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Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC)

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ICES ADVISORY COMMITTEE

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Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC)

22–26 March 2010

Copenhagen, Denmark

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

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Executive summary

Chapter 1 lists the Terms of Reference that the WGDEC attempted to address in 2010. As is usually the case, the ToRs represent a great intellectual as well as time challenge to WGDEC members. As indicated in Chapter 2, the start of the WGDEC meeting saw members accepting leadership and supporting roles in addressing particular ToRs. It has been mentioned that several of the ToRs are not always clear of exactly what is being asked for and what deliverable is expected. In future, WGDEC needs to do a better job in asking clarifying questions well before the start of the annual gathering. Chapter 3 saw an ongoing effort to update maps of the North Atlantic. New information has been obtained for the Northwest Atlantic (e.g. Canada and the USA) in particular for corals and sponges in Hudson Strait, the Gulf of St Lawrence and the Newfoundland-Labrador Shelves/Slopes, Canada, and for Hatton Bank, Beothuk Knoll and the NAFO Regulatory Area, and for Rockall Bank and the Hebridean slopes and the Cantabrian Sea. Data collection is ongoing and it is expected that more updates will be available for 2011. These data will form the basis of an ICES-WGDEC coral and deep-water sponge ARCGIS database that will be developed over the next year. The importance of individual sponges as microhabitat for invertebrate species has been widely demonstrated and includes a wide range of ecological interaction including both facultative and obligate commensalisms. The general co-occurrence of temperate sponge grounds with demersal fish assemblages has been less well documented. In response to this request, in Chapter 4 Kenchington *et al.* (2010) examined the association of 34 demersal fish taxa with *Geodia*-dominated sponge grounds using data collected from 104 research vessel survey trawls of 500 to 1500 m depth along the continental slopes of the Grand Banks and Flemish Cap. In December 2006, the United Nations General Assembly ("UNGA") adopted Resolution 61/105 which, in its Paragraphs 76 to 95, calls on member states and Regional Fisheries Management Organization to take steps to protect vulnerable marine ecosystems in the high seas from the adverse impacts of fisheries. Many of the ecosystems supported by cold-water corals, sponges and other communities have been highlighted as Vulnerable Marine Ecosystems (VME) that are susceptible to Significant Adverse Impacts (SAI). In Chapter 5, WGDEC attempted to review the science used in assessing VME's and the "Encounter Clause". This chapter proved to be the most challenging and controversial for several WGDEC members. While the science currently used for threshold weights indicating the possible location of a VME and the encounter clause and move on rule was reviewed by WGDEC, parts of the earlier drafts also took on a verdict on evils of bottom-trawling mentality. While the damage to VME's caused by bottom trawling was reviewed and discussed, an opinion on the good or evil of bottom fishing methods was not asked for in the ToR. Chapter 6 concluded that it is currently impossible to give precise estimates for total amounts and percentage of VMEs impacted by human activity because the data on coral and sponge distribution is highly patchy and far from complete. Recent advances in predictive habitat modelling may allow comparisons of potential habitat with current distribution to assist in addressing this problem, but the output from such models is not yet available to WGDEC. Consequently there is no direct means of quantifying the impact of human activities on the VMEs over the past decade. It is, however, possible to assess the likelihood that VMEs have been impacted from information on patterns in fishing activity in areas where VME's are known to be present. Lack of knowledge limits the possibilities for assessing the recovery potential of damaged cold-water coral and sponge habitats. The recovery rate of these biotic habitats depends mainly on the rate of colonization and growth. There is a great variation in these factors between species. Growth rates for deep-water sponges are poorly known. Chapter 7 observed that the data collected under the observer programme

needs to address the mentioned criteria and such data should contribute to the impact assessments for the likelihood of significant adverse impacts in a given area. As there is little information on describing sponge species occurring at depths greater than 1500 m, Chapter 8 simply suggested that this be a continuing ToR when such data are received and can be reviewed and discussed. Chapter 9 was not fully addressed as it was felt that it would be best and more thoroughly addressed at a later date. Chapter 10 discussed ocean acidification, a rising global scientific priority. Over the last century, anthropogenic carbon dioxide (CO_2) from the burning of fossil fuels has greatly increased. As anthropogenic CO_2 is absorbed by seawater, the concentration of carbonate ions has increased as well, resulting in a decreased pH of seawater. This 'ocean acidification' (OA) has become an emerging scientific issue that has become a priority among many of the world's nations. This issue has emerged as a scientific priority because of the potential negative effect that it may have on marine ecosystems and the many economic and non-economic services they provide. In order to monitor natural fluctuations and anthropogenic changes in carbonate chemistry and assess the biological response to such changes, a robust ocean acidification observation network must be constructed by enhancing the monitoring capabilities of existing systems, increasing the temporal and spatial coverage of time-series measurements, and continuing current sampling efforts but expanding these efforts to open-ocean and coastal regions. Chapter 11 was not fully addressed as it was felt that it would be best and more thoroughly addressed at a later date. In 2008, ICES recommended to OSPAR and NEAFC that they work together and coordinate the respective protected areas in order to reduce confusion among stakeholders and a better chance of coherent management of human activities in these areas. This approach is still recommended and was discussed in detail in Chapter 12.

1 Opening of the meeting

WGDEC members began discussions at 1300 on March 22, 2010, at ICES Headquarters in Copenhagen, Denmark. Deliberations primarily focused on what was being asked of it by OSPAR, NEAFC, and ICES. It is very important to clearly understand what is being asked before one proceeds with addressing the question. A considerable amount of discussion also focused on data issues such as whether new data can be sent throughout the year to the ICES Data Centre that would later be available for WGDEC analyses. Currently, data are requested (usually via e-mail) as needed during the week and this was deemed to be ineffective due to severe time constraints. Introduction of WGDEC members, assignments of Terms of Reference, and formation of breakout groups were completed.

2 Adoption of the Agenda

2009/2/ACOM26 The **ICES-NAFO Working Group on Deepwater Ecology** [WGDEC] (Chaired by: Robert J. Brock, USA) will meet at ICES Headquarters in Copenhagen, Denmark, 22–26 March to:

a) Continue to update cold-water coral and sponge maps;

b) Assess the association of fish species with sponge grounds using trawl survey data where available;

c) Review the science used in assessing vulnerable marine ecosystems and the "Encounter Clause" and;

d) Monitoring methodologies for ocean acidification (OSPAR request 2010/2);

- i) Provide, on the basis of a review of existing methodologies and experience, recommendations for cost efficient methods for monitoring ocean acidification (OA) and its impacts, including possibilities for integrated chemical and biological monitoring. Specifically this should provide:
- ii) advice on appropriate spatial and temporal coverage for monitoring, considering different oceanographic features and conditions and key habitats/ecosystems at risk from OA in the OSPAR maritime area;
- iii) advice on the status and maturity of potential indicators of OA impacts, on species, habitats and ecosystems that could be considered for inclusion in OSPAR monitoring programmes.

e) Impacts of human activities on cold water corals and sponge aggregations (OSPAR request 2010/5);

- i) Provide advice on impacts of human activities on cold water corals and deep-sea sponge aggregations including:
- ii) total amounts and % of these habitats affected by human activity over the past decade, on a year by year basis, in the OSPAR Maritime Area;
- iii) specific sites within the Northeast Atlantic where records show that more than 100kg of live coral of 1000 kg of live sponges have been have been trawled as a result of human activities in the past;
- iv) what is known about the status of coral reefs and sponge aggregations in these areas
- v) recovery rates of these species if and when damaged or removed;
- vi) possibilities for re-creation of these habitats

f) Comment and make proposals for improvements on draft of a Best Practice Manual for scientific surveys in areas closed to fishing (NEAFC Request);

g) Summarize the environmental factors influencing sponge distribution in the North Atlantic based on the distribution of sponge *taxa*;

h) Provide a description of sponge species occurring at depths greater than 1500 m.

Material and data relevant to the meeting must be available to the group no later than 14 days prior to the starting date.

WGDEC will report by 9 April 2010 to the attention of ACOM.

OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

Meeting of the Environmental Assessment and Monitoring Committee (ASMO).

Bonn: 20–24 April 2009.

A. Scientific Advice

Monitoring methodologies for ocean acidification

To provide, on the basis of a review of existing methodologies and experience, recommendations for cost efficient methods for monitoring ocean acidification (OA) and its impacts, including possibilities for integrated chemical and biological monitoring. Specifically this should provide:

a) advice on appropriate parameters, protocols and quality assurance for monitoring changes in pH and inorganic carbon chemistry in the OSPAR maritime area and other ancillary parameters that should be included in monitoring programmes;

b) advice on the status of current knowledge of spatial and temporal variability of pH and inorganic carbon chemistry in the OSPAR maritime area;

c) advice on appropriate spatial and temporal coverage for monitoring, considering different oceanographic features and conditions and key habitats/ecosystems at risk from OA in the OSPAR maritime area;

d) advice on the status and maturity of potential indicators of OA impacts, on species, habitats and ecosystems that could be considered for inclusion in OSPAR monitoring programmes.

Note: WGDEC has been asked to address c–d.

Impacts of human activities on cold water corals and sponge aggregations

To provide advice on impacts of human activities on cold water corals and deep-sea sponge aggregations including:

a) total amounts and % of these habitats affected by human activity over the past decade, on a year by year basis, in the OSPAR Maritime Area;

b) specific sites within the North-East Atlantic where records demonstrate that more than 100 kg of live coral of 1000 kg of live sponges have been have been trawled as a result of human activities in the past;

c) what is known about the status of coral reefs and sponge aggregations in these areas;

d) recovery rates of these species if and when damaged or removed;

e) possibilities for re-creation of these habitats.

Note: NEAFC has informed that only VMS data are available.

NEAFC requests to WGDEC

Vulnerable deep-water habitats in the NEAFC Regulatory Area

NEAFC requests ICES to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats.

Regarding vulnerable habitats and deep-water species

a. *ICES is requested to provide advice on an experimental design/protocol appropriate for quantifying VME catch thresholds for the fishing gears used in the NEAFC Regulatory Area. It is suggested that the design should take account of:*

1. Differences in the retention efficiency between fishing gears (e.g. bottom trawls, longlines, gillnets and traps) for the VME indicator species (annex1; Guidelines for the management of deep-sea fisheries in the high seas; FAO report N^{o}881, 2009) found in the NEAFC Regulatory

2. Catch threshold differences for a range of seabed features supporting VMEs (e.g. seamounts, mounds, banks, continental slope)

b. *Extending closures on the Mid-Atlantic Ridge Based on a proposal by the European Community to expand the current closed areas in the Mid-Atlantic ridge, ICES is requested to evaluate the proposal and provide advice whether the proposed extension will protect VMEs in the areas concerned against significant adverse impacts resulting from bottom fishing activities.*

3 Continue to update cold-water coral and sponge maps

The Joint ICES/NAFO Working Group on Deepwater Ecology presented information on the distribution of sponge grounds in the North Atlantic (ICES 2009) and called for information from two areas where data were sparse: The coasts of Greenland and the northeast USA. New information has been obtained for both of these areas as well as for corals and sponges in Hudson Strait, the Gulf of St Lawrence and the Newfoundland-Labrador Shelves/Slopes, Canada, and for Hatton Bank, Beothuk Knoll and the NAFO Regulatory Area, and for Rockall Bank and the Hebridean slopes and the Cantabrian Sea. Data collection is ongoing and it is expected that more updates will be available for 2011.

Greenlandic Waters

At the June 2009 meeting of the NAFO Scientific Council, Dr Manfred Stein offered to take a benthic taxonomist on the 2009 German survey of Greenlandic cod and redfish stocks with the purpose of identifying benthic invertebrate taxa. Megan Best from the Department of Fisheries and Oceans, Dartmouth, Canada formed part of the scientific crew of the Walther Herwig III (mission WH-327). The survey took place off the coast of Greenland and along the continental slope, with maximum trawl depths of approximately 400 m. A total of 68 tows was completed using a 140-foot trawlnet in standard configuration (Polyvalent boards, 1500 kg, 4.5 m²). Out of these, 64 tows yielded data collected for the purpose of identifying and analysing benthic invertebrate composition, with an emphasis placed on sponges (*Phylum Porifera*), and corals (*Phylum Cnidaria*, Class *Anthozoa* and Class *Hydrozoa*, Family *Stylasteridae*) as particularly vulnerable components of benthic ecosystems.

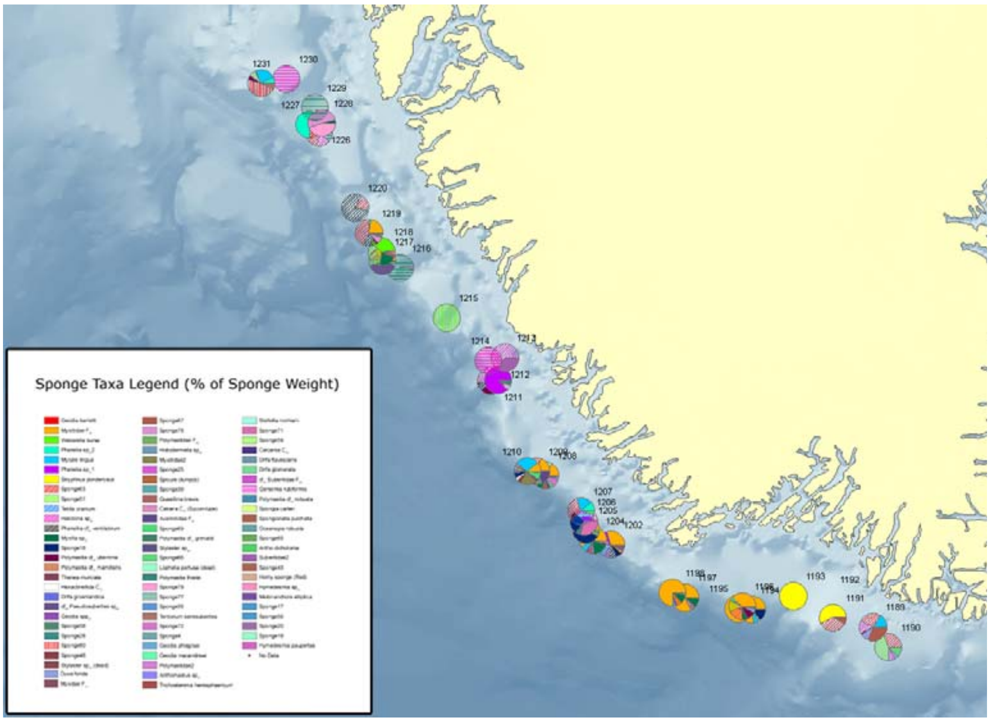

Figure 1. Relative proportions of sponge taxa by weight from research vessel survey trawls along the west coast of Greenland. Numbers refer to tow stations.

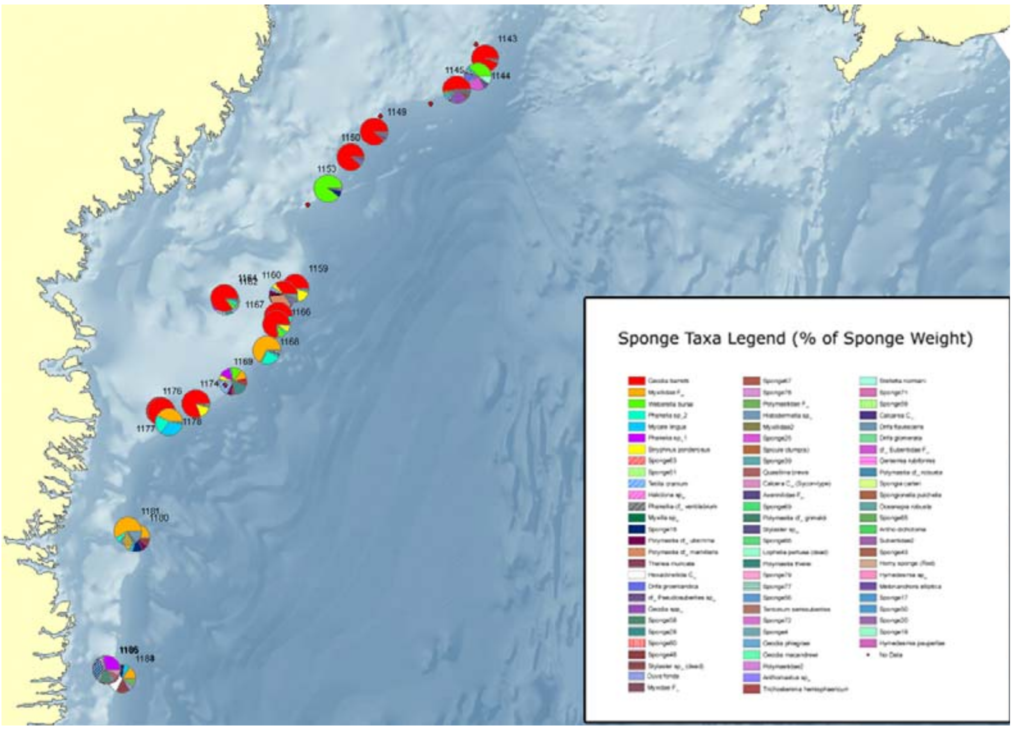

Figure 2. Relative proportions of sponge taxa from research vessel survey trawls along the east coast of Greenland. Note the presence of *Geodia barretti* (red) not seen on the west coast of Greenland (Figure 1). Numbers refer to tow stations.

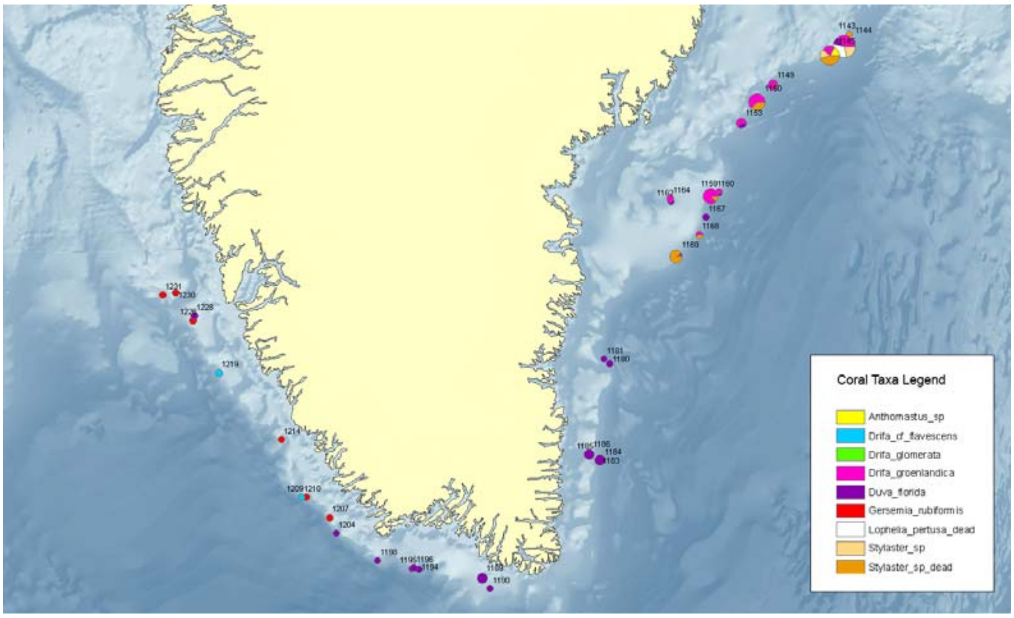

Figure 3. Relative proportions of coral and hydrocoral taxa from research vessel survey trawls along the east and west coasts of Greenland. The sizes of the circles are proportional to the weight of the coral bycatch. Numbers refer to tow stations.

Preliminary analyses of the data demonstrate 74 sponge species and nine coral/hydrocoral taxa. The most commonly encountered sponge was *Tetilla cranium* (N=38 tows), while the largest biomass was produced by the large ball sponge *Geodia barretti*. The soft coral *Duva florida* was the most frequently encountered of the coral/hydrocoral taxa (N=23), while the greatest biomass was collected from another soft coral, *Drifa groenlandica*. One tow (Station 1144) yielded specimens of the reef-forming cold-water coral *Lophelia pertusa*. Preliminary results of the coral/hydrocoral and sponge species composition of the catches (Figures 1–3) indicate differences between the east and west coasts of Greenland in species composition. Further, the sponge composition on the west coast of Greenland (Figure 1) is very different from that on east coast of Baffin Island, Canada which is dominated by *Geodia* spp. (ICES 2009).

Hudson Strait, Canada

Sponges

Research vessel data of sponge bycatch from the Hudson Strait and Ungava Bay area of Canada has been collated (Kenchington *et al*., 2010). In 2007 and 2009 the Canadian Department of Fisheries and Oceans (DFO) conducted shrimp surveys using a Cosmos shrimp trawl in this area, which is known as Shrimp Fishing Area 3 (SFA 3) (see DFO 2008). Tow distance was approximately 1 km. Two species of shrimp, northern shrimp (*Pandalus borealis*) and striped shrimp (*P. montagui*), occur in SFA3, although striped shrimp is the dominant species (DFO 2008). The sponges are distributed throughout the surveyed area and occurred over the entire depth range of the SFA 3 survey from 108 to 968 m (Figure 4). Within this distribution there are relatively larger catches, particularly in Ungava Bay. Sponges were not identified to species but have been described as *Geodia*-like sponges and large branched sponges (cf. Kenchington *et al*., 2010).

Coral

Research vessel data of coral bycatch from the Hudson Strait and Ungava Bay were available for 2007 and 2009 when DFO conducted shrimp surveys using a Cosmos shrimp trawl in this area (see above). The coral are distributed throughout the surveyed area over the entire depth range sampled (99 to 966 m; Figure 5). However the largest catches are in Ungava Bay with one large catch at the opening of Hudson Strait south of Nottingham Island (Figure 5). With one exception, the coral collected during the research vessel surveys are all soft corals of the family *Nephtheidae*. The one exception was a catch which included the sea pen, *Anthoptilum grandiflorum.*

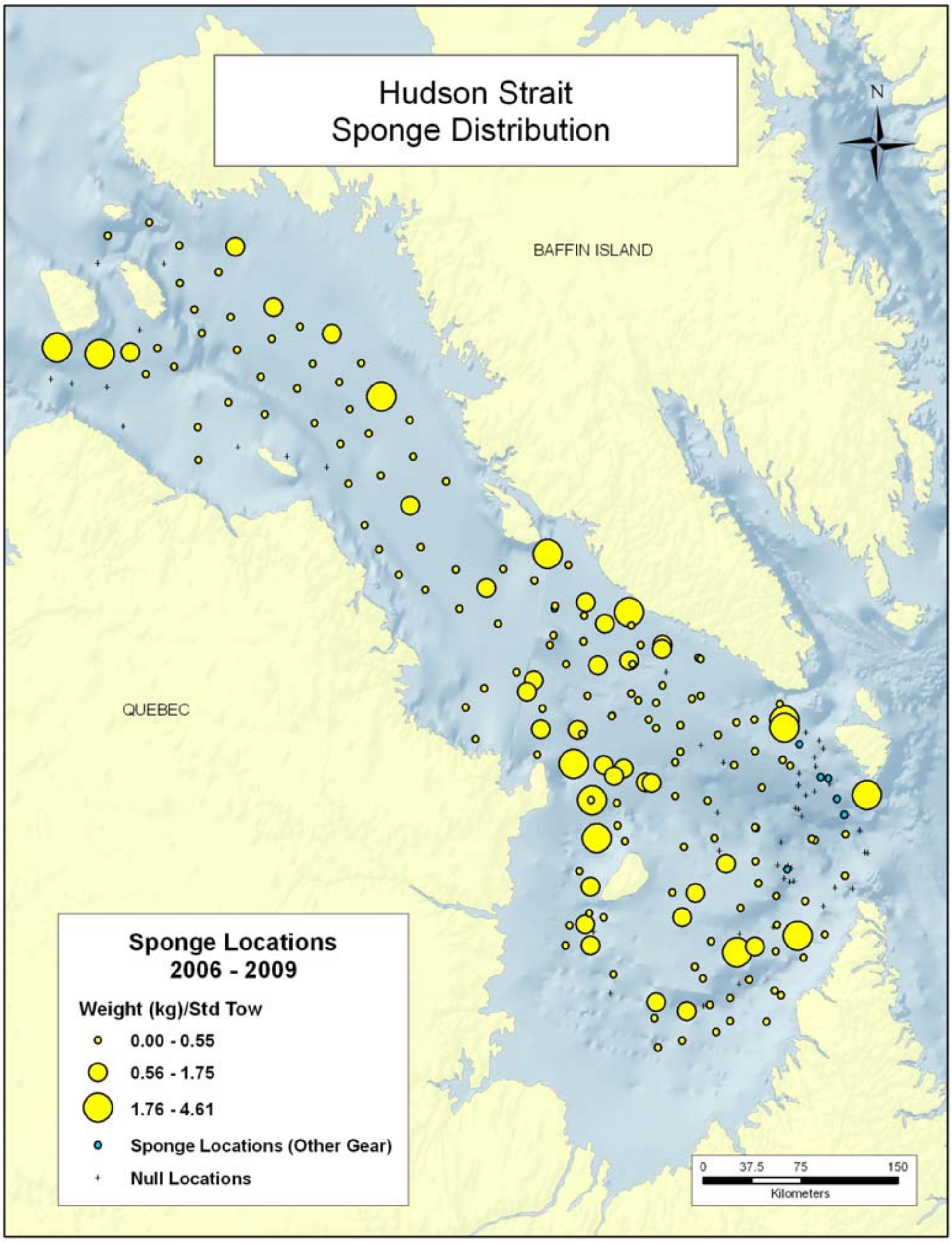

Figure 4. Distribution of sponge bycatch from research vessel surveys using Cosmos shrimp trawls in Hudson Strait.

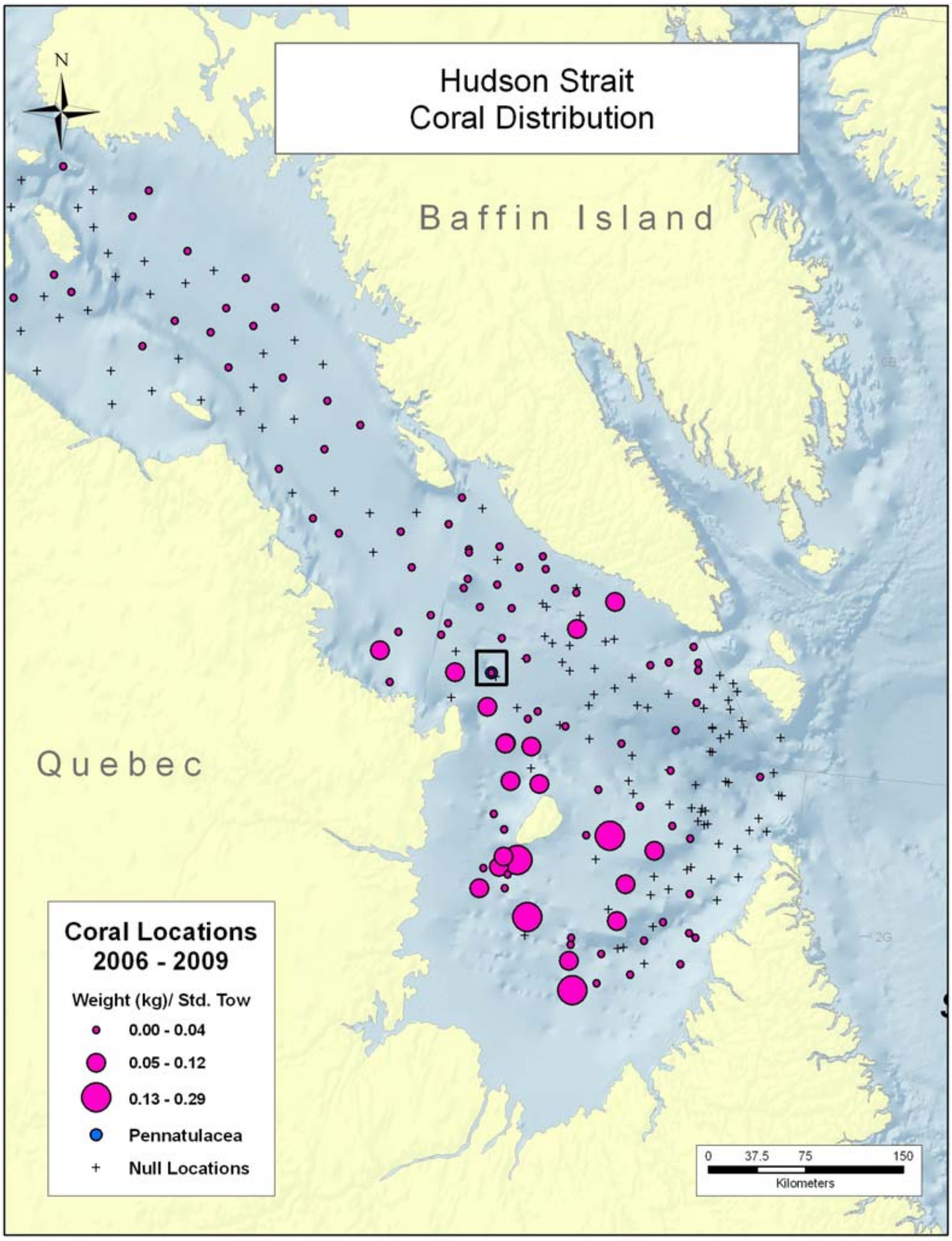

Figure 5. Distribution of *Nephtheidae* coral bycatch from research vessel surveys using Cosmos shrimp trawls in Hudson Strait. The single catch of the sea pen *Anthoptilum grandiflorum* is indicated by the box.

Gulf of St Lawrence, Canada

Sponges

The data available for analysis of sponges in the Gulf of St Lawrence covers 19 years and is dominated by records from the southern Gulf of St Lawrence (Kenchington *et al*., 2010). There were 1834 records with sponges and 3120 records of catches with no sponge from the same surveys. The trawl gear used was primarily the Western IIA in the southern Gulf and the Campelen trawl in the northern Gulf after 2004. In general, the surveyed area includes the NAFO Divisions 4RS, Subdivision 3Pn as well as strata deeper than 183 m (100 fathoms) in Division 4T, including the Lower St Lawrence Estuary (see Kulka *et al.*, 2006). Data on sponges from these surveys was sparse prior to 2006 when a greater emphasis was placed on reporting invertebrate bycatch to facilitate ecosystem studies. Due to differences in gear type only the presence and absence of sponge are provided here.

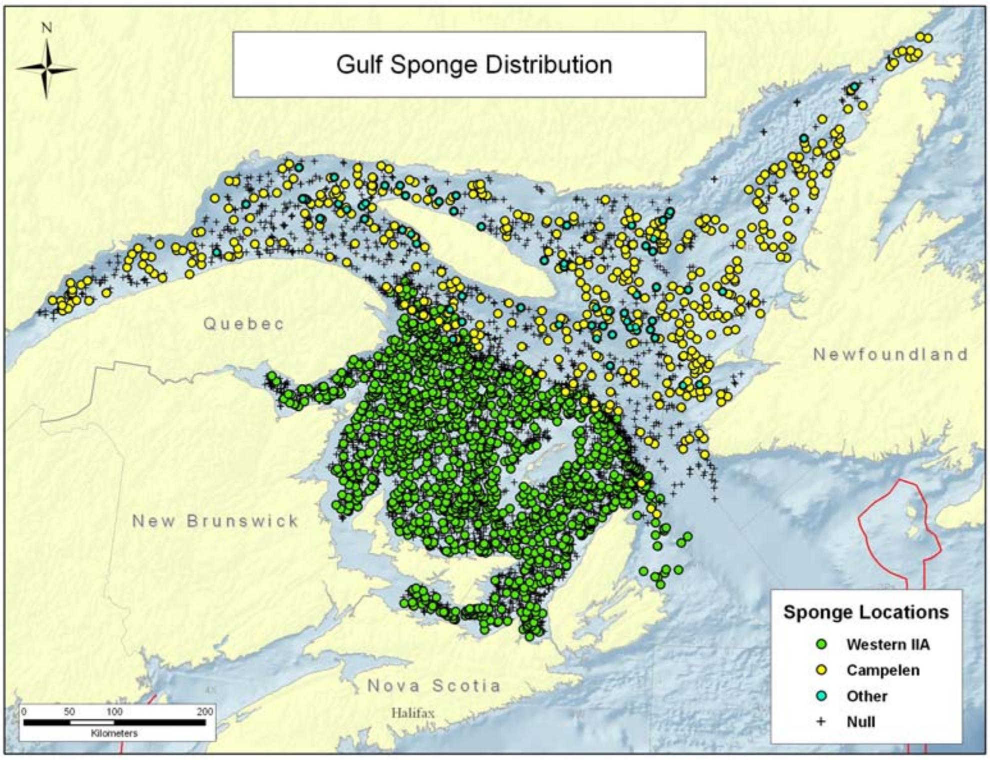

Figure 6. Distribution of sponge bycatch from research vessel surveys using Western IIA and Campelen trawls in the Gulf of St Lawrence.

Fuller, in prep. provided a list of 34 species recorded from the Gulf of St Lawrence combining data collected by herself and those published in Lambe, 1896 and elsewhere. Species compositions of the sponge catches from the 2003 research vessel survey (TEM2003352) of the southern Gulf of St Lawrence have been determined. Table 1 lists the species identified from that survey by Susanna Fuller, Dalhousie University, in prep. Taxonomic classification, species names, authorities and ordering follows that of Hooper and Van Soest, 2002 and have been altered from the Fuller, in prep. manuscript as appropriate. Species names and authorities have changed considerably since the publication of Lambe, 1896. Families and genera are alphabetically listed. All 21 taxa belong to the Class *Demospongiae* (see Kenchington *et al.*, 2010 for more details). Only three species were identified by ICES 2009 as being large structure-forming taxa (Table 1).

Coral

The data available for analysis of coral in the Gulf Biogeographic Zone covers 19 years and is dominated by records from the southern Gulf of St Lawrence (Figure 7). There are 1556 records with corals and 2126 null records from the same surveys that did not report corals. The trawl gear used was predominately the Western IIA in the southern Gulf and the Campelen trawl in the northern Gulf after 2004 (see Kenchington *et al.*, 2010). Eighteen coral taxa are represented in the database. These taxa are not mutually exclusive with some only identified to Class, Order or Genus. Fifty per cent of the records are of soft coral (*Alcyonacea*). Sea pens (Order *Pennatulacea*) comprise 47% of the records. Most of the sea pens are of the genus *Pennatula*, which are known to produce sea pen fields (Cogswell *et al*., 2009). These are distributed along the Laurentian Channel where catches of 193 kg/km have been reported with Western IIA gear (Kenchington *et al*., 2010), and in the northern Gulf. The other corals indicated in Figure 7 are largely soft corals, and *Gersemia rubiformis* is widely distributed, especially in the southern Gulf.

Table 1. Sponge Taxa Identified by Fuller, in prep. from the 2003 Research Vessel Surveys of the Southern Gulf of St Lawrence Using a Western IIA trawl (from Kenchington *et al.*, 2010).**

ORDER	FAMILY	TAXON	TYPICAL MORPHOLOGY
Hadromerida	*Polymastiidae*	*Polymastia robusta* (Bowerbank, 1861)	Cushion, 5 cm h
		Polymastia mamillaris (Mueller, 1806)*†	Enrusting, 30 cm d, 11 cm h
		Polymastia infrapilosa Topsent, 1927	Cushion, 5cm d, 2 cm h
		Trachyteleia hispida (Bowerbank, 1864) (taxon updated from *Polymastia hispida* reported by Fuller, in prep.)	Cushion, 4 cm d, 2.5 cm h
		Tentorium semisuberites (Schmidt, 1870)	Globular, 2.5 cm d, 3 cm h
		Weberella bursa (Muller, 1806)	Globular, 2-10 cm d
	Suberitidae	*Suberites ficus* (Esper, 1794)*	Massive, Lobed, 20 cm d
		Suberites hispidus (Bowerbank, 1864)	
		Suberitidae undetermined	
Poecilosclerida	*Acarnidae*	*Iophon* sp.	Encrusting
	Mycalidae	*Mycale lingua* (Bowerbank, 1866)* †	Massive, 30 cm h
		Mycale sp.	
		Mycalidae undetermined	
	Desmacellidae	*Biemna* cf. variantia (Bowerbank, 1866)	Encrusting, Cushion, 5+ cm h
Halichondrida	*Halichondriidae*	*Halichondria* (*Halichondria*) *panicea* (Pallas, 1766) *	Massive, Branching, 20+ cm h
		Halichondria (*Halichondria*) *bowerbankii* Burton, 1930	Branching, Massive, 25 cm h
		Halichondria (*Halichondria*) *colossea* (Lundbeck 1902)	Massive
		Halichondria (*Eumastia*) *sitiens* Schmidt, 1870	Cushion, 2-3 cm h
		Halichondria sp.	
	Axinellidae	*Phakellia ventilabrum* Linnaeus, 1767* †	Funnel, 20 cm h
Haplosclerida	*Chalinidae*	*Haliclona* (*Haliclona*) *oculata* (Pallas, 1766)*	Branching, 30+ cm h
		Haliclona sp.	

****All taxa belong to the Class Demospongiae. Typical morphologies and maximum dimensions (h=height, d=diameter) are extracted from Fuller, in prep. * Indicates common species reaching 20–30 cm height or diameter. † Indicates taxa identified by ICES 2009 as large, structure-forming sponges typical of sponge grounds in the North Atlantic.**

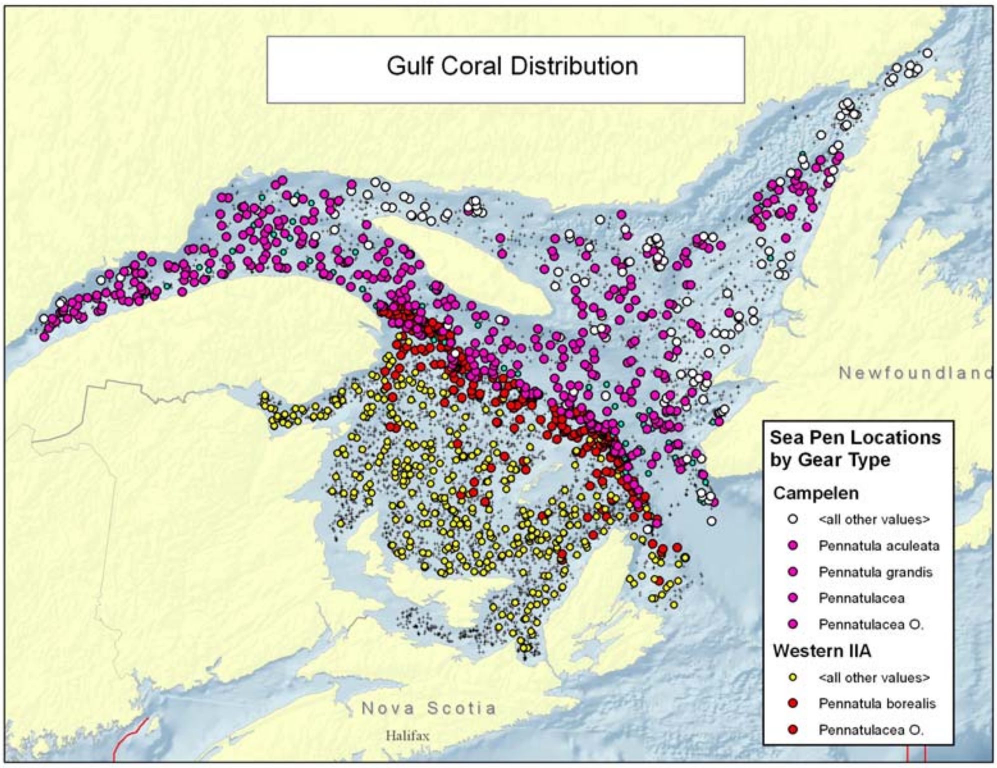

Figure 7. Distribution of pennatulid sea pen bycatch from research vessel surveys using Western IIA and Campelen trawls in the Gulf of St Lawrence.

Newfoundland-Labrador Shelves and Slopes, Canada

The distribution of sponges forming sponge grounds on the Newfoundland and Labrador slopes were previously mapped by ICES 2009, however the taxa were not identified to species and the large catches were assumed to be *Geodia barretti* or similar taxa. Sponges from the 2006 and 2008 surveys were collected and preliminary identifications were made by S.D. Fuller (Dalhousie University, Halifax, Nova Scotia, Canada). The location of sponge taxa which were present in more than nine of the 27 sets (24 from 2008) were plotted and confirm the presence of *Geodia barretti* along the slopes, along with the hexactinellid sponge *Asconema foliata* (Figure 8). The shelves are dominated by the large structure-forming species *Mycale lingua* (Figure 8) and a mixture of smaller sponges (Figure 9).

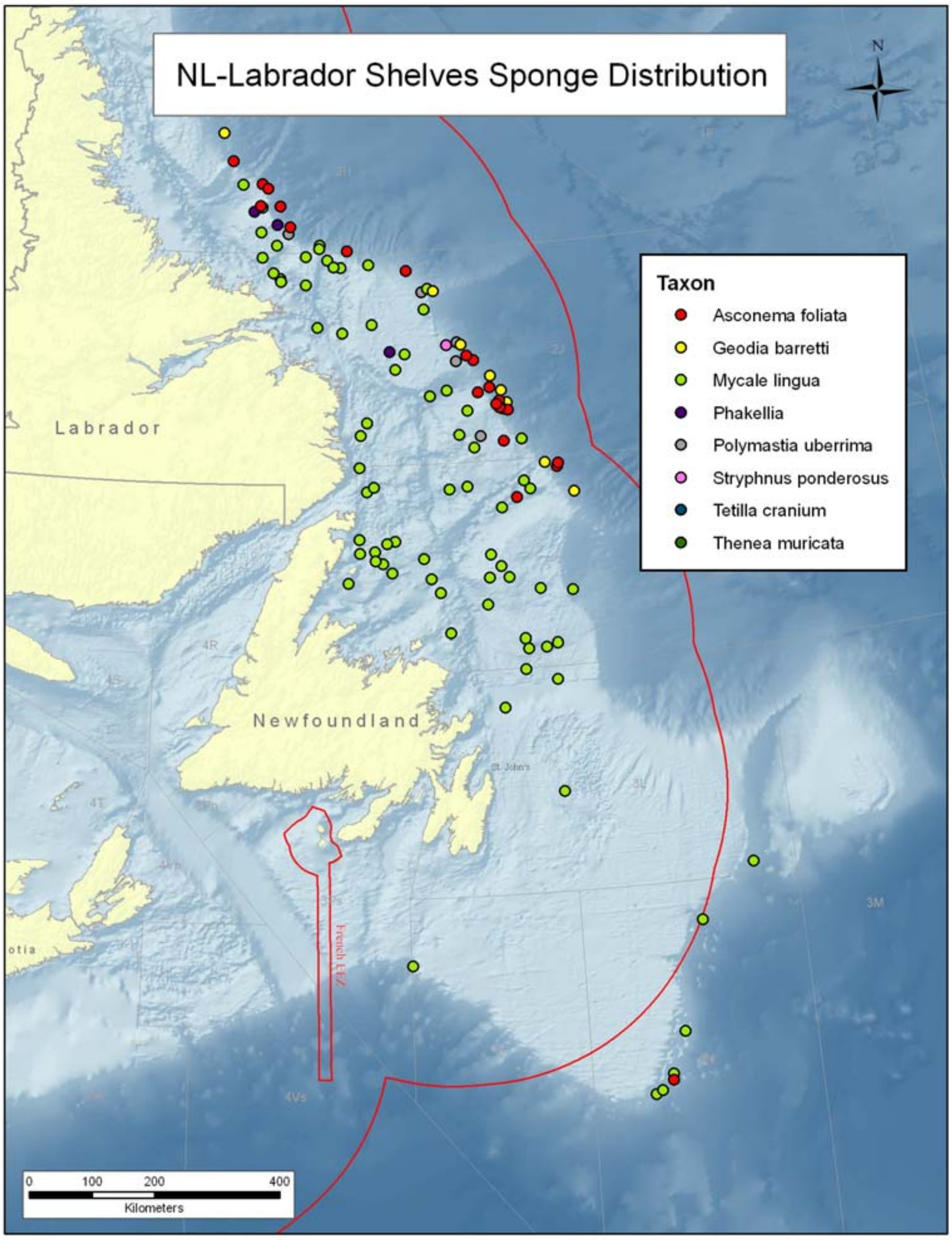

Figure 8. Distribution of structure-forming sponge (cf. ICES 2009) bycatch from 2008 research vessel surveys using Campelen trawls on the Newfoundland-Labrador shelves. Sponge taxa were identified by S.D. Fuller (Dalhousie University, Halifax, NS, Canada).

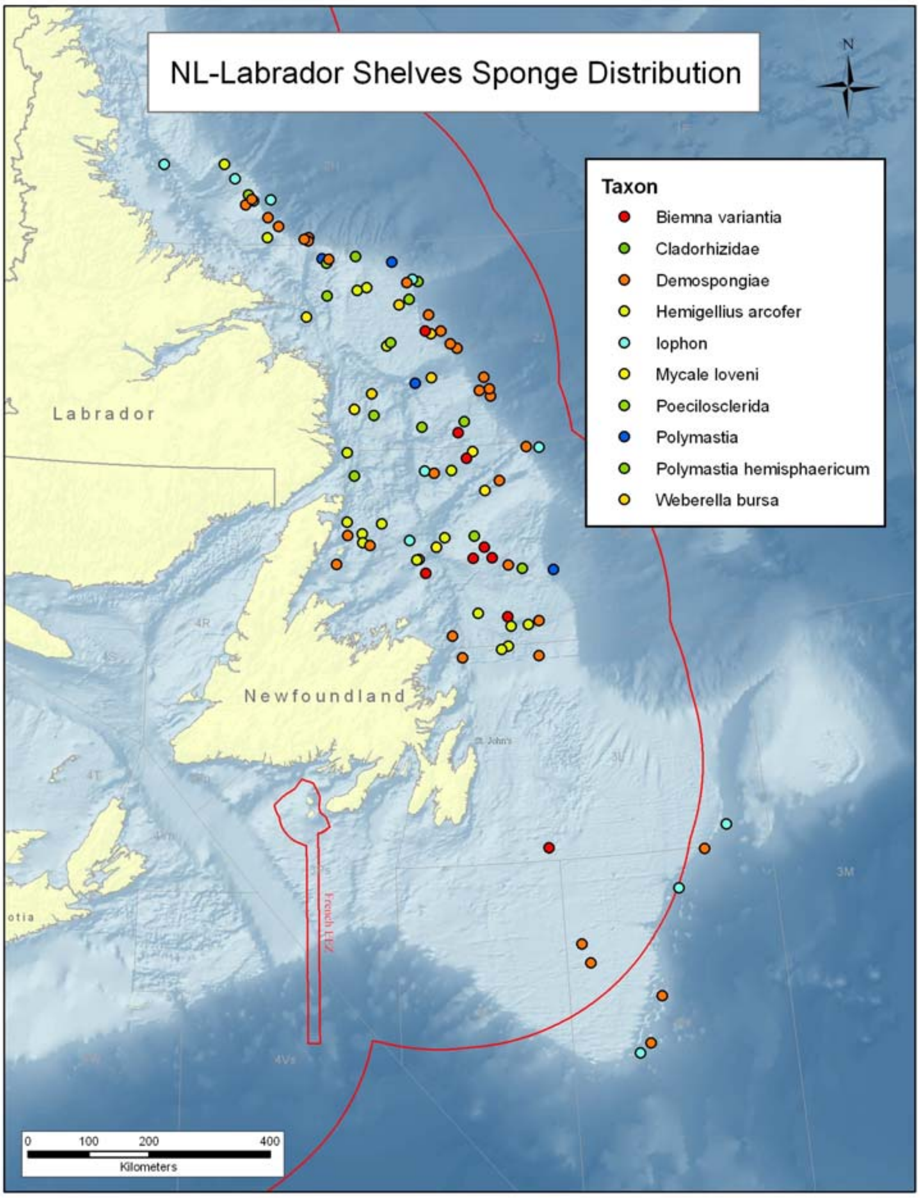

Figure 9. Distribution of sponge bycatch not identified as structure-forming in ICES 2009 from 2008 research vessel surveys using Campelen trawls on the Newfoundland-Labrador shelves. Sponge taxa were identified by S.D. Fuller (Dalhousie University, Halifax, NS, Canada).

