NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N5501 **NAFO SCR Doc. 08/10**

SC WG ON THE ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT – MAY 2008

Preliminary data on cold-water corals and large sponges by-catch from Spanish/EU bottom trawl groundfish surveys in NAFO Regulatory Area (Divs. 3LMNO) and Canadian EEZ (Div. 3L): 2005-2007 period

by

F.J. Murillo[1], P. Durán Muñoz[1], M. Sacau[1], D. González-Troncoso[1] and A. Serrano[2]
[1]Instituto Español de Oceanografía, Vigo, Spain
[2]Instituto Español de Oceanografía, Santander, Spain

ABSTRACT

Since 2005, by-catch of vulnerable invertebrates, such as cold-water corals and large sponges, has been studied with special attention in the Spanish/EU bottom trawl groundfish surveys in Northwest Atlantic (NAFO Divs. 3LMNO). Based on this research, twenty-nine different taxa of cold-water corals have been preliminarily identified in the study area: five alcyonaceans, ten gorgonaceans, ten pennatulaceans, three solitary scleractinians and one antipatharian. No colonial scleractinians were recorded during these surveys and reef structures are unlikely to occur in the study area. The main large sponges found belong to the family Geodiidae.

The volume of cold-water corals and large sponges in the by-catches was generally low in the regularly-used fishing grounds studied. Most of the by-catches were recorded in hauls carried out in areas outside of regular fishing grounds for the bottom trawlers. By-catches of large gorgonians were recorded in three small areas located in Divs. 3LM (two in Div. 3L and one in Div. 3M), indicating that Vulnerable Marine Ecosystems (VMEs) could occur there. Pennatulaceans, solitary scleractinians, alcyonaceans and antipatharians were also observed as part of by-catch in some hauls carried out in Divs. 3LMO, but it is not clear if these by-catches indicate presence of VMEs in the area sampled. Highest diversity of coral species was found in Div. 3M. Large sponges occurred in deep waters, in a narrow band along Northern slope of the Grand Banks (Div. 3N) and Southern Flemish Pass (Div. 3L) as well as in several patches located in North-eastern and Eastern Flemish Cap.

The preliminary information presented here, derived solely from bottom trawl survey by-catch records, it is not enough for identification of VMEs accurately, but it is very valuable to give a general view of where VMEs like to occur or not occur. Previous experience from other North Atlantic high-seas fishing grounds (e.g. NEAFC Regulatory Area) suggests that additional geohabitat mapping and information on fishery footprint will be needed for the accurate delineation of VMEs and for the subsequent adoption of suitable habitat conservation measures such as Marine Protected Areas (MPAs) to preserve cold-water corals and large sponges in NAFO Area.

***Key words*: Cold-water corals, large sponges, NAFO, Vulnerable Marine Ecosystems, Marine Protected Areas, By-catch, Bottom trawl.**

INTRODUCTION

Cold-water corals are widespread along shelf breaks, continental slopes, seamounts and mid-ocean ridges. Corals can create habitats that can be occupied by communities with high biodiversity, can be feeding and spawning sites and sources of shelter for invertebrates and fish. The structural characteristics and long-lived nature of corals make them especially vulnerable to damage by the mechanical impacts of bottom fishing activities (Probert *et al.*, 1997;

Phillipart, 1998; Freiwald *et al*., 2004). As well as cold-water corals, large sponges, particularly Demospongiae and Hexactinellidae, have an important role like habitat-forming organisms (Klitgaard and Tendal 2004) and are vulnerable to trawling (Freese 2001).

Cold-water coral ecosystems are not exclusively the domain of stony corals. Soft coral ecosystems, the so-called coral gardens, are relatively dense aggregations of colonies or individuals of one or more coral species, supporting a rich associated fauna of benthic and epibenthic species. Coral gardens can occur on a wide range of soft and hard seabed substrata (ICES, 2007).

The most Vulnerable Marine Ecosystems (VMEs) are ones that are both easily disturbed and are very slow to recover, or may never recover. Vulnerable ecosystem features may be physically or functionally fragile. According with this definition (FAO, 2008a), and taking into account their three-dimensionally complex and fragile structure easy to disturb, their slow growth and slow recovery, cold-water coral and large sponges ecosystems are considered VMEs.

Marine protected areas (MPAs) are used to safeguard regions where cold-water corals or large sponges form VMEs and to protect them to the adverse impacts of bottom fishing. MPAs are a tool, not an end in themselves. They are essential in order to protect marine biodiversity and achieve sustainable fisheries (Laffoley, 2006).

Following the United Nations General Assembly Resolutions (UNGA, 2005; UNGA, 2007), several management measures in order to protect vulnerable ecosystems in the high seas, such as MPAs, are being implemented by Regional Fisheries Management Organizations (NAFO, 2006; NAFO, 2007; NEAFC, 2007; NEAFC, 2008).

In Northwest Atlantic, the distribution of cold-water corals have been studied by different authors (Mortensen and Mortensen, 2004; Gass and Willison, 2005; Mortensen *et al*., 2006; Edinger *et al*., 2007), but there are some existing gaps in NAFO Regulatory Area (Divs. 3LMNO) which are partially covered by Spanish/EU annual groundfish surveys.

In this paper, we present a compilation of preliminary information on the distribution and biomass of cold-water corals and large sponges in NAFO Regulatory Area (Divs. 3LMNO) and Canadian EEZ (Div. 3L), based on by-catch data from 2005-2007 bottom trawl Spanish/EU groundfish surveys, in order to make this data available to the NAFO-WGEA.

MATERIAL AND METHODS

Spanish Institute of Oceanography (IEO) conducts annual groundfish bottom trawl surveys in NAFO Regulatory Area (Divs. 3LMNO). Surveys in Div. 3M are carried out in collaboration with Spanish (IIM, AZTI) and Portuguese (IPIMAR) institutes (EU Survey). The general purpose of these surveys is to determine the distribution, biomass and abundance of main commercial groundfish species. Moreover, since 2005, vulnerable invertebrate by-catch, such as cold-water corals and large sponges, has been studied. Three different annual surveys are carried out in NAFO Regulatory Area (NRA):

- **Platuxa survey** (Divs. 3NO) began in 1995 and covers the "Tail" of the Grand Banks of Newfoundland between 40 and 1500 m depth;
- **Flemish Cap EU survey** (Div. 3M) began in 1988 and covers all the Flemish Cap, between 130 and 740 m depth since 1988 until 2003 and between 130 and 1450 m depth since 2004;
- **Fletán Negro survey** (Div. 3L) began in 2003 and covers the "Nose" of the Grand Banks of Newfoundland and the Flemish Pass between 110 and 1450 m depth.

In 2007 a new survey for Div. 3L (**Canada EEZ survey)** was carried out by Spain within Canadian EEZ.

All of these surveys were carried out between spring and summer, using a random-stratified sampling design with standardized 30-minutes tows and vessel speed of 3 knots (Casas and Teruel, 2006; González-Troncoso *et al*., 2006a; González-Troncoso *et al*., 2006b; González *et al*., 2007). Since 2003, all of them were on board of the

Spanish *R/V Vizconde de Eza.* A *"Campelen 1800"* bottom trawl gear was used in Divs. 3LNO, whereas a *"Lofoten"* bottom trawl gear was used in Div. 3M.

By-catch data from the surveys undertaken in NAFO Regulatory Area (Divs. 3LMNO) and Canadian EEZ (Div. 3L) during 2005-2007 period are analyzed in this paper. A total number of 910 bottom trawl hauls were studied in the area and period considered (Figure 1). For Divs. 3NO, 349 hauls were analyzed in the three year study period (2005-2007). For Div. 3M, 340 hauls were analyzed (2006-2007). For Div. 3L, 199 hauls were studied (2006-2007). Finally, 22 hauls carried out within Canadian waters in 2007 (Div. 3L) were examined.

In 2005, in 3NO survey and 2006-2007 3LMNO surveys, corals and sponges caught as by-catch were identified in general groups, weighted (the biomass of massive sponge by-catches was extrapolated from samples or estimated visually, based on the observation of the volume of the codend) and recorded by scientific staff on board, and some samples were preserved to posterior studies. Additionally, under the IEO-ECOVUL/ARPA interdisciplinary project, a more detailed invertebrate sampling was made during the 2007 surveys in Divs. 3NO and 3M, and corals and sponges were preserved as vouchers for subsequent definitive identification in the laboratory. These works have not still been concluded.

In order to show all the data at the same taxonomic level, we have grouped all the cold-water corals in five orders: Alcyonacea, Gorgonacea, Pennatulacea, Antipatharia and Scleractinia. Coral samples obtained in 2007 and photographs made in 2005 and 2006 were used to know the main coral species of each group. Different species of large Demospongiae were grouped like "large sponges".

Maps of distribution and biomass of cold-water corals and large sponges are presented in this paper, based on by-catch data from surveys. The location of the coral/sponge records was assigned to the start position of the survey fishing hauls. The size of the symbols (dots) represents the biomass obtained in the hauls. The maps of large sponges present the records bigger than 50 kg/haul (one box per haul approximately). Note that the scale is not the same in all the maps.

