence of *L.pertusa* (yellow dots >10 y old records, red dots <10 y old records) around Norway and Sweden with *L.pertusa* management closures indicated. White lines indicate EEZ boundaries. Bathymetry is shown in 0-200 m, 200-500 m and then 500m depth intervals.

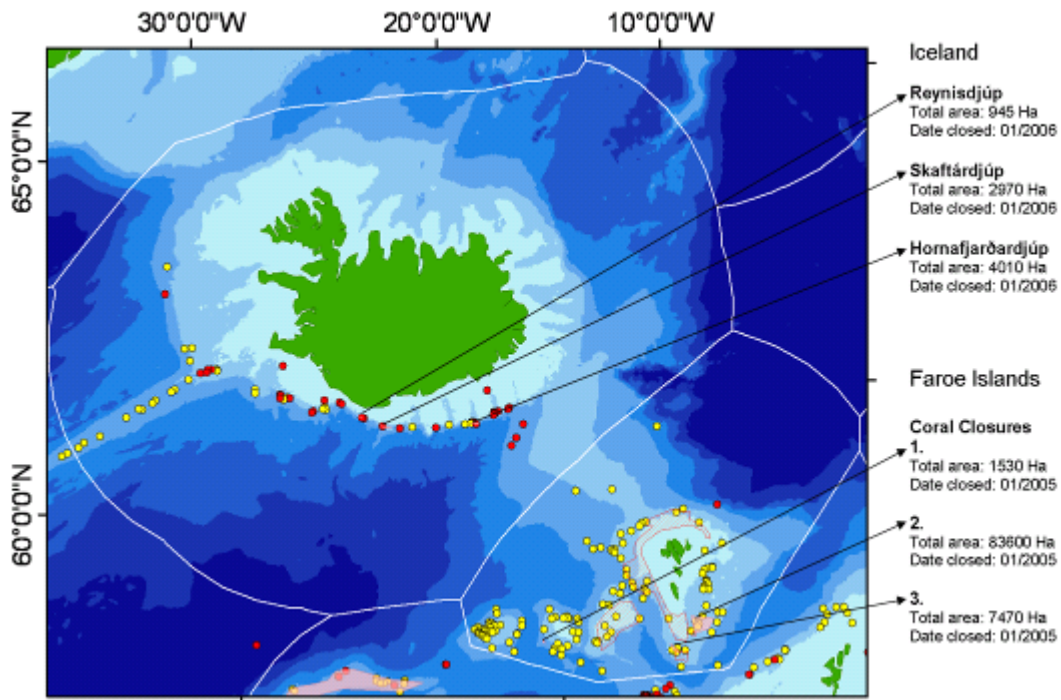
Lisbeth Johnson (Tjarno Marine Lab., Sweden) provided information on the current status of *L.pertusa* reefs in the Kosterfjorden-Väderöfjorden protected area in the Swedish EEZ and adjacent Norwegian waters. She reported that all but one of the six known reefs in the area have been reduced to rubble. Thorough surveys have been made of the Kosterfjord itself but there is the possibility that undiscovered reefs are located in the Skagerrak. Although it is not known how long the reefs have been dead for, reports from fishermen indicate that live coral was still present at two of the reefs 25 years ago. Trawling is considered to be the main reason for their disappearance, yet, due to the reefs' proximity to the coast other factors such as nutrient and suspended particle land runoff might have contributed. Due to a lack of data, it is unclear how large the reefs were prior to their destruction.

**Figure 4.** Areas of *L.pertusa* off the Norwegian-Swedish border where all sites are small (a few 100 m<sup>2</sup>). Sweden (1) Säcken reef, two patches of live and dead corals about 500 m<sup>2</sup> (protected 2001), (2) some dead coral colonies found 2007, extent unknown, presence of live coral unknown, last record of live coral is from 1913, plans are ongoing to protect this site from trawling, (3) small amounts of coral rubble, no records of how long ago the reef was alive but considering the small remains found it has probably been dead considerably longer than 25 years (protected 2001), (4) small amounts of coral rubble and no records of how long ago the reef was alive, considering the small remains found it has probably been dead considerably longer than 25 years (protected 2001), (5) large amount of rubble, live coral found here ca 25 years ago (protected 2001), (6) some rubble, live coral found here ca 25 years ago (protected 2001). Norway (7) Tisler-reef ca 0.5 km<sup>2</sup> in extent including live and dead reef – this is the biggest in the area (protected 2004). Several smaller areas with live and/or dead *L.pertusa* have been found in the Hvaler-area, all are estimated to be 0.05 - 0.2 km<sup>2</sup> (9) North Fjellknausene both live and dead small reefs (protected 2007), (10) Fjellknausene several small live and dead reefs (protected 2004), (11) North Søndre Søstrene only dead reefs found (protected 2007), (12) South Søndre Søstrene with at least six small live reefs and several dead reefs (protected 2007), (8) Djupekrakk, only dead *L.pertusa* found.



