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Vulnerable Marine Ecosystems Dominated by Deep-Water Corals and Sponges in the NAFO Convention Area

by

S. D. Fuller¹, F.J. Murillo Perez², V. Wareham³ and E. Kenchington⁴

¹Biology Department, Dalhousie University, Halifax, Nova Scotia, Canada; ² Instituto Español de Oceanografía, Vigo, Spain; ³Department of Fisheries and Oceans, St. John's, Newfoundland and Labrador, Canada;

⁴Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada

Abstract

Many species of deep-water corals and sponges are important structure forming species in deep-sea environments, however not all coral and sponges meet the criteria associated with vulnerability. Here we review the taxa living within the NAFO regulatory area (NRA) and provide literature supporting their consideration as components of vulnerable marine ecosystems (VMEs). For the sponges, we present the first map of their location in the NRA, as determined from fisheries bycatch information.

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Identification of Vulnerable Marine Ecosystems

The United Nations General Assembly (UNGA) drew attention to the destruction of deep sea coral reefs and other fragile habitats in 2004, through its Resolution 59/25. There was then a call for member states and Regional Fisheries Management Organizations (RFMOs) to take measures to protect these vulnerable ecosystems.

The 2006 UNGA Resolution 61/105 calls upon “States to take action immediately, individually and through regional fisheries management organizations and arrangements, and consistent with the precautionary approach and ecosystem approaches, to sustainably manage fish stocks and protect vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals, from destructive fishing practices, recognizing the immense importance and value of deep sea ecosystems and the biodiversity they contain”. The resolution requires that by 31 December 2008, RFMOs regulate fisheries to prevent significant adverse impacts to areas designated as vulnerable marine ecosystems. To provide States and RFMOs with guidance for implementing the resolution, FAO sponsored an Expert Consultation in Bangkok, Thailand in September 2007 which resulted in a draft set of “International Guidelines for the Management of Deep-Sea Fisheries in the High Seas” (FAO, 2008).

At its 2006 Annual Meeting, NAFO adopted precautionary closures of four seamount areas based on the ecosystem approach to fisheries which included strict conditions under which exploratory fisheries could occur within these seamount areas. Subsequently an area in NAFO Division 3O was closed to protect coral.

The NAFO Working Group on Ecosystem Approach to Fisheries Management has at its May 2008 inaugural meeting advised Scientific Council on areas where vulnerable marine ecosystems (VMEs) are known to occur in the NAFO regulatory area. This document provides background information on the identification of VMEs, including identifying those taxa which should be considered as such based on their life history characteristics and role in the ecosystem.

1.1 Deep-water Corals Underpin Vulnerable Marine Ecosystems

The most vulnerable marine ecosystems are ones that are both easily disturbed and are very slow to recover, or those that may never recover. Vulnerable ecosystem features may be physically or functionally fragile. According to this definition (FAO, 2008), cold-water coral ecosystems are considered VMEs.

Bottom trawling has deleterious impacts on complex habitats (Watling and Norse, 1998; Auster and Langton, 1999). The structural characteristics and long-lived nature of some deep-water 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).

Corals are important structural habitats that contribute to vertical relief and increase the availability of microhabitats (Tissot et al., 2006). Increasing complexity provides feeding opportunities for aggregating species, a hiding place from predators, shelter from high flow regimes, a nursery area for juveniles, fish spawning aggregation sites and attachment substrate for fish egg cases and sedentary invertebrates (Reed, 2002; Fosså et al., 2002; Etnoyer and Morgan, 2003; Etnoyer and Warrenchuk, 2007), all of which have been reported for deep-water coral habitats. In general, coral habitats in deep water represent biodiversity hotspots for invertebrates (Reed et al., 1982; Jensen and Frederiksen, 1992; Reed, 2002; Freiwald et al., 2004, Mortensen and Mortensen, 2005), and commonly support a high abundance of fish (Koening, 2001; Husebo et al., 2002; Krieger and Wing, 2002; Costello et al., 2005; Tissot et al., 2006).

The FAO guidelines recognize that not all coral species are vulnerable or form ecosystems. The following groups of corals are considered indicators and key components of VMEs:

- Antipatharians (Black Corals)
- Gorgonians (Sea Fans)
- Cerianthid anemone fields
- Lophelia and other reef building corals
- Sea pen fields

The rationale behind this list is provided in Sections 1.2 to 1.4 below.

1.2 Subclass Ceriantipatharia: Tube-dwelling Anemones and Black Corals

The subclass Ceriantipatharia includes two orders which are superficially very distinctive. The order Ceriantipatharia includes the solitary tube-dwelling anemone-like forms with elongate bodies adapted for burrowing in soft bottoms. They can be large (over 40 cm) but most of the tube is below the sediment. Their large size and

tendency to form dense aggregations, and occurrence on relatively featureless sandy or muddy bottoms, renders them key structure-forming species (Figure 1.2.1). The genus *Cerianthus* is common in the NAFO region.

Late juvenile redfish *Sebastes fasciatus*, (11-20 cm total length) have been associated with dense patches of cerianthid anemones *Cerianthus borealis* in the Gulf of Maine. The small fish may use the cerianthid habitats on an encounter basis or they may serve as a protective corridor for moving between boulder sites (Auster et al., 2003).

Although cerianthids can retract into their tubes, they are known to be damaged by bottom tending fishing gear (Bullimore, 1985; Langton and Robinson, 1990; Hall-Spencer et al., 1999). Removal of cerianthids may disrupt benthic assemblages as cerianthid predation of scallop and sabellid worm larvae has been hypothesized as an important factor in controlling their spatial distribution (Langton and Robinson, 1990). The strong negative association between predator and prey is broken down by dredging disturbance.

Little is known about the biology of the deep-water cerianthid species. The lifespan of one, *C. lloydii*, has been reported as 11 to 20 years (Manuel, 1988).

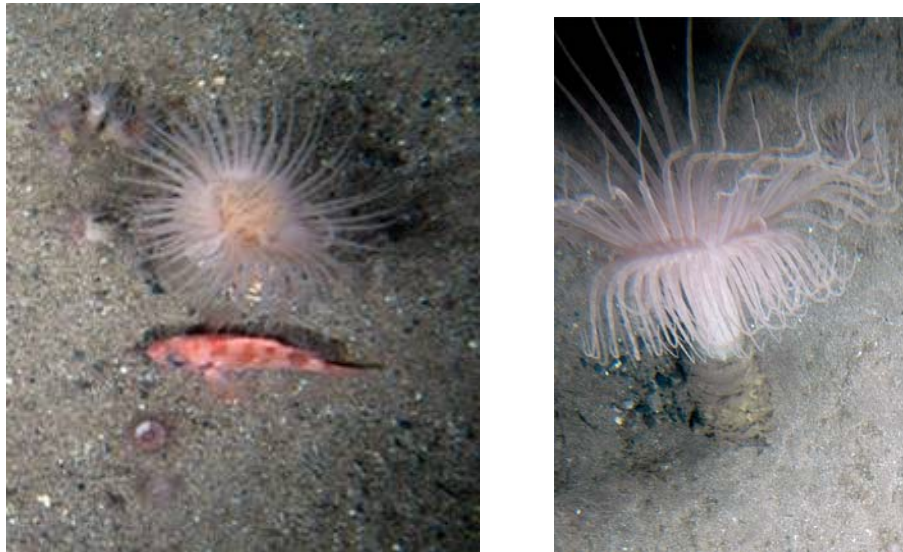


Figure 1.2.1 *Cerianthus borealis* from the Scotian slope (image courtesy of DFO).