The effort data (NAFO observers) corresponding to the bottom trawl Spanish Greenland halibut fishery (González-Troncoso *et al.*, 2007) in NAFO Regulatory Area (Divs. 3LMNO) was analyzed for period 2001-2006 (Figure 2). This is a high-seas deep-sea fishery. For this reason, effort information to depths upper 700 meters, from NAFO observers on board commercial trawlers targeting Greenland halibut, was used for this analysis. There are two others fisheries in the NRA, torny skate fishery and shrimp fishery, both developed in shallow depths of Divs. 3NO and Divs. 3LM respectively (Del Río *et al*., 2003; Casas, 2007), but in these areas, the records of cold-water corals and large sponges by-catches from surveys, were scarce. The coverage of NAFO observers is almost the 100% for the Spanish fleet (it is like a census). For these data, we calculated the percentage of the effort per each rectangle as the percentage of the effort in this rectangle divided for the total effort in all the area, for the study period. Data were checked for consistency, corrected and later converted into an ArcMap compatible format. A planar reference system was used in order to obtain data that could be used and analyzed within the GIS. The analysis was performed per 0.2 x 0.2 degrees rectangles. All the geographical databases were referenced to the WGS84. Moreover, bathymetric curves were exported as shapefiles (ArcMap format) from GEBCO Digital Atlas.

PRELIMINARY RESULTS

Cold-water corals

At least twenty-nine different taxa of cold-water corals have been preliminarily identified in this study (Table 1): five alcyonaceans; ten gorgonaceans; ten pennatulaceans; three solitary scleractinians and one antipatharian. No colonial scleractinians were found in the by-catch. At present, reef structures are unlikely to occur in the survey area. Cold-water corals were recorded as part of the by-catch in 627 of the hauls (69 % of the total hauls conducted), mainly between 600 and 1100 m. In the remaining 31 % of the hauls, no cold-water corals were found.

The volume of cold-water corals recorded in the by-catches was generally low in the regularly-used fishing grounds.

The footprint of the Spanish Greenland halibut fishery (González-Troncoso *et al.*, 2007) for period 2001-2006 is illustrated in map of Figure 2. This map allows us to obtain a general view of the areas of the whole zone studied where the effort of the commercial vessels is higher. For more details on the evolution of the fishing effort distribution along this period, see Figure 3 (from González-Troncoso *et al.*, 2007). This figure suggests that the location of main regularly-used fishing areas were quite constant along this period. Superposing the relevant information on cold-water corals by-catches from groundfish surveys, it is clear that most of the by-catches of cold-water corals, particularly large gorgonians, were recorded in areas outside regular fishing grounds (Figure 4).

Alcyonaceans

Alcyonaceans were the most common cold-water corals in the area, and occurred in 58 % of the hauls. They were quite spread along all the area studied (Figure 5), predominated in the shelf break between 500 and 1000 m depth, due the presence of *Duva florida* and in lesser extent *Anthomastus grandiflorus* and some organisms belonging to family Nephtheidae. Main by-catch of alcyonaceans was recorded in the North of Flemish Cap, around 600-700 m depth, where a few hauls with 21, 10, 7 and 6 kg of alcyonaceans were observed. Moreover, in the shallower part (less than 200 m depth) of Flemish Cap, *Duva florida* was found in the by-catches reaching 10 kg in one haul.

Pennatulaceans

Pennatulaceans (sea pens) occurred in 36 % of the hauls, mainly in the North part of Flemish Cap in a narrow band along the curve of this bank, in the 500-1200 m depth strata, and in an area in Div. 3O (Figure 6), especially in one haul carried out at 1020 m depth, closely to the Canadian EEZ and next to the area protected in 2007 (NAFO, 2007) where 5.5 kg of different pennatulaceans were recorded. The main species found were *Anthoptilum* sp, *Pennatula phosphorea* and *Halipteris* sp.

Solitary scleractinians

Solitary scleractinians (cup corals) occurred in 145 hauls (14 %) and showed a similar distribution (Figure 7) to that of presented by pennatulaceans. The highest by-catches of cup corals (11 kg) were recorded in Div. 3O, at the haul above mentioned (where pennatulaceans were found), and in another haul, close to this one, at 1028 m depth (2 kg). The main species found was *Flabellum alabastrum*. Other solitary scleractinians, like *Vaughanella* cf. *margaritata* or some species of Caryophylliidae were also recorded in a few hauls in Div. 3L.

Gorgonaceans

Gorgonaceans (sea fans) occurred in 14 % of the hauls. In relation with the structure-forming possibility, they were separated in two groups - small and large gorgonians – following similar criteria that used by Edinger *et al*. (2007).

As small gorgonians we have grouped *Acanella arbuscula*, *Radicipes gracilis*, *Anthothela grandiflora* and *Swiftia* sp. The by-catches of small gorgonians were not very important and were distributed with a similar pattern as pennatulaceans, cup corals and antipatharians (Figure 8).

Belonging to large gorgonians group, we have included organisms with an important structure-forming role, like *Paragorgia arborea*, *Primnoa resedaeformis*, *Paramuricea* sp, *Keratoisis ornata* and *Acanthogorgia armata*. Despite this group of organisms was not wide distributed in the study area, important by-catches were recorded in three small areas, two in Div. 3L (both Canadian EEZ and NAFO Regulatory Area) and another in Div. 3M (Figure 9).

The greatest biomass of deep-water gorgonian corals was found at the South part of Flemish Pass (zone mentioned as "A" in the map of Figure 10), between 1200 and 1300 m depth, where by-catch of *Keratoisis ornata* was recorded in two hauls (68.6 kg and 12.6 kg in each of them) and big basal pieces of *Paragorgia arborea*, reaching more than 1 m length, were recorded in other haul.

A second area (zone mentioned as "B" in the map of Figure 10) is localized inside of Canadian EEZ (Div. 3L) around 700 m depth, where great amount of different gorgonians species (*Paragorgia arborea*, *Primnoa resedaeformis* and *Paramuricea* sp) were recorded as by-catch in one single haul (66.2 kg).

At the Southeast part of the Flemish Cap, by-catch of gorgonians was lesser than zones "A" and "B", but there is another small zone (mentioned as "C" in the map of Figure 10), where big colonies of *Paragorgia arborea* and *Paramuricea* sp (1 m total length approximately), occurred in three hauls consecutives.

Antipatharians

Antipatharians (black corals) were the less important corals in terms of biomass values. They were presented in low by-catches along Divs. 3LM (Figure 11), following a similar distribution to that of presented by pennatulaceans and solitary scleractinians, despite of they dwell on hard bottoms, whereas pennatulaceans and solitary scleractinians, like *Flabellum* sp, dwell on soft bottoms.

Notes on biodiversity

The Flemish Cap (Div. 3M) appears to support the highest diversity of coral species (Table 1), where 24 different species were recorded, followed by Div. 3L, with 20 coral species recorded.

Despite of the small area prospected in Div. 3O, by-catches of pennatulaceans and cup corals were recorded between 600 and 1000 m depth, showing the same coral species number (12) than the number recorded for Div. 3N.

Inside of Canadian EEZ (Div. 3L) only 22 hauls were made during the study period, but great by-catches of gorgonians and other corals were recorded in all of the hauls conducted, showing high diversity (11 different species).

Large sponges

Large sponges were recorded as part of the by-catch in 35 of the hauls (3.8 % of the total hauls conducted), mainly between 1000 and 1500 m depth. In the remaining 96.2 % of the hauls, no large sponges were found.

Large sponges occurred in deep waters, in a narrow band along Northern slope of the Grand Banks (Div. 3N) and Southern Flemish Pass (Div. 3L) as well as in several patches located in Eastern Flemish Cap (Figure 12). The highest by-catches of large sponges were recorded in three hauls located at the Southeast of Flemish Cap (zone mentioned as "S" in the map of Figure 13) around 1000 m depth (5000, 2200 and 1030 kg approximately in each of them; estimated weight).

The volume recorded in the by-catches was generally low in the regularly-used fishing grounds. Most of the sponges by-catches were recorded in hauls carried out in areas outside of regular fishing grounds (Figure 13).

The main species forming these sponges aggregations belong to the family Geodiidae.

DISCUSSION

Colonial scleractinians in the study area (NAFO Divs. 3LMNO)

No colonial scleractinians were recorded as by-catch during the three year period analyzed. Taking into account the large coverage of the surveys analyzed, this null report suggests that substantial reef structures or complexes are unlikely to occur in the study area. This observation is coincident with the update maps of structural habitats compiled in 2008 by the ICES-NAFO WGDEC (see ICES-NAFO 2008). In these maps, colonial scleractinians were absent in the Gand Banks, Flemish Pass and Flemish Cap Areas.

Large gorgonians in NAFO Divs. 3LM

The current scientific information on the occurrence of non-reefal corals, such as large gorgonians, in NAFO Area is patchy and derived from different sources (ICES-NAFO, 2008). Large gorgonians are very important like structuring-habitat and joined to their size, longevity and the vulnerability to physical damage, these habitats likely constitute Vulnerable Marine Ecosystems (VMEs).

The results derived from Spanish/EU surveys have allowed the identification of at least three small areas in the region of study, where large gorgonians were recorded as part of the by-catch in bottom trawl survey hauls (Figure 9 and 10).
Some of these areas have already been mentioned in the literature, but either protection measure or better research has been carried out since then. The area inside of Canadian EEZ (Div. 3L) fits in with those found by Gass and Willison (2005) and Edinger *et al.* (2007); and the area at the South of Flemish Pass (Div. 3M) fits in with those mentioned by Edinger *et al.* (2007) and ICES-NAFO (2008). However, is the first time that corals records at Southeast of Flemish Cap (Div. 3M) are published.

Moreover, based on the available fisheries information (Kulka and Pitcher, 2001; González-Troncoso *et al.*, 2007), it seems that these areas are not being subjected to intense bottom trawl fishing (Figure 10), that could indicate that at present they are not suitable for bottom trawling or are not worthwhile for the fishery (although they could be suitable in the future) and for this reason it is expected that the habitats have not been strongly affected by fishing.