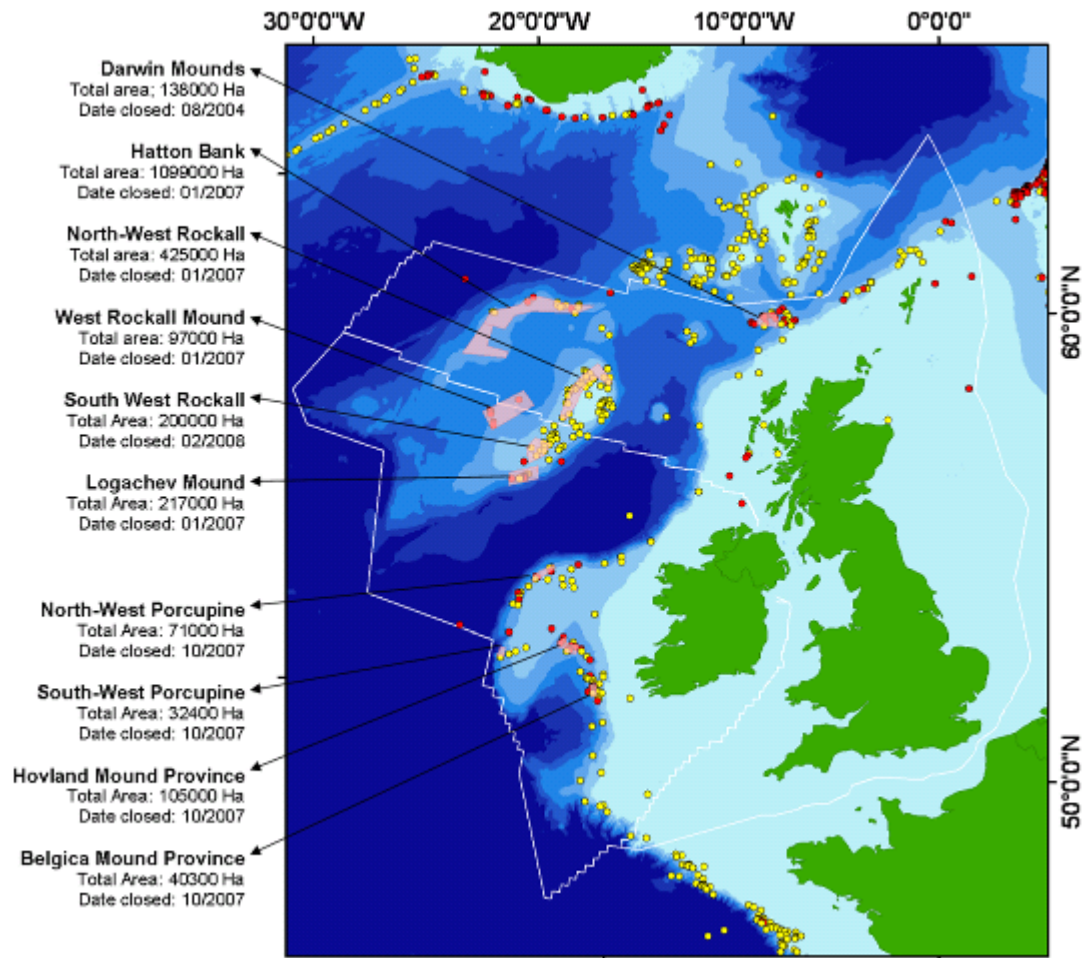
**Iceland and the Faroes:** Steinunn Hilma Ólafsdóttir (Institute of Marine Research, Iceland) noted that there are no new data on the occurrence, extent or status of *L.pertusa* reefs since their surveys in 2004 and that Figure 5 provides an up-to-date set of the Icelandic *L.pertusa* reef protected areas.

Kate Sanderson (Faroese Ministry of Fisheries and Natural Resources) advised that when describing protection levels, risks, and likely impacts, it should be noted that in addition to three specific coral protection areas that were established around the Faroes in 2005, a large part of the Faroe Plateau (60% of areas to 200 m depth) and most of the Faroe Bank is off-limits to trawling all year but these areas are open to static demersal gear types. Eilif Gaard (Faroes Fisheries Research Service) noted that there is evidence of past fishing damage to their reefs but not of on-going damage to the reefs.



**Figure 5.** Occurrence of *L.pertusa* (yellow dots >10 years old records, red dots <10 years old records) around Iceland and the Faroes with *L.pertusa* management closures indicated. Hatched red areas indicate areas closed to bottom trawling for other management purposes. White lines indicate EEZ boundaries. Bathymetry is shown in 0 - 200 m, 200 - 500 m and then 500 m depth intervals.

