ICES Advisory Committee on Ecosystems
ICES CM 2004/ACE:07 Ref. E

Report of the Study Group on Cold-Water Corals (SGCOR)

By Correspondence

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1 INTRODUCTION

1.1 Participation

The following members of the Study Group on Cold-Water Corals (SGCOR) participated in producing this report (see Annex 1 for addresses):

Peter Auster	USA
Mark Costello	Canada/New Zealand
Jan Helge Fosså	Norway
André Freiwald	Germany
Anthony Grehan	Ireland
Pål Mortensen	Norway
Filipe Porteiro	Portugal
Murray Roberts	UK
Sigmar Arnar Steingrímsson	Iceland
Mark Tasker (Chair)	UK
Les Watling	USA
Andy Wheeler	Ireland

1.2 Terms of Reference

At the 90th Statutory Meeting, the Study Group on Cold-Water Corals (SGCOR) was given the following terms of reference:

a) review new information on the occurrence of and threats to cold-water corals in the North Atlantic, including consideration of large slow-growing octocorals;

b) review the importance of *Lophelia pertusa* reefs as a habitat for other species;

c) prepare for the theme session on cold water corals at ASC 2004;

d) invite comment on a draft of its report from relevant ICES Expert Groups in order to enable the provision of any further advice to the European Commission.

1.3 Justification of Terms of Reference

The Terms of Reference are based on a standing request for advice sent by the European Commission asking ICES "to identify areas where cold-water corals may be affected by fishing." There is strong evidence of recent, permanent damage to cold-water coral features in the ICES area. Scientific advice is required to inform possible management measures to avoid further damage. Input from EU projects ACES and ECOMOUND will be used. SGCOR has mostly considered the distribution and occurrence of *Lophelia pertusa* and other colony-forming Scleractinia so far. These are not the only long-lived habitat-forming species at risk from fishing activities in the Northeast Atlantic. We therefore recommend that distribution of, and threats to, large, presumed slow-growing octocorals, especially *Paragorgia arborea* and *Primnoa resedaeformis* is included.

1.4 Acknowledgements

We thank Louise Scharff for her patience and help in producing this report.

2 New information on the occurrence of cold water coral in the north Atlantic

2.1 Introduction

It is assumed for the purposes of this report that cold water corals refer to those coral species that contribute to reef formation in waters less than about 20^{o}C. In North Atlantic waters these include the azooxanthellate scleractinian corals *Desmophyllum cristagalli, Enallopsammia rostrata, Lophelia pertusa, Madrepora oculata* and *Solenosmilia variabilis*. The main reef building species is *Lophelia pertusa*. Other coral species often occur in association with *Lophelia pertusa* and only *Madrepora oculata* has been found forming reefs without *Lophelia pertusa* being present. Zibrowius (1980) gave a good general review of the distribution of cold water coral in European waters. This report builds from our 2002 and 2003 reports (ICES 2002, 2003) and information from those reports is only repeated to put new information in context.

2.2 Distribution of cold water coral

2.2.1 USA

Deepwater corals have been known along the American east coast since at least 1862 when Verrill noted the presence of a *Primnoa* on Georges Bank (Verrill 1862). Several other deep water coral species from depths greater than 200 fathoms off the coasts of New England and Nova Scotia were documented by Verrill during the latter part of the 19th century (e.g. Verrill 1878a, 1878b, 1879, 1884). Many specimens were captured during dredging programs instituted by the U.S. Fish Commission (as the National Marine Fisheries Service was known in those days), but an equally large number of specimens were brought to Verrill's attention by schooner captains who had pulled the corals from the bottom while tub trawling. While no reefs have been found on this side of the Atlantic, the coral fauna is diverse and includes several species in the octocoral group as well as hard corals (Breeze *et al.* 1997).

There are 17 species of scleractinian corals (hard corals) known from Cape Hatteras to the Gulf of Maine (Cairns and Chapman 2001). Only one species (*Astrangia poculata*) occurs in shallow water and 71% of the 17 species occur deeper than 1000 m. Forty-seven percent of the scleractinian corals from the cold temperate U.S. coast are widespread species and 28% occur across the Atlantic, with only a single endemic species *Vaughanella margaritata* (Cairns and Chapman 2001).

Tendal (1992) summarised the known records of the giant gorgonian, *Paragorgia arborea*. In the Atlantic it is found from the tip of Georges Bank, Greenland, Iceland, and the Faroes to northern Norway. Grasshoff (1979) showed this species to be bipolar in its distribution, being found in the colder and deeper waters of the southern hemisphere as well as in the north Atlantic and Pacific oceans.

Photographic transects of the slope and canyon faunas south of Georges Bank recorded over 25 species of both hard corals and octocorals with several taxa dominant in the overall megafaunal community (Hecker *et al.* 1980, 1983; Valentine *et al.* 1980; Cooper *et al.* 1987; Hecker 1990). However, seven species (two hard corals and five soft corals) tend to occur in high densities in different areas of the canyon/slope environment: *Acanella arbuscula*, *Anthomastus agassizii*, *Desmosmilia lymani*, *Eunepthya florida*, *Flabellum alabastrum*, *Paramuricea borealis* (now *P. grandis*), and *Primnoa resedaeformis* (Valentine *et al.* 1980, Hecker 1990).

The benthic fauna of the Northeast Peak of Georges Bank has been characterized as having two octocorals, *Primnoa resedaeformis* and *Paragorgia arborea*, as common components based on dredge sampling (Theroux and Grosslein 1987). Wigley (1968) described *Paragorgia* as a common component of the gravel fauna of the Gulf of Maine and stated that representative gravel faunas occurred on “Cashes Ledge, parts of Great South Channel, the northeastern part of Georges Bank, western Browns Bank, Jeffreys Ledge, and numerous other smaller banks in the Gulf of Maine region.”

The report by Theroux and Wigley (1998) on the distribution of macrobenthic invertebrates off the northeast United States, while an excellent summary of the distribution of major taxonomic groups, lacked taxonomic specificity for corals. Stony corals were lumped with all of the Zoantharia (including burrowing anemones, solitary epibenthic anemones, and colonial anemones). However, the distribution of the Alcyonaria, comprising the soft corals (Alcyonacea and Gorgonacea) and sea pens (Pennatulacea), showed patterns useful for predicting the distribution of soft coral taxa (based on 63 samples, 6% of total). These taxa were patchily distributed primarily along the outer margin of the continental shelf and on the continental slope and rise. They were not collected in samples shallower than 50 m depth (and it is unclear if deeper samples included the shallow soft coral *Gersemia rubiformis,* as there were many samples unidentified to the level of genus in the database). Alcyonaceans and gorgonaceans (soft corals) were collected from gravel and rock outcrop habitats while pennatulids were collected from sand-silt and silt-clay sediments (Figure 2.2.1.1).

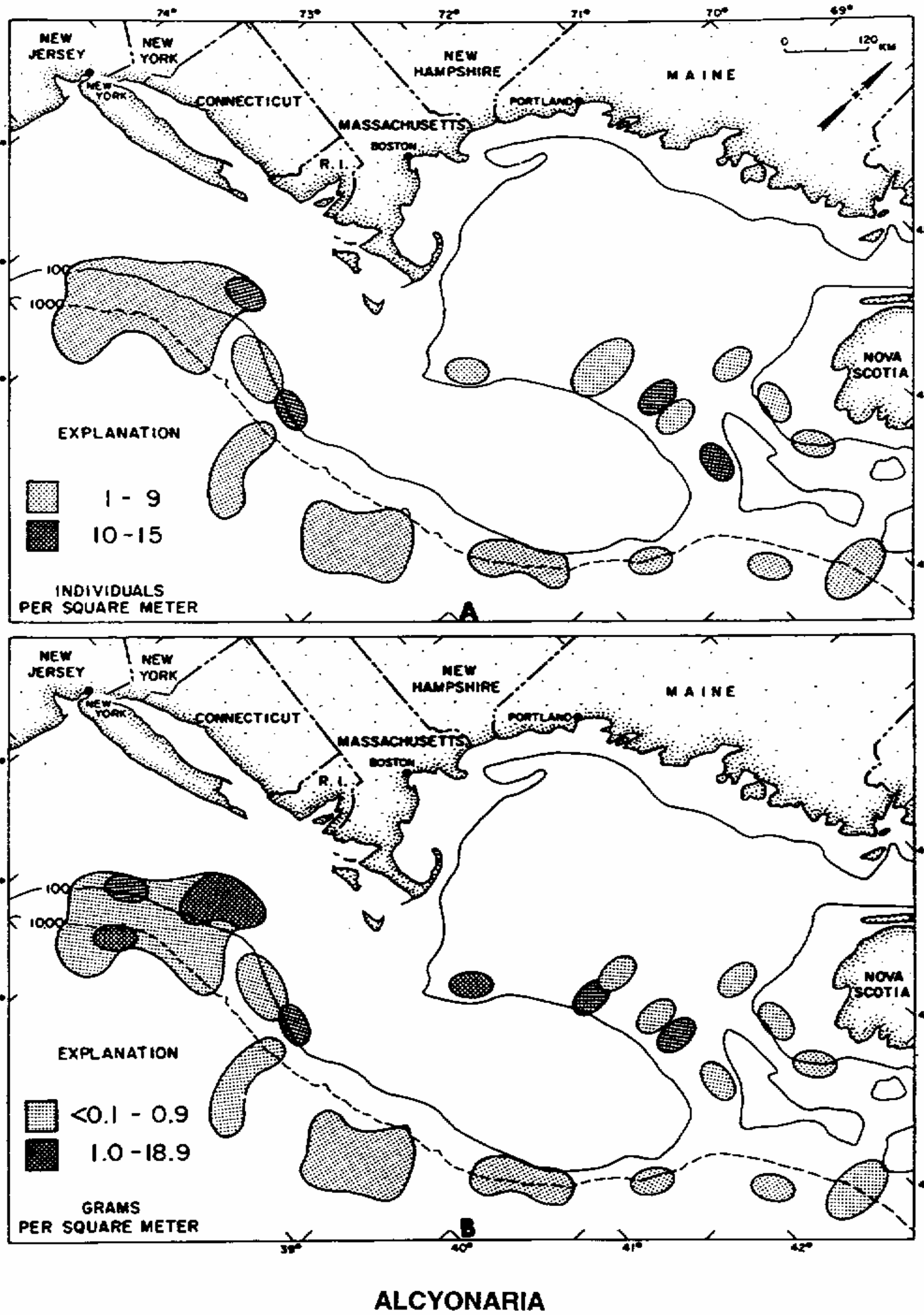

Figure 2.2.1.1 Geographic distribution of Alcyonarians off the northeast United States. Maps illustrate distributions in numbers.m^{-2} (A) and biomass as g.m^{-2} (B). From Theroux and Wigley (1998).

Watling *et al.* (2003) have created a GIS database delineating known occurrences of deepwater corals (soft corals of the family Alcyonacea) off the north-eastern United States. The dataset includes 761 records from published accounts of Verrill (1862, 1878a, b, 1879, 1884), Deichmann (1936), and Hecker *et al.* (1980, 1983), as well as museum records from Yale and Harvard collections, Northeast Fisheries Science Center Benthic Database records (of identified coral taxa), and observations from recent and ongoing NOAA supported studies in 2001–2003 (NURC, Ocean Exploration projects). Figure 2.2.1.2 illustrates large-scale distributions across the region from this work. Note the general concordance with the distribution illustrated from the Theroux and Wigley (1998) study in Figure 2.2.1.1. Figure 2.2.1.3 illustrates detailed coral distributions in Oceanographer and Lydonia submarine canyons. Similar distributions occur in other canyons where data are available. It should be noted that this work does not currently include other known data sources:

(1) photographic transect studies in submarine canyons led by Richard Cooper (e.g. Valentine *et al.* 1980),

(2) video records from the NURC video archive,

(3) records from the Middle Atlantic region (e.g., Hecker *et al*.(1980, 1983), Alvin archive), and

(4) specimens deposited in museums by the Northeast Fisheries Science Center collections and not yet identified.

A new project was initiated in 2003 by the United States Geological Survey to compile observations of deepwater corals along the U.S. east coast and Gulf of Mexico in a geographic database (K. Scanlon, USGS, Woods Hole, Massachusetts).

