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# Report of the Working Group on Deep-water Ecology (WGDEC), 8-11 March 2005

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ICES Advisory Committee on Ecosystems

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## Report of the Working Group on Deep-water Ecology (WGDEC)

8-11 March 2005

ICES Headquarters, Copenhagen



International Council for the Exploration of the Sea  
Conseil International pour l'Exploration de la Mer

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# 1 Introduction

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## 1.1 Participation

The following members of the Working Group on Deep Water Ecology (WGDEC) participated in producing this report (see Annex 1 for addresses).

Peter Auster*	USA
Melanie Bergmann	Germany
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Robert Brock	USA
Sabine Christiansen	Germany
Pablo Duran	Spain
Andre Freiwald*	Germany
Bob George*	USA
Anthony Grehan	Ireland
Jason Hall-Spencer	UK
John Hartley*	UK
Emma Jones	UK
Gui Menezes	Portugal
Pål Mortensen	Norway
Karine Olu	France
Murray Roberts	UK
Sigmar Steingrímsson*	Iceland
Mark Tasker (chair)	UK
Ole Tendal	Denmark
Ole Vestergaard	Denmark
Les Watling	USA

\* = unable to be in Copenhagen, but contributed from afar.

## 1.2 Terms of Reference

The 2004 Statutory meeting of ICES gave the newly-formed Working Group on Deep Water Ecology the following terms of reference:

- a) review and evaluate the available information and references on threats to, and/or decline in the OSPAR area of, seamount habitats. Identify to the extent possible whether these threats are introduced by human activities or whether caused by natural events;
- b) evaluate and report on new information on the distribution and status of cold water corals in the North Atlantic (including consideration of large slow-growing octocorals) and factors that might alter their status;
- c) evaluate and report on the sensitivity of other deep-water habitats (including soft bottom habitats) in the North Atlantic to fishing and other anthropogenic activities, and where possible describe their occurrence;
- d) commence the preparation of a prioritised work plan that would fill the information gaps identified under ToRs b) and c);

The above Term of Reference a) was revised following a letter to ICES from OSPAR in February 2005 and this term of reference was reformulated to:

- a) review the information and references listed at Annex A, and any other relevant information, to provide advice on the threats to, and/or decline of, the benthic communities and the benthopelagic and pelagic communities associated with seamounts, with a focus on:

- i. direct or indirect evidence of damage to seamount communities from different types of fishing activities both within the OSPAR maritime area and elsewhere;
- ii. assessing the degree of threats to seamount communities in the OSPAR regions from types of fishing activity;
- iii. identifying whether and where there are threats from fishing activities within the OSPAR maritime area, and;
- iv. identifying whether there are indications of vulnerability as a result of the genetic isolation of seamount communities.

In addition to this, MCAP referred a request to ICES from the North-East Atlantic Fisheries Commission (NEAFC) to the Working Group:

e) to provide an initial answer to questions regarding a proposal for the protection of vulnerable deep-water habitats:

- i. to evaluate if the boundary lines of the closed areas in the NEAFC Regulatory Area reflect the spatial distribution of vulnerable deep-water habitats in those areas;
- ii. to provide information on the distribution of cold-water corals on the Hatton Bank;
- iii. provide information on the percentage of vulnerable deep-water habitats in the Regulatory Area covered by the proposal;
- iv. provide information on the distribution of cold-water corals on the Western slopes of the Rockall Bank to indicate appropriate boundaries of any closure of areas where cold-water corals are affected by fishing activities;
- v. evaluate the destructiveness of different fishing gears with respect to vulnerable deep-water habitats.

### 1.3 Justification of Terms of Reference

Scientific interest in deep water biology has been re-kindled in recent years due to the improvement in methods and the increase in human activities occurring in these waters. This latter has led to an increase in public concern about impacts, and a corresponding increase in requests to ICES for advice. In the recent past ICES has provided advice on cold-water corals and in the current year a request has arrived from OSPAR on seamounts. It is likely that requests in this area will continue. The need to integrate advice on fisheries in deep waters with advice on ecosystem effects will create a further demand for a group to bring together existing knowledge and to prioritise areas where further knowledge is required. The terms of reference for the first year of this group are limited due to the need to bring new scientists into the ICES network and to prioritise work in this potentially very large subject. This Working Group will continue the work of SGCOR and act as a way of continuing the important contribution of these scientists (who formally had not contributed to ICES) within the ICES framework.

Term of reference a) (as amended) relates to a request from OSPAR to evaluate information surrounding a wish to list Seamounts on the OSPAR list of threatened and declining species and habitats. Previous advice from ICES on this habitat focussed on the physical structure off seamounts and found that there was insufficient evidence to justify listing. The revised request makes it clear the seamount benthic habitats and benthopelagic/pelagic communities should be also assessed.

Term of reference b) is very similar to the term of reference given to SGCOR in all three years of its existence. This allows ICES to capture and evaluate new information on cold-water

corals as it arises and enables full advice on cold-water corals to be provided to the European Commission (among others).

Term of reference c) is aimed at providing a framework to evaluate the sensitivity of deep water habitats. The focus on sensitive habitats has so far been on cold-water corals (and to a lesser extent the habitats and communities around seamounts. This may have been to the detriment of other less charismatic habitats. A framework to assess sensitivity, followed by mapping may help achieve a more appropriate balance in future.

There are large gaps in knowledge in relation to both term of reference b) and c); these will be examined and prioritised by term of reference d).

The request from NEAFC relates to a proposal to NEAFC from Norway to close certain areas to bottom trawling within the NEAFC area. Information from WGDEC will be integrated with that from the Working Group on deep-water fish stocks to provide full advice to NEAFC.

#### **1.4 Overview by the chair**

This is the first report of the Working Group on Deep Water Ecology. It was assembled by twenty-one scientists, including some from most ICES countries with deep water habitats in their areas of jurisdiction. The group met over four days in ICES headquarters in Copenhagen and had five terms of reference, of which four were addressed and one will be completed by correspondence over the coming year.

Two terms of reference derived from requests to ICES from external customers and these received priority attention. The first of these was from OSPAR and concerned advice on seamounts in the OSPAR area. The group had some difficulty in interpreting this rather complex request and hope that the interpretation eventually agreed upon was the correct one. The group would be willing to revisit this issue if clarification or a differing interpretation is received from OSPAR. In summary, the group examined literature suggested by OSPAR and could find no evidence of damage by fishing of seamount benthic habitats in the OSPAR area. However this finding is almost certainly due solely to a lack of suitable studies and, based on evidence from elsewhere, the group felt that it is highly likely that damage from bottom-trawl fisheries, and likely bottom-set gill nets and long-lines had occurred.

The group noted however that 'seamount' habitats were likely to include a very wide range of physical and biological conditions, and that extrapolating evidence of damage from elsewhere to ALL seamounts would be unwise. A classification of seamounts at least based on geographic location (especially latitude), depth at summit and nature of the seabed on the seamount would aid in assessing likelihood of fishing operations having damaged habitats.

The problem of what a benthopelagic or pelagic community associated with a seamount was not resolved. There is no doubt that some fish species aggregate at some seamounts, but the community at seamounts has not been described. It might be possible to generate a 'fished' community of fish species at seamounts if catch records were available at a sufficiently disaggregated basis to identify geographic areas where the only fishing would be at a seamount. It was noted that many stocks of fish assessed (or evaluated) by ICES that occur at seamounts were described as depleted (or similar words), but the degree to which the seamounts were important for these species has not been adequately described. An example of this is orange roughy, described in many places as a classic seamount species, but whose main fishery in the OSPAR area at present is over banks and the continental slope west of Britain and Ireland. Information was provided on the comparative threats from various fishing gears, but a description of the geography of these threats was not possible due to the lack of information on the spatial distribution of seamounts and of fishing in seamount areas.



The second request to ICES, passed onto the working group, was from NEAFC and concerned aspects of the presence of cold-water corals and other sensitive habitats in the NEAFC area. No information was available to the group on the presence of sensitive habitats in four areas closed to fishing by NEAFC in 2004. The group provided evidence, both of specimens and of geophysical traces of the occurrence of cold-water coral on Hatton Bank, but noted that the evidence was insufficient to describe fully all occurrences. Following a description of three strands of evidence for the presence of cold-water coral on the Rockall Bank, three options for boundaries of appropriate areas to close were derived. The choice between these boundaries extends beyond science into the weight that society wishes to give to each of the three strands of evidence. An evaluation of the destructiveness of different fishing gears was provided. Perhaps in contrast to views from SGCOR (and ACE) the group noted that low impact activities, at a high enough magnitude and over a long enough time period can have a significant deleterious effect as well. This may be important in relation to control of non-trawling gear on these Banks and elsewhere. As in earlier advice on cold-water corals provided by ICES, the group agreed that the only way to protect these fragile habitats was to close the areas containing them to towed gears on the seabed. The group felt generally that closures were necessary on both Rockall and Hatton Banks to protect corals.

A short review of 'new' information on the distribution and status of cold water corals in the North Atlantic was given, along with a further evaluation of the importance of these coral habitats to fish. The group will next year consider whether a more permanent, readily updatable and easily accessible source of information of the occurrence of cold-water coral in the ICES area and western North Atlantic than the current series of ICES reports might be established.

The group did not adequately address the sensitivity and geographic occurrence of other deep water habitats in the North Atlantic, but has provided information on a selection of habitats. This term of reference requires the adoption of a suitable habitat classification framework followed by agreement on a method to evaluate sensitivity in the absence of experimental or observational data. These aspects will be considered in preparing a future work plan.

Overall this was a very encouraging first meeting of the group; we all learned a lot about working on these issues in the ICES context and look forward to addressing these and further issues in the future. We note the importance of co-operation with other working groups within ICES, including those on deep water fish stocks (WGDEEP), on marine habitat mapping (WGMHM) and on ecosystem effects of fishing activities (WGECO).

## **1.5 Acknowledgements**

We thank the ICES Secretariat for all of their help – of particular mention this year was the excellent work to rescue a laptop following an experiment to test if it ran better when filled with hot chocolate. Dave Long of the British Geological Survey was of particular help in locating unpublished records and images of apparent coral reefs from the Hatton Bank. Gjermund Langedal (Norwegian Directorate of Fisheries) provided very useful information about the Hatton Bank.

## 2 Review of threats to, and decline of, seamount habitats and communities in the OSPAR maritime area

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Term of Reference: As outlined in the Section 1, this term of reference was reformulated by OSPAR to read:

Review the information and references [listed in an annex by OSPAR], and any other relevant information, to provide advice on the threats to, and/or decline of, the benthic communities and the benthopelagic and pelagic communities associated with seamounts, with a focus on:

- i.) direct or indirect evidence of damage to seamount communities from different types of fishing activities both within the OSPAR maritime area and elsewhere;
- ii.) assessing the degree of threats to seamount communities in the OSPAR regions from types of fishing activity;
- iii.) identifying whether and where there are threats from fishing activities within the OSPAR maritime area, and;
- iv.) identifying whether there are indications of vulnerability as a result of the genetic isolation of seamount communities.

### 2.1 Summary

The terms of reference provided to the group proved difficult to interpret. A review of information available to the group found no evidence of direct or indirect damage to benthic communities on seamounts in the OSPAR area. However, this is probably due to lack of suitable studies and based on information from elsewhere, it is virtually certain that damage to these communities has occurred. This assumption cannot be applied to all seamounts in the OSPAR area as at least some are beyond the fishing range of gear that might damage the benthos, while others may not have been fished due to a natural lack of fish aggregations. The group had difficulty defining 'benthopelagic and pelagic communities associated with seamounts'. It noted that most deep-water fish stocks that were known to aggregate on some seamounts were depleted; however the relationship between these stocks and seamounts has not been fully described or quantified.

Trawl gears that impact the seabed pose the greatest threat to benthic habitats on seamounts, followed by bottom-set gill-nets and long-lines. The degree of threat will be affected by the sensitivity of the habitats on each particular seamount and by the intensity of the fishing activity. An intensive fishery by gill-nets on a sensitive habitat that has a long recovery time could be as threatening as less-intense trawling in these habitats. The degree of threat to benthopelagic and pelagic communities on seamounts was not evaluated, but presumably would again relate to the intensity of each fishery and the susceptibility to capture of each species of fish in the community.

The group had only a little information to say where threats to seamounts might be occurring. The information needed to determine this would be a catalogue of all seamounts and their characteristics (e.g. depth of summit) in the OSPAR area, and geographically disaggregated information on fishing effort by gear that would enable fishing activities on seamounts to be identified. Information from satellite monitoring systems on fishing vessels would also be of great use.

There have been few studies in the OSPAR area of the genetics of species occurring on seamounts. These studies and those from elsewhere indicate that there is likely to be a mix of species types ranging from some endemic on a few seamounts to others that show no genetic variation across wide ranges of ocean. There are insufficient studies to show whether the proportions of species in these categories differ from other deep-water habitats within the OSPAR area.

## 2.2 Introduction

### 2.2.1 Interpretation of the Terms of Reference

The Working Group had some difficulties in interpreting these terms of reference as there appeared to be some overlap between the sub-sections, and differing understanding of the meaning of some words (despite provision of some guidance on definitions by OSPAR). In answering them, we interpreted ‘evidence of damage’ as meaning evidence that detrimental change had actually occurred. ‘Degree of threat’ was taken as meaning the variation in potential damage that might be caused by various fishing gears. The subsidiary term of reference iii.) was taken as referring to knowledge that a particular fishing activity was occurring at a particular location, but when there is no direct evidence of damage at that location (usually due to lack of research and survey). The term ‘genetic isolation’ was taken as referring to possible genetic consequences of the geographical isolation of seamounts, rather than the more common molecular level use of this term.

The Working Group agreed that, for this term of reference, the term ‘seamount’ should be applied only to those bathymetric features rising at least 1000 m above the surrounding seafloor. This is important because in many documents relating to the OSPAR area, seamounts and banks are often dealt with together. OSPAR (2005) used this definition to map at least 23 seamounts in the OSPAR area (Figure 2.2.1.1). The data used for this figure derive from the seamounts online database (<http://seamounts.sdsc.edu>). In order to identify records in the data which complied with the >1000m definition, the data were overlain on a GEBCO (General Bathymetric Chart of the Oceans) map to distinguish those seamounts rising over 1000m from the seafloor. As no set distance was recommended in the OSPAR definition over which to measure the height of a seamount (i.e. the steepness of slope) a degree of interpretation was required to validate each seamount record. Additionally the collective positional differences between GEBCO (a low resolution map) and the seamount dataset meant that some seamount features did not coincide with the GEBCO bathymetric features.

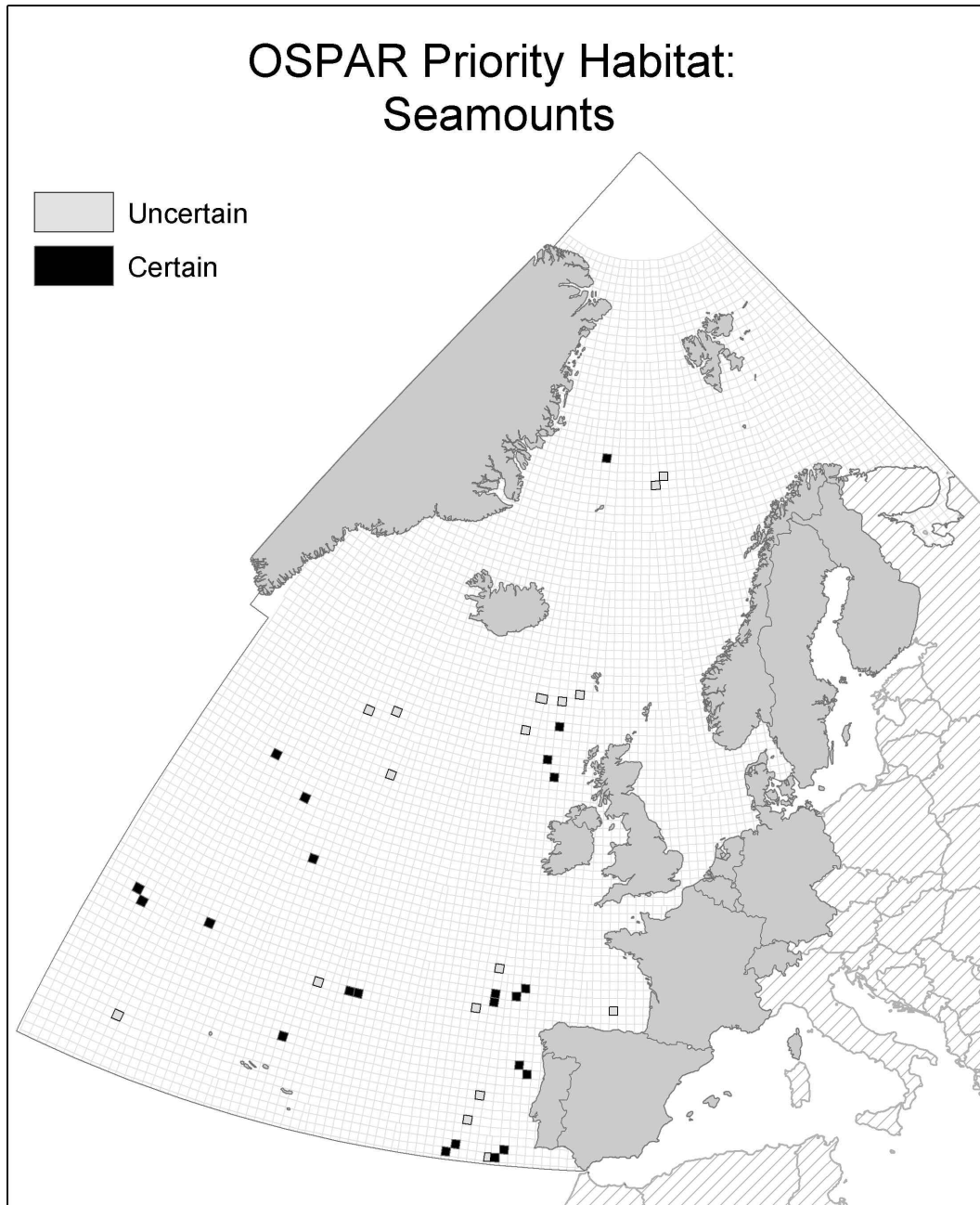
Manchete *et al.* (in press) estimated that there were 136 submarine mounds (banks, guyots, seamounts, etc) in the Azores EEZ. The bathymetric data used to estimate depth contour maps and to derive this estimate were taken from the ‘Global seafloor topography from satellite altimetry and ship depth soundings’ database (Smith and Sandwell 1997; <http://topex.ucsd.edu/sandwell/sandwell.html>). Kriging was used to interpolate data and build bathymetric contour maps using Surfer 7.05 (Surface Mapping System Golden Software Inc.). Areas and distances were estimated using MapViewer 4.00 (Thematic Mapping System, Golden Software Inc.). The criteria used to define a submarine mound were: 1) a peak shallower than 1200 m depth, (where most of the commercial important fish communities are found (Menezes 2003)). 2) having an elevation greater than 100 m, 3) a distance greater than 2 nautical miles (nm) from adjacent mounds.

These mounds include 17 with heights above 1000m, known as seamounts, 37 between 500-1000m known as knolls and 85 with elevations lower than 500m known as hills (general classification based on US Board of Geographic Names, 1981 in Rogers, 1994).

Depth of peaks ranged from very close to the surface to approximately 1200m depth, while base depth ranged from 550 to 2000m. The mounds have a mean elevation of 460m (S.D.= 351m), with mean peak of 813 m (S.D.= 298m) and mean depth at base of 1273 m (S.D.= 309 m). Most of the mapped mounds had an elevation between 100 and 300m.

Other sources have stated that there are at least 800 seamounts in the OSPAR area (e.g. Gubbay 2002). However, the definition used to derive this number was any structure with a relief great than 50 fathoms (c100m) and this number includes everything north of the equator (Epp and Smoot 1989). Kitchingman and Lai (2004) used updated bathymetric data to map

locations of seamounts worldwide, these data have been segregated to map locations of seamounts within the OSPAR area (Figure 2.2.1.2). The working group recommends a check on this dataset and a sub-division of types in a similar fashion to that of Manchete *et al.* (in press) for the OSPAR area in order to understand conservation and research needs.