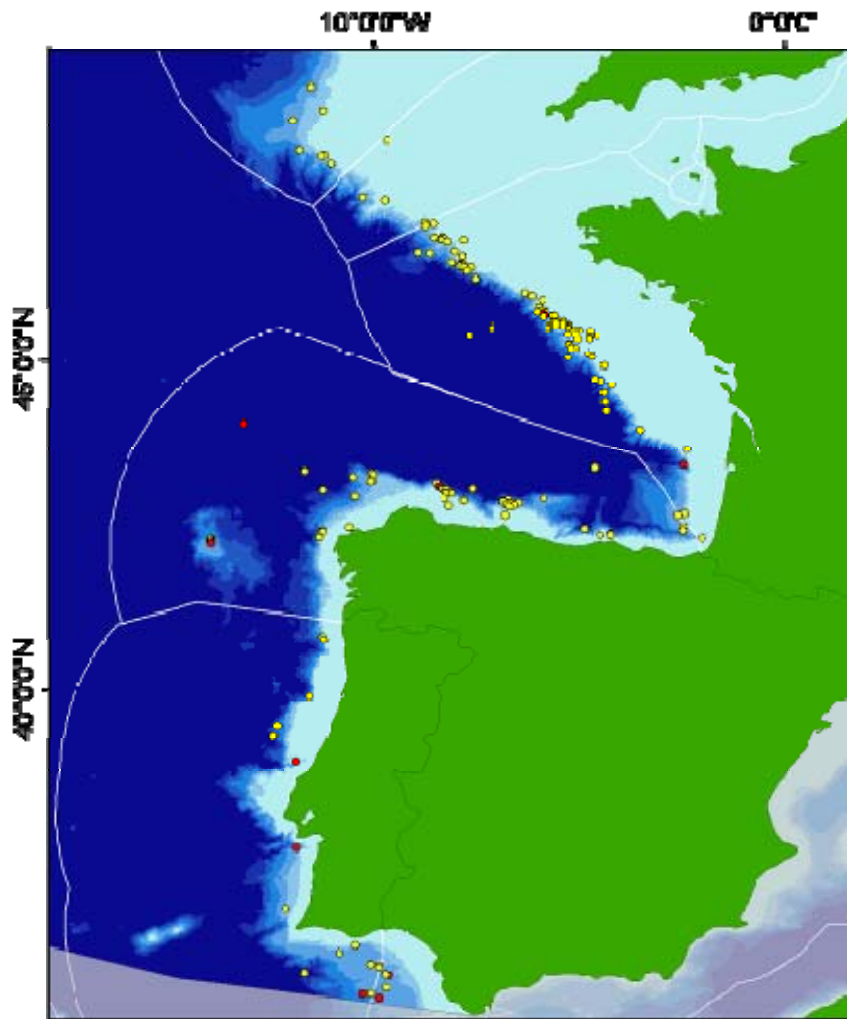
**UK and Ireland:** Eamonn Kelly (Dept. Environment, Heritage & Local Government, Ireland) reported that Ireland currently has four sites which contain *L.pertusa* designated as SACs under the Habitats Directive (Figure 6). The principle threats to *L.pertusa* reefs in these areas were identified as commercial fisheries, oil and gas development and marine scientific research (MSR). In response to these threats at these sites, the EU Council of Fisheries Ministers agreed in 2007 to ban all bottom fishing and created a notification system for access by pelagic fishing vessels. Ireland also decided not to open two of the sites to oil and gas exploration during the 2007 offshore Strategic Environmental Assessment (SEA) and two further sites are under consideration during the current 2008 SEA process. Ireland has also created a permit system and code of practice for MSR activities at the sites. Future monitoring of the site will be through monitoring of human usage and adherence to management arrangements. In addition, 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.



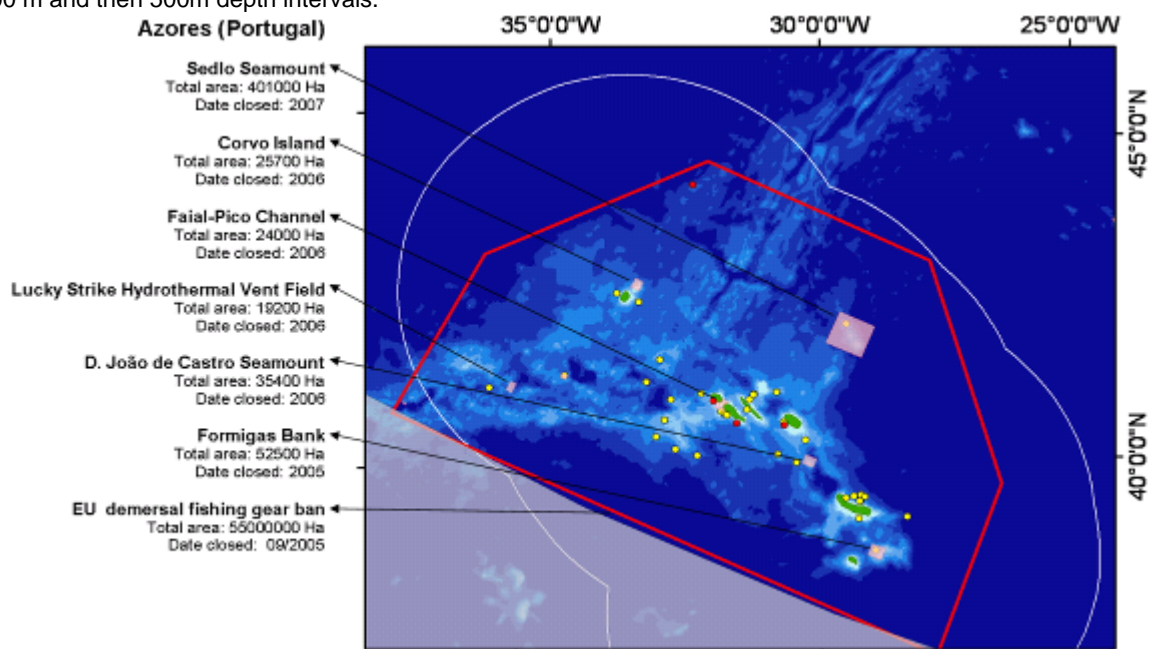
**Figure 6.** Occurrence of *L.pertusa* (yellow dots >10 years old records, red dots <10 years old records) around the UK and Ireland with management closures containing *L.pertusa* indicated. White lines indicate the UK and Irish continental shelf boundaries. Bathymetry is shown in 0 - 200 m, 200 - 500 m and then 500 m depth intervals. The exact limits of the UK Continental Shelf are set out in orders made under section 1(7) of the Continental Shelf Act 1964 (© Crown Copyright). Map produced for illustration purposes only.