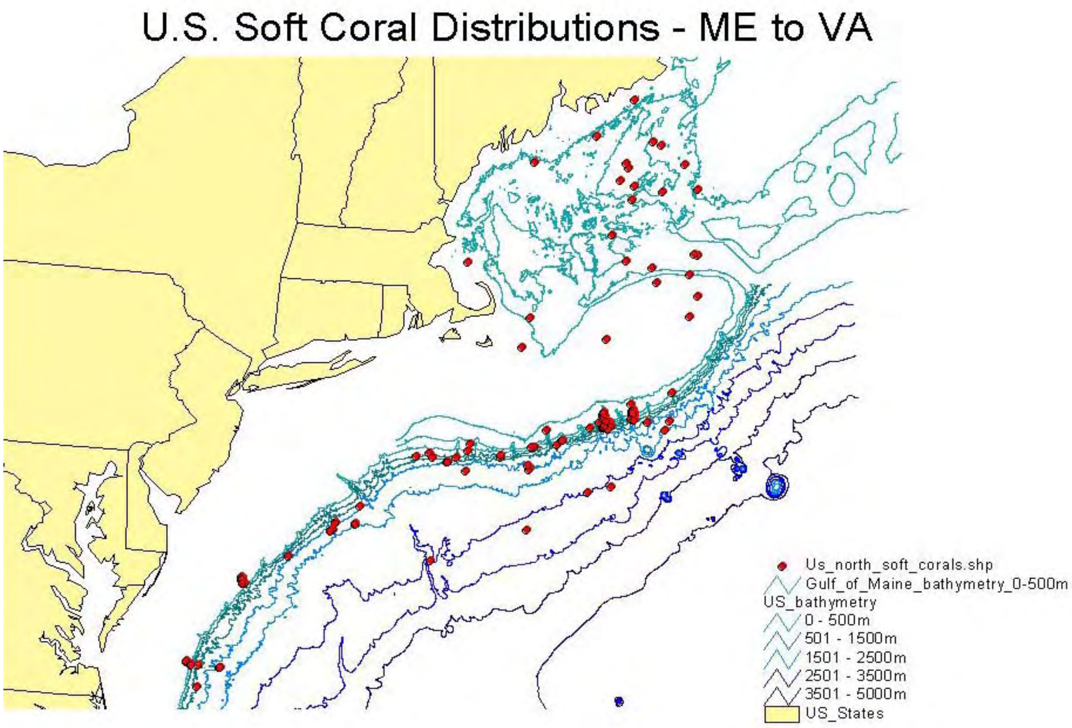

Figure 2.2.1.2. Regional scale distribution of Alcyonaceans across the northeast continental shelf region based on 761 records in Watling *et al.* (2003). Note there are overlapping records that are revealed with fine scale examination of the database (see Figure 2.2.1.3).

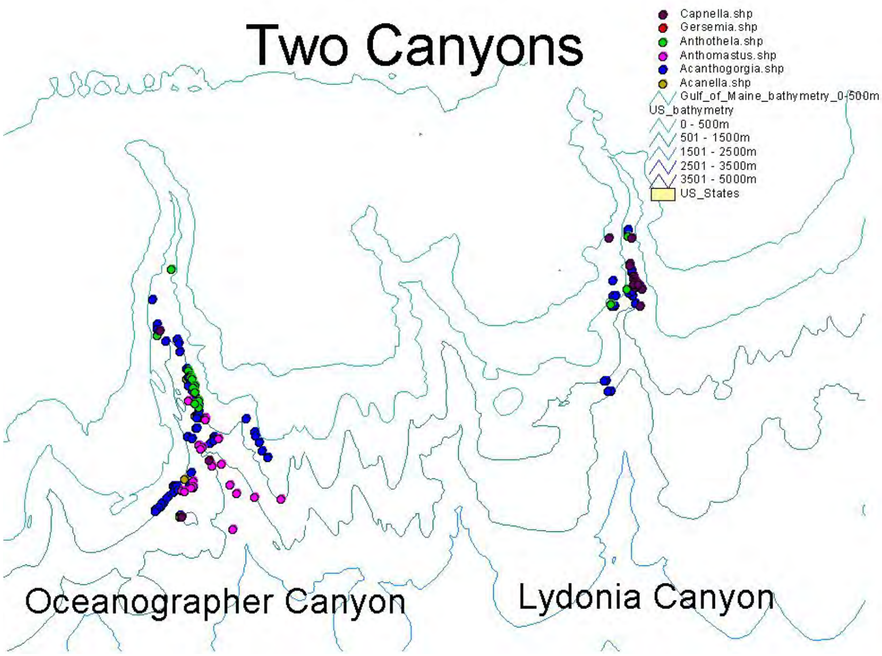

Figure 2.2.1.3. Fine scale distribution of Alcyonacean corals in Oceanographer and Lydonia submarine canyons from Watling *et al.* (2003). Note these data are primarily from camera transects so areas without corals are not necessarily absent of these taxa.

Informal discussions with members of the fishing industry demonstrate there is a good understanding of the distribution of corals in the Gulf of Maine and around the heads of submarine canyons. Compiling such knowledge would add significant information to the limited scientific sampling that has occurred over the past several decades. Breeze *et al.* (1997) is a good demonstration of how such a project was conducted in Atlantic Canada. However, it is worth noting that while such efforts can produce information on the distribution patterns of most common species, much more basic exploration work needs to be done. Note the existence of two new species recently collected during a limited number of submersible and ROV dives (11 dives total), one from the Gulf of Maine and the other from Oceanographer Canyon (L. Watling, pers. comm.).

2.2.1.1 Current Research

Ongoing research is focused on three primary areas: (1) the population biology of corals, (2) their role in mediating patterns of biological diversity, (3) and their role as habitat for fishes. From an ecosystem management perspective, all three areas are important for predicting effects of fishing and non-fishing impacts. These projects are occurring in the submarine canyons along the margin of Georges Bank and in the Gulf of Maine (Alcyonacea), on the New England Seamount chain (Alcyonacea), off North Carolina (*Lophelia*), along the Straits of Florida (*Oculina*) and along the continental margin of the Gulf of Mexico (*Lophelia*).

2.2.2 Canada

Deep-water corals are widespread in Atlantic Canada (Verrill 1922; Deichman 1936; Breeze *et al*. 1997; MacIsaac *et al*. 2001). In 2001-2003, the Environmental Studies Research Fund (ESRF) in Canada funded the Department of Fisheries and Oceans (DFO) to conduct a research program to provide new information on deep-water corals and their associated species in Atlantic Canada. Data and samples were obtained from DFO groundfish surveys, the Fisheries Observer Program, interviews with fishers, and dedicated research cruises using DFO research vessels which visited the Northeast Channel (Figure 2.2.2.1), Scotian Slope, the Gully, the Laurentian Channel, and the southern Grand Banks. Prior to this project most of the available data were anecdotal in nature and based primarily on fishing bycatch information. The summary below is based mainly on publications resulting from DFO’s coral project (Buhl-Mortensen and Mortensen 2004a,b,c; Gass and Willison 2003; Mortensen and Buhl-Mortensen 2004a,b; Mortensen *et al*. 2004a,b; Mortensen *et al*. in prep).

Corals are mainly found below 200 m along the edge of the continental slope, in canyons or in channels between fishing banks. A total of 23 coral taxa were observed (Mortensen *et al*. 2003), including a new species for the area (the antipatharian black coral *Bathypathes arctica*) (Gass and Willison, 2003). The results confirm the importance of the Northeast Channel, the Gully and the Stone Fence as prime coral habitats. They also demonstrate that corals are widespread off Newfoundland and Labrador and extend at least as far north as the Davis Straits. The area off Cape Chidley could be another coral prime habitat. The highest abundance of coral was found in the Northeast Channel while the greatest diversity was found in the Gully.

In late 2002 living *Lophelia pertusa* was discovered for the first time in Atlantic Canada at the Stone Fence in the outer part of the Laurentian Channel. In autumn 2003 a *Lophelia* reef was discovered at the same location (Mortensen *et al*. 2004b; Mortensen *et al*. in prep). The reef was about 1 km long and 500m wide and occurred at depths between 300 and 400 m to the east of Sable Island. More than 90 per cent of the reef was composed of dead coral, with extensive coral rubble and only small patches of live coral. It is assumed that much of the damage was bought about 30 years ago when the area opened to trawl fishing, but there is also evidence of more recent trawling.

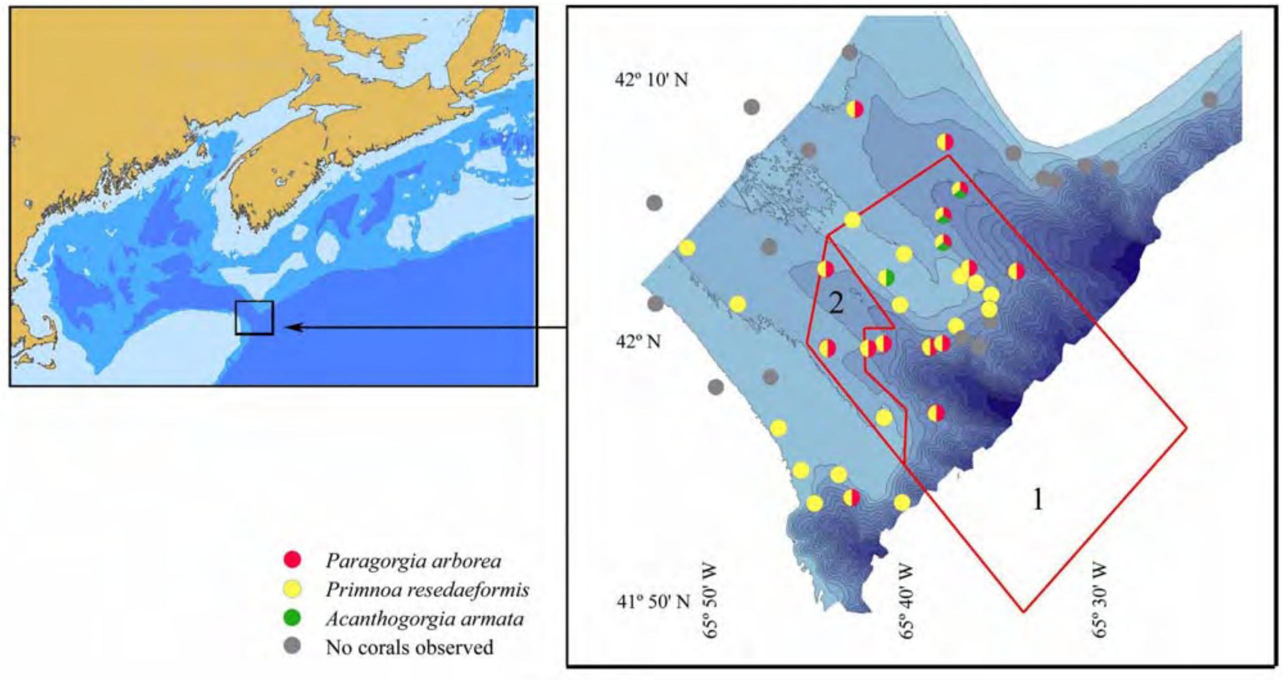

Figure 2.2.2.1. General location map of Northeast Channel and detailed bathymetric map showing distribution of gorgonians in the Northeast Channel based on video records. The coral protection area is outlined in red. 1) Restricted bottom fisheries zone, 2) Limited bottom fisheries zone.

2.2.3 Norway

A number of surveys using Multibeam echosounder, ROV and drop cameras have been conducted in Norwegian waters in the past year. These included the north of the Træna deep, the Røst reef and the continental break from Bleikdjupet and north to Sveinsgrunnen. Steinavær in Andfjorden was also covered (Figure 2.2.3.1).

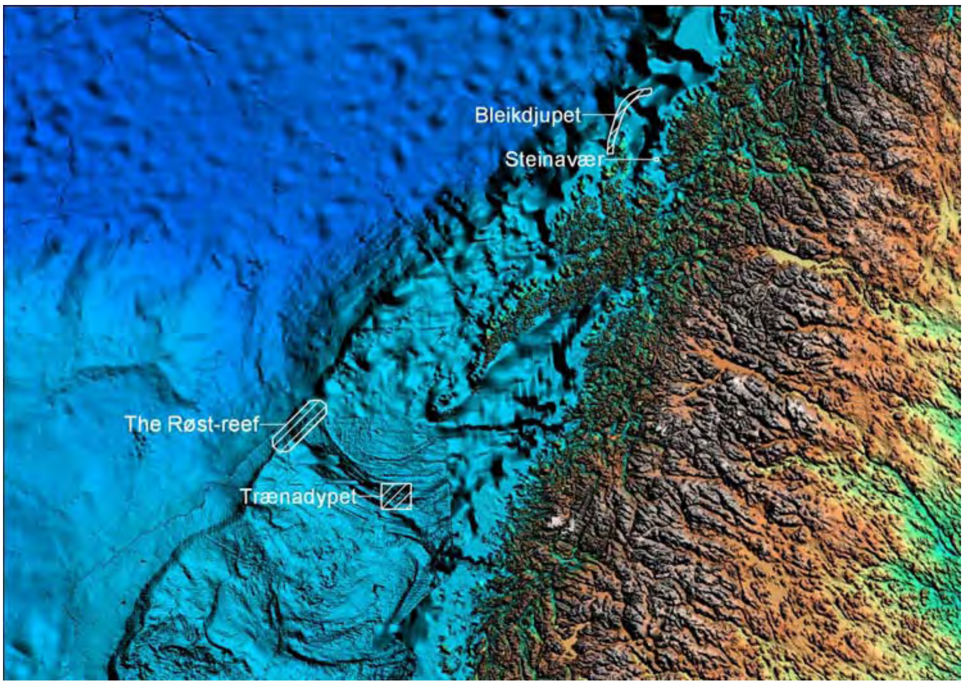

Figure 2.2.3.1. The Røst-reef was discovered and mapped in 2002. In 2003, additional mapping was performed on the Røst-reef and in the other areas marked on the map.