Other cold-water corals in NAFO Divs. 3LMO

Pennatulaceans, solitary scleractinians, alcyonaceans, antipatharians and small gorgonians were also recorded as part of by-catch in the study area.

Quantification of the in situ density of coral by-catch in fishing gear is not possible due to technical or operational restrictions and qualitative or semi-quantitative approach seem to be more appropriated (ICES, 2007).

There are not any international accepted criteria to indicate VMEs presence based on by-catch. Rogers *et al.* (2008) give quantities of corals by-catch from different types of fishing gear that may be associated with the existence of VMEs. They propose these criteria as an indication of the sorts of factors that should be considered when RFMOs or management agencies discuss how to define a significant encounter with a VME in their area of jurisdiction.

Following a semi-quantitative approach, a few hauls (one located in Div. 3O, six in Div. 3L and nine in Div. 3M) where important coral by-catch and different coral groups were recorded have been illustrated in Figure 14, but it is not clear if these by-catches indicate presence of VMEs in the area sampled.

The fact of finding pennatulaceans, solitary scleractinians and some representatives of bamboo corals (family Isididae) closed to antipatharians, typical of soft bottom and hard bottom, respectively (ICES, 2007), seems point out the coexistence of soft and hard bottom at the same area or close enough to be swept by the gear at the same haul or during consecutives hauls.

As well as areas where large gorgonians were found, these areas seem that not being subjected to intense bottom trawl fishing and for this reason it is expected that the habitats have not been strongly affected by fishing.

Large sponges

Despite the role of large sponges as habitat-forming structures and their vulnerability, sponge-dominated biotopes (sponge grounds) have not been well investigated in NAFO Area (ICES-NAFO 2008). Large sponges mass occurrence was recorded as part of the by-catch in six survey stations located in Eastern Flemish Cap. The large by-catches could indicate presence of sponge grounds in the area, but additional research is needed to identify this possible sponge-dominated habitat.

Resolution of available data

The use of vulnerable organisms by-catch information has a lot of limitations (Durán Muñoz *et al*., 2008a) when studying continental slope fisheries (the case of seamount fisheries is very different, due the short duration of the hauls and the geographical characteristics of the seamount: see Murillo *et al.,* 2008). Using by-catch information solely, particularly in commercial fisheries, the coral/sponge presence could be assigned to geographic locations very far away from where they occur (because the distance from the start to the end of the trawls and the extension of the swept area by the gear) or important coral and large sponges sites could be ignored. Organisms that are killed on the seabed may not be retained by the gear or may be destroyed and lost from the gear before it is returned to the deck of the vessel, resulting in underestimates of by-catch and ultimately in the interaction of the gear with VMEs. Thus a lack of by-catch of species that comprise VMEs is not definitive evidence that they are not present in an area that is fished (Rogers *et al*., 2008).

But when the by-catches are analyzed using available interdisciplinary high resolution data (superposing multibeam echosounder, dredge, visual ground truthing and other relevant data layers), complemented with information on fishery footprint, it is possible to identify accurately the location of VMEs and to delineate the appropriate closed area in order to protect the habitats.

This seems that without a properly planned habitat mapping exercise (e.g. multibeam survey, complemented with other relevant interdisciplinary data) it is very difficult, if not impossible, to provide a true picture of the distribution of VMEs, such as cold-water corals and large sponges. Only with these mapping data, the distribution of VMEs can be determined (ICES, 2005).

Identifying priority areas for interdisciplinary surveys

Dedicated surveys for identification of VMEs (Durán Muñoz *et al*., 2008b; ICES-NAFO, 2008) have been carried out successfully in the North Atlantic (e.g. Hatton Bank, NEAFC Regulatory Area) in order to produce advice on MPAs. A similar approach, using interdisciplinary methodology (multibeam survey, very high resolution seismic profiles and biological survey in the form of trawls, dredges, box corer or visual ground truthing), complemented with fishery data studies is needed in NAFO waters in order to produce advice for implement the 2006 UNGA resolution 61/105.

It is recognized that such interdisciplinary approach (Durán Muñoz *et al.*, 2007; Serrano *et al*., 2005) is appropriate when studying the interactions between fisheries and habitats (FAO, 2008b). The utility of this method was also presented and discussed by scientists from both DFO and IEO during the Spain-Canada Workshop on Surveys in February 2008. It was concluded that such interdisciplinary research in the NAFO Regulatory Area would be extremely valuable for identification of VMEs.

The analysis of by-catch data from Spanish/EU conventional groundfish surveys, allow selecting priority areas for interdisciplinary surveys (Figure 15) in the NAFO waters (Divs. 3LMNO). Such priority areas are the following:

1) South part of Flemish Pass (Div. 3L) between 800 and 1500 m depth
2) North-east part of the slope of Grand Banks in Div. 3N, between 1000 and 1500 m depth
3) Eastern part of Flemish Cap (Div. 3M) between 500 and 1500 m depth
4) Northeastern part of Flemish Cap (Div. 3M) between 500 and 1500 m depth
5) Regulatory Area of Div. 3O, close to Canadian EEZ
6) Inside Canadian EEZ (Div. 3L)

It is important to note that surveys for areas 1 and 3 have especial interest, due the records of gorgonians and large sponges. Area 6 is also very interesting due to large gorgonians presence.

Moreover, the Flemish Pass and part of the Regulatory Area of Div. 3O (where priority survey areas 1 and 5 were identified, respectively) have been commented by the ICES-NAFO WG on Deep Water Ecology (ICES-NAFO 2008) in relation with the possibilities to refine the advice for closed areas. For this reason positions of commercial hauls for Greenland halibut fishery (2001-2006) and survey by-catch (2005-2007) of cold-water corals (total cold-water corals per haul) and large sponges (>50 kg per haul) are analyzed with detail for these areas.

The Flemish Pass map (Figure 16) shows that main by-catches from surveys occurred in the South part of the Pass, in non-regularly used fishing grounds, in a deep-water narrow zone located between two important fishing areas. In the North, the by-catches were scarce. In the case of Div. 3O (Greenland halibut fishery), the map (Figure 17) shows a similar pattern, with most of by-catches located in non-regularly used fishing grounds.

In both cases, survey by-catches of corals and large sponges were scarce in the Greenland halibut regular fishing areas.

CONCLUSIONS AND RECOMMENDATIONS

- No colonial scleractinians were recorded as by-catch during the surveys analyzed, and therefore, reef structures are unlikely to occur in the study area.

- The volume of cold-water corals and large sponges recorded in the by-catches was generally low in the regularly-used fishing grounds studied. Most of the by-catches were recorded in hauls carried out in areas outside of regular fishing grounds for the bottom trawlers.

- The results presented here have allowed the identification of at least three small areas in the region of study, where large gorgonians were recorded as part of the by-catch in bottom trawl survey hauls. These areas could constitute VMEs. Pennatulaceans, solitary scleractinians, alcyonaceans and antipatharians were also observed as part of by-catch in some hauls, but it is not clear if these by-catches indicate presence of VMEs in the area sampled.

- Large sponges mass occurrence was recorded mainly in Eastern part of Flemish Cap. This evidence could indicate presence of sponge grounds in the area, but additional research is needed to identify this possible sponge-dominated habitat.

- Based on the available fisheries information, it seems that these areas are not being subjected to intense bottom trawl fishing, and for this reason it is expected that the habitats have not been strongly affected by fishing. This could make easier the establishment and operability of possible protection measures, such as MPAs.

- By-catch data have poor resolution in terms of VMEs identification and delineation. Experience from other North Atlantic Areas (e.g. NEAFC Regulatory Area) suggests that without a properly planned habitat mapping exercise (e.g. multibeam survey, complemented with other relevant interdisciplinary data) it is very difficult, if not impossible, to provide a true picture of the distribution of VMEs such as cold-water corals and large sponges.

- Six priority areas for interdisciplinary surveys have been identified in Divs. 3LMNO, based on the analysis of by-catch data from conventional groundfish surveys.

ACKNOWLEDGEMENTS

This work was possible with the support of the Instituto Español de Oceanografía (IEO) under the ECOVUL/ARPA interdisciplinary project and the Spanish Government (Secretaría General del Mar). Our sincerely thanks to the scientific staff involved in NAFO surveys and to the Heads of these surveys, for make possible the data collection. Authors also would like to thank the research vessels crews (*R/V Vizconde de Eza*) for assistance at the sea. NAFO groundfish surveys are co-funding by EU and Spanish Government.

REFERENCES

CASAS, J.M. 2007. The Spanish Shrimp Fishery on Flemish Cap (Division 3M) and Division 3L in 2006. Serial No. N5463. NAFO SCR Doc. 07/77.

CASAS, J.M. and J. TERUEL. 2006. Northern Shrimp (*Pandalus borealis*, Krøyer) from Spanish Bottom Trawl Survey 2006 in NAFO Divisions 3LNO. NAFO SCR Doc. 06/69, Serial No. N5319.

DEL RÍO, J.L., F. GONZÁLEZ and D. GONZÁLEZ. 2003. The Spanish Fishery (1998, 2000-2002) and the Spanish 3NO survey (1995-2002) in Relation to the Skate fishery in NAFO Divisions 3NO. NAFO SCR Doc., No. 39. Serial No. N4857, 16 p.

DURÁN MUÑOZ, P., M. SAYAGO-GIL, T. PATROCINIO, A. SERRANO, F.J. MURILLO, S. PARRA, L.M. FERNÁNDEZ SALAS, M. SACAU, V. DÍAZ DEL RÍO and X. PAZ. 2007. ECOVUL/ARPA Interdisciplinary Project: Looking for a model to study the interaction between deep-water bottom fisheries and their supporting high seas ecosystems. ICES CM 2007/R:01.