The Order Antipatharia includes the Black Corals. These are upright attached colonial corals with polyps arranged around an axial skeleton of black horny material which projects sharp spines. Black coral are listed in Appendix II of the Convention on International Trade in Endangered Species (CITES). Eleven species of black coral from 4 families and 7 genera are included in the WGDEC coral data base (ICES, 2008a) from the northwest Atlantic (Table 1.2.1; Figure 1.2.2). They are all large, and although some are whip-like, most are branching and sometimes feathery, with some growing several meters high. *In situ* observations have been made along the Scotian and Grand Bank Slopes. Those observations are of single colonies and dense aggregations have not been observed.

Black corals have low rates of growth, fecundity, recruitment, and mortality (Grigg, 1989) and can be very long-lived. The oldest recorded living marine invertebrate (4,000 years) is the antipatharian *Leiopathes glaberrima*, a conspecific of *L. grimaldi* found in the NAFO area (http://www.treehugger.com/files/2008/02/oldest_animal_u.php). In the Newfoundland Region, black corals were collected at average depths > 1000 m (Wareham and Edinger, 2007). Sherwood and Edinger (2008) determined radial growth rates of 65-31 $\mu\text{m}\cdot\text{yr}^{-1}$, and vertical growth at 1.34 $\text{cm}\cdot\text{yr}^{-1}$, respectively, for black corals collected from the Grand Bank. Based on these extremely slow growth rates recovery of deep-sea corals from fishing induced damage will likely take decades to centuries. This extreme longevity and apparent rarity (note that the preferred depth of these taxa below 1500 m is not well studied) qualify the black corals as vulnerable species.

Symbiotic polychaetes were documented on black corals from Indo-Pacific region (Molodtsova and Budaeva, 2007). On the Corner Rise Seamounts black bottle brush corals (*Parantipathes* sp.) from Lyman Seamount oc-

curred often with *Chirostyliad* sp. (<http://oceanexplorer.noaa.gov/explorations/05stepstones/logs/aug14/media/parantipathes.html>). Similar *in situ* observations were made during 2007 ROPOS cruise on the Grand Bank where several deep-sea crabs were observed on a large black coral colony.

Table 1.2.1 List of Antipatharian (Black) Corals in the WGDEC Database. These corals are known to occur in the NAFO Area.

FAMILY	SPECIES
Antipathidae	<i>Antipathes dichotoma</i>
Antipathidae	<i>Antipathes erinaceus</i>
Antipathidae	<i>Antipathes virgata</i>
Antipathidae	<i>Bathypathes patula</i>
Antipathidae	<i>Parantipathes hirondelle</i>
Antipathidae	<i>Stichopathes dissimilis</i>
Antipathidae	<i>Stichopathes flagellum</i>
Antipathidae	<i>Stichopathes richardi</i>
Leiopathidae	<i>Leiopathes grimaldi</i>
Myriopathidae	<i>Antipathella subpinnata</i>
Schizopathidae	<i>Stauropathes arctica</i>



Figure 1.2.2. A black coral colony growing on a cliff face on the Scotian slope on the southeastern edge of Banquereau Bank (area generally referred to as the Stone Fence; photo courtesy of DFO).

1.3 Subclass Hexacorallia: Stony Corals and Sea Anemones

The relationships within the higher-level groups within the anthozoan subclass Hexacorallia remain unresolved. Three of the six orders occur throughout the NAFO region: Actiniaria (sea anemones), Scleractinia (stony corals), Zoanthidea (zoanths).

While all of these taxa are important components of benthic communities, the Scleractinia stand out as VMEs based on their lifehistory characteristics, ecological role and vulnerability to fishing disturbance. Scleractinian coral are listed in Appendix II of the Convention on International Trade in Endangered Species (CITES).

The stony corals are so named because they form a hard aragonite skeleton external to the polp. They may be solitary or colonial and some species are capable of forming extensive reefs. The major reef-building species in the NAFO area is *Lophelia pertusa* (Figure 1.3.1). It occurs along the continental slopes and banks (200 to 1000 m general depth range) of both Canada (as far north as the Laurentian Channel) and the United States (Hourigan et al., 2007) but expansive reef structures have not been identified in the NAFO area. A small reef, heavily damaged by the redfish fishery, was found on the Scotian Shelf on SE Banquereau and has been protected as a Coral Conservation Area by Canada.

Off Norway, extensive reefs spread over hundreds of kilometers with the living coral growing over the skeletons of previous generations (forming structures called bioherms) (Rogers, 1999; Friewald et al., 2004). To the south and west of Ireland several reefs have built mounds of 150 to 200 m height and about 1 km wide (ICES, 2008b). These reefs are home to large numbers of invertebrates and fish who have strong, although rarely obligate, associations with the structures.

In the Norwegian Sea, damage to deepwater coral reefs has been documented in the eastern shelf areas and has resulted in area closures for bottom trawling. It is estimated that 30 to 50% of the coral areas may be damaged or negatively impacted (Fosså et al., 2002; ICES, 2008b).

L. pertusa reefs are recognized as a threatened habitat by the OSPAR Commission for the protection of the marine environment in addition to its generic listing under CITES Appendix II.

Various species of solitary cup coral are found throughout the NAFO region. These may be attached as in species of *Desmophyllym* (Figure 1.3.2) or free living as in species of *Flabellum*. Cup corals are believed to

have a low vulnerability to impacts by fishing gears, at least for those species such as *Flabellum* which live on soft sediments (FAO, 2008). However attached species are vulnerable to trawl and gillnet gears (Wareham and Edinger, 2007) and some of these species, e.g., *Desmophyllym* spp. are very slow growing ($0.5-1.0 \text{ mm. yr}^{-1}$) and long-lived (> 200 years; Lazier et al., 1999; Risk et al., 2002).



Figure 1.3.1. *Lophelia pertusa* colony in the Gully Marine Protected Area on the Canadian continental slope.



Figure 1.3.2. The solitary cup coral *Desmophyllym* sp. Photographed in an aquarium after collection from ~1500m on the Scotian slope (image courtesy of DFO).

The large sessile sea anemones such as *Actinauge verelli* (Figure 1.3.3) are able to contract when contacted by fishing drags or dredges and appear to be undamaged (Freese et al., 1999), although other species do not recover

from the disturbance within 5 years (Hall-Spencer and Moore, 2000). The common frilled anemone *Metridium senile*, can reach 30 cm in height and is typically gregarious, forming dense fields. Thus they can be considered habitat-forming. These taxa have not been considered as being highly vulnerable to bottom trawling, mainly because they are neither exceptionally long-lived nor rare. However, if they are attached to small cobbles they are vulnerable to capture by trawl gear and may not survive even if returned to the sea.



Figure 1.3.3. The sessile sea anemone *Actinauge verelli*.

1.4 Subclass Octocorallia: Soft Corals

As in the Hexacorallia, the high order taxonomy of the Octocorallia is not fully resolved. Traditionally six families were recognized, and the European Registry of Marine Species (ERMS) maintains that classification scheme. However the International Taxonomic Information System (ITIS) combines the gorgonian corals with the alcyonaceans reducing the number of families to five. As the gorgonians are amongst the most vulnerable octocorals to fishing impact while the alcyonaceans are among the least, the ERMS system is adopted here, as was done for the recent NOAA publication from the US (Hourigan et al., 2007).

1.4.1 Alcyonaceans

Alcyonaceans are found over most of the NAFO area and are particularly abundant on the banks. They are frequently caught in trawl gear and can survive repeated disturbances (Henry et al., 2003), although direct removals as bycatch can quickly depopulate an area (Prena et al., 1999). They are not considered VMEs, although they are important ecosystem components. Moreover, Syms and Jones (2001) demonstrated that removal of high densities of soft corals caused no significant changes in the associated fish communities and that the heterogeneity of habitat generated by soft corals was indistinguishable from equivalent habitat formed by rock alone.