2.2.3.1 Træna deep (Trænadypet)

A 23 × 13 km area was mapped in Træna. The multibeam maps have been examined by marine biologists and marine geologists. The results indicate that in this area there are 1447 possible coral reefs with an average length of 150 m (Figures 2.2.3.1.1, 2.2.3.1.2 and 2.2.3.1.3) in an area delineated by the following coordinates: 66°52.9'N, 10°47.6'E;

66°59.1’N, 10°47.2’E; 66°59.2’N, 10°09.1’E; 66°59.2’N, 10°09.1’E; 67°00’N, 11°18.4’E; 66°52.2’N, 11°17.8’E; 66°51.9’N, 11°00’E; 66°52.8’N, 11°59.9’E. The total area of the possible new reefs is 3.63 km^2. However, not all reefs have been ground-truthed visually, but all places checked by the ROV held *Lophelia* corals.

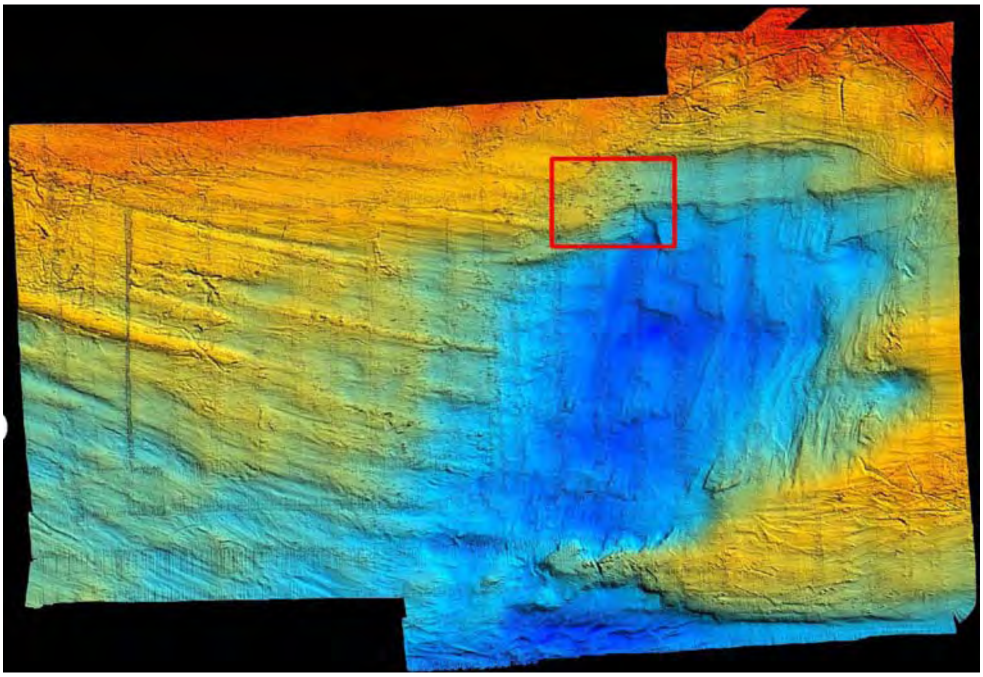

Figure 2.2.3.1.1. In Træna a 23 × 13 km area was mapped with multibeam echosounder. The colours indicate water depth. The darkest blue is about 400 m deep and the yellow is around 300 m. There are 1447 possible coral reefs, marked as dark spots, with an average length of 150 m. The map was produced in cooperation with The Geological Survey of Norway.

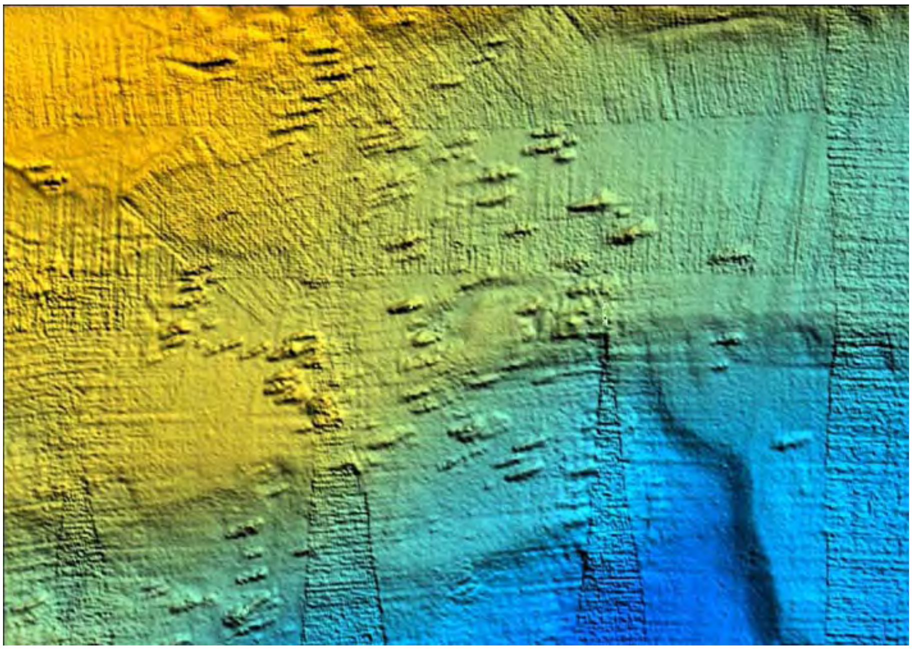

Figure 2.2.3.1.2. Magnified picture of the framed area in Figure 2.2.3.1.1. *Lophelia* corals build characteristic mounds on the sea bottom that can be recognised on a multibeam map. However, mounds of stones and till can be misinterpreted as coral mounds, so ground truthing is necessary.

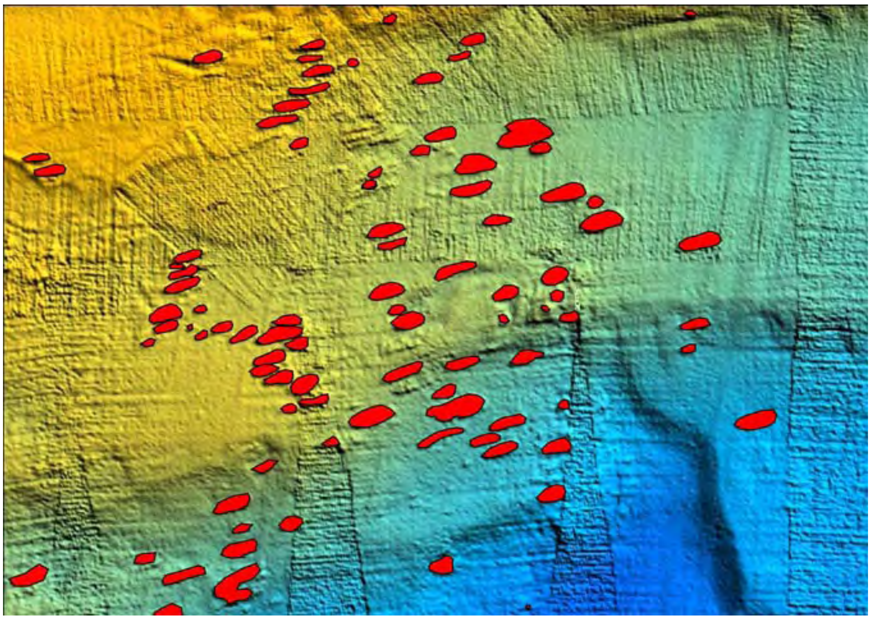

Figure 2.2.3.1.3. Magnified picture of the framed area in Figure 2.2.2.1.1. Red areas are interpreted as being coral mounds.

2.2.3.2 Røst reef

The reef is located in the upper part of a slide area along the continental break on 300–400 m depth. The mid part of the 40 km long Røst reef was mapped in greater detail than in 2002, and video transects were obtained from 500 to 300 m depth. This was carried out in order to describe how the growth of the coral colonies is related to the bottom structures and to the different habitat types in the slide area.

2.2.3.3 The continental break from Bleikdjupet to Sveinsgrunnen

The break was mapped from Bleikdjupet (69°18.0’N, 15°45.0’E) to Sveinsgrunnen (69°44.0’N, 16°20.0’E). Coral reefs were detected in the northern part of the mapped area at about 69°41.5’N, 16°08.5’E. Some reefs on the break were intact but lost long lines and gillnets were found. The shelf area is here heavily trawled and all the reefs in the trawled area were damaged.

2.2.3.4 Steinavær

At Steinavær in Andfjorden, 69°14.2’N, 16°39.0’E, a superb and unusual coral reef was found on both sides of an underwater canyon (Figure 2.2.3.4.1). On the northern side of the canyon, some 500m of ROV survey was conducted. The seabed was covered with a carpet of coral colonies, with many cod and red fish. Here, as in all coral areas, we detected the remains of fishing activity including lost long lines and gillnets.

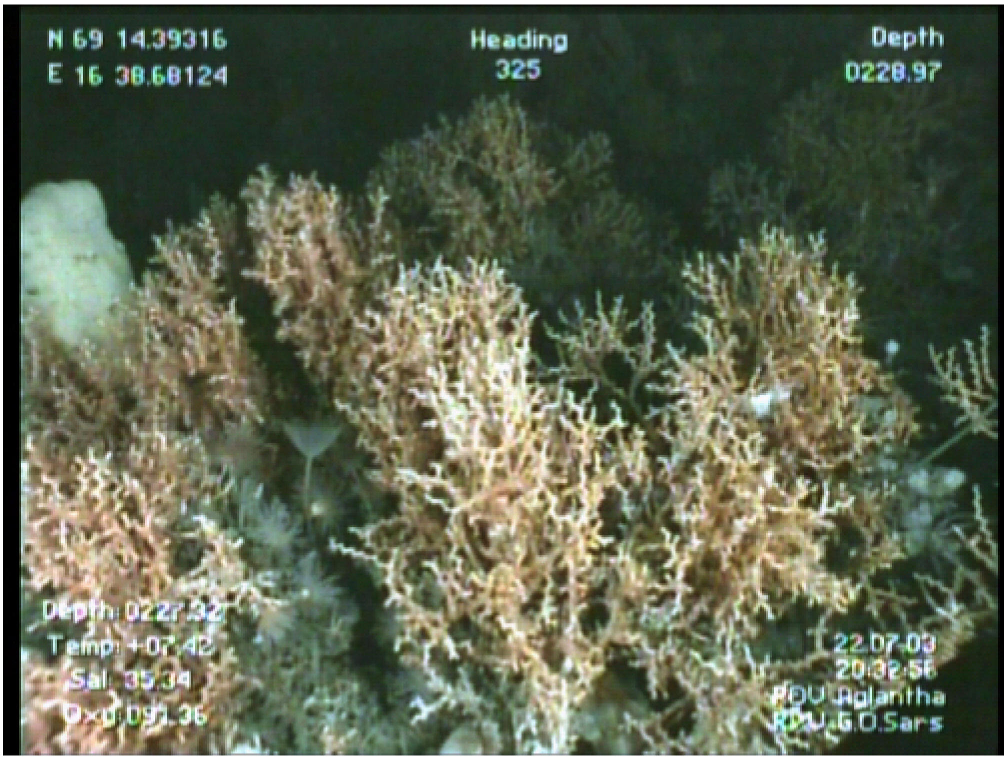

Figure 2.2.3.4.1. At Steinavær there are well-developed stands of *Madrepora oculata* in addition to *Lophelia* at a depth of 229 m.

2.2.3.5 Southern Oslofjord reefs

In November 2003 a joint German-Swedish cruise received permission to map the distribution of *Lophelia* reefs in the southern Oslofjord area close to the Soester Islands (Figure 2.2.3.5.1). The previously known Tisler Reef and the dead coral accumulations on the Djupekrak Sill were also mapped to provide a complete overview.

Of particular interest were about 7 nm-long inlets on both sides of the Soester Islands. These inlets are connected to the main Oslofjord Trough in the North, and the eastward continuation of the Norwegian Channel in the South. Both inlets have complex seabed topography with steep inclined rock outcrops, mud-rich troughs and drumlins as the major elements. The Western Oslofjord Inlet (WOI) consists of 140 to 320m deep troughs that are separated by narrow and generally less than 120m deep thresholds. These thresholds often are moraine deposits with consolidated clays, boulder-rich drumlins and exposed rock. These are all seabed types that generally attract a diverse epibenthic community including corals.