**Figure 2.2.1.1 Preliminary distribution of seamounts in the OSPAR area (OSPAR 2005). (Based on data in the Seamounts Online database (<http://seamounts.sdsc.edu>). Seamount elevation measured using GEBCO bathymetry. Where seamount elevation is greater than 1000m records are marked as 'certain' (i.e. meet the OSPAR definition); where seamount elevation is less than 1000m they are marked as 'uncertain'.**

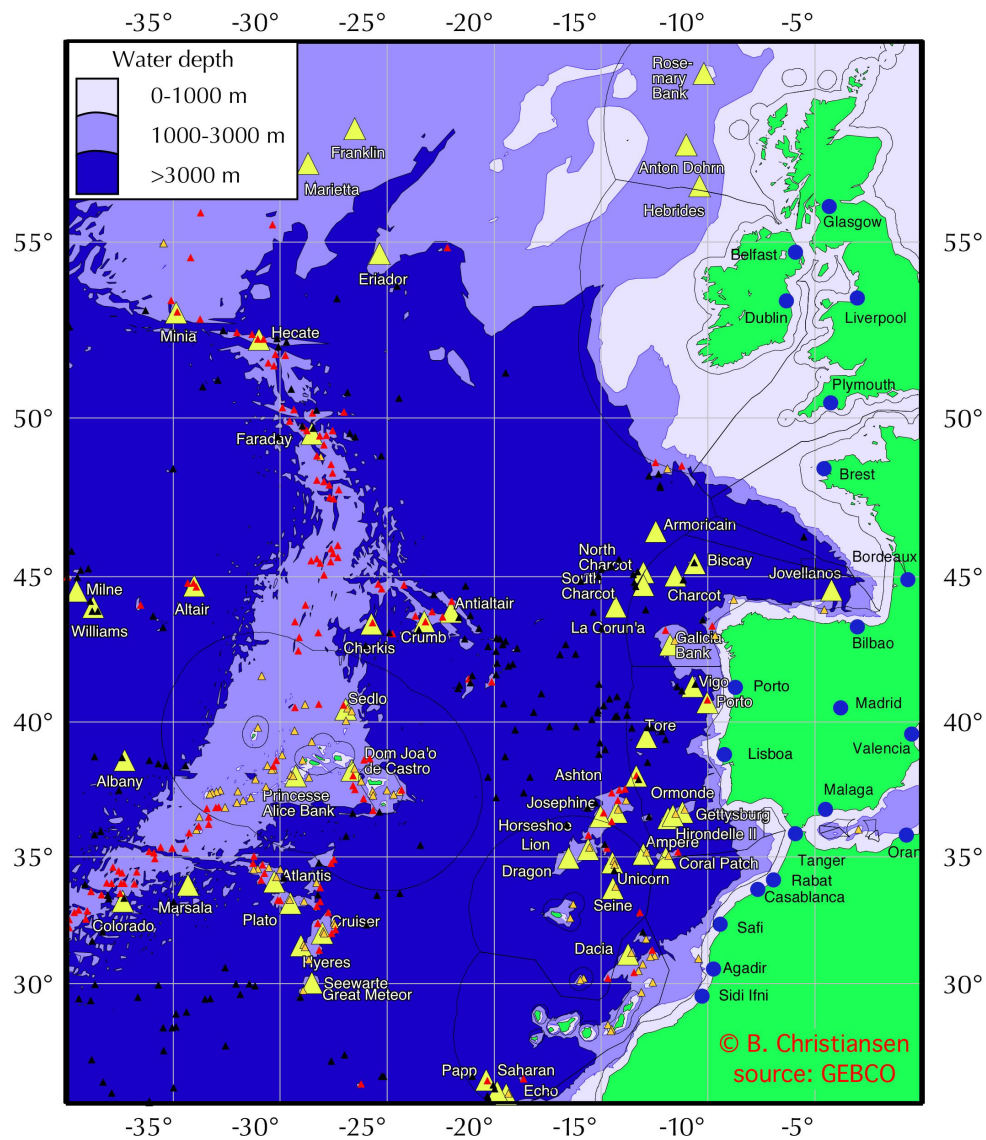


Figure 2.2.1.2 Seamounts and other mound features in the southern part of the OSPAR area based on Kitchingman and Lai (2004). The small yellow triangles mark seabed features rising to within 1000 m of the surface, the small red triangles mark seabed features rising to within 1000-2000 m of the surface and small black triangles mark seabed features rising to within >2000 m of the surface. The large triangles indicate the GEBCO seamounts (Figure 2.2.1.1).

## 2.2.2 Diversity of seamounts

It also needs to be noted that, given the limited data available, the seamounts within the OSPAR area exhibit considerable diversity. That is, there are seamounts around the Azores that are quite shallow while those that are found in the more northern part of the area are much deeper. The summits of the southern seamounts are in waters that are warmer and slightly saltier than the more northern seamounts. Other well known effects of seamounts on the water column, such as the formation of Taylor Caps (where water is retained over the seamount), will be more prevalent over the shallower seamounts, while the extent of water column effects over the deeper seamounts are not as well documented. There are seamounts in the Bay of Biscay and off the coast of France that are more continental in nature, and some have deeper layers of sediments on their summits than those that are offshore, especially those along the Mid-Atlantic Ridge. As a consequence, it is not possible to make generalisations about

habitats on all seamounts in the OSPAR area. Equally it is not possible to make generalisations about habitat or community damage, which further implies that any management of human activities that affect these habitats will need to be specific to each seamount or group of seamounts.

### 2.2.3 Knowledge of seamounts

Rogers (1994) reviewed the knowledge about animal communities associated with seamounts and described common features of the physical environment. Based on an earlier summary by Wilson and Kaufmann (1987), Rogers (1994) reports a total number of 597 invertebrates from 59 seamounts investigated worldwide. Fifteen percent of these species are not known from other locations and can be viewed as potentially endemic. Later, Richer de Forges *et al.* (2000) found a higher number with 850 species from seamounts in the Tasman Sea and the South-eastern Coral Sea. Of these around 30% were new and possibly endemic species. None of the species on seamounts close to Tasmania were recorded on seamounts in northern parts of the Tasman Sea.

Worldwide 60-70 species of fish, shellfish and precious corals are harvested from seamounts (Koslow *et al.* 2001, Garibaldi and Limongelli 2002). Fishing for deep-water fishes on seamounts started in the 1970s in different regions around the globe. Morato *et al.* (2004) found significant differences in longevity and age at maturity among seamount, non-seamount and seamount-aggregating fishes. The longevity of seamount fishes was significantly higher than non-seamount fishes (median = 25 years and 12 years respectively). Seamount-aggregating fishes had the highest longevity (median = 52 years) among the three categories, although the difference was significant only in comparison to non-seamount fishes. These features all mean that recovery from additional mortality (such as that imposed by fishing) will be longer than in fish that reproduce faster.

The special hydrographic conditions and good availability of hard bottom are favourable for sessile suspension feeders which often dominate the community on seamounts (Genin *et al.* 1986). Corals (Scleractinia, Gorgonacea and Antipatharia) may occur in great abundance, especially along the edges of wide seamounts. In the Pacific Ocean seamounts probably represent the most important habitat for cold-water corals. Around New Zealand and Tasmania the scleractinians *Gonicorella dumosa* and *Solenosmilia variabilis* are the most common species respectively (Koslow *et al.* 2001). These are both reef-builders in the southern hemisphere and have a high diversity of associated species, including other corals. Pasternak (1985) reported nineteen species of gorgonians on seamounts in the North Atlantic. Two of these were new to science. A marked biogeographical boundary was found at the Mid-Atlantic Ridge where species east of the ridge were not found on seamounts west of the ridge. The scattered and low sampling effort in the Atlantic means that the impression that the Pacific seamounts have a richer fauna of corals (about 30 species) may not necessarily be a true picture.

### 2.2.4 Fisheries on seamounts

As traditional fisheries along the continental slope declined over the years, technological advances have allowed deepwater fishing fleets to move into previously less accessible areas such as seamounts (Gordon *et al.* 2003). Another important factor for the movement of fisheries to the high seas was the introduction of the 200 nautical mile zone in 1976, which forced foreign fleets to search for new ground outside this zone. On seamounts with high aggregations of marketable species, the yield per unit effort can be very high. Unfortunately, most fisheries on seamounts have usually been 'boom and bust'. Most of these aggregating species are easily fished towards depletion and the life history characteristics of deepwater species (e.g., slow growth rate, late age of sexual maturity) make recolonisation of previously fished seamounts slow.

Gordon *et al* (2003) reviewed deep-sea fisheries for all ICES sub-areas. Most relevant for this report are ICES sub-areas X and XI, because in these areas seamount fisheries predominate. There are likely seamount-directed fisheries in other ICES areas, but segregating catches from seamounts versus other banks and slope habitats is not possible from the data available to this Working Group. In sub-areas X and XI, fisheries have been primarily directed to the seamounts around the Azores and along the Mid-Atlantic Ridge. Within the Azorean EEZ, there have been longline fisheries for red (blackspot) seabream *Pagellus bogaraveo*, wreckfish *Polyprion americanus*, conger eel *Conger conger*, bluemouth *Helicolenus dactylopterus*, Kuhl's scorpionfish *Scorpaena scrofa*, greater forkbeard *Phycis blennoides*, alfonsinos *Beryx* spp., and common mora *Mora moro*. From the 1970s to early 1990s there was also a deep-water gillnet fishery for kitefin shark *Dalatias licha*. Outside the Azores EEZ, trawl fisheries have been conducted by Russian vessels for alfonsinos, orange roughy *Hoplostehus atlanticus*, deepwater cardinal fish *Epigonus telescopus*, black scabbardfish *Aphanopus carbo*, several deep water sharks species, and wreckfish *Polyprion americanus*. In ICES Sub-Area XII, which includes the northern end of the Mid-Atlantic Ridge and the Reykjanes Ridge, most or all of the fishing has been by Russian trawlers for roundnose grenadier *Coryphaenoides rupestris* and alfonsinos, with incidental catch of orange roughy. Gordon *et al* (2003) note that Norwegian and Icelandic longliners began fishing in Sub-Area XII and XIVb for giant redfish *Sebastes mentella* on the Reykjanes Ridge.

### **2.3 Direct or indirect evidence of damage to seamount communities from different types of fishing activities both within the OSPAR maritime area and elsewhere**

#### **2.3.1 Evidence of damage on benthic communities**

Outside the OSPAR area, it has been well-documented that benthic invertebrates on seamounts have been seriously impacted by fishing activities (Koslow, 1997; Roberts, 2002). Clark *et al* (1999) documented a coral bycatch of 3000 kg from six trawls on seamounts off Australia that had not previously been fished for orange roughy, whereas the bycatch levels at heavily-fished seamounts amounted to about 5 kg for thirteen trawl hauls. The by-catch of coral in the first two years (1997-1998) of bottom trawling for orange roughy over the South Tasman Rise reached 1,762 tonnes but was quickly reduced to only 181 tonnes in 1999-2000 (Anderson and Clark 2003), as repeated trawls in the same area were over areas where most of the coral had been destroyed. Within the OSPAR area, Hall-Spencer *et al.* (2002) noted that various species of long-loved scleractinian corals were widespread as by-catch in deep-water commercial trawls along the European continental margin from France to the Norwegian Arctic.

Koslow *et al.* (2001) observed clear differences in faunal composition between fished and unfished seamounts off Tasmania. Most dramatic was the effect on coral habitats which commonly occur on these seamounts. Koslow *et al.* (2000) reported that photographic transects revealed that 95% of the sea bottom was bare rock on fished areas compared with only 10% on comparable unfished seamounts. Similar photographic data has recently been produced by Clark's group for 19 heavily fished seamounts off New Zealand. Bottom trawling for orange roughy off New Zealand has been particularly damaging to benthic habitat.

Loss of habitat caused by fishing gear has clear negative ecological consequences. A large number of studies have documented the effects of mobile fishing gear, including the loss of habitat complexity, shifts in community structure, and changes in ecosystem processes (Auster and Langton 1999, Jennings and Kaiser 1998). On Georges Bank, undisturbed gravel habitat had consistently higher abundance, biomass, and species diversity than fished sites (Collie *et al.* 1997). Koslow *et al.* (2001) compared coral-dominated sites with heavily fished sites and



reported that biomass at the coral-dominated sites had a 7-fold higher mean sample biomass than at heavily fished sites. Engel and Kvitek (1998) compared highly trawled and lightly trawled areas within the Monterey Bay National Marine Sanctuary, California. The difference in the structural complexity of the areas was clear with more trawl marks and broken shells in the highly trawled area. This translated into significantly more abundant epifauna being found in the lightly trawled area. Disturbance to coral communities reduces seafloor habitat and the species that use this habitat.

Figures in NMFS (2004) indicate that about 81.5 metric tons of coral are removed each year as bycatch in Alaska (also see Heifetz 2002). As a result, in Feb 2005, the North Pacific Fisheries Management Council recommended that approximately 949,000 km<sup>2</sup> of seafloor along the outer Aleutian Islands chain be closed to fishing with trawl gear. About 70% of the shallow areas adjacent to the islands will still be open to bottom trawling, however (see [www.fakr.noaa.gov/npfmc/current\\_issues/HAPC/HAPC.htm](http://www.fakr.noaa.gov/npfmc/current_issues/HAPC/HAPC.htm)). In addition, all 16 seamounts in the Gulf of Alaska within the US EEZ were set aside as Habitat Areas of Particular Concern (HAPC) in which no bottom contact gear can be used. In Canada, the drive to close an area in the Northeast Channel as a protected coral habitat was initiated by longliners who had seen that corals were being caught routinely on their gear. As a result, in 2002, 424 km<sup>2</sup> in this channel were closed to all bottom fishing gear (Fisheries and Oceans Canada 2002).

Due to the limited number of investigations, there is limited documentation of human induced damage to benthic habitats on seamounts in the OSPAR area (OSPAR Region V, Open Atlantic). In July 2004, lost trawl netting and longlines were observed by ROVs operated from the Norwegian vessel RV *G.O. Sars* during the international MAR-ECO expedition to the Mid-Atlantic Ridge ([www.mar-eco.no](http://www.mar-eco.no) and Bergstad and Godø 2003). The observations were made in rough terrain on comparatively shallow hills, primarily just south and north of the Charlie-Gibbs Fracture Zone. The ROV footage has however not yet been fully analysed, and quantification of the occurrences of lost gear has not been made. The chartered longliner *MS Loran* that operated in the same areas at the same time also caught lost longlines when fishing on these hills (Dyb and Bergstad 2004).

Based on our knowledge from areas outside the OSPAR area, one can make some predictions about likely impacts of fishing activity on the seamount benthic communities and habitats within OSPAR boundaries. In order to do this, seamounts need to be classified according to depth at summit, and summit substrate composition. A large number of the seamounts in the southern OSPAR area are relatively shallow, i.e., less than 500 m to the summit, and some have unconsolidated sediments covering the summit (off the continental slope). As a consequence, some of these seamounts will be fishable by gill nets as well as longlines or trawl gear, whereas others will be too deep even for gill nets to be used. There are some studies underway or just completed, the results of which will be helpful in assessing the current state of seamount biology and which will then be useable in understanding possible effects of deep-sea fishing on these habitats. The working group is aware that a conference is planned on the fisheries on the Azores seamounts in 2005 and suggests that OSPAR might review the published results of that meeting in due course.

### **2.3.2 Evidence of damage to fish communities**

The working group notes that WGDEEP will wish to input to this section before it is used to provide advice. The following paragraphs are a contribution from WGDEC; we noted that most information relating to fish on seamounts concerned stocks of individual species, rather than communities of fish.

Aggregations of alfonosinos on seamounts in the North Atlantic were detected in the late 1970s (Vinnichenko 1998). Since then, more than 25 000 tonnes of these species have been fished by Russian vessels. The total stock of alfonosinos was at start relatively small (50 000 - 80 000

tonnes). Intense fishing has now significantly reduced the stock. EU fisheries targeting orange roughy in the North Atlantic Ocean has mainly been concentrated in areas within the 200-mile zone off the west coast of the Britain and Ireland. Russian and other East European countries have trawled the Mid-Atlantic Ridge. The activity has decreased in recent years as a result of overfishing and low profit levels. ICES (2002) describe fisheries for deep-water fish (including those on seamounts) as a series of depletions of local stocks. These local stocks or aggregations may be depleted within one season. The recovery of such stocks takes several decades for many species (ICES 2002).

No assessment can be made regarding longline and gillnet fisheries that might have been occurring on the shallower seamounts as there are no concrete data summarizing those efforts. Similarly, specific data are lacking for oceanic seamounts, Reykjanes Ridge and Mid-Atlantic Ridge fisheries using trawls or longlines. Most of the information about effort in these areas is anecdotal and may be dated. It is clear, however, that the degree of threat to these communities will need to be evaluated taking into account the diversity of seamount types and benthic communities on them, as well as up-to-date information on fishing effort.

#### **2.4 Assessing the degree of threats to seamount communities in the OSPAR regions from types of fishing activities**

The Working Group interpreted this as a request to review the degree of threat posed by different types of fishing to seamount communities. The degree of threat will be related to three main features of the fishing activity – the type of gear used, the way that it is used and the intensity of its use. These features may in turn be influenced by the geographic location and nature of the seamount.

In relation to impact on benthic communities, trawl gear that contacts the seabed will have the greatest effect, with ‘heavier’ gears likely to be slightly worse than light gears. Both gill nets and longlines also affect the seabed, including through dragging anchors and ropes across the seabed, but will not be as damaging as bottom-trawl gear. Morgan and Chuenpagdee (2003) used an expert panel to evaluate gears on a scale of severity and negative impacts to the environment. On a scale of 1 to 100, trawl nets scored a value of 91, followed by the bottom-set gillnets with 73 points and longlines at 30.

This scale does not allow for “recoverability” of the habitat and community impacted. If the intensity of a ‘lower impact’ fishing operation is such that there is insufficient recovery time between fishing operations and if those operations are widespread, then there may be little difference between the impacts of one pass of a trawl and intense long-term ‘lesser’ impact by long-lines or gillnets.

The degree of threat by fisheries to an individual seamount will also be affected by its geography. There is probably no technical ‘distance to port’ limitation on the large high seas fishing vessels currently in use, but there are depth limitations on gear. Trawls have been recorded to at least 1400m, but some seamounts do not rise to this depth. A longline fishery off southeastern Greenland fishes at depths down to 1500m, in the Azores and Madeira the longlines are often used in more than 1000m depth. Research surveys in the Azores and Madeira have used longlines as sampling gear down to 2500m (G. Menezes pers. comm.). The working group is unaware of any depth limit for this gear. It is also worth pointing out that not all seamounts will have an aggregated fish fauna, and these may not therefore be fished.

The degree of impact from gillnets may depend also on the geology of the seamount. If the seamount is rocky with irregular hard ground, the likelihood of snagging (and subsequent loss of net) will increase. The seamounts (and banks and oceanic island slopes around the Azores) are typically of recent volcanic origin and are rocky and highly irregular. The likelihood of

lost nets here is greater than on shallower and smoother fishing grounds of the continental margins.

The lack of algal growth and the weaker currents in deep water mean that it is likely that lost gillnets will continue fishing for longer than those in shallow water will. In addition the low price of these nets mean that they are easily expended (and on occasion deliberately dumped (Hareide *et al.* 2005). The ‘ghost fishing’ by these nets will be affecting stocks of those fish that are caught and will contribute to the general degradation of deep-water marine habitats and their fish populations. The scale of such ghost fishing on seamounts is not known.

The Working Group cannot further evaluate the overall threats to seamount communities in the OSPAR area without further information on the location of seamounts and fisheries effort by gear types on those seamounts. It is noticeable that there are no limits on the use of easily expendable gear such as gill-nets on seamount habitats both within and outside EU waters, with the exception of waters within 100 NM of the Azores.

## **2.5 Identifying whether and where there are threats from fishing activities within the OSPAR maritime area**

The Working Group found this question difficult to answer with the information that it had available to it. The “whether” part of this question is essentially dealt with within Section 2.4 (there are threats). The matter of where these threats are relates basically to current fishing effort. Limited information was available to the Working Group on this aspect of the request, but it should be noted that lack of information does not mean there is no threat.

Bottom trawling has occurred and is still occurring on all the three seamounts occurring within the UK continental shelf area (ICES sub area VI) (OSPAR 2004). This is documented by examination of flight data from 1997 to 2004, provided by the Scottish Fisheries Protection Agency. Vessels from 8 European countries were observed fishing on the Anton Dohrn, Rosemary Bank, and Hebrides Terrace seamounts. It is highly likely that the UK seamounts were impacted by bottom trawling associated with the orange roughy fishery that developed in the 1990s.

Vinnichenko (1998) provides information on earlier Russian fishing activities, particularly at the Corner Rise seamounts, but there is no indication that these fisheries are continuing. ICES (2004) reports trawl fisheries from the Mid-Atlantic Ridge for orange roughy, roundnose grenadier, and black scabbard fish.

The Working Group cannot further evaluate the location of threats to seamount communities in the OSPAR area without further information on the location of seamounts and fisheries effort by gear types on those seamounts.

## **2.6 Identify whether there are indications of vulnerability as a result of the genetic isolation of seamount communities**

The Working Group interpreted this term of reference in a geographical sense, recognising that genetic isolation could apply to populations isolated from each other on adjacent seamounts as well as to species endemism on a series or sequence of seamounts or isolated islands. At present, the fauna of seamounts in the OSPAR are so poorly known that specific information about vulnerability cannot be given. Population vulnerability due to genetic isolation or geographical isolation may affect differentially the groups of organisms that are distributed over seamounts of the OSPAR area.

The degree of isolation, and thus the possibility of vulnerability of seamount populations will be dependent on both physical and biological parameters. Biological aspects relate more to the

life history of the species and in particular with their dispersal ability. It is expected that those species with planktotrophic development have a regular or at least possible input of larvae from different sources. Those species without or with a low dispersal may be restricted to one or two seamounts depending on the location and/or others physical parameters of those particular seamounts.

Physical factors that affect seamount communities may act in isolation or simultaneously and will vary between seamounts. The distance between seamounts and continental margins may be large, with more isolated seamounts being more likely to generate genetic effects. Water current-topography interactions on seamounts may also generate trapped parcels of water around these features (e.g. Taylor Caps) acting as larval retention mechanisms (Rogers 1994). The high range of variation in physical factors affecting seamount communities (e.g. depth, location, slope, shape, etc) will mean that there will be no universal rules, and genetic effects will be difficult to predict fully.

The majority of the seamounts in the OSPAR area occur on the Mid-Atlantic Ridge (Gubbay, 2002). Geological studies indicate that they have been generated along the Mid-Atlantic Ridge for the past 35 millions years. There are also some seamounts that occur some distance from the Mid-Atlantic Ridge to south west of Rockall Bank, west of Portugal on the Madeira-Tore Rise, and Milne seamounts to the east of the Mid-Atlantic Ridge.

In the southern Pacific, an important part of the benthic seamount fauna is composed of suspension feeders such as corals that are restricted to the seamount environment and are characterised by high rates of endemism. This suggests that that these species have limited reproductive dispersion (Koslow *et al.* 2001).

Wilson and Kaufmann (1997) estimated that 12-15% of all seamount species were endemic, while other sampling programs have found levels of more than 30% for benthic invertebrates (Parin *et al.* 1997; Richer de Forges *et al.* 2000; Koslow *et al.* 2001). These high rates are not universal and other authors working in different areas, found "only" 9% and 5%, respectively, for fish endemism (Fock *et al.* 2002, Stocks 2004). It is not possible to know how true these proportions of endemism are at present, due to the lack of comprehensive survey. Richer de Forges *et al.* (2000) found that adjacent seamounts in the New Caledonia area shared an average of just 21% of their species, and for seamounts on separate ridges ~1000 km apart, this decreased to ~4%. For some groups the relatively species overlap suggest that seamounts function ecologically as islands groups or chains leading to localized species distributions, and with apparent speciation between these groups (Clark 2001). While we cannot currently estimate global endemism patterns on seamounts, sufficient sampling exists to say that some seamounts have extremely high rates of apparent endemism and in some cases this endemism may be operating at the level of individual seamounts.