Hatton Bank

Areas of Hatton Bank were surveyed in June and July of 2008 by the Royal Netherlands Institute for Sea Research, Texel, The Netherlands (NIOZ 2008). Fifty boxcore samples were analysed for macrofauna. Preliminary results demonstrate the locations of live coral from those samples (Figure 10).

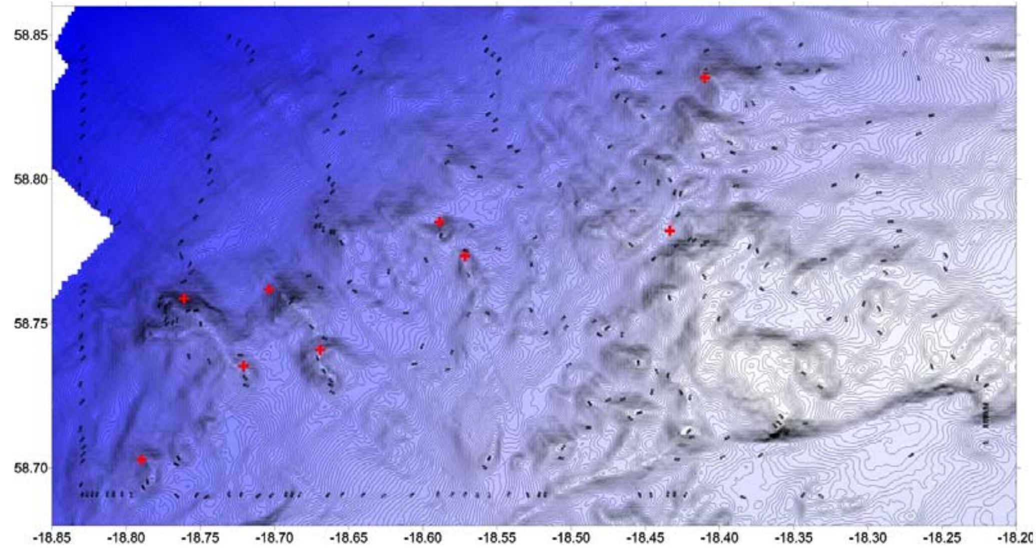

Figure 10. Locations of live coral from boxcorer samples on Hatton Bank (figure from NIOZ 2008).

New data on deep-sea communities and cold-water corals /sponges distribution were presented by Durán Muñoz *et al*., 2010, based on the results from a joint collaboration between the Spanish Institute of Oceanography (IEO) and a longliner, carried out on the Hatton Bank area, Northeast Atlantic, in summer 2008. The objective of the sampling scheme was to study the rocky outcrop of the banks. The study area was divided into eight sampling rectangles. At each station a set of two individual longlines was deployed using two different types of demersal longlines rigged with a similar number of hooks and at similar depths, by means of a manual longlining method. Hooks were baited with sardines. A total of 38 longlines (65 430 hooks) was prepared. Two scientific observers were on board the vessel. They recorded information for each station on: (i) location of the longline, the number of hooks, time and depth for setting and hauling, (ii) catch and discards, (ii) fish length and biological data, by paying special attention to (iii) bycatches of benthic invertebrates and (iv) data on seabirds. Any trash and gillnets found were also recorded by the crew.

For the study of invertebrate bycatch, specimens captured on hooks and/or entangled in different parts of the longlines were recorded. Moreover, invertebrate samples were photographed and some of them were preserved as "vouchers" for subsequent final identification at the IEO. The locations of the coral and sponge taxa captured in the longlines are indicated in Figures 11 to 14 and a list of all taxa identified is presented in Table 2.

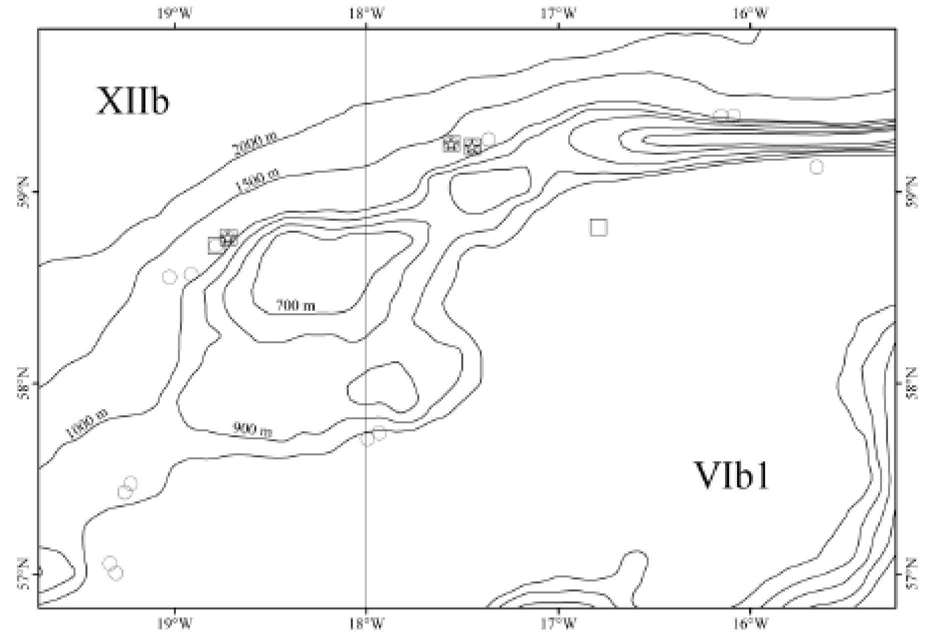

Figure 11. Location of records of lace corals, cup corals and soft corals in the Hatton Bank. Stars, lace corals (0.006–0.789 kg); circles, cup corals (0.005–0.28 kg); squares, soft corals (0.006–0.13 kg).

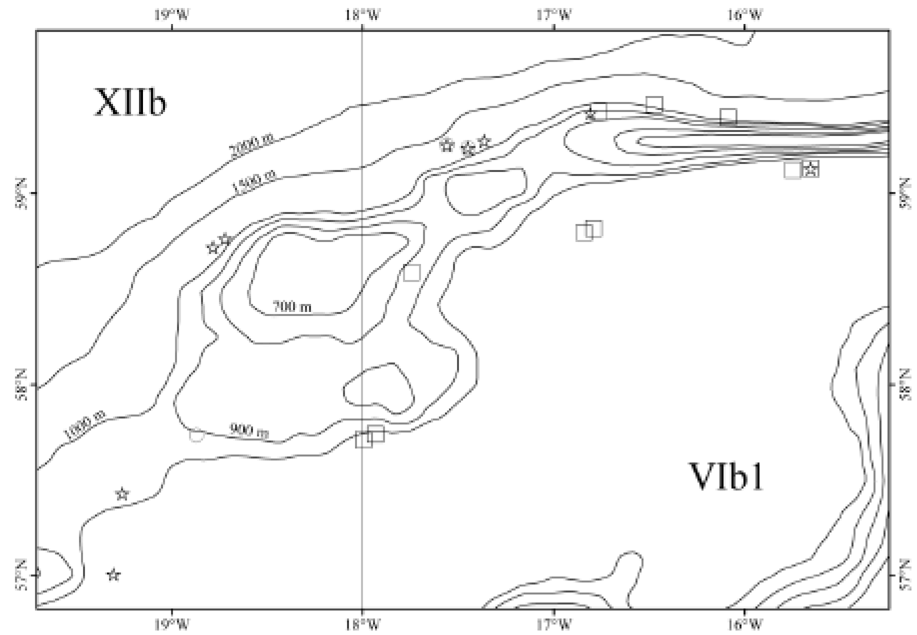

Figure 12. Location of records of seafans, black corals and seapens in the Hatton Bank. Stars, seafans (0.003–0.52 kg); circles, black corals (0.002–1.19 kg); squares, seapens (0.005–0.866 kg).

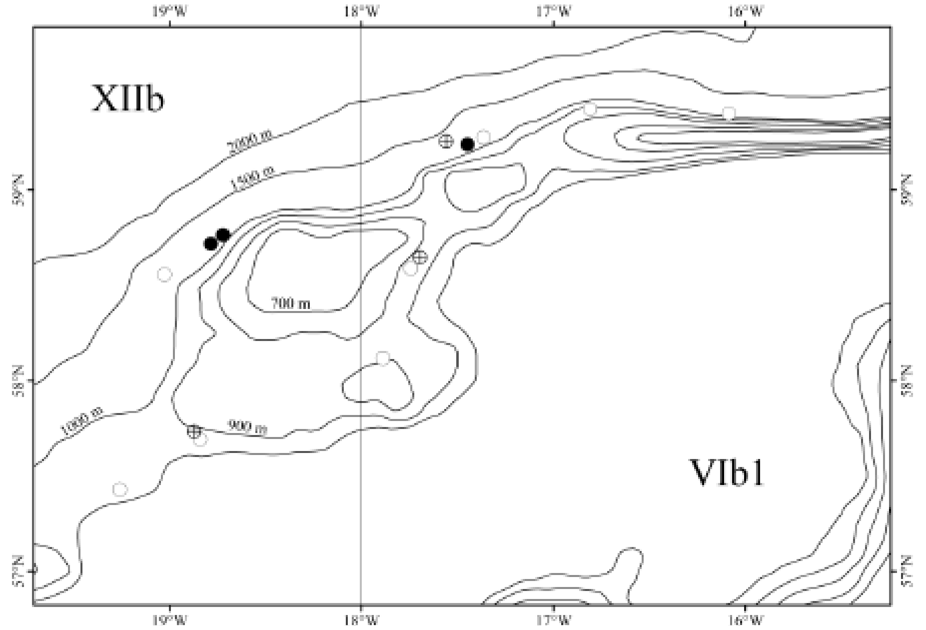

Figure 13. Location of records of colonial Scleractineans in the Hatton Bank. White circles, 0.025–2 kg; circle with cross, > 2–10 kg; black circles, > 10–50.9 kg.

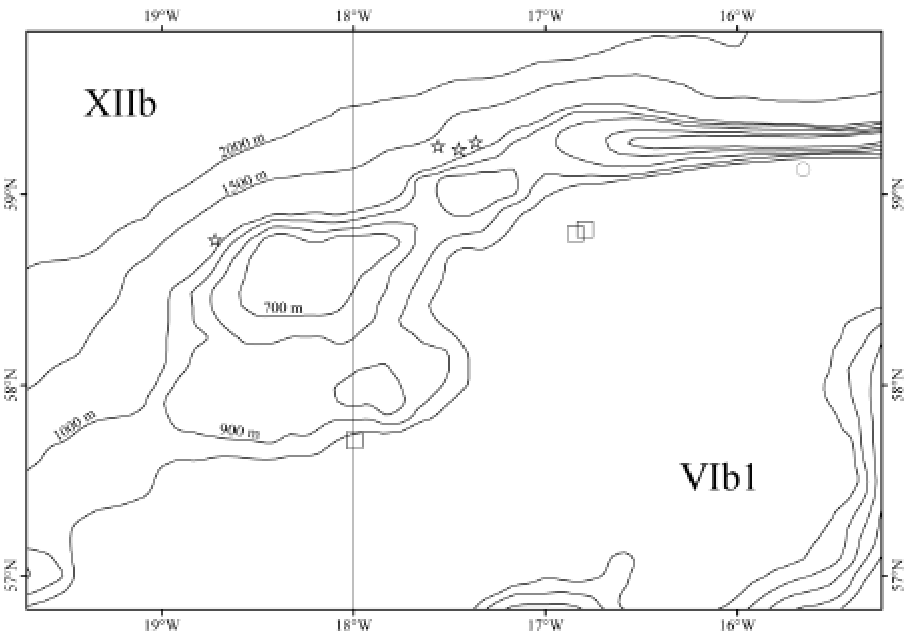

Figure 14. Location of records of sponges in the Hatton Bank. Squares, *Pheronema carpenteri* (0.15–0.7 kg); stars, *Aphrocalistes* sp/*Euplectella* sp (0.008–0.236 kg); circle, Porifera indet (1.038 kg).

Table 2. Vulnerable taxa recorded as part of the bycatch, when longlines were deployed in the outcrop of the western slope of the Hatton Bank. Central Area (CA), Ridges and Mounds Area (RMA), and Northwestern Area (NWA).

	Scientific name	CA	RMA	NWA
Porifera				
	Porifera indet	+	+	+
	Euplectella sp		+	
	Aphrocallistes sp	+	+	
Cnidaria				
	Alcyonacea indet	+		
	Acanthogorgia sp		+	
	Acanella sp	+		
	Isididae indet		+	
	Plexauridae indet	+	+	
	Callogorgia verticillata			+
	Primnoa resedaeformis	+		
	Pennatula sp			+
	Anthoptilum murrayi			+
	Halipteris sp			+
	Capnella florida	+	+	
	Nephtheidae indet		+	
	Leiopathes cf. expansa		+	
	Tylopathes sp		+	
	Thyssopathes sp		+	
	Phanopathes sp		+	
	Caryophyllia sp	+	+	+
	Desmophyllum sp	+	+	
	Lophelia pertusa	+	+	
	Madrepora oculata	+	+	+
	Solenosmilia variabilis			+
	Stephanocyathus moseleyanus	+	+	
	Stylasteridae indet	+	+	

Hudson Canyon and Adjacent Slope Waters, USA

The Hudson Canyon data were compiled by Vince Guida (NOAA, NMFS, NEFSC, New Jersey, USA) from bottom video and still photo images taken by Page Valentine (USGS) and himself using the USGS Seaboss drift vehicle aboard cruises in 2001, 2002, and 2004. During the 2002 and 2004 cruises specimens were also collected for close examination from the same sites with a 2 m beam trawl, giving confidence in the coral identifications. Data from the Hudson Canyon were provided by Dan Dorfman, Marine Conservation Planner, NOAA/NOS/NCCOS/CCMA/Biogeography Branch, Silver Spring, MD, USA. The locations of the solitary hard coral *Dasmosmilia lymani*, the white sea pen coral *Stylatula elegans*, and the zoonathids *Parzonathus* sp. and *Isozoanthus* sp. are indicated in Figure 15 along with densities (number per square decimeter) of sponge (one or two Myxillid sponge species and at least three other unidentified demosponges). Note that only sponges that were colonized by an epizootic zoanthid were mapped (data on general sponge distribution was not recorded).

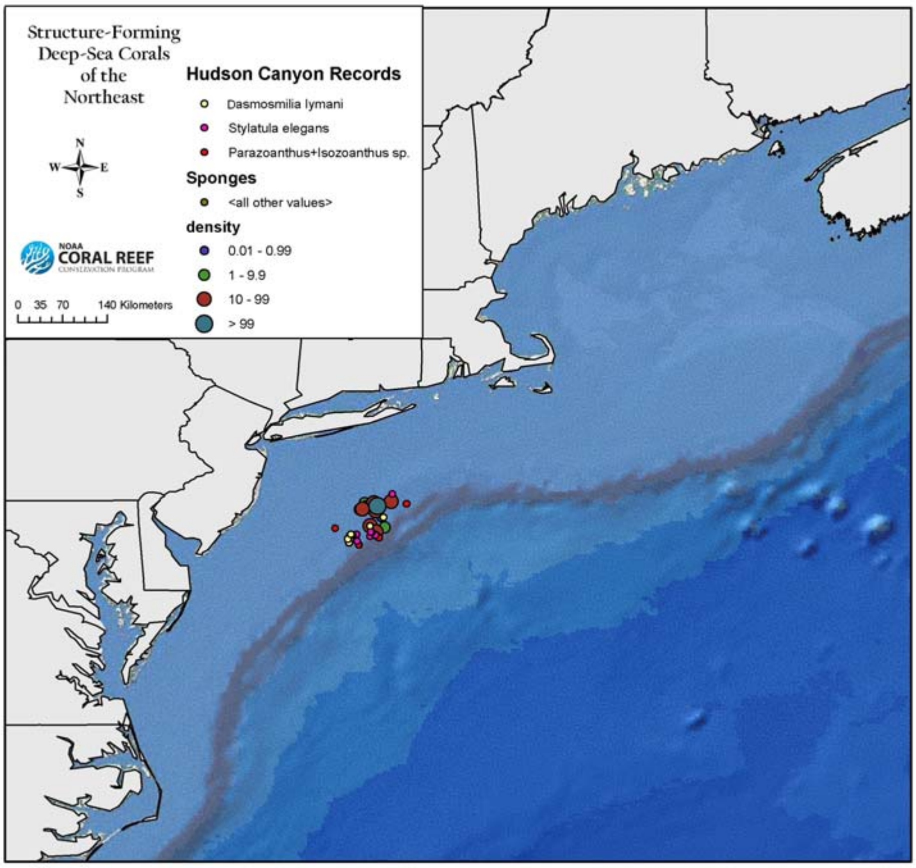

Figure 15. Location of benthic samples from Hudson Canyon and adjacent slope waters (numbers of individuals or colonies per square decameter (dekameter) = per 100 sq m).

Records of the solitary cup coral *Dasmosmilia lymani* and the white sea pen coral *Stylatula elegans* were extracted from the Smithsonian Museum of Natural History online database http://www.nmnh.si.edu/iz. These records are of museum collections held at the Smithsonian and Peabody museums and date primarily from 1975–1977, although 19 records of *Dasmosmilia lymani* collected from 1880 to 1884 by the US Fisheries Commission are also included (Figure 16).

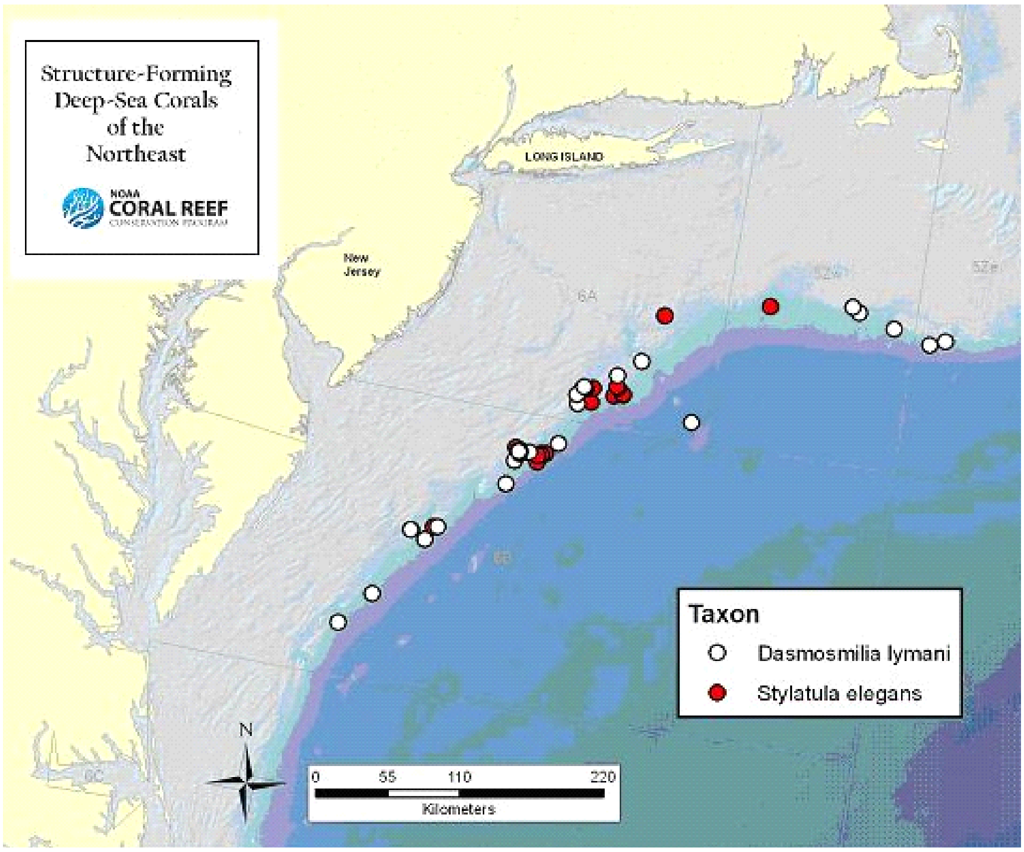

Figure 16. Location of the solitary cup coral *Dasmosmilia lymani* and the white sea pen coral *Stylatula elegans* as determined from museum records and other collections extracted from the Smithsonian Museum of Natural History online database http://www.nmnh.si.edu/iz.

Beothuk Knoll and the NAFO Regulatory Area

Vinnichenko, 2010 provided historical and recent information on the distribution of corals and sponges from Beothuk Knoll and other parts of the NAFO Regulatory Area. Data sources include fisheries observer data on Russian fishing vessels (2008–2009) and research surveys conducted in 1958, 1971 and 1976 using a bottom trawl, a Sigsbi trawl and 0.25m^2 grab samples respectively.

Over most of the Flemish Cap and the Grand Banks, corals were represented by Alcyonaceans: *Eunephthya glomerata, E. fruticosa, E. florida.* On the eastern slope of the Flemish Cap at the depths of 350–450 m and on its western slope between 330–375 m, single catches of *Paragoria* spp. were collected. Sponge assemblages in both areas were registered at depths of 200–500 m and were composed mainly of *Myxilla* spp., *Polymastia* spp., *Tetilla* spp., *Geodia* spp., *Reniera* spp.,and *Tentorium* spp. (Figure 17). The general abundance of both corals and sponges are indicated in Figure 18.

In August–September 2008 during the redfish fishery in the southwestern part of the Flemish Cap Bank (depths 302–355 m) observers occasionally registered small catches (less 0.1 kg) of single coral fragments of *Pennatulacea* spp. (Figure 19).

In May–July 2 during the Greenland halibut fishery in 3 LM Divisions (depths 770–1300 m) sea pens (*Pennatulacea* spp) were frequently encountered (see Vinnichenko, 2010). Catches of all coral taxa did not exceed 0.9 kg per trawl (Figure 20).

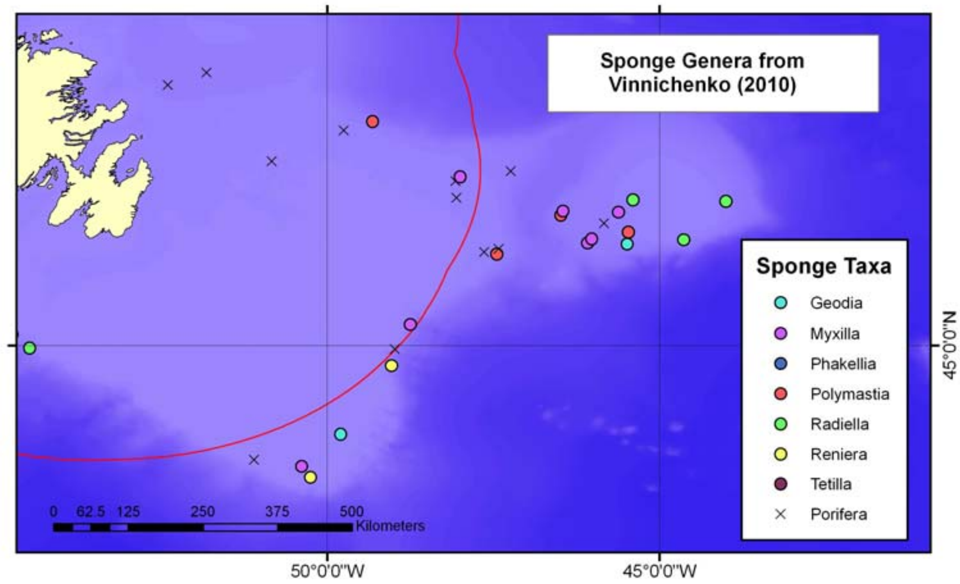

Figure 17. Location of sponge genera and unidentified Porifera from Russian research surveys (1958, 1975, 1976) as reported by Vinnichenko, 2010. The red line indicates the Canadian EEZ. Note some genera are overlain as they were taken from the same sets. A full list is provided in Vinnichenko, 2010.

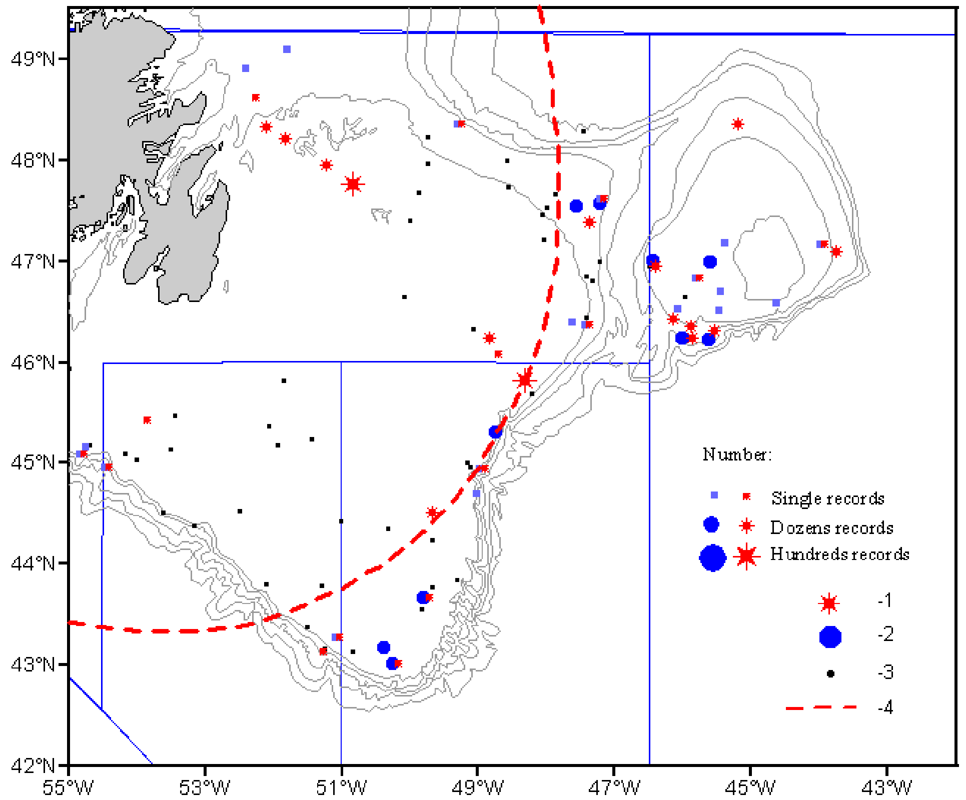

Figure 18. Distribution of VME indicator species on Flemish Cap and Grand Bank (by Soviet benthos surveys in 1959, 1971, 1976): 1 – corals; 2 – sponges; 3 – benthos stations without VME indicator species; 4 – Canadian EEZ (see Vinnichenko, 2010 attached).

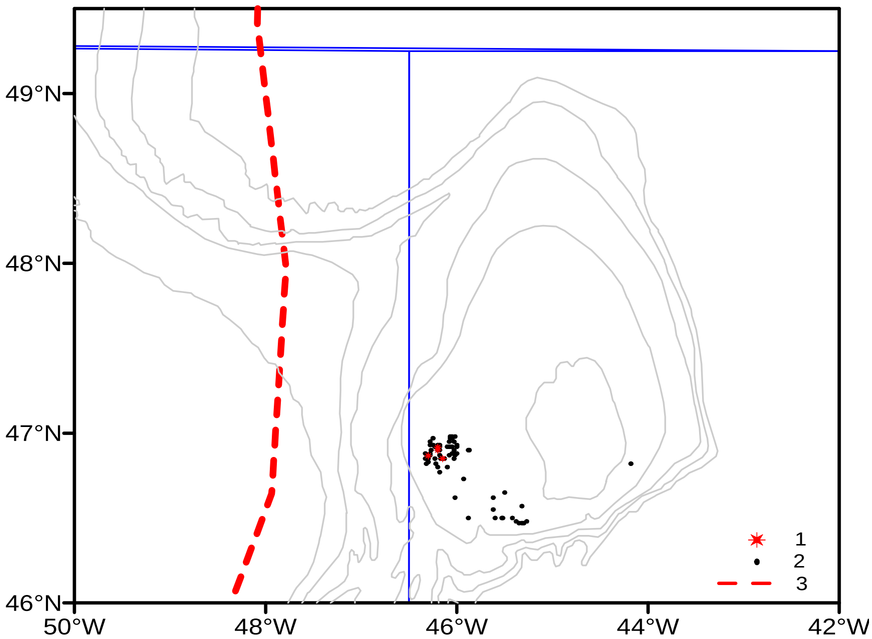

Figure 19. Occurrence of *Pennatularia* spp. in catches of Russian trawler "Matrioska" M-1007 on Flemish Cap in August-September 2008: 1 - occurrence of corals in catches; 2 – first trawl set; 3 – Canadian EEZ (see Vinnichenko, 2010 attached).

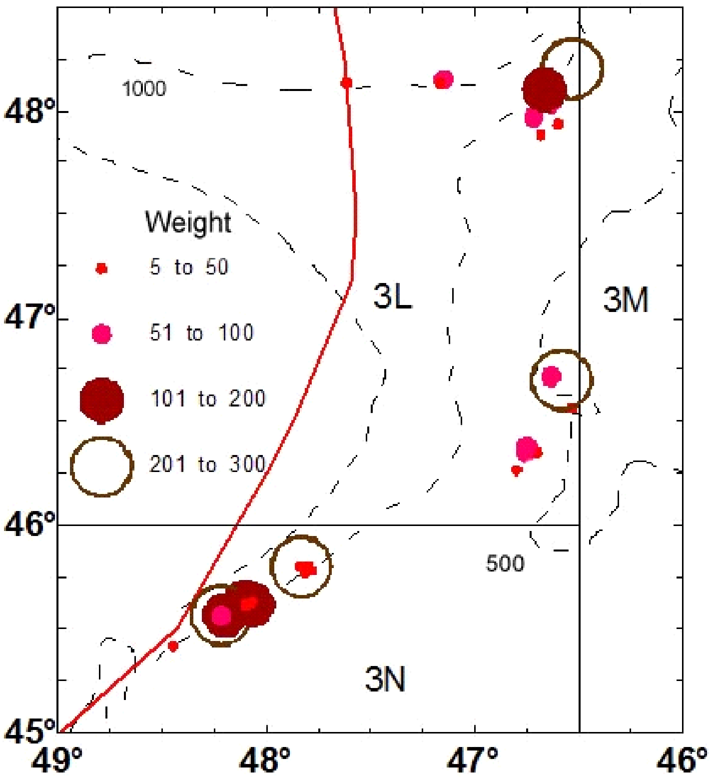

Figure 20. Occurrence of *Pennatularia* spp. in catches of Russian trawler "Melkart-2" M-0418 in Newfoundland in May–July 2009. Weights are g/trawl (see Vinnichenko, 2010 attached).

Rockall Bank and Hebridean Slope

Data on bycatch of coral from trawl surveys (N=102) was provided by Marine Scotland (FRS) for the years 2000 to 2009 (Figure 21). The depth range of the records was 180 to 1800 m.

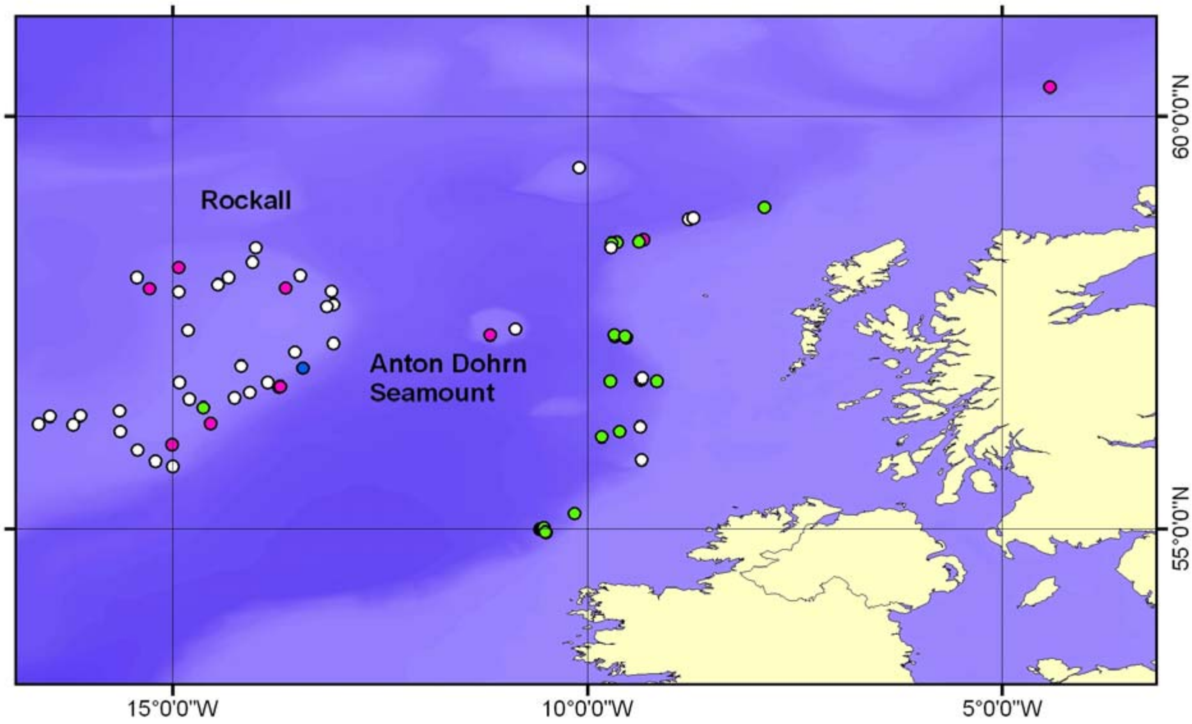

Figure 21. Presence of coral taxa on Rockall Bank and the Hebridean Slope as collected in trawl survey bycatch from 2000 to 2009 (Data source: FRS- MSS). White: Scleractinia, Green: Pennatulacea, Pink: Gorgonacea, Blue: Stylasterid Lace corals, Black: Antipatharia.

Additional coral reef data for Rockall Bank (Figure 22) has been collated from an annual collaboration between Marine Scotland (FRS), JNCC (Joint Nature Conservation Committee) and the University of Plymouth for the years 2005, 2006, 2007 and 2008. Camera tows were conducted at various locations over Rockall. Typically the tows were conducted for 500 m lengths. The videos were assessed for coral reef and are displayed here. In addition, Trade and Industry (DTI) (now Department of Energy and Climate Change: DECC) Strategic Environmental Assessment (SEA 7) of the Irish Sea conducted camera surveys in this area and these videos were assessed by JNCC for coral occurrence. Finally, the Scottish Fisheries Federation (SFF) provided coral records observed during trawling operations from the 1970s to 2008. None of the above data has been furthered described.

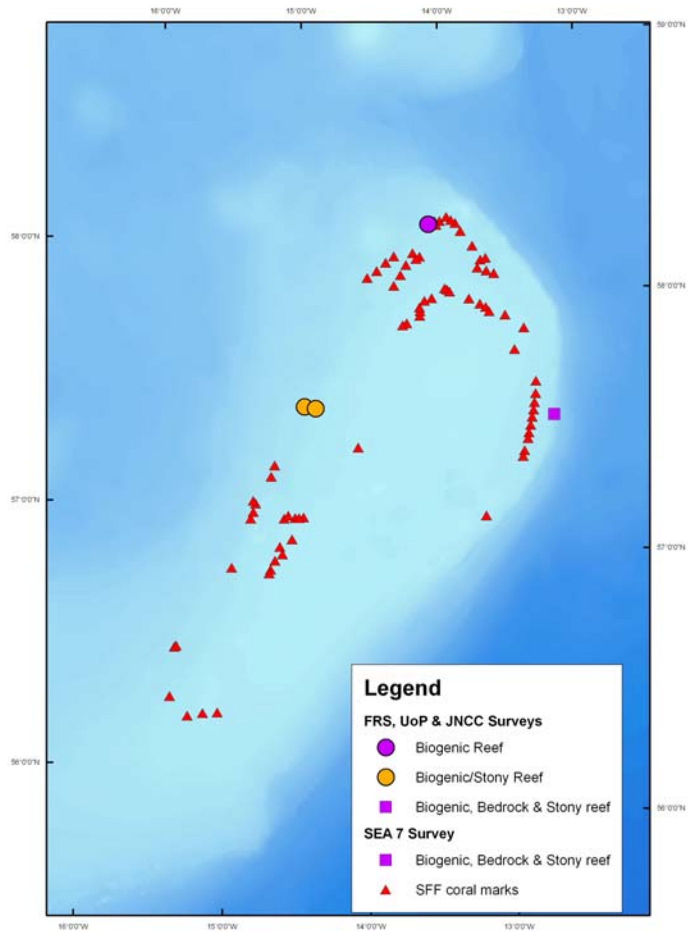

Figure 22. Observed coral occurrence on Rockall Bank from dedicated video surveys conducted by Marine Scotland (FRS), JNCC (Joint Nature Conservation Committee), University of Plymouth and Department of Energy and Climate Change (DECC) and from fisheries data supplied by the SFF.

Cantabrian Sea

New data on the spatial distribution of sponges and cold water corals from the Cantabrian Sea comes from a paper by Sanchez *et al*., 2008 which describes the general trends in the spatial distribution of Le Danois Bank communities in relation to the environmental variables that characterize their habitat. Le Danois Bank locally known by fishermen as 'El Cachucho' fishing ground, is a marginal shelf located in the Cantabrian Sea at 5°W longitude and 44°N latitude (Figure 23). Four main assemblages were described of which two are *Pheronema–Deania* (800–1050 m), characterized by the hexactinellid sponge, *P. carpenteri* and *Callogorgia–Chimaera* (rocky bottoms of the top of the Bank), characterized by the gorgonian, *Callogorgia verticillata* but also where numerous species of sponges of the families Hexactinellidae and Geodidae were found (Figure 24).

Data were derived from two surveys carried out in October 2003 and April 2004 as part of the ECOMARG project from two gear types, a 3.5 m beam trawl and a Porcupine 39/52 type baca otter trawl. From the two samplers, 8 coral species (cnidarians) and 5 sponge species were found as part of a total richness of 221 species. Table 3 shows the standardized biomass (g ha−1) and abundance (n ha−1) indices of those species from both gears (V = beam trawl and B = Baca otter trawl) and both surveys and gear.

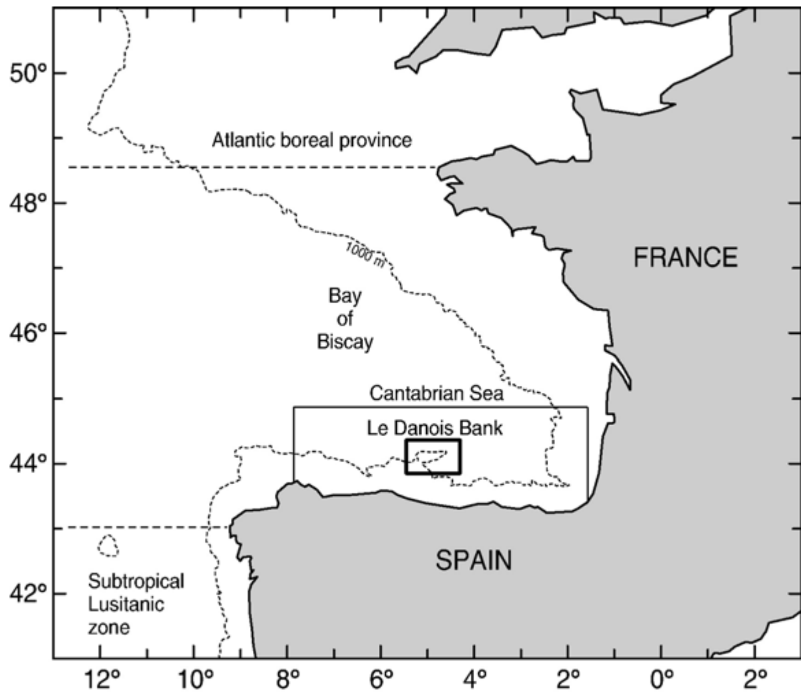

Figure 23. Location of Le Danois Bank from Sanchez *et al.*, 2008.

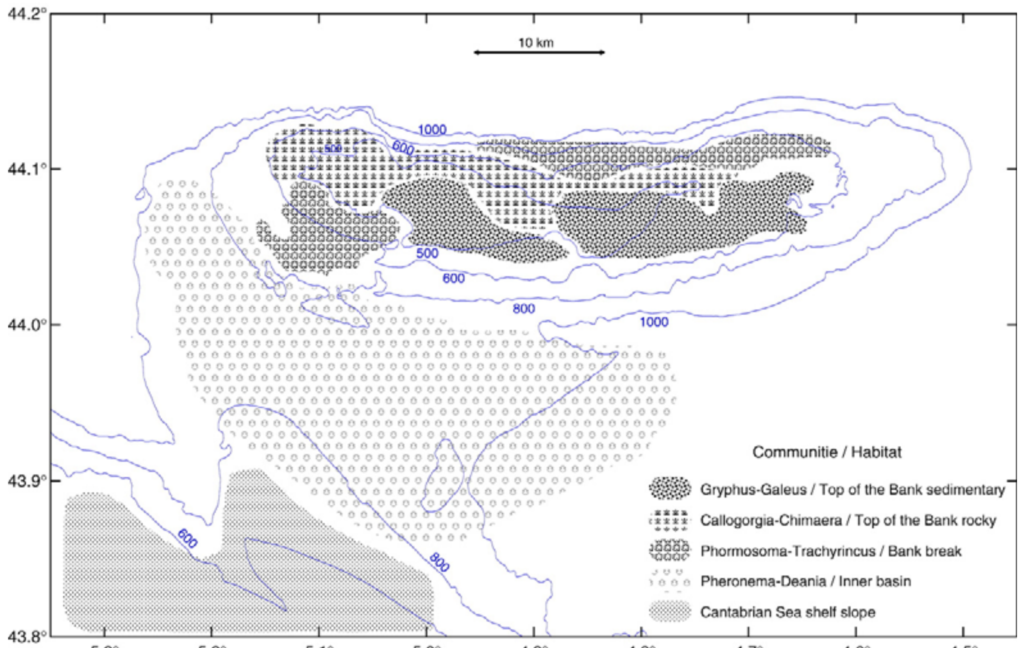

Figure 24. Spatial distribution on main communities on Le Danois Bank study area based on sea-bed reflectivity and depth characteristics of their habitat Bank from Sanchez *et al.*, 2008.

Table 3. ECOMARG Surveys 2003, 2004: Standardized Biomass (g ha–1) and Abundance (n ha–1) Indices of Total Species from Both Gears (V = beam trawl and B = Baca otter trawl) and Both Surveys.

Species	Biomass (g ha−1)	Abundance (n ha−1)	Gear
Cnidarians			
Acanella arbuscula	381.050	3.815	V
Caryophyllia smithii	339.201	109.831	V
Pennatula rubra	16.617	4.928	V
Funiculina quadrangularis	2.988	3.815	V
Virgularia mirabilis	0.476	0.119	B
Parerythropodium coralloides	0.094	4.199	V
Lytocarpia myriophyllum	0.094	0.286	V
Pennatula phosphorea	0.000	0.007	B
Sponges			
Pheronema carpenteri	2307.687	7.393	V
Polymastidae unid.	801.128	4069.425	V
Geodia megastrella	453.161	0.040	B
Asconema setubalense manta	122.969	0.013	B
Phakelia ventilabrum	88.343	0.478	V
Stylocordyla borealis	14.794	13.618	V

A further paper by Sanchez *et al*., 2009, describes a visual study of the deep-sea habitats of the Cantabrian Sea and their macro-epibenthic communities. Two areas were focused on; one in the central Cantabrian Sea outer shelf (150 m depth), near the head of the Lastres Canyon, and another at the summit of the Le Danois Bank (555 m depth). Three habitats were identified on the Cantabrian Sea outer shelf of which one was sponge communities on circalittoral rock. In additional, a typical community appeared on the rocky habitat made up of the yellow coral *Dendrophyllia cornigera* and the cup sponge *Phakellia ventilabrum*. On Le Danois Bank, three habitats were identified and the cnidarians (*Caryophyllia smithii* and *Callogorgia verticillata*) and the sponges (*Asconema setubalense*, *Aplysilla* sp., hexactinellids) characterized the rocky habitats and patchy rock-sand habitats.

WGDEC Database

In 2007, WGDEC collated coral records for various parts of the North Atlantic region. The material was sourced from a combination of the literature, dedicated surveys and from bycatch data of fisheries surveys. The material was mainly supplied from the Fisheries Research Services (FRS), Scotland, the Institute of Marine Research (IMR), Norway and Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Russia. This was updated at WGDEC 2008 with data from Canada (bycatch and ROV data) and in 2010 with data from the FRS and IMR and from the US and Canada. The Norwegian data has come from dedicated Mareano suveys and from the Petroleum Industries Seabed Surveys. Uncertain data from fishermen previously recorded has been removed resulting in a removal of the previous most northerly record of *Lophelia pertusa*. Some of the data are from quite old sources and some time must be spent to review it all and concentrate the files into a single database. The position of records that are currently in the database are illustrated in Figure 25. These data form the basis of an ICES-WGDEC coral and deep-water sponge ARCGIS database which will be developed over the next year.

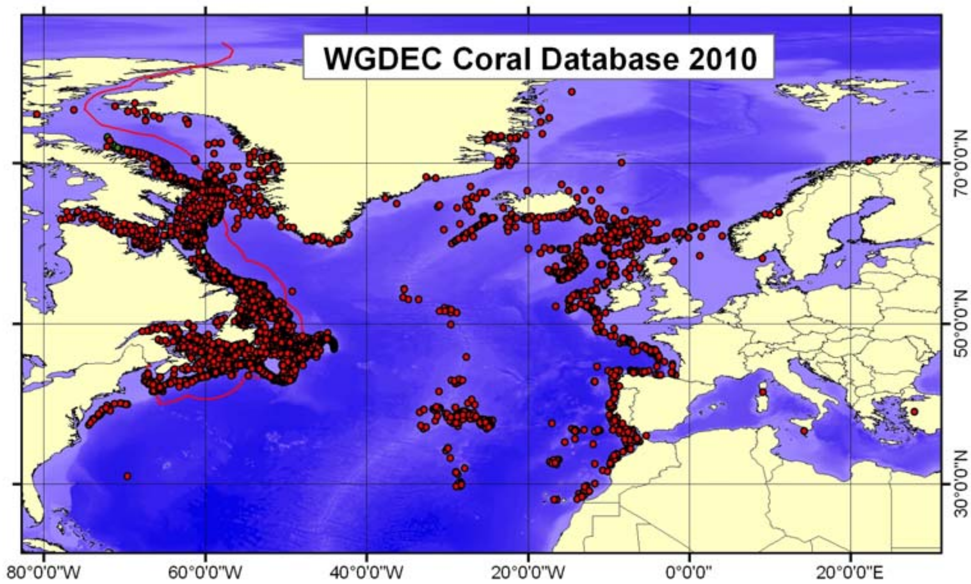

Figure 25. The location of all coral records held in the WGDEC database.

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4 Assess the association of fish species with sponge grounds using trawl survey data where available

The importance of individual sponges as microhabitat for invertebrate species has been widely demonstrated and includes a wide range of ecological interaction including both facultative and obligate commensalisms (see recent reviews by Wulff, 2006 and Bell, 2008, and articles specific to the North Atlantic by Bett and Rice, 1992; Klitgaard, 1995; Klitgaard and Tendal, 2004; ICES 2009; Hogg *et al*., 2010). Sponge architecture is an important determinant of the type and strength of such interactions.

The general co-occurrence of temperate sponge grounds with demersal fish assemblages has been less well documented (ICES 2009; Hogg *et al*., 2010). Fish often use the structural habitat that sponge grounds provide for shelter, reproduction and to forage for food (Bell, 2008). The intricate architecture of sponge grounds also provides important nursery grounds for juvenile fish in their early stages of growth (Auster, 2005). Rockfish (or 'redfish') of the genus *Sebastes* are particularly prevalent in sponge grounds in some areas, living in and between sponges (Freese and Wing, 2003). Other groundfish including cod and ling are often found in trawl catches along with sponges (Hixon *et al*., 1991). There is also some evidence that over time removal of the sponge grounds by trawling changes the composition of the fish fauna (Sainsbury, 1988 in Klitgaard and Tendal, 2004). Thus, it seems that sponge grounds are a crucial refuge and habitat for fish although little ecological work has been carried out to understand the exact nature of this habitat use in the deep sea and most studies to date are limited to tropical waters (e.g. McCormick, 1994; Cleary and de Voogd, 2007).