The Eastern Oslofjord Inlet (EOI) shows the same topographic elements, however, the troughs rarely exceed 200 m water depth. Two larger areas in the EOI are rich in corals: the inlet due east of the southern Soester Island and a narrow confined channel about 1.5nm north of the northern Soester Island. Individual reefs occur in water depths of 80 to 110 m and are formed by *Lophelia pertusa* as the major reef-building coral. Areas dominated by dead corals are intensely overgrown by huge *Geodia* sponges. In places forests of *Paramuricea* octocorals are common.

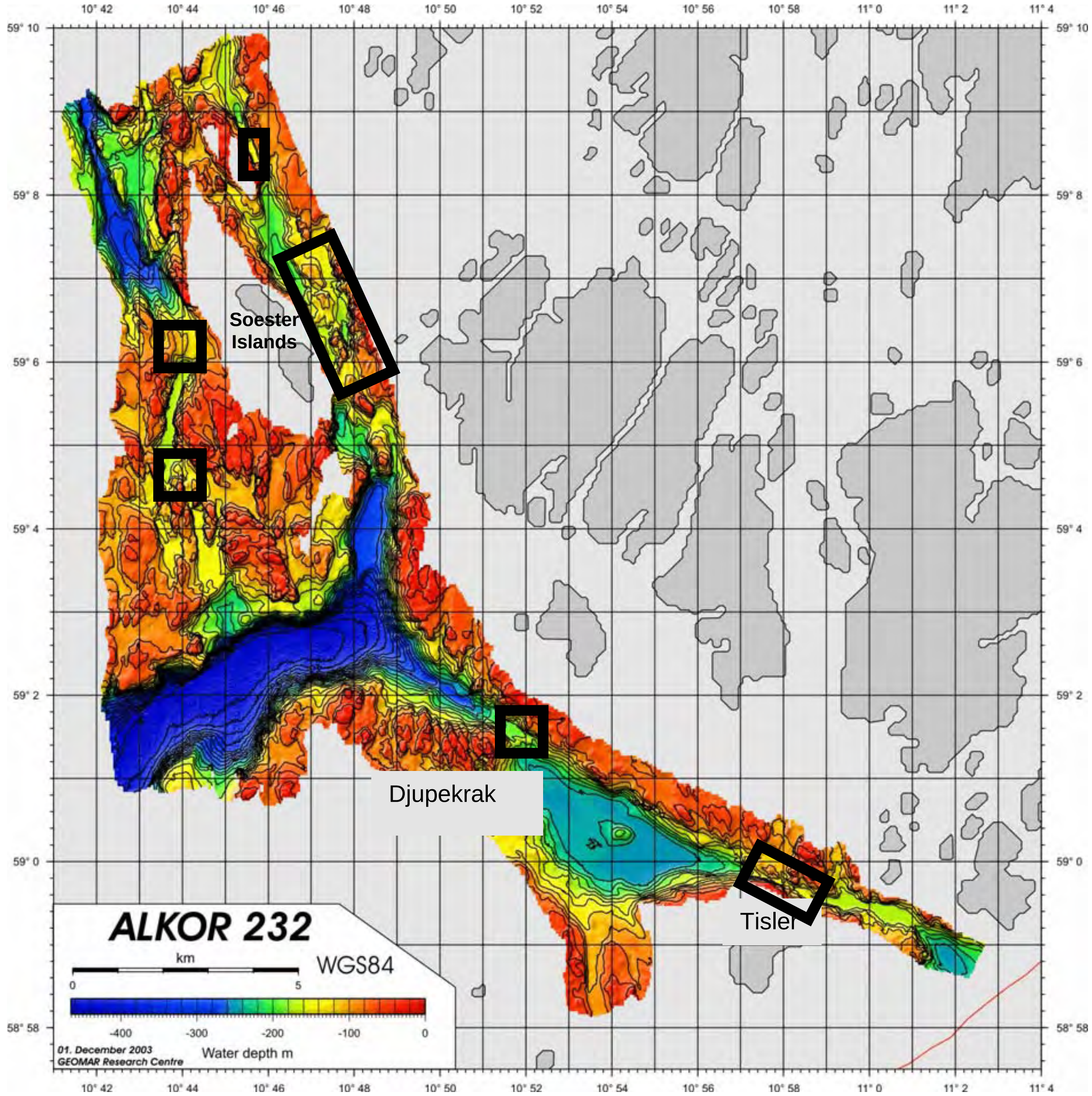

Figure 2.2.3.5.1. Multibeam map of the southern Oslofjord entrance generated during the RV Alkor Cruise 232 in November 2003. The coral reef sites are highlighted in the black rectangles.

2.2.4 Sweden

No new information was available.

2.2.5 Faroes

No new information was available.

2.2.6 Iceland

Information on existing coral aggregations off Iceland has been collected from fishermen over the past few years using questionnaires. The fishermen participating were captains on board trawlers and ships operating setnets and longlines.

In 2003 more than twenty areas off S Iceland were known to have aggregation of corals (Figure 2.2.6.1–2.2.6.4), distributed between Reykjanes Ridge (SW) and Rósagarður (SE), normally close to the shelf break. The surface area of eleven coral grounds could be estimated (1–38 km^2) but in twelve cases this was not possible. Considerable coral existed on the Reykjanes Ridge (Figure 2.2.6.1), within an area protected from bottom trawling, and relatively large areas of coral existed in the Hornafjarðardjúp deep (12 km^2) and in the Lónsdjúp deep (38 km^2) (Figure 2.2.6.4). Other coral grounds are small (commonly around 1 km^2).

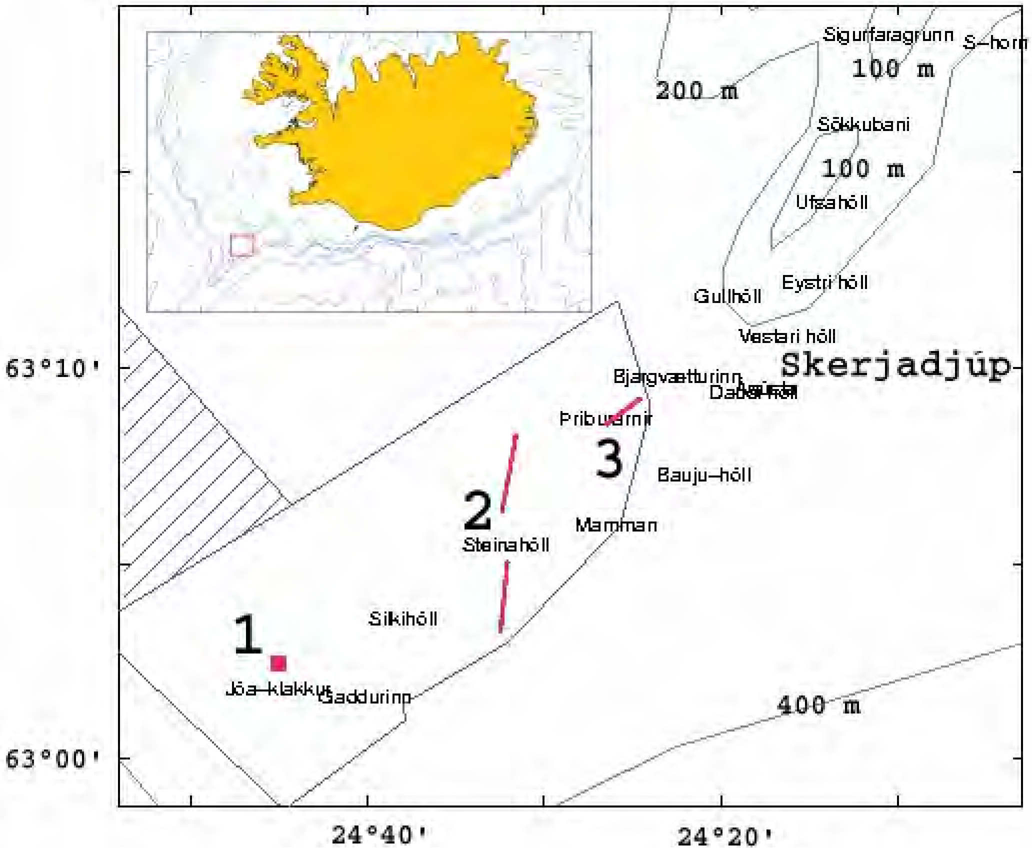

Figure 2.2.6.1. Present occurrence of coral on the Reykjanes Ridge. Results from the MRI questionnaire of 2003, with occurrence of coral grounds indicated with red line or a square (longlines and setnets). Areas closed for otter trawling are outlined with a blue line (closed throughout the year) and blue hatched area (trawling allowed 1 February–15 April). 1) Jóa–klakkur, 2) Steinahóll, 3) Þríburarnir.

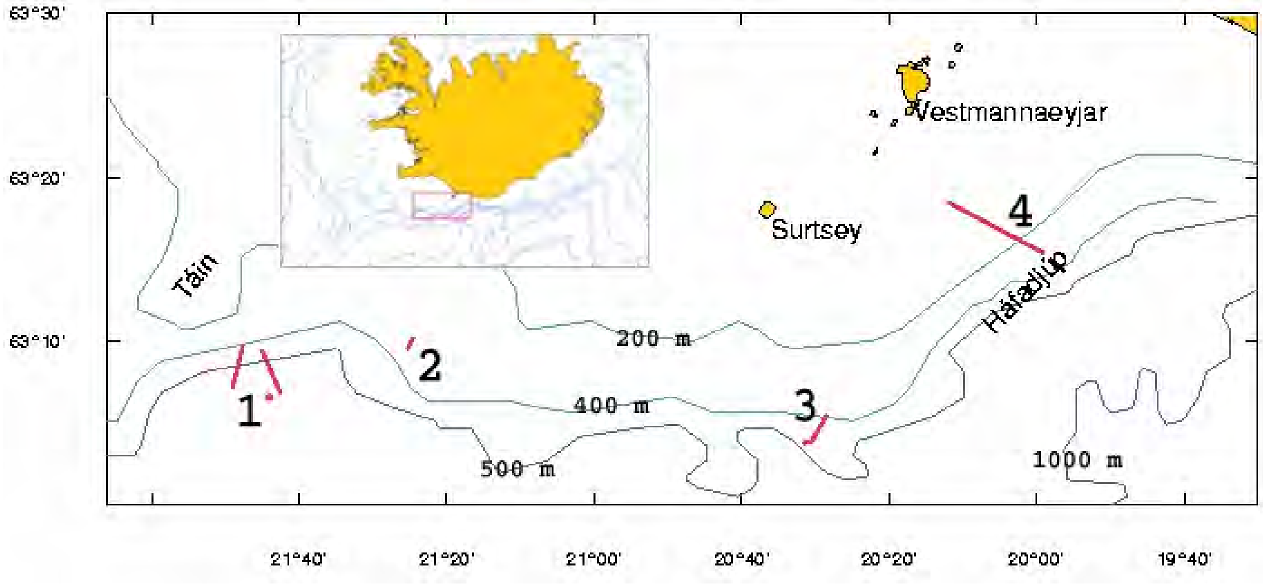

Figure 2.2.6.2. Present occurrence of coral in the area between the Táin and Háfadjúp deep. Results from the MRI questionnaire of 2003, with occurrence of coral grounds indicated with red lines or square (long lines and set nets). 1) “vesturgjá”, tectonic fissure south of the Táin, 2) W of the Surtur, 3) “austurgjá”, tectonic fissure S of Surtsey, 4) S Vestmannaeyjar, the western part of the shelf break of Háfadjúp deep.