There is some evidence to suggest that for octocorals on the Atlantic seamounts this scenario may be different. At present, Watling and Auster (in press) found very little correspondence among the octocoral species found in the eastern and western Atlantic regions south of the boreal fauna (which appears to be continuous across the northern boundary of the North Atlantic). However, the eastern Atlantic data are largely from seamounts while the western Atlantic data are primarily from the continental slope. In contrast, unpublished data of L. Watling on octocorals suggests there may be a broad North Atlantic fauna on seamounts. There is also some evidence that shallower seamounts tends to have a greater component of species with restricted biogeographical ranges in comparison to the deeper seamounts which harbour assemblages of more cosmopolitan species (for example, polychaetes: Gillet and Dauvin 2000). Also, the commercially important fishes, associated with deep-sea coral bank and seamounts in the North Atlantic tends to exhibit a latitudinal species gradient (George 2004).

Information on the genetic structure of deep-sea fish populations is important in determining management units, but also in understanding the impact of overfishing on the overall genetic variability of species. This information can also be used to estimate the likelihood of recolonisation of damaged populations through immigration of individuals from distant localities (Stockley *et al.* 2005). Populations of benthic or benthopelagic species may inhabit continental slopes, the slopes of oceanic islands and seamounts that are separated from each other by thousands of km of the deep ocean. It is not clear whether such species have life histories that are characterised by extremely high dispersal or if their present day distributions are largely historic, resulting from past dispersal events when oceanic conditions and the configuration of geographic features were different.

### 2.6.1 Examples of genetic variation in some species occurring on seamounts

For some deep-water species of fish, there is evidence for genetic differentiation among populations at the trans-oceanic, oceanic and regional scales suggesting that historic long-distance dispersal has largely determined present-day distribution (Rogers 2003). At a regional scale species include roundnose grenadier, Greenland halibut *Reinhardtius hippoglossoides*, and (Pacific) shortspine thornhead *Sebastolobus alascanus* that occur on both seamounts and elsewhere (Aboim *et al.* 2005). The genetic structure of bluemouth (Aboim *et al.* 2005) suggests some intraregional genetic differentiation between populations. The genetic structure also suggests that populations had undergone expansion following bottlenecks and/or they have colonised areas far from their source populations, possibly using major oceanic currents as pathways. A mark and recapture tagging programme running in the Azores strongly suggests that the adult bluemouth have a very sedentary lifestyle as many tagged specimens have been recaptured after more than three years in exactly the same place as they were originally tagged (G. Menezes pers. obs.). Analysis of population structure of red seabream in the Azores, using both D-loop and microsatellite analysis indicates low to moderate but significant genetic differentiation between populations at a regional level. This study supports studies on other deep-sea fish species that indicate that hydrographic or topographic barriers prevent dispersal of adults and / or larvae between populations at regional and oceanographic scales.

It is not known how far the larvae of the coral *Lophelia pertusa* can disperse and whether larva-mediated gene flow is sufficient to maintain the genetic cohesiveness of European populations. However, George and Lundalv (2003) reported a clear difference in thermal tolerance of adult *Lophelia pertusa* populations from the northwest versus the northeast Atlantic Ocean, suggesting possible genetic differences from physiological perspectives. Le Goff-Vitry *et al.* (2004) indicate from studies at several sites in the northeast Atlantic that there is a single offshore genetic population that is differentiated from the population of this coral occurring in Norwegian fjords. However, these authors did not investigate samples of coral from seamounts.

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### **3 Protection of vulnerable deep-water habitats in the NEAFC Convention Area**

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Terms of Reference: These derive from a letter from the North East Atlantic Fisheries Commission (NEAFC) to ICES requesting scientific advice for 2005. NEAFC wished ICES to provide initial answers to questions regarding a proposal for the protection of vulnerable deep-water habitats:

- i. to evaluate if the boundary lines of the closed areas in the NEAFC Regulatory Area reflect the spatial distribution of vulnerable deep-water habitats in those areas;
- ii. to provide information on the distribution of cold-water corals on the Hatton Bank;
- iii. provide information on the percentage of vulnerable deep-water habitats in the Regulatory Area covered by the proposal;
- iv. provide information on the distribution of cold-water corals on the Western slopes of the Rockall Bank to indicate appropriate boundaries of any closure of areas where cold-water corals are affected by fishing activities;
- v. evaluate the destructiveness of different fishing gears with respect to vulnerable deep-water habitats.

#### **3.1 Introduction**

The summary given here must be put in context of the paucity of information available on the distribution of seabed habitats in the NEAFC area. Without a concerted effort to map the distribution of seabed habitats, the available information is at best patchy, for instance in the context of collated records of cold-water corals, or virtually non-existent in the case of other significant habitat types, such as sponge fields. The Working Group stress the danger of relying on such incomplete datasets since decisions to close areas to bottom trawling may inadvertently divert trawling to similarly sensitive habitats that are currently unmapped. Naturally all responses need to be reviewed in light on new data on the distribution of vulnerable habitats in the NEAFC area.

#### **3.2 The spatial distribution of vulnerable deep-water habitats in relation to the boundary lines of the closed areas in the NEAFC Regulatory Area**

The Working Group does not believe enough information exists to comment on the representativeness of the habitats contained within these boundary lines. The members of the group are aware of the current MAR-ECO project which will be completed in 2008 and suggest that information from this research programme and any other relevant surveys be used assess the distribution on vulnerable deep-water habitats in the NEAFC area.

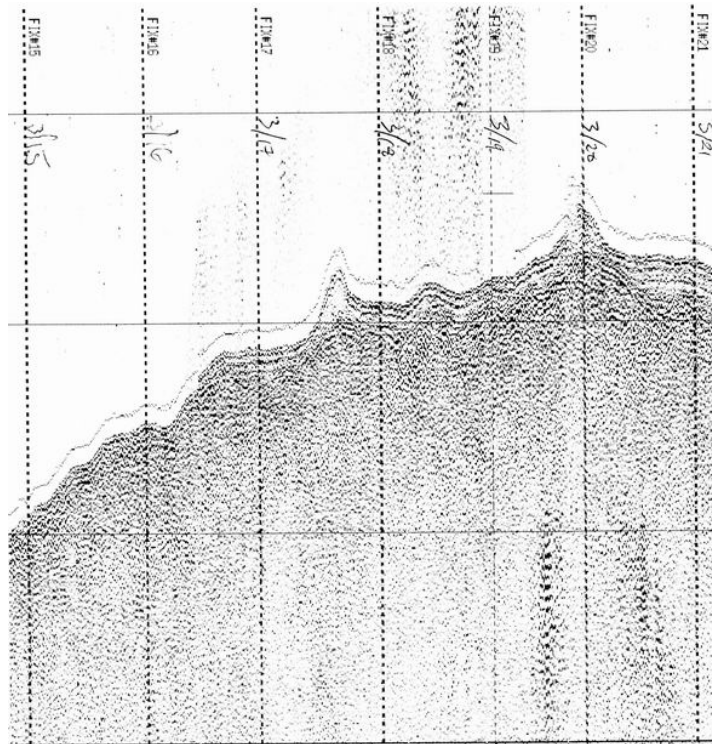
However, in line with the Norwegian letter (AM 2004/28), we believe it is worth acting in a precautionary manner to ensure vulnerable habitats in the NEAFC area, such as those likely to be found in the suggested areas, are protected. Closing these areas to damaging fishing gears would be consistent with this approach.

### 3.3 Information on the distribution of cold-water corals on the Hatton Bank

Information known to the Working Group on the occurrence of cold-water corals on the Hatton Bank is available in the literature from three published sources (Frederiksen et al. 1992; Roberts et al. 2003; Wilson 1979a) and three cruise reports (Chesher 1987, A. Freiwald pers. comm., G. Langedal pers. comm.). These locations are listed in Table 3.1. The published records all refer to the occurrence of *Lophelia pertusa*, acknowledged to be the dominant reef framework-forming coral species in the north-east Atlantic. The geological investigation described by Chesher (1987) used a sub-bottom profiler to identify areas of rock outcrop and used a dredge to collect volcanic rocks from north-east Atlantic seamounts and Banks. Reef-like features, consistent with *Lophelia pertusa* structures, were observed during geophysical 'sparker' surveys of Hatton Bank in 2000 (Figures 3.3.1, 3.3.2) and 2002 (Figure 3.3.3) (D Long, pers. comm.). Freiwald (pers. comm.) reported a substantial number of mound-like elevations, some of which were checked by dredge hauls for cold water coral presence. Each of the successful hauls revealed large quantities of live *Lophelia pertusa* and *Madrepora oculata*, and/or *Primnoa resaediformis* colonies, together with various other coral species. Other information on the occurrence of cold-water corals on the Hatton Bank is available from French and British fishing charts (Figures 3.3.4, 3.3.5).

**Table 3.1 Positions where *Lophelia pertusa* been recorded on the Hatton Bank**

POSITION	WATER DEPTH (M)	REFERENCE
59°N 14°W - 59° 30'N 18°W	457 - 604	Wilson 1979a
59° 16'N 15° 46'W - 59° 17'N 15° 41'W	549 - 530	Wilson 1979a
59° 15'N 15° 52'W - 59° 15'N 15° 47'W	494 - 512	Wilson 1979a
59° 16.30'N 16° 0.60'W - 59° 16.8'N 16° 0.80'W	497	Chesher 1987 (Dredge 32)*
59° 19.00'N 16° 2.00'W - 59° 18.70'N 16° 2.00'W	622 - 605	Chesher 1987 (Dredge 33)*
58° 13.30'N 17° 48.50'W - 58° 14.20'N 17° 49.80'W	990-898	Chesher 1987 (Dredge 46)*
59° 21.57'N 15° 08.04'W - 59° 20.94'N 15° 07.72'W	880-778	Chesher 1987 (Dredge 52)*
59° 11.74'N 15° 12.44'W - 59° 12.79'N 15° 12.88'W	1040-870	Chesher 1987 (Dredge 55)*
59° 11.5'N 17° 14.4'W - 59° 11.1'N 17° 14.2'W	560 - 529	Frederiksen <i>et al.</i> 1992
58° 46.7'N 18° 25.9'W - 58° 46.4'N 18° 25.0'W	646 - 591	Frederiksen <i>et al.</i> 1992
59° 18.5'N 15° 39.5'W - 59° 18.4'N 15° 38.7'W	730	Frederiksen <i>et al.</i> 1992
59° 19.8'N 15° 07.6'W - 59° 20.0'N 15° 03.9'W	747 - 673	Frederiksen <i>et al.</i> 1992
58° 46.9'N 18° 31.1'W - 58° 46.6'N 18° 30.1'W	771 - 710	Frederiksen <i>et al.</i> 1992
59° 23.2'N 15° 07.9'W - 59° 22.5'N 15° 05.9'W	1064 - 977	Frederiksen <i>et al.</i> 1992
59° 16.3'N 16° 00.6'W - 59° 16.8'N 16° 60.8'W	497	Frederiksen <i>et al.</i> 1992
59° 19.0'N 16° 02.0'W - 59° 18.7'N 16° 02.0'W	622 - 605	Frederiksen <i>et al.</i> 1992
59° 21.6'N 15° 08.0'W - 59° 20.9'N 15° 07.4'W	880 - 778	Frederiksen <i>et al.</i> 1992
59° 11.7'N 15° 12.4'W - 59° 12.8'N 15° 12.9'W	1040 - 870	Frederiksen <i>et al.</i> 1992
59° 16.4'N 15° 25.3'W - 59° 18.5'N 15° 15.0'W	500-650	Roberts <i>et al.</i> 2003
59° 18'N 15° 20'W	610-650	G. Langedal pers. comm.
59°18.71'N 17°04.5'W - 59°18.03'N 17°03.5'W	839-780	A. Freiwald pers. comm.
59°18.26'N 17°02.8'W - 59°17.01'N 17°00.34'W	810-760	A. Freiwald pers. comm.
59°11.06'N 17°12.7'W - 59°10.48'N 17°11.21'W	513-519	A. Freiwald pers. comm.



**Figure 3.3.1** Geophysical survey 'sparker' line surveyed in 2000 showing feature on the Hatton Bank in 700-750 m water depth at approx 57°53'N 18°58'W that is likely to be a cold-water coral reef. The mound is 20-30 m high. (D. Long pers. comm.). Image copyright British Geological Survey.

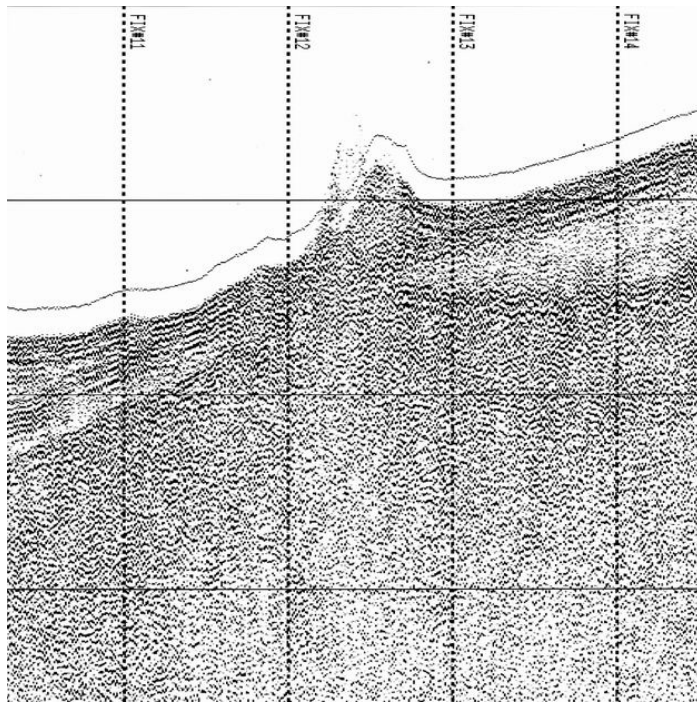


Figure 3.3.2 Geophysical survey 'sparker' line surveyed in 2000 showing feature on the Hatton Bank in 700-750 m water depth at approx 58°28'N 18°40'W that is likely to be a cold-water coral reef. The mound is 20-30 m high. (D. Long pers. comm.). Image copyright British Geological Survey.

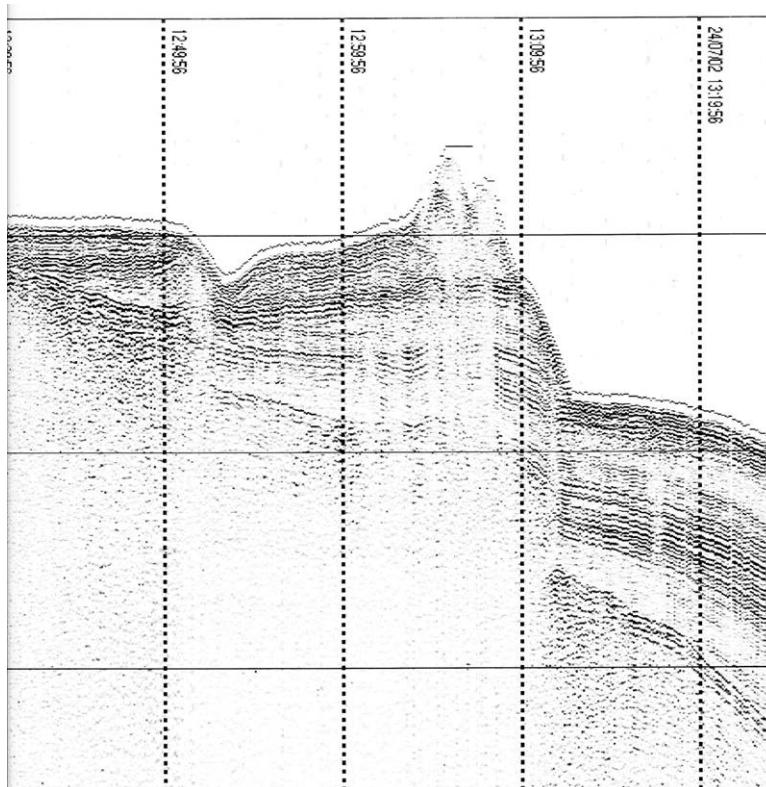
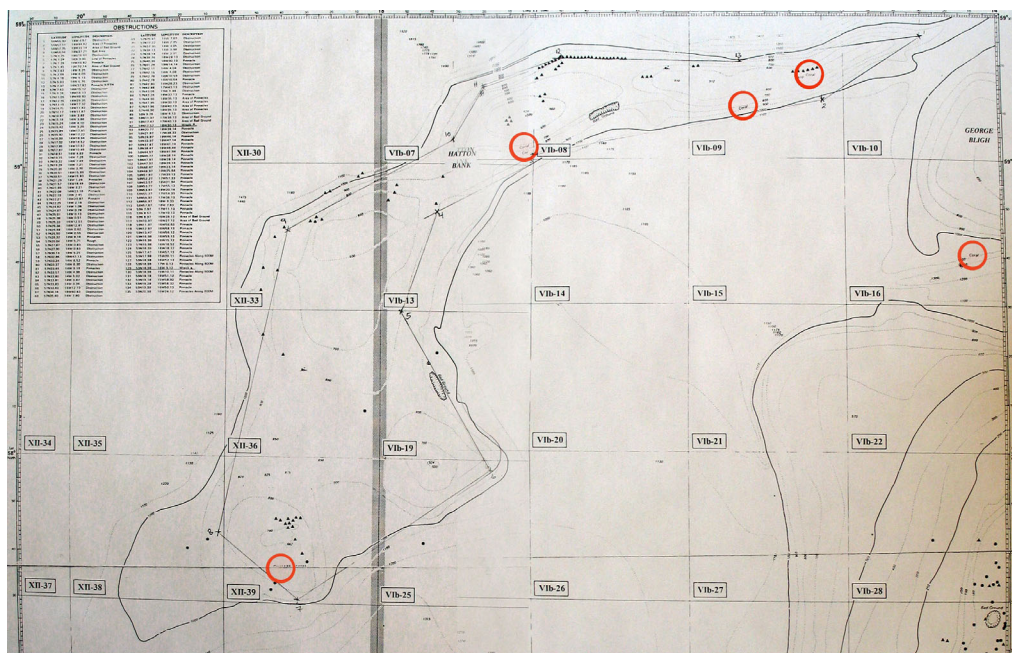


Figure 3.3.3 Geophysical survey 'sparker' line surveyed in 2002 showing feature on the Hatton Bank at approx 58°50'N 17°40'W that is likely to be a cold-water coral reef (D. Long pers. comm.). Image copyright British Geological Survey.



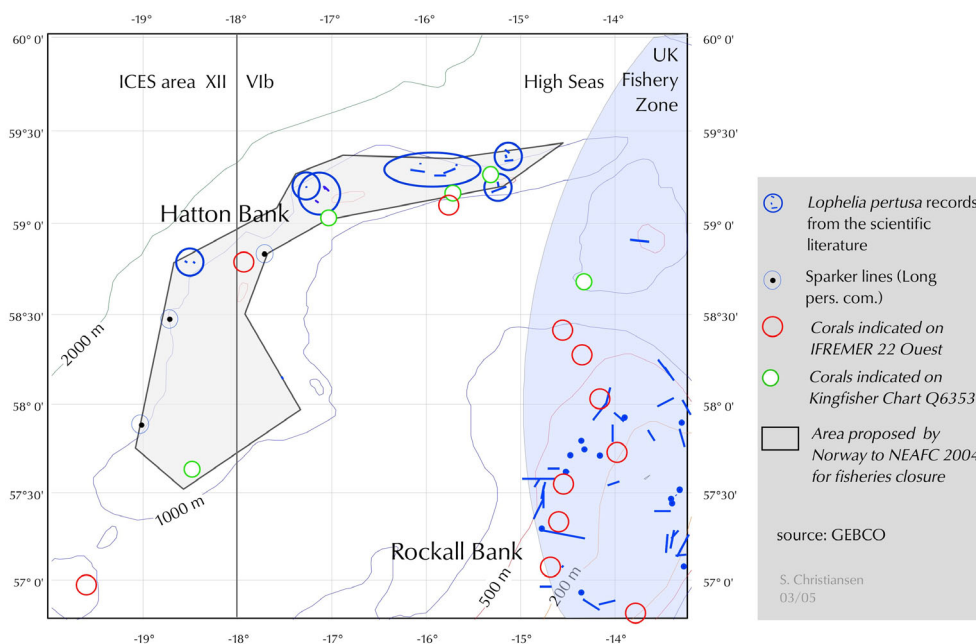
**Figure 3.3.4** Locations (circled) of ‘corals’ recorded on northern portion of IFREMER chart Ouest 22 over Hatton Bank (and NW Rockall)



**Figure 3.3.5** Locations (circled) of ‘corals’ recorded on northern portion of Kingfisher chart Q6353 over Hatton Bank (and NW Rockall).

All of these records are illustrated together on Figure 3.3.6. Based on this information, it is clear that *Lophelia pertusa* occurs on Hatton Bank. It must be remembered that most of these locations correspond to records of *L. pertusa* recovered in trawls or dredge nets and they give no information on whether or not the location supports a reef structure, or how extensive any development may be. However, the sparker line results of Long and the echosounder profiles and sampling of Freiwald indicate strongly that structures exist. In better-investigated areas, such as the Porcupine Seabight, such structures support cold water coral reefs. Therefore, it seems highly likely that sizeable cold-water coral reefs are present on the Hatton Bank. Based on both dredge samples and acoustic surveys Chesher (1987) notes, ‘It is worthy of note that

several coral reefs up to 30 metres in height generally associated with the banks were also identified, in particular on Hatton Bank. These reefs predominate in water depths in excess of 500 metres.’