1.4.2 Gorgonian corals

Gorgonian corals, or sea fans, meet all of the criteria of VMEs. They are long-lived, slow-growing, have episodic recruitment and are highly vulnerable to fishing gear (cf. Hourigan et al., 2007; Figure 1.4.2.1).



Figure 1.4.2.1. Contents of an otter trawl set recovered after a 2-hour commercial trawl for Greenland Halibut in the Hudson Strait, May 2007. The pink colonies are all *Primnoa resedaeformis*; also visible are grey-white sponges. Bycatch of corals in this trawl tow was more than 500 kg. Photo credit: Harry Mercer, photo courtesy of DFO.

Sherwood and Edinger (2008) aged several species of gorgonians (i.e., *Keratoisis ornata*, *Primnoa resedaeformis*, *Paramuricea* sp., *Acanella arbuscula*, and *Paragorgia arborea*) which ranged in age from a few decades up to 200 years for a subfossil colony of *K. ornata*. *Paragorgia arborea* grew at the fastest radial growth rate of $800 \mu\text{m. yr}^{-1}$. Based on known slow growth rates recovery of gorgonian corals from fishing induced damage will likely take centuries.

Gorgonians come in a range of sizes from small arborescent forms less than 20 cm (e.g., species of *Acanella*) to large branching “trees” over 3 metres in height (Figure 1.4.2.2). All are colonial and attached but some such as *Acanella* spp. “root” themselves in soft sediment, while others cement to hard substratum.

Marine megafauna over 5 cm in height have been considered as structure-forming and can have a strong influence on biodiversity (Tissot et al., 2006), and species greater than 1 m in height can profoundly affect benthic community structure (Lissner and Benech, 1993 in Tissot et al., 2006). However, factors such as complexity of morphology and population density, in addition to size determine whether a species can be considered habitat-forming (Tissot et al., 2006).

The arboreal-like structure of gorgonians provide unique habitat for both commercial (e.g., Orange roughy; Figure 1.4.2.3) and non-commercial species. Other species such as *Squaliformis* use gorgonians as potential nurseries as documented in the Gulf of Mexico by Etnoyer and Warrenchuk (2007), as well as observed on samples from the NW Atlantic (Figures 1.4.2.4; 1.4.2.5).

The ICES/NAFO Working group on Deep-water Ecology (WGDEC) following Hourigan et al. (2007) and Tissot et al. (2006) considers the genera listed in Table 1.4.2.1. to be structure-forming taxa which underpin VMEs based on their presence.

Table 1.4.2.1. Examples of gorgonian corals known to occur in the NAFO management area (Divisions 1 to 6). This list is for species included in the WGDEC database (ICES, 2008a) and recorded in the Spanish/EU surveys (Murillo et al., 2008a, Murillo et al, 2008b). Maximum size and propensity for aggregation are indicated for each genus where readily available.

TAXON	SUBORDER	FAMILY	SIZE	GREGARIOUS
Acanella arbuscula	Calcaxonia	Isididae	15 cm	yes
Acanella normani	Calcaxonia	Isididae		
Acanella eburnea	Calcaxonia	Isididae		
Callogorgia verticillata	Calcaxonia	Primnoidae	?	?
Candidella imbricata	Calcaxonia	Primnoidae	?	?
Isidella longifera	Calcaxonia	Isididae	?	?
Keratoisis grandis	Calcaxonia	Isididae	130 cm	yes
Keratoisis ornata	Calcaxonia	Isididae		
Keratoisis palmae	Calcaxonia	Isididae		
Lepidisis sp.	Calcaxonia	Isididae		
Narella bellissima	Calcaxonia	Primnoidae	?	?
Narella versluysi	Calcaxonia	Primnoidae		
Nicella granifera	Calcaxonia	Ellisellidae	?	?
Primnoa resedaeformis	Calcaxonia	Primnoidae	100 cm	yes
Thouarella grasshoffi	Calcaxonia	Primnoidae		?
Thouarella hilgendorfi	Calcaxonia	Primnoidae	70 cm	?
Thouarella variabilis	Calcaxonia	Primnoidae		
Calyptrophora josephinae	Calcaxonia	Primnoidae		
Acanthogorgia armata	Holaxonia	Acanthogorgiidae	20-50 cm	?
Acanthogorgia hirsuta	Holaxonia	Acanthogorgiidae		
Acanthogorgia truncata	Holaxonia	Acanthogorgiidae		
Bebryce mollis	Holaxonia	Plexauridae	?	?
Chelidonisis aurantiaca	Holaxonia	Isididae	?	?
Chrysogorgia agassizii	Holaxonia	Chrysogorgiidae	20 cm	?
Eunicella dubia	Holaxonia	Gorgoniidae	?	?
Iridogorgia sp.	Holaxonia	Chrysogorgiidae	?	?
Muriceides furcata	Holaxonia	Plexauridae	20 cm	?
Muriceides lepida	Holaxonia	Plexauridae		
Muriceides paucituberculata	Holaxonia	Plexauridae		
Paramuricea biscaya	Holaxonia	Plexauridae	50 cm	no
Paramuricea candida	Holaxonia	Plexauridae		
Paramuricea grandis	Holaxonia	Plexauridae		
Paramuricea placomus	Holaxonia	Plexauridae		
Placogorgia intermedia	Holaxonia	Plexauridae	10 cm	yes
Placogorgia massiliensis	Holaxonia	Plexauridae		
Placogorgia terceira	Holaxonia	Plexauridae		
Radicipes gracilis	Holaxonia	Chrysogorgiidae	50 cm	yes
Swiftia pallida	Holaxonia	Plexauridae	< 20cm	yes
Villogorgia bebrycoides	Holaxonia	Plexauridae	?	?
Metallogorgia melanotrichos	Holaxonia	Chrysogorgiidae	45+ cm	?
Anthothela grandiflora	Scleraxonia	Anthothelidae		
Corallium johnsoni	Scleraxonia	Coralliidae	20-50 cm	?
Corallium niobe	Scleraxonia	Coralliidae		
Paragorgia arborea	Scleraxonia	Paragorgiidae	300+ cm	yes
Paragorgia johnsoni	Scleraxonia	Paragorgiidae		
Titanideum obscurum	Scleraxonia	Anthothelidae	70 cm	?



Figure 1.4.2.2. Examples of gorgonian corals considered as vulnerable species which form VMEs. Top: Bamboo coral *Keratoisis* sp.; Middle: *Primnoa* sp. (left) and *Paragorgia arborea* (right); Bottom: the smaller gorgonian *Acanella* sp. Photos courtesy of DFO.



Figure 1.4.2.3. Orange roughy, *Hoplostethus atlanticus*, observed in a *Keratoisis ornata* thicket, Haddock Channel, Southwest Grand Banks at a depth of 660 m. The fish changed from a pale colour to a brilliant red shortly after this photo was taken. Photo courtesy of DFO.



Figure 1.4.2.4. *Acanthogorgia armata* sample with many organisms attached to the colony most notable a *Squaliformis* egg purse. Photo courtesy of DFO.