Association of fish species with sponge grounds using trawl survey data in the NAFO Regulatory Area

In response to this request, Kenchington *et al*., 2010 examined the association of 34 demersal fish taxa with *Geodia*-dominated sponge grounds using data collected from 104 research vessel survey trawls of 500 to 1500 m depth along the continental slopes of the Grand Banks and Flemish Cap. Data used for these analyses come from the DFO Newfoundland Region fall multispecies surveys. These surveys use a Campelen trawl towed for approximately 1 km. The catch is sorted at-sea and the number and weight (kg) of each taxon are recorded using a standard set of species codes. Only records from 2001 to 2007 were used in order to avoid confounding the results by temporal trends due to environmental factors and to ensure consistency of reporting. These records were further reduced 1) to include only those deeper than 500 m, to avoid confounding the results by including both shelf and slope taxa, 2) to include only those from < 50 N latitude, in order to reduce confounding the results by introducing biogeographic differences in community composition, and 3) to include only records with some sponge catch identified in order to avoid confounding the results by assuming that values of 0 meant that no sponge was present when it is possible that it was just not recorded. These criteria produced the 104 trawl records for analysis. Their average depth was 1096 m (range 578–1446 m).

The 104 selected trawls contained non-zero records for 200 taxa. These 200 taxa were reduced to 34 fish taxa (Table 1) by 1) eliminating invertebrate species, 2) combining species to higher-level groupings, and 3) eliminating all rarities after combining the data to include only taxa > 0.1% of total biomass. The second of these steps was done to avoid introducing errors due to taxonomic imprecision among trips, and sets within trips. The third was to eliminate taxa that may not be reliably caught in the trawl, or whose rarity may escape detection in the sorting process. To determine the low end cut off, decisions were made on the size of the taxon relative to the biomass record before removing it from the list.

The weights of each of the 34 taxa were standardized to a 1 km tow. This involved only a minor adjustment to the data as the average tow length was 0.8 ± 0.07 km (range 0.6–1.0). For each trawl, the total biomass of the sponge catch was used to rank the trawl according to one of three Sponge Catch Weight Classes: High (≥ 250 kg), Medium (10.01–249.99 kg), Low (≤ 10 kg). The locations of the tows used in this analysis, identified by their Sponge Catch Weight Class, are illustrated in Figure 1.

Table 1. List of the 34 Fish Taxa Analyzed for Association with Sponge Grounds, Their Common Names, Total Taxon Biomass and Percent of Total Biomass (104 Trawl Sets).

Fish Taxon	Common Name	Total B (kg)	%
Somniosus microcephalus	Greenland Shark	3555.56	26.56
Macrourus berglax	Roughead Grenadier	2477.42	18.51
Antimora rostrata	Blue Hake	1738.51	12.99
Centroscyllium fabricii	Black Dogfish	1091.65	8.16
Reinhardtius hippoglossoides	Turbot	846.83	6.33
Sebastes mentella	Deepwater Redfish	574.43	4.29
Hippoglossoides platessoides	American Plaice	546.04	4.08
Synaphobranchus kaupii	Longnose Eel	543.07	4.06
Coryphaenoides rupestris	Roundnose Grenadier	374.73	2.80
Apristurus profundorum	Deep Sea Catshark	185.44	1.39
Bathyraja spinicauda	Spinytail Skate	171.28	1.28
Nezumia bairdii	Common Grenadier	156.29	1.17
Anarhichas denticulatus	Broadhead Wolfish	134.40	1.00
Notacanthus chemnitzii	Largescaled Tapirfish	112.52	0.84
Amblyraja radiate	Thorny Skate	109.71	0.82
Glyptocephalus cynoglossus	Witch Flounder	96.09	0.72
Gaidropsarus spp.	Threebeard Rockling	89.31	0.67
Hydrolagus affinis	Deepwater Chimaera	87.46	0.65
Amblyraja jenseni	Jensen's Skate	81.82	0.61
Dipturus linteus	White Skate	62.07	0.46
Myctophidae	Lanternfish	51.96	0.39
Notacanthidae	Spiny Eels	38.78	0.29
Lycodes spp.	Eelpout	37.96	0.28
Lycodes vahlii	Vahl's Eelpout	37.37	0.28
Serrivomer beanii	Shortnose Snipe eel	31.25	0.23
Harriotta raleighana	Longnose Chimaera	25.57	0.19
Phycis chesteri	Longfin Hake	19.33	0.14
Bathylagus euryops	Goitre Blacksmelts	19.22	0.14
Anarhichas minor	Spotted Wolfish	16.41	0.12
Bathytroctes spp.	Black Herring	16.39	0.12
Amblyraja hyperborea	Arctic Skate	16.30	0.12
Chauliodus sloani	Viperfish	16.19	0.12
Rajella bathyphilia	Abyssal Skate	12.63	0.09
Stomias boa ferox	Boa Dragonfish	11.31	0.08

The data were the Total Number of Taxa (maximum 34), Total Biomass per Tow, Total Sponge Biomass per Tow and Total Fish Taxon Biomass per Tow, analysed with regression analyses and through community-based approaches. Species composition was evaluated by analysis of similarity (ANOSIM), similarity of per cent contribution (SIMPER) and multidimensional scaling (MDS) performed with PRIMER software.

Regressions between the number of taxa and biomass with depth indicate that there is a significantly higher sponge biomass and a significantly lower fish biomass (of the 34 selected taxa) with increasing depth. The number of sponge taxa demonstrated no relationship with depth. At the same time, both the number of taxa and the total fish biomass significantly decrease with increasing sponge weight. These relationships could represent true ecological properties or they could be artefacts of the handling procedures (both of the net *in situ* and of the catch on deck) when large sponge catches are hauled in (cf. Kenchington *et al*., 2010).

The community analyses (ANOSIM) demonstrated that although distinct faunal assemblages are associated with the low and high sponge catches (ANOSIM R = 0.232, P= 0.001), medium sized sponge catches have similar communities to areas with low sponge (ANOSIM R = 0.056, P= 0.087; Figure 2). This suggests only two community types with respect to sponge biomass - with sponge biomass greater than 250 kg per km distinguishing them. The three taxa which contribute most to the dissimilarity between the low and high sponge catch trawls are black dogfish, blue hake and longnose eel, which were found in both classes of trawl catch and in greater biomass in the low sponge catch class (Table 2). These relationships are visualized in the MDS plot in Figure 2 with stations with an average similarity of 54% circled. This is the average similarity within sponge class groups. It can be seen that although some sets with high sponge catch cluster together, most of the stations share a similarity of taxa that is not explained by the sponge class (Figure 2).

The taxa which distinguish assemblages (SIMPER) associated with high sponge catches by their absence in trawls with low sponge catch are deep-sea catsharks, spinytail skates, white skates, shortnose snipe eels, eelpouts and deep-water chimaeras (Figure 3 in part, Table 2). The deep-sea catshark (*Apristurus profundorum*) is one of the larger species in the trawl catch (Table 1) with lengths up to 50 cm reported. Snipe eels have small biomass but can reach lengths of 150 cm. All are deep-living fish (Rose 2005) and active predators and it is unlikely that these fish would be overlooked in the sorting of catch with lesser amount of sponge. The reverse situation, where species have low biomass with high sponge catches, may be due to the fishing issues or sorting procedures noted above. Four taxa were never found in association with high sponge catches, namely deep-water redfish, American plaice, thorny skate and witch flounder (Table 2). Some of these taxa (e.g. American plaice, witch flounder) are associated with mud or sandy bottoms and their absence in the densest sponge habitat may be genuine.

One of the interesting findings lies in the zero catch of the deep-water redfish (*Sebastes mentella*) in the high weight class of sponge bycatch (Figure 3, Table 2), given that the association of rockfish with sponges is one of the more well-established relationships (e.g. Richards, 1986; Freese and Wing, 2003; Auster, 2005; Burton Marliave *et al*., 2009). Eighty-five per cent of the biomass of *S. mentella* was associated with the low sponge catches (≤ 10 kg/km) with only 15% associated with the medium sponge catches. The lack of association with the sponges is most likely coincidental, with the fish species preferring shallower water and the sponges the deeper water. The density of *S. mentella* in the Northwest Atlantic is known to decrease sharply below about 750 m (D. Power, DFO-NWAFC, St John's, NL, Canada, pers. comm.).

Although the lower depth limit of the redfish is unlikely to be controlled by the upper depth of the sponge grounds, Bell, 2005 cites a number of examples where the chemical compounds of the sponges act as deterrents to other organisms, and Burton Marliave *et al*., 2009 demonstrate regional patterns in British Columbian waters (northeast Pacific) in the association of adult *Sebastes maliger* with the sponge reef structures, with the fish absent from some sponge reefs entirely but present in nearby areas. Burton Marliave *et al*., 2009 further describe habitat partitioning by *S. maliger* where adults are associated with the reef structures (bioherms) and juveniles are associated with single sponges or lower density "sponge gardens". *S. maliger* feeds on benthic crustaceans and the authors hypothesize that increased species richness in the food resource on the sponge gardens drives this distribution pattern. *S. mentella* feeds on zooplankton and undergoes diel migrations to feed in the water column at night even as juveniles (cf. Kelly and Barker, 1961; Auster *et al*., 2003) therefore, it is unlikely that food is the driver for the observations reported herein. Further the tows analysed were not biased by time of day with 14/27 sets containing *S. mentella* conducted in daylight (Kenchington *et al*., 2010). Regardless, *S. mentella* did exhibit a differential response to variation in sponge density. Further research on this observation is needed in order to determine whether the results are representative of an interesting behaviour of *S. mentella*.

Collectively these data suggest that the *Geodia*-dominated sponge grounds of the NAFO Regulatory Area (NRA) host unique fish faunal assemblages, although the active or passive nature of this association is not known. A more detailed analysis of these data using less coarse taxonomic categories may have revealed greater differences in community composition. However, trawl survey bycatch can only give a generalized picture of the species associations for those species that are caught by the gear. The smaller invertebrate and fish species and life-history stages that have been reported elsewhere as associated with sponge grounds require other sampling tools to elucidate. The results reported here will be compared with *in situ* photographic and video data collected in 2009 to further describe the species associated with sponge grounds in the NRA.

Table 2. Taxa Contributing to > 90% of the Dissimilarity (SIMPER) of Research Vessel Catch Composition (2001-2007) Between the Low and High Sponge Weight Classes. (Arrows indicate direction of change with double arrow indicating absence in one or other category).

Taxon	Common Name	Direction of Change Relative to High Sponge Weight Class	Average Log10 (Biomass)		Per cent Contribution to Dissimilarity
			Low Sponge Class	High Sponge Class	
Centroscyllium fabricii	Black Dogfish	▼	1.53	1.22	9.23
Antimora rostrata	Blue Hake	▼	2.58	2.13	7.83
Synaphobranchus kaupii	Longnose Eel	▼	1.50	0.96	6.67
Reinhardtius hippoglossoides	Turbot	▼	2.10	1.76	6.04
Macrourus berglax	Roughead Grenadier	▼	3.00	2.79	5.87
Coryphaenoides rupestris	Roundnose Grenadier	▼	1.24	0.74	5.74
Apristurus profundorum	Deep Sea Catshark	▲	0.29	0.93	5.08
Nezumia bairdii	Common Grenadier	▼	0.95	0.37	4.54
Sebastes mentella	Deepwater Redfish	▼▼	0.76	0.00	4.17
Hippoglossoides platessoides	American Plaice	▼▼	0.79	0.00	4.12
Anarhichas denticulatus	Broadhead Wolfish	▼	0.64	0.15	3.94
Bathyraja spinicauda	Spinytail Skate	▲	0.34	0.42	3.73
Notacanthidae	Spiny Eels	▼	0.59	0.31	3.65
Gaidropsarus spp.	Threebeard Rockling	▼	0.55	0.16	3.20
Myctophidae	Lanternfish	▼	0.47	0.11	2.53
Glyptocephalus cynoglossus	Witch Flounder	▼▼	0.44	0.00	2.34
Dipturus linteus	White Skate	▲	0.03	0.41	2.25
Amblyraja radiata	Thorny Skate	▼▼	0.40	0.00	2.16
Serrivomer beanii	Shortnose Snipe eel	▲	0.18	0.32	1.96
Lycodes spp.	Eelpout	▲	0.09	0.33	1.94
Hydrolagus affinis	Deepwater Chimaera	▲	0.01	0.33	1.61
Amblyraja jenseni	Jensen's Skate	▼	0.19	0.10	1.61

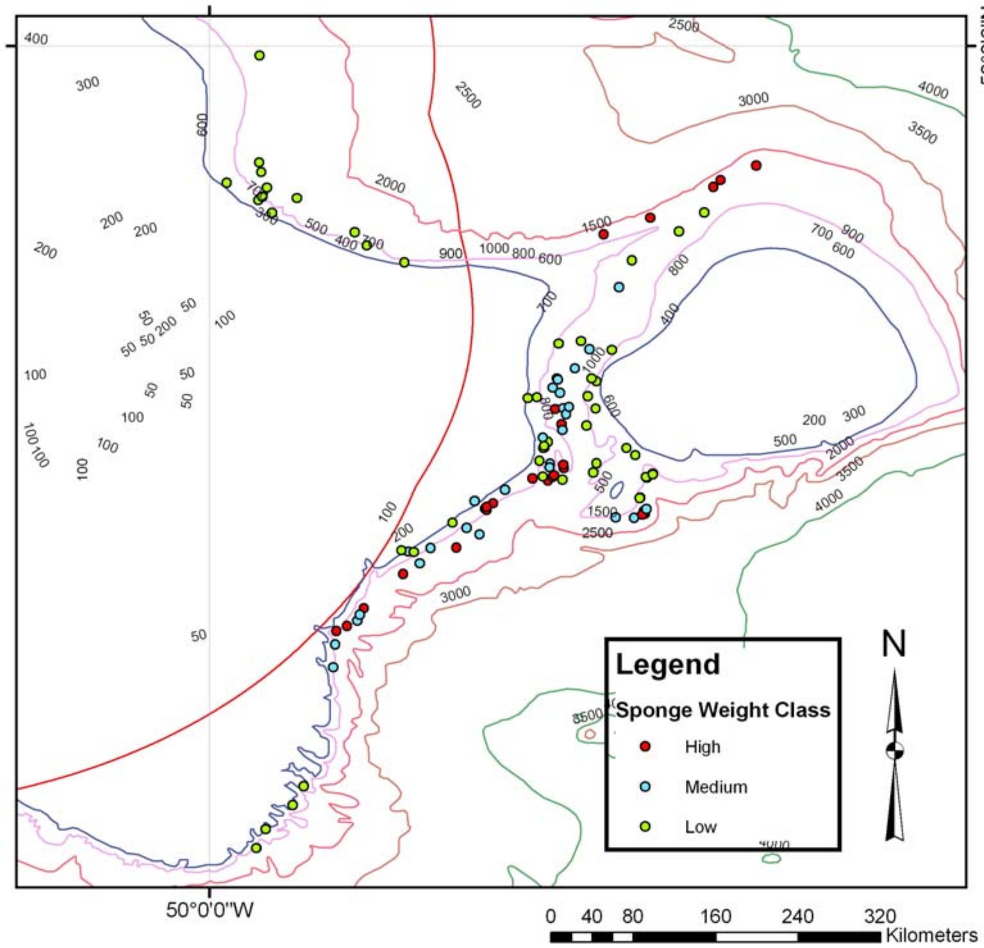

Figure 1. Location of the research vessel trawls used in Kenchington *et al*., 2010 with the corresponding sponge weight class identified.

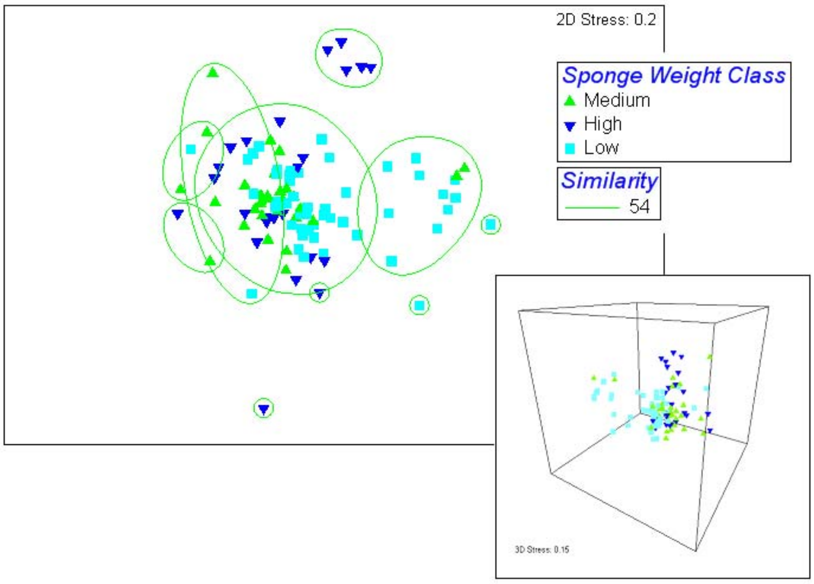

Figure 2. MDS configuration of the trawl catches (2001–2007) in 2D and 3D based on Bray–Curtis similarity matrix calculated from log10-transformed biomass data for each of 34 taxa. Trawl catches are labelled according to Sponge Weight Class. In the 2D representation stations with 54% similarity to each other are indicated. This is the average similarity level within each of the 3 classes.

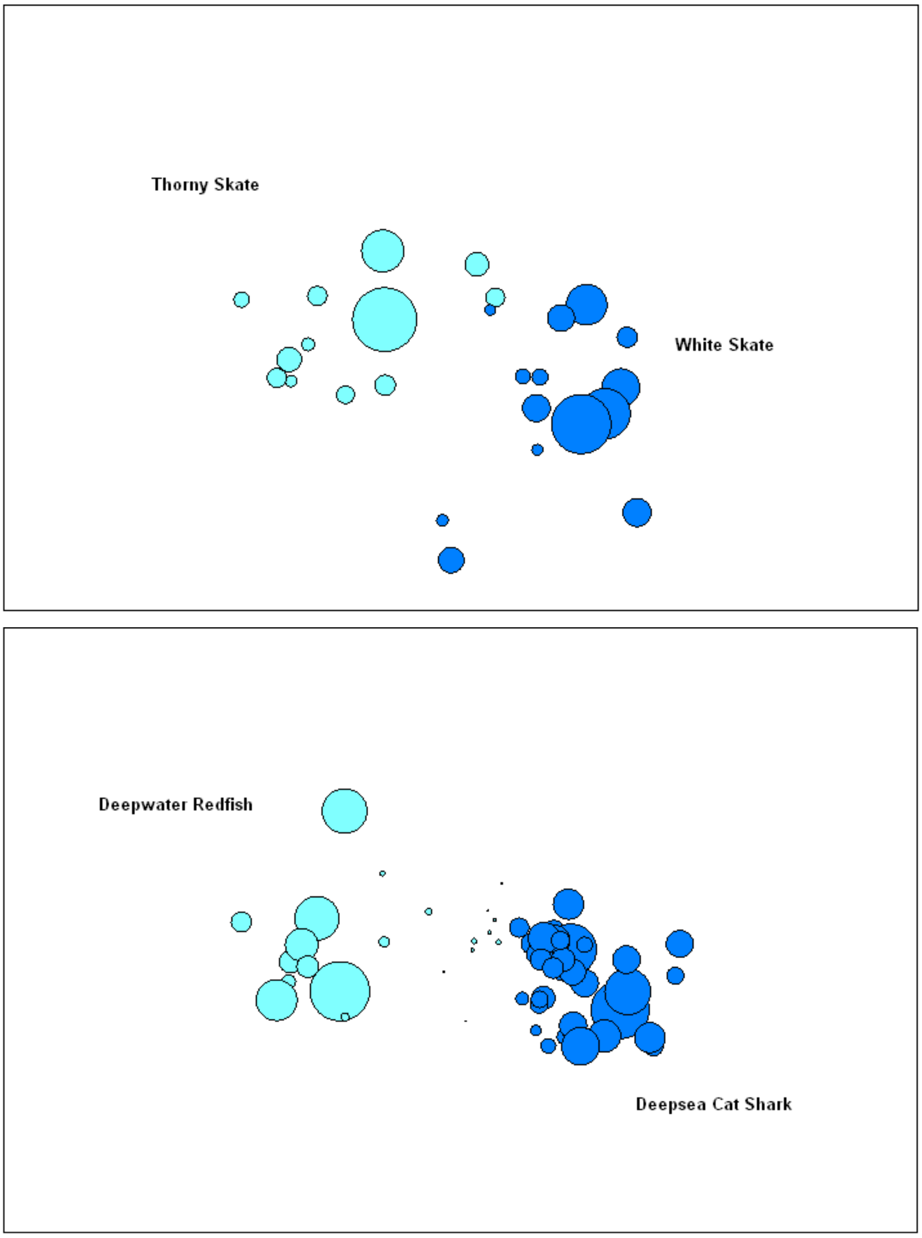

Figure 3. MDS configuration of the trawl catches (2001–2007) based on Bray–Curtis similarity matrix calculated from log10-transformed biomass data for each of 34 taxa. The proportional biomass of pairs of taxa which favour the sponge grounds (High Sponge Weight Class – dark blue) or areas with Low Sponge (light blue) are illustrated. Note that proportions are relative to each taxon.

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5 Review the science used in assessing vulnerable marine ecosystems and the "Encounter Clause"

Background

In December 2006, the United Nations General Assembly ("UNGA") adopted its Resolution 61/105 which, in its Paragraphs 76 to 95, calls on states and RFMO/As to take steps to protect vulnerable marine ecosystems in the high seas from the adverse impacts of fisheries. When Resolution 61/105 was adopted, much of its meaning was unclear and the steps necessary to meet its requirements were unknown. Even the operational meanings of such terms as "vulnerable marine ecosystem" and "significant adverse impact" were in considerable doubt. FAO coordinated two Expert Consultations (November 2006, September 2007), three Workshops (June and November 2007; May 2008) and two sessions of a Technical Consultation (February and August 2008) before its International Guidelines for the Management of Deep-sea Fisheries in the High Seas were adopted in August 2008. Those Guidelines were not formally published until June 2009. In the meanwhile, RFMO/As and their member states necessarily adopted interim measures to meet the UNGA's deadlines.

Among the terms of Resolution 61/105 was Paragraph 83(d):

> To require members of the regional fisheries management organizations or arrangements to require vessels flying their flag to cease bottom fishing activities in areas where, in the course of fishing operations, vulnerable marine ecosystems are encountered, and to report the encounter so that appropriate measures can be adopted in respect of the relevant site.

In autumn 2009, the UNGA reiterated the importance of the "encounter clause" in its resolution 64/72, §119 (c):

> Establish and implement appropriate protocols for the implementation of paragraph 83 (d) of its resolution 61/105, including definitions of what constitutes evidence of an encounter with a vulnerable marine ecosystem, in particular threshold levels and indicator species, based on the best available scientific information and consistent with the Guidelines, and taking into account any other conservation and management measures to prevent significant adverse impacts on vulnerable marine ecosystems, including those based on the results of assessments carried out pursuant to paragraph 83 (a) of its resolution 61/105 and paragraph 119 (a) of the present resolution.

Hence, the UNGA has called for a two-pronged approach: 1) to develop a protocol to minimize damage to VMEs when they are encountered; and 2) to carry out assessments to determine where VMEs are known or likely to occur and to proactively protect these areas.

In this section of the report, WGDEC reviews the science used in assessing vulnerable marine ecosystems and the "Encounter Clause;" i.e. the first of the two approaches. In the two Appendices to this ToR, we additionally consider the state-of-the-art with regard to assessing where VMEs are known or likely to occur; i.e. the second aspect required by the UNGA.

Encounter protocols

Encounter protocols have been used in fisheries management for about twenty years (Shotton and Patchell, 2008). Many of the applications have been put in place as a means of minimizing the bycatch of finfish, usually of small fish or other life-history stages of the target species but also for protected species. For example, CCAMLR brought in a 5-mile "move-on" rule in 1995 for bycatches (all non-target species combined) of more than 5% in the fishery for the myctophid *Electrona carlsbergi*. The vessel which took the higher bycatch was excluded from the 269 km² circle for five days. A very similar rule was introduced for the Patagonian toothfish and Antarctic icefish fisheries during the same year. In those cases, the 5% limit applied only to specified bycatch species. The use of similar rules has since spread within CCAMLR's management of the fisheries of the Southern Ocean, though the 5-mile distance and 5-day time continue to be invoked explicitly pending adoption of more appropriate limits.

In each case where encounter protocols have been used, there has been an expectation that the problem of excessive catch of unwanted animals is limited in space and time, hence that it is best addressed through small-scale, real-time adjustments in fishing locations, without requiring substantial case-specific action by a management agency. Such applications may be appropriate to some mobile fish species associated with vulnerable marine ecosystems, although an assessment of the spatial and temporal stability of the fish taxa concerned would be required. They make less sense for long-lived sessile/sedentary benthic taxa, except as a means of detecting their presence in unexplored areas. This will be addressed further below.

Science used in assessing vulnerable marine ecosystems

Many of the ecosystems supported by cold-water corals, sponges and other communities have been highlighted by FAO 2009 as Vulnerable Marine Ecosystems (VME) that are susceptible to Significant Adverse Impacts (SAI). The 'International guidelines for the management of deep-sea fisheries in the high seas' (FAO 2009) provide a range of recommendations on how to identify VMEs and assess SAIs. The life-history traits presented are directly linked to SAI. The guidelines also note that marine ecosystems should be classified as vulnerable based on the characteristics that it possesses.

The following characteristics have been proposed by FAO 2009 as criteria to identify **VMEs** subject to **SAIs**:

Vulnerable marine ecosystems

The criteria suggested to use to identify VMEs include:

- ***Uniqueness or rarity*** *- an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include*:
  - *habitats that contain endemic species;*
  - *habitats of rare, threatened or endangered species that occur only in discrete areas; or*
  - *nurseries or discrete feeding, breeding, or spawning areas.*
- ***Functional significance of the habitat*** *-are discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.*
- ***Fragility*** *- an ecosystem that is highly susceptible to degradation by anthropogenic activities.*
- ***Life-history traits of component species that make recovery difficult****: ecosystems that are characterized by populations or assemblages of species with one or*

more of the following characteristics: slow growth rates; late age of maturity; low or unpredictable recruitment; or long-lived.

- ***Structural complexity*** *- an ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which depends on the structuring organisms.*

This list of criteria could be adapted and additional criteria could be developed as experience and knowledge accumulate, or to address particular local or regional needs. It is important to note that the guidelines, as stated by the UNGA resolution 61/105, explicitly take a precautionary approach, emphasizing that where site-specific information is lacking, other information that is relevant to inferring the likely presence of vulnerable populations, communities and habitats could be used. This will help lead to the identification of areas where VMEs are 'likely to occur'.

Annex 1 of the FAO Guidelines 2009 provides "Examples of potentially vulnerable species groups, communities and habitats as well as features that support them". They include "**certain** cold-water corals and hydroids, e.g. reef builders and coral forests including: stony corals (*Scleractinia*), alcyonaceans and gorgonians (*Octocorallia*), black corals (*Antipatharia*) and hydrocorals (*Stylasteridae*)"; "some types of sponge dominated communities", "communities composed of **dense** emergent fauna where large sessile protozoans (xenophyophores) and invertebrates (e.g. hydroids and bryozoans) form an important structural component of habitat, and "seep and vent communities composed of invertebrate and microbial species found nowhere else". They also list physical features which are known to host such communities (e.g. canyons, slopes, vents, seeps, seamounts) presumably as an aid to identify VME through "inferring the likely presence of vulnerable populations, communities and habitats", because physical mapping is further advanced than biological mapping in the deep sea. The words "certain" and "dense" are highlighted in the above text because they are the focus of most of the scientific research that has underpinned the current management actions.

Most RFMOs have used the FAO examples to proceed with the development of encounter provisions, and have not independently reviewed the taxa according to the FAO guidelines (e.g. NEAFC, SEAFO). An exception is NAFO who reviewed the species of fish, corals and sponges within its regulatory area (NRA) against the FAO critieria and documented their selection of VME taxa in Fuller *et al.*, 2008 and NAFO 2008a, citing references and rationale for their decisions. They also justified the grouping of VME species based on their similar morphology and biomass, so that, for example, the sea pens in the NRA could be treated as a single conservation unit. ICES 2009 reviewed the sponges occurring at depths of approximately 200–2000 m in the North Atlantic, and provided a list of taxa that met the FAO guidelines. Most of the sponges in this depth range and area are widespread and are not unique or rare as species; however the WG described how sponge grounds met the criteria and provided a list of indicator species for that habitat. The SPRFMO undertook a review of taxa in the south Pacific as indicators of VMEs using the FAO guidelines but noted that "because these taxa are typically phyla, orders, or families, they may include some members that as a species would not be vulnerable because of its specific life history, productivity, or size." (Parker *et al.*, 2009). Penney *et al.*, 2008 and Parker *et al.*, 2009 present contrasting accounts of how the taxa to be considered were selected. In the New Zealand process, that list was both narrowed by the exclusion of taxa not taken in trawls and widened by the addition of taxa associated with hard substrata in deep water that can serve as indicators of the presence of VME, even when no VME organisms are taken. CCAMLR's Scientific Committee 2008 appears to have followed the recommendations of the SPRFMO (Lockhart and Jones, 2009).

The degree to which RFMOs and others are able to refine the FAO examples will depend upon the available data for the area. For most taxa this requires identification at least to the level of genus if not species. NAFO was able to go further than many RFMOs because it had detailed information on the species in the NRA acquired in recent years through detailed identification of all research vessel survey bycatch conducted by Spain (IEO) and Canada (DFO) among others member states.

As noted above, encounter provisions in fisheries management have been used where there is a spatial and/or temporal component to the application. In the case of sessile or sedentary benthic invertebrates which meet the FAO criteria and which may underpin VMEs, their longevity will provide temporal stability, particularly in cases where taxa are known to live for 100s of years. Consequently, they are excellent candidates for protection through spatial closures. Many RFMOs have introduced spatial closures on the basis of the physical features which are known to host VME communities, including both NAFO and NEAFC in the North Atlantic. These have varying degrees of scientific evidence to support their closure in addition to their physical characteristics ranging from no additional information (e.g. Fogo seamounts) to *in situ* observations of VMEs (e.g. New England and Corner Rise seamount chains). In most cases, precautionary closures have been put in place based on physical attributes and available fishing or research vessel information and these have been followed up with targeted research, often involving underwater imagery. Areas with active fisheries have received most scientific attention in order to provide information to refine the boundaries so that fishing is not unduly impacted.

Within the fishing footprint both NEAFC and NAFO have used scientific evidence to close areas to fishing. In the Northeast Atlantic the presence of *Lophelia* reefs has been a focus of conservation efforts (Hall-Spencer *et al*., 2009). These reefs can be remotely sensed using multibeam bathymetry (with appropriate ground-truthing) and so it is possible to get a complete census of the reefs in an area, with precise coordinates for the area occupied. An example of where this technology has been applied is on the Hatton Bank where multibeam surveys and benthic sampling have assisted in the delineation of the closed areas (Durán Muñoz *et al*., 2007; 2009). Because "reef builders" are given as examples in the FAO Annex 1 their inclusion as VME has been accepted without the need for further scientific evaluation.

Some of the taxa listed by FAO do not form such clearly identifiable units (i.e. reefs) and cannot be remotely sensed; the challenge for those becomes defining the **density** at which they can be considered "coral forests" or critical components of ecosystems. The FAO guidelines 2009 for identification of VMEs do not provide guidance as to what constitutes an ecosystem. They do specify that "merely detecting the presence of an element itself is not sufficient to identify a VME" (FAO, 2009).

NAFO sought scientific advice to identify "significant concentrations" of VME coral and sponges within its fishing footprint on Flemish Cap and the southeast Grand Banks. The NAFO WGEAFM 2008a reviewed the research vessel catch distributions of the VME coral taxa they had previously identified and noted that for sea pens and gorgonian corals the research vessel catch distributions were highly skewed towards large numbers of small catches and a few very large catches, with no intermediate catches. The SPRFMO also noted this same bycatch distribution for their VME taxa from commercial vessels (Penney *et al*., 2008, Parker *et al*., 2009). They used bycatch weights (not corrected for tow duration) of each taxon observed in the catches of sets which took at least some coral and/or sponge from deeper than 200 m during the period 1998–2002 (except 1998–2007 for gorgonians and alcyonaceans for which data were scarce). There were 1603 such observed sets (305 high seas, 1298 EEZ), representing about 5% of all deep-water trawl tows in the period.

Both groups recognized that the very large catches were in some way significant but were **unable to provide a biological basis for choosing one cut-off point over another**. NAFO chose the 90% and 97.5% quantiles of the catch distribution for large gorgonians and sea pens respectively (NAFO 2008b), while the SPRFMO chose the median value (Parker *et al*., 2009). The two organizations used these thresholds in *very* different ways. The SPRFMO used the median of the catch distribution in their determination of encounter thresholds (see below) whereas NAFO Scientific Council only used the values to locate the large aggregations of corals and the sponge grounds. NAFO Fisheries Commission then proceeded to close those areas to bottom fishing as interim measures while NAFO scientists launched an international research programme (NEREIDA) led by Spain and involving *in situ* camera surveys, multibeam bathymetric surveys, boxcore and dredge samples (2009–2010) to validate the research vessel data.

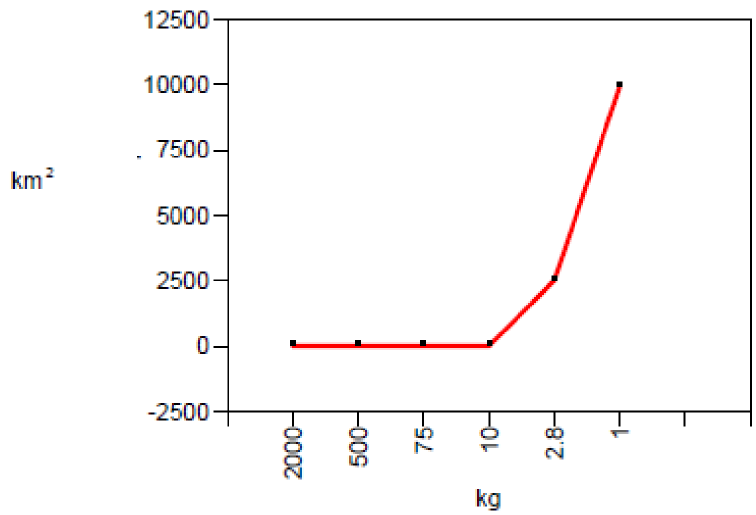

Figure 1. A graph showing the constant area occupied by catches greater than 10 kg with an exponential increase at smaller weight categories from an area on Sackville Spur in the NAFO Regulatory Area. In this example 10 kg would be the catch weight threshold used to identify significant concentrations of the organisms (from Kenchington *et al*., 2009).

NAFO scientists considered further the need for providing a biological basis for identifying “significant concentrations” and felt that a measure of “habitat area” or “patch size” would link the spatial and density properties of their data (NAFO 2009a). Patch size and patch edges are known to influence ecological processes in marine ecosystems with some species associated with edges, and others with the core area, that is, the area unaffected by the edges of the patch (e.g. Murphy *et al*., 2010; Smith *et al*., 2010). Increasing size increases both aspects of the habitat. In coral reef systems, reef size and biodiversity are also related. This development came with the consideration of the request to identify significant concentrations of sponges, and after the advice for the corals was tabled.

Spatial aggregation of large catches was first noted when the “significant concentrations” of sea pens and large gorgonians as defined above were plotted on a map. The locations of the significant coral catches were highly aggregated (NAFO 2008a).

Sponges also form highly aggregated distributions known as sponge grounds. Kenchington *et al*., 2009 formalized a process whereby the area encompassing nearby (in the NAFO context within 25 km of each other) catches of similar weight is used to determine the weight threshold distinguishing catches from the sponge grounds (defined as a VME; ICES 2009) and those of the broader distribution of individual sponges outside the sponge grounds (not considered VME; ICES 2009). This threshold is visualized by dividing the data into weight bins and comparing the area encompassing those catches with that produced by successively lower weight classes (Figure 1). Typically the largest catches demonstrate little increase in area as they define the sponge grounds. The weight class below that which produces a marked increase in area (relative per cent increase) is viewed as the weight threshold for identification of the sponge ground. The use of spatial analyses introduces a biological property (habitat area/patch size) to the decision making process, whereas the selection of quantiles used for the coral was essentially a management decision (NAFO 2008a; Parker *et al*., 2009; Kenchington *et al*., 2009; NAFO 2009). Further, by constructing a model using ArcGIS tools, the determination of weight thresholds based on spatial analyses could be automated (Kenchington *et al*., 2009), thereby reducing the subjectivity of the approach. This method has since been applied by NAFO to sea pens, with an analysis of large gorgonian corals to follow.

This approach works very well where there is good spatial coverage of the data (as is the case for the NAFO NRA), and when the VME taxa are highly aggregated. Of the VME taxa in the NRA sea pen "fields", sponge "grounds" and coral "forests" all were amenable to this approach. Black corals were not. They are relatively rare in the NRA and occur as isolated individuals. For the black coral, NAFO mapped all records of occurrence from the research vessel data and included those areas as potential habitat in their recent coral closures (NAFO 2009b).

Another method for identifying the potential habitat of VME taxa where the taxa are relatively rare and non-aggregating (such as black coral in the NRA), or where there is little benthic data, also involves spatial analyses. Habitat suitability maps have been developed for a number of species and these can be used to assist managers in identifying potential habitat and to assist scientists in planning research programmes aimed at obtaining information on the mapped species. Andrew Davies (Bangor University, UK), John Guinotte and Jeff Ardron (Marine Conservation Biology Institute, Bellevue, WA, USA), provided WGDEC with a case study on the use of this method (see Appendix 2, below).

Science used in assessing the "Encounter Clause"

Gianni, 2009 conducted a survey of global responses to Resolution 61/105 and identified RFMO/As and nations that have developed encounter protocols to address impacts on VMEs. All involve the use of "threshold" values to indicate an encounter with a VME, a move-away distance, and various rules on when a vessel or other vessels in the area can return to the location, some dependent on whether the area is a "new" or "existing" fishing area. None of the current thresholds or move-away distances are scientifically based, although NAFO has put this question to its Scientific Council which meets in June 2010. The SPRFMO used the median value of a commercial catch distribution (not corrected for tow duration) as a basis of their encounter thresholds (Parker *et al*., 2009) but as discussed previously, this selection had no scientific underpinning. NAFO 2009b, in the absence of scientific advice, attempted to scale up research vessel catches used to identify significant concentrations of corals and sponges to commercial catches, but this also had no science base, as was recognized in their report.

The usefulness of such protocols to protect benthic VMEs is highly debatable. In all existing encounter protocols designed to avoid impacts on VME, it has been assumed that encounter events are adequately indicated by the presence of VME organisms among the bycatch from a commercial fishing set. There have been no tests of that assumption during the development of any of the protocols, despite widespread recognition that much epibenthos can be damaged on the seabed without remnants being brought to the surface. Conversely, while the presence of VME organisms among the bycatch must indicate that they were present on the seabed, it does not necessarily demonstrate the presence of VME and, to date, no correlation has been demonstrated between the quantities brought to the surface and those in the path of the gear. Further, once an area has been identified it is not going to move, therefore any protocols which allow continued fishing in the area are highly likely to cause SAI to VMEs.

Science could provide *local* advice on the move-away distance by incorporating knowledge of the patch size of the VMEs and their physical distribution (e.g. depth limits) or determined through using the habitat suitability maps described above. Kenchington *et al.*, 2010 have developed a GIS-based simulation model to help managers gauge the impact of various management decisions, including spatial closures and encounter provisions, associated with sponge catches in the NRA. This model or others like it could be adapted to incorporate retention efficiencies, indirect effects of trawling and life-history characteristics to address issues of SAI.

Summary of scientific work to date

Most of the science underpinning the response of RFMO/As to UNGA Res. 61/105 has been in the review of taxa which meet the FAO guidelines for VMEs. To date this has focused mostly on corals and sponges, although there has been recognition by many groups that other benthic taxa fit the criteria. For many of those taxa the data are just not available to allow further assessment. Research on the spatial distribution of VMEs, underpinning the selection of areas for closure, has also advanced through the use of remote sensing technology (multibeam, seismic) combined with trawl survey data which has been particularly useful in detecting *Lophelia pertusa* reefs in the NEAFC area. Some scientific research has gone towards identifying coral forests, sea pen fields and sponge grounds that cannot be remotely sensed. NAFO has used spatial analysis to identify high concentrations of those taxa. This approach worked well for the taxa in the area in which it was applied, but it was recognized that the technique does not apply to non-aggregating taxa such as black coral. In both the NAFO and NEAFC examples, follow-up research was conducted to validate/refine initial hypotheses, whether determined from spatial analyses or remote sensing. Those RFMOs have thus far been willing to adjust the areas recommended for closure based on updated scientific advice.

Considerations for future improvements

The need for biogeographic differentiation

The North Atlantic deep-sea area encompassed by NAFO and NEAFC is not one biogeographic unit, but probably consists of at least three provinces at bathyal depths (UNESCO 2009). It is appropriate to consider the bathyal (300–3500 m) because most deep-sea faunal biomass occurs shallower than 2000 m. While biological data are still being accumulated to analyse these provinces, it is clear that the major VME indicator species in each province are different and can be summarized as follows:

1) Arctic Province, encompassing the Arctic Basin and adjacent seas and outflows of polar water such as on the East Greenland Shelf and Greenland Sea down to Denmark Strait. Characterized by very cold temperatures, generally below 0°C and high seasonal primary production.

2) The Northern North Atlantic Province (corresponding to the North Atlantic Drift), encompassing the continental slopes of eastern North America, Greenland south of Denmark Strait, Iceland-Faroes Ridge, and Europe north to Svalbard, including the Rockall Trough, and perhaps the Reykjanes Ridge. VME indicators here are primarily large *Geodia* sponges, *Lophelia* reefs, and dense aggregations of octocorals in the genera *Acanthogorgia*, *Paragorgia*, and *Primnoa*.

3) The North Atlantic Province, encompassing the Mid-Atlantic Ridge from the Reykjanes Ridge south to the Azores region (and perhaps even further south), the seamounts in both the eastern and western basins, and the continental slopes of eastern North America and Europe south of the Northern North Atlantic Province to the limits of the OSPAR region. In the eastern Atlantic this province would include the bathyal fauna of the Bay of Biscay.

Exact boundaries for these provinces were not considered as established in the UNESCO 2009 report, so it is possible that assessments of VMEs will need to change as more information becomes available. However, it is likely that the dominant VME indicator species and biological communities in these three biogeographic units will be different, and therefore management rules will need to be tailored for each unit, while sharing a common approach. For example, large demosponge concentrations are best known from the Northern North Atlantic (from the continental slopes of Labrador to Norway) and Arctic Provinces (e.g. Klitgaard and Tendal, 2004). The North Atlantic Province, encompassing the mid-ocean ridges and seamounts, are characterized by a wide diversity of delicate, foliose, but not massive glass sponges, black corals and octocorals that may be tall or short, but always fragile and with low biomass, with scleractinians being a less dominant component of the fauna (Mortensen *et al.*, 2008, see web pages for the Mountains in the Sea and Deep Atlantic Stepping Stones expeditions at www.oceanexplorer.noaa.gov).

Differentiation by taxonomic group

The move-on rules, as currently constituted, may only afford 'damage limitation' to the massive reef-forming corals such as *Madrepora* sp. and *Lophelia* sp., the sponge fields of larger representatives of the genus *Geodia* and possibly the giant gorgonians of the genera *Paragorgia* and *Primnoa.* The move-on rules cannot be expected to afford damage limitation to smaller corals, such as most gorgonians, bamboo corals, black corals or the smaller more fragile species of sponges (Auster *et al.*, in press). This is because these species will almost certainly rarely be encountered in sufficient quantities to exceed 100 kg, or by the time they are brought aboard, will not be in such quantities due to their fragile nature. It is difficult to estimate what would be an appropriate threshold for such species, but even 10 kg in weight could represent 100s of individuals. Typical values for bycatch in research trawls are less than 1 kg. In New Zealand the bycatch threshold could be as low as 1 kg (Penny *et al.*, 2009).

Conclusions and recommendations

1) **Scientific basis**: To date, there appears to have been no scientific base for the commercial encounter thresholds or move-away distances in use. In many cases this is because of a lack of commercial bycatch data and/or

lack of information on the catch efficiency of the gear and of the in situ density of the VME component.

2) **Defensibility of providing numbers**: Given the complexity of the issue as it relates to sessile/sedentary benthic taxa, it may be more practical to deal with encounter protocols using risk-based frameworks, rather than attempt to produce defensible numbers which would have to be species, area, gear, and possibly seasonally based.

3) **Risk-based frameworks** should be developed, and could use the habitat suitability maps detailed in Appendix 2, below, or through zoning according to past fishing history as applied by the SPRFMO.

4) **Other VME species, especially fish**: RFMOs have to date directed their attention primarily to coral and sponges. Commercial fish have been managed through other provisions but a review of commercial fish bycatch in the North Atlantic against the FAO criteria would be useful to determine the VME status of non-commercial fish species.

5) **The threshold quantities** of VMEs triggering the encounter rule as a minimum should be differentiated by:

- biogeographic region,
- taxonomic groups (requiring a taxonomic guide of deep-water corals), and
- geartype and configuration.

6) **Full observer coverage** is recommended for all bottom fisheries.

7) **A real-time closure system** should be implemented, supplementing the current system of accumulating evidence over longer time-scales. Such a system would treat fairly all fishers, rather than penalizing just those who report a VME encounter.

Appendix 1: Assessing where VMEs are known or likely to occur

Rationale

Bycatch is no indicator for damage on the ground

The bycatch in a commercial trawl is not an appropriate basis for estimating the damage occurring on the seabed. The only method available to estimate the actual damage on the ground is by visual observation, as only an unknown fraction of the damaged organisms will be retained in the net or on the hooks of the fishing gear. Freese *et al.*, 1999 found that 67 % of the sponges occurring in the path of a single trawl were damaged, and detected no signs of recovery a year later (Freese, 2001). Heifetz *et al.*, 2009 encountered damaged fauna in 88% of their video transects covering 65 000 m^2 within the fishery footprint in the Aleutian Archipelago and 40–50 % of the sponges encountered in 100–400 m depth were damaged.

The retention efficiency of commercial fishing gear has to be considered very low and in particular preselected in terms of predominance of large, less fragile, abrasion-resistant organisms and pieces thereof (Auster *et al.*, in review). Freese *et al.*, 1999 quantified the catch efficiency of trawl-caught invertebrates by comparing density estimates based on area swept by the trawl with density estimates from seabed imagery at deep-water sites (206–274 m depth) off southeast Alaska. The trawl caught less than 1% of the asteroids, echinoids and molluscs and 4.6% of the holothurians, compared to the visual observations, and octocorals and sponges could not even be quantified in the bycatch, which the authors assumed to be because of the size and fragility of specimens encountered. Also Penney *et al.*, 2009 argue that bottom trawls do not retain invertebrate taxa efficiently, and report seamount trawls taken from areas with dense and diverse structural fauna which arrive on deck with little or no coral bycatch. Auster *et al.*, in review calculated the consequences of different gear configuration and catch efficiencies for retaining invertebrates on the biomass of corals and sponges impacted by that gear: Using the preliminary 2008 threshold values of 100 kg of live coral or 1000 kg of sponge that requires vessels to move on in the NAFO and NEAFC regions of the North Atlantic as reference points, Auster *et al.*, in review predict that at a 10% catch efficiency level for both corals and sponges, 1000 kg of coral and 10 000 kg of sponges are actually impacted. At 1% efficiency, a level more in accordance with the study by Freese *et al.*, 1999, 10 000 kg of coral or 100 000 kg of sponge would be impacted. Also the configuration of the fishing gear is highly relevant: Gear with a net opening two-thirds as wide as another with a 120 m opening requires a 50% higher invertebrate biomass per unit area to trigger the move-on provision - or impact larger areas.