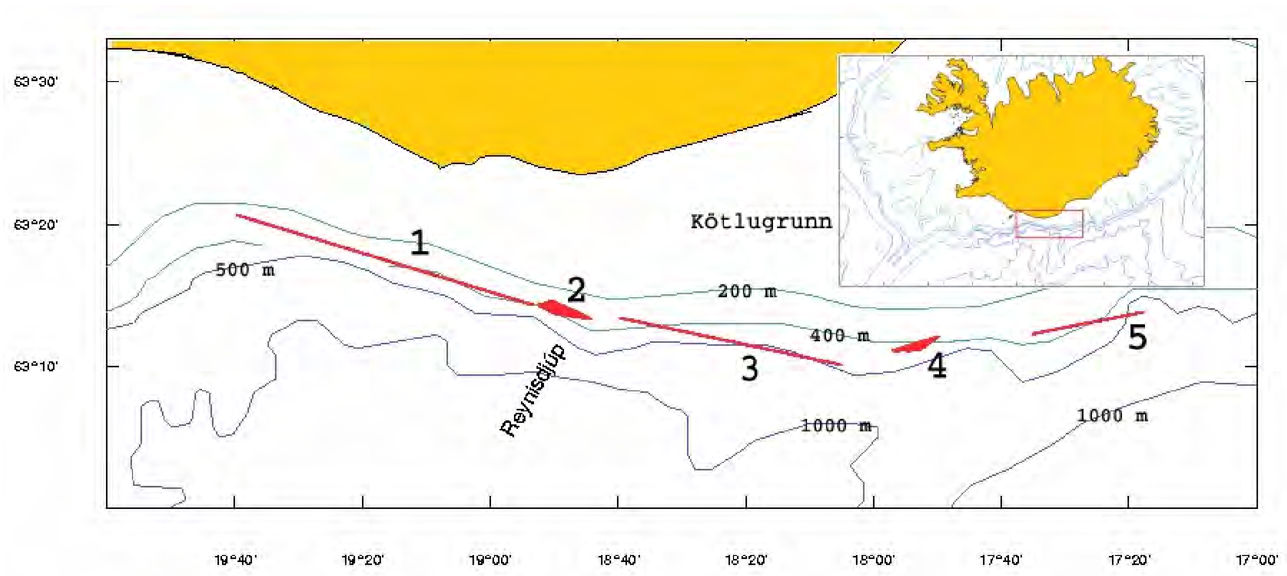

Figure 2.2.6.3. Present occurrence of coral in the area between the Háfadjúp deep and Síðugrunn bank. Results from the MRI questionnaire of 2003, with occurrence of coral grounds indicated with red lines (long lines and set nets) or red tinted area. 1) shelf break SA of Vestmannaeyjar, 2) Reynisdjúp deep (5 km2), 3) Kötlugrunn bank, 4) Skaftárdjúp deep, 5) Síðugrunn bank.

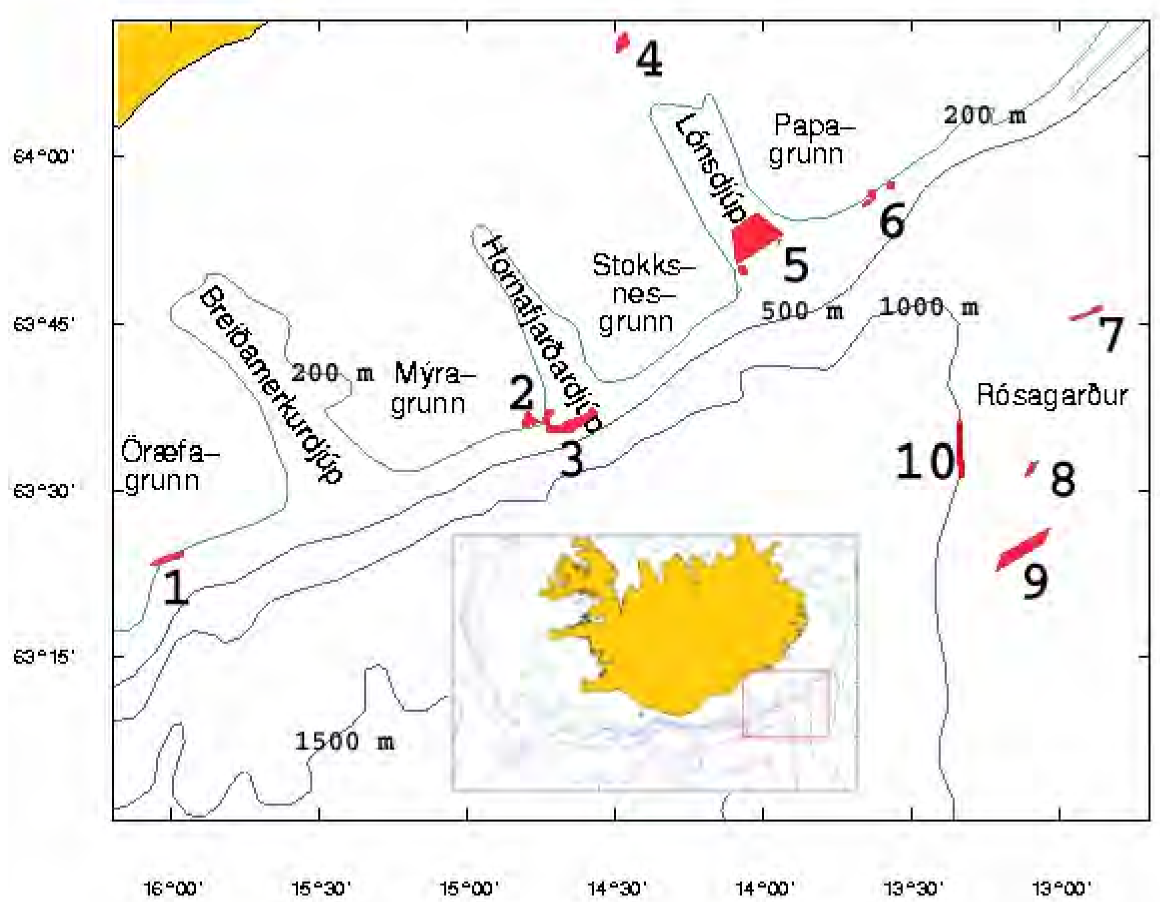

Figure 2.2.6.4. Present occurrence of coral in the area between the Öræfagrunn bank and the Rósagarður ("rose garden"). Results from the MRI questionnaire of 2003, with occurrence of coral grounds indicated with red tinted areas. 1) Öræfagrunn bank (5 km^2), 2) Hornafjarðardjúp deep a, 3) Hornafjarðardjúp deep b (12 km^2), 4) "Lovísa" (5 km^2),, 5) Lónsdjúp deep (38 km^2), 6) Papagrunn bank, 7) Rósagarður a (3 km^2), 8) Rósagarður b (2 km^2), 9) Rósagarður c (18 km^2), 10) Rósagarður d.

A multibeam survey of the coral grounds was completed in May 2004. Some of the grounds will be surveyed with ROV in June 2004, in order to determine which species of coral are present and their status in relation to fishing activities around the coral grounds.

2.2.7 United Kingdom

The distribution of *Lophelia pertusa* around the UK was assessed by Roberts *et al*. (2003) who have generated and maintain a GIS database. Inshore occurrences of cold-water corals were assessed in July 2003 by a consortium led by the Scottish Association for Marine Science (Roberts *et al*. 2004). Multibeam sonar surveys (Kongsberg-Simrad EM2000) were carried out in four areas to the west of Scotland where *Lophelia pertusa* had been recorded. In one area, east of the island of Mingulay, distinctive seabed mounds were found. The mounds are up to 5m high and 30m diameter in water depths of 110-180m (Figure 2.2.7.1). Video images showed extensive coral reef formation and grab samples contained *L. pertusa* coral skeleton colonised by a rich epifaunal community. Skeleton samples were dated to 3800 yr BP (SUERC-1892 & 1893; AMS 14C dating) and it is anticipated that material from the base of the mounds will be significantly older, extending to the early post-glacial period (~10,000yr BP). Quaternary studies suggest that ice retreated from this area 14,000yr BP but it will have taken longer for oceanographic conditions to allow coral growth to begin (Roberts *et al*. 2003). The reef structures were visible on backscatter images which also revealed 'trails' extending downstream from the mounds. The Mingulay Reef Complex is close to a primary productivity centre and mixing layer and the coral mounds are concentrated where currents are likely to be accelerated by rocky seafloor ridges. The authors suggest coral growth has been supported by plankton from surface production transported to the developing reef by dynamic seafloor currents. To date no surveys to assess the “health” of these reefs or whether they have been damaged by fishing activity have been carried out. However, habitat maps integrating visual ground-truthing surveys and acoustic data have been generated and integrated using a GIS database.

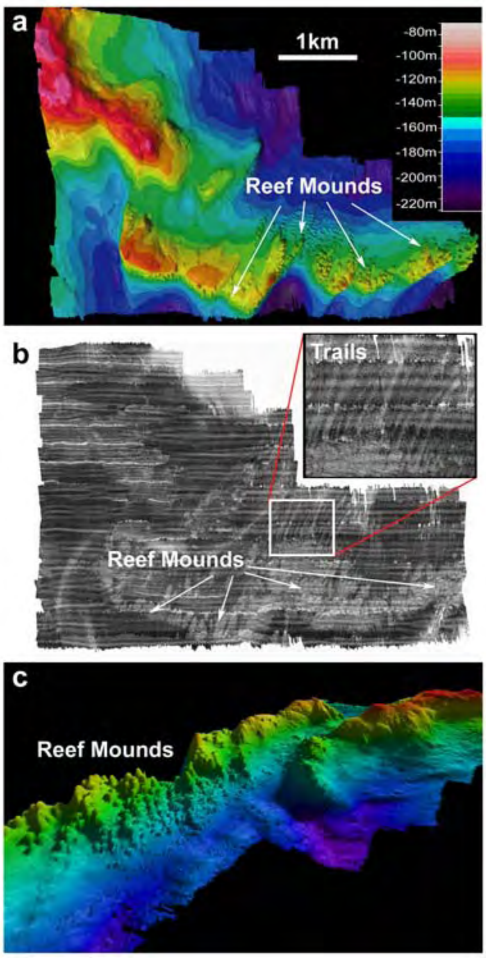

Figure 2.2.7.1. (a) Multibeam bathymetry showing prominent ridge features and Mingulay Reef Complex. (b) Backscatter image clearly delineates the reef mounds and reveals trails extending from them. (c) Three dimensional view of the reef complex from the north east (6 × vertical exaggeration).

2.2.8 Ireland

The German research vessel Meteor conducted a reconnaissance survey of the deeper flank west of Rockall Bank within the Irish EEZ. The Geological Survey of Ireland provided mapping data of suspicious mound-like structures which Meteor could partially ground-truth. Two seabed structures were mapped and rich coral habitats were found and documented using an underwater camera sledge system. The coral habitats occur in depths between 618 to 950 m. Most abundantly *Lophelia pertusa* and *Madrepora oculata* are identified as the major framework builder. Interestingly, the solitary *Caryophyllia sarsiae* lives in large quantities attached to the colonial corals. Benthic life on the adjacent muddy and rippled sand beds was much richer compared to the heavily trawled off mound areas in the Porcupine Seabight.

2.2.9 Spain

Alvarez-Perez *et al.* (2003) described deep-water coral occurrence in the Straits of Gibraltar. A total of 334 dredge samples were taken in 1994 from the Spanish Algeciras shelf and the deeps of the Straits of Gibraltar. Sixteen species of hard corals were found in the samples, with *Lophelia pertusa* and *Madrepora occulata* being the most widespread. *Caryophyllia cyathus* was the next most abundant species with others being more restricted.

Dierk Hebbeln surveyed coral communities living on mud volcanoes in the Gulf of Cadiz in December 2003 (Figure 2.2.9.1). The most abundant habitat-forming coral was found to be *Dendrophyllia alternata* and not the usual *Lophelia*/*Madepora* community.

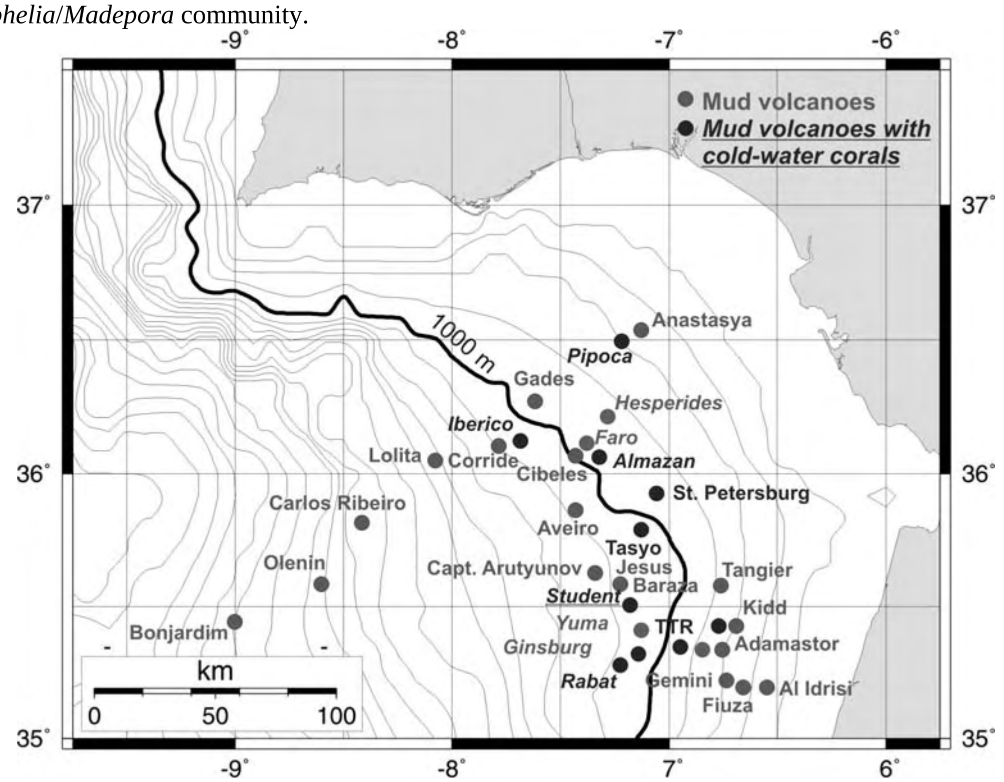

Figure 2.2.9.1 Mud volcanoes found in the Gulf of Cadiz, December 2003, indicating those that have cold water corals growing on them (D. Hebbeln, pers.comm.)