**Bay of Biscay, Iberian Shelf and Azores:** Brigitte Guillaumont (Ifremer, France) reported that in French waters, *L.pertusa* occurs along the continental margin of the Bay of Biscay as patch-reefs. Published and unpublished records have been censused recently by Reveillaud *et al.* (2008) and completed by A-AMP and Ifremer. According to Le Danois' (1948) description and recent surveys, *L.pertusa* occurrence may be underestimated in the deeper zone. A recent survey from the Renard Centre of Marine Geology, Belgium (Biscosystem cruise, 2008) confirms the presence of important *L.pertusa* reefs around 800 m depth and new surveys are planned (2008 - 2010) to confirm this from a regional point of view. The principle threat in this area was identified as commercial fisheries. Historically, trawling occurred mainly in the upper part of the *L.pertusa* zone. No closures with known *Lophelia* records currently exist within the French EEZ, but there are restrictions on deep-water commercial fisheries. New surveys are planned to better estimate the distribution of *L.pertusa* reefs and fisheries impact.

Álvaro Altuna (Paseo de Arriola, Spain) noted that in the southern Bay of Biscay fishing is the main threat to *L.pertusa* reefs, not only through trawling, but perhaps also due to the nets that are lost or abandoned by the vessels and that very likely keep on moving across the bottom.



**Figure 7.** Occurrence of *L.pertusa* (yellow dots >10 years old records, red dots <10 years old records) in the Bay of Biscay and along the Iberian Shelf. White lines indicate EEZ boundaries. Bathymetry is shown in 0-200 m, 200-500 m and then 500m depth intervals.



**Figure 8.** Occurrence of *L.pertusa* (yellow dots >10 years old records, red dots <10 years old records) around the Azores showing the EEZ (white lines), the EU demersal trawling ban area (2005) and six protected areas. Bathymetry is shown in 0 - 200 m, 200 - 500 m and then 500 m depth intervals.

## Annex 2: Detailed description of the recommended monitoring and assessment strategy

### Rationale for proposed monitoring

The proposed approach is designed to provide an appropriate assessment of extent, distribution and condition of *L.pertusa* and associated macrofauna reef inhabitants, to yield information on damage and/or recovery of reefs and adjacent substratum types from human impacts and the effects of ocean acidification at high latitude reefs. It is also intended to provide a means of assessing the effectiveness of management measures which are in place.

### Use of existing monitoring programmes

At present there are no monitoring programmes established for *L.pertusa* habitat, although sites protected as SACs should be subject to periodic monitoring. Records of change have come from fisher's knowledge and/or sequential scientific research surveys.

### Synergies with monitoring of other species or habitats

Deep-sea surveys are usually expensive due to their remote location so *L.pertusa* reef monitoring should be combined with assessments of other deep-sea habitats and species where possible. Monitoring of other OSPAR features, such as carbonate mounds, canyons, coral gardens and deep-sea sponge habitats could be synergized with *L.pertusa* 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.

### Assessment criteria

Visual surveys need to quantify the amount of live and dead coral and its associated (sessile) macrofauna and be tailored to the main threats to the reef habitats in the areas selected. For example, if the reefs can be fished the visual surveys should monitor trawl scars, entangled nets, ghost fishing, and mechanical damage; if the reefs are sampled scientifically using destructive techniques the surveys need to monitor the extent of damage and recovery of sampled areas; if the reefs are adjacent to oil or gas drilling then the effects of drill cuttings, sediment disturbance and infrastructure should be targeted. As regards the impacts of ocean acidification, aragonite saturation states and any associated changes in coral skeletal growth and bioerosion should be recorded at high latitude reefs.

### Techniques/approaches

The design and execution of monitoring programmes needs to be site-specific and depend upon depth, location, available technologies and prevailing threats. Acoustic techniques are needed to determine the extent of reef systems - Fosså *et al.* (2005) provide a summary of these. Visual surveys of reefs are 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 using divers for the shallowest examples, and with drop-down video, ROVs and submersibles for the deeper reef systems. Rogers *et al.* (2008) set out recent and emerging techniques available for monitoring human impacts to *L.pertusa* reefs (*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 and gas



development and marine scientific research) likely to affect protected areas of *L.pertusa* reef. 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 *L.pertusa* reefs in all unprotected areas where this species has been reported to occur. Whilst destructive sampling will not be necessary and should be avoided in most instances, small amounts of sampling would be required to assess the effects of ocean acidification.