DURÁN MUÑOZ, P., F.J. MURILLO, A. SERRANO, M. SAYAGO-GIL, S. PARRA, V. DÍAZ DEL RÍO, M. SACAU, T. PATROCINIO and J. CRISTOBO. 2008a. A Case Study of available methodology for the identification of Vulnerable Ecosystems/Habitats in bottom deep-sea fisheries: Possibilities to apply this method in the NAFO Regulatory Area in order to select Marine Protected Areas. Paper presented to NAFO as *Scientific Council Research Document*. May 2008.

DURÁN MUÑOZ, P., M. SAYAGO-GIL, J. CRISTOBO, S. PARRA, A. SERRANO, V. DÍAZ DEL RÍO, T. PATROCINIO, M. SACAU, J. MURILLO, D. PALOMINO, M. DOMÍNGUEZ and L.M. FERNÁNDEZ-SALAS. 2008b. Suggestion on a new additional closure in order to refine the advice on cold water corals protection in the NEAFC Regulatory Area (*Hatton Bank*: ICES XIIb & VIb1) based on ECOVUL/ARPA data. Working Document presented to the Working Group on Deep-Water Ecology. Copenhagen. 10-14 March 2008.

EDINGER, E., K. BAKER, R. DEVILLERS, and V. WAREHAM. 2007. Cold-water corals off Newfoundland and Labrador: Distribution and Fisheries Impacts. *World Wildlife Fund Canada*, 49 pp.

FAO. 2008a. Technical Consultation on International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Rome, 4-8 Feb 2008: Draft International Guidelines for the Management of Deep-Sea Fisheries in the High Seas. Bangkok 11-14 Sept 2007.

FAO. 2008b. Technical Consultation on International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Rome, 4-8 Feb 2008: Advance Copy of the Report of the Workshop on Data and Knowledge in deep-sea Fisheries in the High Seas. Rome, 5-7 Nov 2007.

FREESE, J.L. 2001. Trawl-induced damage to sponges observed from a research submersible. *Marine Fisheries Review*, 63: 7-13.

FREIWALD, A., J.H. FOSSA, A. GREHAN, T. KOSLOW and J.M. ROBERTS. 2004. Cold-water coral reefs. UNEP-WCMC, Cambridge.

GASS, S.E. and J.M.H. WILLISON. 2005. An assessment of the distribution of deep sea corals in Atlantic Canada by using both scientific and local forms of knowledge. Pages 223-245 in A. Freiwald, and J.M Robertes, eds. *Cold-water Corals and Ecosystems*. Springer-Verlag, Berlin Heidelberg, 1243 pp.

GONZÁLEZ, F., J.L. DEL RÍO, A. VÁZQUEZ, E. ROMÁN, M. CASAS and G. RAMILO. 2007. Spanish Research Report for 2006. NAFO SCS Doc. 07/ 08 Serial No. N5355.

GONZÁLEZ-TRONCOSO, D., E. ROMÁN and X. PAZ, 2006a. Results for Greenland Halibut and American Plaice of the Spanish Survey in NAFO Divisions 3NO: Biomass, Length Distribution and Age Distribution for the Period 1997-2005. NAFO SCR Doc. 06/12 Serial No. N5227.

GONZÁLEZ-TRONCOSO, D., J.M. CASAS and F. SABORIDO-REY. 2006b. Results from Bottom Trawl Survey on Flemish Cap of July-August 2005. *NAFO SCR Doc.06/16 Serial No. N5231.*
GONZÁLEZ-TRONCOSO, D., M SACAU, and F. GONZÁLEZ. 2007. A study of Spanish Greenland halibut commercial effort and CPUE in 3LMNO using GIS with comparisons to the Spanish Div. 3NO survey and EU Flemish Cap survey catches. NAFO SCR Doc. 07/54 Serial No. N5406.

ICES 2005. Report of the Working Group on Deep-water Ecology (WGDEC). ICES CM 2005/ACE:02 REF. E. G.

ICES 2007. Report of the Working Group on Deep-water Ecology (WGDEC). ICES CM 2007/ACE:01 REF. LRC.

ICES-NAFO 2008. Report of the ICES-NAFO Joint Working Group on Deep-water Ecology (WGDEC). ICES CM 2008/ACOM:45 REF. WGECO, WGDEC, NAFO.

KLITGAARD, A.B. and O.S. TENDAL. 2004. Distribution and species composition of mass occurrences of large – sized sponges in the northeast Atlantic. *Progress in Oceanography* 61: 57-98.

KULKA, D.W. and D.A. PITCHER. 2001. Spatial and Temporal Patterns in Trawling Activity in the Canadian Atlantic and Pacific. ICES CM 2001/R:02.

LAFFOLEY, D. d'A. 2006. The WCPA - Marine Plan of Action. Working together to secure a global, representative system of lasting networks of Marine Protected Areas (consultation version). IUCN WCPA, Gland, Switzerland. 26 pp.

MORTENSEN, P.B. and L. BUHL-MORTENSEN. 2004. Distribution of deep-water gorgonian corals in relation to benthic habitat features in the Northeast Channel (Atlantic Canada). *Marine Biology* 144: 1223-1238.

MORTENSEN, P.B., L. BUHL-MORTENSEN and D.C. GORDON. 2006. Distribution of deep-water corals in Atlantic Canada. *Proceedings of 10th International Coral Reef Symposium*: 1832-1848.

MURILLO, F.J., P. DURAN MUÑOZ, M. MANDADO, T. PATROCINIO and G. FERNÁNDEZ. 2008. By-catch of cold-water corals from an Experimental Trawl Survey (NAFO 6EF). WGDEC Meeting. 10-14 March 2008. Copenhagen.

NAFO. 2006. Northwest Atlantic Fisheries Organization. Report of the Fisheries Commission 28th Annual Meeting, 18-22 September 2006. Darmouth, Nova Scotia, Canada. NAFO/FC Doc. 06/14. Serial No. 5312, 58 pp.

NAFO. 2007. Northwest Atlantic Fisheries Organization. Report of the Fisheries Commission 29th Annual Meeting, 18-24 September 2007. Lisbon, Portugal. NAFO/FC Doc. 07/24 Serial No. 5479, 89 pp.

NEAFC. 2007. Recommendation by the North East Atlantic Fisheries Commission at its annual meeting in November 2006 to adopt conservation and management measures by closing certain areas in the Regulatory Area in order to Project deep-water corals. http://www.neafc.org/measures/measures-2007/docs/rec-9-2007_hatton-rockall-closures-pdf.

NEAFC. 2008. Recommendation by the North East Atlantic Fisheries Commission in accordance with article 5 of the convention on future multilateral cooperation in north-east Atlantic fisheries at its annual meeting in November 2007 to adopt conservation and management measures by closing certain areas in the regulatory area in order to protect deep-water corals. http://www.neafc.org/measures/current_measures/docs/09-rec_corals.pdf

PHILIPPART, C.J.M. 1998. Long-term impacts of bottom fisheries on several by-catch species of demersal fish and benthic invertebrates. *ICES J. Mar Sci* 55: 342-252.

PROBERT, P.K., D.G. MCKNIGHT and S.L. GROVE. 1997. Benthic invertebrate by-catch from a deep-water trawl fishery, Chatham Rise, New Zealand. *Aquatic Conservation: Marine and Freshwater Ecosystems* 7: 27-40.

ROGERS, A.D., M.R. CLARK, J.M. HALL-SPENCER and K.M. GJERDE. 2008. 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, Switzerland, 2008.

SERRANO, A., F. SÁNCHEZ, J.E. CARTES, J.C. SORBE, S. PARRA, I. FRUTOS, I. OLASO, F. VELASCO, A. PUNZÓN, A. MUÑOZ, M. GÓMEZ, C. POLA and I. PRECIADO. 2005. ECOMARG Project: A multidisciplinary study of Le Danois Bank (Cantabrian Sea, N Spain) ICES CM 2005/P:11.

UNGA. 2005. Resolución aprobada por la Asamblea General. 59/25. La pesca sostenible, incluso mediante el Acuerdo de 1995 sobre la aplicación de las disposiciones de la Convención de las Naciones Unidas sobre el Derecho del Mar de Diciembre de 1982 relativas a la conservación y ordenación de las poblaciones de peces transzonales y las poblaciones de peces altamente migratorios, e instrumentos conexos. 17 de enero de 2005. Ref.: A/Res/59/25.

UNGA. 2007. Resolución aprobada por la Asamblea General. 61/105. La pesca sostenible, incluso mediante el Acuerdo de 1995 sobre la aplicación de las disposiciones de la Convención de las Naciones Unidas sobre el Derecho del Mar de Diciembre de 1982 relativas a la conservación y ordenación de las poblaciones de peces transzonales y las poblaciones de peces altamente migratorios, e instrumentos conexos. 6 de marzo de 2007. *Ref.: A/Res/61/105.*

Table 1. - Preliminary list of coral species or superior taxa recorded for Spanish/EU groundfish surveys (2005-2007) in NAFO Regulatory Area (Div. 3LMNO) and Canada EEZ (Div. 3L).

