Northwest Atlantic Fisheries Organization

Serial No. N5491 **NAFO SCR Doc. 08/6**

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

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

by

P. Durán Muñoz, F.J. Murillo, A. Serrano, M. Sayago-Gil,
S. Parra, V. Díaz del Río, M. Sacau, T. Patrocinio and J. Cristobo.
Instituto Español de Oceanografía (IEO). ESPAÑA.

Abstract

Information is critical to Ecosystem Approach and to research about Vulnerable Marine Ecosystems/Habitats (VME/Hs), fishing impacts on habitats and *ad-hoc* management measures are high-priority. Therefore, this paper presents the ECOVUL/ARPA Interdisciplinary Approach, a case study of methodology for the identification of VME/Hs in order to advise on conservation measures such as marine protected areas (MPAs). By means of an interactive process involving Conventional Fisheries Science, Geomorphology, Sedimentology and Benthic Ecology, the methodology developed under the ECOVUL/ARPA project, has been useful in order to contribute to define practical criteria to the identification of VME/Hs, to improve the knowledge about VME/Hs distribution and the adverse impacts of bottom trawl fisheries and to produce high quality advice on habitat protection. Applying an interdisciplinary approach, the project identified the deep-water bottom trawl fishery footprint on the Hatton Bank Western slope (NEAFC Regulatory Area), mapped the main fishing grounds and related seabed habitats and studied the interactions between fishing and cold-water corals. This approach was used to suggest, with high level of precision, the spatial limits of an area closed to bottom fishing, as an essential conservation measure to protect the cold-water corals in the framework of the Ecosystem Approach to Fisheries management. We present here the methods used, the main results obtained and discuss on the utility of this approach and the possibilities to apply it in the NAFO Regulatory Area, with the aim to advise on measures for reducing the interactions of bottom fishing with sensitive high-seas habitats and to contribute to implement the UNGA recommendations about habitat conservation.

Keywords: Interdisciplinary research, vulnerable ecosystem, vulnerable habitat, cold-water coral, deep-water bottom fisheries, adverse impacts, mapping, closed areas, marine protected areas.

1. Background. Why research on habitats conservation is a high-priority?

The implementation of Ecosystem Approach to Fisheries (EAF) (FAO 2003, García *et al.* 2003) in the Regional Fisheries Management Organizations (RFMO) is a priority theme due to the United Nations General Assembly (UNGA) recommendations. Information is critical to EAF and key research such as ecosystems and fishery impacts, management measures (closed areas), monitoring and assessments, etc., will be necessary in order to put into practice the EAF (FAO 2005). The process of incorporating ecosystem advice into the Northwest Atlantic Fisheries Organization (NAFO) scientific process began with the 1982 United Nations Convention on the Law of the Sea and the 1995 United Nations Fish Stocks Agreement. However, it was the UNGA Sustainable Fisheries Resolution 61/105 which prompted NAFO to close areas in international waters to protect vulnerable marine ecosystems (some areas were already closed recently by NAFO). This UNGA Resolution requires a response from RFMOs not later than 31 December 2008 (ICES-NAFO 2008). The deadline imposed by the UNGA resolutions and the key research

requirements for the "*ecosystem management perspective*", imply that research on habitat conservation is a very high-priority matter in the RMFOs.

Since 2005, in line with UNGA recommendations (UNGA 2005, UNGA 2007), European Union (EC Regulation No 40/2008) and North East Atlantic Fishery Commission (NEAFC) conservation regulations (EC 2008, NEAFC 2008, NEAFC 2007) and the suggestions about habitat mapping (ICES 2005, ICES-NAFO 2008) given by the Working Group on Deep-sea Ecology (WGDEC) of the International Council for the Exploration of the Sea (ICES) - all of them inscribed in the EAF framework- the Spanish Institute of Oceanography (IEO) is developing the ECOVUL/ARPA interdisciplinary research project (Durán Muñoz *et al.* 2007a) with the aim to looking for a methodology to identify Vulnerable Marine Ecosystems/Habitats (VME/Hs) and to select suitable areas to protect. The main ECOVUL/ARPA targets are related to the key research requirements of EAF, and therefore this project can be considered a case study on incorporation of ecosystem target in the setting of management measures. The priority target is *"to research in order to advise on VME/Hs identification, fishery impacts and appropriate management measures to protect vulnerable habitats, particularly closed areas to bottom fishing to preserve cold-water corals"*. It is recognized by FAO (2008a) that this interdisciplinary methodology is adequate to identify VME/Hs in the high-seas, contributing to the management of deep-sea fisheries.

Nowadays, the Spanish project is focused in the NEAFC Regulatory Area. In fact, their results have been provided to the WGDEC and therefore were used by ICES to produce the advice on closed areas required by NEAFC (ICES 2007, ICES-NAFO 2008). Therefore, the ECOVUL/ARPA interdisciplinary approach is being very useful in the NEAFC framework in relation with European continental margin deep-sea fisheries. A similar approach would be useful also in the NAFO context for North-west Atlantic ones. The present paper summarizes the relevant information on the Spanish project, with the aim to make it available (in a single document) to the First NAFO Working Group on Ecosystem Approach to Fisheries Management, in relation with the following ToRs:

- ToR 2.3: To explore the feasibility of different tools that could be used in management advice in the NAFO area (and related Fisheries Commission request);
- ToR 2.4: Data needs and sampling recommendations.

2. Objectives and current study area

Most of the project objectives are closely related with EAF targets. The project attempts to identify VME/Hs (habitats such as cold-water corals) in relation with bottom trawl fisheries and to select suitable marine areas to protect (EAF management measure), covering fisheries, biological, geological, and ecological aspects. In accordance with this general aim the main scientific goals are:

- Define practical criteria for identification of VME/Hs;
- Identify the footprint of bottom deep-water fisheries and effects;
- Geohabitat mapping and VME/Hs distribution in relation with bottom fishing;
- Advice on which particular areas need protection (MPAs);
- Study the structure and function of deep-sea ecosystems and define communities;
- Integrate the data into a Geographic Information System (GIS) database to VME/Hs conservation monitoring.

The current objective study area is the Western slope of Hatton Bank, a deep-water fishing ground for bottom trawlers (Figure 1) in NEAFC Regulatory Area (NE Atlantic).

3. An approach designed specifically for identification of VME/Hs in the high-seas

As is well known, despite their relatively new establishment, many deep-water fisheries like main NAFO and NEAFC high-sea fisheries, were quite well developed before the implementation of the EAF and were generally managed according the conventional *"target resources"* paradigm. From the point of view of a conventional fishery biologist, one of the priority challenges in the framework of EAF, is the study of the effects of deep-water bottom fisheries on the VME/Hs, in order to advise on which zones those fisheries can be developed and which others, due to their vulnerability or ecological relevance, need protection. However it is recognized that conventional Fisheries Science can not satisfactorily resolve this challenge by itself. The research on this complex matter requires an

interdisciplinary approach (Durán Muñoz *et al.* 2005, Serrano *et al*. 2005). This approach is appropriate when studying the interactions between fisheries and habitats (FAO 2008a). Besides the knowledge on seabed geology and benthic ecology, knowledge about the fishery footprint and their relationship with the seabed geohabitats is necessary to produce appropriate advice on closed areas. For this reason ECOVUL/ARPA approach is based on fisheries knowledge and involves a team of researchers from four disciplines:

- Conventional Fisheries Science;
- Geomorphology;
- Benthic Ecology;
- Sedimentology.

The ECOVUL/ARPA methodology is designed specifically to identify VME/Hs in the high-seas and to select, with high level of precision, the spatial limits of suitable marine areas closed to bottom fishing, optimizing the competing interests of VME/Hs protection and fishing activity. Such approaches have been very useful in delineating VME/Hs for reef-building corals on Hatton Bank (ICES-NAFO 2008).

3.1 Practical criteria for identification of VME/Hs

The project tries to obtain the basis to understand the ecosystem, starting with a good knowledge of the habitat over which the bottom fishery is developed. The word "*ecosystem*" has a very wide meaning and large implications. We recognized that to know the whole ecosystem is a very difficult issue (a lot of variables are involved in it and there are many data/methodology gaps). Fortunately to try to know the seabed habitats is a more realistic (although is expensive) goal. On the other hand, bottom fishing can produce accidental adverse effects on habitats and health of habitats is critical for health and integrity of ecosystem. The majority of the accidental adverse effects are reasonably easy to study by means of ECOVUL/ARPA methodology and these effects can be avoided by means adequate management measures (closed areas). At the beginning of the project the initial criteria for identification of VME/Hs were based in the ICES-NEAFC considerations and recommendations about vulnerability (ICES 2005) and conservation priorities. Both organizations consider as high priority the identification of cold-water coral habitats and the subsequent protection (ICES 2005, ICES 2007, NEAFC 2008, NEAFC 2007). This main criterion was improved in the light of the ongoing research. We consider also the VME/Hs listed by OSPAR (OSPAR 2004), the recommendations of UNGA Sustainable Fisheries Resolution 61/105 about habitat and biodiversity preservation and more recently the VME/Hs definitions produced by FAO (2008a, 2008b). Therefore, the most vulnerable marine ecosystems 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. In relation with the Hatton Bank case study, the practical criteria considered to identify VME/Hs were the next:

- Structural biogenic habitats, particularly reefs of live cold-water corals (such as colonial scleractinians), gorgonians, etc. or high densities of large sponges (such as demosponges and hexactinellids). All of them are fragile three-dimensionally complex habitats;
- Coral rubble and other biogenic debris when support high associated biodiversity. This degradation of coral reefs could be due to either natural or anthropogenic factors (Mortensen *et al*. 2007), but high densities of dead skeletons can act also as fragile three-dimensional habitat, playing an important role in terms of biodiversity(Durán Muñoz *et al.* 2008);
- Significant seabed features (outcrops, ridges, mounds, etc.) supporting structural biogenic habitats or other hotspots of biodiversity;
- Other relevant hotspots of biodiversity (clusters of soft/hard corals as "coral gardens", etc.).