2.2.10 Portugal

The slopes of the islands and seamounts in the Azores comprise of extensive volcanic rocky bottoms in a high energy environment. These areas are ideal for sessile suspension-feeding fauna such as deep-sea cold water hard corals, sea fans and sponges.

The deep-sea coral fauna of the region was studied intensively as a result of the sponsorship of Prince Albert 1 of Monaco (Gravier, 1920, 1921, 1922; Jourdan, 1895; Roule, 1905). These studies are still the most important source of knowledge about the Azores benthic fauna, outside the hydrothermal vent fields. Subsequently, other expeditions targeted the deep-sea fauna of the region and sampled many coral species around the islands. Zibrowius (1980) reviewed those reporting Scleractinia but several other publications deal with corals from the region.

A checklist of the species reported to the Azores region (defined as a rectangle enclosing the Azores EEZ) is presently being compiled along with a database of the geographical and bathymetric data of the stations that produced the material. The study focuses on the corals ecologically classified as biobuilders, namely the orders Stolonifera, Gorgonacea, Alcyonacea (Octocorallia), Antipatharia and Scleractinia (Hexacorallia).

The Department of Oceanography and Fisheries of the University of the Azores (DOP/UAç) has recently launched a small-scale programme with local fishermen to collect corals that are brought to the surface by the demersal gears used in the Azores (i.e., hand-lines, bottom longlines and cages). Material gathered in scientific cruises is also being catalogued and preserved.

A preliminary checklist of the Azorean corals, based both on data mining and new records, includes more than 110 species. A geographical information system will be used to produce distribution maps of these coral occurrences. Preliminary results indicate that some oceanic seamounts (e.g., Açores, Condor, Sedlo, Cavala) support rich assemblages of deep-sea corals. An assessment of the ongoing and potential impacts of bottom gear on those fragile, complex and diverse communities will also be developed. Unfortunately this study of Azores corals has no current funding, but it is carried out by marine biologists from DOP/UAç in collaboration with Dr. Oscar Ocaña of the Instituto de Estudios Ceutíes who provides taxonomic expertise.

3 New information on the impacts of fishing on cold-water corals

3.1 USA

No systematic assessment of the distribution and population dynamics of coral taxa is available for eastern USA waters. Therefore, it is difficult to determine overall distributions of particular taxonomic groups or changes in abundance over time. Coral bycatch has not been consistently identified or enumerated during the groundfish survey of the Northeast Fisheries Science Center so this data set is limited in any assessment of status. (As an aside, the utility of such data is illustrated in an analysis of coral distributions and associated fish taxa collected during similar fishery independent surveys in the Alaska region; Heifetz 2002). However, the rarity of encounters with deepwater corals by us and colleagues over 20 years of submersible dives across complex habitats on the shelf and upper slope of the northeast U.S. suggests that the distribution of these species has significantly contracted since the time of the surveys conducted by Wigley, Theroux and others (i.e., tapes in the National Undersea Research Center video archive at the University of Connecticut and those held by NURC supported investigators).

Fishing has had significant impacts on deepwater coral populations worldwide. Between 30%–50% of *Lophelia* reefs off Norway have been impacted or destroyed by trawling (Fossa *et al.* 2002). More than 90% of *Oculina* habitat in a reserve off the east coast of Florida has been reduced to unconsolidated rubble (Koenig *et al.* in press). These authors present evidence of recent trawling activities as one likely and major cause of the damage but temperature extremes, excess nutrients, disease, strong currents, and other types of ship operations are also potential sources of historic mortalities. Comparisons of fished and unfished communities on seamounts off Tasmania showed that heavy trawling essentially removed the coral aggregate and significantly reduced the number of species and biomass (Koslow *et al.* 2001). There is a high degree of endemism of seamount fauna (de Forges *et al.* 2000) making these habitats particularly sensitive to fishing disturbances. Observations of the impacts of a single trawl tow through *Primnoa* habitat in the Gulf of Alaska, where 1000 kg of coral were landed, showed seven years later that 7 of 31 colonies remaining in the trawl path were missing 80-99% of their branches and boulders with corals attached were tipped and dragged (Krieger, 2001). Damage was restricted to the net path. Approximately 50 colonies were observed within 10 m of the net (where bridles would have swept over the seafloor) and no damaged colonies or disturbed boulders were observed. Longline gear is also noted to tip and dislodge corals (Krieger, 2001). Bycatch data from a longline survey in the Gulf of Alaska and Aleutian Islands showed *Primnoa* and other coral taxa were caught on 619 of 541,350 hooks fished at 150–900 m depths (Krieger, 2001).

Corals are clearly sensitive to fishing gear impacts and recovery rates are extremely slow based on our knowledge of recruitment, growth rates, and age structure. The ability to age deepwater scleractinians and octocorals is relatively new and different methods are used in different studies. For *Primnoa resedaeformis*, a common outer shelf-upper slope species, Risk *et al.* (2002) estimates linear growth rates at the distal tips of the colonies at 1.5–2.5 mm yr^{-1} based on comparisons of live specimens with growth rates through the base of a sub-fossil specimen collected from the Northeast Channel at 450 m. Growth rates of this same species in the Gulf of Alaska are reported as 1.60–2.32 cm yr^{-1}, although these samples were collected at less than 200 m depth (Andrews *et al.* 2002). Age estimates for only a few specimens demonstrate this species lives for hundreds of years. The colony collected from the Northeast Channel (Risk *et al.* 2002) has an estimated age of >300 years, which is in accordance with age estimates of the same species collected in Alaska (>100 years; Andrews *et al.* 2002). *Desmophyllum cristagalli*, a deepwater scleractinian (stony coral), grows at 0.5–1.0 mm yr^{-1} and lives >200 years, with this growth rate verified by a specimen collected from an aircraft sunk in Baltimore Canyon in 1944 (Lazier *et al.* 1999; Risk *et al.* 2002). A pennatulid (sea pen) from the Bering Sea (248 m depth), although from a genus different from the common species in the northwest Atlantic region (*Halipteris willemoesi* in the Bering Sea versus *Pennatula aculeata*), has an estimated age for large specimens of 44.3 yrs. A 1.5 m high colony of the deepwater scleractinian coral *Lophelia pertusa* may be up to 366 years of age (Breeze *et al.* 1997). Deep-water reefs of *Oculina varicosa* form pinnacles and ridges 3–35 m in height off the east coast of Florida and have an average growth rate of 16.1 mm yr^{-1} (Reed 2002). Based simply on age and growth information, recovery of impacted colonies and thickets may take hundreds of years.

Data on recruitment patterns is even more limited. A single series of observations in the Gulf of Alaska suggest that recruitment of *Primnoa* sp. is patchy and aperiodic (Krieger, 2001). No recruitment of new colonies was observed in an area where *Primnoa* was removed by trawling after seven years. However, six new colonies were observed at a second site one year after trawling. Four of these colonies were attached to the bases of colonies removed by trawling. Recruits of *Primnoa* were also observed on two 7 cm diameter cables (>15 colonies each). Our limited observations of corals in the Gulf of Maine and in submarine canyons have not revealed any recent (or abundant) new recruits of coral taxa (Watling, Auster, and France, unpublished observations).

The reproductive biology of anthozoans is well documented with respect to gonadal morphology, gametogenesis, and reproductive cycles (reviewed by Campbell, 1974; Larkman, 1983; Fautin and Mariscal, 1991; Eckelbarger, 1994; Eckelbarger and Larson, 1992; Eckelbarger *et al.* 1998), especially for sea anemones and corals of the Subclass Zoantharia (Hexacorallia). However, very little is known about the reproductive biology of the Subclass Alcyonaria (Octocorallia). In deep sea habitats, the reproductive biology of several anthozoans has been studied (reviewed by Eckelbarger *et al.* 1998) but little is known about octocorals. Recent NURC-sponsored studies of the reproductive biology of sea pens (pennatulid octocorals) in the Gulf of Maine have added a great deal of new information to our knowledge of the Anthozoa (Eckelbarger *et al.* 1998). For example, this work has found fundamental differences in the process of gametogenesis between sea pens and anemones. Additional knowledge about the reproductive anatomy of deep sea corals would fill a major void in our knowledge of the relationships among the major anthozoan groups and would allow more refined predictions to be made regarding reproductive potential, the effects of fishing impacts, and recovery of coral populations.

3.2 Canada

In surveys off Canada (see Section 2.2.2), the most extensive damage from fishing gear was observed at the Stone Fence (Mortensen *et al*. 2004b; Mortensen *et al*. in prep). About 90 per cent of the *Lophelia pertusa* reef discovered in the Stone Fence area off eastern Canada (see Section 2.2) was composed of dead coral, assumed to be caused by trawl fishing, both in the recent (30 year) past but persisting to the present. Live colonies were either small or clearly broken in an unnatural way. Gorgonians also showed signs of disturbance, with broken colonies, small size and unnatural occurrence on the sides of and underneath boulders. Analysis of observer data indicates that the general area of the *Lophelia* reef had been regularly fished with bottom trawling gear between 1980 and 2003. Current fisheries operating in the area are otter trawling for redfish and long-lining for halibut. A lower level of fishing damage was observed in the Northeast Channel (Mortensen *et al*. 2004a). In total, 4% of the observed gorgonian colonies were damaged, and broken or tilted corals were observed on 29% of the 52 survey transects. Lost longlines were observed 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. Analysis of effort data indicates that longline activity is widespread throughout the Channel while otter trawling and gillnet activity are concentrated on the Georges Bank side. Very few indications of fisheries damage to corals were observed in the Gully, just a few trawl tracks and one corroded lost wire from a trawl (Mortensen *et al*. 2004b).

3.3 Norway

In one locality in the south-eastern corner of the mapped area in Træna (see Section 2.3), large quantities of dead corals were detected. It looked very like damage caused by trawling, however, no firm evidence of trawling was documented. Along the continental break between Belikdjupet and Sveinsgrunnen damaged corals were found. This is a heavily trawled area and the reefs on the shelf were smashed to pieces. Lost lines and gill nets were documented in all areas surveyed by Norway in 2003.

3.4 Ireland

A total of 9 dives were carried out with the IFREMER deep-sea 'VICTOR 6000' Remotely Operated Vehicle (ROV) during the RV Polarstern expedition ARK XIX Leg 3A to the Porcupine Sea Bight and Bank to investigate carbonate mound and deep-water coral locations off the west coast of Ireland (Wheeler *et al*. in press). High resolution video and close-up digital stills were used to document the impact of fishing activity and the presence of lost gears. A series of mounds and scarps investigated along the western edge of the Porcupine Bank, in water depths of 600–1000m, were most severely impacted (Grehan *et al*. 2003a). One double mound system, named the Twin Mounds, appeared to be heavily trawled, as evidenced by the presence of trawl scars, barren sediment and flattened coral rubble. On the nearby Giant Mound, images of lost trawl gear filled with coral (some of it still living), provided clear evidence that reefs are being destroyed by present fishing activities. Numerous examples of lost static gears were also found draped over corals and other protrusions on vertical cliffs associated with a several kilometre long scarp feature also in the vicinity. The lines and nets observed did not in most cases appear to have been snagged but rather swept over the ledges by the strong bottom currents in the area.

4 The importance of cold-water coral reefs as a habitat for other species

4.1 USA

Corals are suspension feeders and are often a dominant taxon in deep hard substrate communities and enhance the number and density of associated species. Associates of *Primnoa* spp. in the Gulf of Alaska used the colonies for suspension feeding, shelter, or prey (Krieger and Wing, 2002). Ten megafaunal groups were identified in association with these corals. The predator group included sea stars, nudibranchs, and snails. The suspension feeding group included crinoids, basket stars, anenomes, and sponges. Finally, the shelter seeking group included rockfish (*Sebastes* spp.), mating golden king crabs and shrimp.