**Figure 3.3.6 Known and likely locations of cold-water coral on Hatton Bank.**

It is likely that further information on coral occurrence on Hatton Bank will be available in the fishing diaries of skippers, particularly those of the main nations fishing on this Bank: France, Spain and UK. Norwegian, Russian and Irish vessels are also known to fish in the area..

Without a properly planned habitat mapping exercise based on wide-area acoustic survey (e.g. multibeam sonar) with adequate visual ground-truthing, it is impossible to provide a true picture of the distribution of cold-water corals on the Hatton Bank. Equally it is impossible to provide a true picture of where such habitat-forming species do not occur. Only with these mapping data can the distribution of substantial reef structures on Hatton Bank be determined.

**3.4 Information on the percentage of vulnerable deep-water habitats in the NEAFC Regulatory Area covered by the proposal to close certain areas**

The Working Group had little information to address this question, and believes that this information does not exist. At a minimum a complete wide-area survey would be needed to begin addressing this question.

**3.5 Information on the distribution of cold-water corals on the Western slopes of the Rockall Bank that can be used to indicate appropriate boundaries of any closure of areas where cold-water corals are affected by fishing activities**

**3.5.1 Introduction and background to sources of information**

There has been no comprehensive survey of the benthos of the Rockall Bank and thus no comprehensive view of the occurrence of cold-water corals on the Bank or its slopes. There

are though three sources of information that provide indications of coral occurrence. These are a) scientific records (from both scientific surveys and other sources), b) recent knowledge of fishermen working on the bank and c) 'geographical gaps' in Vessel Monitoring System (VMS) data in areas that are heavily fished. The limitations of each of these sources of data in describing the distribution of corals are reviewed below.

**Scientific records:** These records may derive from any time period from the 18<sup>th</sup> century onwards. Earlier records may not have been accurately plotted (dead reckoning was often used) and where scientific dredges or trawls were used, the exact sampling location along the tow line cannot be known. Records may be of small pieces of coral or of pieces of dead coral that might not represent reef occurrence. There is no easily available background 'effort' information on where earlier scientists or others have looked and not found coral. More recent scientific study includes some wide area surveys with visual ground truthing over the southern (Logachev Mounds) and western (Franken mound and Kiel Mount) parts of the Rockall Bank.

**Recent knowledge of fishermen:** Maps drawn by two fishermen who work frequently on the Bank indicate areas where they would not trawl due to high density of corals. There is no record as to how large an area was considered in outlining these coral rich areas (i.e. how wide a geographical area is known by the fishermen). There was no indication that the fishermen wished to bias their reports one way or another, but there is also no easy way of checking their notes.

**Geographical gaps in VMS coverage:** VMS data gathered over two years indicate some consistent gaps in areas where fishermen trawl. Some of these gaps will be due to dense coral aggregations making it risky to fish (both due to loss/damage to gear and to safety considerations). There may however be other reasons to avoid areas, including rocky ground or poor catches per unit effort.

### 3.5.2 Availability of information

#### 3.5.2.1 Scientific records

In the scientific literature, pioneering work on the distribution of *Lophelia pertusa* around Rockall Bank was published by Wilson (1979a, b, c). However, this work predates the expansion of deepwater trawl fisheries along the western Bank of Rockall that occurred in the 1980s and has affected cold-water coral habitat in the region (Gordon, 2002; Hall-Spencer *et al.*, 2002). An update of all known published records was produced by Roberts *et al.* (2003) but even this source does not include the most recent surveys on the southern Rockall Bank as some of this work is currently in progress (A. Grehan pers. comm.).

In 2001 and 2003, RVs L'Atalante and Meteor surveyed the Logachev Mounds, a series of coral-rich habitats at 598-870 m depth aligned in a narrow zone almost parallel to the slope on the south end of the Rockall Bank (Figure 3.5.2.1.1). These surveys showed widespread occurrence of live coral colonies and sponges of various kinds at mound summits and upper flanks. These coral habitats were in good condition despite 20 years of deep-water fishing activity in the region (Haas *et al.* 2000; Olu-Le Roy 2002, Grehan *et al.* in press). Some of the coral mounds in this region are extensive, several kilometres in diameter and up to 350 m high.

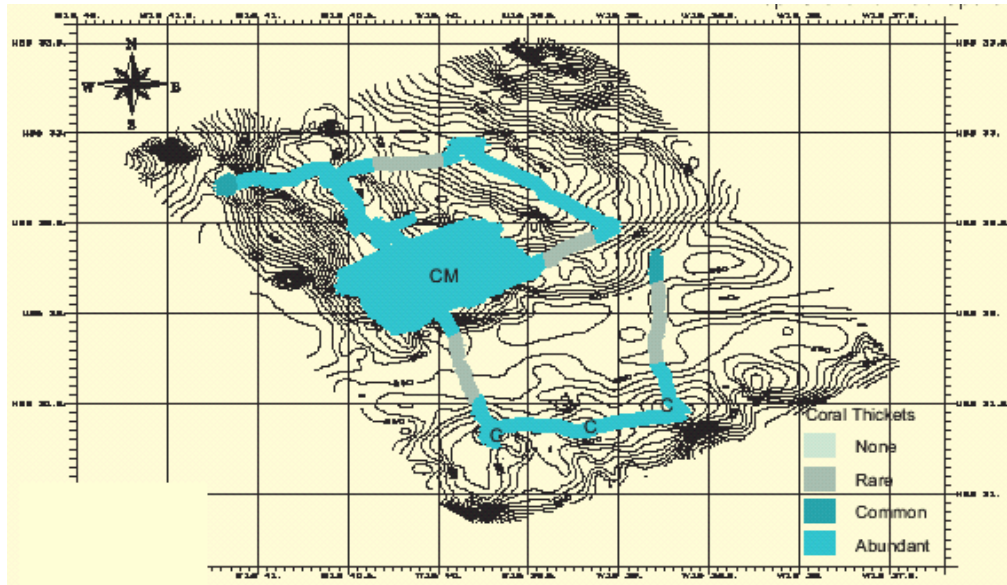


Figure 3.5.2.1.1 Coral occurrences at R2 site in Logachev Mounds (Unnithan *et al.* 2003).

The mounds here are of variable in size and shape. Some occur as single, steep pinnacles rising up to 350m above the seabed with a diameter of 2-3 km at the seabed, while others are large, slightly less high, irregular shaped clusters with a diameter of up to 6 km. The total width of the clustered complex is about 15 km. Mounds higher on the slope are smaller, more isolated and maybe partly buried under a relatively thin sediment cover. To the east and to the south-west the mound complex no longer appears at the surface as it becomes fully buried in the sediment.

A detailed *in situ* investigation of the Logachev mound cluster took place in 2001. High resolution video and close-up digital stills taken with the French VICTOR remotely operated vehicle revealed the extensive occurrence of living deep-water coral reefs constructed principally by the reef-framework forming species, *Lophelia pertusa* and *Madrepora oculata* (Figures 3.5.2.1.2, 3.5.2.1.3, Grehan *et al.* in press). Most of the area is covered by living corals with high densities of other species including gorgonians, anthipatarians and crustaceans. Crinoids were particularly abundant.





Figure 3.5.2.1.2 Crinoids *Koehlerometra porrecta* on *Lophelia pertusa* colonies (R2 site on Logachev Mounds) Caracole cruise. ©Ifremer

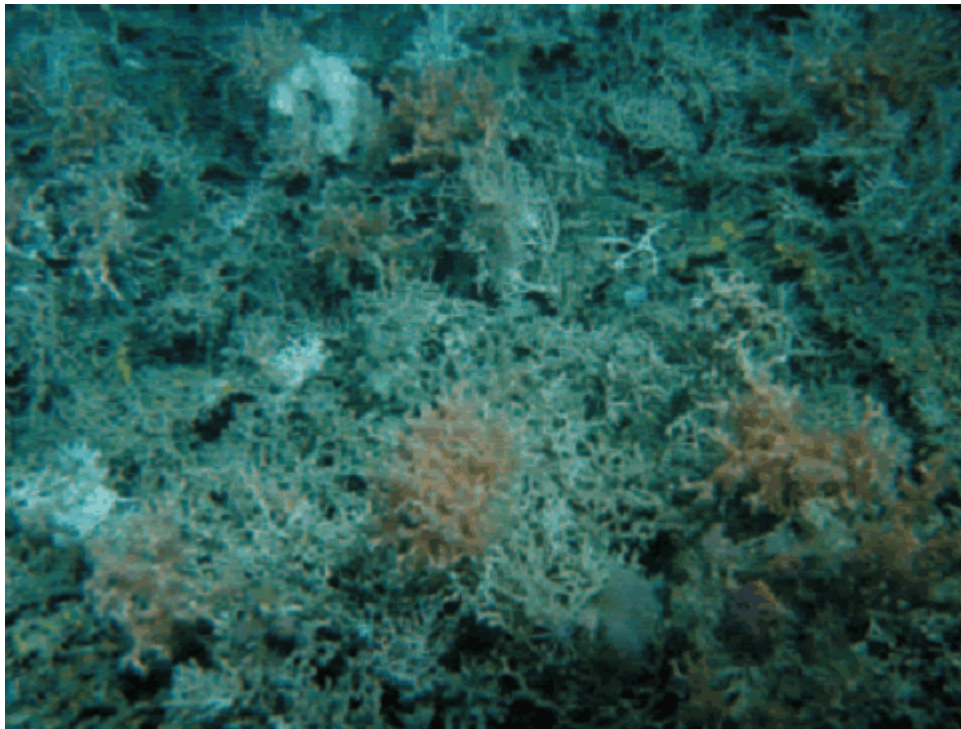


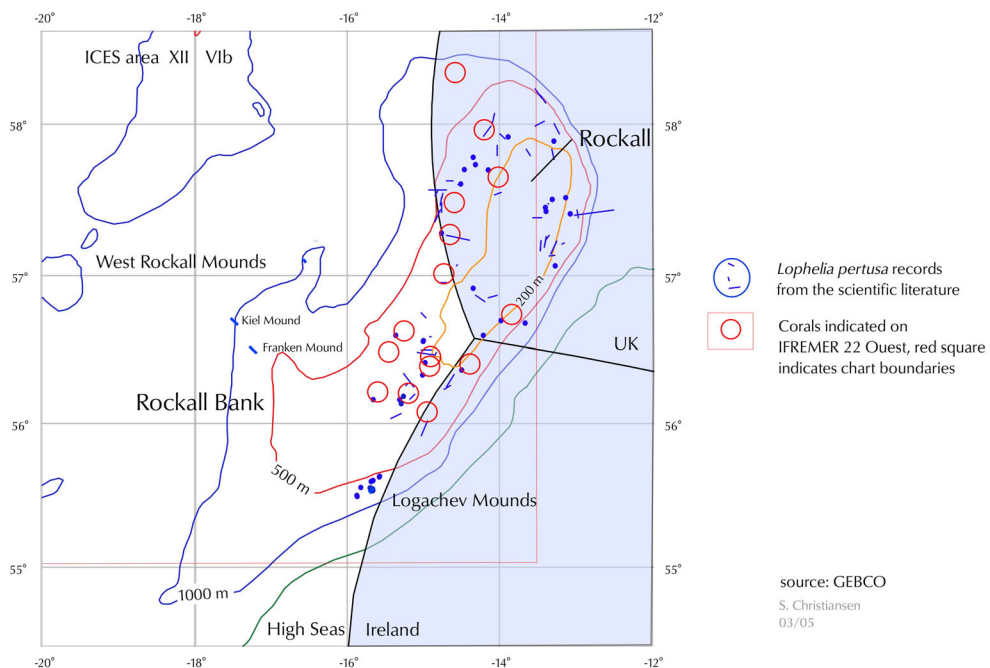
Figure 3.5.2.1.3 Dense coral cover at R2 site in the Logachev Mound province.

All of these records indicate that the coral reefs on the Rockall Bank are dominated by *Lophelia pertusa*, although other cold-water corals such as *Madrepora oculata* occur in the area. The reefs occur along the flanks of the bank in Irish, UK and International waters, predominantly at depths between 150 and 1000 m. The recent glacial history of the region is reflected in the seabed topography with extensive boulder fields, iceberg scour marks, coarse

gravels and isolated dropstones forming the hard substrata that these corals species require for their initial settlement.

Cold-water coral communities were also recently discovered further to the west of Rockall Bank using multibeam bathymetry data from the Irish Seabed Survey to guide specific surveys in 2004 from the research vessel Meteor (A. Freiwald, pers. comm.). For example the Franken Mound at 627 to 700 m depth (56° 29.93N 17° 18.21W) was found to support scleractinian coral communities in 2004 during Meteor cruise M61-1 and M61-3. These thickets had in some places developed to over 1 m in height and were formed by coral frameworks produced by *Lophelia pertusa* and *Madrepora oculata*. The visual inspections of Franken Mound recorded lost fishing gear in these coral areas. To the north and west of the Franken Mound and in deeper waters, the Kiel Mount (56° 42.00N and 17° 30.00W) was also investigated by the Meteor cruise M61-1. Visual inspections (between 833 and 1060m) of this conical volcanic cone at 1100 to 900 m showed that it in some areas scleractinian coral rubble and live gorgonian corals were present. These initial inspections implied that, compared to the shallower Franken Mound, the Kiel Mount was relatively sparsely colonised by scleractinian corals, but supported a richer community of antipatharians, gorgonians and sponges.

All of the above records, along with occurrences of 'coral' shown on the French fishing chart IFREMÉR 22 Ouest are shown in Figure 3.5.2.1.4.



**Figure 3.5.2.1.4 Records on the Rockall Bank of *Lophelia pertusa* from the scientific literature and of corals from a French fishing chart.**

### 3.5.2.2 Recent knowledge of fishermen

Information is available from two fishers that are active in the area has been collected by J. Hall-Spencer (Fig 3.5.2.2.1). The fishers often fish close to these features where some demersal species aggregate, but avoid contact with extensive coral mounds due to the extensive damage that this does both to their gear and to their catch (Fig 3.5.2.2.2).

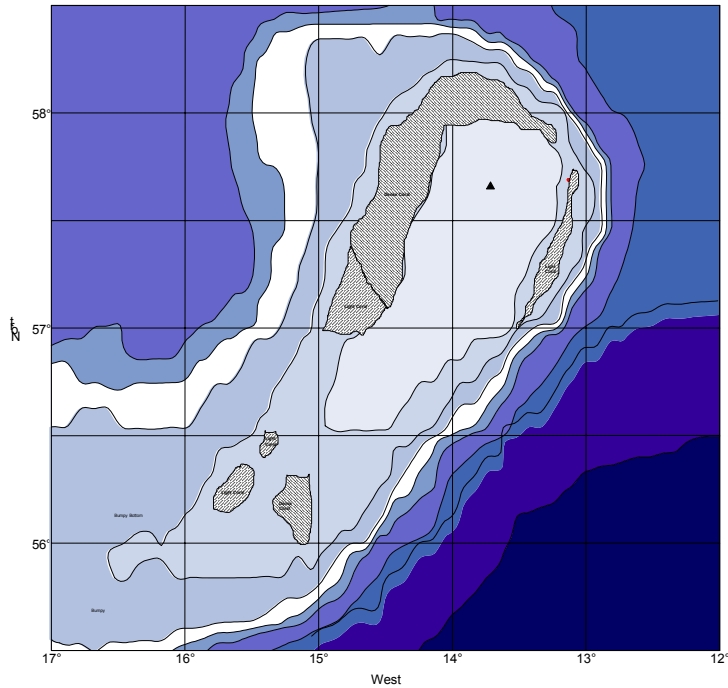


Figure 3.5.2.2.1 The distribution of coral reefs on Rockall Bank from two fishermen's records (J. Hall-Spencer, pers. comm.). The cross-hatched areas indicate presence of *Lophelia* reefs, with denser coral areas shown line heavier cross hatching (NW-SE lines) and lighter hatching as SW-NE lines.

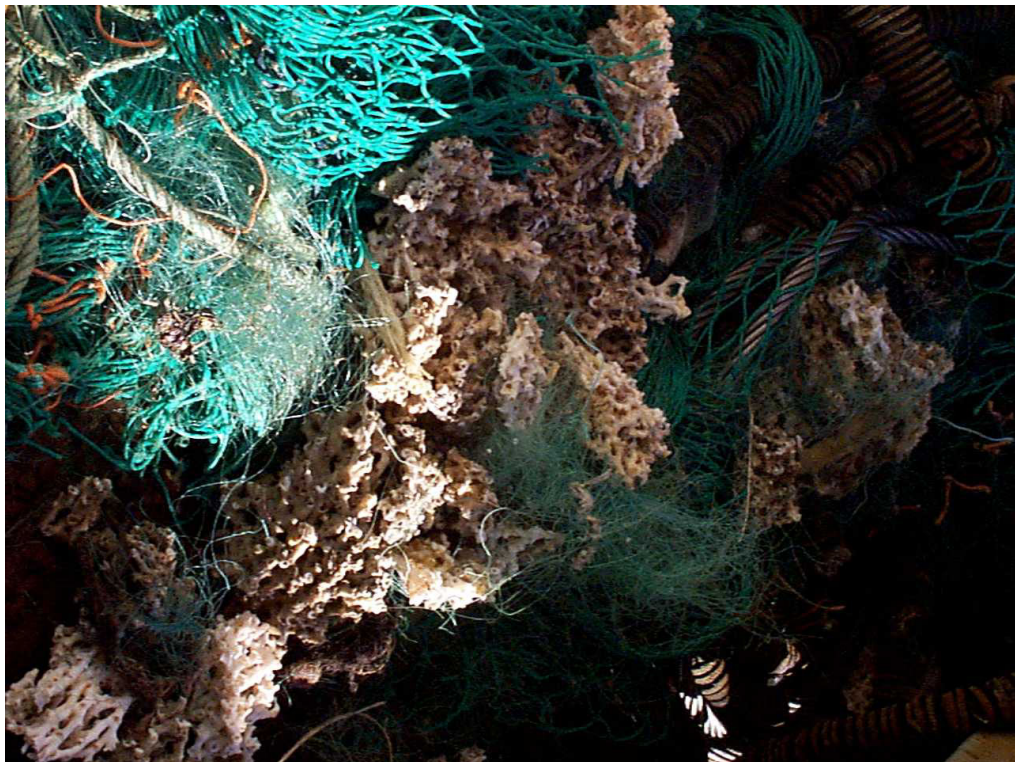
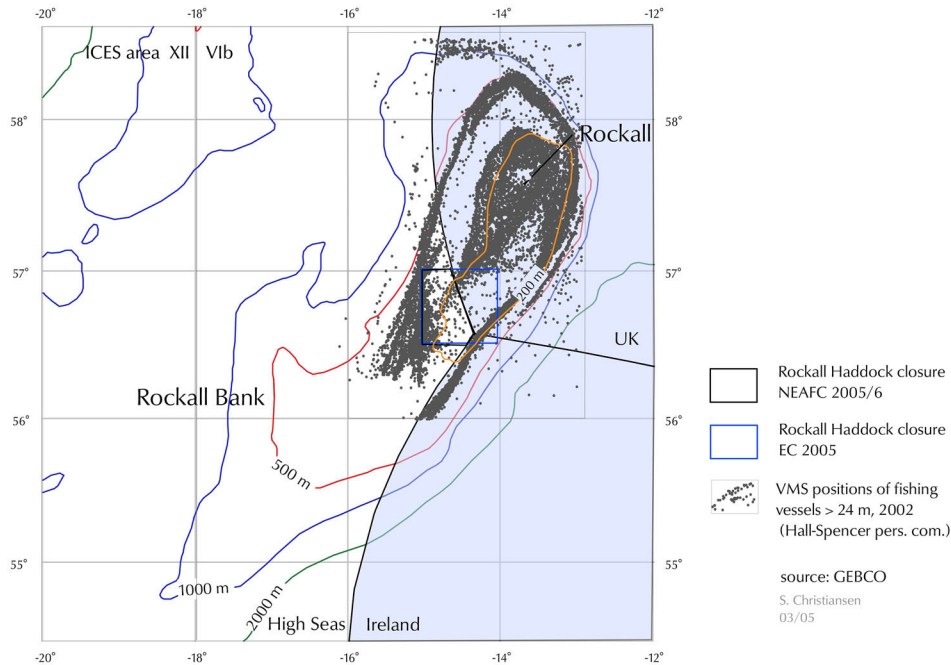


Figure 3.5.2.2.2 Nets damaged by *Lophelia pertusa* reefs on a Scottish demersal trawler fishing West Rockall Bank in 2002 using scraper nets targeting monkfish *Lophius piscatorius* (photo: J Hall-Spencer).

### 3.5.2.3 Geographical gaps in VMS coverage

Preliminary data from satellite tracking of all fishing vessels >24m in length over the northern Rockall Bank on 2002 (Marrs and Hall-Spencer 2002; J. Hall-Spencer, unpublished) indicates that fishers favoured certain depth contours and actively avoided large parts of the north-western Rockall Bank area (Figure 3.5.2.3.1).