3.2 The particular role of the Sciences involved in the approach

Conventional Fisheries Science. Fisheries biologists carried out the identification and the description of the deep-water fisheries in the area, by studying the spatial, temporal and bathymetric historical distribution of the fishing effort on the fishing grounds (fishery footprint), the fishing techniques used by fishermen (gears, fishing methods and strategies), and the by-catch of vulnerable benthic invertebrates, with special attention to cold-water corals and

large sponges, in order to understand the effects of bottom fishing gears on the habitats. The methodology used includes the IEO observers on board the commercial trawlers and the analysis of the Vessel Monitoring System (VMS) graphics provided by the Spanish Ministry of Fisheries. Multidisciplinary surveys were also carried out; besides multibeam sounders and high resolution seismic profiles, the surveys are supported by biological sampling in the form of bottom trawl, dredges and box corer sampling. Cooperative surveys with the fishing industry provided additional information on fishing grounds location, by-catches and commercial fishing techniques. Finally, specialists on benthic taxonomy and GIS databases gave assistance to facilitate the data analysis and the monitoring.

Geomorphology. The main goal of the geomorphology is to identify the most relevant geomorphologic features, with special attention to carbonate mounds. Large areas of seabed have been covered by Multibeam echosounder. Bathymetry and backscatter maps with total coverage were obtained from several oceanographic cruises. Information under the seabed has been collected with sub-bottom profilers. Different sedimentary units and many structural phenomena such as faults, slide, etc., have been identified in this area. Samples from dredges (box-corer, benthic trawling dredge, etc.) have supported the survey. All the information has been integrated into a GIS. Seabed geomorphologic maps have been elaborated, with a focus on the cold-water coral presence or other ecosystems targets. It has been possible to map geohabitats with this method based on geomorphological features on the western flank of Hatton Bank.

Benthic ecology. Benthic ecologists will carry out the study of the structure and function of the ecosystems of the area, and the influence of environmental factors on them. Knowledge about the ecology of these ecosystems will allow the development of the monitoring of the fishing impact on them, and finally determine a set of indicators sensitive to those disturbances. In addition, complementary information about the environmental factors that control the presence and endurance of vulnerable and sensitive habitats will make their conservation easier. As a first step, benthic assemblages will be determined using aggregation techniques from the surveys databases. In the second phase, patterns of spatial distribution of these assemblages will be related to available environmental information using canonical ordination. Finally, assemblage qualities (EcoQ's) will be related with the fishing effort information in order to determine possible indicators of fishing impacts such as; presence of vulnerable populations (corals, sponges), species richness and diversity.

Sedimentology. Sediments studies provide information on the types of benthic and demersal communities in the deep-sea bottoms. In the same way, data on benthic habitats are critical to understand and predict the spatial distribution and abundance of many species of commercial fishes. However the main role of sedimentology in this project is to provide data on sediments characteristics. This information will be used to calibrate the backscatter data, in order to map the study area according to the sedimentary types. Sedimentary maps will serve as a base to locate benthic and demersal communities. Adding information on the remaining biological compartments (demersal fish and megaepibenthic fauna) will be possible to contribute to identify vulnerable areas.

3.3 Interdisciplinary analysis of available data sources

Obviously, one of the most relevant points of the interdisciplinary process is the interchange of knowledge and views of specialists from different (but related) marine Sciences involved in the research, with the objective to *"try to talk in a common language and to work in the same direction in order to produce the best possible advice"*. In this way, data collected from each discipline need to be integrated and analyzed under interdisciplinary approach. This means to put into practice a high level of interactive work during all the scientific process, joining efforts of different specialists under the coordination of conventional fisheries biologists' expert in fishing.

The results of this interdisciplinary analysis are presented to the appropriate RFMOs advisory bodies and are disseminated as scientific literature.

3.4 Utility: Contributing to make the EAF operational in the RFMOs

In the NEAFC context, the process from the data collection to the adoption of EAF management measures can be summarized as follows:

- NEAFC requests to ICES for suitable closed areas to protect VME/Hs.
- ICES examines the available information on VME/Hs (cold-water corals).

- After the data examination, ICES reports to NEAFC on suitable areas to close in order to protect the VME/Hs.
- In the light of the ICES advice, NEAFC can adopt conservation and management measures and consequently close certain areas to bottom fishing (marine protected areas).

In the ICES-NEAFC framework, interdisciplinary research projects (Howell *et al*. 2007, Durán Muñoz *et al.* 2008) are already providing useful information, contributing to produce high quality advice on management measures with an ecosystem target, such as closed areas to fishing with bottom gears in order to protect cold water-corals. In 2005, ICES reviewed current knowledge of *Lophelia pertusa* distribution on Hatton Bank (ICES 2005) following the request made by NEAFC. Subsequent to this review NEAFC made a decision to prohibit bottom trawling and fishing with static gear (including bottom gillnets and long lines) on part of the bank from 1 January 2007. In 2007, ICES took the opportunity to update and correct the location of early records of *L. pertusa* on Hatton Bank (Durán Muñoz *et al.* 2007b). ICES also examined new information on cold-water corals on the bank provided by UK (Narayanaswamy *et al*. 2006; Howell *et al*. 2007) and Spain (Duran Muñoz *et al.* 2007c). It subsequently reported on suitable areas to close (ICES 2007) to the south of the existing closure. In 2007, NEAFC decided to extend the Hatton closure to include this southern section of the bank from 1 January 2008 (NEAFC Recommendation IX-2007 and IX-2008, EC Regulation No 40/2008). Finally, in 2008 Spain present to ICES (ICES-NAFO 2008) new data and a suggestion on an additional closed area to protect the VME/Hs discovered in the Western slope of the bank during the Spanish surveys (Durán Muñoz *et al.* 2008).

A similar advice process would be possible to develop in the NAFO framework, considering the Scientific Council (advisory body) and the Fisheries Commission (management body). But at present, the information about VME/Hs available to NAFO seems to be dispersed. There are information on cold-water coral distribution and cold-water coral by-catch from commercial fisheries (Moore *et al*. 2001, Mortensen and Mortensen 2004, Gass and Willison, 2005, Mortensen *et al*. 2006, Edinger *et al.* 2007, Murillo *et al.* 2008). There are also ongoing ground truthing exercises (Kenchington *pers. com*.), but there are not many interdisciplinary research (Waller *et al*., 2007) trying to link different marine sciences and methods in order to study interactions between fisheries and habitats with the aim to select marine protected areas. This methodology would be appropriate to know the nature of the seabed bottom in NAFO area, the communities that inhabit it, the effects of fishing activities and to suggest suitable closed areas.

4. The Hatton Bank case study (NEAFC Regulatory Area)

4.1 Previous process

Client request. The project started as a result of the request from the Spanish Government to IEO about the interaction between deep-water bottom fisheries and VME/Hs in the Hatton Bank. The Spanish Ministry of Fisheries, Secretaría General de Pesca Marítima (SGPM) required advice on the aforementioned issue (in relation with UNGA/EU recommendations) and two main questions were asked:

- Are there VME/Hs, particularly cold-water corals, in the common grounds used by Spanish bottom trawlers on the bank?
- What kind of scientific data/approach is needed to identify the VME/Hs in order to select candidate geographical areas to protect the coral habitats?

Ecosystem priorities and targets definition. As a first step, IEO fisheries biologists identified and selected the target area and research priorities from their knowledge on the Hatton Bank deep-sea fisheries (Durán Muñoz 2006). In fact, the description of the fishery had been presented to the NAFO Symposium on Deep-sea fisheries by Duran Muñoz and Roman (2001). During the planning phase, the first work carried out by the multidisciplinary team was the selection of a common ecosystem target in relation with the request made by the client. Other project objectives were subordinated to this main target. The priority target selected was *"To identify VME/Hs on the main fishing grounds, in order to protect cold-water corals"*.

Data mining. Intensive literature studies and data mining were carried out in order to summarize the current knowledge on the VME/Hs in the Hatton Bank. ICES WG Reports were used to obtain literature references. These references provided an overview of the current knowledge on the distribution of *Lophelia pertusa* in the Bank (ICES

2005). Based on the literature review made by IEO (Durán Muñoz *et al.*, 2007b), in 2007, ICES took the opportunity to correct the early ICES table of records of *L. pertusa* on Hatton Bank, that contained errors.

Sampling methodology and data needs. The minimum data required to identify VME/Hs and to select closed areas in the framework of ECOVUL/ARPA approach are the following:

- Fisheries data: Data series of fishing effort distribution and vulnerable benthic invertebrate by-catch from observers on board commercial trawlers and cooperative surveys; Fishing strategies and characteristics of fishing gears used; VMS graphics.
- Scientific Survey data: Multibeam data; Sub-bottom profiler data; Bottom trawl data; Dredges and box-corer data.