Auster *et al.* consider it therefore essential to determine the move-on provisions on the basis of gear configuration, catch efficiency, tow time and distribution of indicator taxa, such as already done by CCAMLR conservation measures. However, Parker *et al.*, 2009 did not find a correlation between tow duration and benthic invertebrate bycatch. This is likely to be an expression of the patchiness of invertebrate occurrence resulting in short tows to potentially cause the same damage as long tows.

Move-on rules ineffective when used alone

The current rules adopted by fisheries management organizations requires vessels to move 2 nm or 5 nm away from the likely position of the encounter (NEAFC) or the end of the trawl path (NAFO) which may lead to fishing in potentially previously unfished areas. Demersal fishing effort concentrates in areas of complex topography, mixed sediments and the upper depth strata such as on the slopes of the continental margins, canyons, seamounts and offshore banks. Therefore, moving a mile from a previous trawl track will not prevent significant adverse impacts from occurring but rather run the risk of spreading the impacts to a wider area. Auster *et al*., in review calculated that the relatively flat trawlable summits of three Northwest Atlantic seamounts could be completely trawled with between 32 and 61 tows, respectively, when applying the current NAFO move-on rules.

A proposal for a new, non-destructive, approach to dealing with vulnerable marine ecosystems

The damage caused by deep-sea bottom fishing activities to marine habitats and species, in particular VME indicators, is likely to remain unrecovered for decades to centuries. Reactionary management strategies such as the "encounter clauses" and "move-on rules" are of limited benefit to prevent significant adverse impacts because they still allow damage to occur which will gradually degrade ecosystems over time. We recommend that these strategies only be applied under very specific circumstances within a wider suite of predictive management plans that identify areas of high risk to VMEs. In order to ensure longer term sustainability of VMEs, a more informed approach needs to be adopted, one which uses knowledge of previous fishing effort, biogeography, and habitat suitability modelling predictions for the distribution of vulnerable species.

The approach suggested here follows the requirements of the 2009 UNGA Res. 64/72 §119 (b), which was passed after considering progress made to date regarding resolution 61/105, noted above:

> "Conduct further marine scientific research and use the best scientific and technical information available to identify where vulnerable marine ecosystems are known to occur *or are likely to occur* [emphasis added] and adopt conservation and management measures to prevent significant adverse impacts on such ecosystems consistent with the Guidelines, or close such areas to bottom fishing until conservation and management measures have been established, as called for in paragraph 83 (c) of its resolution 61/105"

After much discussion, the WGDEC decided that because the current encounter and move-on rules would still permit pervasive and cumulative destruction of VMEs in the NAFO and NEAFC management areas, a new management strategy needs to be developed. This new approach is based on the following principles:

1) Bottom habitats at fishable depths within the North Atlantic are not inhabited by one fauna that ranges over the whole region, thus there can be no uniform "rule";

2) exploratory fishing with bottom contact gear in the deep sea is unacceptable because of the long-term damage such gear does to bottom habitats;

3) exploratory fishing with bottom contact gear is unnecessary because modern data management tools and computer modelling techniques can provide a mechanism for making predictions about where vulnerable marine ecosystems are likely to be present; and

4) the burden of proof regarding whether any particular area of the seabed can be fished with bottom contact gear without causing damage to VMEs must reside with the entity proposing to do the fishing.

These principles put fishing on a more equal footing with other industries who extract resources from the ocean and whose activities might have adverse or harmful effects on resident organisms.

Models and VME species

It is now possible, using the latest algorithms and detailed oceanographic/environmental data to model the habitat suitability of large areas of ocean for some VME species, such as the stony coral, *Lophelia pertusa*. An example of such a model is provided by Andrew Davies, John Guinotte and Jeff Ardron, unpublished data as detailed in Appendix 2, below.

Some of the areas where the model predicts suitable habitats for VMEs to occur do not currently contain good examples of VMEs. In some instances, this discrepancy corresponds to high demersal trawling effort and it may be that this activity has historically removed or damaged any VMEs that were present.

High risk areas

Models of habitat suitability for VME species could be used as a tool to identify areas of high risk to bottom trawling. It is recommended that any area where the model suggests a greater than 50% probability of encounter of VME species should not be fished unless and until it can be demonstrated by non-destructive means that no VMEs are present.

Low risk areas

Further, on the basis of either logbook data, or more preferably, data on fishing effort from Vessel Monitoring Systems (VMS), it is possible to know the areas where there has been much bottom fishing effort. These areas have been mapped for much of the NEAFC area. We also know from many studies that heavily fished areas will already have the VME species removed or severely damaged. Because these areas are repeatedly fished, re-growth of VME species is very unlikely.

Regional spatial planning

Taking all these sources of information into account, a map of the seabed in the NAFO and NEAFC areas could be produced that would delineate areas.

1) where the bottom is considered to be degraded and so can continue to be fished with bottom tending gear ("black zone") while still following the encounter protocols (see above ToR), and
2) areas where bottom gear may not be used ("white zone").
3) The remainder of the area would be treated as a "grey zone" subject to a precautionary approach with the requirement that an environmental impact assessment be conducted before any fishing with bottom gear is permitted. That is, it would be incumbent upon the proponents to demonstrate, through the use of bottom cameras or other non-destructive methods, that the areas in which an expansion of fishing is proposed do not contain any VMEs.

It is therefore recommended that NAFO and NEAFC augment their encounter and move-on rules with the following course of action and follow-on rules:

1) The management areas for bottom fishing activities be delimited into management units based on bathyal biogeographic patterns. These are: 1) Arctic Province, 2) Northern North Atlantic Province, and 3) North Atlantic Province, using current boundaries as delimited in the GOODS report (UNESCO 2009).

2) Within each biogeographic unit a map of all known fishing areas where bottom contact gear has been used will be prepared. These areas should not include areas where single or occasional trawl hauls were made, but should include areas that have been historically fished *regularly*. Resolution scale of these maps should be the best available, preferably at 1 km x 1 km resolution when available, but could be as coarse as 10 km x 10 km. These maps will determine the allowable "black zone" bottom fishing areas. Even within these areas, however, there is the chance that some VME species will exist. It is recommended that encounter rules also be used in these areas.

3) Within each biogeographic unit maps demonstrating predicted occurrences or high habitat suitability (defined as >50% probability of occurrence) for cold water scleractinians, black coral, octocorals, sponges, or other VME species be prepared. These maps will be used to delimit areas where no bottom contact gear can be used until or unless it is subsequently demonstrated through non-destructive surveys (i.e. using methods other than bottom trawls or other bottom contact fishing gear) that no VMEs will be encountered. These will be the "white zone", no bottom fishing areas. Resolution of these maps should be at 1 km x 1 km if at all possible.

4) If an entity proponent would like to fish in an area not encompassed in paragraphs 1 or 2 above (i.e. the "grey" zone), it will be incumbent on that proponent to demonstrate, using bottom cameras or other non-destructive devices, that the area to be fished does not harbour VME species. As an additional incentive to do detailed mapping, perhaps the RFMO/A could grant to that fishing entity exclusive right to fish some or all of the area surveyed if no VMEs were found in the area. Resolution of these areas should be as fine as possible but should not be any coarser than 10 km x 10 km. If bottom contact gear is used in an area deemed open to fishing, and VME species are subsequently discovered to be present, all fishing in that 10 km x 10 km block will cease immediately.

5) Information gathered on VME distributions over time as a result of the other management measures should feedback into refining distribution maps on VMEs and thus allow predictive models to be refined and improved.

Appendix 2: A case study Illustrating the Use of Habitat Suitability Maps: predicting *Scleractinian* cold-water coral distribution in the North East Atlantic

Cold-water corals are ubiquitous throughout the world's oceans (Roberts *et al*., 2006). However, repeated surveys and predictive modelling in the North East Atlantic suggest that this region is particularly important for the scleractinian coral *Lophelia pertusa* (Davies *et al*., 2008). In this study, we build upon earlier regional scale modelling by Davies *et al*., 2008 by integrating higher resolution multibeam bathymetry into a North East Atlantic study area.

Methods

Multibeam bathymetry was collected from several sources (Figure 2). However, there were significant difficulties in acquiring some data due to pending publications and other restrictions placed by researchers that had previously published the data. Negotiations are ongoing to acquire data from the UK (Rockall Bank) and Spain (Hatton Bank).

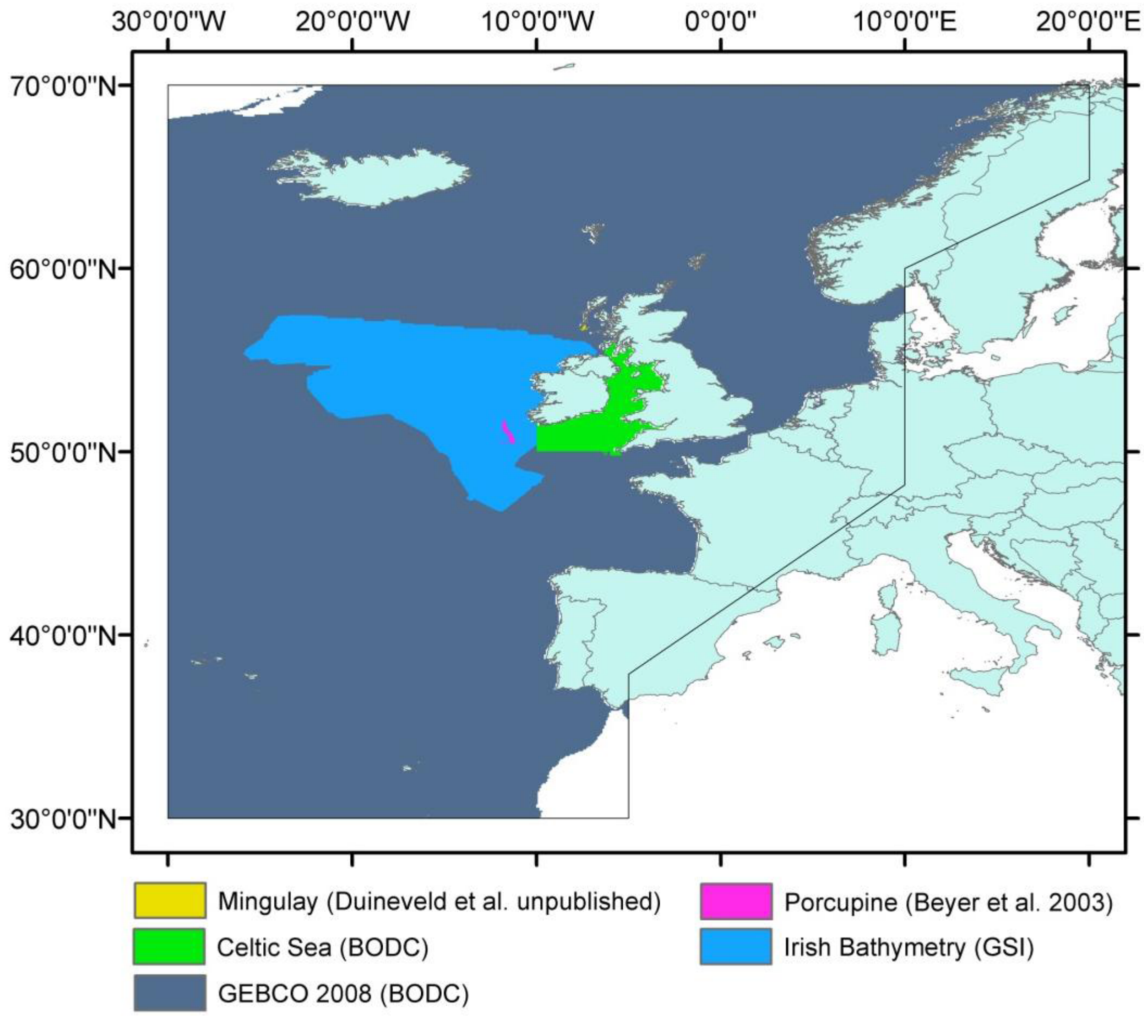

Figure 2. The extents of bathymetries used in this study.

Environmental variables were created the latest global bathymetric data, available at 30 arc second resolution (GEBCO08) created by the Intergovernmental Oceanographic Commission (IOC) and the International Hydrographic Organization (IHO). This underlying data were supplemented by several areas of higher-resolution bathymetry including data from the Geological Survey of Ireland (Irish Bathymetry), the Celtic Sea dataset from BODC, a digital terrain model of the Porcupine Seabight (Beyer *et al.*, 2003) and multibeam bathymetry of the Mingulay Reef Complex (data from Duineveld *et al.*, unpublished, but see Roberts *et al.*, 2009 for an overview of Mingulay). This bathymetry was merged to create a continuous map over the North East Atlantic at approximately 750 m x 750 m resolution (0.005° cell resolution in WGS84 projection).

To create environmental maps, we clipped vertically oceanographic gridded data from sources such as World Ocean Atlas to areas of available seabed at each standardized depth interval. We assumed that conditions at these depth layers were indicative of the conditions that would be found in the area. Several relevant environmental layers were created, including omega aragonite (Orr *et al.*, 2005), dissolved oxygen (Garcia *et al.*, 2006a), surface productivity (MODIS L3 Annual SMI), particle flux (Lutz *et al.*, 2007), salinity (Boyer *et al.*, 2005), silicate (Garcia *et al.*, 2006b) and temperature (Boyer *et al.*, 2005). From the bathymetry, several variables were created at different cell resolutions. Rugosity was calculated using the Benthic Terrain Modeller and slope was calculated using ArcGIS Spatial Analyst. Both variables were calculated in Mercator projection at neighbourhood resolutions of 5 x 5 km, 10 x 10 km, 20 x 20 km and 50 x 50 km.

The habitat suitability model was generated using Maxent software 3.3.2 (Phillips *et al.*, 2006; http://www.cs.princeton.edu/~schapire/maxent/). Default model parameters were used (convergence threshold of 10–5, a maximum iteration value of 1000 and automatic regularization with a value of 10–4); these default settings have been demonstrated to achieve good performance (Phillips and Dudik, 2008). The habitat suitability map was generated by calculating a raw probability value for each grid cell, such that the total of all cell probabilities summed to one. This value was then scaled logistically, resulting in a relative habitat-suitability value ranging from zero to one. The logistic habitat suitability values can be interpreted as an estimate of the probability of presence under a similar level of sampling effort as that used to obtain the known occurrence data (Phillips and Dudik, 2008). We split the presence data into 70% training and 30% test data for model validation purposes, with 100 % of presence points used to develop the final output maps.

In total, 803 presence points of *Lophelia pertusa* were used in analysis and were obtained from sources published in journals, cruise reports and other reports. The comparison data for each environmental variable was created using 10 000 randomly distributed points.

Results

The model was based on several key variables that were selected *a priori* (before we ran the model; Table 1). In the North East Atlantic, the jackknife test of variable importance and the relative contributions of environmental variables both indicate that omega aragonite is the most important variable in determining the distribution of *L. pertusa* (Table 1). Salinity and temperature are also both important in driving the distribution of *Lophelia pertusa* in the North East Atlantic supporting earlier, coarser resolution modelling (Davies *et al.*, 2008).

Splitting the presence dataset into training and validation sets can be used to validate the accuracy of the model produced using the Maxent calculation. The output demonstrated the validation AUC to be 0.947 (values closer to 1 are more accurate models, closer to 0.5 are closer to a random prediction). This indicates that our model performs well, based on the majority of validation points. The region as a whole offers suitable habitat for *L. pertusa*, which is by far the most studied coral in the region. Surprisingly there are only very few records of other scleractinian corals in the region. Suitable habitat for *L. pertusa* is largely restricted to the continental slope with less suitable habitats modelled on seamounts (Figures 3–8).

Table 1. Variable contributions for the Maxent model (higher percentages indicate a stronger relationship with a variable).

Variable	Contribution
Omega aragonite	45.1 %
Salinity	19.3 %
Temperature	14.0 %
Slope (5 km)	5.7 %
Dissolved oxygen	5.7 %
Rugosity (5 km)	4.8 %
Silicate	4.7 %
Depth	0.8 %

Important considerations

There are several limitations must be considered when interpreting habitat suitability maps. Our improved approach addresses many issues with scale, resolution and extent. But the most critical limitation remains, is the fact that predictive maps only demonstrate potentially suitable habitat. Higher values of suitability indicate the likelihood that a species may be found in a given area, but this does not mean that the species is actually present within that area. There may remain barriers to colonization, such as biotic interactions in the form of competitive exclusion or dispersal pathways that are blocked by biogeographic barriers (Guisan and Zimmermann, 2000).

For regional scale modelling such as this, the value of large areas of highly accurate bathymetry is great. However, there are still hurdles to data-access, even after initial publication of data in peer-reviewed journals. One example that should be followed by many countries was by the Geological Survey of Ireland. Using funding acquired from the EU, Ireland recently used multibeam technology to survey vast areas of its exclusive economic zone and made the data freely available through the Internet, providing an incredibly valuable resource for scientists and researchers.

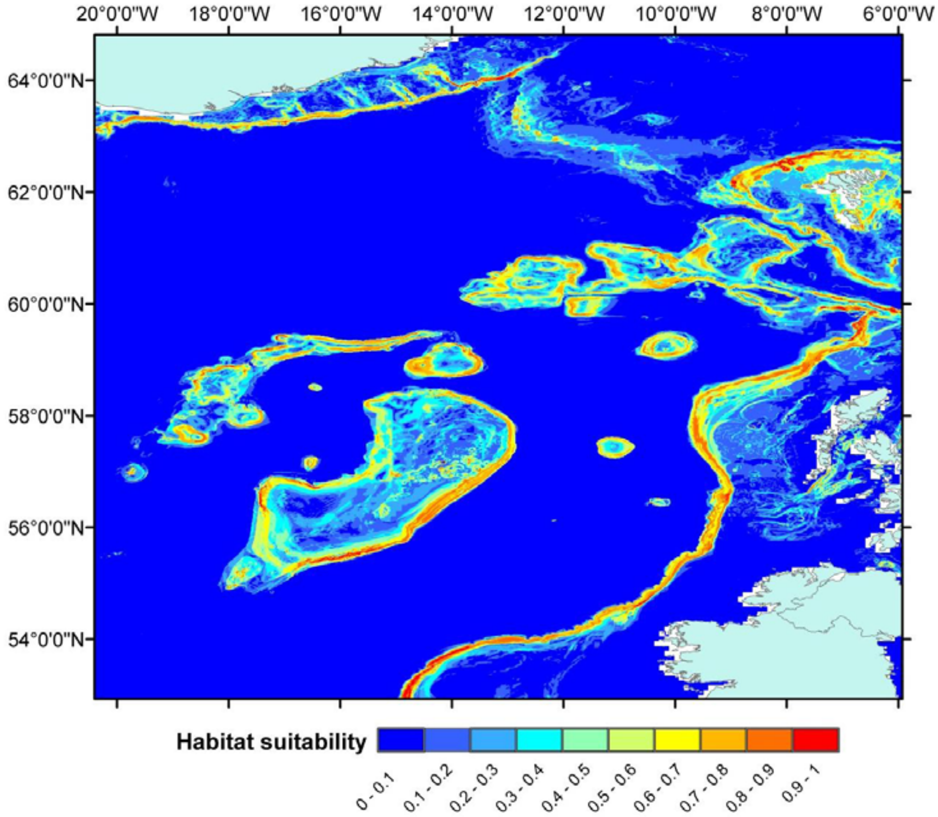

Figure 3. Predicted suitable habitat for *L. pertusa* on Rockall and Hatton Banks; warmer colours are more suitable.

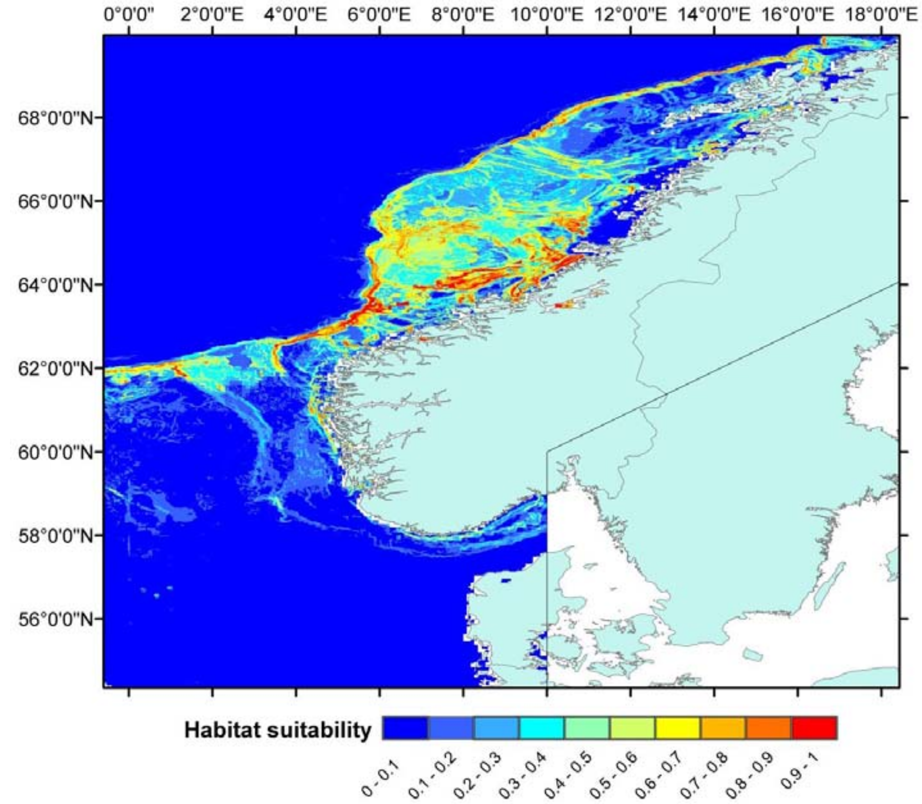

Figure 4. Predicted suitable habitat for *L. pertusa* on the Norwegian Shelf; warmer colours are more suitable.

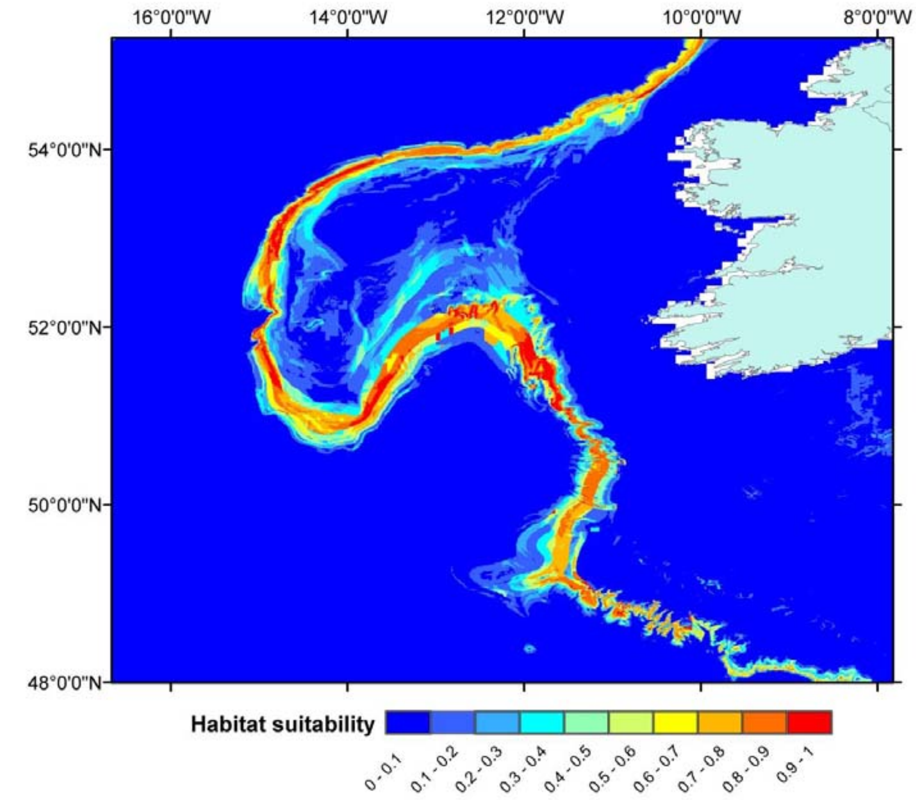

Figure 5. Predicted suitable habitat for *L. pertusa* on Porcupine Seabight; warmer colours are more suitable.

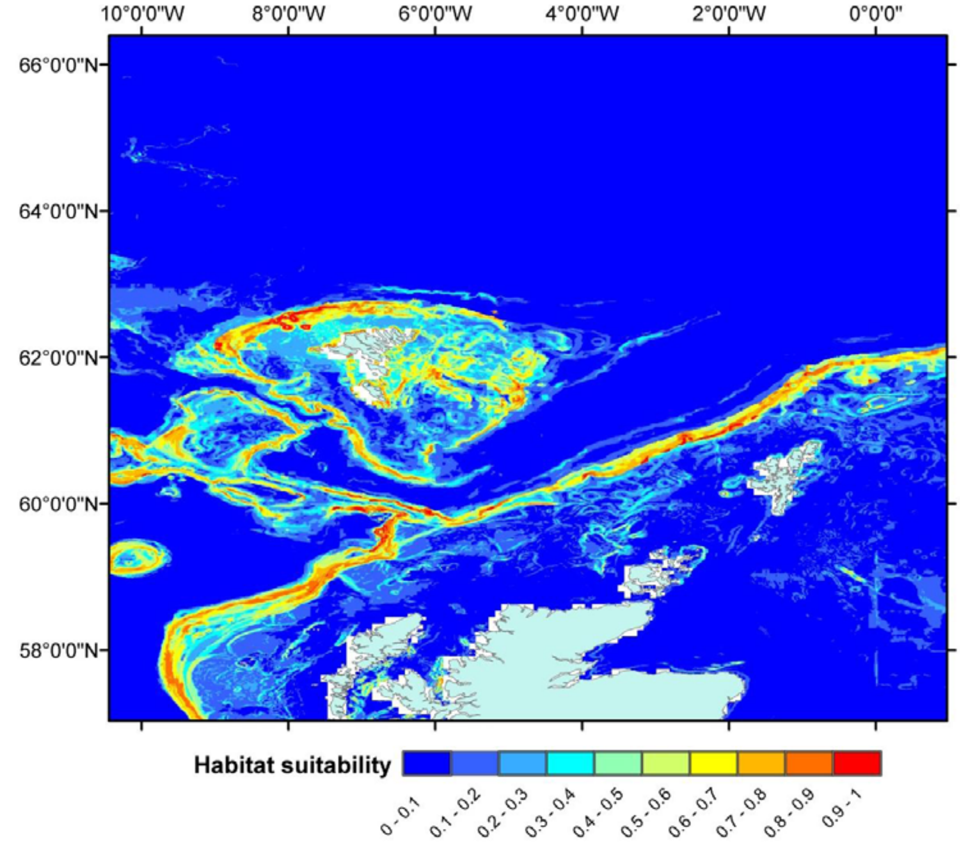

Figure 6. Predicted suitable habitat for *L. pertusa* around the Faroe Islands; warmer colours are more suitable.

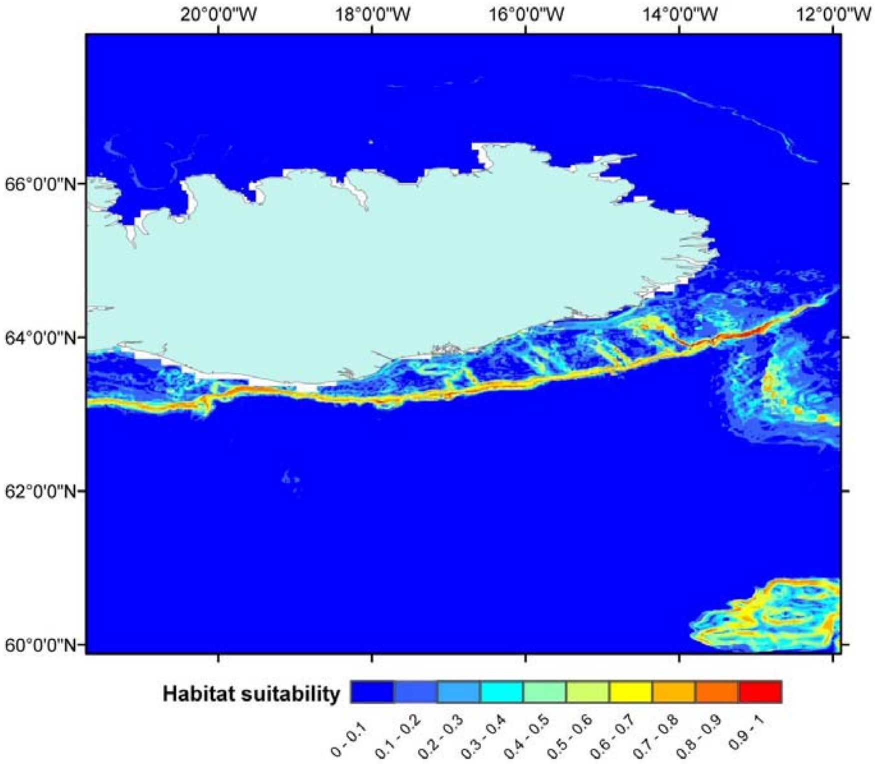

Figure 7. Predicted suitable habitat for *L. pertusa* around Iceland; warmer colours are more suitable.

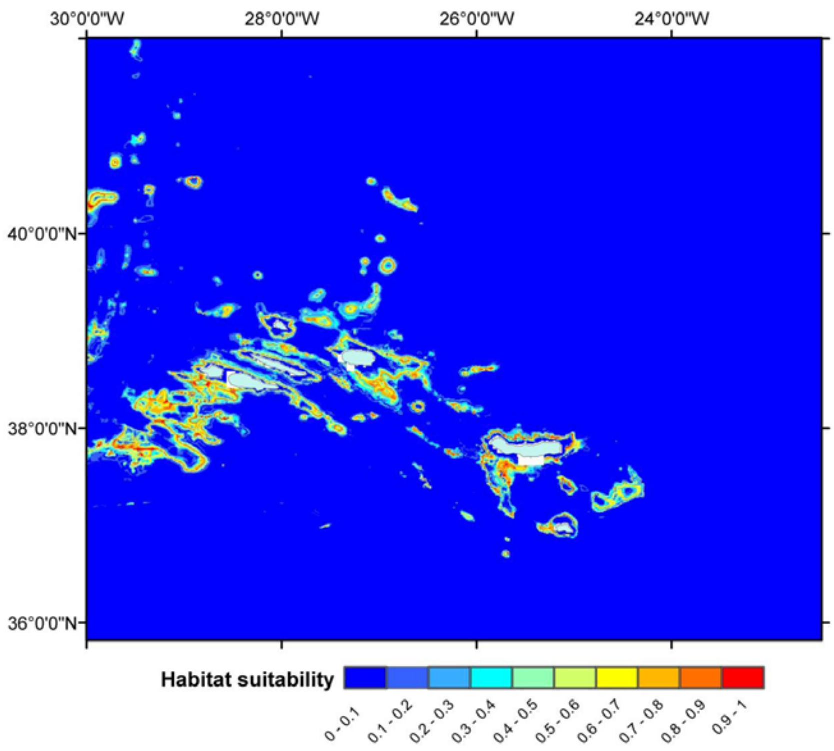

Figure 8. Predicted suitable habitat for *L. pertusa* around the Azores; warmer colours are more suitable.

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6 Impacts of human activities on cold-water corals and sponge aggregations

(OSPAR request 2010/5) - Provide advice on impacts of human activities on cold water corals and deep-sea sponge aggregations including: (a) total amounts and % of these habitats affected by human activity over the past decade, on a year by year basis, in the OSPAR Maritime Area; (b) specific sites within the Northeast Atlantic where records show that more than 100 kg of live coral of 1000 kg of live sponges have been have been trawled as a result of human activities in the past; (c) what is known about the status of coral reefs and sponge aggregations in these areas; (d) recovery rates of these species if and when damaged or removed; (e) possibilities for recreation of these habitats.

Introduction

There is no doubt that human activity has impacted coral reef and sponge habitats which are classed as vulnerable marine ecosystems (VMEs). Fishing by bottom trawl is probably the greatest threat facing coral and sponge grounds, but other fishing activities and aggregate, mineral and fossil fuel extraction all may detrimentally impact VMEs. This has been comprehensively documented by WGDEC over the years (ICES 2005, 2006, 2007, 2008, 2009) with additional recent academic reviews made by Freiwald and Roberts, 2005; Davies *et al*., 2007; Roberts *et al*., 2009. The extent to which VME's have been impacted by human activities has largely been descriptive and rather few quantitative estimates are available (Rogers *et al*., 2008).

Total amounts and % of these habitats affected by human activity over the past decade, on a year by year basis, in the OSPAR Maritime Area

It is impossible to give precise estimates for total amounts and percentage of VMEs impacted by human activity because the data on coral and sponge distribution is highly patchy and far from complete. Recent advances in predictive habitat modelling may allow comparisons of potential habitat with current distribution to assist in addressing this problem (Tittensor *et al*., 2009), but the output from such models is not yet available to WGDEC. Consequently there is no direct means of quantifying the impact of human activities on the VMEs over the past decade. It is, however, possible to assess the likelihood that VMEs have been impacted from information on patterns in fishing activity in areas where VME's are known to be present (Hall-Spencer *et al*., 2009).

The footprint of fishing in deep-water and offshore areas in the OSPAR area

The vast majority of bottom trawling is currently shallower than 1500 m. Because corals are known to occur as deep as 3800 m, there is a significant proportion of VME habitat in the OSPAR area that is out of reach of direct disturbance and thus represented undisturbed VMEs and habitat (Figure 1). However, the diversity and abundance of corals and sponges peaks between depths of 800–1500 m (Rogers *et al*., 2007) meaning that in fact the majority of those VMEs may be at risk of impact. The extent of fishing activity in the OSPAR deep-water and offshore areas has also been investigated using VMS data by WGDEC in the past (e.g. Hall-Spencer *et al*., 2009), although no complete 'footprint' of fishing activity is available due to data provision constraints. WGDEC had access to VMS data from the continental shelf west of the British Isles, northern Norwegian waters, the Bay of Biscay and the area beyond national jurisdiction that is regulated by NEAFC. There are some obvious gaps in the footprint (e.g. around Iceland) that reflect the fact that not all VMS data were available.

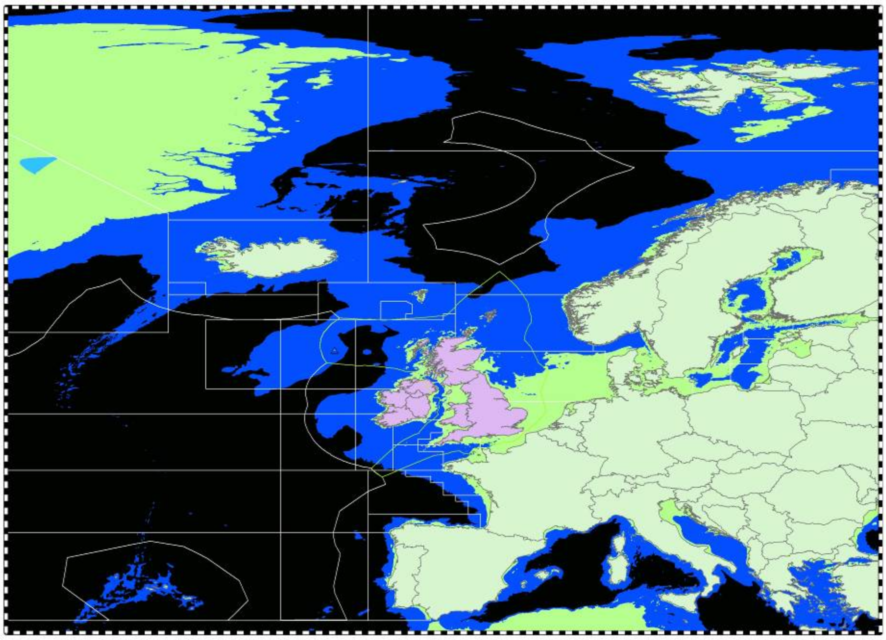

Figure 1. The blue shaded area represents seabed at depths less than 1500 m and thus potentially available to bottom trawling. The black area is that which is deeper than 1500 m and therefore beyond the reach of commercial bottom trawling.

Footprint of fishing in the NEAFC area

In the NEAFC regulated area, VMS data reveals several regions where vessels spent the most amount of time (Figure 2). Two major bottom-trawling fishing areas are apparent; Rockall Bank and Hatton Bank. Other areas of intense activity are not associated with bottom trawling, for example the area to the southwest of Iceland, the NW of Norway and on the MAR and Rejkyanes ridge most likely correspond to pelagic trawling. In the past more detailed analyses of these data have been undertaken and can be found in the reports of WGDEC 2008, 2009 and WGDEEP 2009.

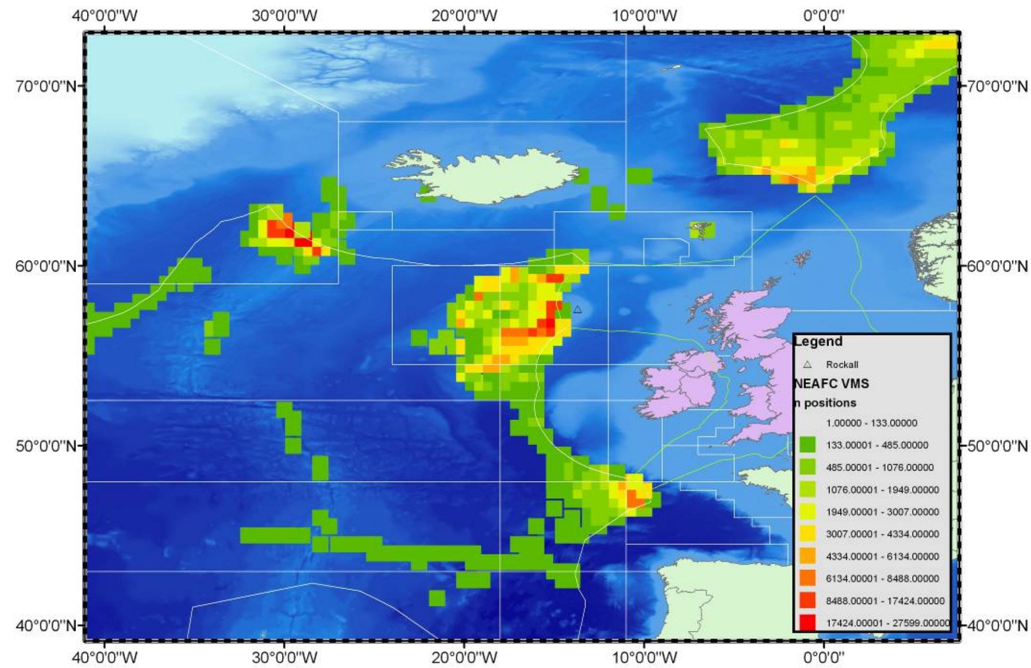

Figure 2. Footprint of fishing vessel activity in NEAFC regulatory region between years of 2002–2005. Note this is based on all VMS records and is reflective of total fishing activity (not only bottom trawling).

Footprint of bottom-trawling activity in EEZ waters (vessels that entered Scottish waters only)

Patterns of bottom-trawling activity inferred from VMS from vessels entering Scottish waters indicate most activity is focused along the continental shelf slope, on Rockall bank, around the Faroe Islands and an area to the south of the Porcupine bank (Figure 3). This data are reflective of bottom trawling at depths >300 m. Gear type information was available and the data were filtered by speed (see WGDEC 2009). Note this is only a subset of bottom trawling in the area as any vessels that did not enter Scottish waters are not included.

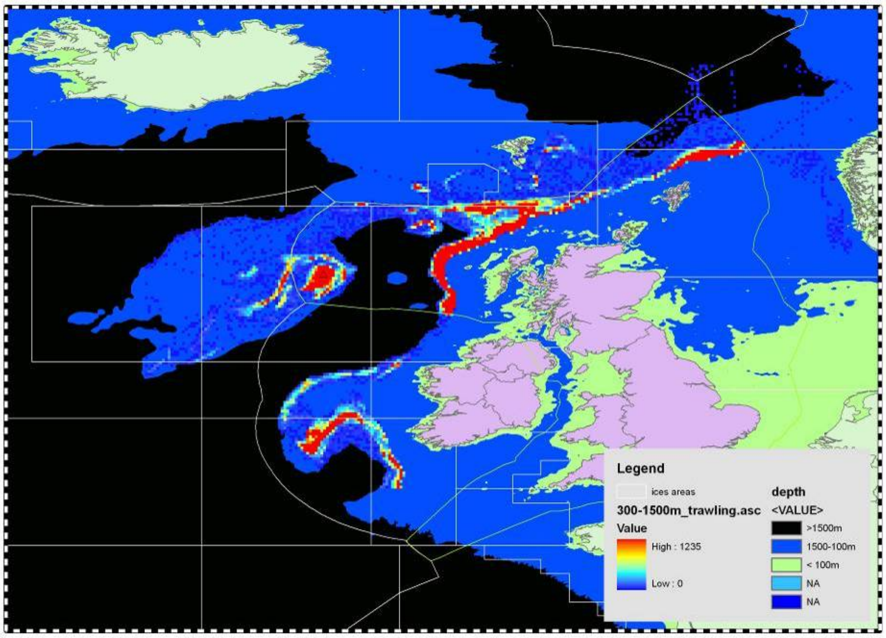

Figure 3. Footprint of bottom trawling of vessels entering Scottish waters in 2007–2008.

Footprint of fishing in the Bay of Biscay (French VMS)

In the Bay of Biscay most fishing effort is at depths less than 200 m, although there is some activity on the shelf break. As the slope is very steep in this region this fishing activity could be in waters deep enough to support coral reefs.

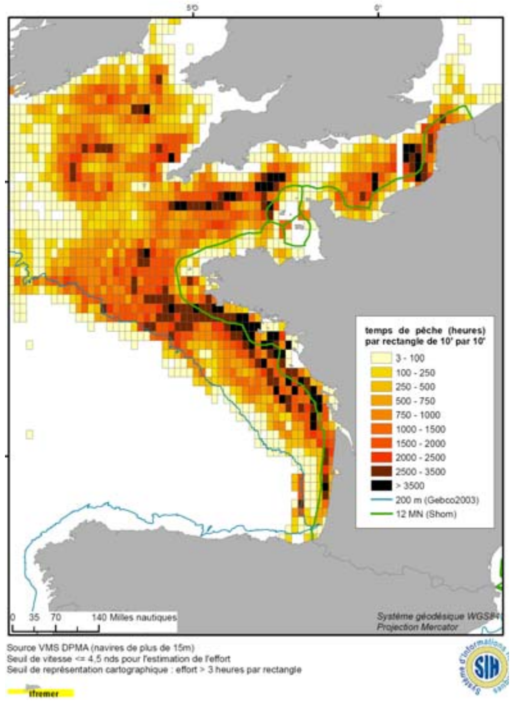

Figure 4. VMS data aggregated at 10′ per 10′ squares - Fishing effort of exclusive bottom trawlers belonging to the French fleet in the Bay of Biscay, Celtic Sea and English Channel.

Footprint of fishing in northern Norway

In northern Norway VMS data indicated fishing activity is concentrated along the shelf break reflecting the fishery for Greenland halibut (Figure 5). Data on trawl marks in the sediments have been quantified and when this is overlain with VMS data a strong spatial overlap is seen (Figure 5) suggesting VMS can be used effectively to assess seabed impact and likelihood that VMEs will be damaged if in the area.

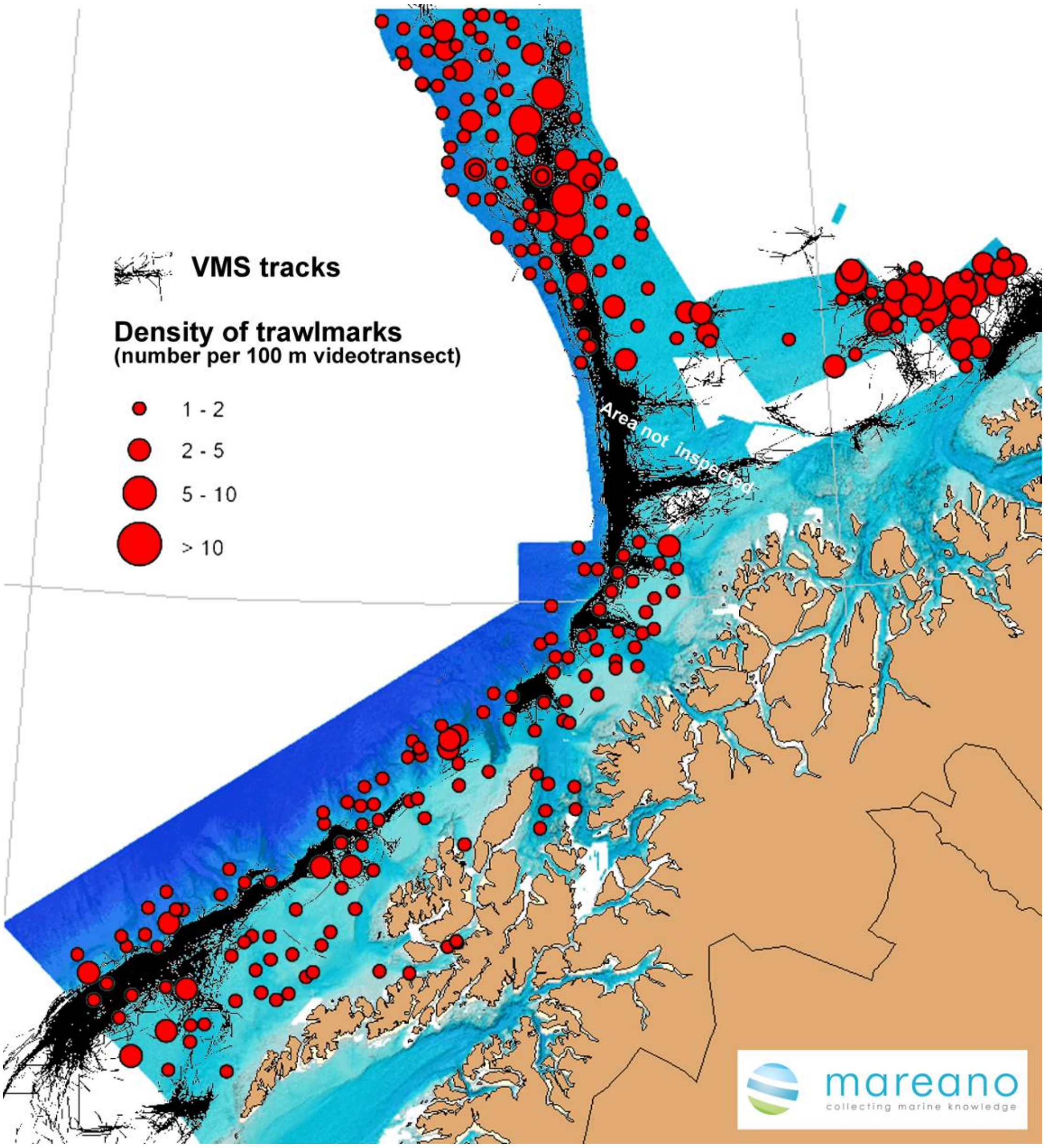

Figure 5. VMS tracks of Norwegian vessels in relation to observed trawl tarcks on the seabed (courtesy of Mareano project: www.mareano.no).