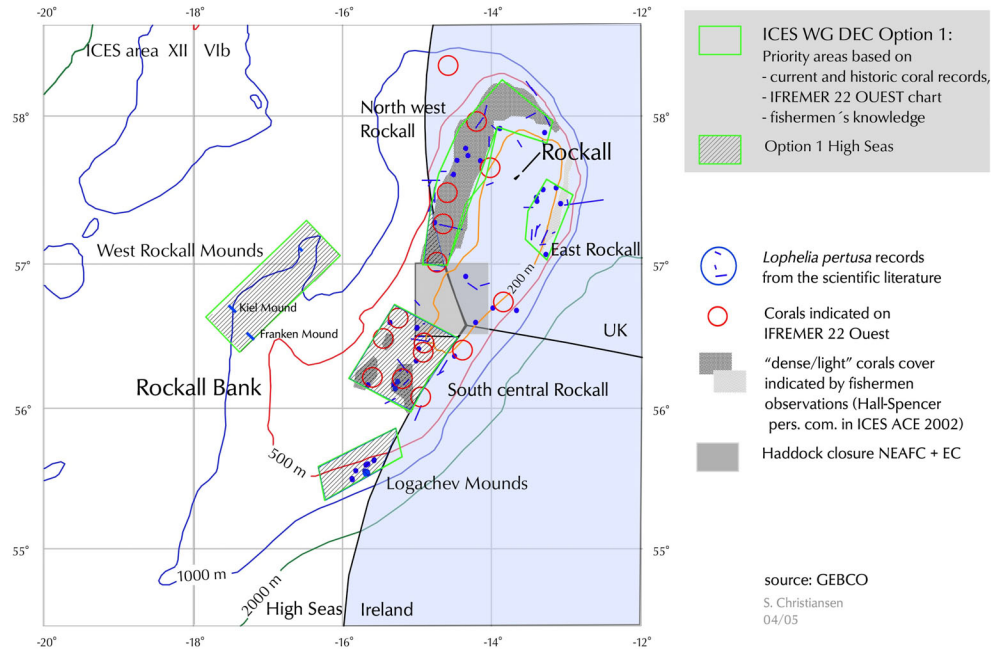
**Figure 3.5.2.3.1 VMS data showing fishing vessel positions (all types of fishing vessels of all nationalities >24 m in length) every 2 hours in 2002 in the northern Rockall Bank area.**

### 3.5.3 Options for appropriate areas to close where cold-water corals may be affected by fishing

The three sources of information on the distribution of cold-water corals may be used to define areas that could be closed to protect cold-water corals. We describe three options to use this information that give three differing areas that would be appropriate for closure. The choice between these areas will depend on the varying degree of importance attached to each source of information and on the ease of management of complex closures. One common feature of all closures for cold water corals is that these ought to be permanent or should at least exist until better information becomes available to choose more appropriate areas. It would be pointless to close an area of importance to cold-water coral on a temporary basis, unless this is a step towards a permanent closure. It is also worth noting that Rockall Bank straddles the area fully managed under the European Union's Common Fisheries Policy and that regulated by the NEAFC. We have ignored this boundary in considering suitable areas to close on the Rockall Bank. If this boundary was not ignored in providing information to NEAFC, then the group felt that there was a serious risk of inadvertently displacing effort into other areas holding cold-water coral. Regulations covering parts of the bank seem likely to affect fishing effort in other parts. Therefore, we examined the whole Rockall Bank and suggest appropriate areas to protect corals on the eastern side of the bank. The Rockall Bank ecosystem should be regarded as one unit for management purposes regardless of the precise responsible authority. The group felt it important that management authorities should work together to protect corals on this bank and agreed with previous ICES advice that closing relevant areas to towed gears that impact the seabed was essential to safeguard coral reefs.

### 3.5.3.1 Option 1 – boundaries based on scientific records and fishers knowledge

This option gives five areas of possible closure – the north-west flank, an area on the eastern flank, and area in the south west, the Logachev mounds to the south and the West Rockall Mounds (Figure 3.5.3.1.1). The latitude and longitude of each corner point is given in Table 3.2.



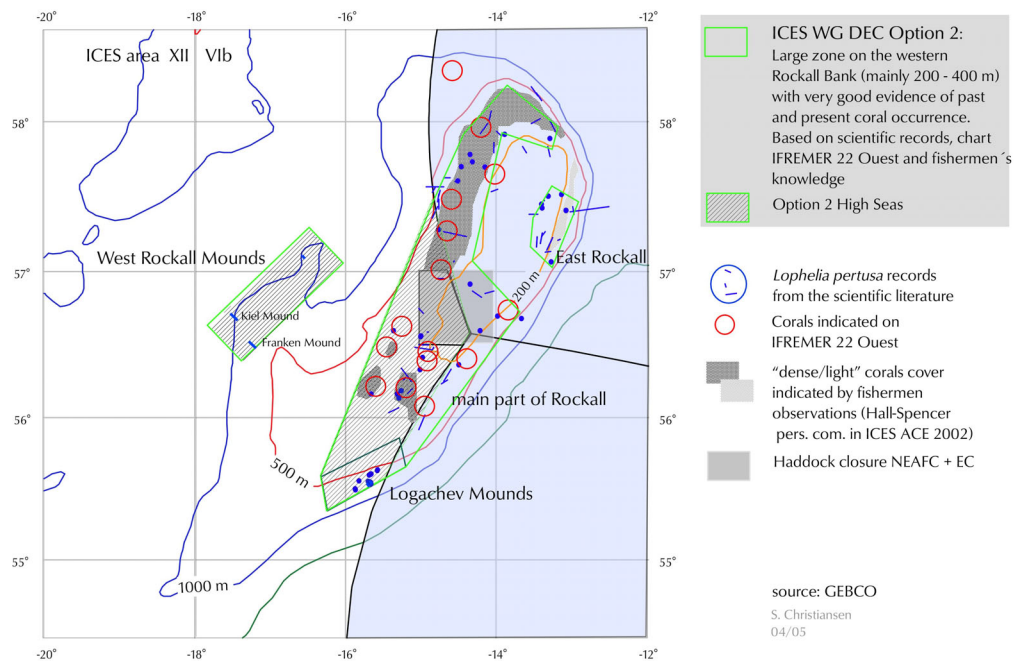
**Figure 3.5.3.1.1 Option 1 for areas appropriate for closure to protect cold-water corals on the Rockall Bank, based primarily on scientific and fisher's records.**

**Table 3.2 Co-ordinates of the corner locations of the five areas illustrated in Figure 3.5.3.1.1. Corner locations in NEAFC area indicated with an asterisk. Approximate co-ordinates of the points where the boundaries cross between EU and NEAFC managed waters are also indicated in brackets. Locations are accurate to nearest minute of latitude and longitude.**

SUGGESTED CLOSURE AREA	LATITUDE AND LONGITUDE OF CORNER POINTS
North west Rockall	58°15'N, 13°50'W 57°58'N, 13°10'W 57°50'N, 13°15'W 57°55'N, 13°55'W 57°00'N, 14°35'W * 57°00'N, 14°55'W * 57°24'N, 14°48'W * 57°37'N, 14°42'W 57°55'N, 14°25'W
East Rockall	57°35'N, 13°15'W 57°30'N, 12°53'W 57°03'N, 13°15'W 57°10'N, 13°30'W 57°22'N, 13°30'W
South central Rockall	56°43'N, 15°17'W * 56°30'N, 14°27'W * 55°59'N, 15°04'W * 56°13'N, 15°54'W *
Logachev Mounds	55°50'N, 15°15'W * (55°49'N, 15°14'W) 55°38'N, 15°08'W (55°35'N, 15°30'W) 55°19'N, 16°11'W * 55°33'N, 16°16'W *
West Rockall Mounds	57°20'N, 16°30'W * 57°05'N, 16°00'W * 56°22'N, 17°20'W * 56°40'N, 17°50'W *

### 3.5.3.2 Option 2 – simplified boundaries based on scientific records and fishers knowledge

This option gives three areas, one long one covering the upper western slope of the Rockall Bank from the north-west to the Logachev Mounds, an area on the eastern flank of Rockall and the West Rockall Mounds (Figure 3.5.3.2.1). The areas included in Option 1 would be regarded as priorities for protection within this Option. The upper western slope area incidentally includes much of the current area within which the use of towed demersal gear is prohibited in an attempt to aid recovery of much reduced Rockall haddock stocks. The latitude and longitude of each corner point is given in Table 3.3.



**Figure 3.5.3.2.1 Option 2 for areas appropriate for closure to protect cold-water corals on the Rockall Bank, a simplified version of Option 1 based primarily on scientific and fisher's records.**

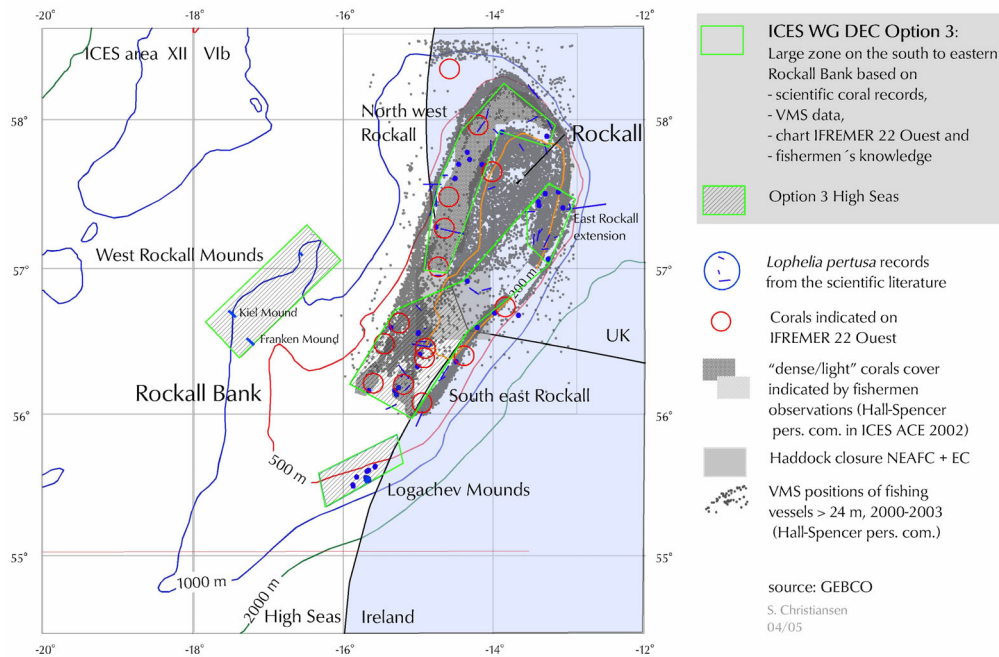
**Table 3.3 Co-ordinates of the corner locations of the three areas illustrated in Figure 3.5.3.2.1. Corner locations in NEAFC area indicated with an asterisk. Approximate co-ordinates of the points where the boundaries cross between EU and NEAFC managed waters are also indicated in brackets. Locations are accurate to nearest minute of latitude and longitude.**

SUGGESTED CLOSURE AREA	LATITUDE AND LONGITUDE OF CORNER POINTS
Main part of Rockall	58°15'N, 13°50'W 57°58'N, 13°10'W 57°50'N, 13°15'W 57°55'N, 13°55'W 57°05'N, 14°20'W 56°45'N, 13°40'W 55°40'N, 15°10'W (55°35'N, 15°30'W) 55°20'N, 16°12'W * 55°35'N, 16°20'W * 57°30'N, 14°48'W 57°55'N, 14°25'W
East Rockall	57°35'N, 13°15'W 57°30'N, 12°53'W 57°03'N, 13°15'W 57°10'N, 13°30'W 57°22'N, 13°30'W
West Rockall Mounds	57°20'N, 16°30'W * 57°05'N, 16°00'W * 56°22'N, 17°20'W * 56°40'N, 17°50'W *

### 3.5.3.3 Option 3 – boundaries based on gaps in VMS, scientific records and fishers knowledge

This option gives five main areas, the north-west flank, an elongated area on the south-east flank, the Logachev mounds and the West Rockall Mounds (Figure 3.5.3.3.1). A possible north-eastwards extension to the area on the south-east flank exists if further scientific records

are taken into account. This would be regarded as an area suitable for coral recovery. The latitude and longitude of each corner point is given in Table 3.4.



**Figure 3.5.3.3.1 Option 3 for areas appropriate for closure to protect cold-water corals on the Rockall Bank, based primarily on VMS and scientific records.**

**Table 3.4 Co-ordinates of the corner locations of the four/five areas illustrated in Figure 3.5.3.3.1. Corner locations in NEAFC area indicated with an asterisk. Approximate co-ordinates of the points where the boundaries cross between EU and NEAFC managed waters are also indicated in brackets. Locations are accurate to nearest minute of latitude and longitude.**

SUGGESTED CLOSURE AREA	LATITUDE AND LONGITUDE OF CORNER POINTS
North west Rockall	58°15'N, 13°50'W 57°58'N, 13°10'W 57°50'N, 13°15'W 57°55'N, 13°55'W 57°00'N, 14°35'W * 57°00'N, 14°55'W * 57°24'N, 14°48'W * 57°37'N, 14°42'W 57°55'N, 14°25'W
South-east Rockall	57°25'N, 13°30'W 57°10'N, 13°30'W 57°00'N, 13°15'W 56°35'N, 14°20'W 55°57'N, 15°00'W * 56°13'N, 15°54'W * 56°43'N, 15°17'W * 56°55'N, 14°23'W
East Rockall extension from south-east	57°35'N, 13°15'W 57°30'N, 12°50'W 57°00'N, 13°15'W 57°10'N, 13°30'W 57°25'N, 13°30'W



Logachev Mounds	55°50'N, 15°15'W * (55°49'N, 15°14'W) 55°38'N, 15°08'W (55°35'N, 15°30'W) 55°19'N, 16°11'W * 55°33'N, 16°16'W *
West Rockall Mounds	57°20'N, 16°30'W * 57°05'N, 16°00'W * 56°22'N, 17°20'W * 56°40'N, 17°50'W *

#### 3.5.3.4 Refining the boundaries

As noted above, the benthic habitats of the Rockall Bank have not been surveyed in detail and the boundaries suggested in section 3.5.3 are appropriate to the various sources of available information. If these boundaries are to be made more precise, then further information will be required. From a scientific perspective, we recommend that basic acoustic seabed mapping and ROV surveys are a priority for the area. However, a wealth of untapped information will also be available from fishermen working in the area. Most trawl fishermen will not want to fish in coral areas due to risk of snagging and net/catch damage. It seems sensible to engage the fishing industry in discussions of appropriate boundaries of any closure of areas where cold-water corals are affected by fishing gear as there is a convergence of interest between industry and habitat management.

### 3.6 Evaluation of the destructiveness of different fishing gears with respect to vulnerable deep-water habitats

Ongoing work within ICES and OSPAR is addressing the issue of threatened and declining habitats. The criteria for such habitats include ecological importance, sensitivity and recoverability of the habitat, rate and extent of decline and regional importance (ICES 2002). For the purposes of this term of reference, the word “vulnerable” was taken to be synonymous with “sensitive”, which this Working Group chose to define as one which is ‘easily adversely affected by a human activity, and/or if affected is expected to only recover over a very long period, or not at all’ (OSPAR/Texel-Faial criteria). Deep-water habitats were defined as those found at depths greater than 200m. Given this definition, fisheries for species that are not necessarily classed as “deep water” by stock assessment working groups are included, e.g. fishing for anglerfish and hake.

In order to address this ToR fully, the full range of deepwater habitats within the NEAFC area should be classified and their relative sensitivity to a range of intensities of fishing activities assessed using a recognized protocol. It should be stressed however, that whilst there have been extensive research into classifying the sensitivity of coastal marine habitats and species to a broad range of fishing activities (e.g. McDonald *et al.* 1996; McMath *et al.*, 2000) very little information currently exists on the full variety and extent of deep-water habitats within NEAFC waters and their relative sensitivities.

A wealth of studies have been made on the effects of most gear types on habitats located in waters <200 m water depth (see Jennings and Kaiser, 1998, Collie *et al.* 2000, Johnson, 2002 for reviews). Potential effect of fishing gear can be divided into a number of categories:

- Alteration of the physical structure:
  - Destruction of complex three-dimensional habitats (e.g., sponge fields/burrows/refuges);
  - Disturbance of sediment structure
  - Changes in topography; evening out the seabed by scraping off high points and filling in depressions.

- Refluxing of chemicals (contaminants and nutrients)
- Resuspension of sediment/increased turbidity (clogging gills and filter-feeding animals)
- Changes to benthic community (relatively immobile species being crushed or buried; changes in the distribution of mobile species)

The physical effects of fishing generally result in a reduction of the heterogeneity of the sediment surface and reduced structure available to the biota as habitat at some level. Sediment resuspension can have implications for nutrient budgets due to burial of organic matter and exposure of deep anaerobic sediment, upward flux of dissolved nutrients in porewater and changes in the metabolism of benthic infauna (Mayer *et al.* 1991; Pilskaln *et al.* 1998). The mixing of subsurface sediments and overlying water may change the chemical makeup of both, which may be significant in deeper, stable waters (Rumohr 1998). Changes to benthic communities include direct impacts such as being crushed, buried or excavated as well as the effects of loss of habitat. Collie *et al.* (1997) found that areas undisturbed by fishing activity had consistently higher abundance, biomass, and species diversity than areas where mobile fishing gear had removed three-dimensional cover from the bottom. Fishing activity can also change the distribution of species through movement away from the area or movement towards it by opportunistic scavenging species (Kaiser and Spencer 1994, Frid and Hall 1999).

The key effect of any fishing gear is its physical impact on the habitat. This will be greatest where contact with the seabed is greatest (e.g. mobile trawled gears) and where the habitat includes three-dimensional structures on the seabed. Deep-water habitats with structures that stand proud of the seabed include biogenic reefs e.g. cold-water scleractinian corals, sponge and xenophyophore fields, geological structures such as seamounts, hydrothermal vent fields and cold seeps and carbonate mounds that may also be covered with biogenic reefs. Such benthic structural complexity is positively correlated with species diversity (Norse and Watling 1999), making these habitats of particular ecological importance. Biogenic reefs are also formed by long-lived, slow growing organisms, making them particularly sensitive.

Less is known about the sensitivity of soft sediment habitats in deep water. In these environments, habitat complexity is provided by less obvious structures on and in the seabed such as e. g. sand ripples, small pebbles, burrows, *lebenspuren* and small depressions. Shallow water studies have demonstrated physical impacts to the surface sediment and the vulnerability of fragile infaunal species that live on or within the surface sediments such as bivalves, holothurians, gastropods (e.g. Bergman and Hup 1992) or long-lived and slow recruiting epifaunal species (e.g. sponges and ascidians). However, in some cases such environments are naturally disturbed, and are relatively resilient to the long-term effects of towed demersal gear (e.g. Currie and Parry 1996). They may be inhabited by more opportunistic species and / or resilient species such as deep-burrowing bivalves and thalassinid shrimps.

Within the ICES area, the destructiveness of different types of fishing practices on vulnerable deep-water habitats, in particular, coldwater corals has been reviewed in a number of reports from the Advisory Committee on Ecosystems (ICES 2002, 2003). The primary gears used in deepwater within the ICES area were listed as:

- Benthic and benthopelagic trawling for species such as roundnose grenadier *Coryphaenoides rupestris*, orange roughy *Hoplostethus atlanticus*, black scabbard *Aphanopus carbo* and blue ling *Molva dypterygia*. A range of nets and groundgear are used, depending on the terrain and size of boat. The most common being 'rockhopper' ground gear that is composed of rubber bobbins of 50-80 cm in diameter, designed for use on very hard ground. Smaller bobbins may be used on smoother terrain;

- Benthic longlines targeting deepwater sharks, ling *Molva molva*, tusk *Brosme brosme*, hake *Merluccius merluccius* and Greenland halibut *Reinhartius hippoglossus*. The lines use hooks either set directly on the seafloor with anchors or just above the seafloor using weights and floats;
- Gillnets and tangle nets targeting anglerfish *Lophius piscatorius*, hake, and deepwater sharks;
- Baited pots used to catch deep-water red crab *Geryon affinis*.

Of all the different habitats and fishing methods, damage to cold-water corals, by benthic and benthopelagic trawling, in particular where they occur on seamounts has received the most attention. (e.g. Koslow, 1997; Koslow *et al.* 2001; Roberts, 2002). This has been shown by the presence of coral fragments in trawl nets. Clark *et al.* (1999) documented coral bycatch at 3000 kg for 6 trawls for seamounts that had not previously been fished for orange roughy, whereas the bycatch levels at heavily fished seamounts amounted to about 5 kg for 13 trawl hauls. The by-catch of coral in the first two years of bottom trawling after orange roughy in the South Tasman Rise (1997-1998) reached 1,762 tonnes although this was reduced to only 181 tonnes in 1999-2000 (Anderson and Clark 2003), as repeated trawls in the same area had already brought up or destroyed most of the coral. In the Northeast Atlantic, Hall-Spencer *et al.* (2002) noted that pieces of scleractinian coral up to 1m<sup>2</sup> were caught in trawls along the shelf break west of Ireland. Some of these coral fragments were carbon dated and estimated to be over 4000 years old. Photographic and acoustic surveys have also revealed trawl marks on coral beds between 200-1400m (Rogers 1999; Fosså *et al.* 2000, 2002; Roberts *et al.* 2000; Bett *et al.* 2001; Grehan *et al.* in press). Using video surveys, Koslow *et al.* (2001) found that 95% of the substrate of heavily fished seamounts was reduced to bare rock and coral rubble and sand contrasting with only 10% on comparable unfished seamounts.

Clearly the primary impact of trawling is mechanical damage to the reef structure and reduction in reef size. Subsequent coral growth is impaired as hydrodynamic and sedimentary processes are altered. The re-suspension of sediment also impairs growth of corals downstream. In addition to the effect on the coral itself, reducing the reef size removes essential habitat for many associated organisms, resulting in a decrease in abundance and diversity of associated fauna (Fosså *et al.* 2000). For example, Koslow *et al.* (2001) found that benthic biomass on unfished seamounts was twice that of fished seamounts and number of species one and a half times greater. The magnitude of the damage clearly depends on the scale and frequency of trawling operations. Damage may range from a decrease in the reef size, and a consequent decrease in abundance and diversity of associated fauna, to a complete disintegration of the reef and its replacement with a low-diversity community (Fosså *et al.* 2000, 2002).

Evidence for trawl damage to other sensitive habitats is less readily available but it can be reasonably assumed that the impacts to three-dimensional habitats such as carbonate mounds and sponge and xenophyophore fields will be equally as damaging. The vulnerability of deep-water soft sediment habitats are unknown in the absence of any known studies.