Other data, such as visual ground truthing, side-scan sonar survey, etc., would be interesting to complement the approach and to obtain high resolution views (Wheeler *et al.* 2005) of particular smaller areas, but they are not possible to obtain at the moment.

4.2 Material and methods

The sampling strategy was planned, trying to use all the available data sources, as follows:

- **1996-2006 IEO-Observers Program** (Durán Muñoz and Román 2001, Durán Muñoz and Román 2002, Durán Muñoz 2003). This data source was used to study the footprint (Figure 1) of the fishery and to select the limits (Western slope of Hatton Bank) and depth range (1000-1500m approx.) of the study area. Additionally, VMS graphics provided by the Spanish Government were used to check the reliability of the observer's data. The map obtained from the observer database (3675 commercial trawl hauls analyzed) resulted quite consistent with the map derived from the VMS available data. In conclusion, both data sources show that in the Hatton Bank, the Spanish trawlers have their main fishing grounds in the Western slope of the Bank, between 1000-1500 m depth. On the other hand, by-catch of vulnerable benthic invertebrates was studied based on 113 commercial trawl hauls (Durán Muñoz *et al.* 2007c).

- **2005 IEO-Industry Cooperative Surveys**. These surveys in cooperation with the fishing industry (Durán Muñoz and Román 2000) were used to study the fishing techniques and strategies employed in the bank, and to research the by-catch of vulnerable benthic invertebrates from different bottom gears (particularly bottom trawl, with special attention to cold-water corals and large sponges) in order to understand the effects of commercial gears on habitats.

- **2005-07 IEO-Multidisciplinary Deep-sea Surveys** (Durán Muñoz *et al.* 2006, Durán Muñoz *et al.* 2007c, Durán Muñoz *et al.* 2008). Surveys were carried out using the Spanish multipurpose research vessels *R/V VIZCONDE DE EZA* (autumn 2005-06) and the new *R/V MIGUEL OLIVER* (summer 2007). Both vessels, owned by SGPM, have geophysics, fishing and dredge facilities. Details on vessels characteristics available in:

  http://www.mapa.es/es/pesca/pags/vizconde_web/index.htm
  http://www.mapa.es/es/pesca/pags/miguel_web/index.htm

  Close to 18760 km^2 of multibeam bathymetry (SIMRAD EM-300) and 1121 km of very high resolution seismic profiles (TOPAS PS 018) were obtained, both on the Western flank of the Hatton Bank. In addition, 38 standardized fishing hauls (30' duration) using LOFOTEN bottom trawl were conducted (depth range: 800-1500m). Dredge sampling were also carried out, obtaining soft sediment and hard substratum samples: 13 BOX-CORER (using two different sampling area: 0.09 m^2 and 0.25m^2, depth range: 970-1509m) and 2 net sediment collector to study sediments and infaunal communities; 22 trawl (ROCK) dredges to study megaepifauna (depth range: 800-1400m). Sediments analysis was performed (Buchanan, 1984, Parra, 2007). Details of survey sampling are presented in Figure 2.

- **International collaboration** with BGS (UK) and IPIMAR (Portugal) provided information in relation with Marine Geology (Sayago-Gil *et al*. 2006, Sayago-Gil *et al.* 2007) and Fish Biology (Moura *et al.* 2008) respectively.

4.3 Results: Identification of VME/Hs and suggestion on marine protected areas (closed areas)

Data collected from the ECOVUL/ARPA datasources were integrated and analyzed under an interdisciplinary approach. The results obtained allowed a preliminary identification of the principal deep-sea habitats in the study area (1000-1500m approx.), developed on the following two geomorphological domains:

- Sedimentary seabed of the *Hatton Drift*;
- Hatton Bank North-western *outcrops*, where vulnerable habitats (taking into account the current vulnerability criteria) occur.

Sedimentary seabed of the *Hatton Drift.* Rebesco (2005) defines the contourites (Drift) as sediments deposited or substantially re-worked by the energetic action of the bottom currents. The *Hatton Drift* develops on the western flank of the Hatton Bank (McCave and Tucholke 1986) and is composed mainly of fine or very fine sediments. The information provided by the Spanish Observers Program, superposed on multibeam bathymetry, added to the preliminary results of the sediment samplings, both obtained in the Spanish Multidisciplinary Surveys, indicates that fishing grounds of the trawl fleet are generally located on flatter and sandy zones of the sedimentary seabed (*Hatton Drift*). The analysis of the samples of superficial sediment obtained with the box-corer confirmed the sedimentary nature on the studied stations (Figure 3), particularly fine sands, very fine sand and muds. It is well-known that the box-corer is an appropriate method to study the sediments and the infauna, not the epifauna. Nevertheless, as complementary information, we noted that the epifauna in the box-corer samples was scarce: One Xhenophyophore; Small Sponges as *Bubaris* sp or *Cladorhiza* sp; Echinoderms as ophiuroidea and echinoidea; Polychaetes; Amphipods; etc. We did not observe coral or coral rubble in these samples. On the other hand, survey hauls carried out in the sedimentary seabed of the *Hatton Drift*, show that in the sedimentary region, in the catches obtained by means of bottom fishing gears, fishes are clearly dominating over invertebrates (Durán Muñoz *et al.* 2007c) and the by-catch of cold-water corals is very scarce (small live coral pieces and/or coral rubble with few associated epifauna) generally related to hauls carried out accidentally over outcrops. This suggests that corals could be found in the area, but distributed in small patches commonly associated to outcrops and placed in very specific locations, never forming substantial reef structures. According to the available information, the sedimentary seabed supported an intense trawl fishing activity and at present, reef structures are unlikely to occur (ICES 2007).

Taking into account this information, following the current VME/Hs criteria, protection of the sedimentary seabed of the *Hatton Drift* is not considered a priority, since currently the evidence for the presence of corals on this soft substrate area seems to be anecdotal and the fishing effort seems to be considerable.

Hatton Bank North-western *outcrops*. The geologic setting of Hatton Bank is complex (Edwards 2002, Hitchen, 2004). We will refer to "*outcrops*" to those parts of the bank, in strict sense, which begin to show in the surface of the seabed and which are not covered by the sedimentary deposit (Drift). According to the available information, it seems that the outcrops studied are not being subjected to intense trawl fishing effort (Figure 4) and for this reason, it is expected that these habitats have not been strongly affected by fishing. They are described here by order, from north to south.

- In the outcrop named as "A" (Figure 4), the multibeam bathymetry shows an irregular relief, with alignments also irregular (700-1740 m depth). They cover an area of 1240 km^2 and an extension of 70 km (approx.) in the shallowest depth (upslope). In the seismic sections, hard outcrops of the bank (basalts) are showed, which gradually are covered for sediments, probably of the Drift. According to samples obtained from trawl dredge (Figure 5) we can deduce that these outcrops make a suitable substratum for settlement of cold water corals since there were observed live colonial scleractinians (small colonies of *Solenosmilia variabilis*) and dead octocorals skeletons. Information obtained from 2005 surveys (Durán Muñoz *et al*. 2007c) also corroborates the evidence for the presence of corals within the area (*Lophelia pertusa* and *Madrepora oculata*, gorgonians and black corals as well as dead fragments with great associated biodiversity).

- In the outcrop named as "B" (Figure 4), the multibeam data reveals elongate and parallel ridges, 5 km apart with sections between 2-7 km and extend more than 40 km. These segments follow four principal directions: N90ºE, N78ºE, N67ºE and N53ºW. They are located at depths between 700-1600 m and present height varying between 5-45 m, generally with maximum gradients downslope (up to 17º). Dozens of small mounds (carbonate reefs) have been identified on the crest of the ridges (Figure 6a). Ponds of sediments exist in the ridges zone upslope (barriers are acting as a sediment trap). This material is a mixture of sediment from the Drift and coral remains (Sayago-Gil *et al*. 2006, Sayago-Gil *et al*. 2007). Below the mounds, the seismic signal is often chaotic and sometimes opaque possibly because of sound attenuation by the mound composition. In addition, also we can observe how the mounds are located on the hard surfaces, the top of basalts in this case. From the analysis of the samples obtained from trawl dredge within this area (Figure 6b) we can deduce that this type of substrate is suitable for settlement of cold water corals. Small colonies of live cold water corals were found in these samples (scleractinians and black corals) as well as skeletons of dead specimens (scleractinians, octocorals, etc.) with a rich associated biodiversity, together with remains of cirripeds and molluscs. Considerable amounts of dead coral was found in locations near to the common fishing grounds, as well as far away from the fishing grounds, which could indicate that diverse non-anthropogenic factors (natural factors, like environmental changes, etc.) could be also affecting the coral viability.

- In the outcrop named as "C" (Figure 4), based on the multibeam data, an irregular surface can be observed without a special trend direction of the relief. The area is of 600 km^2 approximately, covering an extension of 80 km (approx.) in the shallowest depth of the study area. The area is located between 800-1600 m depth. The area boundary describes an elongate morphology which cuts into the Drift. Taking the seismic information we can say that it is an area of outcrop of the bank (basalts), although locally could be covered by sediments of the Drift. According to the analysis of samples obtained from trawling dredges within this area (Figure 7), we can confirm the presence of live cold water corals (small pieces of *Solenosmilia* sp) in the outcrops. Moreover, as well as in area "B", in area "C" were obtained also important amounts of skeletons of dead specimens (colonial scleractinians), over which were observed a great associated biodiversity. In the samples located far away from the regular trawling area, with the exception of few solitary scleractinians, all the remained coral found was dead, which could indicate that non-anthropogenic factors could be also affecting to the viability of coral.