		3 L	Canada EEZ (3L)	3 M	3 N	3 O
ALCYONACEA						
	Anthomastus grandiflorus	X		X	X	X
	Duva florida	X	X	X	X	X
	Gersemia sp	X			X	X
	Nephtheidae	X	X	X	X	
	Telestula sp			X		
GORGONACEA						
	Acanella arbuscula	X	X	X	X	X
	Acanthogorgia armata	X		X		
	Anthothela grandiflora			X		
	Gorgonacea indet.				X	
	Keratoisis ornata	X		X	X	
	Paragorgia arborea	X	X	X		
	Paramuricea sp	X	X	X		
	Primnoa resedaeformis		X	X		
	Radicipes gracilis	X		X		
	Swiftia sp			X		
PENNATULACEA						
	Anthoptilum sp	X	X	X	X	X
	Distichoptilum gracile	X		X		X
	Funiculina quadrangularis	X		X		X
	Halipteris sp	X		X		X
	Kophobelemnon sp			X		
	Pennatula phosphorea	X	X	X	X	X
	Pennatula grandis	X	X	X	X	X
	Pennatulacea indet 1			X		
	Pennatulacea indet 2					X
	Umbellula sp			X	X	
ANTIPATHARIA						
	Antipatharia indet.	X	X	X		
SCLERACTINIA						
	Caryophylliidae indet.	X				
	Flabellum alabastrum	X	X	X	X	X
	Vaughanella cf. *margaritata*	X				

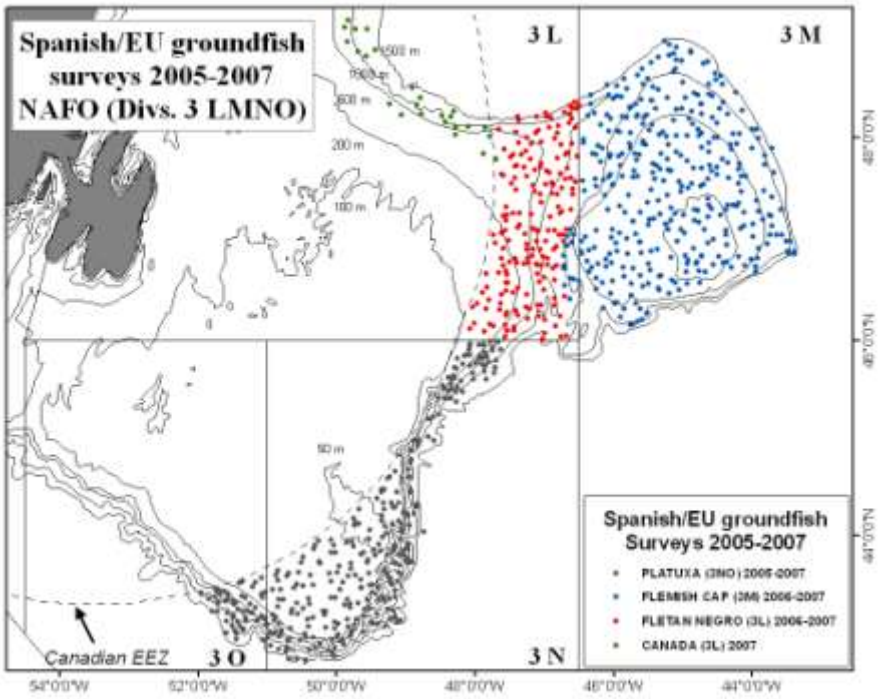

Figure 1. - Spanish/EU groundfish surveys (2005-2007) start haul positions in NAFO Area (Divs. 3LMNO). Grey dots correspond to start haul positions of Plauxa survey 2005-2007 (Divs. 3NO), blue dots correspond to start haul positions of Flemish Cap survey 2006-2007 (Div. 3M), red dots correspond to start haul positions of Fletan Negro survey 2006-2007 (Div. 3L) and green dots correspond to start haul positions of Canada EEZ survey 2007 (Div. 3L).

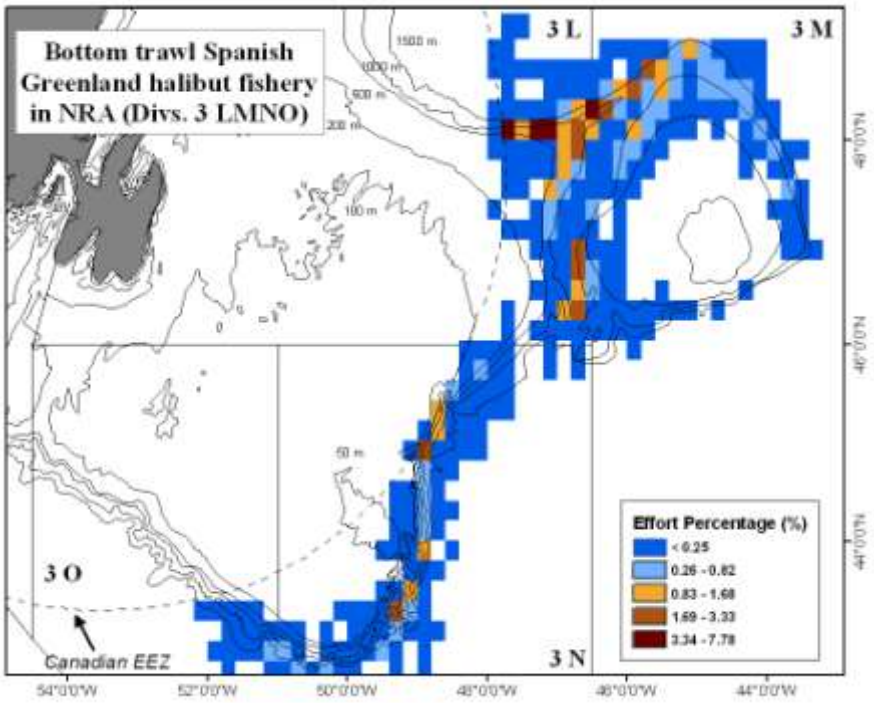

Figure 2. - Footprint of the Spanish Greenland halibut fishery for period 2001-2006 in the NAFO Regulatory Area (Divs. 3LMNO). Information from NAFO observers on board commercial trawlers. Effort percentage values per rectangle of 0.2 x 0.2 degrees. For more details see González-Troncoso *et al.* (2007).

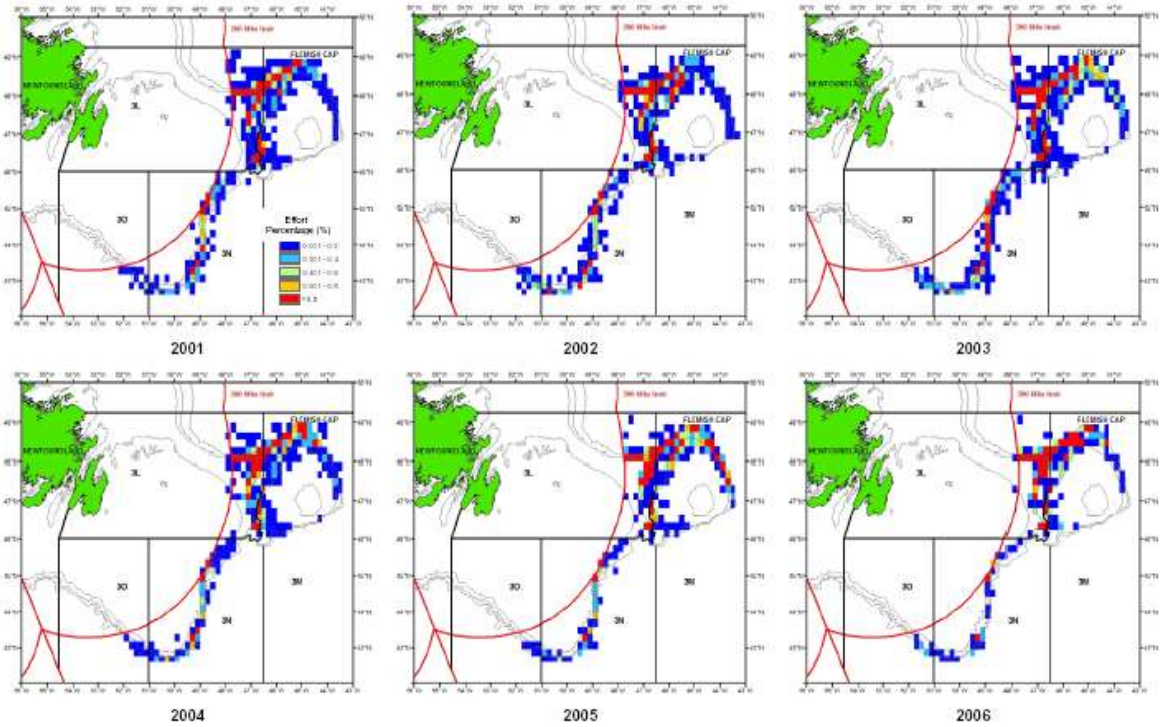

Figure 3. - Spanish Greenland Halibut fishery in NRA for 2001-2006 period. Effort percentage values per rectangle of 0.2 x 0.2 degrees, from González-Troncoso *et al.*, 2007.