The damage caused by static gear such as demersal long lining and gillnets has also been reviewed in the reports of the Advisory Committee on Ecosystems (ICES 2002, 2003). No evidence for large-scale damage was found for demersal long lining although recovery of quite large coral fragments (decimetre scale) as bycatch is known to occur (A. Grehan, pers. comm.). The potential for damage through entanglement and ghost fishing has been highlighted by a recent report on static fishery for anglerfish and deepwater sharks to the north and west of Britain and Ireland. Anecdotal evidence suggested as much as 30km of netting is discarded per vessel per trip as the vessels cannot physically carry all the gear back to port (Hareide *et al.* 2005). Long lining techniques that utilize anchors are likely to cause small-scale physical damage although this is likely to be minor in comparison to trawl damage. Evidence for damage by gillnets was found on carbonate mounds and *Lophelia* reefs in Irish

waters on the western edge of the Porcupine Bank and SW margin of the Rockall Trough where lost gillnets were observed ghost fishing, snagged on corals and filled with corals following unsuccessful attempts at recovery (Grehan *et al.* 2004). Using video surveys in the northwest Atlantic between Georges Bank and Browns Bank, Mortensen *et al.* (in press) observed lost longlines loose on the seabed or entangled in corals on 37% of these transects. Tracks on the seabed, either from longline anchors or parts of otter trawl gear, were present along three transects, while lost gillnets were observed along two transects. The instantaneous effect of long-lining was regarded as of low impact, but cumulatively over time its impact will become far more significant. If this exceeds the rate animal's can recover, long-term damage will result.

In order to assess the damage caused by different fishing gears in US waters, Chuenpadgedee *et al.* (2003) suggested the use of a scale to allow destructiveness to be compared. A 'damage schedule' approach was adopted, merging knowledge of different fishing gears and judgement of fishers, managers and scientists to compare impacts of 10 different gears. The authors assessed 170 reports on damage and bycatch and 1 day workshop and came up with an impact rating of 1 to 5 (very low to very high). Each gear was assessed in terms of benthic habitat and by-catch. Bottom trawls rated at 5 for physical and biological habitat impact and finfish by-catch, 3 for shellfish bycatch. Bottom gillnets rated at 3 (medium impact) and bottom long lines 2 (low impact). The authors recommended that bottom trawls, bottom gillnets and dredges be stringently managed in ecologically sensitive areas. The impacts of pots, traps and bottom long-lines were deemed as moderate. Midwater trawls, purse seines and baited hooks have relatively low impacts. The importance of the intensity of operations was highlighted as a crucial factor in applying this scale. Even low impact activities, at a high enough magnitude and over a long enough time period can have a significant deleterious effect.

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## 4 New information on the distribution and status of cold-water corals in the North Atlantic

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Term of Reference: evaluate and report on new information on the distribution and status of cold water corals in the North Atlantic (including consideration of large slow-growing octocorals) and factors that might alter their status.

This term of reference is a direct descendant of that given to the forerunner group to the Working Group on Deep Water Ecology, the Study Group on Cold-water Corals (SGCOR). This section does not repeat the information in the three reports of the Study Group (ICES 2002, 2003, 2004). A section on the importance of coral communities for fish is included also.

There is no single publication providing a full detailed picture of the distribution of cold-water corals in the North Atlantic. As new areas of cold-water coral habitats have been discovered quite regularly the last years, the message perceived by the general public has led to a misconception that nothing has been known about the distribution of cold-water corals. However, reviews covering the North Atlantic have previously been provided by Madsen (1944); Wilson (1979); Zibrowius (1980); Frederiksen *et al.* (1992); Tendal (1992); Rogers (1999); Cairns and Chapman (2001). Much of this historic information has not been presented in the reports by the previous Study Group on Cold-Water Corals.

### 4.1 Introduction

One theme that has been consistently cited is the need for detailed distribution maps of cold water corals. The distribution, density, and understanding of the functional relationships between cold water corals and associated fishes (as habitat, competitors, and prey) is central to managing exploited demersal populations in a sustainable manner and implementing ecosystem-based management strategies. The linkages between reef associated fishes and their more widely distributed populations across the slope and on the deep continental shelf remain undefined. Our understanding of the ecological and demographic linkages between deep-water (slope and deep sea) structure forming taxa (e.g., corals, sponges) and fishes is still in an exploratory phase. Until these linkages between cold water coral habitat and managed species can be described, assessing the need for and importance of protecting this habitat, especially for agencies mandated to manage fisheries, remains difficult to defend at times.

### 4.2 Distribution

#### 4.2.1 Canada

The distribution of cold-water corals off Atlantic Canada has been reviewed by Mortensen *et al.* (in press). In addition to the data referred to by ICES (2004) they also include historic records (from the literature and museum collections). Five species (*Anthothela grandiflora*, *Desmophyllum dianthus*, *Drifa glomerata*, *Javinia cailleti* and *Paramuricea grandis*) were only represented in the historic data. Except for a few species (*Acanthogorgia armata*, *Bathypathes arctica*, *Keratoisis ornata*, *Paramuricea grandis* and *Trachythela rudis*) the corals off Atlantic Canada occur on both sides of the Atlantic Ocean. *Paragorgia arborea* has an almost continuous occurrence from off George's Bank, Nova Scotia, Grand Banks, Davis Strait, southern Greenland, south of Iceland, Faroe Islands, the coast of Norway and Spitzbergen (Tendal 1992). The northernmost record of *P. arborea* from the groundfish surveys by the Canadian Department of Fisheries and Oceans represents a northward extension of its distribution along the north American coast (Gass and Willison, in press).



#### 4.2.2 United States

In 2003, NOAA's Ocean Exploration program funded the first of two years of research on the New England Seamount Chain. A group of six investigators, with Les Watling and Ivar Babb as co-Principal Investigators, came together to form the Mountains-in-the-Sea Research Group (hereafter referred to as MIS-I and MIS-II for 2003 and 2004 cruises, respectively). MIS-I utilized the HOV *Alvin* and sampled Bear, Kelvin, and Manning seamounts, with two dives on each seamount. MIS-II utilized the ROV *Hercules* from the Institute for Exploration, located in Narragansett, Rhode Island. In addition to adding dives sites to the seamounts explored in MIS-I, Balanus and Retriever seamounts were investigated with one dive each. The focus of the research has been primarily octocorals and fish. Octocoral projects have centred on taxonomy and distribution, reproduction and larval production, and octocorals as hosts for other invertebrates. The fish research has centred on taxonomy, biogeographic relationships and interactions of fish with habitat landscapes. More than 200 samples of individual corals have been collected on all of these dives. All specimens have been preserved and are in the collection at the University of Maine, Yale University, or the Smithsonian Institution. In addition, tissues samples were preserved for genetic analysis and fixed for histological examination. Fish censuses were made from video transects conducted at intervals during the dives. A preliminary list of coral and fish taxa is currently in preparation.

South of the region covering the seamounts and canyons in the northwest Atlantic Ocean, cold coral bioherms and lithoherms (the 'Agassiz Coral Hills') occur on the Blake Plateau (George 2002). These coral hills can rise to 100 m above the sea-floor. This shelf zone is dominated by *Oculina varicosa* off Florida and *Oculina arbuscula* off the Carolinas.

#### 4.2.3 Iceland

Based on information from fishermen, eleven coral areas were known in 1970 close to the shelf break off NW and SE Iceland (Steingrímsson and Einarsson 2004). Since then more coral areas have been found, reflecting the extension of the bottom-trawling fisheries into deeper waters. At present, large coral areas are known on the Reykjanes Ridge, in the Hornafjarðardjúp deep and in the Lónsdjúp deep (SE Iceland). Other known coral areas are small (Figure 4.2.3.1, 4.2.3.2). A significant number of coral areas known to exist prior to 1990 were not reported in responses to a questionnaire circulated to fishermen in 2003. When these areas were examined in relation to bottom-trawling effort, they had normally experienced a considerable pressure for a number of years (an example is given in figure 4.2.3.3). It is very likely that these coral areas do not exist any more which indicates that overall coral distribution on the shelf off Iceland has reduced significantly during the last 20-30 years. Most of the existing coral areas are found on the shelf slope (Figure 4.2.3.1) and on the Reykjanes Ridge (Figure 4.2.3.4).

In 2004, a research programme was started on mapping coral areas off Iceland, using a Remote Operated Vehicle (ROV), based on the results from questionnaires to fishermen on occurrence of such areas. The aim of the programme is to assess the species diversity and the status of coral areas in relation to potential damages by fishing practices. In the first survey, intact *Lophelia* reefs were located in two places on the shelf slope off the south coast off Iceland (Figure 4.2.3.5). There was no evidence of bottom trawling activities in these areas. However, in some of the shelf areas off S Iceland tilted or broken colonies of *Lophelia* and remains of trawl nets and trawl marks were observed, providing evidence of the effects of trawling activities (Figure 4.2.3.6).

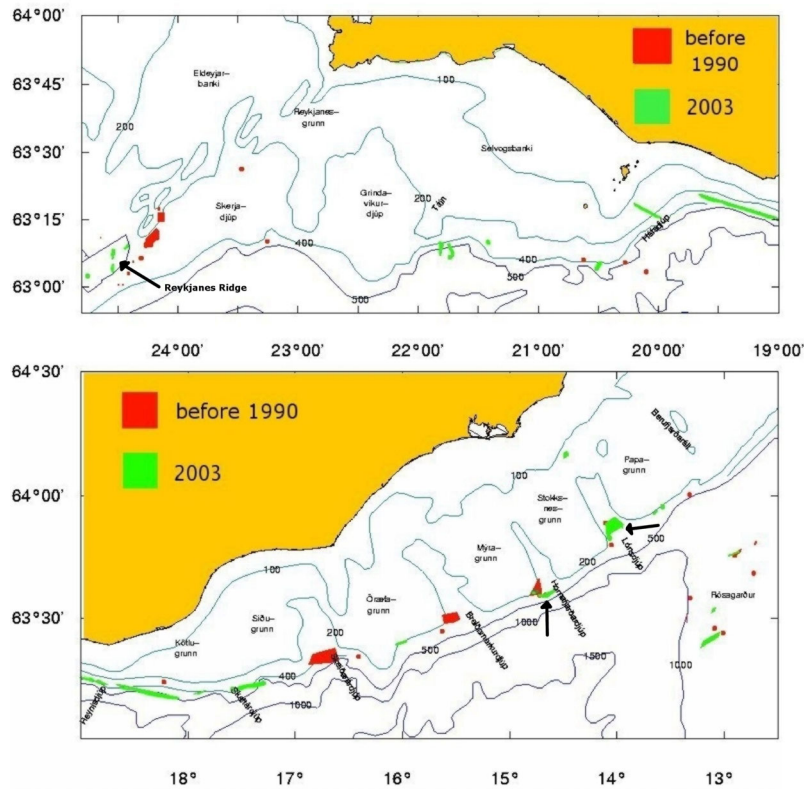


Figure 4.2.3.1 Occurrence of coral areas off Iceland, based on information from fishermen. ■ coral areas known to exist prior to 1990 (various sources of information), ■ coral areas existing in 2003 (results from questionnaire). Arrows indicate the largest existing coral areas. Map: S.A. Steingrímsson.

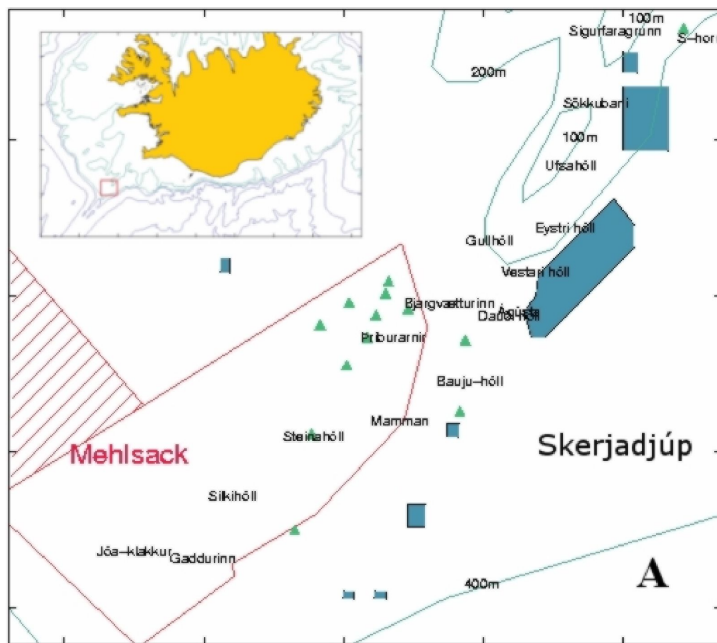


Figure 4.2.3.2 Historical distribution of coral in the Skerjadjúp deep. Shaded areas (■, total area 36 km<sup>2</sup>) indicate coral areas as given on old fishing charts (published 1980-1983), (▲) records on occurrence of coral, based on data from a geological survey on the Reykjanes Ridge (Thors *et al.* 1992) and (▲) records of *Lophelia pertusa*. Areas closed for otter trawling (since 1995) are outlined with a red line (closed throughout the year) and red hatched area (trawling allowed 1 February – 15 April). Map: S.A. Steingrímsson.

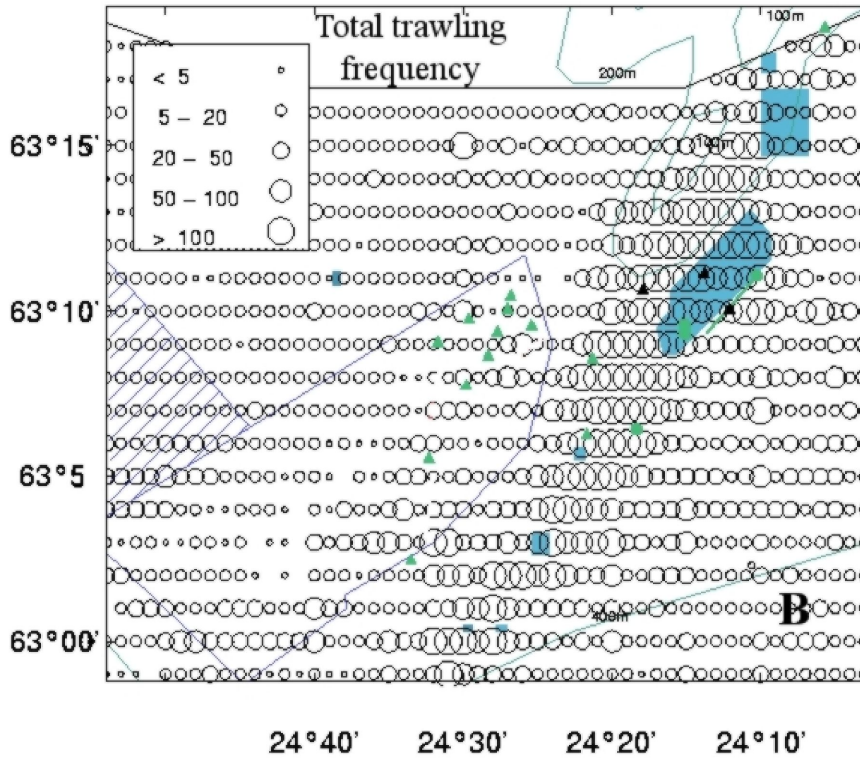


Figure 4.2.3.3 Fishing effort in areas of historical distribution of coral in the Skerjadjúp deep. The same area as Figure 4.2.3.2 with superimposed total otter trawling effort, during 1991-2002. Effort within the closed areas was prior to 1995. Size of circles represents different fishing effort (<5, 5-20, 20-50, 50-100 and >100 tows  $\text{nm}^{-2}$ . (trawling frequency \*  $\text{nm}^{-2}$ , during 1991-2002). Map: S.A. Steingrímsson.

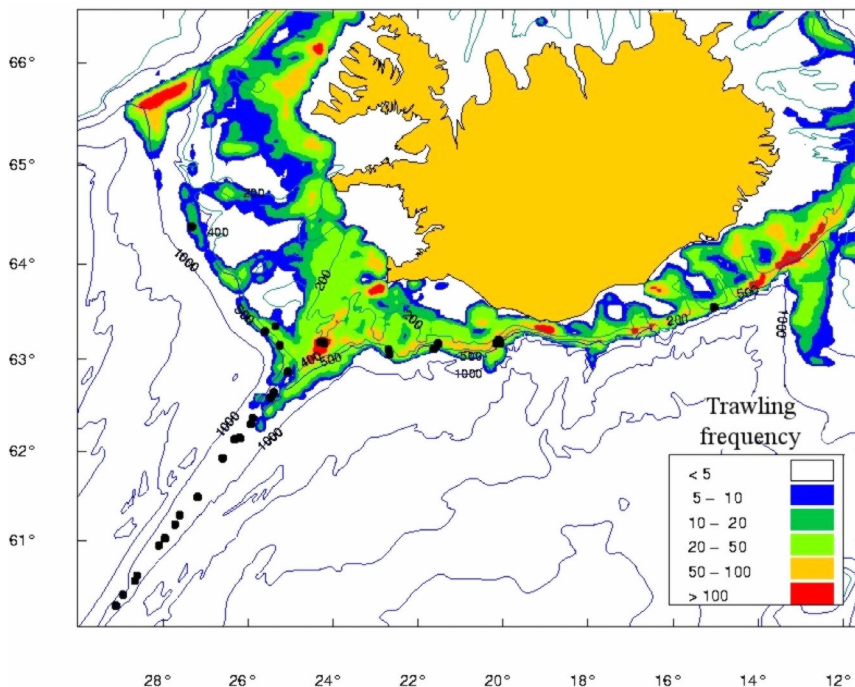
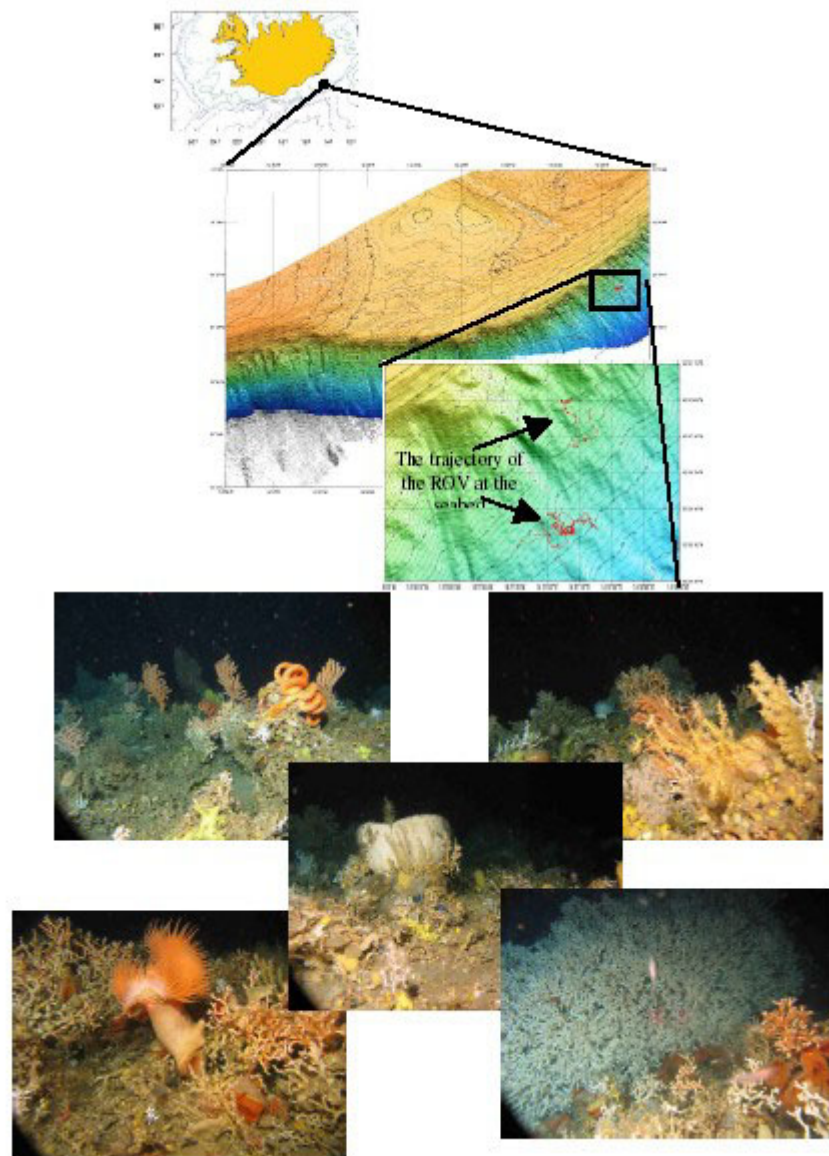


Figure 4.2.3.4 Occurrence of *Lophellia pertusa* off Iceland, based on information from the literature and from the BIOICE database, in relation to otter trawling effort (trawling frequency \*  $\text{nm}^{-2}$  per year). Map by S.A. Steingrímsson.



**Figure 4.2.3.5** *Lophelia* reefs on the slope area off the Hornafjarðardjúp-deep, SE Iceland (approx. 500 m depth). ROV survey indicated diverse biota, including good coverage of *Lophelia pertusa* and various species of octocorals. Photos: S.A. Steingrímsson.