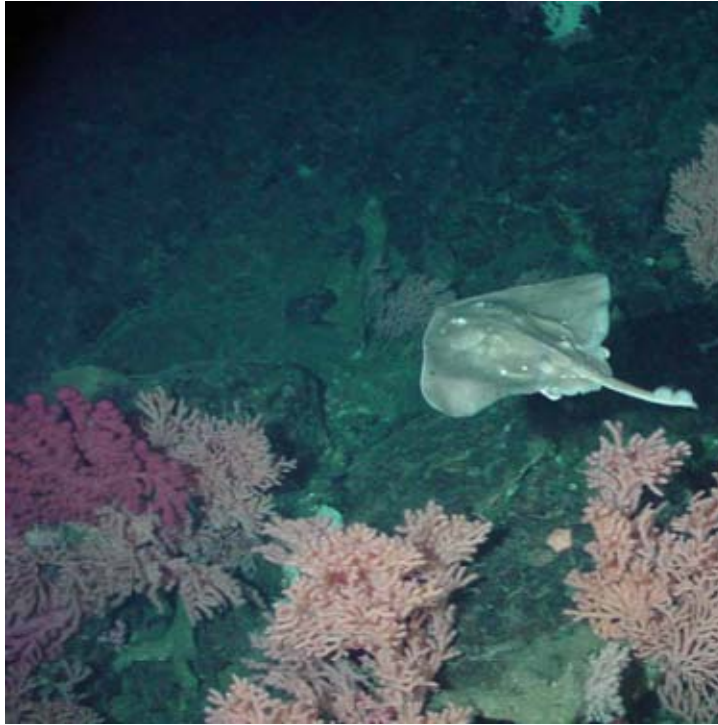


Figure 1.4.2.5. A large skate swims among gorgonian coral colonies in the Northwest Channel. Photo courtesy of the Centre for Marine Biodiversity.

1.4.3 Sea pens

Sea pens belong to the order Pennatulacea. Unlike other octocorals, a sea pen's polyps are specialized to specific functions: a single polyp develops into a rigid, erect stalk (the rachis) and loses its tentacles, forming a bulbous "root" or peduncle at its base which anchors it in the soft sediments of the sea floor (Williams, 1995). The stalks can be over 1.5 metres long with larger species reaching up to 50 yrs (Wilson et al., 2002). Usually sea pens stay in one spot but they are able to uproot themselves and relocate. Some can also forcibly expel water out of themselves propelling deep into the sediments (e.g., *Protoptilum carpenteri*). Consequently, they are not as vulnerable as gorgonian corals to damage by trawl gear. However, sea pen bycatch is an issue and the extensive aggregations formed by some species (Figure 1.4.3.1; Figure 1.4.3.2), known as sea pen fields, are recognized as ecological and biologically significant habitats (DFO, 2005). Aggregations of sea pens may provide important structure in low-relief sand and mud habitats where there is little physical habitat complexity. Also, these organisms may provide refuge for small planktonic and benthic invertebrates, which in turn may be preyed upon by fishes. They also may alter water current flow, thereby retaining nutrients and entraining plankton near the sediment (Tissot et. al, 2006).

Sea pens are recognized as important habitat for both fish and invertebrates (DFO, 2005) and belong to the Initial OSPAR List of Threatened and/or Declining Species and Habitats. A list of species occurring in the NAFO area and for which positional data are available is provided in Table 1.4.3.1.



Figure 1.4.3.1. A sea pen field on the southwest Grand Banks (photo courtesy of DFO).



Figure 1.4.3.2. *Halipteris finmarchia* field on the Scotian Shelf (photo courtesy of DFO).

Table 1.4.3.1. Examples of sea pens known to occur in the NAFO management area (Divisions 1 to 6). This list is for species included in the WGDEC database (ICES, 2008a) and those identified subsequently from 2007 surveys in the Newfoundland region (V. Wareham pers. comm.).

TAXON	SUBORDER	FAMILY
<i>Funiculina quadrangularis</i>	Sessiliflorae	Funiculinidae
<i>Kophobelemnion stelliferum</i>	Sessiliflorae	Kophobelemnidae
<i>Kophobelemnion macrospinosum</i>	Sessiliflorae	Kophobelemnidae
<i>Distichoptilum gracile</i>	Sessiliflorae	Protoptilidae
<i>Protoptilum</i> sp.	Sessiliflorae	Protoptilidae
<i>Protoptilum carpenteri</i>	Sessiliflorae	Protoptilidae
<i>Scleroptilum grandiflorum</i>	Sessiliflorae	Sleroptilidae
<i>Umbellula durissima</i>	Sessiliflorae	Umbellulidae
<i>Umbellula encrinus</i>	Sessiliflorae	Umbellulidae
<i>Umbellula lindahli</i>	Sessiliflorae	Umbellulidae
<i>Umbellula thompsoni</i>	Sessiliflorae	Umbellulidae
<i>Anthoptilum grandiflorum</i>	Subselliflorae	Anthoptilidae
<i>Anthoptilum murrayi</i>	Subselliflorae	Anthoptilidae
<i>Halipteris</i> spp.	Subselliflorae	Halipteridae
<i>Halipteris finmarchia</i>	Subselliflorae	Halipteridae
<i>Pennatula aculeata</i>	Subselliflorae	Pennatulidae
<i>Pennatula borealis</i>	Subselliflorae	Pennatulidae
<i>Pennatula phosphorea</i>	Subselliflorae	Pennatulidae
<i>Crassophyllum</i> spp.	Subselliflorae	Pennatulidae

1.5 Location of Coral VMEs

The report of WGDEC adequately identifies the general location of coral VMEs in the NAFO region. Further information on their distribution and suggestion of additional VMEs based on the Spanish and Russian contributions is presented as maps in other sections of this report.

1.6 Sponges

1.6.1 Preliminary data on sponge catch in Scotia Fundy Observer Records and Newfoundland research trawl surveys in the NAFO Convention Area

In the Northwest Atlantic, there are > 300 species of sponges, ranging in form from thin and encrusting, to branching to mound forming. Species belonging to all three sponge classes Calcarea, Demospongiae and Hexactinellidae are found in the NAFO Convention Area. With specific reference to vulnerable sponge species or species complexes, there are a few key sponge species and species complexes, some of which are circumboreal in distribution. The WGDEC report states that there is little reported information on sponges in the Northwest Atlantic. The data and information included in this report add significantly to known sponge distributions (ICES, 2008a).

1.6.2 Sponges as Ecosystems

Sponges are known to be habitat forming structures, often with numerous other species living within and around their body structures. The extent to which an individual sponge can act as a host for other species is dependent on sponge surface characteristics, size of ostia, and the size of the sponge itself. Klittgaard (1995) found over 200 species within 11 sponges in the North Atlantic. As is found in many other habitats, species richness increases with habitat area for a broad variety of species (see review in Rosenzweig, 1995).

In sponges, volume can be considered a proxy for both habitat size and age. An increase in associated species richness with host volume has been found in sponges (Frith, 1976; Ubelaker, 1977; Westinga and Hoetjes, 1981; Villimizar and Laughlin, 1991; Duarte and Nalesso, 1996; Cinar and Ergen, 1998; Cinar et al., 2002).

There is a distinct lack of data on associated communities of host animals between 100m and 300m and below 800m. The one abyssal point at 4100m, found 134 species associated with the deep-sea sponge *Hyalonema bi-anchortum* (Beaulieu, 2001).

1.6.3 Sponges in the NAFO Convention Area

Sponges are widespread throughout all depths and bottom types in the Northwest Atlantic, however there are particular species and species groups that are vulnerable to fishing impacts. Similar to those areas described by the WGDEC report (ICES, 2008a), sponges in the Northwest Atlantic can be categorized by three main types:

- Hexactinellid patches (*Vazella pourtalesi* (Schmidt 1870)), found to date on the Scotian Shelf in soft sediment areas as well as scattered specimens in areas where deep-sea corals are also found (Fuller, in prep). (Similar to the *Pheronema* patches in the Northeast Atlantic) (Figure 1.6.3.1).
- *Geodia* spp. found along the shelf edge, in gravel or hard bottom areas and have been found in areas in the Northeast Atlantic as well (Klittgaard and Tendal, 2004; Bruntse and Tendal, 2001) (Figure 1.6.3.2).
- *Thenea* sp. generally found in soft bottom, and growing on spicule mats.