## Selection of monitoring locations

Monitoring is required for sites holding *L.pertusa* reefs that are Special Areas of Conservation under the Habitats Directive, such as the Darwin Mounds in UK waters and NW Porcupine, SW Porcupine, Hovland Mound Province and Belgica Mound Province in Irish waters. Complete and detailed acoustic surveys should be undertaken for areas with *L.pertusa* records that have been closed to demersal fishing activities, to determine the likely extent of the reef systems. It would be desirable to also obtain acoustic survey data for all areas with *L.pertusa* records. It is important to verify whether old records represent the existence of reefs as, for example, some of the reefs of another species (*Dendrophyllia cornigera*) mentioned by Le Danois (1948) from the southern part of the Bay of Biscay are not present at the coordinates he gave in his book, which might also be the case with *Lophelia* records (Alvaro Altuna, Paseo de Arriola, Spain, *pers. com.* 2008). Once priority areas of recorded *L.pertusa* occurrence have undergone baseline surveys, acoustic surveys could then be made of relatively unexplored regions that are likely to support *L.pertusa* reef development, such as the 100 - 1500 m depth band along the Mid Atlantic Ridge and around Jan Mayen Island. On the basis of these surveys, targeted visual surveys could then be made of likely reef habitat, including a range of sites from damaged to unaffected sites.

## Timing and frequency of monitoring

To manage *L.pertusa* reefs effectively, continuous assessment of fishing activities in all areas of known reef habitat is recommended, as these activities are known to be the main threat to this habitat. There is a risk that destructive fishing activities present an ongoing conflict with the conservation status of *L.pertusa* reefs even within protected areas. Policing of closures is a highly important element of monitoring; if this attains full compliance then costly annual visual surveys of reef status should not be necessary.

After baseline surveys are complete, repeat surveys should target areas where there is good reason for concerns over a reduction in habitat status. Examples may include fisheries infringements, pollution events or measurable declines in aragonite saturation. 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-year reporting cycle 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.

## Annex 3: References

- Alvarez-Perez, G., Busquets, P., de Mol, B., Sandoval, N.G., Canals, M. and Casamor, J.L., 2005. Deep-water coral occurrences in the Strait of Gibraltar. In: Cold-water corals and ecosystems. Edited by Freiwald, A. and Roberts, J.M., Springer, Berlin. pp. 207-221.
- Armstrong, C.W. and van den Hove, S., 2008. The formation of policy for protection of cold-water coral off the coast of Norway. *Marine Policy* 32, 66-73.
- Bell, N. and Smith, J., 1999. Coral growing on North Sea oil rigs. *Nature* 402, 601.
- Bruntse, G. and Tendal, O.S. (2001) Marine biological observations and assemblages of benthic invertebrates from the Faroe islands. *Kaldbak Marine Biological Library (Faroe)*. 1-12.
- Cairns, S.D., 1994. Scleractinia of the Temperate North Pacific. *Smithsonian Contributions to Zoology* 557, pp. 150
- Copley, J., Tyler, P.A., Shearer, M., Murton, J. and German, C.R., 1996. Megafauna from sublittoral to abyssal depths along the Mid-Atlantic Ridge south of Iceland. *Oecologica Acta* 19, 549-559.
- Costello, M.J., McCrea, M., Freiwald, A., Lundalv, T., Jonsson, L., Bett, B.J., van Weering, T., de Haas, H., Roberts, J.M. and Allen, D., 2005. Role of cold-water *Lophelia pertusa* coral reefs as fish habitat in the NE Atlantic. In: Cold-water corals and ecosystems. Edited by Freiwald, A. and Roberts, J.M., Springer, Berlin. pp. 771-805.
- Davies, A., Roberts, J.M. and Hall-Spencer, J.M., 2007. Preserving deep-sea natural heritage: emerging issues in offshore conservation and management. *Biological Conservation* 138, 299-312.
- Davies, A.J., Wisshak, M., Orr, J.C. and Roberts, J.M., 2008. Predicting suitable habitat for the cold-water coral *Lophelia pertusa* (Scleractinia). *Deep Sea Research I* 55, 1048-1062.
- De Mol, B., Henriët, J.P. and Canals, M., 2005. Developments 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.
- De Mol, B., van Rensbergen, P., Pillen, S., van Herreweghe, K., van Rooij, D., McDonnell, A., Huvenne, V., Ivanov, M., Swennen, R. and Henriët, J.-P., 2002. Large deep-water coral banks in the Porcupine Basin, southwest of Ireland. *Marine Geology* 188, 193-291.
- Dinter, W., 2001. Biogeography of the OSPAR Maritime Area. German Federal Agency for Nature Conservation, Bonn. 167.
- Dodds, L.A., Roberts, J.M., Taylor, A.C. and Marubini, F., 2007. Metabolic tolerance of the cold-water coral *Lophelia pertusa* (Scleractinia) to temperature and dissolved oxygen change. *Journal of Experimental Marine Biology and Ecology* 349, 205-214.
- Dons, C., 1944. Norges korallrev. *Det Kongelige Norske Videnskabers Selskabs Forhandling* 16, 37-82.
- Duineveld, G.C.A., Lavaleye, M.S.S. and Berghuis, E.M., 2004. Particle flux and food supply to a seamount cold-water coral community (Galicia Bank, NW Spain). *Marine Ecology Progress Series* 277, 13-23.
- Duncan, P.M., 1873. A description of the Madreporaria dredged up during the Expeditions of H.M.S. 'Porcupine' in 1869 and 1870. *Trans. Zool. Soc. Lond.* 8, 303-344.