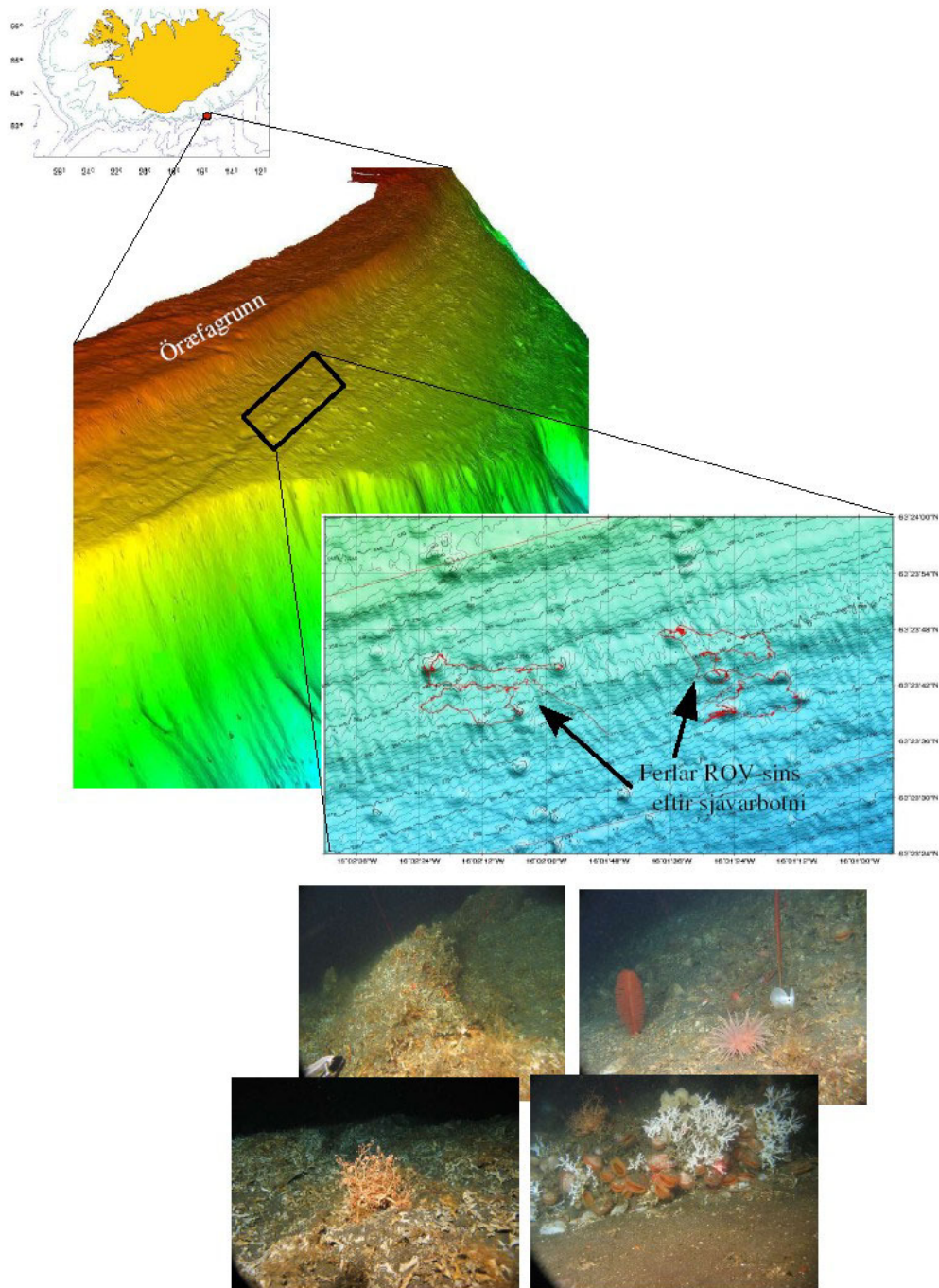
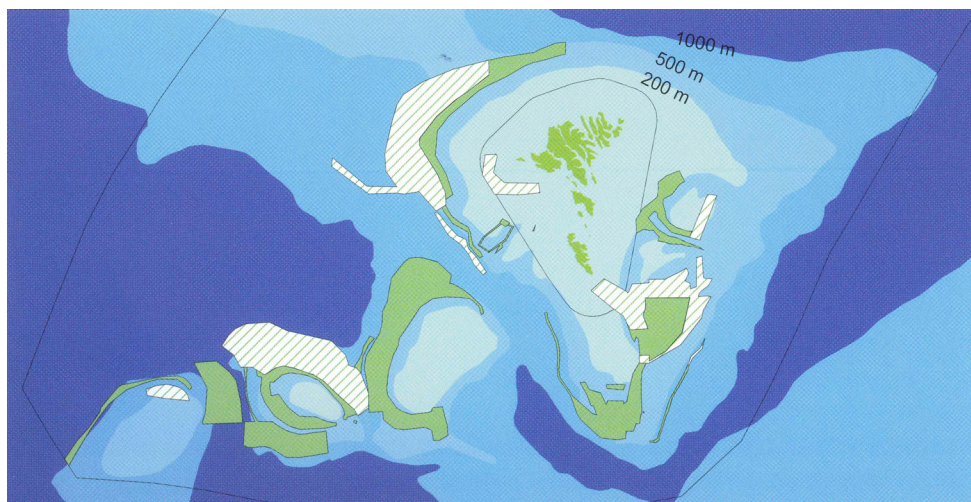


Figure 4.2.3.6 Devastated *Lophelia* reefs off the Öräfagrunn-bank, SE Iceland (approx. 250 m depth). Multibeam map revealed series of mounds, commonly rising 5-10 m high from the bottom. ROV survey documented shattered fragments of dead *Lophelia pertusa* on top of the mounds with muddy sediments, free of *Lophelia*, in between. Live *Lophelia* colonies were rare and normally small when encountered. Evidence of broken trawl wire and pieces of trawl nets were documented. Photos: S.A. Steingrímsson.

#### 4.2.4 The Faroes

Frederiksen *et al.* (1992) mapped the occurrence of *Lophelia* around the Faroes based on a questionnaire to fishermen, literature, and BIOFAR samples. Recently a more comprehensive questionnaire to trawler captains carried through by the Faroese Fisheries Institute has allowed a general mapping of the present and former distribution of coral banks around the islands (Jákupsstova *et al.* 2002) (Figure 4.2.4.1). A rough calculation shows that living coral is found

in an area of about 11000 km<sup>2</sup>, and in earlier times there were a further 8000 km<sup>2</sup> (Jan Sorensen, Kaldbak Laboratory, pers. comm.).



**Figure 4.2.4.1** Distribution of areas with living coral around the Faroes (green fields outside the 200 m depth contour), the hatched areas indicate earlier occurrences of coral, according to information from fishermen (Jákupsstovu *et al.* 2002).

#### 4.2.5 Ireland

An international expedition was mounted in 2003 using RV *Polarstern* as a platform for the IFREMER-owned remote operated vehicle VICTOR (cruise ARK-XIX/3a) (Klages *et al.* 2004). Part of this expedition involved mapping and collecting some of the largest and most obvious sessile organisms associated with the coral habitat, including hard corals (scleractinians), black corals (antipatharians), hydrocorals (stylasterids) and sea fans (gorgonians). This material is presently being worked up with reference to type specimens in the British Natural History Museum (Hall-Spencer and Brennan 2004). The gorgonian *Acanthogorgia* sp. was common and collected in a box cores (PS64/271-1) from the ‘Thérèse Mound’ at 51° 25.75’N 11° 46.18’W (Porcupine Bight) at 900 m depth and from the ‘Twin Mounds’ using the ROV manipulator arm at 53.08995° N –14.82335°W (Porcupine Bank) at 730 m depth. A number of amphipods clung to the surfaces of each of the *Acanthogorgia* sp. collected, the most abundant species showed morphological adaptation for holding onto the gorgonian and proved to be an undescribed species of *Pleusymtes* Barnard, 1969 (Myers and Hall-Spencer, 2004).

#### 4.2.6 Portugal

*Lophelia pertusa* has been collected in several locations within the Azores EEZ sub-area (Figure 4.2.6.1). The species are presented in the slopes of all islands and in many seamounts, (from 800 to 1700m deep). The habitat-building deep-sea corals *Madrepora oculata* and *Solenosmilia variables* have also been recurrently sampled in the Azores bottoms. Apart from those species, *Dendrophyllia* spp. are also important deep-sea reef builders in the region; a large amount of this coral was reported for the channel between Flores and Corvo islands. Other Scleractinia frequently associated with the reef builder corals include the *Desmophyllum cristagalli* and many solitary corals species of the genus *Caryophyllia*. The hard bodied hydrozoa *Errina* sp. is also an important reef builder in the region. Other seamounts where *Lophelia pertusa* has been found include: Princesa Alice, D. João de Castro, Mar da Prata, Sedlo, Cavala, Voador and Ferradura.

The Antipatharia (black corals) are also regularly caught on the slopes of islands and seamounts. The black coral *Leiopathes glaberrima* is frequently sampled from deep-water

areas, but the group includes several other species. Large colonies can reach more than 2 metres high.

The deep sea coral assemblage in the Azores also includes many species of the order Scleractinia. *Paragorgia johnsoni*, *Callogorgia verticillata* are remarkable species colonies often taken from bathyal bottoms. The group includes *Acanthogorgia* cf. *armata* a species from the Isididae and Paramuricea among others. In general the deep-sea coral habitats in the Azores are rich and the samples of structured hard corals have associated a sort of epifauna taxa from sponges, bryozoa, equinoderms, molluscs, and other corals, both Octocorallia and Hexacorallia.

Several areas have been selected for future mapping: Hard Rock Café (offshore deep water isolated seamount); Varadouro Bay slope (exposed island slope); Condor seamount (an intermediate seamount, associated to islands).

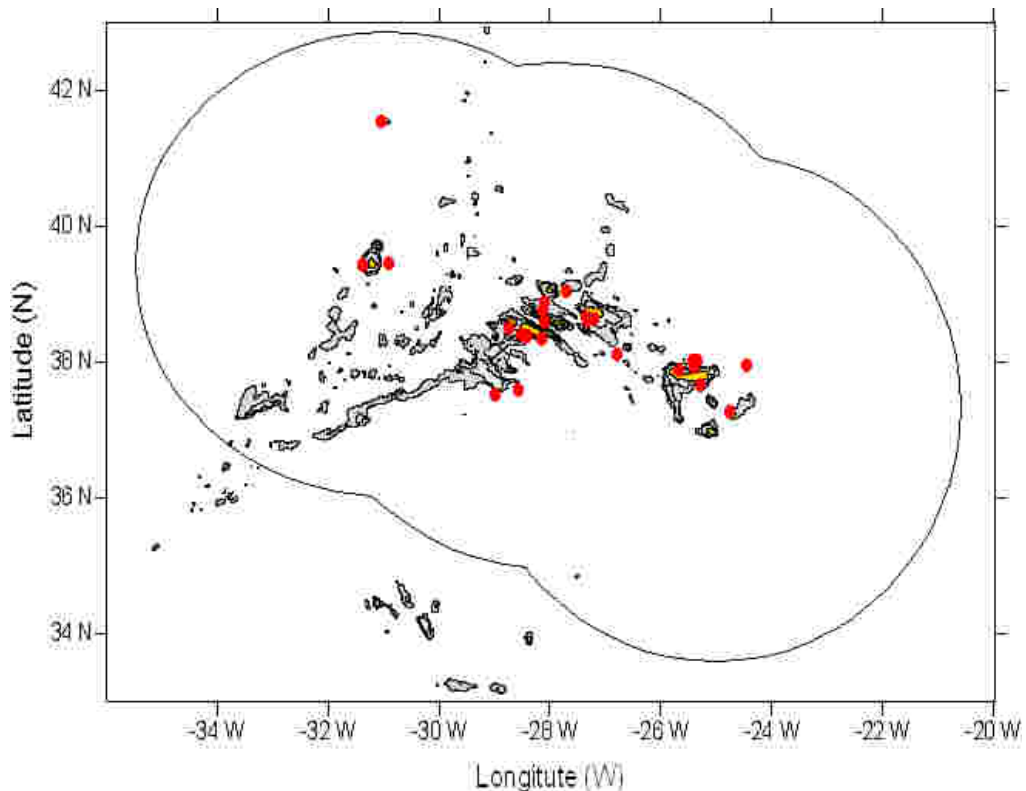


Figure 4.2.6.1 Distribution of *Lophelia pertusa* records within 200 NM of the Azores (F. Porteiro), based on both historical and modern records.

### 4.3 Functional relationships with coldwater corals

Association of fishes with emergent biotic structure occurs along a gradient of habitat complexity from animal-formed depressions and tubes (e.g., Auster *et al.* 1995, 1997) and rocky reefs (Auster *et al.* 2003, Stein *et al.* 1992) to tropical coral reef systems (Hixon 1993). Mechanistic studies have found that such associations enhance survivorship by providing cover from predators (Tupper and Boutilier 1995, Carr *et al.* 2002) and provide sites for enhanced capture of prey (Genin 2004). An expanding and very recent literature documents patterns in the use of cold water coral habitats by fishes. For example, studies of fish communities in *Lophelia pertusa* reef, transitional zone, coral debris and off-reef habitats in the northeast Atlantic showed that depth (above and below 400-600 m) was the most significant parameter influencing species composition (Costello *et al.* in press). Assemblage structure between habitats was less distinct but species richness and abundance was greatest on *Lophelia* reefs. In particular, the role of emergent fauna as habitat for exploited populations

has been examined for a number of shelf fish species. The geographic range of such studies has allowed managers to generalize the importance of conserving such habitats and integrating habitat conservation objectives into the decision-making process. Contrasting patterns of habitat use by fishes associated with octocoral thickets and other complex habitats in the deep basins of the Gulf of Maine indicate that density of fishes was highest in both coral and dense epifauna habitats while diversity only moderately high in such habitats (Auster in press). As with fishes on *Lophelia* reefs, the demographics of fishes that use octocoral thickets are unknown. Habitat selection theory suggests corals are important habitats based on the high density of fishes that occur in such habitats. However, if the spatial extent of such habitats is relatively small, as well as the proportion of populations that occur there, the role of coral habitats may be minimal in sustaining exploited populations (Auster in press).

There appears to be differential use of complex coral and other biogenic habitats by fishes on areas of the continental slope and on seamounts. In the Aleutian Islands region and at the head of Pribilof Canyon in the Bering Sea, there are positive associations between multiple taxa of fishes (many in the genus *Sebastes*) and octocorals, both fan and sea whip morphologies (Brodeur 2001, Stone in prep). However, such patterns do not emerge from similar types of observation programs in other areas (Tissot *et al.* in prep, Parrish in prep.). Submersible transects to census fishes in areas with and without deepwater corals in the Hawaiian Islands showed that areas with tall morphotypes of corals (e.g., *Gerardia* sp.) generally supported higher fish densities than non-coral areas (Parrish in prep.). However, an analysis of fish and coral distributions that accounted for the effects of bottom relief removed any statistically significant association between fish and corals, suggesting that both aggregate in areas of enhanced flows with little interaction. Tissot *et al.* (in prep.) also found that fishes and structure forming invertebrates (including corals) off California co-occur in the same types of habitats with accelerated flows but there is no demonstrable functional relationship between individual invertebrates and fishes. While orange roughy *Hoplostethus atlanticus* off New Zealand generally occur in large spawning and feeding aggregations over seamount summits that support dense coral assemblages (Koslow *et al.* 2000), there is little direct association between fishes and these invertebrates. Observations of orange roughy off the Bay of Biscay in the northeast Atlantic showed that fishes occurred in a dense aggregation over the seafloor in a submarine canyon, in the absence of structured invertebrates, likely to exploit enhanced flows (Lorance *et al.* 2002). No aggregations were observed elsewhere in areas of lower flow regime, providing a demonstration of the requirement for habitats that provide enhanced prey delivery, even in the absence of increased structure.

A common classification scheme for seafloor habitats would aid in comparing studies and combining data sets for understanding the role of structure-forming invertebrates in mediating the distribution and abundance of fishes. From observations in the North Atlantic, Auster *et al.* (in press) developed a hierarchical fish habitat classification scheme for seamounts, based on data from the New England Seamount chain. The scheme integrates geological and biological attributes of the structural components of seafloor habitats as well as flow regime at multiple spatial scales. Initial observations reported in this paper from depths of 2500-1100 m, showed the only coral associated fish, *Neocyttus helgae*, used fan shaped corals (*Paragorgia* sp.) and depressions in basalt pavements habitats as shelter or flow refuge, suggesting that both biological and geological habitats may be functionally equivalent.

#### 4.3.1 Conclusions

Overall, we must acknowledge that all of the aforementioned studies are but snapshots in time. One explanation of the lack of association is that observation programs are missing the time period when juveniles that may be more tightly associated with coral and invertebrate habitats are occurring. Another explanation is that all highly structured habitats are not utilized in a similar manner and use by fishes is more spatially constrained, or more stochastic in nature.



The only way to resolve this issue is to conduct studies over wide areas (i.e., use of spatial replicates) and minimally over seasonal time frames. Adaptive management strategies can aid in developing a mechanistic understanding of the ecological role of coral habitats when responses must be measured at the scale of fish populations or communities (e.g., Sainsbury *et al.* 1997). Studies are best designed to test a series of alternatives (or predictions) rather than simply testing for case of no response (i.e., null hypothesis). There are a number of alternative explanations for the co-occurrence of fishes and corals:

- Both fishes and corals co-occur in areas of high flows for enhanced prey delivery but have no direct association.
- Fishes co-occur with corals for feeding opportunities on coral associated taxa.
- Fishes use corals (and the area of vortices around them) for sites to enhance prey capture (i.e., minimize physiological requirements for station-keeping while maintaining access to enhanced flows delivering prey).
- Fishes use corals as cover from predators (i.e. to enhance survivorship).

These are all not mutually exclusive explanations for observed patterns so sequential sets of observations or experiments may be needed to determine if one or more predictions operate at the same time. Further, there is a separate set of alternative explanations to explain spatial variation (both within and between biogeographic regions) in patterns of use of corals by fishes:

1. Variation in life histories and life history stages of fishes between and within biogeographic regions explain variation in patterns of habitat use.
2. Patterns of coral habitat use are patchy but deterministic (i.e., sufficient spatial replicates are required to identify patterns of habitat use and differentiate attributes of patchy habitats).
3. Stochastic processes create patchiness in patterns of coral habitat use by fishes that vary over short temporal scales (i.e., seasonally or annually).

Knowing if we can generalize our understanding of habitat linkages to fish populations and communities on the continental shelf to those in the deep sea will depend on efforts to gain a better spatial and temporal coverage to elucidate patterns of habitat use and studies designed specifically to test the role of particular mechanisms mediating distribution and abundance.

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## 5 Sensitivity of deep-water habitats in the North Atlantic to fishing and other anthropogenic activities

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Term of Reference: evaluate and report on the sensitivity of other deep-water habitats (including soft bottom habitats) in the North Atlantic to fishing and other anthropogenic activities, and where possible describe their occurrence.

### 5.1 Introduction

For the purposes of this ToR, the working group chose to define >200 m as deep-water habitats. There are a number of different definitions of 'sensitive habitats' (e.g. McDonald *et al.* 1996), along with a range of classification systems for habitat sensitivity (Gundlach and Hayes 1978; Anderson and Moore 1997; McMath *et al.* 2000). However, an adequate habitat classification system for the deep sea is lacking, although progress is being made with seamount habitats (Auster *et al.* in prep.). For the purposes of this term of reference, the Working Group chose to define a 'sensitive habitat' as one which is 'easily adversely affected by a human activity, and/or if affected is expected to only recover over a very long period, or not at all' (OSPAR Texel-Faial criteria). The sensitivity of habitats formed by the scleractinian *Lophelia pertusa* is probably the best documented of deep-water habitat sensitivity in the NE Atlantic (ICES 2002, 2003, 2004a). However, other scleractinians become progressively more important as forming deep-water reefs at lower latitudes within the Atlantic. *Lophelia pertusa* is the only major reef-builder off Europe, as is *Oculina* off the Florida coast (Reed 1992).

Whilst most macrobenthic organisms themselves provide habitat for certain associated species (e.g. parasites and microbial communities), we focus on key-stone species that greatly modify the physico-chemical characteristics of the sediment-water interface and are known to have communities of organisms associated with them. Such habitats that can be sensitive to anthropogenic disturbance because, for example, of the longevity of the individuals that structure the habitat, their susceptibility to increased sedimentation and a poor ability to recover from physical fragmentation. Habitat-forming sponges and octocorals, for example, can live for 100s of years such that any recovery from anthropogenic impacts would take decades affecting the communities of organisms that rely on such habitats (Dayton, 1979; Van Dolah *et al.* 1987; Gatti, 2003; Mortensen and Buhl-Mortensen, in press). Many deep-water habitat-forming species are suspension feeders; these are sensitive to clogging of their filtering mechanisms and burial by sedimentation because this interferes with feeding and respiration. When increased sedimentation events are not lethal (e.g. from dredging, mining, dumping or fishing) there are energetic costs associated with sediment removal, such that growth and reproduction are impaired. Where the integrity of benthic habitats is affected by physical contact (e.g. with towed demersal gear, longlines, cable laying, pipelines and moorings) then this will also compromise feeding and respiration of the habitat-forming species. Some habitat-formers are less susceptible to dislodgement than others; certain sea-pens, for example, can survive trawling dislodgement and re-bury (Kinnear *et al.* 1996; Tuck *et al.* 1998) whereas gorgonians are less able to reattach leaving them open to disease, overgrowth and scavengers (Mortensen *et al.* in press).

Deep-water fishing is clearly the major anthropogenic activity affecting deep-water habitats, although this is depth-limited by the trawling technology currently used (Hall-Spencer *et al.* 2002). Otter trawl tracks have been recorded to depths of 1100 m off the UK (Roberts *et al.* 2000) with reports of demersal trawling activity to maximum depths of 1400 m in the North Atlantic region (ICES 2004b). In recent years a longline fishery has developed off southeastern Greenland at depths down to 1500 m (ICES 2004b). The target species is Greenland halibut, but probably as much as 30% of the by-catch is roughhead grenadier *Macrourus berglax*. The area of this fishery has expanded to eastern and western slopes of the

Reykjanes Ridge south of Iceland. Deep-water longlines are also used to catch for instance common mora *Mora moro* at 500-1100 m depths in the Hatton bank area (Division VIb and Sub-area XII) (Fossen, 2004). Other anthropogenic effects on deep-water habitats include localised contamination effects (e.g. from oil drilling muds and deep sea dumping of waste and dredgings) and physical effects (e.g. from anchors used in hydrocarbon exploration or cable-laying,) which become more common at shallow depths but are known to occur along continental shelf break areas. Diffuse effects of persistent pollutants (e.g. PCBs, plastics, atmospheric nuclear bomb tests and ocean acidification due to increased atmospheric CO<sub>2</sub>) will eventually have effects on all depths of the world's oceans.