Throughout the OSPAR region it is likely that the majority of trawling impact to VMEs happened during the 1970s, 1980s and 1990s. Retired deep-sea fishermen from throughout Europe have stories of hauling up tonnes of coral in this period and at the end of last century Norway estimated that between 30–50% of its reefs had been impacted to some degree by bottom fishing (Ref). Over the entire OSPAR area, fishing effort has largely declined in offshore and deep-water areas over the past decade (ICES WGDEEP 2009). Furthermore efforts to protect cold-water coral habitats in the past decade (Norwegian waters, Hatton bank, Rockall, Porcupine slope and Darwin mounds) has likely further reduced the relative proportion of coral habitats being affected by human activity. While we have not put a figure on what proportion of VME's may have been impacted in this period, it is worth noting that a recent modelling exercise for the NAFO area (Kenchington *et al.*, 2010a) estimated that the recent coral and sponge closures there may have reduced bycatch by as much as 50%. In the NW Pacific over the past decade, in the region of 200 tonnes of coral and sponges taken annually (Shester and Ayres, 2005) and based on TV surveys Stone, 2006 estimated that 40% of the area demonstrated signs of impact. Sponge grounds in the NE Atlantic have received no specific protection measures and it is likely that there is still a heavy impact of fishing on sponges in certain areas. There is also less incentive for fishers to avoid areas where non-reefal corals occur because there are no gear-damaging consequences of taking such organisms as bycatch (unlike 1 tonne of hard coral).

Specific sites within the North-East Atlantic where records demonstrate that more than 100 kg of live coral of 1000 kg of live sponges have been have been trawled as a result of human activities in the past

While there are many observations (presence) of corals and sponges that have been trawled by commercial fishing operations, there are very few records with precise information on quantity. While research vessel surveys do usually record accurately the quantities of VME bycatch, there are very few occasions when more than a few kg have been caught in the last decade. There are some records prior to the year 2000 where corals and sponge bycatch did exceeded 100 kg in research surveys. We have collated these data and the positions of these records are plotted in Figure 6. It should also be noted that as bottom trawls are only likely to retain a small fraction of corals and sponges due to their fragile nature any trawl derived data are likely to be an underestimate of the actual amount impacted by the trawl (Parker *et al*., 2009).

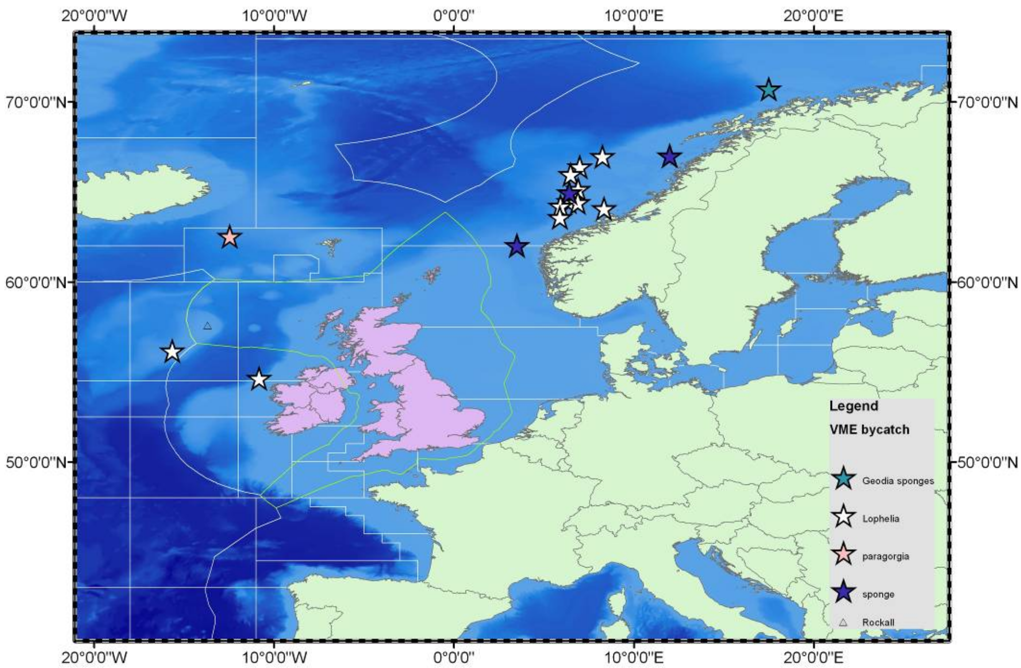

Figure 6. Confirmed cases where large quantities of VMEs have been observed in trawls by fishing and/or research vessels (see text and Table 1 for details).

Reef-forming corals

Hermatypic corals such as *Lophelia pertusa* and *Madrepora oculata* can form massive colonial reefs that if encountered by fishing gear will likely be taken in quantities weighing more than 100 kg. Indeed there are ‘fishermen’s tales’ of > 10 tonnes of coral in a single haul; given that trawls undoubtedly do not capture 100% of coral encountered and the recent discoveries of the extent of some reefs, this is not hard to believe. It should be noted, however, that these corals do also occur in isolation.

In the Rockall area there is only a single reliable record of a coral (*Lophelia* sp) bycatch in excess of 100 kg (estimated to be 2000 kg) which was an observation by a scientist aboard a commercial fishing vessel working in the Rockall area in 2005 (F. Neat, pers. comm.). The area has since been closed (Hall-Spencer *et al*., 2009). There are a number of anecdotal observation mainly from fishermen working the Rockall area where coral was noted (e.g. ‘lots of coral’) which may be taken to be indicative of a large quantity. Unfortunately there is no further means of quantifying this and no precise positions were recorded. The presence/absence of corals in the Rockall area from FRS-MSS data are illustrated in Chapter 3.

On the continental shelf slope Hall Spencer *et al*., 2002 in a study of coral bycatch by fishing vessels operating in the Porcupine Bank Area (54°4 N, 10°5 W) noted that pieces up to ca. 1 m^2 were landed on deck. There is a record of 5–6 tonnes from the shelf slope of the Bay of Biscay (Joubin, 1922) and a large piece of *Dendrophyllia* reef measuring 1 m in height from the central area of the slope of the Bay of Biscay (Le-Danois, 1948).

A number of historical records are available for Norwegian waters including observations from fishing and research vessels (Table 1). There is an area to the North of the Lofoten islands where large *Geodia* sp. sponges are found in dense fields (www.mareno.no) and bycatch in research surveys were often in excess of 100 kg.

Table 1. Records of bycatch by trawl from fishing vessels and research vessels in Norwegian waters. P. Mortensen, unpublished data.

Date	Latitude (N)	Longitude (W)	Depth	Lophelia (kg)	Sponges (kg)
17/03/1982	67.02	12.00	310	500	500
04/04/1987	66.98	8.27	412	250	
18/04/1983	66.42	7.00	375	2500	
17/04/1985	65.98	6.48	300	3500	
14/04/1983	65.17	6.92	289	1000	
07/11/1981	64.97	6.42	350	3000	300
30/04/1992	64.48	6.38	355	200	
13/11/1989	64.43	6.90	300	100	
14/04/1985	64.23	5.93	385	1000	
12/11/1989	64.10	8.35	.	1000	
21/04/1991	63.60	5.88	250	500	
12/11/1981	62.03	3.50	333	3000	100

There are occasional records from research surveys where notable quantities of corals, but less than 100 kg have been brought up in the trawl. This includes several records from Hatton bank of up-to 50 kg (P. Duran, unpublished data) and approximately 15 kg from a station on Rockall (WGDEC 2006).

Non-reefal (ahermatypic) corals

The likelihood that non-reefal corals such as black corals, bamboo corals and gorgonians are ever encountered in quantities greater than 100 kg per trawl is low. This is mainly because they tend to be more sparsely distributed in the OSPAR area and do not form fused colonial reefs or mounds. Certain species of gorgonian however can grow very large such *Paragorgia arborea* and bycatch may exceed 100 kg. In eastern Canada, research vessel trawls have caught 200 kg per km on the NL-Labrador slopes and 500 kg per km in the Davis Strait with Campelen trawls, and 2000 kg per km were taken with an Alfredo trawl also in the Eastern Arctic (Kenchington *et al.*, 2010b). WGDEC 2009 has one such record (Vinnichenko *et al.*, 2009) from a Russian research vessel operating in an area known as the Rosen-Garten southeast of Iceland (62.55 ºN 12.46 ºW) although even a specimen of this size is unlikely to weigh more than 100 kg. There are numerous records from scientific trawl surveys where single specimens or combined weights of specimens are < 1 kg.

Sponges

There are numerous records of large quantities of sponges taken as bycatch in trawls. The WGDEC report of 2009 gives some typical figures for the Faroes of 1–3 tons, places along the Norwegian shelf of up to 12 tons or more and south of Iceland of up to 50 tons. Data from IMR indicate survey trawl catches in excess of 1000 kg are not uncommon in a specific area (Tromsoflaket) to the north of Norway (Figure 7). Records from historical Norwegian fishing and research trawls indicate several catches of less than 1000 kg (Table 1).

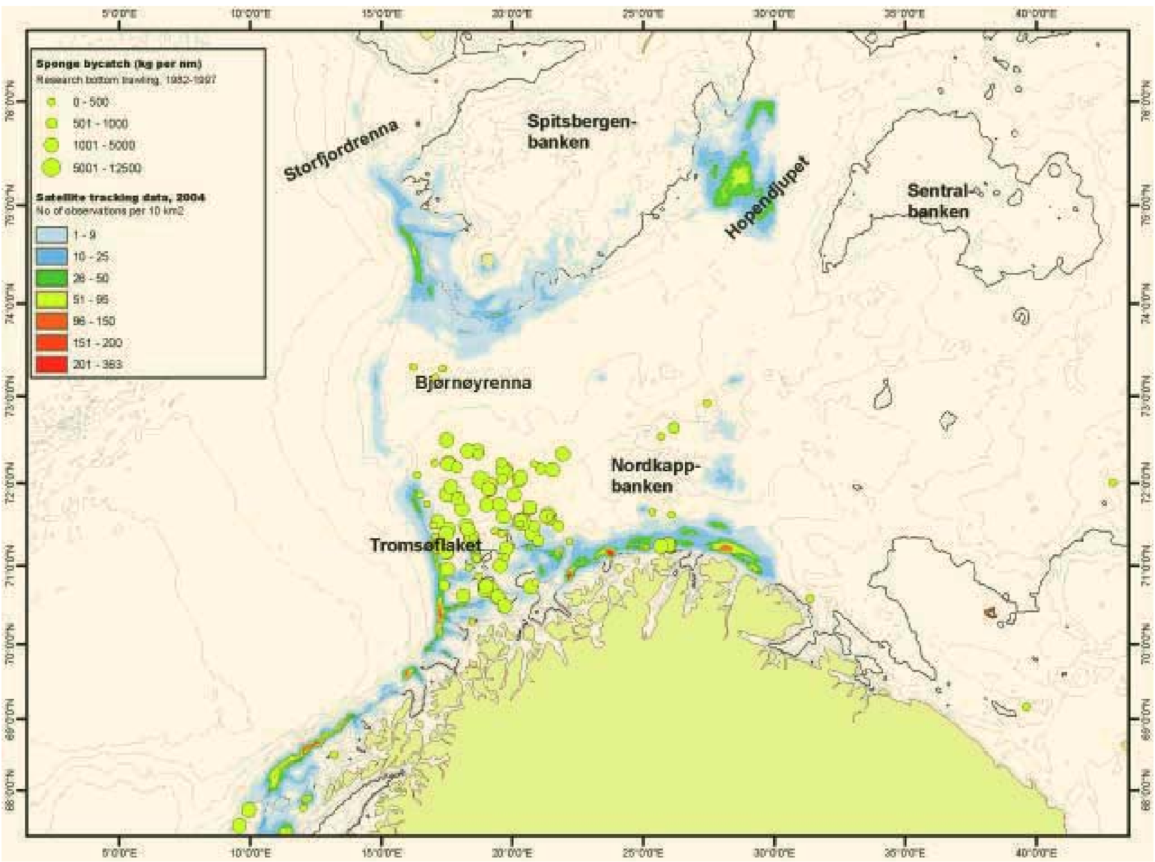

Figure 7. Map showing areas where large quantities of *Geodia* sp. sponges were taken in bycatch (1982–1997) in northern Norway (map and data: Royal Norwegian Ministry of The Environment: Report No. 8 to the Storting (2005–2006) Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands).

What is known about the status of coral reefs and sponge aggregations in these areas

In Norwegian waters large areas have been closed to protect coral reefs and any deliberate attempt to destroy coral reefs by human activities has been outlawed. Each year new reefs are being discovered, the latest as far north at 70 degrees (P. Mortensen, pers.comm.). There is clear evidence of trawl damage in a number of areas, but difficult to ascertain exactly when such damage happened. Reefs known to be dead, impacted and pristine are shown in Figure 8.

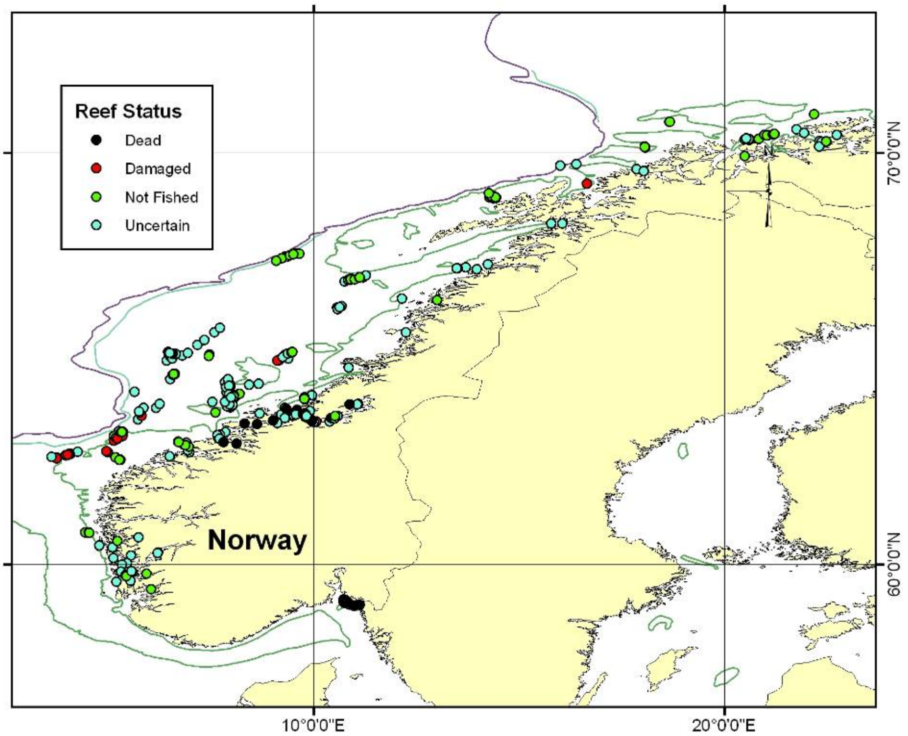

Figure 8. Norwegian cold water coral reefs plotted according to whether they have been impacted by fisheries, are considered undisturbed or status unconfirmed.

In the Rockall area large areas have now been closed to bottom fishing (Hall-Spencer *et al*., 2009). Recent TV surveys in the area (WGDEC 2006) have revealed areas of intact *Lophelia* reefs among larger areas of rocky reef or sedimentary seabed. There are also large areas of dead coral and coral rubble. It is generally difficult to ascertain if areas of dead coral are caused by the impact of trawling or represent the natural cycle of growth and decay of *Lophelia* reefs. If impacted recently there are usually clear plough marks of where the trawl doors have traversed through the reefs (see Hall-Spencer *et al*., 2002).

On the Hatton Bank a large area has also been closed. Recent surveys have revealed undisturbed sites of *Lophelia* and non-reefal corals, although there are also areas outwith the closed area which contain corals (Duran *et al*., 2010).

The area known as the Rosen-Garten to the SE of Iceland has not to our knowledge been properly surveyed for VME's and should be considered as a priority are because it appears to be unique in the NE Atlantic in supporting very large gorgonians.

In the Bay of Biscay, numerous historical records indicated occurrence of *Lophelia pertusa*, M*adrepora. oculata* and *Dendrophyllia. cornigera* reefs between 160 m to 400 m. Now in this depth range, only rubble have been encountered during the recent surveys using videos, some being associated with trawl marks (B. Guillaumont *et al*., unpublished). *L. pertusa/M. oculata* reefs partly living have been observed between 400 to 1100 m depth with a lot of antipatharians, some gorgonians and hexactinellids sponges, some being impacted by fisheries. Vertical cliffs with *Enallopsammia rostrata* occurs around 1500 m. On soft bottom, Pennatulacea, Bamboo corals (sometimes associated with the stalked sponge Hyalonema), Caryophyllia-Flabellum and Cerianthids anemone fields have been encountered as well as *Pheronema carpenteri* grounds. Some of them being impacted. Until now, no marine protected areas have been defined.

Thus for the OSPAR area in general there is good evidence of *Lophelia* reefs that are both impacted reefs and for reefs still in a natural state. Given that significant proportion of those known to be in natural state are now protected, this type of habitat is undoubtedly in a better state than it would be had closures not been effected.

Recovery rates of these species if and when damaged or removed

Lack of knowledge limits the possibilities for assessing the recovery potential of damaged cold water coral and sponge habitats. The recovery rate of these biotic habitats depends mainly on the rate of colonization and growth. There is a great variation in these factors between species. Growth in corals (linear skeleton extension) vary from less than a millimetre per year (*Desmophyllum*) to a couple of centimetres (*Lophelia*). Growth rates for deep-water sponges are poorly known.

Growth in cold-water corals

Cold-water corals are found in all oceans and display a great variety of shapes and sizes. The majority of species are colonial, or pseudocolonial, but among the scleractinians solitary species are most numerous (Cairns and Chapman, 2001). The widespread *Paragorgia arborea* (Gorgonacea) and *Lophelia pertusa* (Scleractinia) often develop large colonies. Sanchez, 2005 reports that *Paragorgia* can probably be higher than seven meters, and *Lophelia's* colonies can have a diameter of more than three meters (Freiwald *et al*., 2002). This is in great contrast to the small solitary corals, which are measured on the centimetre scale. Understanding the mechanisms and processes of growth and reproduction of cold water corals is crucial to assessing the consequences of negative human impacts.

Previous reports on growth and age of cold-water corals suggest decennial lifespans with linear extension rates less than one centimetre (Table 2: Mortensen and Rapp, 1998; Andrews *et al*., 2002; Sherwood *et al*., 2005). This picture is however not a general feature for all species, and growth rates around 2 cm yr^{-1} is not uncommon (Mortensen and Buhl-Mortensen, 2005; Gass and Roberts, 2006).

Andrews *et al*., 2002 have demonstrated that growth rings in the gorgonian *Primnoa resedaeformis* are formed annually. In a study of morphology and growth of *Paragorgia arborea* and *Primnoa resedaformis* (Mortensen and Buhl-Mortensen, 2005) used such sections to age *Primnoa* specimens from Atlantic Canada and found a linear skeleton extension between 1.5 and 2 cm. The growth rate was not constant through the life of the coral but slowed down when the colony exceeded a height of around 50 cm.

Unfortunately, *Paragorgia* does not have the same clear growth rings as *Primnoa*. This is due to the internal skeletal structures with a framework of sclerites rather than a massive structure deposited in layers. But, one indication of the growth rate of *Paragorgia* comes from a radiocarbon dating of a huge specimen collected off New Zealand. This specimen was around 400 yr old, and its height/base-width ratio fitted with those collected from Atlantic Canada (Mortensen and Buhl-Mortensen, 2005). Based on this it seems like an old *Paragorgia* could have had an average growth of 1 cm per year. In-situ measurements of *Paragorgia* at 50 m depth in Trondheimsfjorden, Norway indicated a growth rate varying within the colony from 2.2 to 4.0 cm per year. This colony was moderately tall (about 60 cm) and in a life-phase suggesting high growth rates.

Table 2. Overview of skeletal growth (linear extension) in some cold-water corals.

	Growth rate (cm·yr-1)		
Species	Average	Max	References
Lophelia pertusa	0.72	2.6	Dons, 1944; Bell and Smith, 1999; Mortensen and Rapp, 1998; Mortensen, 2001
Desmophyllum dianthus	0.06	0.31	Cheng *et al*., 2000; Adkins *et al*., 2004
Oculina varicosa	1.6		Reed, 2002
Paragorgia arborea	1.0	4.0	Mortensen and Buhl-Mortensen, 2005
Primnoa resedaeformis	1.7	3.0	Andrews *et al*., 2002; Mortensen and Buhl-Mortensen, 2005

Growth of sponges

An undamaged specimen of *G. barretti* was observed *in situ* during a period of 2 years and did not change appreciably (Hoffmann *et al*., 2003). The observation is in accordance with the impression, based among other things on size frequency analyses of catches, and year-to-year estimation of surface area, that most sponges from the deep grounds are slow-growing (Klitgaard and Tendal, 2004; Austin *et al*., 2007). Antarctic sponges in shallow water demonstrate the same general pattern, only two out of 13 species followed through a ten year period demonstrating measurable growth (Dayton, 1979). Thus, direct observation does not give a clue to the age of large deep-water sponges, and the same goes for other direct methods, like growth marks, stable isotopes and radionuclides (Gatti, 2003).

An indirect approach to age determination is possible through measurements of metabolism (Gatti, 2003). In three species of Antarctic sponges measured respiration data and a modelling procedure gave an estimated average age of individuals in the investigated population and the age of the largest specimen. For *Stylocordyla* sp. (former *S. borealis* in the Antarctic area; new name in prep.), it was ten years and 152 years, respectively. For *Cinachyra antarctica* (closely related to the *Tetilla* species in the North Atlantic sponge grounds) results were more ambiguous but the maximum ages were 126 and 1550 years, respectively. For a *Rosella* species (members of the family are numerous in the Arctic sponge grounds) the estimates were 186 years and 1515 years, respectively.

Possibilities for re-creation of these habitats

Reef-forming corals

The possibility of re-colonization depends on larvae supply. Little is known about larval duration and dispersal capacity, although a nearby source of mature adults would be eventually be the best chance of re-colonization. One indication that the larvae of *Lophelia pertusa* are long lived comes from the colonization of oil platform legs in the North Sea. There are no records of living *Lophelia* within a distance of ca. 200 km from the recently decommissioned Frig platform (Figure 9), and a larva would have drifted for 1–3 weeks before reaching this site. Thus there is little doubt that reef forming corals will settle upon large artificial substratum such as oil rigs and wrecks, but there is even evidence that they wills settle on any hard substratum including lost fishing gear (Figure 10). In areas where reefs have been smashed to such an extent that no stable substratum remains some intervention may be beneficial to re-colonization.

Figure 9. *Lophelia pertusa* colonies on the legs of the Frigg platform, decommissioned in March 2010, after 30 years in the sea (photograph: Erling Svensen).

Figure 10. A specimen of *Madrepora oculata* that colonized a piece of longline fishing gear (photo: F. Neat and J. Drewery, Marine Scotland). The monofilament line ran through the skeleton. Scale; approx 10 cm across.

Non-reefal corals

Re-colonization of destructed coral gardens (i.e. dominated by *Paragorgia* and *Primnoa*) will probably take longer time than what a single colony needs to reach a normal size. Based on the estimate presented by Mortensen and Buhl-Mortensen, 2005 it takes around 20–30 years for *Primnoa* to reach a colony height of 60 cm. However, the colonies in a gorgonian stand can be assumed to settle simultaneously, but will probably colonize gradually. Nothing is known about how long a time such a habitat would need to develop in deep water.

Colonization of corals depends on presence of suitable substratum. If the hard bottom components of a seabed has been removed or buried as consequence of bottom trawling there is not any longer a possibility for recovery of coral habitats. To which degree this is a real problem is not known. Given that suitable substratum is still present in a damaged coral habitat, scattered normal sized colonies could be expected to re-appear after 50 to 100 years. However, much longer time is needed for a coral habitat to develop. For cold-water coral reefs we are speaking of more than 1000 years, how long a time it takes for a lush coral garden to develop is not known, but it will take more than 100 years.

Sponges

Sponges are well known for their tremendous ability to repair damages and to restore lost body parts (Simpson, 1984). The mechanism behind this is the independence and totipotency of single cells in combination with high degree of motility. The majority of investigations on regeneration and somatic reorganization in sponges have been done on shallow water species that are able to survive in aquaria as small explants or even in damaged condition for at least some weeks. While most sponges are able to repair minor injuries in a short time, possibility for and speed of restoration after a more comprehensive (in relation to volume of the sponge) damage seem to depend on the complexity of the sponge (general morphology, skeleton, canal system, density of the interior) and probably also on physiological factors (WGDEC Report 2009).

Close inspection of the specimens in large catches of deep-water sponges often reveal repairs which look as scars, healed biting marks, abnormal form of part of body or of surface, or new surfaces formed around or under epifauna (OST own observation, Hoffmann *et al.*, 2004). Regeneration experiments have been performed with *Geodia baretti* (North Atlantic, mainly at depths from 100–300 m) (Hoffmann *et al.*, 2003). It was found that explants (2–4 cm^3) had rounded off and closed all openings after 2 days, and after 8 months had reorganized and grown into a small sponges with canal system and cortex The weight increase of the explants over 1 year was 40%. Compared to shallow water sponges, e.g. *Halichondria panacea* and *Cliona celata*, the regeneration processes and the growth are slow (Tendall, unpublished observations; Ayling, 1983; Bell, 2002).

While there are many studies in which damage to deep-water sponges as an effect of for example trawling is pointed out, recovery of habitats has only been followed in shallow-water habitats (Van Dolah *et al*., 1987; Probert *et al*., 1997; Freese *et al*., 1999). One reason is that even if population structure can be analysed, estimation of the age of specimens and size classes raises serious problems.

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7 Comment and make proposals for improvements on draft of a Best Practice Manual for scientific surveys in areas closed to fishing (NEAFC Request)

Guidelines for Observer on board fishing vessels authorized to fish in new bottom fishing areas

6) Background to request and terms of reference

In 2008, NEACF adopted recommendation XVI on bottom fishing activities in the NEAFC regulatory areas, which includes procedures for fishing activities in new bottom fishing areas. In areas not previously impacted by bottom fishing gear, fishing should be considered exploratory and shall be conducted in accordance with an Exploratory Bottom Fisheries Protocol. Proposed bottom fishing activities shall be subject to an impact assessment that would determine whether there are significant adverse impacts on vulnerable marine ecosystems (VMEs). Prior to the agreement of an NEACF Exploratory Bottom Fisheries Protocol, an interim protocol, published in Annex 1 of recommendations XVI is to be followed. This protocol is as follows:

Until the Commission adopts a new protocol in accordance with Article 4, paragraph 1 of this Recommendation, exploratory bottom fisheries may commence only when the following information has been provided to the Secretary by the relevant Contracting Party:

a) A harvesting plan which outlines target species, dates and areas. Area and effort restrictions shall be considered to ensure fisheries occur on a gradual basis in a limited geographical area.

b) A mitigation plan including measures to prevent significant adverse impact to vulnerable marine ecosystems that may be encountered during the fishery.

c) A catch monitoring plan that includes recording/reporting of all species caught. The recording/reporting of catch shall be sufficiently detailed to conduct an assessment of activity, if required.

d) A data collection plan to facilitate the identification of vulnerable marine ecosystems/species in the area fished.

In Autumn 2009, NEAFC asked ICES' advice to produce guidelines for observers on board fishing vessels that might be authorized to fish in the so-called "new" bottom fishing areas. In this context, NEAFC suggested to consider their interim Exploratory Bottom Fishing Protocol for New Bottom Fishing Areas.

7) Background material used

In drafting this request, several recent publications were used as guidance, to ensure that methodologies and objectives are consistent with existing international guidelines. The published materials used are:

- International guidelines for the management of deep-sea fisheries in the high seas (FAO, 2009)
- The science behind the guidelines: A Scientific Guide to the FAO Draft International Guidelines (December 2007) for the Management of Deep-Sea Fisheries in the High Seas and Examples of How the Guidelines may be Practically Implemented (IUCN,2008)
- Review of the code of conducts for scientific research in sensitive deep-water habitats (ICES, 2008)

8) Scope of the request

ICES considers that the observer guidelines would be aimed at an observer programme of scientific nature and that the data collected under such a programme would form the scientific basis to provide information that is required to assess fisheries in new bottom habitats. In this respect, ICES considers that the observers would not act in a regulatory or enforcement capacity and guidelines to aid observers how to enact regulatory requirements (such as for example identifying and weighing coral species to enact the follow on rule etc) are not covered in this document.

9) What should the observer programme achieve?

The aims and objectives of such an observer programme should be closely linked to the NEACF interim exploratory bottom fishing protocol for new fishing areas and the international guidelines for the management of deep-sea fisheries in the high seas (FAO 2009). It therefore needs to address the key issues that characterize deep-sea bottom fishing activities as stated in FAO, 2009:

- The catches include species that are characterized by low productivity and therefore can only sustain low exploitation rates;
- the fishing gear is likely to contact the seabed during the normal course of fishing operations.

With this in consideration, the observer programme should achieve the following:

1) Sufficient spatial and temporal information is collected on the vessel operation and effort to determine the fishing footprint and impact of this particular fishery.

2) Sufficient biological data on the target species is collected to understand the population structure and the productivity of the stock(s) and with this knowledge guide the proposals of sustainable exploitation plans.

3) Sufficient biological data are collected on all species caught as bycatch and/or discarded to assess the biological and ecological impact of this fishery on the whole fish community.

4) Sufficient data are collected for the identification and mapping of vulnerable marine ecosystems (VMEs) and to contribute to the assessment of significant adverse effects.

5) Sufficient data are collected on protected, endangered or threatened species (PET species).

6) Sufficient data are collected on the incidental catches of marine mammals, seabirds and sea turtles to assess the impact of the fishery on the wider ecosystem. The collection of general ecosystem data (physical, chemical, biological) should also be included whenever possible.

Details on information that should be collected to achieve each aim:

Aim 1.) Sufficient spatial and temporal information is collected on the vessel operation and effort to determine the fishing footprint and link this in with other datasets to aid their interpretation.

The spatial and temporal resolution of the data needs to be high enough to link catch and effort data to individual seabed features and information needs to be collected on a haul by haul basis. This is particularly important in the deep-water environment where serial depletion of deep-water stocks can occur in close proximity such as on adjacent seamounts (Rogers, 2008). It should be collected in a manner that it can be linked with VMS data and aid their interpretation to compile a fishing footprint and assess the single and cumulative impact of this particular type of fishing operation. This data can also be used to set up cpue series and/or evaluate the intensity of by-catch per unit of effort.

Data that needs to be collected for this aim are:

- Details on vessels: Vessel id and nationality – so it can be linked to NEAFC register.
- Details on vessel capacity: Details on gear type and their specifications and a description of any technical measures that are being used to mitigate bottom impact.
- Details on gear effort- i.e. number of hooks on longlines, number of nets for gillnetting, mesh size of trawls, etc.
- Details on spatial position and timing of fishing operation including details on tow position and duration on a haul by haul basis.
- Total number of hauls, number of unobserved hauls.

Aim 2.) Sufficient biological data on the target species is collected to understand the population structure and the productivity of the stock(s) and with this knowledge guide the proposals of sustainable exploitation plans.

General information required:

- The principal species or species group that is targeted by this fishing trip (if trips target different species/groups then this information needs to be collected on a higher resolution:

Per haul information required:

- Catch weight of target species;
- Length frequencies of total or subsampled catch;
- Biological sampling* on total catch or subsamples for weight measurements, sex ratios, maturity ratios, collection of samples for fecundity analysis;
- Collection of hard structures for possible age determination (otoliths, spines scales);
- Optional collection of tissue samples (finclips, etc) for genetic analysis.

It is important to note that for some species there already exists a series of published data available for some biological variables while for other species this information may be sparse and would not be sufficient exploitation rates. The guidelines should probably include a table of what biological data are available by species and should be included under Aim 2 and Aim 3.

Aim 3.) Sufficient biological data are collected on all species caught as bycatch and/or discarded to assess the biological and ecological impact of this fishery on the whole fish community.

The information collected under this heading has several purposes. Data is collected to assess at the vulnerability of bycatch species which will affect the overall sustainability of the fishery; to determine biodiversity hot spots including the presence of endemic species, which will feed into identification of vulnerable habitats. With the use of indicator species it will further aid the identification of VMEs.

Information needed by haul:

- Total catch weight;
- Species composition of total catch and weight by species;
- Proportion of retained and discarded catch;
- Length–frequency and additional biological sampling* on total or subsampled catch for retained and discarded portion.

*The sustainability of a fishery can be determined by certain bycatch species which might have a higher vulnerability to fishing than the actual target species. When decisions have to be made on the collection of biological data from bycatch and/or discarded species, one of the criteria for prioritization should be the vulnerability of a species- if a bycatch species has a high vulnerability to fishing (i.e. lower productivity, higher longevity) e.g.. Deep-water sharks, than this should take a high priority for biological data collection.

Aim 4). Sufficient data are collected for the identification and mapping of vulnerable marine ecosystems (VMEs).

One of the important aims of the observer programme for bottom fishing in new habitats is the collection of data to aid the identification of VMEs. According to FAO 2009, vulnerable marine ecosystems should be identified according to the criteria of uniqueness, functional ecosystem significance, fragility, life history traits of component species and/or structural complexity. In their guidelines, FAO have given examples of species that could indicate the presence of VMEs such as cold water corals and hydroids, some sponge dominating communities, communities composed of dense emergent fauna such as sessile protozoas and invertebrates and endemic seep and vent communities. Also listed are examples of topographical, hydrographical or geological features that can potentially support these communities such as submerged edges and slopes, seamounts, guyots, banks, knolls and hills,, canyons and trenches, hydrothermal vents and cold seeps.

The data collection under the observer programme therefore needs to address the above mentioned criteria and such data should contribute to the impact assessments for the likelihood of significant adverse impacts in a given area.

Data required of the identification of VMEs is the identification and enumeration of the bycatch of benthic species; this could be done either by photographic records with voucher specimen or the collection of the entire bycatch for further scientific investigation (Rogers, 2008). It is useful to collect wet weight of the bycatch and record every specimen. What needs to be considered when using an observer programme to identify and map VMEs is that fishing gear is highly selective on what is retained in the catch. Fishing gear can impact on organisms that are not necessarily retained in the net or that are retained at very small proportions, resulting in an underestimation of benthic bycatch. This in turn can lead to false conclusions being drawn on the absence of VMEs.

Observers should also record observations on the terrain, the occurrence of bathymetric features, etc. Possible extra data collection for the detection of VMEs by fishing vessels could be:

- Collection of acoustic data by fishing vessels- relating to bathymetry, slope and backscatter that can be used to map areas of potential VMEs;
- Towed and/or net mounted camera systems to use for the identification of benthic organisms and ground-truthing of acoustic data.

Aim 5.) Sufficient data are collected on protected, endangered or threatened species (PET species).

The purpose of this log is to record all protected species sightings. This information is important in determining the temporal and spatial distribution of protected species and the relative abundance and behaviour of animals in the vicinity of fishing operations.

Data required:

A log on protected species sightings.

Aim 6.) Sufficient data are collected on the incidental catches of marine mammals, seabirds and sea turtles to assess the impact of the fishery on the wider ecosystem.

Data required:

- Recording of incidental takes of marine mammal, sea turtle and seabird;
- Note on survival, death, injury, etc.

5) Other data that should be collected on observer trips:

Incorporation of fisher's knowledge- there should be scope in the observer data collection for fishermen's Comments. The purpose of this log would be is to provide fishermen an opportunity to document and record any significant information as it relates to an observed trip (NEFSC 2010). Record comments could relate to gear particulars, unusual species caught, abnormal levels of bycatch, extrapolated weights, uncommon catches, reasons gear was not fishing properly, etc. these data should be on a haul base if possible or trip base.

General notes by observers on the identification of fish behaviours that make them particularly vulnerable- e.g. aggregating behaviour in a targeted fishery.

6) Other considerations:

- Standard data collection procedures and protocols should be implemented, including standardized logbooks and recording sheets. All the data needs to be collected with the associated metadata.
- All coding should be standardized, such as species codes should be according to official FAO species codes.
- All biological specimen collected should be carefully labeled to track them back to haul information;
- The mandatory reporting period should be brief in order to allow for rapid responses if management action is required.
- There should be coordinated programmes on the standardization of species identification including benthic invertebrates.

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8 Summarize the environmental factors influencing sponge distribution in the North Atlantic based on the distribution of sponge *taxa*

In 2009 the Working Group documented the location of sponge grounds across the North Atlantic for the first time, although for most of those areas the species composition of the sponges was not fully described. With new information on species distributions emerging (see Section 3), the Working Group suggested delaying this ToR until those data could be considered in the evaluation, as species-specific information will give more insight into this question.

9 Provide a description of sponge species occurring at depths greater than 1500 m

This ToR was generated by the working group in 2009 with justification:

> 'WGDEC feels that there is now sufficient data to produce a summary of the sponge species inhabiting depths below 1500 m in the North Atlantic and that such a summary would be useful, in particular to researchers working at such depths.'

There is quite a bit of latitude given in interpreting the above and although this request was self-generated by the working group, once we started to address it, it was clear that a response could go in a number of directions, all of which would involve considerable time. To make a full list or a database is a very involved task because the information is very scattered in the literature and the names used have to be brought up to date to conform to the current taxonomy. Here we provide a very brief background to this question and provide some literature references for those interested in the subject.

Geographical

In the deep sea there are no natural geographical zones, like the climatic zones in shallower water. The Working Group used 30°N as the approximate southern limit, and Baffin Bay and the Fram Strait as the northern one (Figure 1).

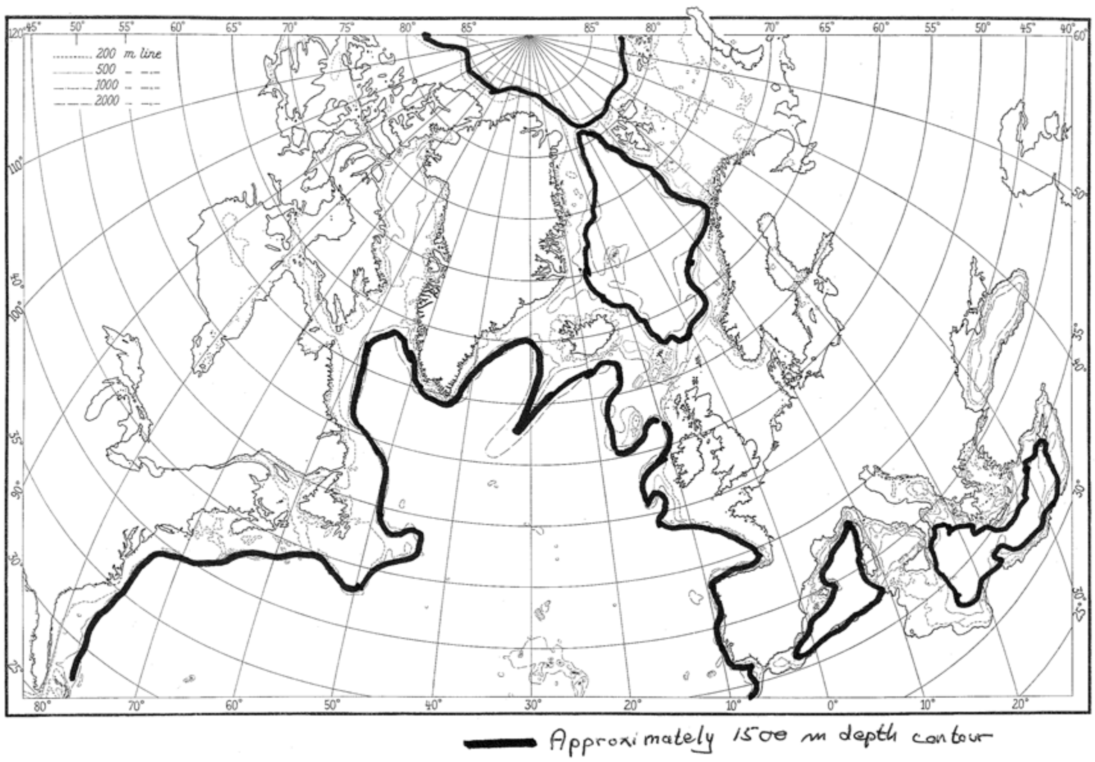

Figure 1. The approximate 1500 m depth contour of the ICES-NAFO area.

Subdivision of the area

The slope and abyssal depths are divided into a number of basins separated by higher or lower ridges and thresholds (Figure 2).

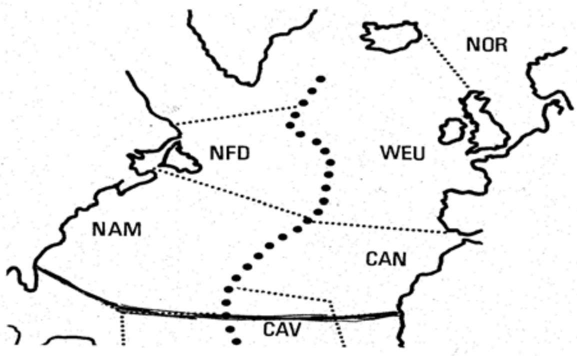

Figure 2. The lower black line is approximately 30°N. NAM: North American Basin. CAN: Canarian Basin. NFD: New Foundland Basin. WEU: Western European Basin (=Eastern Atlantic Basin). NOR: Norwegian Basin. The dotted lines are the Mid-Atlantic Ridge and smaller ridges and thresholds.

Not shown in Figure 2 are: GRE: Greenland Basin. WM: Western Mediterranean Basin and EM: Eastern Mediterranean Basin.

The composition of the fauna of a number of invertebrate groups has been demonstrated to differ from one basin to another (= on the two sides of a ridge). There is probably too few sponge records from these depths to demonstrate something like that in general, but it should be mentioned that GRE-NOR obviously have a characteristic sponge fauna, and that this may also be the case for EM. A first, although incomplete outline, could well serve as an inspiration to further investigations of this question.

Depth

Topographically, the area from 1500 m downwards comprises the continental rise and the abyssal plains and basins.

Faunistically, it is the lower part of the bathyal (archibenthal, slope) fauna and the abyssal fauna (there is no hadal or trench fauna in the area north of 30°N).

Politically, most of the area is in the open ocean, and abyssal plains and basins probably do not represent a problem from our point of view (as far as I know there are no large fields of manganese nodules or phosphates in the area). It is, however, different with parts of the Mid-Atlantic Ridge especially around the islands) and on seamounts reaching depths shallower than 2000 m, where commercial fishery is going on.

The deep-sea sponges

The best known deep-sea sponges (most often caught, identified in *in situ* photographs, some knowledge existing on their biology) are perhaps 15–25 in number.

The number of sponge species known from the area is somewhere between 150 and 200. Sponge grounds (dense aggregations of sponges) are not known from the deep sea.

Some references for further information on deep-sea sponges

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10 Monitoring methodologies for ocean acidification

To provide, on the basis of a review of existing methodologies and experience, recommendations for cost efficient methods for monitoring ocean acidification (OA) and its impacts, including possibilities for integrated chemical and biological monitoring. Specifically this should provide: (a) advice on appropriate spatial and temporal coverage for monitoring, considering different oceanographic features and conditions and key habitats/ecosystems at risk from OA in the OSPAR maritime area, and (b) advice on the status and maturity of potential indicators of OA impacts, on species, habitats and ecosystems that could be considered for inclusion in OSPAR monitoring programmes.

Introduction

Over the last century, anthropogenic carbon dioxide (CO_2) from the burning of fossil fuels has greatly increased. As anthropogenic CO_2 is absorbed by seawater, the concentration of carbonate ions has increased as well, resulting in a decreased pH of seawater. This 'ocean acidification' (OA) has become an emerging scientific issue that has become a priority among many of the world's nations. This issue has emerged as a scientific priority because of the potential negative effect that it may have on marine ecosystems and the many economic and non-economic services they provide. Initial concerns focused primarily on the potential direct impact to shell-forming organisms such as calcifying marine phytoplankton (e.g. coccolithophores), echinoderms (e.g. sea urchins and sea stars) molluscs (e.g. clams, oysters, and mussels), and crustaceans (e.g. krill, zooplankton, crabs, and lobsters). Preliminary work on the ecological impact of ocean acidification demonstrates that as $CaCO_3$ saturation rates decrease due to lowered pH seawater the ability of organisms to produce calcium carbonate shells and skeletons is compromised leading to reduced biodiversity although there are certain organisms that thrive in the acidified conditions (Hall-Spencer *et al.*, 2008). One will notice that many of the organisms cited above have significant ecological as well as economic importance.

Developing an OA monitoring network

In order to monitor natural fluctuations and anthropogenic changes in carbonate chemistry and assess the biological response to such changes, a robust ocean acidification observation network must be constructed by enhancing the monitoring capabilities of existing systems, increasing the temporal and spatial coverage of time-series measurements, and continuing current sampling efforts but expanding these efforts to open-ocean and coastal regions. One of the first ways to expand temporal and spatial coverage of OA chemistry is to encourage all laboratories, aquariums, institutions, businesses, and other infrastructure where flow through systems are currently located to regularly measure pH and carbonate parameters and report the results to a centralized database. This will highlight the current coverage as well as where spatial gaps occur.

As the ICES-NAFO Working Group on Deepwater Ecology (WGDEC) primarily focuses on biogenic habitats such as cold-water corals and other appropriate invertebrates, WGDEC recommends that measurements of pH and carbonate parameters are built into monitoring and surveys of deep-water ecosystems wherever possible and that the data be pooled in online resources such as PANGEA. In the deep sea, changes in the concentration of aragonite may impact reefs at higher latitudes by reducing the depth of the aragonite saturation horizon (ASH). Models of the projected aragonite saturation demonstrate that ca. 70% of current known cold-water coral locations could be undersaturated by 2099 (Guinotte *et al*., 2006). In short, the effects of ocean acidification could be great, but more research needs to be conducted to determine the sensitivity of deep-sea biota and to understand the ecological effects on the deep sea (Davies *et al*., 2007). We recommend that the effects of a shoaling of the ASH should be investigated as a priority for deep-water ecosystems using a suite of laboratory and field techniques.

Monitoring integration

It is very important that physical, biogeochemical, and biological monitoring be closely integrated operationally in order to be able to concurrently observe variability of ocean carbon chemistry and evaluate species response to this change. The existing ocean acidification observation network consists of traditional hydrographic surveys, ship-based and moored time-series stations, and ship-based surface observations (Dickson *et al*., 2007). These methodologies should be continued and expanded, where possible, and laboratory experiments addressing the ecological response of OA should become an important component to all future efforts.

Potential indicators of OA impacts

Monitoring a number of known biological indicators (e.g. coral community metabolic and calcification rates, bivalve recruitment, otolith growth) on a regular basis is recommended. Many potential OA indicators are being tested and it is important to collaborate to reduce potential redundancy. Many groups are currently refining these potential OA indicators and this information should be freely exchanged (Riebesell *et al*., 2010).

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11 NEAFC requests ICES to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats

Section 11 has not been dealt with.

12 ICES is requested to provide advice on an experimental design/protocol appropriate to quantifying VME catch thresholds for the fishing gears used in the NEAFC Regulatory Area

It is suggested that the design should take account of: (a) Differences in the retention efficiency between fishing gears (e.g. bottom trawls, longlines, gillnets and traps) for the VME indicator species (Guidelines for the Management of Deep-Sea Fisheries in the High Seas; FAO report N°881, 2009) found in the NEAFC Regulatory; and (b) Catch threshold differences for a range of seabed features supporting VMEs (e.g. seamounts, mounds, banks, continental slope).

13 Extending closures on the Mid-Atlantic Ridge Based on a proposal by the European Community to expand the current closed areas in the Mid-Atlantic ridge

ICES is requested to evaluate the proposal and provide advice whether the proposed extension will protect VMEs in the areas concerned against significant adverse impacts resulting from bottom fishing activities.

ICES is requested to evaluate and comment on a proposal submitted by the European Community to NEAFC (NEAFC AM 2009/56) to expand the currently implemented area closures to bottom fisheries on the Mid-Atlantic Ridge and the Altair and Antialtair seamounts. These closures to fisheries with bottom-gear were last revised and extended in 2009[1] and came into force in 2010.

ICES 2008 has provided advice to NEAFC asking for evaluation and advice on a proposal to expand the areas closed for fishing on the Mid-Atlantic Ridge (the 2004 closures) in relation to a request from OSPAR for a scientific peer review of proposals for areas to be considered as marine protected areas in the Northeast Atlantic beyond national jurisdiction. ICES 2008 recommended to OSPAR and NEAFC to work together and coordinate the respective protected areas in order to reduce confusion among stakeholders and a better chance of coherent management of human activities in these areas.