The role of deepwater corals as particular habitats for fishes has only been recently addressed in the literature. *Primnoa*, *Lophelia,* and *Oculina* are the taxa that have been the focus of most of this work. Corals may provide structure for shelter seeking fishes as well as enhance rates of prey capture. In the Gulf of Alaska, Krieger and Wing (2002) noted that "less than 1% of the boulders contained coral, but 85% of the large rockfish [*Sebastes* spp.] were next to boulders with corals." Data from research survey trawls off Alaska show rockfish (*Sebastes* spp. and *Sebastolobus alascanus*) and Atka mackerel (*Pleurogrammus monopterygius*) were the most common economically important species collected with gorgonian, cup, and hydrocorals, while flounders and gadids were the most common species associated with *Gersemia* sp., a soft coral primarily in the Bering Sea (Heifetz, 2002).

While many studies have documented high densities of fishes in particular coral habitats versus adjacent non-coral areas, these patterns do not necessarily indicate whether corals are "important" habitats for fishes in a demographic sense. Frequency dependent distribution models provide a basis for assessing the role of deepwater corals where it is necessary to understand the overall habitat-related distributions of fish species, at particular life history stages, in order to assess the particular role of corals. Examining the landscape for ecologically equivalent habitats is one approach for assessing the importance of coral habitats. Measures of the functional equivalence of habitats are demonstrated, as an example, for sites from the Gulf of Maine on the northeast United States continental shelf (Auster, in press). Fish census data based on surveys with a remotely operated vehicle in 2003 showed that communities in habitats dominated by dense corals and dense epifauna were functionally equivalent when compared with five other less complex habitats (e.g., boulder with sparse coral cover). Comparison of species-individual curves showed that sites with dense coral and dense epifauna habitats supported only moderate levels of fish diversity when compared with other sites. Further, density of Acadian redfish *Sebastes fasciatus* in dense coral and dense epifauna habitats, where this species was dominant, was not statistically different but was higher than an outcrop-boulder habitat with sparse epifauna (the only other site where this species was abundant). Such data suggest that coral habitats are not necessarily unique but have attributes similar to other important habitats. However, the level of their importance in the demography of fish populations and communities remains to be demonstrated.

Sulak *et al.* (2003) examined the fish fauna of deep-water *Lophelia* reefs off the south-eastern USA. *Lophelia* banks in this area support a distinctive fish assemblage when compared to non-coral habitats in the same depths. Sixty-five species of more than 30 families have been identified from these reefs. Economically-important species included wreckfish *Polyprion americanus* and black-bellied rosefish *Helicolenus dactylopterus*. *Laemonema melanurum*, *Squalus asper*, *Hoplostethus occidentalis* and *Beryx spendens* appeared to be restricted to the reef habitat.

4.2 Canada

Buhl-Mortensen and Mortensen (2004b) described the fauna associated with the deep-sea gorgonian species *Paragorgia arborea* and *Primnoa resedaeformis* from the continental shelf and slope off eastern Canada. A total of 49 samples were collected by ROV, video grab and bottom trawl from four areas. A total of 80 species were identified including two crustacean species new to science. The fauna with *Paragorgia* was more diverse than that with *Primnoa*, and there were clear differences in faunal composition between the two corals. Crustaceans dominated the fauna, and although the deep-sea corals lacked the diverse decapod fauna of their tropical counterparts, the overall species richness was higher than in tropical gorgonians. Very few obligate symbionts were found (as with *Lophelia*), but several of the species found are rare in other habitats and have been recorded from the same, or similar gorgonian species in the north-eastern Atlantic.

4.3 Norway, Sweden, UK, Ireland and Spain

As part of the EU-funded ACES project, analysis was undertaken of faunal samples taken from *Lophelia pertusa* reefs in these countries (Roberts and Gage, 2003). A summary of the number of major taxa recorded is given in Table 4.2.1.

It is likely that many of the differences between sites in Table 4.2.1 are the result of the following factors:

a) Difference in methodology used. This relates to both differences in sample collection technique (e.g. trawl vs. box core) and sample processing (e.g. preservation in formalin vs. air dried).

b) Difference in size classes collected. For example the only site where the smaller size classes (32–500µm) were analysed was the Belgica Mounds, explaining the preponderance of nematodes reported here.

c) Difference in taxonomic expertise. For example the high number of sponges reported at Propellor Mound where a special study of this group was undertaken compared to the very few recorded at Belgica Mound where this was not undertaken.

Despite the disparity in sampling methodologies and taxonomic resolution applied, a single listing of species recorded from these sites has been compiled. While some further checking may be required, this first compilation sums to a total of 1317 species. This number may by be marginally increased or decreased by further rigorous examination of the list but certainly shows that the species inventory recorded on *Lophelia pertusa* reefs in the NE Atlantic is greater than the 886 species found by Rogers (1999). The vast majority of these species are facultative associates of *Lophelia pertusa*. To date there has been little detailed analysis of obligate associates of cold-water corals. However, the presence of coral rubble does appear to enhance local faunal diversity significantly.

Table 4.2.1 Numbers of species of major phyla recorded at each ACES study site (* data unavailable) (Roberts and Gage, 2003).

Phylum	Sula Ridge	Kosterfjord	Darwin Mounds	Propellor Mound	Belgica Mound	Galicia Bank
Protozoa (Ciliophora)	*	1	*	*	*	*
Foraminifera	55	8	1	16	*	*
Porifera	44	43	20	104	1	1
Cnidaria	19	26	2	10	11	9
Ctenophora	*	1	*	*	*	*
Nematoda	*	*	*	*	131	*
Nemertea	*	1	1	*	*	*
Annelida	24	57	102	*	58	4
Prialupida	*	*	*	*	1	*
Sipuculida	2	4	2	*	2	1
Echiura	2	1	2	1	1	*
Arthropoda	23	37	80	7	31	22
Pycnogonida	*	2	1	*	*	*
Mollusca	39	52	61	160	13	19
Bryozoa	47	6	16	*	2	*
Echinodermata	19	29	20	4	4	3
Phoronida	1	*	*	*	*	*
Brachiopoda	5	3	5	4	3	2
Hemichordata	1	1	*	1	*	*
Chordata (Tunicata)	6	*	1	*	*	*
Chordata (Pisces)	11	26	9	21	*	6

Four hypotheses were used to examine the results of this survey:

A. Cold-water coral structures can be subdivided into a repeatable set of sub-habitats with a species composition grading into the background community

Although a broad characterisation of sub-habitats (e.g. living and non-living coral framework, exposed coral rubble and semi- and fully buried rubble) is possible, finer characterisation seems to be site-specific, and depends on the growth form and the geology and topography of the seabed on which the coral is growing. However, a species composition grading into the background community, rather than an abrupt break seemed to be a feature of some areas (e.g. Galicia Bank and Darwin Mounds) more than others (e.g. Propellor Mound) where topography imposed a steeper environmental gradient into the “background” environment.

B. Living coral structures supports a biodiversity (composition and richness) that is different from that of background areas with similar attributes of the sub-habitat (e.g. presence of hard substratum, food and hydrodynamics)

This hypothesis could be addressed explicitly only for certain taxa (especially fish) in the context of living coral. It was possible to address this with regard to fauna associated with dead coral rubble at the Darwin Mounds compared to background areas containing hard substrata. The results indicated no coral-specific fauna was present, with all species present being already known as associated with hard substrata such as mollusc shells and drop stones. A similar conclusion might be reached from the listing assembled by Rogers (1999) although agreement between the two species lists is surprisingly very limited. What does emerge is that even if identities may differ at species or genus level, a very similar functional type may be found occupying a particular niche provided by the living, or dead, coral framework. An example of this is provided by the small suspension-feeding ophiuroid *Ophiactis balli* that is found to develop dense populations at the shallower sites (e.g. Koster Fjord and Mingulay), while in deeper water (e.g. the Darwin Mounds) the apparently functionally very similar congener *O. abyssicola* is found in large numbers.

C. Species inventory is predictable at different sites regardless of geography and depth

A proper assessment of this hypothesis is difficult as biodiversity descriptions were usually biased by the taxonomic experience of the investigator at each site. Even where similar size classes were examined, differing methodology limited the validity of making direct comparisons. Nevertheless, the hypothesis does not seem to be supported from the data available. Although species are listed that were found at nearly all sites, others seemed to reflect the usual range of the species in the background community. Because of this species inventory at the different sites in the NE Atlantic varied substantially. This is in agreement with the conclusions of Jensen and Frederiksen (1992).

D. There are species found associated with the coral that are found only in this habitat.

The results of ACES (2004) support the view reached by Burdon-Jones and Tambs-Lyche (1960) and Jensen and Frederiksen (1992) that a true obligate fauna associated with *Lophelia*, in the sense of Dons (1944), has yet to be described. Hence the habitat requirement of the rich associated biodiversity is provided by features of the coral framework (e.g. hard, cryptic substratum) or the habitat that is beneficial to coral (strong plankton-carrying flow), may be equally found in other areas. Therefore this biodiversity is comprised of facultative associates that find cold-water coral matches their habitat requirement.

Costello *et al.* (2003 and in press) described the function of *Lophelia* as fish habitat, based on the results of the ACES study described above. A total of 23 species of fish from 17 families (McCrea *et al.* 2003) were recorded over all sites studied. Four habitats were distinguished: reef, transitional, coral debris and off-reef seabed. Multi-variate analysis showed a distinct separation of assemblages at 400-600m depth. The species diversity and abundance of fish was greater on the reef than over the surrounding seabed with 92% of the species and 80% of abundance associated with the reef. The reefs plainly have an important function in deep-water areas in providing fish habitat.

4.4 Faroes

Jensen and Frederiksen (1992) studied 25 blocks of *Lophelia pertusa* weighing a total of 18.5 kg. A total of 256 species were found, with an addition 42 species from loose coral rubble. Most individuals were found in dead coral blocks with a few species close to the terminal branches of live coral. One of these species, the foraminiferan *Pulvinulina punctulana*, lives directly as a parasite on the coral tissue. The overall faunal association was found to be as rich as that found on hermatypic branching species of coral.

4.5 Norway

Mortensen *et al.* (1995) investigated large and visible fauna on *Lophelia pertusa* reefs off Norway using video techniques. Their transects started over soft bottom with scattered patches of stones below bioherms and finished at the top of the bioherms, some of which were 31m high. Five habitats were defined: Soft bottom, Mixed stone bottom, *Lophelia* rubble, dead *Lophelia* and living *Lophelia*. Some 36 taxa were identified, five of which occurred only on the bioherms, and five only over the soft /stony bottom. The *Lophelia* rubble had the lowest diversity but highest average density of individuals. Sponges, gorgonians, squat lobsters, redfish *Sebastes* spp. and saithe *Pollachius virens* dominated in terms of individuals per area. Four species of fish were identified: saithe were often observed feeding on the bottom, but were thought to only be temporary residents at the bioherm as they were only seen on one month of the three when surveys occurred. Redfish feed on plankton and were commonest either over the live *Lophelia* or resting within the *Lophelia* structure. Tusk *Brosme brosme* were present as isolated individuals possibly feeding on squat lobsters present in the bioherms. *Chimera monstrosa* were seen occasionally over soft bottom areas. In summary, no large species was an obligate associate of the *Lophelia* bioherms, and those fish occurring on or around the *Lophelia* reefs were using the structure in a variety of ways.

Husebø *et al.* (2002) carried out experimental fishing with long-lines and gillnets over *Lophelia pertusa* reefs and in nearby non-coral habitats. The abundance and distribution of redfish *Sebastes marinus*, ling *Molva molva* and tusk *Brosme brosme* were quantified in the two habitats. Significantly larger catches of fish (all species lumped together) were made in the coral habitat, but this was mostly caused by large catches of redfish made on long-lines in coral habitats. More fish of each species were caught regardless of method in coral habitat compared with non-coral habitat, but with the exception of redfish on long-lines, none of these differences were significant. Redfish, tusk and ling caught over coral habitat were all generally larger those caught in non-coral habitats. An examination of the stomach contents of the fish caught in these experiments supports the idea that redfish primarily use the habitat for its physical structure (shelter, and possibly a food concentrating mechanism) while tusk feed on other organisms using the reef.

4.6 Ireland

Grehan *et al.* (2003b) examined the isotopic content of biota growing on the deep-water carbonate mounds to the west of Ireland that usually have *Lophelia* reefs associated with them. Some evidence has been published suggesting a link between some of these carbonate mounds and hydrocarbon seeps. However the isotopic content of the carbon and nitrogen of the mound biota was consistent with a reliance on photosynthetically-derived particulate organic matter, rather than hydrocarbon seepage.

Raes and Vanreusel (2003) examined the meiofauna in cold-water coral degradation zones in the Porcupine Seabight. A total of 22 meiofaunal taxa were found of which nematodes were the dominant group. Mixed substrates containing underlying sediment as well as coral and sponge fragments had the most diverse meiofauna, but the nematode fauna was not as diverse as that taken elsewhere in non-coralligenic sediments. Nevertheless only 5 of the 17 species of nematode found were known to science.