There is now a wealth of information available on the effects of most gear types on habitats located in waters <200 m water depth (reviews by Jennings and Kaiser 1998; Kaiser and de Groot 1998, Hall 1999). These studies show that habitats that are relatively resilient to the long-term effects of towed demersal gear are those that occur in naturally disturbed environments, such as shifting sublittoral sand banks. Similarly, there are certain organisms that are more resilient to the effects of fishing, e.g. infaunal bivalves and thalassinid shrimps that are afforded protection by their deep-burrowing habit or those organisms that are small enough to pass through nets and survive. In contrast, long-lived organisms that form biogenic reefs (e.g. maerl and *Modiolus* beds) can be grouped with macrobenthic organisms that stand proud of the seabed (e.g. sponges, sea grasses, sea-pens and sea-fans) and are highly vulnerable to trawling activity because they come into direct contact with towed ground gear. Such organisms occur on soft sediment and hard grounds, so both are strongly modified by trawling activities.

Study of the effects of fishing on deep-water habitats is in its infancy and has largely concentrated on the effects of towed gear on charismatic coral reef communities which are known to be highly vulnerable to towed demersal gear (Koslow *et al.* 2000, 2001; Hall-Spencer *et al.* 2002; Grehan *et al.* in press; Koenig *et al.* in press). Deep-water habitats were once thought to be food limited undisturbed environments with relatively constant conditions. However, exploratory research is revealing that deep-water habitats exhibit a complex mosaic of sedimentary and rocky conditions, from relatively barren current-swept sand plains to structurally intricate glass-sponge reefs. These deep water habitats can exhibit strong seasonality in terms of productivity (Billet *et al.* 1983; Lampitt 1985; Wigham *et al.* 2003), and in some areas are highly dynamic with strong currents and large swings in temperature (e.g. Faroe-Shetland Channel, Hansen *et al.* 2001; Turrell *et al.* 1999; elsewhere, Lampitt *et al.* 2003). This range of conditions results in a range of habitats of which the WGDEC has selected seven for brief discussion (three geological features, and four biological).

1. Hydrothermal vents
2. Cold seeps (including mud volcanoes)
3. Xenophyophore fields
4. Sponge grounds
5. Slopes of oceanic islands
6. Stylasterids (fire corals)
7. Non-scleractinian corals

### 5.1.1 Hydrothermal vents

Hydrothermal vents occur in waters that lie well below fishing depths but it has been suggested that the mineral rich vent chimneys may be an attractive source of precious metals for mining in the future. A preliminary list of biotopes found in deep-sea hydrothermal vent

fields in the Azores triple junction was prepared by Ana Colaço in September 2000 under the scope of OSPAR (see also Van Dover 1995; Van Dover *et al.* 1996; Desbruyères and Segonzac 1997; Colaço *et al.* 1998; Desbruyères *et al.* 2000, 2001; Santos *et al.* 2002, 2003). The most important active hydrothermal vent fields known to date around the Azores are:

- Lucky Strike (-1700m) -37° 17'N, 32° 17'W
- Menez Gwen (-800 m) - 37° 51'N, 31° 31'W
- Saldanha (-2200m) - 36° 34'N, 33° 26'W
- Rainbow (-2300m) - 36° 13'N, 33° 54'W (off EEZ).

Inactive vent fields have also an high scientific importance and one known to date in the Azores is Famous (-2700m) - 36° 57'N, 33° 04'W (off EEZ). Each one of these fields presents distinctive geological, geochemical and ecological features.

These features are sensitive, but not yet vulnerable to trawling as none occurs in their vicinity. The effects of scientific surveys are an area of concern in the Azores where frequent visits using submersibles may be affecting organisms adapted to low light conditions. Presently there is no legislation covering fishing in hydrothermal habitats of the Azores region, although there is a local agreement with the fishermen's associations that these areas are left as No Take Zones (Santos *et al.* 2002, 2003).

### 5.1.2 Cold seeps (including mud volcanoes)

Benthic communities associated with cold seeps rely mainly on methane rich fluids expelled in particular geological environments such as mud volcanoes, pockmarks, slides or diapirs. Microbial chemosynthesis (rather than photosynthesis) underlies very large biomass of benthic fauna at some sites, including large bivalves and siboglinid polychaetes (vestimentiferan tubeworms). This adapted fauna is very similar to the hydrothermal vent fauna, however very few species have been found in both environments although there are strong similarities at the family and genus level. At least two hundred species, including several tens of symbiont-containing species, have been recorded and most of them are species new to science (Sibuet and Olu 1998; Sibuet and Olu-Le Roy 2002) and the diversity could be higher than at vents due to the occurrence of both hard substratum (carbonate concretion) and soft sediments.

A few cold seep areas have been described in the North east Atlantic. The best known site is the Haakon Mosby Mud Volcano located at 1300 m depth along the continental margin of the Western Barents Sea (about 72°N) (Milkov *et al.* 1999, Ginsburg *et al.* 1999, Gebruk *et al.* 2003). The benthic community at this site is dominated by tubeworms (Pogonophora and Polychaeta) and demersal fish. Methane is present in the mud volcano sediments, and the white patches that cover over 75% of the sea floor in some areas, are interpreted to be bacterial mats and/or gas hydrates. Further biological investigations are currently under way based on the results of a 2002 cruise (Klages *et al.* 2002) and further papers will be published (Soltwedel *et al.* in press).

Other seeps are suspected off Norway on the Voringen Plateau near the Storegga Slide as fluid escape features (pockmarks, diapirs) and gas hydrates were inferred from seismic studies (Bouriak *et al.* 2000). No direct seafloor evidence of fluid escape and cold seep communities are available yet but cruises planned for 2006 by the Hermes European Program will investigate some of the geological structure along the slide. Further south, the Pilot Whale diapirs have been surveyed in the northern part of the Faroe-Shetland Channel and no active fluid seep found (Bett 2003; Hughes *et al.* 2003).

Mud volcanoes and gas hydrates have been reported in the Gulf of Cadiz (Mazurenko *et al.* 2002). The composition of mud volcano fluids corresponds to deep oil basin below the Gulf of Cadiz. Chemosynthesis fauna is not well known as only sampled by cores or grabs, but

siboglinid polychaetes (small-size pogonophorans) have been sampled (M. Cunha, pers. com.). More information has been published in TTR reports (TTR9 cruise report), and cruises using ROVs are planned in the next two years (Hermes programme).

### 5.1.3 Xenophyophore fields

Xenophyophores are macrofauna-sized rhizopodan agglutinated protists, closely related to the Foraminifera (Gooday and Tendal 2000). They are a characteristic benthic component of many deep-sea assemblages all over the world, the majority of samples having been taken between 800 and 6000m depth. About 65 species have been described, and based on untreated material from different expeditions it is to be expected that this number will rise to about 100 (Tendal 1996). About 20 species have been reported from the NE Atlantic (Tendal and van der Land 2001).

Owing to their large size (up to about 10 cm in diameter for lumpy and 25 cm for platy flat forms) and weak cementation of the test, most xenophyophores are very fragile. Therefore, they are rarely sampled adequately with towed gear, and most estimates of abundance and size structure of populations have been made from bottom photographs. In fact, some species appear so fragile that they totally disintegrate when hit by the pressure wave from the gear, and the only way to study them may be by photographic methods. Despite of the fragility specimens of such species may be quite abundant on abyssal even seabeds where they, at the 10-cm scale, constitute most of the 3-dimensional relief at the sediment-water interface (Tendal and Gooday 1981).

Only few xenophyophore species occur in the northernmost NE Atlantic. The largest, and one of the first representatives of the group to be described at all, is *Syringammina fragilissima*. In the area it has been found at bathyal depths from the northern part of the Rockall Trough to west of Scotland and Ireland into the northern part of Bay of Biscay (Figure 5.1.3.1; Tendal 1985; Bett *et al.* 1999; Bett 2001; Roberts *et al.* 2000). Although apparently common in parts of the area, it has been recovered relatively rarely, probably due to the delicate nature of its test. Local distribution is patchy, ranging from 1 specimen per 10 m<sup>2</sup> to 10 specimens per 1 m<sup>2</sup> (Bett *et al.* 1999; Bett 2001; Hughes and Gooday 2002). Growth rate is known for only one xenophyophore, the abyssal *Reticulammina labyrinthica*. An *in situ* photo study showed a 3-10 fold increase in volume over an eight month observation period (Gooday *et al.* 1993). It is unclear to what degree this observation can be applied to the more complex-shaped *S. fragilissima*.

Around the Darwin Mounds, an area of sandy mounds with *Lophelia* at approximately 1000m depth in the northern Rockall Trough, video footage has shown that *Syringammina fragilissima* is particularly abundant downstream of the mounds, where it reach abundances of up to approximately 7 individuals/m<sup>2</sup> (Hughes and Gooday 2002). Due to the diaphanous nature of these organisms, they are likely easily damaged by trawled gears and the sediment plume that they create.



**Figure 5.1.3.1** Dense fields of xenophyophores were found on the muddy sediments at 1108 m to the west of Scotland at densities of up to  $10.m^{-2}$  and are likely to be *Syringammina fragilissima*. The ripple marking of the sediment points to an active near-bottom current moving from south west to north east (Roberts *et al.* 2000).

#### 5.1.4 Sponge fields

The phylum Porifera (sponges) comprises three classes: Calcarea (calcareous sponges), Hexactinellida (glass sponges) and Demospongiae (silicious sponges); only members of the two last mentioned classes reach a body size and abundance that would enable the formation of sponge fields (Klitgaard and Tendal, 2001, 2004).

Sponges are found on all types of sea bottom, in all marine geographic and bathymetric regions, and under very diverse ecological conditions. Some species are encrusting and never grow thicker than 1 mm, others are lumpy or barrel-shaped, up to 2 m in height. Most species are in the 2 - 40 cm size range. All larger forms have a skeleton of silicious needles (spicules) or horny fibres (spongine) or a combination of these.

Mass occurrences of large sponges around the Faroes are called ‘ostur’, meaning “cheese bottom”, among the fishermen. This phenomenon was first treated in detail during the BIOFAR investigation (Klitgaard *et al.* 1997; Klitgaard and Tendal 2001, 2004), although it had been previously mentioned in the literature from various parts of the northeast Atlantic and the Arctic. Similar mass occurrences have been found on the eastern slope of the Faroe-Shetland channel (J.P. Hartley, pers. obs.). Elsewhere in the North Atlantic, sponge fields have been found off East Greenland, around Iceland, in the Skagerrak, off Norway, in the Barents Sea and off Svalbard (Klitgaard and Tendal 2004).

The structurally dominating species of the sponge fields are large and provided with proportionally very voluminous and heavy skeletons. Aquarium experiments show that in some species damage can heal relatively rapidly (Hoffman *et al.* 2003), but all observations point to slow somatic growth, in the NE Atlantic probably only during the productive time of the year. No exact ageing has so far been done but both size structure and comparable investigations in Antarctica point to decades if not centuries (Dayton 1979; Gatti 2003). Accordingly, it will take a long time for a sponge dominated area to recover even after partial destruction, and repeated disturbance in a specific area may lead to permanent extirpation of the species there.



The presence of the large sponges adds a low 3-dimensional structure to the bottom, thus increasing habitat complexity and attracting a large number of other, smaller species from many phylae. This associated fauna has been investigated in the Faroes where it was found that the sponges houses about 250 species of invertebrates (Klitgaard 1995). Since only very few species utilize the sponges as a food source the interactions are to be found in the provision of hard substrate, provision of refuges from predation or physical strain, and access to enhanced food supply directly or indirectly from the surrounding water. Even if the sponges themselves also do not offer food for fish, the numerous and abundant fauna must represent a good feeding ground to particular life history stages. Both in samples and in photographs we have regularly observed young redfish (*Sebastes*), sometimes even inside the cavities of large sponges. In the catches there are also often several species of groundfish represented.

The fauna associated with sponge fields is, by experience, estimated to be as least twice as rich in species as the surrounding gravel or soft bottoms, and many species are much more abundant within the fields than outside them (Bett and Rice 1992). All associated species are facultative sponge dwellers, meaning that they are found also in other habitats (Klitgaard 1997).

Both from studies performed outside the region (e.g. Freese *et al.* 1999), within the region (Gage *et al.* in press) and from experience it is found that trawling has the following effects:

1. Damages sponges physically (Figure 5.1.4.1). The possibility of regeneration, multiplication from fragments or death of the animals depends on each species' abilities,
2. overturns substrate like stones and boulders, killing all epifauna (Figure 5.1.4.2),
3. creates a cloud of sediment of varying thickness and duration, that clogs the filters of suspension feeders. In this last respect sponges are especially sensitive as they cannot sort particles but must use energy to filter all kinds of particles from the water in their canal system and send them through the digestive processes.



**Figure 5.1.4.1** *Pheronema carpenteri* (Thompson 1869) hexactinellid sponge. Bycatch in smoothhead (Alepocephalidae) deepwater trawl at 800m off Ireland (photo: J Hall-Spencer).



**Figure 5.1.4.2** Boulder in the Faroe-Shetland Channel boulder, probably recently overturned, in 590 m depth where side scan and visual records show evidence of intense trawling (from Gage *et al.* in press).

### 5.1.5 Oceanic islands slopes

The slopes of the Azores oceanic island groups form a unique habitat in ICES and OSPAR area. The lower parts of these slopes may be equated with seamount communities, but their upper slope habitats do not occur elsewhere (Menezes 2003).

The Azores are the most isolated archipelago in the north-eastern Atlantic, being about 1300km from mainland Europe and about 1730km from North America (Newfoundland). This isolation reduces colonisation rates from elsewhere and therefore may slow recovery times

from perturbation (Menezes 2003). Stockley *et al.* (2005) argue that there is a growing evidence that demersal or benthopelagic deep-water fish and squid species tend to show limited dispersal between geographic areas on a regional scale. Based on the *Pagellus bogaraveo* genetic structure found in the Azores, it seems unlikely that migration between such populations will be sufficient to compensate for impacts arising from excessive fishing pressure, in terms of both biomass and genetic variation of the population. It seems plausible that this situation could be also extrapolated to many other demersal and deep-water species inhabiting the Azorean islands slopes, seamounts and banks.

The Azores, like other volcanic islands are characterised by the absence of shallow water platforms along the shores of the islands. From the perspective of fisheries, the waters around the Azores are comparatively poor compared with other areas with continental shelves. The fish that are present are typically deep-water species that have low reproductive rates and are therefore extremely sensitive to over-exploitation. The recent origin of the Azores, coupled with the lack of continental shelf mean that most of the seabed is free of sediment – this in turn limits the diversity of marine organisms that occur around the islands. The islands location in an oligotrophic part of the Atlantic reduces productivity and scope for growth.

In the last two decades the situation has changed with artisanal exploitation being replaced with commercial fishing (Santos *et al.* 1995, Menezes 1996). As a consequence, the abundance of several species and thus the catch rates of the commercial fleet have started declining in the last few years, while some demersal fish stocks have already displayed signs of intensive exploitation (Pinho and Menezes in prep.). The impacts of fishing on the bottom fauna (e.g. on corals) around the islands is poorly known but likely to occur, despite the use of more environmental friendly gears such as bottom-set longlines. Local demersal fish depletion around some islands (e.g. S. Miguel, Terceira, Faial) is already evident, based on data collected during research longline surveys since 1995 (Menezes, 2003, Pinho and Menezes, in prep.).

Trawling is prohibited around seamounts in the Azores and bottom longlining targeting demersal and deep-water species comprises the most important fishery for the local economy. Even though this fishery does not exceed 5000 tonnes per year, it still locally very valuable (Silva *et al.* 1994, Menezes 1996). The red (blackspot) seabream *Pagellus bogaraveo* has traditionally been the main target species of this fishery, but several other species, such as the alfonsino *Beryx splendens*, bluemouth *Helicolenus dactylopterus*, conger eel *Conger conger*, offshore rockfish *Pontinus kuhlii*, wreckfish *Polyprion americanus*, scabardfish *Lepidopus caudatus*, greater forkbeard *Physis blennoides*, common mora *Mora moro* have also become important (see section 2.2.4). Most of these species are confined to seamounts, offshore banks and upper-slope of the islands, where bottom longlining occurs down to 1000m depth. Despite the large area of the Azorean EEZ (1,000,000 km<sup>2</sup>), potential habitat for commercial bottom longlining occupies less than 3% of its area. The increasing fishing pressure around the islands slope has led to local legislation that implements a buffer zone of 3nm around the islands where longlines and larger vessels are not allowed to operate. Deep-water gillnets were also banned throughout the Azores EEZ, in the end of 2003 (local legislation), however this was not yet transposed by any European Fishing Regulation under the Common Fisheries Policy.

The varied fishery, the discrete, geographically dispersed, fishing grounds and the complex spatial structure of the fish populations bring several challenges for the assessment and management of insular fish stocks and increases their vulnerability to exploitation (Menezes 2003).

#### **5.1.6 Stylasterids (fire corals)**

Stylasterid hydrocorals are sessile, benthic, branched colonial hydrozoans with a heavily calcified skeleton. Members of the group, which comprises about 260 known species, are

found widely distributed in all the World Ocean, from the Arctic Circle to Antarctica, at depths of 0-2800 m (Cairns, 1992). The stylasterid fauna of the NE Atlantic comprises 21 species (Zibrowius and Cairns, 1992).

Most species are found in relatively warm water (4-10°C) at outer shelf and upper slope depths (Cairns 1992). In the NE Atlantic the group follows the water masses of the North Atlantic Current and its branches along the Norwegian coast, south and west of Iceland and around southern Greenland.

As to biotopes Stylasterids show a characteristic preference of distribution, being found in abundance mainly off small islands and on seamounts and ridges. As slow-growing, long-lived forms, they are probably poor competitors to scleractinians and therefore better established in areas with low sedimentation rates and modest nutrient levels (Cairns 1992).

In a benthic fauna investigation around the Faroes (BIOFAR, Tendal *et al.* in press a) most records of stylasterids are from the shelf break area and upper slope (Tendal *et al.* in press b). Apart from the tidal zone and a few special localities at other depths, this is the most dynamic zone with good water exchange, strong currents which are partly of tidal origin, and probably internal wave breaking (Westerberg 1990, Frederiksen *et al.* 1992). It is the experience gained during the cruises that this part of the topography represents the most diverse fauna zone on the Faroes, and that also other slow-growing, long-lived, brood protecting groups that rely on long-term environmental stability are strongly represented here (Frederiksen *et al.* 1992, Klitgaard *et al.* 1997).

#### 5.1.7 Non-scleractinian corals

Although damage to the deep-water habitats formed by scleractinian corals is now well documented in the North Atlantic, other coral taxa are known to form structurally complex benthic habitats but have received scant attention. Sea fans (octocorals) and black corals (antipatharians) are all represented in shallow waters (<200 m depth) of the North Atlantic, but are more diverse and widespread in deeper waters where they can be abundant on hard grounds. In addition, some octocorals add three dimensional complexity to soft sediment habitats, such as sea pens (e.g. *Kophobelemnon*, *Balticina*) and isidids (*Acanella*) (Gass and Willison in press). The most active area of research into fishing impacts on non-scleractinian corals is on the octocoral forests off the NW Atlantic seaboard (Watling and Norse 1998; Watling and Auster in press; Mortensen and Buhl-Mortensen in press) although similar habitats are documented off the NW Atlantic seaboard at depths in which trawl fishing occurs (Hall-Spencer and Brennan 2004). Few North Atlantic data exist on the contribution that is made to deep-water habitat complexity by antipatharians. However, we do know that important habitat-forming seafans include the genera *Paramuricea*, *Paragorgia*, *Primnoa* and to a lesser extent *Acanthogorgia*. It is clear from research into deep-water scleractinian reefs that any large, long-lived sessile organisms that stand proud of the seabed will be highly vulnerable to towed demersal gear.

#### 5.1.8 Additional comments

Although we have concentrated here on fishing impacts, human effects on ocean chemistry, temperature and circulation will no doubt modify the distribution and faunal composition of deep-sea habitats. Planning for the effects of such changes is one of the greatest challenges facing institutions such as ICES. Early signs of such changes can be expected to manifest themselves in some fjordic habitats, where communities typically only found in the deep sea can be monitored for the effects of temperature change and acidification.

### 5.1.9 References

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## 6 Proposed Terms of Reference for next Meeting

The Working Group on Deep-water Ecology [WGDEC] (Chair: Mark Tasker, UK) will meet in Miami, USA from [4/5 to 7/8] December 2005 to:

- a) compile a list of seamounts in the OSPAR area and classify them initially on the basis of physical attributes;
- b) on the basis of evidence to be sought from fisheries managers and other sources, review the distribution of fishing activity on seamounts;
- c) review possible classifications of deep-water habitats in the North Atlantic and frameworks for describing sensitivity to fishing activities;
- d) examine possible ways of describing fish communities on seamounts;
- e) report on new information on the distribution and status of cold water corals in the North Atlantic and recommend ways by which information on the occurrence of these species might be made more easily available and kept up to date.

WGDEC will report by 31 January 2006 for the attention of ACE and the Living Resources Committee.

### Supporting Information

Priority:	High. This is the only group in ICES providing information on deep water ecology that is proving to be an expanding area of interest to fisheries managers and
Scientific Justification:	OSPAR. These recommendations address areas of difficulty encountered by the group in 2005. Information on fisheries over seamounts needs to be sought from others.
Relation to Strategic Plan:	Action plan 1.2.
Resource Requirements:	None
Participants:	Approximately 10–15. Expertise on cold-water corals and on deep-water fishing is required. The Chairs of WGDEC and WGDEEP (Odd Aksel Bergstad, Norway) will consult and coordinate their activities.
Secretariat Facilities:	None
Financial:	None
Linkages to Advisory Committees:	ACE, ACFM
Linkages to other Committees or Groups:	LRC, MHC, WGECO, WGMHM, WGDEEP
Linkages to other Organisations:	EC, OSPAR, NEAFC

## Annex 1: Attendees list

### WORKING GROUP ON DEEP WATER ECOLOGY

#### ICES Headquarters

8 – 11 March 2005

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