Given the lack of in situ documentation of sponges in the NAFO convention area, with the exception of one video transect in the Emerald Basin in 2001 (Fuller, in prep.), it is difficult to know the extent of these patches.



Figure 1.6.3.1. *Vazella pourtalesi* population in the Emerald Basin on the Scotian Shelf, within Canada's EEZ.



Figure 1.6.3.2. Sponge bycatch in the NAFO Convention Area, representative of concentrations of *Geodia* spp.

1.6.4 Data Sources: Spatial and Temporal Coverage

Existing and readily available data sets on sponges in the NAFO Area include:

- Scotia Fundy Observer Data (1977-2007)
- Newfoundland Trawl Survey (1995-2004)
- Spanish / EU Bottom Trawl Groundfish Surveys (3LMNO) (2005-2007)
- Russian observer data (2000-2007) (in Vinnichenko and Skylar, 2008)

Large sponge by-catches are recorded in a relatively low number of trips ($< 5\%$) in both surveys and observer data (Fuller, unpublished; Murillo et al., 2008a). However, large catches of sponges, up to 6000 kg have been recorded on the Scotian Shelf and in deeper waters along the Grand Banks, Flemish Cap and Labrador Shelf. With the progression of fisheries into deeper waters since the 1992 groundfish moratorium, large sponge catches have been recorded between 800 and 1400 meters throughout the Northwest Atlantic (Figure 1.6.4.1).

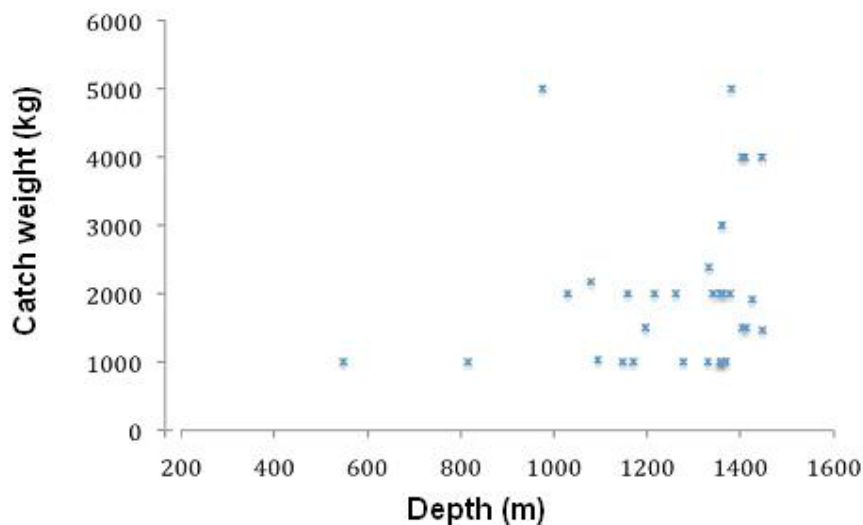


Figure 1.6.4.1. Depth of sponge bycatch > 1000 kg as reported in Canadian trawl survey data (1995-2007).

1.6.5 Distribution of Sponges in the NAFO Area

In the NAFO Convention Area, within the Canadian EEZ, three clear areas emerge as important regions for sponges (Figure 1.6.5.1):

- 1) On the Scotian Shelf, particularly in the Emerald Basin, the monospecific patch of *Vazella pourtalesi* represents a significant and unique population.
- 2) The region along the Labrador shelf is also significant as there are catches greater than 1000 kg per tow.
- 3) Finally, there is a significant concentration of sponges in the Davis Strait that overlaps with the area identified by Edinger et al. (2007).

Canadian surveys do not adequately cover the Flemish Cap area; however, information from Russian and Spanish survey offers additional data providing an increased level of coverage for this area.

For the purposes of identification of vulnerable marine ecosystems, the data available in the NRA clearly show defined areas where sponges are more abundant than in other areas. From Figure 1.6.5.1 and 1.6.5.2, the north-west edge of the Flemish Cap, and the southern region of the Flemish Pass continuing south along the slope stand out as such areas. Large catches have also been recorded southwest of the Flemish Cap (Figure 1.6.5.1 to 1.6.5.2).

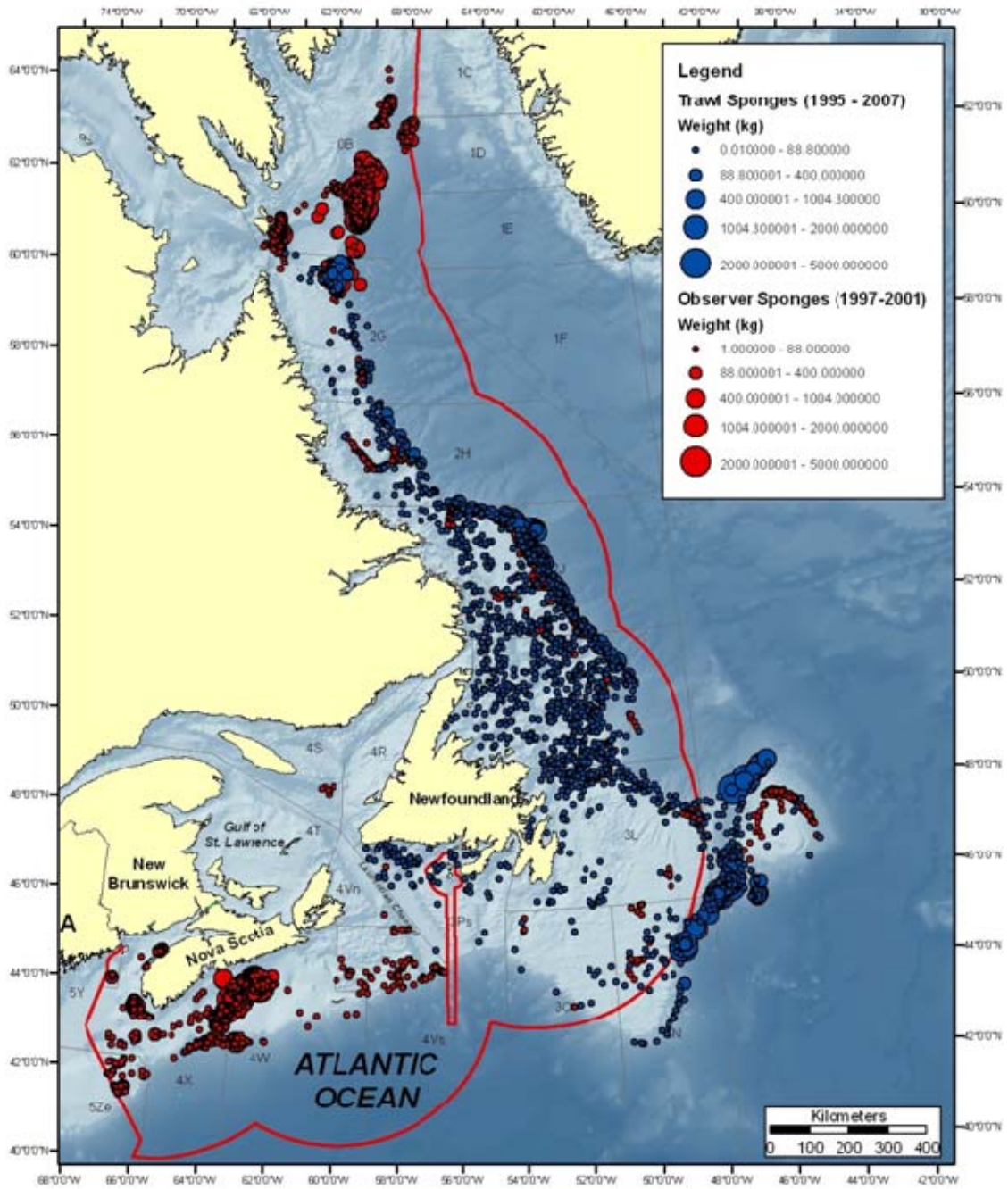


Figure 1.6.5.1. Sponge distribution in the NAFO Area, data is from the Canadian DFO Trawl Survey database (1995-2007) and DFO Scotia Fundy Fisheries Observer database (1977-2001).