Wheeler *et al*. (in press) examined a series of carbonate mounds on the Porcupine Bank to the west of Ireland. These mounds appeared to be comprised mostly of degraded dead coral. The carbonate mounds are colonized by a variety of suspension feeders and associated fauna including framework-building corals (e.g. *Lophelia pertusa* and *Madrepora oculata*) although dense coral-reef like fauna coverage is not evident at present (Figure 4.6.1 A-F). The ecology of the carbonate mounds varied widely. Sessile megafauna, such as sponges, gorgonians and framework building corals (e.g. *Lophelia pertusa*), were abundant on some of the carbonate mounds. Other mounds were relatively barren and appeared to be undergoing a natural senescence, with a much lower biomass of megafauna than is typical of shallow-water coral reefs. Some mounds had been damaged by demersal trawls, with smashed coral and lost gear common, whereas others appeared relatively pristine with occasional evidence of man-made litter.

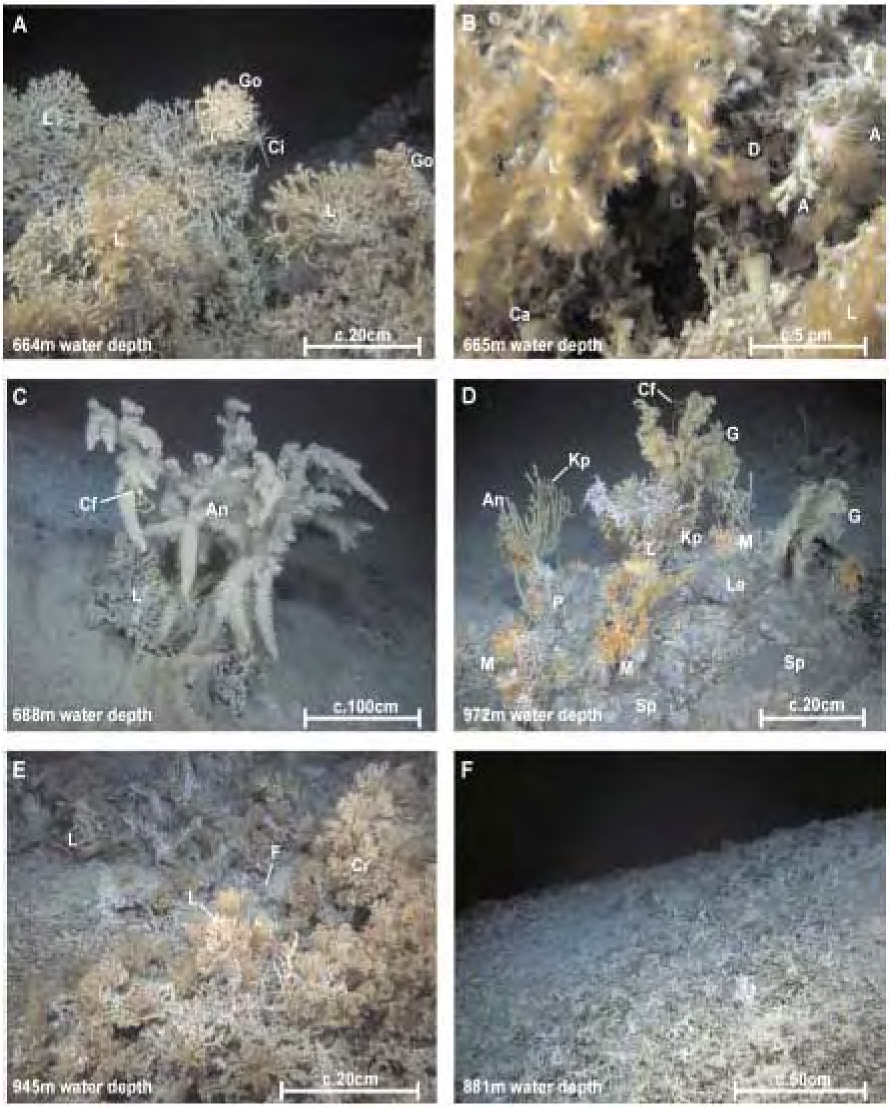

Figure 4.6.1. Selected images showing the variety of organisms and their association encountered on the northwest Porcupine Bank. **A**. *Lophelia pertusa* colonies (L) with *Gorgonocephalus* sp.(Go) and *Cidaris cidaris* (Ci). **B**. Close up of *Lophelia pertusa* colonies (L) with polyps extended. An anemone (A), a gastropod (*Calliostoma* sp.) (Ca) and *Desmopyllum cristagalli* (solitary coral) (D) are also present. **C**. An antipatharian (An) with spider crabs (*Chirostylus formosus*) (Cf) attached to a *Lophelia pertusa* colony (L). **D**. Heavily colonised dropstone with several sponge-species (Sp), *Lophelia pertusa* (L), *Madrepora oculata* (M), antipatharians (An), sylasterids (*Pliobothrus* sp.) (P), crinoids (*Koehlerometra porrecta*)(Kp) and spider crabs (*Chirostylus formosus*) (Cf) attached to gorgonians (*Acanthogorgia* sp. and others) (G) as well as a fish (*Lepidion eques*) (Le). **E**. Crinoids (Cr) attached to *Lophelia pertusa* colonies (L) with a fish (F). **F**. Coral rubble field as a result of demersal trawling activity

5 Location of areas to protect from deep-water trawling

The results of survey project were used by DFO in establishing a 424 km^2 coral conservation area in the Northeast Channel in 2002 and in designing the Marine Protected Area in the Gully that was formally declared in 2004. They are also being used by DFO and the fishing industry to establish protection for the Lophelia reef at the Stone Fence.

While no new sites were put forward for protection, in the case of Ireland, the Irish Government announced at the OSPAR Ministerial Meeting in Bremen in June 2003 its intention to designate a number of offshore sites as cold water coral reef Special Areas of Conservation (SAC) under the EU Habitats Directive. The Irish Department of the Environment, the competent authority, is currently engaged in a data collection exercise prior to identification of suitable sites.

6 Theme session on cold-water coral

A discussion on the theme session to be held at the ICES annual science conference in Vigo, Spain in September 2004 was held at the 2nd International Symposium on deep-sea corals in Erlangen, Germany in September 2003. Several of the members of SGCOR have supplied abstracts for the theme session, and Murray Roberts will be giving a Plenary Lecture.

7 Other relevant items

Two recent workshops have identified research and conservation priorities for deep-sea corals. A workshop held in Ireland in January 2003 identified key information needs, grouped into three areas: mapping, biology and ecology and paleoclimate analysis (McDonough and Puglise, 2003). A workshop on coral conservation was also held in association with the 2nd international symposium on deep-sea corals in Erlangen in September 2003 (Butler *et al*. 2003).). In addition, a report has been published containing the summary records, discussions and conclusions of two stakeholder workshops organised by the Irish Coral Task Force and the Atlantic Coral Ecosystem Study held in Galway, Ireland in 2000 and 2002 (Grehan *et al*. 2003c).

8 Recommendations

Although previous reports have recommended closing areas of coral to fishing, this has not proved possible this year. This is despite new discoveries of coral that are presumably vulnerable to the same gear damage as other areas. In several cases further information is being sought, both on the corals and the fishing occurring in the area. In other cases it is felt important that a specific quantifiable link be made between trawling effort and degree of damage to a reef. SGCOR does not consider that this latter approach is possible or sensible. Information on past fishing effort has invariably been gathered (or is only available) on a relatively coarse and imprecise scale, or is not guaranteed complete. Attempting to compare current reef damage with past effort in the area of that reef will prove very imprecise and unlikely to be quantitative. The alternative of conducting trawling experiments over currently undamaged reef seems not sensible and counter-productive.

SGCOR concurs with past advice from ACE in that the only way to protect cold-water coral reefs from fishing damage is to map the reefs precisely and to close those areas to those forms of fishing that cause damage. In several cases, it now appears that all that remains to be done is for individual countries or fishing authorities to decide to protect reefs in their waters. SGCOR was pleased to note the action of the European Union in closing trawl fishing on the Darwin Mounds.

We consider that the need to continue work in ICES on cold-water corals should continue, and therefore recommend that the Group be reformed as a Working group at the 91st Statutory Meeting. We also recommend that ICES should consider expanding its remit to encompass other cold/deep water habitats that are fragile and sensitive to fishing activities.

We therefore suggest that the Study Group on Cold-Water Corals (SGCOR) should be replaced by the Working Group on Cold-Water Corals that should meet formally (at ICES Headquarters) and be given the following terms of reference:

a) review new information on the occurrence of and threats to cold-water corals in the North Atlantic, including consideration of large slow-growing octocorals;
b) review the sensitivity of other deep-water habitats in the North Atlantic to fishing activities, and where possible describe their occurrence;
c) invite comment on a draft of its report from relevant ICES Expert Groups in order to enable the provision of any further advice to the European Commission.

These Terms of Reference continue to be based on a standing request for advice sent by the European Commission asking ICES "to identify areas where cold-water corals may be affected by fishing." There is strong evidence of recent, permanent damage to cold-water coral features in the ICES area. Scientific advice is required to inform possible management measures to avoid further damage. SGCOR has considered the distribution and occurrence of *Lophelia pertusa* and other colony-forming Scleractinia so far. These are not the only habitats at risk from fishing activities in the Northeast Atlantic and a review of these other habitats and their occurrence would help in providing integrated ecosystem advice to fisheries managers.

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ANNEX 2: Corrections to 2003 report

Erratum Ref 2003 SGCOR REPORT ICES CM 2003/ACE:02

The Irish Coral Taskforce (ICFT) wishes to clarify its position in relation to the Summary and paragraph 4.3 of the ICES SGCOR 2003 Report. The statement that the ICTF has identified four areas as suitable for protection is not correct. The Irish CTF is at the beginning of a process of scientific assessment and advice re: possible sites for the conservation of cold water corals. The ICTF has not identified or formally agreed or indeed recommended to the relevant national authority, any particular areas for protection. The four areas indicated in the above report are areas of research activity, which have been surveyed and have been brought to the attention of the ICTF.

ANNEX 3: copy of clarification letter sent to French fishermen in relation to an enquiry on the Darwin Mounds

The following letter was sent to French fishermen in response to a technical query in relation to ICES advice on the Darwin mounds that was based on the 2003 SGCOR report. It was drafted by the chair of SGCOR and sent under the name of the current ACE chair.

"Thank you for your e-mail. This is a response to your question: "*Are there mounds somewhere else that there where black crosses are indicated (We can only notice that the 'black crosses' are little numerous in the larger area, and even sometimes totally absent)? Nothing seems to prove it in the scientific papers.*"

First, we should explain how the survey of the Darwin Mounds was carried out. It was undertaken by one of the UK's leading oceanographic research institutes, the Southampton Oceanographic Centre (SOC) from a ship called the *Charles Darwin*, using acoustic returns in a system called side-scan sonar. The survey was funded by a consortium of the oil industry and the UK government (AFEN) to find out what was in an area that it was considering exploring. This system is like all other acoustic systems, not precise or perfect, and the data from these require some interpretation. This applies equally to "fish-finder" sonars used by fishermen. The skilled fisherman is the one that is best at interpreting the information from the instrument. The sonar system used would only have reliably detected mounds that were more than 50 m in diameter; mounds less than this size might show up as slight marks in the sonar record. In order to check the interpretation of the echo-sounder traces, a seabed camera system was launched that took the photographs that are shown in the ICES report.

The data and images from this survey were analysed and reported initially to AFEN in a CD report "Atlantic Margin Environmental Survey of the Sea Floor", which is freely available to anyone who requests it (contact: Jennifer Stewart, UKOOA, 9 Albyn Terrace, Aberdeen AB10 1YP, UK). The results are also available through the AFEN website (www.ukooa.co.uk/issues/afen). After this report was submitted, Dr Masson of SOC set out to publish the results in the scientific literature and the paper in the journal "Marine Geology" is the result.

There are differences between the map in the AFEN report and the map in Marine Geology. This is because the analysis for AFEN showed everything that might be a mound, in other words included some of the slight marks that might be smaller mounds, while the Marine Geology report showed everything that was definitely a mound larger than 50 m in diameter. The difference was caused purely by the difficulties of interpreting side-scan sonar records precisely (similar to some problems also experienced by fishermen when looking for fish).

The outline area shown in the ICES advice to the European Commission is based on the data from the AFEN report as ICES felt that it was best to be safe (cautious) in interpreting information rather than to rely on absolute certainty for large mounds. Thus, to answer your question directly: we cannot be certain whether or not there are definitely mounds not marked by crosses in the Masson *et al*. paper in Marine Geology, but we consider that there is a reasonable chance that such mounds are present, and have advised appropriately.

Just for completeness, it is also likely that there are mounds outside the survey area that were not detected."