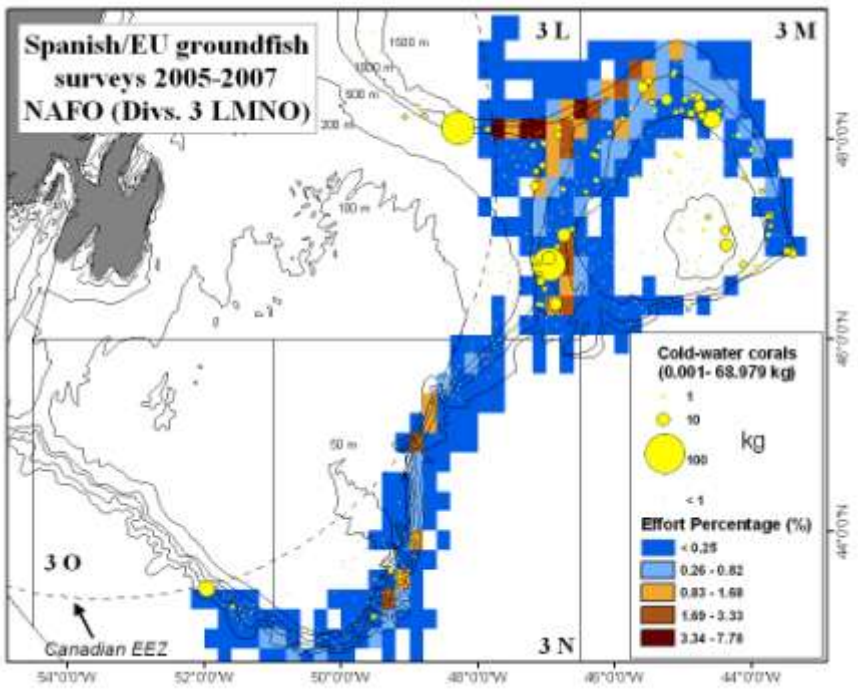

Figure 4. - Total cold-water coral by-catch (kg/haul) recorded during Spanish/EU groundfish surveys (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 68.979 kg to a minimum of 0.001 kg. Footprint of the Spanish Greenland halibut fishery for period 2001-2006 is also represented, showing that most of the by-catches were recorded in hauls carried out in areas outside of regular fishing grounds for the bottom trawlers. Effort percentage values per rectangle of 0.2 x 0.2 degrees.

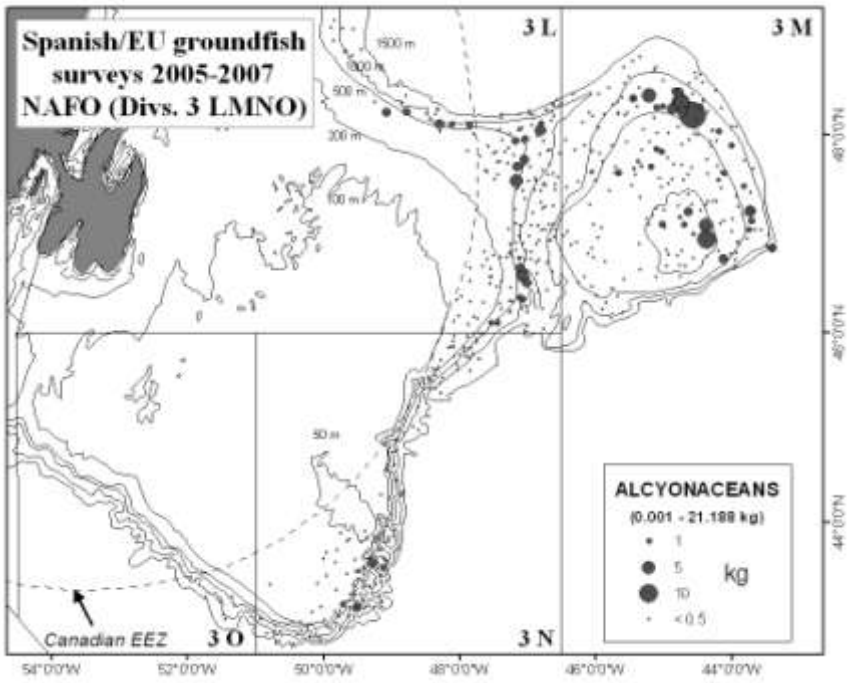

Figure 5. - Records of alcyonaceans by-catch (kg/haul) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 21.188 kg to a minimum of 0.001 kg.

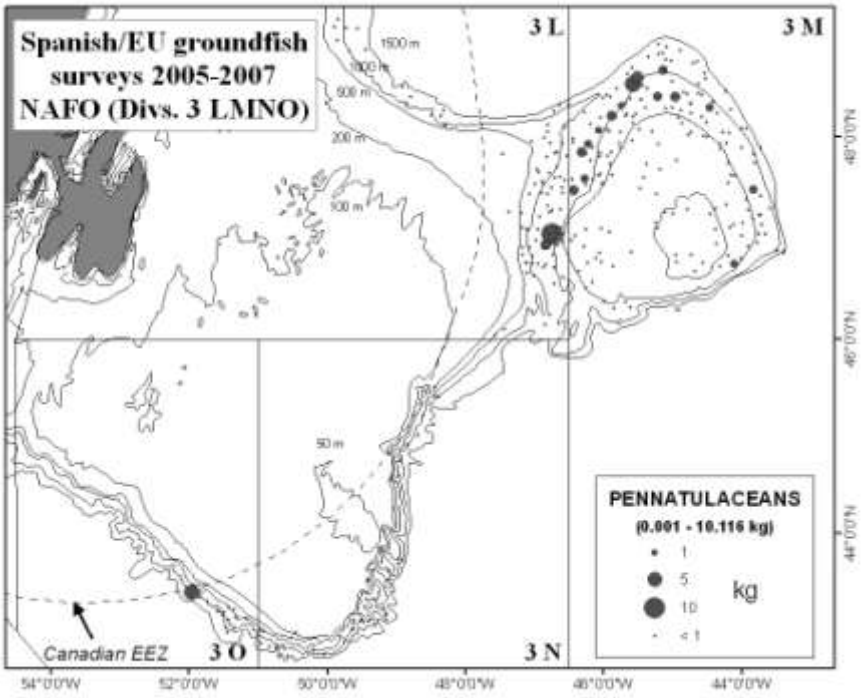

Figure 6. - Records of pennatulaceans (sea pens) by-catch (kg/haul) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 10.116 kg to a minimum of 0.001 kg.

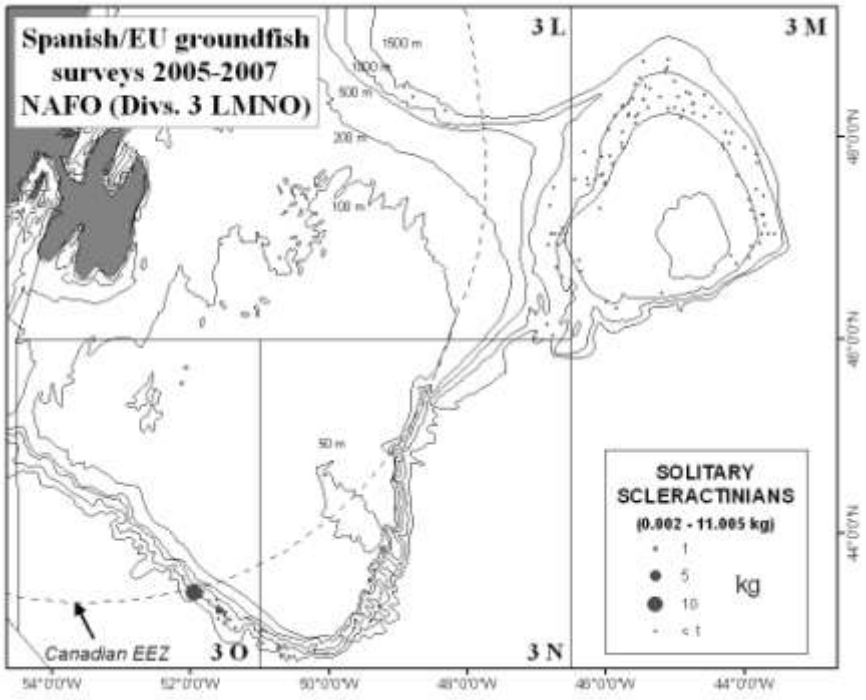

Figure 7. - Records of solitary scleractinians (cup corals) by-catch (kg/haul) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 11.005 kg to a minimum of 0.002 kg.

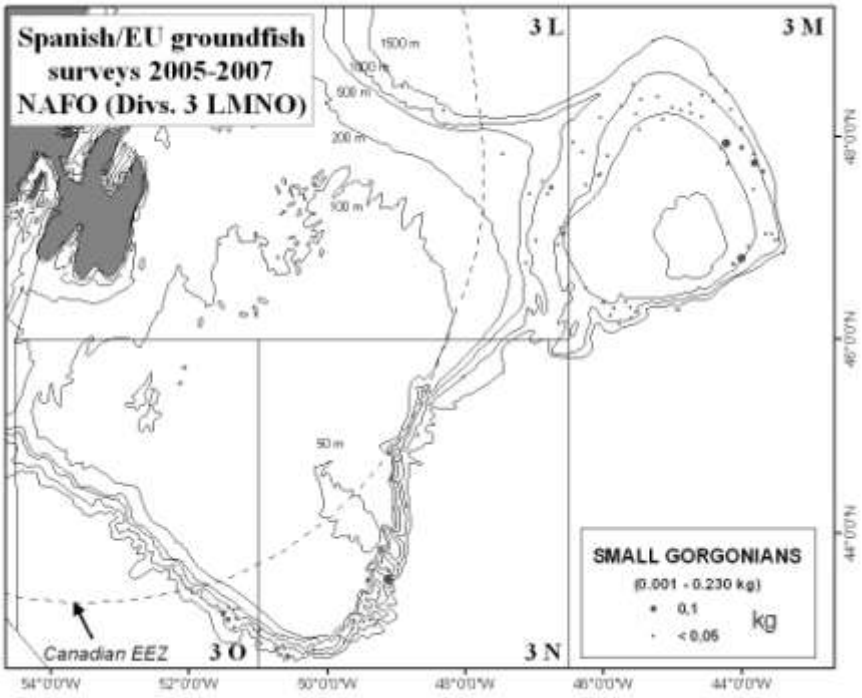

Figure 8. - Records of small gorgonians by-catch (kg/haul) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 0.230 kg to a minimum of 0.001 kg.