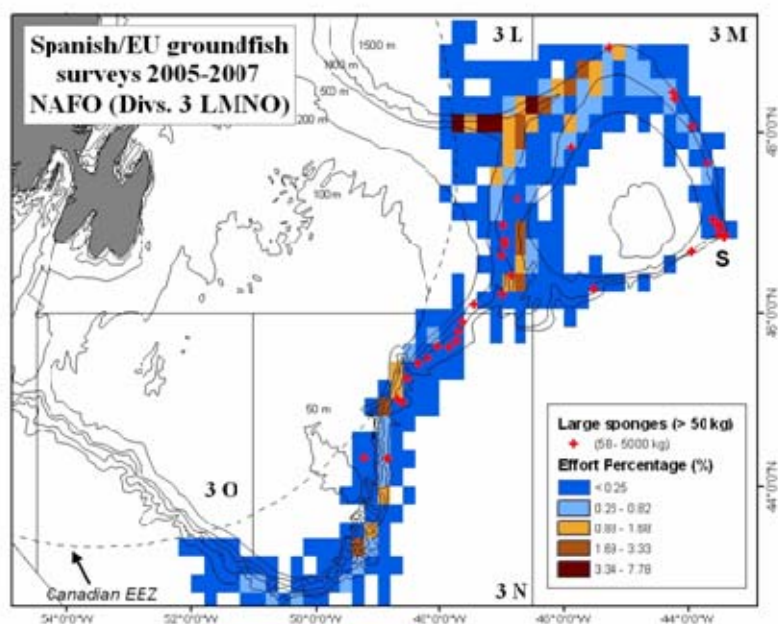


Figure 1.6.5.2. - Records of large sponges by-catch (estimated weights in some cases) derived from Spanish/EU groundfish surveys data sources (2005-2007) in NAFO Area (Divs. 3LMNO), superposing to the footprint of the Spanish Greenland halibut fishery for period 2001-2006, showing that these areas are not being subjected to intense bottom trawl fishing. 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. (from Murillo et al., 2008a).

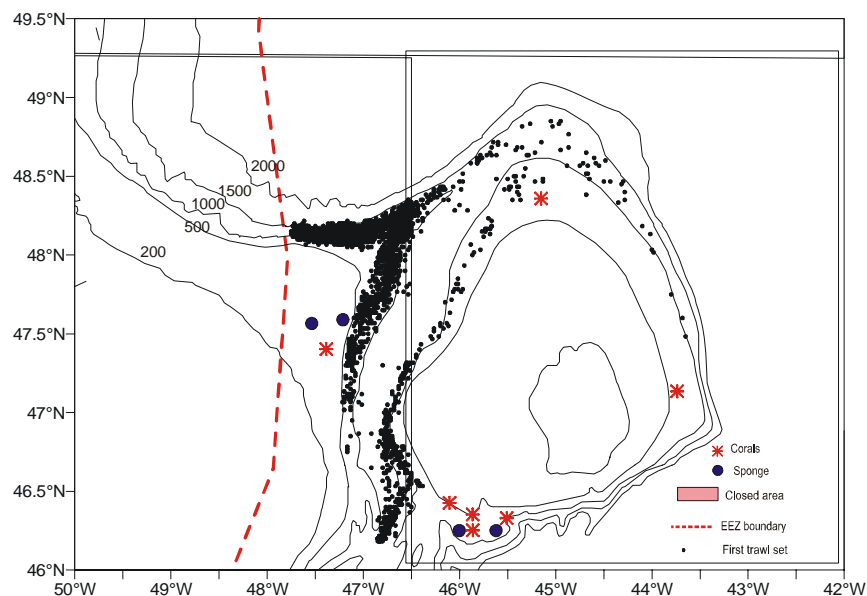


Figure 1.6.5.3. Russian fleet location on Greenland halibut fishery in the NAFO Div. 3LM by observers data (2000-2008) and corals/sponges occurrence by Russian fishery maps and description data (Vinnichenko and Skylar, 2008).

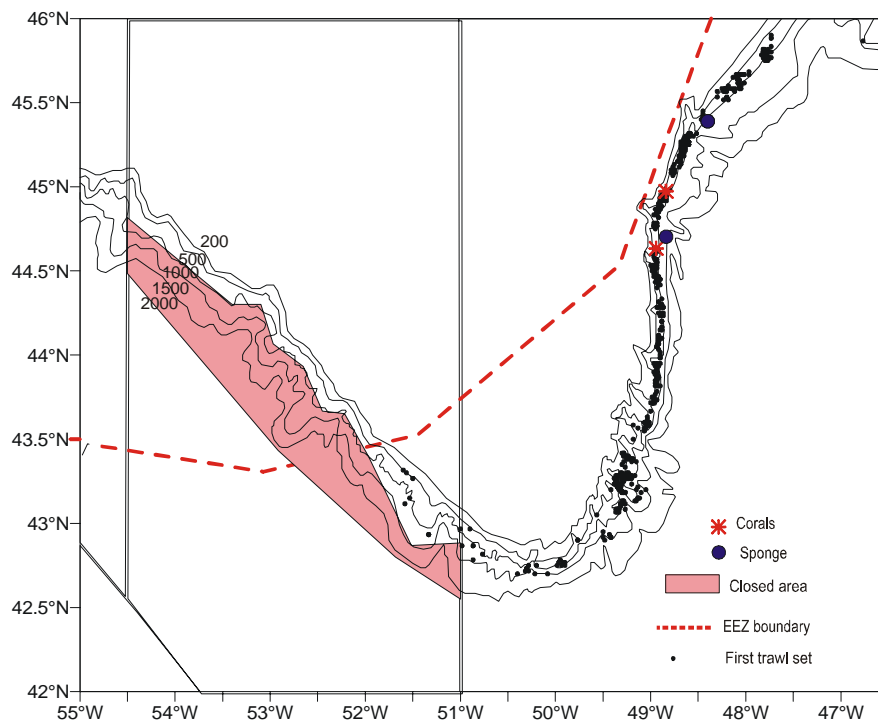


Figure 1.6.5.4. Russian fleet location on Greenland halibut fishery in the NAFO Div. 3NO by observers data (2000-2008) and corals/sponges occurrence by Russian fishery maps and description data (Vinnichenko and Skylar, 2008).

1.6.6 Information Gaps

Sponges are not systematically recorded by fisheries observers in the NRA or in the NCA, however records do exist, particularly when an observer has witnessed a large catch of sponges. Trawl surveys in the Newfoundland Region have been collecting records on sponge catches as have surveys done by the Spanish / EU. There is a need for increased and systematic data collection, as well as mapping of habitats through multibeam as well as in situ investigations. Efforts should be made to develop an identification guide to sponges in the NRA to facilitate further data collection.