Taking into account this information, following the current VME/Hs criteria and verified the presence of cold water corals and associated high biodiversity in the area, protection of the *Hatton Bank North-western outcrops* was considered a high-priority. In this way, the high quality and detailed resolution of the acoustic and biological survey undertaken by the Spanish Institute of Oceanography (data on the distribution of cold-water corals and outcrops likely to support cold water corals), allowed to WGDEC (ICES-NAFO 2008):

- To map vulnerable deep-sea habitats (1000-1500 m approx.) at a high level of accuracy;

- To recommend that the area known as the *Hatton Bank North-western outcrops* be closed to bottom fishing. The boundaries of this recommended closure (a simple polygon that entirely encloses the vulnerable habitats identified and incorporates a minimum "buffer area" of 1 nm) are presented in map of figure 8.

Identification of the mentioned vulnerable habitats, based on available results from ECOVUL/ARPA project, does not exclude the possible identification of other additional areas in the light of future scientific knowledge (Durán Muñoz *et al.* 2008).

5. High resolution of interdisciplinary data *vs* poor resolution of by-catch data

The map of the Figure 9, presents the chart of Hatton Bank showing some examples of commercial trawl hauls with presence of cold-water coral by-catch. These hauls are plotted over the boundaries of the new additional area suggested for closure. Information was obtained from ECOVUL/ARPA data sources (observers on board commercial trawlers and trawl cooperative survey).

It is worthy to note the poor geographic resolution of the by-catch information, if these data are analyzed in absence of gehohabitat knowledge**.**

In the present examples, if we analyze only the by-catch records, the coral presence could be assigned to geographic locations very far away from where coral occurs, because the distance from the start to the end of the trawls can reach up to 20 nautical miles (approx). Conversely, using by-catch information solely, important coral sites could be ignored. Taking account this information, in absence of seabed data, the boundaries of closed areas could be delineated erroneously, and VME/Hs could remain outside the protected area (or zones that not contain VME/Hs could be closed). Consequently, due to this management measure, fishing effort displacement could result in coral damage.

But when these trawls are analyzed using available interdisciplinary data (superposing multibeam, dredge and other relevant data layers), as show Figures 3 and 5 to 7, it is possible to know that these by-catches were recorded in hauls carried out accidentally over outcrops. Taking account this high resolution information it is possible to identify accurately the location of VME/Hs 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 VME/Hs such as cold-water corals. Only with these mapping data can the distribution of VME/Hs (particularly substantial reef structures) be determined (ICES 2005).

6. Applying this approach to NAFO: Available data and necessity of additional data

Data series from the different existent observer programmes could be analyzed to identify the footprint of main deep-sea fisheries in the NAFO Area (e.g. Spanish observer program; NAFO observer program; Canadian observers, etc.). Data on by-catch of cold-water coral and other vulnerable benthic invertebrates provided by these observers or derived from conventional bottom trawl surveys could be used (e.g. Spanish/UE surveys in Div 3NOLM; Canadian Department of Fisheries and Oceans –DFO- surveys covering wide NAFO areas, etc.). Data provided by visual ground truthing exercises (e.g. Canadian cruises with Remote Operated Vehicle –ROV- in Div 3O) are very useful also.

But interdisciplinary surveys in the NAFO waters are needed (multibeam, dredge, box-corer, trawls, ground truthing, etc.). The utility of this methodology and the recent Spanish and Canadian initiatives (including the exploration of multibeam capabilities and opportunities for collaboration and cooperation in surveys) was presented and discussed by scientists from both DFO and IEO during the Spain-Canada Workshop on Surveys (Vigo, Spain. 25-27 February 2008): It was concluded that such interdisciplinary research in the NAFO Regulatory Area would be extremely valuable. The benefits of multibeam research were recognized, and it was agreed that a joint proposal should be pursued for work in the NAFO Regulatory Area on the Grand Banks, in next future. One possible model for such a proposal could be to employ a Spanish vessel, with Spanish and Canadian scientists, and for funding to be sought from both Canada and Spain (e.g. Spain-Canada Memorandum of Understanding) and perhaps EU. See Report from 2008 Spain-Canada Workshop on Surveys (Anon. 2008).

7. Conclusions and recommendations

- Despite that the conservation of habitats is not the final main objective of EAF, the deadline imposed by the UNGA resolutions (31 December 2008) and the key research requirements to put into practice the EAF, imply that the research on habitat conservation is a very high-priority matter in the RMFOs.

- Identification of deep-sea habitats is a realistic (but expensive) goal. Bottom fishing can produce accidental adverse effects on habitats and health of habitats is critical for ecosystem health and integrity, but the majority of accidental adverse effects can be minimized or avoided by means management measures (closed areas).

- The interdisciplinary approach presented here is adequate when studying the interactions between fisheries and habitats in order to select with high level of precision, the spatial limits of suitable areas closed to bottom fishing optimizing the competing interests of VME/Hs protection and fishing activity. Besides the knowledge on seabed geology and benthic ecology, a good knowledge about the fishing footprint and their relationship with the seabed geohabitats is necessary to produce the appropriate advice. This is recognized by FAO (2008a).

- Without a properly planned habitat mapping exercise (e.g. multibeam survey, complement with other relevant interdisciplinary data) it is very difficult, if not impossible, to provide a true picture of the distribution of VME/Hs such as cold-water corals. Only with these mapping data can the distribution of VME/Hs (particularly substantial reef structures) can be determined. This is recognized by ICES (2005). The benefits of multibeam research were recognized also during the 2008 Spain-Canada Workshop on Surveys. It was agreed that a joint proposal should be pursued for work in the NAFO Regulatory Area on the Grand Banks, in next future (Anon. 2008).

- The ECOVUL/ARPA interdisciplinary project, as other similar approaches, is already providing useful information to put into practice the EAF contributing to improve the knowledge on vulnerable habitats/ecosystems in relation with deep-sea fisheries in the high-seas, and to produce the advice on closed areas in order to protect cold-water corals. This existent methodology has been already successfully used in NEAFC deep-waters (1000-1500 m approx.).

- Using the available fisheries data (fishing effort distribution, by-catch of cold-water corals, etc.) and new additional data from possible future dedicated surveys (multibeam data, grab data, etc.), a similar approach would be used in the NAFO context, in order to implement the 2006 UN General Assembly resolution (resolution 61/105) calling for the protection of VME/Hs such as deep-sea corals, contributing to make the EAF operational in the North West Atlantic.

8. Acknowledgements

The ECOVUL/ARPA Project is funded by Spanish Government. *Secretaría General de Pesca Marítima* (SGPM. Ministerio de Agricultura, Pesca y Alimentación) and *Instituto Español de Oceanografía* (IEO. Ministerio de Educación y Ciencia). Our sincerely thanks to the experts and research vessels crews (*R/V Vizconde de Eza and R/V Miguel Oliver*) provided by the SGPM, and to observers and fishermen, for assistance in the data collection on the treacherous Hatton seas. To the *Universidade de Vigo* (Spain) and *IPIMAR* (Portugal), thanks also for assistance on benthos and deep-water elasmobranches taxonomy and biology respectively and to *BGS* (UK) for the data and survey collaboration. Finally, thanks to all IEO staff that collaborate in the logistics and technical matters of our project.

9. References

ANON. 2008. Report of the Spain-Canada Workshop on Surveys. Vigo, Spain. 25-27 February 2008.

BUCHANAN, J.B. 1984. Sediment analysis. In Holme N.A. and McIntyre A.D. (eds.): Methods for the study of marine benthos, pp. 41-65. Blackwell Scientific Publications, Oxford.

DURÁN MUÑOZ, P., M. SAYAGO-GIL, J. CRISTOBO, S. PARRA, A. SERRANO, V. DÍAZ DEL RIO, T. PATROCINIO, M. SACAU, J. MURILLO, D. PALOMINO, M. DOMÍNGUEZ and L. M. FERNÁNDEZ-SALAS. 2008. 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. WDoc. ICES Working Group on Deep-Water Ecology. Copenhagen. 10-14 March 2008.

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. 2007a. 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., MURILLO F. J., M. SACAU, and T. PATROCINIO. 2007b. Some Notes about Information on the Occurrence of Cold-water Corals on the Hatton Bank, summarised in year 2005 by the ICES Working Group on Deep-water Ecology: "Table 3.1 Positions where *Lophelia pertusa* has been recorded on the Hatton Bank" (ICES-WGDEC Report 2005). WDoc. ICES Working Group on Deep-Water Ecology. Plymouth. 26-28 February 2007.

DURÁN MUÑOZ, P., M. SACAU, M. SAYAGO-GIL, T. PATROCINIO, L. M. FERNÁNDEZ-SALAS, F. J. MURILLO, V. DÍAZ DEL RÍO, A. SERRANO and S. PARRA. 2007c. ECOVUL/ARPA (Estudio de los

eCOsistemas VULnerables y los ARtes de PescA): A Spanish Interdisciplinary Research Project Focused on the Study of the Hatton Bank Deep-Sea Fisheries (ICES XIIb & VIb1) and their Relationship with Vulnerable Ecosystems/Habitats, Integrating Fisheries Biology, Geomorphology, Benthic Ecology and Sedimentology. ICES CM 2007/A:01.

DURÁN MUÑOZ, P. 2006. Spanish investigations on the Hatton Bank and adjacent waters during 2005. WDoc. ICES Working Group on Biology and Assessment of Deep-sea Fisheries Resources. Vigo. 2-11 May 2006.