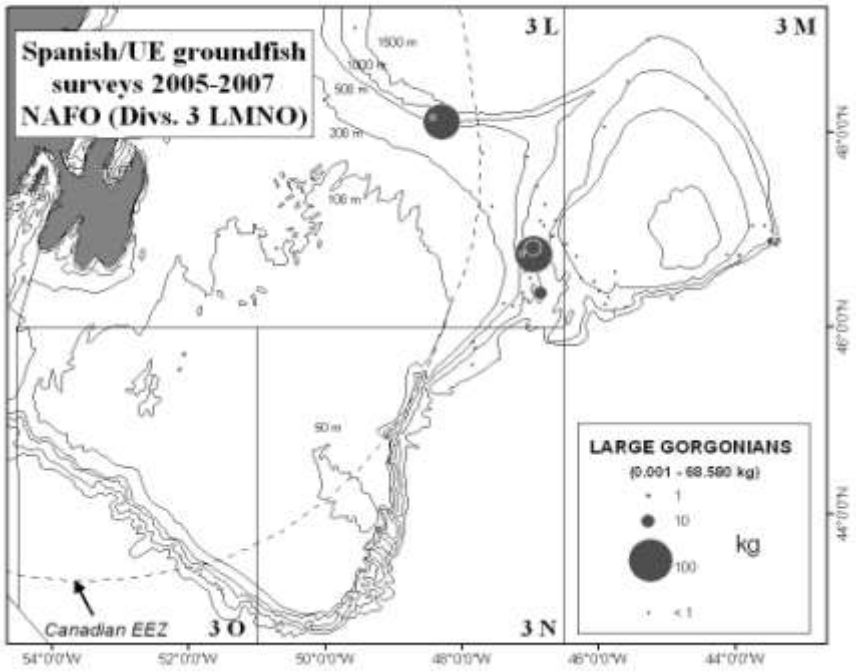

Figure 9. - Records of large gorgonians (sea fans) by-catch (kg/haul) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 68.580 kg to a minimum of 0.001 kg.

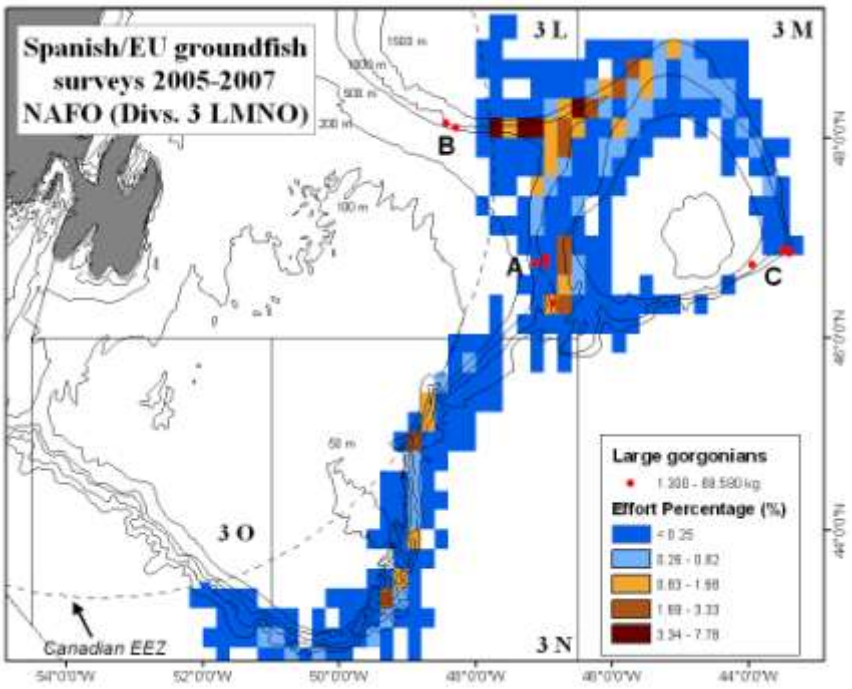

Figure 10. – Haul positions where important by-catches of large gorgonians (sea fans) were recorded during Spanish/EU groundfish surveys (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 68.580 kg to a minimum of 1.300 kg. Three areas have been identified showing that VMEs are likely to occur in NAFO Area (Divs. 3LM). Footprint of the Spanish Greenland halibut fishery for period 2001-2006 is also represented showed that areas A and C are not being subjected to intense bottom trawl fishing. Effort percentage values per rectangle of 0.2 x 0.2 degrees.

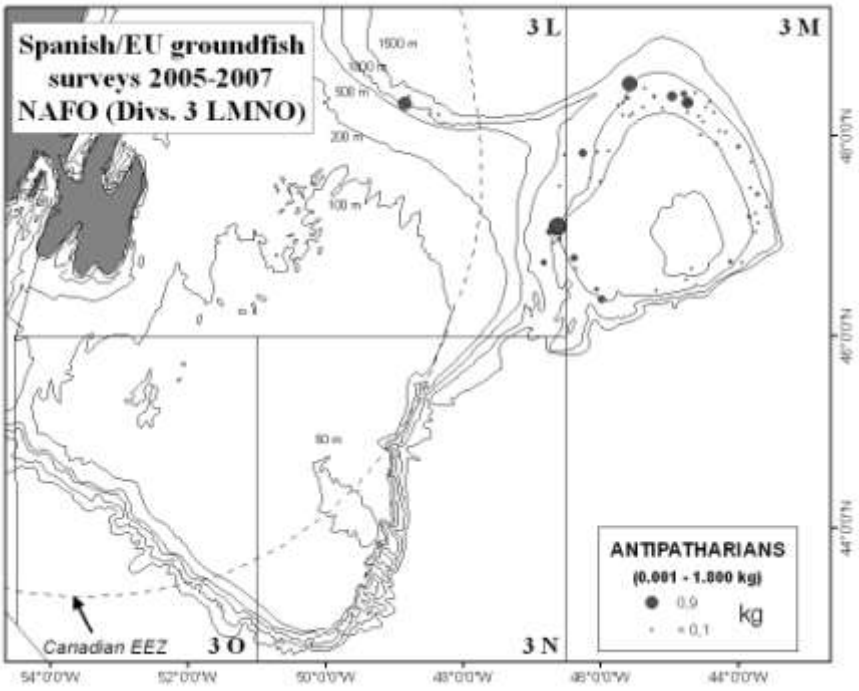

Figure 11. - Records of antipatharians (black corals) by-catch (kg/haul) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 1.800 kg to a minimum of 0.001 kg.

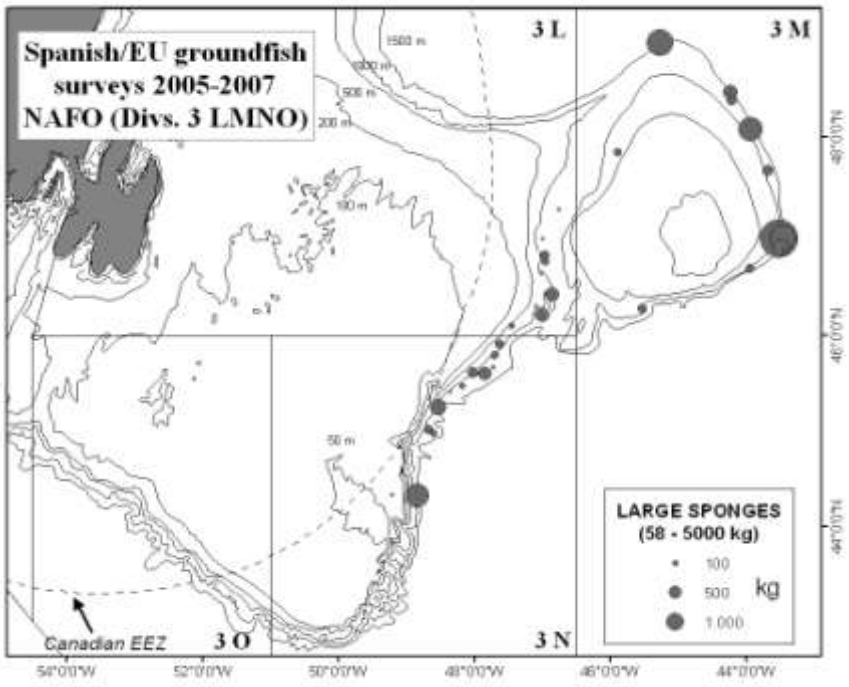

Figure 12. – Haul positions where large sponges by-catches (records bigger than 50 kg/haul; estimated weight in some cases) were recorded during Spanish/EU groundfish surveys (2005-2007) in NAFO Area (Divs. 3LMNO), superposing to the footprint of the Spanish Greenland halibut fishery for period 2001-2006, showing that these areas are not being subjected to intense bottom trawl fishing.