1.6.7 Management Context

There is currently no protection afforded to sponge concentrations in the NAFO Convention Area, however some sponge species may be protected in areas where there are coral closures in the NAFO Convention Area. Given the structural complexity that is known to exist in concentrations of sponges on the seafloor, and the long-lived nature of some deep-sea sponges, the three categories of sponges identified in this report are indicative of vulnerable marine ecosystems and should be included in any mitigation measures adopted to protect such systems from fishing impact, as directed by the UNGA Resolution 61/115.

1.7 Other Benthic Taxa

A number of other benthic taxa meet the FAO criteria for vulnerable species and underpin benthic ecosystems. These include but are not limited to stalked crinoids and tunicates, xenophyophores, file shells, deep-water urchins, sea stars, sea cucumbers and other echinoderms.

Megafaunal invertebrates form structure if they aggregate in high numbers, especially in areas of low relief (Tissot et al., 2006). For example, high density “forests” of crinoids provide refuge and substrata for a wide variety of small fishes and invertebrates (Lissner and Benech, 1993 and Puniwai, 2002 in Tissot et al., 2006). Similarly, high-density aggregations of brittle stars (Metaxas and Giffin, 2004) and brachiopods in boulder-cobble areas,

and fields of sea urchins in sand and mud habitat, also provide space and structure for other organisms (e.g., Brodeur, 2001). Another aspect to consider is that large epibenthic deposit-feeding holothurians may promote deep-sea benthic diversity by suppressing competitive exclusion among the smaller benthos in the surface sediment (Dayton and Hessler, 1972).

In addition, some organisms such as bryozoans, hydroids, ascidians, barnacles, etc., can provide habitat complexity in diverse environments. This biogenic turf can be used by fish as a refuge from predation, especially for juvenile life stages (Malecha et al, 2005).



Figure 1.7.1. Dense beds of the ophiuroid *Ophiacantha abyssicola* on the continental slope in the North-east Channel between Browns and Georges Banks. These brittlestar mats are associated with gorgonian corals. Photo courtesy of DFO.

1.8 References

- Auster, P.J., and R.W. Langton. 1999. The effects of fishing on fish habitat. *American Fisheries Society Symposium*, 22: 150-187.
- Auster, P.J., J. Lindholm, and P.C. Valentine. 2003 Variation in habitat use by juvenile Acadian redfish, *Sebastes fasciatus*. *Environmental Biology of Fishes*, 68: 380-389.
- Beaulieu, S. 2001. Life on glass houses: sponge stalk communities in the deep sea. *Marine Biology*, 138: 803-817.
- Brodeur, R.D. 2001. Habitat-specific distribution of Pacific ocean perch (*Sebastes alutus*) in Pribilof Canyon, Bering Sea. *Cont. Shelf Res.* 21:207-224.
- Bruntse, G., and O.S. Tendal (eds). 2001. *Marine biological investigations and assemblages of benthic invertebrates from the Faroe Islands*. Kaldback Marine Biological Laboratory. The Faroe Islands. 80 pp.
- Bullimore, B. 1985. An investigation into the effects of scallop dredging within the Skomer Marine Reserve Skomer Marine Reserve Subtidal Monitoring Project. Report to the Nature Conservation Council.
- Cinar, M.E., and Z. Ergen. 1998. Polychaetes associated with the sponge *Sarcotragus muscarum* Schmidt, 1864 from the Turkish Aegean coast. *Ophelia*, 48(3): 167-183.
- Cinar, M.E., T. Katagan, Z. Ergen, and M. Sezgin. 2002. Zoobenthos inhabiting *Sarcotragus muscarum* (Porifera: Demospongiae) from the Aegean Sea. *Hydrobiologia*, 482(1-3): 107-117.
- Costello, M.J, M. McCrea, A. Freiwald, T. Lundalv, L. Jonsson, B.J. Bett, T.V. Weering, H. de Haas, J.M. Roberts, and D. Allen. 2005. Functional role of deep-sea cold-water *Lophelia* coral reefs as fish habitat in the

- north-eastern Atlantic. Pages 771–805 in Freiwald A, Roberts JM (eds.), Cold-water corals and ecosystems. Springer-Verlag Berlin Heidelberg.
- Dayton, P.K. and R.R. Hessler. 1972. Role of biological disturbance in maintaining diversity in the deep sea. *Deep-Conservation: Marine and Freshwater Ecosystems*, 5, 205-232.
- DFO. 2005. Eastern Scotian Shelf Integrated Ocean Management Plan (2006-2011): Draft for Discussion. Oceans and Coastal Management Report, 2005-02: 81pp.
- Duarte, L.F.L., and R.C.Nalesso. 1996. The sponge *Zygomycale parishii* (Bowerbank) and its endobiotic fauna. *Estuarine, Coastal and Shelf Science*, 42: 139-151.
- 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.
- Etnoyer, P., and L. Morgan. 2003. Occurrences of habitat-forming deep sea corals in the Northeast Pacific Ocean. Technical Report, NOAA Office of Habitat Conservation, 31 p. Marine Biology Conservation Institute, 15806 NE 47th Ct., Redmond, WA 98052.
- Etnoyer, P., and J. Warrenchuk. 2007. A catshark nursery in a deep gorgonian field in the Mississippi Canyon, Gulf of Mexico. *Bulletin of Marine Science*, 81(3): 553-559.
- FAO. 2008. 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.
- Fosså, J.H, P.B. Mortensen, and D.M. Furevik. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. *Hydrobiologia*, 471:1–12.
- Freese, L., P. J. Auster, J. Heifetz, and B. L. Wing. 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. *Marine Ecology Progress Series*, 182: 199-126.
- Freiwald, A., J.H. Fosså, A. Grehan, T. Koslow, and J.M. Roberts. 2004. Cold-water coral reefs. United Nations Environment Programme - World Conservation Monitoring Centre. Cambridge, UK.
- Frith, D.W. 1976. Animals associated with sponges at North Hayling, Hampshire. *Zoological Journal of the Linnean Society*, 58 :353-362.
- Grigg, R.W. 1989. Precious coral fisheries of the Pacific and Mediterranean, in J.F. Caddy (Ed.), *Marine Invertebrate Fisheries: Their Assessment and Management*, Wiley, New York, 637-645.
- Hall-Spencer, J.M., C. Froggia, R. J. A. Atkinson, and P. G. Moore. 1999. The impact of Rapido trawling for scallops, *Pecten jacobaeus* (L.), on the benthos of the Gulf of Venice. *ICES Journal of Marine Science*, 56: 111–124.
- Hall-Spencer, J.M., and P.G. Moore. 2000. Impact of scallop dredging on maerl grounds. In: *The Effects of Fishing on Non-target Species and Habitats: Biological, conservation and socio-economic issues*, pp. 105-117. (ed. M.J. Kaiser & S.J. de Groot) Oxford: Blackwell Science.
- Henry, L.-A., E.L.R. Kenchington, and A. Silvaggio. 2003. Effects of experimental disturbance on aspects of colony behaviour, reproduction and regeneration in the cold water octocoral *Gersemia rubiformis* (Ehrenberg, 1834). *Canadian Journal of Zoology*, 81:1691-1701.
- Hourigan, Thomas F., S. Elizabeth Lumsden, Gabrielle Dorr, Andrew W. Bruckner, Sandra Brooke, and Robert P. Stone. 2007. State of Deep Coral Ecosystems of the United States: Introduction and National Overview, 64 pp.
- Husebo, A., L. Nottestad, J.H. Fossa, D.M. Furevik, and S.B. Jorgensen. 2002. Distribution and abundance of fish in deep-sea coral habitats. *Hydrobiologia*, 471: 91–99.
- ICES. 2008a. Report of the ICES-NAFO Joint Working Group on Deep-water Ecology (WGDEC), 10–14 March 2008, Copenhagen, Denmark. ICES CM 2008/ACOM:45. 122 pp.
- ICES. 2008b. Report of the Working Group on Biology and Assessment of Deep Sea fisheries resources (WGDEEP). ICES CM2008/ACOM:14. 13 pp.
- Jensen A., and R. Frederiksen. 1992. The fauna associated with the bank-forming deep-water coral *Lophelia pertusa* (Scleractinia) on the Faroe shelf. *Sarsia*, 77: 53-69.