DURÁN MUÑOZ, P., V. DÍAZ DEL RÍO, S. IGLESIAS and J. ACOSTA. 2005. ECOVUL/ARPA: A Spanish Multidisciplinary Deep-Sea Survey Project in Hatton Bank. WDoc. ICES Working Group on Biology and Assessment of Deep-sea Fisheries Resources. Extraordinary Meeting. Copenhagen. 7-9 September 2005.

DURÁN MUÑOZ, P. 2003. The Spanish Scientific Observers Programme as a Tool to Improve the Knowledge on Deep-sea Fisheries. World Conference on Deep-sea Fisheries. 18-19 September 2003. Baiona. Spain.

DURÁN MUÑOZ, P. and E. ROMÁN. 2002. Database of the Spanish Observer Program in North Atlantic International Waters: Exploring how this existing information could be used to investigate the composition and distribution patterns and the biology of the deep-water species. ICES CM 2002/L:08.

DURÁN MUÑOZ, P. and E. ROMÁN. 2001. The Spanish Multi-species Deep-sea Fishery in Hatton Bank (Northeast Atlantic): 1996-2000. NAFO SCR Doc No 120. Serial No N4508.

DURÁN MUÑOZ, P. and E. ROMÁN. 2000. Spanish Experimental Fishings: A cooperative research initiative between scientists and the local fishing industry. ICES CM 2000/W:03.

EC 2008. Reglamento (CE) No 40/2008 del Consejo de 16 de enero de 2008, por el que se establecen, para 2008, las posibilidades de pesca y las condiciones correspondientes para determinadas poblaciones y grupos de poblaciones de peces, aplicables en aguas comunitarias y, en el caso de los buques comunitarios, en las demás aguas donde sea necesario establecer limitaciones de capturas.

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*.

EDWARDS, J.W.F. 2002. Development of the Hatton-Rockall Basin, North-East Atlantic Ocean. *Marine and Petroleum Geology*, 19: 193-205.

FAO 2008a. 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. ftp://ftp.fao.org/FI/DOCUMENT/tc-dsf/2008/inf6e.pdf.

FAO 2008b. 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. ftp://ftp.fao.org/FI/DOCUMENT/tc-dsf/2008/2e.pdf

FAO 2005. Putting into practice the ecosystem approach to fisheries. Rome. FAO. 2005.

FAO 2003. Departamento de Pesca. La ordenación pesquera. 2 El enfoque de ecosistemas en la Pesca. *FAO Orientaciones Técnicas para la Pesca Responsable*. No. 4. Supl. 2. Roma, FAO. 2003.

GARCÍA, S.M., A. ZERBI, C. ALIAUME, T. DO CHI, and G. LASERRE. 2003. The Ecosystem Approach to Fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. *FAO Fisheries Technical Paper*. No.443, Rome, FAO.2003.

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. In Freiwald, A. and Roberts J.M (eds), 2005. *Cold-water Corals and Ecosystems*. Springer-Verlag, Berlin Heidelberg. Pp 223-245

HITCHEN, K. 2004. The geology of the UK Hatton-Rockall margin. *Marine and Petroleum Geology*, 21: 993-1012.

HOWELL, K.L., J.S. DAVIES, D.J. HUGHES, and B.E. NARAYANASWAMY. 2007. Strategic Environmental Assessment-Special Area for Conservation photographic analysis report. UK: Department of Trade and Industry (DTI) and the Department of Food and Rural Affairs (DEFRA).

ICES-NAFO 2008. Report of the ICES-NAFO Joint Working Group on Deep-water Ecology (WGDEC). In press.

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

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

MCCAVE, I.N. and B.E. TUCHOLKE 1986. Deep current-controlled sedimentation in the western North Atlantic. In: P.R. Vogt and B.E. Tucholke (Eds). *The geology of North America Vol M (The Western North Atlantic Region)*. Geological Society of America: 451-468.

MOORE, J.A., VECCHIONE, M., HARTEL, K.E., COLLETTE, B.B., GALBRAITH, J.K., GIBBONS, R., TURNISPEED, M., SOUTHWORTH, M. and E. WATKINS. 2001. Biodiversity of Bear Seamount, New England Seamount Chain: Results of Exploratory Trawling. NAFO SCR Doc. No155 Serial No4549

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.

MORTENSEN, P.B., L. BUHL-MORTENSEN, A.V. GEBRUK, AND E.M. KRYLOVA. 2007. Occurrence of deep-water corals on the Mid-Atlantic Ridge based on MAR-ECO data. *Deep-Sea Research II* (2008), 142-152.

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.

MOURA, T., M.C. SILVA, I. FIGUEIREDO, A. NEVES, M.M. COELHO, P. DURÁN MUÑOZ and L.S. GORDO. 2008. Molecular barcoding of NE Atlantic deep-water sharks: species identification and application to fisheries management and conservation. *Marine and Freshwater Research*. In Press.

MURILLO, F. J., P. DURÁN MUÑOZ, M. MANDADO, T. PATROCINIO and G. FERNÁNDEZ. 2008. By-catch of cold-water corals from an Experimental Trawl Survey in three Seamounts within NAFO Regulatory Area (Divs. 6EFG) during year 2004. WDoc. ICES Working Group on Deep-Water Ecology. Copenhagen. 10-14 March 2008.

NARAYANASWAMY, B.E., K.L. HOWELL, D.J. HUGHES, J.S. DAVIES, and J.M. ROBERTS, 2006. Strategic Environmental assessment Area 7 photographic analysis. A report to the Department of Trade and Industry. 103pp +199pp Appendix.

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

OSPAR 2004. Initial OSPAR List of Threatened and/or Declining Species and Habitats. OSPAR Convention for the protection of the marine environment of the North-east Atlantic Ref. Number: 2004-06. London.

PARRA, S., I. FRUTOS and J. VALENCIA. 2007. Final report on the effects of the *Prestige* oil spill on continental shelf macroinfauna (Galicia, NW Spain). ICES Benthos Ecology Working Group.

REBESCO, M. 2005. Contourites. En: Richard C, Selley RC, Cocks LRM et al (Eds). *Encyclopedia of Geology*, Elsevier, Oxford 4: 513-527.

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.

SAYAGO-GIL, M., L.M. FERNÁNDEZ-SALAS, D. LONG, V. DÍAZ DEL RÍO, K. HITCHEN and J.T. VÁZQUEZ. 2006. Geomorphological features on the Western flank of Hatton Bank (NE Atlantic Ocean). GeoHab International Symposium. Edinburgh.

SAYAGO-GIL, M., P. DURÁN MUÑOZ, D. LONG, L.M. FERNÁNDEZ SALAS, V. DÍAZ DE RÍO, K. HINCHEN, D. PALOMINO and M.C. FERNÁNDEZ PUGA. 2007. ECOVUL/ARPA interdisciplinary

project: Sea-bed mounds on Hatton Bank situated within Deep-water bottom fisheries zones (NE Atlantic Ocean). ICES CM 2007/R:20.

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.*

WALLER, R., L. WATLING, P. AUSTER and T. SHANK. 2007. Anthropogenic impacts on the Corner Rise seamounts, north-west Atlantic Ocean. *Journal of the Marine Biological Association of the UK*, 87: 1075-1076

WHELER A.J., M. KOZACHENKO, A. BEYER A. FOUBERT, V.A.I HUVENNE, M. KLAGES, D.G. MASSON, K. OLU-LE ROY, J. THIEDE. 2005. Sedimentary processes and carbonate mounds in the Belgica Mound province, Porcupine Seabight, NE Atlantic. In Freiwald, A. and Roberts J.M (eds), 2005. *Cold-water Corals and Ecosystems*. Springer-Verlag, Berlin Heidelberg, pp 571-603.

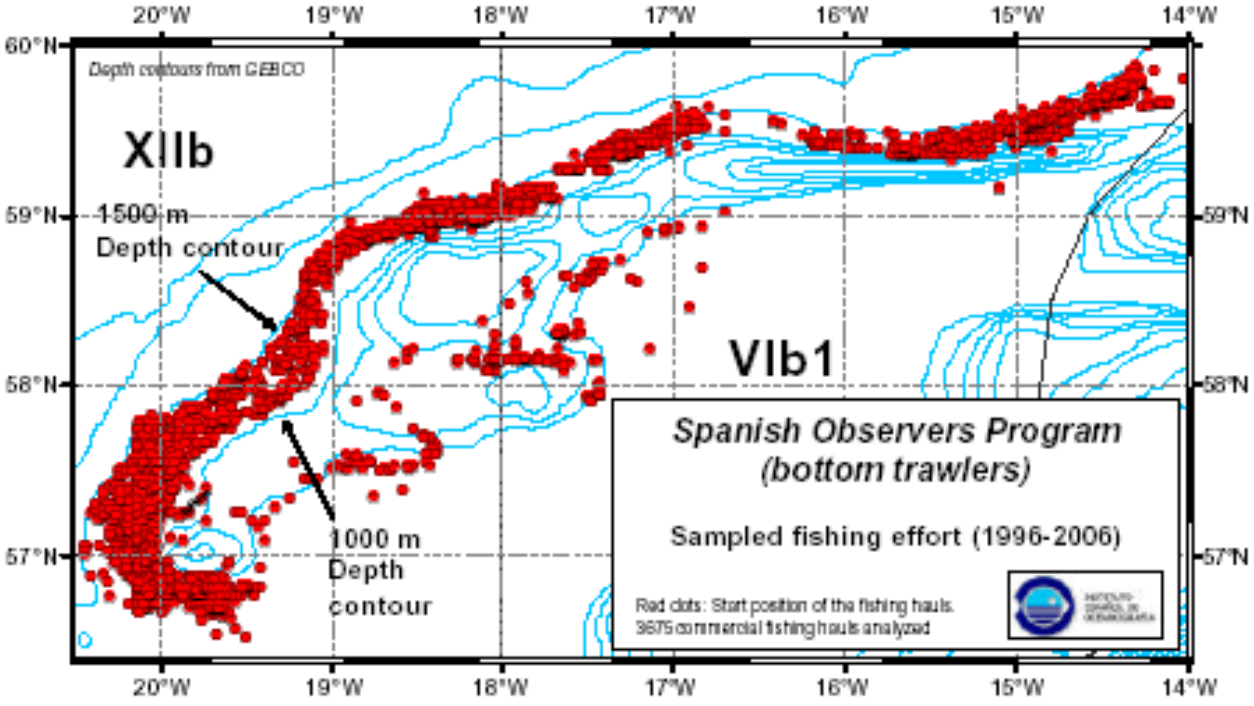

Figure 1.- Footprint of Spanish bottom trawl fishery in Hatton Bank based on IEO observers.