The EC proposal compared with current NEAFC closures

The proposal from the EC consists of a document and a map. To further address the request, we have produced a map (Figure 1) showing both the areas proposed by the EC (yellow) and the currently implemented NEAFC closures (red hatched), and also the EEZ boundaries. This mapping exercise has revealed some inconsistency between the coordinates given in the EC text, and the list of coordinates given on the EC map and the plot. This concerns the NW corner of the 'Middle MAR Area' closure. Our plot in Figure 1 has used the coordinates given in the EC text. However, we suspect that it is the EC map which is correct, and that the coordinate 18 in the text is erroneous.

Unfortunately, the EC proposal does not substantiate the background for the proposed amendments to the existing closures nor does it provide any references. The explanatory memorandum accompanying the map and coordinates only states:

The proposed areas constitute a vast field rich in biodiversity, which needs to be protected from severe adverse impacts from bottom-gear fishing activities. These areas have been studied through different international research projects, coordinated by the Community and Norway (MarEco and EcoMar).

[1] VMEs 2009

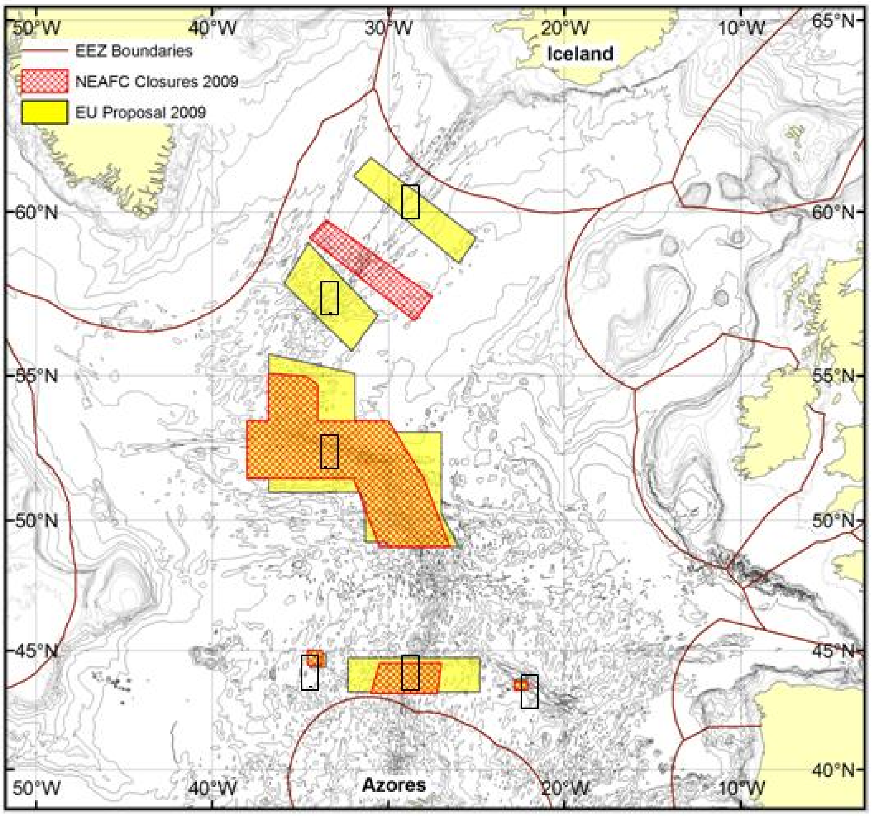

Figure 1. The North Atlantic showing current NEAFC closures (decided on in 2009, implemented in 2010), and the closures proposed by the EC to NEAFC in 2009.

Comparing the current NEAFC closures and the EC proposal the following may be noted:

1) In the EC proposal the current NEAFC closure on the Reykjanes Ridge is abandoned (essentially reopened) and replaced by two new closures (EC areas a and f);
2) The remaining two MAR closures proposed by the EC (areas b, c) are expansions of the current NEAFC closures. The expansions primarily cover areas deeper than 3000m, i.e. not central shallow ridge areas or seamounts;
3) The closures proposed by the EC (d, e) and those already implemented by NEAFC on Altair and Antialtair are very similar, i.e. cover the seamounts and are about the same sizes.

It seems likely that the proposed revision of the NEAFC closures is meant to reflect the marine protected areas proposed since 2008 and envisaged to be designated by OSPAR in 2010. This could explain the proposed boundaries for the Southern MAR (area c) and Middle MAR (area b) areas. However, on the Reykjanes Ridge, OSPAR currently proposes only one marine protected area north of the Charlie-Gibbs Fracture Zone, which likely corresponds to the area f proposed by the EC (see Figure 2 for current OSPAR MPA proposals). The northernmost of the proposed areas (a) may relate to an area proposed as a potential MPA to the technical organs of OSPAR in 2008; however, that proposal has subsequently been set aside in the light of the expected submission by Iceland on an extended continental shelf on the Reykjanes Ridge. Both the current and the 2008 area proposals draw on data gathered during the MarEco expeditions in 2004, to the northern, mid and southern area on the ridge. ICES 2008 found good evidence of the existence of threatened and/or declining species and habitats in all areas proposed by OSPAR.

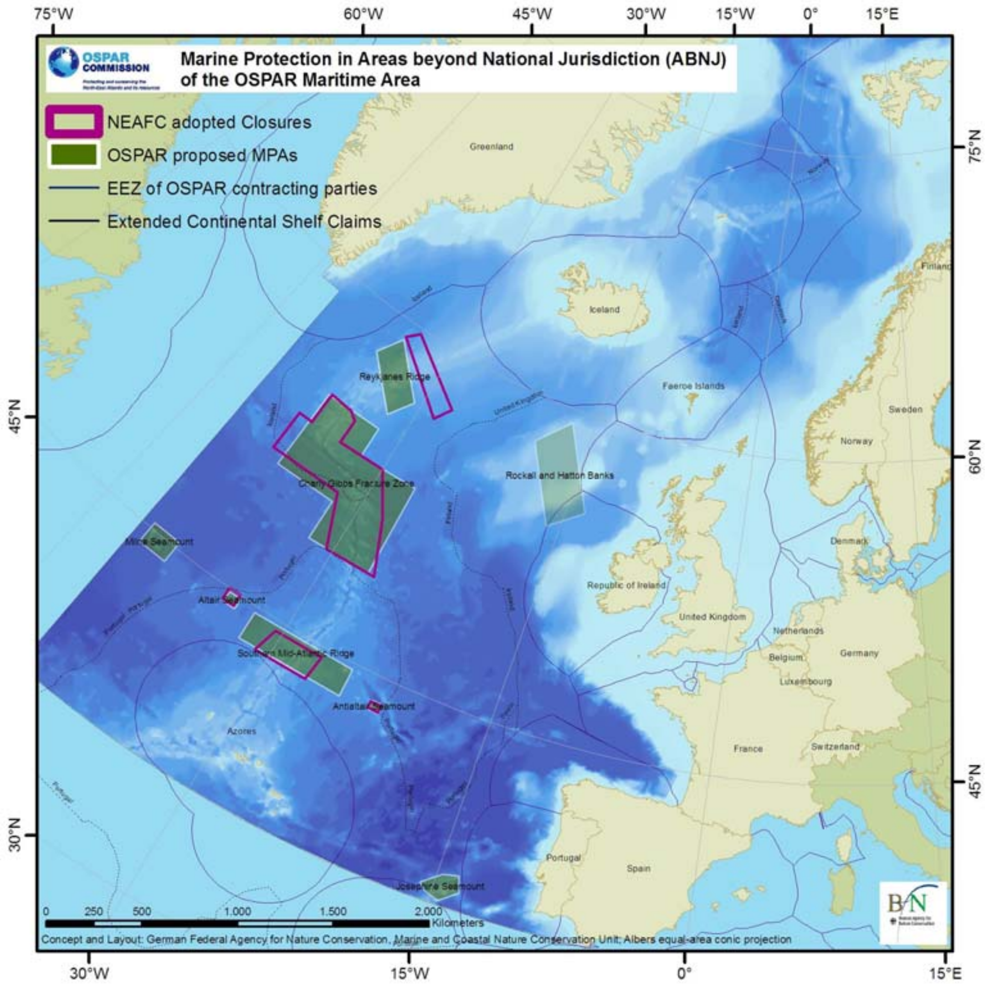

Figure 2. Proposed OSPAR MPAs in Areas beyond National Jurisdiction (ABNJ) and areas closed to bottom fishing by NEAFC in 2010. (OSPAR 09/6/9 Addendum 1).

When NEAFC in 2009 decided to expand closures introduced in 2004, it was based on a proposal reviewed by ICES 2008. Given that very limited areas of the MAR have been studied and mapped with sufficient spatial resolution, the exact locations of all individual VMEs cannot be determined. The decision to close certain areas was therefore based on general information on biogeography and ecology, and specifically the general spatial distribution patterns of elements of the fauna known to be vulnerable to bottom fisheries activity (e.g. corals). The relevant information was extracted from recent and historical investigations. The resulting NEAFC closures comprised three sections of the MAR representing three features:

i) the Reykjanes Ridge north of the Sub-Polar Frontal Zone;

ii) the Sub-Polar Frontal Zone, including the Charlie-Gibbs Fracture Zone;

iii) A section of the Mid-Atlantic Ridge north of the Azores, i.e. south of the Sub-Polar Front.

Closures i) and ii) were supposed to protect a representative selection of VMEs within the faunal provinces north and south of the Sub-Polar Front, respectively, and each closure should contain several features such as ridge hills and slopes likely to have VMEs. However, the exact locations, boundaries and sizes of the closures i) and iii) were not considered critical as long as they contained several hills and a swathe extending from 3000–3500 m on the western to the eastern side of the ridge axis.

Reykjanes Ridge (a and f compared to i)

Evaluating the currently closed area on the MAR, ICES 2008 found evidence of the functional significance of the area to several fish stocks, for fragility, difficult recovery and high structural complexity provided by cold-water corals and considered it being representative of the northern MAR. The major proposed amendment by the EC concerns the replacement of the already accepted and introduced NEAFC closure with two new closures to the north and south (Point 1 above). No rationale is given for this proposal. If the EC proposal was accepted the total area closed would approximately double. A large part of the added area would cover central parts of the MAR where shallow hills occur; hence it is probable that some more VMEs would be protected. However, the quantification of this possibly beneficial effect cannot be made without detailed information on the spatial distribution of VMEs. The existing single Reykjanes Ridge closure and the two replacement closures proposed by the EC are located within the same biogeographical zone, and the two proposed closures may be considered almost as replicates.

Sub-Polar Frontal Zone, including the Charlie-Gibbs Fracture Zone (b compared to ii)

A section of the Mid-Atlantic Ridge north of the Azores, i.e. south of the Sub-Polar Front (c compared to iii)

Closure ii) was intended to protect VMEs associated with the hydrographical feature of the Sub-Polar Frontal Zone and the geomorphological features of the Charlie-Gibbs Fracture Zone and hills/seamounts in the area south and north of that fracture zone. This dynamic area characterized by swift currents and possibly high production is likely to have many VMEs, and the abundance of fauna from many taxa has been demonstrated in recent studies to be elevated compared with other sections of the MAR. Again, the closure was designed to represent all habitat types from the shallowest hills to the deepest troughs and slopes.

The proposed amendments to the boundaries of the NEAFC closed areas ii (Charlie-Gibbs Fracture Zone and Sub-Polar Frontal Zone/area b), and iii (MAR north of the Azores/area c) would expand current NEAFC closures into deeper water away from the ridge axis, i.e. mostly into rise and abyssal depths exceeding 3000 m. The along-ridge expansion is minimal and very little extra shallow ridge area would be included. The current NEAFC closures already reach 3000–3500 m on either side of the ridge axis. Most historical and present fishing activity utilizes resources associated with the shallow hills and slopes where the relevant resources of e.g. grenadier, orange roughy, alfonsinos a.o. occur. The likelihood of future expansion of bottom fisheries into deeper waters would seem minimal. Because the intention is to protect against adverse effects of bottom fishing, then the closures should rather protect shallower ridge hills than more extensive lower rise or abyssal plain waters where the risk of adverse effects of bottom fishing is already minimal.

Altair and Antialtair seamounts (d and e)

The differences between the existing closures of the Altair and Antialtair seamount complexes and the proposals from the EC are so small that it would seem very unlikely that an amendment would have any additional protective effect. The EC proposal does not include any explanation for the proposed minimal amendments to these NEAFC closures.

Conclusion

Given the character of the Mid-Atlantic Ridge between Iceland and the Azores, and the increasing depths from north to south, it is highly likely that all of the ridge, but in particular the northern Reykjanes Ridge will feature VME indicator habitats and species. Several areas on the northern, mid and southern MAR have been investigated in depth by international programmes such as MarEco (Census of Marine Life project coordinated by Norway, www.mareco.no, Bergstad *et al.*, 2008) and EcoMar (UK national funding and coordination, http://www.oceanlab.abdn.ac.uk/ecomar/). Evidence from these representative areas provides support for the occurrence of VME indicators such as *Lophelia pertusa*, gorgonian corals and deep-water sponge aggregations associated to the hills and seamounts all along the ridge. Therefore, any expansion of the closures that affects relatively shallow hills of the Mid-Atlantic Ridge (i.e. areas shallower than 1500–2000 m) may protect additional VMEs against adverse effects of bottom fisheries.

In this respect it is likely that the proposed amendments on the Reykjanes Ridge (replacement of the current NEAFC closure with two new adjacent closures) would have some additional protective benefit. However, due to limited data on the distribution of VMEs at the relevant spatial scale, quantifying this effect is currently not possible.

The other amendments are not considered likely to have significant added value in terms of reducing the risk of adverse impacts from bottom fisheries as it is currently conducted on the Mid-Atlantic Ridge.

A rationale for reopening the existing closure on the Reykjanes Ridge should be provided. Reopening will likely re-expose VMEs to potential adverse impacts.

In view of both the limited information on the exact distribution of VMEs and the likelihood of widespread occurrence of VMEs along the MAR, as well as the need to follow a precautionary approach in fisheries management, a practicable way forward may be to maintain the existing NEAFC closures and in addition to consider expanding these to include the areas proposed by the EC that are not yet covered by the current closures. Such further consideration should then be informed by the rationale and the specific conservation objectives set out for the areas proposed by the EC.

The uncertainty created by the inconsistent coordinates for the NW corner of the proposed 'Middle MAR/Charlie-Gibbs Fracture Zone' closure should be clarified.

References

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ICES 2008. ICES scientific peer review of proposals for areas to be considered as marine protected areas in the North East Atlantic beyond national jurisdiction: 1.5.5.18 Answer to request from OSPAR for a scientific peer review of proposals for areas to be considered as marine protected areas in the North East Atlantic beyond national jurisdiction. 1.5.4.1 Answer to request from NEAFC for evaluation and advice on a proposal to expand the areas closed for fishing on the mid-Atlantic Ridge. OSPAR MASH 08/5/8, 25 pp.

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Annex 2: WGDEC Terms of Reference for 2011

The ICES/NAFO Joint **Working Group on Deep-water Ecology** [WGFB] (Chair: Robert Brock, USA) will meet at ICES, Copenhagen, Denmark from xx–xx March 2011 to:

a) In conjunction with the ICES data centre, design and populate a central database of coral, sponge and other offshore or deep-water VME and habitats in the North Atlantic.

b) Continue to update cold-water coral and sponge maps.

c) Continue to review the science pertaining to progress being in assessing vulnerable marine ecosystems (e.g. threshold weights).

d) Summarizing the environmental factors influencing sponge distribution in the North Atlantic based on the distribution of sponge *taxa*.

e) NEAFC requests ICES to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats.

WGDEC will report by DATE to the attention of the ACOM Committee.

Supporting Information

Priority:	
Scientific justification and relation to action plan:	a) In conjunction with the ICES data centre, design and populate a central database of coral, sponge and other offshore or deep-water VME and habitats in the North Atlantic. b) Continue to update cold-water coral and sponge maps. c) Continue to review the science pertaining to progress being in assessing vulnerable marine ecosystems (e.g. threshold weights). d) Summarizing the environmental factors influencing sponge distribution in the North Atlantic based on the distribution of sponge taxa. e) NEAFC requests ICES to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats
Resource requirements:	
Participants:	The Group is normally attended by some 20–25 members and guests.
Secretariat facilities:	None.
Financial:	No financial implications.
Linkages to advisory committees:	There are no obvious direct linkages with the advisory committees.
Linkages to other committees or groups:	There is a very close working relationship with all the groups of the Fisheries Technology Committee. It is also very relevant to the Working Group on Ecosystem Effects of Fisheries.
Linkages to other organizations:	The work of this group is closely aligned with similar work in FAO and in the Census of Marine Life Programme.

Annex 3: Recommendations

There are no formal recommendations from WGDEC in 2010.

Annex 4: Technical minutes from the Corals Review Group

- RGCOR
- 29 April 2010 at ICES, Copenhagen, Denmark
- Participants: Helge Fosså (Chair), Claus Hagebro and Michala Ovens (ICES Secretariat)
- Working Group: WGDEC

OSPAR requests

Impacts of human activities on cold water corals and sponge aggregations

To provide advice on impacts of human activities on cold-water corals and deep-sea sponge aggregations including: see a–e

OSPAR request a

a. total amounts and % of these habitats affected by human activity over the past decade, on a year by year basis, in the OSPAR Maritime Area

ICES advice/answer

It is impossible to give precise estimates for total amounts and percentage of VMEs impacted by human activity because the data on coral and sponge distribution is highly patchy and far from complete. Recent advances in predictive habitat modelling may allow comparisons of potential habitat with current distribution to assist in addressing this problem, but the output from such models is not yet available to WGDEC. Consequently there is no direct means of quantifying the impact of human activities on the VMEs over the past decade. It is, however, possible to assess the likelihood that VMEs have been impacted from information on patterns in fishing activity in areas where VME's are known to be present.

Basis of advice

The vast majority of fishing is currently shallower than 1500 m depth. Because corals are known to occur as deep as 3800 m, there is a significant proportion of VME habitat in the OSPAR area that is out of reach of direct disturbance and thus represented undisturbed VMEs and habitats (Figure 1). However, the diversity and abundance of corals and sponges peaks between depths of 800–1500 m (Rogers *et al.*, 2007) meaning that in fact the majority of those VMEs may be at risk of impact.

The extent of fishing activity in the OSPAR deep-water and offshore areas has also been investigated using VMS data by WGDEC in the past (e.g. Hall-Spencer *et al.*, 2009), although no complete 'footprint' of fishing activity is available due to data provision constraints. WGDEC had access to VMS data from the continental shelf west of the British Isles, northern Norwegian waters, the Bay of Biscay and the area beyond national jurisdiction that is regulated by NEAFC. There are some obvious gaps in the footprint (e.g. around Iceland) that reflect the fact that not all VMS data were available.

Throughout the OSPAR region it is likely that the majority of trawling impact to VMEs happened during the 1970s, 1980s and 1990s. Retired deep-sea fishermen from throughout Europe have stories of hauling up tonnes of coral in this period and at the end of last century Norway estimated that between 30–50% of its reefs had been impacted to some degree by bottom fishing (Fosså *et al.*, 2002). Over the entire OSPAR area, fishing effort has largely declined in offshore and deep-water areas over the past decade (ICES, WGDEEP 2009). Furthermore efforts to protect cold-water coral habitats in the past decade (Norwegian waters, Hatton bank, Rockall, Porcupine slope and Darwin mounds) has likely further reduced the relative proportion of coral habitats being affected by human activity.

On sponges there are no substantial info.

RGCOR comment

This request is somewhat surprising. We believe that OSPAR has enough knowledge of these issues to know that there is no possibility of answering this question. We hardly know the complete or total distribution of the habitats, let alone the % affected. Furthermore, there is certainly no information about % affected on a year by year basis over the last 10 years.

WGDEC points out that the diversity and abundance of corals and sponges peaks between depths of 800–1500 m (Rogers *et al*., 2007) meaning that in fact the majority of those VMEs may be at risk of impact. We support this conclusion, but will add that in Norwegian waters the coral reef ecosystems demonstrate the highest densities around 200–350 m depth and co-occur with some of the heaviest fished areas on the shelf and along the shelf break.

The information presented in Figures 2–5 is very heterogeneous and represents different scales, different years, different fisheries (e.g. bottom-trawl and total fisheries), and sections of fishing fleets. All kinds of data are valuable, but ICES should try to present more comparable and complete information. To make the maps useful, they should be readable and one obvious thing would be to plot VMS-data upon the known distribution of VMEs.

In the Norwegian case presented in Figure 5, two indirect impact measures are compared, VMS plot and estimated trawlmarks/100 m. There is not a very good agreement between the two. However, a member of WGDEC informed that the VMS was only from the year 2005. Because the trawl marks can have been accumulated over time, they may represent several years of fishing. But again there is a lack of information on VMEs for the area in question. In Norway VMS data are available for many years and for the whole EEZ.

OSPAR request b

> b. specific sites within the North-East Atlantic where records demonstrate that more than 100 kg of live coral and 1000 kg of live sponges have been trawled as a result of human activities in the past.

ICES advice/answer

There are many observations of corals and sponges that have been trawled by commercial fishing operations, but there are very few records with precise information on quantity. While research vessel surveys do usually record accurately the quantities of VME bycatch, there are very few occasions when more than a few kg have been caught in the last decade. There are some records prior to the year 2000 where corals and sponge bycatch did exceeded 100 kg in research surveys. These data are collated and the positions are plotted in Figure 6.

Basis of advice

Reef forming corals

There is a lot of anecdotal information that evidently is true (fishermen's information), but not verified scientifically. There are some verified records from Norway, Rockall and Porcupine Bay. Fosså *et al*., 2000 gives 12 cases for *Lophelia* corals (Table 1).

Non reefal (ahermatypic) corals

The likelihood that non-reefal corals such as black corals, bamboo corals and gorgonians are ever encountered in quantities greater than 100 kg per trawl is low. This is mainly because they tend to be more sparsely distributed in the OSPAR area and do not form fused colonial reefs or mounds. However, some species such as *Paragorgia* may grow very large and bycatch may exceed 100 kg. Scientific evidence is not provided in the WGDEC Report for the OSPAR area. In Canadian waters scientific trawling gives examples of coral catches of 200, 500 and 2000 kg per km.

Sponges

There are numerous records of large quantities of sponges taken as bycatch in trawls (no references). The WGDEC Report of 2009 gives some typical figures for the Faroes of 1–3 tons, places along the Norwegian shelf of up to 12 tons or more and south of Iceland of up to 50 tons, but there are no references to literature. Data from IMR indicate that survey trawl catches in excess of 1000 kg are not uncommon in a specific area (Tromsoflaket) to the north of Norway (Figure 7). Records from historical Norwegian fishing and research trawls also indicate several catches of less than 1000 kg (Table 1).

There is no doubt that large sponges have been caught in large quantities when trawling in the sponge grounds; it is just to look at the pictures taken by for instance scientists. But most records seem not to be verified.

SGCOR comment

The request is somewhat unclear, but it seems that WGDEC has interpreted "have been trawled" as "have been brought on deck as bycatch". It should be noted that as bottom trawls are only likely to retain a fraction of corals and sponges due to their fragile nature and possible low catchability, any trawl-derived data are likely to be an underestimate of the actual amount impacted by the trawl.

The WGDEC Report of 2009 gives some typical figures for the Faroes of 1–3 tons, places along the Norwegian shelf of up to 12 tons or more and south of Iceland of up to 50 tons, but there are no references to literature. However, we anticipate that this has been written by Ole Tendal and that he refers to sampling in, for example, BIOFAR and BIOICE and that the information is truthworthy. In general there seems to be no doubt that large sponges have been caught in large quantities when trawling in the sponge grounds; one only has to look at the pictures taken by, for instance, scientists (see Figure 8.2.1.1 in WGDEC 2009, also own observations JHF). Most records, however, seem to be scientifically unverified.

Below is the reference that Table 1 was derived from.

Fosså, J.H., P.B. Mortensen and D. Furevik. 2000. Lophelia-korallrev langs norskekysten. Forekomst og tilstand. – *Fisken og havet* nr. 2, 2000.

OSPAR request c

c. what is known about the status of coral reefs and sponge aggregations in these areas

ICES advice/answer

For the OSPAR area in general there is good evidence of *Lophelia* reefs that are both impacted reefs and for reefs still in a natural state. Given that significant proportion of those known to be in natural state are now protected, this type of habitat is undoubtedly in a better state than it would be had closures not been effected.

Basis of advice (subheadings: background, results and conclusions, methods)

In Norwegian waters large areas have been closed to protect coral reefs and any deliberate attempt to destroy coral reefs by human activities has been outlawed. Each year new reefs are being discovered, the latest as far north at 70 degrees (P. Mortensen, pers.comm.). There is clear evidence of trawl damage in a number of areas, but difficult to ascertain exactly when such damage happened.

In the Rockall area large areas have now been closed to bottom fishing (Hall-Spencer *et al*., 2009). Recent TV surveys in the area (WGDEC 2006) have revealed areas of intact *Lophelia* reefs among larger areas of rocky reef or sedimentary seabed. There are also large areas of dead coral and coral rubble. It is generally difficult to ascertain if areas of dead coral are caused by the impact of trawling or represent the natural cycle of growth and decay of *Lophelia* reefs. If impacted recently there are usually clear plough marks of where the trawl doors have traversed through the reefs (see Hall-Spencer *et al*., 2002).

The area known as the rose-garden to the SE of Iceland has not to our knowledge been properly surveyed for VME's and should be considered as a priority area because it appears to be unique in the NE Atlantic in supporting very large gorgonians.

On the Hatton Bank a large area has also been closed. Recent surveys have revealed undisturbed sites of *Lophelia* and non-reefal corals, although there are also areas outwith the closed area which contain corals (Duran *et al*., 2010).

In the Bay of Biscay, numerous historical records indicated occurrence of *Lophelia pertusa*, M*adrepora. oculata* and *Dendrophyllia. cornigera* reefs between 160 m to 400 m. Now in this depth range, only rubble have been encountered during the recent surveys using videos, some being associated with trawl marks (B. Guillaumont *et al*., unpublished). *L. pertusa/M. oculata* reefs partly living have been observed between 400 to 1100 m depth with a lot of antipatharians, some gorgonians and hexactinellids sponges, some being impacted by fisheries. Vertical cliffs with *Enallopsammia rostrata* occurs around 1500 m. On soft bottom, Pennatulacea, Bamboo corals (some times associated with the stalked sponge Hyalonema), Caryophyllia-Flabellum and Ceriantids anemone fields have been encountered as well as *Pheronema carpenteri* grounds. Some of them being impacted. Until now, no marine protected areas have been defined.

RGCOR comment

The OSPAR request is slightly ambiguous with "status" not properly defined. The WGDEC answer addresses both "protection status" and "impact status" which RGCOR assume to be appropriate answers.

This request also draws from other sections of the Report that are not referenced to. OSPAR should take note of the maps in Section 3 (Continue to update coral and sponge maps) Figures 1–25 which provide a context of known areas of coral and sponge occurrence in the area. Caution should be taken with respect to "Predicted suitable habitat maps" for the reef-forming *Lophelia pertusa* in NE Atlantic Section 5 Appendix 2 (A case study illustrating the use of habitat suitability maps: predicting scleractinian cold-water coral distribution in the Northeast Atlantic) Figures 3–8. This does not show coral occurrence but areas that are predicted to provide suitable environmental conditions for coral to potentially occur. There is no indication of how reliable this model is; some inputs to the model are also models whose reliability is not constrained and some "suitable areas" are known not to contain coral. Nevertheless, if taken in context and the details of the model used with caution, the general patterns predicted are of some use.

The WGDEC answer is technically correct and reliable but inadequate as they only detail some areas. No comment is made on status in the Irish, Greenland, Canadian or American sectors.

"Rockall area" should refer to "UK sector Rockall Bank". In the Bay of Biscay (Whittard canyon), the ROV footage (RV James Cook cruise JC036) is not mentioned and reveals extensive corals on steep canyon walls where they are topographically protected from trawling and downslope sediment flows.

OSPAR request d

d. recovery rates of these species if and when damaged or removed

ICES advice/answer

Lack of knowledge limits the possibilities for assessing the recovery potential of damaged cold-water coral and sponge habitats. The recovery rate of these biotic habitats depends mainly on the rate of colonization and growth. There is a great variation in these factors between species. Growth in corals (linear skeleton extension) vary from less than a millimetre per year (*Desmophyllum*) to a couple of centimetres (*Lophelia*). Growth rates for deep-water sponges are poorly known.

Basis of advice

Growth in cold-water corals

Previous reports on growth and age of cold-water corals suggest decennial lifespans with linear extension rates less than one centimetre (Table 2: Mortensen and Rapp, 1998; Andrews *et al*., 2002; Sherwood *et al*., 2005). This picture is however not a general feature for all species, and growth rates around 2 cm yr^{-1} is not uncommon (Mortensen and Buhl-Mortensen, 2005; Gass and Roberts, 2006).

Andrews *et al*., 2002 have demonstrated that growth rings in the gorgonian *Primnoa resedaeformis* are formed annually. In a study of morphology and growth of *Paragorgia arborea* and *Primnoa resedaformis* (Mortensen and Buhl-Mortensen, 2005) used such sections to age *Primnoa* specimens from Atlantic Canada and found a linear skeleton extension between 1.5 and 2 cm. The growth rate was not constant through the life of the coral but slowed down when the colony exceeded a height of around 50 cm.

It seems like an old *Paragorgia* could have had an average growth of 1 cm per year. In-situ measurements of *Paragorgia* at 50 m depth in Trondheimsfjorden, Norway indicated a growth rate varying within the colony from 2.2 to 4.0 cm per year.

Growth of sponges

An undamaged specimen of *G. barretti* was observed *in situ* during a period of 2 years and did not change appreciably (Hoffmann *et al.*, 2003). Antarctic sponges in shallow water demonstrate the same general pattern, only two out of 13 species followed through a ten year period demonstrating measurable growth (Dayton, 1979).

An indirect approach to age determination is possible through measurements of metabolism (Gatti, 2003). In three species of Antarctic sponges measured respiration data and a modelling procedure gave an estimated average age of individuals in the investigated population and the age of the largest specimen. For *Stylocordyla* sp. (former *S. borealis* in the Antarctic area; new name in prep.), it was ten years and 152 years, respectively. For *Cinachyra antarctica* (closely related to the *Tetilla* species in the North Atlantic sponge grounds) results were more ambiguous but the maximum ages were 126 and 1550 years, respectively. For a *Rosella* species (members of the family are numerous in the Arctic sponge grounds) the estimates were 186 years and 1515 years, respectively.

RGCOR comment

WGDEC correctly point out the difference between species growth rates and reef recovery rates with recovery rates dependent on additional factors. WGDEC correctly states that we have no information on the rate of reef recovery beyond the estimate of slow.

OSPAR request e

e. possibilities for re-creation of these habitats

ICES advice/answer

The possibility of re-colonization by reef-forming corals depends on larvae supply. Little is known about larval duration and dispersal capacity, although a nearby source of mature adults would eventually be the best chance of re-colonization. In areas where reefs have been smashed to such an extent that no stable substratum remains some intervention may be beneficial to re-colonization.

Re-colonization of destructed coral gardens (i.e. dominated by non-reefal corals *Paragorgia* and *Primnoa*) will probably take longer time than what a single colony needs to reach a normal size.

Given that suitable substratum is still present in a damaged coral habitat, scattered normal sized colonies could be expected to re-appear after 50 to 100 years. However, much longer time is needed for a coral habitat to develop. For cold-water coral reefs we are speaking of more than 1000 years, how long a time it takes for a lush coral garden to develop is not known, but it will take more than 100 years.

While there are many studies in which damage to deep-water sponges as an effect of for example trawling is pointed out, recovery of habitats has only been followed in shallow-water habitats (Van Dolah *et al.*, 1987; Probert *et al.*, 1997; Freese *et al.*, 1999).

Basis of advice

Reef-forming corals

One indication that the larvae of *Lophelia pertusa* are long-lived comes from the colonization of oil platform legs in the North Sea. There are no records of living *Lophelia* within a distance of *ca*. 200 km from the recently decommissioned Frig platform (Figure 9), and a larva would have drifted for 1–3 weeks before reaching this site. Thus there is little doubt that reef forming corals will settle upon large artificial substrata such as oil rigs and wrecks, but there is even evidence that they will settle on any hard substratum including lost fishing gear (Figure 10).

Non-reefal corals

Based on the estimate presented by Mortensen and Buhl-Mortensen (2005) it takes around 20–30 years for *Primnoa* to reach a colony height of 60 cm. However, the colonies in a gorgonian stand can be assumed to settle simultaneously, but will probably colonize gradually. Nothing is known about how long a time such a habitat would need to develop in deep water.

Sponges

Sponges are well known for their tremendous ability to repair damages and to restore lost body parts (Simpson, 1984). ...While most sponges are able to repair minor injuries in a short time, possibility for and speed of restoration after a more comprehensive (in relation to volume of the sponge) damage seem to depend on the complexity of the sponge (general morphology, skeleton, canal system, density of the interior) and probably also on physiological factors (WGDEC Report 2009).

Close inspection of the specimens in large catches of deep-water sponges often reveal repairs which look as scars, healed biting marks, abnormal form of part of body or of surface, or new surfaces formed around or under epifauna (Tendal, own observation, Hoffmann *et al.*, 2004). Regeneration experiments have been performed with *Geodia baretti* (North Atlantic, mainly at depths from 100–300 m) (Hoffmann *et al.*, 2003). It was found that explants (2–4 cm^3) had rounded off and closed all openings after two days, and after eight months had reorganized and grown into a small sponges with canal system and cortex. The weight increase of the explants over one year was 40%. Compared to shallow-water sponges, e.g. *Halichondria panacea* and *Cliona celata*, the regeneration processes and the growth are slow (Tendal, unpublished observations; Ayling, 1983; Bell, 2002).

RGCOR comment

WGDEC reliably outlines our limited known in this area. WGDEC do not comment on the possibility of stimulating reef growth in damaged areas by providing artificial substrata. This has not been tried but we do know reefal corals readily colonize submerged infrastructure.

NEAFC requests

NEAFC request 1

1. Vulnerable deep-water habitats in the NEAFC Regulatory Area

NEAFC requests ICES to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats.

ICES advice/answer

WGDEC 2010 provides substantial additional information from many areas in the North Atlantic including Hatton Bank, Rockall Bank, Hebridean slope and Cantabrian Sea (see Chapter 3). WGDEC also maintains a database of corals and sponges that undergoes periodic updating.

Basis of advice

Updated information from a variety of sources.

RGCOR comment

Relevant parts of Chapter 3 continue to update cold-water coral and sponge maps. The WGDEC has added significant new information to NEAFC. A process for updating the WGDEC database and issuing new information in one standard format would be very useful. Maps such as Figure 25 are problematic because the scale leaves relevant details out. Categories such as taxon, depth and biogeographic province would be very useful to management. We are not aware of other outstanding information.

NEAFC request 2

2. Regarding vulnerable habitats and deep-water species

NEAFC Request 2a

2a. ICES is requested to provide advice on an experimental design/protocol appropriate to quantifying VME catch thresholds for the fishing gears used in the NEAFC Regulatory Area. It is suggested that the design should take account of:

1) Differences in the retention efficiency between fishing gears (e.g. bottom trawls, longlines, gillnets and traps) for the VME indicator species (Annex 1; Guidelines for the management of deep-sea fisheries in the high seas; FAO report No881, 2009) found in the NEAFC Regulatory
2) Catch threshold differences for a range of seabed features supporting VMEs (e.g. seamounts, mounds, banks, continental slope)

ICES advice/answer

The encounter clause is meant to provide a means of minimizing damage to VMEs, while NEAFC is requesting a design for quantifying VME catch thresholds. Obviously the two are related. After its review of available information "the WGDEC decided that because the current encounter and move-on rules would still permit pervasive and cumulative destruction of VMEs in the NAFO and NEAFC management areas, a new management strategy needs to be developed."

The following system of zoning would augment encounter protocols:

This new method is a 3-tier system of zoning (areas already being fished with bottom gear - black zone; areas where bottom gear cannot be used - white zone; and areas subject to a precautionary approach - grey zone. This new management system could be implemented through the following five steps:

1) The management areas for bottom fishing activities be delimited into management units based on bathyal biogeographic patterns. These are: 1) Arctic Province, 2) Northern North Atlantic Province, and 3) North Atlantic Province, using current boundaries as delimited in the GOODS report (UNESCO 2009).
2) Within each biogeographic unit a map of all known fishing areas where bottom contact gear has been used will be prepared. These areas should not include areas where single or occasional trawl hauls were made, but should include areas that have been historically fished regularly. Resolution scale of these maps should be the best available, preferably at 1x1 km resolution when available, but could be as coarse as 10x10 km. These

maps will determine the allowable "black zone" bottom fishing areas. Even within these areas, however, there is the chance that some VME species will exist. It is recommended that encounter rules also be used in these areas.

3) Within each biogeographic unit maps demonstrating predicted occurrences or high habitat suitability (defined as >50% probability of occurrence) for cold-water scleractinians, black coral, octocorals, sponges, or other VME species be prepared. These maps will be used to delimit areas where no bottom contact gear can be used until or unless it is subsequently demonstrated through non-destructive surveys (i.e. using methods other than bottom trawls or other bottom contact fishing gear) that no VMEs will be encountered. These will be the "white zone", no bottom fishing areas. Resolution of these maps should be at 1x1 km if at all possible.

4) If an entity proponent would like to fish in an area not encompassed in paragraphs 1 or 2 above (i.e. the "grey" zone), it will be incumbent on that proponent to demonstrate, using bottom cameras or other non-destructive devices, that the area to be fished does not harbour VME species. As an additional incentive to do detailed mapping, perhaps the RFMO/A could grant to that fishing entity exclusive right to fish some or all of the area surveyed if no VMEs were found in the area. Resolution of these areas should be as fine as possible but should not be any coarser than 10x10 km. If bottom contact gear is used in an area deemed open to fishing, and VME species are subsequently discovered to be present, all fishing in that 10x10 km block will cease immediately.

5) Information gathered on VME distributions over time as a result of the other management measures should feedback into refining distribution maps on VMEs and thus allow predictive models to be refined and improved.

Basis of advice

Some information on encounter clauses is available from other RFMOs, although there is no research that justifies the biological basis of encounter rules. This includes research that can establish appropriate cut-off values at certain amounts of bycatch, as well as move off distances. Other ICES WGDEC advice appears to be novel.

RGCOR comment

We have reviewed information from WGDEC in Chapter 5 (Review the science used in assessing vulnerable marine ecosystems and the "Encounter Clause") and Chapter 12 (ICES is requested to provide advice on an experimental design/protocol appropriate to quantifying VME catch thresholds for the fishing gears used in the NEAFC Regulatory Area).

Note: Chapter 12 is missing in the file of the “complete” draft WGDEC 2010 Report on the RGCORE SharePoint site.

Chapter 5 addresses the "encounter clause" which appears to be the response to this NEAFC request although the two items are not the same. Defining appropriate densities to identify VMEs is problematic and needs additional research. The FAO criteria are a good starting place. The WGDEC correctly identifies problems with allowing additional fishing in areas that might have VMEs, as many are fragile and long-lived and cannot easily recover from fishing contact. Encounter rules provide no guarantee that the goal of reducing impact to VMEs will be attained as the first trawl pass is likely the most damaging, and moving on may only subject another area to damage. Several papers have documented the significant bycatch of corals when fishing starts in a new area, and subsequently decline as the coral is removed with continued fishing. Thus the WGDEC recommendation for an augmentation to encounter rules is sound and necessary. Recent advances in predictive habitat models provide important information that can assist with the regional spatial planning they recommend. However, caution should be taken when considering the predictive habitat maps. See RGCOR comments under OSPAR request c. The implementation of Gray zone rules is innovative, but specific criteria should be established for opening an area to fishing, and the size of the area. A flexible system that could help determine the size of the area to be opened would be to scale the openings and closings of areas to the resolution of the research that is undertaken. Finer-scale research would result in smaller closures should VMEs be encountered by the bycatch observer programme.

NEAFC Request 2b

> 2b. Extending closures on the Mid-Atlantic Ridge Based on a proposal by the European Community to expand the current closed areas in the Mid-Atlantic ridge, ICES is requested to evaluate the proposal and provide advice whether the proposed extension will protect VMEs in the areas concerned against significant adverse impacts resulting from bottom fishing activities.

ICES advice/answer

Three features are part of different MPA proposals for the region:

i) the Reykjanes Ridge north of the Sub-Polar Frontal Zone;

ii) the Sub-Polar Frontal Zone, including the Charlie-Gibbs Fracture Zone;

iii) A section of the Mid-Atlantic Ridge north of the Azores, i.e. south of the Sub-Polar Front.

Conclusion

Given the character of the Mid-Atlantic Ridge between Iceland and the Azores, and the increasing depths from north to south, it is highly likely that all of the ridge, but in particular the northern Reykjanes Ridge will feature VME indicator habitats and species. Several areas on the northern, mid and southern MAR have been investigated in depth by international programmes such as MarEco (Census of Marine Life project coordinated by Norway, www.mareco.no, Bergstad *et al*., 2008) and EcoMar (UK national funding and coordination, http://www.oceanlab.abdn.ac.uk/ecomar/). Evidence from these representative areas provides support for the occurrence of VME indicators such as *Lophelia pertusa*, gorgonian corals and deep-water sponge aggregations associated to the hills and seamounts all along the ridge. Therefore, any expansion of the closures that affects relatively shallow hills of the Mid-Atlantic Ridge (i.e. areas shallower than 1500–2000 m) may protect additional VMEs against adverse effects of bottom fisheries.

In this respect it is likely that the proposed amendments on the Reykjanes Ridge (replacement of the current NEAFC closure with two new adjacent closures) would have some additional protective benefit. However, due to limited data on the distribution of VMEs at the relevant spatial scale, quantifying this effect is currently not possible.

The other amendments are not considered likely to have significant added value in terms of reducing the risk of adverse impacts from bottom fisheries as it is currently conducted on the Mid-Atlantic Ridge.

A rationale for reopening the existing closure on the Reykjanes Ridge should be provided. Reopening will likely re-expose VMEs to potential adverse impacts. In view of both the limited information on the exact distribution of VMEs and the likelihood of widespread occurrence of VMEs along the MAR, as well as the need to follow a precautionary approach in fisheries management, a practicable way forward may be to maintain the existing NEAFC closures and in addition to consider expanding these to include the areas proposed by the EC that are not yet covered by the current closures. Such further consideration should then be informed by the rationale and the specific conservation objectives set out for the areas proposed by the EC. The uncertainty created by the inconsistent coordinates for the NW corner of the proposed 'Middle MAR/Charlie-Gibbs Fracture Zone' closure should be clarified.

SGCOR comment

We have reviewed WGDEC Chapter 13 (Extending closures on the Mid-Atlantic Ridge Based on a proposal by the European Community to expand the current closed areas in the Mid-Atlantic ridge). The EC proposal is similar in extent to existing proposals except for MPAs on the Reykjanes Ridge. Given that the current closed area has been protected and thus potentially under recovery as well as already protecting VMEs, it is likely VMEs will be exposed to fishing gear should this area be reopened. Rationale for its reopening as suggested by the WGDEC advice should be forwarded prior to a decision to reopen the area. Some additional analysis that compares the habitat value and condition of the existing closure with the two areas proposed for closure appears warranted.

Annex 5: Working documents presented to WGDEC

Russian investigations of Vulnerable Marine Ecosystems in the Newfoundland area

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Abstract

Results of the retrospective Soviet and recent Russian investigations of corals and sponges in the Newfoundland area are presented. Bottom fishery map, based on daily ship's reports in 1987–2008 is supplied. Preliminary assessment of validity of the closured areas and recommendations on further investigations of VMEs in the NAFO RA are considered.

Introduction

With a view of implementation the UNGA Resolutions, which called for an assessment of the risk of significant adverse impacts of fishing activities on Vulnerable Marine Ecosystems (VMEs) and the adoption of appropriate mitigating measures, NAFO has undertaken the appropriate work required. It has resulted in advice adopted by NAFO Fisheries Commission (FC) on precautionary closure of 17 areas for bottom fishery on Flemish Cap and Grand Bank, as well as seamounts Orphan Knoll, Corner Rise, New England and Newfoundland seamounts (NAFO, 2009c).

NAFO Scientific Council (SC) is responsible for researches and development of advice for VME protection in the North-West Atlantic (NWA). In 2007 SC has formed a Working Group on Ecosystem Approach of Fishery Management (WGEAFM). Its main task is to locate VME in the NWA and to assess potential adverse fisheries impact on corals and sponges. For the previous period WGEAFM and SC have summarized available data and prepared advice relevant to NAFO position development regarding VME identification and its protection measures. Within the frameworks of SC, the group of scientists has prepared and published coral's identifier (NAFO, 2009a), which will provide an improved quality of samples collection in field conditions.

Appropriate works by Russian Federation on VME studying in the NAFO Regulatory Area (RA) had started in PINRO about three years ago. Scientists from Murmansk provided maps of Russian bottom fishery in the NAFO RA, performed retrospective research and fishery data on distribution VMEs indicator species, organized data collection of VMEs species by observers on fishing vessels. The main results of these works were presented at WGEAFM in 2008 (Vinnichenko and Sklyar, 2008).

Lately scientists from PINRO were focused on improving the quality of the map of the bottom fishery and development the guidance for collecting primary VMEs data on fishing vessels. Besides, analyse of retrospective Soviet benthic researches in the NWA has started.

The main object of this work is to provide information at WGDEC about the results of latest Russian investigations and determine the course of the future investigations of VMEs in the NAFO RA.

Materials and methods

To prepare this paper were used:

- primary data of the Soviet investigation of benthos in the Newfoundland area in 50th and 70th years of the XX century;
- reports provided by observers on Russian fishing vessels in 2008–2009;
- daily ship reports (DSR) data in 1987–2008;
- personal communications of skippers of Russian fishing vessels in the NAFO RA;
- reports of SC, FC and WGFMS NAFO;
- Russian and other countries publications.

Soviet investigations of benthos in the Newfoundland area (Nesis, 1962; 1965) were the main references for searching primary data. As a result, materials from three cruises carried in 1958, 1971, 1976 were found out in the PINRO archive.

Primary data on corals/sponges occurrence on Grand Bank and Flemish Cap were extracted from the all materials (Table 1). Quantitative data were obtained by grab «Ocean-50» (capture square 0,25 m^2) only in 1976. Qualitative data were obtained in 1958 and 1971 using bottom-trawl and Sigsbi trawl. Catch quantity obtained by grab, determined visually and classed to scale: single, dozens and hundreds organisms or fragments of each species. Total number of benthos stations: 101, benthos samples: 121 (Table 1).

In 2008–2009 VMEs data collected by NAFO observers on fishing vessels in seven cruises included:

- VMEs indicator species records in catches without species identification;
- take a photograph of VMEs indicator species;
- records of trawl's hooks locations and assessment of gear damage by corals.

VMEs indicator species identified to the genus level by photos in the PINRO laboratory.

The map of Russian fishery fleet location was used in addition to indicate corals and sponges concentrations. Russian bottom fishery in 1987–2008 was mapped using DSR data (coordinates of the first trawl set) from the PINRO fishery database. In comparison with previous mapping (Vinnichenko and Sklyar, 2008) based on data provided by observers, new map is more representative due to DSR data using. Various target species were used separately for mapping bottom fishery (Table 2). Data were filtered according hydrobionts distribution features and limited with known extreme target fishery depth for each species. Besides all tows made within Canada EEZ were deleted from the base. Totally 40 456 bottom tows were mapped (Table 2). The part of insufficient data consists 8.3%. All bottom fishery data for each target species were compiled to one map. Data on Atlantic cod, American place and Witch flounder fishery as well as on longline fishery were not used to map Russian fishery due to low catches and difficulties of filtration the data for these species.

In 50–60 of the XX century the positions of Russian vessels were determined with the astronomical method, in 70–80 - radio-navigation systems «Loran-C» and «Dekka», in last two decades - satellite-navigation systems GPS.

Results

Soviet benthos surveys

The results of Soviet benthos surveys demonstrated that VMEs indicator species in the research areas occurred relatively seldom. Corals and sponges were registered in 47 from 101 conducted stations and in 57 from 121 collected samples (Table 3, Figure 1).