- Klittgaard, A.B. 1995. The fauna associated with outer shelf and upper slope sponges (Porifera, Demospongiae) at the Faroe Islands, northeastern Atlantic. *Sarsia*, 80: 1–22.
- Klittgaard, A.B., and Tendal, O.S. 2004. Distribution and species composition of mass occurrences of large sized sponges in the northeast Atlantic. *Progress in Oceanography*, 61: 57–98.
- Koenig, C.C. 2001. *Oculina* Banks: habitat, fish populations, restoration and enforcement. Report to the South Atlantic Fishery Management Council. <http://www.safmc.net>
- Krieger K.J., and B.L. Wing. 2002. Megafaunal associations with deepwater corals (*Primnoa* spp.) in the Gulf of Alaska. *Hydrobiologia*, 471:83–90.
- Langton, R.W., and W.E. Robinson. 1990. Faunal associations on scallop grounds in the western Gulf of Maine. *Journal of Experimental Marine Biology and Ecology*, 144: 157-171.
- Lazier, A., J.E. Smith, M.J. Risk, and H.P. Schwarcz. 1999. The skeletal structure of *Desmophyllum cristagalli*: the use of deep-water corals in sclerochronology. *Lethaia*, 32: 119-130.
- Malecha, P.W., R.P. Stone, and J. Heifetz. 2005. Living substrate in Alaska: distribution, abundance and species associations. In P. Barnes and J. Thomas (Editors), *Benthic Habitats and Effects of Fishing*. American Fisheries Society, Bethesda, MD.
- Manuel, R.L. 1988. *British Anthozoa*. Synopses of the British Fauna (New Series) (ed. D.M. Kermack & R.S.K. Barnes), The Linnean Society of London. Avon: The Bath Press. [Synopses of the British Fauna No. 18.]
- Metaxas A, and B. Giffin. 2004. Dense beds of the ophiuroid *Ophiacantha abyssicola* on the continental slope off Nova Scotia, Canada. *Deep Sea Research*, I 51: 1307–1317.
- Molodtsova, T., and N. Budaeva. 2007. Modifications of corallum morphology in black corals as an effect of associated fauna. *Bulletin of Marine Science*, 81(3):469-479.
- Mortensen P.B., and L. Buhl-Mortensen. 2005. Coral habitats in The Gully, a submarine canyon off Atlantic Canada. Pages 247–277 in Freiwald A, Roberts JM (eds.), *Cold-water corals and ecosystems*. Springer-Verlag Berlin Heidelberg.
- Murillo, F.J., P. Duran Munoz, M. Sacau, D. Gonzalez-Troncoso, and A. Seranno. 2008. Preliminary data on cold-water corals and large sponges bycatch from Spanish / EU bottom trawl groundfish surveys in NAFO Regulatory Area (Divs. 3LMNO) and Canadian EEZ (Div. 3L) 2005-2007 period. NAFO SCR Doc 08/10.
- Murillo, F.J., P. Durán Muñoz, M. Mandado, T. Patrocinio, and G. Fernández. By-catch of cold-water corals from an Experimental Trawl Survey in three seamounts within NAFO Regulatory Area (Divs. 6EFG) during year 2004. NAFO SCR Doc 08/6.
- Philippart, C.J.M. 1998. Long-term impacts of bottom fisheries on several by-catch species of demersal fish and benthic invertebrates. *ICES Journal of Marine Science*, 55: 342-252.
- Prena, J., P. Schwinghamer, T. Rowell, D.C. Gordon Jr., K.D. Gilkinson, W.P. Vass, and D. L. McKeown. 1999. Experimental otter trawling on a sandy bottom ecosystem on the Grand Banks of Newfoundland: analysis of trawl bycatch and effects on epifauna. *Marine Ecology Progress Series*, 181: 107-124.
- 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.
- Reed, J.K., R.H. Gore, L.E. Scotto, and K.A. Wilson. 1982. Community composition, structure, areas and trophic relationships of decapods associated with shallow and deep-water *Oculina varicosa* reefs. *Bulletin of Marine Science*, 32: 761-786.
- Reed, J.K. 2002. Deep-water *Oculina* coral reefs of Florida: biology, impacts, and management. *Hydrobiologia*, 471: 43–55.
- Risk, M., J. M. Heikoop, M. Snow, and R. Beukens. 2002. Lifespans and growth patterns of two deep-sea corals: *Primnoa resedaeformis* and *Desmophyllum cristagalli*. *Hydrobiologia*, 471: 125-131.
- Rogers, A.D. 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. *International Review of Hydrobiology*, 84: 315-406.
- Rosenzweig, M.L. 1995. *Species Diversity in Space and Time*. Cambridge University Press. New York. 385pp.
- Sherwood, O.A., and E.N. Edinger. Submitted 2008. Ages and growth rates of some deep-sea gorgonian and antipatharian corals of Newfoundland and Labrador. *Canadian Journal of Fisheries and Aquatic Sciences*.

- Syms, C., and G.P. Jones. 2001. Soft corals exert no direct effects on coral reef assemblages. *Oecologia*, 127:560–571.
- Tissot, B.N., M.M. Yoklavich, M.S. Love, K. York, and M. Amend. 2006. Benthic invertebrates that form habitat structures on deep banks off southern California, with special reference to deep sea coral. *Fisheries Bulletin*, 104: 167-181.
- Ubelaker, J.M. 1977. Cryptofaunal species/area relationship in the coral reef sponge *Gelliodes digitalis*. In Taylor, D. (ed) *Proceedings of the 3rd International Coral Reef Symposium*. 1. Biology. Miami, Florida.
- Villamizar, E., and R.A. Laughlin. 1991. Fauna associated with the sponges *Aplysina archeri* and *Aplysina lacunosa* in a coral reef of the Archipelago de Los Roques, National Park, Venezuela. In *Fossil and Recent Sponges* ed. J. Reitner and H. Keupp. Springer Verlag, Berlin.
- Vinnichenko, V.I., and V.V. Sklyar. 2008. On the issue of areas closure to protect vulnerable marine habitats in the NAFO Regulatory Area. NAFO NAFO Working Group on Ecosystem Approach of Fisheries Management. Working Paper.
- Wareham, V.E., and E.N. Edinger. 2007. Distributions of deep-sea corals in Newfoundland and Labrador waters. *Bulletin of Marine Science*, 81:289-311.
- Watling, L., and E.A. Norse. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. *Conservation Biology*, 12(6):1180–1197.
- Westinga, E., and P.C. Hoetjes. 1981. The intrasponge fauna of *Sphaciospongia vesparia* (Porifera, Demospongiae) at Curaçao and Bonaire. *Marine Biology*, 62: 139-150.
- Wilson, M.T., A.H. Andrews, A.L. Brown, and E.E. Cordes. 2002. Axial rod growth and age estimation of the sea pen *Halipteria willemoesi* Kölliker. *Hydrobiologia*, 471:133-142.
- Williams, G.C. 1995. Living genera of sea pens (Coelenterata: Octocorallia: Pennatulacea): illustrated key and synopses. *Zoological Journal of the Linnean Society*, 113: 93-140.