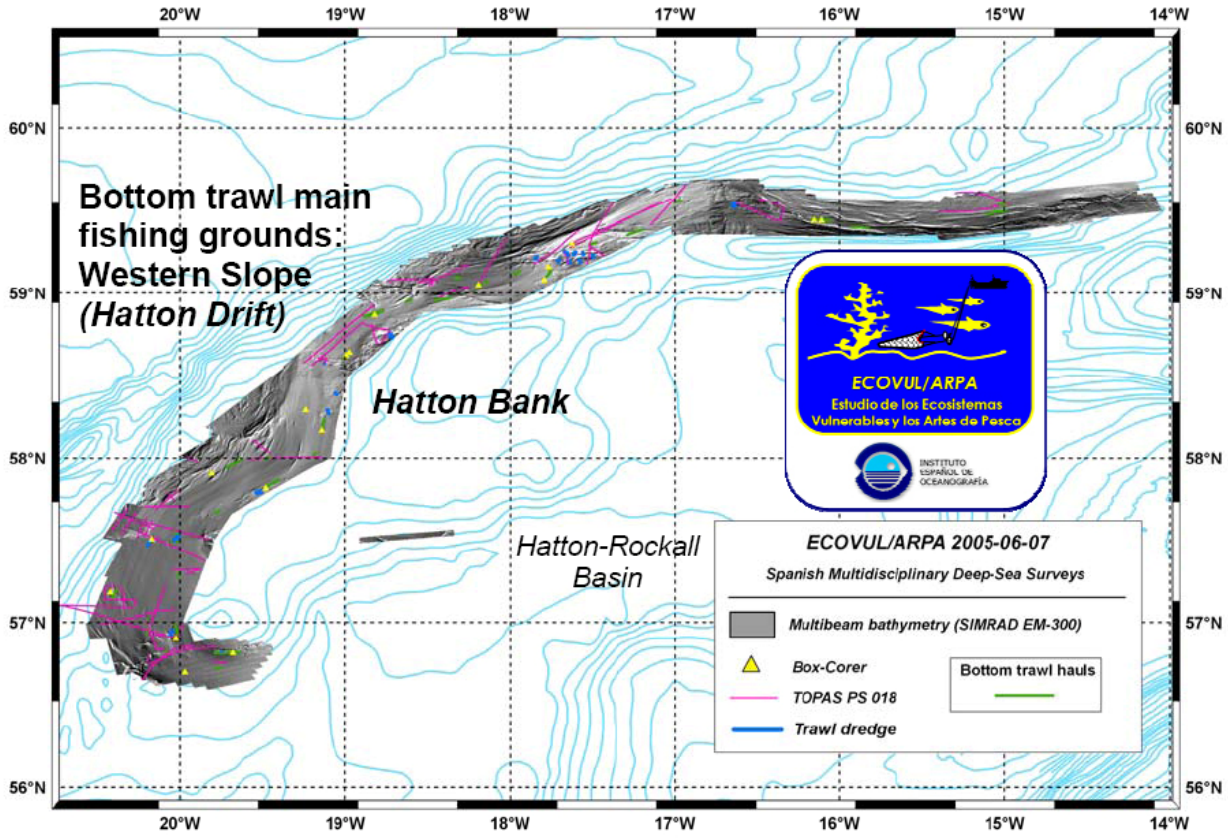

Figure 2.- Updated map showing the sampling carried out during the *ECOVUL/ARPA Spanish Multidisciplinary Deep-sea Surveys* (2005-2007) on the Hatton Bank. Study area covers main trawl fishing grounds.

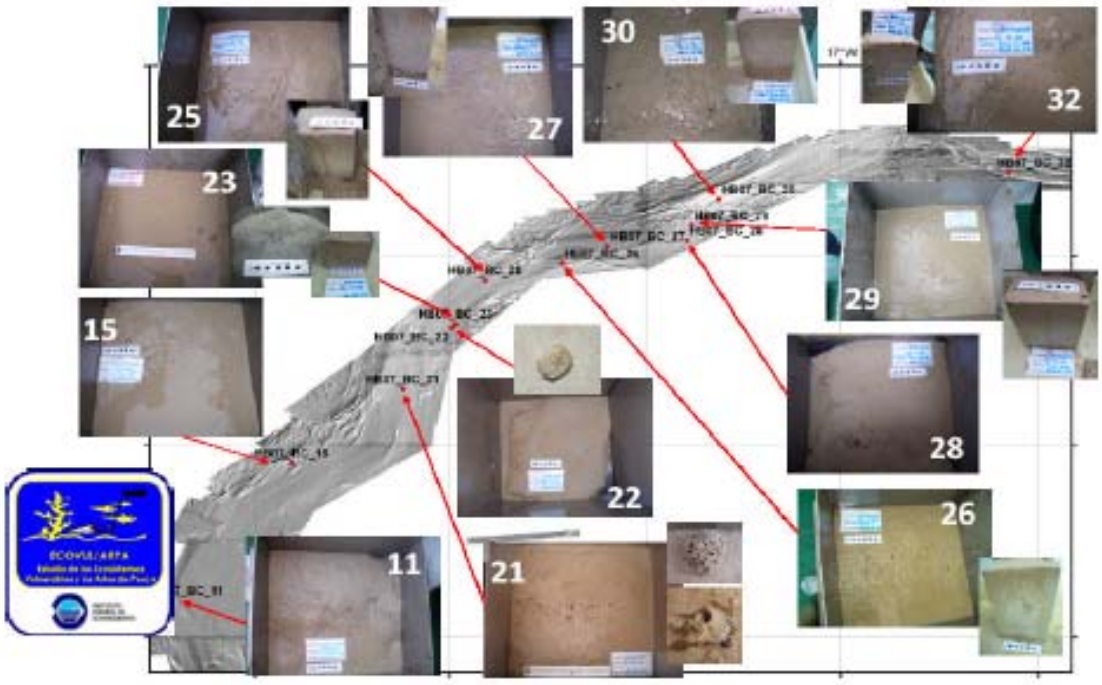

Figure 3.- 2007 Spanish Multidisciplinary Summer Survey. Photos and location from the multibeam bathymetry of the surface sediment, obtained within the trawling fleet fishing area (Hatton Drift) by means of a Box-Corer dredge. Samples are made up of fine sediments, with scarce presence of epifauna. Corals were not found in these samples.

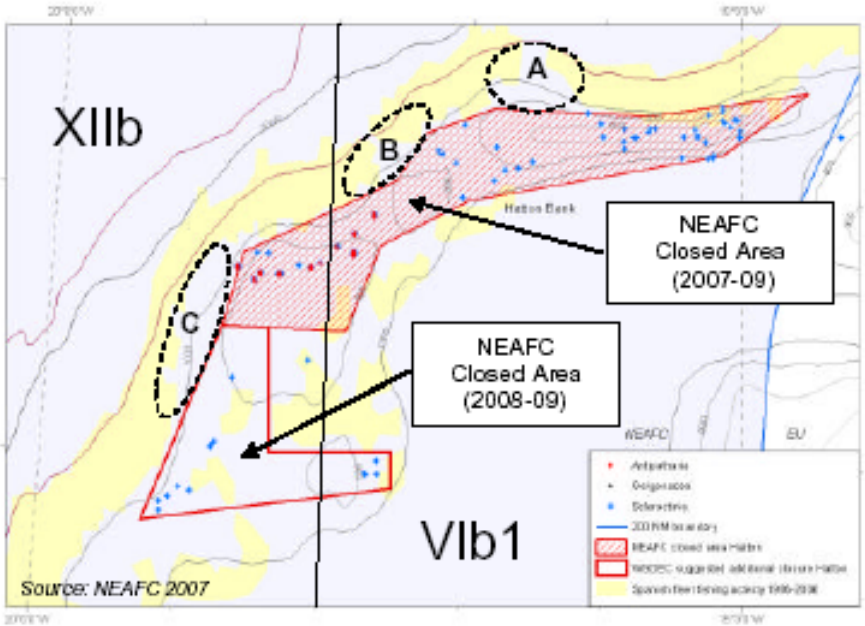

Figure 4.- Map of the Hatton Bank, showing the distribution of the observed fishing effort (Spanish trawlers: 1996-2006. Yellow color). The map presents also the approximated geographical localization of the three vulnerable areas identified by the Spanish Surveys. The mentioned zones are located outside the current *NEAFC Closed Area*. Map modified from NEAFC 2007.