Fosså, J.H., Mortensen, P.B. and Furevik, D.M., 2000. *Lophelia*-korallrev langs Norskekysten forekomst og tilstand. *Fisken og Havet* 2/2000. Havforskningsinstituttet, Bergen.

Fosså, J.H., Mortensen, P.B. and Furevik, D.M., 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. *Hydrobiologia* 471, 1–12.

Fosså, J.H. and Alvsvåg, J., 2003. Mapping and monitoring of coral reefs. In: *Havets Miljø 2003 - Fisken og Havet*, special issue 2/2003. Edited by Asplin, L., and Dahl, E., Havforskningsinstituttet, Bergen. pp. 62–67.

Fosså, J.H., Mortensen, L.B., Christensen, O., Lundälv, T., Svellingen, I., Mortensen, P.B. and Alvsvåg, J. 2005. Mapping of *Lophelia* reefs in Norway: experiences and survey methods. In: *Cold-water corals and ecosystems*. Edited by Freiwald, A. and Roberts, J.M., Springer, Berlin. pp. 359-391.

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

Fredericksen, R., Jensen, A. and Westerberg, H., 1992. The distribution of the scleractinian coral *Lophelia pertusa* around the Faroe Islands and the relation to internal tidal mixing. *Sarsia* 77, 157–171.

Freiwald, A. & Wilson, J.B. 1998. Taphonomy of modern deep, cold-temperate water coral reefs. *Historical Biology*, 13, 37-52.

Freiwald, A., Wilson, J.B. and Henrich, R., 1999. Grounding Pleistocene icebergs shape recent deep-water coral reefs. *Sedimentary Geology* 125, 1–8.

Freiwald, A., Hühnerbach, V., Lindberg, B., Wilson, J.B. & Campbell, J. 2002. The Sula Reef complex, Norwegian Shelf. *Facies* 47, 179-200.

Freiwald, A., Fosså, J.H., Grehan, A., Koslow, J.A. and Roberts, J.M. 2004. Cold-water coral reefs: out of sight no longer out of mind. UNEP-WCC, Cambridge. pp. 84.

Freiwald, A. and Roberts, J.M. eds., 2005. *Cold-water corals and ecosystems*. Springer, Berlin.

Gass, S.E., Roberts, J.M., 2006. The occurrence of the cold-water coral *Lophelia pertusa* (Scleractinia) on oil and gas platforms in the North Sea: Colony growth, recruitment and environmental controls on distribution. *Marine Pollution Bulletin* 52, 549-559.

Gordon, J.D.M., Bergstad, O.A., Figueiredo, I. and Menezes, G., 2003. The deep-water fisheries of the Northeast Atlantic: I Description and current trends. *Journal of Northwest Atlantic Fishery Science* 31, 137-150.

Gravier, C., 1915. Note préliminaire sur les Madréporaires recueillis au cours des croisières de la Princesse-Alice et de l'Hirondelle II, de 1893 a 1913 inclusivement. *Bulletin de l'Institut Océanographique Monaco* 12, 1–22.

Gravier, C., 1920. Madréporaires provenant des campagnes des yachts Princesse Alice et Hirondelle II (1893-1913). *Résultats des Campagnes Scientifiques du Prince Albert Ier de Monaco* 55, 1–123, pls. 1–16.

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.

Guerra-Garcia, J.M., Sorbe, J.C. and Frutos, I., 2008. A new species of *Liropus* (Crustacea, Amphipoda, Caprellidae) from the Le Danois Bank (southern Bay of Biscay). *Org. Divers Ecol.* 7, 253-264.

Guinotte, J.M., Orr, J.C., Cairns, S.D., Morgan, L., George, R., 2006. Will human-induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals? *Frontiers in Ecology and the Environment* 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., Rogers, A., Davies, J. and Foggo, A., 2007. Historical deep-sea coral distribution on seamount, oceanic island and continental shelf-slope habitats in the NE Atlantic. In: *Conservation and adaptive management of seamount and deep-sea coral ecosystems*. Edited by George, R.Y. and Cairns, S.D., Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami. pp. 324.

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

Henry, L.A. and Roberts, J.M., 2007. Biodiversity and ecological composition of macrobenthos on cold-water coral mounds and adjacent off-mound habitat in the bathyal Porcupine Seabight, NE Atlantic. *Deep Sea Research I* 54, 654-672.