The bulk of corals and sponges catches were obtained on the southwestern slope of the Flemish Cap at the depths of 200–500 m and on the northeastern part of the Grand Bank at the depths of 250–500 m (Table 3, Figure 1).

On the major part of the Flemish Cap and the Grand Bank, corals were presented by *Alcyonacea* order: *Eunephthya glomerata, E. fruticosa, E. florida.* Besides, on the eastern slope of the Flemish Cap at the depths of 350–450 m and on its western slope between 330–375 m, single catches of *Paragoria* were obtained.

Sponge’s assemblages on the both banks were registered at the depths of 200–500 m and mainly *Myxilla spp., Polymastia spp., Tetilla spp., Geodia spp., Reniera spp., Tentorium spp*. were presented.

NAFO observers

In August–September 2008 during redfish fishery in the southwestern part of the Flemish Cap Bank (depths 302–355 m) observers occasionally registered catch of single coral fragments of *Pennatulacea spp.* (Table 4, Figure 2). Corals catches at trawlings lasted 0.5–4 hours didn’t exceed 0.1 kg.

In May–July 2009 at Greenland halibut fishery in 3 LM Divisions (depths 770–1300 m) Eleven species of corals of four orders *Alcyonacea, Pennatulacea, Antipatharia, Gorgonacea* were occurred. Catches of the corals didn't exceed 0.9 kg per trawlings (Table 5). Catch of sponge *Geodia spp.* was recorded only once and composed approximately 5 kg.

In other areas and in other fisheries periods VMEs indicator species were absent.

Russian bottom fishery

According to the DSR in the period of 1987–2008 Russian vessels used bottom trawls at depths 30–1600 m (Figure 3). In this period trawlings were conducted mainly on Sackville ridge, on the northeastern and southeastern slopes of the Grand Bank at the depths of 800–1100 m, on southwestern slope of the Grand Bank at the depths of 200–600 m and on all slopes of the Flemish Cap with the depths of 200–700 m (Figure 3). Rather active fishery was also conducted on the northeastern and southeastern parts of the Flemish Pass at the depths of 700–1200 m, on the shallows of the Grand Bank “tail” at the depths less than 100 m and on the northeastern slope of this bank at the depths range of 100–200 m. In the central part of the Flemish Pass with the depths more than 1000 m, on the northern, eastern and southern slopes of the Flemish Cap with the depths more than 500 m, on some shallows and slopes of the Grand Bank, fisheries intensity was insignificant (Figure 3).

Analysis of the fisheries maps demonstrates that Russian fleet didn’t work in the majority of the areas that were closed by FC in VMEs protection purposes. The exceptions are the southwestern part of the area №7 (northern slope of the Flemish Cap) and the area №2 (southern part of the Flemish Pass and adjacent area of the eastern slope of the Grand bank) where Russian vessels repeatedly conducted bottom hauls

(Figure 3). Besides, some trawlings were registered within the areas №4, 9, and 11(Figure 3).

In particular, according to skipper's data, bottom-trawls used to be applied earlier in the areas № 2, 7, 8, 9, 10, 11 where corals and sponges were not registered in catches. At the same time skippers couldn't provide the coordinates of the tows trace conducting within these areas.

Discussion

Limited quantity, fragmentary and insufficient quality of the Soviet benthic available data are not enough to provide the reliable distribution of the cold-water corals and sponges in the Newfoundland area in the 50–70 of the XX century. Results of these investigations can be considered as preliminary, and its comparison with present-day data is possible only for several areas, where investigations were conducted comparatively intensively. As different gears and data collecting methods were used, there is no way to analyse the changes of biomass for the last period.

Southwestern slope of the Flemish Cap and northeastern part of the Grand Bank, evidently, were the relatively more investigated areas by Soviet research surveys in the NAFO RA. It was made nine benthos stations on the southwestern Flemish Cap and eleven stations on the northeastern Grand Bank (Table 3, Figure 1).

Comparative analysis of the retrospective data on corals/sponges distribution in the Newfoundland area demonstrates the general correspondence with nowadays data on VMEs occurrence in this area (NAFO, 2008a; NAFO, 2009d). It's worth noting the resemblance of corals and sponges distribution on the southeastern Flemish Cap provided by Soviet researches (Figure 1) with recent foreign investigations (NAFO, 2008a; NAFO, 2009d). Besides, these data RA correlate well with the Russian information provided before (Vinnichenko and Sklyar, 2008).

Searching and analysing the primary data of the Soviet benthic investigation in the NWA just started. There is possibility to find additional archive data to clarify the species composition and provide the information on distribution features of virgin corals and sponges concentrations in the Newfoundland area. In view of uncertainty of the appropriate works amount, including searching, processing and analysing, now is not possible to define the dates of material provision to WGDEC.

Fishery information as research data appears to be one of the important instruments to identify VMEs location. Corals/sponges records in the catches and their biomass estimation help to identify VMEs location rather precisely (NAFO, 2008a). Until 2008, corals records in the catches haven't been documented on Russian fishing vessels. These data have been collecting by observers in the NAFO RA only last 2 years and its quality and quantity so far appeared to be insufficient, because of lack of observer's experience and methodical guidance. For these reasons, data provided by observers could have been used only to indicate the existence/absence of VMEs indicator species, and their quantity in the catches.

Fishing vessels try to avoid areas with high coral's concentrations, due to gear damage. Therefore bottom fishery footprint can be used to identify the areas of corals/sponges distribution or absence in the area (ICES, 2005). Effectiveness of this method highly depends on accuracy and reliability of bottom fishery data used for footprint. Obviously data on fleet efforts distribution at fishing bottom species could be also applied to identify location of sponge accumulations.

Earlier in PINRO two attempts were made Russian bottom fishery footprint in the NAFO RA. The first map was based on data provided by NAFO observers on the fishing vessels (Vinnichenko and Sklyar, 2008). But this map of the bottom fishery had low reliability because of limited information. The second footprint based on more considerable DSR data, consisted unintentional errors of database that could diminish its practical value (NAFO, 2009b).

The method of DSR data filtered for different target species (see Section "Material and methods") were used to improve the quality and reliability of the footprint (Figure 3). At the same time, this map, as two previous footprint based on the one fishery parameter only, coordinates of the first trawl set. There is lack in PINRO database the coordinates of tow traces and coordinates of tow stop. The lack of this information affects on the map reliability and makes incomplete idea of the spatial distribution of the fishing area. Most probably this fact can explain the discrepancy between the bottom fishery footprint in the NAFO RA and the data compiled by skippers of Russian fishing vessels in areas closed to protect VMEs (see Section "Russian bottom fishery").

Despite all the drawbacks mentioned above as well as discrepancies in volumes and in methods of primary data filtering, Russian map well enough correlates with the similar of international fishery footprint made by NAFO Secretariat (Figures 3 and 4). Moreover Russian map has certain advantages such as impossibility to lose important fisheries information because primary data are filtered by criteria of occurrence at least in two different years.

Future specialised international VMEs researches that are planned to be continued in 2010 on board Spanish research vessel will help to assess the effectiveness and validity of areas proposed for closure by NAFO FC. The precise and accuracy bottom fishery footprint by all NAFO Contracting Parties shall promote this problem solving. The information of coordinates of tow traces should be considered as the most valuable. Up to now the bottom fishery footprint based on coordinates of tow traces was provided by Faroe Islands, Greenland and Estonia (NAFO, 2009b).

Conclusion

1) Data provided by Soviet benthos researches correlate in general with nowadays data on corals/sponges distribution on the southwestern Flemish Cap and northeastern Grand Bank.

2) High intensity of the bottom fishery on Flemish Cap and Grand Bank indicate areas of long damage-free trawl traces without coral accumulations.

3) As an additional tool to analyse bottom fishery footprint it is reasonable to use method of primary data filtering by different species of targeted fishery.

4) The most precise and accurate bottom fishery footprint reasonably to be based on coordinates of tow traces.

5) In view of development the appropriate measure to protect VMEs in the NAFO RA recommended:

- during second stage (2010) of complex benthos Spanish survey it is recommended to focus on investigating areas closed for bottom fishery as well as areas proposed by NAFO SC as candidate VMEs areas;
- to activate collecting of indicator species data on fishing vessels;
- to proceed an improvement of international bottom fishery footprint in the NAFO RA;

- to qualify NAFO observers on collecting primary data and identification of VMEs indicator species;
- to continue for searching and analysing Soviet and other benthic researches in NWA.

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Table 1. Soviet investigations of benthos on Flemish Cap and Grand Bank.

Year	Name of vessel	Area	Depth of investigation, m	Number				
				Stations	Samples			
					Sigsbi trawl	Bottom trawl	Grab «Ocean-50»	Total
1958	«Odessa»	Flemish Cap, Grand Bank	55–475	29	-	29	-	29
1971	«Persey-III»	Flemish Cap, Grand Bank	47–1700	42	41	1	-	42
1976	«Persey-III»	Flemish Cap, Grand Bank	45–350	30	20	5	25	50
Total			45–1700	101	61	35	25	121

Table 2. Primary data for mapping Russian bottom fishery in the NAFO RA in 1987–2008.

Species*	NAFO Div.	Depth, m	Number of tows
Greenland halibut	3LMNO	500–1600	12 836
Atlantic redfish	3LMN	200–1000	7990
	3O	100–800	9573
Scate	3LMNO	30–1100	2821
White hake	3NO	40–300	216
Yellowtail flounder	3NO	40–100	68
Shrimp	3LM	200–500	6952
Total		30–1600	40 456

Table 3. Occurrence of VME indicator species on Flemish Cap and Grand Bank by Soviet benthos investigations in 1958, 1971, 1976.

№	Date	Vessel	Coordinates N	Coordinates W	Gear	Depth, m	VME indicator species: Corals	VME indicator species: Sponge
1	05-03-58	Odessa	47°11'	45°24'	Bottom trawl	260–270		*Myxilla sp., Radiella sp.*
2	05-03-58	Odessa	46°50'	45°50'	Bottom trawl	260–275	Unidentified *Anthozoa*	Unidentified *Porifera*
3	06-03-58	Odessa	46°39'	45°58'	Bottom trawl	260–375		
4	06-03-58	Odessa	46°36'	46°01'	Bottom trawl	390–420		*Myxilla sp.*
5	06-03-58	Odessa	46°32'	46°05'	Bottom trawl	410–430	Unidentified *Anthozoa*	*Myxilla sp.*
6	09-03-58	Odessa	46°35'	44°38'	Bottom trawl	250–260		*Polymastia sp., Radiella sp.*
7	10-03-58	Odessa	47°1'	44°00'	Bottom trawl	450–350	*Paragorgia sp.*	*Myxilla sp., Radiella sp.*

			Coordinates				VME indicator species	
№	Date	Vessel	N	W	Gear	Depth, m	Corals	Sponge
8	11-03-58	Odessa	47°00'	45°37'	Bottom trawl	245–250		*Phakellia sp., Myxilla sp.*
9	12-03-58	Odessa	47°01'	46°27'	Bottom trawl	370–340		*Myxilla sp.*
10	12-03-58	Odessa	47°00'	47°14'	Bottom trawl	325–315		
11	19-03-58	Odessa	46°31'	45°29'	Bottom trawl	325		*Myxilla sp., Radiella sp., Phakellia sp., Geodia baretti*
12	22-03-58	Odessa	46°42'	45°28'	Bottom trawl	230		*Myxilla sp., Radiella sp., Polymastia sp.*
13	01-04-58	Odessa	47°37'	47°14'	Bottom trawl	350–400	*Eunephthya florida*	Unidentified *Porifera*
14	04-04-58	Odessa	48°22'	49°19'	Bottom trawl	415	*Eunephthya florida*	*Myxilla sp., Polymastia sp.*
15	08-04-58	Odessa	45°26'	53°51'	Bottom trawl	80	*Eunephthya fruticosa*	
16	09-04-58	Odessa	45°11'	54°41'	Bottom trawl	130–110		
17	09-04-58	Odessa	45°1'	54°45'	Bottom trawl	160–115		*Myxilla sp., Polymastia sp*
18	09-04-58	Odessa	45°06'	54°51'	Bottom trawl	100–155	*Eunephthya fruticosa*	*Myxilla sp.*
19	10-04-58	Odessa	44°58'	54°29'	Bottom trawl	300–325	*Eunephthya florida*	*Myxilla sp., Radiella sp.*
20	11-04-58	Odessa	45°02'	54°	Bottom trawl	90–80		
21	12-04-58	Odessa	45°49'	51°51'	Bottom trawl	85		
22	14-04-58	Odessa	43°17'	51°06'	Bottom trawl	100–110	*Eunephthya fruticosa*	Unidentified *Porifera*
23	15-04-58	Odessa	43°08'	50°51'	Bottom trawl	115–150		
24	15-04-58	Odessa	43°01'	50°15'	Bottom trawl	100–110	*Eunephthya fruticosa*	*Myxilla sp., Reniera sp.*
25	15-04-58	Odessa	43°11	50°23'	Bottom trawl	60–65		*Reniera, Tetilla, Myxilla*
26	15-04-58	Odessa	43°4'	49°48'	Bottom trawl	55–60	*Eunephthya fruticosa*	*Myxilla sp., Reniera sp., Geodia sp.*
27	18-04-58	Odessa	45°19'	48°45'	Bottom trawl	250–475		*Myxilla sp.*
28	20-04-58	Odessa	46°22'	47°27'	Bottom trawl	350–435	*Eunephthya florida*	*Myxilla sp., Polymastia sp.*
29	27-04-58	Odessa	46°57'	46°29'	Bottom trawl	375–330	*Paragorgia sp.*	*Myxilla sp., Polymastia sp.*
1	24-05-71	Persey III	45°39'	58°26'	Sigsbi	100		
2	25-05-71	Persey III	46°12'	57°02'	Sigsbi	55		

№	Date	Vessel	Coordinates N	W	Gear	Depth, m	VME indicator species Corals	Sponge
3	25-05-71	Persey III	46°21'	56°49'	Sigsbi	47		
4	26-05-71	Persey III	45°58'	55°46'	Sigsbi	61		
5	26-05-71	Persey III	46°04'	56°26'	Sigsbi	54		
6	27-05-71	Persey III	46°07'	57°06'	Sigsbi	120		
7	27-05-71	Persey III	45°49'	56°46'	Sigsbi	70		
8	27-05-71	Persey III	45°39'	56°25'	Sigsbi	49		
9	28-05-71	Persey III	45°23'	55°56'	Sigsbi	50		
10	29-05-71	Persey III	44°59'	56°13'	Sigsbi	260		
11	29-05-71	Persey III	44°54'	55°38'	Sigsbi	160		Unidentified *Porifera*
12	29-05-71	Persey III	45°09'	55°23'	Sigsbi	145		
13	30-05-71	Persey III	45°59'	55°24'	Sigsbi	130		
14	30-05-71	Persey III	45°56'	54°59'	Sigsbi	115		
15	30-05-71	Persey III	45°45'	55°12'	Sigsbi	165		
16	30-05-71	Persey III	45°32'	55°14'	Sigsbi	130		
17	02-06-71	Persey III	44°31'	5337'	Sigsbi	250		
18	03-06-71	Persey III	44°23'	53°1'	Sigsbi	220		
19	03-06-71	Persey III	45°08'	53°3'	Sigsbi	80		
20	03-06-71	Persey III	45°28'	53°27'	Sigsbi	70		
21	06-06-71	Persey III	44°32'	52°3'	Sigsbi	83		
22	07-06-71	Persey III	43°48'	52°06'	Bottom trawl	115		
23	08-06-71	Persey III	43°23'	51°31'	Sigsbi	142		
24	08-06-71	Persey III	43°1'	51°15'	Sigsbi	190		
25	11-06-71	Persey III	43°08'	51°16'	Sigsbi	490	*Alcyonacea*	
26	13-06-71	Persey III	43°5'	51°31'	Sigsbi	170		
27	13-06-71	Persey III	43°47'	51°18'	Sigsbi	75		
28	14-06-71	Persey III	45°11'	51°56'	Sigsbi	72		
29	15-06-71	Persey III	44°26'	51°01'	Sigsbi	70		
30	17-06-71	Persey III	44°21'	50°19'	Sigsbi	65		
31	13-07-71	Persey III	48°37'	52°16'	Sigsbi	250	*Alcyonacea*	
32	13-07-71	Persey III	46°39'	50°05'	Sigsbi	70		
33	17-07-71	Persey III	48°00'	483°5'	Sigsbi	300		
34	17-07-71	Persey III	47°44'	48°33'	Sigsbi	200		
35	17-07-71	Persey III	47°4'	47°52'	Sigsbi	250		
36	18-07-71	Persey III	47°28'	48°04'	Sigsbi	180		Unidentified *Poifera*
37	18-07-71	Persey III	47°13'	48°03'	Sigsbi	130	*Alcyonacea*	Unidentified *Porifera*
38	18-07-71	Persey III	48°17'	47°28'	Sigsbi	1700		
39	19-07-71	Persey III	46°27'	47°25'	Sigsbi	265		Unidentified *Porifera*
40	19-07-71	Persey III	46°24'	47°38'	Sigsbi	165		Unidentified *Porifera*
41	21-07-71	Persey III	46°48'	47°2'	Sigsbi	255		
42	22-07-71	Persey III	46°51'	47°25'	Sigsbi	210		

№	Date	Vessel	Coordinates N	Coordinates W	Gear	Depth, m	VME indicator species Corals	VME indicator species Sponge
1	01-04-76	Persey III	44°57'	48°59'	Sigsbi, Ocean	300–230	*Eunephthya sp.*	Unidentified *Porifera*
2	01-04-76	Persey III	44°58'	49°07'	Sigsbi, Ocean	80–90		
3	01-04-76	Persey III	45°00'	49°10'	Sigsbi, Ocean	50–65	*Eunephthya sp.*	
4	13-04-76	Persey III	45°08'	55°03'	Bottom trawl	140–130		Unidentified *Porifera*
5	16-04-76	Persey III	45°06'	54°11'	Bottom trawl	85–82		
6	19-06-76	Persey III	45°22'	52°04'	Sigsbi, Ocean	75–85		
7	20-04-76	Persey III	45°14'	51°26'	Ocean	85		
8	26-04-76	Persey III	45°24'	59°49'	Bottom trawl	75–85		
9	27-04-76	Persey III	44°31'	49°41'	Sigsbi, Ocean	55	*Eunephthya florida*	
10	27-04-76	Persey III	44°14'	49°41'	Sigsbi, Ocean	45–48		
11	30-04-76	Persey III	43.33'	49°5'	Sigsbi, Ocean	62–65		
12	30-04-76	Persey III	43°46'	49°41'	Ocean	60		
13	30-04-76	Persey III	43°51'	49°19'	Ocean	102		
14	06-05-76	Persey III	44°42'	49°02'	Sigsbi, Ocean	215–220		*Reniera tubulosa*
15	11-05-76	Persey III	46°2'	49°05'	Sigsbi, Ocean	65		
16	11-05-76	Persey III	46°05'	48°43'	Sigsbi, Ocean	75–85	*Eunephthya sp.*	
17	11-05-76	Persey III	45°49'	48°19'	Sigsbi, Ocean	100	*Eunephthya florida*	
18	11-05-76	Persey III	45°41'	48°13'	Sigsbi, Ocean	175–200		
19	16-05-76	Persey III	46°14'	48.50'	Bottom trawl	55–60	*Eunephthya glomerata*	
20	18-06-76	Persey III	49°06'	51°49'	Sigsbi, Ocean	300		Unidentified *Porifera*
21	18-06-76	Persey III	48°55'	52°24'	Ocean	350		Unidentified *Porifera*
22	19-06-76	Persey III	48°2'	52°06'	Sigsbi, Ocean	185	*Eunephthya sp.*	
23	19-06-76	Persey III	48°13'	51°5'	Ocean	265	*Eunephthya sp.*	
24	19-06-76	Persey III	47°57'	51°14	Sigsbi, Ocean	180	*Eunephthya sp.*	
25	19-06-76	Persey III	47°46	50°5'	Sigsbi, Ocean	145	*Eunephthya florida*	Unidentified *Porifera*
26	19-06-76	Persey III	47°24'	50	Sigsbi, Ocean	80–85		

№	Date	Vessel	Coordinates N	Coordinates W	Gear	Depth, m	VME indicator species Corals	VME indicator species Sponge
27	19-06-76	Persey III	47°41'	49°52'	Sigsbi, Ocean	110–115		
28	20-06-76	Persey III	47°58'	49°45'	Sigsbi, Ocean	185		
29	20-06-76	Persey III	48°14'	49°45'	Sigsbi, Ocean	220		Unidentified *Porifera*
30	24-06-76	Persey III	47°32'	48°00'	Bottom trawl	240–235	*Eunephthya florida*	*Myxilla sp.*

Table 5. Occurrence of corals and sponges at Greenland halibut bottom fishery in the NAFO RA in May–July 2009 (observation data from Russian trawler M-0418 "Melkart-2").

Date	Coordinates	Depth, m	Name	Number, ind	Length, cm	Catch, kg
28.05	46°16'N 46°48'W- 46°37'N 46°47'W	1240 1300	*Pennatulacea spp.*	1	24	0,005
01.06	46°56'N 46°45'W- 46°17'N 46°33'W	1100 1174	*Pennatulacea spp.* *Antipatharia spp.*	11 1	16–79	0,055 0,065
01.06	47°28'N 46°04'W- 47°36'N 46°59'W	820 845	*Pennatulacea spp.* *Pennatulacea spp.*	11 1	23–55 14	0,045 0,010
03.06	46°53'N 46°45'W- 46°32'N 46°34'W	995 1150	*Pennatulacea spp.* *Antipatharia spp.*	8 1	18–39 26	0.070 0,020
05.06	46°21'N 46°42'W- 46°40'N 46°35'W	1015 1120	*Pennatulacea spp.*	8	16–40	0,050
06.06	46°47'N 46°42'W- 46°25'N 46°38'W	945 1145	*Pennatulacea spp.*	4	14–31	0,015
07.06	46°39'N 46°34'W- 46°19'N 46°42'W	1025 1112	*Pennatulacea spp.* *Antipatharia spp.*	17 2	9–40 35–45	0,055 0,290
10.06	45°38'N 46°06'W- 45°50'N 47°45'W	920 930	*Pennatulacea spp.*	4	15	0,010
11.06	45°34'N 48°12'W- 45°24'N 47°28'W	954 1000	*Pennatulacea spp.*	8	18–26	0,035
12.06	45°37'N 48°07'W- 45°48'N 47°48'W	910 940	*Pennatulacea spp.*	2	18–25	0,015
13.06	45°48'N 47°50'W- 45°39'N 48°06'W	770 809	*Pennatulacea spp.*	4	23–28	0,070
14.06	45°34'N 48°12'W- 45°24'N 48°30'W	950	*Pennatulacea spp.*	73	11–32	0,293
15.06	46°19'N 46°42'W- 46°41'N 46°36'W	1000 1100	*Pennatulacea spp.*	6	35–41	0,110
16.06	46°49'N 46°45'W- 46°27'N 46°22'W	1075 1080	*Pennatulacea spp.*	32	13–46	0,280
18.06	45°34'N 48°12'W- 45°23'N 48є29'W	950 1020	*Pennatulacea spp.* *Geodia spp.*	6 2	22–42 20	0,110 5.020
19.06	45º25'N 48º26'W- 45º36'N 48º20'W	980 1000	*Pennatulacea spp.*	41	14–29	0,235
20.06	45º37'N 48º04'W- 45º48'N 47º47'W	970 993	*Capnella spp.*	1	7	0,010

Date	Coordinates	Depth, m	Name	Number, ind	Length, cm	Catch, kg
21.06	45°48'N 47°47'W-	950	*Pennatulacea spp.*	9	14–52	0,110
	45°37'N 48°08'W		*Capnella spp.*			0,590
22.06	45°25'N 48°26'W-	900	*Pennatulacea spp.*	18	17–25	0,060
	45є°35'N 48°09'W	1038				
23.06	45º48'N 47°48'W-	908	*Pennatulacea spp.*	10	21–28	0,100
	45°38'N 48°05'W	946	*Capnella spp.*	61		0,510
24.06	45°34'N 48°12'W-	950	*Pennatulacea spp.*	4	22	0,020
	45°23'N 48°08'W	1040				
25.06	45°48'N 47°50'W-	850	*Pennatulacea spp.*	3	21–27	0,010
	45°40'N 48°01'W	1300	*Capnella spp.*	12		0,050
26.06	45°38'N 48°05'W-	888	*Pennatulacea spp.*	7	10–25	0,030
	45°44'N 47°54'W	940	*Capnella spp.*	180		0,820
06.07	47°45'N 46°46'W-	950	*Pennatulacea spp.*	29	11–36	0,070
	48°05'N 46°38'W	1042	*Antipatharia spp.*			0,045
07.07	47°47'N 46°47'W-	821	*Pennatulacea spp.*	12	7–48	0,095
	47°30'N 47°03'W	902	*Antipatharia spp.*			0,030
08.07	46°54'N 46°45'W-	1045	*Pennatulacea spp.*	28	16–50	0,210
	46°36'N 46°32'W	1160				
	45°36'N 48°06'W-	935	*Capnella spp.*			0,200
09.07	45°48'N 47°46'W	1029	*Antipatharia spp.*			0,040
11.07	46°19'N 46°41'W-	1014	*Pennatulacea spp.*	5	17–37	0,015
	46°37'N 46°32'W	1060	*Antipatharia spp.*			0,020
11.07	47°14'N 47°07'W-	945	*Pennatulacea spp.*	1		0,010
	47°36'N 46°53'W	970	*Antipatharia spp.*			0,020
12.07	47°43'N 46°49'W-	950	*Pennatulacea spp.*	46	5–43	0,200
	48°00'N 46°38'W	1045	*Capnella spp.*	1	4	0,005
			Gorgonacea spp.	1		0,001
14.07	48°08'N 47°34'W-	946	*Pennatulacea spp.*	3		0,010
	48°08'N 47°06'W	950				
17.07	48°09'N 47°13'W-	1000	*Gorgonacea spp.*	1		0,001
	48°09'N 47°40'W	1072				
20.07	48°07'N 47°10'W-	900	*Antipatharia spp.*			0,001
	48°08'N 47°35'W	945				
21.07	48°09'N 47°11'W-	1080	*Antipatharia spp.*			0,001
	48°09'N 47°37'W	1170				
26.07	48°12'N 46°32'W-	980	*Pennatulacea spp.*	6	8–31	0,045
	47°53'N 46°41'W	1030	*Antipatharia spp.*			0,010
27.07	48°10'N 46°33'W-	1020	*Pennatulacea spp.*	24		0,150
	47°50'N 46°40'W	1033	*Antipatharia spp.*			0,001
28.07	48°44'N 46°50'W-	880	*Pennatulacea spp.*	60	6–26	0,160
	48°02'N 46°42'W	920	*Antipatharia spp.*			0,060
29.07	48°13'N 46°46'W-	930	*Pennatulacea spp.*	4		0,022
	48°10'N 47°12'W	1130	*Antipatharia spp.*			0,020

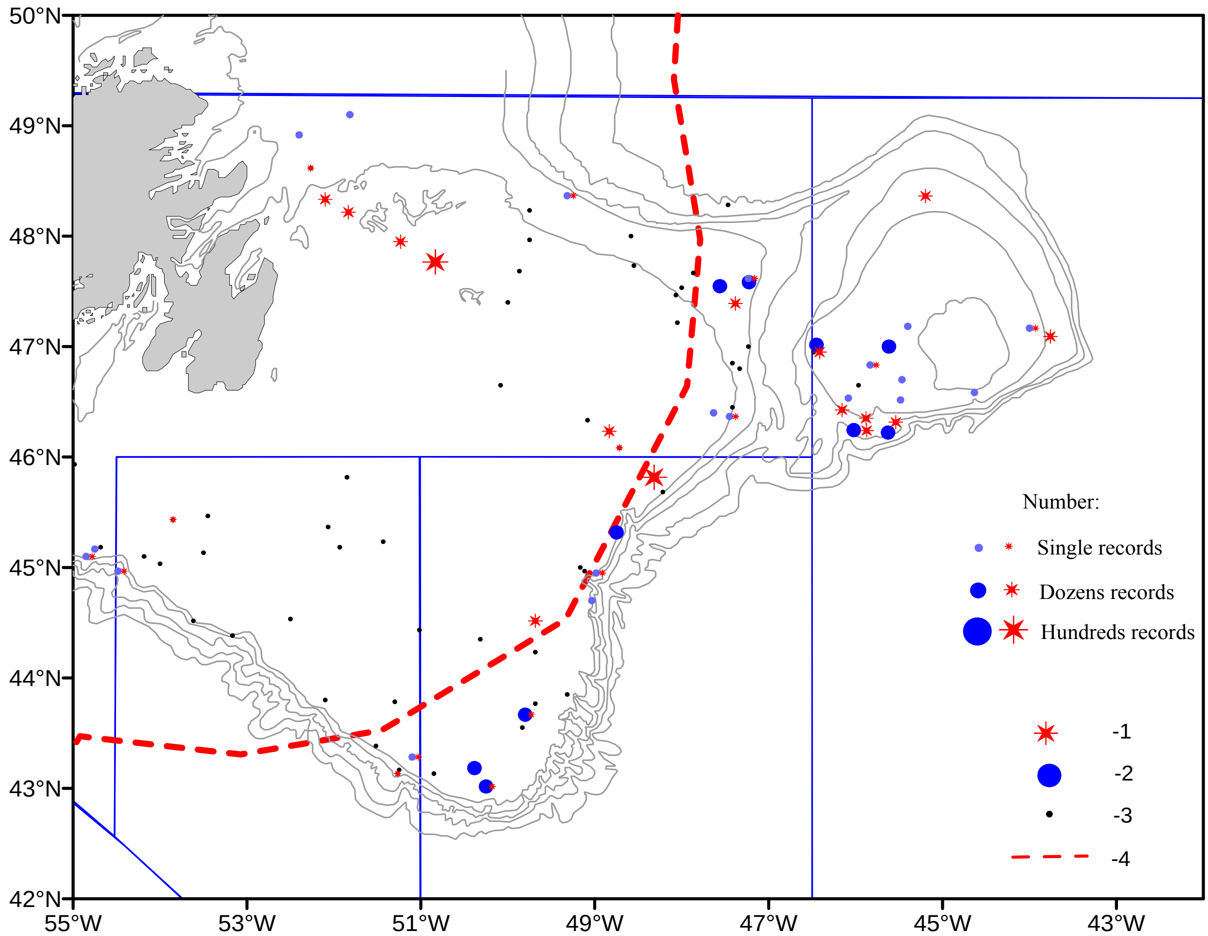

Figure 1. Distribution of VME indicator species on Flemish Cap and Grand Bank (by Soviet benthos surveys in 1959, 1971, 1976). 1 – corals; 2 – sponges; 3 – benthos stations without VME indicator species; 4 – Canadian EEZ.

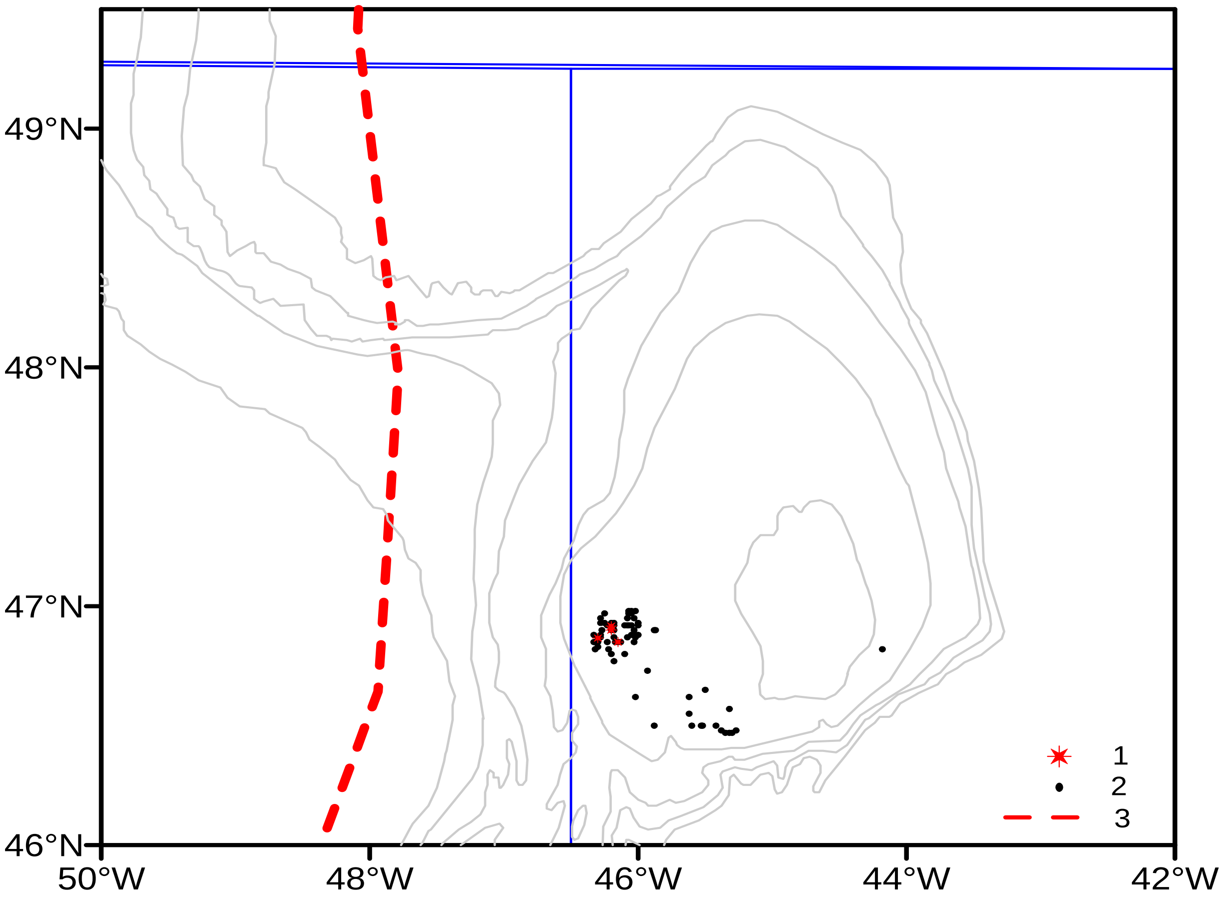

Figure 2. Occurrence of corals *Pennatularia spp.* in catches of Russian trawler "Matrioska" M-1007 on Flemish Cap in August–September 2008. 1 - occurrence of corals in catches; 2 – first trawl set; 3 – Canadian EEZ.

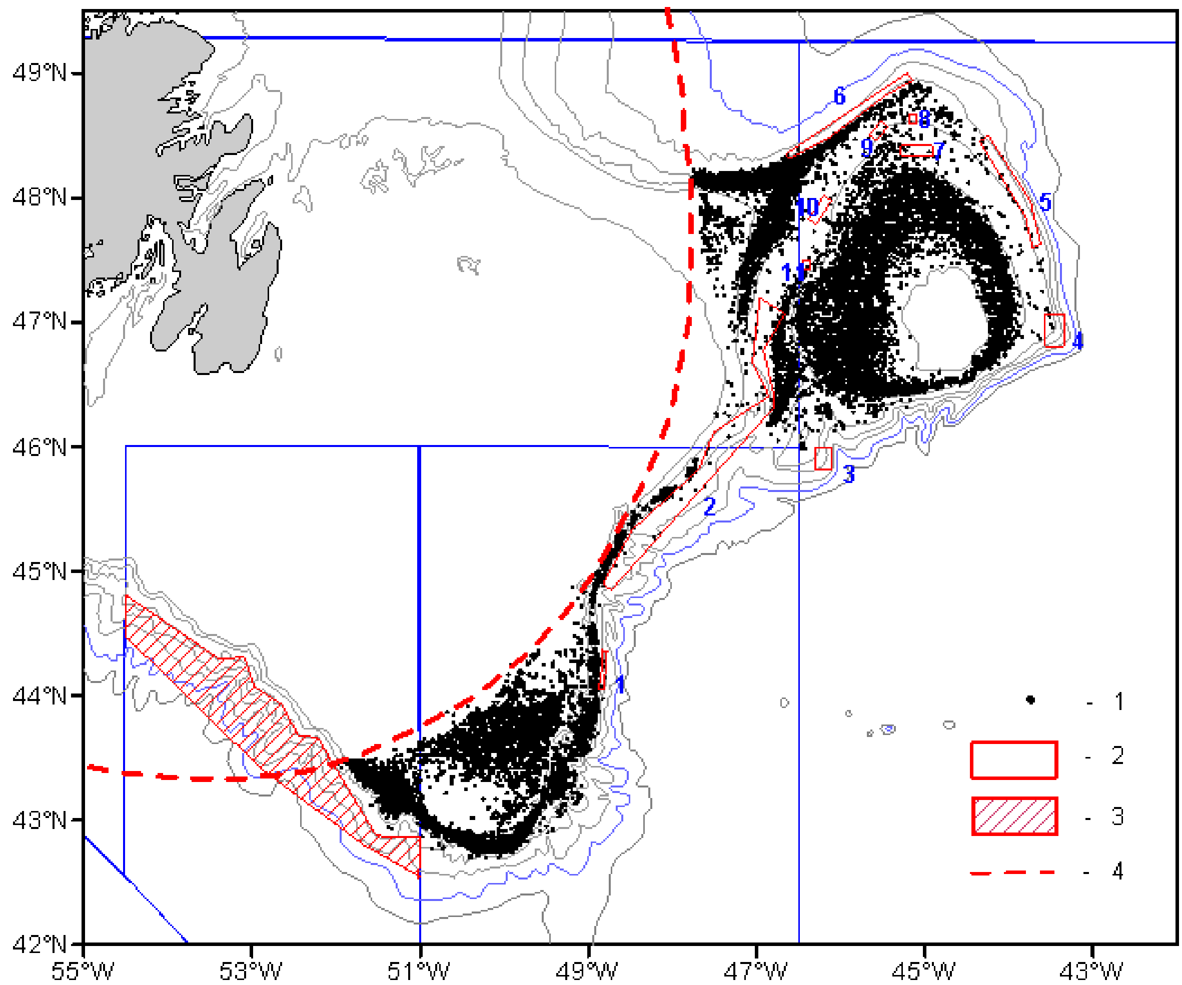

Figure 3. Russian bottom fishery footprint in 1987–2008 and areas closed by the NAFO FC in VMEs protection purposes. 1 - first trawl set; 2 – areas closed for bottom fishery from 1st January 2010; 3 – area closed for bottom fishery from 1st January 2008; 4 – Canadian EEZ.

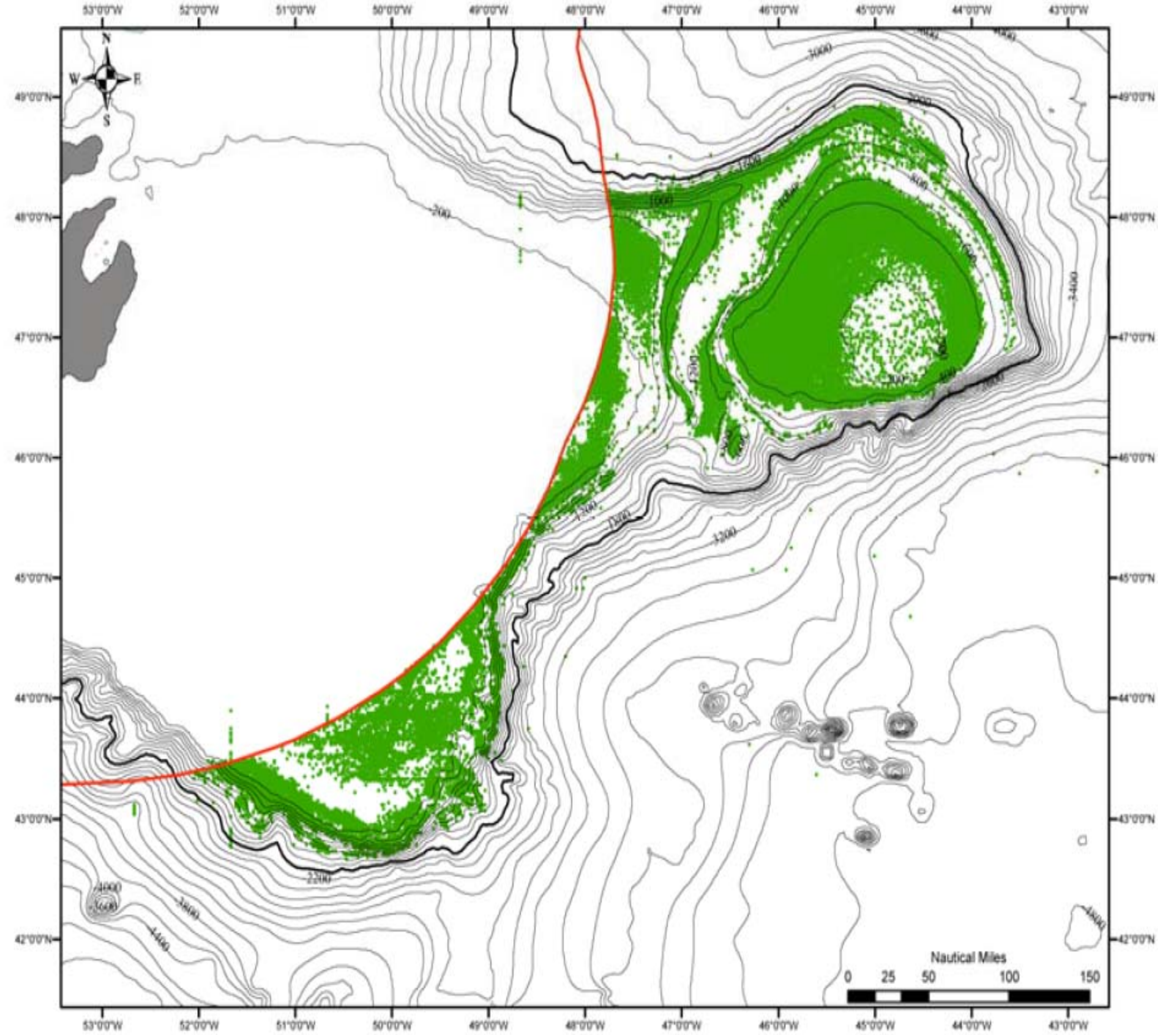

Figure 4. Composite plot of coordinates of bottom fishing activity data submitted by all flag States for 1987–2007 filtered by criteria of occurrence (at least in two different years) and speed (1.0–4.0 knots) (NAFO, 2009b).

The ICES-NAFO Working Group on Deepwater Ecology (WGDEC)
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New data on deep-sea communities and vulnerable marine ecosystems on the Hatton Bank outcrop, Northeast Atlantic

By
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Abstract

New data on deep-sea communities and cold-water corals/sponges distribution are presented, based on the results from a joint collaboration between the Spanish Institute of Oceanography (IEO) and a longliner, carried out on the Hatton Bank area, Northeast Atlantic, in the summer of 2008. Deep-water sharks dominated the catches contributing 80.4% in terms of weight. Bathymetry was the key factor that structured assemblages found. Bycatches of cold-water corals and small sponges were common along the western flank of the Hatton Bank, while large sponges were found along the eastern part. This information supports the recent extension of the Hatton Bank cold-water coral protection area suggested by ICES in 2008. Additional data on distribution of sea garbage and derelict deep-sea gillnets were collected.

Keywords: Bottom longline, bycatch, cold-water corals, collaborative research, deep-water sharks, deep-water sponges, Hatton Bank, impact, sea garbage, vulnerable marine ecosystems.

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1. Introduction

In recent years deep-water species, including sharks, have been exploited on the Hatton Bank deep-sea slopes by longlining (Bensch *et al*., 2008). But sharks have conservative reproductive strategies that suggest that they may not sustain intensive commercial explotaition (Clarke *et al.*, 2001). In summer of 2008, an experimental survey was carried out in collaboration between the Spanish Institute of Oceanography (IEO) and fishermen, with the aim to describe the impacts of longlining on the deep-sea community of the rocky outcrop of the Hatton Bank (Durán Muñoz, *et al.*, 2009a), a non-habitual fishing ground for Spanish deep-sea longliners (Piñeiro *et al.*, 2001). Sampling onboard a longliner provided an opportunity to target large predators and scavengers in rugged terrain and hard substrate of the banks (Fossen *et al*., 2008). The purpose of the study is to contribute to the understanding of the deep-sea fishery and to provide input to advisory processes, in regard to conservation of deep-water fish and benthic invertebrates which may contribute to forming vulnerable marine ecosystems (VMEs) in hard substrates. According with the Term of Reference "a" of the 2010 ICES-WGDEC meeting, we present new data and maps on VMEs distribution, that support the recent extension of the Hatton Bank cold-water coral protection area suggested by ICES (ICES, 2008a; EC, 2009; NEAFC, 2009). In addition, this survey provided a chance to collect extra data on sea garbage and derelict nets. It is known that plastics produce damage on marine fauna, such as seabirds (Robards *et al*., 1997; Hutton *et al.*, 2008) and benthic invertebrates (Graham and Thompson, 2009), and that abandoned or lost deep-sea gillnets on rocky and three-dimensional bottoms can produce "gosth fishing", (Matsuoka *et al.*, 2005).

2. Material and methods

2.1. Study area

The study area (Figure 1) is situated in international waters of the Northeast Atlantic, within the NEAFC Regulatory Area (ICES Subdivision VIb_1 and Division XIIb), on the Hatton Bank and surroundings (750-1500 m depth), outside the areas closed to bottom fishing in force during 2008 (EC, 2008; NEAFC, 2007, 2008). The Hatton Bank is a large offshore bank, situated to the west of the European continental shelf and belongs to the Rockall Plateau, a structural and geomorphological high (Edwards, 2002). The habitats along the western flank of the bank (Durán Muñoz *et al*. 2009b) are located on two geomorphological domains, namely; the contouritic sedimentary seabed of the (i) Hatton Drift (Rebesco, 2005), a ground frequented by trawlers, and the rugged seabed of the (ii) Hatton Bank outcrop, a ground feasible for longlining. Sayago-Gil, *et. al.,* (2009) have described the geomorphological setting of the bank. The term outcrop strictly refers to those parts of the bank that project from the seabed surface and which are not covered -or slightly covered - by sedimentary deposit (Drift).Three areas of cold-water corals has been reported by Durán Muñoz *et al*. (2009b) along the outcrop of the bank on the western deep-sea slope.

2.2 Survey methodology

The experimental survey was carried out over twenty days during the summer of 2008, using a Spanish bottom longliner (336 GT). The objective of the sampling scheme was to study the rocky outcrop of the banks. The study area was divided into eight sampling rectangles. At each station (Figure 1), a set of two individual longlines was deployed using two different types of demersal longlines (Bjordal and Lokkeborg, 1996), rigged with a similar number of hooks and at similar depths, by means of a manual longlining method. Hooks were baited with sardines. A total of 38 longlines (65,430 hooks) were prepared. Hooks of relative small size were used in order to minimize the effects of selectivity with the aim to sample a wide length range of fish. Both types of longlines were adapted for deep-water fishing on hard substrates. Lines were weighting in order to reduce the effects of bottom currents and to increase the sinking speed to protect seabirds. Due that Hatton Bank is an unusual ground for Spanish longliners, the choice of the gears is related with the experience from a previous experimental survey in the area. A number of devices and operational measures were used in a combined manner during all the setting and hauling operations. Most of them are described in the European regulation in force in the Antarctic fisheries (EC, 2004).