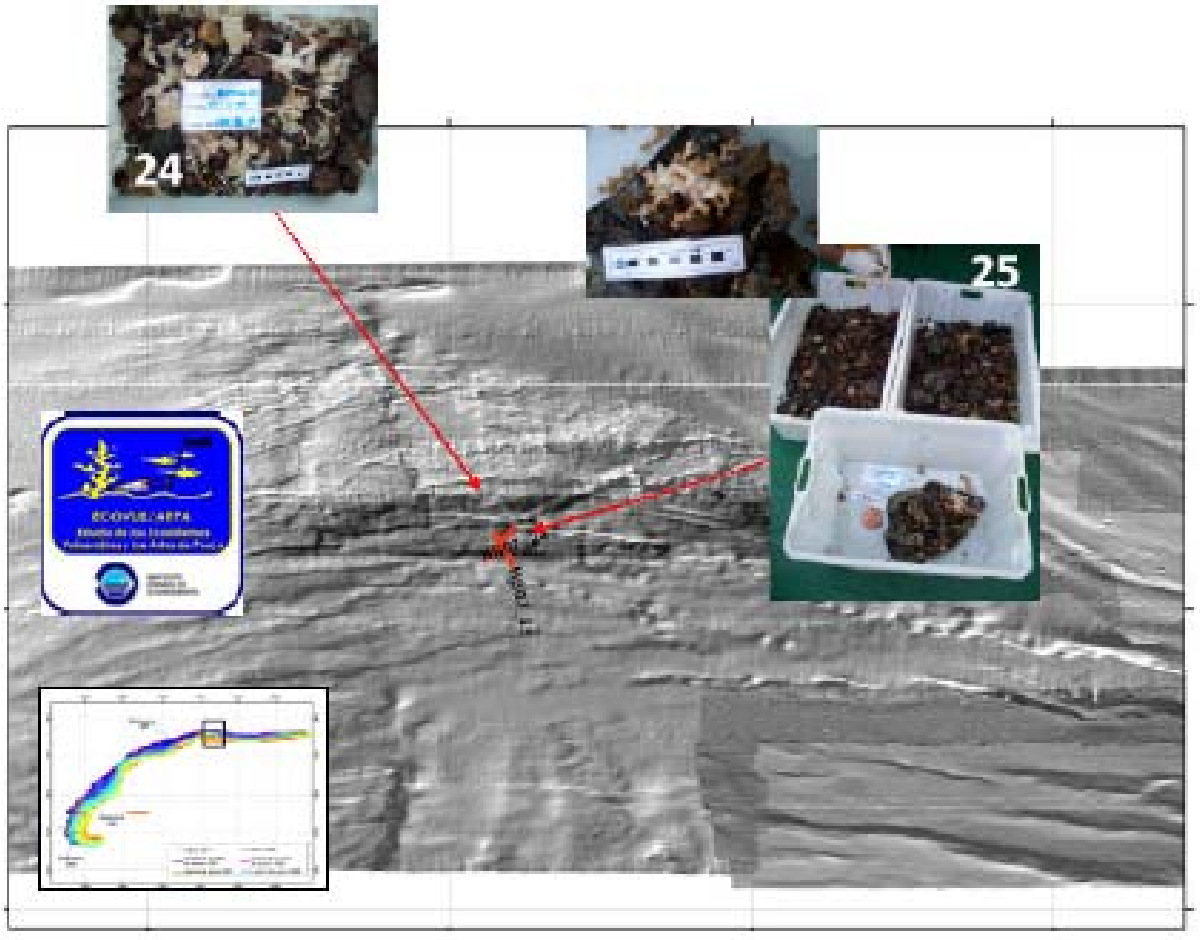

Figure 5.- 2007 Spanish Multidisciplinary Summer Survey. Outcrop "A". Photos and location of the substratum samples (shown on underlying multibeam bathymetry) from the surface of the seabed, obtained outside regular trawling area by means of a trawl dredge. In sample 25, most of the corals were live. In sample 24 only was found dead coral (octocorals skeletons). In both samples rich associated fauna, particularly small sponges, was found.

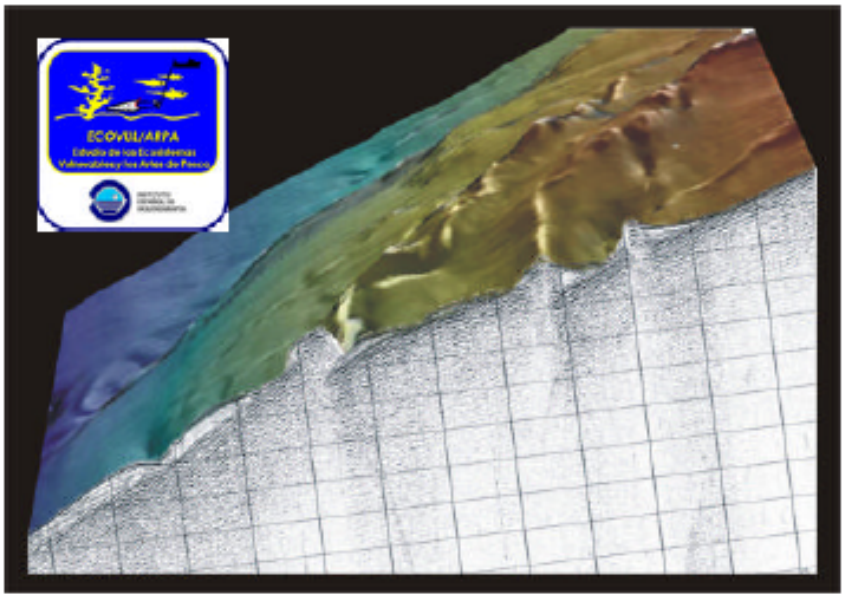

Figure 6a.- 2007 Spanish Multidisciplinary Summer Survey. Outcrop named "B" (Ridges and mounds Area). Multibeam data and seismic data combined, showing superficial and sub-bottom mounds images.

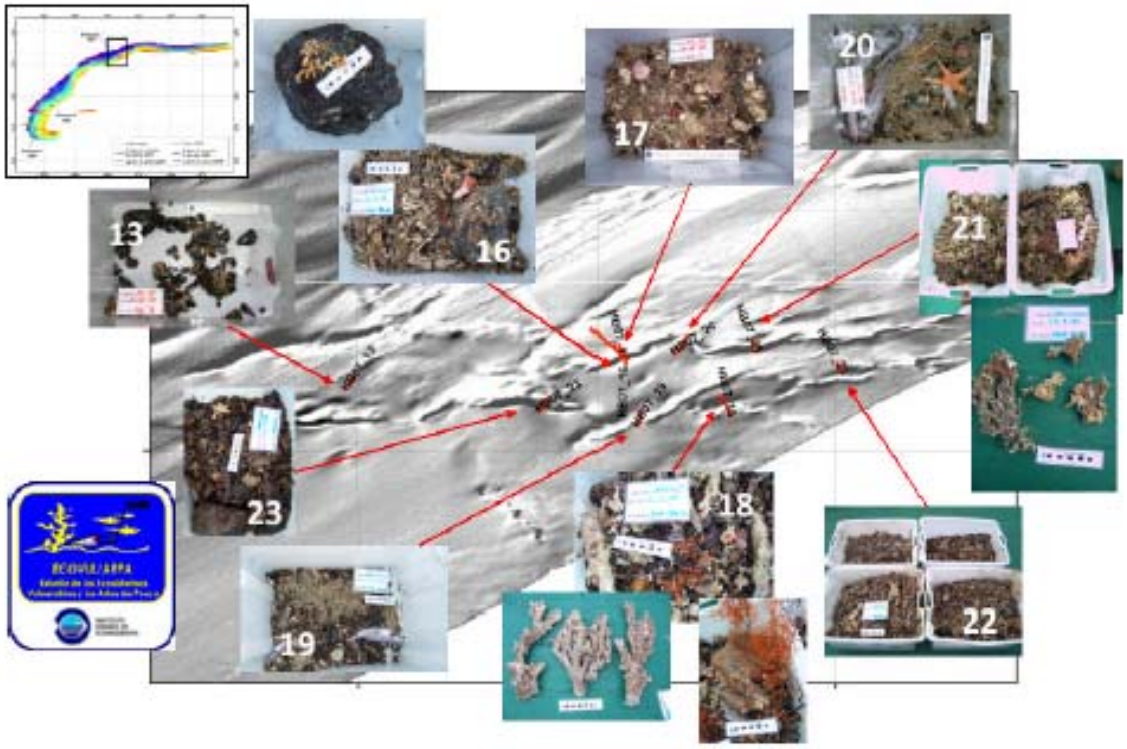

Figure 6b.- 2007 Spanish Multidisciplinary Summer Survey. Outcrop named "B" (Ridges and mounds Area). Photos and location of the substratum samples (shown on underlying multibeam bathymetry) from the surface of the seabed, obtained outside regular trawling area by means of a trawl dredge. In samples 16, 18 and 21, dead corals and live corals were observed. Samples 17,19, 20, 22 and 23 only contained dead coral (Coral skeleton pieces together with remains of cirripeds and molluscs). In all of them, a rich associated fauna was observed (sample 18 showed a special abundance and diversity of organisms). Dead coral was found both in the locations closer to the common fishing grounds and also away from the fishing grounds. The remaining sample yielded no coral and the associated fauna was scarce.