Hovland, M., 2008. *Deep-water coral reefs: Unique Biodiversity hotspots*. Praxis Publishing (Springer), Chichester, UK, 278 pp.

Hovland, M., Mortensen, P.B., Brattegard, T., Strass, P. and Rokoengen, K., 1998. Ahermatypic coral banks off mid-Norway: Evidence for a link with seepage of light hydrocarbons. *Palaios*, 13, 189-200.

Husebo, A., Nottestad, L., Fosså, J.H., Furevik, D.M. and Jorgensen, S.B., 2002. Distribution and abundance of fish in deep-sea coral habitats. *Hydrobiologia* 471, 91-99.

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, 2002a. Report of the Study Group on Mapping the Occurrence of Cold Water Corals. ICES CM 2002/ACE:05. Ref:E, WGECO.

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

ICES, 2005. Report of the Working Group on Deep-water Ecology, 8-11 March, 2005, ICES Headquarters, Copenhagen. ICES CM 2005/ACE:02. pp 76.

ICES, 2007. Report of the Working Group on Deep-water Ecology, 26-28 February 2007, Marine Biological Association Plymouth, ICES CM 2007/ACE:01 REF.LRC

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

Jensen S., Neufeld J. D., Birkeland N. K., Hovland M. and Murrell J. C. 2008. Insight into the microbial community structure of a Norwegian deep-water coral reef environment. *Deep Sea Research Part I*. doi:10.1016/j.dsr.2008.06.008.

- Jonsson, L.G., Nilsson, P.G., Floruta, F. and Lundalv, T., 2004. Distributional patterns of macro and megafauna associated with a reef of the cold-water coral *Lophelia pertusa* on the Swedish west coast. *Marine Ecology Progress Series* 284, 163-171.
- Joubin, L., 1922a. Les coraux de mer profonde nuisibles aux chalutiers. Notes et mémoires. Office scientifique et technique des pêches maritimes 18. pp. 16.
- Joubin, L., 1922b. Distribution géographique de quelques coraux abyssaux dans les mers occidentales européennes. *Compte rendu hebdomadaire des séances de l'Académie des sciences* 175, 930–933.
- Jourdan, E., 1890. Note préliminaire sur les zoanthaires provenant des campagnes du yacht l'Hirondelle (Golfe de Gascogne, Açores, Terre-Neuve, 1886, 1887, 1888). *Bulletin de la Société Zoologique de France* 15, 174–176.
- Jourdan, E., 1895. Zoanthaires provenant des campagnes du yacht l'Hirondelle (golfe de Gascogne, Açores, Terre Neuve). *Résultats des Campagnes Scientifiques du Prince Albert 1er de Monaco* 8, 1–36, pls. 1–2.
- Kourti, N., Shepherd, I., Greidanus, H., Alvarez, M., Aresu, E., Bauna, T., Chesworth, J., Lemoine, G. and Schwartz, G., 2005. Integrating remote sensing in fisheries control. *Fisheries Management and Ecology* 12, 295-307.
- Kuruc, M., 2005. Vessel Monitoring System (VMS) proves the case in court. In: *Deep Sea 2003: Conference on the Governance and Management of Deep-sea Fisheries, Part 1: Conference Reports*. Edited by Shotton, R., Food and Agriculture: Fisheries Proceedings 3/1, Queenstown, New Zealand. pp. 342-362.
- Le Danois, E., 1948. Les profondeurs de la mer. Trente ans de recherche sur la faune sous-marine au large des côtes de France, Payot, Paris. pp. 303.
- Linné, C. 1758. *Systema naturae per Regna tria naturae, secundum classes, ordines, genera, species*. Tomus I. Regnum animale. 10 Edition, Stockholm, 824 p.
- Lindberg, B., Berndt, C., Mienert, J., 2007. The Fugløy Reef at 70°N: Acoustic signature, geomorphologic and oceanographic setting. *International J. Earth Sci. (Geol. Rundsch.)*, 96, 201-213.
- Mortensen, P.B., 2000. *Lophelia pertusa* (Scleractinia) in Norwegian waters. Distribution, growth, and associated fauna. Dr. scient. thesis, Univ. Bergen, Norway.
- Mortensen, P.B., Hovland, M., Brattegard, T. and Farestveit, R., 1995. Deep water bioherms of the scleractinian coral *Lophelia pertusa* (L.) at 64° N on the Norwegian shelf: structure and associated megafauna. *Sarsia* 80, 145–158.
- Mortensen, P.B., Hovland, M.T., Fosså, J.H. and Furevik, D.M., 2001. Distribution, abundance and size of *Lophelia pertusa* coral reefs in mid-Norway in relation to seabed characteristics. *Journal of the Marine Biological Association of the United Kingdom* 81, 581–597.
- Mortensen, P.B. and Fosså, J.H., 2006. Species diversity and spatial distribution of invertebrates on *Lophelia* reefs in Norway. *Proceedings of the 10<sup>th</sup> International Coral reef Symposium, 1849-1868*. Okinawa.
- Murawski, S.A., Wigley, S.E., Fogarty, M.J., Rago, P.J. and Mountain, D.G., 2005. Effort distribution and catch patterns adjacent to temperate MPAs. *ICES Journal of Marine Science* 62, 1150-1167.