2.3 Data collection and analysis

Two scientific observers were onboard the vessel. They recorded information for each station on: (i) location of the longline, time and depth for setting and hauling, (ii) catch and discards, (ii) fish length and biological data, by paying special attention to (iii) bycatches of benthic invertebrates and (iv) data on seabirds. Any trash and gillnets found were also recorded by the crew. Fish species measurements (total length, in the case of deep-water sharks and lotids) were taken by sex, randomly. For the study of invertebrate bycatch, specimens captured on hooks and/or entangled in different parts of the longlines were recorded. Moreover, invertebrate samples were photographed and some of them were preserved as "vouchers" for subsequent final identification at the IEO. Despite expected differences in catchability, catch data from the two gears were pooled, in order to simplify analyses (Fossen *et al*., 2008). Faunal abundances (in terms of biomass) by species were analyzed to classify sets into groups with similar species composition. The PRIMER analytical package (Clarke and Warwick, 1994) was used for the cluster analysis of species-site data, based on Bray-Curtis similarity on log-transformed data. Discriminating species for each assemblage were identified using the similarity of percentages procedure (SIMPER). Average values and standard deviation of species richness, biomass, number of individuals and diversity in terms of biomass using the Shannon-Wiener diversity index were calculated for each assemblage, as well as vulnerable species recorded. Moreover, information from the ECOVUL/ARPA multidisciplinary surveys (2005-2007) on the western slope of Hatton Bank (Durán Muñoz *et al*., 2009b) was used to complement data from the present study. Such information consisted of: (i) nearly 18 760 km^2 of multibeam echosounder (Simrad EM-300) data and 1121 km of seismic profiles (Topas PS-18), (ii) 22 dredges on rocky grounds, (iii) 13 boxcores on sandy-muddy terrains, and (vi) 38 standardized bottom trawls mainly on the Drift.

3. Results

3.1 Catch composition and biological aspects of target species

Of the total catch of 13 286.5 kg (Table 1), fish comprised 13 140.2 kg (98.9% of the catches) and invertebrates made up the remaining 146.3 kg (1.1%). 35 taxa of fish (11 taxa of deep-water sharks, 6 of skates, 1 of chimerid, and 17 of teleosteans) and 72 taxa of invertebrates (6 taxa of sponges, 30 of cnidarians, 2 of polychaetes, 14 of arthropods, 7 of molluscs; 1 bryozoan; 11 of echinoderms and 1 ascidean) were identified (Tables 2 and 3). Deep-water sharks dominated the catches and contributed with 80.4% in terms of weight. This was due to the dominance of two species, *Centrophorus squamosus* and *Centroscyllium fabricii*. Teleosteans represented 16.8% of the catches, with dominance of lotids (13.1%), particularly the species *Molva dypterygia*. With respect to biomass of invertebrates, cnidarians were clearly dominant with 125.4 kg (0.9%), particularly the Scleractinians.

Centrophorus squamosus, and *Centroscymnus coelolepis* together accounted for 33% of the total biomass obtained during the survey. *Centrophorus squamosus* was the first fish species in terms of biomass caught, whereas *Centroscymnus coelolepis* was in seventh position. Both of these deep-water shark species were recently included in the OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR, 2008). *Centrophorus squamosus* is also considered under “vulnerable category” (White, 2003) by the International Union for Conservation of Nature (IUCN) and *Centroscymnus coelolepis* (Stevens and Correia, 2003) is considered to be “near threatened”. *Centrophorus squamosus* captured showed a length range of 82-138 cm (N=516). *Centroscymnus coelolepis* captured showed a length range of 74 -140 cm (N=59). In as far as the two main teleostean fish caught, *Molva dypterygia* and *Brosme brosme* jointly accounted for 13% of the total biomass: *Molva dypterygia* was third and *Brosme brosme* was ninth respectively in terms of weight caught. Both are gadoid species (family Lotidae) that are considered vulnerable for exploitation (ICES, 2008b, 2008c). *Molva dypterygia* showed a length range of 70 - 136 cm (N=356). *Brosme brosme* showed a length range of 50 - 94 cm (N=104).

3.2 Effects on VMEs

Six different taxa of deep-water sponges (including small glass sponges and large hexactinellid ones) and twenty-four different taxa of deep-water corals including reef builders and coral garden components (two bamboo corals, five seafans, five seapens, three soft corals, two black corals, four cup corals, three colonial stony corals and one lace coral) were identified in the study area as part of longline bycatches (Tables 3 and 4). According to the FAO (2008), these are examples of taxa which may contribute to forming VMEs.

The most important bycatches of vulnerable taxa occurred when longlines were deployed on the seabed outcrop along the western flank of Hatton Bank (Table 4, Figures 2 to 5). This area belongs to the outcrop at the top of the bank and can be subdivided into three parts termed as (i) Central Area, (ii) Ridges and Mounds Area, and (iii) Northwestern Area (ICES, 2008a). Cold-water corals were most abundant in longline bycatches when fishing along the Central Area (rectangle No 4) and the Ridges and Mounds Area (rectangle No 5), between 800 and 1100 m depth. The strict outcrop was a suitable hard substratum to these vulnerable taxa, but some of the species found such as bamboo corals and seapens, could be associated also with sandy-mud deposit (Drift) that sometimes slightly covers the outcrop.

The Central Area was assessed based on multibeam and seismic data (Durán Muñoz *et al*., 2009b), as an uneven surface without any set trend direction of relief. The area measures about 600 km^2 and describes an elongated morphology which cuts into the sedimentary drift at depths of between 800 and 1600 m. Seismic information indicated that it is an outcrop (possibly basaltic) surrounded by drift deposits (sandy-mud sediments). Stony corals (*Lophelia pertusa* and *Madrepora oculata*) were abundant in this area, as a part of the bycatch. Other species found were cup corals (genus *Carophyllia*, *Desmophyllum* and *Stephanocyathus*), bamboo corals (*Acanella* sp), seafans (Alcyonacea indet, family Plexauridae and *Primnoa resedaeformis*), soft corals (*Capnella florida*), and lace corals (family Stylasteridae). Glass sponges such as *Aphrocallistes* sp were also recorded.

In the Ridges and Mounds Area, the multibeam surveys (Durán Muñoz *et al*., 2009b) revealed elongated and parallel ridges above 1600 m water depth that were 5 km apart, with 2-7 km sections and extended for more than 40 km. These segments follow four principal directions and could have been originated by deep faults. The height of the ridges generally varies from 5-45 m, with maximum gradients downstream (up to 17º). Sayago-Gil *et al*. (2009) identified many small mounds (possibly carbonate mounds) on the crests of these ridges. These mounds stand 10 to 25 m above the ridges and are a few hundred metres wide. Ridges are considered to be composed of hard substrate (possibly basalts) and dead coral. Seismic data showed that mounds are located on top of these basalts. Ridges act as barriers trapping sediment and generate the so-called ponded-deposits. These deposits seem to be a mixture of sandy-mud sediments from the drift and dead coral remains and generate an adequate platform for a rich associated biodiversity. Just like in the case of the Central Area, the stony corals *Lophelia pertusa* and *Madrepora oculata* were recorded as part of the bycatch. Cup corals were also present (*Carophyllia* sp, *Desmophyllum* sp and *Stephanocyathus moseleyanus*) as well as bamboo corals (family Isididae), seafans (*Acanthogorgia* sp and the family Plexauridae), soft corals (*Capnella florida* and the family Nepththeidae), black corals (*Leiopathes cf. expansa, Tylopathes* sp, *Thyssopathes* sp, and *Phanopathes* sp) and lace corals (family Stylasteridae). Fragile and small glass sponges (*Euplectella* sp, *Aphrocalistes* sp and Porifera indet) were also recorded in this part of the Hatton Bank slope.

In the Northwestern Area (rectangle No 6) the geophysical survey (Durán Muñoz *et al*., 2009b) revealed an uneven surface with irregular alignments that comprised the bulk of the bank, which is shown as a curved-form on the multibeam image. The area is located between 700-1400 m water depths and covers an area of about 1200 km^2. Seismic sections show hard outcrops of the bank (possibly basalts) that make a suitable substratum for settlement of cold-water corals. Bycatches of vulnerable taxa were obtained at depths from 850 to 1200m. Stony corals *Madrepora oculata* and *Solenosmilia variabilis* were recorded in the area as part of the longline bycatch, in addition to gorgonians (*Callogorgia verticilata*) and cup corals (*Caryophyllia* sp). The outcrop was gradually covered by drift sediments and formed a suitable soft substrate for pennatulaceans. This is possibly why seapens (*Pennatula* sp, *Anthoptilum murrayi* and *Halipteris* sp) were observed as a part of the bycatch.

Contrary to the small glass sponges found on the western slope, large hexactinellid species (*Pheronema carpenteri*) that characterize sponge-dominated biotopes (Barthel *et al*., 1996) on sandy-muddy grounds were recorded in deep eastern zones (800-1100 m depth) within rectangles No 7 and No 8 (Figure 5). Moreover, the small demospongid species *Radiella* sp, was found in rectangle No 7 (1100 m depth).

3.3 Effects on deep-sea communities

A cluster analysis was applied on log-transformed faunal abundances (in terms of biomass) using the Bray-Curtis similarity index. The key factor that structured assemblages was observed to be bathymetry while geographical factor happened to be of low importance. Three assemblages are found based on bathymetry. The first assemblage (group I; Figure 6) consists of shallowest longline sets, between 750 and 1000 m depth, characterised by the deep-water shark *Centrophorus squamosus,* the gadiform *Molva dypterygia* and fish species of shallower affinities such as the sharks *Deania calceus, Galeus melastomus* and the gadiforms *Brosme brosme* and *Mora moro.* The second assemblage group lay between 1000 and 1250 m depth (group II, Figure 6). This is typified by the sharks *Centroscyllium fabrici, Centrophorus squamosus, Centroselachus crepidater, Centroscymnus coelolepis, Etmopterus princeps* and the gadiform *Molva dypterygia*. The third assemblage (group III, Figure 6) is the deepest (>1250 m) and is characterised by low catches of the deep-water sharks *Centroscyllium fabricii, Etmopterus princeps, Centrophorus squamosus* and the gadiform *Antimora rostrata,* with presence of the pleuronectiform *Reinhardtius hippoglossoides*. The two aforementioned shallower assemblages, present similar ecological indices, whereas the deepest assemblage presents low indices of biomass and specific richness (Table 5). Bycatch of vulnerable invertebrate taxa, such as cold-water corals and glass sponges, was higher in the shallowest assemblage. At some stations located along the outcrop areas described in previous sections (particularly Central Area and Ridges and Mounds Area), sizeable numbers of *Lophelia pertusa* and *Madrepora oculata* were recorded as part of the longline bycatch. Moreover, the hexactinellid *Pheronema carpenteri*, was present in the second assemblage (1000-1250 m depth).

3.4 Extra data on sea garbage and derelict deep-sea gillnets

During hauling, a variety of trash items weighing 13 kg were recorded entangled and/or hooked in the longlines, including some fishery-related items. The composition of this sea garbage was very diverse: (i) glass, (ii) plastic, (iii) metal, (iv) steel and (v) textile. Fragments of derelict deep-sea gillnets were fished in the northwest and in southern parts of the bank (rectangles No 3 and No 6), a fragment of longline was captured in the northeastern part (rectangle No 7) and a piece of steel rope was recorded in rectangle No 8. The highest numbers of encounters were recorded on the eastern slope of the Hatton Bank. No sea garbage was recorded in the southern part. Despite the ban of the use of deep-sea gillnets (EC, 2007; NEAFC, 2006), an abandoned deep-sea gillnet was observed in the shallow part of the study area (sampling rectangle No 8) at 800 m depth approx.

4. Discussion

4.1 Vulnerable fish species

Catch composition from present longline survey on the Hatton Bank outcrop (hard seabed), was largely dominated by deep-water sharks. Hook size affect the number of species caught. So, impact of the longline fishery on these species is strictly related to the size of hooks and to the particular type of longline used, the bait, and the feeding behaviour (Bjordal and Lokkeborg, 1996). Our results agree with other studies in the Northeast Atlantic with different type of longlines and baits, and larger hook sizes (Fossen *et al*., 2008). This suggests that deep-water bottom longlining, seems to be a specialized fishing technique to fish large chondrychthyes on rugged grounds. The dominance of chondrychthyes is in line with survey results from one bottom trawl haul that contained amounts of coral (Durán Muñoz *et al*., 2009b), carried out on the Hatton Bank outcrop (< 1000 m depth), where elasmobranchs, mainly chondrychthyes, accounted for 50% of the biomass. Hall-Spencer *et al.*, (2002), reported several deep-water shark species from a commercial trawl haul taken in the Rockall Trough (Northeast Atlantic) that was noted for coral by-catch. Associations of shark species and cold-water corals have been reported by other authors (Buhl-Mortensen *et al.*, 2010; Ross and Quattrini, 2007). Buhl-Mortensen *et al.* (2010) reviewed the literature on fish habitats and indicated that Furevik et al., (1999) reported that longline catches of lotids in reef areas can be greater than in non-reef areas. This suggests that complex habitats such as the Hatton Bank outcrop, supports a suitable environment for deep-water sharks and other deep-sea species. A noteworthy observation is that the longline catch composition from the present cooperative longline survey for the outcrop of the bank (hard seabed) was very different from the bottom trawl cooperative survey results carried out on the deep slopes of the Hatton Drift (sedimentary seabed), where osteichthyes were clearly dominant typifying the assemblages found (Durán Muñoz *et al.*, 2009b). Buhl-Mortensen *et al.* (2010) suggested that the environmental setting influences the species composition of the deep-sea ocean margin. Moreover, the number of fish taxa recorded in the present longline survey was the half of the number of taxa recorded in those bottom trawl surveys (IEO data unpublished). This could be explained due the differences in selectivity between gears, the differences of species composition between sedimentary and hard bottoms or both combined.

The study of length distributions of the catches of present survey with respect to data described in the literature for maturity size, indicates that in the study area, summertime longline catches of both shark species, *Centrophorus squamosus* and *Centroscymnus coelolepis* were preferably composed of large adult individuals, with the exception of *Centrophorus squamosus* females which mature at very large sizes and were scarce. Only were observed two individuals of *Centrophorus squamosus* larger than 128 cm, the female maturity size, but 70% of the individuals measured were larger than 101 cm in length, the male maturity size (Clarke *et al*., 2002a). In relation with *Centroscymnus coelolepis*, 72% of the individuals were larger than 102 cm in length, the female maturity size (Girard and Du Buit, 1999). The absence of smaller specimens was also reported from other Northeast Atlantic areas (Bañón *et al.*, 2006; Clarke et *al*., 2002a; Girad and De Buit, 1999). In the present survey, longlines were rigged with relatively small hooks, but small individuals were not caught. Clarke *et al*. (2001, 2002a) suggested that this absence cannot be explained by the selectivity of the gears, since both shark species undertake extensive migrations associated with reproduction. In terms of the *Molva dypterygia* and *Brosme brosme*, catches of both species were also preferably composed of large and adult individuals, as was reported from other parts of Northeast Atlantic. The length distributions of *Molva dypterygia* revealed that 80% of the individuals measured were larger than 88 cm in length, the female maturity size (Magnusson and Magnusson, 1995). In the case of *Brosme brosme*, all of the individuals were larger than 45 cm, the maturity size for both sexes (Magnusson *et al.*, 1997). This suggests that the adult fraction of deep-water species populations such as deep-water sharks and lotids, is vulnerable to bottom longline, and this should be taken in consideration in terms of deep-sea fisheries management.

4.1 Benthic habitat

Bycatch data from the present longline survey agree with results from Northeast Atlantic (Fossa, *et al*., 2002; Mortensen *et al*., 2008; Sampaio *et al*., 2009) and other areas (Bavastrello *et al*., 1997; Butler and Gass, 2001; Gass and Wilson, 2005; Orejas, *et al*., 2009; Reed, 2002; Krieger, 2001; Krieger and Wing, 2002; Mortensen *et al*., 2005; Witherel and Coon, 2001) that suggest some degree of negative impacts of longlining on cold-water corals.

The geomorphological (Durán Muñoz *et al*. 2009b; Edwards, 2002; Long *et al*., 2006; Roberts *et al*. 2008; Sayago-Gil *et al*., 2009) and environmental setting of the large outcrop of the Hatton Bank, provided a favourable framework (Mortensen and Buhl-Mortensen, 2004) for the presence of vulnerable species groups referred to by FAO (2008). Our observations demonstrate that species which contribute to forming VMEs occur in the outcrop area of the bank, since these taxa, especially cold-water corals, were recorded as a part of longline bycatch. Despite that Chuenpagdee *et al*. (2003) indicated that the level of bycatch and the habitat impact associated with demersal longlines is moderate, our results suggest that longlining can cause damage, if VMEs distributions overlap with the fishery. In presence of strong currents, large weights were required for bottom longlining, and such weights can also damage corals (Reed, 2002). Clark and Koslow (2007) suggest bigger impacts if there are strong currents dragging the lines across the bottom, and we often observed differences in the geographic position between setting and hauling, indicating movements of the longlines over the seabed. On the other hand, line weighting to minimize seabird bycatch can contribute to longlines get entangled in corals. Multibeam results suggested that the vulnerable taxa can also be threatened by bottom trawls (Durán Muñoz *et al.,* 2009b) since parts of the outcrop have been gradually covered by sediments and such areas could be suitable for trawling.

Longline bycatch revealed occurrence of small glass sponges in the rocky outcrop of the bank. Data on large sponges from the present survey and information from earlier bottom trawl cooperative surveys (Durán Muñoz *et al*., 2007) suggest that sponge-dominated communities occur to the Northeastern part of the bank. Both small and large sponges have ecological role as builders of habitat for juvenile fish and other marine fauna (Buhl-Mortensen *et al*., 2010).

The results suggest that always there is a possibility of negative fishing effects on vulnerable species when spatial distributions of VMEs overlap with bottom fisheries. Even though fixed gears such as bottom longlines are expected to be much less damaging to corals than mobile gears such as trawls, it may still represent a serious threat with high fishing intensity (Bavastrello *et al*., 1997; Mortensen *et al*., 2005). An additional concern is the skill of longlines to fish on seabed areas that are inaccessible to mobile gears. From a conservation point of view, marine spatial planning (Ardon *et al.,* 2008) based on interdisciplinary research, including fisheries data and collaboration with fishers, can contribute to better management of deep-sea fisheries in the high seas (UNGA, 2007).

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TABLES AND FIGURES

Table 1. Biomass caught (kg) by main taxonomic groups and their contribution to the total catches in terms of weight (%). The groups are listed by weight.

	Taxonomic group	kg	%
Elasmobranchii	Deep-water sharks	10686.5	80.4
	Skates	192.3	1.4
	Subotal Elasmobranchii	10878.8	81.9
Osteichthyes	Lotidae	1736.4	13.1
	Moridae	350.0	2.6
	Macrouridae	21.4	0.2
	Others	126.5	1.0
	Subotal Osteichthyes	2234.2	16.8
Holocephalii	Chimaeridae	27.2	0.2
	Subtotal Holocephalii	27.2	0.2
Subtotal fishes		13140.2	98.9
Cnidaria	Scleractinia	116.7	0.9
	Actiniaria	2.6	<0.1
	Pennatulacea	1.8	<0.1
	Antipatharia	1.5	<0.1
	Alcyonacea	1.5	<0.1
	Hidrozoa (Stylasteridae)	0.8	<0.1
	Zoanthidea	0.2	<0.1
	Others	0.3	<0.1
	Subtotal Cnidaria	125.4	0.9
Mollusca	Cephalopoda	7.9	0.1
	Bivalvia and Gastropoda	0.1	<0.1
	Subtotal Mollusca	8.0	0.1
Arthropoda (Subphylum crustacea)	Decapoda	6.5	<0.1
	Cirripedia	<0.1	<0.1
	Subtotal Arthropoda	6.5	<0.1
Porifera	Large sponges	2.6	<0.1
	Small sponges	1.0	<0.1
	Subtotal Porifera	3.6	<0.1
Echinodermata	Asteroidea	1.2	<0.1
	Ophiuroidea	0.6	<0.1
	Echinoidea	0.5	<0.1
	Holothuroidea	0.4	<0.1
	Crinoidea	0.1	<0.1
	Subtotal Echinodermata	2.8	<0.1
Other invertebrates	Other invertebrates	0.1	<0.1
	Subtotal other invertebrates	0.1	<0.1
Subtotal invertebrates		146.3	1.1
TOTAL CATCHES		13286.5	

Table 2. List of fishes captured during the survey.

Class	Order	Suborder	Family	Subfamily	Specie
Elasmobranchii	Carchariniformes		Scyliorhinidae		*Galeus melastomus* Rafinesque, 1810
					Galeus sp.
					Apristurus sp.
			Pseudotriakidae		*Pseudotriakis microdon* Capello, 1867
	Squaliformes		Dalatiidae		*Centroscyllium fabricii* (Reinhardt, 1825)
					Centroscymnus coelolepis Bocage & Capello, 1864
					Centroselachus crepidater (Bocage & Capello, 1864)
				Etmopterinae	*Etmopterus princeps* Collett, 1904
					Etmopterus spinax (Linnaeus, 1758)
			Centrophoridae		*Centrophorus squamosus* (Bonnaterre, 1788)
					Deania calceus (Lowe, 1839)
	Rajiformes		Rajidae		*Rajella fyllae* Lütken, 1888
					Raja oxyrinchus Linnaeus, 1758
					Raja sp.
					Amblyraya hyperborea Collet, 1879
					Dipturus nidarosiensis Storm, 1881
					Leucoraja fullonica Linnaeus, 1758
Holocephali	Chimaeriformes		Chimaeridae		*Chimaera monstrosa* Linnaeus, 1758
Actinopterygii	Anguilliformes		Synaphobranchidae	Synaphobranchinae	*Synaphobranchus kaupi* Johnson, 1862
[=Osteichthyes]	Lampriformes		Trachipteridae		*Trachypterus articus* (Brünnich, 1788).
	Gadiformes		Macrouridae	Macrourinae	*Caleorhinchus occa* (Goode & Bean, 1886)
					Coryphaenoides rupestris Gunnerus, 1765
					Macrourus berglax Lacepède, 1801
			Moridae		*Lepidion eques* (Günther, 1887)
					Mora moro (Risso, 1810)
					Antimora rostrata (Günther,1878)
			Lotidae		*Molva dypterygia* (Pennant, 1784)
					Brosme brosme (Ascanius, 1772)
	Lophiiformes		Lophiidae		*Lophius piscatorius* Linnaeus, 1758
	Scorpaeniformes	Cottoidei	Psychrolutidae		*Cottunculus thompsoni* (Günther, 1882)
	Perciformes	Percomorphi	Bramidae		*Brama brama* (Bonnaterre, 1788)
		Zoarcoidei	Zoarcidae		*Lycodes* sp.
			Anarhichadidae		*Anarhichas denticulatus* Kroyer, 1845
			Trichiuridae		*Aphanopus carbo* Lowe,1839
	Pleuronectiformes	Pleuronectidae	Pleuronectinae		*Reinhardtius hippoglossoides* (Walbaum, 1792)

Table 3. List of invertebrates captured during the survey.

Phylla	Class	Subclass	Superorder	Order	Family	Specie
Porifera						Porifera indet.
	Demospongiae			Hadromerida	Polymastiidae	*Tentorium* sp
						Radiella sp
	Hexactinellida			Amphidiscosida	Pheronematidae	*Pheronema carpenteri* (Thomson, 1869)
				Lyssacinosida	Euplectellidae	*Euplectella* sp
				Hexactinosida	Aphrocallistidae	*Aphrocallistes* sp
Cnidaria	Anthozoa	Octocorallia		Alcyonacea		Alcyonacea indet.
					Nephtheidae	*Capnella florida* (Rathke, 1806)
						Nephtheidae indet.
					Acanthogorgiidae	*Acanthogorgia* sp
					Isididae	*Acanella* sp
						Isididae indet.
					Plexauridae	Plexauridae indet.
					Primnoidae	*Callogorgia verticillata* (Pallas, 1766)
						Primnoa resedaeformis (Gunnerus, 1763)
				Pennatulacea		Pennatulacea indet.
					Anthoptilidae	*Anthoptilum murrayi* Kölliker,1880
					Halipteridae	*Halipteris* sp
					Pennatulida	*Pennatula* sp
					Umbellulidae	*Umbellula* sp
		Hexacorallia		Actiniaria		Actiniaria indet.
					Actinernidae	*Actinernus* sp
					Hormathiidae	Hormathiidae indet.
		Corallimorpharia				Corallimorpharia indet.
		Zoanthidea			Epizoanthidae	*Epizoanthus paguriphilus* Verrill, 1883
						Epizoanthidae indet.
				Antipatharia	Leiopathidae	*Leiopathes cf. expansa*
						Leiopathes cf. glaberrima
					Aphanipathidae	*Phanopathes* sp
					Antipathidae	*Stichopathes gravieri*
						Tylopathes sp
					---	*Thyssopathes* sp

Table 3 (Cont.). List of invertebrates captured during the survey.

Phylla	Class	Subclass	Superorder	Order	Family	Specie
				Scleractinia	Caryophylliidae	*Caryophyllia* sp
						Desmophyllum sp
						Lophelia pertusa (Linnaeus, 1758)
						Madrepora oculata Linnaeus, 1758
						Solenosmilia variabilis Duncan, 1873
						Stephanocyathus moseleyanus (Sclater, 1886)
					Flabellidae	*Flabellum alabastrum* Moseley, 1876
	Hydrozoa			Filifera	Stylasteridae	Stylasteridae indet.
Annelida						Polychaeta indet.
	Polychaeta			Terebellida	Terebellidae	*Lanice* sp
Arthropoda (Crustacea)	Maxillopoda					Crustacea indet
		Thecostraca	(Cirripedia)			Cirripedia indet.
			Thoracica	Pedunculata	Poecilasmatidae	Poecilasmatidae indet.
						Scalpellomorpha indet.
				Sessilia		Balanomorpha indet.
	Malacostraca	Eumalacostraca		Decapoda	Chirostylidae	*Gastroptychus formosus* (Filhol, 1884)
						Uroptychus sp
					Parapaguridae	*Parapagurus pilosimanus* Smith, 1879
					Lithodidae	*Neolithodes grimaldii* (A. Milne-Edwards & Bouvier, 1894)
					Galatheidae	*Munidopsis* sp
						Galatheidae indet.
					Majidae	*Rochinia carpenteri* (Thomson, 1873)
						Dorhynchus thomsoni Thomson, 1873
					Geryonidae	*Chaceon inglei* Manning & Holthuis, 1989

Table 3 (Cont.). List of invertebrates captured during the survey.

Phylla	Class	Subclass	Superorder	Order	Family	Specie
Mollusca	Gastropoda			Neogastropoda	Buccinidae	*Neptunea despecta* (Linnaeus, 1758)
	Bivalvia					Bivalvia indet.
		Pteriomorphia		Ostreoida	Pectinidae	Pectinidae indet.
		Heterodonta		Veneroida	Astartidae	*Astarte* sp
		Anomalodesmata		Pholadomyoida	Verticordiidae	*Halicardia* sp
	Cephalopoda			Teuthida		*Todarodes sagittatus* (Lamarck, 1798)
				Octopoda	Octopodidae	*Benthoctopus* sp
Bryozoa						Bryozoa indet
Echinodermata	Asteroidea					Asteroidea indet.
				Paxillosida	Astropectinidae	*Plutonaster* sp
	Ophiuroidea			Velatida	Solasteridae	Solasteridae indet.
						Ophiuroidea indet.
				Euryalina	Asteronychidae	*Asteronyx loveni* J. Müller & Troschel, 1842
					Gorgonocephalidae	*Gorgonocephalus* sp
	Echinoidea			Cidaroida	Cidaridae	Cidaridae indet.
				Echinothuroida		Echinothuroida indet.
				Echinoida		Echinoida indet.
	Holothuroidea			Dendrochirotida	Psolidae	*Psolus* sp
	Crinoidea					Crinoidea indet.
Chordata (Tunicata)	Ascidiacea					Ascidiacea indet.

Table 4. Vulnerable taxa recorded as part of the bycatch, when longlines were deployed in the outcrop of the western slope of the Hatton Bank. Central Area (CA), Ridges and Mounds Area (RMA), and Northwestern Area (NWA).

	Scientific name	CA	RMA	NWA
Porifera				
	Porifera indet	+	+	+
	Euplectella sp		+	
	Aphrocallistes sp	+	+	
Cnidaria				
	Alcyonacea indet	+		
	Acanthogorgia sp		+	
	Acanella sp	+		
	Isididae indet		+	
	Plexauridae indet	+	+	
	Callogorgia verticillata			+
	Primnoa resedaeformis	+		
	Pennatula sp			+
	Anthoptilum murrayi			+
	Halipteris sp			+
	Capnella florida	+	+	
	Nephtheidae indet		+	
	Leiopathes cf. expansa		+	
	Tylopathes sp		+	
	Thyssopathes sp		+	
	Phanopathes sp		+	
	Caryophyllia sp	+	+	+
	Desmophyllum sp	+	+	
	Lophelia pertusa	+	+	
	Madrepora oculata	+	+	+
	Solenosmilia variabilis			+
	Stephanocyathus moseleyanus	+	+	
	Stylasteridae indet	+	+	

Table 5. Assemblages found in the study area with the longline cooperative survey.

Assemblage	Typifying Species (W)	Average indices	Vulnerable invertebrates
Group I (< 1000 m)	*Centrophorus squamosus,* *Deania calceus,* *Molva dypterygia,* *Brosme brosme,* *Galeus melastomus,* *Mora moro.*	*S*=15.2 ± 6.8 *W*=400.4 ± 168.2 *H'W*=2.4 ± 1	*Lophelia pertusa* *Madrepora oculata* *Solenosmilia variabilis* *Aphrocalistes* sp *Euplectella* sp Stylasteridae Antipatharians Gorgonians Pennatulaceans Solitary Scleractinians
Group II (1000 – 1250 m)	*Centroscyllium fabricii,* *Centrophorus squamosus,* *Molva dypterygia,* *Centroscymnus crepidater,* *Centroscymnus coelolepis,* *Etmopterus princeps.*	*S*=14.5 ± 6.7 *W*=406.5 ± 252 *H'W*=2.3 ± 1.1	*Lophelia pertusa* *Madrepora oculata* *Solenosmilia variabilis* *Pheronema carpenteri* *Aphrocalistes* sp Stylasteridae Antipatharians Gorgonians Pennatulaceans Solitary Scleractinian
Group III (> 1250 m)	*Centroscyllium fabricii,* *Etmopterus princeps,* *Antimora rostrata,* *Centrophorus squamosus,* *Reinhardtius hippoglossoides.*	*S*=10 ± 3.4 *W*=58.4 ± 50.6 *H'W*=2.4 ± 0.7	*Solenosmilia variabilis* *Euplectella* sp Gorgonians Solitary scleractinians

SIMPER results. Average values ± SD of richness (*S*), biomass (*W*) and diversity in terms of biomass (*H'W*).

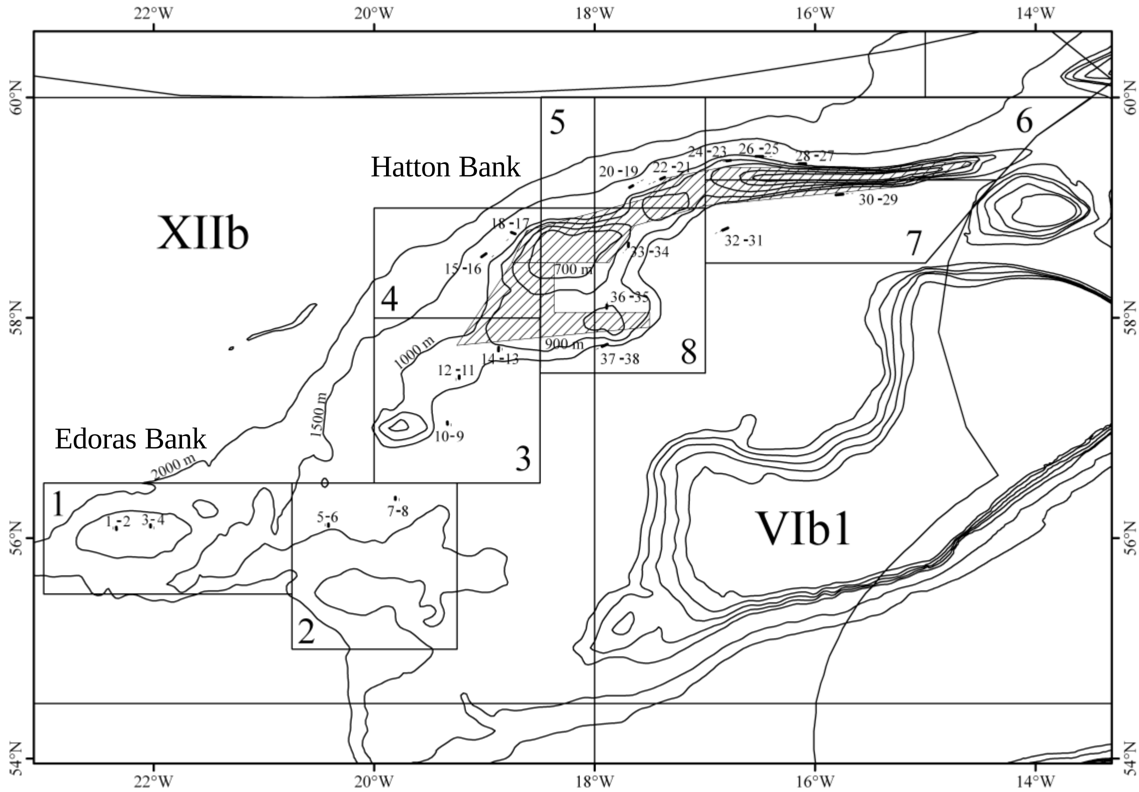

Figure 1. Map of the study area showing the boundaries of the eight rectangles and the location of the 38 longline sets. Longlines were deployed outside the areas closed to bottom fishing (EC, 2008; NEAFC, 2007, 2008) in force during 2008. (black line, multifilament gear; dotted line, monofilament gear; striped area, area closed to bottom fishing by NEAFC/EU during 2008).

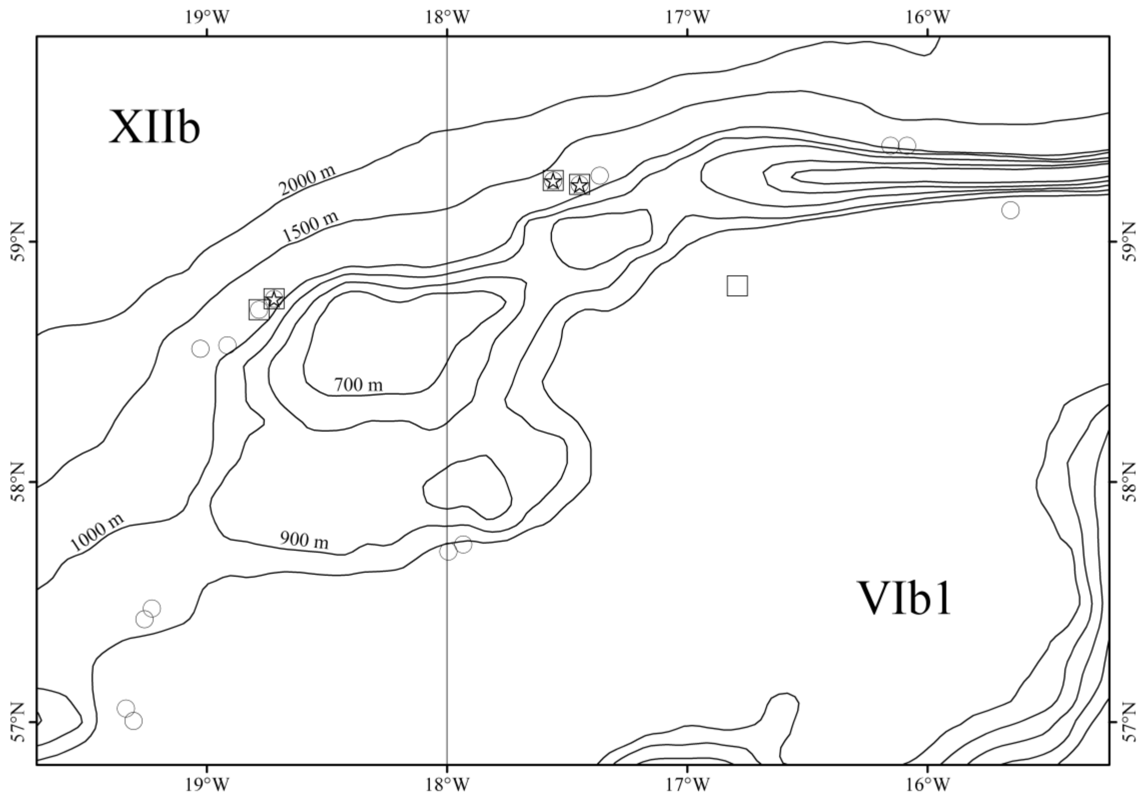

Figure 2. Location of records of lace corals, cup corals and soft corals in the Hatton Bank. Stars, lace corals (0.006 – 0.789 kg); circles, cup corals (0.005 – 0.28 kg); squares, soft corals (0.006 – 0.13 kg).

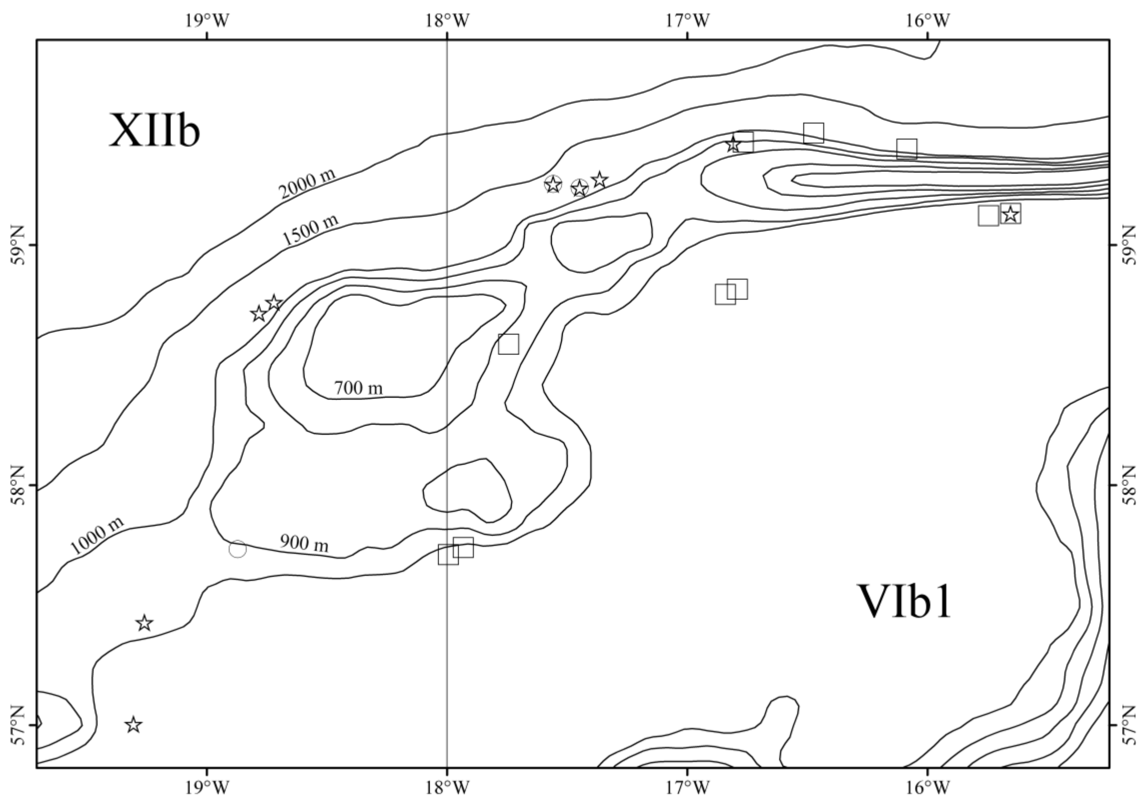

Figure 3. Location of records of seafans, black corals and seapens in the Hatton Bank. Stars, seafans (0.003 – 0.52 kg); circles, black corals (0.002 – 1.19 kg); squares, seapens (0.005 – 0.866 kg).

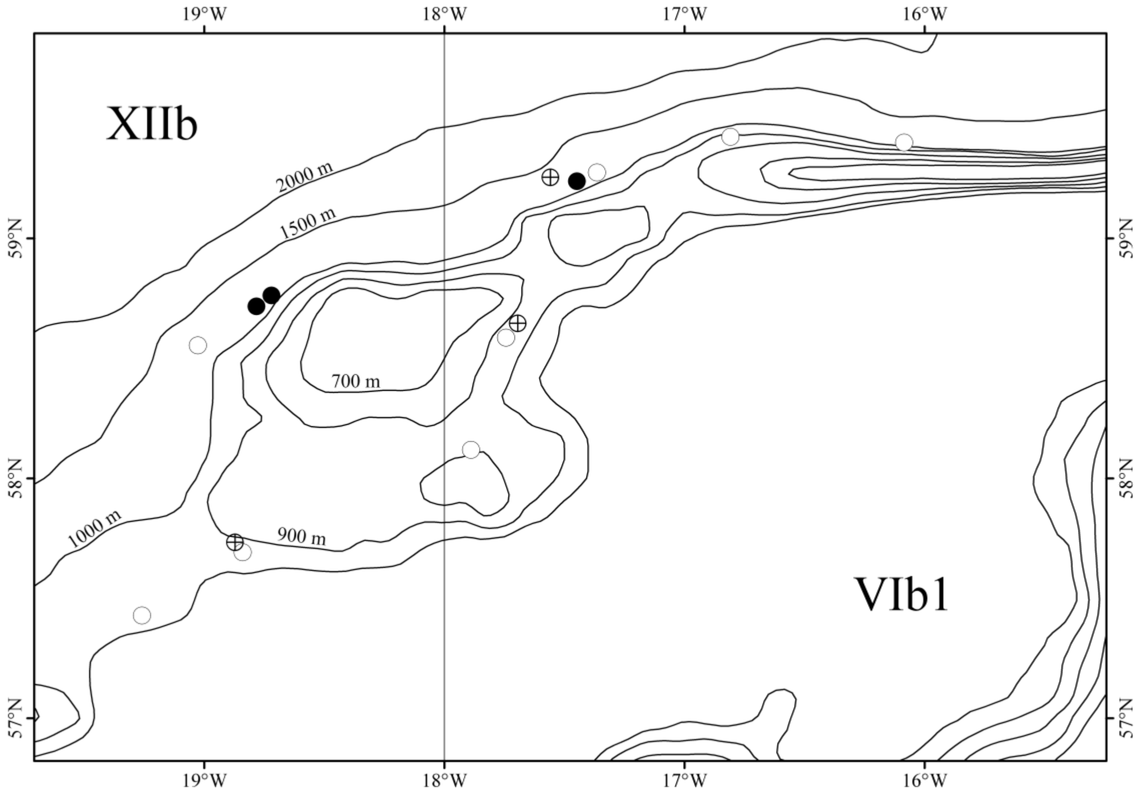

Figure 4. Location of records of colonial Scleractineans in the Hatton Bank. White circles, 0.025 – 2 kg; circle with cross, > 2 – 10 kg; black circles, > 10 – 50.9 kg.

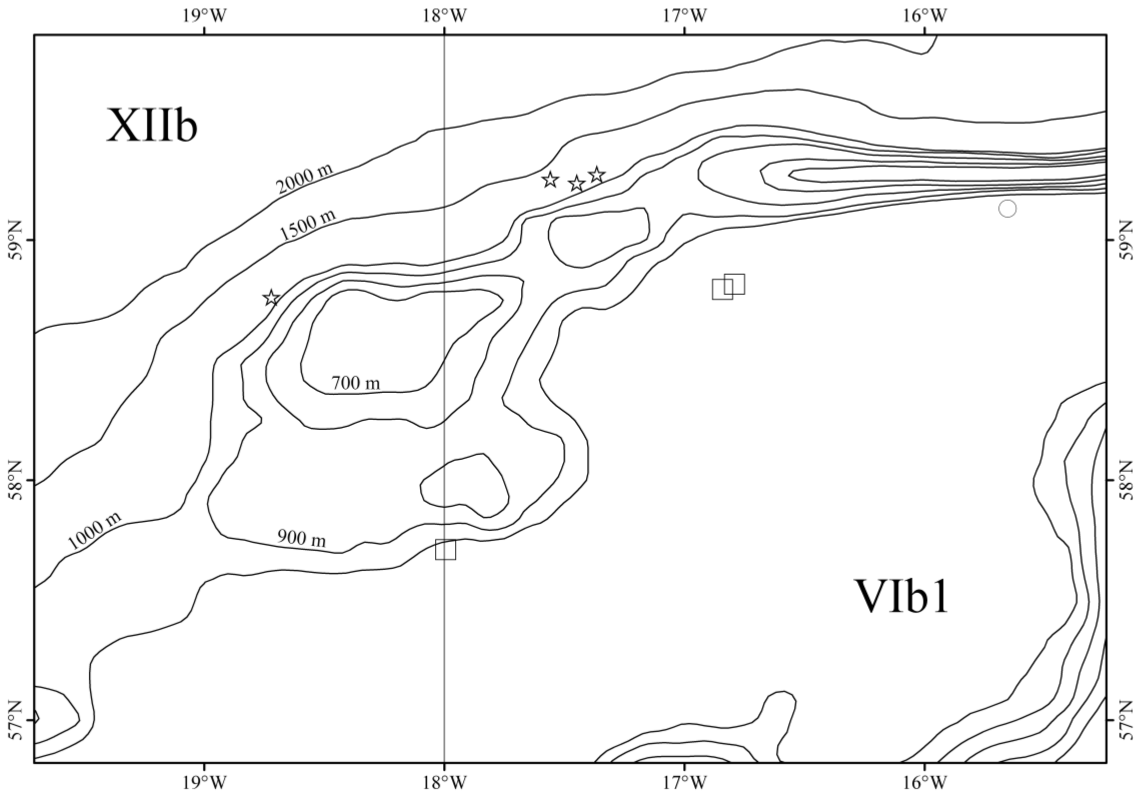

Figure 5. Location of records of sponges in the Hatton Bank. Squares, *Pheronema carpenteri* (0.15 - 0.7 kg); stars, *Aphrocalistes* sp/*Euplectella* sp (0.008 - 0.236 kg) ; circle, porifera indet (1.038 kg).

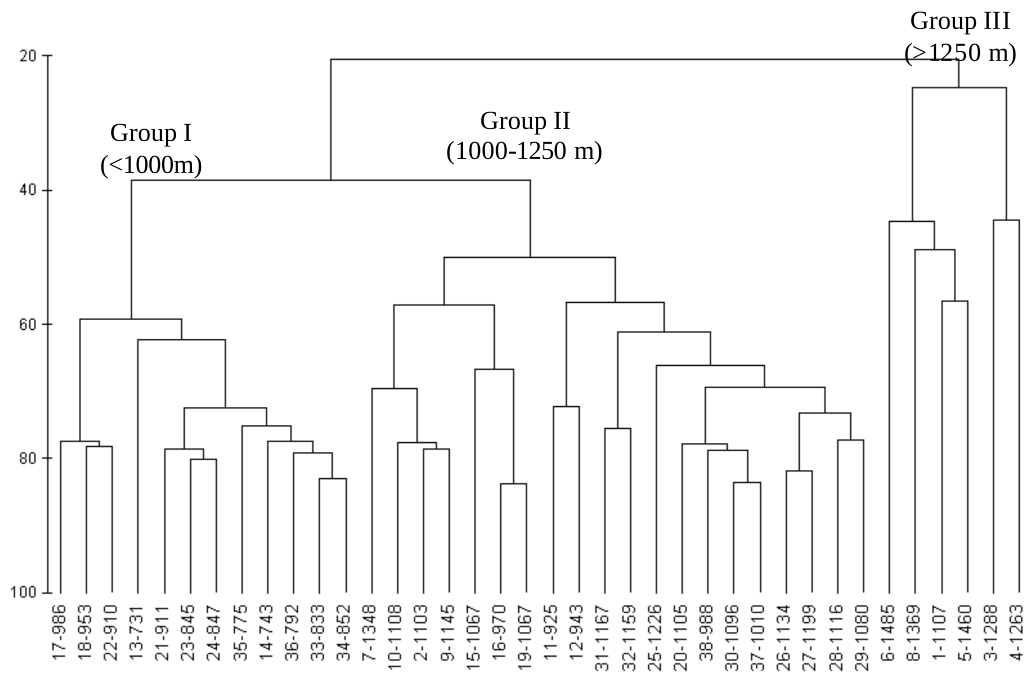

Figure 6. Dendrogram of similarity among sets. Labels show longline set number and depth (m).