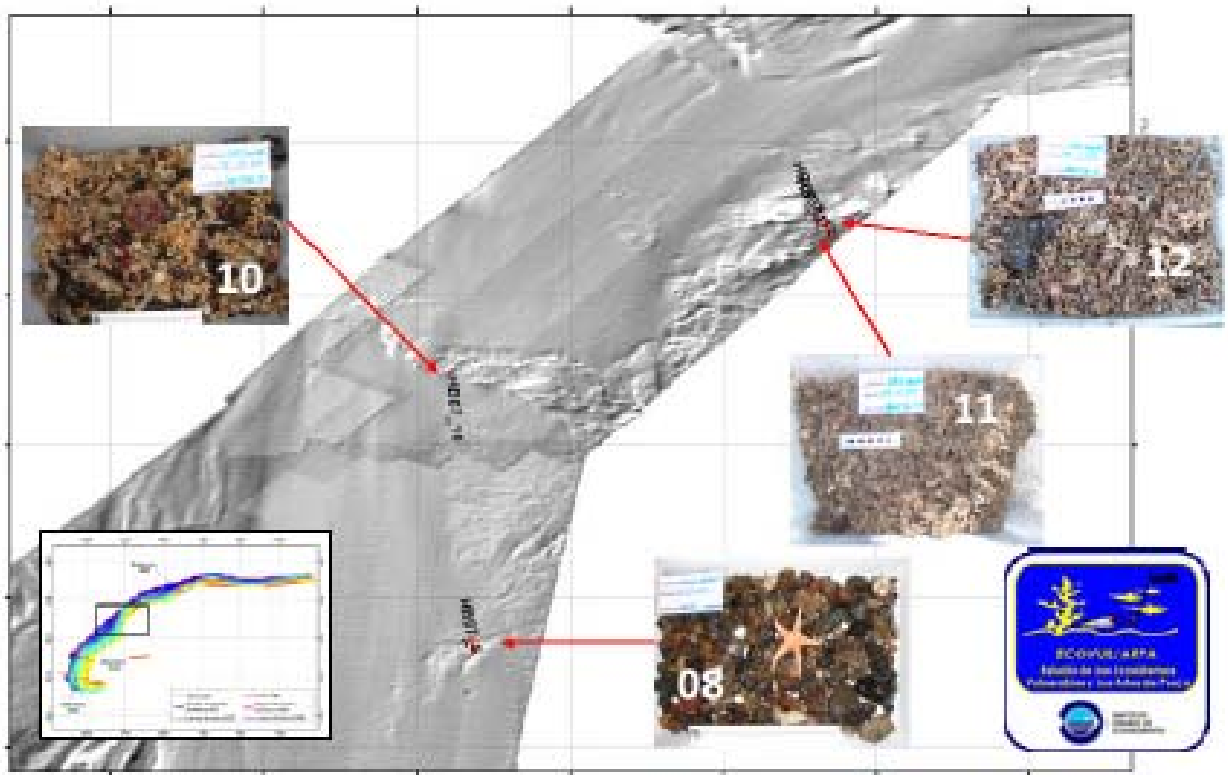

Figure 7.- 2007 Spanish Multidisciplinary Summer Survey. Outcrop named "C". Photos and location of the substratum samples (shown on underlying multibeam bathymetry) from the surface of the seabed, obtained outside regular trawling area by means of a trawl dredge. In sample 10 dead and live corals were observed. In samples 11 and 12, even being very far away of the trawling area (with the exception of some solitary scleractinians in sample No12) all the coral was dead (pieces of coral skeletons with remains of cirripeds and gastropods). In all of them, it was observed a rich fauna associated with coral pieces. Sample 08 yielded no coral and the associated fauna was scarce.

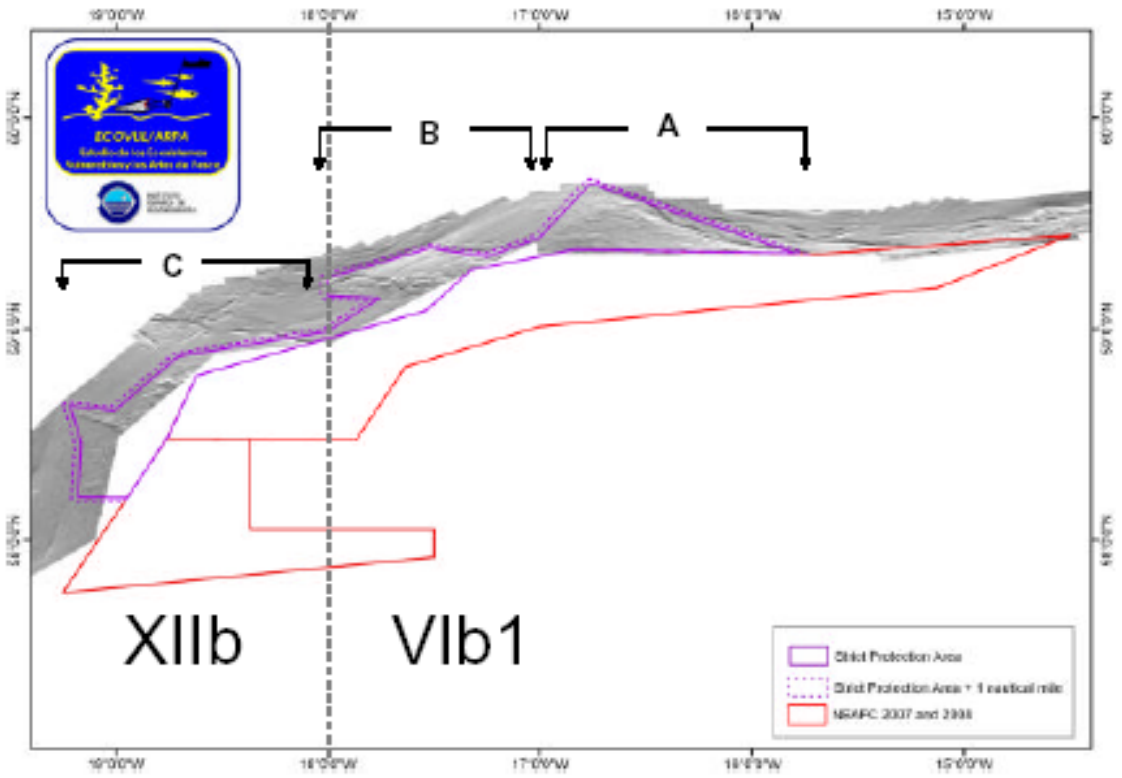

Figure 8.- Map of the Hatton Bank showing the multibeam bathymetry and the boundaries of the new additional area suggested for closure (purple dot line) in order to protect cold-water corals in the main outcrops (A, B & C) identified by the Spanish Multidisciplinary Surveys.

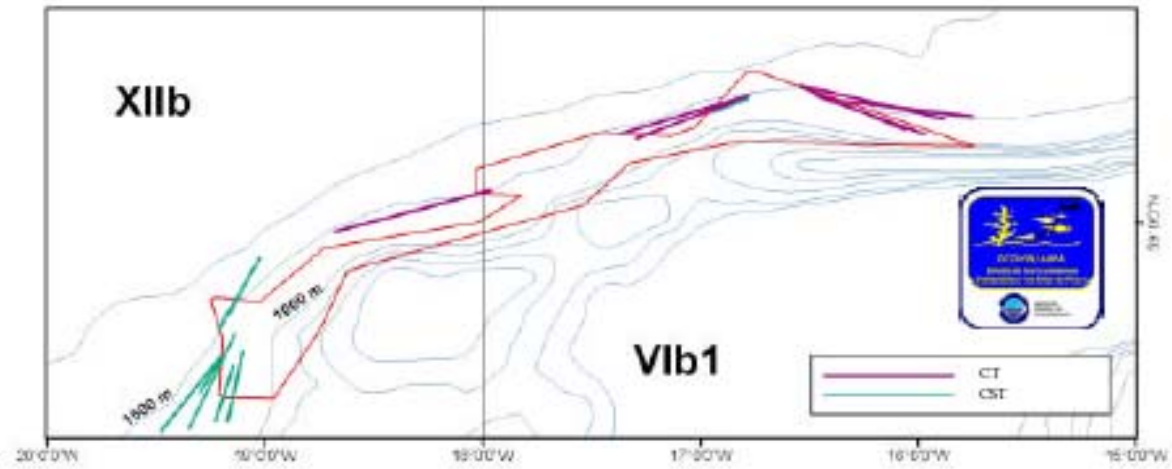

Figure 9.- Chart of the Hatton Bank showing some examples of trawl hauls with presence of cold-water corals by-catch. These hauls are presented over the boundaries of the new additional area suggested for closure. These by-catches were recorded in trawls carried out accidentally over outcrops inside the suggested closed area. It is worthy to note the poor geographic resolution of the information derived from by-catch, if these data are analyzed in absence of gehohabitat information. In the present examples, if we use only by-catch records, the coral presence could be assigned to geographic locations very far away from where coral occurs. Conversely, using this information solely, important coral sites could be ignored (See chapter 5). CT = Commercial Trawl; CST = Cooperative Survey Trawl.