Myers, A.A. and Hall-Spencer, J.M., 2004. A new species of amphipod crustacean, *Pleusymtes comitari* sp. nov., associated with *Acanthogorgia* sp. gorgonians on deep-water coral reefs off Ireland. *Journal of the Marine Biological Association of the United Kingdom* 84, 1029-1032.

OSPAR (2005) Case reports for the initial list of threatened and/or declining species and habitats in the OSPAR maritime area. OSPAR Commission.

Ottensen 2000 reference not found (misquoted in OSPAR 2005).

Reveillaud, J., Freiwald, A., Van Rooij, D., Le Guilloux, E., Altuna, A., Foubert, A., Vanreusel, A., Olu-Le Roy, K. and Henriët, J.-P., 2008. The distribution of scleractinian corals in the Bay of Biscay, NE Atlantic. *Facies* 54, 317-331.

Roberts, J.M., Harvey, S.M., Lamont, P.A. & Gage, J.A., 2000. Seabed photography, environmental assessment and evidence for deep-water trawling on the continental margin west of the Hebrides. *Hydrobiologia* 44, 173-183.

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* 54, 297-316.

Rogers, A.D., 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. *International. Rev. Hydrobiol.* 84, 315-406.

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.

Sampaio, I., Braga-Henriques, A. and Porteiro, F. 2008. "Vulnerability of deep-water corals of the Azores to the demersal fisheries". XV Simpósio Ibérico de Estudos de Biologia Marinha, Funchal, Portugal

Sars, M. 1865. Om de i Norge forekommende fossile dyrelevninger fra Quart\_rperioden. Universitetets program for forste halvaar 1864. Christiania, 134p.

Schröder-Ritzrau, A., Freiwald, A. and Mangini, A. 2005. U/Th-dating of deep-water corals from the eastern North Atlantic and western Mediterranean. In: Freiwald, A. and Roberts, J.M. (eds) Cold-water corals and ecosystems. Springer-Verlag Berlin Heidelberg, pp 157-172.

Strømngren, T. 1971. Vertical and horizontal distribution of *Lophelia pertusa* (Linné) in Trondheimsfjorden on the west coast of Norway. *Det Kongelige Norske Videnskabers Selskabs Skrifter*, 6: 1–9.

Taviani, M., Remia, A., Corselli, C., Freiwald, A., Malinverno, E., Mastrototaro, F., Savini, A. and Tursi, A., 2005. First geo-marine survey of living cold-water *Lophelia* reefs in the Ionian Sea (Mediterranean basin). *Facies* 50, 409-417.

Thiem, Ø., Ravagnan, E., Fosså, J.H., and Berntsen, J., 2006. Food supply mechanisms for cold-water corals along the continental shelf edge. *Journal of Marine Systems* 60, 207-219.

UNGA, 2006. Impacts of fishing on vulnerable marine ecosystems: actions taken by states and regional fisheries management organisations and arrangements to give effect to paragraphs 66 to 69 of General Assembly resolution 59/25 on sustainable fisheries, regarding the impacts of fishing on

vulnerable marine ecosystems. UNGA A/61/105. pp 46. Available at: [http://www.un.org/Depts/los/general\\_assembly/general\\_assembly\\_reports.htm](http://www.un.org/Depts/los/general_assembly/general_assembly_reports.htm)

Wheeler, A.J., Bett, B.J., Billett, D.S.M., Masson, D.G. and Mayor, D., 2005. The impact of demersal trawling on NE Atlantic deep-water coral habitats: the Darwin Mounds, U.K. In: Proceeding from the Symposium on the Effects of Fishing Activities on Benthic Habitats: Linking Geology, Biology, Socioeconomics and Management. Edited by Thomas, J. and Barnes, P., American Fisheries Society, Bethesda, MD, USA.

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

Wilson, J.B., 1979. The distribution of the coral *Lophelia pertusa* (L.) [*L. prolifera* (Pallas)] in the north-east Atlantic. *Journal of the Marine Biological Association of the United Kingdom* 59, 149–164.

Zibrowius, H., 1980. Les Scléactiniaires de la Méditerranée et de l'Atlantique nord oriental. *Memoires de l'Institut oceanographique* No 11. pp 226.



New Court  
48 Carey Street  
London WC2A 2JQ  
United Kingdom

t: +44 (0)20 7430 5200  
f: +44 (0)20 7430 5225  
e: [secretariat@ospar.org](mailto:secretariat@ospar.org)  
[www.ospar.org](http://www.ospar.org)

**OSPAR's vision is of a healthy and diverse North-East Atlantic ecosystem**

ISBN 978-1-906840-63-1  
Publication Number: 423/2009

© OSPAR Commission, 2009. Permission may be granted by the publishers for the report to be wholly or partly reproduced in publications provided that the source of the extract is clearly indicated.

© Commission OSPAR, 2009. La reproduction de tout ou partie de ce rapport dans une publication peut être autorisée par l'Editeur, sous réserve que l'origine de l'extrait soit clairement mentionnée.