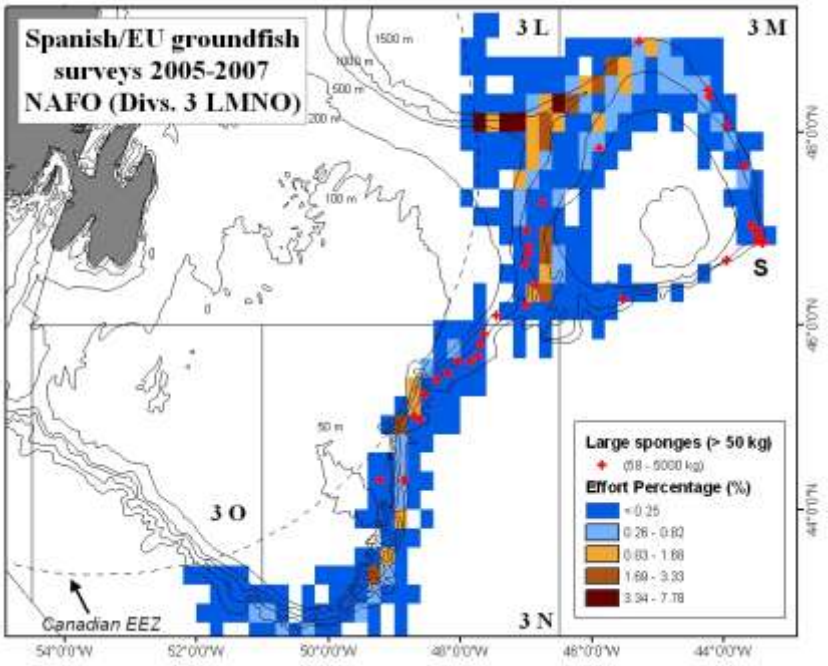

Figure 13. - Records of large sponges by-catch (estimated weights in some cases) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 5000 kg to a minimum of 58 kg (only records bigger than 50 kg/haul are represented). Effort percentage values per rectangle of 0.2 x 0.2 degrees.

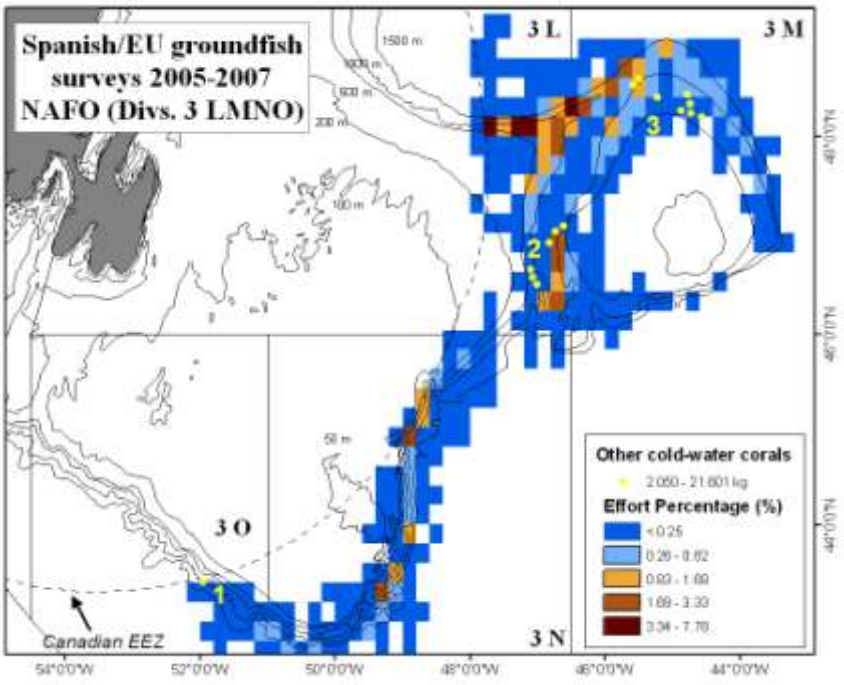

Figure 14. – Haul positions where important by-catches of cold-water corals (alcyonaceans, pennatulaceans, antipatharians and solitary scleractinians) were recorded during Spanish/EU groundfish surveys (2005-2007) in NAFO Area (Divs. 3LMNO). In terms of biomass, bottom trawl by-catches obtained by haul ranged from a maximum of 21.601 kg to a minimum of 2.050 kg. Three areas have been identified in NAFO Area (Divs. 3LMO), but it is not clear if they constitute VMEs. Footprint of the Spanish Greenland halibut fishery for period 2001-2006 is also represented, showing that these areas are not being subjected to intense bottom trawl fishing. Effort percentage values per rectangle of 0.2 x 0.2 degrees.

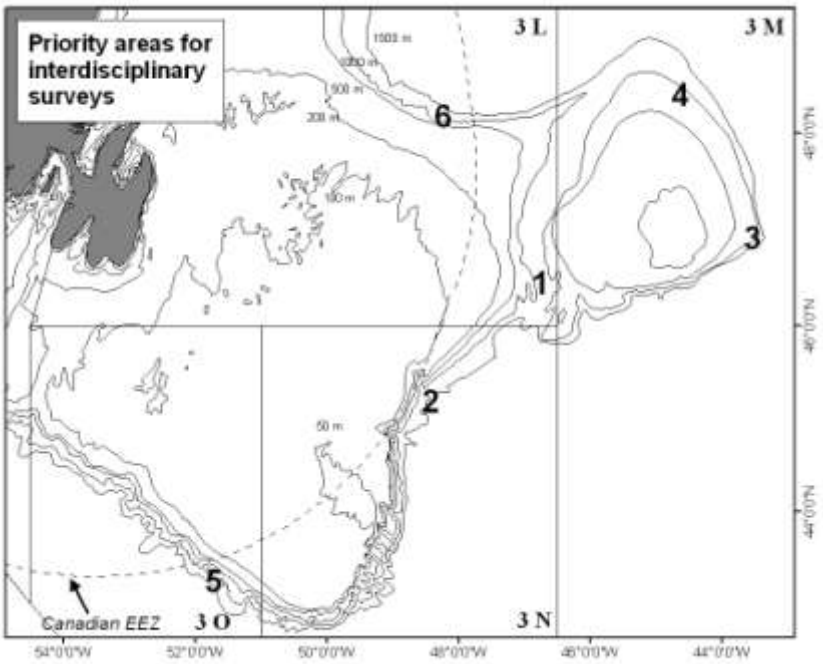

Figure 15. - Priority areas for interdisciplinary surveys in the NAFO waters (Divs. 3LMNO).

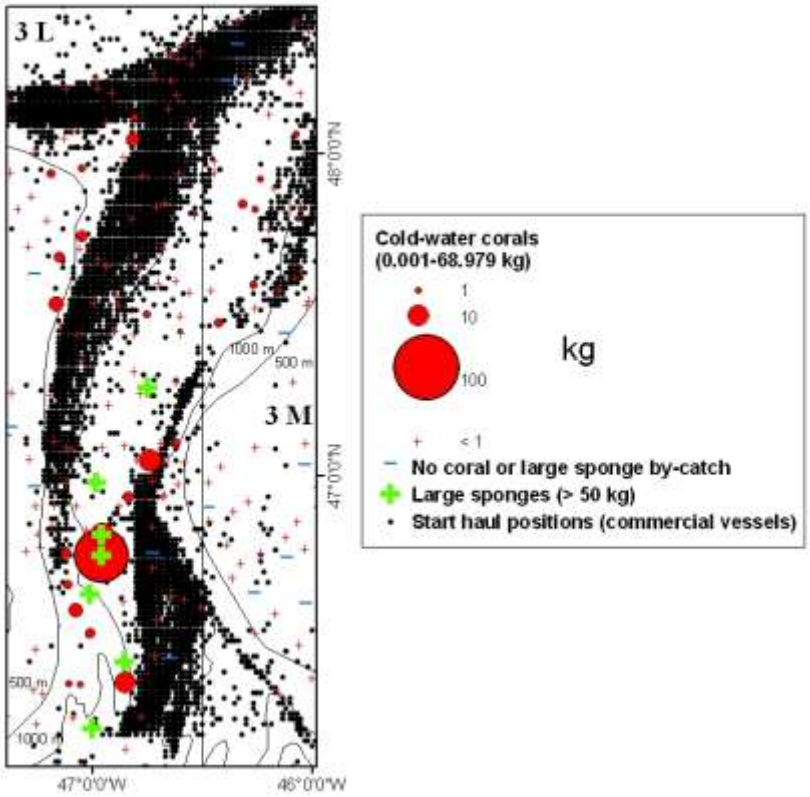

Figure 16. – Positions of commercial hauls for Greenland halibut fishery (2001-2006) and survey by-catch (2005-2007) of cold-water corals (total cold-water corals per haul) and large sponges (>50 kg per haul) for the Flemish Pass, where priority survey area 1 was identified. Main by-catches from surveys occurred in the south part of the Pass, in non-regularly used fishing grounds.

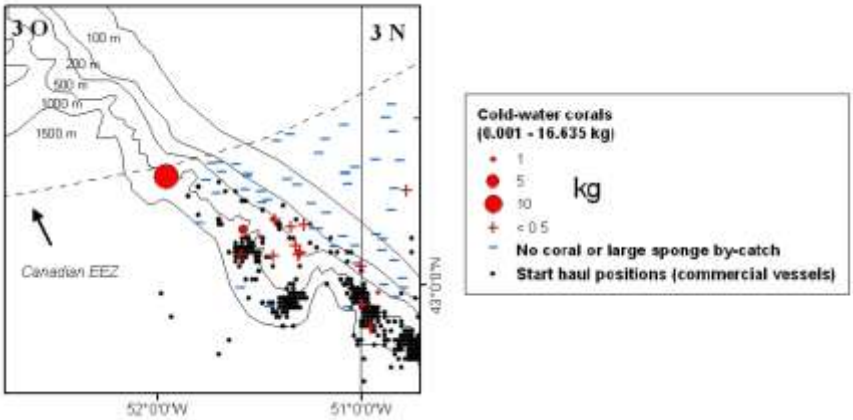

Figure 17. - Positions of commercial hauls for Greenland halibut fishery (2001-2006) and survey by-catch (2005-2007) of cold-water corals (total cold-water corals per haul) for the Regulatory Area of Div. 3O. No large sponges were found. Main by-catches of cold-water corals from surveys occurred in non-regularly used fishing grounds, closely to EEZ.